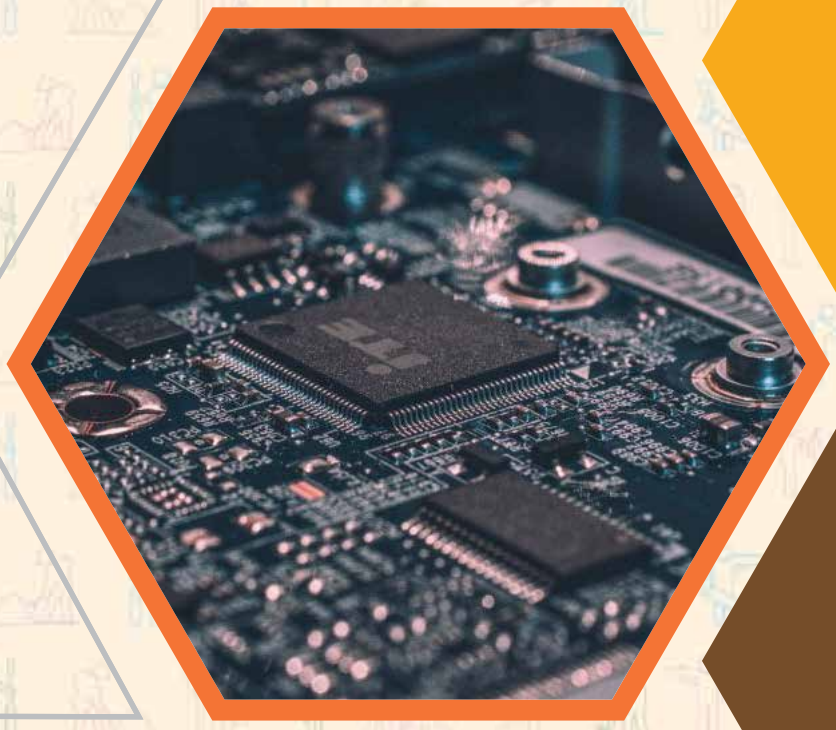
Skill India
कौशल भारत-कुशल भारत

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

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

ESSCI
Skilling India in Electronics

Participant Handbook



Sector
Electronics

Sub-Sector
Semiconductor & Components

Occupation
Product Design

Reference ID: **ELE/Q1405, Version 2.0, NSQF Level 5**

IoT Hardware Analyst

Scan this QR Code to access eBook

Published by
Electronics Sector Skill Council of India (ESSCI)
155, 2nd Floor, ESC House, Okhla Industrial Area-Phase 3, New Delhi- 110020, India
Email: info@essc-india.org
Website: www.essc-india.org
Phone: +91 8447738501

First Edition, August 2022

> 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

Skill India
कौशल भारत-कुशल भारत

ESSCI
Skilling India in Electronics

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

Certificate

COMPLIANCE TO QUALIFICATION PACK - NATIONAL OCCUPATIONAL STANDARDS

is hereby issued by the

Electronics Sector Skill Council of India

for

SKILLING CONTENT : PARTICIPANT HANDBOOK

Complying to National Occupational Standards of

Job Role/ Qualification Pack: "IoT Hardware Analyst" ' QP No. ELE/Q1405, NSQF Level 5

Date of Issuance: Sep 9th 2022

Valid up to*: June 2ND 2025

*Valid up to the next review date of the Qualification Pack

Authorised Signatory
Electronics Sector Skill Council of India

Acknowledgements

This participant's handbook meant for IoT Hardware Analyst is a sincere attempt to ensure the availability of all the relevant information to the existing and prospective job holders in this job role. We have compiled the content with inputs from the relevant Subject Matter Experts (SMEs) and industry members to ensure it is the latest and authentic. We express our sincere gratitude to all the SMEs and industry members who have made invaluable contributions to the completion of this participant's handbook. We'd also like to thank all the experts and organizations who have helped us by reviewing the content and providing their feedback to improve its quality.

This handbook will help deliver skill-based training in the field of IoT hardware assembly and testing. We hope that it will benefit all the stakeholders, such as participants, trainers, and evaluators. We have made all efforts to ensure the publication meets the current quality standards for the successful delivery of QP/NOS-based training programs. We welcome and appreciate any suggestions for future improvements to this handbook.

About this book

This participant handbook has been designed to serve as a guide for participants who aim to obtain the required knowledge and skills to undertake various activities in the role of an IoT Hardware Analyst. Its content has been aligned with the latest Qualification Pack (QP) prepared for the job role. With a qualified trainer's guidance, the participants will be equipped with the following for working efficiently in the job role:

- **Knowledge and Understanding**: The relevant operational knowledge and understanding to perform the required tasks.
- **Performance Criteria**: The essential skills through hands-on training to perform the required operations to the applicable quality standards.
- **Professional Skills**: The Ability to make appropriate operational decisions about the field of work.

The handbook details the relevant activities to be carried out by an IoT Hardware Analyst. After studying this handbook, job holders will be adequately skilled to carry out their duties efficiently according to the applicable quality standards. The handbook is aligned with the following National Occupational Standards (NOS) detailed in the IoT Hardware Analyst QP:

1. **ELE/N1407:** Create requirement specifications and detailed design documents
2. **ELE/N1408:** Design circuit and PCB layout for the IoT system
3. **ELE/N1409:** Build and test the complete IoT system
4. **ELE/N9905:** Work effectively at the workplace
5. **ELE/N1002:** Apply health and safety practices at the workplace

The handbook has been divided into an appropriate number of units and sub-units based on the content of the relevant QP. We hope it will facilitate easy and structured learning for the participants. We sincerely hope that participants will obtain enhanced knowledge and skills after studying this handbook and make career progress in the relevant and senior job roles.

Symbols Used


Key Learning Outcomes


Steps


Exercise


Notes


Unit Objectives

Table of Contents

Skill India
कौशल भारत-कुशल भारत

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

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

1. Introduction and Orientation to the Role of an IoT Hardware Analyst

ESSCI
Skilling India in Electronics

Unit 1.1 - About Electronics Industry

Unit 1.2 - About Role of an IoT Hardware Analyst

Bridge Module

Key Learning Outcomes

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

1. Describe about electronics industry
2. List applications of electronics industry
3. Describe trends and challenges in electronics industry
4. Describe IOT design requirements
5. Describe components of IoT design document
6. List requirements of an IoT System

Unit 1.1: About Electronics Industry

Unit Objectives

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

1. Describe about electronics industry
2. List applications of electronics industry
3. Describe trends and challenges in electronics industry

1.1.1 Introduction

The electronics industry is the economic sector that produces electronic devices. It emerged in the 20th century and is today one of the largest global industries. Contemporary society uses a vast array of electronic devices built-in automated or semi-automated factories operated by the industry.

Electronics industry, the business of creating, designing, producing, and selling devices such as radios, televisions, stereos, computers, semiconductors, transistors, and integrated circuits etc. The electronics industry transformed factories, offices, and homes, emerging as a key economic sector that rivalled the chemical, steel, and auto industries in size.

The electronics sector produces electronic equipment and consumer electronics and manufactures electrical components for a variety of products. Common items in the electronics sector include mobile devices, televisions, and circuit boards. Industries within the electronics sector include telecommunications, networking, electronic components, industrial electronics, and consumer electronics.

Growth in the Electronics Sector

The electronics sector is growing rapidly as a result of increasing demand from emerging market economies. As a result, many countries are increasingly producing more electronics, and investment in the foreign production of electronics has increased dramatically.

Electronics sector growth is accelerated by increased consumer spending around the world. As developing economies grow, consumer demand for electronics also grows. Countries that produce electronics now have strong consumer bases that can afford new electronic products. At the same time, increased competition is driving the costs of electronics production down, making products even cheaper for individuals.

The supportive role of the electronics sector in providing equipment and components for other industries is also a factor of growth as consumers demand more automobiles, energy-efficient homes, and medical technologies.

1.1.2 Application of Electronics in Different Fields

The various electronics applications are:

- **Consumer Electronics:** The devices and equipment meant for daily use are known as customer electronics; this industry is widely applicable to the common people. Some of its applications included office gadgets like computers, scanners, calculators, FAX machines, projectors etc.

  It also includes home appliances like washing machines, refrigerators, microwaves, TVs, vacuum cleaners, video games, loudspeakers etc. and some advanced storage devices such as HDD jukebox, DVDs etc.

- **Industrial applications of electronics:** Electronics engineering has a huge impact on the smooth functioning of the industries as it is used in various systems, grids and processing units. For example, smart electric systems collect information from the communication technology department, and several machines use automation and motor control systems using electronics; also, it is used in extracting 3D images from 2D using image processing systems.
- **Robotics and artificial intelligence:** Apart from image processing that involves computer graphics, electronic systems are also used in artificial intelligence and robotics technologies for inspection, navigation and assembly. Virtual reality and face gesture recognition are computer-based, and these developments have been possible because of electronics engineering.
- **Medical applications:** For data recording and physiological analysis, advanced, sophisticated instruments are being developed using the latest technologies and electronics engineering, and these instruments are very useful in diagnosing diseases and for healing purposes.
- Electronics play a vital role in the functioning of medical instruments; for instance, the stethoscope is used to listen to the inner sounds of the human or animal body, a glucose metre for checking sugar levels, a pacemaker for dropping and increasing heartbeat count and so on.
- **Defence and Aerospace:** Electronics technology has been used extensively in the defence and aeronautical systems, which include missile launching systems, cockpit controllers, military radars, aircraft systems, rocket launchers for space and many more.
- **Automobiles:** Electronics are widely used in the latest automobile technologies, like anti-collision units, anti-lock braking systems, traction controls, window regulators and several electronic control units.

1.1.3 Electronic Industry Trends and Challenges

The electronics sector appears to be overgrowing, owing to increased demand from developing countries. Before the virus outbreak, due to increased demand, electronics production skyrocketed, accompanied by a surge in investment.

The global electronic products market is expected to be worth nearly $1,191.2 billion in 2020, with a Compound Annual Growth Rate (CAGR) of 5.4 percent since 2015. The increase is primarily due to the increasing demand for various electronic products as employees and students have transitioned to online.

Consumer Electronics Market size was valued at over USD 1 trillion in 2020 and is estimated to grow at a CAGR of more than 8% from 2021 to 2027. Rapidly increasing internet penetration across the globe will drive the market growth.

Consumer electronics are electronic equipment for non-commercial use. Consumer electronics include devices that provide one or more functionalities such as computers, laptops, mobile devices, smart wearables, television sets, refrigerators, smartphones, and home appliances.

Continuous investments by market players in R&D for the development of new consumer electronic products with enhanced features will fuel the industry growth of consumer electronics.

Challenges in Electronic Industry

Regardless of its merits, the electronic industry faces disruptive forces that will test its business model and ability to survive and thrive.

The global electronic industries are the fastest-growing sector, worth trillions of dollars, and play a critical role in driving consumers to purchase innovative and smart electronic products. The global market for electronic components is expected to grow at a compound annual growth rate (CAGR) of about 4.8 percent from 2020 to 2025.

Electronic industries have always been at the forefront of the most recent technological innovations to reduce costs and improve efficiency with such a large future market potential. Many SMEs have found it challenging to keep up with the trends/changes as technology has advanced faster.

For example, top players such as Apple, Samsung, Microsoft, and Intel, to name a few, are investing heavily in new cutting-edge technology to expand their technological capabilities and remain competitive. They are the leading example of an IR4.0 (industrial Revolution 4.0) Eco-friendly system.

The integration of digital tools and technologies has increased revenue and productivity, improved product quality, reduced waste, and operational costs, and met the most recent customer/global demands.

Electronic Industry Trends

Here are some predictions for the specific trends that are likely to have the most significant impact in 2022. The most important trends in 2022 will likely focus on the convergence of technology trends as tools emerge that let us combine them in new and amazing ways.

1. **The 5G Optimization:** 5G is laying the groundwork for a fully digitalized and connected world. We have seen many new field trials and an increasing number of commercial rollouts over the last two years. Furthermore, we are seeing 5G being adopted in various industries, ranging from manufacturing to healthcare.

   With its high output and ultralow latency, 5G can access many high-value areas such as 3D robotic control, virtual reality monitoring, and remote medical control that previous technologies could not. 5G is redefining and accelerating industries like automotive, entertainment, computing, and manufacturing. It will eventually change the way we work and live.

2. **Digitization, data, and virtualization:** Many of us witnessed the virtualization of our offices and workplaces in 2020 and 2021, as remote working arrangements were quickly implemented.

This was simply a crisis-driven acceleration of a much longer-term trend. In 2022, we'll be more familiar with the concept of a **"metaverse"** - persistent digital worlds that exist alongside the physical world we live in.

3. **Concentrate on Software Quality Standards:** The focus on quality will be the trend for 2022 and beyond. Software solutions will be integrated into our daily lives and the majority of the goods and appliances we use. As a result, software must meet the quality standards of the manufacturing industry.
4. **Teleworking:** Teleworking will continue to grow in 2022, bringing advances in software development. Companies worldwide will need to support hybrid forms of team management and collaboration to increase the productivity of their workforces. As the trend of conducting online meetings and video sales calls continues, this new standard will grow even more in 2022.
5. **Green, Clean, and Lean Energy:** Renewable energy was the only type of energy that saw an increase in use during the pandemic. As industries shut down and people stayed at home, global non-renewable energy consumption decreased, resulting in an 8% reduction in emissions. As a result, increased investment in renewable energy generation is expected in the coming years.

   According to the International Energy Agency (IEA), 40% more renewable energy was generated and used in 2020 than the previous year. This trend is expected to continue through 2022. Overall, the cost of generating renewable energy from various sources, such as onshore and offshore wind, solar, and tidal, has decreased by 7 to 16%. This will be highly beneficial to countries and businesses attempting to meet emissions targets such as becoming carbon neutral or even carbon negative.

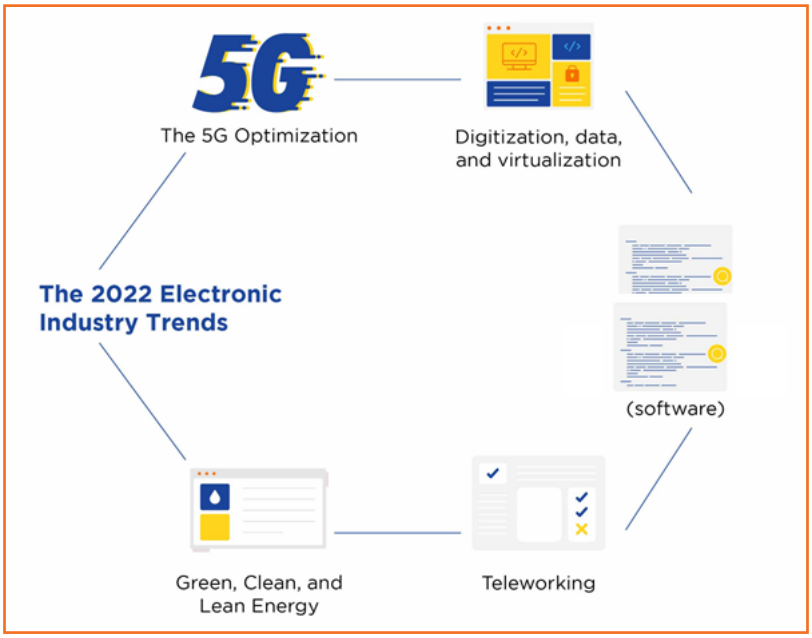


Fig 1.1.1: Trends in electronics industry

Electronics manufacturing trends for 2022

1. **Advanced Materials:** The semiconductor industry has been reliant on silicon for decades, but there is a limit to how far you can etch, lithograph, and pattern a silicon material. As a result,

innovation to increase the performance of integrated circuits is coming from new materials and architectures. Startups and scaleups are developing silicon alternatives and other semiconductor materials or composites for high performance and efficiency.

2. **Organic Electronics:** Organic Electronics offer massive advantages over traditional inorganic electronics. They are cost-effective, flexible, indissoluble, optically transparent, lightweight, and consume low power. In addition, the rise in awareness for sustainable development and eco-friendly manufacturing attracts manufacturers to opt for organic electronics. Designing circuits with microbial components or producing devices with biodegradable and recyclable materials is seen to be the next electronics manufacturing trend.
3. **Artificial Intelligence:** AI-powered solutions are gaining popularity in every sector. AI impacts the growth of semiconductor manufacturing in two ways, one is by building demand for innovative AI-capable electronics components, and two, enhancing the product manufacturing and design processes. The conventional methods have limitations to reshaping product development cycles, improving product design processes, and reducing defects. But the application of AI is solving all these limitations.
4. **Internet of Things:** The rapid growth of the Internet of Things represents an unprecedented opportunity for the electronics manufacturing industry. It re-evaluates the fabrication process and manages practices that are found to be difficult to achieve with conventional approaches. In other ways, the IoT enables electronic manufacturing machines to self-process and store data while being digitally connected. Continuous improvements in the fabrication of sensors are also required since sensors are the key components that enable IoT applications. Further, the transition to 5G-enabled devices requires flawless, innovative chips with more efficient architectures at lower costs.
5. **Embedded Systems:** Embedded systems are an unavoidable part of any electronic device nowadays and it has a crucial role in deciding the speed, security, size, and power of the devices. Since we are in the transition phase of a connected world, there is high demand for embedded systems. So the designing and manufacturing sector of such systems is undergoing numerous innovations to improve performance, security, and connectivity capabilities.
6. **Printed Electronics:** Printing electronics components on a semiconductor substrate is the most effective way to reduce the overall cost of the manufacturing process. So, manufacturers are always trying to tackle this challenge by searching for new technologies and advancements in conventional printing technologies. Unlike traditional semiconductors that use tiny wires as circuits, printed electronics rely on conductive inks and often flexible films. Further, the advancements in printing technologies allow the flexible hybrid electronics field to obtain enough momentum. Therefore, startups and scaleups are developing solutions for advanced printing technologies.
7. **Advanced IC Packaging:** In recent years, chip packaging has become a hot topic along with chip design. The traditional way to scale a device based on Moore's law has limitations nowadays. The other way to get the benefits of scaling is to put multiple complex devices in an advanced package. So, semiconductor manufacturers develop new advanced IC packaging technologies to provide greater silicon integration in increasingly miniaturized packages. This also enables manufacturers to offer customization and improve yields by vertically stacking modular components.

8. **Additive Manufacturing:** 3D Printing in electronics manufacturing eliminates the need for flat circuit boards. It enables new innovative designs and shapes that cannot be produced through conventional means. 3D printers also fabricate electronic components as a single, continuous part, effectively creating fully functional electronics that require little or no assembly. Consequently, the implementation of this electronics manufacturing trend speeds up prototyping, offers mass customization, and decentralizes parts production. In general, 3D printing technology made possible electronic components production in terms of 3D design and not only 2D, with new ways of stacking the circuits.

Notes

Unit 1.2: About Role of an IoT Hardware Analyst

Unit Objectives

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

1. List role and responsibilities of an IoT hardware Analyst

1.2.1 Role and Responsibilities of IoT Hardware Analyst

IoT Hardware Analyst prepares complete blueprint of the hardware including schematics and layout. The individual also prepares quality and verification requirements and perform PCB testing in compliance with regulatory standards and records them in a design document. The individual will also be responsible for working and efficient functioning of the system.

Responsibilities of an IoT Hardware Analyst

1. To research, build, test, and document state-of-the-art IoT solutions with integrated electronics and firmware development.
2. To test IoT device software that includes monitoring, execution, and self-healing processes.
3. To design innovative IoT services that communicate with server-side technologies.
4. To learn the functioning of and implement new state-of-the-art tools/techniques to showcase experience in quick prototyping methods and structured implementation.
5. To design and develop platform solutions for cloud-to-edge IoT applications with customizable configuration abilities for deployment to different clients with different needs.
6. To work with dynamic IoT, Computer Vision, and MEAN technology stack to find solutions to complex real-world problems.
7. To plan and build efficient tools to optimize support QA, deployment, and support services.

Notes

Skill India
कौशल भारत-कुशल भारत

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

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

2. Process of Creating Requirement Specifications and Detailed Design Documents

ESSCI
Skilling India in Electronics

Unit 2.1 – IOT System

Unit 2.2 – IOT Design Requirements and Specifications

ELE/N1407

Key Learning Outcomes

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

1. Describe IOT
2. List advantages and disadvantages of IOT
3. List components and applications of IOT
4. Describe IOT design requirements
5. Describe components of IoT design document
6. List requirements of an IoT System

Unit 2.1: IOT System

Unit Objectives

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

1. Describe IOT
2. List advantages and disadvantages of IOT
3. List components and applications of IOT

2.1.1 IoT (Internet of Things)

IoT (Internet of Things) is an advanced automation and analytics system which exploits networking, sensing, big data, and artificial intelligence technology to deliver complete systems for a product or service. These systems allow greater transparency, control, and performance when applied to any industry or system.

IoT systems have applications across industries through their unique flexibility and ability to be suitable in any environment. They enhance data collection, automation, operations, and much more through smart devices and powerful enabling technology.

IoT - key features

The most important features of IoT include -

1. **AI:** IoT essentially makes virtually anything **"smart"**, meaning it enhances every aspect of life with the power of data collection, artificial intelligence algorithms, and networks.
2. **Connectivity:** New enabling technologies for networking, and specifically IoT networking, mean networks are no longer exclusively tied to major providers. Networks can exist on a much smaller and cheaper scale while still being practical. IoT creates these small networks between its system devices.
3. **Sensors:** IoT loses its distinction without sensors. They act as defining instruments which transform IoT from a standard passive network of devices into an active system capable of real-world integration.
4. **Active Engagement:** Much of today›s interaction with connected technology happens through passive engagement. IoT introduces a new paradigm for active content, product, or service engagement.
5. **Small Devices:** Devices, as predicted, have become smaller, cheaper, and more powerful over time. IoT exploits purpose-built small devices to deliver its precision, scalability, and versatility.

IoT - Advantages

The advantages of IoT are -

- **Improved Customer Engagement:** Current analytics suffer from blind-spots and significant flaws

in accuracy; and as noted, engagement remains passive. IoT completely transforms this to achieve richer and more effective engagement with audiences.

- **Technology Optimization:** The same technologies and data which improve the customer experience also improve device use, and aid in more potent improvements to technology. IoT unlocks a world of critical functional and field data.
- **Reduced Waste:** IoT makes areas of improvement clear. Current analytics give us superficial insight, but IoT provides real-world information leading to more effective management of resources.
- **Enhanced Data Collection:** Modern data collection suffers from its limitations and its design for passive use. IoT breaks it out of those spaces, and places it exactly where humans really want to go to analyze our world. It allows an accurate picture of everything.

IoT - Disadvantages

Though IoT delivers an impressive set of benefits, it also presents a significant set of challenges. It's some major issues are -

- **Security:** IoT creates an ecosystem of constantly connected devices communicating over networks. The system offers little control despite any security measures. This leaves users exposed to various kinds of attackers.
- **Privacy:** The sophistication of IoT provides substantial personal data in extreme detail without the user's active participation.
- **Complexity:** Some find IoT systems complicated in terms of design, deployment, and maintenance given their use of multiple technologies and a large set of new enabling technologies.
- **Flexibility:** Many are concerned about the flexibility of an IoT system to integrate easily with another. They worry about finding themselves with several conflicting or locked systems.
- **Compliance:** IoT, like any other technology in the realm of business, must comply with regulations. Its complexity makes the issue of compliance seem incredibly challenging when many consider standard software compliance a battle.

2.1.2 IoT - Technology and Protocols

IoT primarily exploits standard protocols and networking technologies. However, the major enabling technologies and protocols of IoT are RFID, NFC, low-energy Bluetooth, low-energy wireless, low-energy radio protocols, LTE-A, and WiFi-Direct. These technologies support the specific networking functionality needed in an IoT system in contrast to a standard uniform network of common systems.

- **NFC and RFID:** RFID (radio-frequency identification) and NFC (near-field communication) provide simple, low energy, and versatile options for identity and access tokens, connection bootstrapping, and payments.

  i. RFID technology employs 2-way radio transmitter-receivers to identify and track tags associated with objects.

ii. NFC consists of communication protocols for electronic devices, typically a mobile device and a standard device.

- **Low-Energy Bluetooth:** This technology supports the low-power, long-use need of IoT function while exploiting a standard technology with native support across systems.
- **Low-Energy Wireless:** This technology replaces the most power hungry aspect of an IoT system. Though sensors and other elements can power down over long periods, communication links (i.e., wireless) must remain in listening mode. Low-energy wireless not only reduces consumption, but also extends the life of the device through less use.
- **Radio Protocols:** ZigBee, Z-Wave, and Thread are radio protocols for creating low-rate private area networks. These technologies are low-power, but offer high throughput unlike many similar options. This increases the power of small local device networks without the typical costs.
- **LTE-A:** LTE-A, or LTE Advanced, delivers an important upgrade to LTE technology by increasing not only its coverage, but also reducing its latency and raising its throughput. It gives IoT a tremendous power through expanding its range, with its most significant applications being vehicle, UAV, and similar communication.
- **WiFi-Direct:** WiFi-Direct eliminates the need for an access point. It allows P2P (peer-to-peer) connections with the speed of WiFi, but with lower latency. WiFi-Direct eliminates an element of a network that often bogs it down, and it does not compromise on speed or throughput.

2.1.3 Components of an IoT System

IoT Hardware includes a wide range of devices such as devices for routing, bridges, sensors etc. These IoT devices manage key tasks and functions such as system activation, security, action specifications, communication, and detection of support-specific goals and actions.

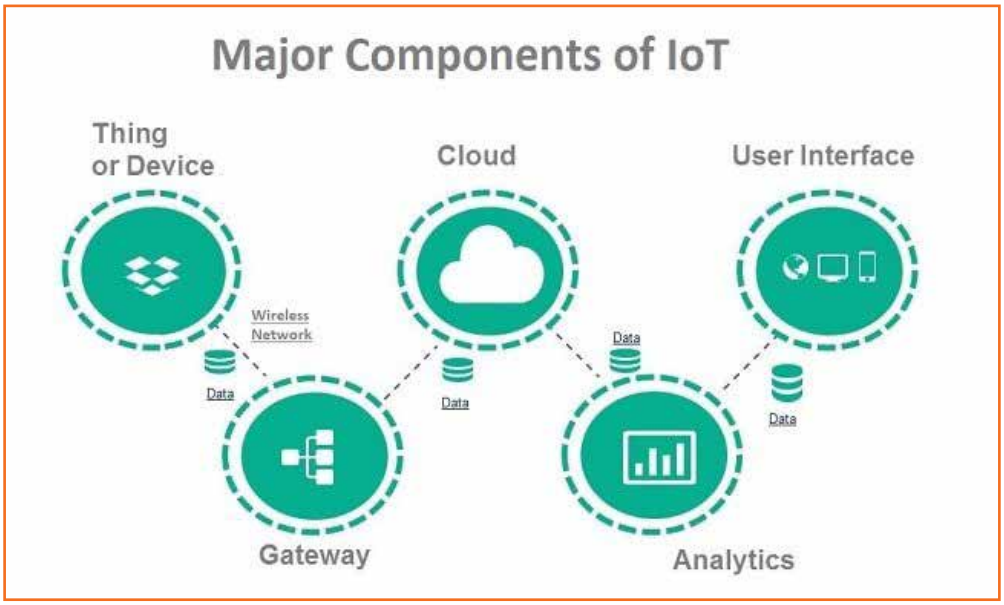


Fig 2.1.1: Components of an IoT system

1. **Smart devices and sensors - Device connectivity:** Devices and sensors are the components of the device connectivity layer. These smart sensors are continuously collecting data from the environment and transmit the information to the next layer.

Fig 2.1.2: Sensor

Latest techniques in the semiconductor technology is capable of producing micro smart sensors for various applications.

Common sensors are:

- ❑ Temperature sensors and thermostats
- ❑ Pressure sensors
- ❑ Humidity / Moisture level
- ❑ Light intensity detectors
- ❑ Moisture sensors
- ❑ Proximity detection
- ❑ RFID tags

Fig 2.1.3: Wi-fi netwirks

How the devices are connected?

Most of the modern smart devices and sensors can be connected to low power wireless networks like Wi-Fi, ZigBee, Bluetooth, Z-wave, LoRAWAN etc. Each of these wireless technologies has its own pros and cons in terms of power, data transfer rate and overall efficiency.

Developments in the low power, low cost wireless transmitting devices are promising in the area of IoT due to its long battery life and efficiency. Latest protocols like 6LoWPAN- IPv6 over Low Power Wireless Personal Area Networks have been adapted by many companies to implement energy efficient data transmission for IoT networks.

2. **Gateway:** IoT Gateway manages the bidirectional data traffic between different networks and protocols. Another function of gateway is to translate different network protocols and make sure interoperability of the connected devices and sensors.

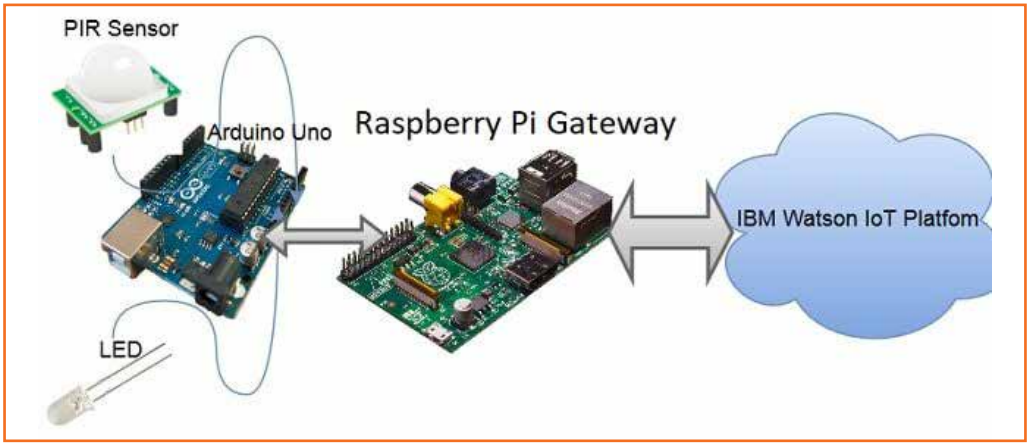


Fig 2.1.4: Gateway platforms

Gateways can be configured to perform pre-processing of the collected data from thousands of sensors locally before transmitting it to the next stage. In some scenarios, it would be necessary due to compatibility of TCP/IP protocol.

IoT gateway offers certain level of security for the network and transmitted data with higher order encryption techniques. It acts as a middle layer between devices and cloud to protect the system from malicious attacks and unauthorized access.

3. **Cloud:** Internet of things creates massive data from devices, applications and users which has to be managed in an efficient way. IoT cloud offers tools to collect, process, manage and store huge amount of data in real time. Industries and services can easily access these data remotely and make critical decisions when necessary.

   Basically, IoT cloud is a sophisticated high performance network of servers optimized to perform high speed data processing of billions of devices, traffic management and deliver accurate analytics. Distributed database management systems are one of the most important components of IoT cloud.

4. **Analytics:** Analytics is the process of converting analog data from billions of smart devices and sensors into useful insights which can be interpreted and used for detailed analysis. Smart analytics solutions are inevitable for IoT system for management and improvement of the entire system.

Fig 2.1.5: System analysis

   One of the major advantages of an efficient IoT system is real time smart analytics which helps engineers to find out irregularities in the collected data and act fast to prevent an undesired scenario. Service providers can prepare for further steps if the information is collected accurately at the right time.

   Big enterprises use the massive data collected from IoT devices and utilize the insights for their future business opportunities.

5. **User interface:** User interfaces are the visible, tangible part of the IoT system which can be accessible by users. Designers will have to make sure a well designed user interface for minimum effort for users and encourage more interactions.

Fig 2.1.6: User interface

   Modern technology offers much interactive design to ease complex tasks into simple touch panels controls. Multicolor touch panels have replaced hard switches in our household appliances and the trend is increasing for almost every smart home devices.

   User interface design has higher significance in today's competitive market, it often determines the user whether to choose a particular device or appliance. Users will be interested to buy new devices or smart gadgets if it is very user friendly and compatible with common wireless standards.

2.1.4 Working of an IoT System

First, sensors or devices collect data from their environment. This data could be as simple as a temperature reading or as complex as a full video feed.

Next, that data is sent to the cloud, but it needs a way to get there. The sensors/devices are connected to the cloud through a variety of methods including - cellular, satellite, WiFi, Bluetooth, low-power wide-area networks (LPWAN), connecting via a gateway/router or connecting directly to the internet via ethernet

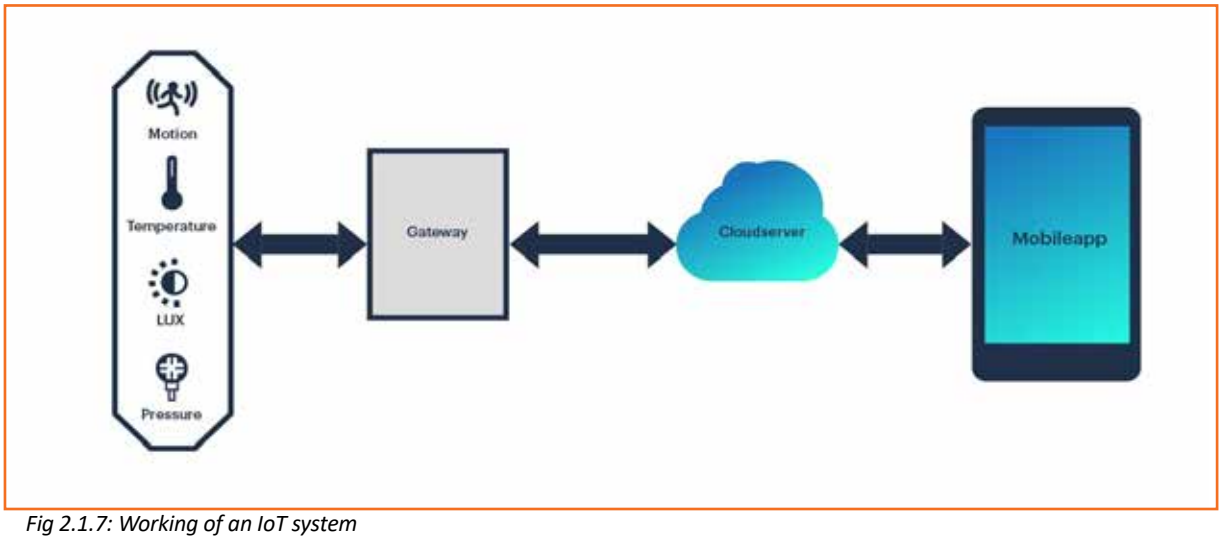


Fig 2.1.7: Working of an IoT system

Once the data gets to the cloud software performs some kind of processing on it. This could be very simple, such as checking that the temperature reading is within an acceptable range or it could also be very complex, such as using computer vision on video to identify objects.

Next, the information is made useful to the end-user in some way. This could be via an alert to the user (email, text, notification, etc). For example, a text alert when the temperature is too high in the company's cold storage.

A user might have an interface that allows them to proactively check in on the system. For example, a user might want to check the video feeds on various properties via a phone app or a web browser.

However, it's not always a one-way street. Depending on the IoT application, the user may also be able to perform an action and affect the system. For example, the user might remotely adjust the temperature in the cold storage via an app on their phone.

2.1.5 Applications of an IoT System

IoT has applications across all industries and markets. It spans user groups from those who want to reduce energy use in their home to large organizations who want to streamline their operations. It proves not just useful, but nearly critical in many industries as technology advances and we move towards the advanced automation imagined in the distant future.

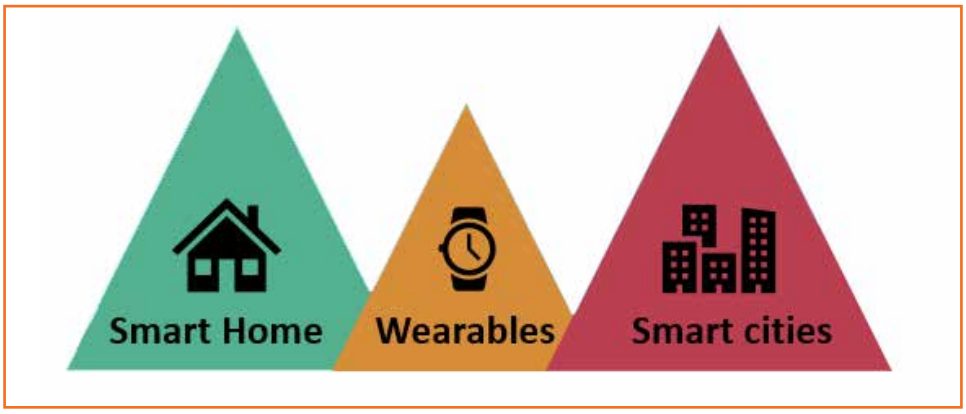


Fig 2.1.8: Applications of an IoT system

1. **Smart Home and Office:** Smart home applications with the use of smart sensors are becoming popular now. Any smart device can be configured and connected to the internet and control using simple mobile application.

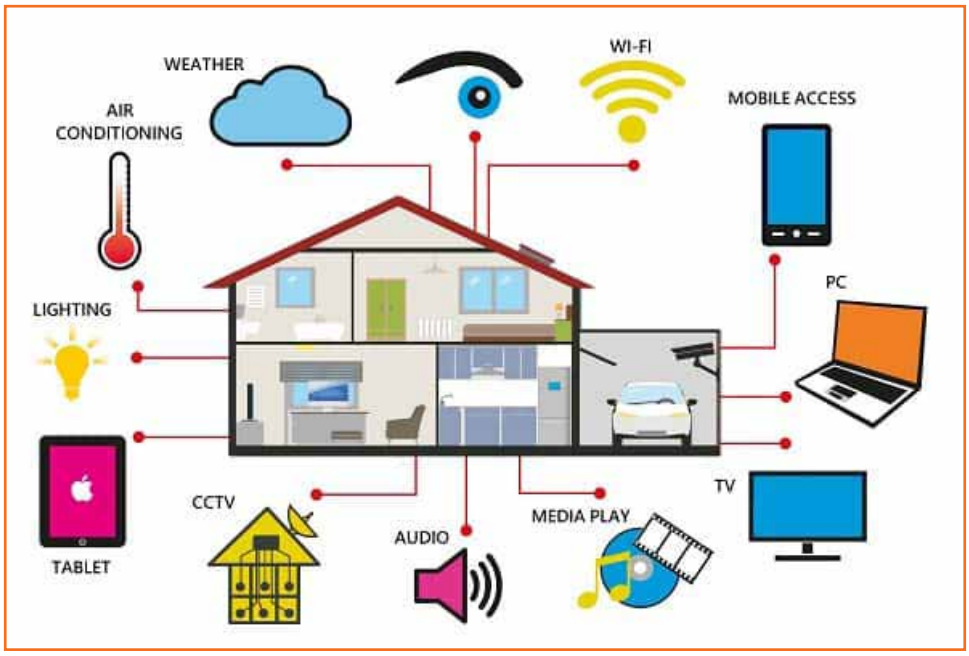


Fig 2.1.9: Applications in smart home and office

Few examples of IoT devices in home are:

- **Smart Door access control system:** Smart locks and door access systems are one of the most popular and cost effective solutions of Internet of Things. Smart locks are easy to implement and control using a web interface or Smartphone application. Integration with RDIF tags, smart door accessing systems can be securely implemented. Users can grant access to the doors using mobile app and lock again once the person leaves the premises.

- **Smart lighting for home and office:** Smart lighting is one the attractive smart home application using internet of things. In addition to energy saving, it also enables us to manage effectively. Light ambience can be changed using smart hub devices or smart phone app.
- **Automated Gate and garage:** Using smart sensor technology and internet of things, gates and garages can be controlled (operated) conveniently. Once you are about to enter the house or after leaving the premises, you may open or close the gate using mobile devices.
- **Smart thermostats and humidity controllers:** Smart thermostats are cost effective and convenient smart home solutions which can be controlled using an internet connection and smart hub device (or using Smartphone app).
- **Traffic Management:** Analyzing traffic over a period of time gives an insight of possible trends and pattern that could occur during peak hours. It will help to inform commuters to take alternative routes to avoid congestion and delay.
- **Pollution monitoring and reporting:** Increasing air pollution is one of the challenges we are facing in every growing cities. In order to solve this issue, smart sensors are deployed across the cities to continuously monitor any changes.
- **Smart Parking Solutions:** Smart sensors installed on parking area are collecting information about availability of parking slots and updating it to the database real time. Once the spot is occupied, it will be updated without any delay.
- **Water / waste management:** Populations in cities are increasing every year, based on statistics this trend will grow in coming years. Increase in population contributes to increase in wastes as well.

2. **Wearable Devices:** Wearable smart devices introduced as smart watches around a decade ago and many more functions were added since then. Now our smart watches and wearable are capable of reading text messages, showing notifications of other apps, tracking location, monitor workout status, remind schedules and continuously monitoring health conditions.

   - With Internet of Things, wearable technology can be used beyond these functions. Major smart wearable manufacturers are developing special operating systems and applications dedicated for smart wearable devices.

Fig 2.1.10: Applications in wearable devices

3. **Healthcare:** Healthcare industry has been utilizing the possibilities of Internet of Things for life saving applications. Starting from collecting vital data from bed side devices, real-time diagnosing process, accessing medical records and patient information across multiple departments, the entire system of patient care can be improved with IoT implementation.

Fig 2.1.11: Applications in healthcare

IoT will offer convenience for medical practitioners, improve accuracy in the information (helps to reduce error in the data), increase overall efficiency and saves time for each procedures.

4. **Autonomous Driving:** Autonomous driving has been evolving with the use of artificial intelligence and smart sensor technology in Internet of Things. Earlier generation of autonomous vehicle (partial automation) will assists drivers to drive safely, avoid collisions and warn about the conditions of the road and vehicle. Example - cruise control assistance, parking assistance, line changing assistance and efficient fuel /energy management etc.

Fig 2.1.12: Applications in driving

5. **Agriculture and Smart farming:** There are lot of challenges in the agriculture and farming industry to produce more crops and vegetable to feed increasing human population. Internet of Things can assists farmers and researchers in this area to find more optimized and cost effective ways to increase production.

Fig 2.1.13: Applications in farming

Internet of Things is one of the promising solutions to make entire agriculture and farming industry more efficient with less number of workers. Smart sensor technology will help improve each stages of agriculture and automation helps to reduce manual labor.

6. **Industrial IoT for manufacturing:** Manufacturing industry is one of the early adopters of Internet of Things which entirely changed several stages of a product development cycle. Industrial IoT will help optimize various stages of product manufacturing such as

Fig 2.1.13: Applications in industrial manufacturing

- Monitoring of supply chain and inventory management
- Optimization in product development
- Automate mass production processes
- Quality testing and product improvement
- Improves packaging and management
- Process optimization using data collected from huge number of sensor networks
- Cost effective solution for overall management of factories

7. **Disaster management:** Internet of Things with wide range of smart sensors allow engineers to build a more effective emergency response system for factories, schools, hospitals, airports and any other public gathering places. Any emergency situations like fire outbreak or flooding will be automatically detected using sensors and this information is shared to responsible work groups in real time.

   During an emergency, fire department, emergency response volunteers, police force, ambulance units and nearby hospitals will receive an alert about the scenario. Automated warning system improves the preparedness and allows authorities to plan and handle any kind of situations immediately.

Fig 2.1.14: Applications in disaster management

   Some of the common sensors: smoke detector, temperature sensor, humidity sensor, CO2 monitoring sensors and precipitation detector.

8. **Logistic and fleet management:** Smart logistics is a complex task since the goods must be handled with greater care and efficiency. Apart from moving from one location to another location, service providers have to make sure perfect condition is maintained during transportation.

   Smart sensors capable of connecting to IoT network continuously monitoring the GPS location, temperature, humidity, shock and tilt angle of the container used for transpiration. Data collected from these sensors are processed and analyzed in a central cloud system.

Fig 2.1.15: Applications in logistics management

9. **Smart grids and energy management:** Smart grid concept is an enhancement of existing power

grids with sensors deployed on the transmission lines and individual customer outlets. Theses sensors helps to notify any failure, abnormality in the line, understand the nature of usage and behavior pattern over time.

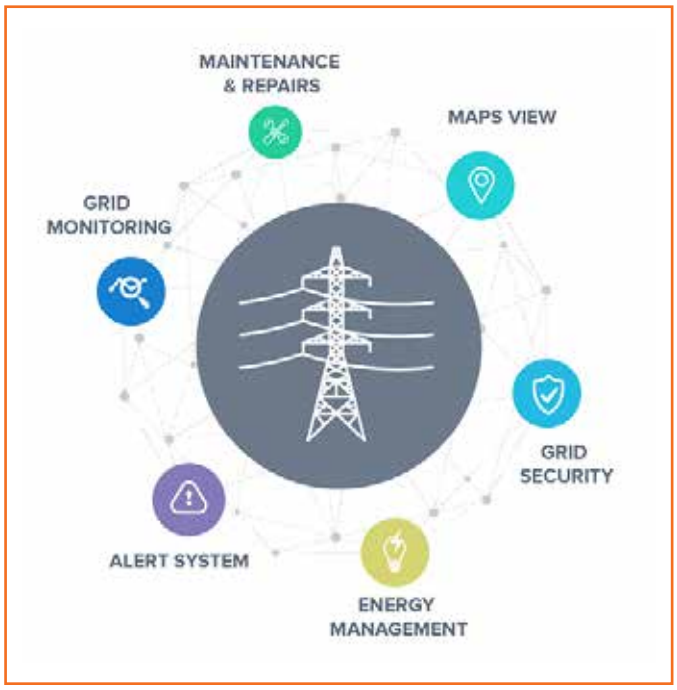


Fig 2.1.16: Applications in energy management

This data can be used to find out areas of improvement, lossy nodes during transmission, and peak time usage statistics with the use of smart meters and sensors. Energy companies can use this information to improve existing grids and implement new changes during upgrade and thus reduce carbon emission.

10. **Big Data Analytics:** One of the basic components of big data analytics is the data itself; many organizations consider data as most valuable asset to grow their business strategies. The source of data could be from anywhere like machines, environment, plants, peoples or even animals.

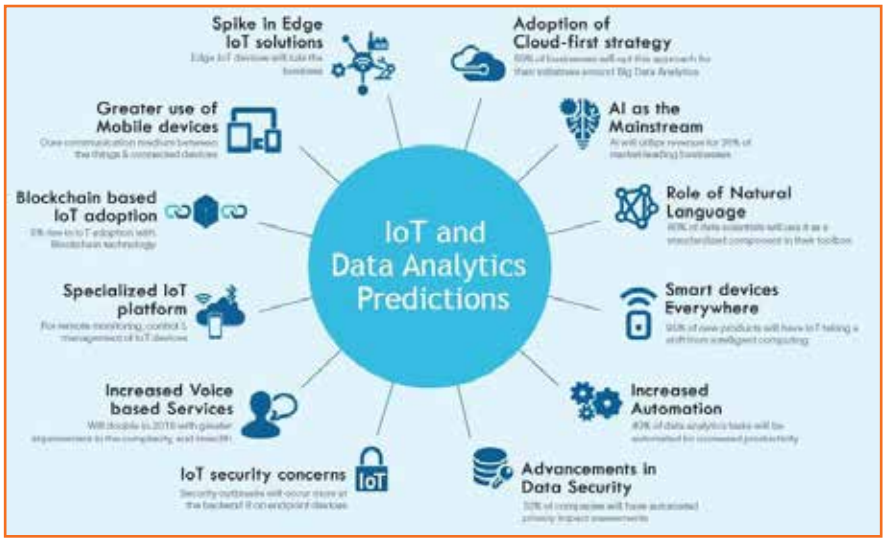


Fig 2.1.17: Applications in Big Data Analytics

Internet of Things uses hundreds of types of sensors designed to collect data from wide range of applications. Huge amount of data from millions of smart sensors will help big data analytics to improve its decision making algorithm using artificial intelligence and machine learning.

Notes

Scan the QR code or click on the link to watch related videos

www.youtube.com/watch?v=Hl6XAHeX9y0
Introduction to IoT

www.youtube.com/watch?v=Zn4ozz3CkhY
Components of IoT

Unit 2.2: IOT Design Requirements and Specifications

Unit Objectives

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

1. Describe IOT design requirements
2. Describe components of IoT design document
3. List requirements of an IoT System

2.2.1 IOT Hardware Design Requirements

IoT forces designers to ask questions they've never before had to face. Rather than thinking about how consumers interact with electronics, it's becoming more and more standard to evaluate how they interact with traditionally tech-less items. In this way, the approaches to PCB design are changing, and with increasing demand for household products to become IoT devices, the importance to minimize reliability and assembly errors is more critical than ever.

The process of creating IoT-optimized products begins with evaluating new form possibilities and from there transitioning into the phases of choosing PCB materials and layouts. Throughout the product design flow, the requirements for assembly into a completed product need to be considered.

When designing a PCB ideal for IoT, few key design areas needed to pay special attention. Here are some of these areas along with tips on making PCB as flawless as possible for IoT use -

- **Size requirements:** Small devices are only getting smaller. PCB designers no longer have extra board layout space in their strategic placement of tracks, vias and components. Now, proper functionality and flexibility in tiny areas are only made possible through HDI and rigid-flex boards. And with these smaller forms, it is more crucial than ever to make sure all IoT product designers are on the same page from the very beginning of the design stage.
- **Product fitting:** In addition to the size of your PCB, you'll want to do enough virtual prototyping to make sure you can easily incorporate the shape of your design into the IoT form it's intended for. Circuits in IoT often will need to fit around non-traditional materials for best functionality, and you may find yourself opting for a mesh or plastic component in your designs that you did not expect.
- **Adapting for the human body:** Another set of qualities that will require thorough simulation tests to optimize are the mechanics that may be affected by human body temperature, moisture and constant movement. Naturally, this is only if the intended final IoT product is wearable or comes in contact with human skin. Pay close attention to thermal effects and aim for a design that will enable sufficient cooling when necessary.
- **Power consumption:** IoT requires a focus on extended battery life and power integrity wherever possible, as these devices are in constant communication with their networks. Energy usage

needs to be kept to a strict budget within the individual circuit blocks on your PCB to help the product as a whole remain in a suitable range of power consumption. The key is to plan power consumption precisely and follow up your plans with thorough testing of the various task cycles of your PCB, including sending and standby power states.

- **Reliability standards:** Industry norms for the trustworthiness of electronic devices are consistently advancing. Flexible circuit boards, for example, have various **"dos and dont's"** associated with ensuring they are reliable enough not to crack in the midst of changing stresses and environments. Consumers want to make sure their devices are operational and will stay accurate over long periods of time. With the pressure designers feel to create products that withstand a myriad of potential conditions, many turn to simulation software to test out their designs.
- **Wireless connectivity:** The internet is in the name of IoT, and being able to access it is a core requirement for any IoT PCB. Collecting and sending data about surroundings will require installing the right wireless modules and RF circuit components. To choose the right parts, you'll want to remember to keep power consumption, network range and speeds, and any security needs in mind.

2.2.2 Design Document for Designing and IoT System

Having well defined, specified, and documented requirements will save you precious time and money in the development and prototyping phase. More importantly, it will help you think about your IoT / hardware product from various perspectives and prioritize features, which will inevitably help you design a better product.

Let's discuss contents for preparing the design document"

1. **Market research and validation of product idea with potential customers:** First highlight the importance of idea validation before specifying the hardware and software of product -
   - Customers feedback and suggestions about the product.
   - Product substitutes in the market!
   - Business Model
2. **Purpose and the functions of product:** It is essential understand and define the exact need and purpose of product. It is generally easier to understand the purpose and functions of B2B hardware products. These are designed to solve a particular business problem, eliminate a specific problem/issue, or cut some process cost down or speed up an operation or a business process, i.e., increase value.

   In B2C product development, it is a bit harder to formulate the purpose/problem, as it is typically tied to a particular feature or a parameter that differentiates your device and makes people want to pay for your product.
3. **Users of product:** This section describes product's user. There can be different types of users for product. For example, for the same hardware product there can be 2 users, for example - an

end-user and a service engineer or a technician, or a hospital patient, and a nurse. Some users of your product may use just the hardware device, and other users will have access to only the software part.

4. **Define use-cases:** With users defined, further describe the use-cases, which are the cornerstone for any design type i.e. electronics, mechanical and industrial. Documenting and describing use-cases may appear to be boring. Still, by getting deeper into the new product development, you will be pushed to write them down yourself, or else you will need to pay an expensive professional design consultancy of a freelance industrial designer to do so.
5. **User scenarios/user stories:** This section enlisted users and use-cases. These are incredibly beneficial in designing product logics and algorithms, which help place the product in the relevant environment and allow you to capture the important user-specific features attributed to your idea, invention, or product.

Now the product definition splits into three major parts:

- Specify hardware requirements in your own way(both the electronics, electrical, and mechanical requirements), or in a PRD format (Product Requirements Document).
- Specify software requirements, in the professional world, are typically referred to as SRS (Software Requirements Specification).
- Towards the end of your product development program, you will need to think of specifying -
  i. Packaging requirements;
  ii. CMF (Colors, Materials, and Finish) includes the desired list of materials, colors, and coatings.

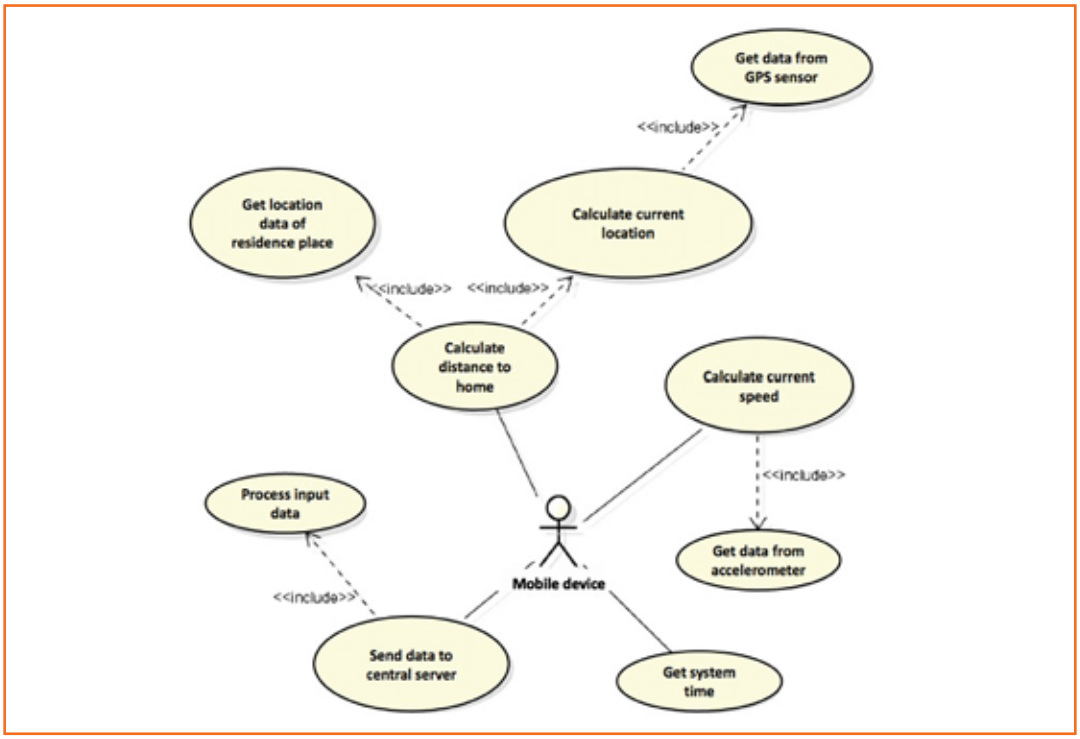


Fig 2.2.1: IoT Hardware requirement specification

The description below focuses on hardware requirements specification.

6. **Features of hardware product:** This section lists hardware features of product. Essentially, you can do this exercise in three consecutive steps -

   i. **Try to list and document ALL the features of your future product:** for both hardware and software.

   ii. Define the most important features or MVP (main parameters/features of value)

   iii. Prioritize all the features from the very important (list MPVs first) to the least important.

7. **How many discrete devices do you have?:** It is quite common that products comprise two or more discrete devices. Let us give you a few examples -

   i. For instance, you are developing a new IoT toothbrush powered by a battery, and you want it to rest and charge on a charging station.

   ii. Or your IoT device and/or IoT sensors use Bluetooth to channel data to a cloud and in order to do it requires an IoT gateway, which is a separate device of its own.

   iii. **A case from e-transport can be relevant here:** when designing an e-scooter or an e-bike, it is important to have a charging station or at least a charger, so the rover can replenish its battery.

8. **Specify future retail price / MSRP:** This section specifies the retail price is tied to your future product's future production cost (COGS - Cost of Goods Sold). The MSRP (Manufacturer's Suggested Retail Price) terms are the **"retail price"** equivalents.

   Knowing the product cost / retail price target is highly beneficial for designers when choosing the right components and optimizing volume production costs. Design engineers usually use the term 'design-to-cost' (DTC), referring to the process of optimizing the development strategy to meet a defined cost and design parameter in the product development process.

9. **Physical constraints - product weight and dimensions:** Estimate and provide the right sizes of product. Specify if it is critical to have small sizes/dimensions. Think about how critical is a small size, as designing miniature electronics adds cost to the design. It takes a lot more time and effort to design a small PCB (Printed Circuit Board) because it is a lot harder for the electronics designer to arrange the components tightly and produce a multilayer PCBA. Not to mention the various noise and interference issues that might arise from densely packed copper layers and components.

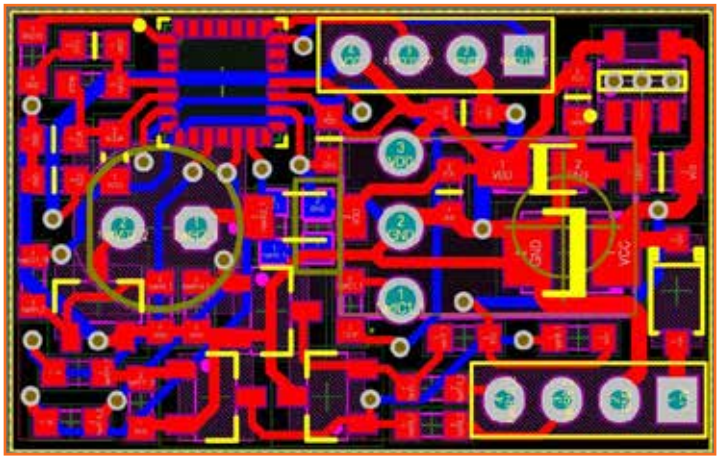


Fig 2.2.2: PCB

Weight and dimensions are obviously important in B2C consumer products, but in designing a

B2B product it is also good to think about it upfront. For example, you should consider how the B2B product will be installed or moved around - will you need to disassemble the wall to mount it in the operational environment?

10. **Operation environment:** Generally, the environment can be indoor, outdoor, or used in water. Water resistance can be an essential but costly feature of enclosure. Designing a waterproof casing is always more expensive when achieving specific IP protection in the prototyping and production validation tests - it requires certain techniques and tricks.

    Temperature and humidity are the other two important factors that impact your future design. While humidity impacts the lifespan of your product and certain measures should be implemented in enclosure design, temperature impacts electronics, and battery performance. For operating temperatures below 0 deg. C (32 deg. F) the designers should implement certain measures to prevent mechanical parts from freezing - add permanent heating for the battery or even consider replacing certain materials that change their physical properties at low temperatures.

11. **How product be powered?: Product can be powered by a limited number of ways:** batteries, power socket, solar. It is more exotic to have a fuel-cell-powered device or pneumo-powered products.

    Li-ion and Li-Poly are the most common rechargeable batteries used nowadays and there can be complications in enabling the IC design (e.g., designing electronics enabling charging from an AC outlet is more complicated than a DC power source) and further certification. It can be a smart move to use a replaceable alkaline or even a Ni - MH battery in your first iteration product, which will save you much time and development costs.

12. **Connectivity and wireless requirements:** Wireless requirements are tied to the use cases of your product. A high transmission rate of your connected hardware product will require a lot of power, and in some cases (e.g., a metallic enclosure), a custom external antenna should be selected or designed.

    The leanest way to enable the connectivity is to pair your device with a smartphone using Bluetooth. But there are other wireless protocols available that serve certain needs depending on your use-case - Wi-Fi, Cellular (2G, 3G, 4G, 5G, LTE, GSM, etc.).

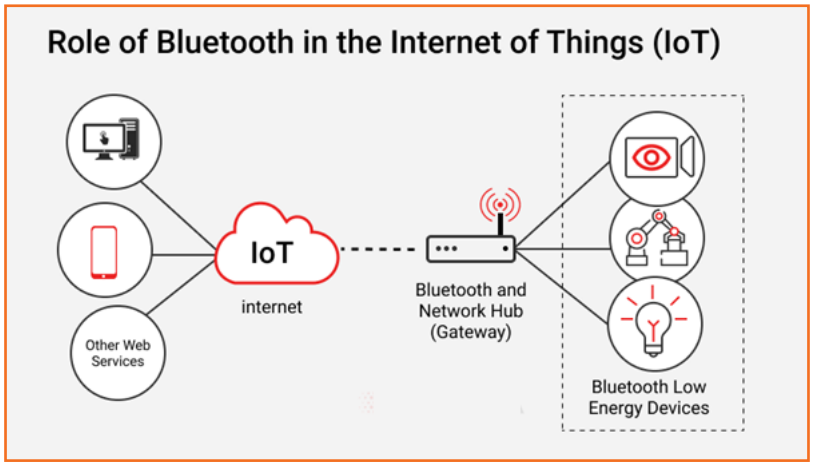


Fig 2.2.3: Role of bluetooth in IoT

13. **Sensor requirements for an IoT connected product:** With the advances in semiconductor and material science technologies, there exists a whole range of sensors that one can employ to deliver the main functions of a particular IoT product. These include -

- GPS/BEIDOU/GLONASS,
- Various accelerometers and gyroscopes,
- Pressure sensors,
- Compass (magnetometer) and
- Magnetic field sensors,
- CO2 (carbon dioxide) and CO sensors,
- Temperature and pressure sensors,
- Humidity sensors.

Medical (IoMT) devices can have

- HRM (Heart Rate Monitor),
- EKG sensor,
- blood oxygenation sensor.

Modern consumer and wearable products require fingerprint and touch sensors, and there can be many more.

Remember that each sensor technology has intrinsic limitations in terms of accuracy. So it is highly beneficial to specify whether the data acquired from any type of sensor should be highly accurate, precise, or rather be qualitative.

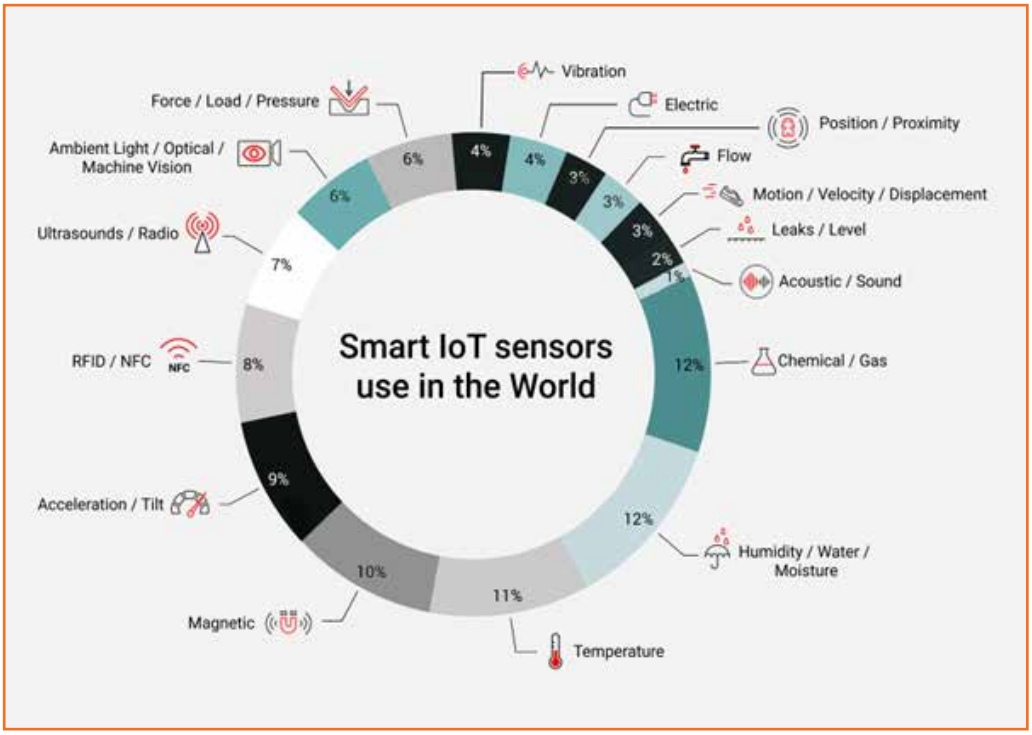


Fig 2.2.4: Smart IoT sensors available

14. **Processing capacity: There are four options to choose from:**

    i. Microcontroller (MCU),

    ii. Chips,

    iii. Microprocessor

    iv. FPGA.

    MCUs and chips are the typical choices for an IoT device and in 85% of the cases, one can easily get away with a cheap and reliable MCU in their design. Microcontrollers are used for low computation capacity for the data arriving from various sensors.

    Chips can be viewed as miniature versions of the MCUs, incorporating some functionality of both the microcontrollers and auxiliary components like BLE, GPS, cellular, etc. Using chips is highly beneficial in wearables design, but it is sometimes forbidden as chip vendors are not willing to provide documentation and SDKs for these chips if one is not planning to place an order of 1 million chips upfront. However, in recent years some chip providers lowered the entry barrier for low volume chip procurement (such as the very popular Nordic Semiconductors) and provide very good documentation and development kits for their chips.

    Microprocessors find a very particular application when one needs high computation capacity, such as real-time processing of large amounts of data from sensors or any sort of video-processing (such as in machine vision or for hardware-enabled AI/ML). You can also think of a microprocessor as a microcomputer that runs a Linux embedded, Android, or Windows operating system.

15. **Display:** The display will be one of the most expensive components in BOM and will drive unit cost. The display will be consuming most of your power budget and will drain your portable device's battery - so think about how big your display should be and what colors it should have (e.g., LCD or LED). Describe what information you want to show on your display - is it just text lines, or would you like some graphical information, pictograms, or even video to be shown?

Fig 2.2.5: System display

    In some cases, it may be a good idea to replace an expensive LED/LCD display with a few simple and cheap LED indicators.

16. **Specify enclosure design and product appearance:** This section define and describe the appearance of enclosure upfront is highly beneficial for the design engineer or industrial designer.

17. **Specify moving mechanical parts:** Designing moving mechanical parts can be tricky. If product have any moving parts or features (fans, gears or lids), or if product is foldable, this section specify that and envision the scenarios of these mechanical features as it might bring an R&D component into your product development program.

Notes

Scan the QR code or click on the link to watch related videos

https://www.youtube.com/watch?v=nw_O23o6Dr0

IoT design methodology

Skill India
कौशल भारत-कुशल भारत

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

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

3. Process of Designing Circuit and PCB Layout for the IoT System

ESSCI
Skilling India in Electronics

Unit 3.1 – PCB Layout Designing for IoT System

Unit 3.2 – Building Prototype of PCB Design

ELE/N1408

Key Learning Outcomes

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

1. Describe PCB development process
2. Demonstrate PCB layout designing process
3. Describe need of building prototype of PCB design
4. Demonstrate procedure of building prototype of PCB design
5. Demonstrate testing of prototype

Unit 3.1: PCB Layout Designing for IoT System

Unit Objectives

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

1. Describe PCB development process
2. Demonstrate PCB layout designing process

3.1.1 PCB

A printed circuit board (PCB) is a flat plate or base of insulating materials that contains a pattern of conducting material and components. PCB provides mechanically support and electrically connect electronic components using conductive pathways, tracks usually etched from copper sheets laminated onto a non-conductive substrate. Components are fixed in position by drilling holes through the board, locating the components and then soldering them in place.

Different kinds of PCBs available are:

1. Double / Single Sided
2. Flexi
3. High Layer Count Multilayer
4. Controlled Impedance
5. Microwave and RF
6. Aluminum backed PCBs

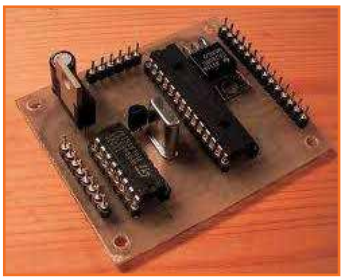


Fig 3.1.1: Single sided PCB

Single sided PCB:

Single-sided PCB are usually a single layer of copper on a rigid base material. This type of PCB can be used for both through hole and SMD components

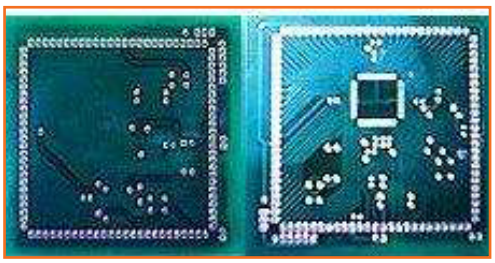


Fig 3.1.2: Double sided PCBs

Double sided PCBs:

It consist of two copper layer on a base material, the two copper layers are not connected. This type of PCB can also be used for both through hole and SMD components. Usually they are connected through vias.

Flexible PCBs:

Flexible PCB's are being used where flexibility matters in a large number of different applications

Advantages of flexible PCBs are as follows

Fig 3.1.3: Flexible PCBs

1. Solving interconnecting problems
2. Reduction of weight
3. Reduction of space and reduced assembly costs.

Applications include:

- Dynamic flexing applications like in slide mobile phones etc.
- Flexing or stress over a period of time at elevated temperatures.

Multi-layer PCB:

In multi-layer PCBs we would be having multi traces on a substrate or a clad. The multilayer PCB is also very useful in high-speed circuit. The multi-layer PCB can provide more space for the conductor pattern and power.

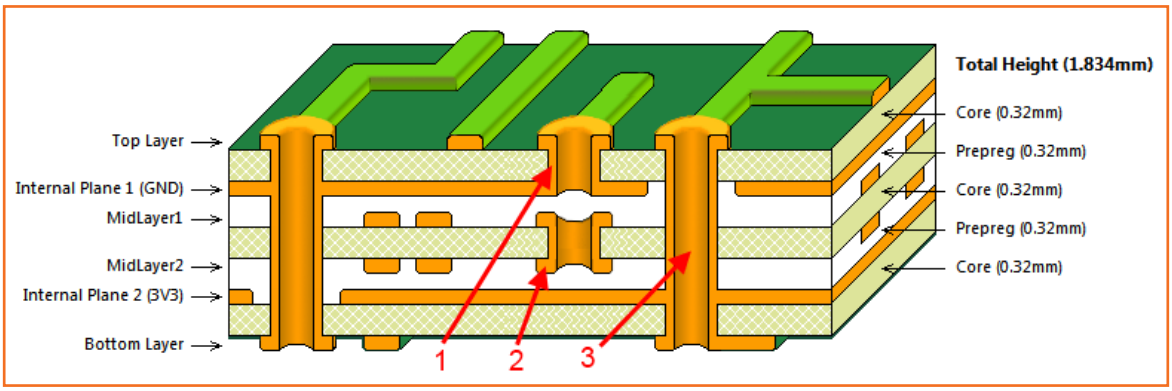


Fig 3.1.4: Multi-layer PCBs

Controlled Impedance printed circuit boards

These are used across a broad range of applications to help ensure high signal integrity. PCB traces need to be considered not as simple connections but as transmission lines .

The impedance of a PCB trace is controlled by its configuration

- Dimensions (trace width and thickness and height of the board material)
- Dielectric constant of the board material

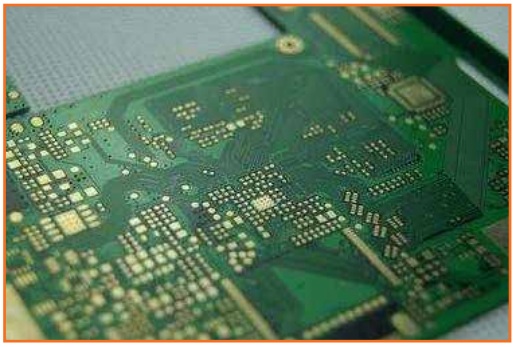


Fig 3.1.5: Controlled Impedance printed circuit boards

Aluminium Backed PCBs

Aluminium backed PCB's are now being used in place of traditional PCBs for high power LED applications. This is due to rapidly changing developments in LED technology, with brighter more powerful LED's coming on to the market all most daily. This raised a problem to designers and PCB manufactures with larger amounts of heat being generated by the components to overcome this problem they developed aluminium backed PCBs.

Aluminium backed PCB with the use of thermally conductive pre-preg between the copper and the aluminium the thermal performance is 8–10 times better than a normal PCB.

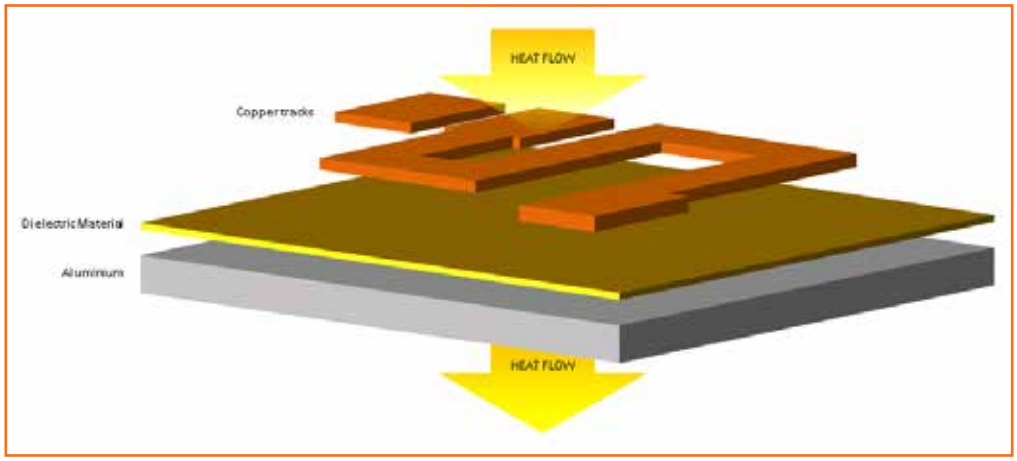


Fig 3.1.6: General composition of an Aluminium single Sided PCB (SMI)

RF and microwave PCBs

Usually RF and microwave PCB need to be designed where Dielectric Loss, Resistive Loss and Skin Effect are parameters, these Can be High at Frequencies Above 500 MHz. To prevent this we need to go for microwave PCBs.

3.1.2 PCB Development Process

The PCB development process consists of three stages:

Design ⇒ Build ⇒ Test

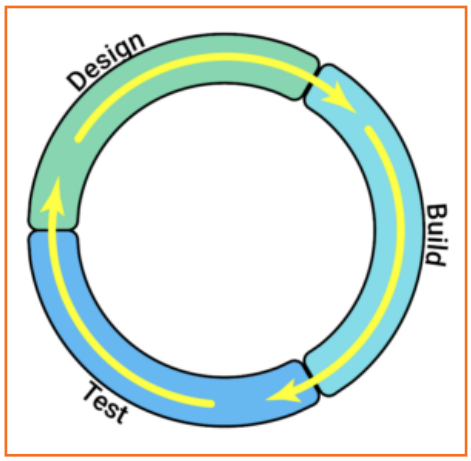


Fig 3.1.7: PCB development process

- **Design:** This initial stage includes drawing the schematic, selecting components, creating the PCB layout, and generating the design file(s), while BOM defines the intent of the design.
- **Build:** During this stage, which follows design for constructing the board. This is a two-step procedure that consists of board fabrication and PCB assembly. The result is the physical display of design.
- **Test:** Once board is built, PCB design testing needs to be done. First, operation and performance must be checked. Once the functionality is confirmed, regulatory compliance may need to be assured through additional testing.

For prototyping of PCB development, this sequence is repeated and the design is continually refined until all errors are removed and performance validated. This iteration cycle is essential to achieve the best design.

3.1.3 PCB Design Process

From the initial drawings to the final files, here are the 9 steps toward designing a printed circuit board -

1. **Understand the electrical parameters**

   Before starting a PCB design, you should know and understand the electrical parameters of the system, including -

   - Maximum current
   - Voltages
   - Signal types
   - Capacitance limitations
   - Impedance characteristics
   - Shielding considerations
   - Type and location of circuit components and connectors
   - Detailed net wire listing and schematic

2. **Creating the schematic**

   Everything that gets built needs a blueprint, and for a circuit board that blueprint is the schematic. A schematic is a logical representation of the electrical connections between various electronic components of the circuit board to be built and uses industry-standard symbols and notations to represent different components and their values. Each physical component that gets used on a circuit board, such as a resistor, will have an identifying symbol representing that component on the schematic.

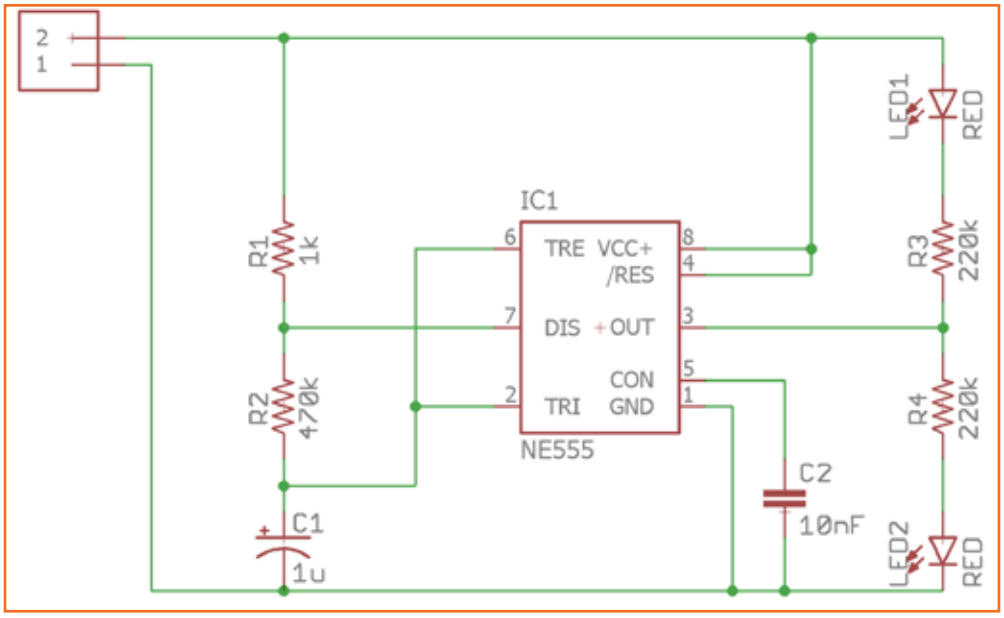


Fig 3.1.8: Schematic diagram

The schematic is created in an electronic CAD system specifically made for designing printed circuit boards. Each logical symbol will have one or more pins on it to represent the actual pins of the real component which will eventually be reported in the bill of materials. The PCB designer will place these symbols onto a schematic sheet within the CAD system, and then draw lines

between the pins to connect them together. This connection is referred to as a net, and a net will have two or more pins all connected together.

Verify the following in a schematic:

- Verification of labels and pin numbering in component symbols
- Polarity check for all the polarized components
- Overlapping labels and pins
- Validation of the component value, location and reference designators
- Description of the schematic symbols
- Decoupling capacitor check for all ICs, ground pin separation according to the signal type i.e. analog or digital
- Netlist check for design correctness and wrong connections

3. **Use a schematic capture tool to create PCB layout**

To develop a schematic, select a right software platform, which shows you exactly how the board will operate and where the components will be placed. Once schematic is ready, load the design and determine how it will fit in the intended device.

4. **Design PCB stackup**

This is important to consider early on in the PCB design stage due to impedance, which refers to how much and how quickly electricity can travel down a trace. The stackup is an important attribute if PCB design. It defines the structure of a multilayer circuit board in a sequential manner. Stackup provides information about the material thickness and copper weights which is vital for circuit board manufacturing.

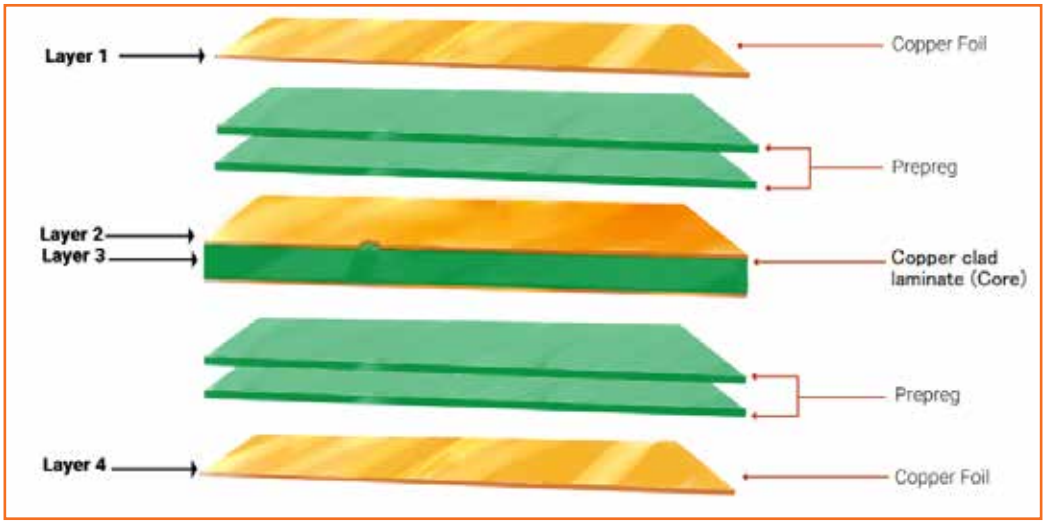


Fig 3.1.9: Design PCB stackup

It is important to know the controlled impedance of requirements, including the number of differential pairs, as it will impact the number of layers in board. The routing density of the circuit board will also impact the number of layers.

5. **Define design rules and requirements**

Once all of the symbols are placed and the nets are connected in the schematic, the circuit board is ready for physical design in a process called **"PCB layout."** The component information from the schematic symbols as well as the net connectivity will all be converted into the data needed for PCB layout. There are a number of other steps that also have to be done however before layout can begin -

- **Library parts:** Models of the physical components, such as a resistor, need to be created within the layout tools. These models are referred to as footprints or land patterns, and will contain a representation of the metal pad that the component pins will eventually solder too. They will also contain the shape of the component as well as specific electrical, pin, and 3D data.
- **Design rules:** The PCB layout must be completed without any of the nets coming in contact with each other, or else those nets would be shorted together when the board is built. To prevent this, PCB design CAD tools have extensive rules and constraint systems built into them to govern the size and spacing of metal objects. These rules must be completely set up or copied from a previous design before the layout begins.
- **Board outline:** The physical shape and structure of the circuit board also need to be set up in the layout database. This requires creating the outline of the board in the CAD system and setting up how many layers the board will have in it and in what order they are to be stacked up.

This step is largely dictated by standards and acceptability criteria from the IPC, which is the industry association for PCB and electronics manufacturing. These standards tell everything you need to know regarding PCB manufacturing.

Once these steps are complete, the design is ready for layout.

6. **Placing components**

It is easier to create footprints of few components when they come in standardized packages. In some cases, the footprints of standard packages are available in software's library, otherwise you to create it based on the data sheet of the component.

To identify the correct pattern and its landing pattern, it is essential to use the numbering key accurately from the data sheet.

The following example shows and example of a numbering key and a variety of footprints.

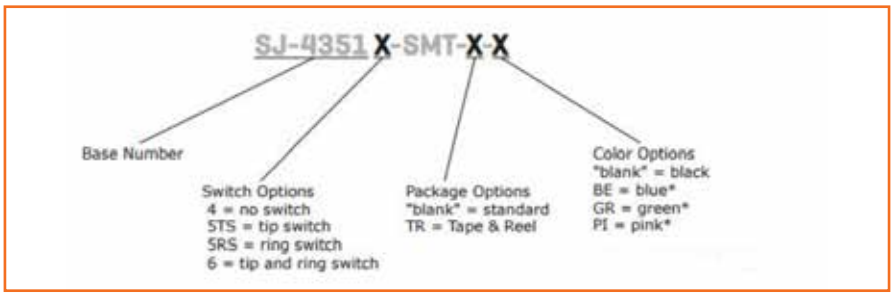


Fig 3.1.10: Footprint

The symbols that were placed in the schematic are now associated with the PCB footprints in the layout database to become PCB components. Now place these component footprints on the board in the CAD system, usually in the following order -

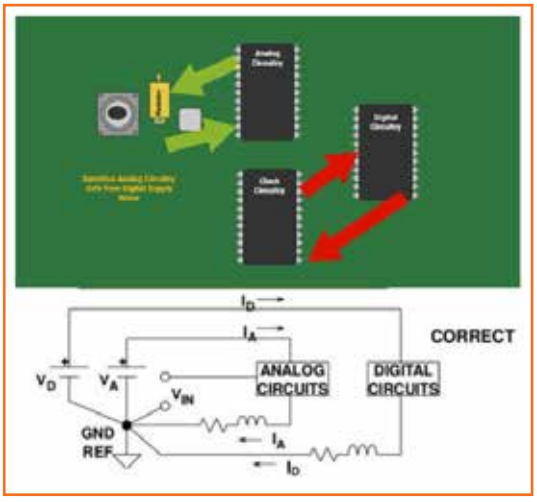


Fig 3.1.11: Schematic footprint

i. **Fixed parts:** Components such as connectors, switches, or other mechanical parts are usually required to be in a specific location and should be placed first. This ensures that they will mate correctly with plugs or openings in the system enclosure. Once these fixed parts are placed in the layout database, the remaining parts can then be placed in order from them.

ii. **Critical parts:** Microprocessors, memory chips, power supplies, or other main components of the board are usually the next parts to be placed. They need to be placed close to the fixed parts that they are associated with yet with enough space to place other parts around them. It is also important to balance the needs of circuit performance with thermal management when placing these components.

iii. **Supporting parts:** Power supply components will have additional parts associated with them, as will microprocessors and memory devices. These supporting parts are often discrete components such as capacitors, resistors, and inductors, and they must be placed close enough to work directly with the critical parts.

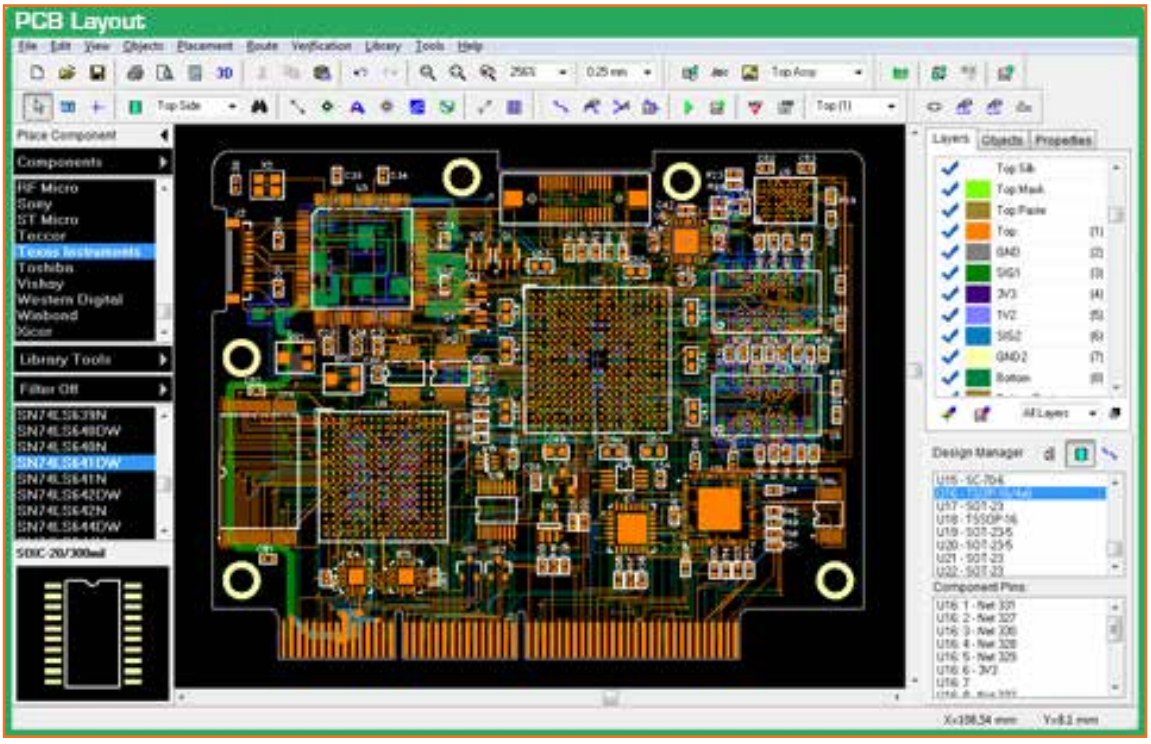


Fig 3.1.12: PCB layout

iv. **Remaining parts:** The final parts in the layout may not necessarily support a critical part directly, but their placement may still be important for the correct functioning of the overall circuit. These could include terminating resistors or bulk decoupling capacitors.

Another critical aspect of component placement is making sure that the board can be manufactured without any errors.

7. **Insert drill holes**

This step is driven by the components and a connection. About half of the flex circuits on the market are double-sided, which means they have connection to the drill hole on the bottom layer.

8. **Route the traces**

With the components in place, the next step is to connect the nets between the pins in a process known as trace routing. These traces will ultimately become the metal connections in and on the circuit board when it is fabricated. The PCB Design CAD system will display the unconnected nets as straight lines, and the designer will use one of many different routing features in the CAD system to create the trace routing -

- **Manual routing:** All design tools give the user the ability to pick one of the nets, and draw its trace in manually. This is done using straight or curved lines, right angles, or placing a hole in the board called a via to transition to another layer.
- **Semi-automated routing:** Many CAD systems give their users various versions of automated routing. These different features may route a signal net, a portion of a net, or groups of nets at the same time.
- **Auto-interactive routing:** These specialized features combine manual routing with automated functionality. This gives the user the ability to direct where they want the routing to go, but rely on the system to do the actual routing and adhering to signal integrity rules. These features are useful for pushing other traces out of the way, and winding through dense areas of routing that would take a lot of manual effort to complete.
- **Batch auto-routing:** These tools will automatically route the entire board for the user. Care has to be exercised though because the CAD system may not always yield the desired results. Here is where the experienced designer will pre-route areas by hand first, and set up a complete list of routing rules before using the auto-router.

While some nets can be simply connected together, the majority of nets may have specific rules that have to be followed. These can include the trace width, what layer they are routed on, areas of the board to avoid, and their length. In some cases, trace lengths have to match other trace lengths, while other traces may have to be routed tightly together in pairs. All of these requirements can be set up in the initial design rules.

Another important part of connecting nets together is the use of large areas of metal called fills, planes, or poured copper. Large areas of metal for the power and ground nets provide a simple way to connect various components to those nets. In addition, most designs will use the ground planes for a return path for the signals that are conducted through the trace routing. Here again,

is where the skill of the designer becomes very important. These planes must be designed to provide adequate power and ground coverage, a clean signal return path, EMI shielding for the traces, and thermal dissipation for hot components.

At this point, the circuit board is fully placed and routed, but there is still more work that has to be done.

9. Add labels and identifiers

Now is the time to add any labels, identifiers, markings, or reference designators to the layout. Reference designators are helpful in showing where specific components will go on the board.

10. **Generate design/layout files**

Although the circuit board is functionally complete at this point, there are still some additional tasks that need to be done before it can be manufactured -

- **Test:** To verify the assembly process and the functionality of the board, the completed board will be run through a variety of testing. Test points must be assigned during layout to create the test documentation needed to create the test fixtures.

  Keep an eye on the following:

  - ❑ **Board side:** All test points should be located on the same side of board to facilitate testing.
  - ❑ **Minimum test point distance:** The minimum distance between test points is 0.100 inches. It maximizes test effectiveness.
  - ❑ **Test point distribution:** Distribute test points evenly on circuit board to make testing easier.
  - ❑ **Area for taller components:** Designating the area for taller components can streamline the testing.
  - ❑ **Manufacturing tolerances:** Consider manufacturing tolerances while designing a layout to accommodate space for test points.
- **Silkscreen:** In order to identify the completed board and its components, ink markings and reference designators are silk-screened onto the board. The silkscreen layer is prepared in the CAD system as one of the last steps of the PCB layout.
- **Drawings:** Fabrication and assembly drawings are also created by the designer using the PCB design tools. These drawings give detailed instructions on how to manufacture the circuit board.
- **Final manufacturing files:** All of the circuit board image files, drawings, test files, and other documentation will be gathered into one set of manufacturing files for the PCB contract manufacturer.

3.1.4 PCB Design Issues

The most basic form of design for manufacture as it applies to PCBs is the use design rules and design rule checking in PCB design software. Design rule checking (DRC) is the process of looking at a design to see if it conforms to the manufacturing capabilities of a PCB fabricator. Design rule checks are commonly integrated into PCB design software and are not typically considered as add on service. More advanced design for manufacture analysis software is also available to look for more complex and less obvious design flaws.

1. **Starved thermals:** Starved thermals occur when the thermal relief traces connected to a pad are not properly connected to the associated copper plane. Quite often, the spacing between vias will pass a basic design rule check, but the attached thermal relief traces will be interrupted and the effected vias will be inappropriately isolated from their assigned copper pours. This issue is most commonly seen when multiple vias are placed in proximity to each other.
2. **Acid traps:** When two traces are joined at a highly acute angle it is possible that the etching solution used to remove copper from the blank board will get **"trapped"** at these junctions. This trap is commonly referred to as an acid trap. Acid traps can cause traces to become disconnected from their assigned nets and leave these traces open circuited. The issue of Acid traps has been reduced in recent years by fabricators switching to the use of photo activated etching solutions. So, while it is still a good idea to make sure that your traces do not meet acute angles, the issue is less of a worry than it had been in the past.
3. **Silvers:** If very small portions of a copper pour are only connected to larger portions of the same copper pour through a narrow trace, it is possible for them to break off during fabrication, **"float"** to other parts of the board and cause unintended shorts. The problems presented by silvers have been reduced in recent years by fabricators switching to the use of photo activated etching solutions. So while silvers are still to be avoided in designs, they are not as predominate of an issue as in the past.
4. **Insufficient annular ring:** Vias are made by drilling through pads on either side of a board and plating the walls of these holes to connect the two sides of the board. If the pad size called out in the design is too small, the via may fail due to the drill hole taking up too large of a portion of the pads. Minimum annular ring size is commonly part of the DRC process. This issue is mentioned here because of the not uncommon occurrence of missed drill hits in prototyping boards.
5. **Via in Pads:** Occasionally it may be convenient to design via to be positioned within a PCB pad. However, via in pads can cause issues when the time comes for the board to be assembled. Via will draw solder away from the pad and cause the component associated with the pad to be improperly mounted.

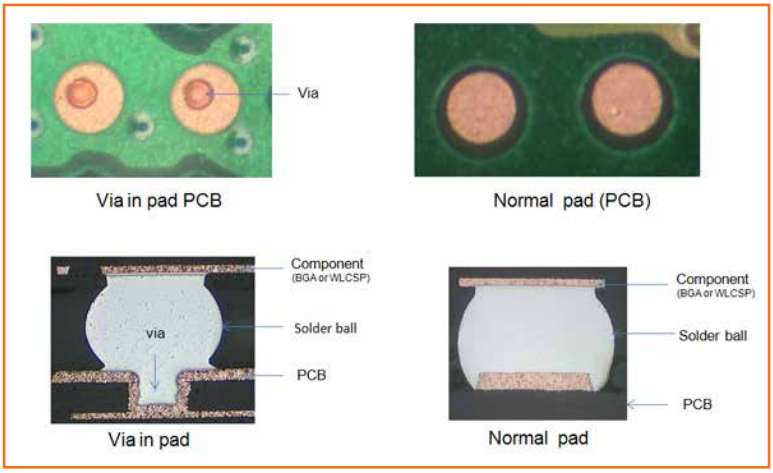


Fig 3.1.13: Via in Pads

6. **Copper too close to board edge:** Normally caught during design rule checks, placing copper layers too close to the edge of a board can cause those layers to short together when the board is cut to size during the fabrication process. While this sort of error should be caught using DRC features typically available in PCB design software, a PCB fabricator that does a DFM check will also catch this issue.
7. **Missing solder mask between pads:** In very tightly spaced, small pin pitch devices, it is quite common for there to be no solder mask between pins due to standard design settings. The omission of said solder mask can lead to solder bridges forming more easily when the fine pin pitched component is attached to the PCB during assembly.

Fig 3.1.14: Missing solder mask between pads

8. **Tombstoning:** When small passive surface mount components are soldered to a PCB assembly using a reflow process, it is common for them to lift up on one end and **"tomb stone"**. Tombstoning can greatly affect PCB yields and quickly drive up production costs. The source of tombstoning can be incorrect landing patters and imbalanced thermal relief to the pads of the device. Tombstoning can be effectively mitigated by the use of DFM checks.

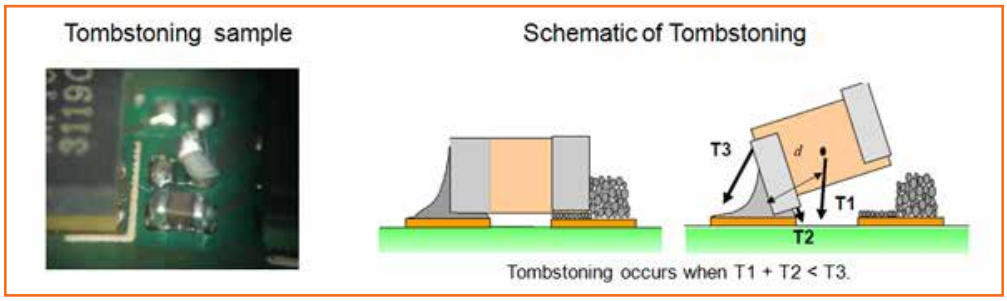


Fig 3.1.15: Tombstoning and schematic tombstoning

PCB Designing Tools

To design these kind of PCB we need some software. these kind of software's are know as computer aided software tools.

Some of the popular tools available are:

- EAGLE(Easily Accessible Graphical Layer Editor)
- Ki Cad
- Orcad
- Dip Trace
- Altium designer
- DX Designer
- Ares

Factors a PCB designer should keep in Mind:

1. PCB designers are key persons in research and development (R&D), electronics production units as well as in the PCB industry. It's not only about making interconnections between electronic

components but also understanding the functioning of the circuit.

2. He/she should have a strong knowledge on type of circuit and tools using for designing
3. Understanding of the functioning of an electronic circuit.
4. Knowledge of IPC/Mil standards.
5. Know the process of PCB manufacturing, assembling and testing.
6. Good knowledge of various electronic components' packaging.
7. Know about different PCB base materials.
8. Able to interact with circuit designers, PCB manufacturing and assembling team.
9. Knowledge of EMI/EMC

3.1.5 PCB Layout Designing on Software

When designing a circuit board make sure you have the right circuit board design software.

Laying out traces for routing and copper placement, or managing the layer needed for solder can become difficult without an accurate and reliable integration from schematic capture to layout.

Steps for designing layout on software:

1. **Schematic Capture:** When generating circuit board design from a template or creating printed circuit board from scratch, it is probably best to begin with the schematic. It is similar to the blueprints of new device or system. First, your schematics show you the following -
    - Which components are used in circuit board design
    - How components are connected together
    - The relationships between groups of components in different schematics

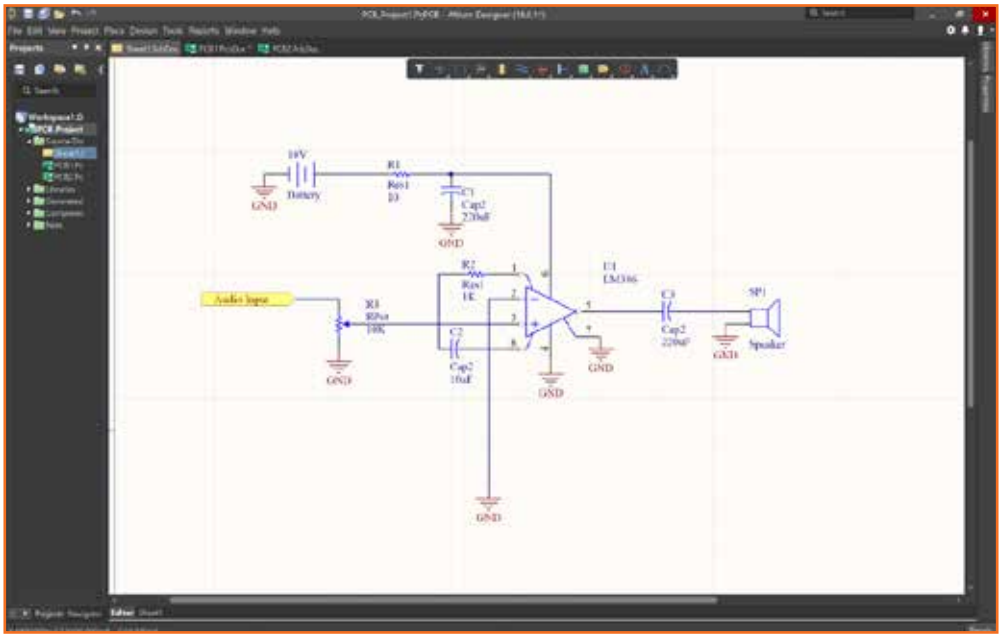


Fig 3.1.16: General circuit board template

In software, not only is circuit interconnectivity easier to define and edit, but converting a schematic to a circuit board layout is much easier than designing directly on the board. For components, use extensive database of parts libraries in the software. It provides access to thousands of component libraries and adds flexibility to your design. However, you can also design your own schematic symbols and create footprints. Or, if you would like to take advantage of pre-existing component footprints, try using the Manufacturer Part Search Panel.

It's also important to annotate your schematics, as well as name nets when schematics get large and complex. As higher pin count devices are added to schematics, you can use net name assignments to keep things organized and easily track connectivity between components. Using net names is also helpful once you're in the PCB layout as you'll be able to quickly identify nets during placement and routing. This will also help once you go to test your finished prototype as you'll be able to quickly track nets in the corresponding PCB layout in software.

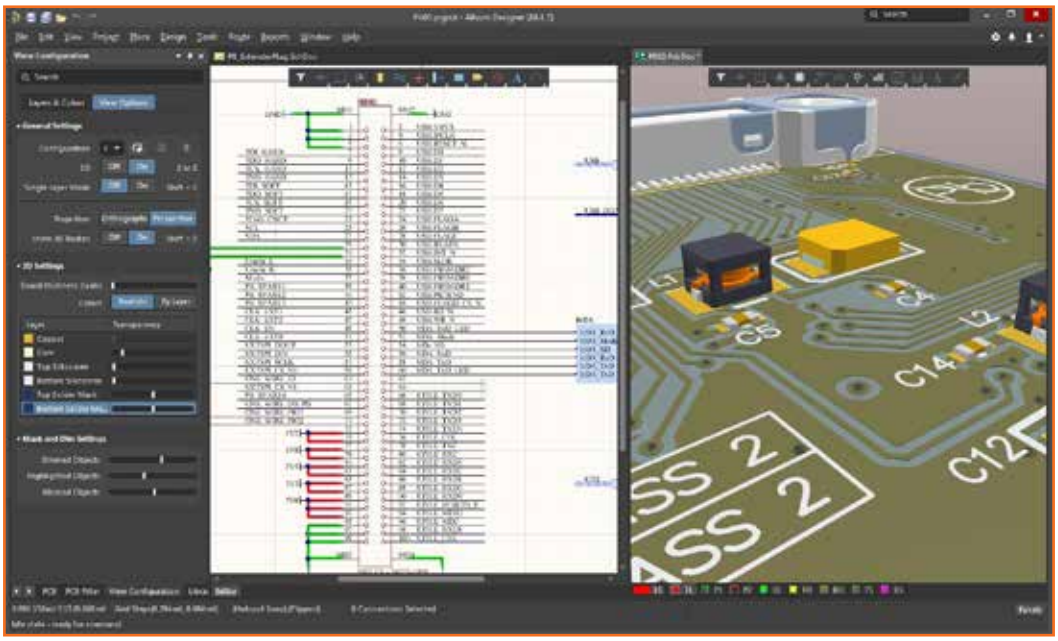


Fig 3.1.17: PCB layout in software

2. **Create a Blank PCB Layout:** After you've created schematic, now use the schematic capture tool to import components into a blank PCB layout. First, create a blank printed circuit board document which will generate a PcbDoc file. This is done from the main menu in, as shown below.

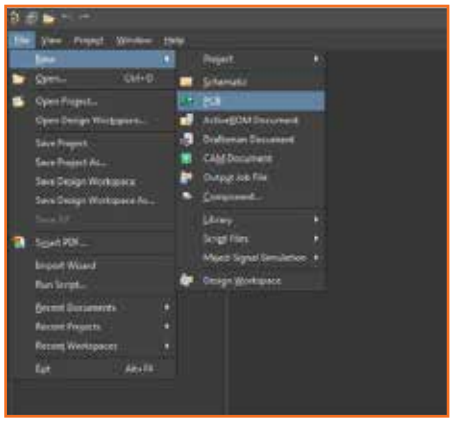


Fig 3.1.18: PcbDoc menu

If the printed circuit board shape, dimensions, and layer stackup for your board have already been determined, you can set them now. Schematic information is made available for the PcbDoc by compiling the SchDoc. The compilation process includes verifying the design and the generation of your several project documents that allow you to inspect and correct the design prior to transfer to the PcbDoc, such as those shown below. It is highly recommended that you review and update

the Project Options at this point, which are used to create the PcbDoc information.

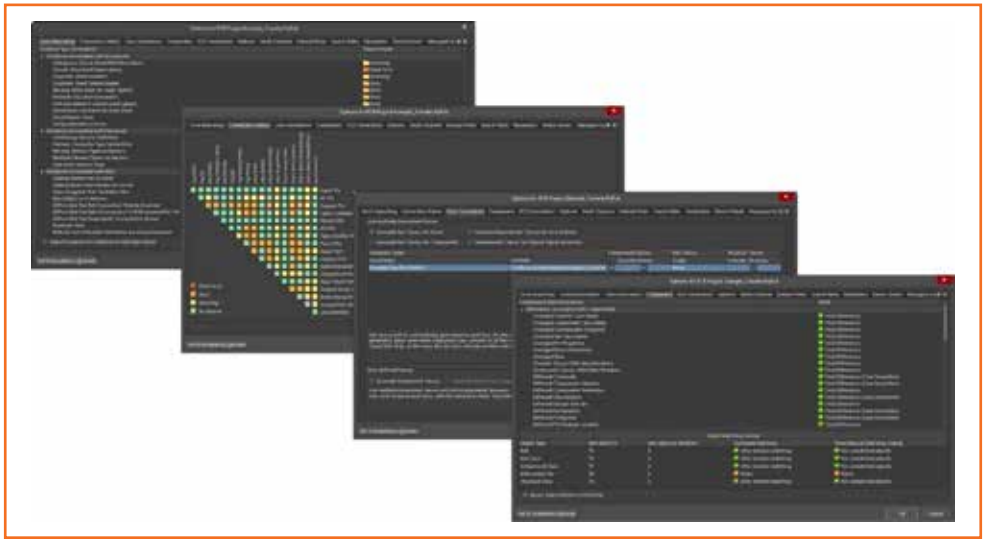


Fig 3.1.19: PcbDoc information

3. **Synchronize Schematics to Your PCB Board Design:** All the tools in software work in a united design environment, where the schematic, printed circuit board layout, and BOM are interlinked and can be accessed simultaneously. To transfer SchDoc information to the newly created PcbDoc, click on Design » Update PCB {Filename of your new PCB}.PcbDoc. An Engineering Change Order (ECO) dialog will open listing all components and nets from the schematic, similar to the one below.

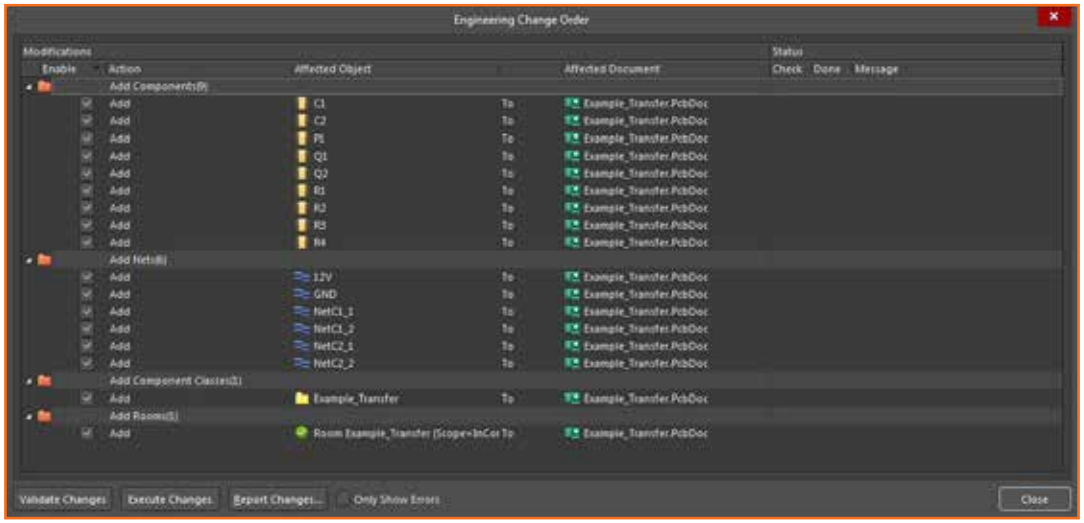


Fig 3.1.20: Synchronize Schematics to Your PCB Board Design

Verify the changes (addition of the SchDoc information to the project without error) by clicking on the Validate Changes tab. If the status for all items is green, then click on the Execute Changes tab. To complete the process, close the dialog.

4. **Designing PCB Stackup:** When you transfer schematic information to the PcbDoc the component footprints are shown in addition the board outline specified. Prior to placing components you should define the PCB layout (i.e. shape, layer stackup) using the Layer Stackup Manager, shown below.

You can also take advantage of the Materials Stackup Library; this lets you choose from a range of different laminates and unique materials for your printed circuit board.

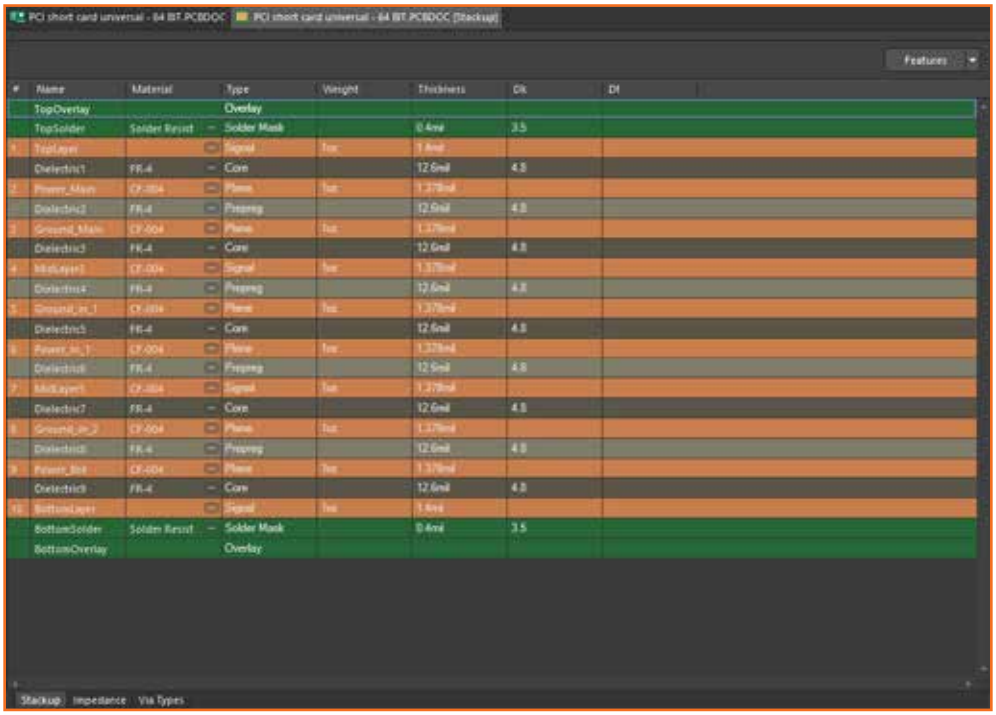


Fig 3.1.21: PCB layout layer stackup

If you're working on a high speed/high frequency circuit board design, you can use the built-in impedance profiler to ensure impedance control in your board.

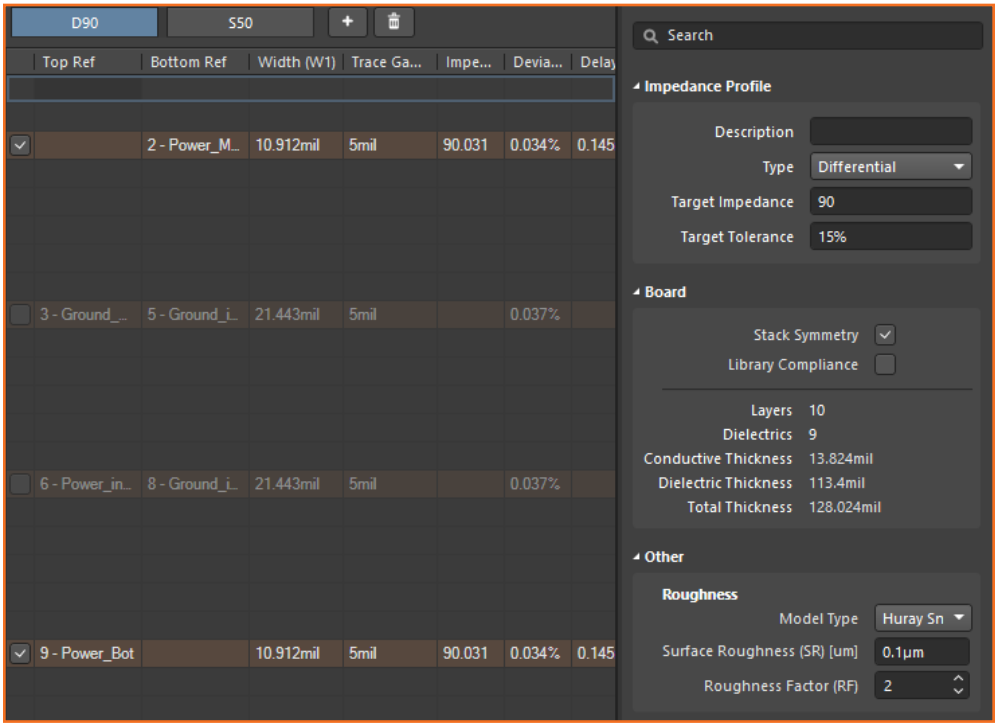


Fig 3.1.22: impedance control

Make sure you decide the routing style before you start calculating impedances.

For example, will you be using a coplanar line on a thicker dielectric layer, such as in this example, or will you be using a standard microstrip/stripline on a thinner dielectric? These choices are important because they affect the trace width you can use in the circuit board design; different routing styles will enforce different trace widths in order to hit your required impedance.

Also note whether you'll be using any differential pair routing in the design. The impedance solver in the Layer Stack Manager enables differential pair solutions as well as single-ended, so you can determine both requirements and use these when routing. After the layer stack is created and any impedance profiles are determined, it›s time to set up your circuit board design rules so that you can start placing and routing components.

5. **Defining PCB Board Design Rules and DFM Requirements:** The number of PCB board design rule categories is extensive and you may not need to use all of these available rules for every design. You can select/deselect individual rules by right clicking on the rule in question from the list in the PCB Rules and Constraints Editor, below. Your PCB board design rules are divided into several categories, which includes -

   - Clearances between objects in the PCB layout, such as between traces and pads
   - Copper or solder mask feature size limits, such as holes and solder mask slivers
   - Routing rules, including trace width and length limitations that can be enforced on certain nets
   - High speed and signal integrity limits, such as overshoot
   - Board fabrication limits and clearances, such as board edge clearance

   This is just a sample of the rules that can govern any PCB layout, but these rules are designed to help ensure a board is manufacturable at the required scale with your fabricator's standard capabilities.

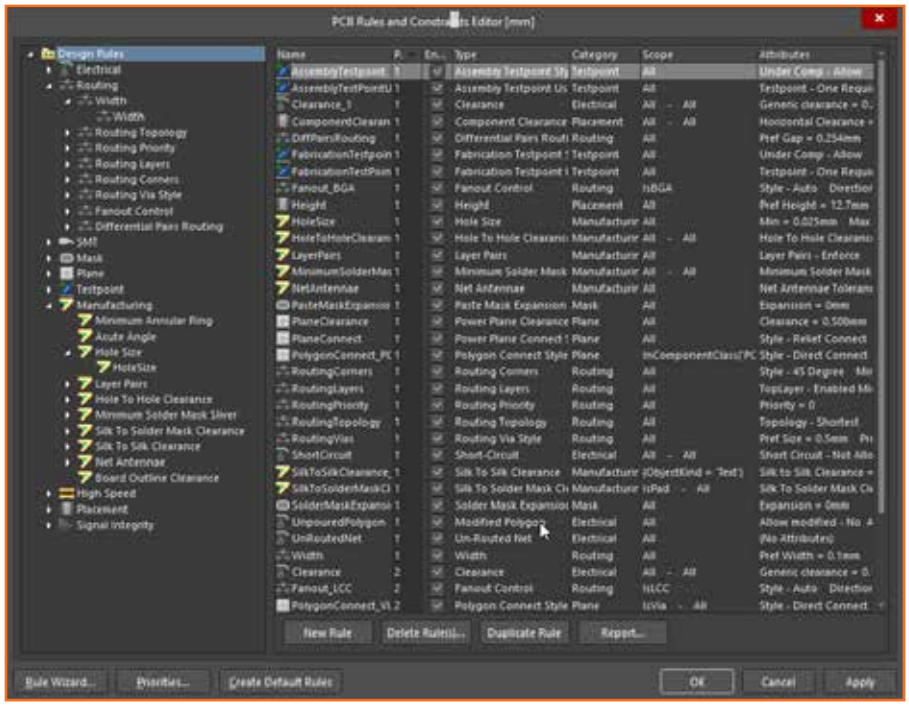


Fig 3.1.23: Defining PCB Board Design Rules and DFM Requirements

The rules that you do use, especially for manufacturing, should be inline with the specifications and tolerances for PCB board manufacturer's equipment. Advanced circuit board designs, such as impedance controlled designs and a number of high speed/high frequency designs, may require very specific design rules that need to be followed in order to ensure your product works properly. Always check your component datasheets for these design rules. If necessary, you can create new circuit board design rules by following the steps of Design Rule Wizard.

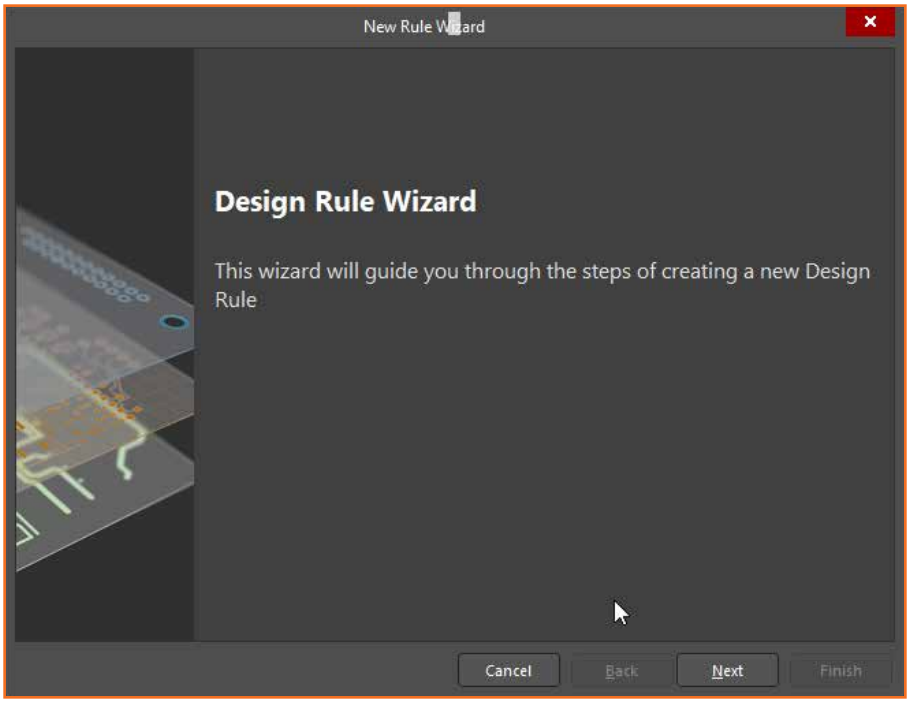


Fig 3.1.24: Design rule wizard

As you place components, vias, drill holes, and traces, the design engine will check the layout against these rules and will flag you visually if there is a violation.

6. **Place Components:** You can have your components automatically arranged or you can place them manually. You can also use these options together, which allows you to take advantage of the speed of auto-placement and ensure your board is laid out according to good component placement guidelines.

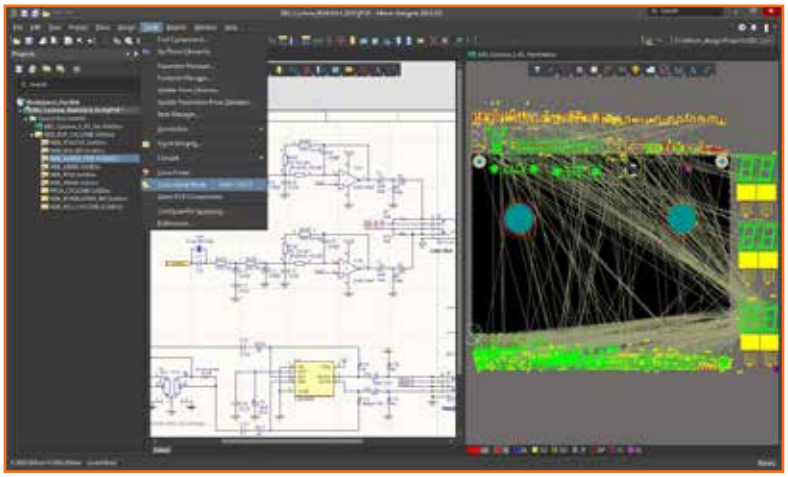


Fig 3.1.25: Auto placement guidelines

7. **Insert Drill Holes:** Before routing traces, place your drill holes (mounting and vias). If your circuit board design is complicated you may need to modify at least some of the via locations during trace routing. This can be done

easily from the via Properties dialog, shown below.

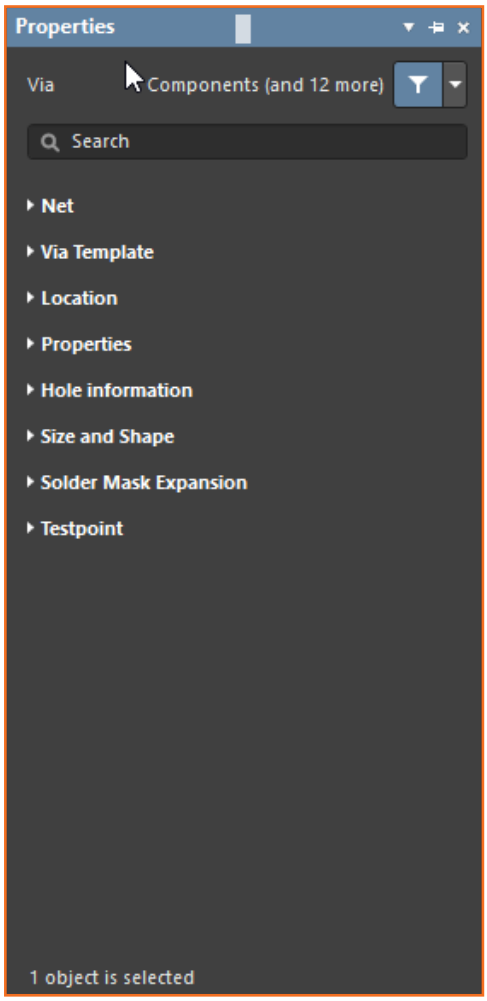


Fig 3.1.26: Insert Drill Holes

Your preferences here should be guided by the design for manufacturing (DFM) specifications of your PCB manufacturer.

8. **Route Traces:** Once you've placed components, now route the traces. As you route the board, try to come up with a strategy to finish your important routes first, then fill in the gaps with the remaining connections as needed. Some of the important routes will include your power nets, any impedance-controlled nets, and any noise-sensitive nets like low-level analog signals.

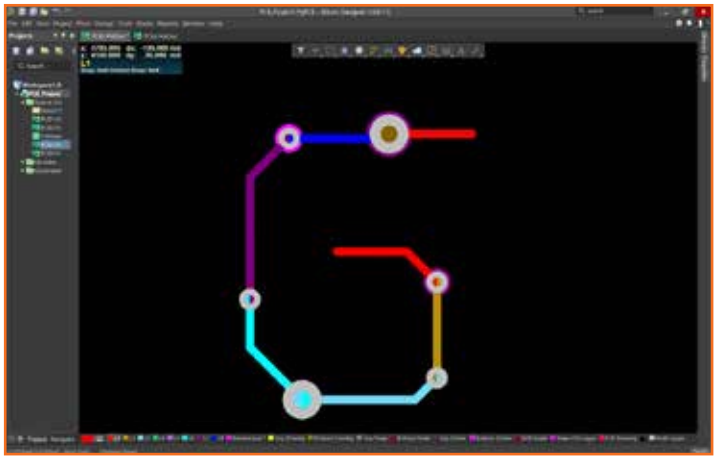


Fig 3.1.27: Route traces

The auto-interactive routing tools allow you to guide an automated routing feature so that you can speed up complicated routes between components. These tools will operate on multiple nets

simultaneously, making it easy to route a large number of traces in tandem.

9. **Add Labels and Identifiers:** With the circuit board layout verified now add labels, identifiers, markings, logos, or any other imagery to board. It is a good idea to include reference designators for components as this will assist in PCB board assembly. Also, make sure to keep any polarity indicators, pin 1 indicators, and any other labels visible as these will aid PCB assembly and testing. It will also help if you ever need to debug the board while testing. You can also add a company logo and part numbers using the image tools and text tools in the PCB Editor. These elements need to be placed in the Top Overlay or Bottom Overlay layers in the PCB layout.

Fig 3.1.28: Add Labels and Identifiers

10. **Generate Design Output Files:** Before you create manufacturer deliverables, verify the circuit board layout by running a design rule check (DRC). If your board checks out, then you're ready to release your manufacturer deliverables.

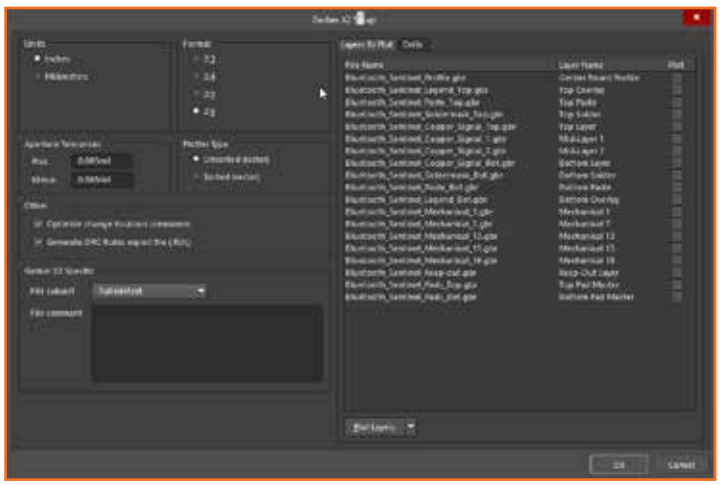


Fig 3.1.29: Generate Design Output Files

Once your board has passed the final DRC, you need to generate the design files for your manufacturer. The design files should include all the information and data necessary to build your board; including any notes or special requirements to ensure that your manufacturer is clear on what you require. For most manufacturers, you will be able to use a set of Gerber files as shown below; however, some manufacturers prefer other manufacturing file formats (IPC-2581 or ODB++).

By following the above steps, the process of creating a comprehensive PCB board design is as

easy as counting to ten. Using a systematic approach such as this ensures that all aspects of your circuit board design are accounted for inherently during the process, with minimal need to retrace your steps.

Notes

Scan the QR code or click on the link to watch related videos

www.youtube.com/watch?v=ESnDQl7ZM5o
Basic concepts of PCB design

www.youtube.com/watch?v=2KBCR9gwa8E
PCB designing

Unit 3.2: Building Prototype of PCB Design

Unit Objectives

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

1. Describe need of building prototype of PCB design
2. Demonstrate procedure of building prototype of PCB design
3. Demonstrate testing of prototype

3.2.1 PCB Prototype

PCB prototypes are early samples of products built with the sole purpose of testing design ideas to see if they work. Although most prototypes, in general, are made to test basic user functionality, engineers require somewhat, if not entirely, functional PCB prototypes to check the complete functionality of designs.

Engineers and designers use different types of PCB prototypes to test different design aspects. Throughout a project, your design teams may use several PCBs at various stages of their design processes. Example of these prototypes include -

- **Visual Models:** They illustrate the physical aspects of PCB designs and show the overall component structure and shape. As the initial prototypes in your design process, engineers use visual models to review and communicate the design easily and affordably.
- **Proof-of-Concept Prototypes:** These prototypes focus on the replication of the primary function of PCB boards without carrying all of the final product's capabilities. They show viability.
- **Working Prototype:** These are functioning boards containing all the planned functions and features of the final product. They help identify problems and weaknesses in designs but rarely represent what or how the final product will look like when finished.
- **Functional Prototype:** Designers make these to resemble the final product. They provide the most accurate idea of the final design.

Benefits of PCB Prototyping

- Detect design flaws early in the production process
- Cost-effectively test multiple designs
- Get an accurate interpretation of how the board will function

The objective of the prototyping process is to transform design into a quality product. There are many forms of the PCB development process that may result in achieving the design objective.

3.2.2 Preparing for Prototyping Process

Prototypes are ideal for when you want to test your design or perform a quality check of your board.

Before starting prototyping process, you'll need to collate some information about the design. The information required -

- Number of layers required
- Board thickness and dimensions
- Copper thickness and weight
- Design constraints like minimum hole size, minimum space between traces and vias, pad-pad and pad-trace clearances etc.
- Surface finish details like ENIG, OSP, HASL
- Solder mask color, silkscreen and aperture information
- NC Excellon Drill files, and tool list
- Pick and place files, assembly drawing files, 3D model details (if available)

3.2.3 PCB Prototyping Process

Once you gathered the necessary information, you can begin the prototyping process.

Steps for PCB prototyping process are:

1. **Prepare Design:** The first step in making a prototype PCB is designing.
2. **Prepare Schematic Design:** The schematic design describes crucial information required during the production process.
   - It includes information about the materials, components and hardware used in production
   - It also determines the board's function, characteristics and the placement of components.
   - Some crucial aspects of this phase are selecting the right panel size and grid.

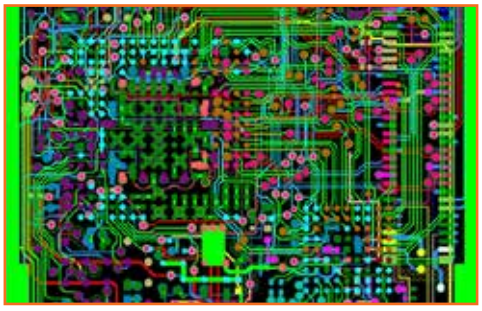


Fig 3.2.1: Prototype PCB is design

Schematic design is part of the initial design phase. Once first schematic design is completed, then run a preliminary check for potential defects and correct any that show up.

After that run simulations using a specialized PCB design tool to ensure the board function properly and it acts as a more in-depth design check.

Lastly convert the electronic design into a netlist, which describes the interconnectivity of the included components.

It's helpful to run design rule checks regularly throughout the design process rather than just at the end.

3. **Prepare Bill of Materials (BOM):** You also need to create a bill of materials, or BOM. This is a list of all the components and materials needed for production. For sourcing the parts, this document ensures that, you will get the right ones.

   The BOM includes vital information for each component, including -

   - **Quantity:** The number of components required.
   - **Reference Designators:** Codes used to identify individual parts.
   - **Value:** The specifications for each component described in the appropriate units, such as ohms or farads.
   - **Footprint:** The location of each component on the board.
   - Manufacturer Part Number

   Once the BOM and schematic are finished, check the document and collect necessary parts.

   Before validating the BoM, ensure that parts should be validated with respect to the following fields -

   - Serial number
   - Part description
   - Designators matching the schematic
   - Quantity of the parts
   - MPI
   - VPB
   - DNI (do not install) components

4. **Prepare Routing Design:** Now you have to design the routing, by way of traces, that you will use to connect each element of the PCB. Various factors play a role in planning routing, including power levels, signal noise generation and noise sensitivity.

   Fig 3.2.2: Routing Design

   Most PCB design software programs use the netlist you've already developed to plan the routing. Many of these programs can automatically calculate the optimal routes based on the number of available layers and other factors. This process can take a while — especially for larger circuit boards or boards with a lot of components.

5. **Checking of Design:** Check your design regularly throughout the process for any functionality issues.

   Common problems to look out for include thermal issues such as heat spots. Always keep the board at one consistent temperature. Some design features such as the presence of thermal paths, varying copper thicknesses, a large PCB size and the number of PCB layers can contribute to heat spots and inconsistent temperatures.

In addition to a thermal check, conduct a design rule check, a layout-versus-schematic (LVS) check, an electrical rule check (ERC) and an antenna check.

After completing checks, send the designs for next several steps, which together comprise the fabrication process.

6. **Create Photo Film:** Use the design to create a photo film of the PCB with a printer called a plotter for each layer and solder mask of the board. This film is a plastic sheet printed with a photo negative of the board, which marks the parts that will be conductive (copper) and those which are non-conductive.

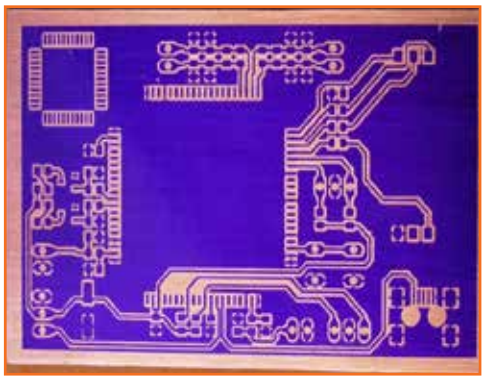


Fig 3.2.3: Create Photo Film

7. **Print the Inner layers:** In this step, apply copper to substrate material.

   Begin by pre-bonding copper to the substrate and then apply a layer of photoresist — a photosensitive film which hardens when exposed to ultraviolet light. Use UV light to harden it.

   Any areas blocked by black ink from the plotter remain unhardened. Remove the unhardened photoresist, which leaves hardened photoresist covering and protecting the place where copper is applied. Next, remove the hardened photoresist, revealing the copper in the exact spots where it is indicating in the design.

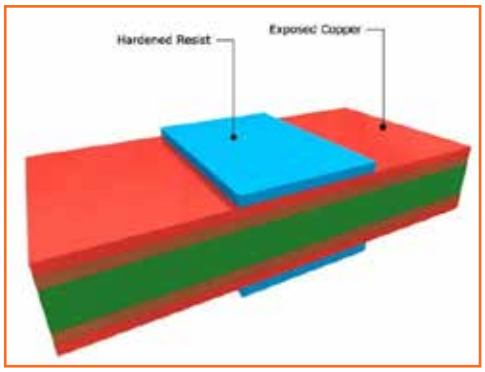


Fig 3.2.4: Print the Inner layers

8. **Align the Layers:** If you have multiple layers, then align them and punch accurate registration holes. It's crucial they line up perfectly, because it is difficult to correct inner layers once the layers are combined.

9. **Fuse the Layers Together:** This step involves fusing together these outer and inner layers, which occurs in two stages - layer-up and bonding.

   Place the outer layer over an alignment basin, then stack the substrate layer, copper sheet, an aluminum foil and copper press plate. These layers fit into pins attached to a steel table.

   Use a bonding press to heat up the stack, applying pressure and then cools the stack.

   After that unpack the stack by removing the pins and the pressure plate. Now you are left with is a PCB.

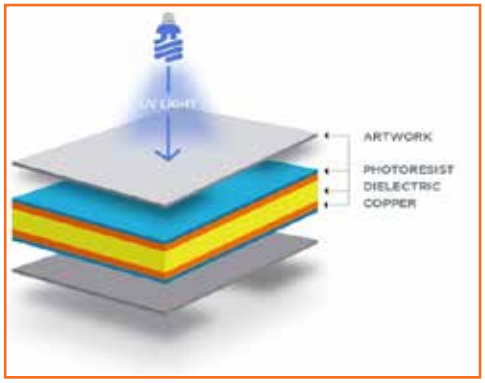


Fig 3.2.5: Layers alignment

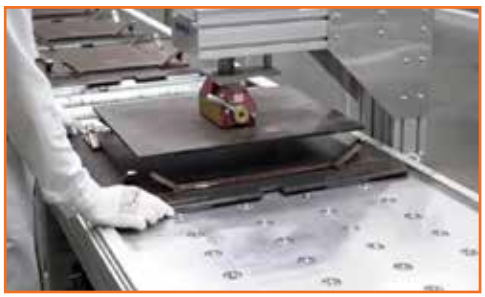


Fig 3.2.6: Fusing Layers Together

10. **Drill Holes in Board:** Now drill holes into the stack. The

holes need to be precisely drilled to about 100 microns in diameter. You can use an x-ray locater to target the correct hole locations and computer controls the drills themselves. Although the drill moves quickly, this process can take a while — PCBs typically have more than 100 holes.

Fig 3.2.7: Drill Holes in Board

11. **Perform Copper Plating:** The next step is plating, which uses a chemical bath to deposit a layer of copper about one micron thick on the panel's surface. The copper covers the entire panel, including the interior walls of the holes. This covers the fiberglass material of the inside of the panel that the holes previously exposed. Computers precisely control this process.

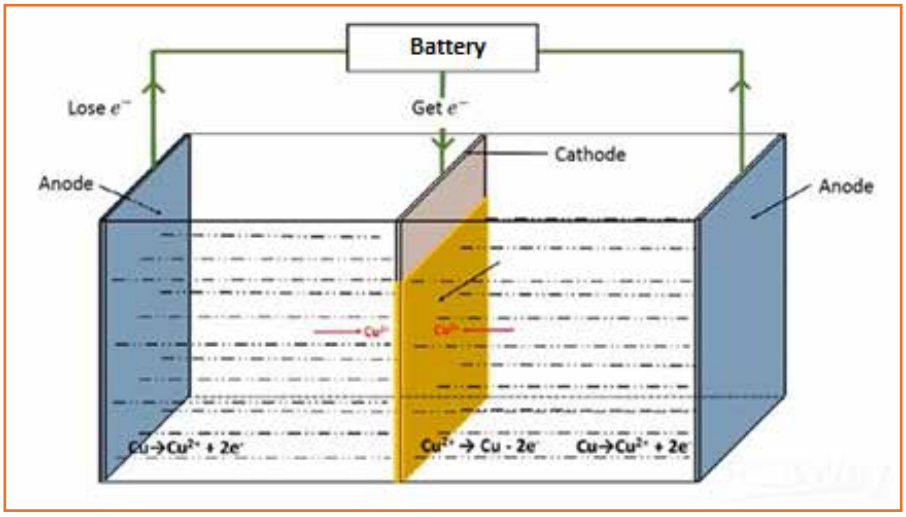


Fig 3.2.8: Perform Copper Plating

12. **Prepare Outer Layer Imaging:** Next, apply another layer of photoresist to the panel to image the outer layers with PCB design. This follows a process similar to the one used earlier and creates an inversion of the inner layers.
13. **Perform Copper and Tin Plating:** Now do another round of copper plating. The photoresist layer ensures that the copper only deposits on the desired parts of the board. Then, the board typically receives tin plating, which serves to guard the copper during the next stage.
14. **Perform Final Etching:** Chemical solutions then remove any excess copper, while the tin plating protects the copper that creates the conductive areas. After this stage is completed, the conductive connections are established.

Fig 3.2.9: Perform Final Etching

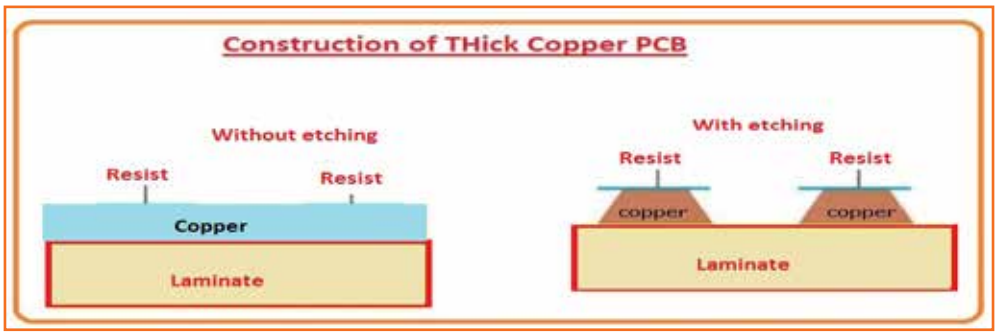


Fig 3.2.10: With and without etching

15. **Apply the Solder Mask:** Now clean the panel and apply an epoxy solder mask ink. The board then undergoes UV light, which passes through the solder mask photo film and hardens the film. Any covered, unhardened parts are removed.

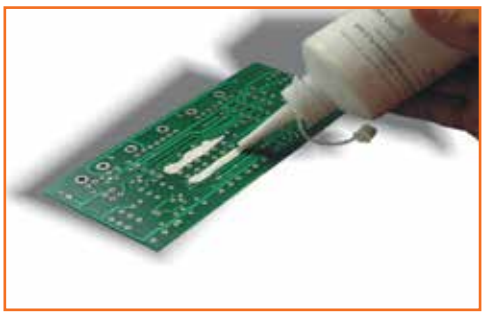


Fig 3.2.11: Apply the Solder Mask

16. **Obtain Required Surface Finish:** Now deposit more plating, often of gold or silver and use hot air leveling to ensure the pads are uniform and you have a required surface finish.
17. **Apply Silkscreen:** Apply a silkscreen to the surface of the PCB with ink-jet printer that conveys critical information about the board. The Silkscreen PCB aims to help you distinguish the PCB components, test points, warning symbols, and other parts of the PCB.

    Though the Silkscreen has nothing to do with the functionality of the Printed Circuit Board, the PCB Silkscreen provides information on

Fig 3.2.12: Apply Silkscreen

- **Warning Symbols:** The warning symbols indicate the parameters on the high voltage points that you need to avoid or handle.
- **Polarity Indicators:** It helps you to trace the polarized component's orientation.
- Locating the parts via reference designators
- It helps in identifying the test points and unique numbers for each board.
- **Reference indicators:** It helps in identifying the component types via BOM. The Pin 1 indicator helps you to connect the pins to the suitable pads in the footprint. The leading pattern of the component outline would show the placement of a component. The polarity indicators provide you with the polarized component's orientation
- **Pin 1 indicator:** It indicates the connection of pins on the correct pads of the footprints.
- **Component Online:** It enables you to place the components on PCB through indications.

18. **Cutting of Board:** After conducting a final electrical test to ensure the board functions as intended, cut and separate the board from larger panel by using either a router or a v-groove. After cutting

with one of these methods, you can easily pop the boards out of the panel.

19. **Sourcing of Components:** To prepare for the PCB assembly prototype stage, arrange all the components required from leading authorized distributors or from the channels.

    Use BOM to identify the requirements of components

Fig 3.2.13: Assembly of Board and Components

20. **Assembly of Board and Components:** The next stage is assembly — or PCBA for printed circuit board assembly — in which attach the required components to board by applying appropriate assembling methods.
21. **Solder Paste Stenciling:** First, apply a solder paste to the board, which mixes with a flux to help the solder melt and bond to the PCB surface.

    Place a stainless steel stencil over the PCB so the applicator only applies solder paste to the places where components will be in the finished PCB. It spreads it evenly to every open area. Then, the stencil is removed, leaving the solder paste in the desired locations.

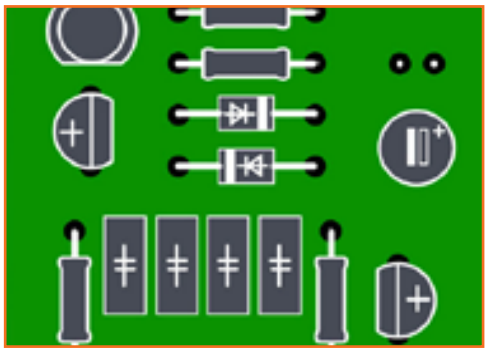


Fig 3.2.14: Solder Paste Stenciling

22. **Pick and Place:** Pick and place surface mount components, or SMDs on the PCB. Place these non-connector components on top of the soldering paste in pre-programmed locations.
23. **Reflow Soldering:** The reflow process solidifies the solder paste, which attaches the surface mount components to the board.

    In this step, place the PCB on a conveyor belt that moves the board through a reflow oven. This oven has a series of heaters to slowly heat up the board to around 480 degrees Fahrenheit, melting the solder in the solder paste. It then gradually reduces the temperatures, cooling and solidifying the melted solder, and permanently attaching the SMDs to the board.

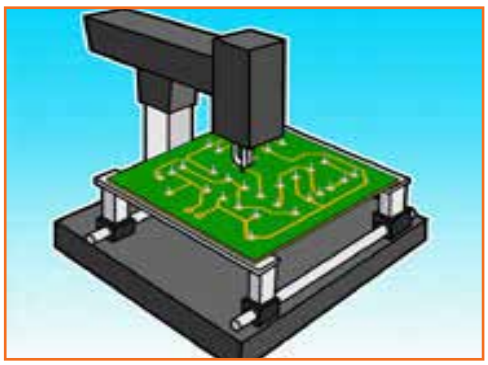


Fig 3.2.15: Pick and Place

- For two-sided PCBs, you need to apply stenciling and conduct reflowing separately on each side.

24. **Inspection and Quality Control:** After the reflow process is complete and the mount components are soldered into place, comes the PCB inspection. The assembled board should be tested and inspected for functionality. Ways to check the PCBA for quality control include.

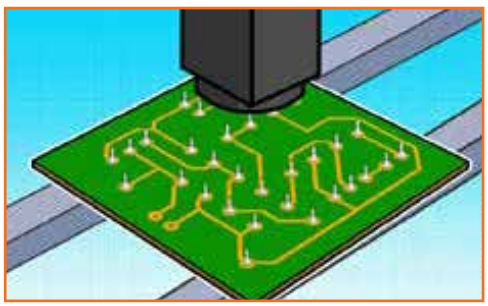


Fig 3.2.16: Inspection and Quality Control

- **Manual checks:** A visual inspection done in person by a designer to ensure the quality of a PCB.
- **Automatic optical inspection:** An inspection method more appropriate for larger batches of PCBAs. An automatic optical inspection machine, or AOI machine, uses high-powered cameras, set at different angles to view the solder connections.
- **X-ray inspection:** An inspection used for more complex PCBs by examining the layers of the PCB and identifying potential problems

Also do test for functionality and connection quality.

25. **Inserting Through-Hole Components:** A plated through-hole, or PTH, component is a hole in the PCB that is plated through the board. Rather than soldering paste, more specialized soldering method is required for PTHs.

    - **Manual soldering:** A manual, through-hole insertion.
    - **Wave soldering:** The automated version on manual soldering where a wave of molten solders all the holes in the bottom of the board at once.

    Note: A solder paste applier, pick-and-place machine, high-speed chip shooter, and infrared oven inserted in a conveyor configuration can apply solder, pick-and-place, and solder 50,000 parts or more in an hour.

26. **Conducting a Functionality Test:** Once the soldering process of the PCB board assembly is complete, it is time to do a final inspection and functional test. Run power and simulated signals to test the PCBs electrical characteristics. A sign that the PCB has failed is when it shows the fluctuation of electrical signals during the test. If the PCB fails the final inspection, it should be scrapped and the process begins all over until a successful PCB is produced.

3.2.4 PCB Prototype Testing

Once the prototype is designed, manufactured and assembled, you have a completed prototype. Now test it before moving on to a full production run of PCB.

Test the prototype according to reason for creating it. Check for design flaws and areas that could use improvement. If you have multiple prototypes of different designs, run identical tests on the boards and compare the results. It is helpful to run tests that simulate as accurately as possible the conditions in which the board will operate.

If running tests reveal problems with the design, correct them and create a new prototype to test the corrected design. Once the prototype achieves the required performance and quality, now it is ready for a full production run.

Notes

Notes

Scan the QR code or click on the link to watch related videos

www.youtube.com/watch?v=zRdJrE80Vjk

PCB prototyping

www.youtube.com/watch?v=5WuScHKaz8o

PCB manufacturing and assembly

Skill India
कौशल भारत-कुशल भारत

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

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

ESSCI
Skilling India in Electronics

4. Process of Building and Testing the Complete IoT System

Unit 4.1 - Building an IoT System

Unit 4.2 – Testing an IoT System

ELE/N1409

Key Learning Outcomes

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

1. Describe types of PCB assembly process
2. Demonstrate PCB assembly and inspection process
3. Demonstrate IoT system building process
4. Describe types of testing in IoT
5. Describe various testing methods to test PCB
6. Describe root cause analysis of faults in PCB

Unit 4.1: Building an IoT System

Unit Objectives

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

1. Describe types of PCB assembly process
2. Demonstrate PCB assembly and inspection process
3. Demonstrate IoT system building process

4.1.1 Types of PCB Assembly Process

As we already discussed, the PCB fabrication and assembly process in previous unit in brief, here we will discuss only about methods of assembling.

The PCB assembly process has automated and manual process, depends on the organisation to organisation. The manufacturing process of an assembled PCB is known as PCB assembly process or PCBA. In this process, the required electronics components are mounted on the PCB.

The copper lines on bare board, known as traces, electrically link connectors and components to each other. These traces run signals between these features, allowing the circuit board to function in a specifically designed way.

Their are three types of PCB assembly process:

- Thru-Hole Technology (THT) Assembly Process
- Surface Mount Technology (SMT) Assembly Process
- Mixed Technology

Through-Hole Technology (THT) Assembly Process

Through Hole Technology (THT) is a method for constructing electronic circuits in which the pin-through-hole (PTH) components are inserted through holes drilled into printed circuit boards (PCBs).

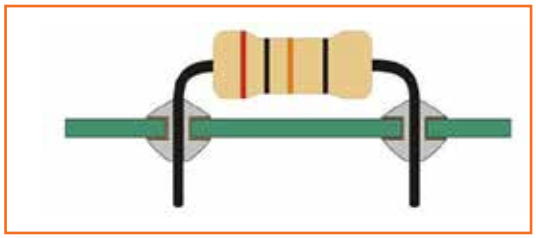


Fig 4.1.1: Thru-Hole Technology (THT) Assembly Process

The ends, or leads, are then affixed to pads on the opposite side with molten metal solder using wave soldering or reflow soldering equipment. This process is also called through-hole assembly.

Through Hole technology replaced early electronics assembly techniques such as point-to-point construction.

The three key steps of Through Hole Technology (THT) assembly process are as below -

1. **Components Placement:** This step is achieved

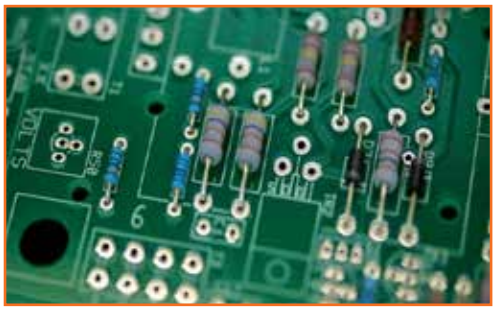


Fig 4.1.2: Constructing electronic circuits

manually. You only need to precisely place components on corresponding positions based on PCB design files.

Component placement must conform to regulations and operation standards of through-hole mounting process to guarantee high-quality end products.

2. **Inspection & Rectification:** Once component placement is completed, the board is then placed in a matching transport frame where board with components plugged in will be automatically inspected so as to determine whether components are accurately placed.

   If issues concerning component placement are observed, it's easy to get them rectified immediately as well. After all, this takes place prior to soldering in PCBA process.

3. **Wave Soldering:** Now the THT components should be accurately soldered onto circuit board. In the wave soldering system, the board moves slowly over a wave of liquid solder at high temperature, approximately 500°F.

Surface Mount Technology (SMT) Assembly Process

Surface-mount technology (SMT) is a method for constructing electronic circuits in which the components are mounted directly onto the surface of printed circuit boards (PCBs) with solder paste. The SMT components are very small sizes and comes in various packages like 0402, 0603, 1608 packages for resistors and capacitors. Similarly for Integrated circuits ICs we have SOIC, TSSOP, QFP and BGA.

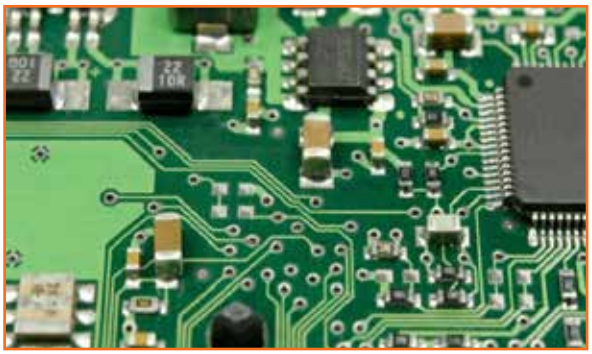


Fig 4.1.3: Surface Mount Technology (SMT) Assembly Process

Electronic devices made this way are called surface-mount devices (SMDs).

An SMT component is usually smaller than its through-hole counterpart because it has either smaller leads or no leads at all.

The three key steps in surface-mount technology are paste, place, and reflow.

1. **Solder Paste Printing:** Solder paste is applied on the board through a solder paste printer. A template or stencil or solder screen ensures that solder paste can be accurately left on correct places where components will be mounted.
2. **Components Mounting:** After coming out of solder paste printer, PCB will be auto-sent to pick-and-place machine where components or ICs will be mounted on corresponding pads due to the tension of solder paste.

   Components are mounted on PCB board through component reels in the machine. Component reels carrying components rotate to provide parts to the machine, which will quickly stick parts to the board.

3. **Reflow Soldering:** After every component is placed, the board passes through a 23-foot-long furnace (reflow oven) with a temperature of 500°F .

   The solder paste must be heated until it melts and forms strong and reliable joints between the

components and the surface of the board. This is accomplished through the use of a reflow oven which heats the solder to the proper temperature and then cools it down to a solid again. This way the SMD components are bound firmly to the board.

As compared to through-hole mounting process, Surface mounting process has a high degree of automation, reducing labor costs and increasing production rates. SMDs can be one-quarter to one-tenth the size and weight, and one-half to one-quarter the cost of equivalent through-hole parts.

While through-hole mounting provides stronger mechanical bonds than surface-mount technology techniques, the additional drilling required makes the boards more expensive to produce. It also limits the available routing area for signal traces on multilayer boards since the holes must pass through all layers to the opposite side. For these reasons, through-hole mounting is normally reserved for bulkier components such as electrolytic capacitors or semiconductors in large packages that require additional mounting strength to endure physical stress.

Mixed Technology

With the recent developments, electronic products are becoming increasingly complex. These complex electronic products need more complicated, integrated and smaller size PCB boards.

It is almost impossible for PCBAs containing only one type of component to perform such complex tasks. Hence, for this purpose, a mixed technology board with both SMD and through-hole components will be required.

Such type of boards carry Thru-hole components and SMD components, which requires collaboration of thru-hole technology and surface mount technology.

Nevertheless, soldering is a complicated process that tends to be affected by too many elements. Thus, it becomes extraordinarily significant to better arrange the sequence of thru-hole tech and surface mount technology.

PCBA with application of mixed technologies should be carried out in the following situations:

i. **Single Side Mixed Assembly:** Single side mixed assembly process has the following manufacturing procedure -

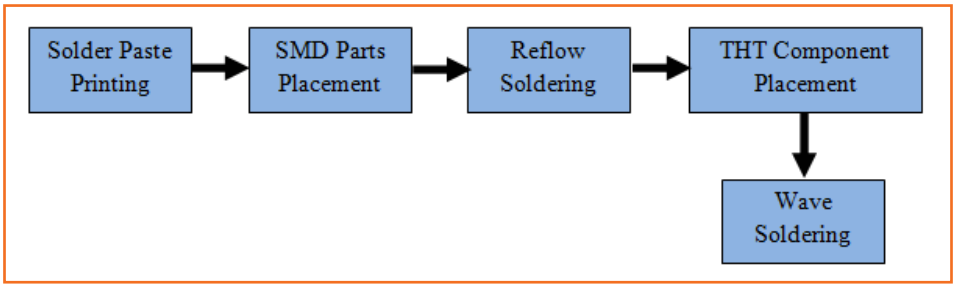


Fig 4.1.4: Single Side Mixed Assembly

Hand soldering can be applied instead of wave soldering only when a small quantity of THT components is required for this type of assembly.

ii. **One Side SMT & One Side THT:** One side SMT and One side THT assembly process has the following manufacturing procedure -

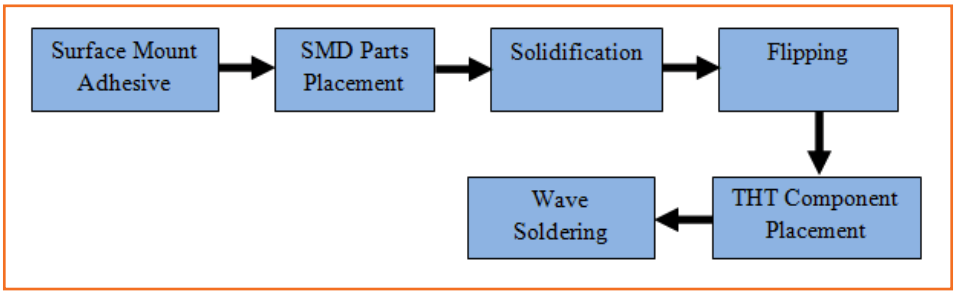


Fig 4.1.5: One Side SMT & One Side THT

This type of PCB assembly procedure is not recommended since adhesives will burden the total cost of PCBA and possibly lead to some soldering issues.

iii. **Double Side Mixed Assembly:** In case of double side mixed assembly methods, there are two alternatives - PCBA with application of adhesives and PCBA without adhesive.

The application of adhesives increases the overall cost of PCB assembly. Moreover, during this PCBA process, heating has to be carried out for three times, which tends to lead to low efficiency.

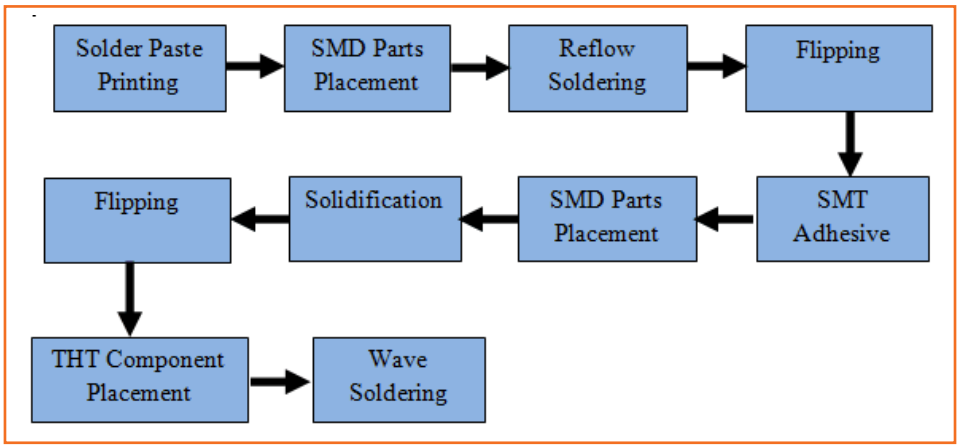


Fig.4.1.6: Double Side Mixed Assembly (1)

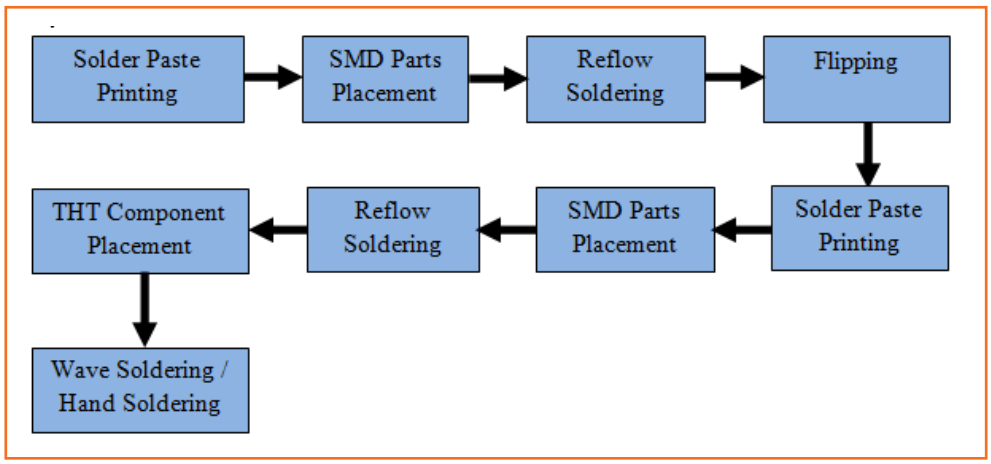


Fig.4.1.7: Double Side Mixed Assembly (2)

4.1.2 PCB Assembly Process

Step 1: Apply Solder Paste Using Stencil

First apply the solder paste on the areas of the printed circuit board assemblies where the components will fit. This is done by applying solder paste on the stainless steel stencil.

1. The stencil and the PCB are hold together by a mechanical fixture and then the solder paste is applied evenly to all openings in the board.
2. The applicator spreads the solder paste equally, so a right amount of solder paste must be used in applicator.
3. When the applicator is removed the paste will remain in the desired areas of PCB. The grey color solder paste is 96.5% made of tin and contains 3% of silver and 0.5% of copper and it is lead free. This solder paste will melt and creates a strong joint upon application of heat.

Step 2: Placement of Components

The second step in PCBA is the automated placement of SMT components on PCB board. This is done by using pick and place robot. At the design level the designer creates a file that will be fed to the automated robot. The pick and place robots will pick the components from its vacuum grip and place exactly on top of solder paste.

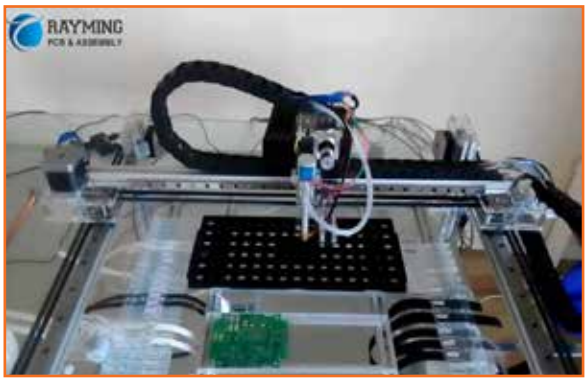


Fig 4.1.8: Placement of Components

Step 3: Reflow Soldering

The third step after the components are set and solder paste applied is reflow soldering. The reflow soldering is the process where the PCBs along with the components are put on the conveyer belt. This conveyer belt then moves the PCBs and components in a big oven, which creates a temperature of 250o C. This temperature is enough for the solder to melt. The melted solder will then fix the components upon the PCB and create joints. After the PCB is treated with high temperature, it then goes in to coolers. These coolers then solidifies the solder joints in controlled fashion. This will create a permanent joint between SMT component and PCB.

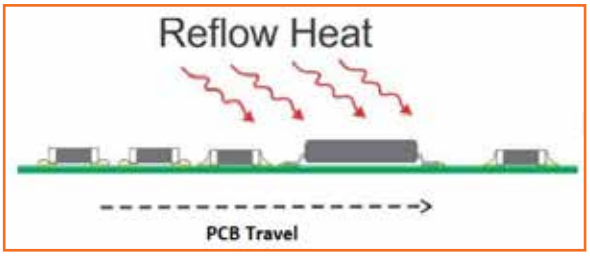


Fig 4.1.9: Reflow Soldering

Step 4: QC and Inspection

After the reflow soldering, there is a chance that due to some erroneous movement in PCB holding tray, the components got misaligned and may result in short circuit or open connection. These flaws are need to be identified and this identification process is called inspection. Inspection can be manual and automated.

1. **Manual Inspection:** As the PCB has the small SMT components, so visually check the board for any misalignment or faults. So this method is not feasible for advance SMT boards due to inaccurate results. However this method is feasible for boards having THT components and lesser

components density.

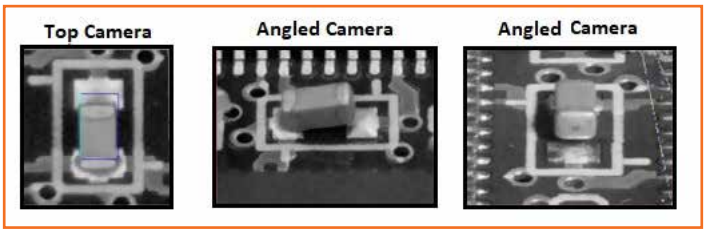


Fig 4.1.10: Optical Inspection

2. **Optical Inspection:** For the large batches of PCB, this method is feasible. This method uses the automated machine that has the high powered and high resolution cameras installed at various angles to view the solder joints from various directions. The light will reflect the solder joints in different angles according to the quality of solder joints. This automated Optical Inspection (AOI) machine is very high speed and take very short time to process large batches of PCBs.

Fig 4.1.11: X-ray Inspection

3. **X-ray Inspection:** The X-Ray machine allows you to look through the PCB to see the inner layer defects. This is not a common inspection method and is only used in complex and advance PCBs. These inspection methods if not properly applied may cause rework or scrap PCB.

Step 5: THT Component Fixation and Soldering

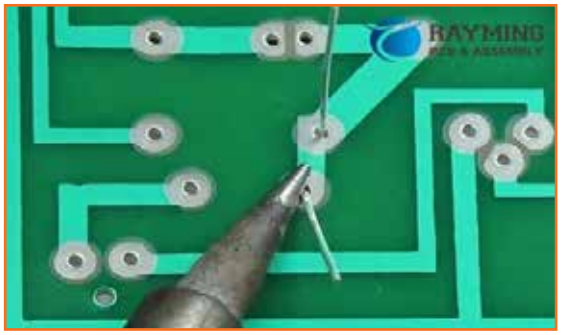


Fig 4.1.12: Manual Soldering

The through-hole components are commonly found on many PCB boards. These components are also known as Plated through Hole (PTH). These components have leads that will pass through the hole in the PCB. These holes connect to other holes and vias by means of copper traces. When these THT components are inserted and soldered in these holes, then they are electrically connected to other hole in the same PCB as the circuit designed. These PCBs may contain some THT components and many SMD components so the soldering method as discussed above in case of SMT components like reflow soldering will not work on THT components. So the two main types of THT components soldering are:

1. **Manual Soldering:** The manual soldering method is the common and typically takes more time than compared to automated setup for SMT. Usually one technician is designated to insert one component at a time and the board is passed on to other technician who inserts another component on the same board. So the board will move all around the assembly line to get the PTH components stuffed upon it.
2. **Wave Soldering:** The automated version of manual soldering is wave soldering. In this method, once the PTH components are placed on the PCB, the PCB is put on the conveyer belt and is moved to specialized oven. Here a wave of molten solder is splashed on the PCB bottom layer

where the components leads are present. This will solder all the pins at once. However this method is only for single sided PCBs and not for double sided because this molten solder while soldering one side of PCB can damage components on other side. After this, the PCB fabrication and assembly is moved for final inspection.

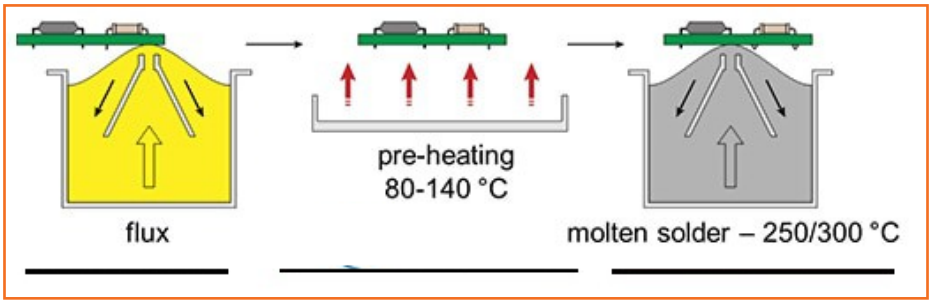


Fig 4.1.13: Wave Soldering

Step 6: Final Inspection and Functional Test

Now the PCB is ready for testing and inspection. This is the functionality test, where electrical signals and power supply is given to the PCB at the specified pins and output is checked at the specified test points or output connectors. This test requires common lab instruments like oscilloscope, DMM, function generator etc.

This test is to check the functionality and electrical characteristics of PCB and to verify current, voltage, analog and digital signals as described in the requirements of PCB and circuit design

If any of the parameters of the PCB shows unacceptable results, then the PCB is discarded or scrapped as per the company standard procedures. Testing phase is very important because it determines the success or failure of the entire process of PCBA.

Notes

Unit 4.2: Testing an IoT System

Unit Objectives

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

1. Describe types of testing in IoT
2. Describe various testing methods to test PCB
3. Describe root cause analysis of faults in PCB

4.2.1 IoT Testing

IoT testing is a sub-category of testing to check IoT devices. We now need to provide better and faster services. There is a huge global demand to access, create, use and transfer data. The aim is to provide insight and control, of various interconnected devices. That is why IoT testing framework is so important.

Types of Testing in IOT

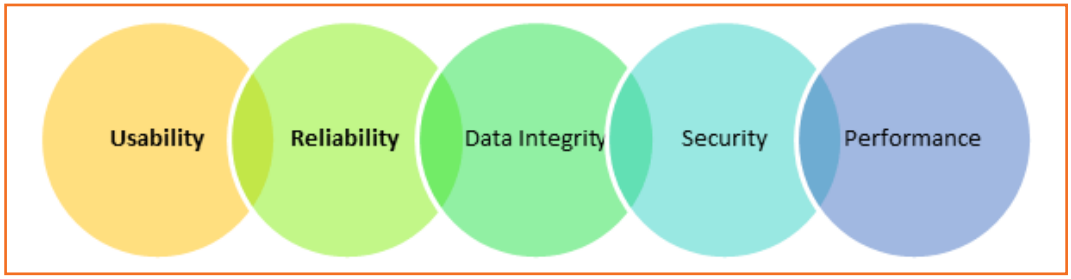


Fig 4.2.1: Types of Testing in IOT

- **Usability Testing:** Users use many devices of varying shape and form factors. Also, the perception varies from user to user. This is why investigating the usability of the system is very important in IoT testing. The usability of each device used in IoT must be determined. In healthcare, the tracking devices used must be portable so that they can be moved to different divisions. The equipment used should be smart enough to push notifications, error messages, warnings, etc. The system must log all the events occurring to provide clarity to the end users.
- **Compatibility Testing:** There are lots of devices which can be connected though IOT system. These devices have varied software and hardware configuration. Each one of them has a high degree of variability in terms of the firmware and hardware models and versions; network type, speed, protocols and versions; operating system type and versions; browser type and versions; screen sizes and display resolutions to name a few. It is important to test the application in all possible combinations of these versions to reduce failures in the field.

  Compatibility testing is also important due to the complex architecture of the IoT system. Testing items like OS versions, browser types, devices' generation, communication modes is vital for compatibility testing.

- **Connectivity Testing:** This testing involves checking the device and application behavior by subjecting the network through a load, intermittent failures, and total loss of connectivity. By inducing these real-life scenarios, the robustness of the device, edge, platform and application are checked.
- **Reliability and Scalability Testing:** Reliability and Scalability is important for building an IOT test environment which involves simulation of sensors by utilizing virtualization tools and technologies.
- **Data Integrity Testing:** It's important to check the Data integrity in IOT testing as it involves large amount of data and its applications.
- **Security testing:** In the IOT environment, a large number of users are accessing a massive amount of data. Thus, it is important to validate user via authentication, have data privacy controls as part of security testing.
- **Performance Testing:** Performance testing is important to create strategic approach for developing and implementing an IOT testing plan. On the device, these tests check their responsiveness to user actions and on a platform layer, they check the ability to handle spikes in traffic gracefully. They are based on metrics for assessing the responsiveness of the device/application and underlying system performance. Load generators and performance measuring tools on the cloud rate system performance under normal and full load.

Challenges faced in IoT testing

- Both, the network and internal communication, needs to be checked.
- One of the biggest concerns in IoT testing is security and privacy because the tasks are done via Internet.
- The software complexity as well as the system itself may conceal the bugs or defects found in the IoT technology.
- There are limitations on memory, processing power, bandwidth, battery life, etc.

Suggestions to make IoT testing effective

- Gray box testing and IoT testing should be performed simultaneously as it enables the designing of effective test cases. This helps us understand the operating system, architecture, third-party hardware, new connectivity, and hardware restrictions.
- Real-time OS is vital to provide scalability, modularity, connectivity, and security, all of which are essential to IoT.
- To make it effective, IoT testing can be automated.

Prerequisites of IoT Testing

- **Setting up IoT device:** The IoT device must be turned on, and can be accessed and used in real life. E.g., while testing a smart watch, make sure to wear it on wrist. Placing it on a table would not be regarded as a real user case.
- **Setting up of IoT Hub:** IoT hub is a server that can connect with IoT devices and gather information from them. An IoT hub may be an application in a mobile device or a web server on a cloud. The IoT hub must be set up properly.

- **Setting up network:** We need a strong wireless connection to connect IoT hub and the IoT device together. This can be possible with a Wi-Fi, Bluetooth, satellite signals, NFC (near field communication), etc. While connecting wearable device with a mobile app, ensure the following –
  - ❑ The Bluetooth of both the devices is turned on.
  - ❑ Both the devices are paired together.
  - ❑ Both the devices are in range of each other.

4.2.2 PCB Testing

IoT testing is a sub-category of testing to check IoT devices. We now need to provide better and faster services.

PCB assembly testing methods are an integral part of the manufacturing process. Reputable electronics contract manufacturers (ECMs) offer a variety of PCB testing methods, but the seven main types include -

1. **IN-CIRCUIT TESTING**

   In-circuit testing (ICT) is the most robust type of PCB testing in existence and it can find 98% of faults.

   This testing method uses special PCB testing steps and equipment, including -

   - **In-circuit tester:** The tester system contains a matrix of hundreds or thousands of drivers and sensors, which perform the measurements for the test.
   - **Fixture:** A fixture connects to the in-circuit tester and is the part that interacts directly with the board being tested. This fixture looks like a bed of nails and is designed specifically for the board in question. Each **"nail,"** or sensor point, connects to relevant points on the test board, feeding information back to the tester. Fixtures are generally the most expensive part of this system.

   Fig 4.2.2: In-circuit testing

   - **Software:** Software for the tester instructs the system on what tests to perform for each type of board being tested and dictates the parameters for a pass or fail.

   This test involves using fixed probes laid out in a way that matches the design of the PCB. The probes checks the integrity of the solder connection. The bed of nails fixture simply pushes the board down on the bed of probes to start the test. There are access points predesigned in the board that allows the ICT testing probes to make connections with the circuit. They put a certain amount of pressure on the connection to make sure it stays intact.

Using the ICT method, a manufacturer can test individual components and measure their performance, regardless of the other components attached to them.

2. **FLYING PROBE TESTING**

Flying probe testing is a tried-and-true option that's less expensive than in-circuit testing. It's a nonpowered type of test that checks for

- Opens
- Shorts
- Resistance
- Capacitance
- Inductance
- Diode issues

The test works through the use of needles attached to a probe on an x-y grid obtained from basic CAD. Your ECM programs coordinates to match the circuit board and then runs the program.

Fig 4.2.3: Flying probe testing

In some cases, ICT makes it unnecessary to use flying probe testing, but the PCB has to be designed to fit with the test fixture, which means a higher initial cost. ICT can be faster and less error-prone than flying probe testing, so you might find the extra cost is worth it. While flying probe testing can be cheaper initially, it may actually be less cost-effective for large orders.

One final word of caution: A PCB flying probe test does not power up the board.

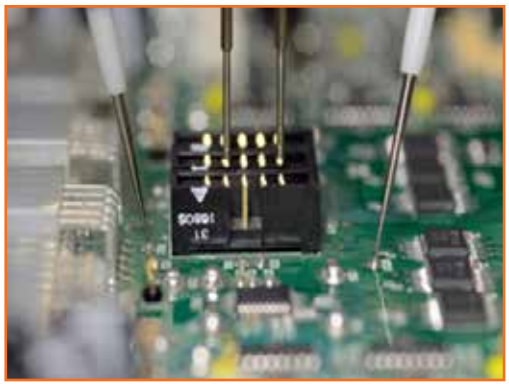


Fig 4.2.4: Flying probe testing

3. **AUTOMATED OPTICAL INSPECTION (AOI)**

AOI uses either a single 2D camera or two 3D cameras to take photos of the PCB. The program then compares the photos of your board to a detailed schematic. If there is a board that does not match the schematic to a certain degree, the board is flagged for inspection by a technician.

AOI can be useful for detecting issues early to ensure production is shut down ASAP. However, it does not power up the board and may not have 100% coverage for all part types.

Never rely solely on an automated optical inspection. AOI should be used in conjunction with another test. Some of our favorite combos are -

- AOI and flying probe
- AOI and in-circuit test (ICT)
- AOI and functional testing

4. **BURN-IN TESTING**

Burn-in testing is a more intense type of testing for PCBs. It's designed to detect early failures and establish load capacity. Because of its intensity, burn-in testing can be destructive to the parts being tested.

Burn-in testing pushes power through your electronics, usually at its maximum-specified capacity. The power is run through the board continuously for 48 to 168 hours in a burn in test chamber. If a board fails, it is known as an infant mortality. For military or medical applications, boards with high infant mortality are clearly not ideal.

Fig 4.2.5: Burn-in testing

Burn-in testing can shorten the product's lifespan, especially if the test puts your board under more stress than it's rated for. If few or no defects are found, it's possible to reduce the testing limit after a shorter period to avoid over-stressing your PCBs.

5. **X-RAY INSPECTION**

Also referred to as AXI, this type of **"testing"** is really more of an inspection tool, at least for most ECMs.

During this test, an X-ray technician is able to locate defects early during the manufacturing process by viewing -

- Solder connections
- Internal traces
- Barrels

There are 2D and 3D AXI tests, with 3D offering a faster testing period.

X-ray testing can check elements that are usually hidden from view, such as connections and ball grid array packages with solder joints underneath the chip package. While this check can be very useful, it does require trained, experienced operators.

Also, note that your ECM can't necessarily inspect every layer of a board using an X-ray machine. It's true we can see through the board to detect internal defects, but it's a very time-consuming and expensive process (for both ECM and customers).

6. **FUNCTIONAL TESTING**

This test does require a few things -

- External pieces of equipment
- Fixtures
- Requirements for UL, MSHA, and other standards

This functional test and its parameters are usually provided by the customer. Some ECMs can help develop and design such a test.

It does take time, But from a quality and longevity standpoint, functional testing can save face and save money.

7. **OTHER FUNCTIONAL TESTS**

There are other types of functional tests that can be used to check PCB, depending on the circumstances.

A PCB functional test verifies a PCB's behavior in the product's end-use environment. The requirements of a functional test, its development, and procedures can vary greatly by PCB and end product.

Other PCB assembly testing types include:

- **Solderability test:** Ensures surface sturdiness and increases chances of forming a reliable solder joint
- **PCB contamination testing:** Detects bulk ionics that can contaminate your board, causing corrosion and other issues
- **Micro-sectioning analysis:** Investigates defects, opens, shorts, and other failures
- **Time-domain reflectometer (TDR):** Finds failures in high-frequency boards,
- **Peel test:** Finds the measure of strength required to peel the laminate from the board
- **Solder float test:** Determines the level of thermal stress a PCB's holes can resist

4.2.3 Troubleshooting of PCB by Bench Test Instruments

1. **Multimeter**

For testing a circuit by multimeter, you need following basic tools -

- Analog/Digital multimeter
- Soldering gun
- Desoldering station
- Magnifying glass

Steps for using multimer for checking a circuit board

i. **Plugging:** First observe the polarity and then probe in the multimeter. Every multimeter device comes with two types of probes, namely red and black. While the red one is the positive probe, the black one is the jack at the end of the probe wire.

ii. **Testing:** Select the multimeter function first to check a

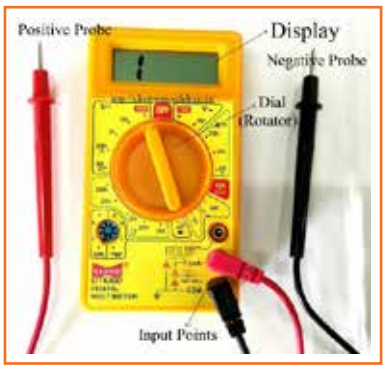


Fig 4.2.6: Multimeter

circuit board. Multimeters are modeled in such a way that they can measure both voltage and resistance. In case you have to test the power or voltage, turn the function knob or select the AC or DC voltage. The circuit board and the overall voltage will then be displayed on the device.

iii. **Checking:** Circuit boards are made up of many components in general and are placed inside an electrical device. Thus, to know if all parts are working in sync with each other, first unplug the device and the housing. Then switch it on and make sure that you do not touch any of the wirings.

Fig 4.2.7: Circuit Checking

iv. **Measure Voltage and Resistance:** The next thing to do using a multimeter is to check for voltage and resistance. For this step to work out smoothly, you need to do a basic test first. To test circuit board properly, touch the multimeter probes to the test points present on the board.

Make sure while playing out this step you have your hands on the plastic portion of the probes. You can then go on to check either the voltage or resistance. When measuring the resistors' resistance, connect one probe to the end of each resistor.

Fig 4.2.8: Measure Voltage & Resistance

v. **Check The Final Result:** Multimeters are used for checking the working functionality of the circuit board. Thus, to check and see if all the components are working properly repeats the step 1 to 4 for every component present on the board.

Checking the circuit board

- If the components look fine, power up the circuit board. Measure the voltage of the power rails with the multimeter. Both the input and output of the voltage regulator need to show the expected values.
- Check the fuse if the input voltage measured at the voltage regulator is 0V. If the fuse is replaced and immediately breaks after power-up, it means other components are shorted and draining a huge amount of current.
- A voltage of 0V, or below VCC, at the output often means that the regulator or a component along the voltage rail has a short circuit. If that's the case, the damaged component will heat up quickly.
- If there aren't signs of overheated components then look for broken traces. A broken trace could result in the voltage being detected at some points of the trace but not in others. Use your multimeter to narrow down where the discontinuity is.

Troubleshooting a PCB is very important nowadays. It is because, with the rising demand for electrical appliances, the supply for circuit boards has also increased. Thus, a minor distraction in the board can make it non-functional or damage the components. This can be easily traced with the help of a multimeter.

2. **Oscilloscope**

The oscilloscope is a particularly useful item of test equipment that can be used for testing and fault-finding a variety of electronic circuits from logic circuits through analogue circuits to radio circuits. By knowing the basics of using an oscilloscope it is possible to fault find circuits more effectively and more swiftly as well as gaining a better understanding of how they the circuits work.

The main purpose of an oscilloscope is to graph an electrical signal as it varies over time. Most scopes produce a two-dimensional graph with time on the x-axis and voltage on the y-axis.

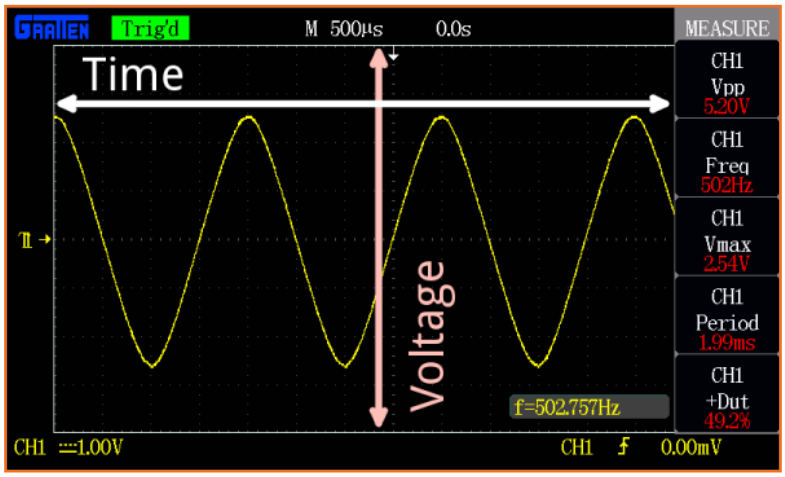


Fig 4.2.9: Oscilloscope WAVEFORMS

An example of an oscilloscope display. A signal (the yellow sine wave in this case) is graphed on a horizontal time axis and a vertical voltage axis.

Controls surrounding the scope's screen allow you to adjust the scale of the graph, both vertically and horizontally - allowing you to zoom in and out on a signal. There are also controls to set the trigger on the scope, which helps focus and stabilize the display.

What Can Oscilloscope Measure

Many oscilloscopes have measurement tools, which help to quickly quantify frequency, amplitude, and other waveform characteristics. In general a oscilloscope can measure both time-based and voltage-based characteristics -

- **Timing characteristics:**
  - **Frequency and period:** Frequency is defined as the number of times per second a waveform repeats. And the period is the reciprocal of that (number of seconds each repeating waveform takes). The maximum frequency a scope can measure varies, but it›s often in the 100›s of MHz (1E6 Hz) range.
  - **Duty cycle:** The percentage of a period that a wave is either positive or negative (there are both positive and negative duty cycles). The duty cycle is a ratio that tells you how long a signal is **«on»** versus how long it›s **«off»** each period.
  - **Rise and fall time:** Signals can›t instantaneously go from 0V to 5V, they have to smoothly rise. The duration of a wave going from a low point to a high point is called the rise

time, and fall time measures the opposite. These characteristics are important when considering how fast a circuit can respond to signals.

- **Voltage characteristics:**
  - ❑ **Amplitude:** Amplitude is a measure of the magnitude of a signal. There are a variety of amplitude measurements including peak-to-peak amplitude, which measures the absolute difference between a high and low voltage point of a signal. Peak amplitude, on the other hand, only measures how high or low a signal is past 0V.
  - ❑ **Maximum and minimum voltages:** The scope can tell you exactly how high and low the voltage of your signal gets.
  - ❑ **Mean and average voltages:** Oscilloscopes can calculate the average or mean of your signal, and it can also tell you the average of your signal›s minimum and maximum voltage.

Steps in using an oscilloscope

i. **Turn power on:** This may appear obvious but is the first step. Usually the switch will be labelled **«Power»** or **«Line»**. Once the power is on, it is normal for a power indicator or line indicator light to come on. This shows that power has been applied.

ii. **Wait for oscilloscope display to appear:** Although many oscilloscopes these days have semiconductor based displays, many of the older ones still use cathode ray tubes (crts), and these take a short while to warm up before the display appears. Even modern semiconductor ones often need time for their electronics to **"boot-up"**. It is therefore often necessary to wait a minute or so before the oscilloscope can be used.

iii. **Find the trace:** Once the oscilloscope is ready it is necessary to find the trace. Often it will be visible, but before any other waveforms can be seen, this is the first stage. Typically the trigger can be set to the centre and the hold-off turned fully counter-clockwise. Also set the horizontal and vertical position controls to the centre, if they are not already there. Usually the trace will become visible. If not the **«beamfinder"** button can be pressed and this will locate the trace.

iv. **Set the gain control:** The next stage is to set the horizontal gain control. This should be set so that the expected trace will nearly fill the vertical screen. If the waveform is expected to be 8 volts peak to peak, and the calibrated section of the screen is 10 centimetres high, then set the gain so that it is 1 volt / centimetre. This way the waveform will occupy 8 centimetres, almost filling the screen.

v. **Set the timebase speed:** It is also necessary to set the timebase speed on the oscilloscope. The actual setting will depend on what needs to be seen. Typically if a waveform has a period of 10 ms and the screen has a width of 12 centimetres, then a timebase speed of 1 ms per centimetre or division would be chosen.

vi. **Apply the signal:** With the controls set approximately correctly the signal can be applied and an image should be seen.

vii. **Adjust the trigger:** At this stage it is necessary to adjust the trigger level and whether it triggers on the positive or negative going edge. The trigger level control will be able to control where

on the waveform the timebase is triggered and hence the trace starts on the waveform. The choice of whether it triggers on the positive or negative going edge may also be important. These should be adjusted to give the required image.

viii. **Adjust the controls for the best image:** With a stable waveform in place, the vertical gain and timebase controls can be re-adjusted to give the required image.

Steps for checking PCB by oscilloscope

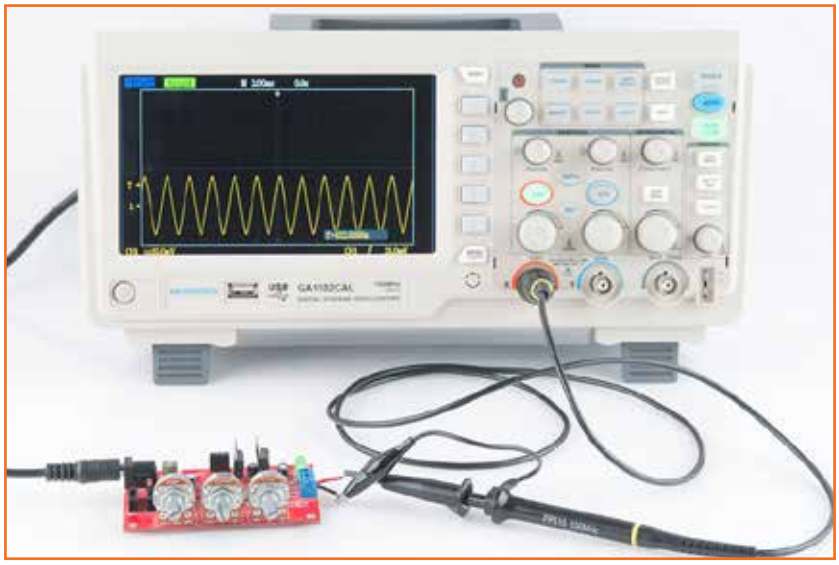


Fig 4.2.10: Checking PCB by oscilloscope

Step 1: Set the constant current and voltage to minimum

Before turning the power supply on, make sure that you twist every button value to zero. Now connect the GND pole of the power supply to the ground of your PCB and turn the power supply on.

Fig 4.2.11: Checking PCB by oscilloscope

Step 2: Carefully rise the voltage

Now connect both poles of the power supply to your PCB. Smoothly rise the voltage until it reaches the required voltage level. Some kind of indicator can be helpful on your printed circuit board, for example a built in LED showing if the board is working.

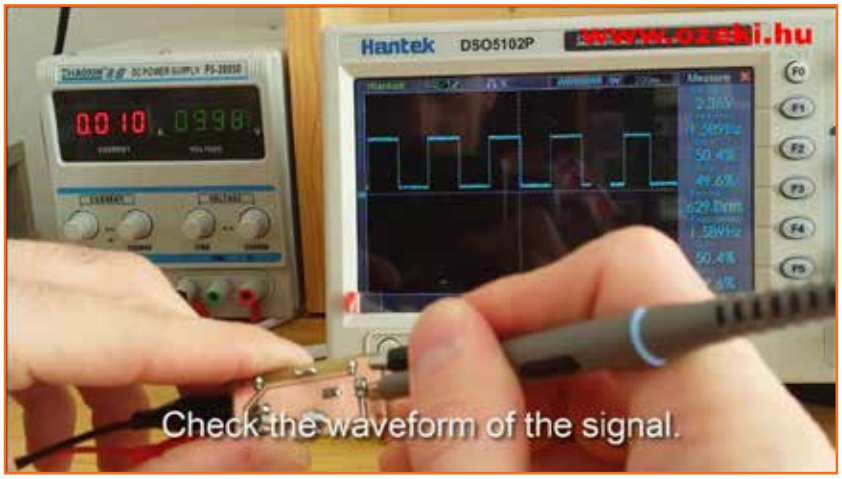


Fig 4.2.12: Checking PCB by oscilloscope

Step 3: Check the waveform of the signal with an oscilloscope

If everything went as expected you should do the final measurements with an oscilloscope. This can be useful for measuring signals. It can measure voltage in real time between two points. For example if you connect the oscilloscope on a blinking LED, you should see a PWM signal. If the signal is HIGH the LED is turned on or if the signal is LOW the LED is turned off.

3. **Signal generator**

A radio frequency (RF) signal generator is used to create continuous radio frequency signals with known characteristics to test the design of circuits, primarily those in communication equipment. An RF signal generator doesn't make any measurements itself, it simply sets up the right conditions for other instruments to measure the device under test.

Fig 4.2.13: Radio frequency (RF) signal TESTING

An RF signal generator is typically a signal source used to test circuits being developed for RF communications such as wireless and cellular communications, radar, electronic warfare etc. Engineers can set amplitude, frequency and apply modulations to the signal using system controls.

Fig 4.2.14: RF SIGNAL GENERATOR

The easiest way to generate RF frequency is to use the front panel of the RF Signal Generator

and set the frequency, amplitude, modulation, and a number of other signal characteristics right before connecting your RF signal generator to the device under test (DUT).

RF signal generator operation

Within a modern RF signal generator there are a number of major circuit blocks or sections:

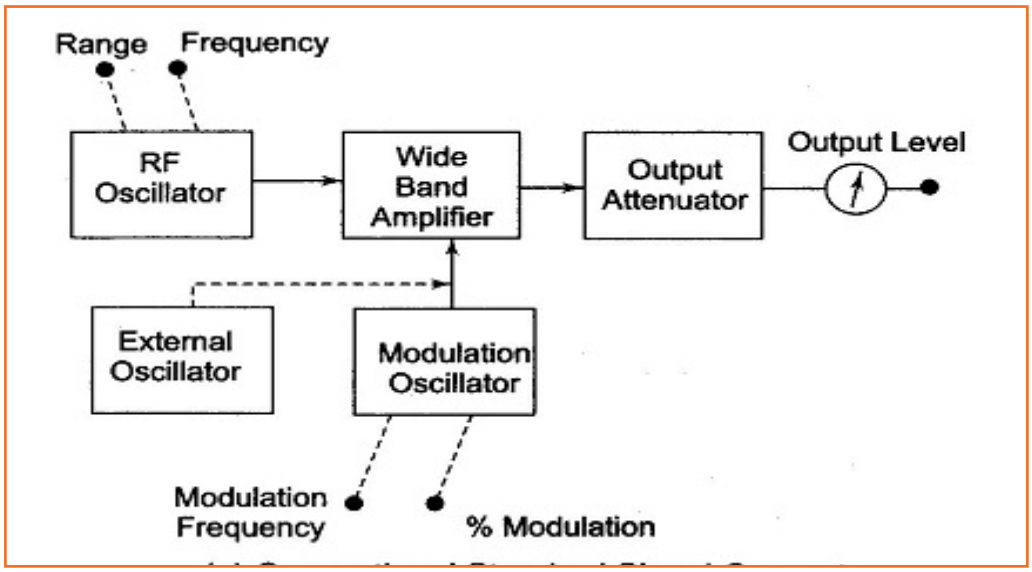


Fig 4.2.15: RF Signal generator diagram

- **Oscillator:** The most important block within the RF signal generator is the oscillator itself. This can be any form of oscillator, but today it would almost certainly be formed from a frequency synthesizer. This oscillator would take commands from the controller and be set to the required frequency.
- **Amplifier:** The output from the oscillator will need amplifying. This will be achieved using a special amplifier module. This will amplify the signal, typically to a fixed level. It would have a loop around it to maintain the output level accurately at all frequencies and temperatures. This loop is closely controlled because the accuracy of the final output is dependent upon it.
- **Attenuator:** An attenuator is placed on the output of the signal generator. This serves to ensure an accurate source impedance is maintained as well as allowing the generator level to be adjusted very accurately. In particular the relative power levels, i.e. when changing from one level to another are very accurate and represent the accuracy of the attenuator. It is worth noting that the output impedance is less accurately defined for the highest signal levels where the attenuation is less. levels may often be adjusted in increments of 0.1dB over the range.
- **Control:** Advanced processors are used to ensure that the RF and microwave signal generator is easy to control and is also able to take remote control commands. The processor will control all aspects of the operation of the test equipment. Also a large screen and controls are present on many modern signal generators.

RF signal generator functions

- **Frequency range:** Naturally the frequency range of the RF signal generator is of paramount

importance. It must be able to cover all the frequencies that are likely to need to be generated. For example when testing a receiver in an item of equipment, be it a mobile phone or any other radio receiver, it is necessary to be able to check not only the operating frequency, but other frequencies where the issues such as image rejection, etc.

- **Output level:** The output range for an RF and microwave signal generator is normally controlled to a relatively high degree of accuracy. The output within the test equipment itself is maintained at a constant level and then passed through a high grade variable attenuator. These are normally switch to give the highest degree of accuracy. The range is normally limited at the top end by the final amplifier in the RF signal generator. A typical level output range might be -127dBm to +7 dBm in 0.1 dB steps.
- **Modulation:** Some RF or microwave signal generators have inbuilt oscillators that can apply modulation to the output signal. Others also have the ability to apply modulation from an external source. The capabilities of different signal generators vary considerably, but the top end test instruments offer very high levels of capability.
- **Control:** There are many options for controlling RF and microwave signal generators these days. While they tend to have traditional front panel controls, there are also many options for remote control.
- **Sweep:** For some signal generator applications it is necessary to be able to sweep the frequency of the RF signal generator. If this facility is required, then it is necessary to check the specification for the test instruments that are being considered as not all RF signal generators provide a sweep of this nature although programming progressively increasing the frequency of the output in steps may be one option that might suffice.

Using a RF signal generator to check the RF signal in PCB

This is how to use a RF Signal generator to test a circuit's behavior -

1. **Power on the generator and select the desired output signal:** square wave, sine wave or triangle wave.
2. Connect the output leads to an oscilloscope to visualize the output signal and set its parameters using the amplitude and frequency controls.
3. Attach the output leads of the RF Signal generator to the input of the circuit you wish to test.

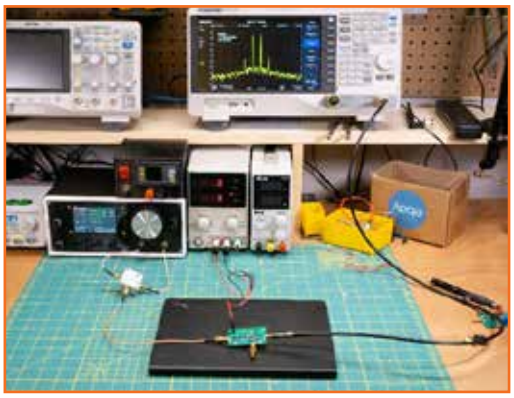


Fig 4.2.16: RF signal in PCB

4. Attach the output of your circuit to a meter or oscilloscope to visualize the resulting change in signal.

A RF Signal generator, which is used for testing the response of circuits to RF signals, produces various voltage patterns at different frequencies and amplitudes. You connect the RF Signal generator's electrical leads to the ground and the signal input terminals to the device under test (DUT).

4.2.4 Root Cause Analysis of PCB Faults

It is important for a printed circuit board to perform its function and support the larger electronic device. Consequently, you must have a system in place that monitors and tests each component to ensure that it meets various standards and delivers maximum performance.

When a component fails, analysts must utilize various processes, tools and techniques. With accuracy, they must determine why the device failed and how to prevent future failures. The following processes present unique challenges for electronics failure analysis -

- Increased density
- Higher lead-free process temperature requirements
- Hazardous material
- Recycling requirements
- The need to tune PCBs to precise values
- Other associated changes in PCB manufacturing

Root Cause Analysis

The fabrication of a complete PCB assembly requires an array of machines and materials, which include -

- Screen printers
- Conveyors
- Pick-and-place systems
- Reflow ovens
- Automated optical inspection
- Solder paste
- Different components

Some machines have automated features that perform checks at various points, and operators perform visual inspections before, during or immediately after the completion of a task.

Many PCBs will fail the final test. When a problem does occur, it is important to perform an effective electronics failure analysis in order to obtain clear and precise details about the source of the problem — and to ensure that it does not happen again.

You need to conduct a root cause analysis to identify the cause of the failure — not the symptoms — and take corrective action to fix the issue. Failure analysis also provides invaluable feedback to design engineers on how to -

- Correct minor faults that might have gone unnoticed during the initial design
- Improve the product

Any company that produces electronic hardware strives to achieve zero-defect production. To realize this objective, you must have the capability to perform some level of printed circuit board failure analysis.

Electronic device failure analysis provides a systematic process to help organizations investigate and understand why an electronic part failed. Depending on the nature of the failure, an effective investigation

can identify the failure mode, mechanism and elements, such as stresses inducing the failure and other issues.

For example, solder joint defects make up a large percentage of PCB failures. Youcan discover the root cause of the defective joints, like

- lack of solder paste,
- gap between the PCB pad and component lead, or
- poor reflow profile

Then implement preventative measures. To eliminate future failures, possible solutions may be to avoid solder paste contamination or ensure the correct aspect ratio. The methods used in the analysis depend on the severity of the failure and the type of issue. They can range from simple electrical measurements to the evaluation of sample cross-sections under a microscope.

An effective and efficient root cause analysis ensures that you can initiate the necessary corrective action to prevent reoccurrence of the problem. Failure analysis processes evaluate the reliability of a component product under operation and determine how to improve the product.

What are the Common Types of PCB Failure Analysis Tests?

There are a number of tests suitable for identifying defects. When the failure analyst understands the faults and how to prevent them, you can improve the production process as well as the assemblies it manufactures.

The traditional techniques used for printed circuit board failure analysis focus on the **"slice and dice"** method. This technique employs a combination of external techniques, such as electrical testing, visual inspection, X-ray and cross-sectioning to the relevant area.

The following PCB tests have the highest success rate and offer advantages for PCB manufacturers -

1. **Micro-sectioning Analysis**

   Micro-sectioning, sometimes called Cross-sectioning or Metallographic Preparation, refers to a PCB testing method used to investigate -

   - Thermo-mechanical failures
   - Component defects
   - Opens or shorts
   - Processing failures due to solder reflow
   - Raw material evaluations

   In this, you have to remove a two-dimensional slice out of a sample, which uncovers features within the board. Consider a destructive testing method, micro-sectioning analysis provides the technician with a precise technique that isolates the relevant electronic component and removes the part from the PCB sample.

   Now put the component into an epoxy resin or other potting medium and leaves it to cure and solidify. After the component cures, use an abrasion technique to retreat and expose the

component, and polishes the part until it is reflective and ready for testing.

Now, you have to compare the sample against another functioning component. One advantage of this testing method is the ability to position the sample on a flat surface and invest each of its parts together.

Electron and optical microscopy equipment can examine plate thickness, intermittent metallic layer thickness or failures to solder joints. The analyst must highlight the damage and identify the cause of the destruction.

2. **Solderability Testing**

PCB manufacturing process can be the source of assembly problems, especially issues related to oxidation and misapplications of the solder mask. To minimize the probability of failure, you have to test component and PCB pad solder ability to ensure the robustness of the surface and increase the probability of forming a reliable solder joint.

The solderability failure method evaluates the strength and quality of wetting of a solder by reproducing the contact between the solder and the material. The wetting balance process measures the wetting force and the time from contact to wetting force generation. Solderability testing can verify that the components will meet specifications and quality standards.

The technique also helps determine what effect, if any, storage has on solder components in PCBs. It also provides an accurate measure of why a fault may have occurred. Solderability testing works for a variety of applications, including -

- PCB coating evaluation
- Solder evaluation
- Flux evaluation
- Benchmarking
- Quality control

You must have the experience to differentiate the various surface conditions and understand the acceptable requirements of the testing technique.

3. **PCB Contamination Testing**

Contamination can cause a variety of issues, including corrosion, degradation, metallization and rapid deterioration of wire bond interconnects. Although printed circuit board processing and assembly take place in an extremely clean environment designed to keep the air and components free of contamination, infection does occur and represents one the most common causes of part failure.

Human by-products, handling, flux residues and reaction products are often sources of contamination. Many manufacturers employ aggressive chemistry processes during PCB fabrication, including the following -

- Copper etching liquid
- Hot air leveling fluxes

- Electrolytic solutions
- Water soluble soldering

The use of chemicals typically requires a cleaning process. The electronic industry introduced ionic contamination testing, which measures the cleaning efficiency and stability of the cleaning process. Contamination testing measures the amount of ionic contamination contained in a sample. The process of testing for contamination involves the immersion of the PCB sample into a solution. The solution dissolves the ionic contamination, which causes a change in the constitution of the solution and has a significant influence on the values or readings.

The technician measures the change in the resistance of the solution solvent — a change in resistance that a failure analyst can measure. Then, the analyst plots the contamination level on a contamination-testing curve and compares the value with industry standards.

When a reading exceeds an established level, it confirms that the manufacturer has a problem with the cleaning process. This can cause detrimental effects, including corrosion and electrochemical migration, when parts remain in the component. This dissolving technique can detect even the smallest parts.

4. **Optical Microscopy/SEM**

Optical microscopy may be one of the most popular and preferred testing methods used for detecting faults, defects and problems associated with soldering and assembly. Many customers choose optical microscopy because of its speed and accuracy. The process uses a high power microscope with visible light. The microscope, which can reach up to 1000X, has a small depth field and shows features in a single plane. Board integrity represents a major concern and frequent cause of failure in electronics. Microscopy testing can verify improper construction, which can lead to stresses that can expose flaws at certain cross sections.

Sometimes PCB failure analysis requires more powerful magnification tools. Scanning electron microscopes or SEMs offer a highly-effective testing technique for performing semiconductor die failure analysis. Even if a defect on an integrated circuit measures only a few nanometers wide, SEM provides the failure analyst detailed images at higher magnifications, up to 120,000X. It is typical to have magnifications of 50,000 to 100,000X, and feature resolutions down to 25 angstroms. The analyst produces a recording and record of the findings based on the images.

With SEM technology, the depth of the field provides failure analysts a three-dimensional view of the sample. SEM examinations can verify semiconductor die metallization, integrity and quality. SEM also provides evidence of heat treatment and identifies the metal or alloy used. Many analysts pair SEM with micro-sectioning testing.

5. **X-ray Inspection**

Many X-rays provide users a powerful tool for non-invasive failure analysis. With a choice of basic film X-ray, real time X-ray and 3-dimensional X-ray systems, users can employ the tools to detect actual or potential defects. They can also inspect a component that has hidden joints or parts located underneath a chip. The analyst uses an X-ray inspection instead of visible light equipment

to evaluate the PCB.

Even with basic X-ray inspection capabilities, technicians can conduct the following types of internal component examinations -

- Internal particles
- Internal wire dress
- Die attach quality
- Voids in the sealing lid
- Substrate /printing wiring board trace integrity
- Insufficient excessive or poor solder

The advantage of this testing method is the ability to detect surface and internal flaws in a non-destructive manner while keeping samples in pre-testing condition.

Common PCB Challenges

On top of rapid innovation, shrinking components and sophisticated circuit geometries, the fabrication of a printed circuit board consists of many steps and moving parts. The nature of the manufacturing process provides numerous opportunities to introduce a defect in the mix, unintentionally.

Consequently, failure analysts face a variety of challenges when finding manufacturing defects -

- **High-speed Printed Circuit Boards (HSCBs):** HSCBs, which have grown more complex and use a variety of integrated components, continue to grow in popularity. However, the components require boards that are composed of two or three materials that increase the possibility of failure in extreme high-speed applications. Failures also occur from pins and chip placed in an incorrect manner on the board.
- **Lead-free Assembly Process:** The lead-free assembly process requires a higher temperature and traditional tin-lead solder, which leads to higher temperatures for the reflow and wave soldering. This results in an adverse effect on the solder joint and electronic components.
- **Plated Through Hole Barrel Cracking:** Barrel fatigue, which is the circumferential cracking of the copper plating that forms the plated through hole (PTH wall), is the most prevalent failure mode. It occurs as a result of differential expansion between the copper plating and the out-of-plane coefficient of thermal expansion (CTE) of the printed board.
- **Correct Surface Finish Selection:** The most important decision for the electronic assembly may be the surface furnish, which affects the process yield, the amount of rework necessary, field failure rate, the ability to test, the scrap rate and the cost.
- **Conductive Anodic Filament:** Conductive Anodic Filaments (CAF) or metallic electro-migration describes an electro-chemical process that involves the transport of a metal across a non-metallic medium under the influence of an applied electric field. The condition causes current leakage, intermittent electrical shorts and dielectric breakdown between conductors in PCBs.

Notes

Scan the QR code or click on the link to watch related videos

www.youtube.com/watch?v=9QiNMUUdAgg
Types of IoT testing

www.youtube.com/watch?v=o8NOK1JJbgw
PCB inspection methods and defects

Skill India
कौशल भारत-कुशल भारत

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

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

ESSCI
Skilling India in Electronics

5. Work effectively at the workplace

Unit 5.1 - Effective Communication and Coordination at Work

Unit 5.2 - Working Effectively and Maintaining Discipline at Work

Unit 5.3 - Maintaining Social Diversity at Work

ELE/N9905

Key Learning Outcomes

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

1. Dsicuss about work ethics and workplace etiquettes
2. Describe ways to communicate work effectively at workplace
3. Discuss the importance of following organizational guidelines for dress code, time schedules, language usage and other behavioural aspect
4. Explain the importance of working as per the workflow of the organization to receive instructions and report problems
5. Explain the importance of conveying information/instructions as per defined protocols to the authorised persons/team members
6. Explain the common workplace guidelines and legal requirements on non-disclosure and confidentiality of business-sensitive information
7. Describe the process of reporting grievances and unethical conduct such as data breaches, sexual harassment at the workplace, etc.
8. Discuss ways of dealing with heightened emotions of self and others.
9. Explain the concept and importance of gender sensitivity and equality
10. Discuss ways to create sensitivity for different genders and Persons with Disabilities (PwD)

Unit 5.1: Effective Communication and Coordination at Work

Unit Objectives

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

1. Dsicuss about work ethics and workplace etiquettes
2. Describe ways to communicate work effectively at workplace

5.1.1 Importance of Work Ethics and Workplace Etiquette

Workplace ethics are a set of moral and legal guidelines that organizations follow. These guidelines influence the way customers and employees interact with an organization. Workplace ethics essentially guide how an organization serves its clients and treats its employees.

For example, if a company seeks to fulfil the promises it makes, it may develop processes and set up a robust support system to address this policy and build customer/client loyalty. To achieve this goal, the company may implement specific incentive programs for employees to encourage them to produce high-quality work and ensure the organization fulfils the promises it makes to its clients/ customers.

Many organizations, often the large ones, set detailed ethical codes to guide their operations and control how the organizational processes impact the stakeholders. These ethics usually help organizations maintain certain standards of responsibility, accountability, professionalism and among others, as they navigate through different challenges and day-to-day circumstances. By following these guidelines, organizations often experience several benefits that improve the lives of stakeholders, such as customers, employees, leaders, etc.

Examples of Common Workplace Ethics

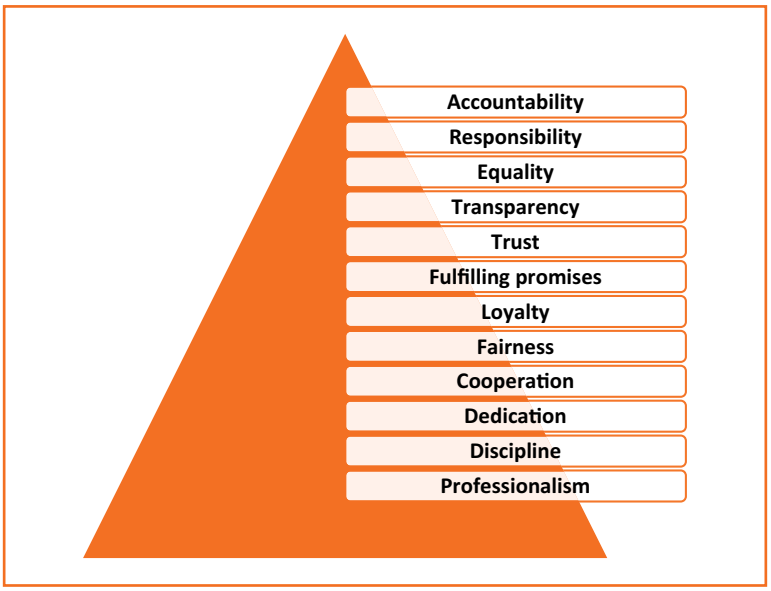


Fig 5.1.1: Examples of Common Workplace Ethics

Workplace ethics are essential for a successful organization with a satisfied and loyal team. High ethical standards help in ensuring all stakeholders, such as customers, investors, employees, and other individuals involved in the workplace operations, feel the organization is safeguarding their interests. By creating and implementing ethical guidelines, organizations can keep the best interests of their employees in mind while maintaining a positive influence on those they impact through their processes.

As a result, employees maintain the organization's best interests by being ethical in their daily work duties. For example, fairly-treated employees of an organization who understand the organization's commitments to environmental sustainability are usually less likely to behave in a manner that causes harm to the environment. Thus, they help maintain a positive public image of the organization. It means that workplace ethics help in maintaining reciprocal relationships that benefit organizations at large and the individuals associated with and influenced by the organizational policies.

Benefits of Workplace Ethics

There are various benefits of implementing workplace ethics. When organizations hold themselves to high ethical standards, leaders, stakeholders, and the general public can experience significant improvements. Following are some of the key benefits of employing ethics in the workplace -

Fig 5.1.2: Benefits of Workplace Ethics

5.1.2 Interpersonal Communication

Interpersonal communication is a process that involves sharing ideas and emotions with another person, both - verbally and non-verbally. It is essential to interact effectively with others in both personal and professional lives. In professional life or the workplace, strong interpersonal skills play a crucial role in achieving effective collaboration with colleagues.

Interpersonal Skills

Interpersonal skills, in other terms, are known as people skills, which are used to communicate and interact with others effectively. These are soft skills one uses to communicate with others and understand them. One uses these skills in daily life while interacting with people

Examples of Interpersonal Skills

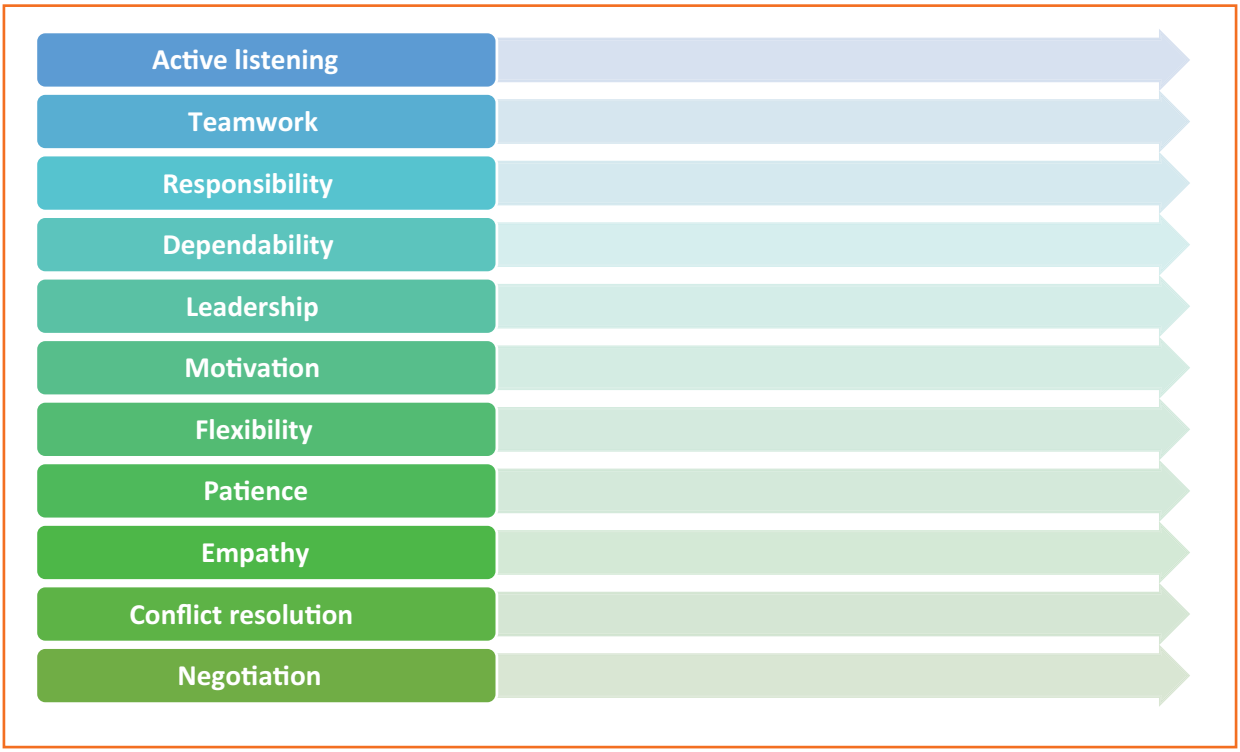


Fig 5.1.3: Examples of Interpersonal Skills

Numerous interpersonal skills involve communication. Communication can be verbal, such as persuasion or tone of voice - or non-verbal, such as listening and body language.

Importance of Interpersonal Skills

Interpersonal skills are essential for communicating and collaborating with groups and individuals in both personal and professional life. People with strong interpersonal skills often are able to build good relationships and also tend to work well with others. Most people often enjoy working with co-workers who have good interpersonal skills.

Among other benefits of good interpersonal skills is the ability to solve problems and make the best decisions. One can use the ability to understand others and good interpersonal communication skills to find the best solution or make the best decisions in the interest of everyone involved. Strong interpersonal skills help individuals work well in teams and collaborate effectively. Usually, people who possess good

interpersonal skills also tend to be good leaders, owing to their ability to communicate well with others and motivate the people around them.

Interpersonal communication is the key to working in a team environment and working collectively to achieve shared goals. Following are the interpersonal communication skills that vital for success at work -

Verbal Communication

The ability to speak clearly, appropriately and confidently can help one communicate effectively with others. It is vital to select the appropriate vocabulary and tone for the target audience.

For example: one should speak formally and professionally in the work environment, while informal language is acceptable in an intimate environment with close friends and family. Also, one should avoid using complex or technical language while communicating with an audience that may not be familiar with it. Using simple language in a courteous tone helps achieve better communication, irrespective of the audience.

Active Listening

Active listening is defined as the ability to pay complete or undivided attention to someone when they speak and understand what they are saying. It is important for effective communication because without understanding what the speaker is saying, it becomes difficult to carry forward a conversation. One should ensure to use appropriate verbal and non-verbal responses, e.g. eye contact, nodding, or smiling, to show interest in what the speaker says. Active listening is also about paying attention to the speaker's body language and visual cues. Asking and answering questions is one of the best ways to demonstrate an interest in conversing with the other person.

Active listening is critical for communicating effectively without ambiguity. It helps one understand the information or instructions being shared. It may also encourage co-workers to share their ideas, which ultimately helps achieve collaboration.

Body Language

One's expression, posture, and gestures are as important as verbal communication. One should practice open body language to encourage positivity and trust while communicating. Open body language includes - maintaining eye contact, nodding, smiling and being comfortable. On the other hand, one should avoid closed body language, e.g. crossed arms, shifting eyes and restless behaviour.

Empathy

Empathy is the ability to understand the emotions, ideas and needs of others from their point of view. Empathy is also known as emotional intelligence. Empathetic people are good at being aware of others' emotions and compassionate when communicating with them. Being empathetic in the workplace can be good to boost the morale of employees and improve productivity. By showing empathy, one can gain the trust and respect of others.

Conflict Resolution

One can use interpersonal communication skills to help resolve disagreements and conflicts in the workplace. This involves the application of negotiation and persuasion skills to resolve arguments

between conflicting parties. It is also important to evaluate and understand both sides of the argument by listening closely to everyone involved and finding an amicable solution acceptable to all.

Good conflict resolution skills can help one contribute to creating a collaborative and positive work environment. With the ability to resolve conflicts, one can earn the trust and respect of co-workers.

Teamwork

Employees who communicate and work well in a team often have better chances of achieving success and common goals. Being a team player can help one avoid conflicts and improve productivity. One can do this by offering to help co-workers when required and asking for their feedback and ideas. When team members give their opinions or advice, one should positively receive and react to the opinions/advice. One should be optimistic and encouraging when working in groups.

Improving Interpersonal Skills

One can develop interpersonal skills by practising good communication and setting goals for improvement. One should consider the following tips to improve their interpersonal skills -

- One should ask for feedback from co-workers, managers, family or friends to figure out what needs improvement concerning their interpersonal skills.
- One can identify the areas of interpersonal communication to strengthen by watching others.
- One can learn and improve interpersonal skills by observing co-workers, company leaders and professionals who possess good interpersonal skills. This includes watching and listening to them to note how they communicate and the body language used by them. It is vital to note their speed of speaking, tone of voice, and the way they engage with others. One should practice and apply such traits in their own interactions and relationships.
- One should learn to control their emotions. If stressed or upset, one should wait until being calm to have a conversation. One is more likely to communicate effectively and confidently when not under stress.
- One can reflect on their personal and professional conversations to identify the scope of improvement and learn how to handle conversations better or communicate more clearly. It helps to consider whether one could have reacted differently in a particular situation or used specific words or positive body language more effectively. It is also vital to note the successful and positive interactions to understand why they are successful.
- One should practice interpersonal skills by putting oneself in positions where one can build relationships and use interpersonal skills. For example, one can join groups that have organized meetings or social events. These could be industry-specific groups or groups with members who share an interest or hobby.
- Paying attention to family, friends and co-workers and making efforts to interact with them helps a lot. One should complement their family, friends and co-workers on their good ideas, hard work and achievements. Trying to understand someone's interests and showing interest in knowing them can help one build strong interpersonal skills. Offering to help someone, especially in difficult situations, helps build stronger and positive workplace relationships.

- One should avoid distractions, such as a mobile phone, while interacting with someone. Giving someone full attention while avoiding distractions helps achieve a clear exchange of ideas. By listening with focus, one can understand and respond effectively.
- One can attend appropriate courses on interpersonal skills or sign up for workshops at work to improve interpersonal skills. One can find many resources online also, such as online videos.
- For personal mentoring, one can approach a trusted family member, friend, co-worker, or current/former employer. A person one looks up to with respect and admires is often a good choice to be selected as a mentor. One can even hire a professional career or communication coach.
- Interpersonal communication skills often help one boost their morale, be more productive in the workplace, complete team projects smoothly and build positive and strong relationships with co-workers.

Scan the QR code or click on the link to watch related videos

www.youtube.com/watch?v=u16EPwFmdis

Effective communication skills

Unit 5.2: Working Effectively and Maintaining Discipline at Work

Unit Objectives

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

1. Discuss the importance of following organizational guidelines for dress code, time schedules, language usage and other behavioural aspect
2. Explain the importance of working as per the workflow of the organization to receive instructions and report problems
3. Explain the importance of conveying information/instructions as per defined protocols to the authorised persons/team members
4. Explain the common workplace guidelines and legal requirements on non-disclosure and confidentiality of business-sensitive information
5. Describe the process of reporting grievances and unethical conduct such as data breaches, sexual harassment at the workplace, etc.
6. Discuss ways of dealing with heightened emotions of self and others.

5.2.1 Discipline at Work

Discipline is essential for organizational success. It helps improve productivity, reduce conflict and prevent misconduct in the workplace. It is important to have rules concerning workplace discipline and ensure that all employees comply with them. In the absence of discipline, a workplace may experience conflicts, bullying, unethical behaviour and poor employee performance. An efficient workplace disciplinary process helps create transparency in the organization. Benefits of disciplinary standards:

All employees follow the same rules which helps establish uniformity and equality in the workplace

Managers and supervisors have defined guidelines on what action to take while initiating disciplinary action

With well defined and enforced disciplinary rules, an organization can avoid various safety, security, rupational risks

Fig 5.2.1: Benefits of Disciplinary Standards

Maintaining an organized and cohesive workforce requires maintaining discipline in both personal and professional behaviors. It is important to follow the appropriate measures to keep employees in line without affecting their morale.

Defining Discipline

The first and crucial step in maintaining workplace discipline is to define what is meant by discipline. It helps to evaluate common discipline problems and devise guidelines for handling them effectively. Among a number of areas, discipline usually covers -

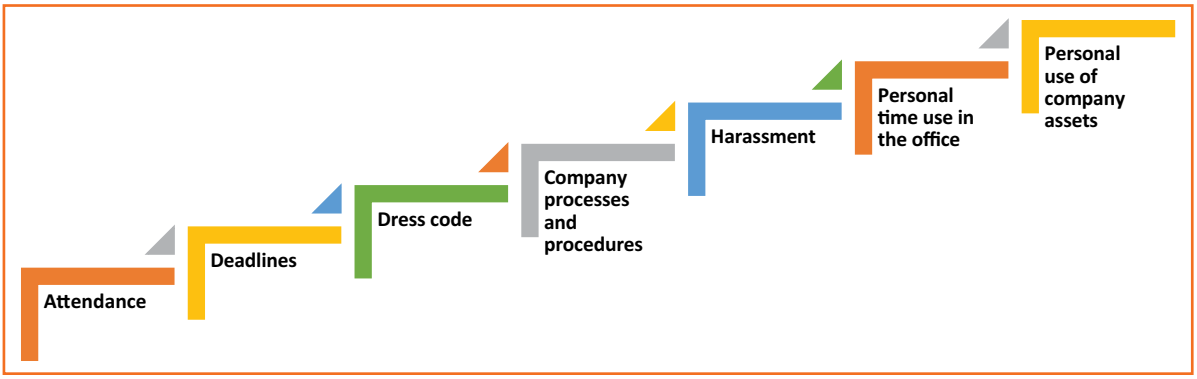


Fig 5.2.2: Examples of Workplace Discipline

According to demography and local issues, it may also include substance use and related issues. It is vital for a workplace to have an employee handbook or company policy guide, to serve as a rulebook for employees to follow. The employee handbook/ company policy guide should be reviewed and updated periodically according to any issues or areas, or concerns identified concerning workplace discipline. Such manuals should also cover all the laws and regulations governing workplace behaviour.

Defining and documenting workplace rules aids in their implementation, ensuring little or no ambiguity. All employees in a workplace should also have easy access to the workplace guidelines so that they can refer to them to get clarity whenever required. To maintain discipline at work, it is also critical to ensure uniform application of workplace guidelines to all employees without exception.

5.2.2 Employee Code of Conduct

The employee code of conduct manual serves as a guide for employees to inform them regarding the behavior expected from them at work. It helps create a good work environment with consistent behavior from employees. The manual should list examples of acceptable and not acceptable behaviors at work. The code of conduct should be discussed with employees so that they have the clarifications required.

For example, an organization may create guidelines concerning the conduct with clients to ensure no contact is made with them except for business purposes, also prescribing the use of appropriate means of communication.

Employees should have a clear understanding concerning their job responsibilities and the behaviors expected from them with all stakeholders, e.g. company personnel, clients and associated third parties. It is critical to have documented guidelines for employees to follow concerning all aspects of work. It should also document the disciplinary action to be followed in case of non-compliance, e.g. verbal and then written warning, temporary suspension or eventual termination of service in case of repeated non-compliance with the employee code of conduct. Employees should know what the company rules are

and what will happen if they break the rules. However, disciplinary action should be initiated only when reasonably required to avoid its misuse for employee harassment.

There should also be an effective mechanism for employees to raise their concerns/ grievances and have them addressed while maintaining privacy, as required, e.g. raising concerns regarding the behavior of a co-worker.

The employee code of conduct manual must be duly reviewed and approved by the concerned stakeholders, such as the Human Resources (HR) department and company executives.

5.2.3 Interpersonal Conflicts

Interpersonal conflict is any type of conflict between two or more people. These are found in both - personal and professional relationships - among friends, family, and co-workers. In the workplace, interpersonal conflict is often observed when a person or group of people interfere with another person's attempts at completing assignments and achieving goals. It is critical to resolve conflicts in the workplace to boost the morale of employees, repair working relationships among them, and improve customer satisfaction.

Reasons for Workplace Conflicts

Workplace conflicts are often observed when two or more people have different points of view. This can happen between managers, co-workers, or clients and customers. In general, interpersonal conflicts are caused by a lack of communication or unclear communication.

Some of the leading reasons for workplace conflicts are:

- Difference in values
- Personality clashes
- Poor communication

Example of poor communication: if a manager reassigns a task to another employee without communicating with the employee to whom it was originally assigned, interpersonal conflict can arise among them. This may potentially make the first employee, i.e. who was originally assigned the task, feel slighted and mistrusted by the manager. It may even cause animosity in the first employee toward the employee who has now been assigned the task.

Types of Interpersonal Conflict

Following are the four types of interpersonal conflicts -

1. **Policy-related interpersonal conflict**

   When a conflict relates to a decision or situation that involves both parties, it can be called a policy-related interpersonal conflict. Example – two people or groups working on the same project, trying to adopt different approaches. To resolve policy-related interpersonal conflicts, the parties involved should try to look for a win-win situation or make a compromise. This is especially critical

to resolve trivial issues so that work is not affected and common goals are achieved.

2. **Pseudo-conflicts**

   Pseudo-conflict arises when two people or groups want different things and cannot reach an agreement. Pseudo-conflicts usually involve trivial disagreements that tend to hide the root of the issue.

3. **Ego-related interpersonal conflicts**

   In ego conflicts, losing the argument may hurt or damage a person's pride. Sometimes ego conflicts arise when a number of small conflicts pile up on being left unresolved. To resolve ego-related conflicts, it's best to find the root of the issue and work towards a resolution.

4. **Value-related interpersonal conflicts**

   Sometimes conflicts may occur between people when they have different value systems. Such conflicts can be difficult to identify initially, making the people involved think the other party is being disagreeable or stubborn, wherein they just have different values. Some co-workers may highly value their personal/ family time after office that they may be unreachable to clients during non-office hours, while others may place a high value on client satisfaction and may still be available for clients during non-office hours. Conflict may arise among such people when they may be required to coordinate to help a client during after-office hours. Value-related interpersonal conflicts are often difficult to settle since neither party likes to compromise.

Resolving Interpersonal Conflicts

Conflicts are usually likely in the workplace; they can, however, be prevented. Often resolving interpersonal conflicts through open communication helps build a stronger relationship, paving the way for effective coordination and success. Some ways to resolve interpersonal conflict:

- **Communication:** A great way to resolve interpersonal conflicts is for the opposing parties to listen to one another's opinions and understand their viewpoints. Meeting in person and keeping the conversation goal-oriented is important. One can have effective communication by following some measures, e.g. staying on the topic, listening actively, being mindful of the body language, maintaining eye contact, etc.
- **Active Listening:** One should patiently listen to what the other person is saying without interrupting or talking over them. It helps one display empathy and get to the root of the issue. Asking questions to seek clarification when required helps in clear communication and conveys to the other person that one is listening to them. Practising active listening is a great way to improve one's communication skills.
- **Displaying Empathy:** Listening attentively and identifying the anxieties/ issues of co-workers is a great way to show empathy and concern. It is essential to understand their feelings and actions to encourage honesty and avoid future conflict.
- **Not Holding Grudges:** With different types of people and personalities in a workplace, it is common for co-workers to have conflicts. It is best to accept the difference in opinions and move on. Being forgiving and letting go of grudges allows one to focus on the positive side of things and

perform better at work.

Work-related interpersonal conflicts can be complicated because different people have different leadership styles, personality characteristics, job responsibilities and ways in which they interact. One should learn to look above interpersonal conflicts, resolving them to ensure work goals and environment are not affected.

5.2.4 Importance of Following Organizational Guidelines

Policies and procedures or organizational guidelines are essential for any organization. These provide a road map for the operations of the organization. These are also critical in ensuring compliance with the applicable laws and regulations by guiding the decision-making process and business operations.

Organizational guidelines help bring uniformity to the operations of an organization, which helps reduce the risk of unwanted and unexpected events. These determine how employees are supposed to behave at work, which ultimately helps the business achieve its objectives efficiently.

However, organizational guidelines are ineffective and fail to serve their purpose if they are not followed. Many people don't like the idea of following and abiding by specific guidelines. Such people should be made to understand the benefits of following the organizational guidelines. Some of the key benefits are given below:

With well-defined organizational guidelines in place, no individual can act arbitrarily, irrespective of their position in the organization. All individuals will know the pros and cons of taking certain actions and what to expect in case of unacceptable behaviour. Benefits of following organizational guidelines:

- **Consistent processes and structures:** Organization guidelines help maintain consistency in operations, avoiding any disorder. When all employees follow the organizational guidelines, an organization can run smoothly. These ensure that people in different job roles operate as they are supposed to, knowing what they are responsible for, what is expected of them, and what they can expect from their supervisors and co-workers. With clarity in mind, they can do their jobs with confidence and excellence. With every person working the way intended, it's easy to minimise errors.
- With all the staff following organizational guidelines, the organization has a better scope of using time and resources more effectively and efficiently. This allows the organization to grow and achieve its objectives.
- **Better quality service:** By following organizational guidelines, employees perform their duties correctly as per the defined job responsibilities. It helps enhance the quality of the organization's products and services, helping improve the organization's reputation. Working with a reputable organization, employees can take pride in their work and know they are contributing to the reputation.
- **A safer workplace:** When all employees follow organizational guidelines, it becomes easy to minimise workplace incidents and accidents. It reduces the liabilities associated with risks for

the organization and limits the interruptions in operations. Employees also feel comfortable and safe in the workplace, knowing their co-workers are ensuring safety at work by following the applicable guidelines.

Different organizations may have different guidelines on dress code, time schedules, language usage, etc. For example – certain organizations in a client-dealing business requiring employees to meet clients personally follow a strict dress code asking their employees to wear formal business attire. Similarly, organizations operating in specific regions may require their employees to use the dominant regional language of the particular region to build rapport with customers and serve them better. Certain organizations, such as banks, often give preference to candidates with knowledge of the regional language during hiring.

Working hours may also differ from one organization to another, with some requiring employees to work extra compared to others. One should follow the organizational guidelines concerning all the aspects of the employment to ensure a cohesive work environment.

5.2.5 Workflow

Workflow is the order of steps from the beginning to the end of a task or work process. In other words, it is the way a particular type of work is organised or the order of stages in a particular work process.

Workflows can help simplify and automate repeatable business tasks, helping improve efficiency and minimise the room for errors. With workflows in place, managers can make quick and smart decisions while employees can collaborate more productively.

Other than the order that workflows create in a business, these have several other benefits, such as -

- **Identifying Redundancies:** Mapping out work processes in a workflow allows one to get a clear, top-level view of a business. It allows one to identify and remove redundant or unproductive processes.

  Workflow gives greater insights into business processes. Utilizing such useful insights, one can improve work processes and the bottom line of the business. In many businesses, there are many unnecessary and redundant tasks that take place daily. Once an organization has insight into its processes while preparing workflow, it can determine which activities are really necessary.

  Identifying and eliminating redundant tasks creates value for a business. With redundant tasks and processes eliminated, an organization can focus on what's important to the business.

- **Increase in Accountability and Reduction in Micromanagement:** Micromanagement often causes problems in a business setting as most employees don't like being micromanaged, and even many managers don't like the practice. Micromanagement is often identified as one of the reasons why people quit their job.

  However, the need for micromanagement can be minimized by clearly mapping out the workflow. This way, every individual in a team knows what tasks need to be completed and by when and

who is responsible for completing them. This makes employees more accountable also.

With clearly defined workflow processes, managers don't have to spend much time micromanaging their employees, who don't have to approach the manager to know what the further steps are. Following a workflow, employees know what is going on and what needs to be done. This, in turn, may help increase the job satisfaction of everyone involved while improving the relationships between management and employees.

- **Improved Communication:** Communication at work is critical because it affects all aspects of an organization. There are instances when the main conflict in an organization originates from miscommunication, e.g. the management and employees disagreeing on an aspect, despite pursuing the same objectives. Poor communication is a common workplace issue that is often not dealt with.

  This highlights why workflow is important. Workplace communication dramatically can increase with the visibility of processes and accountability. It helps make the daily operations smoother overall.

- **Better Customer Service:** Customers or clients are central to a business. Therefore, it is imperative to find and improve ways to improve customer experience. Relying on outdated manual systems may cause customer requests or complaints to be overlooked, with dissatisfied customers taking their business elsewhere. However, following a well-researched and defined workflow can help improve the quality of customer service.

  By automating workflows and processes, an organization can also reduce the likelihood of human error. This also helps improve the quality of products or services over time, resulting in a better customer experience.S

5.2.6 Following Instructions and Reporting Problems

All organizations follow a hierarchy, with most employees reporting to a manager or supervisor. For organizational success, it is vital for employees to follow the instructions of their manager or supervisor. They should ensure they perform their duties as per the given instructions to help achieve the common objectives of the organization and deliver quality service or products. This consequently helps maintain the reputation of the organization.

It is also important to be vigilant and identify problems at work or with the organizational work processes. One should deal with the identified within their limits of authority and report out of authority problems to the manager/ supervisor or the concerned person for a prompt resolution to minimise the impact on customers/clients and business.

5.2.7 Information or Data Sharing

Information or data is critical to all organizations. Depending on the nature of its business, an organization may hold different types of data, e.g. personal data of customers or client data concerning their business operations and contacts. It is vital to effective measures for the appropriate handling of different types of data, ensuring its protection from unauthorized access and consequent misuse.

One should access certain data only if authorised to do so. The same is applicable when sharing data which must be shared only with the people authorised to receive it to use it for a specific purpose as per their job role and organizational guidelines. For example – one should be extra cautious while sharing business data with any third parties to ensure they get access only to the limited data they need as per any agreements with them. It is also critical to monitor how the recipient of the data uses it, which should strictly be as per the organizational guidelines. It is a best practice to share appropriate instructions with the recipient of data to ensure they are aware of the purpose with which data is being shared with them and how they are supposed to use and handle it. Any misuse of data must be identified and reported promptly to the appropriate person to minimise any damage arising out of data misuse.

These days most organizations require their employees and business partners or associated third parties to sign and accept the relevant agreement on the non-disclosure of business-sensitive information. In simple terms, business-sensitive information is confidential information. It is proprietary business information collected or created during the course of conducting business, including information about the business, e.g. proposed investments, intellectual property, trade secrets, or plans for a merger and information related to its clients. Business-sensitive information may sometimes also include information regarding a business's competitors in an industry.

The release of business-sensitive information to competitors or the general public poses a risk to a business. For example, information regarding plans for a merger could be harmful to a business if a competitor gets access to it.

5.2.8 Reporting Issues at Work

Most organizations have defined guidelines on appropriate reporting processes to be followed for reporting different types of issues. For example – one can report any grievances or dissatisfaction concerning co-workers to their manager/supervisor, e.g. data breaches or unethical conduct. If the concern is not addressed, then the employee should follow the organizational guidelines and hierarchy for the escalation of such issues that are not addressed appropriately.

For example: any concern related to sexual harassment at the workplace should be escalated to the concerned spokesperson, such as Human Resources (HR) representative, and if not satisfied with the

5.2.8 Reporting Issues at Work

Most organizations have defined guidelines on appropriate reporting processes to be followed for reporting different types of issues. For example – one can report any grievances or dissatisfaction concerning co-workers to their manager/supervisor, e.g. data breaches or unethical conduct. If the concern is not addressed, then the employee should follow the organizational guidelines and hierarchy for the escalation of such issues that are not addressed appropriately.

For example: any concern related to sexual harassment at the workplace should be escalated to the concerned spokesperson, such as Human Resources (HR) representative, and if not satisfied with the the senior management for their consideration and prompt action.

5.2.9 Dealing with Heightened Emotions

Humans are emotional beings. There may be occasions when one is overwhelmed by emotions and is unable to suppress them. However, there may be situations when one must manage emotions well, particularly at work.

Stress in one's personal and professional life may often cause emotional outbursts at work. Managing one's emotions well, particularly the negative ones, is often seen as a measure of one's professionalism. Anger, dislike, frustration, worry, and unhappiness are the most common negative emotions experienced at work.

Ways to manage negative emotions at work:

- **Compartmentalisation:** It's about not confining emotions to different aspects of one's life. For example, not letting negative emotions from personal life affect work-life and vice versa. One should try to leave personal matters and issues at home. One should train their mind to let go of personal matters before reaching work. Similarly, one can compartmentalise work-related stresses so that negative emotions from work don't affect one's personal life.
- **Deep breathing and relaxation:** Deep breathing helps with anxiety, worry, frustration and anger. One should take deep breaths, slowly count to ten - inhaling and exhaling until one calms down. One can also take a walk to calm down or listen to relaxing music. Talking to someone and sharing concerns also helps one calm down.
- **The 10-second rule:** This is particularly helpful in controlling anger and frustration. When one feels their temper rising, they should count to 10 to calm down and recompose. If possible, one should move away to allow temper to come down.
- **Clarify:** It is always good to clarify before reacting, as it may be a simple case of misunderstanding or miscommunication.
- **Physical activity:** Instead of losing temper, one should plan to exercise, such as running or going to the gym, to let the anger out. Exercise is also a great way to enhance mood and release any physical tension in the body.
- **Practising restraint:** One should avoid replying or making a decision when angry, not allowing anger or unhappiness to cloud one's judgement. It may be best to pause any communication while one is angry, e.g. not communicating over email when angry or upset.

- **Knowing one's triggers:** It helps when one is able to recognise what upsets or angers them. This way, one can prepare to remain calm and plan their reaction should a situation occur. One may even be able to anticipate the other party's reaction.
- **Be respectful:** One should treat their colleagues the same way one would like to be treated. If the other person is rude, one need not reciprocate. It is possible to stay gracious, firm and assertive without being aggressive. Sometimes, rude people back away when they don't get a reaction from the person they are arguing with.
- **Apologise for any emotional outburst:** Sometimes, one can get overwhelmed by emotions, reacting with an emotional outburst. In such a case, one should accept responsibility and apologise immediately to the affected persons without being defensive.
- **Doing away with negative emotions:** It is recommended to let go of anger, frustration and unhappiness at the end of every workday. Harbouring negative emotions affects one emotionally, affecting their job performance also. Engaging in enjoyable activities after work is a good stress reliever.

Notes

Unit 5.3 : Maintaining Social Diversity at Work

Unit Objectives

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

1. Explain the concept and importance of gender sensitivity and equality
2. Discuss ways to create sensitivity for different genders and Persons with Disabilities (PwD)

5.3.1 Gender Sensitivity

Gender sensitivity is the act of being sensitive towards people and their thoughts regarding gender. It ensures that people know the accurate meaning of gender equality, and one's gender should not be given priority over their capabilities.

Fig 5.3.1. Gender Equality

Women are an important source of labour in many sectors, yet they have limited access to resources and benefits. Women should receive the same benefits and access to resources as men. A business can improve its productivity and quality of work by providing better support and opportunities to women.

Important Terms

- Gender Sensitivity-Gender sensitivity is the act of being sensitive to the ways people think about gender.
- **Gender Equality:** It means persons of any gender enjoy equal opportunities, responsibilities, and rights in all areas of life.
- **Gender Discrimination:** It means treating an individual unequally or disadvantageously based on their gender, e.g. paying different wages to men and women for similar or equal job positions.

Strategies for Enhancing Gender Equity

To enhance gender equity, one should -

- Follow gender-neutral practices at all levels at work.

- Participate together in decision-making.
- Help in promoting women's participation in different forums.
- Assist women in getting exposure to relevant skills and practices.
- Assist women in capacity building by mentoring, coaching or motivating them, as appropriate.
- Assist in the formation and operation of women support groups.
- Assist in the implementation of women-centric programmes.
- Combine technical training with reproductive health and nutrition for coffee farming households.
- Assist in making a work environment that is healthy, safe, and free from discrimination.

Bridging Gender Differences

Men and women react and communicate very differently. Thus, there are some work differences as both genders have their style and method of handling a situation.

Although, understanding and maturity vary from person to person, even between these genders, based on their knowledge, education, experience, culture, age, and upbringing, as well as how one's brain functions over a thought or problem.

In order to bridge the gap, one should:

- Not categorize all men and women in one way.
- Be aware of the verbal and non-verbal styles of communication of every gender to avoid any miscommunication and work better.
- Be aware of partial behaviour and avoid it.
- Encourage co-workers of different genders to make room by providing space to others.

Ways to reduce Gender Discrimination

- Effective steps against sexual harassment by the concerned authorities and general public.
- Gender stereotypes are how society expects people to act based on their gender. This can only be reduced by adopting appropriate behaviour and the right attitude.
- Objectification of females must be abolished.
- Ways to Promote Gender Sensitivity in the Workplace
- Practices that promote gender diversity should be adopted and promoted.
- All genders should receive equal responsibilities, rights, and privileges.
- All genders should have equal pay for similar or the same job roles/ positions.
- Strict and effective workplace harassment policies should be developed and implemented.
- An open-minded and stress-free work environment should be available to all the employees, irrespective of their gender.
- Women should be encouraged to go ahead in every field of work and assume leadership roles.
- Follow appropriate measures for women's empowerment.
- Men should be taught to be sensitive to women and mindful of their rights.

5.3.2 PwD Sensitivity

Some individuals are born with a disability, while others may become disabled due to an accident, illness or as they get old. People with Disabilities (PwD) may have one or more areas in which their functioning is affected. A disability can affect hearing, sight, communication, breathing, understanding, mobility, balance, and concentration or may include the loss of a limb. A disability may contribute to how a person feels and affect their mental health.

Important Terms

- **Persons with Disabilities (PwD):** Persons with Disabilities means a person suffering from not less than 40% of any disability as certified by a medical authority.
- **Types of Disability:**
    i. **Blindness:** Visually impaired
    ii. Low Vision
    iii. Leprosy Cured
    iv. Hearing impairment
    v. Locomotor disability
    vi. Mental retardation
    vii. Mental illness

PwD Sensitivity

PwD sensitivity promotes empathy, etiquette and equal participation of individuals and organizations while working with individuals with a disability, e.g. sensory, physical or intellectual.

Ways to be PwD Sensitive

To be sensitive to PwD, one should -

- Be respectful to all Persons with Disabilities (PwD) and communicate in a way that reflects PwD sensitivity.
- Always be supportive and kind towards a PwD with their daily chores.
- Be ready to assist a PwD to help them avail of any benefit/ livelihood opportunity/ training or any kind that helps them grow.
- Encourage and try to make things easier and accessible to PwD so that they can work without or with minimum help.
- Protest where feasible and report any wrong act/behaviour against any PwD to the appropriate authority.
- Learn and follow the laws, acts, and policies relevant to PwD.

Appropriate Verbal Communication

As part of appropriate verbal communication with all genders and PwD, one should -

- Talk to all genders and PwD respectfully, maintaining a normal tone of voice with appropriate politeness. It is important to ensure one's tone of voice does not have hints of sarcasm, anger, or unwelcome affection.

- Avoid being too self-conscious concerning the words to use while also ensuring not to use words that imply one's superiority over the other.
- Make no difference between a PwD and their caretaker. Treat PwD like adults and talk to them directly.
- Ask a PwD if they need any assistance instead of assuming they need it and offering assistance spontaneously.

Appropriate Non-verbal Communication

Non-verbal communication is essentially the way someone communicates through their body language. These include -

- **Facial expressions:** The human face is quite expressive, capable of conveying many emotions without using words. Facial expressions must usually be maintained neutral and should change according to the situation, e.g. smile as a gesture of greeting.
- **Body posture and movement:** One should be mindful of how to sit, stand, walk, or hold their head. For example - one should sit and walk straight in a composed manner. The way one moves and carries self, communicates a lot to others. This type of non-verbal communication includes one's posture, bearing, stance, and subtle movements.
- **Gestures:** One should be very careful with their gestures, e.g. waving, pointing, beckoning, or using one's hands while speaking. One should use appropriate and positive gestures to maintain respect for the other person while being aware that a gesture may have different meanings in different cultures.
- **Eye contact:** Eye contact is particularly significant in non-verbal communication. The way someone looks at someone else may communicate many things, such as interest, hostility, affection or attraction. Eye contact is vital for maintaining the flow of conversation and for understanding the other person's interest and response. One should maintain appropriate eye contact, ensuring not to stare or look over the shoulders. To maintain respect, one should sit or stand at the other person's eye level to make eye contact.
- **Touch:** Touch is a very sensitive type of non-verbal communication. Examples are - handshakes, hugs, pat on the back or head, gripping the arm, etc. A firm handshake indicates interest, while a weak handshake indicates the opposite. One should be extra cautious not to touch others inappropriately and avoid touching them inadvertently by maintaining a safe distance.

Rights of PwD

PwD have the right to respect and human dignity. Irrespective of the nature and seriousness of their disabilities, PwD have the same fundamental rights as others, such as -

- Disabled persons have the same civil and political rights as other people
- Disabled persons are entitled to the measures designed to enable them to become as self-dependent as possible
- Disabled persons have the right to economic and social security
- Disabled persons have the right to live with their families or foster parents and participate in all

social and creative activities.

- Disabled persons are protected against all exploitation and treatment of discriminatory and abusive nature.

Making Workplace PwD Friendly

- One should not make PwD feel uncomfortable by giving too little or too much attention
- One should use a normal tone while communicating with a PwD and treat them as all others keeping in mind their limitations and type of disability
- Any help should be provided only when asked for by a PwD
- One should help in ensuring the health and well-being of PwD.

Expected Employer Behaviour

Some of the common behavioural traits that employees expect from their employers are -

- **Cooperation:** No work is successful without cooperation from the employer's side. Cooperation helps to understand the job role better and complete it within the given timeline.
- **Polite language:** Polite language is always welcomed at work. This is a basic aspect that everybody expects.
- **Positive Attitude:** Employers with a positive attitude can supervise the work of the employees and act as a helping hand to accomplish the given task. A person with a positive attitude looks at the best qualities in others and helps them gain success.
- **Unbiased behaviour:** Employers should always remain fair towards all their employees. One should not adopt practices to favour one employee while neglecting or ignoring the other. This might create animosity among co-workers.
- **Decent behaviour:** The employer should never improperly present oneself before the employee. One should always respect each other's presence and behave accordingly. The employer should not speak or act in a manner that may make the employee feel uneasy, insulted, and insecure.

Notes

Skill India
कौशल भारत-कुशल भारत

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

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

ESSCI
Skilling India in Electronics

6. Basic Health and Safety Practices

Unit 6.1 - Workplace Hazards

Unit 6.2 – Fire Safety

Unit 6.3 – First Aid

Unit 6.4 – Waste Management

ELE/N1002

Key Learning Outcomes

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

1. Discuss job-site hazards, risks and accidents
2. Explain the organizational safety procedures for maintaining electrical safety, handling tools and hazardous materials
3. Describe how to interpret warning signs while accessing sensitive work areas
4. Explain the importance of good housekeeping
5. Describe the importance of maintaining appropriate postures while lifting heavy objects
6. List the types of fire and fire extinguishers
7. Describe the concept of waste management and methods of disposing of hazardous waste
8. List the common sources of pollution and ways to minimize them
9. Elaborate on electronic waste disposal procedures
10. Explain how the administer appropriate first aid to victims in case of bleeding, burns, choking, electric shock, poisoning and also administer first aid to victims in case of a heart attack or cardiac arrest due to electric shock

Unit 6.1: Workplace Hazards

Unit Objectives

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

1. Discuss job-site hazards, risks and accidents
2. Explain the organizational safety procedures for maintaining electrical safety, handling tools and hazardous materials
3. Describe how to interpret warning signs while accessing sensitive work areas
4. Explain the importance of good housekeeping
5. Describe the importance of maintaining appropriate postures while lifting heavy objects
6. Explain safe handling of tools and Personal Protective Equipment to be used.

6.1.1. Workplace Safety

Workplace safety is important to be established for creating a safe and secure working for the workers. The workplace has to be administered as per the rules of the Occupational Safety and Health Administration (OSHA). It refers to monitoring the working environment and all hazardous factors that impact employees' safety, health, and well-being. It is important to provide a safe working environment to the employees to increase their productivity, wellness, skills, etc.

The benefits of workplace safety are:

- Employee retention increases if they are provided with a safe working environment.
- Failure to follow OSHA's laws and guidelines can result in significant legal and financial consequences.
- A safe environment enables employees to stay invested in their work and increases productivity.
- Employer branding and company reputation can both benefit from a safe working environment.

6.1.2. Workplace Hazards

A workplace is a situation that has the potential to cause harm or injury to the workers and damage the tools or property of the workplace. Hazards exist in every workplace and can come from a variety of sources. Finding and removing them is an important component of making a safe workplace.

Common Workplace Hazards

The common workplace hazards are:

- **Biological:** The threats caused by biological agents like viruses, bacteria, animals, plants, insects and also humans, are known as biological hazards.

- **Chemical:** Chemical hazard is the hazard of inhaling various chemicals, liquids and solvents. Skin irritation, respiratory system irritation, blindness, corrosion, and explosions are all possible health and physical consequences of these dangers.
- **Mechanical:** Mechanical Hazards comprise the injuries that can be caused by the moving parts of machinery, plant or equipment.
- **Psychological:** Psychological hazards are occupational hazards caused by stress, harassment, and violence.
- **Physical:** The threats that can cause physical damage to people is called physical hazard. These include unsafe conditions that can cause injury, illness and death.
- **Ergonomic:** Ergonomic Hazards are the hazards of the workplace caused due to awkward posture, forceful motion, stationary position, direct pressure, vibration, extreme temperature, noise, work stress, etc.

Workplace Hazards Analysis

A workplace hazard analysis is a method of identifying risks before they occur by focusing on occupational tasks. It focuses on the worker's relationship with the task, the tools, and the work environment. After identifying the hazards of the workplace, organisations shall try to eliminate or minimize them to an acceptable level of risk.

Control Measures of Workplace Hazards

Control measures are actions that can be taken to reduce the risk of being exposed to the hazard. Elimination, Substitution, Engineering Controls, Administrative Controls, and Personal Protective Equipment are the five general categories of control measures.

- **Elimination:** The most successful control technique is to eliminate a specific hazard or hazardous work procedure or prevent it from entering the workplace.
- **Substitution:** Substitution is the process of replacing something harmful with something less hazardous. While substituting the hazard may not eliminate all of the risks associated with the process or activity, it will reduce the overall harm or health impacts.
- **Engineering Controls:** Engineered controls protect workers by eliminating hazardous situations or creating a barrier between the worker and the hazard, or removing the hazard from the person.
- **Administrative Controls:** To reduce exposure to hazards, administrative controls limit the length of time spent working on a hazardous task that might be used in combination with other measures of control.
- **Personal Protective Equipment:** Personal protective equipment protects users from health and safety hazards at work. It includes items like safety helmets, gloves, eye protection, etc.

6.1.3. Risk for a Drone Technician

A drone technician may require to repair the propeller, motor and its mount, battery, mainboards, processor, booms, avionics, camera, sensors, chassis, wiring and landing gear. A technician may face some risks while repairing the drones' equipment.

- The technician is susceptible to being physically harmed by propellers.
- Direct contact with exposed electrical circuits can injure the person.
- If the skin gets in touch with the heat generated from electric arcs, it burns the internal tissues.
- Major electrical injuries can occur due to poorly installed electrical equipment, faulty wiring, overloaded or overheated outlets, use of extension cables, incorrect use of replacement fuses, use of equipment with wet hands, etc.

6.1.4. Workplace Warning Signs

A Hazard sign is defined as 'information or instruction about health and safety at work on a signboard, an illuminated sign or sound signal, a verbal communication or hand signal.'

There are four different types of safety signs:

- Prohibition / Danger Alarm Signs
- Mandatory Signs
- Warning Signs
- And Emergency

1. **Prohibition Signs:** A **"prohibition sign"** is a safety sign that prohibits behaviour that is likely to endanger one's health or safety. The colour red is necessary for these health and safety signs. Only what or who is forbidden should be displayed on a restriction sign.

Fig 6.1.1: Prohibition Warning Signs

2. **Mandatory Signs:** Mandatory signs give clear directions that must be followed. The icons are white circles that have been reversed out of a blue circle. On a white background, the text is black.

Fig 6.1.2: Mandatory Signs

3. **Warning Signs:** Warning signs are the safety information communication signs. They are shown as a 'yellow colour triangle'.

Fig 6.1.3: Mandatory Signs

4. **Emergency Signs:** The location or routes to emergency facilities are indicated by emergency signs. These signs have a green backdrop with a white emblem or writing. These signs convey basic information and frequently refer to housekeeping, company procedures, or logistics.

Fig 6.1.4: Emergency Signs

6.1.5. Cleanliness in the Workplace

Workplace cleanliness maintenance creates a healthy, efficient and productive environment for the employees. Cleanliness at the workplace is hindered by some elements like cluttered desks, leftover food, waste paper, etc. A tidy workplace is said to improve employee professionalism and enthusiasm while also encouraging a healthy working environment.

Benefits of cleanliness in the workplace:

1. **Productivity:** Cleanliness in the workplace can bring a sense of belonging to the employees, also motivating and boosting the morale of the employees. This results in increasing their productivity.
2. **Employee Well-being:** Employee well-being can be improved by providing a clean work environment. Employees use fewer sick days in a workplace where litter and waste are properly disposed of, and surfaces are cleaned regularly, resulting in increased overall productivity.
3. **Positive Impression:** Cleanliness and orderliness in the workplace provide a positive impression on both employees and visitors.
4. **Cost saving:** By maintaining acceptable levels of cleanliness in the workplace, businesses can save money on cleaning bills and renovations, which may become necessary if the premises are not properly kept.

Reasons for cleaning the workplace

- Cleaning of dry floors, mostly to prevent workplace slips and falls.

- Disinfectants stop bacteria in their tracks, preventing the spread of infections and illness.
- Proper air filtration decreases hazardous substance exposures such as dust and fumes.
- Light fixture cleaning improves lighting efficiency.
- Using environmentally friendly cleaning chemicals that are safer for both personnel and the environment.
- Work environments are kept clean by properly disposing of garbage and recyclable items.

6.1.6. Lifting and Handling of Heavy Loads

Musculoskeletal Injuries (MSIs), such as sprains and strains, can occur while lifting, handling, or carrying objects at work. When bending, twisting, uncomfortable postures and lifting heavy objects are involved, the risk of injury increases. Ergonomic controls can help to lower the risk of injury and potentially prevent it.

Types of injuries caused while lifting heavy objects:

- Cuts and abrasions are caused by rough surfaces.
- Crushing of feet or hands.
- Strain to muscles and joints

Fig 6.1.5: Lifting loads technique

Preparing to lift

A load that appears light enough to bear at first will grow increasingly heavier as one carries it further. The person carrying the weight should be able to see over or around it at all times.

The amount of weight a person can lift, depends on their age, physique, and health.

It also depends on whether or not the person is used to lifting and moving hefty objects.

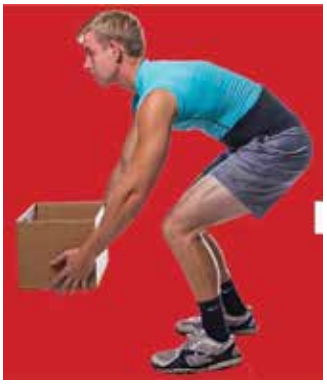
Common causes of back injuries

The most common causes of back injuries are -

1. **Inadequate training:** The individual raising the load receives no sufficient training or guidance.
2. **Lack of awareness of technique:** The most common cause of back pain is incorrect twisting and posture, which causes back strain.
3. **Load size:** The load size to consider before lifting. If the burden is too much for one's capacity or handling, their back may be strained and damaged.
4. **Physical strength:** Depending on their muscle power, various persons have varied physical strengths. One must be aware of their limitations.
5. **Teamwork:** The operation of a workplace is all about working together. When opposed to a single person lifting a load, two people can lift it more easily and without difficulty. If one of two people isn't lifting it properly, the other or both of them will suffer back injuries as a result of the extra strain.

Techniques for lifting heavy objects

Technique	Demonstration
1. Ensure one has a wide base of support before lifting the heavy object. Ensure one's feet are shoulder-width apart, and one foot is slightly ahead of the other at all times. This will help one maintain a good balance during the lifting of heavy objects. This is known as the Karate Stance.	
2. Squat down as near to the object as possible when one is ready to lift it, bending at the hips and knees with the buttocks out. If the object is really heavy, one may wish to place one leg on the floor and the other bent at a straight angle in front of them.	

3. Maintain proper posture as one begin to lift upward. To do so, one should keep their back straight, chest out, and shoulders back while gazing straight ahead.	
4. By straightening one's hips and knees, slowly elevate the thing (not the back). As one rises, they should extend their legs and exhale. Lift the heavy object without twisting the body or bending forward.	
5. Do not lift bending forward.	
6. Hold the load close to the body.	

7. Never lift heavy objects above the shoulder	
8. Use the feet (not the body) to change direction, taking slow, small steps.	
9. Set down the heavy object carefully, squatting with the knees and hips only.	

Table 6.1.1. Techniques for lifting heavy objects

6.1.7. Safe Handling of Tools

Workers should be trained on how to use tools safely. When tools are misplaced or handled incorrectly by workers, they can be dangerous. The following are some suggestions from the National Safety Council for safe tool handling when they are not in use -

- Never carry tools up or down a ladder in a way that makes it difficult to grip them. Instead of being carried by the worker, tools should be lifted up and down using a bucket or strong bag.
- Tools should never be tossed but should be properly passed from one employee to the next. Pointed tools should be passed with the handles facing the receiver or in their carrier.
- When turning and moving around the workplace, workers carrying large tools or equipment on their shoulders should pay particular attention to clearances.
- Pointed tools such as chisels and screwdrivers should never be kept in a worker's pocket. They can be carried in a toolbox, pointing down in a tool belt or pocket tool bag, or in hand with the tip always held away from the body.
- Tools should always be stored while not in use. People below are put in danger when tools are left sitting around on an elevated structure, such as a scaffold. In situations when there is a lot of vibration, this risk increases.

6.1.8. Personal Protective Equipment

Personal protective equipment, or **"PPE,"** is equipment worn to reduce exposure to risks that might result in significant occupational injuries or illnesses. Chemical, radiological, physical, electrical, mechanical, and other job dangers may cause these injuries and diseases.

PPE used for protection from the following injuries are:

Injury Protection	Protection	PPE
Head Injury Protection	Falling or flying objects, stationary objects, or contact with electrical wires can cause impact, penetration, and electrical injuries. Hard hats can protect one's head from these injuries. A common electrician's hard hat is shown in the figure below. This hard hat is made of non conductive plastic and comes with a set of safety goggles.	

Injury Protection	Protection	PPE
Foot and Leg Injury Protection	In addition to foot protection and safety shoes, leggings (e.g., leather) can guard against risks such as falling or rolling objects, sharp objects, wet and slippery surfaces, molten metals, hot surfaces, and electrical hazards.	
Eye and Face Injury Protection	Spectacles, goggles, special helmets or shields, and spectacles with side shields and face shields can protect against the hazards of flying fragments, large chips, hot sparks, radiation, and splashes from molten metals. They also offer protection from particles, sand, dirt, mists, dust, and glare.	
Protection against Hearing Loss	Hearing protection can be obtained by wearing earplugs or earmuffs. High noise levels can result in permanent hearing loss or damage, as well as physical and mental stress. Self-forming earplugs composed of foam, waxed cotton, or fibreglass wool usually fit well. Workers should be fitted for moulded or prefabricated earplugs by a specialist.	

Injury Protection	Protection	PPE
Hand Injury Protection	Hand protection will aid workers who are exposed to dangerous substances by skin absorption, serious wounds, or thermal burns. Gloves are a frequent protective clothing item. When working on electrified circuits, electricians frequently use leather gloves with rubber inserts. When stripping cable with a sharp blade, Kevlar gloves are used to prevent cuts.	
Whole Body Protection	Workers must protect their entire bodies from risks such as heat and radiation. Rubber, leather, synthetics, and plastic are among the materials used in whole-body PPE, in addition to fire-retardant wool and cotton. Maintenance staff who operate with high-power sources such as transformer installations and motor-control centres are frequently obliged to wear fire-resistant clothes.	

Table 6.1.2. Personal protective equipment

Unit 6.2: Fire Safety

Unit Objectives

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

1. List the types of fire and fire extinguishers

6.2.1. Fire Safety

Fire safety is a set of actions aimed at reducing the amount of damage caused by fire. Fire safety procedures include both those that are used to prevent an uncontrolled fire from starting and those that are used to minimise the spread and impact of a fire after it has started. Developing and implementing fire safety measures in the workplace is not only mandated by law but is also essential for the protection of everyone who may be present in the building during a fire emergency.

The basic Fire Safety Responsibilities are:

- To identify risks on the premises, a fire risk assessment must be carried out.
- Ascertain that fire safety measures are properly installed.
- Prepare for unexpected events.
- Fire safety instructions and training should be provided to the employees.

6.2.2. Respond to a Workplace Fire

- Workplace fire drills should be conducted on a regular basis.
- If one has a manual alarm, they should raise it.
- Close the doors and leave the fire-stricken area as soon as possible. Ensure that the evacuation is quick and painless.
- Turn off dangerous machines and don’t stop to get personal items.
- Assemble at a central location. Ascertain that the assembly point is easily accessible to the employees.
- If one’s clothing catches fire, one shouldn’t rush about it. They should stop and descend on the ground and roll to smother the flames if their clothes catch fire.

6.2.3. Fire Extinguisher

Fire extinguishers are portable devices used to put out small flames or minimise their damage until fire-fighters arrive. These are maintained on hand in locations such as fire stations, buildings, workplaces, public transit, and so on. The types and quantity of extinguishers that are legally necessary for a given region are determined by the applicable safety standards.

Types of fire extinguishers are:

There are five main types of fire extinguishers -

1. **Water:** Water fire extinguishers are one of the most common commercial and residential fire extinguishers on the market. They're meant to be used on class-A flames.	
2. **Powder:** The L2 powder fire extinguisher is the most commonly recommended fire extinguisher in the Class D Specialist Powder category, and is designed to put out burning lithium metal fires.	
3. **Foam:** Foam extinguishers are identified by a cream rectangle with the word **"foam"** printed on it. They're mostly water-based, but they also contain a foaming component that provides a quick knock-down and blanketing effect on flames. It suffocates the flames and seals the vapours, preventing re-ignition.	
4. **Carbon Dioxide (CO2):** Class B and electrical fires are extinguished with carbon dioxide extinguishers, which suffocate the flames by removing oxygen from the air. They are particularly beneficial for workplaces and workshops where electrical fires may occur since, unlike conventional extinguishers, they do not leave any toxins behind and hence minimise equipment damage.	

5. **Wet Chemical:** Wet chemical extinguishers are designed to put out fires that are classified as class F. They are successful because they can put out extremely high-temperature fires, such as those caused by cooking oils and fats.	

Table 6.2.1 Fire Extinguishers

Scan the QR code or click on the link to watch related videos

www.youtube.com/watch?v=DaYwcH1GMEg

Workplace emergency procedures

Unit 6.3: First Aid

Unit Objectives

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

1. Explain how the administer appropriate first aid to victims in case of bleeding, burns, choking, electric shock, poisoning
2. Explain how to administer first aid to victims in case of a heart attack or cardiac arrest due to electric shock.

6.3.1. First Aid

First aid is the treatment or care given to someone who has sustained an injury or disease until more advanced care can be obtained or the person recovers.

The aim of first aid is to:

- Preserve life
- Prevent the worsening of a sickness or injury
- If at all possible, relieve pain
- Encourage recovery
- Keep the unconscious safe.

First aid can help to lessen the severity of an injury or disease, and in some situations, it can even save a person's life.

6.3.2. Need for First Aid at the Workplace

In the workplace, first aid refers to providing immediate care and life support to persons who have been injured or become unwell at work.

Many times, first aid can help to lessen the severity of an accident or disease.

It can also help an injured or sick person relax. In life-or-death situations, prompt and appropriate first aid can make all the difference.

6.3.3. Treating Minor Cuts and Scrapes

Steps to keep cuts clean and prevent infections and scars:

- **Wash Hands:** Wash hands first with soap and water to avoid introducing bacteria into the cut and causing an infection. One should use the hand sanitiser if one is on the go.
- **Stop the bleeding:** Using a gauze pad or a clean towel, apply pressure to the wound. For a few minutes, keep the pressure on.
- **Clean Wounds:** Once the bleeding has stopped, clean the wound by rinsing it under cool running water or using a saline wound wash. Use soap and a moist washcloth to clean the area around the wound. Soap should not be used on the cut since it may irritate the skin. Also, avoid using hydrogen peroxide or iodine, as these may aggravate the wound.
- **Remove Dirt:** Remove any dirt or debris from the area. Pick out any dirt, gravel, glass, or other material in the cut with a pair of tweezers cleaned with alcohol.

6.3.4. Heart Attack

When the blood flow carrying oxygen to the hea rt is blocked, a heart attack occurs. The heart muscle runs out of oxygen and starts to die.

Symptoms of a heart attack can vary from person to person. They may be mild or severe. Women, older adults, and people with diabetes are more likely to have subtle or unusual symptoms.

Symptoms in adults may include:

- Changes in mental status, especially in older adults.
- Chest pain that feels like pressure, squeezing, or fullness. The pain is most often in the centre of the chest. It may also be felt in the jaw, shoulder, arms, back, and stomach. It can last for more than a few minutes or come and go.
- Cold sweat.
- Light-headedness.
- Nausea (more common in women).
- Indigestion.
- Vomiting.
- Numbness, aching or tingling in the arm (usually the left arm, but the right arm may be affected alone, or along with the left).
- Shortness of breath.
- Weakness or fatigue, especially in older adults and in women.

First Aid for Heart Attack If one thinks someone is experiencing a heart attack, they should:

- Have the person sit down, rest, and try to keep calm.
- Loosen any tight clothing.

- Ask if the person takes any chest pain medicine, such as nitro-glycerine for a known heart condition, and help them take it.
- If the pain does not go away promptly with rest or within 3 minutes of taking nitro-glycerine, call for emergency medical help.
- If the person is unconscious and unresponsive, call 911 or the local emergency number, then begin CPR.
- If an infant or child is unconscious and unresponsive, perform 1 minute of CPR, then call 911 or the local emergency number.

Scan the QR code or click on the link to watch related videos

www.youtube.com/watch?v=BumbKHqXJo0

First-aid practices

Unit 6.4: Waste Management

Unit Objectives

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

1. Describe the concept of waste management and methods of disposing of hazardous waste.
2. List the common sources of pollution and ways to minimize them.
3. Elaborate on electronic waste disposal procedures.

6.4.1. Waste Management and Methods of Waste Disposal.

The collection, disposal, monitoring, and processing of waste materials is known as waste management. These wastes affect living beings' health and the environment. For reducing their effects, they have to be managed properly. The waste is usually in solid, liquid or gaseous form.

The importance of waste management is:

Waste management is important because it decreases waste's impact on the environment, health, and other factors. It can also assist in the reuse or recycling of resources like paper, cans, and glass. The disposal of solid, liquid, gaseous, or dangerous substances is the example of waste management.

When it comes to trash management, there are numerous factors to consider, including waste disposal, recycling, waste avoidance and reduction, and garbage transportation. Treatment of solid and liquid wastes is part of the waste management process. It also provides a number of recycling options for goods that aren't classified as garbage during the process.

6.4.2. Methods of Waste Management

Non-biodegradable and toxic wastes, such as radioactive remains, can cause irreversible damage to the environment and human health if they are not properly disposed of. Waste disposal has long been a source of worry, with population increase and industrialisation being the primary causes. Here are a few garbage disposal options.

1. **Landfills:** The most common way of trash disposal today is to throw daily waste/garbage into landfills. This garbage disposal method relies on burying the material in the ground.
2. **Recycling:** Recycling is the process of transforming waste items into new products in order to reduce energy consumption and the use of fresh raw materials. Recycling reduces energy consumption, landfill volume, air and water pollution, greenhouse gas emissions, and the preservation of natural resources for future use.
3. **Composting:** Composting is a simple and natural bio-degradation process that converts organic

wastes, such as plant remnants, garden garbage, and kitchen waste, into nutrient-rich food for plants.

4. **Incineration:** Incineration is the process of combusting garbage. The waste material is cooked to extremely high temperatures and turned into materials such as heat, gas, steam, and ash using this technology.

6.4.3. Recyclable, Non-Recyclable and Hazardous Waste

1. **Recyclable Waste:** The waste which can be reused or recycled further is known as recyclable waste.
2. **Non-recyclable Waste:** The waste which cannot be reused or recycled is known as non-recyclable waste. Polythene bags are a great example of non-recyclable waste.
3. **Hazardous Waste:** The waste which can create serious harm to the people and the environment is known as hazardous waste.

6.4.4. Sources of Pollution

Pollution is defined as the harm caused by the presence of a material or substances in places where they would not normally be found or at levels greater than normal. Polluting substances might be in the form of a solid, a liquid, or a gas.

- **Point source of pollution:** Pollution from a point source enters a water body at a precise location and can usually be identified. Effluent discharges from sewage treatment plants and industrial sites, power plants, landfill sites, fish farms, and oil leakage via a pipeline from industrial sites are all potential point sources of contamination. Point source pollution is often easy to prevent since it is feasible to identify where it originates, and once identified, individuals responsible for the pollution can take rapid corrective action or invest in longer-term treatment and control facilities.
- **Diffuse source of pollution:** As a result of land-use activities such as urban development, amenity, farming, and forestry, diffuse pollution occurs when pollutants are widely used and diffused over a large region. These activities could have occurred recently or in the past. It might be difficult to pinpoint specific sources of pollution and, as a result, take rapid action to prevent it because prevention often necessitates significant changes in land use and management methods.

Pollution Prevention

Pollution prevention entails acting at the source of pollutants to prevent or minimise their production. It saves natural resources, like water, by using materials and energy more efficiently.

Pollution prevention includes any practice that:

- Reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to

recycling, treatment, or disposal;

- Reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants (these practices are known as **"source reduction"**);
- Improved efficiency in the use of raw materials, energy, water, or other resources, or Conservation is a method of safeguarding natural resources.
- Improvements in housekeeping, maintenance, training, or inventory management; equipment or technology adjustments; process or method modifications; product reformulation or redesign; raw material substitution; or improvements in housekeeping, maintenance, training, or inventory control.

6.4.5. Electronic Waste

Lead, cadmium, beryllium, mercury, and brominated flame retardants are found in every piece of electronic waste. When gadgets and devices are disposed of illegally, these hazardous compounds are more likely to contaminate the earth, pollute the air, and leak into water bodies.

When e-waste is dumped in a landfill, it tends to leach trace metals as water runs through it. The contaminated landfill water then reaches natural groundwater with elevated toxic levels, which can be dangerous if it reaches any drinking water bodies. Despite having an environmentally benign approach, recycling generally results in international shipment and dumping of the gadgets in pits.

Some eco-friendly ways of disposing of e-waste are:

- Giving back the e-waste to the electronic companies and drop-off points
- Following guidelines issued by the government
- Selling or donating the outdated technology-based equipment
- Giving e-waste to a certified e-waste recycler

Notes

ANNEXURE - QR Codes

S.No.	Chapter No.	Unit No.	Topic Name	Page No.	QR code(s)	URL
1	Chapter 2: Process of Creating Requirement Specifications and Detailed Design Documents	Unit 2.1: IOT System	Introduction of IoT	24		https://www.youtube.com/watch?v=Hl6XA-HeX9y0
2		Unit 2.1: IOT System	Components of IoT	24		https://www.youtube.com/watch?v=Z-n4ozz3CkhY
3		Unit 2.2: IOT Design Requirements and Specifications	IoT design methodology	32		https://www.youtube.com/watch?v=nw_O23o6Dr0
4	Chapter 3: Process of Designing Circuit and PCB Layout for the IoT System	Unit 3.1: PCB Layout Designing for IoT System	Basic concepts of PCB design	54		https://www.youtube.com/watch?v=ESnD-Ql7ZM5o
5		Unit 3.1: PCB Layout Designing for IoT System	PCB designing	54		https://www.youtube.com/watch?v=2KBCR9g-wa8E
6		Unit 3.2: Building Prototype of PCB Design	PCB prototyping	64		https://www.youtube.com/watch?v=zRd-JrE80Vjk

S.No.	Chapter No.	Unit No.	Topic Name	Page No.	QR code(s)	URL
7	Chapter 3: Process of Designing Circuit and PCB Layout for the IoT System	Unit 3.2: Building Prototype of PCB Design	PCB manufacturing and assembly	64		https://www.youtube.com/watch?v=o-8NOK1JJbgw
8	Chapter 4: Process of Building and Testing the Complete IoT System	Unit 4.2: Testing an IoT System	Types of IoT testing	92		https://www.youtube.com/watch?v=9QiN-MUUdAgg
9		Unit 4.2: Testing an IoT System	PCB inspection methods and defects	92		https://www.youtube.com/watch?v=5WuS-cHKaz8o
10	Chapter 5: Work effectively at the workplace	Unit 5.1: Effective Communication and Coordination at Work	Communication skills	100		https://www.youtube.com/watch?v=u16EPw-Fmdis
11	Chapter 6: Basic Health and Safety Practices	Unit 6.2 – Fire Safety	Workplace emergency procedures	133		https://www.youtube.com/watch?v=DaYwcH-1GMEg
12		Unit 6.3 – First Aid	First-aid practices	136		https://www.youtube.com/watch?v=BumbKH-qXJo0

Skill India
कौशल भारत-कुशल भारत

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

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

Scan this QR Code to access eBook

ESSCI
Skilling India in Electronics

Address: Electronics Sector Skill Council of India
155, 2nd Floor, ESC House Okhla Industrial Area-Phase 3, New Delhi- 110020
Email: info@essc-india.org
Web: www.essc-india.org
Phone: +91-84477-38-501

Price: ₹