कौशल गुणवत्ता प्रगति

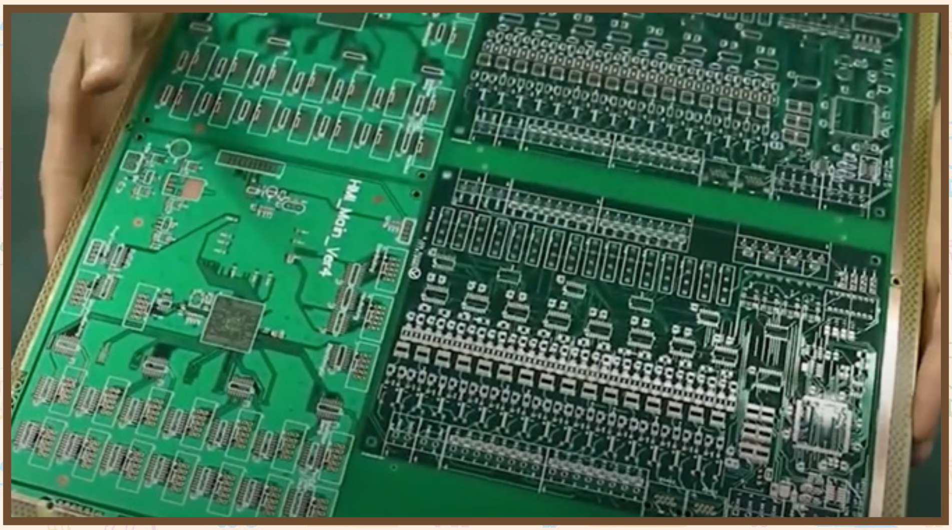
Skill India
कौशल भारत-कुशल भारत

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

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

Telecom
Sector
Skill
Council

# Facilitator Guide



Sector
**Telecom**

Sub-Sector
**Semiconductor-Manufacturing & Packaging**

Occupation
**Semiconductor – M&P**

Reference ID: **TEL/Q7205, Version: 1.0**
**NSQF Level: 6**

# Substrate Design and Process Manager

**This book is sponsored by**
Telecom Sector Skill Council (TSSC)
Address: Estel House, 3rd Floor, Plot No:- 126, Sector 44
Gurugram, Haryana 122003
Phone: 0124-2222222
Email: tssc@tsscindia.com
Web: www.tsscindia.com

**First Edition, August 2024**
**First Edition**

**Copyright © 2025**
Under Creative Commons License: CC-BY-SA
Attribution-Share Alike: CC-BY-SA

**Disclaimer**

The information contained herein has been obtained from sources reliable to Telecom Sector Skill Council. Telecom Sector Skill Council disclaims all warranties to the accuracy, completeness or adequacy of such information. Telecom Sector Skill Council shall have no liability for errors, omissions, or inadequacies, in the information contained herein, or for interpretations thereof. Every effort has been made to trace the owners of the copyright material included in the book. The publishers would be grateful for any omissions brought to their notice for acknowledgements in future editions of the book. No entity in Telecom Sector Skill Council shall be responsible for any loss whatsoever, sustained by any person who relies on this material.

> 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

## Acknowledgements

The Telecom Sector Skill Council (TSSC) would like to thank all the individuals and institutions who contributed in various ways towards the preparation of this facilitator guide. The guide could not have been completed without their active contribution. Special gratitude is extended to those who collaborated during the development of the different modules in the facilitator guide. Wholehearted appreciation is also extended to all who provided peer review for these modules.

The preparation of this guide would not have been possible without the telecom industry's support. Industry feedback has been extremely beneficial since inception to conclusion, and it is with the industry's guidance that we have tried to bridge the existing skill gaps in the industry. This facilitator guide is dedicated to the aspiring youth, who desire to achieve special skills that will be a lifelong asset for their future endeavours.

## About this book

The facilitator guide (FG) for Substrate Design and Process Manager is primarily designed to facilitate skill development and training of people, who want to become Network System Associate in various organizations. The facilitator guide is aligned to the Qualification Pack (QP) and the National Occupational Standards (NOS) as drafted by the Sector Skill Council (TSSC) and ratified by National Skill Development Corporation (NSDC).

It includes the following National Occupational Standards (NOSs)-

1. TEL/N7216: Substrate Design Support
2. TEL/N7217: Process Integration and Collaboration
3. TEL/N7218: Quality Assurance and Documentation
4. DGT/VSQ/N0103: Employability Skills (90 Hours)

Post this training, participants will be able to develop structural blueprints for semiconductor substrates, design layouts meeting electrical and thermal performance criteria while ensuring manufacturability, select materials, conduct simulations, collaborate with fabrication teams, and iterate designs based on testing feedback. We hope this Participant Handbook will provide sound learning support to our young friends to build an attractive career in the telecom industry.

## Symbols Used

Ask
Explain
Elaborate
Notes
Unit Objectives
Do
Demonstrate
Activity
Team Activity
Facilitation Notes
Practical
Say
Resources
Example
Summary
Role Play
Learning Outcomes

# Table of Contents

NCVET
कौशल गुणवत्ता प्रगति

Skill India
कौशल भारत - कुशल भारत

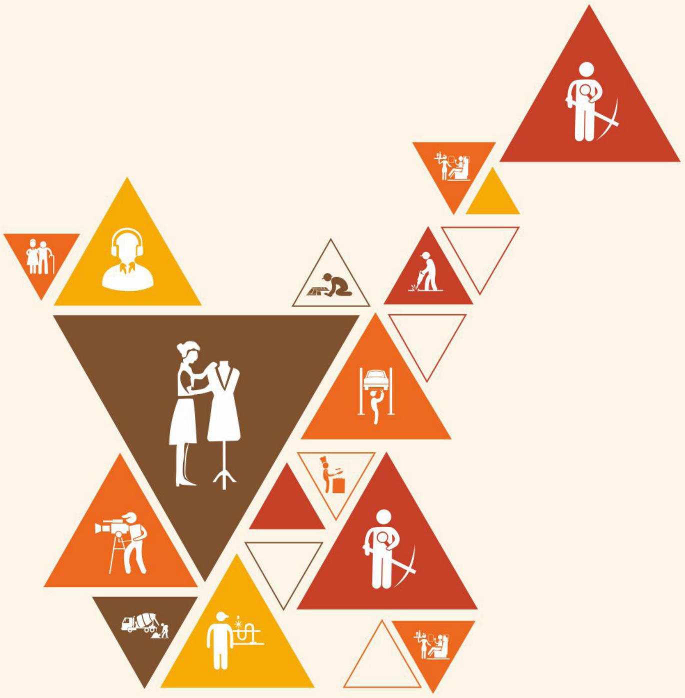
सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

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

Telecom
Sector
Skill
Council

# 1. Role and Responsibilities of Telecom Substrate Design Support Engineer (SDSE)

Unit 1.1: Introduction to Telecom Substrate Design
Unit 1.2: Quality Control and Industry Standards in Telecom Substrate Production
Unit 1.3: Safety and Handling of Telecom Substrates
Unit 1.4: Career Development and Role of Telecom Substrate Design Support Engineer (SDSE)



TEL/N7216

## Key Learning Outcomes

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

1. Explain the different types of substrates used in telecom network equipment (wired and wireless).
2. Identify the key considerations for substrate design in the context of telecom applications.
3. Explain the basic functionality of semiconductors in telecom devices.
4. Describe the importance of quality control procedures in ensuring the functionality and reliability of telecom substrates.
5. Explain the role of industry standards and regulations in telecom substrate design and production.
6. Identify essential safety precautions to be followed in a cleanroom environment.
7. Identify key technical skills and knowledge areas required for career advancement in telecom substrate design.
8. Explain the role and responsibilities of a Telecom Substrate Design Support Engineer (SDSE) within the semiconductor manufacturing process.
9. Explain the importance of proper handling procedures for telecom substrates to maintain quality and prevent damage.
10. Identify the appropriate PPE required for handling telecom substrates in a controlled environment.

# Unit 1.1: Introduction to Telecom Substrate Design

## Unit Objectives

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

1. Understand the different types of substrates used in telecom network equipment (wired and wireless).
2. Recognize the key considerations for substrate design in telecom applications.
3. Explain the basic functionality of semiconductors in telecom devices.

## Resources to be Used

Participant handbook, pen, notebook, whiteboard, flipchart, markers, laptop, overhead projector, laser pointer, etc.

## Note

In this unit, we will discuss the different types of substrates used in telecom network equipment, including both wired and wireless applications. You will learn about key considerations for substrate design in telecom devices and understand the basic functionality of semiconductors in these devices. This foundational knowledge will help you grasp the critical roles substrates and semiconductors play in ensuring optimal telecom performance.

## Ask

**Ask the participants the following questions:**

- What do you think are the most important factors when designing a substrate for telecom devices, and why?

Write down the participants' answers on a whiteboard/flipchart. Take appropriate clues from the answers and start teaching the lesson.

## Elaborate

### Substrates in Telecom Network Equipment

Substrates are materials used as the foundational layer in telecom network equipment, providing the support for electronic components such as semiconductors. The substrates used in telecom equipment vary based on their type, functionality, and the nature of the telecom devices being built. These materials play a vital role in ensuring the durability, performance, and functionality of telecom devices, whether wired or wireless.

## 1. Types of Substrates Used in Telecom Network Equipment

The substrates used in telecom devices are mainly classified into two categories: wired and wireless telecom applications.

**Wired Telecom Substrates:** In wired telecom equipment, substrates typically include materials that support the physical transmission of electrical signals. Common wired telecom substrates include:

- **Printed Circuit Boards (PCBs):** PCBs are essential for mounting and interconnecting components in wired telecom systems. They provide mechanical support and electrical paths for the communication devices. These boards are made from a combination of resin-based materials and metallic conductors. The designs of PCBs vary, such as multi-layered boards for complex equipment and flexible PCBs for space-constrained applications.
- **Ceramic Substrates:** These are used for high-frequency applications like amplifiers, filters, and oscillators. They offer good insulation properties and are used in applications requiring high stability and minimal signal loss.

**Wireless Telecom Substrates:** Wireless telecom equipment, such as mobile phones, base stations, and antennas, requires substrates designed to handle higher frequencies, with an emphasis on low-loss and heat dissipation. Examples include:

- **High-Density Interconnect (HDI) PCBs:** These substrates are designed for high-speed signal transmission. They are used in applications requiring small form factors and high-frequency signal integrity, such as in 5G base stations and wireless communication equipment.
- **Dielectric Materials:** These materials are used in high-frequency applications where signal loss needs to be minimized. Dielectrics provide insulation and are used in antennas, microwave devices, and filters.
- **Gallium Arsenide (GaAs) Substrates:** Often used in high-frequency semiconductors for wireless communication due to their ability to handle microwave frequencies efficiently. They are commonly found in radio frequency (RF) components.

## 2. Key Considerations for Substrate Design in Telecom Applications

When designing substrates for telecom applications, there are several critical factors to consider:

a. **Electrical Performance:** The primary function of telecom substrates is to facilitate electrical connections and signal integrity. For high-frequency wireless applications, substrates should exhibit low signal attenuation, minimal interference, and fast signal propagation. This ensures efficient communication, especially in environments like 5G networks where high-speed data transmission is crucial.

b. **Thermal Management:** Substrates need to have excellent heat dissipation properties to ensure that the electronic components, especially semiconductors, do not overheat. Excessive heat can cause equipment failure or reduced performance. Ceramic and metallic substrates are commonly chosen for their superior thermal conductivity in many telecom applications.

c. **Mechanical Stability:** The substrates must maintain their shape and structural integrity during the operation of telecom devices. They should withstand vibrations, thermal cycling, and external mechanical stresses, which are prevalent in environments like mobile towers or outdoor base stations.

d. **Compatibility with Semiconductor Devices:** Telecom substrates must support the effective integration of semiconductor devices, ensuring optimal electrical performance. For example, semiconductor materials like GaAs and Silicon Carbide (SiC) are often chosen for high-frequency wireless applications due to their ability to handle high power and speed.

e. **Cost and Manufacturing Considerations:** Cost efficiency and scalability are key when selecting substrates for telecom network equipment. While advanced substrates like GaAs offer superior performance, they are more expensive to produce compared to conventional PCB materials. Hence, designers often weigh the cost-benefit ratio of substrate materials for large-scale production.

f. **Environmental Sustainability:** With growing concerns over environmental impact, designers are increasingly focused on using environmentally friendly materials. Materials that are easier to recycle or those that meet regulatory standards, such as RoHS (Restriction of Hazardous Substances), are becoming more common in substrate design.

### 3. Basic Functionality of Semiconductors in Telecom Devices

Semiconductors are the backbone of all modern telecom devices. They serve as the heart of many electronic components used in telecom network equipment, from mobile phones to satellite systems. Their primary function is to control and manipulate electrical signals in the form of current.

a. **Signal Amplification:** Semiconductors are used in amplifiers to increase the strength of weak signals. In telecom devices, this is crucial for improving the range and quality of the signal. For example, in wireless communication, semiconductors in RF amplifiers help ensure the signal reaches the desired distance without degradation.

b. **Signal Modulation and Demodulation:** Telecom systems often require signals to be modulated for transmission and demodulated for reception. Semiconductors, especially those integrated into modulation and demodulation circuits, are responsible for converting signals to the correct frequencies and formats, ensuring accurate data transfer.

c. **Switching and Routing:** Telecom devices require the efficient switching and routing of data. Semiconductors enable the processing of routing tables and switching circuits that allow data to travel across networks. This functionality is essential in routers, switches, and other telecom infrastructure that manage large volumes of data transmission.

d. **Frequency Generation:** Telecom networks rely heavily on accurate frequency generation to ensure synchronization between devices and systems. Semiconductors such as oscillators generate precise frequencies, allowing telecom systems to function efficiently, especially in applications like time-division multiplexing (TDM) and frequency-division multiplexing (FDM).

e. **Power Control:** Telecom devices, especially in wireless communication, require efficient power management to optimize performance and extend battery life. Power semiconductors control the flow of power to different components, balancing the energy consumption and transmission power in devices like smartphones and base stations.

f. **Integrated Circuits (ICs):** Telecom devices typically use integrated circuits (ICs) for various functionalities. ICs can contain multiple transistors, capacitors, and resistors, all within a single chip, allowing for compact designs and better performance. They play critical roles in signal processing, data handling, and other essential functions of telecom systems.

g. **High-Frequency Operations:** In wireless telecom devices, high-frequency semiconductors, like those made from GaAs and InP (Indium Phosphide), enable efficient operation at GHz frequencies. These materials are ideal for RF applications in 4G, 5G, and other wireless technologies, where high-speed and high-frequency data transfer is required.

The substrates used in telecom devices are integral to the functionality, reliability, and efficiency of the systems. Whether wired or wireless, the choice of materials impacts the signal integrity, mechanical stability, heat management, and overall performance of telecom equipment. Coupled with semiconductors, which control and amplify electrical signals, these substrates form the foundation of modern telecom infrastructure. Understanding the materials, their considerations, and the role of semiconductors is crucial for designing and maintaining advanced telecom systems that are critical to global communication networks.

## Say

Let us participate in an activity to explore the unit a little more.

## Activity

- Arrange the class in a semi-circle/circle.
- Each of us will tell the class their name, hometown, hobbies and special quality about themselves, starting with the 1st letter of their name. I will start with mine.
- Say your name aloud and start playing the game with your name.
- Say, "Now, each of one you shall continue with the game with your names till the last person in the circle/ semi-circle participates".
- Listen to and watch the trainees while they play the game.
- Ask questions and clarify if you are unable to understand or hear a trainee.

| Activity | Duration | Resources used |
|---|---|---|
| Ice Breaker | | Pen, Notebook, etc. |

**Remember to:**

- Discourage any queries related to one's financial status, gender orientation or religious bias during the game.
- Try recognising each trainee by their name because it is not recommended for a trainer to ask the name of a trainee during every interaction

## Do

- Guide the trainees throughout the activity
- Ensure that all trainees participate in the activity

## Notes for Facilitation

- Prompt groups to think about material benefits (e.g., why FR4 is used in PCBs for wired systems).
- Highlight how semiconductors interact with substrates, especially regarding thermal and electrical properties.
- Relate the designs to real telecom devices like routers and phones to show practical implications.

# Unit 1.2: Quality Control and Industry Standards in Telecom Substrate Production

## Unit Objectives

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

1. Explain the importance of quality control procedures in ensuring the functionality and reliability of telecom substrates.
2. Describe the role of industry standards and regulations in telecom substrate design and production.

## Resources to be Used

Participant handbook, pen, notebook, whiteboard, flipchart, markers, laptop, overhead projector, laser pointer, etc.

## Note

In this unit, we will discuss the significance of quality control procedures in ensuring the reliability and functionality of telecom substrates. We will explore the role of industry standards and regulations that guide substrate design and production, emphasizing how they impact the overall performance and compliance of telecom devices.

## Ask

**Ask the participants the following questions:**

- What do you think would happen to a telecom device if the substrate used in its production wasn't properly tested for quality?

Write down the participants' answers on a whiteboard/flipchart. Take appropriate clues from the answers and start teaching the lesson.

## Elaborate

### Importance of Quality Control Procedures in Telecom Substrates

Quality control (QC) procedures are critical to ensuring that telecom substrates meet performance, safety, and reliability standards. Telecom substrates, which serve as the base material for printed circuit boards (PCBs) and semiconductor packaging, play a vital role in the overall functionality of telecom devices. If a substrate fails to meet required specifications, it can lead to device malfunctions, reduced lifespan, or even system failure, impacting network performance.

1. **Performance Reliability:** QC procedures help verify that substrates have the correct material properties, such as impedance, dielectric constant, and thermal conductivity. These properties ensure that signals are transmitted accurately and efficiently without interference. Thorough

testing, including mechanical and electrical stress tests, guarantees that substrates will not fail under operational conditions.

2. **Consistency in Manufacturing:** Quality control is essential for achieving uniformity in substrate production. Even small variations in material composition or processing steps can result in significant functional problems in telecom devices. Regular QC inspections, including visual, dimensional, and functional testing, ensure that each batch of substrates meets consistent quality standards, improving the overall reliability of telecom equipment.
3. **Preventing Failures:** By identifying issues early in the production process, QC procedures prevent defects that could lead to failures in telecom devices, such as overheating, signal loss, or improper signal routing. Inspecting substrates for physical imperfections such as cracks or bubbles also ensures that components are durable and can withstand environmental stressors like temperature fluctuations or humidity.
4. **Enhanced Product Lifespan:** Telecom networks and devices are expected to have long service lives, which makes the longevity of substrates particularly important. Quality control ensures that the substrates used can withstand continuous use without degrading, preventing the need for frequent repairs or replacements.
5. **Cost Efficiency:** Proactive quality control minimizes the risk of product recalls, repairs, and warranty claims, which can be expensive for manufacturers. By ensuring that substrates meet high standards before they reach the production line, companies can avoid costly rework and maintain customer satisfaction.

### Role of Industry Standards and Regulations in Telecom Substrate Design and Production

Telecom substrate design and production are governed by a variety of industry standards and regulations that help ensure the consistency, performance, and safety of telecom products. These standards serve as benchmarks for manufacturers, helping them produce substrates that meet global requirements and are suitable for integration into telecom systems.

1. **Ensuring Global Compatibility:** Industry standards, such as those set by the International Telecommunication Union (ITU) or the Institute of Electrical and Electronics Engineers (IEEE), provide a common framework for designing substrates that can be used across different networks and systems. Compliance with these standards ensures that telecom devices will function seamlessly in diverse environments and are compatible with a wide range of equipment.
2. **Material Specifications:** Regulations also define material properties that substrates must meet to function effectively in telecom applications. These properties include electrical characteristics (e.g., resistance, conductivity), thermal properties (e.g., heat dissipation), and mechanical properties (e.g., stress resistance). Industry standards ensure that manufacturers choose appropriate materials and processes that enhance the performance of the final telecom device.
3. **Safety and Environmental Compliance:** Telecom substrate production must also adhere to safety standards that protect consumers and workers. For example, materials used must meet fire-retardant and low-toxicity requirements. Environmental standards, such as those set by the Restriction of Hazardous Substances (RoHS) directive, restrict the use of hazardous materials, promoting sustainability in the manufacturing process.
4. **Performance Testing:** Telecom substrates must undergo rigorous testing to verify that they meet specific functional requirements. Standards like ISO 9001 and MIL-STD (Military Standard) provide guidelines for testing substrates under various environmental conditions to ensure they can withstand high temperatures, humidity, and electromagnetic interference (EMI). These testing protocols help prevent device malfunctions and ensure optimal telecom system performance.
5. **Certification for Market Acceptance:** Regulatory compliance and certifications demonstrate to customers and end-users that substrates meet high-performance and safety standards. This

certification process is crucial for companies that wish to enter international markets or work with high-profile telecom companies. Non-compliance with industry standards can result in product rejection, reputational damage, and legal liabilities.

In summary, quality control procedures and adherence to industry standards are indispensable for ensuring the functionality, reliability, and safety of telecom substrates. These practices help manufacturers produce substrates that perform well under operational stress, comply with international regulations, and enhance the longevity of telecom equipment.

## Say

Let us participate in an activity to explore the unit a little more.

## Activity

**Group Activity:** Telecom Substrate Quality Control and Standards

**Activity Description:** Divide the participants into small groups. Each group will be assigned a scenario where they must apply quality control procedures to a telecom substrate (e.g., a PCB for wireless or wired equipment). The group will discuss and identify the relevant industry standards and regulations that would govern their design and production. Each group should then present their approach to quality control and the specific standards and regulations that should be adhered to in their design process.

**Steps:**

1. **Scenario Assignment:** Provide each group with a different telecom substrate scenario (e.g., a PCB for a mobile phone, a router, or a base station).
2. **Identify Quality Control Procedures:** Groups discuss the quality control steps they would take to ensure the functionality and reliability of the substrate in their given scenario.
3. **Standards and Regulations:** Each group will identify the relevant industry standards (e.g., IPC standards, ISO certifications) and regulations that apply to their assigned substrate.
4. **Presentation:** Groups will present their findings, detailing the quality control procedures and standards they would follow.

**Examples of Scenario Cards:**

**Scenario Card 1:**Wireless Device PCB Design

**Scenario:**

Your team is designing a printed circuit board (PCB) for a new wireless communication device. The device must operate within a highly regulated frequency band and withstand outdoor environmental conditions. The PCB needs to be both cost-effective and reliable.

**Task:**

- Identify three key quality control procedures you would implement to ensure the functionality and reliability of the PCB.
- Discuss the relevant industry standards and regulations (e.g., IPC standards) that must be adhered to in the design and production process of the PCB.

**Scenario Card 2:** Router Substrate Manufacturing

**Scenario:**

You are part of a team working on the design and production of the substrate for a new router used in high-speed internet services. The router must support a large volume of data traffic with minimal downtime. The substrate must also comply with stringent safety and electromagnetic interference (EMI) regulations.

**Task:**

- Describe two critical quality control procedures to ensure the substrate will work effectively in a high-demand environment.
- Explain the industry standards and regulations (e.g., ISO, CE) that should guide the production of the router substrate.

**Scenario Card 3:** Base Station PCB for 5G Network

**Scenario:**

Your company is manufacturing a PCB that will be used in a base station for a 5G network. The PCB needs to handle high-frequency signals, be durable under extreme temperatures, and meet international safety standards. It must also have low signal loss and minimal power consumption.

**Task:**

- List and explain three quality control steps to ensure the PCB will perform optimally in 5G base stations.
- Discuss the standards and regulations that are relevant for the production of this PCB (e.g., environmental standards, electromagnetic compatibility).

| Activity | Duration | Resources used |
|---|---|---|
| Telecom Substrate Quality Control and Standards | | Chart paper or whiteboard, Markers, Sticky notes (different colors), Scenario cards (described below), etc. |

## Do

- Guide the trainees throughout the activity
- Ensure that all trainees participate in the activity

## Notes for Facilitation

- Encourage participants to connect scenarios to real-world experiences or observations for practical insights.
- Guide discussions to ensure alignment with the learning objectives and relevance to the Skill India Mission.
- During the debrief, highlight key themes across groups and reinforce how skill development impacts personal, industrial, and economic growth.

# Unit 1.3: Safety and Handling of Telecom Substrates

## Unit Objectives

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

1. Identify essential safety precautions to be followed in a cleanroom environment.
2. Explain the importance of proper handling procedures for telecom substrates to maintain quality and prevent damage.
3. Identify the appropriate PPE required for handling telecom substrates in a controlled environment.

## Resources to be Used

Participant handbook, pen, notebook, whiteboard, flipchart, markers, laptop, overhead projector, laser pointer, etc.

## Note

In this unit, we will discuss the essential safety precautions necessary for working in a cleanroom environment, focusing on how to handle telecom substrates properly to maintain their quality. We will also explore the appropriate personal protective equipment (PPE) needed to ensure safe and effective handling of these sensitive materials in controlled settings.

## Ask

**Ask the participants the following questions:**

- Why is it important to follow safety precautions and use the correct PPE when handling telecom substrates in a cleanroom environment?

Write down the participants' answers on a whiteboard/flipchart. Take appropriate clues from the answers and start teaching the lesson.

## Elaborate

### Essential Safety Precautions in a Cleanroom Environment

A cleanroom environment is critical for maintaining the quality and integrity of telecom substrates during production. In these controlled environments, the presence of particulate contamination can significantly impact the performance and reliability of telecom devices. To prevent such contamination, the following safety precautions must be followed:

1. **Controlled Airflow and Ventilation:** Cleanrooms use specialized HVAC systems to maintain high air quality standards. The air is filtered through HEPA filters to remove particulate matter. Maintaining optimal airflow direction (laminar flow) ensures that contaminants are carried away from critical processing areas.

2. **Minimized Particle Contamination:** Personnel must wear cleanroom suits to prevent skin flakes, hair, and other particles from contaminating the workspace. These suits include coveralls, gloves, face masks, and shoe covers. The suits are made of materials that prevent particle shedding.
3. **Strict Access Control:** Only authorized personnel are allowed to enter cleanrooms. Entry and exit protocols include gowning areas where personnel don protective gear before entering the cleanroom and de-gowning areas for disinfection upon exit. This minimizes the risk of introducing external contaminants.
4. **Surface and Equipment Cleaning:** Regular cleaning of surfaces and equipment is essential. Use of non-abrasive wipes, isopropyl alcohol, and other cleaning solutions is common for cleaning equipment, benches, and work surfaces. The surfaces should be disinfected frequently to maintain the cleanroom's integrity.
5. **Temperature and Humidity Control:** Cleanrooms often maintain specific temperature and humidity levels to avoid conditions that could lead to static discharge or material degradation. Temperature control also ensures the substrates' properties remain stable during processing.

### Proper Handling Procedures for Telecom Substrates

Telecom substrates are delicate and require careful handling to avoid physical damage or contamination, which can degrade their performance. The following guidelines ensure telecom substrates are handled correctly:

1. **Handling with Clean Tools and Hands:** Substrates should only be handled using clean tools, such as tweezers or vacuum handling systems, designed for delicate components. Direct contact with hands should be avoided, as oils or dust from skin can damage the substrates or cause contamination.
2. **Use of Protective Packaging:** When not in use, telecom substrates should be stored in protective, anti-static packaging. Packaging materials should be clean and designed to prevent electrostatic discharge (ESD) and physical damage during transportation or storage.
3. **Minimizing Physical Stress:** Substrates are sensitive to mechanical stress, such as bending or flexing. It's essential to avoid dropping, pressing, or bending substrates to prevent cracks, warping, or other damage. Transporting substrates on clean, cushioned surfaces helps prevent accidental damage.
4. **Environmental Conditions:** Maintain substrates in a controlled environment, free from extreme temperatures, humidity, or direct sunlight. For telecom substrates, temperature stability is crucial, as excessive heat or cold can cause warping or changes in electrical properties.
5. **Labeling and Documentation:** Each batch of telecom substrates should be appropriately labeled with relevant information, such as batch number, manufacturing date, and specific handling instructions. Accurate documentation ensures traceability and helps detect any defects that might arise during testing or usage.

### Appropriate PPE for Handling Telecom Substrates

Personal Protective Equipment (PPE) is crucial for safeguarding both the telecom substrates and the personnel working in controlled environments. Proper PPE is used to prevent contamination and damage during handling. Here are the necessary PPE components:

1. **Cleanroom Suit:** A full-body cleanroom suit is the primary PPE worn when handling telecom substrates. These suits are made from lint-free materials and prevent contamination from human skin, hair, and clothing. They cover the entire body, including the head, arms, and legs, ensuring that no particles are released into the controlled environment.
2. **Gloves:** Disposable gloves are worn to prevent oils, dirt, or other contaminants from being transferred from the hands to the telecom substrates. Gloves should be made of materials that

prevent electrostatic buildup, such as nitrile or latex. They must also be regularly inspected for damage to avoid any potential risk of contamination.

3. **Face Mask and Hairnet:** To prevent particles from the face, mouth, and hair from entering the cleanroom, face masks and hairnets are worn. These help reduce the risk of contamination from airborne particles. The face mask should also be designed to prevent any potential dust or bacteria from being expelled by the wearer's breath.
4. **Shoe Covers:** Shoe covers are worn to prevent dirt or contaminants from being transferred from shoes into the cleanroom. These covers are typically made from non-woven fabric that can trap dirt and particles. They must be worn by everyone entering the cleanroom to maintain the integrity of the environment.
5. **Anti-Static Wristbands:** In environments where electrostatic discharge could damage sensitive telecom substrates, personnel should wear anti-static wristbands. These devices ensure that any built-up static electricity is safely discharged to the ground, preventing damage to components during handling.

Maintaining the integrity and quality of telecom substrates requires a disciplined approach to safety and handling procedures. Cleanroom environments are designed to control contamination, and it is crucial to adhere to safety protocols, including the proper use of PPE, surface cleaning, and maintaining environmental stability. Proper handling procedures protect the telecom substrates from physical damage, contamination, and degradation, ensuring their optimal performance in the final telecom devices. By following these safety measures and handling guidelines, technicians can contribute to the successful and reliable functioning of telecom equipment.

## Say

Let us participate in an activity to explore the unit a little more.

## Activity

**Group Activity:** Cleanroom Handling and PPE Simulation

**Objective:**

To demonstrate understanding of essential safety precautions, proper handling procedures, and the use of PPE for telecom substrates in a controlled environment.

**Instructions:**

1. **Group Formation:** Divide participants into small groups.
2. **Scenario Setup:** Create different cleanroom setups (or use a simulated area) with various telecom substrates (mock materials).
3. **Roles:** Assign roles within each group—one for PPE selection, one for handling substrates, and one for monitoring safety procedures.
4. **Task:** Groups will walk through a series of steps to handle substrates in a cleanroom setting, ensuring all safety measures and proper PPE use are followed
5. **Debrief:** Discuss the importance of each step, what went well, and what could be improved..

**Examples of Scenario Cards:**

**Scenario Card 1:** Improper Handling of Telecom Substrate

**Situation:**

You are working in a cleanroom environment and need to transfer a telecom substrate from one workstation to another. You forget to wear gloves and the substrate is placed directly on the workbench.

**Task:**

Identify the risks associated with improper handling and contamination of the telecom substrate. What immediate actions should you take to resolve the situation and prevent future errors?

**Scenario Card 2:** Incorrect PPE Selection

**Situation:**

You are preparing to work in a cleanroom, but the PPE options are not labeled properly. You have to select gloves, a mask, and gown. You're unsure whether the PPE you choose is suitable for handling telecom substrates.

**Task:**

Discuss the importance of selecting the appropriate PPE for the task. What would you do in this situation to ensure you are using the correct PPE for substrate handling?

**Scenario Card 3:** Cleanroom Contamination

**Situation:**

While working with telecom substrates in the cleanroom, you notice that the workstation is not properly sanitized. There is visible dust on the surface and the air filtration system has malfunctioned.

**Task:**

What immediate actions should you take to prevent contamination of the telecom substrates? How would you address the issue of the malfunctioning filtration system and ensure it does not affect the substrates?

| Activity | Duration | Resources used |
|---|---|---|
| Cleanroom Handling and PPE Simulation | | Whiteboard or chart paper, Markers, Sticky notes (different colors), Role description cards (described below), etc. |

## Do

- Guide the trainees throughout the activity
- Ensure that all trainees participate in the activity

## Notes for Facilitation

- Ensure participants understand the correct PPE for handling substrates in cleanrooms (e.g., gloves, masks, gowns).
- Emphasize gentle handling to avoid contamination or damage to substrates.
- Stress the importance of maintaining cleanliness and preventing contamination by following cleanroom procedures.

# Unit 1.4: Career Development and Role of Telecom Substrate (SDSE)

## Unit Objectives

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

1. Identify key technical skills and knowledge areas required for career advancement in telecom substrate design.
2. Explain the role and responsibilities of a Telecom Substrate Design Support Engineer (SDSE) within the semiconductor manufacturing process.

## Resources to be Used

Participant handbook, pen, notebook, whiteboard, flipchart, markers, laptop, overhead projector, laser pointer, etc.

## Note

In this unit, we will discuss the essential technical skills and knowledge required for career advancement in telecom substrate design. We will also explore the role and responsibilities of a Telecom Substrate Design Support Engineer (SDSE) in the semiconductor manufacturing process. You will learn about the key tasks performed by SDSEs and the required expertise to support effective substrate design and production.

## Ask

**Ask the participants the following questions:**

- What do you think are the most important skills needed to work as a Telecom Substrate Design Support Engineer?

Write down the participants' answers on a whiteboard/flipchart. Take appropriate clues from the answers and start teaching the lesson.

## Elaborate

**Key Technical Skills and Knowledge Areas for Career Advancement in Telecom Substrate Design**

1. **Understanding of Substrate Materials:** A solid knowledge of different materials used in telecom substrates is crucial for designing substrates with the right properties. Engineers must understand how materials such as ceramics, plastics, and metals impact performance in telecom applications like signal transmission and heat management.
2. **Design and Simulation Tools:** Proficiency in design software and simulation tools is vital for developing telecom substrates. Familiarity with tools such as AutoCAD, SolidWorks, and specialized electronic design automation (EDA) tools allows engineers to create, model, and tes substrate designs effectively. These tools help simulate how substrates will behave in real-world conditions.

3. **Electromagnetic Theory:** Telecom substrates often need to manage high-frequency signals. Knowledge of electromagnetic theory, including wave propagation, signal integrity, and impedance matching, is essential to designing substrates that minimize interference and signal degradation.
4. **Thermal Management:** Telecom equipment often generates heat, making thermal management a key consideration in substrate design. Engineers must know how to incorporate heat dissipation techniques such as using heat sinks or optimizing the substrate layout for heat flow.
5. **Material Testing and Reliability:** Understanding material testing methods to ensure substrates meet performance and reliability standards is crucial. Substrate design engineers need to evaluate how materials will perform under stress, such as temperature changes, mechanical stress, and electrical load.
6. **Manufacturing Processes:** Knowledge of the manufacturing process for substrates—such as lithography, etching, and lamination—is essential to ensure that designs are both feasible and cost-effective to produce. Understanding how substrates are fabricated helps engineers optimize designs for scalability and mass production.
7. **Industry Standards and Compliance:** Telecom substrate designers must be familiar with industry standards (such as ISO 9001) and regulatory requirements to ensure that their designs meet safety, environmental, and performance criteria. Awareness of certifications, testing protocols, and compliance requirements ensures that products meet market expectations.
8. **Problem-Solving and Troubleshooting:** Strong analytical and problem-solving skills are required to identify and address design or manufacturing issues, such as poor signal integrity, thermal inefficiency, or material defects, and to provide timely solutions.
9. **Collaboration and Communication:** Telecom substrate design engineers often work with cross-functional teams, including engineers, designers, and manufacturers. Effective communication skills and the ability to collaborate ensure that design and production issues are addressed quickly and accurately.

**Role and Responsibilities of a Telecom Substrate Design Support Engineer (SDSE)**

1. **Design Support:** A Telecom Substrate Design Support Engineer (SDSE) provides technical support to the substrate design process by assisting with design calculations, simulations, and layout reviews. They help ensure that substrate designs meet performance, thermal, and mechanical specifications.
2. **Prototype Testing and Evaluation:** SDSEs are responsible for conducting prototype testing on telecom substrates. This includes evaluating the design's functionality, conducting stress tests, and ensuring that prototypes meet quality control standards. Based on test results, they recommend improvements or modifications to the design.
3. **Material Selection and Sourcing:** An SDSE plays an essential role in identifying and sourcing the appropriate materials for substrate manufacturing. They analyze the properties of different materials, such as dielectric constants, thermal conductivity, and mechanical strength, to ensure optimal performance.
4. **Manufacturing Support:** SDSEs support the manufacturing team by providing technical expertise and ensuring that the production process aligns with the design specifications. They may help resolve issues that arise during the manufacturing phase, ensuring that substrates are produced with the correct specifications and quality.
5. **Troubleshooting and Problem Resolution:** When issues arise in substrate design or manufacturing, the SDSE is responsible for diagnosing and troubleshooting problems. This could include solving issues related to material defects, electrical signal integrity, or manufacturing defects that affect the substrate's performance.

6. **Collaboration with Cross-Functional Teams:** The SDSE works closely with design engineers, materials scientists, and production teams to ensure seamless communication between all departments. Their input helps ensure that designs are manufacturable and that potential challenges are addressed early in the process.
7. **Documentation and Reporting:** SDSEs are responsible for maintaining detailed records of all design, testing, and troubleshooting activities. They provide comprehensive reports documenting issues, solutions, and results, ensuring that the process is traceable and can be referenced for future projects.
8. **Customer and Vendor Interaction:** SDSEs may also engage with vendors to evaluate new materials or manufacturing technologies. They ensure that the telecom substrates meet customer requirements by working closely with stakeholders and customers to understand their needs.

By developing these technical skills and excelling in these responsibilities, telecom substrate design support engineers can advance in their careers, taking on more complex projects, managing teams, and contributing to the strategic direction of telecom substrate development.

## Say

Let us participate in an activity to explore the unit a little more.

## Activity

**Group Activity:** Career Pathway Planning in Telecom Substrate Design

**Objective:**

This activity will help participants understand the key skills and responsibilities associated with a career in telecom substrate design, specifically the role of a Telecom Substrate Design Support Engineer (SDSE). It will also allow participants to explore pathways for career advancement within this field.

**Activity Instructions:**

1. **Step 1:** Divide the participants into small groups (3-5 people per group).
2. **Step 2:** Each group will discuss and list the key technical skills and knowledge areas required for a career in telecom substrate design. This can include topics such as:
   - Material science (specifically for substrates)
   - Circuit design and simulation
   - Cleanroom protocols
   - Manufacturing processes
   - Quality control and testing
3. **Step 3:** Each group will also define the roles and responsibilities of a Telecom Substrate Design Support Engineer (SDSE). This includes tasks such as:
   - Collaborating with the design and production teams
   - Troubleshooting issues related to substrate quality
   - Providing technical support during the substrate manufacturing process

4. **Step 4:** Each group will create a visual career progression map or diagram. The map should include the necessary technical skills and key milestones for career advancement in telecom substrate design. Participants should consider the SDSE role as an entry-level position and explore potential advancements into senior roles like Design Engineer or Project Manager.
5. **Step 5:** Groups will present their career progression maps and findings to the larger group, highlighting key skills for advancement and the role of the SDSE.

**Examples of Scenario Cards:**

**Scenario 1:** Signal Integrity Issue

**Problem:**

During testing, it's discovered that there is significant signal loss and crosstalk in the high-frequency range (5 GHz to 10 GHz). The current substrate layout includes densely packed signal traces and insufficient ground planes.

**Challenge:**

- Identify the root cause of the signal integrity issue.
- Propose layout or material changes to minimize signal loss and crosstalk.
- Ensure that the changes don't increase production costs significantly.

**Scenario 2:** Thermal Management Challenge

**Problem:**

The telecom module is experiencing thermal hotspots around the power amplifier components, leading to reduced reliability and occasional system shutdowns. Current heat sinks and vias seem insufficient.

**Challenge:**

- Suggest design modifications to improve heat dissipation (e.g., additional thermal vias, material changes).
- Propose ways to optimize thermal management without affecting the signal integrity.
- Ensure that the proposed solution is feasible for mass production.

**Scenario 3:** Manufacturability Concern

**Problem:**

The manufacturing team reports issues with via reliability in a multilayer substrate design. The vias are too small for the available fabrication process, leading to high rejection rates during production.

**Challenge:**

- Recommend adjustments to the via design (e.g., size, placement, or plating process).
- Balance the need for reliable manufacturing with maintaining electrical performance.
- Ensure the design changes align with industry standards and do not increase production time.

| Activity | Duration | Resources used |
|---|---|---|
| Career Pathway Planning in Telecom Substrate Design | | Whiteboard or flipchart, Markers, Sticky notes, Scenario cards (described below), etc. |

## Do

- Guide the trainees throughout the activity
- Ensure that all trainees participate in the activity

## Notes for Facilitation

- Briefly explain key concepts (e.g., signal integrity, thermal management, DFM).
- Suggest assigning roles (e.g., materials expert, layout designer, presenter) to streamline group work.
- Encourage groups to explore diverse ideas and challenge each other's assumptions constructively.

## Exercise

**Multiple-Choice Questions (MCQs)**

**1.** Which of the following is a commonly used substrate material in telecom applications?

a) Polyethylene

b) BT Resin

c) Acrylic

d) Nylon

**Answer:** b) BT Resin

**2.** What is the primary function of semiconductors in telecom devices?

a) To provide mechanical support

b) To amplify and control electrical signals

c) To act as a thermal insulator

d) To provide structural stability

**Answer:** b) To amplify and control electrical signals

**3.** Which industry standard is commonly followed for telecom substrate design?

a) IEEE 802.11

b) IPC-2221

c) ISO 14001

d) ASME B31.3

**Answer:** b) IPC-2221

**4.** What is a critical safety precaution in a cleanroom environment?

a) Avoid wearing gloves

b) Use PPE, including anti-static garments

c) Leave the door open for ventilation

d) Use regular household cleaning agents

**Answer: b)** Use PPE, including anti-static garments

**Fill in the Blanks**

**1.** The primary purpose of ________ control procedures is to ensure the reliability and functionality of telecom substrates.

**Answer:** quality

**2.** ________ is a substrate material known for its excellent high-frequency performance in telecom applications.

**Answer:** Ceramic

**3.** Proper ________ procedures are essential to prevent contamination and damage to telecom substrates.

**Answer:** handling

**4.** Personal Protective Equipment (PPE) such as gloves and ________ must be worn in a controlled environment to prevent contamination.

**Answer:** anti-static garments

**Match the following:**

| Column A | Column B |
|---|---|
| 1. DFM | a) Key tool for layout creation |
| 2. Pin count | b) A design principle to ensure manufacturability |
| 3. Signal integrity | c) A measure of a component's input/output connections |
| 4. CAD software | d) The ability of a substrate to maintain accurate signal transmission |

**Answers:** 1 - b, 2 - c, 3 - d, 4 - a

**Match the following:**

| Column A | Column B |
|---|---|
| 1. Anti-static garments | a. Prevent contamination of substrates |
| 2. Cleanroom air filtration system | b. Reduce particulate contamination |
| 3. Proper substrate handling | c. Minimize static charge damage to components |
| 4. Quality control procedures | d. Ensure reliability and functionality |

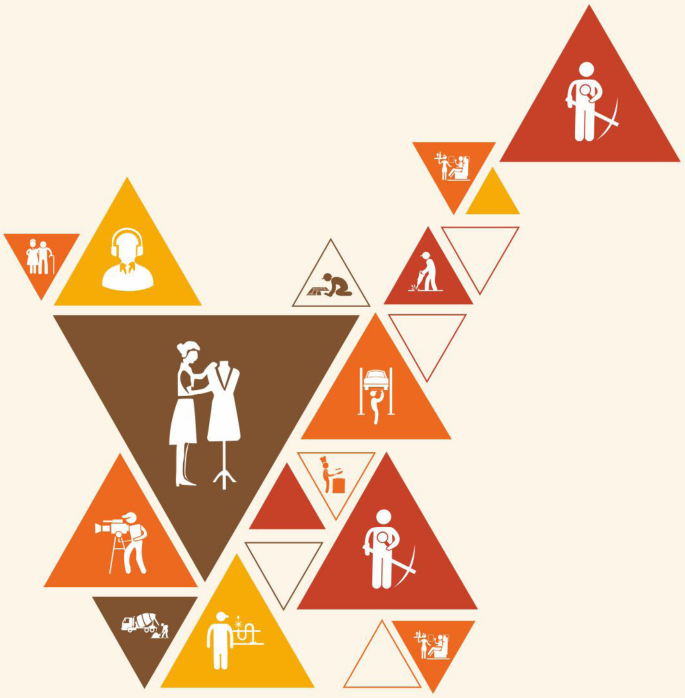
**Answers:** 1 - c, 2 - b, 3 - a, 4 - b

**Match the following:**

| Column A | Column B |
|---|---|
| 1. Wafer Preparation Process | a) Ensures proper thickness and flatness for wafer integration. |
| 2. Cleanroom Standards | b) To ensure workers' safety and reduce contamination risks. |
| 3. PPE in Semiconductor Manufacturing | c) Adhering to protocols for contamination control, including gowning and cleanliness. |
| 4. Technician's Role in Wafer Lapping | d) Involves removing material from wafers to achieve desired thickness. |

**Answers:** 1 - a, 2 - c, 3 - b, 4 - d

# 2. Substrate Design Support



TEL/N7216

## Key Learning Outcomes

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

1. Explain the functionalities and key parameters of telecom integrated circuits (ICs).
2. Describe how substrate requirements are derived from IC features like pin count and power needs.
3. Define critical dimensions, tolerances, and material properties for substrates.
4. Explain the purpose and content of design documents like layer stack-up, routing guidelines, and placement constraints.
5. Describe the role of design meetings and collaboration in substrate development.
6. Explain performance targets like signal integrity and thermal dissipation.
7. Analyze the impact of layout choices on manufacturability and cost (e.g., layer count, routing complexity).
8. Explain how material properties influence cost and performance of the substrate.
9. Identify common manufacturability limitations of fabrication processes.
10. Understand the concept of Design for Manufacturability (DFM) and its importance.
11. Demonstrate proficiency in using CAD software to create basic layouts for telecom substrates.
12. Apply established design rules and layer definitions during layout creation.
13. Place and route components and signals according to design specifications and performance requirements.
14. Perform Design Rule Checks (DRC) to ensure the layout adheres to manufacturing guidelines.
15. Demonstrate analyzing feedback from senior designers and addressing manufacturability concerns in the layout.
16. Modify existing layouts based on feedback and identified issues, existing layouts based on feedback and identified issues.
17. Analyze the layout for potential manufacturability issues like minimum feature size limitations, via density, and complex routing patterns.
18. Demonstrate identifying areas where the design might exceed equipment capabilities or introduce processing challenges.
19. Show how to document key decisions and steps taken during the design process as well as identified DFM issues in a clear and concise manner.
20. Propose solutions for DFM issues with supporting rationale for further review and approval.

# Unit 2.1: Telecom IC Requirements and Substrate Design Essentials

## Unit Objectives

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

1. Explain the functionalities and key parameters of telecom integrated circuits (ICs).
2. Describe how substrate requirements are derived from IC features like pin count and power needs.
3. Define critical dimensions, tolerances, and material properties for substrates.
4. Explain the purpose and content of design documents like layer stack-up, routing guidelines, and placement constraints.

## Resources to be Used

Participant handbook, pen, notebook, whiteboard, flipchart, markers, laptop, overhead projector, laser pointer, etc.

## Note

In this unit, we will discuss the functionalities and key parameters of telecom integrated circuits (ICs) and how these parameters influence substrate requirements, including pin count, power distribution, and thermal management. Additionally, we will explore critical dimensions, tolerances, and material properties for substrates, as well as the purpose and content of essential design documents like layer stack-ups, routing guidelines, and placement constraints.

## Ask

**Ask the participants the following questions:**

- What is the primary role of a substrate in supporting telecom integrated circuits (ICs)?

Write down the participants' answers on a whiteboard/flipchart. Take appropriate clues from the answers and start teaching the lesson.

## Elaborate

### Functionalities and Key Parameters of Telecom Integrated Circuits (ICs)

Telecom Integrated Circuits (ICs) are essential components in modern telecom devices, performing a wide range of tasks to enable high-speed data transmission, signal processing, and power management. Their functionalities and key parameters include:

1. **Functionalities:**
    - **Signal Processing:** Process analog or digital signals for modulation, demodulation, encoding, and decoding.

- **Power Management:** Regulate voltage and current for optimal device performance and energy efficiency.
- **Data Transmission:** Enable high-speed communication using protocols like 5G, Wi-Fi, and Ethernet.
- **Clock Management:** Provide accurate timing signals critical for synchronized data flow.
- **Error Detection and Correction:** Improve data integrity through built-in error-checking mechanisms.

2. **Key Parameters:**
    - **Operating Frequency:** Determines the speed of data processing and transmission. Higher frequencies are essential for modern telecom systems.
    - **Power Consumption:** Defines the IC's efficiency and impacts the overall thermal management of the system.
    - **Pin Count:** Reflects the complexity and functionality of the IC, affecting the substrate's design and interconnect density.
    - **Thermal Resistance:** Indicates the IC's ability to dissipate heat, essential for reliable operation under high workloads.
    - **Signal Integrity:** Ensures minimal loss or distortion of signals during transmission.

### Substrate Requirements Derived from IC Features

Substrate design must align with the specific characteristics of the IC to ensure seamless functionality and reliability. Key factors include:

1. **Pin Count and Interconnect Density:**
    - High pin counts require dense routing of signal traces, which impacts the number of substrate layers and the layout of vias (vertical interconnections).
    - Dense interconnects demand advanced materials with low dielectric constants to maintain signal integrity.
2. **Power Needs and Thermal Management:**
    - High-power ICs generate significant heat, requiring substrates with excellent thermal conductivity (e.g., ceramic or metal-core substrates).
    - Power delivery networks (PDNs) within the substrate must support stable voltage levels, necessitating thicker copper layers for efficient current flow.
3. **Frequency Requirements:**
    - ICs operating at high frequencies (e.g., 5G systems) require substrates with low loss tangent and minimal electromagnetic interference (EMI).
    - Materials like PTFE or high-frequency laminates are used to support these requirements.
4. **Mechanical Reliability:**
    - Substrates must withstand mechanical stresses from thermal cycling and external forces. For ICs with tight tolerances, substrates with minimal warpage and high dimensional stability are crucial.

### Critical Dimensions, Tolerances, and Material Properties for Substrates

The precise fabrication of substrates ensures reliable performance and compatibility with ICs. Important considerations include:

1. **Critical Dimensions:**
   - **Trace Width and Spacing:** Determines signal integrity and crosstalk. Typically, high-frequency designs require smaller trace widths and tighter spacing.
   - **Via Size and Aspect Ratio:** Critical for ensuring robust electrical connections between layers. The aspect ratio (via depth-to-diameter) impacts manufacturability and reliability.
   - **Layer Thickness:** Influences impedance control, thermal performance, and mechanical stability.
2. **Tolerances:**
   - **Dimensional Tolerance:** Ensures that the physical dimensions of traces, pads, and vias remain within specified limits to maintain electrical performance.
   - **Impedance Tolerance:** Essential for high-frequency applications to prevent signal reflections and losses.
3. **Material Properties:**
   - **Dielectric Constant (Dk):** Affects signal speed and impedance. Low Dk materials are preferred for high-speed designs.
   - **Loss Tangent (Df):** Determines signal loss; lower values are critical for high-frequency performance.
   - **Thermal Conductivity:** Ensures efficient heat dissipation, reducing the risk of component failure.
   - **Coefficient of Thermal Expansion (CTE):** Should match the IC's CTE to prevent mechanical stress during thermal cycling.

### Purpose and Content of Design Documents

Design documents are vital for communicating substrate design requirements and ensuring consistency across the development and manufacturing processes. Key documents include:

1. **Layer Stack-Up:**
   - **Purpose:** Defines the sequence and thickness of substrate layers (e.g., signal, ground, and power planes). It ensures proper impedance control, power distribution, and thermal performance.
   - **Content:** Includes the material type, dielectric constant, and thickness for each layer. It also specifies the location of ground and power planes to minimize noise.
2. **Routing Guidelines:**
   - **Purpose:** Provides rules for the layout of signal traces to maintain signal integrity and prevent crosstalk or EMI.
   - **Content:** Covers trace width, spacing, routing angles, and preferred signal routing paths. For high-speed designs, guidelines for differential pair routing and length matching are included.
3. **Placement Constraints:**
   - **Purpose:** Ensures optimal component placement to reduce signal delay, improve thermal performance, and simplify assembly.
   - **Content:** Specifies the location of critical components (e.g., ICs, decoupling capacitors) and the required spacing between them. Guidelines may also include restrictions for areas under BGA (Ball Grid Array) packages to facilitate inspection and repair.

The design of telecom substrates is a complex process that requires alignment with the specific functionalities and key parameters of ICs. Understanding how IC features, such as pin count and power needs, influence substrate requirements ensures optimal performance and reliability. Critical dimensions, tolerances, and material properties play a pivotal role in achieving high-frequency operation and mechanical stability. Design documents, such as layer stack-ups, routing guidelines, and placement constraints, provide a comprehensive framework for ensuring consistency and quality in substrate manufacturing. By adhering to these principles, Telecom Substrate Design Support Engineers (SDSEs) contribute to the advancement of reliable and efficient telecom systems.

## Say

Let us participate in an activity to explore the unit a little more.

## Activity

**Group Activity:** Telecom Integrated Circuit (IC) Substrate Design Challenge

**Objective:**

To collaboratively design a substrate based on the requirements of a specific telecom IC, considering key parameters like pin count, power needs, critical dimensions, and material properties. Participants will also create design documents that outline key design guidelines.

**Group Size:** 4-6 participants

**Materials Needed:**

- Whiteboard or flipchart
- Markers
- Paper or digital tools for substrate layout (if available)
- Sample telecom IC data (pin count, power requirements, etc.)
- Layer stack-up and routing guidelines templates (optional)

**Activity Instructions**

1. **Introduction to IC Parameters (10 minutes)**
    - Briefly explain the key features of telecom ICs, such as pin count, power requirements, signal types, and frequency ranges.
    - Provide an overview of how these parameters impact substrate design, including material choice, layer stack-up, and routing considerations.
2. **Distribute IC Specifications (5 minutes)**
    - Provide each group with a telecom IC specification sheet. This sheet should include details like:
        - Pin count
        - Power consumption (e.g., high-power vs. low-power pins)
        - Critical signal paths (e.g., RF, analog, or digital)
        - Environmental constraints (e.g., temperature tolerance, EMI protection)

3. **Group Design Task (25 minutes)**

   **Each group will:**

   - Derive substrate requirements based on the provided IC specifications.
   - Determine the material properties (e.g., thermal conductivity, dielectric constant).
   - Propose a suitable layer stack-up and routing plan to accommodate the IC's features.
   - Identify critical dimensions and tolerances, considering factors like signal integrity and power delivery.
   - Discuss and propose potential challenges (e.g., thermal management, via placement).

4. **Design Documentation (10 minutes)**

   **Each group will:**

   - Create a design document outlining their proposed layer stack-up, routing guidelines, and placement constraints.
   - Ensure the document clearly explains their reasoning for selecting specific materials and design parameters.

5. **Group Presentations (10 minutes)**

   - Each group presents their substrate design and the rationale behind their decisions.
   - Highlight how the IC's features influenced substrate choices and discuss challenges faced during the design process.

**Examples of Scenario Cards:**

**Scenario 1:** High-Power IC Integration

**Problem:**

You are tasked with designing a substrate for a telecom IC that operates at high power (up to 20W). The IC has a high pin count (500+ pins), and several pins require high-speed signal integrity. The design also requires thermal management due to the heat generated by power consumption.

**Challenge:**

- Select appropriate materials for the substrate to handle both the power and signal integrity requirements.
- Propose a layer stack-up that will accommodate high-power pins and signal paths.
- Address the thermal dissipation challenge and suggest routing or cooling solutions.

**Scenario 2:** High-Frequency RF IC

**Problem:**

You are designing a substrate for a telecom IC used in a 5G base station with RF signals operating between 3 GHz to 100 GHz. The IC has a medium pin count (100-150 pins) and includes both analog and digital signal paths. The primary concern is minimizing electromagnetic interference (EMI) and signal degradation at high frequencies.

**Challenge:**

- Propose a material selection that minimizes loss and ensures efficient signal transmission at high frequencies.

- Suggest critical dimensions, tolerances, and via placements to minimize EMI and preserve signal integrity.
- Consider how to handle the differing requirements for analog vs. digital signal paths.

**Scenario 3:** Compact IC for Small Form Factor Device

**Problem:**

You need to design a substrate for a telecom IC to be used in a compact, low-power IoT device with limited space. The IC has a low pin count (30-50 pins) but requires precise placement and routing to meet performance standards. Power consumption is minimal, but the design must be robust enough to handle environmental factors such as temperature fluctuations.

**Challenge:**

- Design a compact and efficient substrate layout that meets the size and routing constraints.
- Choose materials that balance performance and manufacturability within the compact space.
- Identify key tolerances and critical dimensions that ensure reliability under varying environmental conditions.

| Activity | Duration | Resources used |
|---|---|---|
| Telecom Integrated Circuit (IC) Substrate Design Challenge | | Whiteboard or flipchart, Markers, Sticky notes (different colors), Scenario cards (described below) |

## Do ✓

- Guide the trainees throughout the activity
- Ensure that all trainees participate in the activity

## Notes for Facilitation

- Emphasize how power needs, pin count, and signal types directly influence material selection and layout.
- Focus on real-world design solutions that balance performance, manufacturability, and cost.
- Encourage team members to collaborate, discuss trade-offs, and solve design challenges together.

# Unit 2.2: Design Collaboration and Performance Criteria

## Unit Objectives

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

1. Describe the role of design meetings and collaboration in substrate development.
2. Explain performance targets like signal integrity and thermal dissipation.
3. Analyze the impact of layout choices on manufacturability and cost (e.g., layer count, routing complexity).
4. Explain how material properties influence cost and performance of the substrate.

## Resources to be Used

Participant handbook, pen, notebook, whiteboard, flipchart, markers, laptop, overhead projector, laser pointer, etc.

## Note

In this unit, we will discuss the importance of design meetings and collaboration in substrate development, focusing on how team discussions shape the design process. We will explore performance targets like signal integrity and thermal dissipation and analyze how layout choices, such as layer count and routing complexity, impact manufacturability and cost. Additionally, we will examine how material properties affect both cost and performance of telecom substrates.

## Ask

**Ask the participants the following questions:**

- What factors do you think influence the choice of materials and layout in telecom substrate design?

Write down the participants' answers on a whiteboard/flipchart. Take appropriate clues from the answers and start teaching the lesson.

## Elaborate

### 1. Role of Design Meetings and Collaboration in Substrate Development

Design meetings and collaboration play a vital role in the substrate development process. These meetings foster communication between different teams—design engineers, materials experts, manufacturing specialists, and quality assurance personnel. Effective collaboration ensures that all aspects of the substrate design, from performance requirements to manufacturability, are addressed early in the process.

**Key Points:**

- **Cross-functional Collaboration:** Design meetings enable seamless integration of knowledge from different experts, ensuring a holistic approach to substrate development. Engineers can exchange ideas, discuss trade-offs, and identify potential issues related to signal integrity, power management, or material selection.

- **Issue Resolution:** Early identification of potential design flaws or challenges is essential. Regular collaboration helps teams promptly address issues, such as heat dissipation concerns, poor signal integrity, or manufacturing constraints.
- **Design Refinement:** Continuous feedback during design meetings allows engineers to refine the substrate design iteratively, ensuring that each design modification meets the performance targets.
- **Optimization:** Collaboration ensures that designs are optimized for manufacturability, cost-effectiveness, and scalability. Teams can identify the most efficient manufacturing processes, minimizing waste and reducing production costs.
- **Risk Mitigation:** By working together early on, teams can mitigate risks related to compliance with industry standards, material compatibility, and production delays.

### 2. Performance Targets: Signal Integrity and Thermal Dissipation

Performance targets are the critical benchmarks that a telecom substrate must meet to ensure that it operates efficiently within a system. Two of the most important performance targets in telecom substrate design are signal integrity and thermal dissipation.

**Signal Integrity**

Signal integrity refers to the ability of the substrate to transmit electrical signals without distortion or degradation. In telecom applications, this is crucial as high-frequency signals are often transmitted over long distances.

**Key Points:**

- **Minimizing Noise and Crosstalk:** To ensure signal integrity, the substrate design must minimize electromagnetic interference (EMI) and crosstalk between adjacent signal traces. This can be achieved by ensuring adequate separation between signal paths and implementing proper shielding.
- **Material Selection:** High-performance materials with low dielectric loss are crucial to maintaining signal integrity, especially for high-frequency and RF applications. Materials like PTFE (polytetrafluoroethylene) or ceramic-based substrates are commonly used in high-frequency designs.
- **Trace Width and Impedance Matching:** The width of the signal traces and the design of the substrate must maintain a controlled impedance to prevent signal reflections and loss.

**Thermal Dissipation**

Thermal dissipation is essential to prevent overheating, which can degrade the performance of telecom devices and shorten their lifespan. In telecom substrate design, efficient thermal management is a critical consideration due to the high-power consumption of many devices.

**Key Points:**

- **Heat Distribution:** A well-designed substrate must effectively distribute heat generated by active components like power amplifiers, processors, and RF circuits. This involves careful planning of the layout, using thermal vias, heat sinks, and selecting materials with good thermal conductivity.
- **Thermal Materials:** Materials with high thermal conductivity, such as copper or ceramic, are

**Challenge:**

- Propose a material selection that minimizes loss and ensures efficient signal transmission at high frequencies.

- **Thermal Expansion Compatibility:** The substrate design must consider the coefficient of thermal expansion (CTE) of the materials used. Mismatched CTEs between components and the substrate can lead to mechanical stresses, warping, or failure over time.

### 3. Impact of Layout Choices on Manufacturability and Cost

Layout choices significantly impact the manufacturability and cost of telecom substrates. The design decisions made during the layout phase can either streamline the manufacturing process or introduce complexities that increase costs and lead times.

#### Layer Count

The number of layers in a substrate design plays a crucial role in both its manufacturability and cost. A substrate with more layers generally offers better performance by allowing for more complex routing and better signal integrity, but it also increases production complexity and cost.

**Key Points:**

- **Increased Layer Count:** More layers mean more expensive manufacturing processes, higher material costs, and a greater likelihood of defects during production. The cost of fabricating multi-layer substrates increases due to the additional materials, fabrication steps, and the complexity of aligning the layers.
- **Trade-offs:** Engineers must balance performance needs (such as routing complexity) with the associated cost of additional layers. For high-performance telecom substrates, additional layers might be necessary for signal integrity or power distribution, but for low-cost devices, minimizing the number of layers is often a priority.

#### Routing Complexity

The complexity of routing—how signal traces are laid out on the substrate—also influences both manufacturability and cost. More complex routing may be necessary for high-performance designs, but it can increase the chances of errors, production time, and overall cost.

**Key Points:**

- **Impact on Yield:** Complex routing requires precise manufacturing, and intricate designs can lead to lower yields if errors occur during the fabrication process. This, in turn, increases the cost per unit.
- **Optimizing Routing:** Engineers work to optimize routing by minimizing trace length, reducing the number of vias, and ensuring proper layer transitions. Simplifying the routing complexity reduces the potential for defects and lowers production costs.

#### Cost Implications

The choice of materials, the number of layers, and the complexity of routing all directly impact the cost of the substrate. High-performance materials and multi-layer designs will increase the overall price, while simpler, more straightforward designs help reduce costs.

**Key Points:**

- **Cost Trade-offs:** Telecom devices often need to strike a balance between performance and cost. High-performance substrates may offer superior electrical and thermal properties, but at ahigher price point. Manufacturers must decide how to best meet the required performance targets while keeping costs manageable.

### 4. Material Properties and Their Influence on Cost and Performance

Material properties have a profound impact on both the performance and cost of telecom substrates. Choosing the right material is crucial for achieving optimal performance in terms of signal integrity, thermal management, and manufacturability.

### Performance Influence

Different materials exhibit unique electrical, thermal, and mechanical properties that affect the performance of the substrate.

**Key Points:**

- **Dielectric Constant:** Materials with a low dielectric constant, such as PTFE and ceramics, are often used in high-frequency applications. These materials reduce signal loss and improve signal integrity.
- **Thermal Conductivity:** Materials with high thermal conductivity, such as copper and ceramics, are crucial for efficient heat dissipation and preventing thermal-related issues in high-power telecom devices.
- **Mechanical Strength:** Materials must also have sufficient mechanical strength to withstand the stresses imposed during manufacturing and operational use.

### Cost Influence

The cost of materials can vary significantly depending on their properties, availability, and complexity to process.

**Key Points:**

- **Cost of High-Performance Materials:** While high-performance materials provide superior thermal and electrical properties, they tend to be more expensive. For example, ceramic substrates are more costly than standard FR-4 materials, but they offer better performance for high-frequency applications.
- **Balancing Cost and Performance:** Engineers must weigh the trade-offs between the cost of materials and the performance they offer. In some cases, a less expensive material like FR-4 might suffice for less demanding applications, while in high-performance telecom systems, higher-cost materials may be necessary.

In conclusion, substrate development for telecom applications is a highly complex process that requires a careful balance between performance, manufacturability, cost, and material properties. Design meetings and collaboration between various teams ensure that all requirements are met efficiently. Signal integrity and thermal dissipation are key performance targets that influence material selection, layout, and design choices. At the same time, the impact of layout choices on manufacturability and cost must be carefully considered to ensure that the final design is both efficient and cost-effective. Finally, the selection of materials plays a central role in achieving the desired performance while maintaining a manageable production cost.

## Say

Let us participate in an activity to explore the unit a little more.

## Activity

**Group Activity:** Substrate Design Optimization Simulation

**Objective:**

To collaborate in a design meeting scenario where participants analyze and optimize a telecom substrate design based on performance targets, layout choices, material properties, and manufacturability.

**Group Size:** 4-6 participants

**Materials Needed:**

- Whiteboard or flipchart
- Markers
- Substrate design templates (if available)
- Telecom IC specification sheet (with required performance targets, pin count, power consumption, etc.)
- Material property data sheet (including cost and performance characteristics)

**Activity Instructions**

1. **Introduction to Design Context (10 minutes)**
    - Briefly explain the role of design meetings in substrate development: addressing challenges, aligning design goals, and discussing trade-offs.
    - Review key concepts: signal integrity, thermal dissipation, layout choices (layer count, routing complexity), and how material properties affect both performance and cost.
2. **Distribute Substrate Design Challenges (5 minutes)**
    - Provide each group with a substrate design challenge. Each challenge should include:
        - Target performance metrics (e.g., signal integrity, thermal dissipation).
        - Constraints like pin count, power consumption, environmental conditions, etc.
        - A set of material options (e.g., cost and performance considerations).
        - Details on the impact of layout choices on manufacturability and cost.
3. **Group Design and Optimization (25 minutes)**
    - Groups will collaborate as a team to:
        - Discuss how to meet the performance targets (signal integrity, thermal dissipation).
        - Evaluate the impact of layout choices on manufacturability (e.g., layer count, via placement, routing complexity).
        - Optimize material selection, balancing performance and cost.
        - Propose a final substrate design and create a design summary (including layer stack-up, material choices, routing guidelines).
4. **Group Presentations (10 minutes)**
    - Each group presents their design choices, explaining how they addressed performance targets, layout constraints, and material considerations.
    - Participants should also discuss how they balanced manufacturability with cost and performance.
5. **Debrief and Discussion (10 minutes)**
    - Facilitate a discussion on the different approaches each group took, focusing on trade-offs and lessons learned.
    - Highlight key factors that influence substrate design decisions in a real-world scenario.

**Examples of Scenario Cards:**

**Scenario 1:** High-Speed Data Transmission Substrate Design

**Problem:**

You are tasked with designing a telecom substrate for an IC used in a high-speed data transmission module (10+ Gbps). The IC has 200+ pins, and there are strict requirements for signal integrity, especially at high frequencies. Thermal dissipation is also a concern due to power consumption, which can reach 15W during peak operation.

**Challenge:**

- Select materials that can minimize signal degradation and maintain high-frequency performance.
- Propose a layer stack-up that ensures low signal loss and adequate thermal dissipation.
- Balance routing complexity to avoid increased cost or manufacturability issues.

**Scenario 2:** Low-Cost, High-Density Substrate Design for 5G Device

**Problem:**

You are designing a substrate for a low-cost, high-density telecom IC used in a 5G network device. The IC has a medium pin count (120-150 pins) but requires high-density interconnects due to space constraints. Signal integrity must be maintained, but cost is a significant factor, and the IC will operate at moderate power levels.

**Challenge:**

- Propose a material solution that balances cost with signal integrity and power management.
- Determine the optimal layer count and routing guidelines that allow for compactness without compromising performance.
- Ensure manufacturability while considering the trade-offs between routing complexity and cost.

**Scenario 3:** Rugged Telecom Substrate for Outdoor Equipment

**Problem:**

You are designing a substrate for a telecom IC used in outdoor equipment exposed to varying environmental conditions. The IC has low power consumption and moderate pin count (50-80 pins), but the key challenge is ensuring long-term reliability in extreme temperatures (-40°C to 85°C) and humidity.

**Challenge:**

- Select materials that are durable and can handle temperature and environmental stress.
- Propose a robust layer stack-up that supports reliable operation in harsh conditions.
- Address the impact of environmental factors on both performance and cost, ensuring manufacturability in outdoor telecom devices.

| Activity | Duration | Resources used |
|---|---|---|
| Substrate Design Optimization Simulation | | Whiteboard or flipchart, Markers, Sticky notes (different colors), Scenario cards (described below), etc. |

## Do

- Guide the trainees throughout the activity
- Ensure that all trainees participate in the activity

## Notes for Facilitation

- Guide participants to work as a team, considering multiple perspectives to find optimal design solutions.
- Emphasize the balance between performance (signal integrity, thermal dissipation) and manufacturability (layer count, routing complexity).
- Prompt discussion on how material properties affect both performance (e.g., signal loss, thermal conductivity) and cost.
- After each presentation, encourage peer questions and feedback to explore alternative solutions or improvements.

# Unit 2.3: Design for Manufacturability (DFM) Principles

## Unit Objectives

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

1. Identify common manufacturability limitations of fabrication processes.
2. Understand the concept of Design for Manufacturability (DFM) and its importance.
3. Explain how material properties influence cost and performance of the substrate.

## Resources to be Used

Participant handbook, pen, notebook, whiteboard, flipchart, markers, laptop, overhead projector, laser pointer, etc.

## Note

In this unit, we will discuss the key aspects of substrate design, focusing on the manufacturability limitations of fabrication processes. We will explore the concept of Design for Manufacturability (DFM) and its importance in creating cost-effective, high-performance substrates. Additionally, we will examine how material properties impact both the cost and overall performance of substrates used in telecom applications.

## Ask

**Ask the participants the following questions:**

- What do you think are some of the challenges designers face when ensuring a telecom substrate is both manufacturable and cost-effective?

Write down the participants' answers on a whiteboard/flipchart. Take appropriate clues from the answers and start teaching the lesson.

## Elaborate

1. **Common Manufacturability Limitations of Fabrication Processes**

   Manufacturability limitations refer to the challenges or constraints faced during the production of a product due to the inherent characteristics of the materials, design, or fabrication processes. In the context of telecom substrates, some of the common limitations include:

   - **Material Constraints:** Certain materials, such as high-frequency dielectric materials or advanced laminates, can be difficult to process due to their high costs, specific processing requirements, or lack of availability in desired thicknesses. For example, ceramic materials, although ideal for high-frequency performance, may be difficult to machine accurately or are expensive to source.
   - **High Layer Count:** Substrate designs with a high number of layers (e.g., for complex telecom circuits) can result in difficulty during fabrication. More layers increase complexity in terms of

alignment, via placement, and handling during the manufacturing process. This complexity can lead to increased error rates, longer production times, and higher manufacturing costs.

- **Tight Tolerances and Dimensions:** Telecom substrates often require highly accurate placement of components and vias. Tight tolerances for critical dimensions (e.g., via hole size, trace width) can be difficult to achieve, especially in mass production. Tight tolerances increase the risk of defects and necessitate more advanced, and therefore more expensive, manufacturing techniques.
- **Via and Trace Complexity:** As the complexity of the circuit increases, so do the challenges in via routing and trace width design. Minimizing signal loss and ensuring reliability in high-speed or high-power applications requires intricate routing, which increases production difficulty and cost.
- **Thermal and Mechanical Stress:** Different materials used in telecom substrates have varying coefficients of thermal expansion (CTE). Mismatches between the CTE of different materials can lead to mechanical stress, which can compromise the performance of the final product. Managing thermal dissipation while preventing warping during the manufacturing process is a significant challenge.
- **Assembly and Handling:** Substrates with fine features or those that are overly thin can be prone to damage during handling and assembly. Careful attention is required to avoid breakage, bending, or contamination during the fabrication and assembly stages.

## 2. Design for Manufacturability (DFM) and Its Importance

Design for Manufacturability (DFM) refers to the practice of designing a product with its manufacturability in mind. The goal of DFM is to create designs that are easy and cost-effective to manufacture while maintaining quality and performance. For telecom substrates, DFM principles are crucial because they:

- **Simplify the Production Process:** By focusing on how the substrate will be manufactured, designers can reduce complexity, which leads to easier fabrication processes and fewer chances for defects. Simplifying the number of layers, via placements, and trace widths can significantly reduce production costs.
- **Minimize Material Waste:** Effective DFM reduces material waste by ensuring the design uses the available materials in the most efficient manner possible. This is particularly important in telecom substrate manufacturing where high-performance materials are often expensive.
- **Improve Assembly Efficiency:** A well-designed substrate will consider the ease of component placement, reducing the risk of mistakes during the assembly process. This includes ensuring that the layout is conducive to automated assembly tools and aligning with component package types for minimal handling.
- **Lower Production Costs:** DFM allows for designs that can be produced with existing manufacturing equipment and without requiring additional specialized processes. This lowers the overall cost of production by reducing the need for additional tooling, setup, and processing steps.
- **Enhance Product Quality:** A design optimized for manufacturability tends to have fewer defects, higher consistency, and improved reliability. By avoiding overly complex designs, products are less prone to failure during the manufacturing process.
- **Speed Time to Market:** DFM can also improve time-to-market by simplifying the prototyping and production phases. The more a design can be aligned with existing processes, the faster it can be produced and brought to market.

**Key principles of DFM for telecom substrates include:**

- Reducing complexity in layer stack-ups and routing
- Using standardized materials that are widely available and easy to process
- Ensuring alignment with fabrication capabilities to avoid excessive customizations or overly tight tolerances
- Incorporating design reviews early in the process to identify potential manufacturability issues.

### 3. How Material Properties Influence Cost and Performance of the Substrate

The choice of material is one of the most crucial factors influencing both the cost and performance of telecom substrates. Different materials have distinct characteristics, which impact the substrate's overall performance, reliability, and cost. Here are the key material properties that influence telecom substrate design:

- **Dielectric Constant (Dk):** The dielectric constant of the substrate material determines the speed at which signals travel through the material. For high-frequency telecom applications (such as 5G), substrates with a low dielectric constant are preferred because they help maintain signal integrity by reducing signal delay and loss. However, materials with low Dk values often come at a higher cost due to their specialized nature.
- **Thermal Conductivity:** Telecom substrates must dissipate heat efficiently, particularly in high-power applications. Materials with high thermal conductivity, such as copper or ceramics, can help manage thermal dissipation, ensuring the longevity and reliability of the components. Substrates with poor thermal conductivity may lead to overheating and performance degradation, especially in high-density circuits.
- **Coefficient of Thermal Expansion (CTE):** Materials with matching CTE values to the components they support are crucial for avoiding thermal stress during heating and cooling cycles. Mismatched CTEs between the substrate and the ICs or other components can cause warping, cracking, or failure. Materials with compatible CTEs may be more expensive, but they are vital for ensuring the substrate's reliability.
- **Loss Tangent (Df):** The loss tangent of a material indicates how much energy is lost as heat when an electrical signal passes through it. Low loss tangent materials are preferred for high-speed and high-frequency applications, as they reduce signal degradation. Materials with low loss tangents are typically more expensive but necessary for high-performance telecom substrates.
- **Cost Considerations:** High-performance materials, such as ceramics, Teflon-based composites, or advanced laminates, are more expensive than standard materials like FR-4 (fiberglass epoxy). The selection of material thus directly impacts the overall cost of manufacturing. Designers must balance the need for high-performance materials with cost constraints, especially in mass-production telecom products.
- **Mechanical Strength and Flexibility:** For some telecom applications, substrates need to withstand physical stress or be flexible to fit in compact or portable designs. Materials such as polyimide are commonly used for flexible substrates. While these materials are cost-effective, they may compromise performance in high-frequency or high-power scenarios compared to rigid substrates.
- **Environmental Resistance:** Materials that are resistant to environmental factors like humidity, temperature fluctuations, and UV exposure are essential for outdoor or rugged telecom equipment. Substrates designed for harsh environments require materials with superior resistance, which typically increases cost but ensures longevity and reliability.

## Say

Let us participate in an activity to explore the unit a little more.

## Activity

**Group Activity:** Design for Manufacturability (DFM) Challenge

**Objective:**

To understand the importance of Design for Manufacturability (DFM) by identifying and addressing common limitations in fabrication processes while balancing material properties, cost, and performance.

**Group Size:** 4-6 participants

**Materials Needed:**

- Whiteboard or flipchart
- Markers
- Substrate design templates (if available)
- A set of DFM guidelines or manufacturing limitations (e.g., via sizes, layer count, material constraints)
- Material property data sheet (including cost and performance characteristics)

**Activity Instructions**

1. **Introduction to DFM and Manufacturing Limitations (10 minutes)**
    - Explain the concept of Design for Manufacturability (DFM) and its importance in ensuring that designs are practical, cost-effective, and manufacturable.
    - Discuss common limitations in fabrication processes (e.g., via size restrictions, layer count, resolution limits, material availability) and how they impact substrate design.
2. **Distribute Design Challenge (5 minutes)**
    - Provide each group with a substrate design challenge, which should include:
        - Performance targets (signal integrity, thermal dissipation, etc.)
        - Material options with cost and performance details
        - DFM constraints (e.g., minimum via sizes, layer count, routing limitations)
3. **Group Design and DFM Optimization (25 minutes)**
    - Groups will work together to:
        - Design a substrate layout based on given performance targets while adhering to DFM guidelines.
        - Optimize material selection, keeping in mind both performance and cost constraints.
        - Ensure the design is manufacturable within the provided constraints (e.g., via size, layer count, material properties).
4. **Group Presentations (10 minutes)**
    - Each group presents their design and explains how they addressed the DFM constraints, material properties, and performance targets.
    - Discuss the trade-offs made to ensure manufacturability without compromising key design parameters.

5. **Debrief and Discussion (10 minutes)**
    - Facilitate a class discussion on the different approaches taken by each group.
    - Discuss lessons learned about balancing design goals with manufacturability and material constraints.

**Examples of Scenario Cards:**

**Scenario 1:** Complex Multi-Layer Substrate Design

**Problem:**

You are designing a substrate for a high-performance telecom IC with 300+ pins. The IC requires a complex multi-layer stack-up for high-speed data transmission and power management. However, the fabrication process has strict limitations on the number of layers that can be used and the size of vias due to cost constraints.

**Challenge:**

- How will you optimize the layer count to balance performance and manufacturability while meeting signal integrity and thermal dissipation requirements?
- What strategies will you use to minimize via sizes and routing complexity without affecting performance?

**Scenario 2:** Cost-Effective Substrate for Mass Production

**Problem:**

You are tasked with designing a cost-effective substrate for a low-cost telecom device with 50-100 pins. The design needs to meet basic performance requirements, but the primary concern is reducing production costs. Material cost and manufacturability are critical factors, as the device will be produced in large quantities.

**Challenge:**

- How can you choose materials that balance cost with adequate performance (e.g., signal integrity and power dissipation)?
- What DFM techniques will you employ to optimize routing, via sizes, and overall design for cost-effective mass production?

**Scenario 3:** High-Speed Substrate with Thermal Management

**Problem:**

You are designing a telecom substrate for a high-speed 5G IC that operates at 3 GHz. The IC generates significant heat and requires robust thermal management. The fabrication process has limitations on material thickness and via sizes. The challenge is to ensure the design meets performance targets while staying within the fabrication constraints.

**Challenge:**

- How will you select materials that provide good thermal conductivity while meeting the performance requirements for signal integrity at high speeds?
- What design modifications can you make to minimize thermal issues and ensure manufacturability, given the material and fabrication limitations?

| Activity | Duration | Resources used |
|---|---|---|
| Designing an Effective Housekeeping Staff Training Program | | Whiteboard or flipchart, Markers, Sticky notes (different colors), Scenario cards (described below), etc. |

## Do

- Guide the trainees throughout the activity
- Ensure that all trainees participate in the activity

## Notes for Facilitation

- Emphasize designs that are cost-effective and manufacturable within process limits.
- Ensure participants balance performance with manufacturability (via size, layer count).
- Guide on choosing materials that meet performance without exceeding budget.
- Encourage realistic designs considering manufacturing constraints.

# Unit 2.4: CAD Layout Design and Rule Compliance

## Unit Objectives

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

1. Demonstrate proficiency in using CAD software to create basic layouts for telecom substrates.
2. Apply established design rules and layer definitions during layout creation.
3. Place and route components and signals according to design specifications and performance requirements.
4. Perform Design Rule Checks (DRC) to ensure the layout adheres to manufacturing guidelines.

## Resources to be Used

Participant handbook, pen, notebook, whiteboard, flipchart, markers, laptop, overhead projector, laser pointer, etc.

## Note

In this unit, we will discuss the essential skills needed to create telecom substrate layouts using CAD software. We will explore how to apply design rules, layer definitions, and place and route components and signals according to performance specifications. Additionally, we will cover how to perform Design Rule Checks (DRC) to ensure the layout meets manufacturing guidelines and industry standards.

## Ask

**Ask the participants the following questions:**

- What are the key design rules you need to follow when creating a layout for a telecom substrate?

Write down the participants' answers on a whiteboard/flipchart. Take appropriate clues from the answers and start teaching the lesson.

## Elaborate

**Proficiency in Using CAD Software for Telecom Substrate Layouts**

**Introduction to CAD Software for Telecom Substrate Design**

Computer-Aided Design (CAD) software plays a crucial role in the development of telecom substrates. It allows designers to create precise and optimized layouts that meet functional, performance, and manufacturability requirements. Telecom substrates are integral in ensuring the proper functioning of telecom devices, such as network equipment, routers, and other communication devices. The role of CAD software in this process is to assist engineers in translating theoretical design concepts into actual layouts for manufacturing.

### Key CAD Tools and Their Use in Telecom Substrate Design

There are several CAD tools designed specifically for electronics and substrate layout, including Allegro PCB Designer, Mentor Graphics, KiCad, and Autodesk Eagle. These tools offer features like schematic capture, layout design, and 3D visualization, which are essential for ensuring a successful substrate design.

1. **Schematic Capture:** This step involves translating the electrical design into a schematic diagram. It serves as the blueprint from which the physical layout will be developed. CAD software ensures that the schematic corresponds with the performance specifications for the substrate.
2. **Layer Stack-Up Design:** In telecom substrates, multiple layers are often used to support signal routing, power distribution, and thermal management. CAD software helps in designing the appropriate stack-up, considering the number of layers, their function, and material properties.
3. **Routing and Placement:** One of the most critical aspects of substrate design is the placement and routing of components. CAD tools automatically or manually help in placing components and routing connections while ensuring that there is no interference with other components and signal integrity is maintained.

### Importance of Layer Definitions and Design Rules

In substrate design, design rules refer to the set of guidelines that ensure the layout is manufacturable, functional, and reliable. They govern aspects such as spacing between components, trace width, via sizes, and pad sizes, among others.

### Application of Design Rules and Layer Definitions

### Layer Definitions in Telecom Substrate Design

Telecom substrates typically consist of multiple layers to accommodate power and signal distribution, thermal management, and isolation between components. The layer stack-up in a substrate is defined based on the application and the performance requirements of the telecom device.

1. **Signal Layers:** These layers carry the electrical signals that drive telecom devices. Proper signal integrity must be maintained, which requires the correct trace width, spacing, and routing techniques to reduce noise and crosstalk.
2. **Power Layers:** Power layers are used to distribute power to the components on the substrate. They must be well-designed to handle current flow and minimize voltage drop across the substrate.
3. **Ground Layers:** These layers serve as the return path for signals and power. Grounding is essential for minimizing noise and ensuring signal integrity.
4. **Thermal Management Layers:** Heat dissipation is a significant concern, especially in high-power telecom devices. CAD software helps engineers place thermal management features like heat sinks, vias, and copper pours to effectively distribute and dissipate heat.

### Design Rule Implementation in Layout Creation

Once the layers are defined, CAD software uses a set of Design Rules to ensure that the layout adheres to best practices and can be manufactured reliably. These rules are critical for ensuring that the substrate design meets performance and manufacturability standards. Some key design rules include:

1. **Trace Width and Spacing:** The width of traces and the spacing between them must be optimized to avoid signal degradation and to meet the current carrying capacity. CAD tools help in setting up these parameters based on the material properties and electrical requirements of the circuit.

2. **Via Size:** Vias are used to connect different layers in the substrate. Their size and placement are dictated by the current-carrying requirements and the overall design complexity. The size of vias impacts both the electrical performance and the manufacturability of the substrate.
3. **Pad Size and Placement:** The pads where components are soldered must have the correct dimensions and placement to ensure a reliable connection. Design rules also govern the minimum pad sizes and clearances to avoid manufacturing defects.
4. **Stack-Up Optimization:** The number of layers and the materials used for each layer must be chosen to support the desired performance at an acceptable cost. The layout needs to be optimized to minimize signal loss, electromagnetic interference (EMI), and thermal buildup.

### Placing and Routing Components

### Component Placement

Placing components in a telecom substrate requires careful consideration of their functionality and electrical requirements. CAD tools help with the following placement strategies:

1. **Functionality-Based Placement:** Components such as power regulators, amplifiers, and communication modules must be placed logically, ensuring that they interact optimally while minimizing noise and signal interference.
2. **Thermal Considerations:** Power-consuming components should be placed in areas with adequate thermal dissipation, avoiding hot spots and ensuring the overall temperature remains within safe limits.
3. **Signal Integrity:** Critical signal paths should be given priority placement, ensuring they are as short and direct as possible. Components that handle high-speed signals must be positioned to minimize trace lengths and avoid noise.

### Routing Signals

Once components are placed, the next task is to route the signal traces. Signal routing is one of the most complex aspects of substrate design and is closely linked to performance. CAD tools assist in:

1. **Maintaining Signal Integrity:** For high-frequency signals, it is essential to maintain impedance control and minimize reflections. Routing traces must follow specific guidelines to minimize crosstalk and EMI.
2. **Power Distribution:** Power traces need to be wide enough to handle the required current. CAD software can simulate power distribution to ensure voltage drops are minimal.
3. **Minimizing Layer Transitions:** Minimizing the number of vias and layer transitions helps maintain signal integrity. Excessive via usage can lead to signal loss and degradation.

### Performing Design Rule Checks (DRC)

### Importance of DRC in Substrate Design

Design Rule Checking (DRC) is a crucial step in the CAD-based design process. It ensures that the layout adheres to predefined design rules and manufacturing constraints. DRC verifies that the design is free from issues that could affect performance, manufacturability, or reliability.

1. **Electrical DRC:** This involves checking for signal integrity issues such as trace width violations, via size mismatches, or incorrect spacing between components. It ensures that the design will function as expected electrically.
2. **Manufacturability DRC:** This type of check ensures that the design is feasible to manufacture. It checks for issues like insufficient clearance, excessive via density, and other layout violations that could make fabrication difficult or costly.

3. **Thermal DRC:** This ensures that the thermal management features are correctly implemented. It checks if heat-dissipating elements like vias and copper pours are properly placed and sized.
4. **Final Verification:** After performing DRC, engineers perform a final check to verify that all design goals are met. This includes running simulations to ensure the substrate will work reliably under the expected operational conditions.

Mastering CAD software for telecom substrate design is crucial for ensuring that substrates meet both electrical and mechanical performance requirements. CAD tools allow engineers to optimize designs by adhering to design rules, ensuring manufacturability, and performing critical checks. Understanding the importance of layer definitions, applying design rules, placing and routing components effectively, and performing DRC are all essential skills for creating functional and manufacturable telecom substrates. By following these steps, designers can ensure that their layouts meet the required specifications, perform reliably in their applications, and are manufacturable within cost and time constraints.

## Say

Let us participate in an activity to explore the unit a little more.

## Activity

**Group Activity:** Telecom Substrate Layout Design Using CAD Software

**Objective:**

To demonstrate proficiency in using CAD software to create basic telecom substrate layouts, apply design rules, and perform Design Rule Checks (DRC).

**Group Size:** 3-5 participants

**Materials Needed:**

- Access to CAD software (e.g., Eagle, Altium Designer, KiCad)
- Telecom substrate design specifications (component list, signal requirements, layer definitions)
- Design Rule Check (DRC) guidelines
- Whiteboard or flipchart (for group discussion and planning)

**Activity Instructions**

1. **Introduction to CAD and Design Rules (10 minutes)**
    - Briefly review the basic layout creation process using CAD software.
    - Explain key design rules (e.g., via sizes, trace widths, layer stack-ups) and the importance of adhering to these rules to ensure manufacturability and performance.
2. **Distribute Design Challenge (5 minutes)**
    - Provide each group with a telecom substrate design challenge, which includes:
        - A list of components to be placed on the substrate.
        - Signal routing requirements (e.g., high-speed, analog vs. digital).
        - Layer stack-up details and design rules (e.g., maximum trace width, via size).
        - Performance requirements (signal integrity, power dissipation).

3. **Group Design and Layout Creation (25 minutes)**
    - Each group will use the CAD software to:
        - Place and route the components according to the design specifications.
        - Ensure that the layout adheres to the provided design rules and layer definitions.
        - Perform DRC within the CAD tool to check for rule violations.
        - Optimize the layout to meet performance requirements and manufacturability.
4. **Group Presentations (10 minutes)**
    - Each group presents their layout design, explaining how they adhered to design rules, routing constraints, and performance requirements.
    - Discuss any challenges faced and how they were resolved.
5. **Debrief and Discussion (10 minutes)**
    - Facilitate a class discussion on the different approaches taken by each group.
    - Highlight key lessons learned about CAD tools, design rules, and the importance of DRC.

**Examples of Scenario Cards:**

**Scenario 1:** High-Speed Signal Routing Challenge

**Problem:**

You are designing a telecom substrate for a high-speed 5G IC that requires precision signal routing. The IC operates at frequencies over 10 GHz, and signal integrity is critical. The design requires a tight routing area, and the traces need to be as short as possible to minimize latency and signal degradation.

**Challenge:**

- How will you route the high-speed signals to maintain integrity while adhering to layer stack-up and trace width constraints?
- How can you ensure minimal signal interference while keeping the layout compact and manufacturable?

**Scenario 2:** Mixed Signal Substrate Design

**Problem:**

You are tasked with designing a telecom substrate that integrates both analog and digital circuits. The substrate needs to handle signals with different requirements, such as low-noise analog signals and high-speed digital signals, while ensuring power dissipation is managed effectively. The component placement must prevent interference between analog and digital traces.

**Challenge:**

- How will you place and route the components to separate analog and digital signals effectively?
- What design rules will you apply to minimize interference and ensure thermal management?

**Scenario 3:** Cost-Effective Substrate with Limited Layers

**Problem:**

You are designing a low-cost telecom substrate for a basic network module that requires no more than four layers. The component density is moderate, but there are strict routing limitations due to the limited number of layers. The design should meet performance requirements while keeping costs low, which may require creative routing solutions.

**Challenge:**

- How will you manage the limited number of layers while meeting signal integrity and power dissipation requirements?
- What design rules and techniques will you use to optimize the layout for manufacturability while minimizing cost?

| Activity | Duration | Resources used |
|---|---|---|
| Telecom Substrate Layout Design Using CAD Software | | Whiteboard or flipchart, Markers, Sticky notes (different colors), Scenario cards (described below), etc. |

## Do ✓

- Guide the trainees throughout the activity
- Ensure that all trainees participate in the activity

## Notes for Facilitation

- Ensure participants are familiar with the CAD tool's layout creation features (component placement, routing, layer management). Offer support as needed.
- Remind groups to adhere strictly to design rules for trace width, via sizes, and layer stack-up to avoid manufacturability issues.
- Stress the importance of performing DRC throughout the design process to catch potential errors early and ensure the layout is manufacturable.

# Unit 2.5: Layout Refinement, Feedback, and DFM Issue Resolution

## Unit Objectives

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

1. Analyze feedback from senior designers and address manufacturability concerns in the layout.
2. Modify existing layouts based on feedback and identified issues.
3. Analyze the layout for potential manufacturability issues like minimum feature size limitations, via density, and complex routing patterns.
4. Demonstrate identifying areas where the design might exceed equipment capabilities or introduce processing challenges.
5. Show how to document key decisions and steps taken during the design process as well as identified DFM issues in a clear and concise manner.
6. Propose solutions for DFM issues with supporting rationale for further review and approval

## Resources to be Used

Participant handbook, pen, notebook, whiteboard, flipchart, markers, laptop, overhead projector, laser pointer, etc.

## Note

In this unit, we will discuss the process of analyzing feedback from senior designers and addressing manufacturability concerns in telecom substrate layouts. We will cover how to modify layouts based on feedback, identify manufacturability issues (e.g., feature size limitations, via density), and propose solutions for these issues. Additionally, we will explore how to document key decisions and steps taken to resolve Design for Manufacturability (DFM) problems.

## Ask

**Ask the participants the following questions:**

- How do you think feedback from senior designers can impact the manufacturability of a telecom substrate design?

Write down the participants’ answers on a whiteboard/flipchart. Take appropriate clues from the answers and start teaching the lesson.

## Elaborate

**Analyzing Feedback and Addressing Manufacturability Concerns in Telecom Substrate Layouts**

1. **Understanding Feedback from Senior Designers**

   Feedback from senior designers is critical in refining a telecom substrate design and ensuring that it meets both functional and manufacturability requirements. Senior designers bring valuable experience to the table and can identify potential issues that might not be immediately obvious during the initial design phase. Their input typically covers various aspects of the design, including layout, signal integrity, power dissipation, and manufacturability concerns. These professionals provide feedback on how to optimize designs for efficiency, performance, and cost-effectiveness while maintaining compliance with industry standards and design rules.

When receiving feedback, it's important to focus on key areas such as:

- **Signal Integrity:** Ensuring the layout allows for smooth signal routing with minimal interference.
- **Thermal Management:** Assessing whether the design has the necessary thermal pathways to prevent overheating.
- **Layer Utilization:** Evaluating if the layer stack-up and routing are well-optimized.
- **Cost and Manufacturability:** Understanding any potential challenges related to fabricating the design at a reasonable cost, considering factors like via sizes, routing complexity, and material selection.

### 2. Addressing Manufacturability Concerns in the Layout

Once feedback is provided by senior designers, it's essential to address the manufacturability concerns that arise. The primary objective is to modify the existing layout to ensure it is feasible to produce while meeting all performance and cost targets.

**Manufacturability concerns often include:**

- **Minimum Feature Size Limitations:** Modern PCB fabrication processes have specific limitations on the smallest features that can be reliably manufactured, such as trace widths, via diameters, and hole sizes. Designers must ensure that all components, traces, and vias adhere to these limitations to avoid issues during production.
  - **Solution:** Identify areas where the feature size might be too small and adjust the layout to increase the size of traces, pads, or vias without compromising the design's functionality.
- **Via Density:** High-density designs can lead to excessive via usage, which can increase manufacturing complexity and cost. Excessive via density might also cause signal integrity issues and affect the electrical performance of the design.
  - **Solution:** Review the routing pattern and replace excessive vias with more efficient routing strategies, such as using wider traces or redistributing components to reduce the need for vias.
- **Complex Routing Patterns:** Highly complex routing can be difficult to manufacture, particularly in high-density designs with many layers. Overcomplicated routing patterns can lead to manufacturing delays, yield issues, and increased costs.
  - **Solution:** Simplify routing patterns by using larger spaces for traces or optimizing the component layout to reduce the overall complexity of routing. Additionally, employing design tools like automatic route optimization can help manage complex routing patterns.

### 3. Modifying Layouts Based on Feedback

Modifying existing layouts based on feedback requires a methodical approach. Feedback is often constructive and helps identify issues that could potentially hinder the manufacturability or performance of the design. Some of the changes that might need to be made based on senior designers' feedback include:

- Component Placement Adjustments: Moving components around to improve signal routing, minimize interference, or optimize thermal performance. Proper placement can reduce routing complexity and ensure efficient layer usage.

- Adjusting Trace Widths and Spacings: Modifying trace widths to meet the minimum fabrication requirements and ensuring proper spacing to avoid short circuits or signal integrity issues.
- Layer Stack-Up Changes: Modifying the number of layers used in the substrate design to optimize signal routing and thermal dissipation while considering cost and manufacturability.
- Via Placement Optimization: Reducing the number of vias by optimizing the placement of components and traces. Avoiding high-density vias and ensuring they comply with manufacturing specifications is crucial for cost-effectiveness.

In this step, it's essential to iterate the design, frequently consulting the feedback and design guidelines to make sure that the design continues to align with the overall project goals.

### 4. Identifying Manufacturability Issues in the Layout

An important aspect of improving a layout is identifying potential manufacturability issues early in the design process. These issues often arise when the layout exceeds the capabilities of the fabrication equipment or introduces processing challenges that could compromise the final product.

**Some common manufacturability challenges include:**

- **Feature Size Limitations:** As mentioned earlier, PCB manufacturers have strict limitations on the minimum size of components, traces, and vias. For example, if the traces in a design are too narrow or the vias are too small, they may not be manufacturable using standard processes. Additionally, some complex components may require special handling that isn't feasible with standard processes.
    - **Solution:** By comparing the design with the manufacturing equipment's capabilities and rules, designers can ensure that their features comply with industry standards and avoid using components that might be difficult or impossible to manufacture.
- **Layer Count and Complexity:** A design that uses too many layers or overly complex layer structures can significantly increase manufacturing costs. Additionally, layers can introduce difficulties with signal integrity and require careful handling during production.
    - Solution: Limiting the number of layers and carefully planning layer usage based on functionality and complexity can help streamline the design and reduce manufacturing challenges.
- **Routing Congestion:** High-density designs with tight routing can lead to congestion, causing problems in terms of signal quality and manufacturability. Routing congestion makes it difficult for fabricators to maintain consistent trace widths and can lead to increased manufacturing defects.
    - **Solution:** Using wider trace paths, simplifying the layout, or adding additional layers can help ease congestion and make the design more manufacturable.

### 5. Documenting Key Decisions and DFM Issues

As the design process unfolds, documenting key decisions and DFM issues is crucial for future reference, troubleshooting, and stakeholder communication. Documentation ensures that all team members are aligned on the design direction and that any modifications made are well-understood.

**Key points to include in the documentation:**

- Design Rule Compliance: A clear record of the design rules followed, including trace width, via sizes, and layer stack-up.
- Design Decisions: Document decisions made during the layout process, such as changes in component placement, routing strategies, and material choices.

- Manufacturability Issues: List all identified manufacturability challenges, such as excessive via density, feature size limitations, or routing complexity. Include how these issues were addressed.
- Approved Modifications: Document any modifications made to the layout based on feedback, including why changes were necessary and how they impact the overall design.

Proper documentation helps ensure that future design iterations and reviews proceed smoothly and that any issues can be traced back to their origin.

### 6. Proposing Solutions for DFM Issues

Once manufacturability issues have been identified, the next step is to propose solutions that can address the concerns while maintaining the design's performance and cost objectives.

**Proposed solutions should be justified with rationale, considering the following factors:**

- **Signal Integrity:** Solutions should ensure that signal quality remains intact, and any proposed changes should enhance signal routing or reduce interference.
- **Cost-Effectiveness:** Solutions should consider the cost of implementing changes. For example, reducing layer count may lower costs but might require additional component reorganization.
- **Manufacturing Feasibility:** Proposals should prioritize changes that align with fabrication capabilities and don't exceed the limits of available equipment or processes.
- **Thermal Management:** Proposals should take into account heat dissipation, ensuring that the design can handle the operational temperature range without overheating.

When proposing solutions, it's essential to show how the changes will help improve manufacturability, reduce potential defects, and ensure that the design meets performance targets. Support your solutions with data, such as the impact of design changes on signal integrity, layer utilization, or production costs.

Design for Manufacturability (DFM) is a critical process that ensures a telecom substrate design is feasible to produce while meeting performance, cost, and manufacturability requirements. By incorporating feedback from senior designers, identifying potential manufacturability issues, and modifying layouts accordingly, designers can address key challenges early on. Additionally, documenting decisions and proposed solutions helps ensure that designs are clear and aligned with project objectives. By applying these principles, designers can create high-quality telecom substrates that are both functional and cost-effective to manufacture.

## Say

Let us participate in an activity to explore the unit a little more.

## Activity

**Group Activity:** DFM Review and Layout Modification

**Objective:**

To analyze feedback from senior designers, address manufacturability concerns in the layout, and modify an existing design to meet DFM standards.

**Group Size:** 3-5 participants

**Materials Needed:**

- CAD software access (e.g., Eagle, Altium Designer, KiCad)
- Existing substrate layout (with some pre-identified DFM issues)
- List of feedback from senior designers (e.g., via size, feature density, routing complexity)
- Design Rule Check (DRC) guidelines
- Whiteboard or flipchart for documenting decisions and solutions

**Activity Instructions**

1. **Review of Existing Layout and Senior Designer Feedback (10 minutes)**
    - Provide participants with an existing telecom substrate layout that includes potential manufacturability issues (e.g., via density, complex routing patterns, minimum feature size violations).
    - Share feedback from senior designers, which outlines specific concerns regarding the layout's manufacturability (e.g., traces being too close, excessive via usage, or design complexity).
2. **Analyze the Layout for DFM Issues (10 minutes)**
    - Groups will use CAD software to analyze the existing layout for DFM issues such as:
        - Minimum feature size violations
        - Via density and size
        - Complex or impractical routing patterns
    - Encourage the group to evaluate whether any design elements could exceed equipment capabilities or introduce processing challenges.
3. **Modify the Layout Based on Feedback (25 minutes)**
    - Groups will address the identified DFM concerns by modifying the layout according to design rules and the feedback provided. This may include:
        - Reducing via density or size
        - Simplifying complex routing paths
        - Adjusting component placement to improve manufacturability
    - Apply DRC checks to confirm compliance with manufacturability requirements.
4. **Document Decisions and Propose Solutions (10 minutes)**
    - Each group will document key decisions made during the modification process, explaining how the issues were addressed.
    - They will also propose solutions for unresolved DFM issues, providing rationale for why the changes improve the design's manufacturability.
5. **Group Presentations (5 minutes)**
    - Each group will present their modified layout, the steps they took to address DFM concerns, and their proposed solutions.
    - Discuss challenges faced and the rationale behind design modifications.

**Examples of Scenario Cards:**

**Scenario 1:** Complex Routing with High Via Density

**Problem:**

The telecom substrate design has highly complex routing patterns, resulting in a high density of vias in certain areas. Senior designers have raised concerns that the excessive via usage could cause yield issues in the manufacturing process and increase production costs. Additionally, the routing complexity may exceed the equipment's processing capabilities.

**Challenge:**

- How will you reduce via density and simplify routing without compromising signal integrity or performance?
- What changes can you make to the layout to ensure manufacturability and cost-efficiency?

**Scenario 2**: Minimum Feature Size Violations

**Problem:**

- The layout includes traces that are narrower than the minimum feature size defined by the fabrication process. This could lead to manufacturing defects, such as open circuits or short circuits. Senior designers have flagged these areas for revision to prevent reliability issues in the final product.

**Challenge:**

- How will you adjust the trace widths to comply with the minimum feature size requirements?
- What steps can you take to optimize the layout while ensuring compliance with the manufacturing constraints?

**Scenario 3:** High Component Density and Thermal Dissipation Concerns

**Problem:**

The telecom substrate design features a high component density, which may lead to thermal management challenges. The close placement of components increases the risk of overheating and could affect performance, particularly in high-speed circuits. Senior designers have expressed concern over the insufficient spacing for heat dissipation.

**Challenge:**

- How will you re-arrange the components to improve thermal dissipation while maintaining manufacturability?
- What design changes can you propose to address both component density and thermal issues?

| Activity | Duration | Resources used |
|---|---|---|
| DFM Review and Layout Modification | | Whiteboard or flipchart, markers, sticky notes, scenario cards. |

## Do ✓

- Guide the trainees throughout the activity
- Ensure that all trainees participate in the activity

## Notes for Facilitation

- Emphasize the importance of adhering to manufacturing constraints (e.g., via density, trace width, layer count) to ensure a functional and cost-effective design.
- Ensure design adheres to key manufacturing constraints (via density, trace width).
- Simplify routing and reduce vias while maintaining performance.

## Exercise

### Multiple Choice Questions (MCQs)

**1.** What is the primary purpose of performing Design Rule Checks (DRC) during telecom substrate layout?

a) To improve signal integrity

b) To ensure compliance with manufacturing guidelines

c) To reduce the pin count of components

d) To optimize the thermal dissipation of the substrate

**Answer: b)** To ensure compliance with manufacturing guidelines

**2.** Which of the following substrate characteristics directly influences manufacturability?

a) Layer count

b) Pin count

c) Power needs

d) Signal frequency

**Answer: a)** Layer count

**3.** Which of the following is a common limitation in the fabrication process of telecom substrates?

a) Component size

b) Via density

c) Pin count

d) Power consumption

**Answer: b)** Via density

**4.** In substrate design, what is the significance of material properties?

a) They determine the aesthetic appearance of the final product

b) They influence the thermal performance, cost, and signal integrity

c) They affect only the signal routing capabilities

d) They are irrelevant to manufacturability

**Answer: b)** They influence the thermal performance, cost, and signal integrity

### Fill in the Blanks

**1.** The process of modifying a design to improve its manufacturability, ensuring it meets manufacturing constraints, is called _________.

**Answer:** Design for Manufacturability (DFM)

**2.** Substrate designs should meet performance targets such as signal integrity and _________ dissipation.

**Answer:** thermal

**3.** A key document in telecom substrate design that defines the arrangement of different layers and materials is known as the _________.

Answer: layer stack-up

**4.** The analysis of layout choices, including trace width, via placement, and layer count, can help assess their impact on _________.

**Answer:** cost and manufacturability

**Match the Following:**

| Column A | Column B |
|---|---|
| 1. DFM | a) Key tool for layout creation |
| 2. Pin count | b) A design principle to ensure manufacturability |
| 3. Signal integrity | c) A measure of a component's input/output connections |
| 4. CAD software | d) The ability of a substrate to maintain accurate signal transmission |

**Answers:** 1 - b, 2 -c, 3 - d, 4 - a

**Match the Following:**

| Column A | Column B |
|---|---|
| 1. Minimum feature size | a) Influences heat management in the design |
| 2. Thermal dissipation | b) Defines the size and arrangement of layers in a substrate |
| 3. Via density | c) Affects the number of vias used in the design |
| 4. Layer stack-up | d) Dictates the smallest trace or feature that can be created during fabrication |

**Answers:** 1 - d, 2 - a, 3 - c, 4 - d

NCVET
कौशल गुणवत्ता प्रगति

Skill India
कौशल भारत - कुशल भारत

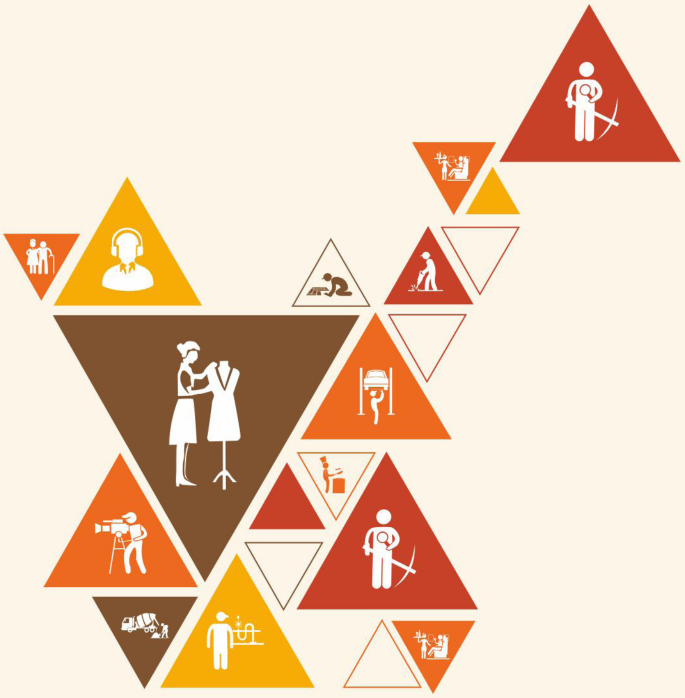
सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

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

Telecom
Sector
Skill
Council

# 3. Process Integration and Collaboration

Unit 3.1: Telecom Substrate Design Fundamentals
Unit 3.2: Effective Communication in Substrate Design Integration
Unit 3.3: Collaborative Problem Solving and Process Improvement
Unit 3.4: Identifying Risks and Improving Production Flow



TEL/N7217

## Key Learning Outcomes

1. Explain telecom substrate functionalities and key specifications.
2. Describe the principles of Design for Manufacturability (DFM).
3. Identify production capabilities and limitations relevant to substrate assembly.
4. Explain quality control procedures for telecom substrates.
5. Explain the importance of effective communication and interpersonal skills in process integration.
6. Analyze potential challenges in integrating substrate design with the existing production workflow.
7. Describe the role of effective communication channels and documentation practices in facilitating information flow.
8. Explain the purpose and benefits of data analysis techniques for identifying process improvement opportunities.
9. Role play participating in simulated design meetings focused on telecom substrate specifications.
10. Ask clarifying questions and contribute to discussions on technical details in a simulated environment.
11. Develop plans for collaboration with production and quality control teams based on hypothetical scenarios.
12. Identify potential bottlenecks and quality risks by analyzing case studies or mock production processes.
13. Collaborate with peers to establish clear inspection procedures for completed substrates in a simulated setting.
14. Develop and document clear communication channels between design, production, and quality control teams based on hypothetical scenarios.

# Unit 3.1: Telecom Substrate Design Fundamentals

## Unit Objectives

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

1. Explain the functionalities and key specifications of telecom substrates.
2. Describe the principles of Design for Manufacturability (DFM) in substrate design.
3. Identify production capabilities and limitations relevant to substrate assembly.
4. Explain quality control procedures for telecom substrates.

## Resources to be Used

Participant handbook, pen, notebook, whiteboard, flipchart, markers, laptop, overhead projector, laser pointer, etc.

## Note

In this unit, we will discuss the key functionalities and specifications of telecom substrates, focusing on their design, production, and quality control. We will explore the principles of Design for Manufacturability (DFM), production capabilities and limitations, and the importance of quality control procedures to ensure the reliability and performance of telecom substrates. Understanding these concepts is essential for optimizing substrate designs in real-world applications.

## Ask

**Ask the participants the following questions:**

- What are telecom substrates, and why are they important in the design of telecom network equipment?

Write down the participants' answers on a whiteboard/flipchart. Take appropriate clues from the answers and start teaching the lesson.

## Elaborate

**Telecom Substrates: Key Specifications and Functionalities**

Telecom substrates are essential components in the design and manufacturing of telecom devices, providing the physical and electrical foundation for integrated circuits (ICs) and components. These substrates support signal transmission, power distribution, and mechanical integrity in telecom equipment.

1. **Functionalities and Key Specifications of Telecom Substrates:**

   The primary role of telecom substrates is to act as a carrier for electrical components, supporting signal pathways while maintaining thermal and mechanical stability. The key specifications that define the performance of telecom substrates include:

   - **Material Properties:** Substrates are typically made of materials like FR4 (epoxy resin), ceramic, and metal-clad laminates. The choice of material influences the substrate's electrical performance (e.g., dielectric constant), thermal conductivity, and mechanical strength. For high-frequency applications, materials with low dielectric loss and controlled thermal expansion are critical.

- **Dielectric Constant and Loss Tangent:** The dielectric constant (relative permittivity) influences the speed of signal transmission through the substrate, while the loss tangent determines signal loss at high frequencies. Telecom substrates used in RF (radio-frequency) applications must have a low loss tangent to minimize signal attenuation.
- **Thermal Management:** Substrates must efficiently dissipate heat generated by the telecom components. Materials with good thermal conductivity, such as aluminum oxide or copper, are often used to ensure that temperature-sensitive components do not overheat.
- **Pin Count and Routing Density:** Telecom substrates must accommodate the pin count of components while ensuring adequate routing space for signals and power lines. Substrates with higher routing density are needed for devices with many connections, such as multi-layered substrates for complex telecom equipment.
- **Mechanical Strength:** Substrates must provide physical integrity to the assembled components, withstanding vibrations, thermal cycling, and mechanical stresses encountered during operation.

### Design for Manufacturability (DFM) in Substrate Design

2. **Principles of Design for Manufacturability (DFM):**

   Design for Manufacturability (DFM) is a set of principles aimed at ensuring that a substrate is designed to be easily, efficiently, and cost-effectively manufactured. DFM helps identify and eliminate potential issues that could arise during production, improving yield rates, reducing costs, and shortening production timelines. The core principles of DFM in substrate design include:

   - **Minimization of Complex Features:** DFM stresses the importance of simplifying the design, particularly in terms of routing, via placement, and layer count. Complex features that are difficult to manufacture, such as tight spacing between traces or excessive via density, should be avoided.
   - **Design for Process Capability:** DFM ensures that the design does not exceed the production capabilities of the manufacturing process. It considers the limits of equipment, such as the minimum trace width, via size, and the number of layers that can be produced effectively. By staying within these limits, DFM reduces the likelihood of design errors during fabrication.
   - **Standardization:** Standardizing components, via sizes, and design rules across multiple substrate designs allows manufacturers to optimize their processes, reduce tooling costs, and speed up production. Adherence to industry-standard design rules also ensures compatibility with various manufacturing equipment and technologies.
   - **Design for Assembly (DFA):** This involves designing the substrate layout to minimize assembly complexity. For instance, placing components symmetrically or ensuring uniform via spacing helps reduce the complexity of the assembly process.
   - **Manufacturing Process Feedback:** In DFM, continuous feedback from the manufacturing process is essential. Design teams must work closely with production engineers to ensure that designs are optimized for current process capabilities, reducing the need for costly redesigns or adjustments.

### Production Capabilities and Limitations in Substrate Assembly

testing assesses whether the substrate performs according to the design specifications, such as signal integrity, power distribution, and thermal management.

3. **Production Capabilities and Limitations:**

   Understanding the production capabilities and limitations of the substrate assembly process is crucial for designing substrates that are not only functional but also manufacturable at scale. The key aspects to consider include:

   - **Fabrication Equipment Limitations:** The manufacturing process for telecom substrates often involves photolithography, etching, and lamination. Each of these steps has inherent limitations, such as the minimum feature size that can be accurately fabricated (e.g., the smallest trace width or via size). Substrate designers must ensure that their layouts do not push these limits too far, which can lead to yield issues or production delays.
   - **Material Constraints:** While materials like FR4 are widely available, high-performance substrates (e.g., those used in RF applications) require more expensive materials with specific properties, such as low loss tangents or high thermal conductivity. The cost and availability of such materials can limit the scope of substrate designs, requiring designers to balance performance with cost constraints.
   - **Layer Count:** Increasing the number of layers in a substrate allows for more complex routing and component placement. However, this also increases the difficulty of manufacturing, including the risk of signal interference between layers and challenges in achieving consistent via placements. Multi-layer designs often result in higher costs and longer manufacturing times.
   - **Via Technology:** The use of vias to connect different layers of a substrate can impact its manufacturability. Through-hole vias are more reliable but increase the overall size and complexity of the design. Blind and buried vias, while allowing for more compact designs, can be more difficult to fabricate, increasing costs and manufacturing complexity.
   - **Soldering and Assembly:** Once the substrate is fabricated, components are soldered onto it. Challenges in this process, such as insufficient solder paste volume or inaccurate component placement, can lead to defects in the final product. Soldering issues often result in unreliable connections, which is a critical concern in telecom applications where reliability is paramount.

**Quality Control Procedures for Telecom Substrates**

4. **Quality Control Procedures:**

   To ensure that telecom substrates meet the required performance standards, quality control (QC) is essential throughout the design and manufacturing process. QC procedures include:

   - **Incoming Material Inspection:** Quality control begins with the inspection of incoming raw materials, including base laminates and conductive layers. Materials must be checked for consistency in properties like dielectric constant, thermal conductivity, and thickness.
   - **In-Process Testing:** During the fabrication process, substrates undergo various tests to verify that the dimensions and electrical characteristics meet design specifications. These tests may include checks for trace width, via integrity, and layer alignment. Automated optical inspection (AOI) systems are often used to detect defects in the substrate's physical characteristics.
   - **Electrical Testing:** Electrical continuity testing is used to identify any open circuits or short circuits that may have occurred during the fabrication process. This testing helps ensure the signal integrity of the substrate before it moves to assembly.
   - **Thermal Cycling and Stress Testing:** To simulate real-world operating conditions, substrates undergo thermal cycling tests, where they are subjected to extreme temperatures to test their durability and performance under thermal stress. Mechanical stress testing also evaluates the ability of the substrate to withstand physical forces during operation.

- **Final Inspection and Functional Testing:** Before shipping, a final inspection is conducted to ensure that the substrates meet the quality standards required for telecom applications. Functional testing assesses whether the substrate performs according to the design specifications, such as signal integrity, power distribution, and thermal management.

The design, manufacturing, and assembly of telecom substrates involve a complex set of specifications and considerations. The key to successful telecom substrate design lies in understanding the functionalities of the substrate, applying principles of Design for Manufacturability (DFM), addressing production limitations, and implementing rigorous quality control procedures. By balancing performance, cost, and manufacturability, telecom substrates can be optimized for reliability and efficiency, ensuring their success in the highly demanding telecom industry.

## Say

Let us participate in an activity to explore the unit a little more.

## Activity

**Group Activity:** DFM Analysis and Quality Control Simulation

**Objective:**

To analyze telecom substrate designs for manufacturability and quality control, addressing production limitations and applying DFM principles.

**Group Size:** 4-6 participants

**Materials Needed:**

- Existing telecom substrate design (with identified DFM issues)
- List of production capabilities and limitations (e.g., minimum feature size, via density, layer count, etc.)
- Quality control checklist (e.g., visual inspection, DRC, X-ray inspection, etc.)
- Whiteboard or flipchart for documentation

**Activity Instructions**

1. **Introduction to DFM and Quality Control (10 minutes)**
    - Provide a brief overview of DFM principles, such as reducing complexity, minimizing feature size violations, and considering production capabilities.
    - Review key quality control procedures for telecom substrates, including visual inspections, Design Rule Checks (DRC), and functional tests.
2. **Review the Existing Design (15 minutes)**
    - Provide participants with a telecom substrate design that has some known DFM and quality issues (e.g., high via density, trace width violations, or layer count concerns).
    - Ask groups to review the design and identify potential manufacturability issues based on DFM principles and production limitations.
3. **Propose DFM Solutions (15 minutes)**
    - Groups will suggest modifications to the design to address the identified DFM concerns, such as reducing via density, simplifying routing, or adjusting the layer stack-up.
    - Encourage groups to consider the production limitations (e.g., equipment capabilities,

minimum feature size) while making adjustments.

4. **Apply Quality Control Procedures (15 minutes)**
    - Groups will simulate applying quality control checks to their modified design. This includes:
        - Running DRC to check for design violations
        - Reviewing key inspection criteria like via alignment, trace width, and layer connectivity
        - Simulating a visual inspection or X-ray inspection for component placement accuracy and solder joint quality
5. **Group Presentations (5 minutes)**
    - Each group will present their design modifications and how they addressed manufacturability concerns.
    - Discuss how their proposed solutions align with DFM principles and how they ensure quality control during substrate production.

**Examples of Scenario Cards:**

**Scenario 1:** High Via Density in a Complex Routing Area

**Problem:**

The telecom substrate design has high via density in a complex routing area, which could lead to manufacturing defects and a higher likelihood of signal integrity issues. Senior designers have flagged this as a potential risk for yield loss and increased production costs.

**Challenge:**

- How will you reduce via density while maintaining the integrity of the design?
- What steps can you take to simplify the routing without compromising performance?

**Scenario 2:** Minimum Feature Size Violation

**Problem:**

A section of the layout has traces that are narrower than the minimum feature size allowed by the fabrication process. This could lead to open circuits or short circuits during production. Senior designers have recommended revising the layout to meet the minimum feature size requirements.

**Challenge:**

- How can you adjust the trace widths to meet the minimum feature size requirements?
- What changes can you make to ensure the layout remains manufacturable and cost-effective?

**Scenario 3:** Component Placement Leading to Thermal Issues

**Problem:**

The current layout has components packed too closely together, potentially causing thermal management issues. The high density of components may lead to overheating and performance degradation, especially in high-speed circuits.

**Challenge:**

- How will you rearrange the components to improve thermal dissipation?
- What layout changes can be made to reduce the risk of thermal issues while maintaining manufacturability?

| Activity | Duration | Resources used |
|---|---|---|
| DFM Analysis and Quality Control Simulation | | Whiteboard or flipchart, markers, sticky notes (different colors), scenario cards (described below), etc. |

## Do

- Guide the trainees throughout the activity
- Ensure that all trainees participate in the activity

## Notes for Facilitation

- Focus on manufacturability and ensure solutions are feasible within production constraints.
- Remind participants to apply DFM guidelines, such as reducing complexity and improving layout efficiency.
- Highlight the importance of DRC, visual, and functional inspections for ensuring design reliability.
- Ensure all members contribute ideas and collaborate on design modifications.

# Unit 3.2:Effective Communication in Substrate Design Integration

## Unit Objectives

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

1. Explain the importance of effective communication and interpersonal skills in process integration.
2. Analyze potential challenges in integrating substrate design with the existing production workflow.
3. Describe the role of communication channels and documentation practices in facilitating information flow.
4. Develop clear communication channels between design, production, and quality control teams based on hypothetical scenarios.

## Resources to be Used

Participant handbook, pen, notebook, whiteboard, flipchart, markers, laptop, overhead projector, laser pointer, etc.

## Note

In this unit, we will discuss the importance of effective communication and interpersonal skills in substrate design and production integration. We will explore the challenges of integrating substrate design with existing workflows, focusing on the role of communication channels and documentation practices. The unit will also highlight how clear communication between design, production, and quality control teams can ensure smooth information flow and successful process integration.

## Ask

**Ask the participants the following questions:**

- How can effective communication improve the integration of substrate design into the production process?

Write down the participants' answers on a whiteboard/flipchart. Take appropriate clues from the answers and start teaching the lesson.

## Elaborate

**Importance of Effective Communication and Interpersonal Skills in Process Integration**

Effective communication and interpersonal skills are crucial in the process integration of substrate design, especially when coordinating across multiple teams in a semiconductor manufacturing environment. Substrate design involves complex technical processes that require the collaboration of design, production, and quality control teams. Poor communication can lead to misunderstandings, delays, and increased production costs, while strong communication helps in identifying potential issues early in the design phase, streamlining the production process, and maintaining high-quality standards.

**Key Benefits:**

1. **Prevention of Errors and Miscommunication:** Clear communication ensures that all teams involved in the substrate production process understand the design requirements and specifications. Misunderstandings can result in faulty designs or misaligned expectations, which could lead to costly mistakes during production.
2. **Streamlining Workflow:** Effective communication allows for the seamless flow of information between teams, reducing bottlenecks and delays. Whether through regular meetings, shared documentation, or direct channels of communication, effective interactions enable teams to stay aligned and respond promptly to challenges.
3. **Conflict Resolution:** When working across different teams, conflicts may arise due to varying priorities or interpretations of requirements. Having strong interpersonal skills helps mitigate conflicts, allowing for constructive discussions that resolve issues quickly, preventing project delays.
4. **Decision-Making Efficiency:** Communication fosters a collaborative environment where stakeholders can share ideas, making decision-making more efficient. This is especially critical in process integration where quick and informed decisions are needed to avoid production downtime or redesigns.
5. **Building Trust and Morale:** Effective communication creates a positive working atmosphere, fostering trust between teams. When teams feel informed and involved, they are more likely to be engaged, leading to better morale and overall team performance.

**Challenges in Integrating Substrate Design with Existing Production Workflow**

Integrating substrate design into the existing production workflow presents several challenges. The key is to ensure that both the design and manufacturing processes align effectively, as any misalignment can lead to inefficiencies, delays, and additional costs. Some of the major challenges include:

1. **Design Complexity and Manufacturing Limitations:** Substrate designs often have specific electrical, mechanical, and thermal requirements that may not always align with manufacturing capabilities. The design might involve features such as narrow traces, small vias, or multi-layered structures that are difficult or expensive to produce. This mismatch can result in issues such as higher production costs, yield loss, or even rework.
2. **Communication Gaps Between Design and Production Teams:** A lack of effective communication between the design and production teams can cause delays in production. For example, if the production team does not understand certain aspects of the design, it can lead to incorrect implementation, requiring costly revisions. Similarly, design teams may not always understand the limitations of the production process, leading to impractical designs.
3. **Inadequate Design for Manufacturability (DFM):** One of the main challenges is ensuring that the design is manufacturable within the existing production capabilities. Without proper adherence to DFM principles, designs may become difficult or impossible to manufacture, leading to inefficiencies, increased costs, or longer lead times.
4. **Integration of New Designs into Legacy Systems:** Many manufacturing plants work with legacy systems that may not support newer or more advanced substrate designs. Integrating new designs into these systems can require modifications to the existing infrastructure, which can be costly and time-consuming.
5. **Supply Chain and Material Constraints:** Substrate designs often require specific materials that may not be readily available in the required quantities or specifications. These material constraints can hinder the integration of the design into production, potentially delaying the process.

6. **Testing and Validation:** Ensuring that the final substrate meets all the required performance standards can be a significant challenge. The testing process must be well-integrated into the production workflow to catch issues early and prevent defects from reaching the customer.

### Role of Communication Channels and Documentation Practices in Facilitating Information Flow

Communication channels and documentation practices are fundamental to maintaining a smooth process integration between substrate design, production, and quality control. The flow of accurate information between different teams ensures that all parties are aligned and that potential issues are addressed promptly.

1. **Structured Communication Channels:**
   - Clear, structured communication channels help facilitate the efficient exchange of information. Regular meetings, status reports, and progress tracking tools can ensure all teams are up-to-date on the project's progress and any changes to the design.
   - Effective communication tools, such as project management software, email, or dedicated collaboration platforms, allow for real-time updates, minimizing delays in decision-making.
2. **Role of Documentation in Information Flow:**
   - Proper documentation serves as the foundation for maintaining a clear record of decisions, design iterations, and changes. Design documents, such as layer stack-ups, routing guidelines, and design rule checks, must be accessible to all teams involved in the process.
   - Documentation ensures that there is a clear reference point for all stakeholders and helps mitigate potential risks associated with human error or miscommunication.
3. **Integration of Design and Manufacturing Data:**
   - Integrating design data with manufacturing and quality control data is key to maintaining alignment throughout the process. Using software tools that allow teams to track and visualize the design and production progress ensures that both the design team and production team are on the same page.
   - Automated systems that update production specifications in real-time based on design changes improve the efficiency and accuracy of the integration process.
4. **Clear Feedback Channels:**
   - Feedback from production teams, quality control, or testing should be integrated into the design process. If a design modification is necessary based on production or testing feedback, it should be communicated quickly and clearly to the design team. Having a formalized system for feedback ensures that all modifications are well-documented and addressed before moving forward.
5. **Cross-Departmental Collaboration:**
   - Cross-functional collaboration ensures that all departments (design, production, quality control) are aligned in their goals. Regular check-ins and collaborative reviews help surface potential issues early in the process and improve overall workflow integration.

### Developing Clear Communication Channels Between Design, Production, and Quality Control Teams Based on Hypothetical Scenarios

To develop clear communication channels between design, production, and quality control, it's essential to create systems that ensure all teams have the information they need to work efficiently and effectively. Here's how it can be achieved through hypothetical scenarios:

**Scenario 1:** Design Changes Affecting Production Timeline

**Situation:** The design team has made a late-stage modification to the substrate layout that significantly impacts the production timeline.

**Solution:** A clear communication channel between design and production teams ensures the change is communicated immediately. The production team is informed of the design change, and an updated production schedule is developed. Documentation of the changes and the associated timeline is shared with both teams to ensure everyone is aligned.

**Scenario 2:** Quality Control Identifies Defect in Substrate

**Situation:** The quality control team identifies a defect in a batch of substrates, potentially due to a design flaw.

**Solution:** Quality control must immediately communicate the findings to both the design and production teams. A detailed report, including root cause analysis and potential solutions, is shared through a structured feedback channel. The design team revises the design to prevent recurrence, and production is updated with the new specifications.

**Scenario 3:** Production Faces Manufacturing Limitation

**Situation:** During production, a limitation in the equipment's capability prevents the manufacturing of a specific feature in the substrate design.

**Solution:** Production immediately informs the design team about the limitation. A joint meeting is held to discuss potential design changes that would make the feature manufacturable within existing equipment constraints. Both teams document the change and update all related materials, ensuring alignment across the workflow.

In substrate design, effective communication and interpersonal skills are key to overcoming integration challenges. By ensuring strong communication channels, adhering to Design for Manufacturability principles, and facilitating clear feedback loops, teams can work together to streamline the production process. Proper documentation practices also play a critical role in ensuring that all teams remain informed and aligned, reducing errors and delays in the design and production workflow.

## Say

Let us participate in an activity to explore the unit a little more.

## Activity

**Group Activity:** Communication and Process Integration Simulation

**Objective:**

To develop effective communication strategies and integrate substrate design with production and quality control processes through collaboration and clear documentation.

**Group Size:** 4-6 participants

**Materials Needed:**

- Hypothetical scenario cards (described below)
- Whiteboard or flipchart for documenting communication flow and solutions
- Markers and sticky notes

**Activity Instructions**

1. **Introduction to Communication and Process Integration (10 minutes)**
    - Provide an overview of the importance of communication and interpersonal skills in process integration.
    - Discuss the key challenges when integrating substrate design with production workflows and quality control.
2. **Review the Scenario Cards (10 minutes)**
    - Distribute scenario cards to each group. Each card presents a situation where communication or process integration between design, production, and quality control is critical.
    - Ask the groups to identify the communication challenges and discuss potential solutions.
3. **Develop Communication Solutions (20 minutes)**
    - Groups will develop a communication strategy for their scenario, addressing:
        - How information will be shared between teams (design, production, quality control)
        - What documentation is needed to ensure smooth information flow
        - The role of feedback loops in ensuring process integration
4. **Present Solutions (15 minutes)**
    - Each group will present their scenario, proposed communication channels, and solutions.
    - Encourage other groups to ask questions and offer suggestions for improvement.
5. **Debrief and Key Takeaways (5 minutes)**
    - Facilitate a discussion on the importance of clear communication in integrating substrate design, production, and quality control processes.
    - Highlight how good communication reduces errors, improves efficiency, and enhances collaboration between teams.

**Examples of Scenario Cards:**

**Scenario 1:** Misalignment in Production Schedule

**Problem:**

The design team submits their substrate design late, causing a delay in the production schedule. Production needs to start as soon as possible, but there is confusion about the revised timeline. Challenge: How will the teams (design, production, quality control) communicate the new timeline effectively to ensure the project stays on track?

**Scenario 2:** Design Issues Impacting Quality Control

**Problem:**

A design feature is identified during quality control inspections that does not meet the production standards. Quality control has not received any prior communication about the design constraint. Challenge: How can quality control communicate the issue with the design team and ensure that future designs adhere to production specifications?

**Scenario 3:** Cross-Departmental Feedback Loop

**Problem:**

A key feedback loop between design and production teams has been broken, leading to frequent design revisions and increased rework. The design team is not aware of the production constraints affecting the design process. Challenge: How will the design and production teams re-establish a clear feedback loop to improve communication and reduce revisions?

| Activity | Duration | Resources used |
|---|---|---|
| Communication and Process Integration Simulation | | Whiteboard or flipchart, Markers, Sticky notes (different colors), Scenario cards. |

## Do

- Guide the trainees throughout the activity
- Ensure that all trainees participate in the activity

## Notes for Facilitation

- Ensure open, timely information exchange between design, production, and quality control.
- Stress the importance of documenting decisions and communication for clarity and future reference.
- Encourage teams to collaborate and understand each other's challenges to avoid delays and errors.
- Identify and address potential communication barriers (e.g., misunderstandings, time zones).

# Unit 3.3: Collaborative Problem Solving and Process Improvement

## Unit Objectives

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

1. Explain the purpose and benefits of data analysis techniques for identifying process improvement opportunities.
2. Role-play participating in simulated design meetings focused on telecom substrate specifications.
3. Ask clarifying questions and contribute to discussions on technical details in a simulated environment.
4. Develop plans for collaboration with production and quality control teams based on hypothetical scenarios.

## Resources to be Used

Participant handbook, pen, notebook, whiteboard, flipchart, markers, laptop, overhead projector, laser pointer, etc.

## Note

In this unit, we will discuss the importance of data analysis techniques in identifying process improvement opportunities within telecom substrate design. Participants will also role-play in simulated design meetings, practicing how to ask clarifying questions and contribute to technical discussions. Additionally, we will explore how to collaborate with production and quality control teams through hypothetical scenarios to ensure seamless integration of design processes.

## Ask

**Ask the participants the following questions:**

- How do energy management and sustainability practices impact the housekeeping department’s efficiency and environmental responsibility?

Write down the participants’ answers on a whiteboard/flipchart. Take appropriate clues from the answers and start teaching the lesson.

## Elaborate

### Data Analysis Techniques for Identifying Process Improvement Opportunities

### Purpose and Benefits of Data Analysis Techniques

Data analysis is critical for identifying areas where processes can be improved, especially in complex fields such as telecom substrate design. These techniques help organizations make data-driven decisions that can improve efficiency, quality, and performance. The core purpose is to gather, interpret, and leverage data to uncover inefficiencies, bottlenecks, and areas for optimization. In the telecom substrate manufacturing process, data analysis plays a vital role in streamlining design and production workflows, enhancing the quality of the substrate, and ensuring that performance targets are met.

**Key benefits include:**

1. **Improved Decision-Making:** Data-driven insights reduce guesswork, enabling informed decisions based on factual evidence rather than assumptions.
2. **Cost Savings:** By identifying inefficiencies, companies can optimize resource use, reducing waste and minimizing unnecessary production costs.
3. **Quality Enhancement:** Continuous monitoring and analysis of production data help identify defects, quality variances, or areas of improvement in the substrates.
4. **Time Efficiency:** By analyzing historical data, organizations can optimize schedules, improve throughput, and eliminate delays.
5. **Enhanced Innovation:** Data analysis also provides insights into areas where new designs or materials could improve the substrate's performance or reduce production complexity.

**Techniques commonly used include:**

- **Statistical Process Control (SPC):** Monitors production processes using statistical methods to detect deviations and prevent defects.
- **Root Cause Analysis (RCA):** Identifies underlying causes of issues in the production process, helping in effective corrective actions.
- **Pareto Analysis:** Focuses on identifying the most significant issues (the 20%) that cause the majority of the problems (80%) in the process.
- **Six Sigma and Lean Principles:** These techniques aim to reduce waste and variation, driving efficiency and continuous improvement.
- **Predictive Analytics:** Uses historical data and algorithms to predict future issues and optimize the process proactively.

### Participating in Simulated Design Meetings Focused on Telecom Substrate Specifications

### Role of Simulated Design Meetings

Simulated design meetings are an effective method for practicing collaboration and communication in a controlled, risk-free environment. They allow team members to role-play and engage in scenarios where telecom substrate specifications are being discussed and refined. The purpose is to ensure that each participant understands their role in the design process, can ask relevant questions, and contribute to the overall discussion based on their area of expertise.

**Steps in a Simulated Design Meeting:**

1. **Preparation:** Participants review the key substrate design specifications beforehand, including materials, dimensions, and performance requirements.
2. **Role-Playing:** Each participant adopts a role, such as a designer, production engineer, or quality control expert, and participates in the meeting according to their role's responsibilities.
3. **Discussion:** Focuses on understanding requirements, challenges, and potential improvements in the design, ensuring all aspects (thermal management, electrical performance, manufacturability, etc.) are covered.
4. **Feedback & Clarification:** Participants ask clarifying questions to ensure all team members fully understand the technical details, constraints, and needs.

**Benefits of Simulated Meetings:**

- **Enhanced Communication:** Encourages participants to communicate clearly and concisely, avoiding misunderstandings.
- **Problem-Solving:** Provides a platform for identifying and solving potential issues before actual production begins.
- **Teamwork and Coordination:** Improves collaboration between departments (design, production, quality control) by fostering a shared understanding of goals and constraints.
- **Skill Development:** Develops technical, interpersonal, and decision-making skills in participants, preparing them for real-life situations.

### Asking Clarifying Questions and Contributing to Discussions in a Simulated Environment

#### Purpose of Asking Clarifying Questions

In a design meeting, asking clarifying questions is crucial to ensuring a deep understanding of the technical specifications, constraints, and challenges. As telecom substrate designs often involve complex technical details, asking well-informed questions can help:

- **Prevent Misunderstandings:** Clarifying ambiguities prevents errors that could result from incorrect assumptions.
- **Ensure Complete Information:** Ensures all relevant information has been considered, particularly when discussing complex aspects like material properties, electrical signals, or thermal dissipation.
- **Facilitate Effective Collaboration:** Encourages team members to speak up and contribute their knowledge, ensuring that all perspectives are considered.

**Examples of clarifying questions include:**

- “Can you explain how this routing choice impacts the thermal performance of the substrate?”
- “How will the material selection affect the overall manufacturability and cost?”
- “What are the minimum and maximum tolerances for this layer stack-up?”

Contributing to discussions goes beyond asking questions and involves sharing insights, offering solutions, and helping the team reach consensus on the best course of action. For example, participants can contribute by:

- Suggesting ways to simplify the routing while maintaining performance targets.
- Offering alternative materials that may improve manufacturability.
- Proposing solutions to overcome identified process challenges.

### Developing Collaboration Plans with Production and Quality Control Teams

#### Importance of Collaboration Across Teams

Effective collaboration between the design, production, and quality control teams is essential for the success of telecom substrate design and manufacturing. Without proper coordination, there can be misalignments between design intent and production realities, which can lead to delays, increased costs, or poor-quality products.

**Steps to Develop a Collaboration Plan:**

1. **Establish Clear Communication Channels:** Define how the teams will communicate throughout the process. Regular meetings, email updates, and collaborative tools can be used to ensure everyone is on the same page.
2. **Align on Specifications:** Ensure that design, production, and quality control teams understand the technical requirements, constraints, and performance targets for the substrate.
3. **Feedback Mechanism:** Develop a structured process for providing feedback between teams, ensuring that issues identified in production or quality control are addressed promptly by the design team.
4. **Risk Management:** Identify potential risks in the design that could affect manufacturing or quality and develop mitigation plans. For example, if a design feature has a high risk of manufacturing defects, the production team should work with design engineers to adjust the layout before production.
5. **Documentation:** Ensure that all discussions, decisions, and changes are documented and accessible to all teams. This includes design documents, meeting notes, and performance test results, which can be referred to throughout the lifecycle of the project.

**Scenario-**Based Collaboration:

**Scenario 1:**

Design Modifications Based on Production Constraints: If production faces challenges due to the complexity of the layout, the design team must collaborate to simplify the design without compromising its performance.

**Scenario 2:**

Quality Control Identifies Defects: If the quality control team identifies defects in the substrate, they must immediately communicate these findings to the design team so that corrective actions can be taken.

**Benefits of Effective Collaboration Plans:**

- **Increased Efficiency:** Ensures that all teams are aligned and working towards the same goals, reducing the risk of rework and delays.
- **Better Quality Control:** Allows for early identification and resolution of potential quality issues, leading to better overall product quality.
- **Cost-Effective Production:** By working closely together, teams can find cost-saving solutions that do not sacrifice performance or reliability.
- **Faster Time-to-Market:** Streamlined collaboration accelerates the design and manufacturing process, ensuring that products reach the market faster.

In conclusion, data analysis techniques, effective communication, and strong collaboration plans are key components in ensuring the success of telecom substrate design and production. By applying data analysis to identify process improvements, participating actively in design meetings, asking clarifying questions, and fostering collaboration across teams, individuals can ensure that telecom substrate designs are optimized for manufacturability, performance, and cost-effectiveness. These efforts ultimately lead to higher-quality products, more efficient workflows, and a better alignment between design, production, and quality control teams.

## Say

Let us participate in an activity to explore the unit a little more.

## Activity

**Group Activity:** Simulated Design Meeting for Telecom Substrate Improvement

**Objective:**

To practice participating in design meetings, contribute to discussions, ask clarifying questions, and develop collaboration plans with production and quality control teams.

**Group Size:** 4-6 participants

**Materials Needed:**

- Whiteboard or flipchart for documenting ideas
- Markers and sticky notes
- Hypothetical scenario cards (described below)
- Handouts outlining key technical details (optional)

**Activity Instructions**

1. **Introduction to the Activity (10 minutes)**
    - Provide an overview of the purpose and benefits of data analysis in identifying process improvement opportunities.
    - Introduce the importance of clear communication and technical discussions during design meetings in telecom substrate development.
2. **Scenario Card Distribution (5 minutes)**
    - Each group will receive a scenario card outlining a challenge related to telecom substrate specifications, production, or quality control.
    - Scenarios should require team discussions, clarifying questions, and technical input from all members.

. **Simulated Design Meeting (25 minutes)**

- Groups will role-play a design meeting where they:
    - Discuss the technical challenge or improvement opportunity based on the scenario.
    - Ask clarifying questions to understand the details of the situation.
    - Contribute ideas for resolving the issue or improving the process.
    - Develop a plan for collaborating with the production and quality control teams.
    - Document key decisions, suggestions, and action items.

4. **Group Presentations (15 minutes)**
    - Each group will present their scenario, the discussion process, and the collaboration plan developed during the meeting.
    - Other participants can ask questions or provide suggestions to refine the proposed solutions.
5. **Debrief and Key Takeaways (5 minutes)**
    - Facilitate a class-wide discussion on the importance of collaboration, clear communication, and technical analysis in process improvement and design meetings.

**Scenario Cards (Examples)**

**Objective:**

To practice participating in design meetings, contribute to discussions, ask clarifying questions, and develop collaboration plans with production and quality control teams.

**Group Size:** 4-6 participants

**Materials Needed:**

- Whiteboard or flipchart for documenting ideas
- Markers and sticky notes
- Hypothetical scenario cards (described below)
- Handouts outlining key technical details (optional)

**Activity Instructions**

1. **Introduction to the Activity (10 minutes)**
   - Provide an overview of the purpose and benefits of data analysis in identifying process improvement opportunities.
   - Introduce the importance of clear communication and technical discussions during design meetings in telecom substrate development.
2. **Scenario Card Distribution (5 minutes)**
   - Each group will receive a scenario card outlining a challenge related to telecom substrate specifications, production, or quality control.
   - Scenarios should require team discussions, clarifying questions, and technical input from all members.
3. **Simulated Design Meeting (25 minutes)**
   - Groups will role-play a design meeting where they:
     - Discuss the technical challenge or improvement opportunity based on the scenario.
     - Ask clarifying questions to understand the details of the situation.
     - Contribute ideas for resolving the issue or improving the process.
     - Develop a plan for collaborating with the production and quality control teams.
     - Document key decisions, suggestions, and action items.
4. **Group Presentations (15 minutes)**
   - Each group will present their scenario, the discussion process, and the collaboration plan developed during the meeting.
   - Other participants can ask questions or provide suggestions to refine the proposed solutions.
5. **Debrief and Key Takeaways (5 minutes)**
   - Facilitate a class-wide discussion on the importance of collaboration, clear communication, and technical analysis in process improvement and design meetings.

**Scenario Cards (Examples)**

**Scenario 1:** Substrate Material Performance Issue

**Problem:**

**Scenario 1:** Substrate Material Performance Issue

**Problem:**

The quality control team has reported that the substrate material is not meeting performance expectations under certain temperature conditions. This issue is affecting product reliability.

**Challenge:**

- How would you address this in a design meeting?
- What additional data or analysis would help identify a solution?
- What role would production and quality control play in addressing this?

**Scenario 2:** Manufacturing Yield Drop Due to Complex Layer Stack

**Problem:**

The production team has observed a decrease in yield due to the complexity of the substrate layer stack, which is causing difficulties in the manufacturing process.

**Challenge:**

- How would you contribute to the discussion on simplifying the layer stack?
- What alternative approaches can be suggested to improve manufacturability without compromising performance?

**Scenario 3:** Delay in Design Approval Due to Incomplete Specifications

**Problem:**

The design team is facing delays in getting design approval because some specifications were unclear or incomplete, leading to confusion and multiple iterations.

| Activity | Duration | Resources used |
|---|---|---|
| Simulated Design Meeting for Telecom Substrate Improvement | | Whiteboard or flipchart, Markers, Sticky notes (different colors), Scenario cards. |

## Do ✓

- Guide the trainees throughout the activity
- Ensure that all trainees participate in the activity

## Notes for Facilitation

- Ensure everyone asks questions, shares ideas, and contributes to solving the issue.
- Guide participants in using data and technical details to drive decisions and identify root causes.
- Emphasize the importance of clear communication and teamwork across design, production, and quality control to address challenges effectively.

# Unit 3.4: Identifying Risks and Improving Production Flow

## Unit Objectives

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

1. Identify potential bottlenecks and quality risks by analyzing case studies or mock production processes.
2. Collaborate with peers to establish clear inspection procedures for completed substrates in a simulated setting.
3. Develop and document communication channels to ensure effective integration of design, production, and quality control processes.

## Resources to be Used

Participant handbook, pen, notebook, whiteboard, flipchart, markers, laptop, overhead projector, laser pointer, etc.

## Note

In this unit, we will discuss how to identify potential bottlenecks and quality risks in telecom substrate production by analyzing case studies and mock production processes. You will collaborate with peers to establish inspection procedures for completed substrates and develop clear communication channels to ensure effective integration between design, production, and quality control processes.

## Ask

**Ask the participants the following questions:**

- What are some common challenges that can occur during the telecom substrate production process, and how can they be addressed effectively?

Write down the participants' answers on a whiteboard/flipchart. Take appropriate clues from the answers and start teaching the lesson.

## Elaborate

### Identifying Potential Bottlenecks and Quality Risks in Telecom Substrate Production

In telecom substrate design and production, identifying bottlenecks and quality risks is critical for maintaining efficient workflows and high-quality outputs. Bottlenecks occur when one stage of the process limits the overall speed or efficiency, while quality risks arise when defects or issues are not properly detected, potentially affecting the final product.

By analyzing case studies or mock production processes, teams can identify where delays are likely to occur and proactively address these concerns. Potential bottlenecks may include:

1. **Material Sourcing:**

   Limited availability or issues with material quality can delay the entire production process. For example, if a specific material used in the substrate is delayed or requires additional testing, it can halt production, impacting timelines and increasing costs.

2. **Fabrication Complexity:**

   Substrate designs that require complex layering, intricate routing, or the use of specialized materials might create manufacturing difficulties. Inadequate equipment or overly complicated designs can extend production time, increase chances of defects, and reduce yield.

3. **Inspection and Testing:**

   Quality control issues might emerge if inspection processes are inefficient or not stringent enough. Insufficient testing of substrates, especially with regard to performance under specific conditions (e.g., high-frequency signals or extreme temperatures), can lead to undetected defects reaching the final product.

4. **Supply Chain Interruptions:**

   Delays in the supply chain for raw materials or components, such as copper for conductive traces or resins for substrate bonding, can severely impact production schedules, causing downtime and inefficiencies.

To address these risks, teams must implement clear, data-driven strategies. For instance, analyzing process flowcharts, production logs, or throughput data can help pinpoint bottlenecks. Once identified, teams can work to mitigate them by adjusting timelines, redistributing tasks, or investing in upgraded equipment.

### Collaborating to Establish Clear Inspection Procedures

Effective collaboration between design, production, and quality control teams is essential for establishing comprehensive inspection procedures. Once substrates are fabricated, it is crucial to implement clear, standardized procedures to ensure each substrate meets the necessary performance and safety standards.

**Key steps in creating inspection procedures include:**

1. **Defining Inspection Criteria:**

   Teams should agree on what constitutes acceptable substrate quality. This includes verifying that all critical parameters, such as layer thickness, trace width, and alignment, meet the design specifications. Electrical performance tests, such as continuity checks and impedance measurements, should also be included.

2. **Developing Inspection Stages:**

   The process should be broken down into different stages of inspection:

   - Pre-production Inspection: Material quality checks and readiness verification.
   - In-process Inspection: Monitoring the production process at various stages, such as layer bonding and trace etching, to detect defects early.
   - Post-production Inspection: Final checks for mechanical integrity, electrical functionality, and performance under expected operational conditions.

3. **Inspection Tools and Techniques:**

   Teams should employ tools like automated optical inspection (AOI), X-ray inspection, and scanning electron microscopy (SEM) to detect hidden faults, such as microcracks, poorly formed vias, or faulty connections. These tools are critical for ensuring that even minute defects do not go unnoticed.

4. **Clear Documentation:**

   Detailed documentation of each inspection step helps ensure consistency and accountability. All test results should be logged, along with any corrective actions taken. This transparency improves communication between teams and ensures that any issues can be traced and addressed promptly.

By collaborating on establishing clear inspection criteria and procedures, teams reduce the risk of quality issues and ensure that substrates meet the required standards before they are integrated into final telecom equipment.

### Developing Communication Channels for Design, Production, and Quality Control

Clear communication is at the heart of efficient substrate production. Without proper communication channels, misunderstandings can lead to errors, rework, and delays. Effective integration of design, production, and quality control processes requires that information flows smoothly and accurately between teams. Key strategies include:

1. **Centralized Communication Platforms:**

   Utilize collaborative platforms (such as project management tools or cloud-based document sharing) to centralize communication and ensure that all teams have access to the most up-to-date information. For example, if there is a change in design specifications or materials, it must be communicated immediately to the production and quality control teams.

2. **Regular Cross-Department Meetings:**

   Frequent check-ins between design, production, and quality control teams ensure that everyone is on the same page. These meetings allow teams to discuss potential challenges, provide updates, and adjust plans if necessary. They also serve as a forum for feedback, where design teams can receive insights on manufacturability, and production teams can discuss limitations or suggest improvements.

3. **Establishing Clear Protocols for Feedback:**

   Feedback loops between teams are crucial for identifying issues early in the process. Clear protocols should be in place for reporting defects, concerns, or delays. For instance, if quality control notices an issue with substrate performance during testing, the design team should be alerted quickly to investigate possible design modifications or material changes.

4. **Integrated Documentation Systems:**

   Using a unified documentation system helps ensure that design revisions, production adjustments, and quality control reports are properly tracked. This minimizes the chance of critical information being overlooked or misunderstood. Teams should ensure that all relevant documents (e.g., specifications, inspection reports, and production schedules) are accessible in a central location.

5. **Visual Communication Tools:**

   Diagrams, flowcharts, and visual aids are helpful in conveying complex information, especially when discussing technical details. Using these tools during meetings or in documentation can help clarify misunderstandings and ensure that everyone has the same understanding of the process.

6. **Establishing Roles and Responsibilities:**

   Clear definitions of each team's role in the communication process are essential. For example, design teams are responsible for providing complete specifications, production teams must communicate any challenges with fabrication, and quality control should ensure that the final product meets the required performance standards.

communicate any challenges with fabrication, and quality control should ensure that the final product meets the required performance standards.

Effective communication and collaboration between design, production, and quality control teams are crucial for ensuring smooth substrate production in telecom applications. Identifying potential bottlenecks and quality risks early, establishing clear inspection procedures, and fostering seamless communication channels can significantly improve production efficiency and product quality. By applying these strategies, telecom companies can reduce delays, prevent costly errors, and optimize their manufacturing processes for better performance and reliability in the final product.

## Say

Let us participate in an activity to explore the unit a little more.

## Activity

**Group Activity:** Simulated Production Process and Quality Risk Management

**Objective:**

To identify potential bottlenecks and quality risks in the production process, develop clear inspection procedures, and establish communication channels for effective integration between design, production, and quality control.

**Group Size:** 4-6 participants

**Materials Needed:**

- Whiteboard or flipchart
- Markers and sticky notes
- Mock production flowchart or case study handouts
- Scenario cards (described below)

**Activity Instructions**

1. **Introduction to the Activity (10 minutes)**
    - Introduce the concept of bottlenecks and quality risks in the production process.
    - Explain the importance of collaboration between design, production, and quality control teams for identifying and addressing these risks.
    - Provide an overview of the process flow and quality inspection procedures in telecom substrate production.
2. **Scenario Card Distribution (5 minutes)**
    - Each group will receive a scenario card outlining a specific challenge related to production bottlenecks, quality risks, or communication issues in a mock telecom substrate production process.
3. **Group Analysis and Discussion (25 minutes)**
    - Groups will analyze the scenario, identifying:
        - Potential bottlenecks or risks in the process.

        - Quality control issues related to the production flow.
        - Clear inspection procedures for the completed substrates.
        - Effective communication channels for coordination between design, production, and quality control teams.
    - Teams will document their findings on the whiteboard and outline steps to address each challenge.

4. **Group Presentations (15 minutes)**
    - Each group will present their analysis, including identified bottlenecks, quality risks, proposed inspection procedures, and communication channels.
    - Other groups can ask questions or provide feedback on the proposed solutions.
5. **Debrief and Key Takeaways (5 minutes)**
    - Facilitate a class-wide discussion on the importance of identifying and addressing bottlenecks, quality risks, and communication gaps.
    - Discuss how these solutions can be applied in real production environments.

**Examples of Scenario Cards:**

**Scenario 1:** Material Shortage During Production

**Problem:**

The production team encounters a shortage of a critical material, delaying the production process. This causes a bottleneck at a specific stage in the manufacturing line.

**Challenge:**

- How would you address the material shortage to minimize delays?
- What quality control measures should be put in place to ensure the substrates are unaffected by production delays?
- Scenario 2: Defective Substrate Detection During Final Inspection

**Problem:**

During final inspection, a high number of substrates are found to have microfractures, leading to concerns about the manufacturing process and material handling.

**Challenge:**

- How would you develop inspection procedures to detect these defects earlier in the production process?
- How would you communicate these issues to the production and design teams?

- **Scenario 3:** Inefficient Communication Between Teams

**Problem:**

The design and production teams are not aligned on the specifications for the substrate, leading to rework and delays. The quality control team is also not receiving timely updates on design changes, affecting their inspections.

**Challenge:**

- How would you establish communication channels to ensure all teams are aligned?

- What tools or processes can be used to improve information flow between teams?

| Activity | Duration | Resources used |
|---|---|---|
| Simulated Production Process and Quality Risk Management |  | Whiteboard or flipchart, markers, sticky notes (different colors), scenario cards (described below), etc. |

## Do ✓

- Guide the trainees throughout the activity
- Ensure that all trainees participate in the activity

## Notes for Facilitation

- Guide teams to identify bottlenecks and quality risks, proposing actionable solutions.
- Highlight the importance of clear communication and alignment across design, production, and quality control.
- Ensure solutions are realistic, focusing on improving production flow and quality inspection processes.

## Exercise

**Multiple-Choice Questions (MCQs)**

**1.** What is the primary purpose of Design for Manufacturability (DFM) in telecom substrate design?

a) To reduce the number of design iterations

b) To improve the aesthetics of the substrate

c) To ensure the design can be easily and cost-effectively manufactured

d) To increase the number of features on the substrate

**Answer: c)** To ensuWre the design can be easily and cost-effectively manufactured

**2.** Which of the following is a key quality control procedure in telecom substrate manufacturing?

a) Adding unnecessary layers to the design

b) Regular inspections and testing of materials and components

c) Skipping design rule checks (DRC) to save time

d) Ignoring the material properties during production

**Answer: b)** Regular inspections and testing of materials and components

**3.** What is the main benefit of effective communication channels in process integration?

a) To increase the complexity of the design

b) To ensure alignment and reduce miscommunication across teams

c) To shorten the production cycle

d) To increase costs in the manufacturing process

**Answer: b)** To ensure alignment and reduce miscommunication across teams

**4.** In the context of substrate design, why is it important to perform data analysis on the production process?

a) To determine the market trends for substrates

b) To identify opportunities for process improvement and efficiency gains

c) To compare costs of production with other industries

d) To design more complex substrates

**Answer: b)** To identify opportunities for process improvement and efficiency gains

**Fill in the Blanks**

**1.** In telecom substrate design, Design for Manufacturability (DFM) ensures that the design can be ___________ and ___________.

**Answer:** easily manufactured, cost-effective

**2.** Effective communication and ___________ practices between design, production, and quality control teams are essential to ensure smooth integration and avoid delays.

**Answer:** documentation

**2.** Effective communication and ___________ practices between design, production, and quality control teams are essential to ensure smooth integration and avoid delays.

**Answer:** documentation

**3.** One of the key challenges in integrating substrate design with existing production workflows is addressing potential ___________, which can lead to delays and cost overruns.

**Answer:** bottlenecks

**4.** A thorough ___________ analysis helps identify issues such as signal integrity and thermal dissipation, which impact the overall performance and manufacturability of telecom substrates.

**Answer:** data

**Match the Following**

1 Match the following terms with their descriptions:

| Term | Description |
|---|---|
| a) Design for Manufacturability (DFM) | 1. Helps improve communication and reduce errors in design and production |
| b) Quality Control Procedures | 2. Aimed at identifying manufacturing challenges and improving cost-efficiency |
| c) Communication Channels | 3. Measures that ensure substrates meet specifications and function as intended |
| d) Process Bottlenecks | 4. Potential obstacles that slow down the production flow or increase costs |

**Answers:** a-2, b-3, c-1, d-4

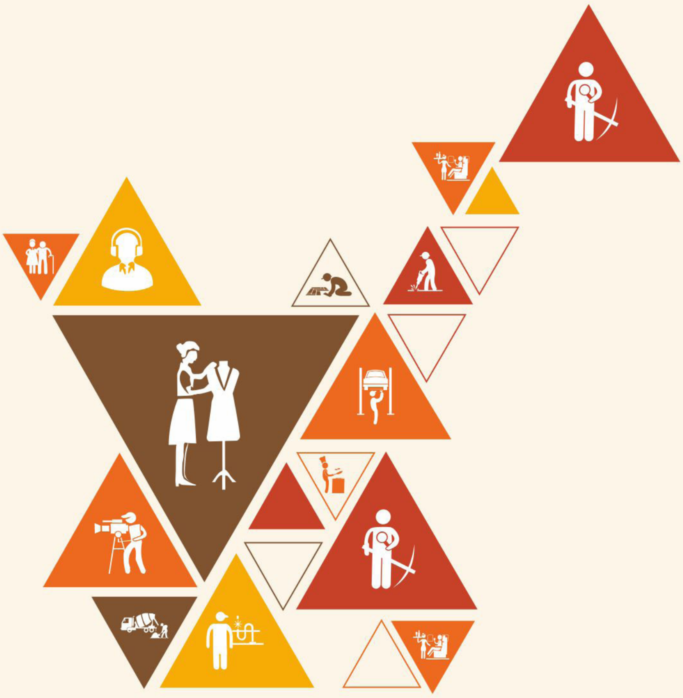
2 Match the following stakeholders with their responsibilities:

| Column A | Column B |
|---|---|
| 1. Portion Yield | A. Helps determine whether an item should be promoted or removed from the menu |
| 2. Mark-up Procedure | B. Method to calculate the selling price by applying a multiplier to the raw food cost |
| 3. Sales Data Analysis | C. Data used to understand the popularity and performance of menu items |
| 4. Menu Pricing Adjustment | D. Adjusting prices based on competitor pricing and market trends to remain competitive |

**Answers:** 1-C, 2-B, 3-A, 4-D

# 4. Quality Assurance and Documentation

Unit 4.1: Determining the Scope and Nature of Required Budgets
Unit 4.2: Types of Budgets in Hospitality and Analyzing Factors Impacting Budgets
Unit 4.3: Budget Preparation Process and Monitoring Techniques
Unit 4.4: Understanding Budget Deviations



TEL/N7218

## Key Learning Outcomes

1. Explain the functionality of basic inspection tools and equipment commonly used for substrate inspection (e.g., microscopes, calipers)
2. Explain the importance of accurate and complete documentation in substrate design.
3. Describe established procedures for maintaining design files and revisions.
4. Explain how to prepare clear and concise technical documentation for completed substrate designs.
5. Explain quality control principles and procedures relevant to substrate design.
6. Describe data analysis techniques to identify areas for improvement in QC practices.
7. Analyze observations and inspection data to identify areas for improvement in existing QC practices.
8. Explain non-conformance documentation procedures, including identifying root causes.
9. Explain effective communication protocols for escalating quality issues.
10. Visually inspect mock substrates to identify potential defects (e.g., dimensional errors, surface imperfections).
11. Utilize basic inspection tools and equipment as needed during simulated inspections.
12. Accurately record inspection results and document all relevant activities based on simulations or case studies.
13. Practice maintaining design files and revisions according to established procedures using a simulated design file management system.
14. Analyze data from simulated inspections to identify areas for improvement in QC practices.
15. Identify deviations from design specifications or process standards in scenario-based exercises.
16. Document non-conformances with clear descriptions and potential root causes based on the scenarios.

# Unit 4.1: Inspection Tools and Techniques

## Unit Objectives

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

1. Explain the functionality of basic inspection tools and equipment commonly used for substrate inspection (e.g., microscopes, calipers).
2. Visually inspect mock substrates to identify potential defects (e.g., dimensional errors, surface imperfections).
3. Utilize basic inspection tools and equipment as needed during simulated inspections.

## Resources to be Used

Participant handbook, pen, notebook, whiteboard, flipchart, markers, laptop, overhead projector, laser pointer, etc.

## Note

In this unit, we will discuss the functionality and use of basic inspection tools and equipment, such as microscopes and calipers, that are commonly used in substrate inspection. We will also explore how to visually inspect mock substrates to identify potential defects, including dimensional errors and surface imperfections. Additionally, you will gain hands-on experience in utilizing these tools during simulated inspections.

## Ask

**Ask the participants the following questions:**

- What are some common inspection tools used to check for defects in substrates, and how do they help ensure quality?

Write down the participants' answers on a whiteboard/flipchart. Take appropriate clues from the answers and start teaching the lesson.

## Elaborate

**Functionality of Basic Inspection Tools and Equipment in Substrate Inspection**

In telecom substrate manufacturing, ensuring the quality and reliability of substrates is paramount. Basic inspection tools and equipment are crucial for identifying defects early in the process, ensuring that substrates meet the design specifications, and maintaining the required performance standards. Below, we explore the functionality of key inspection tools and how they contribute to substrate quality.

1. **Microscopes**

   Microscopes are among the most commonly used tools in substrate inspection. They allow inspectors to examine the fine details of substrates, which is essential for identifying microscopic defects that are invisible to the naked eye. Different types of microscopes are employed, including:

- **Optical Microscopes:** These are used for general inspection of substrates. They provide magnification typically in the range of 10x to 1000x, allowing inspection of fine surface features such as scratches, cracks, and surface contamination. They can be used to check solder joints, etch patterns, and other microstructures.
- **Stereo Microscopes:** These microscopes offer a three-dimensional view, which helps in depth perception of surface features. This type of microscope is particularly useful when inspecting the surface of substrates for larger defects or variations in texture.
- **Electron Microscopes:** For more advanced inspection, electron microscopes (like Scanning Electron Microscopes or SEM) are used to achieve extremely high magnification (up to 1,000,000x). These are typically used in research and development environments where the finest details, like surface texture at the nanometer scale, need to be examined.

### 2. Calipers and Micrometers

Calipers and micrometers are essential tools for measuring the dimensions of substrates and their components. Accuracy in measurements is critical for ensuring that the substrate fits within the designed specifications and works reliably in the final product.

- **Vernier Calipers:** These are used for measuring the outer and inner dimensions of substrates, such as the thickness, width, and diameter. The caliper has a sliding scale that allows for precise measurements, typically with a resolution of 0.02mm or finer. They are commonly used for dimensional checks in prototype stages and ongoing production.
- **Digital Calipers:** These are similar to Vernier calipers but include a digital display, making it easier to read measurements. Digital calipers can provide greater accuracy and are typically used in high-precision applications.
- **Micrometers:** For even higher precision, micrometers are used to measure the thickness of substrates and small components. A micrometer can measure with an accuracy of up to 0.001mm, making it ideal for critical checks, such as verifying the thickness of a substrate layer or checking for any warping or bending.

### 3. Surface Profilers and Optical Inspection Equipment

Surface profilers and optical inspection equipment are used to assess the surface finish of substrates. These tools are crucial in detecting surface imperfections that may affect substrate performance.

- **Surface Profilers:** These tools use a stylus or laser to trace the surface of a substrate and measure its profile. Surface roughness, height variations, and dimensional uniformity can be evaluated using this equipment. It is essential for ensuring that the substrate surface meets the specifications for smoothness, which impacts signal integrity and other performance characteristics.
- **Optical Inspectors:** These devices employ cameras and advanced imaging techniques to inspect the surface of substrates. They are often used in conjunction with image processing software to identify imperfections, such as contamination, scratches, or misalignment of components. Optical inspection is valuable for non-contact, fast inspections, which are essential for quality control in high-throughput manufacturing environments.

### 4. Automated Optical Inspection (AOI) Systems

Automated Optical Inspection (AOI) systems represent an advanced, automated method of inspecting substrates for defects. AOI systems are equipped with high-resolution cameras that capture images of the substrate surface and analyze them for potential defects.

- **Functionality:** The AOI system compares the captured image with a reference design to identify discrepancies, such as missing or misaligned components, soldering defects, and incorrect dimensions. It is particularly useful for inspecting complex substrates with intricate designs that would be time-consuming and difficult to inspect manually.
- **Benefits:** AOI systems improve the speed and efficiency of inspections while reducing human error. They can perform high-throughput inspections, ensuring that substrates meet the required standards before being processed further.

### 5. Optical and Laser Scanning

Optical scanning and laser-based equipment are used to examine the structural integrity and dimensions of substrates. These tools provide detailed 3D models of the substrate surface and can be used to measure complex features with high precision.

- **Laser Scanning Micrometers:** These devices use laser beams to scan the surface of the substrate and determine its exact geometry. The laser provides accurate readings of the substrate's topography and dimensional features without making direct contact, which prevents potential damage to delicate substrates.
- **Optical Scanners:** These are used to capture a high-definition image of the substrate's surface and analyze any variations from the design specifications. Optical scanners are useful for inspecting large areas quickly and for detecting defects like scratches, dents, and foreign particles.

### Visual Inspection of Mock Substrates

Visual inspection involves examining substrates for visible defects. Inspectors use various tools, including microscopes, calipers, and AOI systems, to perform these inspections. Some common defects identified through visual inspection include:

- **Dimensional Errors:** Substrates may have incorrect dimensions, such as oversize or undersize holes, misaligned layers, or incorrect thickness. These dimensional errors can affect the functionality and manufacturability of the substrate.
- **Surface Imperfections:** Scratches, dents, contamination, and other surface flaws can compromise the integrity of the substrate. These imperfections may also impact the electrical performance of the substrate, such as causing short circuits or interference in signal transmission.
- **Cracks or Fractures:** Fine cracks or fractures in the substrate material can cause failure during the manufacturing or operational processes. Inspecting for these defects early ensures that substrates are not processed further without repair.
- **Misalignment:** In multi-layered substrates, misalignment during layer bonding or component placement can result in faulty substrates. Misalignment can lead to manufacturing defects, reducing the overall yield and quality of the production batch.

### Using Inspection Tools in Simulated Inspections

In simulated inspections, participants practice utilizing various inspection tools to detect defects in mock substrates. This exercise allows them to become familiar with the tools' functionalities and gain experience in identifying issues that may not be immediately obvious. For example:

- Inspecting mock substrates using microscopes helps trainees understand how to spot small surface imperfections and verify the substrate's structural integrity.
- Using calipers and micrometers allows trainees to practice measuring substrate dimensions and ensuring that they conform to the design specifications.

- Optical inspection tools allow for the detection of surface contaminants or alignment issues without requiring physical contact, improving the inspection speed and reducing potential damage to the substrate.

By engaging in simulated inspections, trainees develop hands-on experience that prepares them to handle real-world inspection tasks effectively, ensuring high-quality standards in telecom substrate production.

## Say

Let us participate in an activity to explore the unit a little more.

## Activity

**Group Activity:** Substrate Inspection Simulation

**Activity Overview:**

This group activity focuses on utilizing basic inspection tools and equipment to inspect mock substrates for potential defects. Participants will practice inspecting substrates for dimensional errors and surface imperfections using tools such as microscopes and calipers.

**Materials Needed:**

- Mock substrates (can be paper or plastic cutouts with simulated defects)
- Microscopes (or magnifying lenses)
- Calipers (digital or manual)
- Rulers
- Markers or stickers for identifying defects
- Inspection checklists (for tracking defects)

**Instructions:**

1. **Introduction (5 minutes):**
    - Briefly explain the purpose of substrate inspection and the types of defects that can be found (e.g., dimensional errors, surface imperfections).
    - Introduce the tools that will be used for inspection, such as microscopes, calipers, and rulers.
    - Divide participants into small groups (3-4 people per group).
2. **Inspection Simulation (30 minutes):**
    - Give each group a mock substrate with a few intentional defects (e.g., misalignment, scratches, or incorrect dimensions).
    - Allow the groups to inspect the substrate using microscopes, calipers, and rulers, following the inspection checklist.
    - Instruct the participants to identify and document defects on the substrate, marking them with stickers or notes.

3. **Debrief and Discussion (10 minutes):**
   - After the inspection, gather the groups and discuss the defects they identified.
   - Ask each group to present their findings and the tools they used.
   - Discuss the importance of thorough inspections and how accurate measurements can prevent potential issues in substrate production.

**Examples of Scenario Cards:**

**Scenario 1:** Surface Imperfection

- **Description:**

  During the inspection of a substrate, you notice a small, visible scratch running diagonally across the surface. The scratch is shallow but spans a considerable portion of the substrate.

- **Task:**

  Determine the potential impact of this scratch on the substrate's functionality. How would you document this defect for quality control, and would you consider it a critical defect for rejection?

**Scenario 2:** Dimensional Error

- **Description:**

  Upon measuring the width of a substrate, you find that it deviates from the specified dimension by 0.2 mm. The substrate has multiple components that rely on exact placement, and this error could potentially affect the fitting of connectors.

- **Task:**

  Using a caliper, recheck the measurement and assess the importance of this dimensional error. Should the substrate be sent back for adjustments, or is it acceptable within tolerances? Discuss the next steps.

**Scenario 3:** Misalignment of Layers

- **Description:**

  During the inspection, you notice that the top layer of the substrate is slightly misaligned with the underlying layers. The misalignment is subtle but could lead to poor electrical conductivity in some areas of the substrate.

- **Task:**

  Analyze how this misalignment could affect the substrate's performance and reliability. Should the alignment issue be flagged as a defect for correction, or is it within acceptable limits? Document your findings.

| Activity | Duration | Resources used |
|---|---|---|
| Substrate Inspection Simulation | | Whiteboard or flipchart, Markers, Sticky notes (different colors), Budget planning template (with categories for revenue, expenses, and key goals), Organizational goals list (with brief descriptions), etc. |

## Do

- Guide the trainees throughout the activity
- Ensure that all trainees participate in the activity

## Notes for Facilitation

- Ensure participants understand how to correctly use microscopes, calipers, and rulers to detect defects.
- Focus on common defects like scratches, dimensional errors, and misalignment. Emphasize the impact on substrate functionality.
- Encourage collaboration to ensure thorough inspections and accurate defect identification. Share findings to promote quality assurance.

# Unit 4.2: Documentation and Revision Control

## Unit Objectives

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

1. Explain the importance of accurate and complete documentation in substrate design.
2. Describe established procedures for maintaining design files and revisions.
3. Prepare clear and concise technical documentation for completed substrate designs.
4. Practice maintaining design files and revisions according to established procedures using a simulated design file management system.

## Resources to be Used

Participant handbook, pen, notebook, whiteboard, flipchart, markers, laptop, overhead projector, laser pointer, etc.

## Note

In this unit, we will discuss the importance of accurate and complete documentation in substrate design. We will explore procedures for maintaining design files, handling revisions, and ensuring all documentation is clear and concise. Additionally, you will practice using a simulated design file management system to maintain and revise substrate designs effectively.

## Ask

**Ask the participants the following questions:**

- Why is it important to keep track of design revisions and maintain accurate documentation during the substrate design process?

Write down the participants' answers on a whiteboard/flipchart. Take appropriate clues from the answers and start teaching the lesson.

## Elaborate

### 1. Importance of Accurate and Complete Documentation in Substrate Design

Accurate and complete documentation plays a critical role in substrate design, ensuring that the design process is efficient, traceable, and compliant with both technical specifications and industry standards. Substrate designs are intricate and involve various steps, from initial conceptualization to final production. Proper documentation provides clarity, minimizes the risk of errors, and facilitates communication between design, manufacturing, and quality control teams.

**Key reasons for the importance of documentation in substrate design:**

- **Traceability:** Detailed documentation helps trace the design decisions, material choices, and design iterations over time. This is vital for identifying the origin of any issues that may arise during manufacturing or after deployment.

- **Collaboration:** Substrate designs typically involve multiple stakeholders, including design engineers, production teams, and quality control experts. Accurate documentation ensures all parties are on the same page, reducing misunderstandings and enhancing collaboration.
- **Compliance:** Design documents often need to meet regulatory and industry standards. Proper documentation helps meet compliance requirements, such as electrical standards or safety regulations.
- **Reproducibility:** Complete records ensure that a substrate design can be reproduced or updated as needed. If a new batch or variant is required, the original documentation provides the necessary details for replication.
- **Troubleshooting and Maintenance:** If a defect or failure occurs after deployment, the design documents serve as a reference for troubleshooting and corrective actions.

### 2. Established Procedures for Maintaining Design Files and Revisions

Maintaining design files and revisions is crucial in substrate design to ensure that all changes are well-documented and easily retrievable. There are several best practices and procedures that need to be followed to ensure organized and effective management of design files.

**Key procedures for managing design files and revisions:**

- **File Organization:** Design files should be organized systematically with clear naming conventions to avoid confusion. Directories should be categorized based on project names, stages of development (e.g., concept, draft, final), and file types (e.g., schematics, CAD layouts, and documentation).
- **Version Control:** A version control system should be employed to track changes in the design. Each change or revision should be clearly labeled with a version number or date, and previous versions should be stored for reference. Tools like Git, SVN, or PDM systems are commonly used to manage revisions.
- **Documentation of Changes:** Each design change should be documented with a brief explanation of what was changed, why, and how it affects the overall design. This may include adjustments in material selection, layout, signal routing, or layer stack-up.
- **Access Control:** Only authorized personnel should be able to make changes to critical design files. Access permissions should be clearly defined, with the ability to track who made specific changes.
- **Backup and Redundancy:** Regular backups of design files are essential to prevent data loss. These backups should be stored securely and be accessible in the event of system failure.
- **Clear Revision History:** Each design revision should include a history log that documents all changes and updates made to the design files. This helps ensure accountability and provides a clear audit trail for future reference.

### 3. Preparing Clear and Concise Technical Documentation for Completed Substrate Designs

Creating clear and concise technical documentation for completed substrate designs is essential for communicating the technical specifications, performance targets, and manufacturing instructions to the production and quality control teams. The documentation should be comprehensive yet straightforward to avoid ambiguity.

**Components of technical documentation for substrate design:**

- **Design Specifications:** Include all technical details such as dimensions, material properties, electrical specifications, signal integrity requirements, and thermal dissipation needs. This section should also include any constraints related to the manufacturing process.

- **Design Layout:** Visual representation of the substrate layout, including layer stack-up, routing diagrams, component placement, and any critical manufacturing instructions. Clear annotations should be provided for each section of the layout to explain the functionality and relationship between components.
- **Manufacturing Instructions:** Include step-by-step instructions for fabricating the substrate. This may include recommended materials, layer build-up procedures, and process guidelines (e.g., photolithography, etching, soldering). Manufacturing instructions should also note any special considerations for assembly and testing.
- **Test Procedures:** Provide instructions on how the substrate should be tested after fabrication. Include specific tests related to electrical performance, signal integrity, and thermal management.
- **Revision and Change Logs:** Include a section that tracks changes made to the design and their corresponding reasons. This helps ensure clarity in case of future modifications or updates.
- **Compliance and Standards:** Cite any industry standards or regulatory requirements that the design must adhere to, such as ISO standards or environmental regulations (e.g., RoHS compliance).
- **Reference Data:** Provide references to any relevant research, studies, or previous designs that influenced the current design. This helps establish the rationale behind design choices.

A well-structured technical document should be easy to follow, with each section clearly labeled and logically organized. Visual aids such as diagrams, charts, and tables should be used to enhance understanding and reduce ambiguity.

### 4. Maintaining Design Files and Revisions Using a Simulated Design File Management System

Maintaining design files and revisions using a simulated design file management system allows engineers to practice managing a design project from start to finish in a structured, virtual environment. This provides real-world experience in managing design changes, tracking progress, and collaborating with team members.

Steps involved in maintaining design files using a file management system:

- **File Creation and Upload:** Begin by creating the initial design files (e.g., CAD files, layout diagrams) and uploading them to the system. Each file should be appropriately named and tagged with relevant metadata (e.g., project name, design phase, revision number).
- **Revision Control:** As the design progresses, each modification should be saved as a new revision. The system should allow users to compare different versions and ensure that the latest revision is always accessible.
- **Change Management:** For every revision, include a description of what changes were made and why. This log should be updated each time a change is made to ensure that the history of the design is fully documented.
- **Collaboration and Communication:** The system should allow collaboration between team members, enabling engineers, designers, and quality control personnel to leave comments, ask questions, and make suggestions.
- **Approval Process:** Once a design is completed, it should go through an approval process. The file management system should facilitate sign-offs by relevant stakeholders (e.g., senior designers, quality assurance teams) to ensure the design is ready for production.
- **Archiving and Backup:** Upon completion, the final design and all its revisions should be archived. Additionally, regular backups of all design files should be scheduled to prevent data loss.

The use of a simulated file management system allows participants to practice organizing and managing their design work in a controlled environment, ensuring familiarity with industry-standard practices. Accurate documentation and the proper management of design files are indispensable in the substrate design process. Well-maintained documentation ensures the design process is efficient, transparent, and traceable. By adhering to established procedures, engineers and designers can effectively track design iterations, prevent errors, and ensure that the final substrate meets all technical and quality requirements. In the modern design environment, utilizing tools and systems for version control and file management provides an added layer of efficiency, helping teams collaborate seamlessly and maintain a high standard of quality across all stages of the design process.

## Say

Let us participate in an activity to explore the unit a little more.

## Activity

**Group Activity:** Substrate Design File Management Simulation

**Activity Overview:**

In this activity, participants will practice maintaining accurate and up-to-date design files and revisions using a simulated design file management system. They will also prepare clear, concise technical documentation for completed substrate designs.

**Materials Needed:**

- Mock substrate design files (digital or paper)
- Computers or devices (for digital file management) or folders/physical files (for paper-based file management)
- Revision history templates
- Checklist for documentation format
- Example design documentation (for reference)

**Instructions:**

1. **Introduction (5 minutes):**
    - Briefly explain the importance of accurate documentation in substrate design.
    - Introduce the concepts of version control, file organization, and maintaining revision history.
2. **File Management Simulation (25 minutes):**
    - Divide participants into small groups (3-4 people per group).
    - Provide each group with a mock substrate design file with incomplete or outdated revision history.
    - Instruct each group to update the file according to established procedures, including:
        - Adding revisions to the history.
        - Documenting changes made to the design.
        - Creating clear and concise technical documentation summarizing the design.
    - Use a simulated system (digital or paper) for organizing the updated files and revisions.

3. **Group Discussion (10 minutes):**
    - After completing the task, ask each group to present how they handled the file management and documentation process.
    - Discuss any challenges they faced in organizing the design files and maintaining revisions.
4. **Wrap-Up and Key Takeaways (5 minutes):**
    - Summarize the importance of effective documentation practices and version control in substrate design.
    - Highlight the role of proper documentation in ensuring design integrity and smooth collaboration.

**Examples of Scenario Cards:**

**Scenario 1:** Missing Revision History

- **Description:**

  You receive a substrate design file that lacks a clear revision history. It appears to have been updated multiple times, but the changes are not documented. Without revision records, it's difficult to understand what was changed or why.

- **Task:**

  How would you proceed in updating this file with proper revision history? What steps would you take to ensure the file is organized for future reference? What documentation practices should you implement to avoid this issue in the future?

**Scenario 2:** Inconsistent Documentation Format

- **Description:**

  You find that a design file has been updated with new changes, but the format used for documentation is inconsistent with previous files. There are missing sections, and the layout is unclear, making it hard for others to understand the design rationale.

- **Task:**

  How would you standardize the documentation format to ensure consistency across all design files? What guidelines would you introduce for future documentation practices to improve clarity and consistency?

**Scenario 3:** Outdated Design File

- **Description:**

  You receive a substrate design file from an older project that hasn't been updated in several months. The design includes components that have since been revised, but the file does not reflect these updates.

- **Task:**

  What steps would you take to update this file with the latest design changes? How would you track the changes and ensure the file is now accurate and up-to-date? What processes would you use to ensure that outdated files don't cause confusion in future

| Activity | Duration | Resources used |
|---|---|---|
| Substrate Design File Management Simulation | | Whiteboard or flipchart, Markers, Scenario cards (described below), Budget template (including sections for various budget types such as operating, capital, and cash flow), etc. |

## Do ✓

- Guide the trainees throughout the activity
- Ensure that all trainees participate in the activity

## Notes for Facilitation

- Ensure proper revision tracking and documentation to avoid errors and maintain design integrity.
- Encourage consistency in documentation format to make files easy to understand and refer back to.
- Guide participants to regularly update design files and maintain clear revision history to avoid outdated information.

# Unit 4.3: Quality Control Procedures and Data Analysis

## Unit Objectives

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

1. Explain quality control principles and procedures relevant to substrate design.
2. Describe data analysis techniques to identify areas for improvement in QC practices.
3. Analyze observations and inspection data to identify areas for improvement in existing QC practices.
4. Analyze data from simulated inspections to identify areas for improvement in QC practices.

## Resources to be Used

Participant handbook, pen, notebook, whiteboard, flipchart, markers, laptop, overhead projector, laser pointer, etc.

## Note

In this unit, we will discuss the principles and procedures of quality control (QC) in substrate design, focusing on techniques for analyzing inspection data to enhance QC practices. You will learn how to identify defects, interpret data from inspections, and propose improvements to existing processes, ensuring higher reliability and performance of substrates.

## Ask

**Ask the participants the following questions:**

- What is the main purpose of quality control in substrate design?

Write down the participants' answers on a whiteboard/flipchart. Take appropriate clues from the answers and start teaching the lesson.

## Elaborate

**Quality Control Principles and Procedures in Substrate Design**

Quality control (QC) is essential in substrate design to ensure that products meet specifications and function reliably. Key principles include:

1. **Defining Quality Standards**
    - Establish measurable parameters such as dimensional accuracy, surface finish, and thermal performance.
    - Use standards like IPC or JEDEC to guide substrate design and production.

2. **Inspection Procedures**
    - Implement both visual inspections (to detect surface imperfections, misalignments) and dimensional inspections (to measure features using calipers, microscopes).
    - Perform functional testing to ensure electrical performance, such as signal integrity.
3. **Acceptance Criteria**
    - Define tolerance limits for substrate dimensions, material properties, and alignment.
    - Establish clear pass/fail criteria for defects based on severity and potential impact on performance.
4. **Documentation and Record-Keeping**
    - Maintain thorough records of inspection data, non-conformance reports, and corrective actions.
    - Use these records to track recurring issues and improve QC processes.
5. **Continuous Improvement**
    - Regularly review QC procedures to identify inefficiencies.
    - Use feedback loops to adjust processes and maintain high product standards.

### Data Analysis Techniques in QC

Effective QC relies on analyzing data to pinpoint defects and process inefficiencies. Common data analysis techniques include:

1. **Statistical Process Control (SPC)**
    - Monitor production processes using control charts to detect variations.
    - Identify patterns or trends that may indicate potential issues before defects occur.
2. **Pareto Analysis**
    - Apply the 80/20 rule to focus on the most common or severe defects.
    - Helps prioritize efforts on areas that will yield the greatest improvement.
3. **Root Cause Analysis (RCA)**
    - Investigate the underlying causes of defects or failures using tools like fishbone diagrams or the “5 Whys” technique.
    - RCA ensures that corrective actions address the root cause rather than symptoms.
4. **Correlation Analysis**
    - Analyze relationships between variables, such as material properties and defect rates.
    - Helps identify factors contributing to defects.
5. **Trend Analysis**
    - Examine historical inspection data to identify recurring issues over time.
    - Supports proactive measures to prevent future defects.

### Improving QC Practices through Data Analysis

Data analysis enables targeted improvements in QC by revealing inefficiencies and problem areas. The process involves:

1. **Identifying Key Metrics**
    - Focus on metrics like defect rate, yield, and mean time to failure.
    - Prioritize metrics that directly impact product quality and reliability.
2. **Analyzing Inspection Data**
    - Compare defect rates across production batches to identify inconsistencies.
    - Use histogram analysis to understand the frequency distribution of defects.
3. **Implementing Corrective Actions**
    - Based on findings, modify production processes to address identified issues.
    - For instance, if misalignments are a recurring issue, adjust alignment tools or protocols.
4. **Feedback and Training**
    - Share insights from data analysis with QC and production teams.
    - Conduct training sessions to improve adherence to QC procedures and standards.

**Simulated Data for QC Improvements**

Simulated inspections allow teams to practice QC techniques and refine procedures without disrupting actual production. Here's how simulated data contributes to improving QC:

1. **Defect Detection Practice**
    - Participants inspect mock substrates to identify surface imperfections, misalignments, and dimensional errors.
    - Helps improve their accuracy and speed in real-world inspections.
2. **Data Interpretation**
    - Analyze simulated inspection data to identify trends and recurring issues.
    - For example, consistent dimensional errors in simulations may highlight the need for equipment recalibration.
3. **Scenario-Based Learning**
    - Use scenarios like unexpected increases in defect rates to challenge participants to propose corrective actions.
    - Encourages critical thinking and decision-making in QC practices.
4. **Testing New Procedures**
    - Simulations provide a low-risk environment to test revised QC procedures or tools.
    - Ensures that changes will be effective when implemented in actual production.

Effective QC in substrate design relies on well-defined principles, thorough inspections, and robust data analysis techniques. By analyzing inspection data and simulating scenarios, teams can identify inefficiencies and improve QC practices. These improvements lead to higher product quality, reduced defects, and greater reliability in telecom substrates, ensuring they meet performance and customer expectations.

## Say

Let us participate in an activity to explore the unit a little more.

## Activity

**Group Activity:** Simulated Quality Control (QC) Data Analysis

**Activity Overview:**

Participants will analyze simulated inspection data to identify quality control (QC) issues and propose improvements to current QC practices.

**Materials Needed:**

- Mock inspection data (e.g., error rates, defect counts, process times)
- Charts or graphs showing trends (printed or digital)
- QC guidelines for reference
- Whiteboard or flipchart for group presentations

**Instructions:**

1. **Introduction (5 minutes):**
    - Briefly explain QC principles, common defects in substrates, and data analysis techniques.
2. **Data Analysis and Discussion (25 minutes):**
    - Divide participants into groups of 4-5.
    - Provide each group with mock inspection data showing trends like increased defect rates or process inefficiencies.
    - Groups will analyze the data to identify patterns and potential root causes of QC issues.
    - Based on their analysis, each group will suggest improvements to current QC procedures.
3. **Group Presentations (10 minutes):**
    - Each group presents their findings, including identified issues and recommended improvements.
4. **Debrief and Key Takeaways (5 minutes):**
    - Discuss common observations and proposed solutions.
    - Highlight the importance of data-driven QC practices.

**Examples of Scenario Cards:**

**Scenario 1:** High Defect Rate in Final Inspection

- **Description:**

  During the final inspection stage, the defect rate has increased from 2% to 8% over the last three production batches. Common defects include surface scratches and incorrect dimensions.
- **Task:**

  Analyze the provided inspection data. Identify potential root causes for the increase in defects and propose improvements to reduce the defect rate.

**Scenario 2:** Inconsistent Inspection Results Across Shifts

- **Description:**

Inspection reports show significant variation in defect identification rates between different production shifts. Some shifts report higher defect counts, while others report minimal issues for similar batches.

- **Task:**

  Examine the inspection data to determine possible causes for the inconsistency. Recommend changes to standardize inspection procedures across all shifts.

**Scenario 3:** Delays in QC Process Due to Equipment Downtime

- **Description:**

  Inspection times have increased by 20% due to frequent downtime of critical inspection equipment, resulting in production bottlenecks.

- **Task:**

  Review the data on equipment usage and downtime. Propose solutions to optimize the QC process and reduce delays caused by equipment issues.

| Activity | Duration | Resources used |
|---|---|---|
| Simulated Quality Control (QC) Data Analysis | | Whiteboard or flipchart, Markers, Budget draft template (including sections for costs, revenue projections, and departmental allocations), Scenario cards (described below), etc. |

## Do

- Guide the trainees throughout the activity
- Ensure that all trainees participate in the activity

## Notes for Facilitation

- Make sure participants understand the entire process, from drafting the budget based on departmental needs and forecasts, to getting approval, and then implementing continuous monitoring practices to ensure the budget is followed.
- Help participants focus on practical tools like variance analysis, financial reports, and key performance indicators (KPIs) to monitor and adjust the budget effectively. Discuss how to incorporate flexibility in the budget to deal with unforeseen circumstances.
- Encourage groups to consider potential risks that may lead to budget deviation, such as unexpected costs or changes in external factors. Discuss how adjusting forecasts and allocating contingency funds can help mitigate such risks.

# Unit 4.4: Non-conformance and Communication

## Unit Objectives

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

1. Explain non-conformance documentation procedures, including identifying root causes.
2. Explain effective communication protocols for escalating quality issues.
3. Identify deviations from design specifications or process standards in scenario-based exercises.
4. Document non-conformances with clear descriptions and potential root causes based on the scenarios.
5. Accurately record inspection results and document all relevant activities based on simulations or case studies.

## Resources to be Used

Participant handbook, pen, notebook, whiteboard, flipchart, markers, laptop, overhead projector, laser pointer, etc.

## Note

In this unit, we will discuss the importance of non-conformance documentation in quality control, including procedures for identifying root causes and recording deviations from design specifications. We will also explore effective communication protocols for escalating quality issues and practice documenting inspection results with clear, concise descriptions. By analyzing simulated scenarios, participants will gain hands-on experience in recording non-conformances and proposing corrective actions.

## Ask

**Ask the participants the following questions:**

- What is the purpose of non-conformance documentation in quality control?

Write down the participants' answers on a whiteboard/flipchart. Take appropriate clues from the answers and start teaching the lesson.

## Elaborate

**Non-Conformance Documentation Procedures and Root Cause Identification**

1. **Purpose of Non-Conformance Documentation:**

   Non-conformance documentation ensures that any deviations from design specifications or process standards are systematically recorded. This provides a clear history of quality issues, supports root cause analysis, and facilitates corrective actions.

2. **Key Steps in Non-Conformance Documentation:**
   - Identify the Non-Conformance: Clearly define the nature of the deviation (e.g., incorrect dimensions, surface defects).
   - Record Relevant Details: Document the date, time, batch number, and the specific area of the process where the issue occurred.
   - Assess Impact: Determine whether the non-conformance affects product functionality, reliability, or safety.
   - Initiate Root Cause Analysis (RCA): Use tools like the 5 Whys or Fishbone Diagram to identify underlying issues.

3. **Root Cause Analysis (RCA):**

   RCA is essential for preventing recurring issues.
   - Data Collection: Gather inspection data, process logs, and feedback from operators.
   - Analyze Contributing Factors: Investigate machine performance, material quality, and operator error.
   - Develop Corrective Actions: Implement process changes, employee training, or equipment upgrades to eliminate root causes.

**Effective Communication Protocols for Escalating Quality Issues**

1. **Importance of Communication Protocols:**

   Clear and structured communication protocols ensure that quality issues are addressed promptly and appropriately. This minimizes the risk of defects propagating through the production cycle.

2. **Escalation Levels:**
   - **Immediate Supervisor:** Minor issues or deviations that can be resolved at the team level.
   - **Quality Control (QC) Team:** For recurring or medium-severity issues requiring further investigation.
   - **Management:** Major non-conformances affecting product delivery or safety.

3. **Components of Effective Communication:**
   - **Timeliness:** Report issues as soon as they are identified.
   - **Clarity:** Use concise language and standardized terms to describe the problem.
   - **Documentation:** Provide detailed records, including images, data, and test results, to support the escalation.

4. **Tools for Communication:**
   - Use standardized forms or software to report issues.
   - Conduct regular cross-departmental meetings to discuss ongoing quality concerns.
   - Maintain a centralized database for tracking escalations and resolutions.

### Identifying Deviations from Design Specifications or Process Standards

1. **Recognizing Deviations:**
   - Compare inspection results against predefined tolerances, material specifications, and design documents.
   - Use inspection tools like calipers, microscopes, or automated systems to detect inconsistencies.

2. **Common Types of Deviations:**
   - **Dimensional Errors:** Variations in substrate thickness, width, or hole sizes.
   - **Surface Defects:** Scratches, delamination, or contamination.
   - **Electrical Failures:** Incorrect impedance or signal losses in telecom substrates.

3. **Addressing Deviations:**
   - **Immediate Action:** Segregate defective products to prevent further processing.
   - **Root Cause Investigation:** Identify whether the issue stems from raw materials, equipment, or human error.
   - **Process Improvement:** Adjust machine settings, update work instructions, or conduct additional employee training.

### Documenting Non-Conformances and Root Causes

1. **Key Elements of a Non-Conformance Report (NCR):**
   - **Description of Non-Conformance:** Clearly outline what went wrong.
   - **Location and Time:** Indicate where and when the issue was identified.
   - **Responsible Parties:** List the operator, inspector, or department involved.
   - **Impact Assessment:** Describe the effect on product quality and production timelines.
   - **Root Cause Analysis Summary:** Include findings from RCA, such as specific machine failures or procedural lapses.

2. **Benefits of Proper Documentation:**
   - Provides a clear record for audits and compliance checks.
   - Enhances transparency across teams.
   - Facilitates tracking and closure of corrective actions.

3. **Tools for Documentation:**
   - **Digital Systems:** Use software like ERP or QMS to automate report creation and storage.
   - **Templates and Forms:** Standardized NCR forms streamline reporting and ensure completeness.

### Recording Inspection Results and Documenting Activities

1. **Importance of Accurate Record-Keeping:**

   Accurate inspection records provide a reliable basis for decision-making and continuous improvement. They also demonstrate compliance with industry standards and customer requirements.

2. **Types of Records to Maintain:**
    - **Inspection Logs:** Record details like dimensions, visual observations, and test results.
    - **Checklist Verification:** Confirm that all required checks (e.g., material verification, dimensional analysis) have been performed.
    - **Photographic Evidence:** Attach images of defects or non-conforming products for reference.

3. **Documentation Best Practices:**
    - **Use Clear Formats:** Ensure that reports are easy to read and interpret.
    - **Include Relevant Data:** Document batch numbers, operator initials, and inspection dates.
    - **Secure Storage:** Store records in a centralized system for easy retrieval during audits or reviews.

4. **Benefits of Effective Documentation:**
    - Enhances traceability and accountability.
    - Simplifies root cause analysis and corrective actions.
    - Supports compliance with quality standards like ISO 9001.

Effective non-conformance documentation, communication protocols, and inspection record-keeping are critical components of substrate design quality control. These practices help ensure that deviations are identified, documented, and addressed efficiently. By leveraging tools like RCA, standardized reporting templates, and clear communication channels, organizations can improve their QC processes, minimize risks, and deliver reliable products.

## Say

Let us participate in an activity to explore the unit a little more.

## Activity

**Group Activity:** Non-Conformance Documentation and Root Cause Analysis

**Activity Overview:**

Participants will work in teams to analyze a quality issue in a simulated scenario, document the non-conformance, and identify potential root causes. They will then propose a resolution and outline a communication plan for escalating the issue.

**Materials Needed:**

- Scenario cards with mock quality issues
- Non-conformance report templates
- Whiteboard or flipchart for group presentations
- Pens and paper

**Instructions:**

1. **Introduction (5 minutes):**
    - Briefly explain non-conformance documentation, root cause analysis, and escalation protocols.
2. **Scenario Analysis and Documentation (25 minutes):**
    - Divide participants into groups of 4-5.
    - Distribute a scenario card to each group.
    - Groups will:
        - Analyze the scenario to identify the non-conformance.
        - Fill out the non-conformance report template with a clear description of the issue, potential root cause(s), and corrective actions.
        - Outline a communication plan to escalate the issue.
3. **Group Presentations (10 minutes):**
    - Each group presents their findings and proposed solutions.
4. **Debrief and Key Takeaways (5 minutes):**
    - Discuss the importance of accurate documentation and clear communication in addressing quality issues.

**Examples of Scenario Cards:**

**Scenario 1:** Dimensional Inconsistencies in Substrates

- **Description:**

  During the inspection of a batch of telecom substrates, you discover that several of them do not meet the required dimensional specifications. The width of the substrates is consistently 0.2mm larger than specified.

- **Task:**

  Document the non-conformance in the report. Identify potential root causes for the dimensional inconsistency and suggest corrective actions. Propose a communication plan for escalating the issue.

**Scenario 2:** Surface Scratches on Finished Substrates

- **Description:**

  After completing the substrate manufacturing process, surface scratches are found on the finished product. These scratches appear on multiple substrates but were not identified during earlier inspection stages.

- **Task:**

  Record the non-conformance and document the potential root causes, considering factors like handling, equipment settings, or inspection protocols. Suggest corrective actions and escalate the issue to the relevant teams.

**Scenario 3:** Incorrect Layer Stack-Up in Design

- **Description:**

  During the review of a telecom substrate design, it's discovered that the layer stack-up does not align with the required design specifications. The misalignment could lead to signal integrity issues in the final product.

- **Task:**

  Document the non-conformance and identify the root cause of the incorrect stack-up (e.g., design miscommunication, software error). Propose corrective actions and escalate the issue to the design team for further review.

| Activity | Duration | Resources used |
|---|---|---|
| Non-Conformance Documentation and Root Cause Analysis | | Whiteboard or flipchart, Markers, Budget template (including revenue, costs, and deviations), Scenario cards (described below), etc. |

## Do ✓

- Guide the trainees throughout the activity
- Ensure that all trainees participate in the activity

## Notes for Facilitation

- Emphasize the importance of clear and concise documentation to ensure effective problem resolution.
- Foster collaboration within groups to analyze the scenario and propose solutions effectively.
- Ensure participants understand when and how to escalate issues to relevant stakeholders.

## Exercise

**Multiple Choice Questions (MCQs):**

**1.** Which of the following tools is most commonly used for precise dimensional inspection of substrates?

a) Oscilloscope

b) Calipers

c) Multimeter

d) Soldering iron

**Answer: b)** Calipers

**2.** Why is accurate and complete documentation important in substrate design?

a) It ensures the final product has the correct shape.

b) It aids in debugging the design flaws.

c) It maintains a historical record for future reference and audits.

d) It speeds up the manufacturing process.

**Answer: c)** It maintains a historical record for future reference and audits.

**3.** What is the primary goal of non-conformance documentation?

a) To identify defective products for discard.

b) To document the root cause and corrective actions for quality issues.

c) To verify that products meet customer expectations.

d) To analyze market trends for new products.

**Answer: b)** To document the root cause and corrective actions for quality issues.

**4.** Which of the following is a quality control principle relevant to substrate design?

a) Avoiding collaboration between design teams

b) Ensuring consistency and accuracy in all inspection data

c) Ignoring deviations from design specifications

d) Prioritizing speed over quality in inspections

**Answer: b)** Ensuring consistency and accuracy in all inspection data

**Fill in the Blanks:**

**1.** The primary purpose of using inspection tools such as microscopes and calipers is to detect _____________ in substrates, such as dimensional errors or surface imperfections.

**Answer:** defects

**2.** ___________ is an essential process in quality assurance, where detailed reports document the issues, their root causes, and the corrective actions taken.

Answer: Non-conformance documentation

**3.** For maintaining design files and revisions, a system known as _____________ is used to track design changes and ensure all team members work with the latest version.

**Answer:** version control

4. One of the most important data analysis techniques in quality control is _____________, which helps identify patterns in defects and improve manufacturing processes.

**Answer:** root cause analysis

**Match the Following:**

1. **Match the Quality Control Tools to Their Functions:**

| Tool | Function |
|---|---|
| a) Microscopes | i) Measure precise physical dimensions |
| b) Calipers | ii) Detect surface imperfections and cracks |
| c) Inspection Reports | iii) Document deviations and propose corrective actions |

**Answer:** a - ii, b - i, c - iii,4.

2. **Match the Non-Conformance Procedure to the Correct Step:**

| Procedure | Step |
|---|---|
| a) Identify Root Causes | i) Analyze data to find patterns |
| b) Document Non-Conformance | ii) Describe the issue clearly and record findings |
| c) Escalate the Issue | iii) Inform the relevant teams and management |

**Answer:** a - i, b - ii, c - iii

NCVET
कौशल गुणवत्ता प्रगति

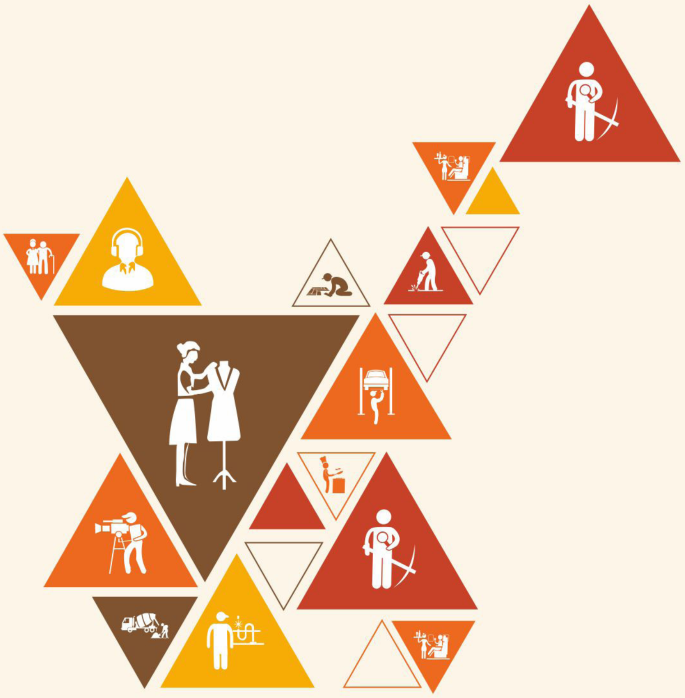
Skill India
कौशल भारत - कुशल भारत

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

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

Telecom
Sector
Skill
Council

# 5. Employability Skills



DGT/VSQ/N0102

**Scan the QR codes or click on the link for the e-books**

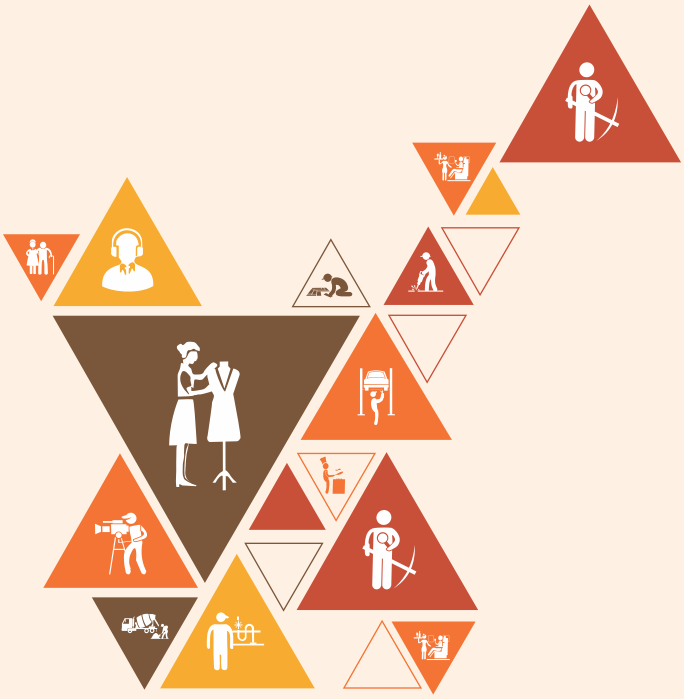
https://www.skillindiadigital.gov.in/content/list

Employability Skills

Telecom
Sector
Skill
Council

# 6. Annexures

Annexure -I
Annexure -II
Annexure -III



# Annexure -I

# Training Delivery Plan

| | | | |
|---|---|---|---|
| **Program Name** | Substrate Design and Process Manager | | |
| **Qualification Pack and reference ID** | Substrate Design and Process Manager- TEL/Q7205 | | |
| **Version No.** | 1.0 | Version Update Date | NA |
| **Pre-Requisite License or Training** | NA | | |
| **Training Outcomes** | **At the end of the program, the learner should have acquired the listed knowledge and skills to:**<br>• Understand the core principles of semiconductor substrate design, including performance and manufacturability.<br>• Apply CAD tools to create substrate layouts, ensuring signal integrity and thermal management.<br>• Analyze design feedback to identify potential issues and improve manufacturability.<br>• Evaluate design modifications based on performance data and test results.<br>• Create detailed technical documentation and improvement plans with supporting data | | |

| S No. | Module Name | Session Name | Session Objectives | NOS Reference | Methodology | Training Tools Aids | Duration |
|---|---|---|---|---|---|---|---|
| 1. | Role and Responsibilities of Telecom Substrate Design Support Engineer (SDSE) | Unit 1.1: Introduction to Telecom Substrate Design | 1. Understand the different types of substrates used in telecom network equipment (wired and wireless).<br>2. Recognize the key considerations for substrate design in telecom applications.<br>3. Explain the basic functionality of semiconductors in telecom devices. | TEL/N7216: Substrate Design Support | Interactive Lecture in the Class | Whiteboard, Marker, Duster, Projector, Laptop, PowerPoint Presentation, PPE Kit | **T : 05:00**<br>**P : 00:00** |
| | | Unit 1.2: Quality Control and Industry Standards in Telecom Substrate Production | 1. Explain the importance of quality control procedures in ensuring the functionality and reliability of telecom substrates.<br>2. Describe the role of industry standards and regulations in telecom substrate design and production.. | | Interactive Lecture in the Class | LCD Projector for PPT and Video Presentation, Speakers, and Whiteboard & marker | **T : 05:00**<br>**P : 00:00** |
| | | Unit 1.3: Safety and Handling of Telecom Substrates | 1. Identify essential safety precautions to be followed in a cleanroom environment.<br>2. Explain the importance of proper handling procedures for telecom substrates to maintain quality and prevent damage.<br>3. Identify the appropriate PPE required for handling telecom substrates in a controlled environment | | Interactive Lecture in the Class | LCD Projector for PPT and Video Presentation, Speakers, and Whiteboard & marker | **T : 05:00**<br>**P : 00:00** |

| S No. | Module Name | Session Name | Session Objectives | NOS Reference | Methodology | Training Tools Aids | Duration |
|---|---|---|---|---|---|---|---|
| | | Unit 1.4: Career Development and Role of Telecom Substrate Design Support Engineer (SDSE) | 1. Identify key technical skills and knowledge areas required for career advancement in telecom substrate design.<br>2. Explain the role and responsibilities of a Telecom Substrate Design Support Engineer (SDSE) within the semiconductor manufacturing process. | | Interactive Lecture in the Class | LCD Projector for PPT and Video Presentation, Speakers, and Whiteboard & marker | T : 05:00<br>P : 00:00 |
| 2. | Substrate Design Support | | 1. Explain the functionalities and key parameters of telecom integrated circuits (Ics).<br>2. Describe how substrate requirements are derived from IC features like pin count and power needs.<br>3. Define critical dimensions, tolerances, and material properties for substrates.<br>4. Explain the purpose and content of design documents like layer stack-up, routing guidelines, and placement constraints. | TEL/N7216: Substrate Design Support | Interactive Lecture in the Class | Training kit (Trainer guide, Presentations), White board, Marker, Projector, Laptop, Presentation, Participant Handbook and Related Standard Operating Procedures,<br>CAD Software for Substrate Design, Microscopes (for visual inspection), Calipers (for dimensional measurements), (Optional) Additional Inspection Tools (depending on specific program) | T : 05:00<br>P : 00:00 |
| | | Unit 2.2: Design Collaboration and Performance Criteria | 1. Describe the role of design meetings and collaboration in substrate development.and safety considerations. | | Interactive Lecture in the Class | Training kit (Trainer guide, Presentations), White board, Marker, Projector, Laptop, Presentation, Participant Handbook and | T : 25:00<br>P : 90:00 |

| S No. | Module Name | Session Name | Session Objectives | NOS Reference | Methodology | Training Tools Aids | Duration |
|---|---|---|---|---|---|---|---|
| | | | 2. Explain performance targets like signal integrity and thermal dissipation.<br>3. Analyze the impact of layout choices on manufacturability and cost (e.g., layer count, routing complexity).<br>4. Explain how material properties influence cost and performance of the substrate. | | Interactive Lecture in the Class | Related Standard Operating Procedures, CAD Software for Substrate Design, Microscopes (for visual inspection), Calipers (for dimensional measurements), (Optional) Additional Inspection Tools (depending on specific program) | T:55:00<br>P: 60:00 |
| | | Unit 2.3: Design for Manufacturability (DFM) Principles | 1. Identify common manufacturability limitations of fabrication processes.<br>2. Understand the concept of Design for Manufacturability (DFM) and its importance.<br>3. Explain how material properties influence cost and performance of the substrate. | | Interactive Lecture in the Class | Training kit (Trainer guide, Presentations), White board, Marker, Projector, Laptop, Presentation, Participant Handbook and Related Standard Operating Procedures,<br>CAD Software for Substrate Design, Microscopes (for visual inspection), Calipers (for dimensional measurements), (Optional) Additional Inspection Tools (depending on specific program) | T: 55:00<br>P: 60:00 |
| | | Unit 2.4: CAD Layout Design and Rule Compliance | 1. Demonstrate proficiency in using CAD software to create basic layouts for telecom substrates.<br>2. Apply established design rules and layer definitions during layout creation.<br>3. Place and route components and signals according to design specifications and performance requirements.<br>4. Perform Design Rule Checks (DRC) to ensure the layout adheres to manufacturing guidelines. | | Interactive Lecture in the Class | Training kit (Trainer guide, Presentations), White board, Marker, Projector, Laptop, Presentation, Participant Handbook and Related Standard Operating Procedures, | T: 55:00<br>P: 60:00 |

| S No. | Module Name | Session Name | Session Objectives | NOS Reference | Methodology | Training Tools Aids | Duration |
|---|---|---|---|---|---|---|---|
| | | Unit 2.5: Layout Refinement, Feedback, and DFM Issue Resolution | 1. Analyze feedback from senior designers and address manufacturability concerns in the layout.<br>2. Modify existing layouts based on feedback and identified issues.<br>3. Analyze the layout for potential manufacturability issues like minimum feature size limitations, via density, and complex routing patterns.<br>4. Demonstrate identifying areas where the design might exceed equipment capabilities or introduce processing challenges.<br>5. Show how to document key decisions and steps taken during the design process as well as identified DFM issues in a clear and concise manner.<br>6. Propose solutions for DFM issues with supporting rationale for further review and approval | | Interactive Lecture in the Class | Training kit (Trainer guide, Presentations), White board, Marker, Projector, Laptop, Presentation, Participant Handbook and Related Standard Operating Procedures,<br>CAD Software for Substrate Design, Microscopes (for visual inspection), Calipers (for dimensional measurements), (Optional) Additional Inspection Tools (depending on specific program) | T: 25:00<br>P: 90:00 |
| 3. | Process Integration and Collaboration | Unit 3.1: Telecom Substrate Design Fundamentals | 1. Explain the functionalities and key specifications of telecom substrate.<br>2. Describe the principles of Design for Manufacturability (DFM) in substrate design.<br>3. Identify production capabilities and limitations relevant to substrate assembly | | Interactive Lecture in the Class | Training kit (Trainer guide, Presentations), White board, Marker, Projector, Laptop, Presentation, Participant Handbook and Related Standard Operating Procedures, | |

| S No. | Module Name | Session Name | Session Objectives | NOS Reference | Methodology | Training Tools Aids | Duration |
|---|---|---|---|---|---|---|---|
| | | Unit 3.2: Effective Communication in Substrate Design Integration | 1. Explain the importance of effective communication and interpersonal skills in process integration.<br>2. Analyze potential challenges in integrating substrate design with the existing production workflow.<br>3. Describe the role of communication channels and documentation practices in facilitating information flow.<br>4. Develop clear communication channels between design, production, and quality control teams based on hypothetical scenarios. | | Interactive Lecture in the Class | Training kit (Trainer guide, Presentations), White board, Marker, Projector, Laptop, Presentation, Participant Handbook and Related Standard Operating Procedures, Tools, Equipment and Other Requirements: Computers (for simulations, presentations, report writing), Presentation software (e.g., PowerPoint, Google Slides), Collaboration tools (e.g., online whiteboards, shared document platforms), Case study materials (printed or digital), Role-playing scenario handouts, Basic prototyping materials (optional, for mock inspection procedures) | T: 30:00<br>P: 60:00 |
| | | Unit 3.3: Collaborative Problem Solving and Process Improvement | 1. Explain the purpose and benefits of data analysis techniques for identifying process improvement opportunities.<br>2. Role-play participating in simulated design meetings focused on telecom substrate specifications.<br>3. Ask clarifying questions and contribute to discussions on technical details in a simulated environment.<br>4. Develop plans for collaboration with production and quality control teams based on hypothetical scenarios. | | Interactive Lecture in the Class | Training kit (Trainer guide, Presentations), White board, Marker, Projector, Laptop, Presentation, Participant Handbook and Related Standard Operating Procedures, Tools, Equipment and Other Requirements: Computers (for simulations, presentations, report writing), Presentation software (e.g., PowerPoint, Google Slides), Collaboration tools (e.g., online whiteboards, shared document platforms), Case study materials (printed or digital), Role-playing scenario handouts, Basic prototyping materials (optional, for mock inspection procedures) | |

| S No. | Module Name | Session Name | Session Objectives | NOS Reference | Methodology | Training Tools Aids | Duration |
|---|---|---|---|---|---|---|---|
| | | Unit 3.4: Identifying Risks and Improving Production Flow | 1. Identify potential bottlenecks and quality risks by analyzing case studies or mock production processes.<br>2. Collaborate with peers to establish clear inspection procedures for completed substrates in a simulated setting.<br>3. Develop and document communication channels to ensure effective integration of design, production, and quality control processes. parameters. | | Interactive Lecture in the Class | TTraining kit (Trainer guide, Presentations), White board, Marker, Projector, Laptop, Presentation, Participant Handbook and Related Standard Operating Procedures, Tools, Equipment and Other Requirements: Computers (for simulations, presentations, report writing), Presentation software (e.g., PowerPoint, Google Slides), Collaboration tools (e.g., online whiteboards, shared document platforms), Case study materials printed or digital), Role-playing scenario handouts, Basic prototyping materials (optional, for mock inspection procedures)marking equipment (for | T: 30:00<br>P: 60:00 |
| 4. | Quality Assurance and Documentation | Unit 4.1: Inspection Tools and Techniques | 1. Explain the functionality of basic inspection tools and equipment commonly used for substrate inspection (e.g., microscopes, calipers).<br>2. Visually inspect mock substrates to identify potential defects (e.g., dimensional errors, surface).<br>3. Utilize imperfections basic inspection tools and equipment as needed during simulated inspections. | TEL/N7218: Quality Assurance and Documentation | Interactive Lecture in the Class | Computers (essential for documentation, presentations, data analysis), Presentation software (e.g., PowerPoint, Google Slides), Word processing software (e.g., Microsoft Word, Google Docs), Spreadsheet software (e.g., Microsoft Excel, Google Sheets), Data analysis software (optional, depending on the complexity of data analysis exercises), Case study materials (printed or digital), Collaborative whiteboard or online platform (optional, for group brainstorming or documentation), Sample documentation templates (e.g., inspection checklists, non-conformance reports), Basic prototyping materials (optional, for mock inspections or demonstrations) | T: 30:00<br>P: 60:00 |

| S No. | Module Name | Session Name | Session Objectives | NOS Reference | Methodology | Training Tools Aids | Duration |
|---|---|---|---|---|---|---|---|
|  |  | Unit 4.2: Documentation and Revision Control | 1. Explain the importance of accurate and complete documentation in substrate design.<br>2. Describe established procedures for maintaining design files and revisions.<br>3. Prepare clear and concise technical documentation for completed substrate designs.<br>4. Practice maintaining design files and revisions according to established procedures using a simulated design file management system. |  | Interactive Lecture in the Class | Computers (essential for documentation, presentations, data analysis), Presentation software (e.g., PowerPoint, Google Slides), Word processing software (e.g., Microsoft Word, Google Docs), Spreadsheet software (e.g., Microsoft Excel, Google Sheets), Data analysis software (optional, depending on the complexity of data analysis exercises), Case study materials (printed or digital), Collaborative whiteboard or online platform (optional, for group brainstorming or documentation), Sample documentation templates (e.g., inspection checklists, non-conformance reports), Basic prototyping materials (optional, for mock inspections or demonstrations) | T: 30:00<br>P: 60:00 |
|  |  | Unit 4.3: Quality Control Procedures and Data Analysis | 1.Explain quality control principles and procedures relevant to substrate design.<br>2. Describe data analysis techniques to identify areas for improvement in QC practices.<br>3. Analyze observations and inspection data to identify areas for improvement in existing QC practices.<br>4.Analyze data from simulated inspections to identify areas for improvement in QC practices. |  | Interactive Lecture in the Class | Computers (essential for documentation, presentations, data analysis), Presentation software (e.g., PowerPoint, Google Slides), Word processing software (e.g., Microsoft Word, Google Docs), Spreadsheet software (e.g., Microsoft Excel, Google Sheets), Data analysis software (optional, depending on the complexity of data analysis exercises), Case study materials (printed or digital), Collaborative whiteboard or online platform (optional, for group brainstorming or documentation), Sample documentation templates (e.g., inspection checklists, non-conformance reports), Basic prototyping materials (optional, for mock inspections or demonstrations) | T: 30:00<br>P: 60:00 |

| S No. | Module Name | Session Name | Session Objectives | NOS Reference | Methodology | Training Tools Aids | Duration |
|---|---|---|---|---|---|---|---|
| | | Unit 4.4: Non-conformance and Communication | 1. Explain non-conformance documentation procedures, including identifying root causes.<br>2. Explain effective communication protocols for escalating quality issues.<br>3. Identify deviations from design specifications or process standards in scenario-based exercises.<br>4. Document non-conformances with clear descriptions and potential root causes based on the scenarios.<br>5. Accurately record inspection results and document all relevant activities based on simulations or case studies. | | | Computers (essential for documentation, presentations, data analysis), Presentation software (e.g., PowerPoint, Google Slides), Word processing software (e.g., Microsoft Word, Google Docs), Spreadsheet software (e.g., Microsoft Excel, Google Sheets), Data analysis software (optional, depending on the complexity of data analysis exercises), Case study materials (printed or digital), Collaborative whiteboard or online platform (optional, for group brainstorming or documentation), Sample documentation templates (e.g., inspection checklists, non-conformance reports), Basic prototyping materials (optional, for mock inspections or demonstrations) | T: 30:00<br>P: 65:00 |
| 5 | Employability Skills | Employability Skills | | DGT/VSQ/N0103: Employability Skills (90 Hours | Interactive Lecture in the Class | Employability Skills Participant handbook, Projector Whiteboard, Marker, and Duster | **T : 30:00**<br>**P : 30:00** |
| 6. | On-the-Job Training | | | | | | **180 Hours** |

# Annexure-II

## Assessment Criteria

### CRITERIA FOR ASSESSMENT OF TRAINEES

| | |
|---|---|
| Job Role | Substrate Design and Process Manager |
| Qualification Pack | TEL/Q7205 |
| Sector Skill Council | Telecom Sector Skill Council |

| S.No. | Assessment Guidelines |
|---|---|
| 1 | Criteria for assessment for each Qualification Pack will be created by the Sector Skill Council. Each Element/ Performance Criteria (PC) will be assigned marks proportional to its importance in NOS. SSC will also lay down proportion of marks for Theory and Skills Practical for each Element/ PC. |
| 2 | The assessment for the theory part will be based on knowledge bank of questions created by the SSC. |
| 3 | Assessment will be conducted for all compulsory NOS, and where applicable, on the selected elective/option NOS/set of NOS. |
| 4 | Individual assessment agencies will create unique question papers for theory part for each candidate at each examination/training center (as per assessment criteria below). |
| 5 | Individual assessment agencies will create unique evaluations for skill practical for every student at each examination/ training center based on these criteria. |
| 6 | To pass the Qualification Pack assessment, every trainee should score the Recommended Pass 70 % aggregate for the QP. |
| 7 | In case of unsuccessful completion, the trainee may seek reassessment on the Qualification Pack. |

| NOS | Assessment Criteria for Outcomes | Theory Marks | Practical Marks | Project Marks | Viva Marks |
|---|---|---|---|---|---|
| **1. TEL/N7216: Substrate Design Support** | *Interpret and Analyze Technical Specifications* | **12** | **14** | **-** | **3** |
| | PC1. review and analyze IC datasheets and application notes for features, pin count, and power needs | 1 | 1 | - | 1 |
| | PC2. analyze signal integrity requirements for telecom applications | 1 | 2 | - | - |
| | PC3. identify critical substrate dimensions based on IC features and functionality | 1 | 1 | - | - |
| | PC4. identify critical tolerances for substrate dimensions | 1 | 1 | - | - |
| | PC5. research and select appropriate material properties for the substrate | 1 | 1 | - | 1 |
| | PC6. extract layer stack-up information from design documents | 1 | 1 | - | - |
| | PC7. analyze routing guidelines from design documents | 1 | 1 | - | - |
| | PC8. identify placement constraints from design documents | 1 | 1 | - | - |
| | PC9. analyze power dissipation of the integrated circuit (IC) | 1 | 1 | - | - |
| | PC10. evaluate thermal management requirements for the substrate | 1 | 1 | - | - |
| | PC11. prepare a summary of key design considerations for internal discussions | 2 | 2 | - | 1 |
| | *Develop Substrate Layouts* | **10** | **12** | **-** | **2** |
| | PC12. participate in design meetings with senior engineers to discuss substrate layout concepts | 2 | 2 | - | - |
| | PC13. identify potential layout options that meet performance targets like signal integrity and thermal dissipation | 1 | 1 | - | 1 |
| | PC14. analyze manufacturability limitations of available fabrication processes | 1 | 1 | - | - |
| | PC15. modify layout concepts to address manufacturability limitations | 1 | 2 | - | 1 |
| | PC16. analyze potential cost implications of different layout choices (e.g., layer count, routing complexity) | 1 | 1 | - | - |
| | PC17. research material properties based on cost and performance needs | 2 | 1 | - | - |
| | PC18. identify materials compatible with processing requirements | 1 | 2 | - | - |

| NOS | Assessment Criteria for Outcomes | Theory Marks | Practical Marks | Project Marks | Viva Marks |
|---|---|---|---|---|---|
| | PC19. collaborate with engineers to select the most suitable material | 1 | 2 | - | - |
| | *Utilize CAD Software for Layout Creation/Modification* | **10** | **12** | **-** | **2** |
| | PC20. use CAD software to create basic layouts for telecom substrates | 1 | 1 | - | - |
| | PC21. following established design rules and layer definitions | 1 | 1 | - | - |
| | PC22. place and route components and signals according to design specifications and performance requirements | 1 | 2 | - | 1 |
| | PC23. perform basic design rule checks (DRC) to ensure the layout adheres to manufacturing guidelines | 1 | 1 | - | - |
| | PC24. route signals according to design specifications and performance requirements | 1 | 1 | - | - |
| | PC25. analyze the feedback from senior engineers on layout design | 1 | 2 | - | - |
| | PC26. identify and address manufacturability concerns in the layout | 1 | 1 | - | - |
| | PC27. modify existing layouts based on feedback or identified manufacturability concerns | 1 | 1 | - | 1 |
| | PC28. document key decisions and steps taken during the design process | 1 | 1 | - | - |
| | PC29. maintain version control of layout files for future reference | 1 | 1 | - | - |
| | *Perform Basic Design for Manufacturability (DFM) Analysis* | **8** | **12** | - | - |
| | PC30. analyze the layout for potential manufacturability issues such as minimum feature size limitations, via density, and manufacturability of complex routing patterns | 2 | 2 | - | - |
| | PC31. identify areas where the design might exceed equipment capabilities | 1 | 2 | - | - |
| | PC32. identify potential processing challenges based on the layout | 1 | 2 | - | 1 |
| | PC33. collaborate with design and manufacturing engineers to find solutions that optimize both performance and manufacturability | 2 | 2 | - | - |
| | PC34. document identified DFM issues and proposed solutions for further review | 1 | 2 | - | 1 |

| NOS | Assessment Criteria for Outcomes | Theory Marks | Practical Marks | Project Marks | Viva Marks |
|---|---|---|---|---|---|
| | PC35. pro  pose solutions for DFM issues with supporting rationale for review and approval | 1 | 2 | - | - |
| | **NOS Total** | **40** | **50** | **-** | **10** |
| **2. TEL/N7217: Process Integration and Collaboration** | *Facilitate Technical Communication* | **14** | **30** | **-** | **5** |
| | PC1. attend design meetings to focused on telecom substrate specifications | 1 | 3 | - | 1 |
| | PC2. ask clarifying questions and contribute to discussions on technical details | 1 | 3 | - | - |
| | PC3. collaborate with design engineers to clarify technical requirements for the substrate | 2 | 4 | - | - |
| | PC4. discuss and clarify performance targets for signal integrity, thermal dissipation, etc | 1 | 3 | - | - |
| | PC3. forecast levels of stock required at different times to facilitate effective scheduling and ordering | 1 | 4 | - | - |
| | PC4. perform stock taking as per the standards and order cleaning equipment, linen, room and cleaning supplies, as required | 1 | 3 | - | - |
| | PC5. identify and raise potential manufacturability concerns based on design choices | 1 | 4 | - | - |
| | PC6. participate in meetings with production and quality control teams to understand capabilities, limitations | 1 | 2 | - | 1 |
| | PC7. identify potential bottlenecks and quality risks in the current production process for telecom substrates | 1 | 3 | - | - |
| | PC8. collaborate with QC to establish clear inspection procedures for completed substrates. | 2 | 4 | - | 10 |
| | PC9. develop and document clear communication channels between design, production, and quality control teams | 3 | 6 | - | 1 |
| | PC10. identify and implement communication channels (e.g., meetings, shared platforms) to facilitate smooth information exchange | 1 | 3 | - | 1 |
| | *Streamline Integration & Improvement* | **16** | **30** | **-** | **5** |

| NOS | Assessment Criteria for Outcomes | Theory Marks | Practical Marks | Project Marks | Viva Marks |
|---|---|---|---|---|---|
|  | PC11. analyze potential integration challenges between substrate design and existing production workflow | - | - | - | - |
|  | PC12. propose solutions to streamline the integration of substrate design processes | - | - | - | - |
|  | PC13. participate in test runs and pilot productions of new substrate designs | - | - | - | - |
|  | PC14. monitor the integration process and identify any arising issues or areas for improvement | - | - | - | - |
|  | PC15. utilize data analysis techniques to pinpoint areas for efficiency gains or quality enhancement | 40 | 40 | - | 20 |
| 3. THC/N9902: Ensure effective communication and service standards at workplace | PC16. identify trends and patterns in data that suggest potential improvement areas | 20 | 20 | - | 10 |
|  | PC17. collaborate with engineers and technicians to develop and implement process improvement solutions | - | - | - | - |
|  | PC18. identify solutions that address identified inefficiencies or quality concerns | - | - | - | - |
|  | PC19. monitor the effectiveness of implemented improvements through data analysis and feedback | - | - | - | - |
|  | PC20. suggest further refinements or adjustments to the improvement solutions | - | - | - | - |
|  | NOS Total | - | - | - | - |
|  | *Perform Quality Control Inspections & Quality Improvement* | 30 | 60 | - | 10 |
|  | PC1. visually inspect completed substrates to identify potential defects (e.g., dimensional errors, surface imperfections) | 2 | 4 | - | 1 |
|  | PC2. utilize basic inspection tools and equipment as needed (e.g., microscopes, calipers) | 2 | 4 | - | 1 |
|  | Pc3. accurately record inspection results and document all substrate design activities | 3 | 6 | - | 1 |
|  | PC4. document all substrate design activities, including inspection results | 2 | 5 | - | 1 |
|  | PC5. maintain design files and revisions according to established procedures | 2 | 6 | - | 1 |

| NOS | Assessment Criteria for Outcomes | Theory Marks | Practical Marks | Project Marks | Viva Marks |
|---|---|---|---|---|---|
| 4. THC/N9910: Ensure to maintain organizational confidentiality and guest's privacy | PC6. prepare clear and concise technical documentation for completed substrate designs | 3 | 5 | - | 1 |
| | PC7. participate in the development and implementation of quality control procedures for substrate design | 3 | 6 | - | - |
| | PC8. Analyze observations and inspection data to identify areas for improvement in existing QC practices | 3 | 5 | - | 1 |
| | PC9. suggest improvements to existing QC practices based on observations and data analysis | 2 | 6 | - | 1 |
| | PC10. identify any deviations from design specifications or process standards during inspections or review processes | 3 | 5 | - | 1 |
| | PC11. document non-conformances with clear descriptions and potential root causes | 2 | 4 | - | 1 |
| | PC12. escalate identified issues to the appropriate personnel for timely resolution | 3 | 4 | - | - |
| | NOS Total | 30 | 60 | - | 10 |
| | *Introduction to Employability Skills* | 1 | 1 | - | - |
| | PC1. understand the significance of employability skills in meeting the current job market requirement and future of work | - | - | - | - |
| | PC2.identify and explore learning and employability relevant portals | - | - | - | - |
| | PC3. research about the different industries, job market trends, latest skills required and the available opportunities | - | - | - | - |
| | Constitutional values – Citizenship | 1 | 1 | - | - |
| | PC4. recognize the significance of constitutional values, including civic rights and duties, citizenship, responsibility towards society etc. and personal values and ethics such as honesty, integrity, caring and respecting others, etc. | - | - | - | - |
| | PC5. follow environmentally sustainable practicesinformation | - | - | - | - |
| | *Becoming a Professional in the 21st Century* | 1 | 3 | - | - |
| | PC6. recognize the significance of 21st Century Skills for employment | - | - | - | - |

| NOS | Assessment Criteria for Outcomes | Theory Marks | Practical Marks | Project Marks | Viva Marks |
|---|---|---|---|---|---|
| 4. THC/N9910: Ensure to maintain organizational confidentiality and guest's privacy | PC7. practice the 21st Century Skills such as Self-Awareness, Behaviour Skills, time management, critical and adaptive thinking, problem-solving, creative thinking, social and cultural awareness, emotional awareness, learning to learn for continuous learning etc. in personal and professional life | - | - | - | - |
| | PC8. adopt a continuous learning mindset for personal and professional development | - | - | - | - |
| | Basic English Skills | 3 | 4 | - | - |
| | PC9. use basic English for everyday conversation in different contexts, in person and over the telephone | - | - | - | - |
| | PC10. read and understand routine information, notes, instructions, mails, letters etc. written in English | - | - | - | - |
| | PC11. write short messages, notes, letters, e-mails etc. in English | - | - | - | - |
| | *Career Development & Goal Setting* | 1 | 2 | - | - |
| | PC12. identify career goals based on the skills, interests, knowledge, and personal attributes | - | - | - | - |
| | PC13. prepare a career development plan with short- and long-term goals | - | - | - | - |
| | *Communication Skills* | 2 | 2 | - | - |
| | *PC14. follow verbal and non-verbal communication etiquette while communicating in* | - | - | - | - |
| | PC15. use active listening techniques for effective communication | - | - | - | - |
| | PC16. communicate in writing using appropriate style and format based on formal or informal requirements | - | - | - | - |
| | PC17. work collaboratively with others in a team | - | - | - | - |
| | Diversity & Inclusion | 1 | 1 | - | - |
| | PC18. communicate and behave appropriately with all genders and PwD | - | - | - | - |
| | PC19. escalate any issues related to sexual harassment at workplace according to POSH Act | - | - | - | - |
| | *Financial and Legal Literacy* | 2 | 3 | - | - |

| NOS | Assessment Criteria for Outcomes | Theory Marks | Practical Marks | Project Marks | Viva Marks |
|---|---|---|---|---|---|
| 4. THC/N9910: Ensure to maintain organizational confidentiality and guest's privacy | PC21. carry out offline and online financial transactions, safely and securely, using various methods and check the entries in the passbook | - | - | - | - |
| | PC23. identify relevant rights and laws and use legal aids to fight against legal exploitation | - | - | - | - |
| | *Essential Digital Skills* | 3 | 5 | - | - |
| | PC24. operate digital devices and use their features and applications securely and safely | - | - | - | - |
| | PC25. carry out basic internet operations by connecting to the internet safely and securely, using the mobile data or other available networks through Bluetooth, Wi-Fi, etc. | - | - | - | - |
| | PC26. display responsible online behaviour while using various social media platforms | - | - | - | - |
| | PC27. create a personal email account, send and process received messages as per requirement | - | - | - | - |
| | PC28. carry out basic procedures in documents, spreadsheets and presentations using respective and appropriate applications | - | - | - | - |
| | *PC29. utilize virtual collaboration tools to work effectively* | - | - | - | - |
| | *Entrepreneurship* | 2 | 3 | - | - |
| | PC30. identify different types of Entrepreneurship and Enterprises and assess opportunities for potential business through research | - | - | - | - |
| | PC31. develop a business plan and a work model, considering the 4Ps of Marketing Product, Price, Place and Promotion | - | - | - | - |
| | PC32. identify sources of funding, anticipate, and mitigate any financial/ legal hurdles for the potential business opportunity | - | - | - | - |
| | *Customer Service* | 1 | 2 | - | - |
| | PC33. identify different types of customers and ways to communicate with them | - | - | - | - |

| NOS | Assessment Criteria for Outcomes | Theory Marks | Practical Marks | Project Marks | Viva Marks |
|---|---|---|---|---|---|
| | PC34. identify and respond to customer requests and needs in a professional anner | - | - | - | - |
| | PC35. use appropriate tools to collect customer feedback | - | - | - | - |
| | PC34. identify and respond to customer requests and needs in a professional manner | - | - | - | - |
| | PC35. use appropriate tools to collect customer feedback | - | - | - | - |
| | PC36. follow appropriate hygiene and grooming standards | - | - | - | - |
| | *Getting ready for apprenticeship & Jobs* | 2 | 3 | - | - |
| | PC37. create a professional Curriculum vitae (Résumé) | - | - | - | - |
| | PC38. search for suitable jobs using reliable offline and online sources such as Employment exchange, recruitment agencies, newspapers etc. and job portals, respectively | - | - | - | - |
| | PC39. apply to identified job openings using offline /online methods as per requirement | - | - | - | - |
| | PC40. answer questions politely, with clarity and confidence, during recruitment and selection | - | - | - | - |
| | PC41. identify apprenticeship opportunities and register for it as per guidelines and requirements | - | - | - | - |
| | NOS Total | 20 | 30 | - | - |
| | *Prepare beverages for the guests* | 10 | 10 | - | 5 |
| | PC1. handle beverage and syrup bottles as per organizational SOP considering their shelf life and storage procedure | - | - | - | - |
| | PC2. prepare drinks as per standard recipe of the bar | - | - | - | - |
| | PC3. use proper glassware to suit the ordered beverage | - | - | - | - |
| | PC4. ensure glassware are sparkling clean and not cracked or chipped | - | - | - | - |
| | PC5. follow standard procedure for mixing, pouring and, garnishing the prepared drinks | - | - | - | - |

| NOS | Assessment Criteria for Outcomes | Theory Marks | Practical Marks | Project Marks | Viva Marks |
|---|---|---|---|---|---|
| | PC6. measure quantity of different beverages for making cocktail/details | - | - | - | - |
| | PC7. prepare the beverages of guest's choice using correct spirit/ beverage and mixes | - | - | - | - |
| | PC8. apply techniques like stirring, shaking, blending, layering, or flaming etc. to make cocktails as per guest's preference | - | - | - | - |
| | PC9. follow specific instructions for preparation of ordered drink | - | - | - | - |
| | PC10. shake the ingredients using a cocktail shaker with ice cubes (for cocktails) as per guest preference | - | - | - | - |
| | PC11. ensure there is no overpouring or spillage of beverage | - | - | - | - |
| | PC12. garnish the drink to make it attractive | - | - | - | - |
| | *Serve the beverages to the guests* | 10 | 10 | - | 5 |
| | PC13. handle the tray as per organizational policy (holding at chest height, above shoulder level) if serving at tables) | - | - | - | - |
| | PC14. hold the glass stem or base of stemmed glasses | - | - | - | - |
| | PC15. use corkscrew, bottle opener, knife, etc. for opening the bottles without any damage | - | - | - | - |
| | PC16. pour the beverage into the guest's glass if order is for wine/beer | - | - | - | - |
| | PC17. ensure there are adequate napkins on the table | - | - | - | - |
| | PC18. follow serving guidelines such as serving on the right-hand side of the guest | - | - | - | - |
| | PC19. handle glasses, bottles as per procedure to avoid contamination | - | - | - | - |
| | PC20. serve the beverages with ice cubes or according to guest's preference | - | - | - | - |
| | PC21. ensure all ordered dish/ complimentary snacks are served along with the beverages | - | - | - | - |
| | PC22. avoid interrupting guests while serving beverages | - | - | - | - |
| | *Handle guest's queries/issues* | 5 | 5 | - | 5 |
| | PC23. inform the bar manager/ other operations department about any issues like brawls, rowdy behaviour, of the guest etc. and resolve them | - | - | - | - |

| NOS | Assessment Criteria for Outcomes | Theory Marks | Practical Marks | Project Marks | Viva Marks |
|---|---|---|---|---|---|
| | PC24. notify the front desk/manager to assist the guest in hiring cab/car to return home, if inebriated | - | - | - | - |
| | PC25. refuse any drink order politely, if guest is inebriated as per organizational protocol | - | - | - | - |
| | PC26. respond to all guest queries | - | - | - | - |
| | *Prepare the bill as per order* | 5 | 5 | - | 5 |
| | PC27. prepare the bill as per SOP | - | - | - | - |
| | PC28. verify the bill detail with the order before presenting it to guests | - | - | - | - |
| | PC29. collect cash and return balance along with the invoice | - | - | - | - |
| | PC30. process payment by card, get signature, and return the card after swipe transaction | - | - | - | - |
| | PC31. bill to room, in case of guests staying in hotel | - | - | - | - |
| | *Perform end of day activity* | 10 | 10 | - | 5 |
| | PC32. ensure the bar is cleaned before closure | - | - | - | - |
| | PC33. clean up and organize the refrigerator and drinks shelves/cabinets | - | - | - | - |
| | PC34. make sure equipment and machines are stripped down, cleaned and sanitized | - | - | - | - |
| | PC35. ensure products are condensed and are properly stored for the next day’s use | - | - | - | - |
| | PC36. put away the products with rotation in mind | - | - | - | - |
| | PC37. wash and store the glassware and other tools safely | - | - | - | - |
| | PC38. empty and clean out the taps for the night | - | - | - | - |
| | PC39. lock and close bar cabinet, refrigerator, etc. | - | - | - | - |
| | PC40. turn off electric signages, lights, ACs, etc | - | - | - | - |
| | PC41. take note of the closing inventory | - | - | - | - |
| | PC42. follow bar closing timings as per regulations | - | - | - | - |
| | NOS Total | 40 | 40 | - | 20 |

# Annexure - III

| Chapter no. | Unit No. | Subject Name | Page No. | Link with QR code | QR code |
|---|---|---|---|---|---|
| Module 1:<br>Role and Responsibilities of Telecom Substrate Design Support Engineer (SDSE) | Unit 1.1:<br>Introduction to Telecom Substrate Design | 1.1.1<br>Understanding Telecom Substrate Design | 23 | https://www.youtube.com/watch?v=DCoZTzMgJOg | Substrate Integrated waveguide |
| Module 1:<br>Role and Responsibilities of Telecom Substrate Design Support Engineer (SDSE) | Unit 1.2:<br>Quality Control and Industry Standards in Telecom Substrate Production | 1.2.2<br>Importance of Quality Control Procedures in Ensuring Functionality and Reliabilityroduction | 23 | https://www.youtube.com/watch?v=0viDDeGLODs | Quality Control |
| Module 1:<br>Role and Responsibilities of Telecom Substrate Design Support Engineer (SDSE) | Unit 1.4:<br>Career Development and Role of Telecom Substrate Design Support Engineer (SDSE) | 1.4.1<br>Professional Growth and Career Prospects for Telecom Substrate Design Support Engineers | 23 | https://www.youtube.com/watch?v=eu86T1AK2Cg | Substrate Integrated Waveguide Design using Ansys HFSS |
| Module 2:<br>Substrate Design Support | Unit 2.1:<br>Telecom IC Requirements and Substrate Design Essentials | 2.1.1<br>Functionalities and Key Parameters of Telecom Integrated Circuits (Ics) | 23 | https://www.youtube.com/watch?v=I7sG0RHvZFY | IC Full Details |
| Module 2:<br>Substrate Design Support | Unit 2.3:<br>Design for Manufacturability (DFM) Principles | 2.3.3<br>Influence of Material Properties on Cost and Performance | 23 | https://www.youtube.com/watch?v=RoTlt1unOMw | Material Property Landscape |

# Annexure - III

| Chapter no. | Unit No. | Subject Name | Page No. | Link with QR code | QR code |
|---|---|---|---|---|---|
| Module 1:<br>Role and Responsibilities of Telecom Substrate Design Support Engineer (SDSE) | Unit 1.1:<br>Introduction to Telecom Substrate Design | 1.1.1<br>Understanding Telecom Substrate Design | 23 | https://www.youtube.com/watch?v=DCoZTzMgJOg | Substrate Integrated waveguide |
| Module 1:<br>Role and Responsibilities of Telecom Substrate Design Support Engineer (SDSE) | Unit 1.2:<br>Quality Control and Industry Standards in Telecom Substrate Production | 1.2.2<br>Importance of Quality Control Procedures in Ensuring Functionality and Reliabilityroduction | 23 | https://www.youtube.com/watch?v=0viDDeGLODs | Quality Control |
| Module 1:<br>Role and Responsibilities of Telecom Substrate Design Support Engineer (SDSE) | Unit 1.4:<br>Career Development and Role of Telecom Substrate Design Support Engineer (SDSE) | 1.4.1<br>Professional Growth and Career Prospects for Telecom Substrate Design Support Engineers | 23 | https://www.youtube.com/watch?v=eu86T1AK2Cg | Substrate Integrated Waveguide Design using Ansys HFSS |
| Module 2:<br>Substrate Design Support | Unit 2.1:<br>Telecom IC Requirements and Substrate Design Essentials | 2.1.1<br>Functionalities and Key Parameters of Telecom Integrated Circuits (Ics) | 23 | https://www.youtube.com/watch?v=I7sG0RHvZFY | IC Full Details |
| Module 2:<br>Substrate Design Support | Unit 2.3:<br>Design for Manufacturability (DFM) Principles | 2.3.3<br>Influence of Material Properties on Cost and Performance | 23 | https://www.youtube.com/watch?v=RoTlt1unOMw | Material Property Landscape |

| | | | | | |
|---|---|---|---|---|---|
| Module 2: Substrate Design Support | Unit 2.5: Layout Refinement, Feedback, and DFM Issue Resolution | 2.5.1 Analyzing feedback from senior designers | 23 | https://www.youtube.com/watch?v=3K_dkmQqyWE | design feedback |
| Module 3: Process Integration and Collaboration | Unit 3.1: Telecom Substrate Design Fundamentals | 3.1.3 Design for Manufacturability (DFM) in Substrate Design | 51 | https://www.youtube.com/watch?v=ypHooP4DFYc | DFM: Design for Manufacturing |
| Module 3: Process Integration and Collaboration | Unit 3.3: Collaborative Problem Solving and Process Improvement | 3.3.4 Collaboration Plans | 51 | https://www.youtube.com/watch?v=004PqWMfshY | Collaboration Plans |
| Module 3: Process Integration and Collaboration | Unit 3.4: Identifying Risks and Improving Production Flow | 3.4.1 Identifying potential bottlenecks and quality risks | 85 | https://www.youtube.com/watch?v=e0lk2D0KI_c | Quality Management - Risk Based Thinking |
| Module 4: Quality Assurance and Documentation | Unit 4.1: Inspection Tools and Techniques | 4.1.1 Tools and Techniques for Ensuring Substrate Quality | 85 | https://www.youtube.com/watch?v=VgrnCg9TSK0 | Beginner substrate method |
| Module 4: Quality Assurance and Documentation | Unit 4.3: Quality Control Procedures and Data Analysis | 4.3.1 Enhancing Substrate Design through Data Analysis and Quality Control | 85 | https://www.youtube.com/watch?v=IEhk5NX0NMs | Design for Quality |
| Module 4: Quality Assurance and Documentation | Unit 4.4: Non-conformance and Communication | 4.4.4 Recognizing Design and Process Standard Deviations in Simulated Scenarios | | https://www.youtube.com/watch?v=VDOLGKnqiko | Standard Deviation ( Sigma ) |

NCVET
कौशल गुणवत्ता प्रगति

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

Telecom
Sector
Skill
Council

**Address:** Estel House, 3rd Floor, Plot No:- 126, Sector 44
Gurugram, Haryana 122003
**Phone:** 0124-2222222
**Email:** tssc@tsscindia.com
**Web:** www.tsscindia.com

Price:

978-1-111-22222-45-7