



(Job Role)

Automotive IIOT Application Technician

(Qualification Pack: ASC/Q6413)

Sector: Automotive

Grade XI



PSS CENTRAL INSTITUTE OF VOCATIONAL EDUCATION

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Automotive IIOT Application Technician (Job Role)

**QUALIFICATION PACK - ASC/Q6413
SECTOR - AUTOMOTIVE**

Draft Study Material for Grade XI



राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद
National Council of Educational Research and Training

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PREFACE

Vocational Education is a dynamic and evolving fields and ensuring that every student has access to quality learning materials is of paramount importance. The journey of the PSS Central Institute of Vocational Education toward producing comprehensive and inclusive study material is rigorous and time-consuming, requiring thorough research, expert consultation, and publication by the National Council of Educational Research and Training (NCERT). However, the absence of finalised study material should not impede the educational progress of our students. In response to this necessity, we present the draft study material, a provisional yet comprehensive guide, designed to bridge the gap between teaching and learning, until the official version of the study material is made available by the NCERT. The draft study material provides a structured and accessible set of materials for teachers and students to utilise in the interim period. The content is aligned with the prescribed curriculum to ensure that students remain on track with their learning objectives.

The contents of the modules are curated to provide continuity in education and maintain the momentum of teaching-learning in vocational education. It encompasses essential concepts and skills aligned with the curriculum and educational standards. We extend our gratitude to the academicians, vocational educators, subject matter experts, industry experts, academic consultants, and all other people who contributed their expertise and insights to the creation of the draft study material.

Teachers are encouraged to use the draft modules of the study material as a guide and supplement their teaching with additional resources and activities that cater to their students' unique learning styles and needs. Collaboration and feedback are vital, therefore, we welcome suggestions for improvement, especially by the teachers, in improving upon the content of the study material.

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MODULE 1**INTRODUCTION TO AUTOMOTIVE IIOT AND TECHNICIAN ROLE****Module Overview**

This module introduces the Indian automobile manufacturing sector, highlighting major OEMs, their products, and industry practices. It provides foundational knowledge of automotive systems, covering key components such as the engine, transmission, brakes, and electrical systems. It also explores emerging technologies including electric vehicles, hybrids, autonomous systems, and connected cars, preparing students for future industry trends.

This module covers the basics of the Industrial Internet of Things (IIOT), its difference from regular IoT and Industry 4.0, and its real-world applications. Students will study how machines, sensors, and networks share data to improve efficiency, with a special focus on IIOT in the automotive industry for smart manufacturing, safety, and predictive maintenance.

Additionally, this module explains the role, responsibilities, and skills required of an Automotive IIOT Application Technician, along with related career opportunities. Students will also understand industry-standard manufacturing and networking procedures essential for modern workplaces.

Learning Outcomes

After completing this module, you will be able to:

- Understand the Indian automobile manufacturing sector, major OEMs, and their products.
- Explain the basic structure, key components, and functioning of automotive systems, along with emerging technologies.
- Understand the core concepts of IIOT, its distinction from IoT and Industry 4.0, and how it functions in real-time industrial environments.
- Recognize and explain the use of IIOT in automotive processes and smart manufacturing.
- Describe the role, responsibilities, and essential skills of an Automotive IIOT Application Technician.

Module Structure

Session 1: Overview of Indian automobile manufacturing market

Session 2: Introduction to the Automotive Industry

Session 3: Introduction to IIOT

Session 4: Role & Responsibilities of an Automotive IIOT Application Technician

SESSION 1: OVERVIEW OF INDIAN AUTOMOBILE MANUFACTURING MARKET

Rahul, a curious 7th-grade student, was amazed when his uncle visited in a new smart, automatic car powered by the Internet of Things (IoT). The car could connect to the internet, unlock with face recognition, check its tire pressure using sensors, and find the best route by sensing live traffic and road conditions. It had advanced features like auto-braking, lane assist, parking sensors, voice commands, and emergency collision alerts.

The engine and parts had IIOT sensors that continuously sent data to the manufacturer for maintenance updates and performance checks.

The car also communicated with nearby traffic signals and charging stations for better energy use and smoother travel. Seeing how IoT made the car safer, smarter, and more efficient, Rahul got inspired and dreamed of building a smart school bus that could drive itself, ensure student safety, and report problems automatically to the school and service center.



The automobile manufacturing industry is one of the most significant sectors of the Indian economy, contributing substantially to industrial growth, employment generation, and exports. Over the years, India has emerged as a major global hub for the production of automobiles and auto components, supported by a large domestic market, a skilled workforce, and a strong manufacturing ecosystem. The industry encompasses a wide range of vehicle segments, including two-wheelers, passenger vehicles, commercial vehicles, and three-wheelers, catering to diverse consumer and business needs. With increasing urbanization, rising disposable incomes, supportive government policies, and advancements in manufacturing technologies, the Indian automobile market continues to expand and evolve. The growing adoption of electric vehicles (EVs), smart manufacturing practices, and sustainable mobility solutions is further shaping the future of the industry.

I often see many types of vehicles like bikes, cars, buses, and trucks on roads. I never knew India is one of the world's largest automobile markets!



1.1 Overview of Indian automobile manufacturing market

India's automobile manufacturing industry is a key contributor to the nation's economy, accounting for nearly 7.1% of the overall GDP and about 49% of the manufacturing GDP. By 2023, India had become the world's third-largest automobile market in terms of sales, surpassing Japan. The sector is broadly divided into four main segments:

- **Two-wheelers:** India is the largest two-wheeler market in the world. In FY 2022–23, over 15.8 million units were sold, with companies like Hero MotoCorp, Bajaj Auto, TVS Motor, and Honda dominating this space. The segment caters largely to middle-income and rural populations due to affordability and fuel efficiency.
- **Passenger vehicles:** The PV segment—including hatchbacks, sedans, and SUVs—sold 3.9 million units in FY 2022–23. Maruti Suzuki remains the market leader, followed by Hyundai, Tata Motors, Mahindra & Mahindra, and Kia. A strong shift is observed toward compact SUVs and electric passenger cars.
- **Commercial vehicles:** India sold around 962,000 CV units in FY 2022–23. Tata Motors and Ashok Leyland dominate this segment. The demand is closely tied to infrastructure development, logistics growth, and mining activities.
- **Three-wheelers:** With over 400,000 units sold, this segment is also witnessing electrification trends, especially in urban transport and last-mile connectivity.

In FY 2024–25, the two-wheeler segment maintained its dominance, with an estimated 18.5 million units sold till now, reinforcing India's position as the world's leading manufacturer and exporter of two- and three-wheelers. The passenger vehicle segment also saw a continued rise, recording sales of approximately 4.4 million units, driven by strong demand for compact SUVs and electric cars.

The commercial vehicle segment reached around 1.1 million units, reflecting steady recovery supported by infrastructure development and logistics growth. The three-wheeler category recorded approximately 500,000 units, with increasing electrification in urban areas and last-mile transport.

The Indian electric vehicle (EV) market is experiencing rapid growth. In FY 2024–25, EV sales rose to approximately 2.1 million units, marking a 33% increase over the previous year. The government's vision aims to make 30% of total vehicle sales electric by 2030, supported by initiatives to build charging infrastructure, domestic battery manufacturing, and EV component production (Fig.1.1).

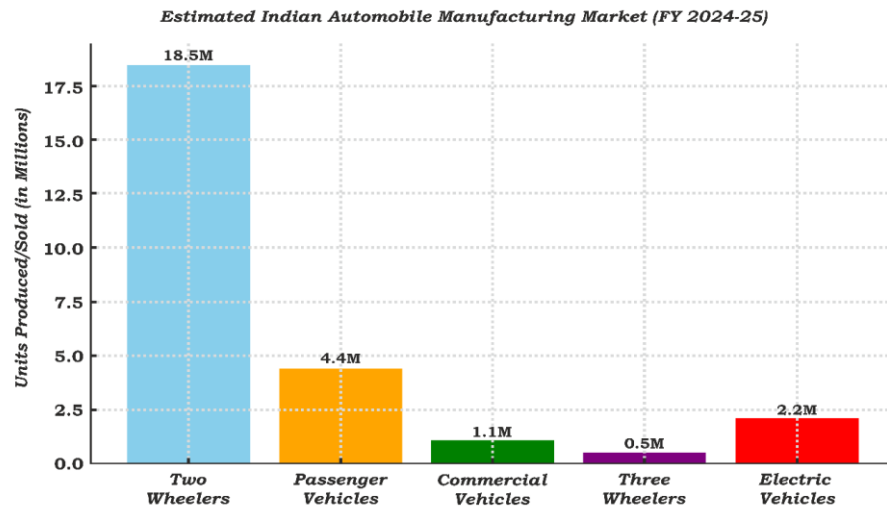


Fig.1.1: Indian Automobile Manufacturing Market during FY 2024-25

Major automobile manufacturing hubs remain concentrated in Maharashtra, Tamil Nadu, Haryana, Gujarat, and Karnataka, which host production facilities for major players like Maruti Suzuki, Tata Motors, Mahindra & Mahindra, Hyundai, Honda, Bajaj Auto, and Hero MotoCorp. Across these regions, India operates over 35 large-scale automobile manufacturing plants, supported by a vast network of component suppliers and engineering service providers. The sector directly and indirectly employs over 37 million people.

To support sustainable growth and global competitiveness, the Government of India has implemented several progressive initiatives:

Make in India: Promotes domestic automotive manufacturing and export capabilities.

FAME II Scheme (Rs.10,000 crore): Encourages faster adoption of electric vehicles by providing subsidies for EVs and infrastructure.

PLI Scheme for the Auto Sector (Rs. 25,938 crore): Offers incentives for advanced automotive technologies, including electric and hydrogen-fueled vehicles.

Additionally, the transition to smart manufacturing and Industry 4.0 practices is gaining momentum. Automotive companies are increasingly integrating AI, IoT, robotics, cloud platforms, and big data analytics to enhance quality control, reduce downtime, and enable predictive maintenance.

Due to increasing urbanization, a growing middle class, and supportive government policies, the automobile industry is expected to grow at a CAGR of 10–12% in the next five years. This growth will help India become a global hub for smart and sustainable mobility solutions. In the last five years, the Indian automobile manufacturing industry has moved from recovery to strong growth (Fig.1.2).

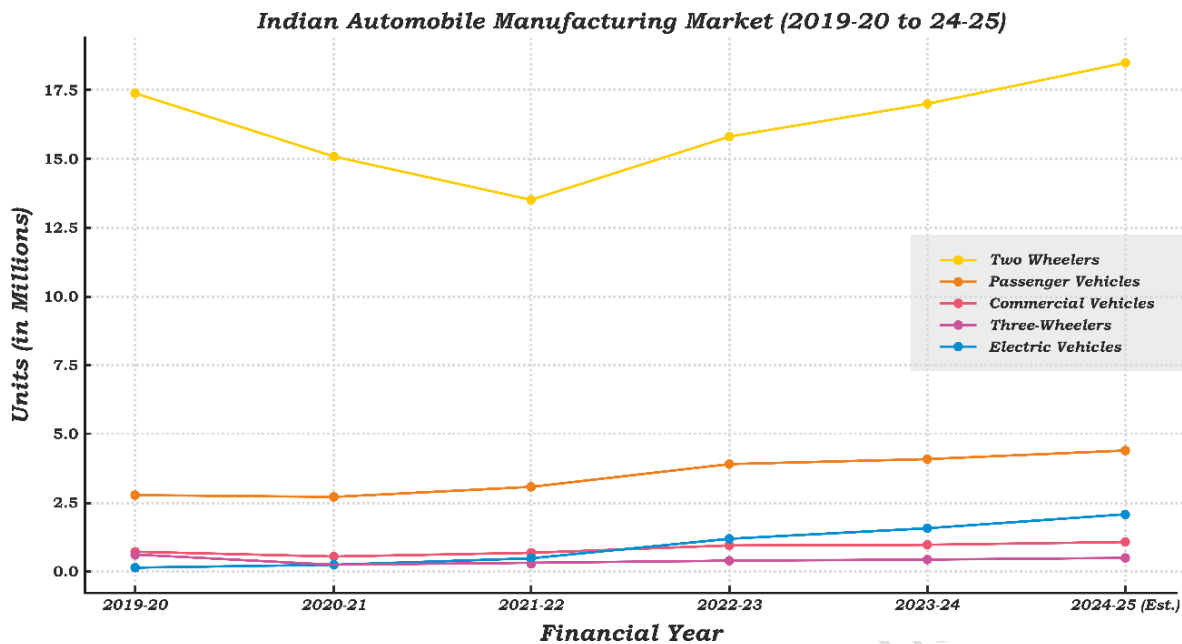


Fig. 1.2: Last Five-Year Growth of Indian Automobile Manufacturing Market

1.2. Study of various automobile Original Equipment Manufacturers (OEMs)

a) Introduction to OEMs in the Automotive Industry

Original Equipment Manufacturers (OEMs) are companies that design, develop, and produce vehicles or vehicle components that are marketed under their own brand names. Original Equipment Manufacturers (OEMs) are the backbone of the automobile industry. They are responsible for the design, engineering, production, and marketing of vehicles and their components. OEMs either manufacture complete vehicles or produce specific modules and components that go into building a vehicle under their brand name. Studying various OEMs helps in understanding different business models, production processes, market segmentation, and technological strategies employed in the global and Indian automobile sectors.

In the context of the automotive sector, OEMs can be classified into two main types:





Full-Vehicle OEMs: Companies that manufacture entire vehicles including engine, chassis, body, interiors, etc.

Component OEMs: Companies that specialize in manufacturing original parts or subsystems like infotainment units, brakes, powertrains, etc.

b) Classification of Automobile OEMs





i) Global OEMs

These companies have a worldwide presence and operate manufacturing plants across multiple countries. They focus on high-volume production, export markets, and cutting-edge technologies like electric vehicles (EVs), autonomous driving, and connectivity. Some examples of global OEMs are:

<p>Toyota (Japan): Known for lean manufacturing and hybrid technologies. Flagship models: Toyota Corolla, Prius, Fortuner.</p>	
<p>Volkswagen Group (Germany): Known for innovation and high build quality. Owns multiple brands, including Audi, Skoda, and Porsche.</p>	
<p>Ford (USA): Pioneers of assembly line production. Focus on trucks and SUVs like F-150, Mustang.</p>	
<p>Hyundai-Kia (South Korea): Rapidly growing global OEM with strong design and affordability.</p>	

ii) Indian OEMs

These companies are based in India and cater mainly to domestic and South Asian markets. Many are now expanding globally and investing in EVs and digital technologies. Examples of Indian OEMs are:

<p>Tata Motors: A leading Indian OEM known for cars like Tiago, Nexon, and heavy-duty trucks. Owner of Jaguar Land Rover (UK).</p>	
<p>Mahindra & Mahindra: Strong presence in SUVs and tractors. Expanding into electric mobility through Mahindra Electric.</p>	
<p>Maruti Suzuki: A joint venture between Maruti and Suzuki (Japan). Dominant player in Indian passenger vehicle market.</p>	
<p>Ashok Leyland: Major player in commercial vehicles like buses and trucks.</p>	

iii) Joint Ventures and Collaborations

Many OEMs form joint ventures to share technology, reduce costs, and enter new markets, for example:

- Maruti Suzuki India Ltd. (Suzuki + Indian Govt.)
- Toyota Kirloskar Motor (Toyota + Kirloskar Group)
- Renault-Nissan Alliance (Global partnership with operations in India)

c) Key Functions of Automobile OEMs

Product Design and Development

OEMs carry out extensive research and development (R&D) to design vehicles with improved aesthetics, performance, fuel efficiency, and safety. For example, Tata Motors developed the Nexon EV as part of its electric mobility program with in-house battery management systems.

Manufacturing and Assembly

Modern OEMs utilize automation, robotics, and Industry 4.0 practices to enhance productivity and reduce errors. Plants are equipped with robotic arms, programmable logic controllers (PLCs), and IIOT systems. Like as Toyota's production system (Lean Manufacturing) has become a benchmark for efficient production.

Supply Chain and Vendor Management

OEMs coordinate with Tier 1, Tier 2, and Tier 3 suppliers for various components. Tier 1 suppliers provide complete systems or modules like ABS or engine assemblies. Tier 2 and Tier 3 vendors support by supplying sub-components, raw materials, and parts.

Marketing, Sales, and After-Sales Support

OEMs create a network of dealers and service centres to reach customers and provide long-term support. Warranty, free servicing, and spare parts availability are critical for customer satisfaction.

Innovation and Sustainability

OEMs are increasingly investing in green technologies such as:

- Battery Electric Vehicles (BEVs)
- Plug-in Hybrids (PHEVs)
- Hydrogen Fuel Cell Vehicles

For example, Hyundai's NEXO and Toyota's Mirai are hydrogen-based vehicles.

d) Contribution to Indian Economy and Exports

OEMs in India contribute significantly to GDP and employment. India is emerging as a global hub for small car and two-wheeler production. Exports by Indian OEMs are increasing in regions like Africa, Southeast Asia, and South America.



- Think of a car you know. What parts or systems in it might be built by different OEMs?
- What if all cars in India suddenly became electric?

PRACTICAL ACTIVITY

ACTIVITY 1:

Identification of Two-Wheeler and Four-Wheeler Manufacturers in The School Parking Area

Objective: To identify different automobile manufacturers and classify vehicles based on their type and brand.

Materials Required

- Notebook
- Pen/Pencil

Procedure:

Step 1: Form Groups

Divide the class into small groups of 3–4 students to facilitate observation and teamwork.

Step 2: Visit the Parking Area

Each group visits the school parking area with the required materials.

Step 3: Identify the Vehicles

Observe the vehicles parked in the area and identify:

- Type of vehicle (Two-Wheeler or Four-Wheeler)
- Manufacturer name from the logo or badge
- Vehicle model (if visible)

Examples of manufacturers include Hero, Honda, Bajaj, TVS, Maruti Suzuki, Tata Motors, Hyundai, Mahindra, etc.

Step 4: Record the Observations

Prepare a table in the notebook and record the collected information.

S. No.	Vehicle Type (2W/4W)	Vehicle Model	Manufacturer Name
1			
2			
3			

Step 5: Verify Information

If the manufacturer logo or brand name is unclear, verify it by:

- Comparing it with known vehicle logos, or
- Politely asking the vehicle owner (if available).

Step 6: Categorize and Count

Count the number of vehicles belonging to each manufacturer and categorize them as two-wheelers or four-wheelers.

Example:

- Hero – 8 Two-Wheelers
- Honda – 6 Two-Wheelers
- Maruti Suzuki – 5 Four-Wheelers
- Tata Motors – 3 Four-Wheelers

Step 7: Prepare a Summary

Create a summary showing:

- List of manufacturers identified
- Number of vehicles from each manufacturer

Represent the findings using a simple **bar graph** or **pie chart**.

Step 8: Group Discussion and Presentation

Each group presents its observations and findings to the class. Discuss:

- Which manufacturer was most common?
- Why certain brands may be more popular than others?
- Differences observed between two-wheeler and four-wheeler manufacturers.

ACTIVITY 2:**Identification of EV and Non-EV Vehicles**

Objective: To identify and differentiate Electric Vehicles (EVs) and Non-Electric Vehicles (Non-EVs) based on observable features.

Materials Required

- Notebook
- Pen/Pencil

Procedure:**Step 1: Visit the Parking Area**

Go to the school parking area and observe the parked vehicles.

Step 2: Observe the Number Plate

Identify the type of vehicle based on the color of the number plate:

- Green Number Plate → Electric Vehicle (EV)
- White, Yellow, or Black Number Plate → Non-Electric Vehicle (Non-EV)

Step 3: Check for Vehicle Badges or Stickers

Look for labels or markings on the vehicle:

- “EV”, “Electric”, or “Zero Emission” → EV

- “Petrol”, “Diesel”, or “CNG” → Non-EV

Step 4: Observe the Exhaust System

Examine the vehicle for the presence of an exhaust pipe:

- **No exhaust pipe** → EV
- **Exhaust pipe present** → Non-EV

Step 5: Record the Observations

Prepare an observation table in your notebook and record the details.

Observation Table:

S. No.	Vehicle Type (2W/4W)	Vehicle Name/Model	EV/Non-EV	Identification Method
1				
2				
3				

Step 6: Analyze the Data

Count the total number of:

- Electric Vehicles (EVs)
- Non-Electric Vehicles (Non-EVs)

Prepare a simple summary showing the number of EVs and Non-EVs observed in the parking area.

Step 7: Class Discussion

Discuss the observations with the class:

- Which type of vehicle was more common?
- What are the visible differences between EVs and Non-EVs?
- Why is the adoption of EVs increasing?

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. Examine the vehicle sales trends for FY 2024–25 and identify which segment shows the highest consumer demand and market share.
 - a) Commercial Vehicles
 - b) Three-Wheelers
 - c) Passenger Vehicles
 - d) Two-Wheelers
2. Identify which scheme directly supports the adoption and manufacturing of electric vehicles in India.
 - a) Smart Bharat Yojana

- b) FAME II
c) Ayushman Bharat
d) Swachh Vehicle Mission
3. Considering India's automobile industry structure, identify the company that represents a domestic Original Equipment Manufacturer (OEM) contributing to local vehicle production.
a) Toyota
b) Hyundai
c) Tata Motors
d) Volkswagen
4. Based on economic data, identify the approximate percentage contribution of the automobile sector to India's GDP.
a) 4.5%
b) 7.1%
c) 10.2%
d) 12%
5. To align with national sustainability goals, by 2030 what percentage of total vehicle sales should be electric, as targeted by the Government of India?
by 2030?
a) 15%
b) 20%
c) 25%
d) 30%

B. Match the following

Column A	Column B
1. IIOT (Industrial Internet of Things)	A. Company that produces parts or complete vehicles under its own brand
2. OEM (Original Equipment Manufacturer)	B. Hyundai-Kia
3. Make in India	C. Uses sensors and connected devices to automate industrial processes
4. Tata Motors	D. Promotes domestic automotive manufacturing and export capabilities
5. Indian OEMs	E. A leading Indian automobile manufacturer

C. Fill in the blanks

- The automobile sector contributes approximately _____% to India's GDP.
- Passenger vehicle sales in FY 2022–23 were about _____ million units.
- The commercial vehicle segment demand is closely linked to _____ development and logistics growth.

4. The PLI scheme supports advanced automotive technologies including _____ and hydrogen-fueled vehicles.
5. India operates more than _____ large-scale automobile manufacturing plants across major hubs.

D. Answer the following

1. How would you describe the major segments of the Indian automobile industry when analyzing its overall structure and product diversity?
2. In what way does the dominant segment of the Indian automobile market reflect consumer preferences and economic factors?
3. When identifying suitable locations for new automobile plants, what factors would guide your selection of leading manufacturing states in India?
4. Imagine the Indian automobile industry faces rising production costs and supply chain delays. What challenges might result, and how could they be managed effectively?
5. While studying India's electric vehicle roadmap, how would you explain the importance of government initiatives in supporting EV growth and adoption?

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SESSION 2: INTRODUCTION TO THE AUTOMOTIVE INDUSTRY

Ravi, a curious schoolboy, loved toy cars and always wondered how real cars worked. One day, his science teacher explained the Automotive System like a human body. The power train was like muscles, helping the car move using engines and wheels. The chassis system acted like the skeleton, giving shape and support. The braking and steering systems worked like arms and legs, helping the car stop and turn. Inside, the electrical and electronics system was like the brain and nerves, powering lights, music, and windows. The control and communication system used smart computers called ECUs to talk to each part of the car, like teamwork. The HVAC and comfort

system kept passengers cool, warm, and entertained. Lastly, the body and safety systems kept everyone safe with seatbelts, airbags, and strong panels. Ravi was amazed—he never imagined his toy car had so much going on inside!



1.3 Introduction to Automotive System

Automotive system is an integration or combination of mechanical, electrical, and electronic subsystems that work collectively to perform a task that consists of vehicle performance, safety, comfort, and other related features. These components are meticulously planned to convert energy to movement, control the vehicle, protect it and add to a user's driving experience.

The modern vehicles are not mere mechanical machine, but they are complex mechatronics systems with sophisticated sensor, interaction, connectivity and automation capabilities (Fig.1.3).

It is necessary to understand automotive systems for:

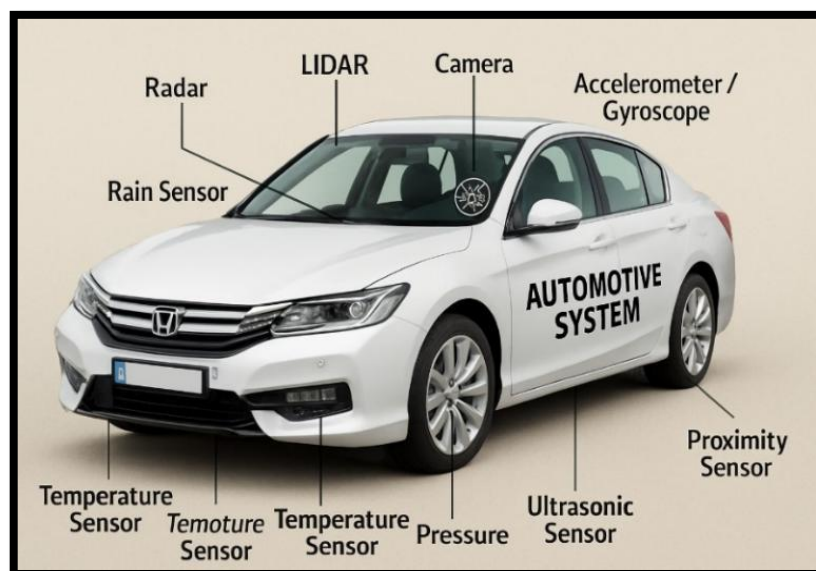


Fig. 1.3: Automotive System

- Troubleshoot and fix vehicle problems.
- Developing cutting-edge automotive technology.
- Safe, efficient, and sustainable transportation across the state.
- Adjusting to an era of electric and self-driving cars.

The automotive systems have undergone a rapid development in the past few decades. They have moved from purely mechanical systems to intelligent machines consisting of sensors, microcontrollers and software.

A vehicle works like the human body. The engine acts like muscles, the chassis like a skeleton, and electronic systems like the brain!

1.4 Basic Components of Automotive System

An automotive control system may be generally organized into a variety of main components with different functions:

a) Power train:

Did You Notice?

When we press the accelerator of a vehicle, the engine generates power and sends it to the wheels to move the vehicle.



This system is responsible for generating power and delivering it to the wheels. Engine used in this system is Internal combustion engine (ICE) that can be petrol, diesel, hybrid, or electric vehicle (EV). The drive train consists of drive shaft, differential, and axles, which transmit power to the wheels.

b) Chassis System: The chassis serves as the foundation for all other systems in the vehicle.

Suspension System: Shock absorbers deliver a smooth ride for vehicle occupants.

Braking System: Compels the bike to slow down smoothly (disc, drum, ABS).

Steering System: By allowing driver to guide the vehicle in the direction of choice.

Frame: The base structural component holding everything together.

c) Electrical and Electronics System: The system energizes electrical components while maintaining vehicle automation. Electric power delivery and management functions are performed by both battery and alternator systems. The lighting system

comprises an intricate assembly of headlights, indicators, and brake lights. Wiring Harness transmits electrical signals throughout the vehicle network. Electronic Control Units (ECU) manage systems ranging from engine performance to window operations and infotainment controls.

d)Control and Communication System: Modern automobiles depend on instantaneous data communication combined with automated functions.

Microcontrollers & ECUs: Control separate systems such as engine components, braking mechanisms, and infotainment units.

Communication Protocols: CAN (Controller Area Network), LIN, FlexRay.

Drive-by-wire Systems: Traditional mechanical connections give way to electronic control systems.

e) Heating, Ventilation, Air Conditioning (HVAC) and Comfort Systems: These systems enhance user experience by boosting both comfort and usability.

Climate Control (HVAC): Oversees the intricate systems of heating, ventilation, and air conditioning management.

Infotainment Systems: The system integrates audio and video functions with navigation tools and smart connectivity features.

The arrangement of dashboard controls combined with driver assistance systems and seat comfort creates an intricate ergonomic design.

f) Body and Safety Systems: The exterior body serves as a protective shell for passengers while simultaneously boosting aerodynamic efficiency.

Crash Protection Systems: Crumple zones, airbags, seat belts.

Active and Passive Safety Systems: ABS, ESP, airbags, seatbelt tensioners.

Body Panels and Structure: Fabricated using steel, Aluminium, or composite materials. These parts are shown in Fig.1.4.

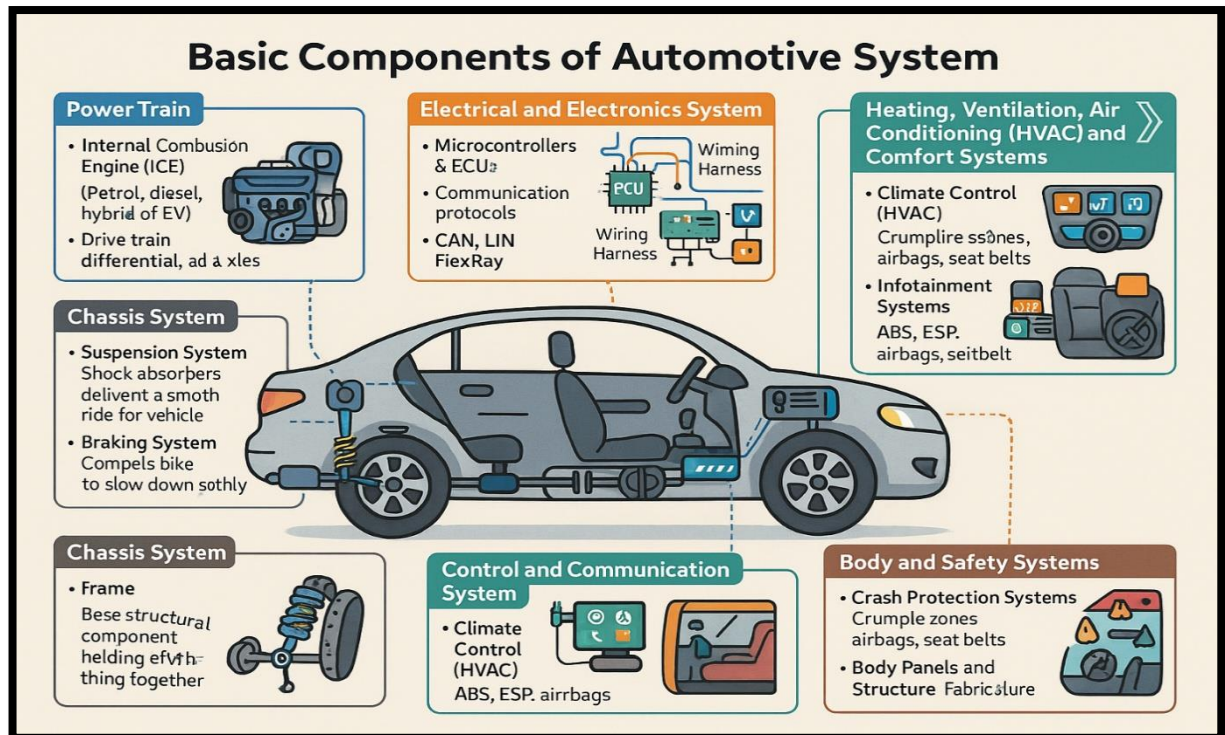


Fig. 1.4: Basic Components of Automotive System

1.5 Emerging Technologies in Automotive Systems

The automotive industry is experiencing major technological changes to improve efficiency, safety, user experience, and reduce environmental impact. Modern vehicles are now becoming intelligent and connected systems instead of just mechanical machines. These new technologies are changing the future of transportation and the way vehicles operate (Fig. 1.5).

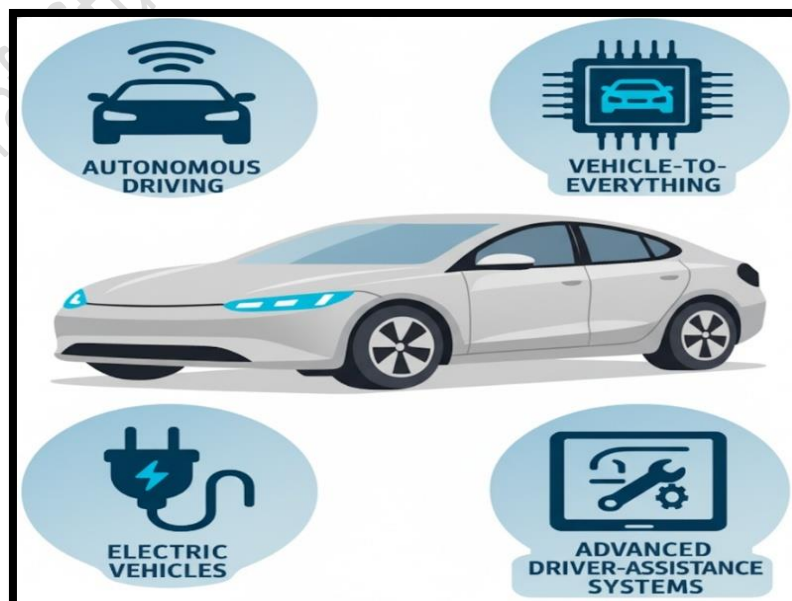


Fig.1.5: Emerging Technologies in Automotive Systems

Electric Vehicles (EVs)

Electric vehicles are among the most significant developments in the automotive sector. Unlike traditional vehicles that use petrol or diesel, electric vehicles (EVs) operate using electric motors and rechargeable batteries. This technology helps in significantly reducing air pollution and greenhouse gas emissions (Fig.1.6).

With improvements in battery technology, such as lithium-ion and solid-state batteries, modern EVs offer higher energy efficiency, longer driving ranges, and faster charging times. As charging infrastructure expands, EVs are becoming more accessible and practical for everyday use.

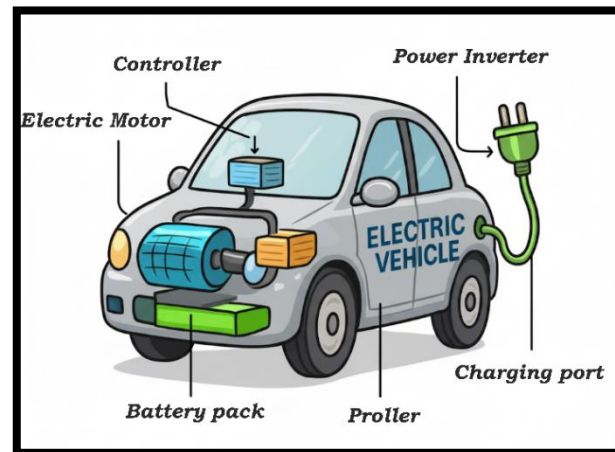


Fig. 1.6: Electric Vehicles (EVs)

Around Us

Electric scooters and cars are becoming common because they reduce pollution and save fuel costs.

Hybrid Vehicles

Hybrid vehicles combine an internal combustion engine with one or more electric motors. These vehicles switch between or combine power sources to improve fuel efficiency and reduce emissions. Common types include mild hybrids, full hybrids, and plug-in hybrids. Hybrid technology serves as a transitional step between traditional fuel-powered vehicles and fully electric vehicles, offering better mileage without fully depending on battery charging infrastructure.

Autonomous Driving Technologies

Imagine This!

What if a car could drive itself safely without human control? Modern autonomous vehicles use sensors, cameras, and AI to make this possible.



Autonomous or self-driving vehicles use technologies such as cameras, radar, LiDAR, GPS, and artificial intelligence to understand their surroundings and move without human control. These systems range from basic driver assistance features, like lane-keeping and cruise control, to fully automated driving. Their main aim is to reduce accidents caused by human error, improve mobility for people who cannot drive, and make traffic flow more efficient. Although fully self-driving vehicles are still being tested and regulated, many modern vehicles already use partial automation features.

Connected Vehicles and V2X Communication

Connected vehicles use internet and wireless communication technologies to share data with other vehicles, road infrastructure, and cloud platforms. This system, known as V2X (Vehicle-to-Everything), provides features such as real-time traffic updates, hazard warnings, remote diagnostics, navigation assistance, and software updates. Continuous data exchange helps improve driver safety, traffic management, and vehicle performance.

Advanced Driver Assistance Systems (ADAS)

ADAS (Advanced Driver Assistance Systems) are technologies that improve vehicle safety and driving comfort by helping the driver in real time. These systems include features such as adaptive cruise control, automatic emergency braking, blind-spot detection, lane departure warning, and parking assistance. ADAS uses sensors and smart algorithms to monitor the surroundings and help prevent accidents. Today, these features are commonly available in many mid-range and premium vehicles.

Artificial Intelligence (AI) and Machine Learning (ML)

AI and machine learning are playing an increasingly important role in automotive development. AI is used for voice recognition, driver behaviour monitoring, predictive maintenance, and personalized infotainment systems. Machine learning helps in analyzing large amounts of sensor data for better decision-making in autonomous driving and system optimization. These technologies enable smarter, more responsive, and more user-friendly vehicle systems.

Look Around You



- Visit a nearby parking lot and count how many two-wheelers and cars are there. Which brand is most common?
- Find out if there are any electric vehicle (EV) charging stations near your school or home. Are they easy to access?

PRACTICAL ACTIVITY

ACTIVITY 1:

Identification of Parts of an Automotive System

Objective: To identify and name the major parts of an automotive system from the given image.

Materials Required:

- Automotive system image/diagram
- Notebook
- Pen/Pencil

Procedure:

Step 1: Observe the Image

Step 2: Identify the Components

Step 3: Name the Parts in the space provided in the image.











CHECK YOUR PROGRESS**A. Multiple Choice Questions**

1. While selecting materials for designing a car body, which material would *not* be considered based on common industrial practices mentioned for body panels and structure?
 - a) Steel
 - b) Aluminium
 - c) Composite materials
 - d) Titanium
2. Suppose a vehicle workshop is transitioning to eco-friendly transport solutions. Which power system should be implemented for electric vehicles?
 - a) Diesel engines
 - b) Petrol engines
 - c) Electric motors and rechargeable batteries
 - d) Compressed air
3. When developing a hybrid vehicle prototype, which combination of power systems would best represent its operation?
 - a) Two petrol engines
 - b) An internal combustion engine with one or more electric motors
 - c) Diesel and petrol tanks
 - d) Gas turbine and solar panels
4. A new car model includes lane departure warning and automatic emergency braking features. Under which vehicle system category would these technologies be applied?
 - a) ADAS
 - b) V2V
 - c) HVAC
 - d) ECU functions
5. During the design of an autonomous vehicle, which technologies should be integrated for accurate perception and navigation in real-time traffic environments?
 - a) LiDAR, GPS, and AI
 - b) Solar panels and wind sensors
 - c) Thermal imaging only
 - d) ABS and ESP

B. Match the following

Column A	Column B
1. Power train	A. Systems of heating, ventilation, and air conditioning management
2. ECU	B. Exchanges data with vehicles and infrastructure
3. HVAC	C. Uses AI, sensors, GPS for navigation
4. V2X Communication	D. Controls engine, breaking, infotainment
5. Autonomous Driving	E. Generates and delivers power to wheels

C. Fill in the blanks

- An automotive system is an integration of _____, _____, and _____ subsystems.
- Modern vehicles are complex _____ systems with sensors, interaction, connectivity, and automation.
- ECU stands for _____.
- Electric vehicles are powered by _____ motors and _____ batteries.
- Hybrid vehicles combine an internal combustion engine with one or more _____ motors.

D. Answer the following

- How would you describe the functioning of an automotive system to show how its parts work together efficiently?
- In what way do the main subsystems of vehicles such as engine, transmission, and electrical systems etc., contribute to its overall performance?
- When integrating communication between sensors and controllers, how would you decide which automotive communication protocol to use?
- Imagine designing a car with ADAS features. How could these systems improve driver safety and comfort?
- While developing a smart vehicle, explain how AI applications could enhance driving experience and vehicle diagnostics?

SESSION 3: INTRODUCTION TO IIOT

Riya was a curious 12-year-old girl who loved machines and how they worked. One day, her uncle, who was an engineer, took her to a chocolate factory. But this wasn't an ordinary factory—it was a **smart factory** powered by something called **IIOT!**

As they walked in, Riya saw machines moving on their own, conveyor belts stopping and starting perfectly, and robots packing chocolates faster than human hands ever could.

“How do they all know what to do?” Riya asked.

Her uncle smiled and said, “Because they talk to each other!”

Riya laughed, “Machines talk?!”

“Yes,” said her uncle. “In this factory, all machines have tiny sensors. These sensors collect data like temperature, speed, and timing. Then they send this data to a central computer using something called the **Industrial Internet of Things**, or **IIOT.**”

He showed her a screen where data from all the machines was being monitored in real-time. “If a machine is too hot, the system alerts the engineers. If a part is about to break, it tells us before it stops working!”

Riya's eyes lit up. “So, the factory can fix problems before they even happen?”

“Exactly!” her uncle said. “IIOT helps save time, reduce waste, and keep workers safe.” That day, Riya decided that she would grow up to build smart machines that could “talk” just like in the chocolate factory.



Today's industries are becoming smarter and more connected, thanks to the use of advanced technologies like the Industrial Internet of Things (IIOT). IIOT connects machines, sensors, and systems to collect and share data in real-time, helping

industries improve efficiency, safety, and decision-making. This module introduces the basic concepts of IIOT, how it works, and how it differs from regular IoT and Industry 4.0. It also explores practical applications of IIOT, with a special focus on its growing role in the automotive industry.

Real-Life Connection

In smart factories, machines can communicate with each other using sensors and internet technology to improve production.

1.6 Basic Concept of IIOT

Have you ever wondered how modern factories can detect machine problems before a breakdown occurs? The answer lies in the **Industrial Internet of Things (IIOT)**.

The Industrial Internet of Things (IIOT) is the use of smart sensors, machines, and communication technologies to collect, share, and analyze data in industrial environments. It connects physical equipment with digital systems, enabling industries to monitor operations and make informed decisions based on real-time information.

The main idea behind IIOT is that connected machines can continuously generate valuable data about their performance and operating conditions. This data can be analyzed to identify trends, detect abnormalities, and provide insights that help improve industrial processes.

By using IIOT, industries can:

- ✓ Monitor equipment performance in real time
- ✓ Detect problems before they lead to failures
- ✓ Reduce downtime and maintenance costs
- ✓ Improve productivity and product quality
- ✓ Optimize energy and resource utilization
- ✓ Support faster and more accurate decision-making

For example, a vibration sensor installed on a motor can continuously monitor its condition. If abnormal vibrations are detected, the system can alert the maintenance team before the motor fails, preventing costly breakdowns and production interruptions.

Today, IIOT is widely used in manufacturing, asset tracking, energy management, quality monitoring, predictive maintenance, and supply chain management. By enabling smarter operations and data-driven decision-making, IIOT helps industries become more efficient, reliable, and competitive.

1.7 Working of IIOT

IIOT is a network of interconnected smart devices, machines, sensors, and software systems that work together to collect, exchange, monitor, and analyze data in real time). By enabling seamless communication between industrial assets, IIOT helps organizations improve operational efficiency, productivity, and decision-making.

A typical IIOT ecosystem consists of the following key components:

- **Smart Devices and Sensors:** Devices equipped with sensing, processing, and communication capabilities that collect data from machines, equipment, and industrial processes.
- **Communication Infrastructure:** Wired or wireless networks that facilitate the secure transfer of data between devices, machines, gateways, and cloud platforms. This infrastructure may be public or private depending on organizational requirements.
- **Data Storage:** Storage systems such as cloud platforms, databases, or on-premise servers that securely store the large volumes of data generated by IIOT devices.
- **Analytics and Applications:** Software tools and applications that process and analyze collected data to generate meaningful insights, reports, and actionable information.
- **People:** Operators, maintenance personnel, engineers, managers, and decision-makers who use the generated insights to monitor operations and make informed decisions.

The working of an IIOT system can be understood through the following data flow:

Sensors and Smart Devices → **Communication Network** → **Data Storage** → **Analytics and Applications** → **People and Business Actions** (refer Fig. 1.7)

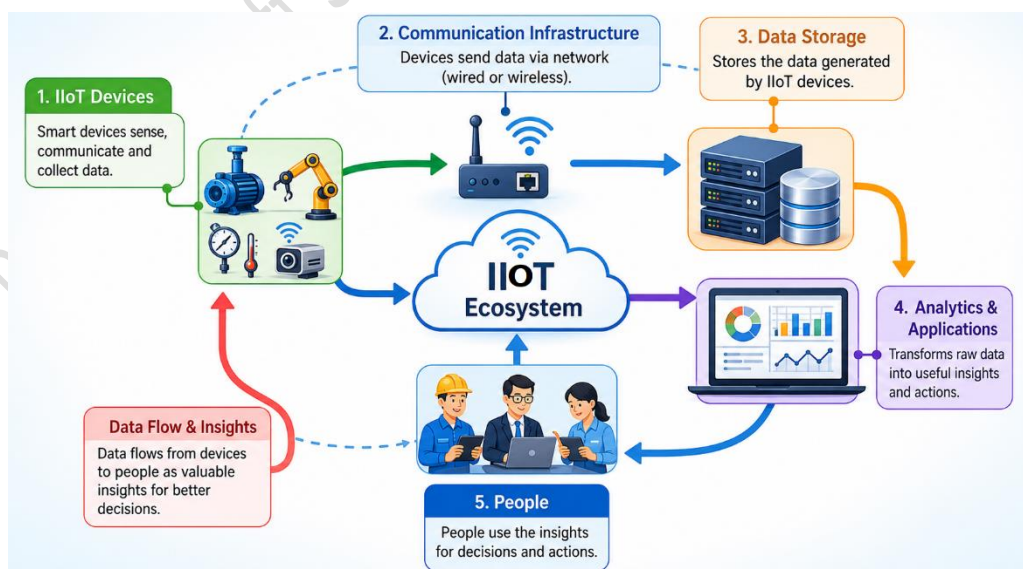


Fig.1.7: IIOT Ecosystem

In an IIOT system, sensors and smart devices continuously collect operational data from industrial equipment. This data is transmitted through the communication network to storage and analytics platforms, where it is processed and transformed into useful information. The resulting insights help organizations monitor equipment health, detect abnormalities, predict potential failures, optimize maintenance schedules, improve production efficiency, and enhance overall business performance.

1.8 Difference between IoT and IIOT

The Internet of Things (IoT) and the Industrial Internet of Things (IIOT) are technologies that enable devices to connect, communicate, and exchange data. While IoT is commonly associated with consumer applications such as smart homes and wearable devices, IIOT is applied in industrial environments such as manufacturing, energy, transportation, and infrastructure. IIOT uses connected sensors, machines, and automation systems to monitor processes, collect operational data, and support informed decision-making. The key differences between IoT and IIOT are summarized in Table 1.1.

Table 1.1.: Difference between IoT and IIOT

Feature	IoT (Internet of Things)	IIOT (Industrial Internet of Things)
Purpose	Connects everyday devices to improve convenience and user experience.	Connects industrial machines and systems to improve productivity, efficiency, and reliability.
Environment	Homes, offices, smart buildings, and personal spaces.	Factories, manufacturing plants, warehouses, power plants, and oil refineries.
Devices Used	Smartphones, smart TVs, wearable devices, smart speakers, home appliances.	Sensors, actuators, PLCs, SCADA systems, industrial robots, and machines.
Data Type	Mostly consumer and lifestyle data.	Critical operational and process data.
Reliability Requirement	Moderate reliability; occasional downtime is acceptable.	High reliability; downtime can lead to production losses.
Performance Requirement	General-purpose performance.	High-speed, real-time performance with low latency.
Security Requirement	Standard security measures.	Advanced security due to critical industrial operations.
Connectivity	Wi-Fi, Bluetooth, Zigbee, Cellular networks.	Ethernet/IP, PROFINET, Modbus, OPC UA, 5G, Industrial Ethernet.
Data Processing	Usually cloud-based for user insights.	Edge and cloud-based for real-time monitoring and control.
Typical Applications	Smart homes, fitness trackers, smart appliances, connected vehicles.	Predictive maintenance, asset tracking, process optimization, condition monitoring.
Impact of Failure	Causes inconvenience to users.	May cause production loss, safety risks, and financial losses.
Primary Goal	Improve convenience and quality of life.	Improve operational efficiency, productivity, and business performance.

1.9 IIOT applications and examples

The Industrial Internet of Things (IIOT) connects industrial machines, sensors, and software systems to enable real-time data collection, communication, and analysis. By providing continuous visibility into operations, IIOT helps improve efficiency, reliability, safety, and automation across industries such as manufacturing, energy, transportation, and logistics. Common IIOT applications include predictive maintenance, remote monitoring, asset tracking, and energy management. Real-world examples of IIOT can be found in smart factories, power grid monitoring systems, and intelligent logistics networks. (Fig. 1.8).

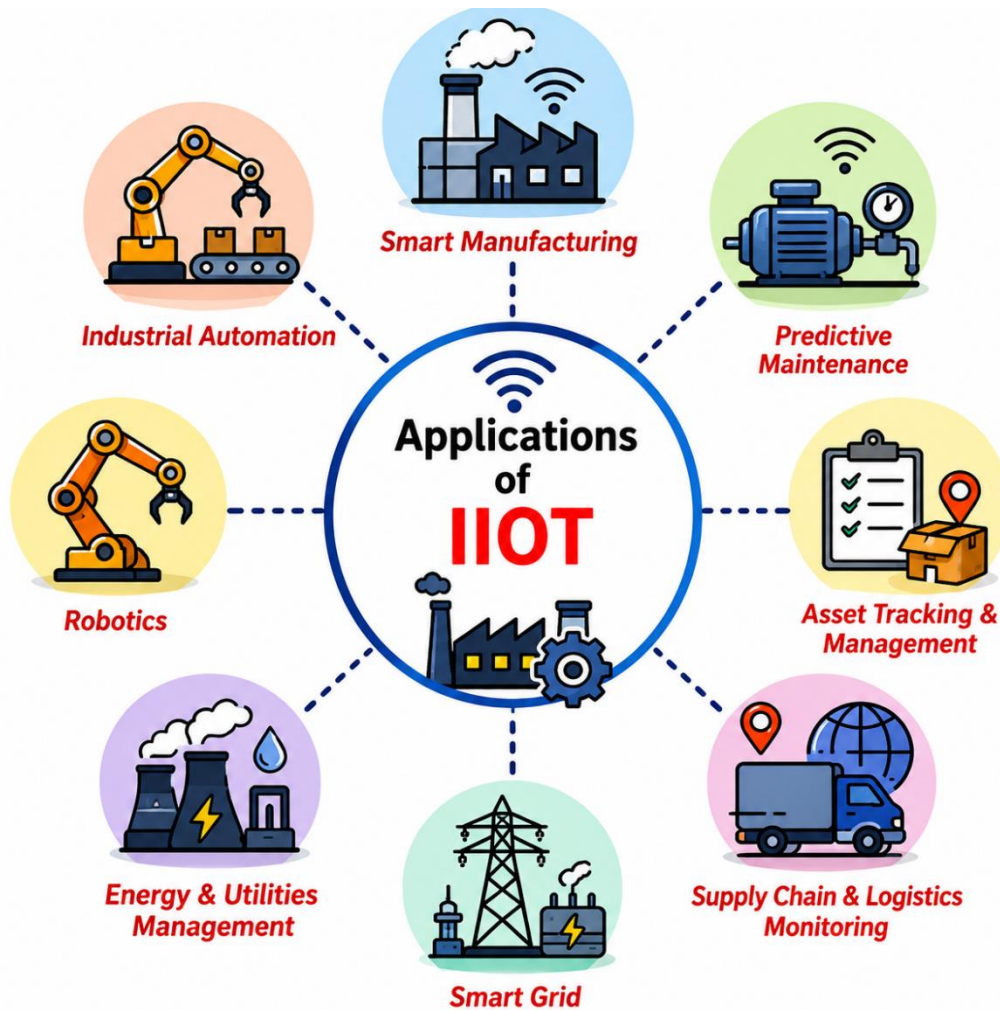


Fig. 1.8: Applications of IIOT

1.10 Applications of IIOT in the Automotive

The automobile sector is rapidly evolving with the integration of Industrial Internet of Things (IIOT) technology. IIOT offers improved communication between machines, systems, and people, allowing automobile makers to boost production, cut costs, and enhance safety. Below are important uses of IIOT in the automotive sector:

A) Predictive Maintenance

Think About It!

Wouldn't it be helpful if machines could tell us about a problem before they stop working?

IIOT helps monitor the health of machines and vehicles through sensors that track parameters like temperature, vibration, oil level, and motor speed. These sensors send real-time data to cloud platforms or on-premises systems, where analytics detect unusual patterns. This allows technicians to predict equipment failures before they occur, thus avoiding unexpected breakdowns and reducing downtime and maintenance costs in both manufacturing equipment and vehicles (Fig.1.9).



Fig. 1.9: Predictive Maintenance

B) Smart Manufacturing and Automation

Modern automotive manufacturing relies on automated assembly lines with robotic arms, conveyor systems, and CNC machines. IIOT connects these machines into a single network, allowing them to communicate and coordinate. For example, if one machine slows down, the rest of the line can adjust automatically. This improves production speed, reduces human error, and ensures high-quality output (Fig.1.10).

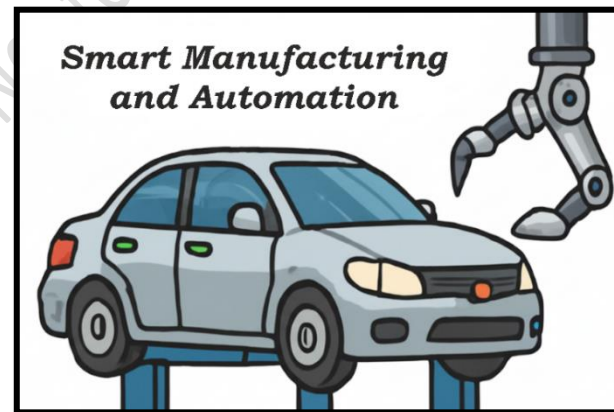


Fig. 1.10: Smart Manufacturing and Automation

Have You Observed?

Robotic arms in factories can perform welding, painting, and assembly operations faster and more accurately than humans.

C) Quality Control and Inspection

IIOT is used to monitor quality at every stage of vehicle manufacturing. High-resolution cameras and smart sensors check dimensions, surface finish, paint quality, and proper assembly. Real-time data collection helps identify defects early, preventing faulty products from reaching the market. Data-driven quality assurance improves customer satisfaction and reduces recall costs (Fig.1.11).



D) Supply Chain and Inventory Management

Automotive manufacturing depends on complex supply chains with thousands of parts. IIOT enables real-time tracking of materials and components using RFID, barcode scanners, and GPS sensors. Manufacturers can monitor inventory levels, delivery schedules, and warehouse conditions. This minimizes delays, avoids overstocking or stockouts, and ensures a smooth flow of parts to the assembly line (Fig.1.12).



Fig.1.12: Supply Chain and Inventory Management

E) Vehicle Telematics and Post-Sale Monitoring

IIOT extends beyond manufacturing to the vehicles themselves. Telematics systems collect data from onboard sensors after the vehicle is sold. This includes information on engine performance, fuel efficiency, driving behavior, and maintenance needs. Manufacturers can use this data to improve future designs; plan recalls more efficiently and offer personalized services to customers (Fig.1.13).

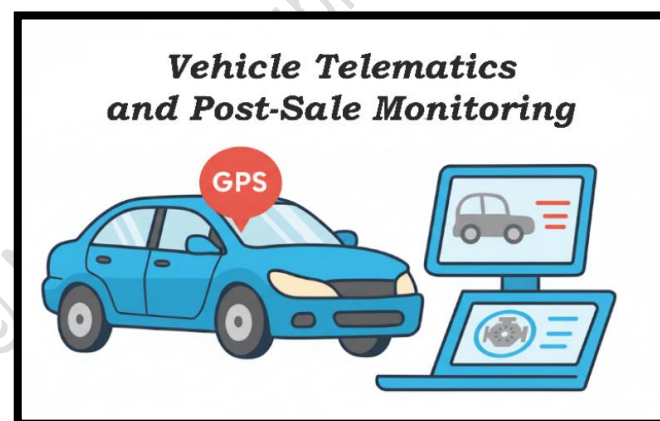


Fig. 1.13: Vehicle Telematics and Post-Sale Monitoring

F) Energy Management in Factories

Automotive plants consume large amounts of energy for welding, painting, and machining. IIOT systems track energy usage in different departments and equipment. Real-time insights help managers identify energy leaks, optimize usage, and reduce electricity costs. This also supports environmental goals and compliance with green manufacturing standards (Fig.1.14).

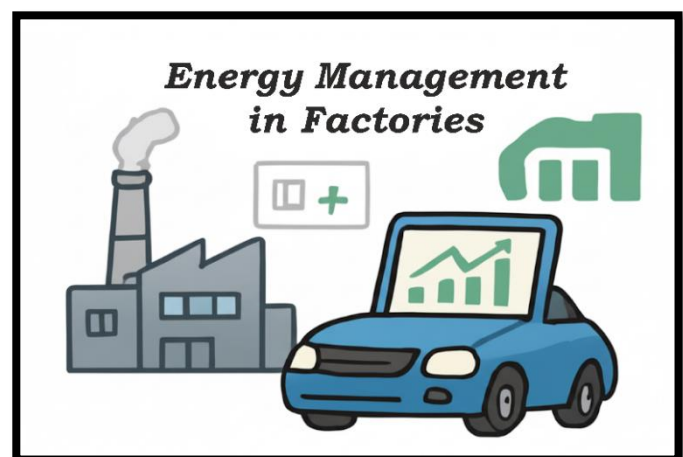


Fig. 1.14: Energy Management in Factories

G) Remote Diagnostics and Over-the-Air (OTA) Updates

Modern vehicles are becoming like computers on wheels. IIOT allows for remote diagnostics of vehicle health through internet connectivity. If a problem is detected, the manufacturer can notify the user and sometimes even fix it by sending a software

update wirelessly. This reduces the need for service center visits and improves customer convenience (Fig.1.15).

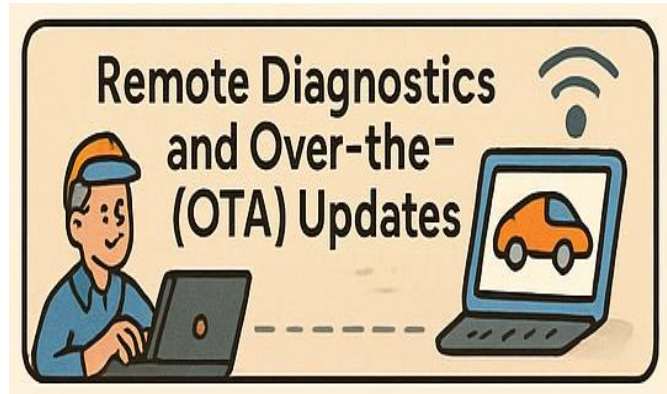


Fig. 1.15: Remote Diagnostics and Over-the-Air (OTA) Updates

H) Workplace Safety and Human Monitoring

In automotive factories, worker safety is critical. IIOT-enabled wearables (like smart helmets or vests) can monitor worker location, posture, fatigue, and exposure to hazards. Sensors on factory floors can detect spills, high temperatures, or gas leaks and trigger automatic alarms or shutdowns to protect workers (Fig.1.16).



Fig.1.16: Workplace Safety and Human Monitoring

👉 Let's Do!

- List three examples of IIOT devices you might find in an automotive factory.
- Identify one machine in your surroundings and imagine how IIOT could make it “smart.”

PRACTICAL ACTIVITY

ACTIVITY 1:

Identification of IoT, IIOT, and Non-IoT Applications from Images

Objective: To identify and classify different applications as IoT, IIOT, or Non-IoT based on their features and functionality.

Materials Required:

- Worksheet or printed images
- Notebook
- Pen/Pencil

Procedure:

Step 1: Observe the Images

Step 2: Analyze the Application:

- Is it IoT (smart devices connected to the internet for daily life)?
- Is it IIOT (smart devices and sensors used in industries)?
- Or is it non-IoT (not connected to the internet)?

Step 3: Identify the Category.

1.		2.		3.	
4.		5.		6.	
					

ACTIVITY 2:**Identify Examples of IIOT in Different Application Areas**

Objective: To recognize and classify Industrial Internet of Things (IIOT) applications across different industrial sectors.

Materials Required:

- Activity worksheet
- Notebook
- Pen/Pencil

Procedure:**Step 1: Observe the Application Areas**

Carefully read the application areas provided in the table.

Step 2: Recall IIOT Concepts

Think about how sensors, machines, controllers, and communication networks are used to collect, monitor, and analyze data in industrial environments.

Step 3: Identify Suitable Examples

For each application area, write one or more examples of IIOT applications.

Step 4: Complete the Table

Fill in the table with appropriate examples.

S. No.	Application Area	Example of IIOT Application
1	Agriculture	
2	Transportation and Logistics	
3	Energy and Utilities	
4	Healthcare	
5	Manufacturing	
6.	Oil and Gas	
7.	Mining	
8.	Smart Grid	

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. How could the Industrial Internet of Things (IIOT) be applied to improve efficiency in a manufacturing plant?
 - a) To enhance user experience in smart homes
 - b) To connect people through social media
 - c) To improve manufacturing and industrial operations using smart sensors
 - d) To provide entertainment services

2. When designing an IIOT system, which component would you exclude to keep it focused on industrial operations?
 - a) Smart devices with sensors
 - b) Communication infrastructure
 - c) Social networking platforms
 - d) Analytics and data storage solutions

3. A factory wants to reduce sudden equipment failures. Which IIOT application should be implemented?
 - a) Quality control
 - b) Predictive maintenance
 - c) Energy management
 - d) Inventory tracking

4. How could IIOT technologies help maintain worker safety in a factory environment?
 - a) By using CCTV cameras only
 - b) By avoiding use of machines
 - c) Through wearables that monitor workers' safety parameters
 - d) By reducing work hours

5. When applying IIOT in an automobile plant, which method best ensures consistent product quality?
 - a) By collecting feedback from customers
 - b) Through wearable technology
 - c) By using smart sensors and cameras to detect defects
 - d) By reducing the need for human labour

B. Match the following

Column A	Column B
1. Smart Manufacturing	A. Monitors fuel efficiency and engine performance
2. Quality Control	B. Uses robotic systems and connected machines
3. Vehicle Telematics	C. Sensors/devices that collect and transmit machine data

4. Edge Devices	D. Monitor worker safety and location
5. Wearables in Factories	E. Uses sensors and cameras for defect detection

C. Fill in the blanks

1. IIOT connects machines, sensors, and systems to collect and share data in _____, helping industries improve efficiency, safety, and decision-making.
2. IIOT helps monitor the health of machines and vehicles through sensors that track parameters like _____, vibration, oil level, and motor speed.
3. IIOT enables real-time tracking of materials and components using RFID, barcode scanners, and _____ sensors.
4. IIOT allows for remote diagnostics of vehicle health through _____ connectivity.
5. Sensors on factory floors can detect spills, high temperatures, or _____, and trigger automatic alarms or shutdowns.

D. Answer the following

1. How would you identify three key components while designing an IIOT ecosystem for an industry setup?
2. In what ways can IIOT be applied to improve efficiency and productivity in automotive manufacturing?
3. How do sensors and actuators work together to enable smart operations in an IIOT system?
4. If you were setting up an IIOT system in a factory, which two real-world applications would you choose and why?
5. How can IIOT technologies be used to lower maintenance costs in automotive industries?

SESSION 4: ROLE & RESPONSIBILITIES OF AN AUTOMOTIVE IIOT APPLICATION TECHNICIAN

1.11 Role and Responsibilities of an Automotive IIOT Application Technician

An Automotive IIOT Application Technician plays a key role in integrating, installing, maintaining, and supporting IIOT systems within automotive manufacturing and service environments. As the industry moves toward smart factories and connected vehicles, this role has become increasingly important to ensure that intelligent, data-driven technologies operate effectively to improve production efficiency, vehicle performance, and overall system monitoring (Fig.1.17).

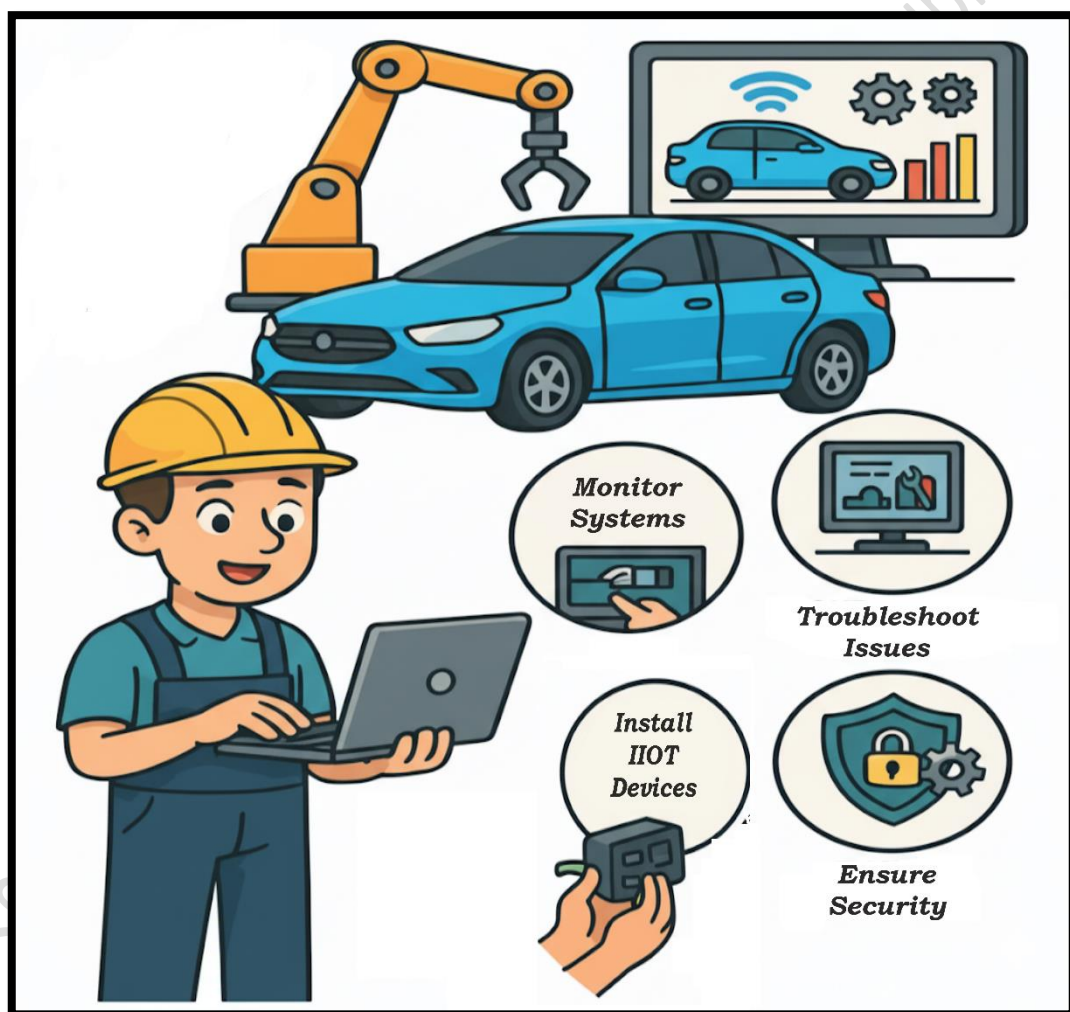


Fig.1.17: Role and Responsibilities of an Automotive IIOT Application Technician

The Automotive IIOT Application Technician is responsible for:

- Installing and configuring IIOT devices and networks.
- Ensuring secure data communication between machines and central systems.

- Supporting smart factory operations using connected sensors and devices.
- Assisting in system diagnostics, upgrades, and maintenance.
- Collaborating with engineers, IT professionals, and machine operators.

Core Responsibilities

A. Installation and Setup of IIOT Systems

- Mounting sensors (temperature, pressure, proximity, vibration, etc.) on machines and robots.
- Setting up IIOT gateways to collect and transmit data.
- Installing I/O modules, controllers (PLCs), and networking devices.

B. Network Configuration and Communication

- Configuring industrial communication protocols like:
- MODBUS, PROFINET, PROFIBUS, CC-Link, OPC UA, MQTT
- Setting IP addresses, communication ports, and parameters for device connectivity.
- Connecting devices using topologies (STAR, LINE, RING) and managing network switches/routers.

C. Device Integration and Programming Support

- Assisting in device programming using configuration software tools.
- Uploading firmware or control logic to programmable devices.
- Performing system integration between hardware and SCADA/HMI/Cloud interfaces.

D. Data Monitoring and Logging

- Ensuring that real-time sensor data is logged and transmitted for monitoring.
- Assisting in setting up dashboards for visual analytics using software like ThingWorx, Node-RED, or proprietary OEM tools.
- Validating data quality and addressing signal drop or noise issues.

E. System Testing and Validation

- Conducting functional tests and trial runs to verify IIOT network performance.
- Monitoring latency, throughput, and device response.
- Supporting engineers during commissioning and troubleshooting phases.

F. Maintenance and Troubleshooting

- Diagnosing faulty sensors, connectors, or communication breakdowns.
- Replacing damaged cables, updating firmware, or restoring network connectivity.
- Maintaining logs of service activities and updates.

G. Safety and Compliance

- Following electrical and cyber safety protocols while installing or servicing IIOT devices.
- Assuring compliance with industry standards like ISO 26262 (for automotive safety) or IEC 62443 (for cyber security in automation).

H. Documentation and Reporting

- Preparing and maintaining technical documentation such as:
- Wiring diagrams
- Network layout drawings
- Installation checklists
- Maintenance records
- Reports on faults, modifications, and trials

I. Team Collaboration and Communication

- Coordinating with automation engineers, IT departments, and machine manufacturers.
- Attending meetings and training sessions related to new IIOT tools and upgrades.

1.12 Skill Set Required for Automotive IIOT Application Technician

An Automotive IIOT Application Technician requires a diverse set of technical and practical skills to support the integration of smart devices and systems in modern automotive manufacturing environments. This role demands a strong understanding of how to connect, configure, monitor, and maintain various IIOT components such as sensors, controllers, communication networks, and data platforms. The role of an Automotive IIOT (Industrial Internet of Things) Application Technician demands a multi-disciplinary skill set that combines mechanical, electrical, electronics, and IT knowledge. The technician must be able to integrate smart devices, manage

Sensor & Device Knowledge		Industrial Protocols	
Specific Skills	Apperption / Application	Specific Skills	Apperption / Application
Installation & Calibration	Mounting, wiring, and calibrating IIOT sensors, and actuator (rsuzs)	Protocol Configuration	Setting up MODBUS/RTU, TCP, Profinet, Profibus, DPC UA, MOTT, CC-LinK, etc
Signal Understanding	Interpreting analog (4–20 mA, 0–10 V) and digital (PNP/ (NPN) outputs	Communication Troubleshooting	Resolving errors in RS-485, Ethernet, or CAN-based comu
Device Testing	Using multimeters and test tools signal verification	Shielding & Grounding	Avoiding noise, loops, and ensuring reliable signal flow.
Software Proficiency		Troubleshooting Skills	
Specific Skills	Description / Application	Specific Skills	Apperption / Application
Configuration Tools	Configuration Tools using Siemens TIA Portal, Rockwell RSLogix, Codesys.	Hardware Diagnosis	Finding faults in sensors, wiring, connectors, I/O modules
SCADA / HMI Tools	Set up monitoring dashboards using SCADA or tools like Node-RED	Network Diagnostics	Using tools like Wireshark, ping tests, protocol analyzers
Cloud Platforms	Basic use of AWS IoT Core, Azure Hub, or MindSphere	System Testing	Supporting trial runs, loop tests, and verify performance
Electrical & Safety Skills		Soft Skills	
Specific Skills	Description Application	Qualification	Certifications (Optional)
Electrical Safety	Following safety protocols, handling live circuits, use PPE	ITT / Diploma / B Tech in Electronics, Electrical, Mechatronics, or Instrumentation	PLC & SCADA, IIS Fundamentals, Networking Basics, Industrial Cybersecurity
Diagram Interpretation	Diagram interpretation. In academic analogics records		

Fig.1.18: Skill Set Required for Automotive IIOT Application Technician

industrial communication networks, perform troubleshooting, and ensure reliable data flow from machines and sensors to control or cloud systems (Fig.1.18).

1.13 Job opportunities for an Automotive IIOT Application Technician

An Automotive IIOT Application Technician works with smart technologies used in the automotive and vehicle-related industries. Their main job is to set up, operate, and maintain systems that use sensors, controllers, and machines to make vehicle production faster, safer, and more efficient.



The automotive industry is rapidly changing. Modern factories now use smart and connected systems known as the Industrial Internet of Things (IIOT), where machines, robots, and sensors communicate with each other to share information and improve performance.

Work areas for automotive IIOT application technicians can be described as follows:

Vehicle Manufacturing Companies (OEMs)

Major companies such as Tata Motors, Mahindra, Maruti Suzuki, and Hyundai build vehicles in large factories. These factories have machines and robots doing important jobs like welding, painting, and assembling parts. Technicians install and maintain sensors that collect real-time data (e.g., temperature, speed, or vibration) to ensure smooth operations.

Automobile Component Manufacturers

Companies that produce parts like engines, brakes, and batteries use smart machines for testing and quality control. IIOT technicians connect and monitor these systems, helping detect and fix issues quickly using sensor data.

Vehicle Testing and Research Centers

Before vehicles are launched, they undergo safety and performance tests. Technicians install data-recording devices in test vehicles to help engineers analyze performance and make improvements.

Smart Factories (Industry 4.0)

In fully automated digital factories, machines communicate and make real-time decisions. IIOT technicians maintain the network that connects these machines, helping prevent downtime through predictive maintenance.

Vehicle Repair and Service Centers

Modern vehicles send health data directly to workshops through telematics. Technicians help install and check these systems, allowing faster diagnosis and repair.

and test new systems. They also train workers on how to use the new equipment.

Automation and System Integration Companies

These companies design and install smart factory systems for automakers. Technicians work on-site to set up, test, and train staff on new IIOT-based technologies.

Electric Vehicle and Battery Factories

EV factories use IIOT systems to monitor battery health, temperature, and voltage. Technicians ensure these systems are accurate and safe during production.

Startups and Innovation Labs

In research labs and technology startups, IIOT technicians assist in developing and testing new smart devices and automation tools, gaining hands-on experience with emerging technologies.

1.14 Manufacturing and Networking Standards and Procedures in an Organization

In any modern manufacturing organization, especially in industries like automotive, electronics, or industrial automation; it is important to follow certain standards and procedures to ensure that products are made correctly, systems work efficiently, and safety is maintained. These standards also help different machines and teams work together smoothly.

1.14.1 Manufacturing Standards and Procedures

Manufacturing standards are rules and guidelines that tell how things should be made in a consistent, safe, and high-quality way. These are usually set by national or international bodies like ISO (International Organization for Standardization).

Common Manufacturing Standards

ISO 9001: For quality management. It ensures the organization makes good-quality products and improves processes.

ISO 14001: For environmental management. It helps reduce waste and pollution.

ISO/TS 16949: Specifically used in the automotive industry to maintain product quality, traceability, and safety.

Manufacturing Procedures: This procedure helps to deliver high product quality, to maintain safe working conditions, to make efficient use of materials and energy, and comparatively less machine downtime. Manufacturing Procedures includes the following:

Standard Operating Procedures (SOPs): Written steps for doing specific tasks like welding, painting, or assembling parts.

Work Instructions: Clear instructions given to workers or machines for each stage of production.

Inspection and Testing: Quality checks done during and after manufacturing to ensure products meet specifications.

Maintenance Schedules: Timely service of machines to avoid breakdowns.

1.14.2 Networking Standards and Procedures

Networking standards are technical rules that define how devices like machines, sensors, and controllers connect and communicate in a factory.

In modern smart factories (Industry 4.0), many machines are connected to each other and to central systems using industrial networks. These connections follow strict communication rules to ensure devices work together properly and data is secure.

Common Networking Standards:

IEEE Standards (e.g., IEEE 802.3): For Ethernet communication, widely used in industrial networks.

OPC UA (Open Platform Communications – Unified Architecture): Used for secure and reliable data exchange between machines.

MODBUS, PROFINET, EtherCAT, CC-Link, CAN Bus: Protocols used to connect sensors, PLCs, and industrial controllers.

Networking Procedures: These procedures are required to ensure fast and accurate communication, less downtime due to network errors, for better control and automation, and to achieve data security and privacy. Networking Procedures can be listed as follows:

Device Configuration: Setting up IP addresses, protocols, and communication parameters for each device.

Signal Testing and Troubleshooting: Ensuring signals between devices are strong and error-free.

Network Mapping: Creating diagrams to show how all devices are connected.

Cyber security Measures: Using passwords, firewalls, and encryption to protect data from unauthorized access.

Backup and Recovery Plans: Making copies of software and settings in case of system failure.

These manufacturing and networking standards are important for:

- Maintain consistent product quality
- Improve safety and reduce accidents
- Increase productivity and reduce waste
- Allow smooth communication between different systems and teams
- Stay compliant with government or international regulations
- Build customer trust and open global business opportunities

PRACTICAL ACTIVITY

ACTIVITY 1:

Explore the Scope of Automotive Industry and Write Examples For Each Area

Objective: To understand the various sectors of the automotive industry and identify examples associated with each area.

Materials Required

- Notebook
- Pen/Pencil

Procedure:

Step 1: Discuss and identify the major areas of the automotive industry, such as:

- Making vehicles (cars, bikes, buses, trucks)
- Electric vehicles
- Service and repair
- Spare parts and accessories

- Transport and logistics
- Jobs and careers, etc.

Step 2: For each area, write one suitable example. Examples may include automobile manufacturers, EV companies, service centers, logistics providers, or job roles

Step 3: Complete the table given below:

S. No.	Area of Automotive Industry	Example
1	Manufacturing	Maruti Suzuki (car production)
2	Electric Vehicles (EV)	electric scooters
3	Service and Repair	Local automobile workshop (vehicle servicing)
4	Spare Parts & Accessories	
5	Transport & Logistics	
6	Jobs & Careers	

ACTIVITY 2:

Visit the Nearby Bank ATM Machine and Observe the Software, Hardware, Tools and Equipment

Objective: To identify and understand the hardware, software, tools, and supporting equipment used in an Automated Teller Machine (ATM) system.

Materials Required

- Notebook
- Pen/Pencil

Procedure:

Step 1: Visit a nearby bank ATM (with teacher/parent permission).

Step 2: Observe the ATM machine carefully and identify different parts such as

- Input devices: Card slot, keypad, touchscreen.
- Output devices: Screen/display, speakers, cash dispenser, receipt printer.
- Security devices: CCTV camera, biometric sensors (if available).

Step 2: Identify the software features

- Notice the ATM welcome screen and menu.
- Observe user interface elements (language selection, transaction options, instructions).
- Understand that software connects the ATM to the bank server securely.

Step 3: Observe supporting tools & equipment

- Electrical supply: UPS/Power backup.
- Networking tools: Router/modem for internet connection.
- Security tools: Alarm systems, security guard.

Step 4: Write your observations in the table given below.

Observation Table:

S. No.	Component Observed	Type (Hardware/Software/Tool)	Example / Function
1			
2			
3			
4			
5			

ACTIVITY 3:

Identify and List the Components of a Smart Factory

Objective: To identify the key components of a smart factory and understand their functions in an automated industrial environment.

Materials Needed:

- Notebook & pen
- Laptop or tablet with internet access
- Images or videos of smart factories (optional, for reference)

Procedure:

Step 1: Discuss what a smart factory is (a factory that uses automation, sensors, and internet-connected devices).

Step 2: Observe reference materials and identify the major components commonly used in a smart factory, such as:

- Sensors (temperature, pressure, proximity, etc.)
- Actuators (motors, valves)
- Machines/Robots
- Controllers (PLC, microcontrollers)
- Industrial IoT (IIOT) devices
- Communication networks (Wi-Fi, Ethernet)
- Software (monitoring dashboards, control systems)

Step 3: Write one example or function for each component.

Step 4: Complete the Observation Table.

S. No.	Component of Smart Factory	Example / Function
--------	----------------------------	--------------------

1	Sensors	
2	Actuators	Control movement (motors, valves)
3	Robots/Machines	Perform automated tasks
4	Controllers (PLC)	
5	IIOT Devices	Connect machines to internet
6	Communication Network	Transfer data between devices
7	Software/Dashboard	

Observation Table**CHECK YOUR PROGRESS****A. Multiple Choice Questions**

1. A technician finds that sensor data is not reaching the cloud dashboard in a smart factory. What should be the most appropriate first action?
 - a) Replace all sensors immediately
 - b) Check network configuration and communication settings
 - c) Stop the entire production line
 - d) Ignore the issue and continue monitoring

2. In an automotive plant, machines need to communicate in a ring topology. What should the technician focus on while setting up the system?
 - a) Installing only sensors
 - b) Ensuring proper network connectivity and loop configuration
 - c) Removing IP addressing
 - d) Avoiding use of switches

3. A technician is asked to improve system reliability by reducing unexpected machine downtime. Which approach should be applied?
 - a) Increase manual inspection only
 - b) Use predictive maintenance with IIOT sensors
 - c) Stop data logging
 - d) Reduce communication protocols

4. While installing IIOT devices, a technician must ensure safe operations. What action reflects correct compliance practice?
 - a) Ignoring safety standards to save time
 - b) Following ISO and cybersecurity guidelines
 - c) Using untested devices
 - d) Avoiding documentation

5. During system integration, a mismatch occurs between PLC and SCADA communication. What should the technician do?
 - a) Disconnect all devices
 - b) Reconfigure communication protocols and parameters
 - c) Replace SCADA system
 - d) Ignore integration errors

B. Match the following

Column A	Column B
1. OPC UA	A. Quality management standard
2. ISO 9001	B. Secure data communication protocol
3. MQTT	C. Lightweight messaging protocol
4. PLC	D. Industrial controller device
5. Network Mapping	E. Diagram of device connections

C. Fill in the blanks

- The process of setting IP addresses and communication parameters is called _____.
- _____ topology connects devices in a closed loop for communication.
- ISO 14001 is related to _____ management.
- _____ is used to protect IIOT systems from unauthorized access.
- A device used to control industrial processes is called a _____.

D. Answer the following

- A technician observes inconsistent sensor readings on a dashboard in a smart factory. What approach should the technician follow to diagnose and fix the problem?
- After installation, a technician finds that sensors are not sending data to the control system. What actions should the technician take to restore connectivity?
- A technician is assigned to integrate new automated machines into an existing IIOT system. How should the technician ensure smooth integration without affecting current operations?
- A technician notices frequent communication drops between devices in an industrial network. How should the technician identify the cause and resolve the issue?
- A technician is responsible for improving cybersecurity in an IIOT setup. What measures should the technician implement to protect system data and communication?

MODULE 2**BUILDING BLOCKS OF AUTOMOTIVE IIOT****Module Overview**

This module provides a foundational understanding of the key elements that make up Automotive Industrial Internet of Things (IIOT) systems.

Students begin by understanding microcontrollers, which act as the core processing units in automotive systems. They learn how these devices take inputs, process data, and control outputs to perform specific functions. The module then introduces various sensors and actuators used in automotive IIOT, explaining how sensors collect real-time data from the environment and how actuators respond by performing actions such as movement or control operations.

Further, students gain practical knowledge of how sensors are connected and interfaced with microcontrollers. They understand how data from sensors is read, processed, and used to control devices, forming the basis of automation and smart decision-making in vehicles.

By the end of this module, students develop a clear understanding of how microcontrollers, sensors, and actuators work together as building blocks of automotive IIOT systems, enabling real-time monitoring, control, and automation in modern vehicles.

Learning Outcomes

After completing this module, you will be able to:

- Identify the basic components of Automotive IIOT systems.
- Explain the role of microcontrollers in automotive applications.
- Describe the function of sensors and actuators.
- Demonstrate basic interfacing of sensors with a microcontroller.
- Understand how these components work together in smart automotive systems.

Module Structure

Session 1: Fundamentals of Microcontrollers

Session 2: Automotive IIOT Sensors and Actuators

Session 3: Interfacing Sensors with Microcontroller

SESSION 1: FUNDAMENTALS OF MICROCONTROLLERS

2.1 Introduction to Microcontrollers (MCU)

Think About It!

Have you seen automatic washing machines, traffic lights, or microwave ovens working automatically? Small computers called microcontrollers help control these devices.



In today's digital and connected world, electronic devices play an important role in automation, robotics, communication, and the Internet of Things (IoT). At the center of many of these systems is the Microcontroller (MCU). It is often called the brain of electronic devices because it controls operations and makes decisions based on programmed instructions.

A microcontroller is a small computer built on a single chip, specially designed to control electronic devices automatically.

Basic Components of a Microcontroller

A typical microcontroller contains three main components:

i) Central Processing Unit (CPU):

This is the brain of the microcontroller. It reads the program instructions stored in memory and performs actions based on them.

ii) Memory:

- ROM (Read-Only Memory) – stores the program permanently.
- RAM (Random Access Memory) – temporarily stores data while the program runs.
- Flash Memory – stores both program and data, allowing updates when needed.

iii) Input /Output (I/O) Ports:

These are pins used to connect external devices such as sensors, switches, LEDs, motors, and displays.

2.1.1 How a Microcontroller Works

The working of a microcontroller can be understood in three basic steps:

Input → Process → Output

Input: Sensors or external devices send data to the microcontroller. For example, a temperature sensor sends the current temperature).

Process: The microcontroller processes this data according to its program. For example, if the temperature is high, it decides to turn on a fan).

Output: The controller sends signals to output devices, like a motor or LED to perform an action. For example, in an automatic water pump, the microcontroller reads data from a water level sensor (input), compares it with a set level (process), and then turns the pump ON or OFF (output).

👉 Real-Life Connection

When you clap to switch ON a smart light, the sensor detects sound (input), the controller processes it, and the light turns ON (output).

2.1.2 Popular Microcontrollers

Some commonly used microcontrollers are as follows (Fig.2.1):

Arduino (ATmega328P) – Popular for beginners, students, and hobby projects.

PIC Microcontrollers – Widely used in industrial control systems.

ARM Cortex-M Series – Used in advanced embedded systems, vehicles, and smart devices.

ESP32 / ESP8266 – Commonly used in IoT projects because of built-in Wi-Fi and Bluetooth.

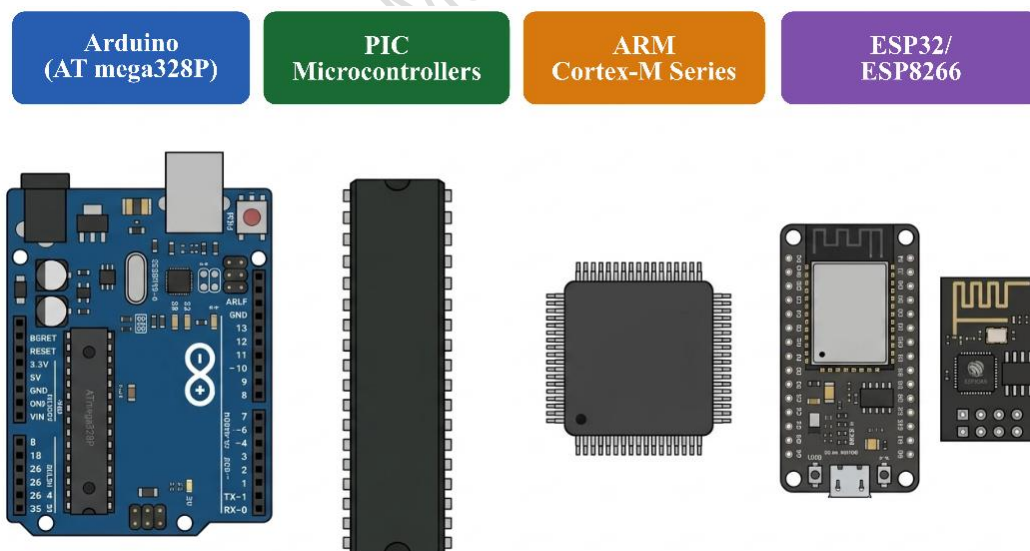


Fig.2.1 Popular Microcontrollers

2.1.3 Programming a Microcontroller

A microcontroller is a programmable device, meaning instructions can be written to control its operation. Programming is usually done in languages such as C, C++, or MicroPython using software like Arduino IDE.

Once the program is uploaded, the microcontroller runs it automatically, even without being connected to a computer.

For example, an Arduino can be programmed to blink an LED, measure temperature, to control a small robot, and to operate home appliances etc.

☞ *A microcontroller follows only the instructions written in the program, just like a student follows instructions given by a teacher.*

2.1.4 Characteristics of Microcontrollers

- Low cost and power efficient.
- Small size and easy to integrate in embedded systems.
- Performs dedicated functions, not general-purpose computing.
- Real-time operation capability.
- Limited memory and processing power compared to SBCs.

2.1.5 Applications of Microcontrollers

Microcontrollers are used almost everywhere in daily life, such as:

- Home Appliances: Washing machines, microwave ovens, air conditioners, refrigerators.
- Automobiles: Engine control, airbag systems, parking sensors, and wipers.
- Healthcare: Digital thermometers, heart-rate monitors, and medical instruments.
- Smart Devices: Smart door locks, home automation systems, and security alarms.
- Robotics and IoT: Line-following robots, drones, and connected smart devices.

2.2 Getting Started with Arduino Uno

The Arduino Uno is an open-source microcontroller board developed by Arduino, based on the ATmega328P microchip. It is one of the most widely used boards for learning electronics, automation, and IoT applications due to its simplicity and versatility.

The board features a set of digital and analog input/output pins that can be interfaced with expansion boards and external circuits. It includes 14 digital input/output (I/O) pins, 6 analog input pins, a 16 MHz quartz crystal, a reset button, and an ICSP header. These features make it easy to connect with other boards, sensors, actuators, and other electronic components. The Arduino Uno can be powered through a USB cable, an AC-to-DC adapter, or a battery, providing flexibility for various project setups (Fig. 2.2).

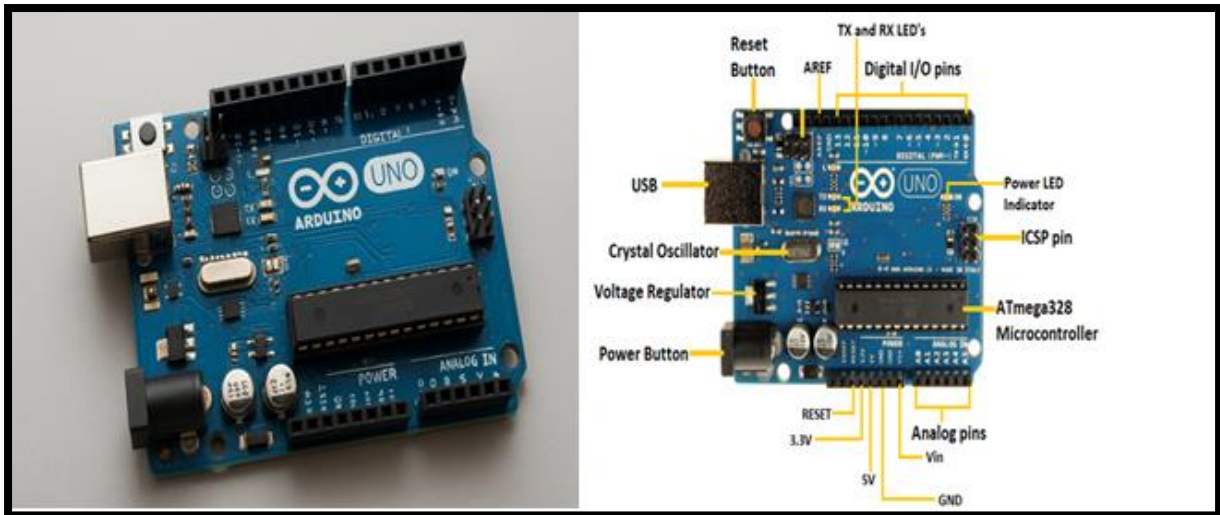


Fig. 2.2: Arduino Uno Board

The Arduino Uno board can be programmed to perform specific functions using the open-source Arduino Integrated Development Environment (IDE). This platform allows users to design and implement electronic and IoT systems with ease. The Uno's USB interface enables seamless communication with a computer for programming and serial data transfer.

2.2.1 Pin Configuration of an Arduino Uno Board

The Arduino microcontroller has several pins which are used for different functions. The pin layout of an Arduino board is displayed in the Fig.2.3.

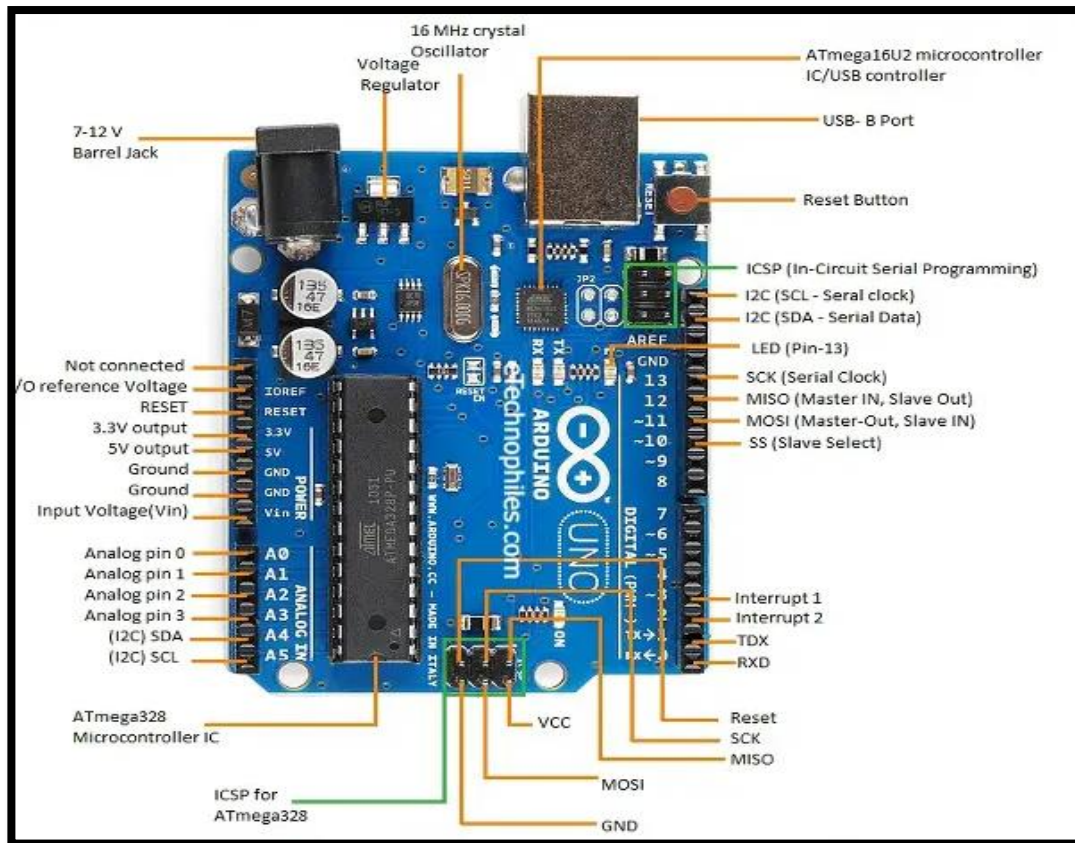


Fig.2.3: Pin configuration of Arduino Uno board

The functions of important pins are as follows:

- ❖ **USB** – The computer’s USB connector can be connected to the Arduino board with a USB port.
- ❖ **Voltage Regulator** – A voltage regulator controls the voltage supplied to the Arduino board. It regulates the DC voltage supplied to the processor or other components.
- ❖ **Crystal Oscillator** – This is an electronic oscillator that creates electric voltage signals by utilizing the mechanical resonance produced by the vibration of piezoelectric quartz crystals. The crystal oscillator is used to keep track of time and frequency for the Arduino board. The crystal oscillator normally has a frequency of 16MHz.
- ❖ **Reset** – Arduino reset is required to reset the values of the Arduino board to their inherent values. This is useful when coding a new program function. Although Arduino comes with its own reset button, the user can also have an external Arduino reset button, so that it can be reset externally. An Arduino board can be reset to its factory settings. The UNO board can be reset by two methods. By using the reset button on the board or connecting the external reset button to the Arduino pin labelled RESET.
- ❖ **Power Button** – Arduino can be powered from the Barrel Jack or USB connector.

- ❖ **GND Pin** – This is the “Ground pin” which is used to ground the circuit.
- ❖ **3.3V Pin** – Supply 3.3 output volt.
- ❖ **5V Pin** – Supply 5 output volt.
- ❖ **Vin** – This pin can be used to power the Arduino board from an external power source.
- ❖ **Analog Pins** – The Arduino Uno board is equipped with six analog input pins labeled A0 to A5. Analog sensors, such as temperature or humidity sensors, send signals to these pins. The board then converts these analog signals into digital values, which are processed by the microcontroller as input data.
- ❖ **Microcontroller** (ATmega 328 microcontroller): The main microcontroller on the Arduino Uno board is used to perform all the complex functions of an IoT device.
- ❖ **ICSP Pin** – ICSP is an AVR tiny programming header for the Arduino. It is also known as Serial Peripheral Interface (SPI), which is a kind of "expansion" of the output, and the output device is a slave to the master of the SPI bus.
- ❖ **Power LED Indicator** – The power LED indicator shows the status of the power supply in the microcontroller device. It lights up when the Arduino is properly connected to a power source. If the LED does not turn on, it indicates a possible fault in the connection or power supply. Power LED indicators use various modes to indicate the status which are as follows:
 - **Slow flashing green** – On aircraft mode using low power
 - **Flashing green** – Using battery power with good battery power
 - **Fast flashing amber** – Using a battery with low power
 - **Rapid flashing red** – Power on with very low power using battery
 - **No LED** – Power off or battery empty
- ❖ **Tx and Rx LEDs** – The Arduino Uno board features two labeled indicators, TX (Transmit) and RX (Receive), positioned separately. These orange/yellow LEDs are linked to the USB interface and display the flow of data within the circuit. The TX LED indicates data being sent from the Arduino to the computer, while the RX LED shows data being received from the computer by the microcontroller (Fig.2.4).

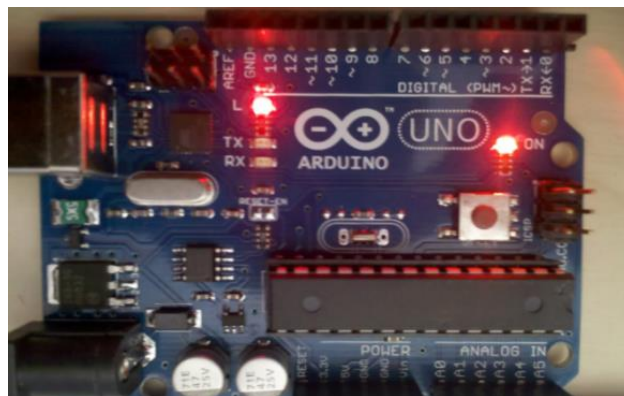


Fig.2.4: Tx and Rx LEDs on Arduino board

- ❖ **Digital I/O** – Arduino UNO board comes with 14 digital I/O pins, out of which 6 are used for Pulse Width Modulation (PWM) output. These pins can be coded as input digital pins to read logic values (0 or 1) or as digital output pins for connecting LEDs, relays and so on. The pins marked “~” can be used to generate PWM.
- ❖ **Analog Reference (AREF)** – AREF feeds the reference voltage from external power supply in the Arduino. The voltage supplied from a voltage regulator IC of a maximum of 3.3V is directed to the AREF pin.

2.3 Introduction to NodeMCU Development Board

NodeMCU is an open-source development board based on the ESP8266 Wi-Fi module, developed by Espressif Systems. It is widely used for building Internet of Things (IoT) applications because it combines a microcontroller with built-in Wi-Fi connectivity. NodeMCU enables electronic devices to connect to the internet, exchange data, and be controlled remotely. Therefore, it is commonly known as an IoT-enabled development board.

The board provides multiple General-Purpose Input/Output (GPIO) pins, which can be used to connect sensors, relays, LEDs, motors, and other external devices. Due to its low cost, compact size, and wireless capability, NodeMCU is widely used in embedded systems, smart automation, and IoT projects (Fig.2.5).

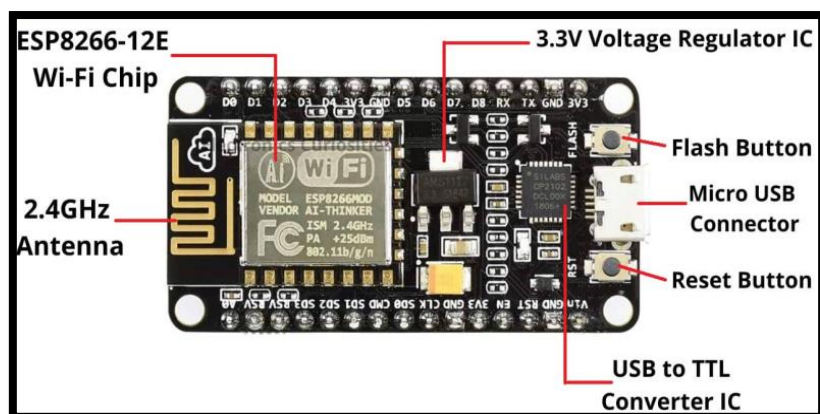


Fig.2.5: Node MCU ESP8266 IoT-enabled Board

2.3.1 Key Features of NodeMCU

The general features of this board are as follows:

- Based on ESP8266 microcontroller with built-in Wi-Fi
- Also known as a System-on-Chip (SoC) board
- Compact, lightweight, and affordable
- Easy to use for beginners and developers
- Can be programmed using Arduino IDE, Lua, or MicroPython
- Supports multiple GPIO pins for interfacing devices
- Can work in Station Mode (connect to Wi-Fi router) or Access Point Mode (create own Wi-Fi network)
- Suitable for real-time and event-driven applications
- Includes an onboard antenna for wireless communication

IoT application: Smart home devices where real-time data is uploaded directly to IoT platforms like ThingSpeak, Blynk, or MQTT brokers.

2.3.2 Applications of NodeMCU

NodeMCU is commonly used in:

- Smart home automation systems
- Wireless temperature and humidity monitoring
- Smart energy meters
- IoT-based agriculture systems
- Security and alarm systems
- Remote device control through mobile apps

For example, in a smart home system, NodeMCU collects sensor data and uploads it to IoT platforms such as ThingSpeak, Blynk, or MQTT brokers for real-time monitoring and control.

2.3.3 Why NodeMCU is Popular

- Low power consumption
- Built-in Wi-Fi reduces extra hardware requirement
- Low cost compared to many other IoT boards
- Large online community support
- Ideal for learning and rapid prototyping

2.3.4 Comparison of Arduino Uno and Node MCU Microcontroller Boards

Table 2.1 compare different parameters of Arduino Uno and Node MCU.

Table 2.1: Comparison of Arduino Uno and Node MCU Microcontroller Boards

Feature	Arduino Uno	NodeMCU
Microcontroller	ATmega328P	ESP8266
Operating Voltage	5V	3.3V
Input Voltage	7V – 12V (recommended)	5V (via Micro USB)
Clock Speed	16 MHz	80 MHz / 160 MHz
Flash Memory	32 KB	4 MB (typical)
SRAM / RAM	2 KB SRAM	Higher RAM than Arduino Uno
Digital I/O Pins	14	Multiple GPIO pins
Analog Input Pins	6	1 (A0)
Wi-Fi Connectivity	Not built-in	Built-in Wi-Fi
Bluetooth	Not available	Not available (ESP8266 version)
Programming Software	Arduino IDE	Arduino IDE / Lua / MicroPython
Communication	UART, SPI, I2C	UART, SPI, I2C
Power Consumption	Low	Low to moderate
Best For	Basic electronics, learning, sensor interfacing	IoT, cloud connectivity, smart automation
Cost	Moderate	Low and economical

2.3.5 Pin Configuration of Node MCU Development Board (Refer Fig. 2.6)

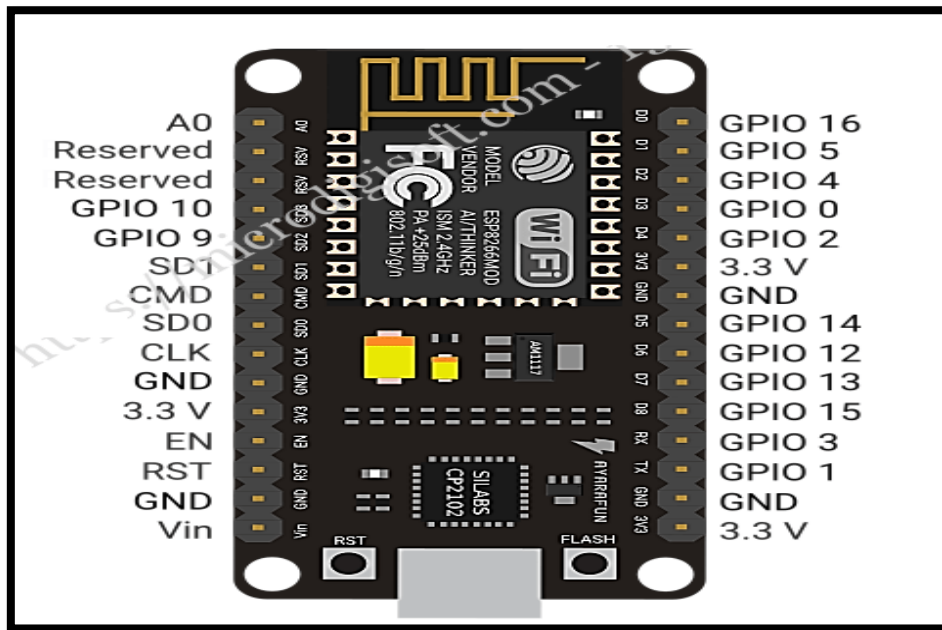


Fig.2.6: Node MCU ESP8266 Pin Diagram

The functions of important pins are discussed in Table 2.2.

Table 2.2: Node MCU Development Board Pin Configuration

Pin Category	Name	Description
Power Pins	Micro-USB, 3.3V, GND, Vin	Micro-USB: Used to power the NodeMCU board through USB. 3.3V: Provides regulated 3.3V supply to power external devices or the board. GND: Ground pins. Vin: Used to supply external input power.
Control Pins	EN, RST	EN (Enable): Enables the chip when HIGH. RST (Reset): Resets the microcontroller using the pin or onboard reset button.
Analog Pin	A0	Used to read analog voltage signals. Input range is typically 0–3.3V (board dependent).
GPIO Pins	GPIO0 to GPIO16	NodeMCU provides multiple General-Purpose Input/Output (GPIO) pins for interfacing sensors, LEDs, relays, switches, etc.
SPI Pins	SD1, CMD, SD0, CLK	Used for SPI (Serial Peripheral Interface) communication with external devices.
UART Pins	TXD0, RXD0, TXD1	NodeMCU supports UART serial communication. UART0 (TXD0, RXD0) is generally used for programming and serial monitor. UART1 (TXD1) is transmit only.
I2C Pins	User Configurable	NodeMCU supports I2C communication through software. Commonly used pins are D1 (SCL) and D2 (SDA).

2.4 Introduction to Software Tools

To learn electronics, embedded systems, and IoT programming, software tools are very important. Two commonly used tools are Arduino IDE and Tinkercad. These tools are widely used by students, teachers, hobbyists, and professionals for designing, programming, and testing electronic systems.

2.4.1 Arduino IDE Basics and Programming Structure

Arduino IDE (Integrated Development Environment) is an open-source software used to write, compile, and upload programs to Arduino boards and other supported microcontrollers. It allows users to program boards such as Arduino Uno and ESP8266-based boards using simple programming languages like C and C++.

Arduino platform has two main parts:

Hardware (Arduino Board): A programmable circuit board containing a microcontroller that acts as the “brain” of the project. It can interface with sensors, motors, LEDs, displays, and other electronic devices.

Software (Arduino IDE): The Arduino Integrated Development Environment is a user-friendly tool for writing, compiling, and uploading code to the board.

A) Arduino IDE Installation

To program Arduino boards, Arduino IDE must be installed. Arduino IDE can be downloaded from the official website: <https://www.arduino.cc/en/software>.

After downloading, install the software by following the setup instructions.

1.If the operating system displays a warning message during driver installation, allow the installation to continue. Then, select the required components for installation (Fig. 2.7).

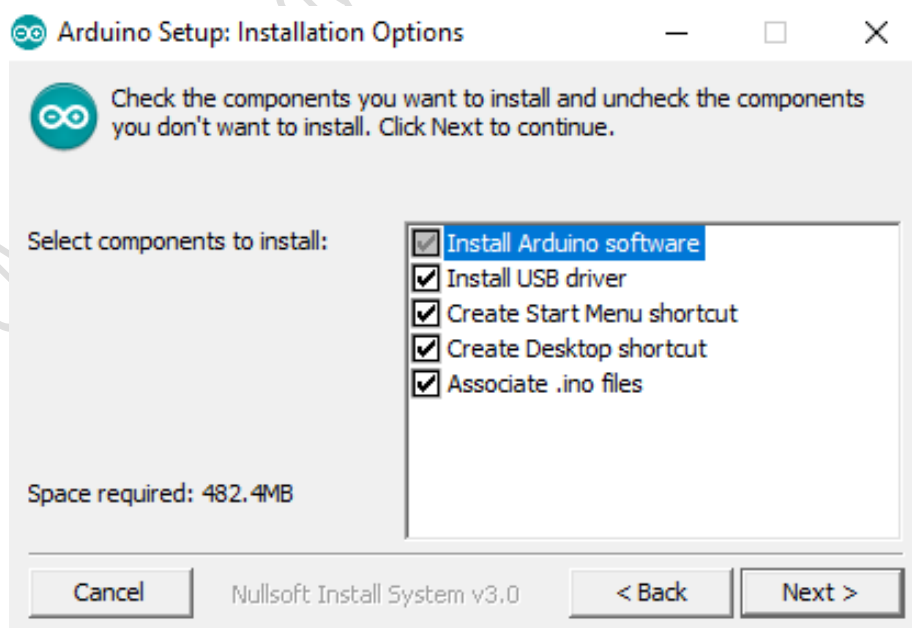


Fig. 2.7: Installing Components Window

2. Choose the installation directory (Fig. 2.8).

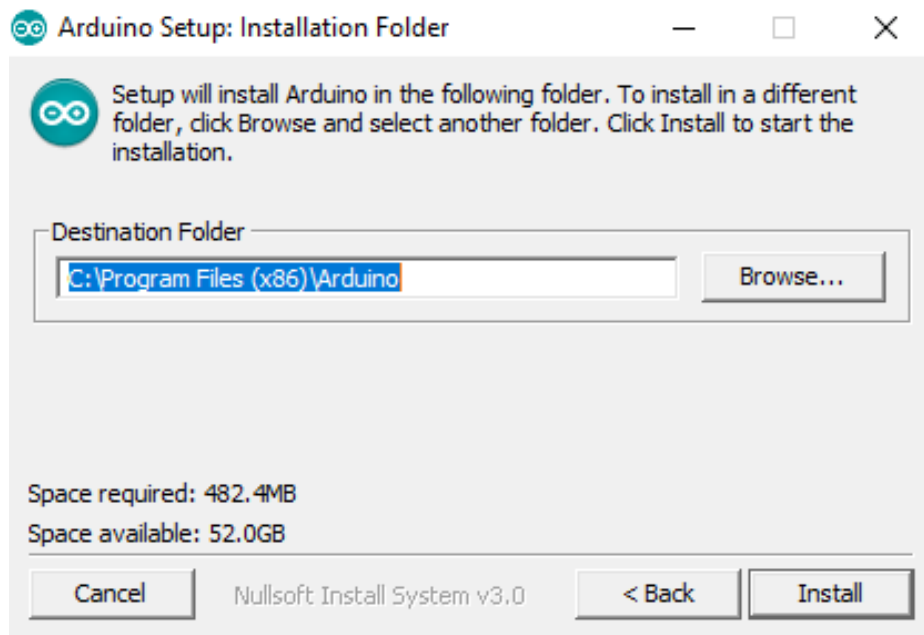


Fig.2.8: Screenshot for Installation Directory

3. Now Installation is in progress. The process will extract and install all the required files to execute properly the Arduino Software (IDE) (Fig.2.9).

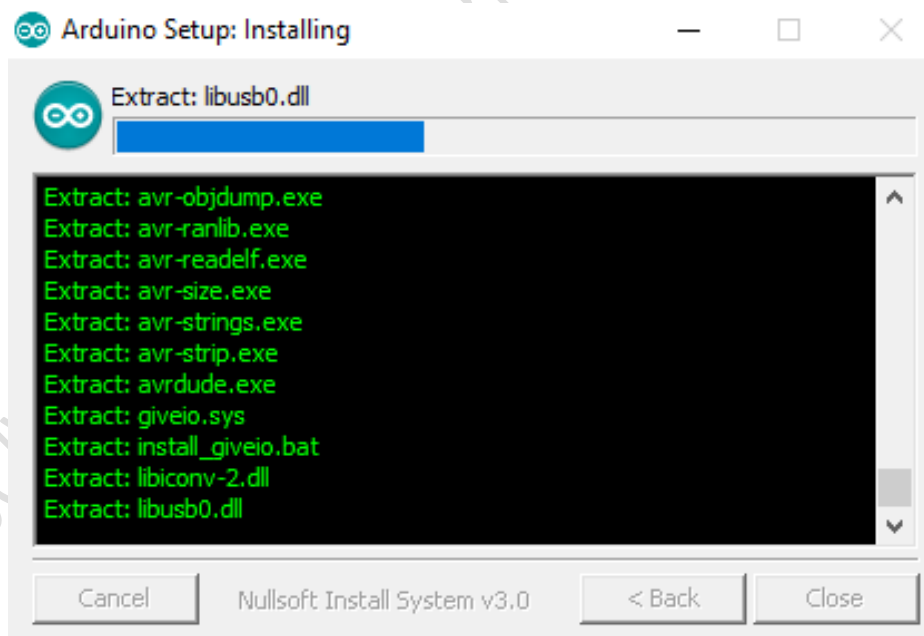


Fig.2.9: Installation Progress Window

4. Now, accept the security for the installation three times. Click on the 'Install' button (Fig.2.10).

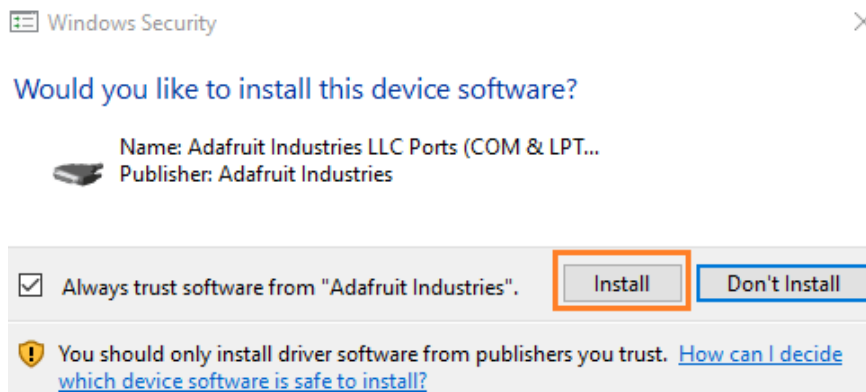


Fig.2.10: Installation Window

5. Again, click on the 'Install' button (Fig.2.11).

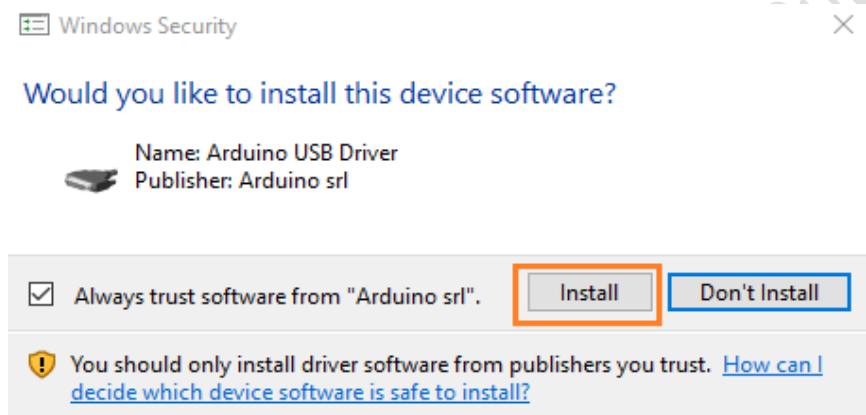


Fig.2.11: Driver Installation Window

6. After completing the installation processes, the window will appear (Fig.2.12).

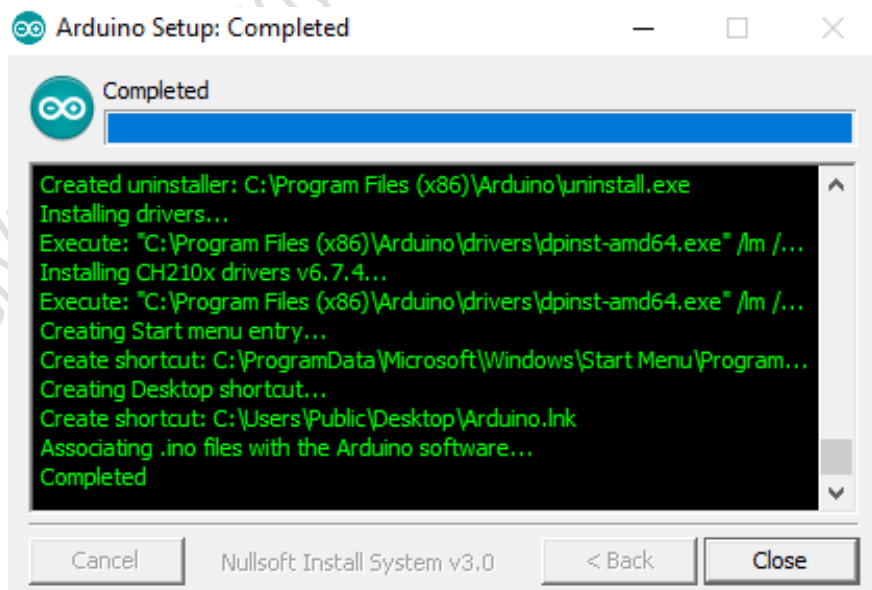


Fig.2.12: Installation Completion Window

7.The Arduino IDE software icon will appear on the desktop (Fig.2.13).



Fig.2.13: Arduino IDE Software Icon on Screen

8.To start with Arduino software, the Arduino window will appear (Fig.2.14).



Fig.2.14: Arduino IDE Window

B) Working with Arduino IDE

Common parts of Arduino IDE include (Fig.2.15):

- Menu Bar
- Toolbar
- Code Editor
- Message Window
- Serial Monitor

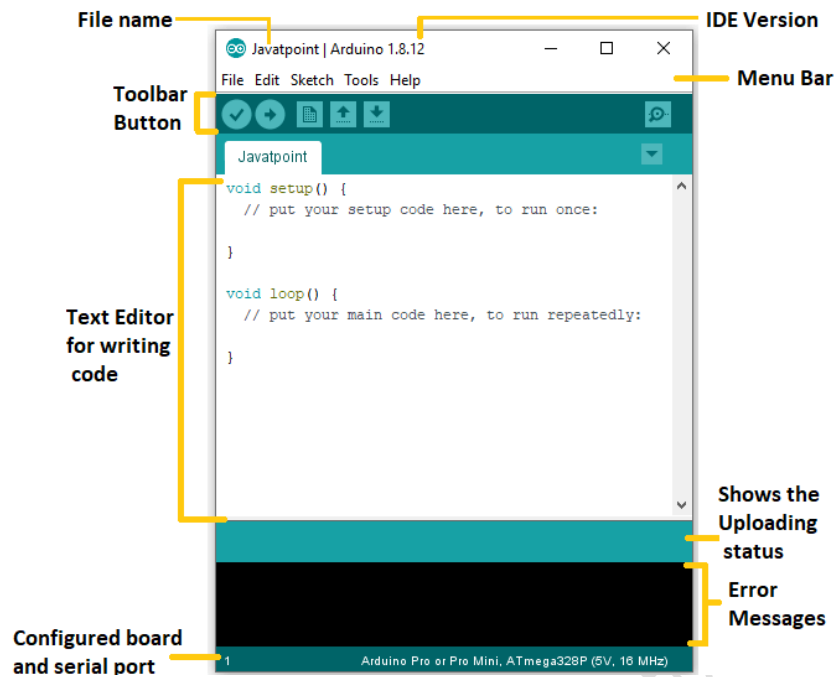


Fig.2.15: Different Parts of Arduino IDE Window

Uploading a Program

- 1.Connect Arduino board to computer.
- 2.Open Arduino Environment Software and Select the Arduino board type under Tools>Boards>Arduino UNO (Fig.2.16 (a)).

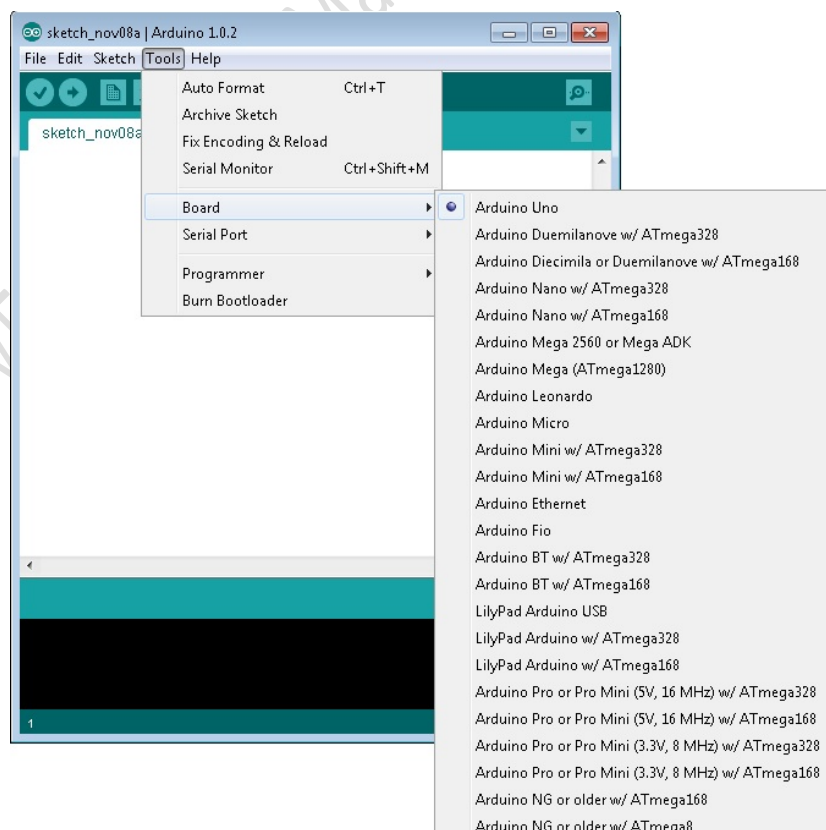


Fig.2.16: (a) Identifying the board

3. Selected ESP 8266 board in Arduino IDE (Fig.2.16 (b)).

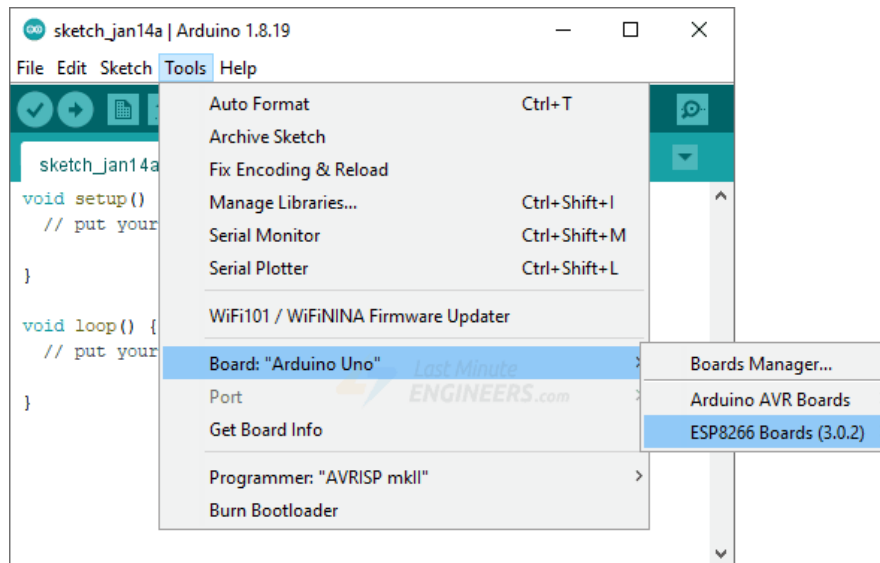


Fig.2.16: (b) Selecting ESP 8266 board

4. Choose the serial port under Tools>Serial Port>COM 4 (COM # depending on what COM port is free during setup) (Fig.2.17).

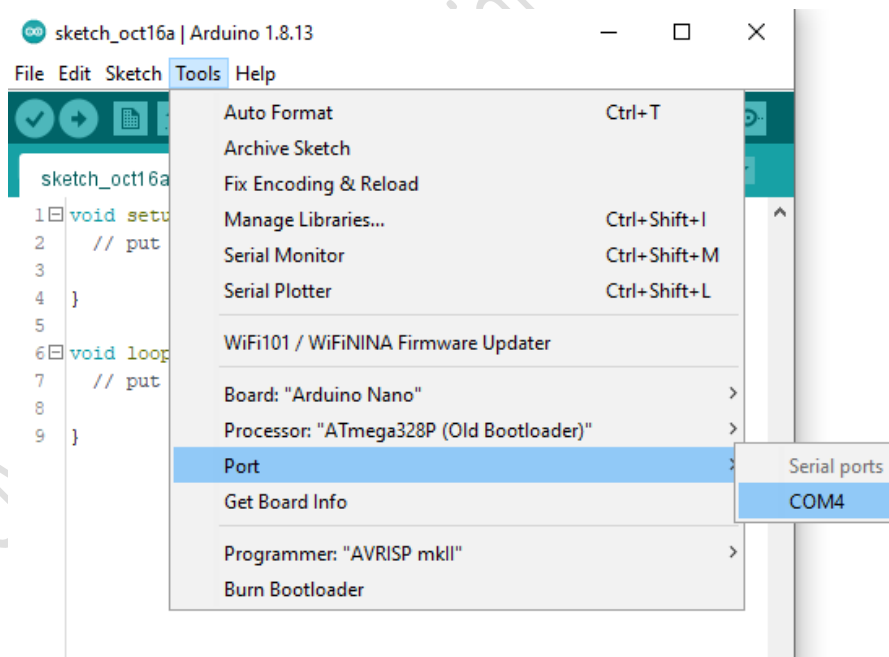


Fig.2.17: Selecting the serial port

5. Open an example code by clicking File->Examples->Basics->Blink. A screen will appear as shown in Fig.2.18.

```

1  /*
2  Blink
3
4  Turns an LED on for one second, then off for one second, repeatedly.
5
6  Most Arduinos have an on-board LED you can control. On the UNO, MEGA and ZERO
7  it is attached to digital pin 13, on MKR1000 on pin 6. LED_BUILTIN is set to
8  the correct LED pin independent of which board is used.
9  If you want to know what pin the on-board LED is connected to on your Arduino
10 model, check the Technical Specs of your board at:
11 https://www.arduino.cc/en/Main/Products
12
13 modified 8 May 2014
14 by Scott Fitzgerald
15 modified 2 Sep 2016
16 by Arturo Guadalupi
17 modified 8 Sep 2016
18 by Colby Newman
19
20 This example code is in the public domain.
21
22 https://www.arduino.cc/en/Tutorial/BuiltInExamples/Blink
23 */
24
25 // the setup function runs once when you press reset or power the board
26 void setup() {
27   // initialize digital pin LED_BUILTIN as an output.
28   pinMode(LED_BUILTIN, OUTPUT);
29 }
30
31 // the loop function runs over and over again forever
32 void loop() {
33   digitalWrite(LED_BUILTIN, HIGH); // turn the LED on (HIGH is the voltage level)
34   delay(1000); // wait for a second
35   digitalWrite(LED_BUILTIN, LOW); // turn the LED off by making the voltage LOW
36   delay(1000); // wait for a second
37 }
38
39

```

Fig.2.18: Screenshot of the code

Let's see at the code by Blink.Ino in Arduino software.

Blink.Ino

```
/*
```

This is a comment at the top of a program, it will not be recognized as code. Very good to add an explanation of what your code does here.

This sketch shows how to read a value from a sensor connected to pin A1, print it out in the Serial Monitor, and turn on an LED connected to pin number 2 if a conditional is met.

```
*/
```

```
int sensorPin = A1; //define pin A1 (analog pin)
```

```
int ledPin = 2; //define pin 2 (digital pin)
```

```
int sensorValue; //create variable for storing readings
```

```

//void setup is for configurations on start up
void setup() {
Serial.begin(9600); //initializes serial communication
pinMode(ledPin, OUTPUT); //define LedPin as an output
}

void loop() {
sensorValue = analogRead(sensorPin); // do a sensor rec

Serial.print("Sensor value is: "); //print a message to
Serial.println(sensorValue); //print the value to the s

//check if sensorValue is below 200
if(sensorValue < 200) {
digitalWrite(ledPin, HIGH); //if it is, turn on the
}
//if sensorValue is above 200, turn off the LED
else {
digitalWrite(ledPin, LOW);
}
}
}

```

6. Click on the upload button to upload the code to Arduino. Wait till the “Done Uploading” message status appears (Fig.2.19).

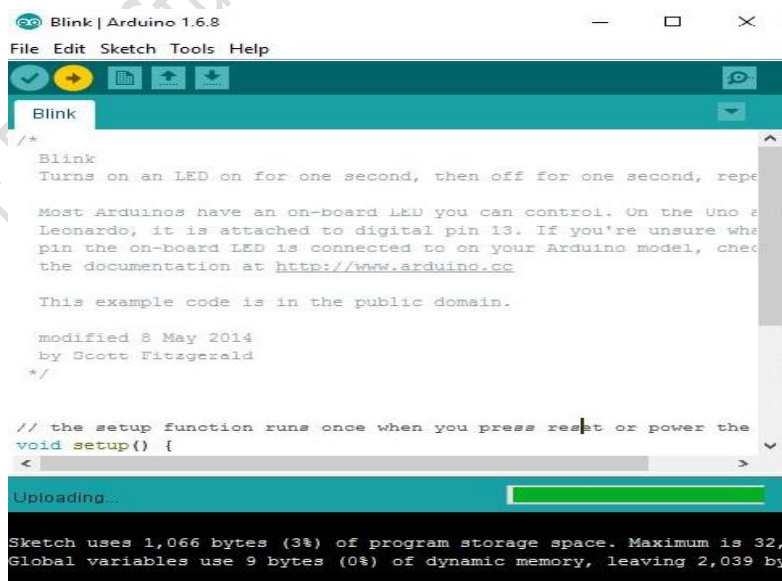


Fig.2.19: Uploading a code

2.4.2 Tinkercad

Tinkercad is a free, web-based platform developed by Autodesk. It is used for designing 3D models, simulating electronic circuits, and learning coding through interactive tools. Users can create 3D objects, build virtual circuits, and test ideas without physical hardware (Fig.2.20).

Tinkercad also provides educational resources such as tutorials, lesson plans, and project ideas, making it useful for learning STEM concepts.

One of its important features is integration with Arduino. Users can build circuits with virtual components and simulate Arduino programs online, making prototyping and testing easier.

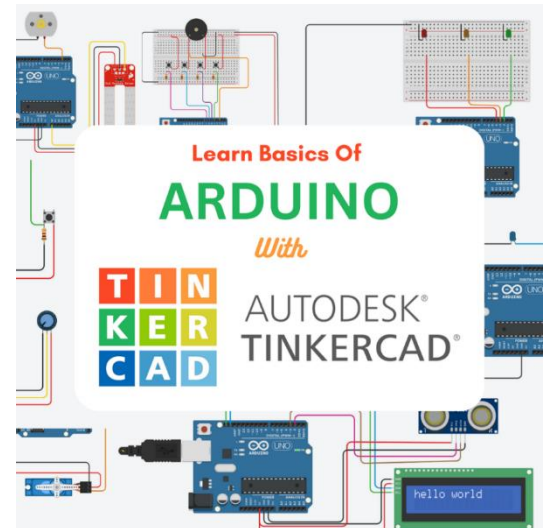


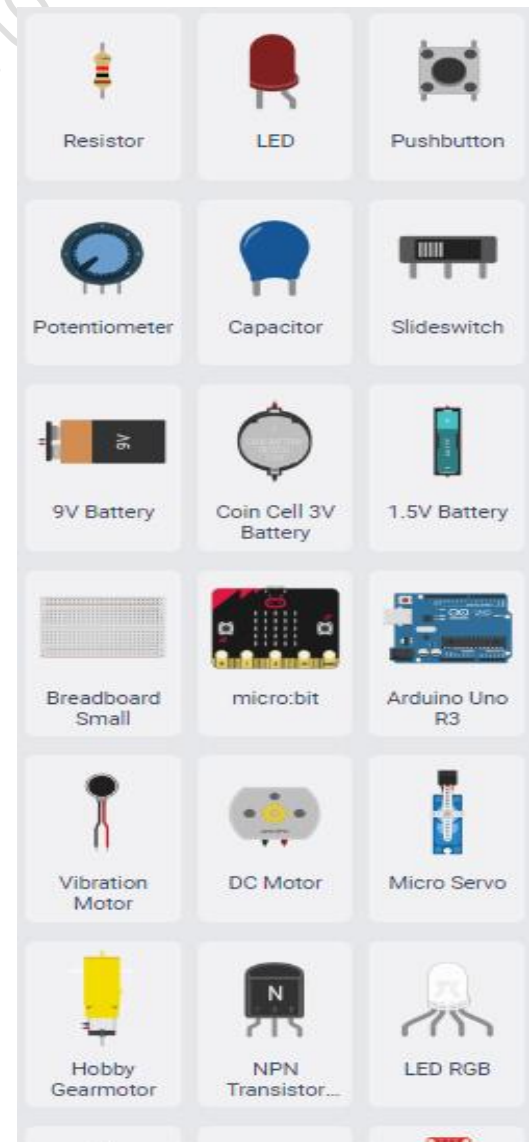
Fig.2.20: Autodesk Tinkercad Platform

Autodesk Tinkercad Circuits

Autodesk Tinkercad Circuits is a powerful, online tool for designing, simulating, and programming electronic circuits. As part of the Tinkercad suite, it integrates 3D design, circuit simulation, and coding into one easy-to-use environment. It offers a simple drag-and-drop interface and includes components such as resistors, LEDs, switches, sensors, and microcontrollers (Fig.2.21).

Its simulation feature allows users to test circuits, measure voltage and current, and identify errors before building real hardware.

It also includes a built-in code editor for block coding and Arduino programming, making it ideal for students, educators, and beginners in electronics, programming, and IoT.



Tinkercad Circuit Examples:

1. **LED Blink:** In this example, an LED is made to blink ON and OFF with a time interval of 0.5 second (500 milliseconds).
 - Drag and drop an Arduino Uno and an LED from the components list into the workspace (Fig. (2.22(i))).

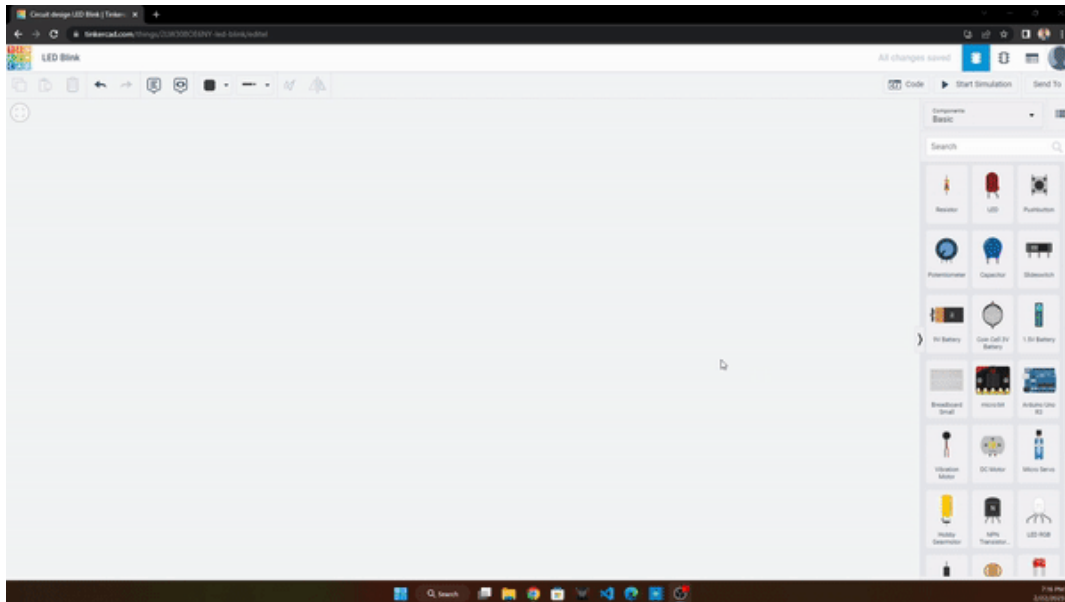


Fig.2.22(i): LED Blink

- Connect the anode (+) of the LED to Pin 2 of Arduino Uno.
- Connect the cathode (-) of the LED to GND of Arduino Uno.
- Generally, black wire is used for GND, red wire for 5V/3.3V supply, and other colors for signal connections.
- After completing the circuit connections, click on the Code option at the top-right corner.
- In Arduino programming, two main sections are used:
 - on start / void setup() – This section runs only once when the board is powered ON or reset.
 - forever / void loop() – This section runs continuously again and again until power is removed.
- In the on-start section, add a message such as Hello World to the Serial Monitor.
- In the forever section, set Pin 2 HIGH to turn the LED ON and display the message LED ON.
- Add a wait block of 0.5 second.
- Then set Pin 2 LOW to turn the LED OFF and display the message LED OFF.
- Again, add a wait block of 0.5 second before turning the LED ON again.
- This process repeats continuously, causing the LED to blink.
- The Serial Monitor displays the messages LED ON and LED OFF repeatedly (Fig.2.22(ii)).

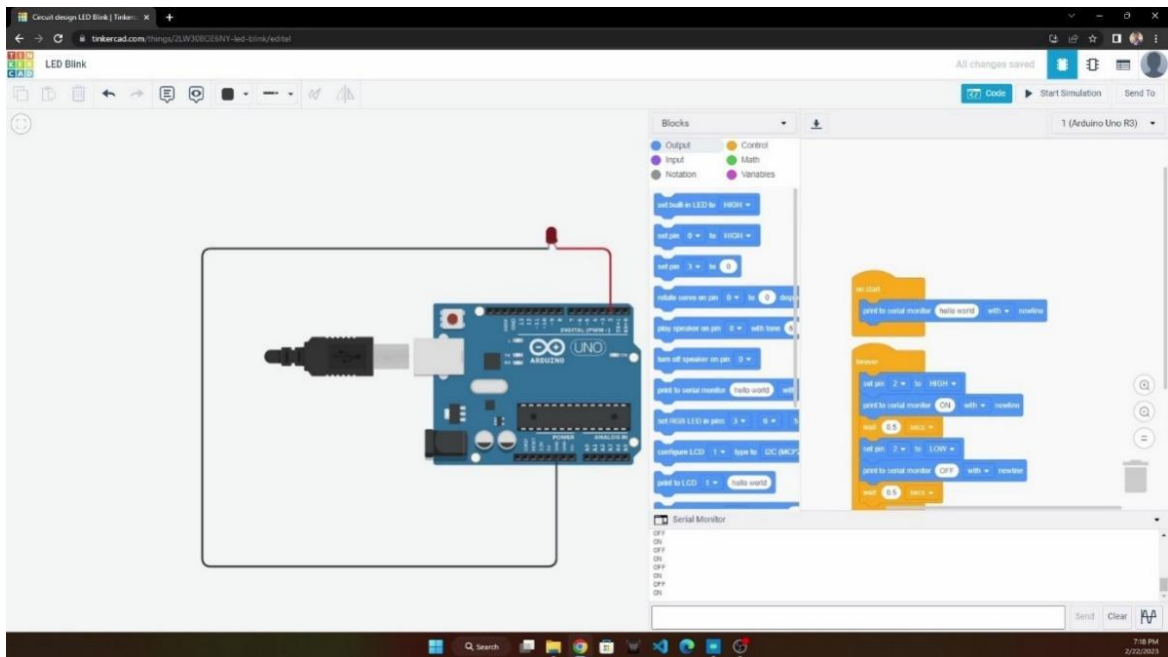


Fig.2.22(ii): LED Blink Circuit

2. Push Button: In this example, a push button is connected to Arduino Uno to read digital input signals.

- Drag and drop an Arduino Uno, a push button, and a 10 k Ω resistor into the workspace.
- Connect one terminal of the push button to Pin 2 of Arduino Uno.
- Connect the same terminal to GND through a 10 k Ω resistor.
- Connect the opposite terminal of the push button to 5V.
- The resistance value can be changed by clicking on the resistor component in Tinkercad.
- In this circuit, the resistor acts as a Pull-Down resistor.
- When the push button is pressed, Pin 2 receives HIGH (5V) signal.
- When the push button is released, the resistor connects the input to GND, making the pin LOW (0V).
- Therefore, the input remains LOW when the button is not pressed and becomes HIGH only when the button is pressed.
- This prevents false or floating input signals.
- Similarly, a Pull-Up resistor can also be used by connecting the resistor between the input pin and 5V. In that case, the input remains HIGH normally and becomes LOW when the button is pressed.
- This circuit helps in understanding digital input interfacing using switches and buttons (Fig.2.23).

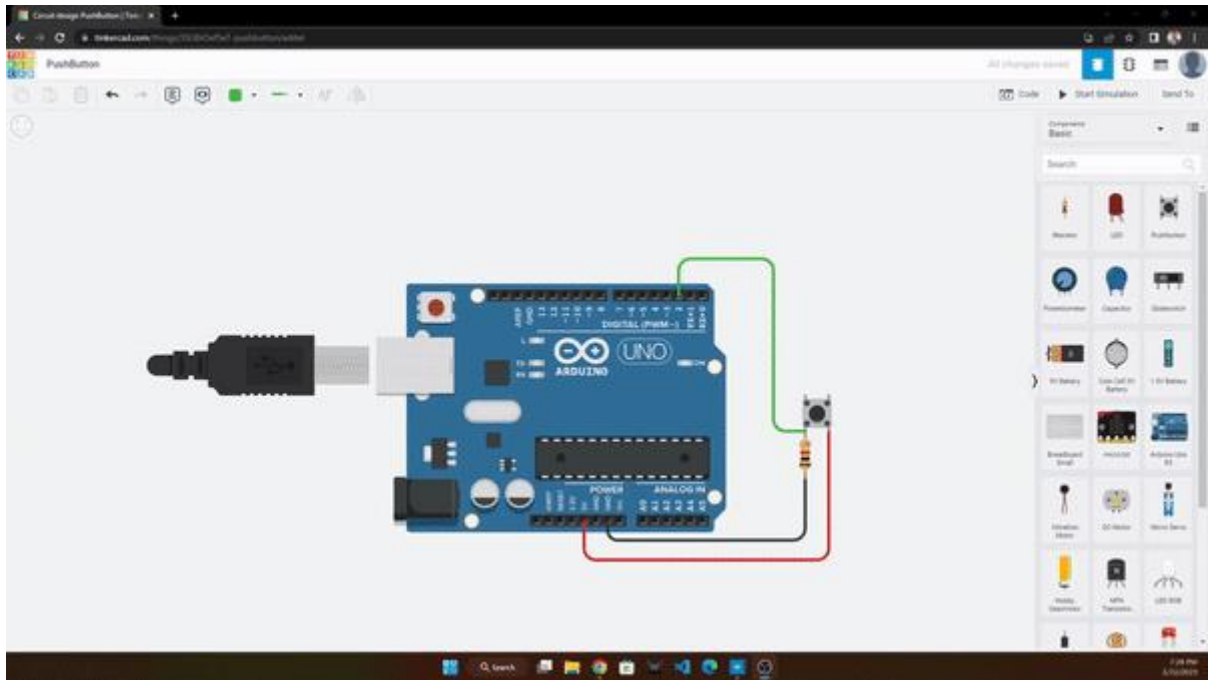


Fig.2.23(i): Push Button Circuit

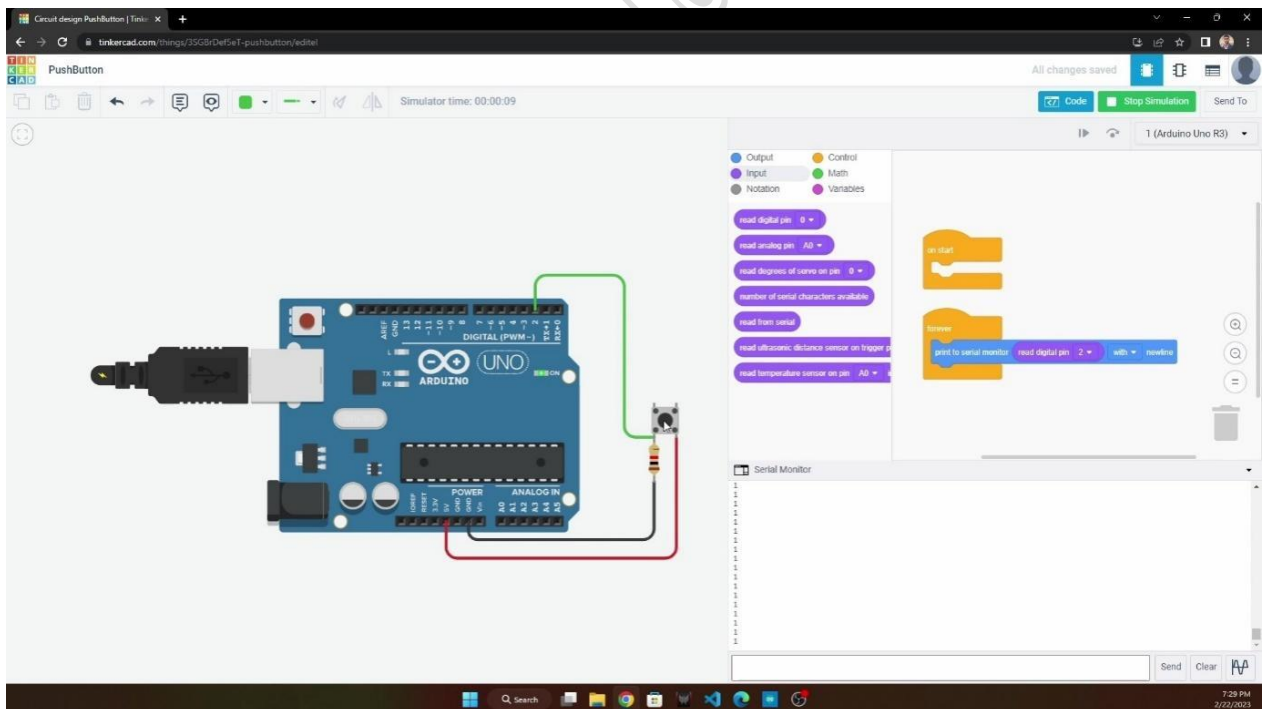


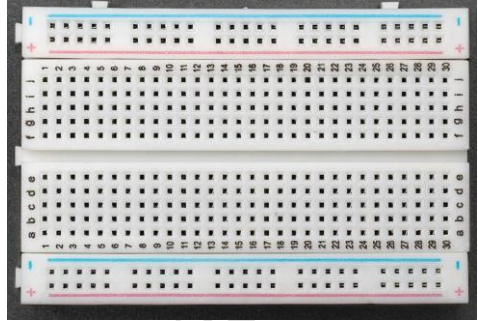
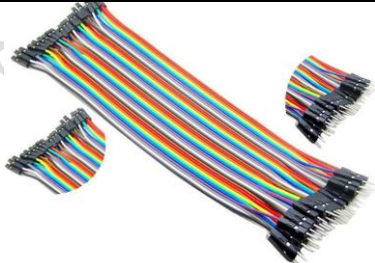



Fig.2.23(ii): Push Button Circuit

2.5 Hardware Tools

Hardware tools are essential for building, testing, and troubleshooting microcontroller-based circuits. These tools help users connect components, supply

power, upload programs, and create prototypes. Basic Hardware Tools are listed in the Table 2.3.

Table 2.3: Hardware Tools

S. No.	Hardware Tool	Use / Purpose	Image
1	Breadboard	Used to make temporary circuit connections without soldering	
2	Jumper Wires	Used to connect components, sensors, and boards	
3	USB Cable	Used for power supply and uploading programs	
4	Power Adapter / Battery	Used to power standalone projects	
5	LED	Used as output indicator and testing circuits	

6	Resistor	Limits current and protects components	
7	Push Button Switch	Used as digital input device	
8	Multimeter	Measures voltage, current, and resistance	
9	Buzzer	Used for sound indication or alarms	
10	Relay Module	Used to control AC/DC appliances using microcontroller	

11	DC Motor / Servo Motor	Used for motion and automation applications	
12	Sensors	Used to detect temperature, light, motion, humidity, etc.	
13	Screwdriver Set	Used for assembly and tightening connections	
14	Soldering Iron	Used for permanent circuit connections	
15	Wire Cutter / Stripper	Used to cut and strip wires for connections	

PRACTICAL ACTIVITY

ACTIVITY 1:

Connecting Arduino Board to a Computer and Setting Up Data Transfer

Objective: To connect an Arduino board to a computer, establish communication, and verify that the board is ready for programming.

Material Required: Arduino Board, USB type-B cable, Computer/laptop with Arduino IDE installed

Procedure:

Step 1: Collect all the required materials. Connect the USB Type-B cable to the Arduino board and connect the other end to the USB port of the computer. The USB cable is used to transfer the program from the computer to the Arduino board and also provides power supply to the board (Fig. 1).

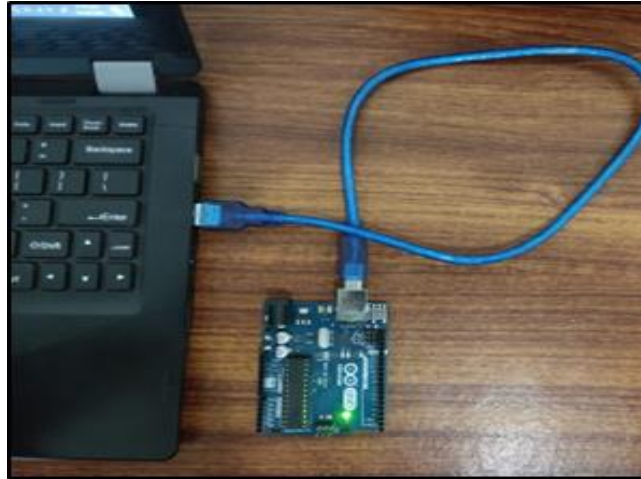


Fig. 1: USB cable connection with PC

Step 2: After connecting the board, an LED on the Arduino board may start blinking. This indicates that the board is receiving power and is functioning properly. Fig.2 and Fig.3 show the connection of the USB cable to the board.

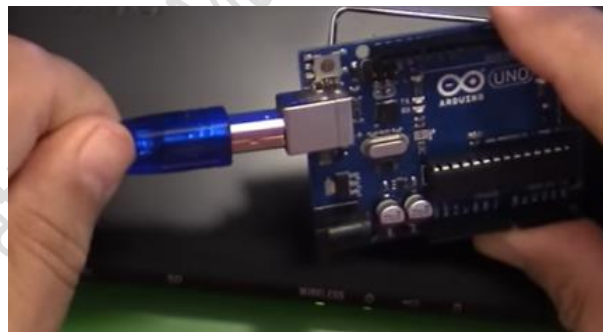


Fig.2: Connecting the USB plug to the board

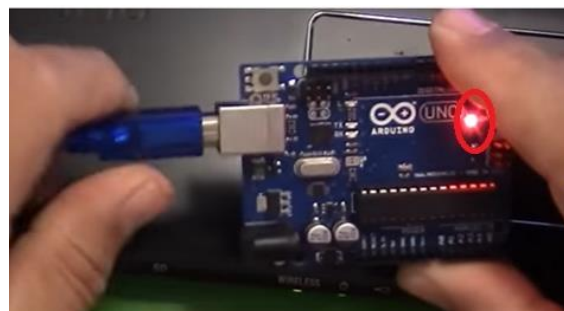


Fig.3: LED blinking on the Arduino board after connecting the USB cable

Step 3: Check the blinking LED on the board. This onboard LED is used to verify that the Arduino board is working correctly and ready for programming. Fig.4 shows the complete setup of the Arduino board connected to the computer.



Fig.4: Arduino board Set up

ACTIVITY 2: Single LED Blinking Circuit Using Arduino Uno

Objective: To interface an LED with a microcontroller and make it blink continuously at a fixed time interval.

Components Required:

- Arduino Uno / Microcontroller Board
- LED
- 220 Ω Resistor
- Breadboard
- Connecting Wires
- USB Cable
- Computer/Laptop with Arduino IDE

Theory: A microcontroller can control output devices such as LEDs by sending HIGH and LOW signals through digital output pins. When the pin is HIGH, the LED glows. When the pin is LOW, the LED turns OFF. By repeating this process with delay, the LED blinks continuously.

Circuit Connections:

- Connect the anode (+) terminal of the LED to Digital Pin 8 of Arduino Uno through a 220 Ω resistor.
- Connect the cathode (-) terminal of the LED to the GND pin of Arduino Uno.
- Connect the Arduino Uno board to the computer using a USB cable.

Procedure:

1. Assemble the Circuit

- Place the LED on the breadboard.
- Connect the long leg (anode) of the LED to one end of the 220 Ω resistor.
- Connect the other end of the resistor to Digital Pin 8 of Arduino Uno.
- Connect the short leg (cathode) of the LED to the GND rail of the breadboard.

- Connect the GND rail to the GND pin of Arduino Uno (Fig.1).

2. Connect Arduino to the Computer

- Use the USB cable to connect the Arduino Uno board to the computer.

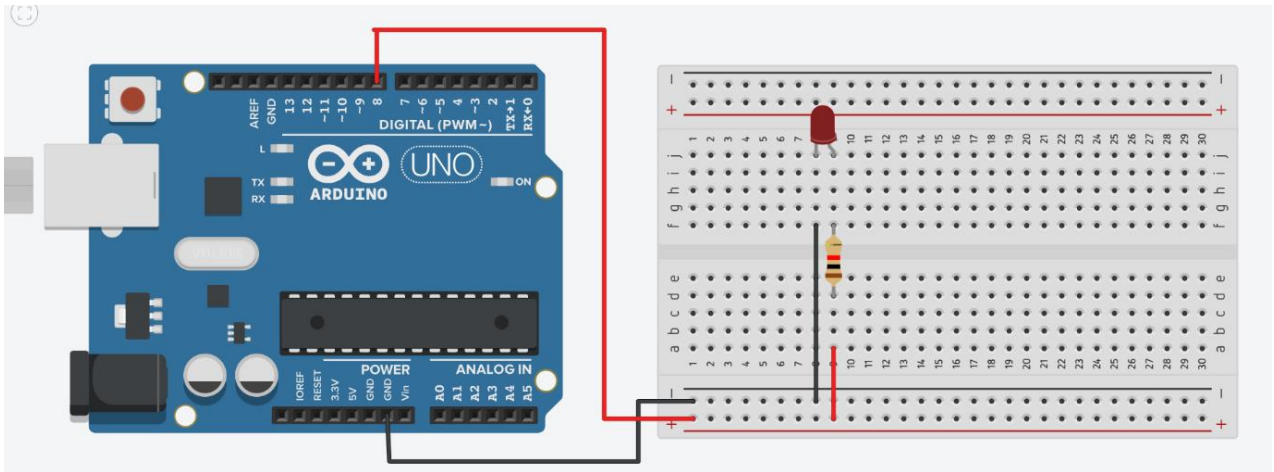


Fig.1: Circuit Connection Diagram

3. Open Arduino IDE

- Open the Arduino IDE software on the computer.
- Select:
 - **Board:** Arduino Uno
 - **Port:** Appropriate COM Port

Arduino Program

```
int ledPin = 8;

void setup() {
  pinMode(ledPin, OUTPUT);
}

void loop() {
  digitalWrite(ledPin, HIGH); // LED ON
  delay(1000);                // Wait for 1 second
  digitalWrite(ledPin, LOW);  // LED OFF
  delay(1000);                // Wait for 1 second
}
```

4. Upload the Program

- Type or paste the program into the Arduino IDE.
- Click the **Upload** button to transfer the program to Arduino Uno.

5. Observe the Output

- The LED connected to Pin 8 starts blinking continuously.
- It remains ON for one second and OFF for one second repeatedly.

Working Principle:

The Arduino Uno sends a digital signal from pin 8 to the LED. When the signal is HIGH, current flows through the resistor and LED, turning it ON. When the signal is LOW, current stops, and the LED turns OFF. This cycle repeats continuously, producing a blinking effect.

Observation:

- The LED blinks continuously at one-second intervals.
- Changing the value inside the delay () function changes the blinking speed.

Example:

- delay(500) → Faster blinking
- delay(2000) → Slower blinking

Activity 3:

Push Button Controlled LED using Arduino Uno

Objective: To interface a push button and an LED with Arduino Uno and control the LED using the push button switch.

Components Required:

- Arduino Uno Board
- LED
- Push Button Switch
- 220 Ω Resistor
- 10 k Ω Resistor
- Breadboard
- Connecting Wires
- USB Cable
- Computer/Laptop with Arduino IDE

Theory: A push button is an input device used to send digital signals to the Arduino Uno. The Arduino reads the button status through a digital input pin. When the push button is pressed, the Arduino receives a HIGH signal and turns the LED ON. When the push button is released, the Arduino receives a LOW signal and turns the LED OFF. This activity demonstrates how Arduino can read input signals and control output devices.

Circuit Connections:

LED Connections

1. Connect the anode (+) terminal of the LED to Digital Pin 8 of Arduino Uno through a 220 Ω resistor.
2. Connect the cathode (-) terminal of the LED to GND.

Push Button Connections

1. Connect one terminal of the push button to 5V of Arduino Uno.
2. Connect another terminal of the push button to the GND, and put a 10k Ohm resistor in between. This resistor will act as a “pull down” resistor, which means that the default button’s state will be LOW.
3. Connect Arduino Uno to the computer using a USB cable.

Procedure:

1. Assemble the Circuit

- Place the LED and push button on the breadboard.
- Connect the LED circuit using the 220 Ω resistor.
- Connect the push button to GND and 5V.
- Connect the 10 k Ω resistor between push button and GND (Fig.1).

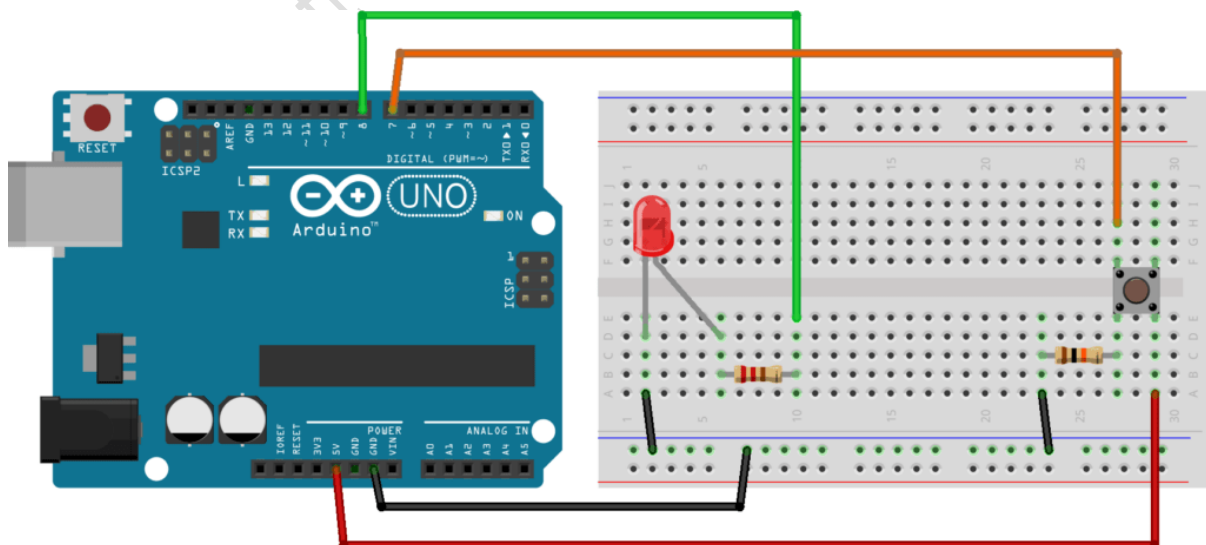


Fig.1: Circuit Connection Diagram

2. Connect Arduino to the Computer

- Use the USB cable to connect Arduino Uno to the computer.

3. Open Arduino IDE

- Open the Arduino IDE software.
- Select:
 - **Board:** Arduino Uno
 - **Port:** Appropriate COM Port

Arduino Program:

```
int ledPin = 8;
int buttonPin = 2;
int buttonState = 0;

void setup() {
  pinMode(ledPin, OUTPUT);
  pinMode(buttonPin, INPUT);
}

void loop() {
  buttonState = digitalRead(buttonPin);

  if (buttonState == HIGH) {
    digitalWrite(ledPin, HIGH); // LED ON
  }
  else {
    digitalWrite(ledPin, LOW); // LED OFF
  }
}
```

4. Upload the Program

- Type or paste the program into Arduino IDE.
- Click the Upload button.

5. Observe the Output

- Press the push button → LED turns ON.
- Release the push button → LED turns OFF.

Working Principle:

The push button acts as an input device for Arduino Uno. When the button is pressed, Pin 2 receives a HIGH signal. The Arduino processes this signal and sends a HIGH output to Pin 8, turning the LED ON. When the button is released, Pin 2 becomes LOW through the pull-down resistor, and the Arduino turns the LED OFF.

Observation:

- The LED glows only when the push button is pressed.
- The LED turns OFF when the button is released.
- The push button controls the LED operation successfully.

ACTIVITY 4: Fading LED using Arduino

Objective: To interface an LED with Arduino Uno and control its brightness using PWM (Pulse Width Modulation) to create a fading effect.

Components Required:

- Arduino Uno Board
- LED
- 220 Ω Resistor
- Breadboard
- Connecting Wires
- USB Cable
- Computer/Laptop with Arduino IDE

Theory: A push button is an input device used to send digital signals to the Arduino Uno. The Arduino reads the button status through a digital input pin. When the push button is pressed, the Arduino receives a HIGH signal and turns the LED ON. When the push button is released, the Arduino receives a LOW signal and turns the LED OFF. This activity demonstrates how Arduino can read input signals and control output devices.

Procedure:

1. Assemble the Circuit

- Place the LED on the breadboard.
- Connect the resistor between Arduino Pin 9 and the LED anode.
- Connect the LED cathode to GND.

2. Connect Arduino to the Computer

- Use the USB cable to connect Arduino Uno to the computer (Fig.1).

3. Open Arduino IDE

- Open the Arduino IDE software.
- Select:
 - **Board:** Arduino Uno
 - **Port:** Appropriate COM Port

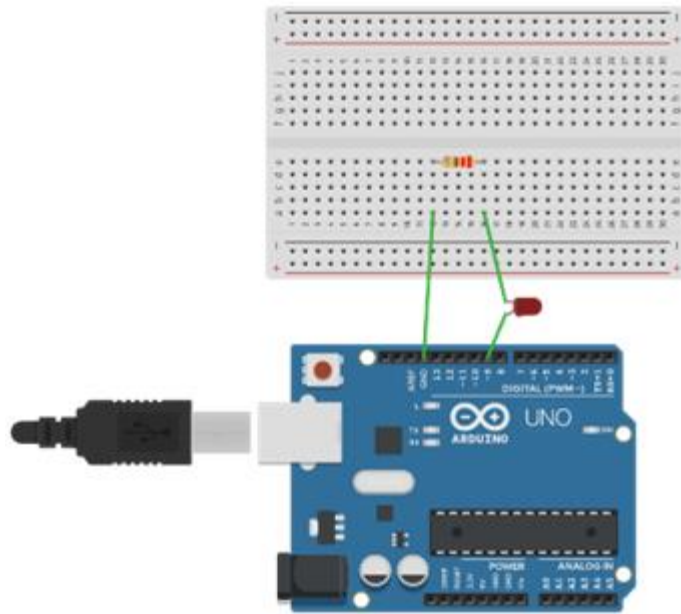


Fig.1: Circuit Connection Diagram

Arduino Program

```
int ledPin = 9;
int brightness = 0;
int fadeAmount = 5;

void setup() {
  pinMode(ledPin, OUTPUT);
}

void loop() {
  analogWrite(ledPin, brightness);
```

```

brightness = brightness + fadeAmount;

if (brightness <= 0 || brightness >= 255) {
  fadeAmount = -fadeAmount;
}

delay(30);
}

```

4. Upload the Program

- Type or paste the program into Arduino IDE.
- Click the Upload button.

5. Observe the Output

- The LED gradually increases in brightness.
- After reaching maximum brightness, it gradually dims.
- The fading process repeats continuously.

Working Principle:

This circuit uses PWM (Pulse Width Modulation) to control the LED brightness. The `analogWrite()` function rapidly switches the LED ON and OFF at different duty cycles.

- When the PWM value increases, the LED appears brighter.
- When the PWM value decreases, the LED appears dimmer.

Arduino continuously changes the PWM value, producing a smooth fading effect.

Observation

- The LED brightness gradually increases to maximum intensity and then decreases smoothly.
- The fading effect repeats continuously in a loop.
- Changing the `fadeAmount` or `delay()` value changes the speed of fading.

ACTIVITY 5: Building a Basic Torch Circuit

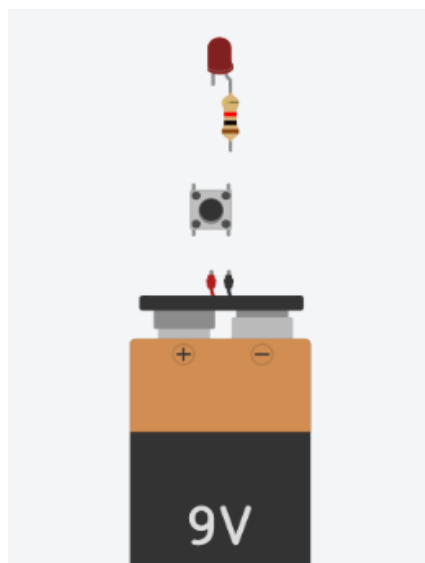
Objective: To design and simulate a simple torch circuit using an LED, resistor, push button, and battery in Tinkercad Circuits.

Components Required:

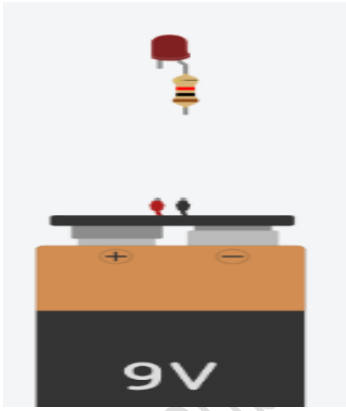
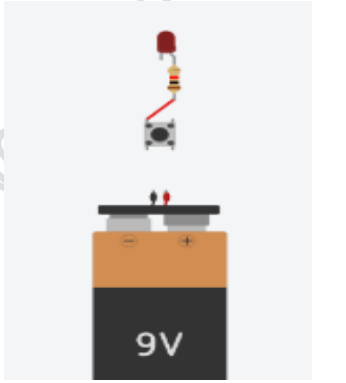
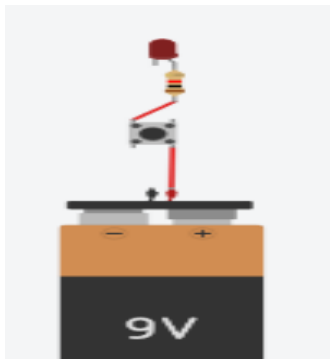
Component Name	Quantity	Specification / Description
LED	1	Any color (Red/White recommended)
Resistor	1	220 Ω
Push Button	1	Normally open type
Battery	1	9V DC
Breadboard	1	—
Connecting Wires	As required	—

Procedure in Tinkercad

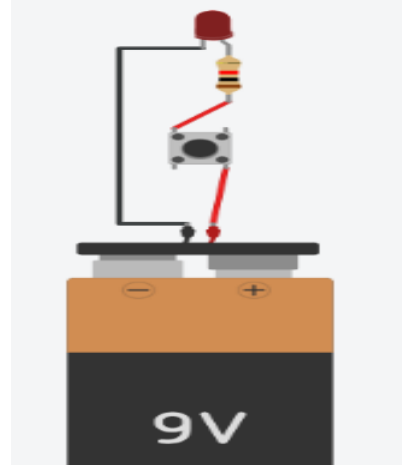
1. Open Tinkercad Circuits
 - Go to www.tinkercad.com.
 - Log in or create a free account.
 - Click “Circuits” → “Create New Circuit.”
2. Place the Components
 - From the components list, drag and drop the LED, resistor, push button, and 9V battery onto the workspace.



3. Make the Connections as shown below.

<p>Connect one terminal of the resistor to the anode (long leg) of the LED.</p>	
<p>Connect one terminal of the push button (1B) to the free end of the resistor.</p>	
<p>Connect the other terminal of the push button (2A) to the positive terminal of the battery.</p>	

Connect the cathode (short leg) of the LED to the negative terminal of the battery.



4. Start Simulation

- Click on “Start Simulation” at the top-right corner.
- Press the push button in the simulation.
- Observe that the LED lights up when the button is pressed and turns off when released.

Working Principle:

The torch circuit operates on a simple series connection of a battery, resistor, LED, and push button. When the push button is pressed, it completes the circuit, allowing current to flow from the battery through the resistor and LED. The resistor limits the current to protect the LED from damage. When the button is released, the circuit opens, and the LED turns off.

Observation:

- The LED glows only when the push button is pressed.
- The brightness of the LED depends on the resistor value and battery voltage.

ACTIVITY 5: Measurement of Battery Voltage

Objective: To measure the voltage of a battery using a digital multimeter.

Components Required:

Component Name	Quantity	Specification / Description
Battery	1	9V DC or AA (1.5V)
Digital Multimeter	1	For DC voltage measurement
Breadboard	1	(Optional, for mounting components)

Connecting Wires	As required	—
-------------------------	-------------	---

Procedure:

1. Set the digital multimeter to the DC voltage (V=) range.
2. Identify the positive (red) and negative (black) probes of the multimeter.
3. Connect the red probe to the positive terminal of the battery.
4. Connect the black probe to the negative terminal of the battery.
5. Read the voltage value displayed on the multimeter screen.
6. Note the reading. A typical 9V battery will show between 8.5 V and 9.0 V if new, or lower if discharged.

**Working Principle**

A battery produces a direct current (DC) voltage due to the chemical reaction between its electrodes and electrolyte. The digital multimeter, when set to the DC voltage mode, measures the potential difference between the two terminals of the battery. This voltage represents the electromotive force (EMF) available to drive current in a circuit.

Observation

Battery Type	Rated Voltage	Measured Voltage (V)	Condition
9V Battery	9.0V	8.8V	Good
AA Cell	1.5V	1.4V	Slightly discharged
AAA Cell	1.5V	1.3V	Weak

CHECK YOUR PROGRESS

A. Multiple Choice Questions

- A student wants to build a project that turns an LED ON and OFF automatically every 1 second. Which type of Arduino pin should be used to connect the LED?
 - Analog input pin
 - Digital I/O pin
 - Vin pin
 - AREF pin
- A user wants to upload a program from a computer to an Arduino Uno board. Which connection is most suitable?
 - HDMI cable
 - USB cable
 - Audio cable
 - Ethernet cable
- A smart home project needs a board with built-in Wi-Fi for remote control through a mobile app. Which board should be selected?
 - Arduino Uno
 - NodeMCU
 - PIC16F877A
 - ATmega328P IC only
- A push button connected to Arduino shows unstable values when it is not pressed. What should be used to keep the input LOW normally?
 - LED
 - Pull-down resistor
 - Crystal oscillator
 - TX LED
- A learner wants to test an LED blinking circuit without using physical hardware. Which tool is most suitable?
 - MS Word
 - Tinkercad Circuits
 - Paint
 - Calculator

B. Match the following

Column A	Column B
1. Arduino Uno	A. Built-in Wi-Fi board
2. NodeMCU	B. Stores temporary data
3. RAM	C. Popular beginner microcontroller board
4. GPIO Pins	D. Connect external devices
5. Tinkercad	E. Virtual circuit simulation tool

C. Fill in the blanks

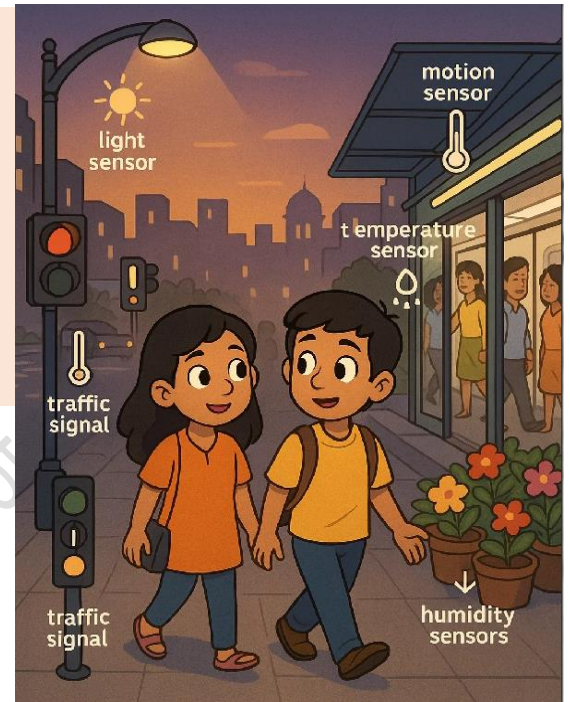
1. A microcontroller is often called the _____ of electronic devices.
2. The _____ pin on Arduino Uno is used to connect external analog inputs.
3. NodeMCU is based on the _____ microcontroller.
4. _____ is used to write and upload programs to Arduino boards.
5. In Tinkercad, circuits can be tested without using _____ hardware.

D. Answer the following

1. An LED connected to Arduino Uno is not blinking after uploading the program. What steps would you check to identify the problem?
2. A home automation project requires wireless control of lights through a mobile phone. Which board would you choose between Arduino Uno and NodeMCU? Give reason.
3. A push button connected to Arduino gives random HIGH and LOW readings. How would you modify the circuit to get stable input values?
4. You want to test an LED blinking circuit before assembling real hardware. Which software tool would you use and how would it help?
5. A project needs a device that runs on battery power and performs one dedicated task continuously. Why is a microcontroller suitable for this application?

SESSION 2: AUTOMOTIVE IIOT SENSORS AND ACTUATORS

One evening, Ananya and Rohan were walking through their busy Indian city when they began noticing sensors and actuators everywhere. A streetlight flickered on as the sun dipped below the horizon, thanks to a light sensor. At a traffic signal, pressing a pedestrian button changed the lights so people could cross safely. In the metro station, motion sensors slid the doors open as passengers approached, while temperature sensors kept the air cool inside. At a roadside plant shop, humidity sensors triggered a gentle mist over the flowers. Even the city buses used pressure sensors to open and close doors automatically. Seeing all this, Ananya and Rohan realized how quietly these devices worked behind the scenes, making their daily lives smoother and smarter.



Sensors and actuators are important parts of any Industrial Internet of Things (IIOT) system. Sensors collect information from machines and the environment, such as temperature, pressure, vibration, or speed. Actuators use this information to perform actions, like turning on a motor or opening a valve. Actuators can be electric, hydraulic, or air-powered (pneumatic), depending on the task. Both sensors and actuators work with microcontrollers, which read the sensor data and send signals to control the actuators. This allows machines to respond quickly and work efficiently in industrial systems.

Think About It!

Have you noticed automatic doors opening at malls or metro stations? Sensors detect people nearby and actuators help open the doors automatically.



2.6 Introduction to Sensors

A sensor is a device that detects and responds to changes in its physical environment. These changes, called inputs, may include light, heat, motion, moisture, pressure, or other environmental conditions. The sensor converts these inputs into an output signal, usually electrical, which can either be displayed directly in a human-readable form or transmitted over a network for monitoring, analysis, or further processing (Fig.2.25).

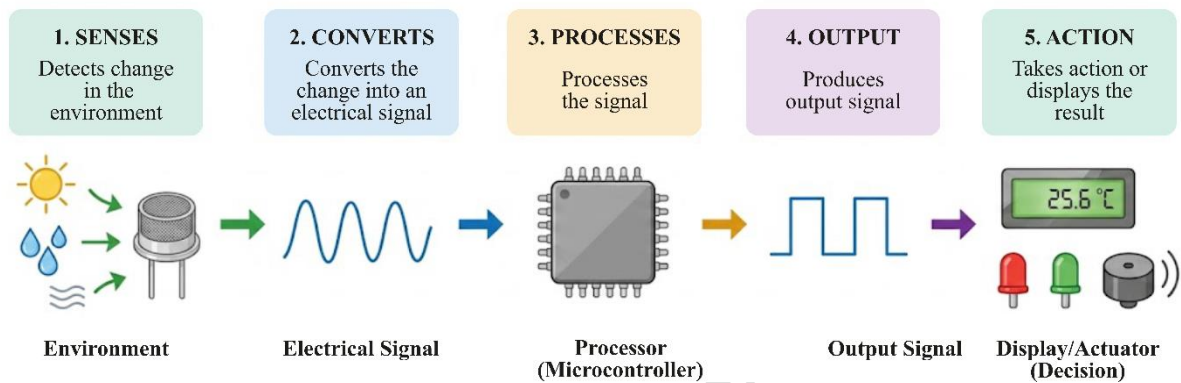


Fig. 2.25: How a Sensor Works

👉 Did You Know?

Sensors work like human sense organs. Just as our eyes detect light and ears detect sound, sensors detect temperature, pressure, motion, and many other physical conditions.

2.6.1 Importance of Sensors in IoT

In IoT (Internet of Things) architecture, sensors represent the “Things” of the system. They are placed at the front end of devices and continuously collect real-time data from machines and the surrounding environment. Depending on their design, sensors can operate automatically or be controlled by users. The output of sensors may appear as measurable changes in resistance, capacitance, impedance, voltage, or current. These outputs are processed by microcontrollers or controllers for monitoring and decision-making.

Sensors are commonly integrated with IoT technology and microcontrollers to provide accurate and reliable real-time information. They help smart devices detect environmental conditions and respond automatically without human intervention. Thus, sensors play an important role in making devices intelligent, automatic, and responsive.

The main purpose of a sensor is to collect data from its surroundings and send it to a controller, which can further control actuators to perform required actions. For example, a door sensor can detect whether a door is open or closed.

Sensors are widely used in smart devices such as:

- Mobile phones
- Smart home appliances
- Fire alarms
- Air conditioners
- Cars
- Industrial machines

Real-Life Connection

Smart phones use many sensors such as touch sensors, light sensors, and motion sensors to perform different functions automatically.

2.6.2 Working of Sensors in IoT

Sensors are embedded in IoT devices to sense their environment. The data collected is stored in a suitable format within the device. Examples of such devices include cell phones, coffee makers, microwaves, geysers, air conditioners, fire alarms, and cars.

These embedded sensors continuously generate information about the device's environment and operation. The collected data can then be processed and sent to the cloud via an IoT gateway, access point, or hub using various communication methods, and then action is taken through actuator or alert system (Fig. 5.2).

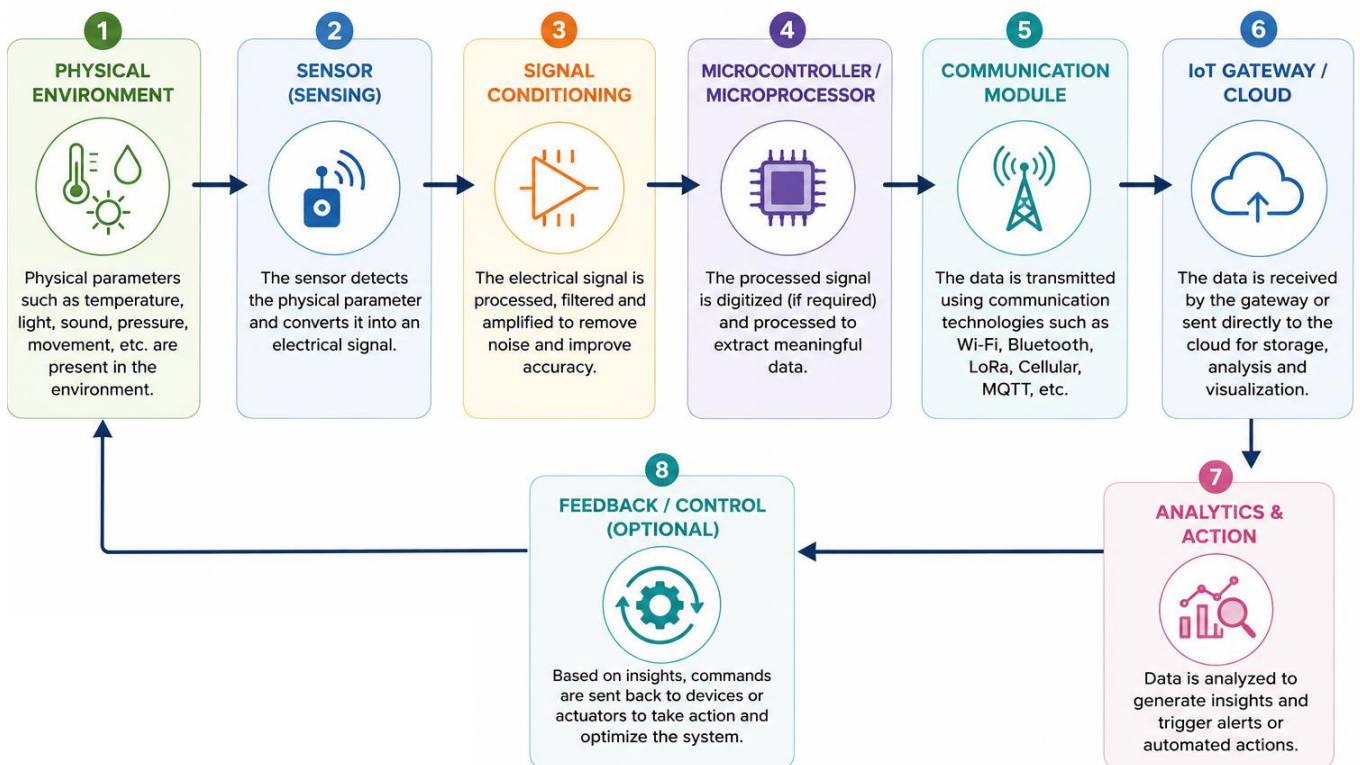


Fig.2.26: Working of Sensors in IoT

2.6.3 Classification of Sensors

Sensors are used in a wide range of fields and are highly adaptable to different measurement and detection requirements. They are commonly used in industries, automotive systems, healthcare, environmental monitoring, and consumer electronics.

Sensors can be classified in several ways depending on their characteristics and applications. One common method is based on the physical quantity measured, such as temperature, pressure, light, humidity, or motion.

Another method of classification is based on their working principle or transduction mechanism, such as resistive, capacitive, inductive, optical, and piezoelectric sensors. Sensors can also be grouped according to their power requirements, output signal type, or specific application areas (Fig. 2.27).

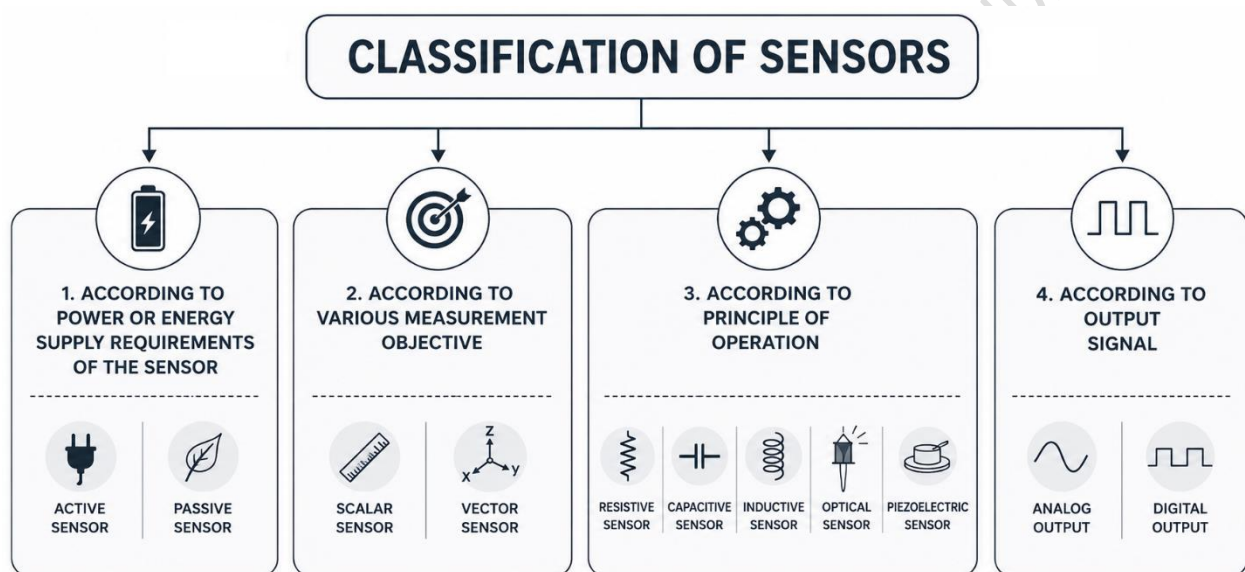


Fig.2.27: Classification of Sensors

A) According to power or energy supply requirements of the sensor

Passive and Active:

Passive Sensors cannot independently sense the input. Ex- Accelerometer, soil moisture, water level and temperature sensors.

Active Sensor can independently sense the input. Example - Radar, sonar and laser altimeter sensors.

B) According to output signal

Analog and Digital:

Sensors that produce an analog output signal that is a continuous function with respect to time input are called analog sensors. The signals generated by these sensors are measured proportionally. There are various analog sensors. Accelerometers, pressure sensors, light sensors, sound sensors and temperature sensors are some of the examples of analog sensors.

Sensors in which data conversion and transmission is done digitally are called digital sensors. A digital sensor mainly consists of three parts: the sensor, cable and transmitter. The measured signal is internally converted to a digital signal by the digital sensor itself. Cable transmits this digital information digitally. They are different types of digital sensors. A digital accelerometer and a digital temperature sensor are examples of digital sensors.

C) According to various measurement objective

Scalar and vector:

Scalar sensor detects the input parameter only based on its magnitude. The response of the sensor is a function of the magnitude of some input parameter, and it is not affected by the direction of input parameters. Example – temperature, gas, strain, color and smoke sensor.

In the working of vector sensor, the response of the sensor depends on the magnitude of the direction and orientation of the input parameter. Example – Accelerometer, gyroscope, magnetic field and motion detector sensors.

2.6.4 Types of Sensors Used in Automotive IIOT

In modern automotive systems, Industrial Internet of Things (IIOT) plays a critical role in enhancing vehicle performance, safety, efficiency, and connectivity. Sensors are the backbone of IIOT, collecting real-time data from the vehicle and its environment. These sensors enable predictive maintenance, automated control, driver assistance systems, and improved overall vehicle intelligence. Automotive IIOT uses a variety of sensors, broadly categorized based on their applications.

1. Temperature Sensors

Temperatures sensors are essential components in automotive systems, designed to monitor the temperature of various critical parts such as the engine, exhaust, battery, and cabin. Their primary purpose is to ensure that these systems operate within safe temperature ranges, preventing damage and maintaining optimal performance. By constantly tracking temperature changes, these sensors provide vital data that can be used for both monitoring and control (Fig.2.28).

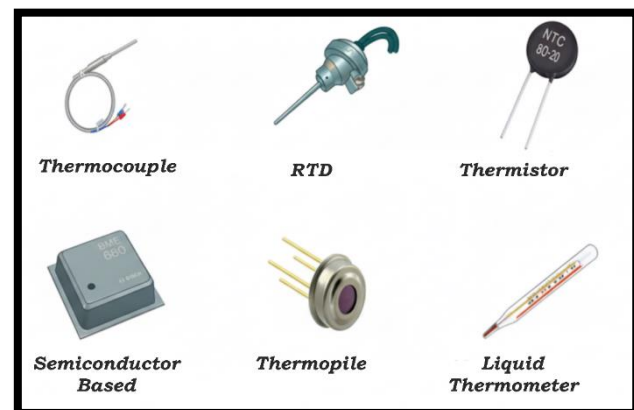


Fig.2.28: Temperature Sensor Types

The function of temperature sensors is to convert temperature variations into electrical signals that can be interpreted by the vehicle's control systems. These signals enable real-time adjustments, such as regulating engine cooling, managing battery temperature in electric vehicles (EVs), or controlling cabin climate for passenger comfort. This conversion from physical temperature to an electrical signal is crucial for automated systems in modern vehicles.

Common types of temperature sensors include thermistors, which change resistance with temperature; Resistance Temperature Detectors (RTDs), known for their accuracy and stability; and infrared (IR) sensors, which measure temperature without direct contact, making them suitable for specific applications like exhaust monitoring. These sensor types are chosen based on the accuracy, response time, and environment of the measurement.

Applications: Temperature sensors have a wide range of applications in the automotive industry. They are used for engine temperature monitoring to prevent overheating, for battery thermal management in EVs to enhance performance and longevity, and for cabin climate control to maintain a comfortable environment for passengers.

Think About It!

When a vehicle engine becomes too hot, temperature sensors help warn the driver and prevent engine damage.

2. Pressure Sensors

Pressure sensors are devices designed to measure the pressure of fluids or gases in different vehicle systems. Their main purpose is to ensure that the pressure levels remain within safe and optimal ranges, which is crucial for both performance and safety. By continuously monitoring pressure, these sensors help prevent system failures and maintain efficient operation of the vehicles (Fig.2.29).



Fig.2.29: Pressure Sensor

The function of a pressure sensor is to convert mechanical pressure into an electrical signal that can be read and processed by the vehicle's electronic control unit (ECU) or displayed to the driver. This conversion allows real-time monitoring and, in some cases, automatic adjustments to maintain proper system function.

Common types of pressure sensors include piezoelectric sensors, which generate an electric charge in response to mechanical stress; capacitive sensors, which measure changes in capacitance due to applied pressure; and strain gauge sensors, which detect deformation in a material when pressure is applied. Each type is chosen based on the specific requirements of the vehicle system in which it is used.

Applications: Pressure sensors find applications across various vehicle systems. In Tire Pressure Monitoring Systems (TPMS), they continuously monitor tire pressure to alert drivers of under-inflated or over-inflated tires. They are also essential in fuel injection systems, helping to regulate fuel delivery for optimal engine performance. In braking systems, pressure sensors ensure that hydraulic pressure is sufficient for safe and effective braking. Additionally, they are used in turbocharger pressure monitoring to maintain engine efficiency and prevent damage.

Have You Seen?

Modern vehicles display tire pressure warnings on the dashboard when air pressure becomes too low.

**3. Proximity Sensors**

Proximity sensors are designed to detect the presence or absence of an object. These sensors are crucial for enhancing safety and assisting drivers in various driving situations. By continuously monitoring the surroundings, they help vehicles respond to obstacles and prevent potential accidents (Fig.2.30).

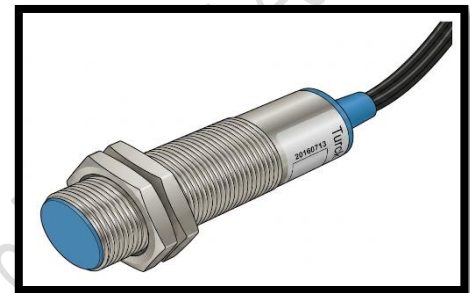



Fig.2.30: Proximity Sensor

The primary function of these sensors is to generate signals based on the presence or distance of nearby objects. Depending on the technology used, the sensor emits waves; such as sound, radio, or light—that reflect off objects and return to the sensor. The system then interprets these signals to determine how close an object is or whether it is present in a particular area around the vehicle.

Several types of sensors are used to measure proximity and distance, each with unique advantages. Ultrasonic sensors use sound waves to detect nearby objects and are often used in parking systems. Radar sensors employ radio waves and are effective at longer distances and in adverse weather conditions. LiDAR (Light Detection and Ranging) sensors use laser light to create precise 3D maps of the environment, supporting advanced driver-assistance systems. Infrared sensors detect objects by measuring emitted or reflected infrared light, commonly used in low-light conditions. These sensors collectively contribute to safer and smarter driving experiences, forming an integral part of automotive IIOT systems.

Applications: Proximity sensors are widely applied in modern vehicles for safety and convenience. They are commonly used in parking assistance systems to help drivers manoeuvre into tight spaces without collisions. They also form the backbone of collision avoidance systems, alerting drivers or triggering automatic braking when obstacles are detected. Additionally, these sensors are essential for blind spot detection, helping drivers avoid accidents while changing lanes.

 **Around Us**

Parking sensors in cars help drivers avoid hitting nearby objects while reversing.

4. Speed and Position Sensors

Speed and position sensors are designed to measure the rotational speed of components, linear position, or wheel movement in a vehicle. These sensors provide critical information about how fast parts of the vehicle are moving and their exact position, which is essential for the safe and efficient operation of modern vehicles (Fig.2.31).



Fig.2.31: Speed and Position Sensor

These sensors work by generating signals that reflect the movement or position of a part. This real-time feedback is sent to the vehicle's control systems, such as the engine control unit (ECU) or transmission controller, allowing precise

adjustments to optimize

performance, safety, and handling.

The most common types of speed and position sensors include Hall-effect sensors, which detect magnetic fields to measure movement; optical encoders, which use light to track rotational or linear position; and magneto resistive sensors, which measure changes in magnetic resistance to determine speed or position. Each type has its specific advantages depending on the application and required precision.

Applications: Speed and position sensors are widely used in several automotive systems. In Anti-lock Braking Systems (ABS), they monitor wheel speed to prevent wheel lock-up during sudden braking. They are also critical for traction control systems, which help maintain vehicle stability on slippery surfaces. Additionally, these sensors monitor engine components like the crankshaft and camshaft for accurate timing and efficient operation. They are further applied in steering and suspension systems to ensure proper alignment and smooth handling.

Did You Know?

Anti-lock Braking Systems (ABS) use wheel speed sensors to prevent skidding during sudden braking.

5.Vibration and Acceleration Sensors

Vibration and acceleration sensors are used to measure acceleration, vibration, tilt, and dynamic motion in mechanical and electronic systems. Their primary purpose is to monitor movement-related changes, which is important for maintaining safety, performance, and efficiency in vehicles, industrial machines, and automation systems.

These sensors convert mechanical motion such as shaking, tilting, impact, or rapid movement into electrical signals that can be measured and analyzed in real time. This allows systems to respond quickly, detect faults early, and operate safely. They are also useful for identifying abnormal vibrations caused by:

- Wear and tear
- Misalignment
- Imbalance
- Loose parts
- Mechanical failure

Common types of vibration and acceleration sensors include MEMS-based accelerometers, which are compact and highly sensitive; gyroscopes, which measure angular velocity and orientation; piezoelectric vibration sensors, which generate electrical signals in response to mechanical stress and Gyroscope sensors, that Measure angular velocity and orientation. These sensors are fundamental in modern vehicles and industrial equipment for ensuring safety, performance, and reliability.

Applications: In automotive applications, vibration and acceleration sensors play a vital role. They are used in vehicle stability control systems to maintain traction and prevent skidding. They also enable crash detection systems for airbags, allowing rapid deployment in the event of an accident. Additionally, they help monitor engine vibrations to detect faults early and optimize suspension systems for smoother rides.

a) Accelerometer Sensor

These are dynamic sensors that can measure speed target speed change using microelectromechanical sensors (MEMS). These sensors are used to measure the vibration of machines or to detect a change in the speed moving objects. The accelerometer measures the change of speed in one, two, or three axes. Data transmission interface of accelerometers can be either analog, digital or pulse width modulated (Fig.2.32).



Fig.2.32: Accelerometer Sensor

Applications: Accelerometer sensor is used to control acceleration in cars and machine parts and warns of inappropriate acceleration conditions. The sensor can be installed in a system that detects speed, vibration, position or gravitational acceleration and sets the orientation of the device. For example, the sensors in smart phones help to rotate their display depending on how the phone is tilted. The Fig.2.33 shows the changing of the display orientation of a smart phone.

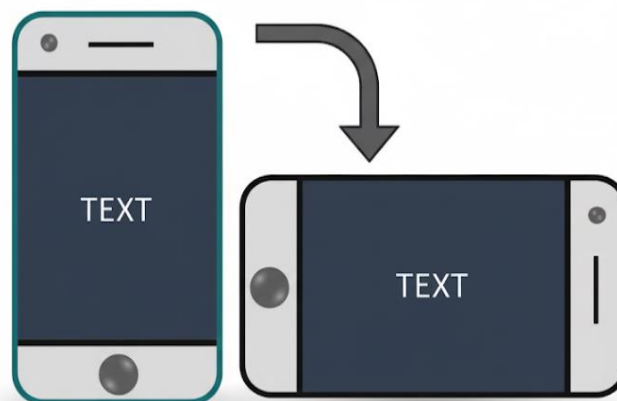


Fig.2.33: Changing the display orientation of smartphone

b) Piezoelectric Sensors

These sensors use a piezoelectric material (such as quartz or ceramic) that generates an electric charge when subjected to mechanical stress or vibration. They are highly sensitive and widely used in high-frequency vibration detection.

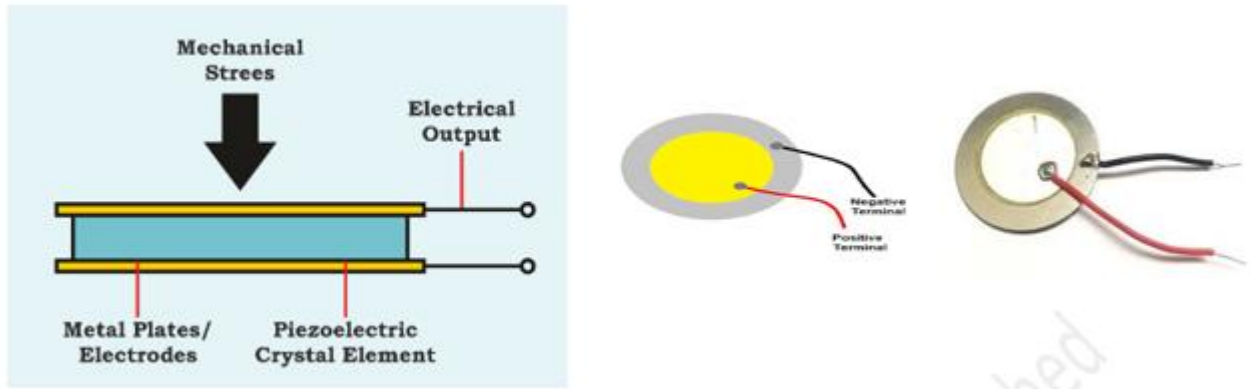


Fig.2.34: Piezoelectric Sensors

C) Gyroscope Sensor

Gyroscope sensors are often used together with accelerometers to provide accurate motion sensing. While an accelerometer measures change in velocity and linear movement, a gyroscope measures the angular rate of rotation or spin of an object. The sensor detects changes in orientation, balance, and turning movement, making it useful in robotics, drones, and autonomous navigation systems for maintaining stability and direction. The output of a gyroscope sensor may be digital or analog.

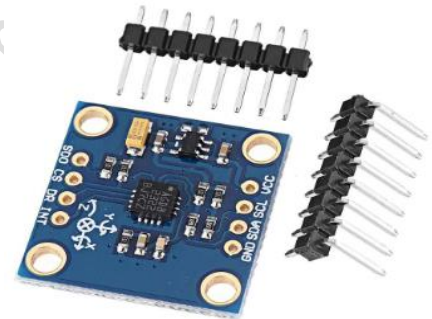


Fig.2.35: Gyroscope Sensors

Applications: Gyroscope sensors allow mobile apps to trigger an event. Modern self-balancing scooters or hoverboards and virtual reality goggles both use gyroscopic sensors (Fig.2.36).

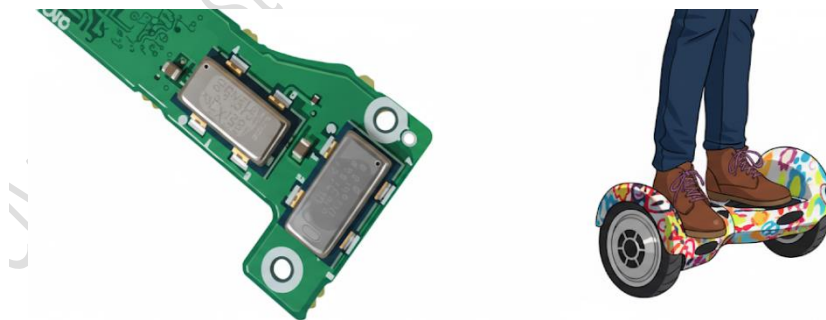


Fig.2.36: Use of Gyroscopic sensors

6.Humidity and Moisture Sensors

Humidity and moisture sensors are essential components in modern vehicles for monitoring moisture levels in the air as well as in critical vehicle components. Their primary purpose is to measure the relative humidity and detect moisture to ensure the proper functioning of systems and maintain passenger comfort.

These sensors work by sending signals to the vehicle's control systems, which can then take corrective actions to prevent potential damage caused by excess moisture or to optimize environmental conditions inside the cabin (Fig.2.37).

Applications: In practical applications, humidity and moisture sensors play a vital role in cabin climate control, ensuring the air inside the vehicle remains comfortable and safe for passengers. In electric vehicles (EVs), these sensors are used for battery moisture detection, preventing potential short circuits or degradation due to unwanted humidity. Additionally, they are employed in anti-fogging systems to maintain visibility by regulating humidity levels on windshields and windows.

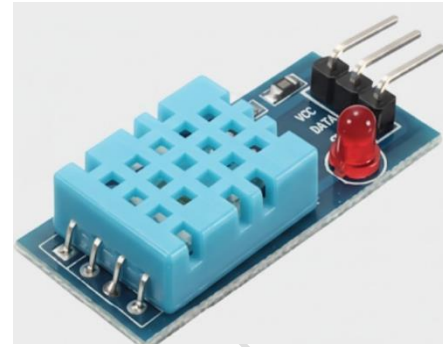


Fig.2.37: Humidity and Moisture Sensors

The most common types of humidity and moisture sensors used in automotive applications are capacitive humidity sensors, which measure changes in capacitance caused by moisture, and resistive humidity sensors, which detect changes in electrical resistance in response to humidity. These sensors are critical for enhancing both safety and comfort in modern vehicles, especially as automotive IIOT continues to advance.

Observe it!

Humidity sensors help prevent fog formation on vehicle windows during rainy or cold weather.



7. Optical and Light Sensors

Optical and light sensors are vital in modern vehicles for detecting ambient light intensity and environmental lighting conditions. Their primary purpose is to sense changes in light levels and provide real-time feedback to the vehicle's control systems. By doing so, these sensors enable automatic adjustments in vehicle lighting or display systems, enhancing both safety and driving comfort.

The most common types of optical and light sensors used in automotive applications include photodiodes, which convert light into electrical current; phototransistors, which amplify light signals for more precise detection; and ambient light sensors, which measure overall light levels in the vehicle's environment. Together, these sensors enhance driving safety, convenience, and overall vehicle intelligence, making them indispensable in the era of connected and autonomous vehicles (Fig.2.38).



Fig.2.38: Light Sensor

Applications: Optical and light sensors are commonly used for automatic headlight control, allowing headlights to turn on or off depending on the surrounding light conditions, such as entering tunnels or driving at dusk. They are also integrated with rain sensors for wipers, where light detection helps determine raindrop presence and intensity, triggering the wipers automatically. Furthermore, these sensors support adaptive lighting systems in smart

vehicles, which adjust the angle, intensity, and distribution of headlights to optimize visibility without dazzling other drivers.

Did You Notice?

Many modern vehicles automatically switch ON headlights at night using light sensors.



8. Motion Sensors

Motion sensors are essential components in modern vehicles for detecting movement both inside the cabin and around the vehicle. Their primary purpose is to monitor dynamic activity and provide real-time feedback to the vehicle's control systems. By detecting motion, these sensors help enhance passenger safety, vehicle stability, and security, making them an integral part of automotive IIOT systems.

The most common types of motion sensors used in automotive applications include MEMS-based accelerometers, which measure linear acceleration; gyroscopes, which detect angular velocity; and infrared (IR) sensors, which sense movement based on changes in infrared radiation caused by moving objects. Together, these sensors improve vehicle safety, comfort, and intelligence, making them indispensable in modern connected and autonomous vehicles (Fig.2.39).



Fig.2.39: Motion Sensor

Applications: Motion sensors are commonly used to detect passengers in the vehicle, helping systems like airbags and seatbelt reminders work correctly. For instance, airbags can deploy safely based on whether a seat is occupied, and seatbelt warnings alert when a passenger is not buckled. These sensors also help monitor vehicle movement for stability and rollover prevention, using accelerometers and gyroscopes to detect changes in speed, tilt, or rotation. Additionally, motion sensors are used in anti-theft and parking security systems, where infrared or radar sensors detect unauthorized movement and trigger alarms.

9. Gas and Emission sensors

Gas and emission sensors are important components in modern vehicles for detecting the presence and concentration of various gases. Their primary purpose is to ensure that the vehicle complies with emission standards and maintains a safe environment for passengers and the surroundings. These sensors continuously monitor gases and provide real-time data to the vehicle's control systems, enabling timely adjustments and alerts when necessary.

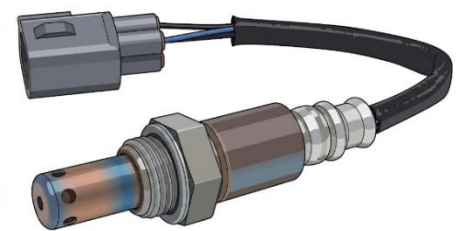


Fig.2.40: Oxygen (O₂) Sensors

The most common types of gas and emission sensors used in automotive applications include oxygen (O₂) sensors, which measure oxygen levels in the exhaust to optimize combustion (Fig.2.40); carbon monoxide (CO) sensors, which detect the presence of this toxic gas; and nitrogen oxide (NO_x) sensors, which monitor emissions from the engine to meet environmental regulations. Together, these sensors help vehicles operate efficiently while reducing their environmental impact and improving passenger safety.

Applications: Gas and emission sensors are widely used for exhaust gas monitoring, helping to control harmful emissions released into the atmosphere. They are also employed

in cabin air quality sensors, ensuring that the air inside the vehicle remains safe and comfortable for passengers. Additionally, these sensors monitor the fuel system, detecting leaks or inefficiencies that could affect performance and safety.

10. Torque and force sensors

Torque and force sensors are critical components in modern vehicles that measure the amount of torque or force applied to mechanical components. Their primary purpose is to convert mechanical strain into electrical signals that can be used by the vehicle's control systems for monitoring and adjusting performance. By providing accurate data on force and torque, these sensors help ensure both safety and efficiency in vehicle operations.

The most common types of torque and force sensors used in automotive applications include strain gauge-based sensors, which measure deformation caused by force, and piezoelectric force sensors, which generate an electrical signal in response to applied stress (Fig.2.41). Together, these sensors provide precise feedback that enhances vehicle performance, safety, and overall driving experience.

Applications: Torque and force sensors are used in vehicles to measure the amount of force or torque in different parts. In steering systems, they help improve handling by sensing how much force the driver is applying. In engines and transmissions, they monitor torque to make sure power is delivered efficiently and parts are not damaged. These sensors are also used in brakes to measure force, helping systems like brake force distribution and stability control work properly.



Fig.2.41: strain gauge-based Force

11. Current, Voltage, and Battery Sensors

Current, voltage, and battery sensors help vehicles keep track of their electrical systems. They measure how much electricity is flowing, the voltage levels, and how much charge is left in the battery. This information helps the car work safely and efficiently. Common types include Hall-effect sensors (measure current without touching wires), voltage dividers (measure voltage), and Coulomb-counting sensors (track battery charge over time). These sensors make sure the car's electrical systems and batteries work properly (Fig.2.42).

Applications: These sensors are used in electric vehicle (EV) battery systems to check battery health, in alternators and power systems to make sure electricity is stable, and in charging stations to safely charge the battery.



Fig.2.42: Current, voltage, and battery sensor

12. Touch Sensor

A touch sensor is an electronic device that detects physical contact, such as the touch of a finger or a stylus, and generates a corresponding output signal. It is widely used in modern electronic systems for user interaction and control (Fig.2.43).

Touch sensors are sensitive to touch, force, or pressure and are among the simplest and most commonly used sensors. Their operation is similar to that of a basic switch. When a person touches the sensor surface, the internal circuit is activated, allowing current to flow and producing an output signal. When the touch is removed, the circuit returns to its original state, stopping the flow of current.



Fig.2.43: Touch Sensor

Due to their simplicity, reliability, and ease of use, touch sensors are commonly found in devices such as smartphones, touch panels, home appliances, automobiles and industrial control systems. The working principle of a touch sensor is illustrated in Fig.2.44.

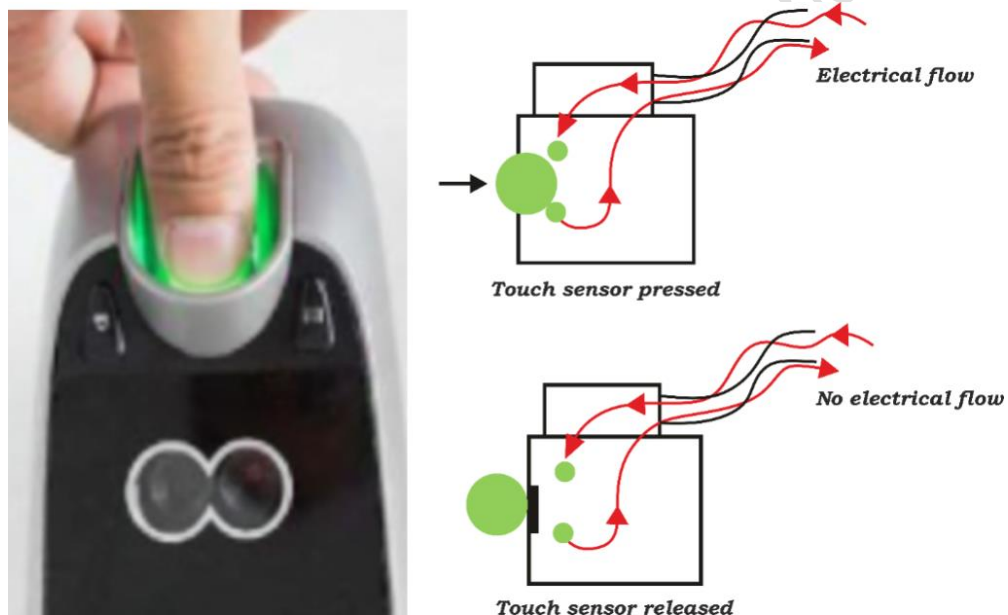


Fig.2.44: Working Principle of a Touch Sensor

Applications: Touch sensors are widely used in consumer electronics, security systems, and automation applications. Common examples include smartphones, tablets, touchscreens, electronic door locks, access control systems, and security devices. They are also used in home appliances, control panels, and industrial equipment to provide a simple and reliable user interface.

13. Range (Distance) Sensor

A range sensor measures the distance between the sensor and an object without physical contact. It can detect how near or far an object is from the sensing position and is therefore often used as a proximity or distance sensor. Range sensors use various technologies such as capacitance, inductance, magnetic fields, ultrasonic waves, infrared signals, radio waves,

or lasers to determine distance. Short-range sensing is typically performed using capacitance, inductance, or magnetic techniques, while longer-range sensing employs ultrasonic, radio, or laser-based methods (Fig.2.45).

Applications: Range sensors are widely used in robotics, industrial automation, smart manufacturing, and IIOT systems for distance measurement, obstacle detection, object tracking, positioning, and process monitoring. They provide real-time data to support efficient and safe industrial operations.



Fig.2.45: Range (Distance) Sensor

14. Other specialized sensors

Other specialized sensors in vehicles help improve safety, comfort, and performance by handling specific tasks.

- Rain and fog sensors detect moisture on the windshield or changes in weather conditions, allowing automatic wipers and headlights to operate without driver intervention.
- Occupancy sensors monitor the presence of passengers in the vehicle, ensuring systems like airbag deployment and seatbelt reminders work accurately. These sensors help protect passengers by adjusting safety features based on who is in the seat.
- Tire condition sensors track the health of tires, including tread wear and overall tire performance. This information helps maintain proper traction, vehicle stability, and safety on the road.

2.7 Introduction of Actuators

Actuators are essential components in modern automation, robotics, and control systems. An actuator is a device that converts an electrical, hydraulic, or pneumatic energy into physical motion (Fig.2.46).

While sensors detect and measure changes in the environment, actuators are responsible for performing the required action, such as moving a robotic arm, opening a valve, or controlling a vehicle's steering mechanism.

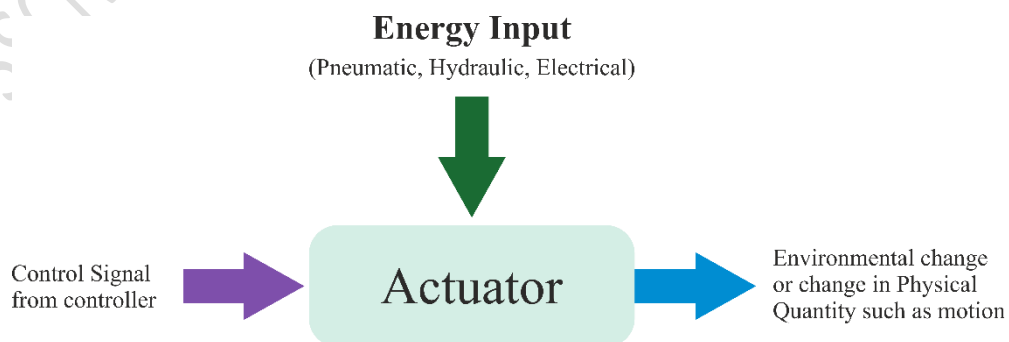


Fig.2.46: What is Actuator

2.7.1 Working of Actuator

The working of an actuator can be compared to the human body. Just as muscles convert chemical energy into motion to move our arms or legs, actuators transform electrical, hydraulic, or pneumatic energy into mechanical movement, enabling machines to perform specific tasks efficiently (Fig.2.47).

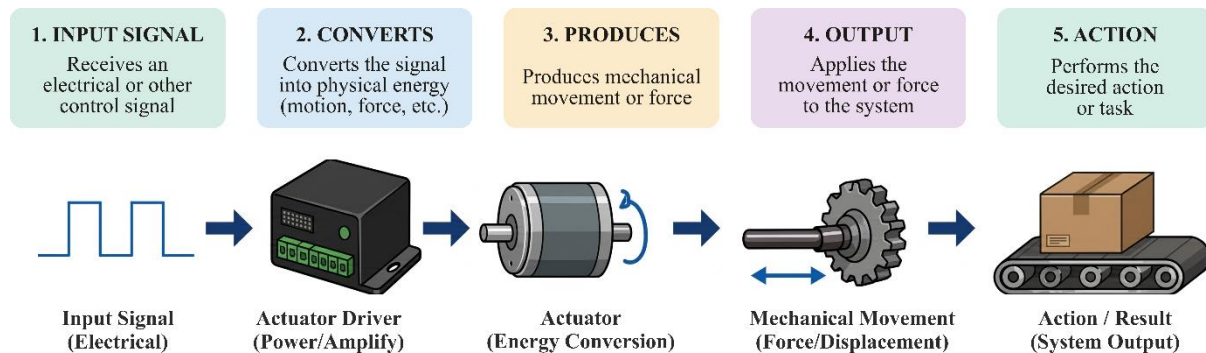


Fig.2.47: How Actuator works

For example, in a typical IoT system, a sensor collects information and sends it to a control center. Based on predefined logic or programmed instructions, the system decides and sends a command to an actuator. The actuator then performs the required action in response to the sensor input. In this way, sensors and actuators work together to make IoT systems function effectively. It is illustrated in the Fig.2.48, where temperature sensor detects the temperature, sends information to the control center that gives command to the actuator. The actuator that is a water sprinkler start working after getting the command. So, the information obtained in the form of temperature is converted into the mechanical form.

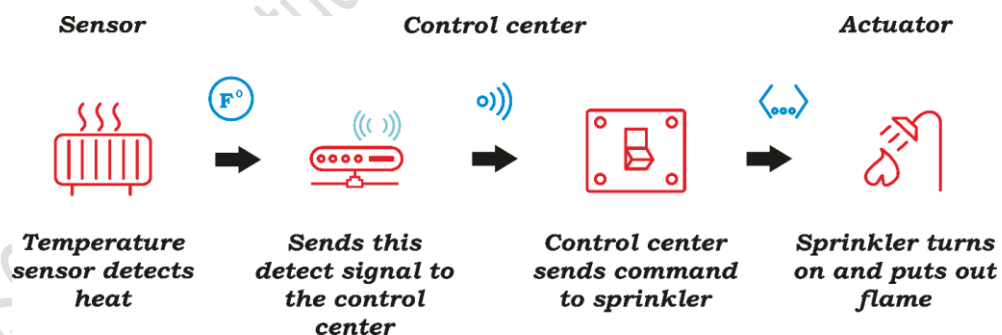


Fig.2.48: Example of Actuator in an IoT based system

2.7.2 Classification of Actuators

Actuators can be classified according to the type of movement they produce: linear or rotary. Linear actuators create motion in a straight line, while rotary actuators produce circular or rotational movement.

Both linear and rotary actuators can also be grouped based on the type of energy used to operate them. Different actuators use different energy sources to generate movement and control mechanical systems.

i) Pneumatic Actuators

Pneumatic actuators produce motion by compressing air. They can be employed in a number of ways, like controlling valve positions or moving machine parts. This type of actuators is used in the applications that require high force, quick response times, or explosion-proof environment. Types of pneumatic actuators mostly used in industries are (Fig.2.49):

1. Pneumatic Cylinder – linear push/pull motion
2. Rotary Pneumatic Actuator – rotational motion
3. Single-Acting Pneumatic Actuator – one-direction motion with spring return
4. Double-Acting Pneumatic Cylinder – movement in both directions
5. Rodless Pneumatic Actuator – long stroke linear motion
6. Pneumatic Gripper – object gripping and pick-and-place use
7. Compact Pneumatic Actuator – industrial automation systems

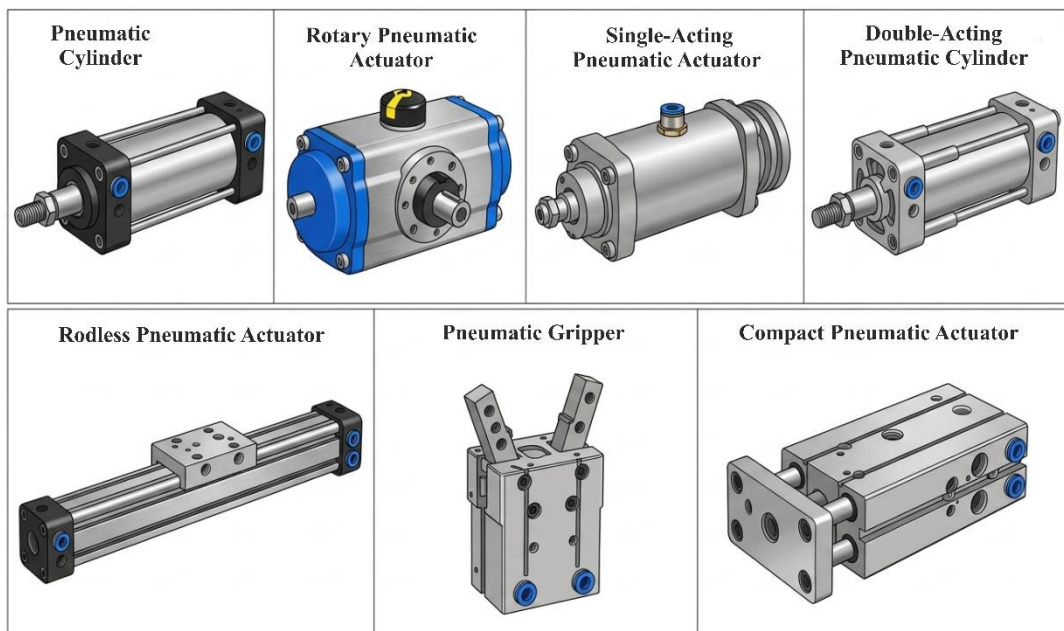


Fig.2.49: Pneumatic Actuator-Types

Have You Seen?

Bus doors and industrial robotic arms often use compressed air systems called pneumatic actuators.



ii) Hydraulic Actuators

These devices produce motion by applying fluid pressure. They are frequently employed in heavy-duty applications like industrial robots, manufacturing machinery, and construction equipment. Common hydraulic actuators used in industries are (Fig.2.50):

1. Hydraulic Cylinder – linear push/pull motion
2. Rotary Hydraulic Actuator – rotational motion
3. Excavator Hydraulic Piston – heavy equipment uses
4. Double-Acting Cylinder – movement in both directions
5. Compact Hydraulic Actuator – industrial automation systems

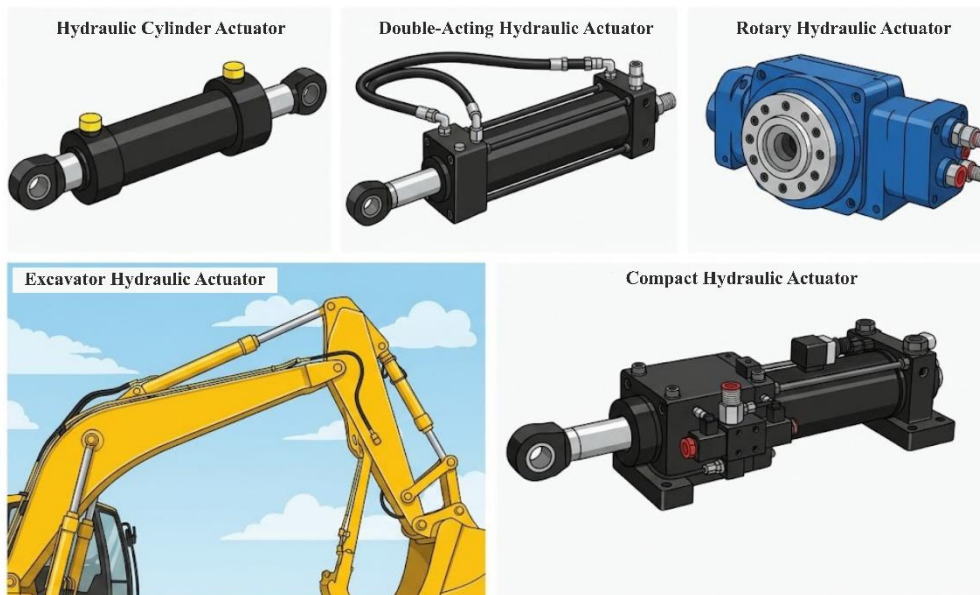


Fig.2.50: Hydraulic Actuator-Types

iii) Electric Actuators

Electric actuators convert electrical energy into mechanical movement. They are usually operated using AC or DC motors and are widely used in applications that require accurate control, quiet operation, and low maintenance. These actuators can produce either linear or rotary motion.

Electric actuators are commonly used in automation systems, robotics, medical devices, and laboratory equipment. Some common types of electric actuators are shown in Fig. 2.51:

1. DC Motor – continuous rotational motion (used in battery / low-voltage systems)
2. AC Motor – industrial continuous rotational motion (used in fans, pumps, conveyors, machines)
3. Servo Motor – precise controlled rotation (used in robotics / CNC / automation)
4. Stepper Motor – stepwise rotational motion (used in printers / positioning systems)
5. Electric Linear Actuator – linear push/pull motion
6. Rotary Electric Actuator – controlled rotational motion
7. Compact Electric Actuator – industrial automation systems

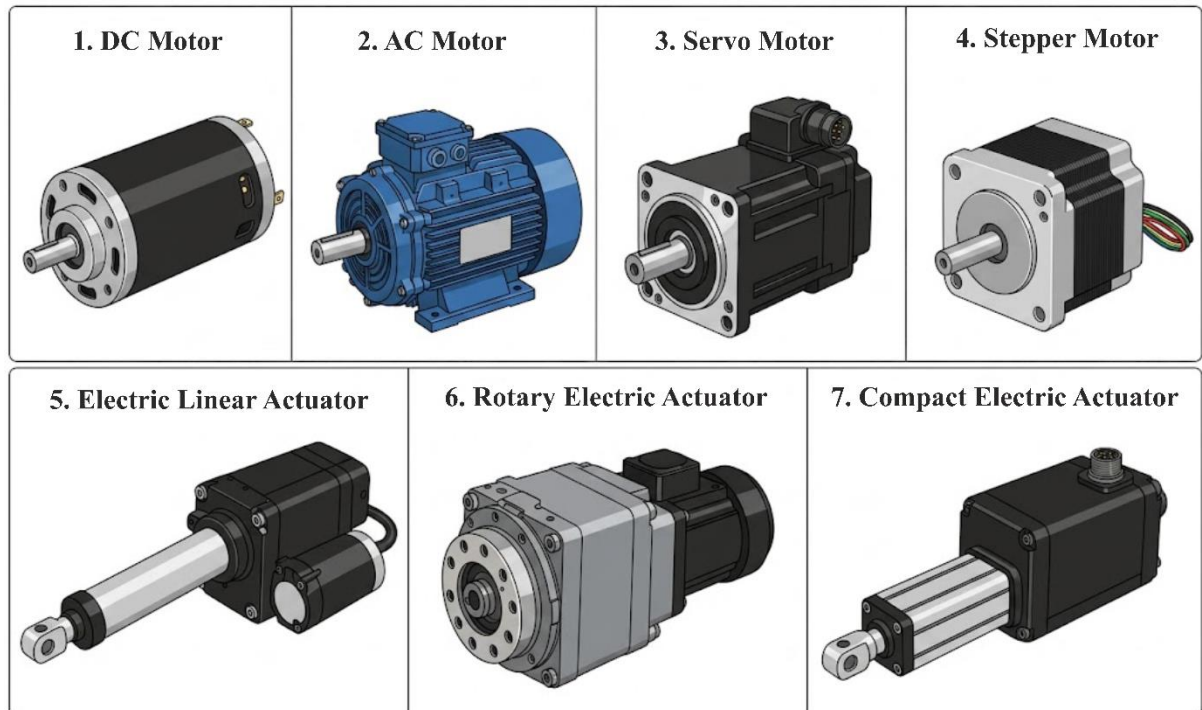


Fig.2.51: Electric Actuator-Types

Around Us

Electric motors used in fans, washing machines, and robots are common examples of electric actuators.

iv) Magnetic and Thermal Actuators

Actuators that use magnetic or thermal changes to produce motion are referred to as magnetic actuators and thermal actuators, respectively. Magnetic actuators produce force by means of magnetic fields. The expansion or contraction of materials in response to temperature changes is used by thermal actuators. Micro-electromechanical systems (MEMS) and other miniaturized applications frequently use both actuators. Commonly used magnetic and thermal actuators are (Fig.2.52):

1. Solenoid Actuator – short linear push/pull motion
2. Electromagnetic Actuator – attraction/holding motion
3. Bimetal Thermal Actuator – temperature-based bending motion
4. Shape Memory Alloy Actuator – motion by heating metal

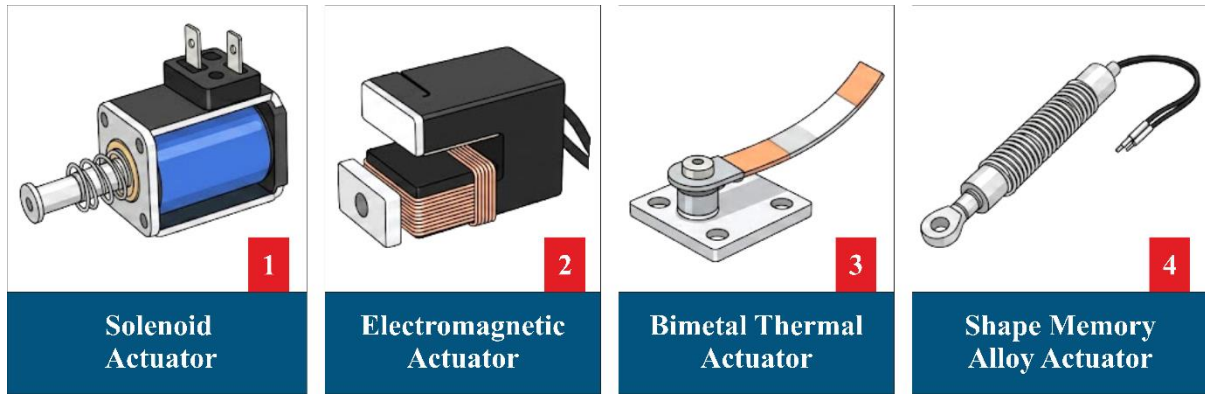


Fig.2.52: Magnetic and Thermal Actuators -Types

v) Mechanical Actuators – To create motion, mechanical actuators rely on tangible components like gears, levers, or cams. When durability, ease of use, and affordability are crucial, mechanical actuators are frequently employed. Mechanical locks, manual valve systems, and hand crank machines are a few examples. Some common mechanical actuators are (Fig.2.53):

1. Lead Screw Actuator – rotary to linear motion
2. Rack and Pinion Actuator – rotary to linear motion
3. Lever Actuator – force amplification/manual motion
4. Spring Actuator – stored energy return motion

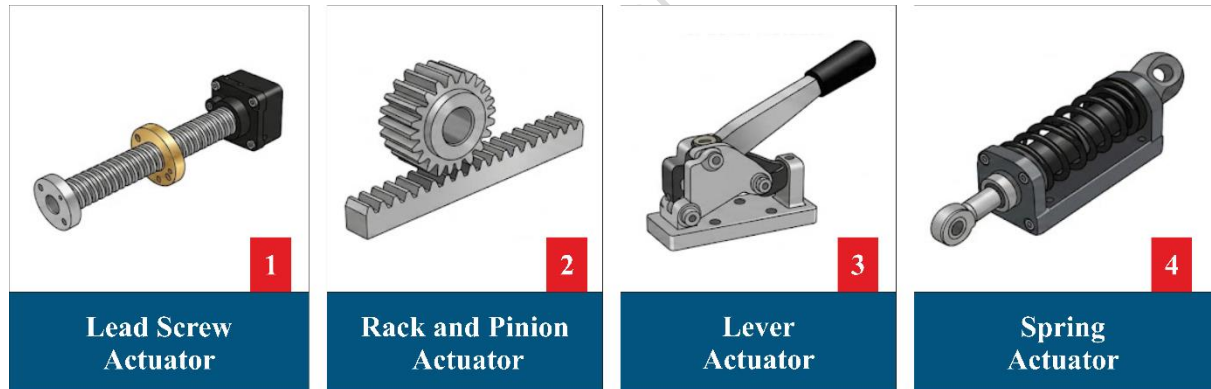


Fig.2.53: Mechanical Actuators -Types

2.8 Difference between Sensors and Actuators

In Industrial Internet of Things applications, data accuracy is critical. Actuators integrated with sensors help ensure precise and reliable system performance. A comparison between sensors and actuators is presented in Table 2.4.

Table 2.4: Comparison between sensor and actuators

S.N.	Sensor	Actuator
1	Sensor converts physical quantities and characteristics into electrical signals.	Actuator converts electrical signals into physical action such as force and motion.
2	It acts as an input device in any control system and placed in input port	It acts as an output device in a control system and placed in output port

3	Sensor takes input from environment and senses surroundings condition.	Actuator takes input from output signal conditioning unit of system.
4	Sensor gives output to input signal conditioning unit of the system to convert into electrical form.	It gives output to environment and makes an impact on load to control parameters.
5	It gives information to the system about environment condition to monitor and control.	It accepts command from system to deliver physical action.
6	Sensors are often used to measure process pressure, temperature, fluid levels, flow, vibration, speed etc.	Actuators are often used to operate control valves, dampers, guide vanes, and to move objects from one place to another, to move conveyor belts in robotic arms movement etc.
7	Sensor examples- Thermocouple, photo cell, RTD, LVDT, strain gauge, Load cell, hall sensors, differential flow meters, speed probes, PH meter etc	Actuator examples- motor actuator, servo motor, stepper motor, heaters, electro pneumatic actuator, electro-hydraulic actuator, magnetic actuator etc

PRACTICAL ACTIVITY

ACTIVITY 1:

Testing The Temperature Sensor (TMP36) Using A Multimeter

Objective: To measure and verify the output voltage of the TMP36 temperature sensor using a multimeter.

Material Required: TMP36 sensor, multimeter, connecting wires, AA batteries

Procedure:

Step 1. Connect a power supply (2.7V–5.5V, such as 2–4 AA batteries) to the TMP36 sensor as shown in the Fig.1.

Step 2. Ensure proper pin connections:

- Pin 1 (left) → Power supply (+V)
- Pin 2 (middle) → Output
- Pin 3 (right) → Ground

Step 3. Set the multimeter to DC voltage mode. Connect:

- Black probe → Ground (Pin 3)

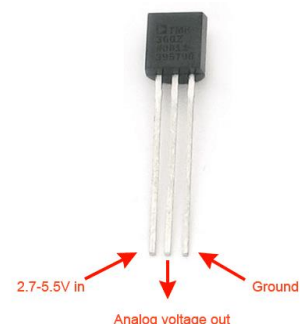


Fig.1: TMP36 Pins

- Red probe → Output (Pin 2)

Step 4: Observe the voltage reading at room temperature (~25°C):

- For TMP36 → approximately 0.75 V It is shown in Fig.2.
- (If using LM35 → approximately 0.25 V)



Fig.2: TMP36 sensor testing at room temperature

Step 5: Gently press the sensor with your fingers to warm it.

- Observe that the temperature and voltage increase as shown in Fig.3.

Step 6: Touch the sensor with an ice cube (use a plastic cover to avoid water contact).

- Observe that the temperature and voltage decrease.
- As an ice-cube is pressed against the sensor, temperature drops down to 68.6°C / 65.5°F (Fig.4).



Fig.3: TMP36 sensor testing at high temperature



Fig.4: TMP36 sensor testing at low temperature

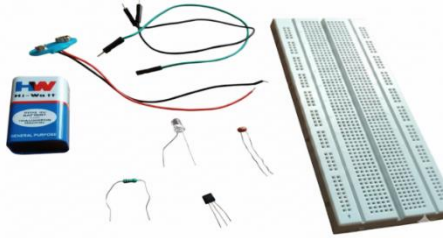
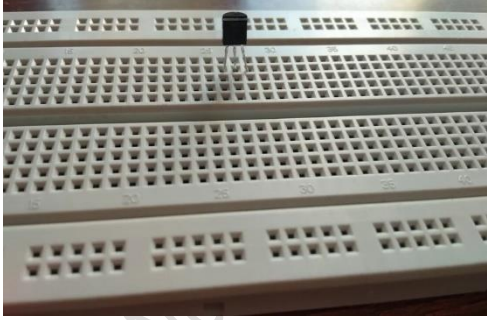
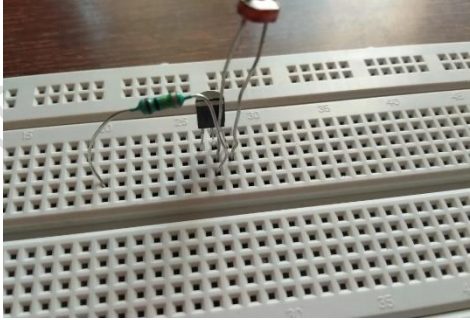
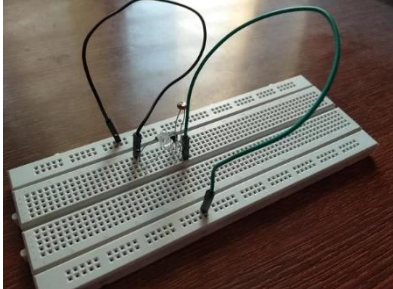
ACTIVITY 2:

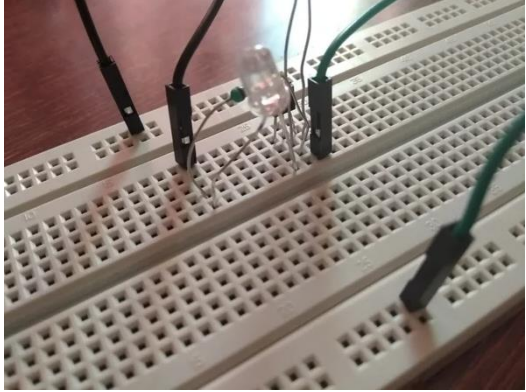
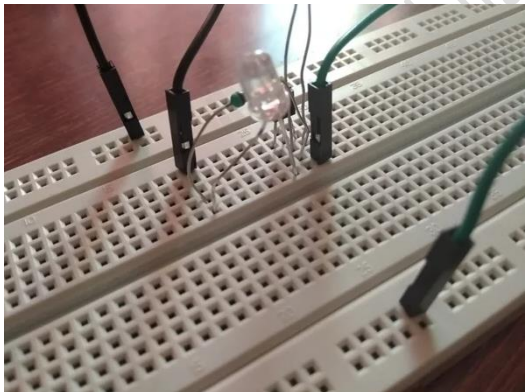
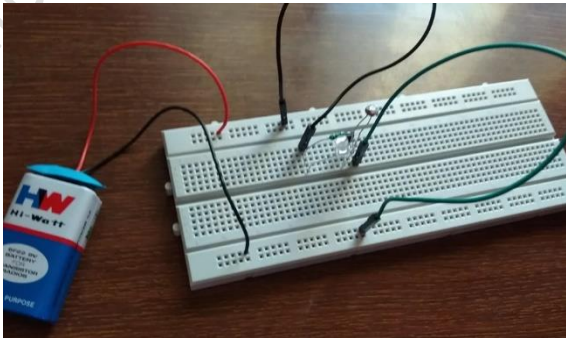
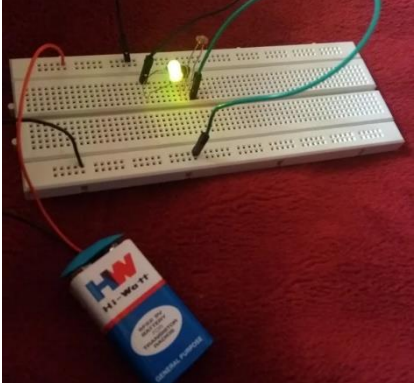
Demonstrating Light Sensing using a Light-Dependent Resistor (LDR) Sensor

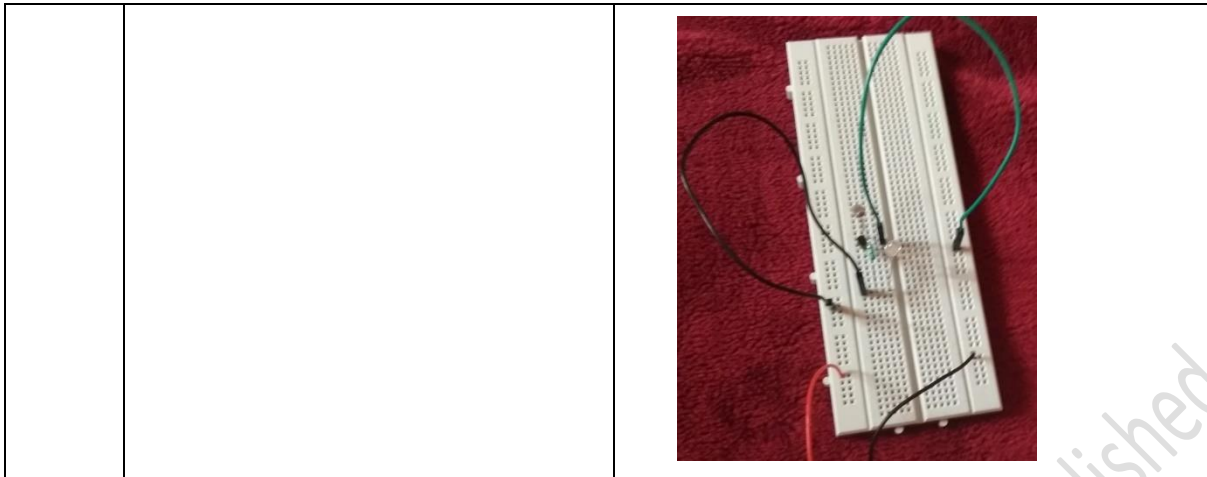
Objective: To observe and understand how a Light-Dependent Resistor (LDR) changes its resistance with varying light intensity.

Materials Required: Light-dependent resistor (LDR) Resistor (10kΩ), Breadboard, LED, BC547 Transistor Power source (e.g., battery or power supply), Multimeter (optional, for measuring resistance)

Procedure:

Step	Action	Image
1.	Collect all the required components.	
2.	Insert the BC547 transistor into the breadboard correctly.	
3.	Connect the LDR between the base and emitter of the transistor.	
4.	Connect one end of the 100 kΩ resistor to the base of the transistor and the other end to the anode (+) of the LED.	

<p>5. Connect the cathode (-) of the LED to the collector of the transistor.</p>		
<p>6. Complete the wiring by connecting:</p> <ul style="list-style-type: none"> • Emitter to the negative line • Remaining ends of components as shown in the circuit diagram 		
<p>7. Connect the battery:</p> <ul style="list-style-type: none"> • Positive (+) → Resistor and LED (anode) • Negative (-) → Emitter of transistor and one end of LDR 		
<p>8. Observe the LED in different lighting conditions:</p> <ul style="list-style-type: none"> • In light → LED remains OFF • In darkness → LED glows 		



ACTIVITY 3:

Demonstrating the Working of a PIR Motion Sensor

Objective: To understand and observe how a PIR (Passive Infrared) motion sensor detects movement and responds to changes in infrared radiation.

Materials Needed: PIR motion sensor, jumper wires, 9V batteries, LED or buzzer

Procedure:

Step 1. Connect Batteries are connected across VCC and GND of the sensor.

Step 2. Connect a LED to the output pin through a 220Ω current limiting resistor. A buzzer can also be connected here (Fig.1).

Step 3. Now, when the PIR detects any motion around, the output pin will go “high” and this will light up the LED.

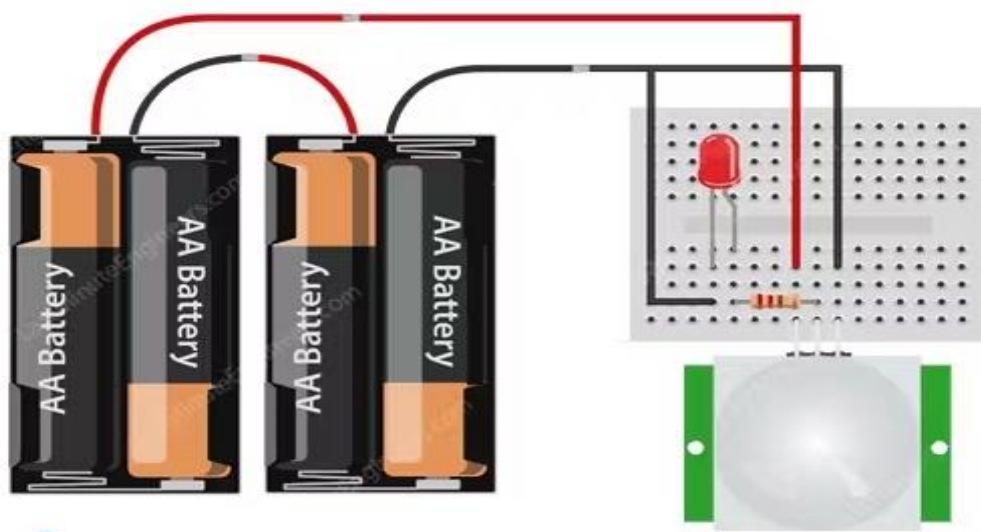


Fig.1: circuit connection

ACTIVITY 4: Dipper Circuit (Flashing LED Demonstration)

Objective: To design and test a simple dipper circuit using the IC 555 timer to blink an LED at regular intervals.

Components Required:

Name / Symbol	Quantity	Specification
IC 555 Timer (U1)	1	—
Resistor (R1)	1	100 k Ω
Resistor (R2)	1	33 k Ω
Resistor (R3)	1	70 Ω
LED (D1)	1	Red
Capacitor (C1)	1	10 μ F, 16 V (Electrolytic)
Battery (BAT1)	1	9 V DC
Connecting wires	As required	—
Breadboard	1	—

Procedure in Tinkercad

1. **Open Tinkercad Circuits**

- Go to www.tinkercad.com.
- Log in or create a free account.
- Click on “**Circuits**” → “**Create New Circuit.**”

2. **Place Components** (Fig.1)

- From the components panel, drag and drop the following:
 - Breadboard, IC 555 Timer, Resistors (R1, R2, R3), LED, Capacitor (C1), and 9V Battery.

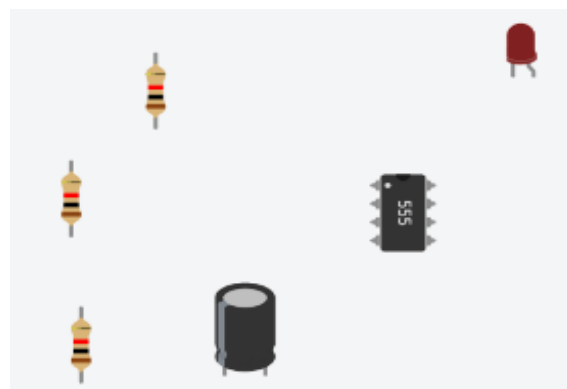
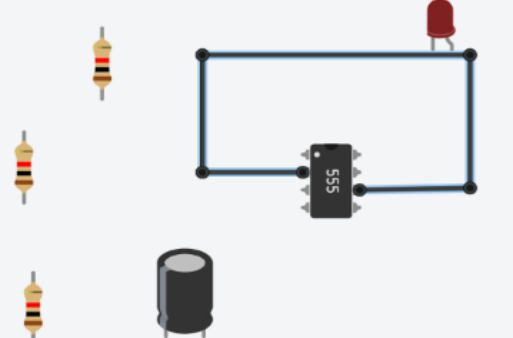
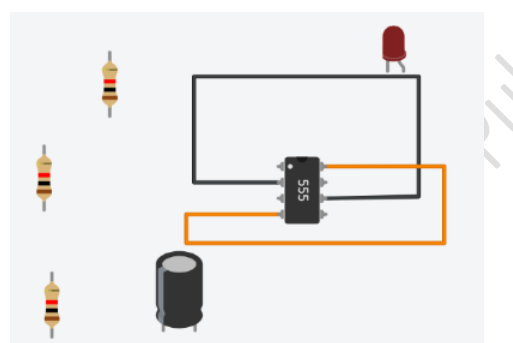
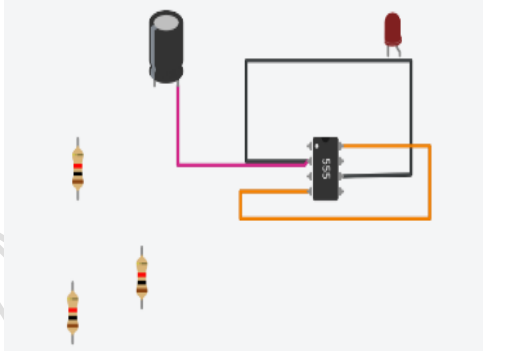
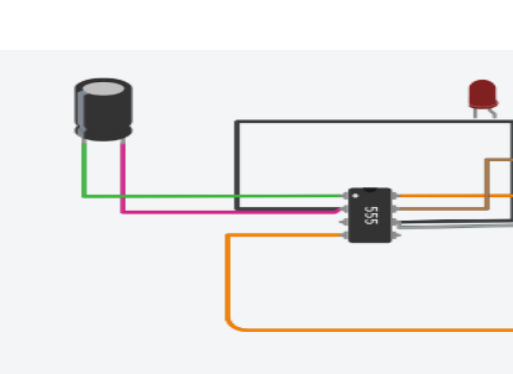
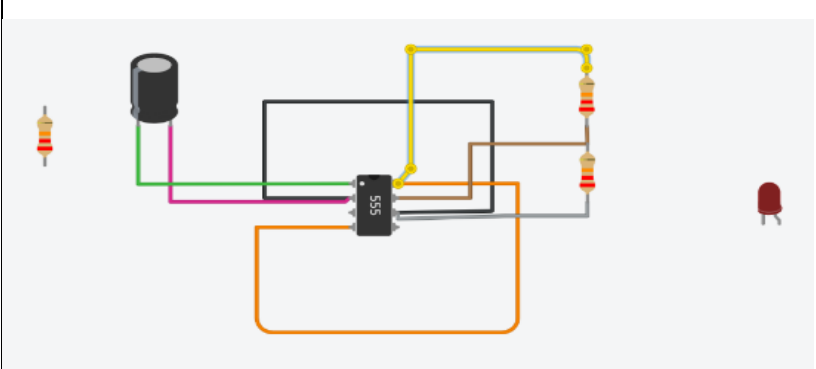


Fig.1. drag and drop Components on Tinkercad Platform

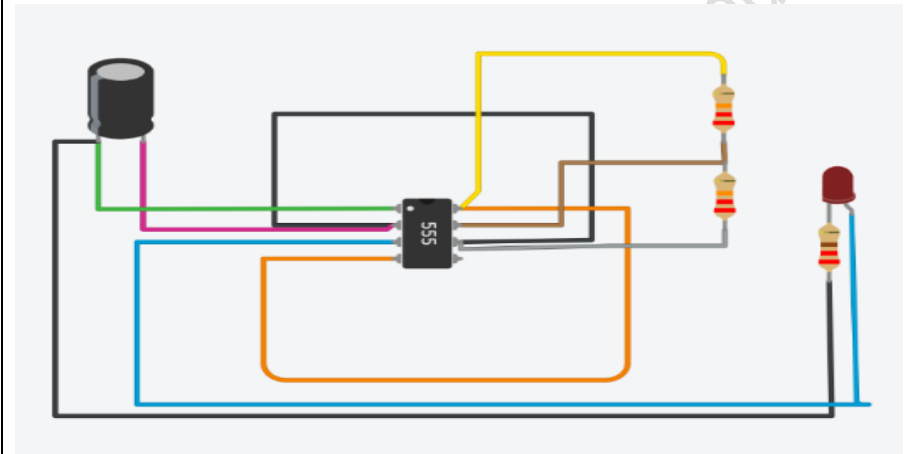
3. Make the Connections as shown below:

<p>Connect pin 2 (TRIG) and pin 6 (THRESH) of IC 555 together with a jumper wire.</p>	
<p>Connect IC 555 pin 4 (RESET) directly to pin 8 (VCC).</p>	
<p>Connect one side of C1 (10 μF) to pins 2 and 6 of IC 555, and the other side to GND.</p>	
<p>Connect R2 (33 kΩ) between pins 6 and 7 of IC 555.</p>	

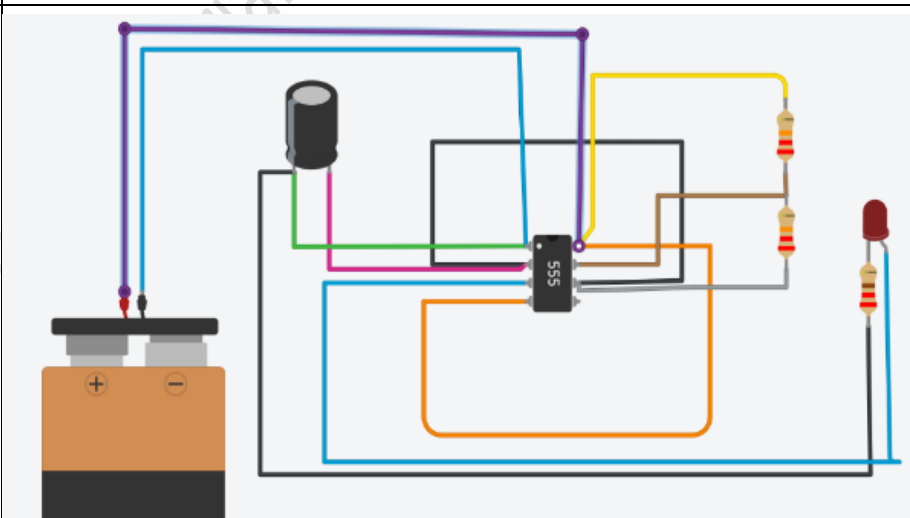
Connect R1 (100 k Ω) between pins 7 and 8 of IC 555



Connect R3 (70 Ω) between anode (long pin) of LED and negative pin of capacitor C1 (10 μ F).
Connect the cathode of LED (LED short pin) to IC555 output pin 3.



Connect battery between GND pin and Power supply pin of IC555.



4. Start Simulation

- Click the “**Start Simulation**” button on the top-right corner of Tinkercad.
- Observe the LED blinking continuously at a fixed rate.

Working Principle

The IC 555 timer is configured in astable mode, meaning it continuously switches between high and low output states. When the capacitor C1 charges through resistors R1 and R2, the output at pin 3 goes HIGH, turning the LED ON. When the capacitor discharges through

R2, the output goes LOW, turning the LED OFF. This cycle repeats continuously, making the LED blink at a frequency determined by the resistor and capacitor values.

Observation

- The LED blinks continuously, showing the timing function of the IC 555 in astable mode.
- Changing the values of R1, R2, or C1 in Tinkercad will change the blinking rate.

Exercise

Perform the same activity using actual hardware components and verify the operation of the circuit.

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. In an automated factory, a system must detect the presence of objects and send this information to a controller for processing. Which function of a sensor is being applied here?
 - a) Detect events within a specified environment
 - b) Separate physical parameters
 - c) Track and transfer data to computer processors
 - d) Both a and c
2. A packaging machine needs to detect bottles moving on a conveyor belt without touching them to avoid damage. Which type of sensor should be applied?
 - a) Contact type
 - b) Non-contact type
 - c) Both a and b
 - d) Partially contact
3. In a robotic arm used for assembly, components are required to produce motion and control mechanical movement. Which of the following can be applied as actuators in this system?
 - a) Gears
 - b) Pistons
 - c) Valves
 - d) All of the above
4. In an industrial automation setup, a system requires fast and clean movement using compressed air for operating cylinders. Which actuator should be applied?
 - a) Hydraulic piston
 - b) Pneumatic actuator
 - c) Solenoid coil
 - d) Piezo stack
5. While designing a car parking assistance system, you need a sensor that can measure the distance between the vehicle and nearby obstacles. Which sensor should be applied?

- a) Ultrasonic sensor
- b) Thermocouple
- c) Pressure sensor
- d) Tachometer

B. Match the following

Column A	Column B
1. DC Motor	A. Generates voltage from mechanical stress
2. Temperature Sensor	B. Rotates to a precise angle using feedback
3. Piezoelectric Sensor	C. Converts electrical energy into precise linear movement
4. Servo Motor	D. Measures heat level in a system
5. Linear Actuator	E. Converts electrical energy into rotational motion

C. Fill in the blanks

1. Sensors fetch _____ data to control devices.
2. The most basic example of a temperature sensor is a _____.
3. An actuator is a device which actuates the movement by converting _____.
4. A touch sensor is a sensitive device that detects _____ and carries out the required operations.
5. A device used to measure humidity levels in the environment is called a _____.

D. Answer the following

1. In a bottling plant, you need a system that automatically stops the conveyor when a bottle is not present at the filling station. Which type of sensor would you apply and why?
2. A lifting mechanism in a warehouse must handle very heavy loads smoothly. Which type of actuator would you select for this application and why?
3. In an automated irrigation system, soil moisture is measured and water flow is adjusted accordingly. How are sensors and actuators working together in this system?
4. A CNC machine requires precise positioning of its cutting tool at specific coordinates. Which actuator system would you apply to achieve high accuracy and repeatability?
5. In a packaging unit, products must be counted as they pass through a line at high speed without contact. Which sensing method would you apply and why?

SESSION 3: INTERFACING SENSORS WITH MICROCONTROLLERS

2.9 Introduction to Interfacing

Have you seen automatic streetlights turning ON at night? Sensors detect darkness and the microcontroller controls the light automatically.



Interfacing sensors with a microcontroller means connecting sensors so a system can sense, think, and act based on real-world conditions. It is a core concept in electronics, robotics, and IoT systems. Sensor interfacing helps machines understand the physical world and respond intelligently, making it the foundation of modern embedded and IoT systems.

Interfacing involves both hardware and software components working together. The hardware aspect includes physically connecting sensors to the input pins of a microcontroller, ensuring proper signal transmission. The software aspect involves programming the microcontroller to read, interpret, and respond to the sensor data, enabling the system to perform appropriate actions based on real-time inputs.

Sensors work like the human senses of a machine; they detect temperature, light, motion, pressure, or sound and convert them into electrical signals. The microcontroller then processes this data and takes action, such as turning on a fan, triggering an alarm, or sending data online. When done correctly, this creates a smart system that can monitor, decide, and control. It also allows multiple sensors to work together in applications like smart homes, weather stations, and automated factories.

For example, in a temperature-controlled fan, the sensor detects heat, the microcontroller compares it with a set value, and switches the fan ON or OFF automatically (Fig.2.54).

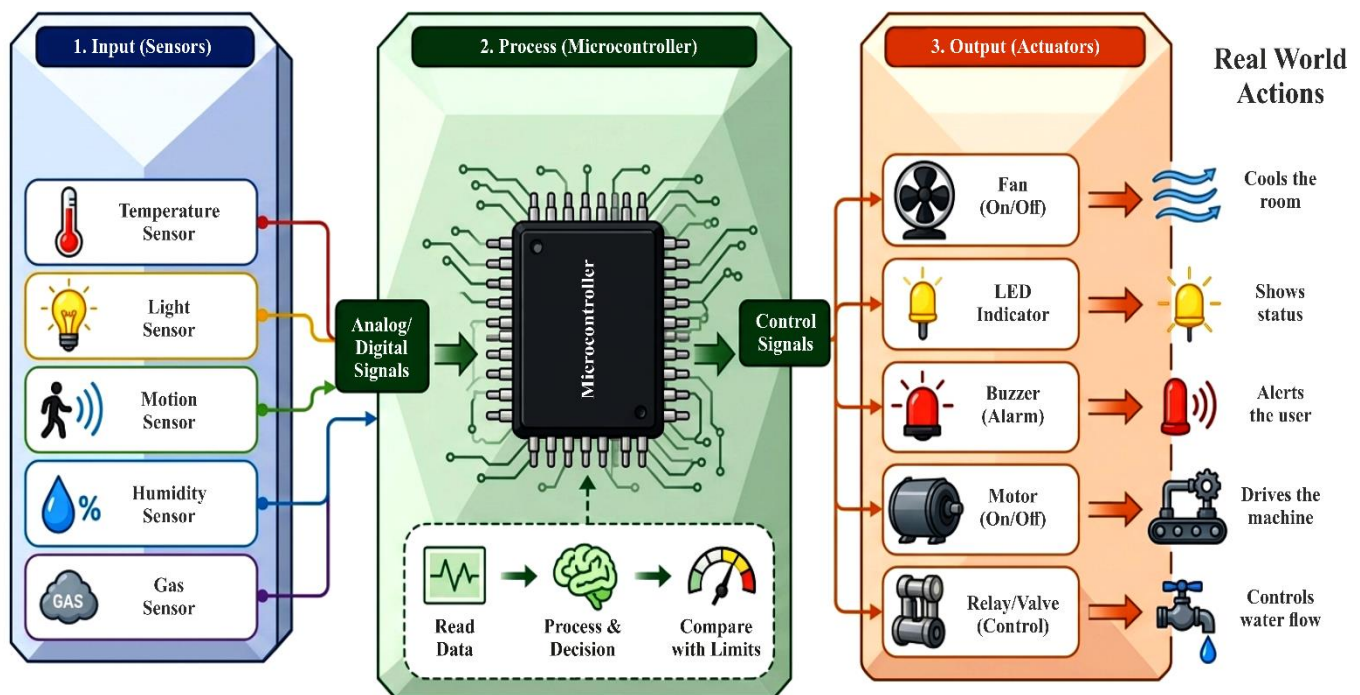


Fig.2.54: Application of Interfacing

2.10 Understanding Analog and Digital Signals

In electronic systems, signals are used to transmit information. Sensors communicate with microcontrollers using electrical signals. Understanding these types of signals is crucial for correctly interfacing sensors and writing appropriate programs for data processing. These signals can be classified in two types: analog and digital.

i) Analog Signals

Analog signals are continuous and vary smoothly over time, representing real-world quantities such as sound, light, or temperature. For example, when you speak into a microphone, it converts sound waves into a varying electrical signal (Fig.2.55).

Characteristics of Analog Signals

- Continuous variation over a range of values
- Represented as a smooth waveform
- Can take infinite values within the range

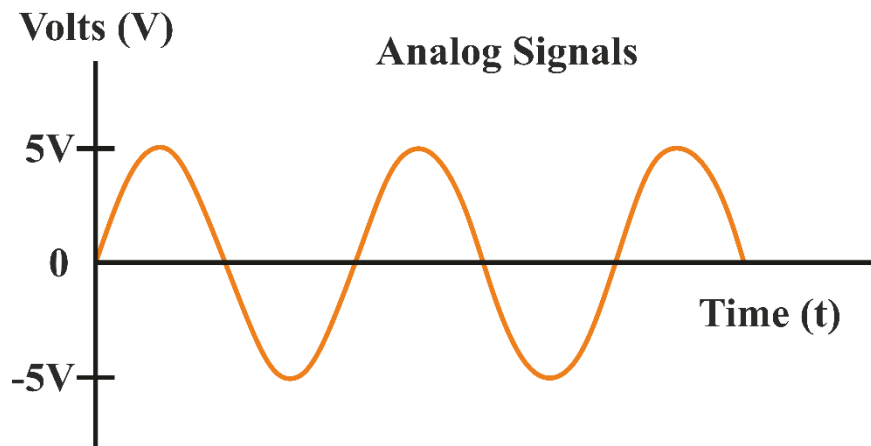


Fig.2.55: Analog Signals

In Arduino, analog signals are read using analog input pins (A0–A5). These pins are connected to an Analog-to-Digital Converter (ADC) that converts the continuous analog signal (0–5V) into a digital value between 0 and 1023.

These inputs are commonly used with sensors like temperature, light, and pressure sensors, converting analog data into digital values the microcontroller can process. For example, when using a temperature sensor (LM35), the output voltage changes proportionally with temperature, higher temperature results in higher voltage.



Think About It!

When we slowly increase the volume of a speaker, the sound changes smoothly. This is similar to an analog signal.

ii) Digital Signals

Digital signals are discrete signals that can have only two states: HIGH (1) or LOW (0). These signals represent binary information and are commonly used in on/off control systems. For example, a PIR motion sensor outputs HIGH when it detects movement and LOW when there is none (Fig.2.56).

Characteristics of Digital Signals

- Represented as square waves
- Easier to process and less affected by noise
- Used in switches, motion sensors, and digital modules

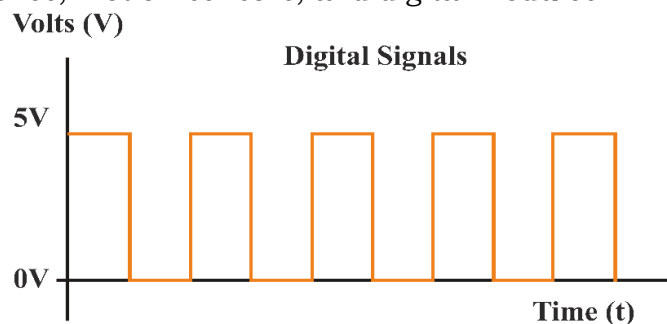


Fig.2.56: Digital Signals

In Arduino, digital pins (D0–D13) are used to read input states (e.g., from buttons or switches) and control outputs (e.g., LEDs, motors, or relays).

 **Real-Life Example**

A simple electric switch works digitally because it has only two conditions: ON or OFF.

2.11 Connecting and Reading Sensors with Arduino Uno

The Arduino Uno is one of the most widely used microcontroller development boards. It is based on the ATmega328P microchip and features both analog and digital I/O pins, making it ideal for sensor interfacing.

Interfacing sensors with the Arduino Uno involves a clear sequence of steps, from making connections to reading and using data. Basic Steps for Sensor Interfacing with Arduino Uno are as follows:

Step 1: Identify the Type of Sensor

Before connecting, determine whether the sensor is:

- Digital sensor → gives HIGH/LOW output (e.g., IR sensor, push button)
- Analog sensor → gives variable output (e.g., temperature, light sensor)

This helps in selecting the correct arduino pin to connect the sensor: digital pins or analog pins.

Step 2: Make Hardware Connections

Connect the sensor to the Arduino Uno using three basic pins:

- VCC → connect to 5V (or 3.3V if required)
- GND → connect to ground
- Signal pin →
 - Digital pin (e.g., D2, D3...) for digital sensors
 - Analog pin (e.g., A0, A1...) for analog sensors
- If needed, include supporting components like resistors, modules, or voltage dividers.

Step 3: Set Up the Arduino Environment

- Install and open the Arduino IDE
- Select the correct board (Arduino Uno)
- Choose the appropriate COM port

Step 4: Write the Program (Code)

Define the sensor pin and initialize it:

- For digital sensor:
 - Set pin mode as INPUT
- For analog sensor:

- Directly read from analog pin

Step 5: Reading Sensor Data

Once connected, the Arduino reads sensor data using built-in functions:

- `digitalRead(pin)` → (for digital sensors) reads HIGH or LOW
- `analogRead(pin)` → (for analog sensors) reads value (0–1023)

These values represent the physical condition sensed (like light intensity or temperature).

Step 6: Process the Data

- Compare sensor values with a threshold
- Convert raw values into meaningful units (e.g., °C, lux)
- Apply decision logic (if-else conditions)

Step 7: Perform Action (Output)

Based on the sensor data, the Arduino can:

- Turn ON/OFF an LED
- Activate a buzzer
- Control a motor or relay
- Display data on Serial Monitor or LCD

This process can be easily understood by the example of temperature sensor. A temperature sensor LM35 connected to an analog pin sends voltage signals based on temperature. The Arduino reads this value using `analogRead()`, converts it into temperature, processes it, and switches ON a fan if temperature exceeds a set limit or display the reading (Fig.2.57).

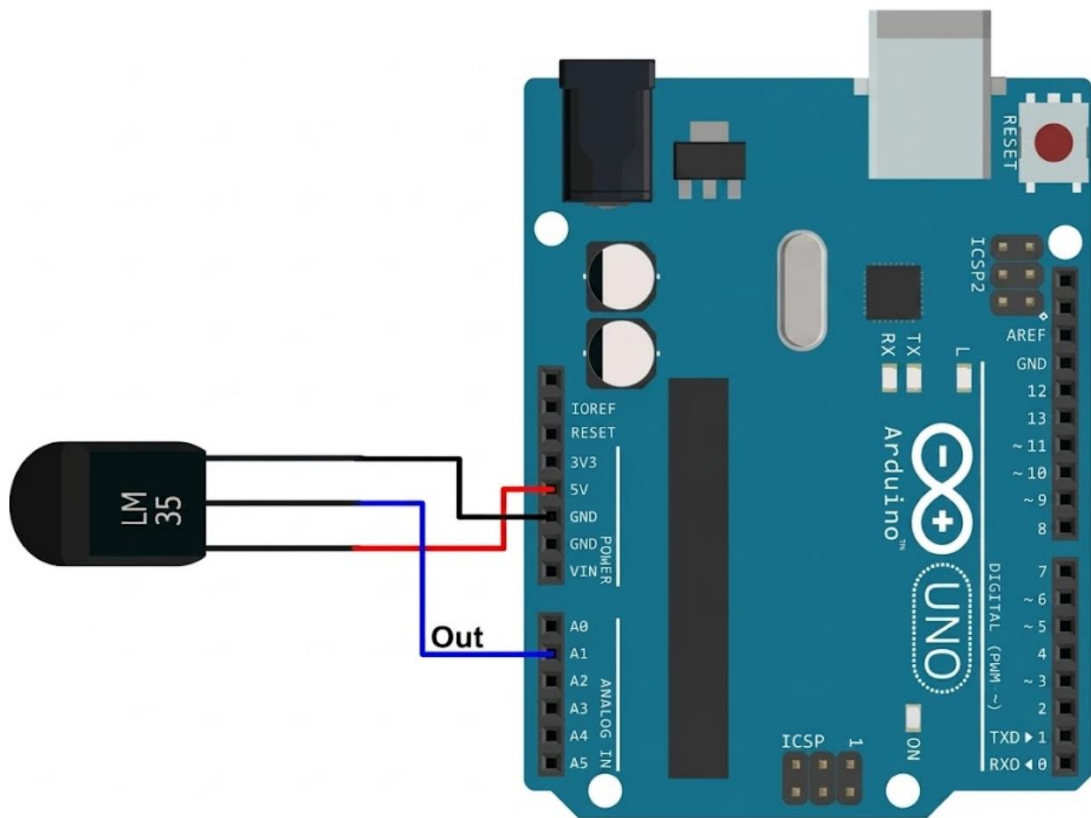


Fig.2.57: Interfacing LM35 With Arduino UNO

The most commonly used sensor interfaces with the Arduino Uno are listed in the Table 2.5.

Table 2.5: Interfacing of Sensors with Arduino Uno

Sensor Name	Signal Type	Pin Connections	NodeMCU Pin Used	Output Behavior / Use
LM35 Temperature Sensor	Analog	VCC → 5V GND → GND OUT → A0	A0 (Analog Input)	Outputs voltage proportional to temperature (10 mV/°C)
LDR (Light Dependent Resistor)	Analog	One side to 5V Other side to A0 + 10kΩ resistor to GND	A0	Detects light intensity; lower resistance in bright light
PIR Motion Sensor	Digital	VCC → 5V OUT → D2 GND → GND	D2 (Digital Input)	Outputs HIGH when motion is detected
Ultrasonic Sensor (HC-SR04)	Digital	VCC → 5V GND → GND TRIG → D6 ECHO → D7	D6, D7	Measures distance using sound waves
DHT11 Humidity & Temperature Sensor	Digital	VCC → 5V DATA → D4 GND → GND	D4	Provides temperature and humidity readings
Gas Sensor (MQ-135)	Analog	VCC → 5V GND → GND OUT → A1	A1	Detects air quality and gas concentration

IR Obstacle Sensor	Digital	VCC → 5VOUT → D8GND → GND	D8	Detects nearby obstacles using infrared light
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2.12 Connecting and Reading Sensors with NodeMCU

The NodeMCU is a powerful and versatile microcontroller development board based on the ESP8266 Wi-Fi module. It not only reads sensor data but can also send it over Wi-Fi, making systems smart and connected. It combines a programmable microcontroller with built-in Wi-Fi connectivity, making it ideal for Internet of Things (IoT) applications where data is transmitted to cloud platforms or mobile dashboards.

NodeMCU allows students to design smart systems such as weather stations, home automation setups, and industrial monitoring units; all using simple programming and low-cost components.

Basic Steps for Sensor Interfacing with NodeMCU are as follows:

Step 1: Identify the Type of Sensor

Determine whether the sensor is:

- Digital sensor → gives HIGH/LOW output
- Analog sensor → gives varying voltage

Note: NodeMCU has only one analog pin (A0).

Step 2: Make Hardware Connections

Connect the sensor using basic pins:

- VCC → 3.3V (important: NodeMCU works on 3.3V)
- GND → Ground
- Signal pin →
 - Digital pins (D0–D8) for digital sensors
 - A0 for analog sensors
- Ensure the input voltage to A0 does not exceed safe limits (usually 1V on bare ESP8266, though some boards have internal scaling).

Step 3: Set Up the Programming Environment

- Install and open the Arduino IDE
- Add ESP8266 board support
- Select NodeMCU 1.0 (ESP-12E Module)
- Choose the correct COM port

Step 4: Write the Program (Code)

Define the sensor pin and initialize it:

- Digital → `pinMode(pin, INPUT)`
- Analog → directly read from A0

Step 5: Read Sensor Data

Use functions:

- `digitalRead(pin)` → reads HIGH/LOW
- `analogRead(A0)` → reads value (0–1023)

Step 6: Process the Data

- Convert raw data into meaningful values
- Compare with threshold (if-else logic)
- Prepare data for display or transmission

Step 7: Perform Action or Send Data

NodeMCU can:

- Control devices (LED, relay, motor)
- Send data to cloud platforms (ThingSpeak, Blynk, etc.)
- Display data on Serial Monitor or web dashboard

Step 8: Upload and Test

- Upload the code
- Open Serial Monitor to observe readings
- Verify Wi-Fi data transmission (if used)

Interfacing Example: A soil moisture sensor is connected to pin A0 of the NodeMCU. The sensor measures the moisture level in the soil and outputs a varying voltage. The NodeMCU reads this value using `analogRead()`, processes it, and compares it with a preset threshold (Fig.2.58).

If the soil is dry, the NodeMCU automatically turns ON a water pump (via a relay). If the soil has enough moisture, it turns OFF the pump. Additionally, the system can send real-time moisture data to a mobile app or cloud platform, enabling remote monitoring and smart irrigation control.

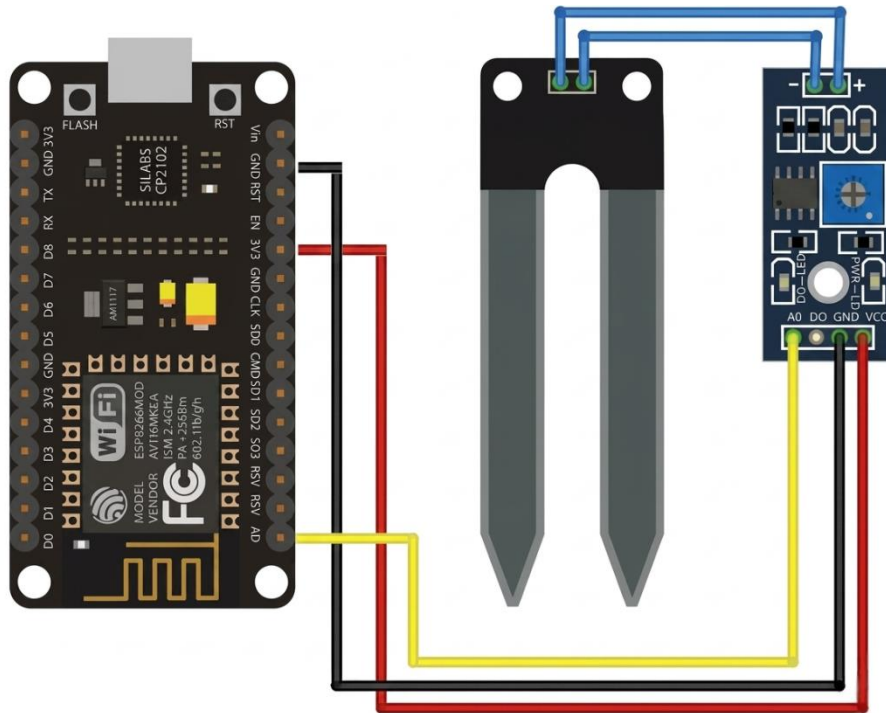


Fig.2.58: Interfacing Soil moisture Sensor with NodeMCU

Smart Farming Insight
 Smart irrigation systems save water by automatically watering plants only when the soil becomes dry.

The most commonly used sensor interfaces with the NodeMCU are listed in the Table 2.6.

Table 2.6: Interfacing of Sensors with NodeMCU

Sensor Name	Signal Type	Pin Connections	NodeMCU Pin Used	Output Behavior / Use
DHT11 (Temp & Humidity)	Digital	VCC → 3.3 V D4 → DATA D4 → GND	D4	Outputs temperature & humidity data every 2 s
LDR (Light Sensor)	Analog	One side → 3.3 V Other side → A0 + 10 kΩ resistor to GND	A0	Detects light intensity; voltage decreases with more light
Ultrasonic Sensor (HC-SR04)	Digital	VCC → 5 V GND → GND TRIG → D6 ECHO → D7	D6, D7	Measures distance using sound waves (use 3.3 V logic divider)
PIR Motion Sensor	Digital	VCC → 3.3 V D2 → VOUT D2 → GND	D2	HIGH when motion detected

MQ-135 Sensor	Gas	Analog	VCC → 3.3 A0GND → GND	VOUT → A0	Detects air quality or gas concentration
IR Sensor	Obstacle	Digital	VCC → 3.3 D3GND → GND	VOUT → D3	Detects objects or obstacles in front of sensor

2.13 Role of Cloud in IIOT

After sensors collect data and microcontrollers like Arduino Uno or NodeMCU process it, the cloud plays a crucial role in making this data useful, accessible, and intelligent. It acts as a central platform for storing, analyzing, and managing large volumes of data generated across industrial systems.

Real-Life Connection

Cloud platforms allow users to monitor machines and devices remotely through computers or smartphones.

2.13.1 How Cloud Works in IIoT Systems?

Data Collection: Sensors measure parameters like temperature, pressure, or vibration in machines.

Data Transmission: Microcontrollers such as NodeMCU or Arduino (with Wi-Fi or GSM shield) send this data to the cloud using internet protocols.

Storage and Processing: The cloud stores large volumes of sensor data for analysis and trend prediction.

Visualization: Users can monitor real-time dashboards, graphs, and alerts from any location using computers or mobile devices.

For example, in a smart factory, NodeMCU modules continuously monitor machine temperature and vibration. This data is sent to the cloud for real-time monitoring. If temperature exceeds a set limit, the system automatically sends an alert to the operator's smartphone, helping prevent equipment failure.

Note: *Factories use dashboards and graphs to monitor machine performance in real time."*

2.13.2 What Cloud Enables in IIoT

- Live monitoring of sensor data (temperature, humidity, machine status)
- Historical data storage for analysis and optimization
- Trend analysis and insights for improving efficiency
- Alerts and notifications for abnormal conditions
- Remote control of devices from anywhere

For example, in a smart irrigation system, a NodeMCU sends soil moisture data to the cloud. The cloud platform displays this data on a dashboard and can automatically trigger irrigation or notify the user when the soil is dry.

2.13.3 Popular Cloud Platforms

- ✚ **ThingSpeak:** Open-source platform for data logging and graph plotting.
- ✚ **Blynk:** App-based IoT platform for real-time monitoring and control.
- ✚ **AWS IoT Core, Google Cloud IoT, Azure IoT Hub:** Enterprise-level cloud services for industrial automation.

2.13.3 Benefits of Cloud in IIOT

- Real-time data monitoring
- Predictive maintenance and fault detection
- Remote accessibility and control
- Scalability for large systems
- Integration with Artificial Intelligence (AI) and analytics

PRACTICAL ACTIVITY

ACTIVITY 1:

Interfacing MQ-7 CO Gas Sensor With Arduino Uno for Carbon Monoxide Monitoring

Objectives:

1. Understand how a gas sensor works
2. Interface an MQ-7 CO sensor with Arduino
3. Read analog sensor data using Arduino
4. Display sensor readings on the Serial Monitor
5. Build a basic gas detection system

Components Required:

Component	Quantity
Arduino UNO	1
MQ-7 CO Gas Sensor	1
Jumper Wires	4
USB Cable	1

Theory

Carbon Monoxide (CO) is a harmful gas that is colorless and odorless but very dangerous for humans. Monitoring CO levels is important for industrial safety, home safety, and environmental monitoring. In this activity, a MQ-7 Carbon Monoxide Gas Sensor is interfaced with an Arduino Uno to detect CO gas levels. The sensor sends an analog signal to the Arduino, which processes it and displays the gas concentration value on the Serial Monitor.

Hardware Connection:

The sensor's analog output pin (AO) sends a voltage proportional to CO concentration to the Arduino analog pin A0.

CO Sensor Pin	Arduino Connection
VCC	5V
GND	GND
AO (Analog Output)	A0
DO (Digital Output)	D2

Circuit Diagram:

Fig.1: CO Sensor Module

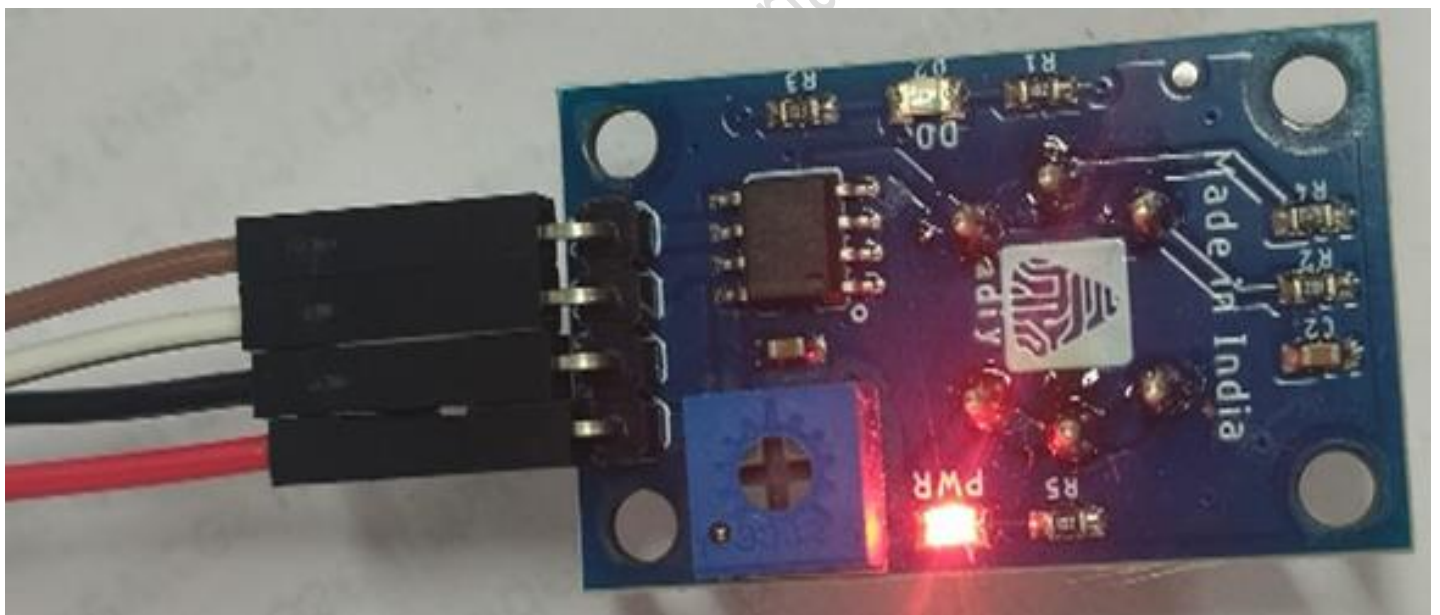


Fig.1: CO Sensor Pins

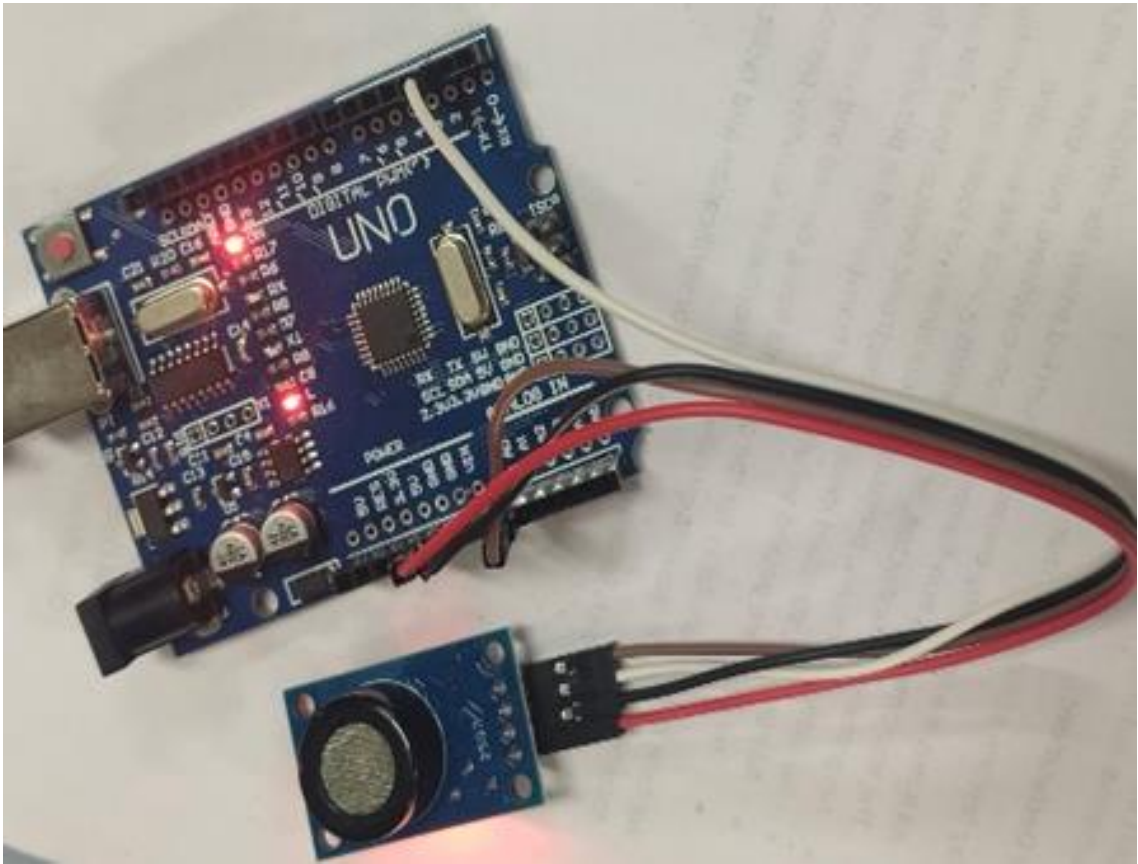


Fig.3: CO Sensor to Arduino Uno connection

Fig.3 above shows how the CO gas sensor is connected with Arduino UNO using jumper wires and a breadboard.

Working Principle:

1. The MQ-7 sensor detects CO gas using a semiconductor sensing material. The sensor contains a sensitive layer that reacts with carbon monoxide gas.
2. When CO gas is present, the resistance of the sensor changes.
3. This change in resistance produces a different output voltage.
4. The analog output voltage is sent to Arduino analog pin A0.
5. The Arduino Uno converts the analog voltage into a digital value (0 – 1023).
6. The measured value is displayed on the Serial Monitor.

Procedure:

Step 1: Connect CO Sensor to Arduino

Using jumper wires, make the connections shown in the Hardware Connection table above.

Double-check all wire connections before powering the Arduino.

Step 2: Connect Arduino to Computer

Connect the Arduino UNO to your computer via USB cable and open Arduino IDE.

Step 3: Write the Program

Copy and paste the following code:

```
// Arduino Code
int gasPin = 2;
void setup() {
  Serial.begin(9600);
  pinMode(gasPin, INPUT);
}

void loop() {
  int gas = digitalRead(gasPin);
  if (gas == LOW) {
    Serial.println("Current Air Status          : Hazardous");
  } else {
    Serial.println("Current Air Status          : Normal");
  }
  delay(1000);
}
```

Step 4: Upload the Code

1. Select board: Tools → Board → Arduino UNO
2. Select port: Tools → Port
3. Click Upload and wait for 'Done uploading'

Step 5: Observe Output

1. Open Tools → Serial Monitor, baud rate 9600
2. Observe CO level readings (0–1023) updating every second



```
sketch_mar12a.ino
1  int gasPin = 2;
2
3  void setup() {
4    Serial.begin(9600);
5    pinMode(gasPin, INPUT);
6  }
7
8  void loop() {
9
10   int gas = digitalRead(gasPin);
11
12   if (gas == LOW) {
13     Serial.println("Current Air Status          : Hazardous");
14   } else {
15     Serial.println("Current Air Status          : Normal");
16   }
17
18   delay(1000);
19 }

Output Serial Monitor X
Message (Enter to send message to 'Arduino UNO' on 'COM3')
Current Air Status          : Normal
Current Air Status          : Normal
Current Air Status          : Normal
Current Air Status          : Normal
Current Air Status          : Normal
Current Air Status          : Normal
Current Air Status          : Normal
Current Air Status          : Normal
Current Air Status          : Normal
Current Air Status          : Normal
Current Air Status          : Normal
Current Air Status          : Normal
Current Air Status          : Normal
Current Air Status          : Normal
Current Air Status          : Normal
```

Fig.4: Serial Monitor output — CO sensor readings

Exercise

Modify the code to print a warning message when the CO value exceeds 500, indicating a higher CO concentration. Use an if-else condition.

ACTIVITY 2:**PIR Motion Sensor-Based LED Control Using Arduino Uno****Objectives:**

1. Understand the working principle of a PIR motion sensor
2. Interface a PIR sensor with Arduino
3. Control an LED using sensor input
4. Write and upload Arduino programs using Arduino IDE
5. Implement basic motion-based automation systems

Components Required:

Component	Quantity
Arduino UNO	1
HC-SR501 PIR Motion Sensor	1
LED	1
Breadboard	1
Jumper Wires	6
USB Cable	1

Theory

Motion detection systems are widely used in security systems, automatic lighting, and smart home automation. A Passive Infrared (PIR) sensor detects motion by sensing changes in infrared radiation emitted by objects such as humans or animals.

In this activity, a HC-SR501 PIR Motion Sensor is interfaced with an Arduino Uno to control an LED. When motion is detected, the LED turns ON. When no motion is detected, the LED remains OFF.

Hardware Connection:**PIR Sensor to Arduino:**

PIR Connection	Arduino Connection
VCC	5V
GND	GND
OUT	D2

LED Connection:

LED Pin	Arduino Connection
Anode (+)	D8
Cathode (-)	GND

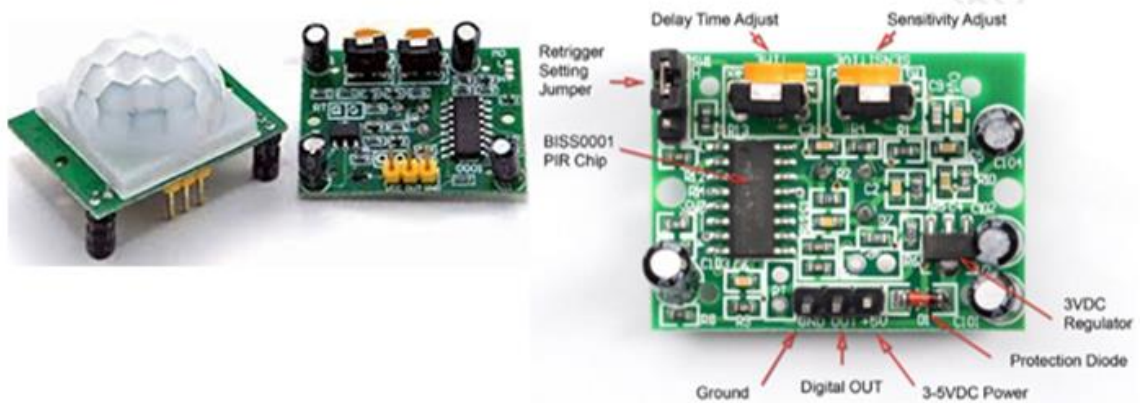
Circuit Diagram:

Fig.1: PIR Sensor Module

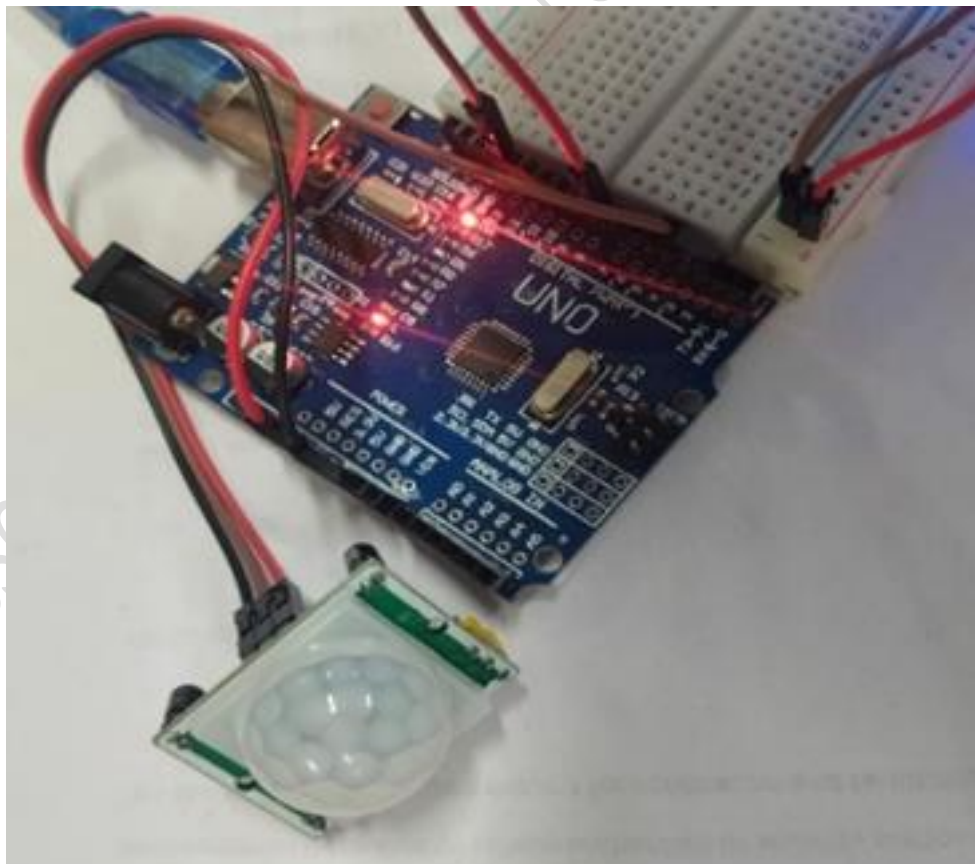


Fig.2: Circuit Connection of PIR Sensor Module with Arduino Uno

Procedure:**Step 1:** Wire the Components

Connect the PIR sensor (VCC→5V, GND→GND, OUT→D2) and LED (Anode→D8, Cathode →GND via breadboard).

Step 2: Connect Arduino to Computer

Plug in the USB cable and open Arduino IDE.

Step 3: Write the Program

Enter the following code:

```
// Arduino Code
int pirPin = 2;
int ledPin = 8;
int pirVal = 0;

void setup() {
  Serial.begin(9600);
  pinMode(pirPin, INPUT);
  pinMode(ledPin, OUTPUT);
}

void loop() {
  pirVal = digitalRead(pirPin);
  if (pirVal == HIGH) {
    digitalWrite(ledPin, HIGH);
    Serial.println("Motion Detected! LED ON");
  } else {
    digitalWrite(ledPin, LOW);
    Serial.println("No Motion. LED OFF");
  }
  delay(500);
}
```

Step 4: Upload and Test

1. Select board Arduino UNO and correct COM port
2. Click Upload
3. Open Serial Monitor at baud rate 9600
4. Wave your hand in front of the PIR sensor and observe the LED

Output:

- When No Motion — LED OFF (Shown in red circle in Fig.3)
- When Motion Detected — LED ON (Shown in red circle in Fig.4)

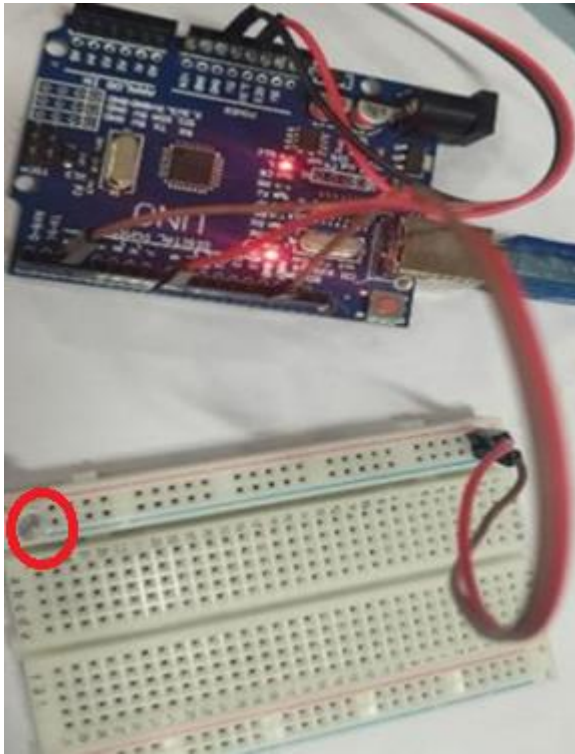


Fig.3: No Motion — LED OFF

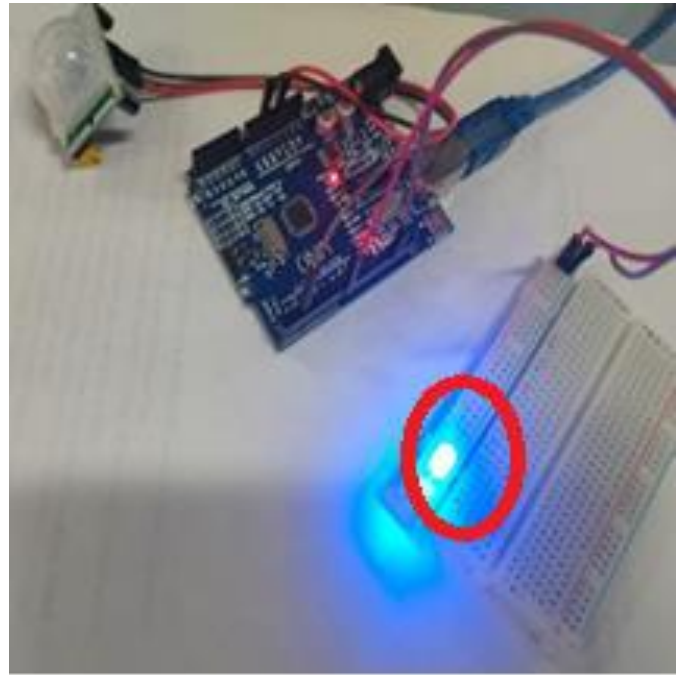


Fig.4: Motion Detected — LED ON

Exercise

Add a buzzer to the circuit on pin D9. Modify the code so the buzzer also activates when motion is detected.

ACTIVITY 3:

Proximity Sensor Interfacing With Arduino Uno

Objectives:

1. Understand the working principle of proximity sensors
2. Interface a proximity sensor with an Arduino UNO
3. Read digital input signals from sensors
4. Display sensor status on the Serial Monitor
5. Implement object detection using Arduino

Components Required:

Component	Quantity
Arduino UNO	1
E18-D80NK Proximity Sensor	1
Jumper Wires	3
USB Cable	1


Theory

Proximity sensors are widely used in industrial automation and embedded systems to detect the presence of nearby objects without physical contact.

In this activity, an Arduino UNO is interfaced with an E18-D80NK Infrared Proximity Sensor to detect objects. When an object comes within the detection range, the sensor sends a signal to the Arduino, which displays the detection status on the Serial Monitor.

Hardware Connection:

Proximity Sensor Pin	Arduino Pin
VCC	5V
GND	GND
OUT	D2

 The output pin sends a digital HIGH or LOW signal depending on whether an object is detected.

Circuit Diagram:

Fig .1: Proximity Sensor to Arduino UNO Circuit Connection

Procedure:**Step 1:** Wire the Proximity Sensor

Connect VCC → 5V, GND → GND, OUT → D2 of Arduino UNO.

Step 2: Connect Arduino to Computer

Plug in the USB cable and open Arduino IDE.

Step 3: Write the Program

Enter the following code:

```
const int proxPin = 2; // Proximity sensor output connected to D2
const int ledPin = 13; // Built-in LED
void setup() {
  pinMode(proxPin, INPUT); // External pull-up resistor used
  pinMode(ledPin, OUTPUT);
  Serial.begin(9600);
  Serial.println("Proximity Sensor Test Started");
}
void loop() {
  int sensorState = digitalRead(proxPin);
  // For NPN NO sensor with pull-up:
  // No object -> HIGH
  // Object near -> LOW
  if (sensorState == LOW) {
    Serial.println("Object Detected");
    digitalWrite(ledPin, HIGH);
  } else {
    Serial.println("No Object");
    digitalWrite(ledPin, LOW);
  }
  delay(300);
}
```

Step 4: Upload and Test

1. Select board Arduino UNO and correct COM port
2. Click Upload
3. Open Serial Monitor at baud rate 9600
4. Move your hand in front of the sensor and observe status changes

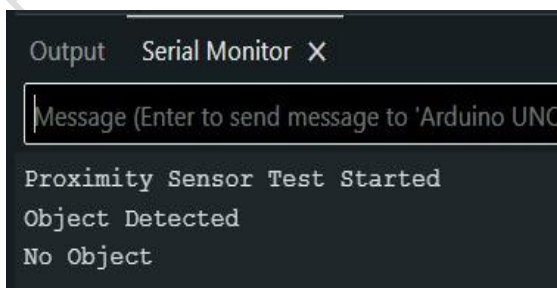
Output:

Fig.2: No object in Serial Monitor



Fig.3: Object present — Serial Monitor

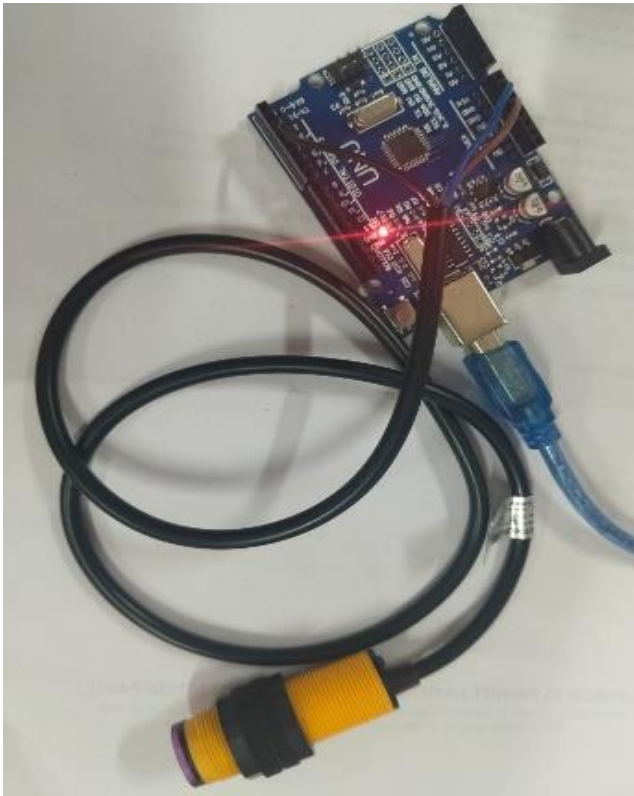


Fig.4: Object not Present

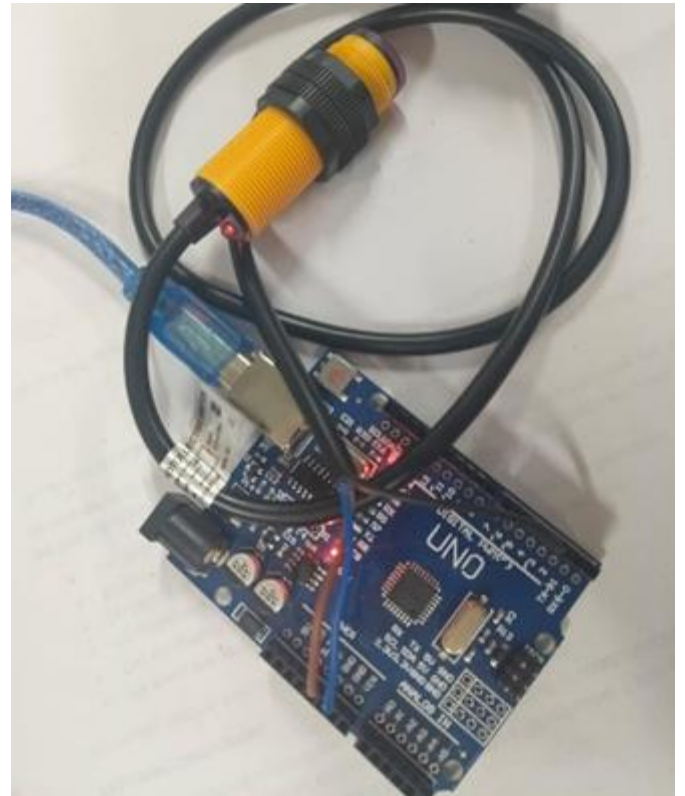


Fig.5: Object Detected

Exercise

Modify the code to count the number of objects detected and display a running count on the Serial Monitor.

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. A smart home system needs to automatically turn ON a fan when the room temperature increases. Which combination is most appropriate?
 - a) PIR sensor + digitalRead()
 - b) LM35 sensor + analogRead()
 - c) LDR sensor + digitalRead()
 - d) Push button + analogRead()
2. In an automated irrigation system, a farmer wants the water pump to turn ON only when the soil is dry. Which setup should be applied?
 - a) PIR sensor with digital input
 - b) Soil moisture sensor with analog input
 - c) Ultrasonic sensor with digital input
 - d) Temperature sensor with digital input

3. A system needs to detect whether a door is open or closed and trigger an alarm accordingly. Which type of signal and function should be used?
 - a) Analog signal with analogRead()
 - b) Digital signal with digitalRead()
 - c) Analog signal with digitalRead()
 - d) Digital signal with analogRead()

4. In an IIOT-based factory, machine temperature data is continuously sent to a cloud platform for monitoring. What is the main advantage of using the cloud here?
 - a) Reduces sensor cost
 - b) Enables remote monitoring and alerts
 - c) Eliminates need for microcontroller
 - d) Converts analog signals to digital

5. A student connects an LDR sensor to measure light intensity using Arduino. Which pin and method should be applied for accurate readings?
 - a) Digital pin with digitalRead()
 - b) Analog pin with analogRead()
 - c) Digital pin with analogRead()
 - d) Analog pin with digitalRead()

B. Match the following

Column A	Column B
1. LM35 Sensor	A. Detects motion
2. PIR Sensor	B. Measures temperature
3. LDR	C. Measures light intensity
4. analogRead()	D. Reads analog values
5. NodeMCU	E. Wi-Fi enabled microcontroller

C. Fill in the Blanks

1. Sensors convert physical quantities into _____ signals.
2. _____ signals are continuous and vary smoothly over time.
3. The function _____ is used to read digital input in Arduino.
4. NodeMCU operates at _____ V logic level.
5. The cloud helps in _____ and analyzing large amounts of data in IIOT systems.

D. Answer the following

1. A temperature sensor is connected to Arduino. How will the system control a fan automatically?
2. In a smart irrigation system, how will NodeMCU control a water pump using a soil moisture sensor?
3. You need to detect motion in a room and turn ON a light. Which sensor and pins will you use?
4. A system needs to measure light intensity. Which sensor and input type will you choose and why?
5. How will you connect and read data from a PIR sensor using Arduino Uno?

MODULE 3**Industrial Network Design and Integration****Module Overview**

This module focuses on the design, structure, and integration of Industrial Internet of Things (IIOT) networks used in smart manufacturing and automotive industries. It introduces learners to how connected devices, sensors, and controllers communicate and exchange data securely across an industrial environment.

Students will first explore IIOT network architecture and devices, understanding how different layers work together for efficient data flow and system management. The module then explains various network topologies and communication protocols such as Ethernet, Modbus, MQTT, and OPC-UA that enable seamless connectivity among industrial systems.

Further, learners will study sensor and device integration within IIOT networks, gaining insight into how data from multiple machines and sensors is collected, transmitted, and processed for automation and real-time decision-making.

At the last the module covers data types, physical security, and system documentation, emphasizing best practices for ensuring reliable network performance, data protection, and proper record-keeping. By the end of this module, students will be able to design, analyze, and document IIOT networks that support secure, efficient, and scalable industrial operations.

Learning Outcomes

After completing this module, you will be able to:

- Explain the structure and components of IIOT network architecture, including sensors, gateways, edge devices, and cloud systems.
- Identify and compare different network topologies and communication protocols used in industrial environments.
- Integrate sensors and devices within IIOT networks for effective data acquisition and system control.
- Apply best practices for maintaining data integrity, physical security, and system documentation in IIOT systems.
- Design and evaluate simple IIOT network layouts that ensure secure and efficient data communication in industrial applications.

Module Structure

Session 1: IIOT Network Architecture and Devices

Session 2: Network Topologies and Protocols

Session 3: IIOT Sensor and Device Integration

Session 4: Data Management, Security and Documentation in IIOT Networks

SESSION 1: IIOT NETWORK ARCHITECTURE AND DEVICES

In an IIOT system, communication happens through a layered network architecture that connects various machines and devices. Each layer has a specific function, such as collecting data, processing information, or controlling operations. Devices like sensors, actuators, controllers, and robots are connected through switches, routers, and gateways. These components work together to enable smooth data flow and automation in industrial environments. Automation elements are essential for improving efficiency and real-time decision-making by linking physical systems with digital networks.

Think About It!

Have you seen machines in factories working together automatically? IIOT networks help machines, sensors, and computers communicate with each other in real time.



3.1 Network Architecture Layers

The network architecture comprises of seven layers, each with specific responsibilities, to ensure smooth and reliable communication between devices.

📖 Industrial networks work in layers, just like a postal system where each step has a specific role in delivering a letter.

This layered structure helps to standardize how different devices and systems communicate with each other with compatibility and efficiency. Seven-layer network architecture is shown in Fig. 3.1.

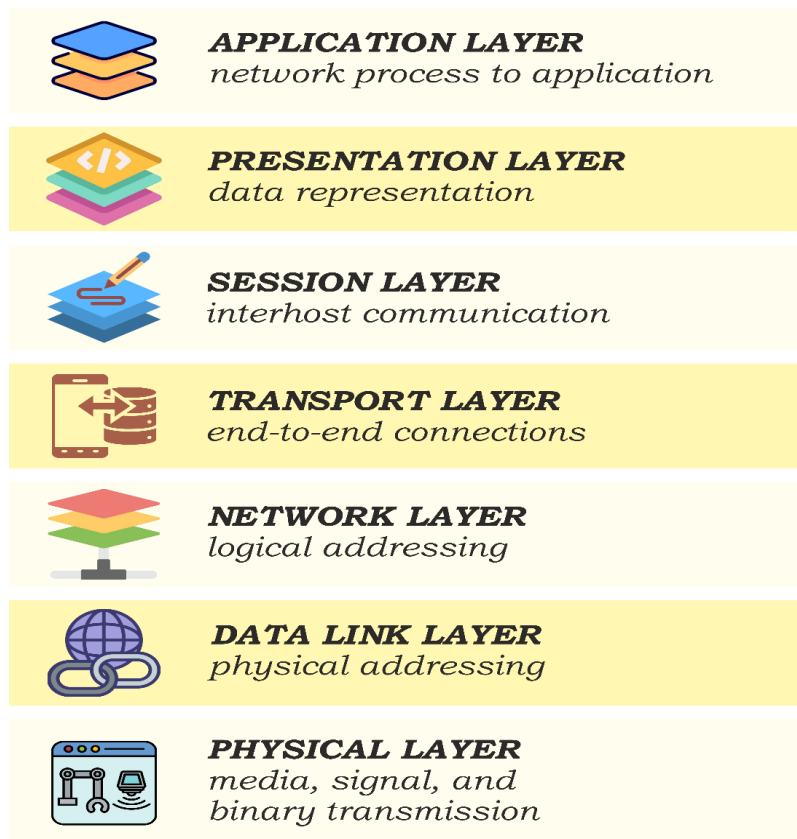


Fig.3.1: Seven Layer Network Architecture

1. The Physical Layer

The Physical Layer serves as the foundation for the network architecture. Among other physical media, it is responsible for transmitting raw data bits via cables, fiber optics, or wireless communications. This layer manages hardware, including network interface cards, cables, switches, and connectors. For creating and maintaining the physical link between systems, it specifies mechanical, electrical, and procedural criteria.

🔗 Network cables, fiber optics, and Wi-Fi signals help transfer data between machines and devices.

2. Data Link Layer

The Data Link Layer is above the physical layer and guarantees accurate and dependable data transport between two devices that are directly connected. It adds hardware (MAC) addresses, divides data into frames, and checks for transmission faults. It is crucial for local area networking and controls how devices connect to the network medium. switches, and other functioning devices at this layer.

3. Network Layer

Data transmission between devices over various networks is managed by the network layer. It chooses the best way for data to move between routers and assigns logical addresses, also referred to as IP addresses. Even in cases when the network is complicated or spans several locations, this layer makes sure that data packets get at their destination.

📖 IP addresses work like home addresses that help data packets reach the correct destination.

4. Transport Layer

The Transport Layer is responsible for ensuring reliable data communication between devices. It handles tasks such as error checking, flow control, and proper sequencing of data so that information reaches its destination correctly and in order. Protocols such as TCP (Transmission Control Protocol) and UDP (User Datagram Protocol) work at this layer, providing a balance between reliability and speed based on the application requirements.

Think About It!

When you watch videos online without interruption, transport layer protocols help ensure smooth and reliable data transfer.



5. Session Layer

The Session Layer manages and controls the sessions or conversations between devices. It keeps track of connections, ensures they remain open during data exchange, and properly closes them when communication ends. This layer is vital in applications where continuous data exchange occurs, like video conferencing or remote desktops.

📖 Video calls and online meetings use session management to maintain continuous communication.

6. Presentation Layer

The Presentation Layer ensures that the data sent from one device can be understood by another. It is responsible for translating data formats, encrypting and decrypting information for security, and compressing data to reduce bandwidth usage. This layer acts as a translator between the application and the network.

📖 Encryption used in online banking and messaging apps helps protect data during communication.

7. Application Layer

At the top is the Application Layer, which provides the interface through which users and applications interact with the network. It includes protocols and services like web browsing (HTTP), email (SMTP), and file transfer (FTP). This layer directly supports end-user processes and enables access to network resources.

🔑 Applications like email, web browsing, and file sharing work through the Application Layer.

3.2 IIOT Network Devices

In an IIOT system, network devices play a crucial role in enabling seamless communication between machines, sensors, and control systems. These devices are responsible for collecting, transferring, and processing data across industrial networks, ensuring that operations remain smooth, reliable, and secure.

The IIOT connects a wide range of industrial equipment and systems to enable real-time data exchange, automation, remote monitoring, and smart decision-making. By working together, these interconnected devices help industries improve efficiency, reduce downtime, and create more intelligent and responsive manufacturing environments. Some of the key IIOT network devices and systems are as follows:

1. Sensors and Actuators

Sensors are one of the most important parts of an IIOT network. They collect data from machines and the environment, such as temperature, pressure, humidity, vibration, and gas levels. These sensors are installed on equipment to monitor working conditions and help identify problems early.

Actuators are devices that act based on the information from sensors. They can open or close valves, start motors, or move robotic arms. Common types include pneumatic, hydraulic, and electric actuators. They help in performing physical tasks as part of an automated system.

2. Controllers (PLC, Microcontrollers)

PLCs (Programmable Logic Controllers) and microcontrollers like Arduino, Raspberry Pi, and ESP32 are used to control machines and systems. They receive data from sensors, process it, and send commands to actuators. While microcontrollers are good for simple applications, PLCs are designed for tough industrial environments.

3. Edge devices and gateways

These devices are used to process data near the source instead of sending everything to the cloud. This reduces delays and improves speed. Gateways also help different types of machines communicate by converting data between old and new systems.

4. Switches and Routers

Switches connect multiple devices within a local industrial network (LAN), ensuring fast and organized data flow. Managed switches provide control over network settings, VLANs, and data traffic.

Routers direct data between different networks or subnets and manage communication between the factory floor and external networks such as the cloud.

5. Industrial Access Points and Wireless Devices

These devices enable wireless communication between IIoT nodes using Wi-Fi, Bluetooth, Zigbee, or 5G.

Wireless access points are especially useful in areas where cabling is difficult or where mobile equipment is used, such as in warehouses and robotic systems.

6. Industrial Machines and Equipment

Many types of industrial machines such as CNC machines, compressors, and conveyors are connected to IIOT networks. These machines generate useful data that helps with predictive maintenance, quality control, and improving production output.

7. Robots and Automation Systems

Robots are also part of IIOT systems. These include pick-and-place robots, welding robots, and collaborative robots (cobots). With IIOT, these robots can be monitored and controlled in real time, improving accuracy and efficiency in manufacturing.

8. Human-Machine Interface (HMI) and SCADA Systems

HMI devices (such as touch screens or control panels) allow operators to monitor and control processes visually.

SCADA (Supervisory Control and Data Acquisition) systems collect and display real-time data from sensors and controllers across the plant.

9. Cloud Platforms

Cloud platforms like AWS IoT, Microsoft Azure IoT, and Siemens MindSphere store large amounts of data from industrial systems. These platforms support advanced tools like machine learning, predictive analytics, and remote monitoring through dashboards.

To connect everything, communication devices like routers, switches, and modems are used for wired connections. Wireless technologies such as Wi-Fi, Bluetooth, Zigbee, LoRa, and 5G allow flexible and wide-ranging communication across the entire IIOT network.

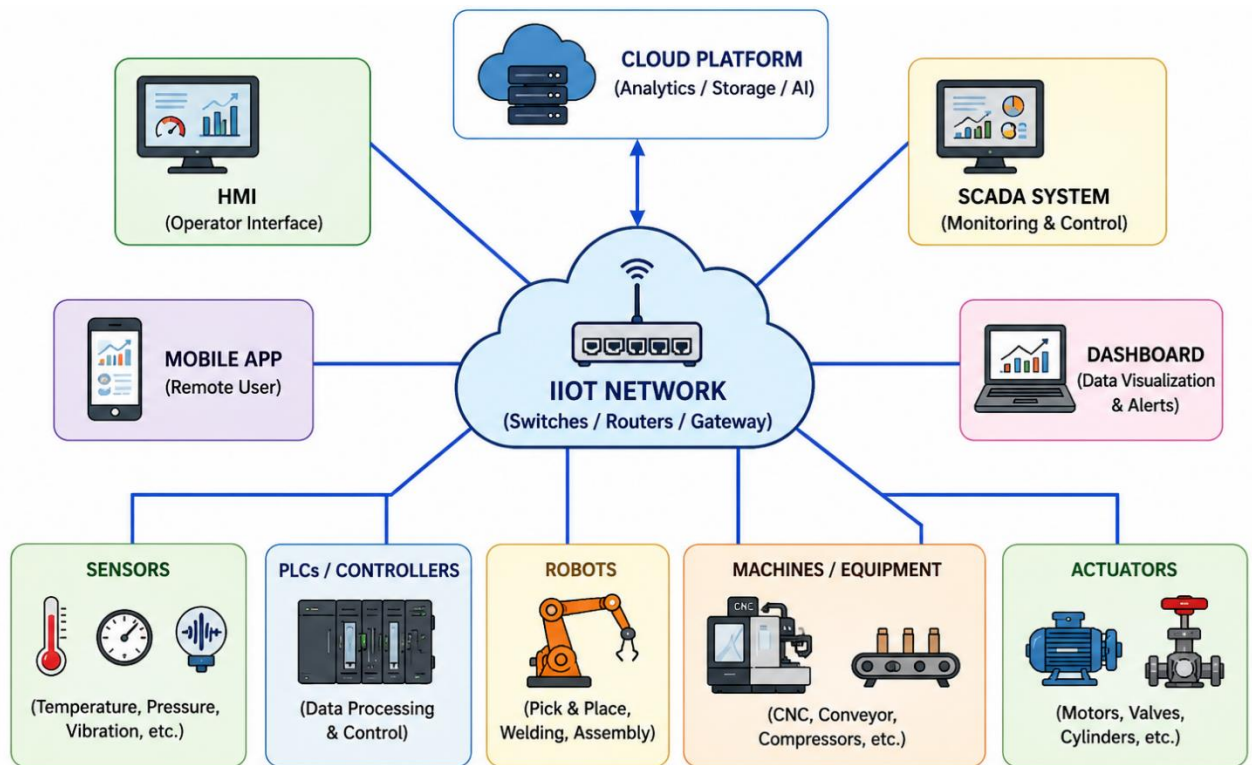


Fig.3.2: Interconnection of Devices and Systems in an IIOT Network

3.3 Function of network devices

In modern industrial environments, where IIOT technologies are adopted, reliable communication between various machines and systems is essential. This communication is made possible by a range of network devices that handle data flow, connectivity, and signal management. Devices like routers, switches, gateways, and access points are not just passive links—they actively define that how well the network performs.

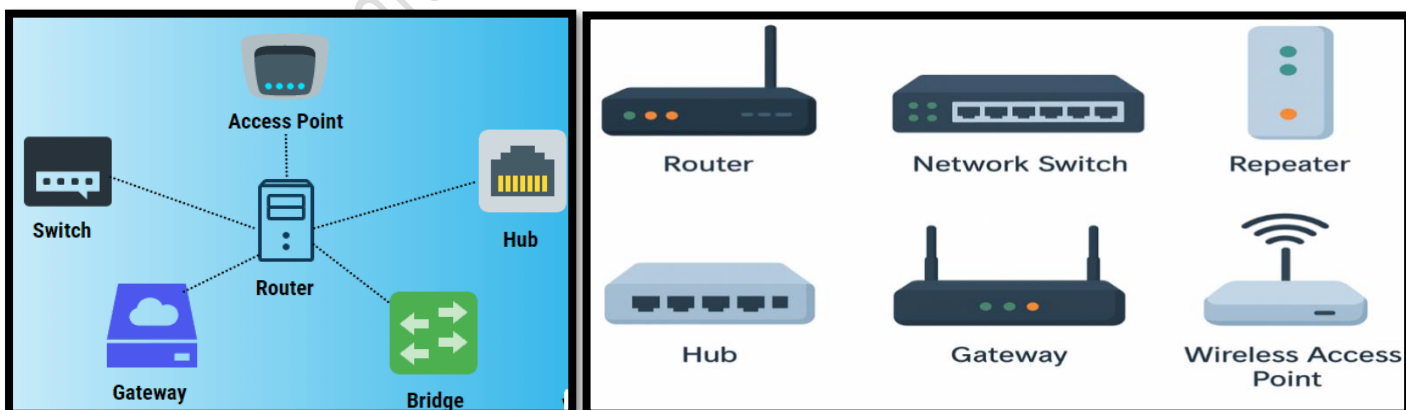


Fig.3.3: Different Types of Devices Connected in Network

Each device contributes to ensuring that data reaches its destination quickly, securely, and without interruption. For engineers and technicians working in IIOT, should have knowledge of how these devices function. It is crucial for building systems that are both effective and adaptable to real-world industrial demands. Various network devices used in IIOT are discussed here.

3.3.1 Routers

Routers are used to connect multiple networks, typically a local network (LAN) to a wide area network (WAN) such as the internet. In an IIOT setup, routers help direct data from factory floor devices to cloud platforms or external control systems. They determine the most efficient path for data using IP addresses and can also provide features like network address translation (NAT), firewall security, and VPN support for remote access.

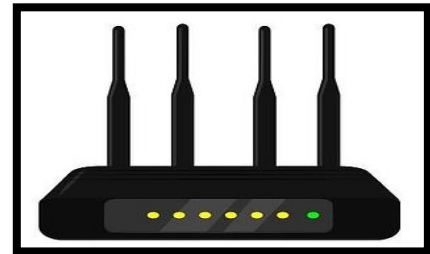


Fig.3.4: Router

3.3.2 Switches

Switches connect multiple devices within the same network and forward data only to the intended recipient device, identified by MAC address. This targeted communication reduces unnecessary traffic. In industrial applications, managed switches allow configuration, monitoring, and control of the network, supporting features like VLANs, redundancy protocols, and traffic prioritization—crucial for time-sensitive IIOT operations.



Fig. 3.5: Switch

3.3.3 Repeaters

Repeaters are used to extend the range of a network by amplifying weak or degraded signals. In large industrial environments with long cable runs or wireless coverage issues, repeaters ensure consistent signal strength and reliable communication between devices.



Fig. 3.6: Repeaters

🏠 Wi-Fi repeaters used at home help improve internet signals in distant rooms.

3.3.4 Hubs

A hub is a basic networking device that connects multiple Ethernet devices, making them act as a single network segment. Unlike switches, hubs broadcast data to all connected devices, which can cause network congestion. While hubs are mostly outdated, they may still be found in simple or legacy IIOT system



Fig.3.7: Hubs

3.3.5 Wireless Access Points (WAPs)

Access points allow wireless devices such as laptops, tablets, or mobile sensors to connect to a wired network using Wi-Fi. In IIOT, they enable flexible connectivity for mobile operators, remote monitoring units, or wireless sensor nodes. Industrial-grade WAPs support robust security protocols and operate in harsh environments.

3.3.6 Gateways

Gateways act as translators between different communication protocols, enabling devices with different standards to communicate. For example, an IIOT gateway might convert Modbus protocol to MQTT to facilitate cloud communication. Gateways often perform edge computing functions such as data filtering, encryption, and pre-processing, reducing the load on central servers.



Fig.3.8: Gateways

3.3.7 Firewalls

Firewalls monitor and control incoming and outgoing network traffic based on predefined security rules. In IIOT environments, firewalls protect critical infrastructure from unauthorized access and cyber threats. They can be hardware-based or software-based, often integrated into routers or gateways.

🔑 Firewalls protect industrial networks from hackers and unauthorized access.

3.3.8 Bridges

A bridge is a device used to connect LAN cable segments. Bridges connect and filter traffic between two network segments to make them function as a single network. They are useful when integrating different physical network types, such as Ethernet and Wi-Fi, or connecting new systems with legacy infrastructure.



Fig.3.9: Bridges

PRACTICAL ACTIVITY

ACTIVITY 1: IDENTIFYING SYSTEM IP ADDRESS

Objectives:

1. Understand what an IP address is and why it matters
2. Open and use the Command Prompt (Windows) or Terminal (Linux/Mac)
3. Run the ipconfig command on Windows
4. Run the ifconfig command on Linux / Mac
5. Identify and record your system's IP address

Theory

Every device connected to a network is assigned a unique IP (Internet Protocol) address. This address identifies the device on the network and allows it to communicate with other devices.

In this activity, you will use a simple command-line tool to find the IP address assigned to your own computer. This is an essential skill for IoT and networking work — you need to know your device's IP to configure MQTT brokers, Node-RED, and serial communication tools.

ipconfig (Windows)

A command-line utility on Windows that displays all network interface information — including IP address, subnet mask, and default gateway.

ifconfig (Linux / macOS)

The equivalent tool on Linux and Mac systems. It displays the same network configuration details for all active interfaces.

Procedure:

Step 1: Open Command Prompt (Windows) or Terminal (Linux)

On Windows:

1. Press Windows Key + R to open the Run dialog
2. Type “cmd” and press Enter
3. The black Command Prompt window will open

On Linux / macOS:

1. Open the Terminal application from your apps menu
2. Alternatively, press Ctrl + Alt + T on most Linux systems

Step 2: Run the IP Configuration Command

Type the appropriate command for your operating system and press Enter:

Operating System	Command to Type
Windows	ipconfig
Linux	ifconfig
macOS	ifconfig

```
// Command
> ipconfig                (Windows)

$ ifconfig                (Linux / macOS)
```

Step 3: Read and Identify the IP Address

Look through the output for your active network adapter. The key fields to find are:

- ▶ IPv4 Address : 192.168.x.x (Windows)
- ▶ inet 192.168.x.x (Linux / macOS — look under eth0 or wlan0)

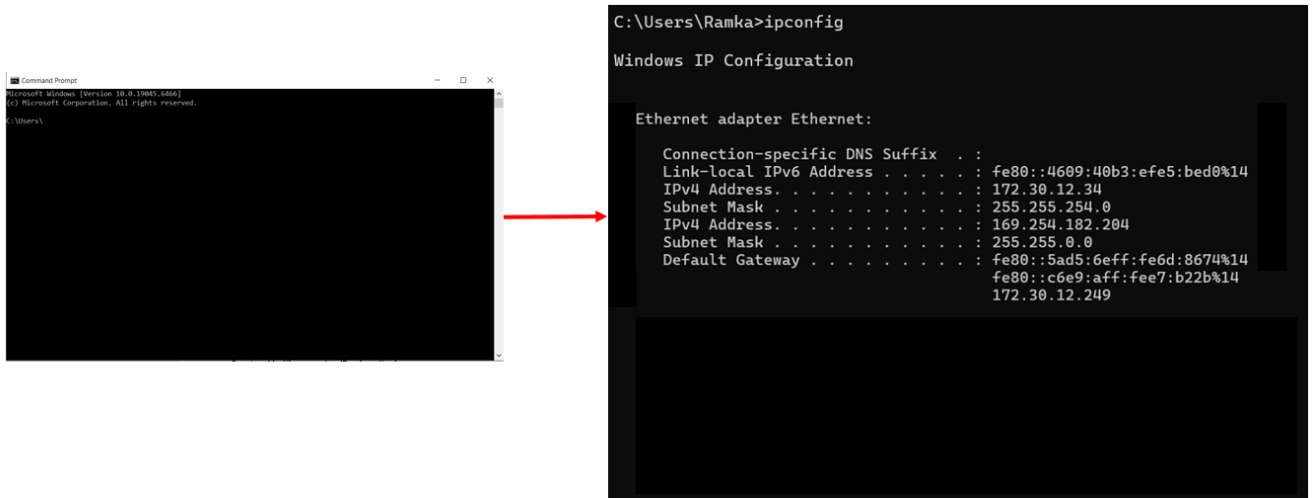


Fig. 1: Sample ipconfig output — IPv4 Address

Step 4: Record Your System IP Address

Write down the IP address shown on your screen in the box below:

My System IP Address:

Understanding the Output: The ipconfig output contains several pieces of network information. Here is what each field means:

Field	What It Means
IPv4 Address	The unique IP address assigned to your computer on the local network
Subnet Mask	Defines the network range — typically 255.255.255.0 on home/school networks
Default Gateway	The IP address of your router — the gateway to other networks and the internet
IPv6 Address	The newer 128-bit IP address format — not commonly used on local networks yet

Why This Matters for IIOT?

- ▶ When setting up an MQTT Broker, you use your system's IP so ESP32 can connect to it
- ▶ When running Node-RED, other devices access the dashboard using your IP (e.g. 192.168.1.5:1880)
- ▶ When configuring ESP32 over Wi-Fi, both devices must be on the same network and subnet
- ▶ Knowing your IP helps you troubleshoot connectivity issues between IoT devices

 **Exercise**

Using the ipconfig command, find and record the following information from your computer:

1. Your IPv4 Address: _____
2. Your Subnet Mask: _____
3. Your Default Gateway: _____

Then, on a separate computer or device on the same network, run the same command and record that device's IP. Can you ping one device from the other?

CHECK YOUR PROGRESS**A. Multiple Choice Questions**

1. When setting up a smart factory network, which layer would you configure to manage IP addressing and select the most efficient routing paths for data flow?
 - a) Data Link Layer
 - b) Transport Layer
 - c) Network Layer
 - d) Session Layer
2. While troubleshooting communication issues between controllers and cloud servers, which Transport Layer protocol would you verify for reliable data transfer?
 - a) HTTP
 - b) TCP
 - c) MAC
 - d) FTP
3. If an IIOT setup requires communication between devices using Modbus and MQTT, which device would you use to enable smooth data exchange?
 - a) Switch
 - b) Gateway
 - c) Router
 - d) HMI
4. During remote monitoring of a production line, which system would you use to supervise and control industrial processes in real time?
 - a) HMI
 - b) MES only
 - c) SCADA systems
 - d) Arduino boards
5. In an I/O-Link-based automation setup, which layer integrates systems like SCADA and MES for higher-level monitoring and decision-making?

- a) Field Layer
- b) Control Layer
- c) Supervisory Layer
- d) Enterprise Layer

B. Match the following

Column A	Column B
1. Data Link Layer	A. Connects multiple networks and determines best data paths
2. Presentation Layer	B. Monitoring systems like SCADA and MES
3. Router	C. Supervisory control and data acquisition
4. Supervisory Layer	D. Translates, encrypts, and compresses data
5. SCADA	E. Manages data framing and MAC addressing

C. Fill in the blanks

1. The _____ layer transmits raw data bits using cables, fiber optics, or wireless communication.
2. In IIOT systems, _____ allow human operators to interact with machines via dashboards and control panels.
3. The _____ layer ensures reliable data transmission between directly connected devices and detects errors in transmission.
4. _____ devices are used to process data close to the source, reducing latency.
5. The _____ device connects multiple devices within the same network and forwards data using MAC addresses.

D. Answer the following

1. While configuring an IIOT network in a manufacturing plant, how would the Network Layer help ensure efficient data routing and communication between multiple devices?
2. If data congestion occurs in an IIOT network, how would using a switch instead of a hub improve system performance and data management?
3. When setting up a smart production line, how can edge devices process data locally to reduce delays and improve decision-making efficiency?
4. During machine integration, how does an I/O-Link Master manage communication between sensors, actuators, and the central control system?
5. In a connected factory, which types of devices would you link through an I/O-Link network to collect real-time machine data and improve automation accuracy?

SESSION 2: NETWORK TOPOLOGIES AND PROTOCOLS

In industrial environments, machines, sensors, and controllers need to communicate with each other to perform tasks efficiently. This is made possible through specific network structures called topologies and communication methods known as protocols. Understanding how devices are connected, how data travels, and how to choose and set up the right protocol is essential in modern smart factories. Common protocols like MODBUS, PROFINET, and MQTT help in linking various devices. Setting up these systems also involves using software and checking important signal parameters to ensure reliable and accurate communication.

Network topology refers to the layout and connection style of devices in a network. In IIOT systems, topology affects reliability, speed, and maintenance of the system. Choosing the right network protocol and topology is crucial for ensuring efficient, reliable, and scalable communication in IIOT systems. The selection depends on specific application needs like data speed, range, cost, device compatibility, and required robustness.

Think About It!

Just like roads connect different places in a city, network topologies connect machines and devices in an industrial system.



3.4 Different Types of Network Topologies

A) Star Topology

- All devices are connected to a central hub or switch.
- Easy to manage and expand.
- If the central node fails, the entire system can go down.

📌 Wi-Fi routers used in homes create a star topology where all devices connect through a central router.

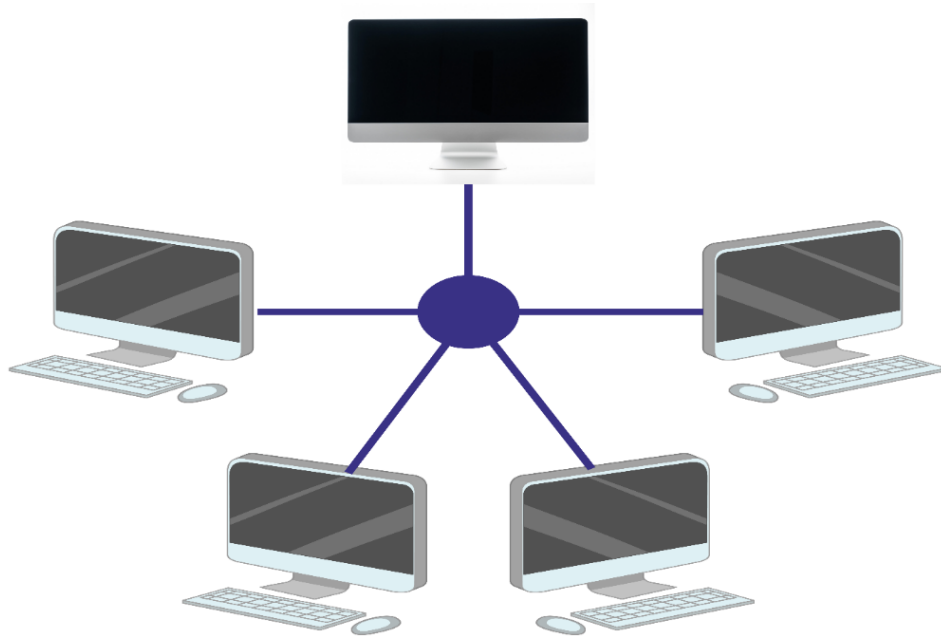


Fig.3.10: Star Topology

B) Bus Topology

- Devices are connected sequentially along a single cable.
- Economical and easy to install.
- Failure in one segment may affect the entire network.

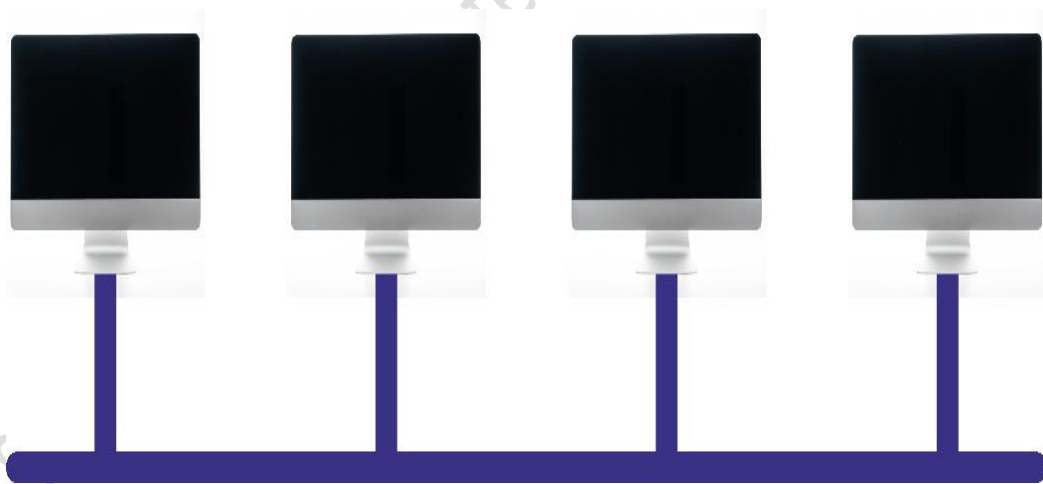


Fig.3.11: Bus Topology

C) Ring Topology

- Devices are connected in a circular fashion.
- Data travels in one direction until it reaches its destination.
- A break in the ring can bring down the network unless redundant paths are used.



Fig.3.12: Ring Topology

D) Mesh Topology

- Each device is connected to multiple other devices.
- Highly reliable and fault tolerant.
- Complex and expensive to implement.

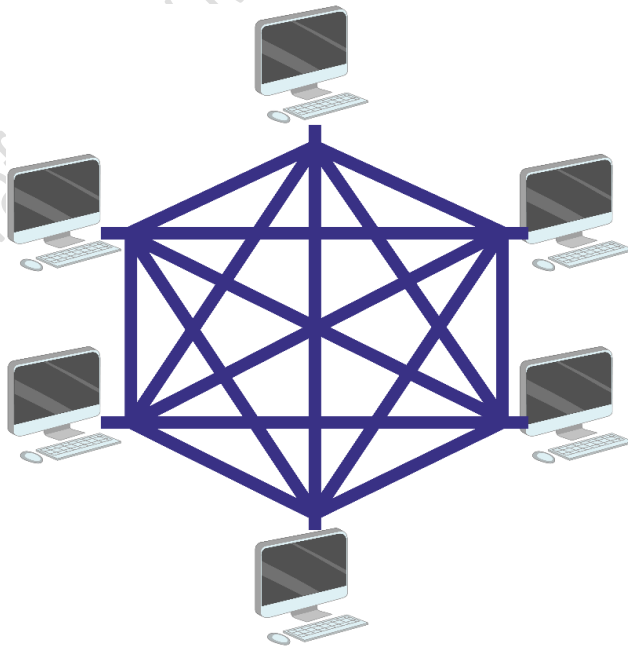


Fig.3.13: Mesh Topology

E) Tree Topology

- A hybrid of star and bus topology.
- Hierarchical structure is suitable for large-scale networks.
- Easy to identify and isolate faults.

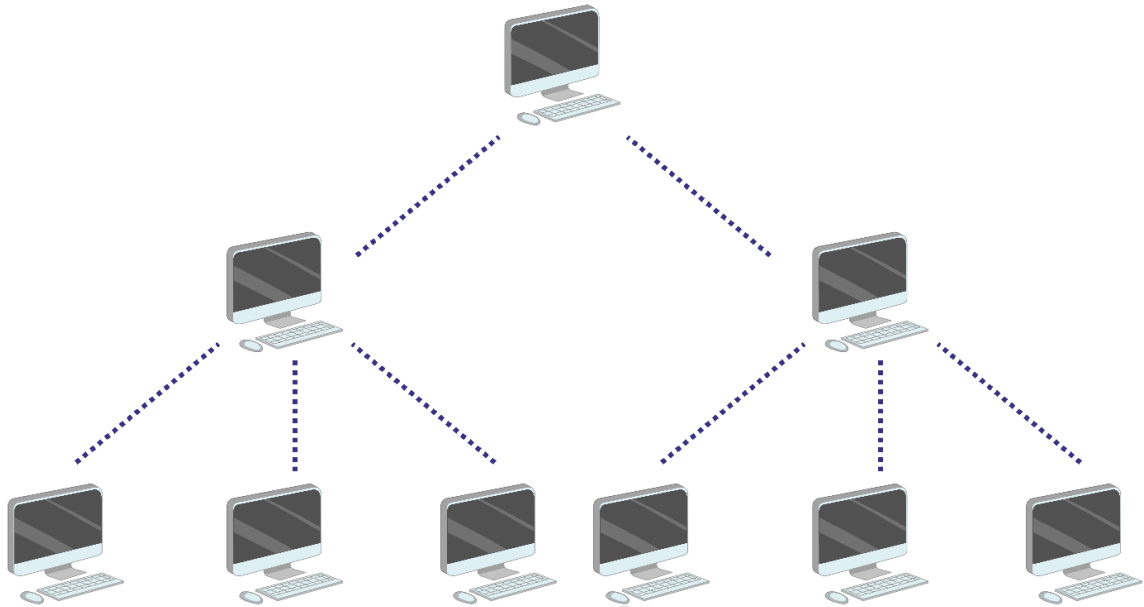


Fig.3.14: Tree Topology

F) Hybrid Topology

- Combines two or more topologies based on application requirements.
- Offers flexibility and optimization in performance and cost.
- Common in large industrial setups.

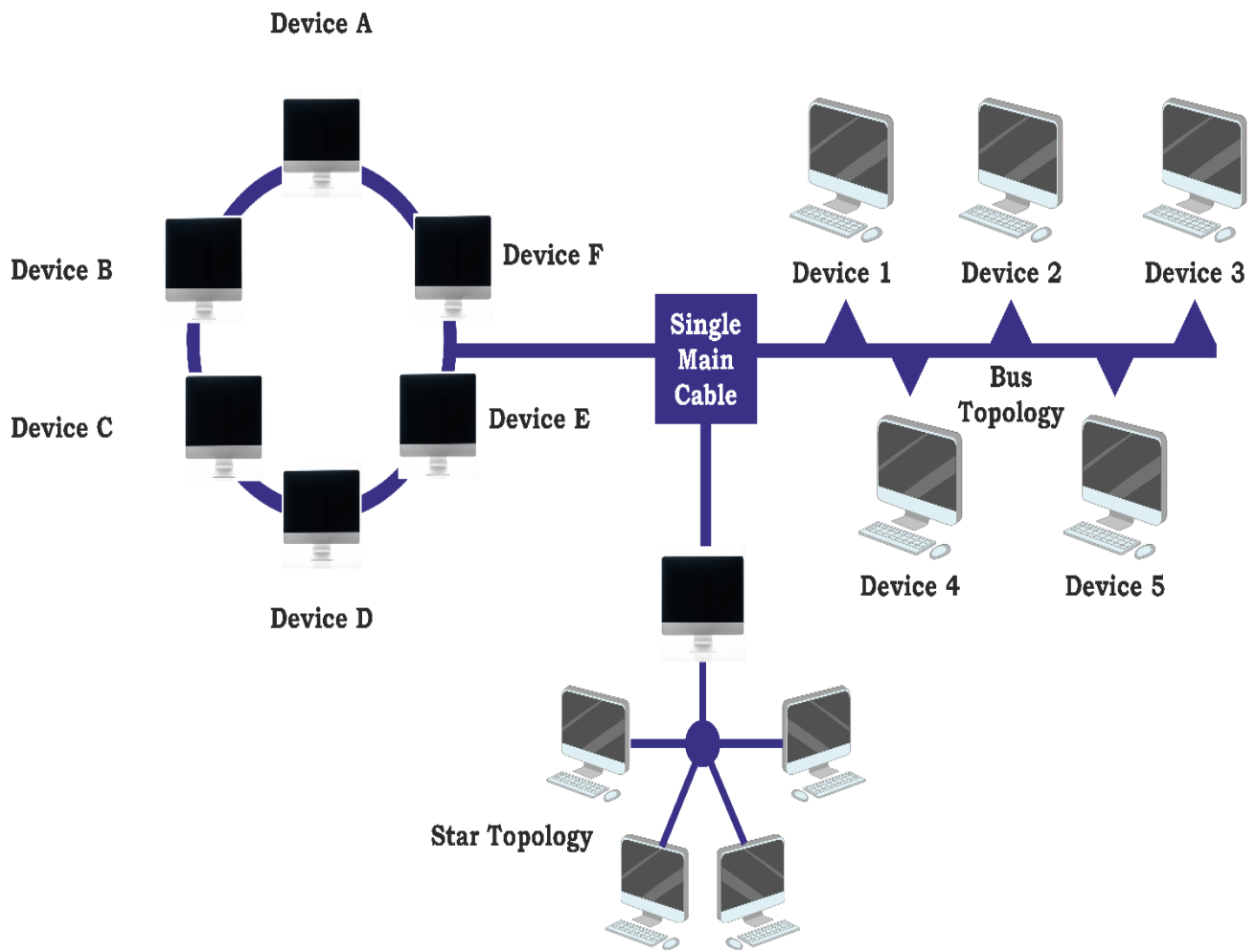


Fig.3.15: Hybrid Topology



Design a mini network at home

Sketch how your phone, smart TV, printer, and router are connected. Analyze which topology does it look like?

3.4.1 Real-world examples of Topologies in Automotive IIOT

- Assembly line sensors using Bus topology:** In this topology, sensors are connected in a single line (bus), one after another, to a controller. Data travels along this shared communication line. In an automotive assembly line, temperature, vibration, and proximity sensors are connected in a bus topology to monitor each workstation sequentially.

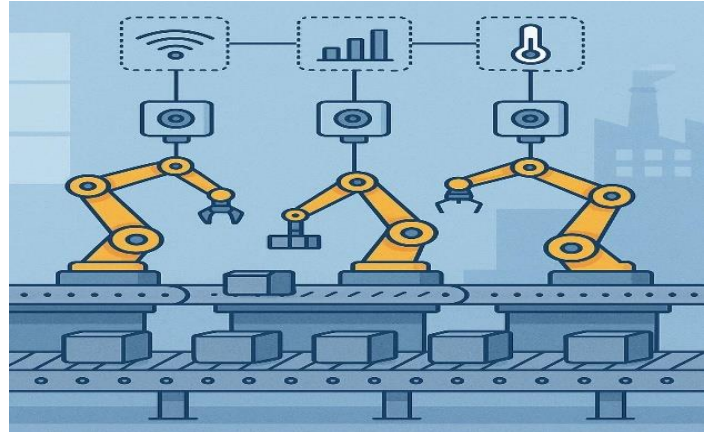


Fig.3.16: Assembly line sensors using Bus topology

- Robots in a workshop connected in Star topology:** Here, all robots are connected to a **central controller (hub/gateway)**. Each robot communicates only through this central point. In an automotive workshop, multiple robotic arms performing welding, painting, or assembly are linked in a star network with a central controller.

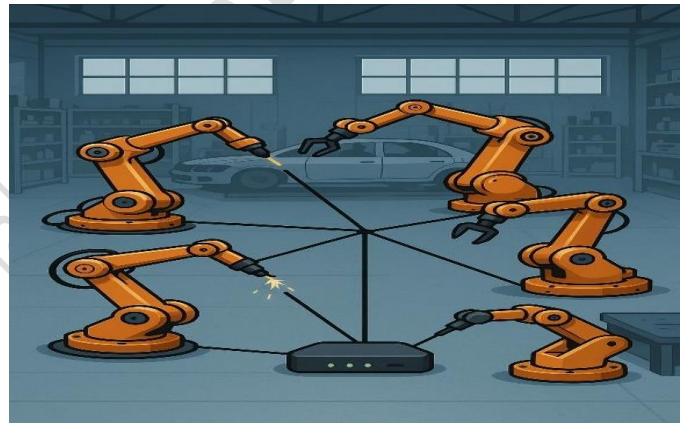


Fig.3.17: Robots in a workshop connected in Star topology

Smart factory floor using Hybrid topology: Hybrid topology is a **combination of bus and star**. Some devices are connected in a star around a gateway, while others are arranged in a bus line. On a smart automotive factory floor, robotic systems (star) are connected to a gateway, while conveyor belt sensors (bus) are also linked to the same gateway.

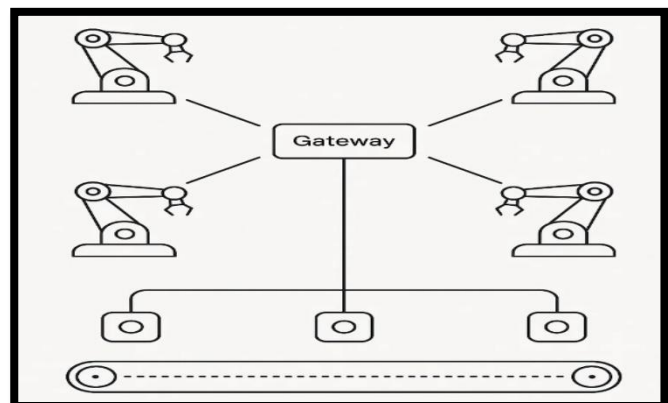


Fig.3.18: Smart factory floor using Hybrid topology

3.5 Connecting devices using network topologies

Connecting intelligent devices in industrial and IIOT systems requires careful planning to ensure reliable communication, scalability, and performance. The following steps outline a systematic approach:

A. Evaluating System Requirements

Before establishing connections, begin with a detailed evaluation of system needs. Identify all devices involved, such as sensors, actuators, PLCs, HMIs, robots, and edge controllers.

Consider key communication requirements as follows:

- Speed (bandwidth) – amount of data to be transmitted
- Latency – delay in communication (critical for real-time control)
- Reliability – system stability and fault tolerance
- Data type – analog, digital, or mixed signals

Also assess environmental and physical factors such as:

- Electromagnetic Interference (EMI) in industrial environments
- Cable routing and distance limitations
- Power availability and safety constraints
- Future expansion needs (scalability)

B. Choosing the Appropriate Network Topology

Select a network topology based on system size, performance needs, and fault tolerance. It can be summarized as follows:

- Star Topology: All devices are connected to a central controller (hub/switch).
 - Easy to install, manage, and troubleshoot
 - Failure of one device does not affect others
 - Central node failure can stop the entire system
- Bus (Line) Topology: All devices share a single communication line.
 - Cost-effective and simple wiring
 - A single cable fault can disrupt the entire network
 - Limited scalability
- Ring Topology: Devices are connected in a closed loop.
 - Better data flow control and reliability
 - Can support redundancy (in industrial rings)
 - Failure in one node may affect the network (unless dual ring is used)
- Hybrid Topology: Combination of two or more topologies (e.g., star + bus).
 - Flexible and scalable
 - Suitable for complex industrial systems
 - More complex design and higher cost

C. Selecting Communication Protocols

Choose suitable industrial communication protocols based on application:

- **Modbus, CAN, Profibus** → reliable industrial communication

- **Ethernet/IP, PROFINET** → high-speed industrial networks
- **MQTT, HTTP** → IIOT and cloud communication

D. Implementing Physical Connections

- Use appropriate cables (twisted pair, coaxial, fiber optic)
- Ensure proper shielding and grounding to reduce noise
- Follow standard wiring practices and labelling
- Use connectors, switches, or routers as required

E. Testing and Validation

- Check connectivity between all devices
- Test data transmission accuracy and speed
- Simulate fault conditions to verify reliability
- Ensure system meets performance requirements

3.6 Types of Industrial Network Protocols

Network protocols define the rules and conventions for communication between network devices. In IIOT, these protocols ensure real-time data exchange, reliability, and compatibility across a wide range of industrial devices such as sensors, controllers, machines, and supervisory systems. These protocols ensure interoperability, reliability, and real-time performance in industrial automation. Broadly, they can be classified into the following categories:

1. Fieldbus Protocols: Used for real-time communication between field devices (sensors, actuators) and controllers.

- **MODBUS:** One of the oldest and most widely used. It is a widely used serial communication protocol for connecting industrial devices. It supports communication between PLCs and sensors/actuators. It works over RS-232, RS-485, or TCP/IP. Mostly used versions of this protocol are MODBUS RTU (serial) and MODBUS TCP (Ethernet-based).
- **PROFIBUS (Process Field Bus):** This is developed by Siemens and widely used in process and factory automation. It provides fast and reliable communication between automation systems and field devices. It operates in master-slave mode with high-speed data exchange. Available Variants of this protocol include PROFIBUS DP (for factory automation) and PROFIBUS PA (for process automation).
- **DeviceNet:** Based on CAN bus, used for connecting industrial devices like sensors and drives.
- **CANopen:** Lightweight protocol built on CAN bus, used in embedded and industrial control systems.
- **CC-Link:** It is high-speed network protocol developed in Japan. It supports seamless device connectivity across a wide range of field devices. This protocol offers versions like CC-Link IE (Industrial Ethernet) for better speed and reliability.

2. Industrial Ethernet Protocols: Adapt Ethernet technology for industrial use, offering high speed and real-time communication.

- **PROFINET:** It is Ethernet-based version of PROFIBUS. It supports high-speed, real-time industrial Ethernet communication. This protocol is used in for complex automation applications like motion control and robotics.

- **EtherCAT (Ethernet for Control Automation Technology):** Provides ultra-fast communication with low latency.
- **EtherNet/IP:** This is based on standard Ethernet and the Common Industrial Protocol (CIP). It Supports real-time control and device interoperability. It uses standard Ethernet for control and information exchange. It is common in North American automation industries.
- **POWERLINK:** It is real-time industrial Ethernet protocol used in motion control.

3. Wireless Industrial Protocols: Enable mobility, remote monitoring, and flexible deployment.

- **WirelessHART:** Wireless extension of HART protocol, used in process industries.
- **ISA100.11a:** Designed for secure and reliable wireless communication in automation.
- **Zigbee / LoRaWAN:** Used for low-power, wide-area IIOT applications.
- **Wi-Fi / 5G:** High-speed wireless connectivity for modern smart factories.

4. IIOT and Message-Oriented Protocols: Focus on device-to-cloud and machine-to-machine (M2M) communication.

- **MQTT (Message Queuing Telemetry Transport):** It is lightweight, publish-subscribe-based messaging protocol. It is ideal for low-bandwidth, high-latency, or unreliable networks. This protocol is commonly used for cloud-based IIOT applications and remote sensor data transmission.
- **OPC UA (Open Platform Communications – Unified Architecture):** It is Platform-independent, secure, and open protocol for industrial communication. It enables machine-to-machine communication and integration with IoT systems. It is highly scalable and extensible.
- **AMQP (Advanced Message Queuing Protocol):** Reliable protocol for message-oriented middleware in IIOT.
- **CoAP (Constrained Application Protocol):** Optimized for low-power devices in IoT.

5. Proprietary and Specialized Protocols: Developed by specific manufacturers for industrial automation systems.

- **Siemens S7 Protocol:** Used in Siemens PLC communication.
- **BACnet:** Widely used in building automation and control systems.
- **FOUNDATION Fieldbus:** Focused on process automation in industries like oil and gas.

All above mentioned protocols are summarized in Table 3.1.

Table 3.1: Types of Industrial Network Protocols

Category	Protocol	Key Features/ Description	Typical Applications
Fieldbus Protocols	MODBUS (RTU/TCP)	Oldest and widely used; connects PLCs, sensors, and actuators via RS-232, RS-485, or TCP/IP.	Factory automation, device monitoring.
	PROFIBUS (DP/PA)	Developed by Siemens; reliable master-slave communication; used in	Process plants, manufacturing.

		process and factory automation.	
	DeviceNet	Based on CAN bus; connects devices like sensors and drives.	Machine control, motor drives.
	CANopen	Lightweight protocol on CAN bus; supports embedded and industrial systems.	Robotics, automotive applications.
	CC-Link/CC-Link IE	High-speed Japanese network: Ethernet-based version offers better speed and reliability.	Factory automation in Asia, machine networking.
Industrial Ethernet Protocols	PROFINET	Ethernet-based PROFIBUS; supports real-time, high-speed communication.	Motion control, robotics, complex automation.
	EtherCAT	Ultra-fast Ethernet protocol with low latency.	High-speed motion and control systems.
	EtherNet/IP	Based on Common Industrial Protocol (CIP); ensures real-time control and interoperability.	North American industrial automation.
	POWERLINK	Real-time Ethernet protocol for motion control.	Robotics, precise motion systems.
Wireless Industrial Protocols	WirelessHART	Wireless version of HART for process industries.	Process automation, remote monitoring.
	ISA100.11a	Secure and reliable wireless communication for industrial automation.	Oil, gas, and chemical industries.
	Zigbee/LoRaWAN	Low-power, wide-area IIoT communication.	Smart cities, environmental monitoring.
	Wi-Fi / 5G	High-speed wireless for smart factories and mobile robotics.	Smart manufacturing, data transmission.
IIOT and Message-Oriented Protocols	MQTT	Lightweight publish-subscribe protocol; ideal for	IIoT gateways, sensor networks.

		cloud and remote data transmission.	
	OPC UA	Secure, platform-independent protocol; supports machine-to-machine and IoT integration.	Smart factories, MES/SCADA systems.
	AMQP	Reliable middleware protocol for message-oriented data exchange.	Industrial IoT data hubs.
	CoAP	Designed for low-power IoT devices; uses REST model.	Embedded and wireless sensor networks.
Proprietary and Specialized Protocols	Siemens S7	Proprietary Siemens PLC communication protocol.	Siemens-based automation systems.
	BACnet	Standard for building automation and HVAC control.	Building management systems.
	FOUNDATION Fieldbus	Digital protocol for process industries, especially oil and gas.	Process automation, energy plants.

3.7 Selection Criteria of Communication Protocols

Selecting an appropriate communication protocol is essential for the effective design and deployment of industrial and IIOT networks. The protocol plays a key role in enabling communication between devices, managing data exchange, coordinating system responses, and integrating with controllers, edge components, and cloud-based platforms. The following factors should be considered during protocol selection:

- **Compatibility with Devices and Controllers:** The chosen protocol must be compatible with all intended system components, including PLCs, sensors, actuators, HMIs, and SCADA platforms. For instance, MODBUS offers broad compatibility with budget-friendly devices, PROFINET works well within Siemens-based environments, and CC-Link is typically preferred for Mitsubishi automation setups.
- **Communication Speed and Real-Time Performance:** High-speed communication is necessary for real-time control and precise synchronization. PROFINET IRT (Isochronous Real-Time) and EtherCAT offer deterministic and high-speed data transfer. MODBUS RTU and Profibus DP are slower but sufficient for less time-critical tasks.
- **Scalability and Network Size:** Assess the number of devices to be integrated and the overall complexity of the network. For extensive, cloud-enabled IIOT infrastructures, protocols such as OPC UA and MQTT are well-suited. Within factory settings, PROFINET and Profibus offer reliable scalability for automation networks."
- **Type of Network:** Fieldbus protocols such as Profibus, CC-Link, and MODBUS RTU operate over serial communication and are well-suited for older or basic automation setups. In contrast, Ethernet-based protocols like PROFINET, OPC UA, and MODBUS

TCP are ideal for advanced systems that demand high performance and seamless integration with IT networks.

- **Determinism and Time Sensitivity:** Time-sensitive applications such as motion control require deterministic protocols. EtherCAT, PROFINET IRT provide real-time deterministic communication. MQTT and OPC UA are not deterministic but suitable for monitoring and cloud communication.
- **Data Handling and Flexibility:** For complex data structures, semantic modeling, and flexible data exchange, OPC UA is the best choice. MQTT is excellent for lightweight, publish-subscribe messaging in IoT applications.
- **Ease of Integration and Configuration:** Protocols like MODBUS are easy to implement and configure with minimal hardware or software requirements. OPC UA requires more configuration but provides strong interoperability between devices from different manufacturers.
- **Security Features:** For modern IIOT systems, security is a priority. OPC UA and MQTT offer advanced security features like encryption and user authentication. Legacy protocols like MODBUS RTU have minimal or no built-in security.
- **Cost and Licensing:** Some protocols require licensed stacks or vendor-specific hardware/software. MODBUS and MQTT are open and license-free, making them cost-effective. PROFINET, Profibus, and CC-Link may involve costs related to tools or proprietary components.
- **Application Domain:** Industrial communication protocols are selected based on the application domain, system requirements, and performance needs. Each protocol is optimized for specific environments such as factory automation, process industries, or IIOT/cloud integration as follows:
 - **Factory Automation:** Factory automation is used in high-speed, real-time control systems such as assembly lines, robotics, and CNC machines. These systems require fast and deterministic communication to ensure precise and synchronized operations. Protocols like PROFINET, PROFIBUS, and EtherCAT are commonly used in this domain because they support rapid data exchange and reliable control in industrial environments.
 - **Process Automation:** Process automation is applied in industries such as oil & gas, chemical plants, water treatment, and power generation, where continuous monitoring and control are essential. These systems prioritize reliability, stability, and long-distance communication over extremely high speed. Protocols like MODBUS, HART, and PROFIBUS PA are widely used, as they are robust and well-suited for handling process data in harsh industrial conditions.
 - **IIOT and Cloud Integration:** IIOT and cloud integration focus on connecting industrial systems to cloud platforms for data analytics, remote monitoring, and intelligent decision-making. These systems enable real-time data access from anywhere and support scalability across large networks. Protocols such as OPC UA, MQTT, and AMQP are commonly used because they facilitate secure, efficient, and platform-independent data exchange between devices and cloud services.

The Table 3.2 shows practical applications where the protocol is typically implemented in real-world industrial environments.

Table 3.2: Applications of Network Protocols

Protocol	Typical Application / Use Case
MODBUS	Small systems, simple and cost-effective device communication (PLC–sensor/actuator)
PROFINET	High-speed industrial automation, real-time control in factories
CC-Link	Mitsubishi-based automation systems and production lines
PROFIBUS	Legacy systems, reliable field-level communication

OPC UA	Platform-independent data exchange, IIOT integration, SCADA connectivity
MQTT	Cloud-based monitoring, lightweight IoT communication (publish/subscribe model)

3.8 Installation of Network Protocols

Installing industrial protocols like MODBUS, CC-LINK, PROFINET, PROFIBUS, OPC UA, and MQTT is essential for enabling reliable communication between sensors, controllers, machines, and cloud systems. Proper setup ensures seamless data exchange, device compatibility, and efficient automation across the IIOT network. General installation steps for network protocols can be described as follows:

1. Network Planning
2. Hardware Setup & Cabling
3. Device Connection and Addressing
4. Protocol Installation and Configuration
5. Testing and Verification
6. Documentation and Backup
7. Security and Updates

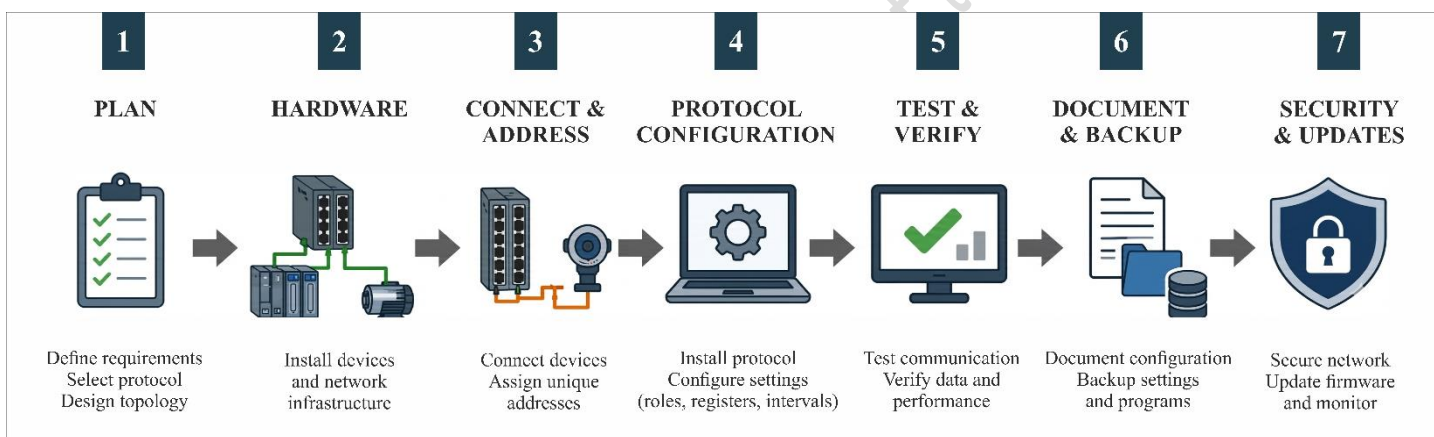


Fig.3.19: Installation of Network Protocols

1. Network Planning

Before installation, a well-thought-out network design is essential. This includes:

- Selecting the appropriate protocol based on device compatibility and system requirements.
- Defining the network topology (e.g., line, star, ring).
- Listing all devices (PLCs, sensors, HMIs, SCADA, etc.) to be connected.
- Allocating IP addresses or station IDs and determining cable routing.
- Consider Environmental Considerations like interference, temperature, distance, etc.

2. Hardware Setup & Cabling

Each protocol has specific physical media requirements. For serial or fieldbus-based communication protocols such as MODBUS RTU, Profibus, and CC-Link, RS-485 or RS-232 cables are typically used for physical connectivity. The devices should be arranged

in a daisy chain, also known as a bus topology, where each device is connected in sequence. It is essential to install termination resistors at both ends of the communication line to prevent signal reflections and ensure data integrity. Additionally, proper grounding and shielding of the cables must be done to minimize the effects of electromagnetic interference (EMI), which is common in industrial environments.

For Ethernet-based communication protocols such as MODBUS TCP, Profinet, OPC UA, and MQTT, shielded Cat5e or Cat6 Ethernet cables are commonly used to ensure reliable and high-speed data transmission. These systems typically follow a star topology, where all devices are connected through industrial-grade switches or routers to form a centralized network structure. It is important to label all cables and connectors clearly to facilitate easy identification, maintenance, and troubleshooting during installation and future upgrades.

3. Device Connection and Addressing

- Assign Device IDs: For fieldbus systems like PROFIBUS or MODBUS RTU, set station IDs using software or hardware DIP switches.
- IP Configuration: For Ethernet-based systems (e.g., OPC UA, MQTT), assign unique IP addresses within the same subnet.
- Ensure each device has a unique identifier to avoid communication conflicts.

4. Protocol Installation and Configuration

A. MODBUS (RTU & TCP)

- Install MODBUS-compatible drivers on the PLC or SCADA.
- Configure parameters like baud rate, parity, stop bits (for RTU), or TCP port (for TCP).
- Define slave/master roles and map input/output registers.

B. CC-LINK

- Use Mitsubishi-compatible PLCs or gateways.
- Connect devices in a daisy-chain (for CC-Link V2) or star (for IE Field).
- Assign station numbers and set communication cycle time.

C. PROFINET

- Use Siemens or PROFINET-compatible devices.
- Install GSDML files (device descriptors) in the PLC programming software (e.g., TIA Portal).
- Assign IP addresses, set I/O mapping, and configure the device name.

D. PROFIBUS

- Install GSD files for each device.
- Use appropriate terminators and maintain signal integrity.
- Set baud rate and assign slave IDs.

E. OPC UA

- Set up an OPC UA server (embedded in PLC or SCADA) and client (HMI, MES, cloud).
- Configure security certificates, namespaces, and endpoint URLs.
- Define data access levels and publish variables for access.

F. MQTT

- Set up a broker (e.g., Mosquitto or AWS IoT Core).
- Configure MQTT clients (edge devices, sensors) with broker URL, topic names, QoS levels.
- Use authentication credentials for secure data exchange.

5. Testing and Verification

- Use protocol analyzers or diagnostic tools (e.g., Wireshark for Ethernet, PROFIBUS Tester, or MODBUS Poll).
- Validate device communication, data consistency, and response time.
- Ensure SCADA or HMI is reading/writing the correct data from/to devices.

6. Documentation and Backup

Maintain complete records of:

- IP address map or station ID list.
- Device configuration files (GSD/GSDML).
- Cable routing diagrams.
- Backup of PLC/HMI programs and configuration files.

7. Security and Updates

- Update firmware regularly to patch known vulnerabilities.
- Apply encryption and authentication (especially for OPC UA and MQTT).
- Use firewalls, VLANs, or secure tunnels to segment industrial networks.

3.9 Communication and Signal Parameters

In automotive IIOT systems, communication reliability and performance are strongly influenced by factors such as bend radius, grounding, termination, and cable length. Proper management of these elements is essential for maintaining accurate data transmission, supporting predictive diagnostics, and enabling safe and efficient working of the system.

Bend Radius

The bend radius of a cable is the smallest curve it can handle without damage or performance loss. Exceeding this limit can deform internal parts, disrupt signals, or cause insulation cracks, leading to faults. For data and fiber optic cables, ignoring bend radius can cause data loss or signal weakening. Following the guidelines, typically a bend radius 4 to 10 times the cable diameter, is essential to ensure cable durability and reliable communication.

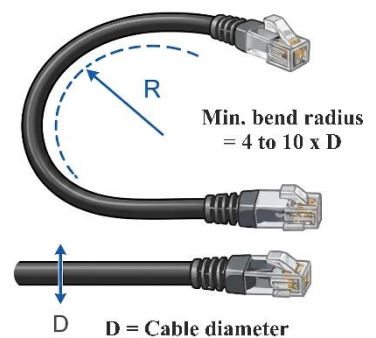


Fig.3.20: Bend Radius

Signal Ground

Signal grounding is the practice of providing a common electrical reference point for all devices within a communication system. Proper signal grounding is essential to ensure clean and stable voltage levels between connected devices. Inadequate or improper grounding can lead to what is known as ground loops, where voltage differences between grounding points cause unwanted current

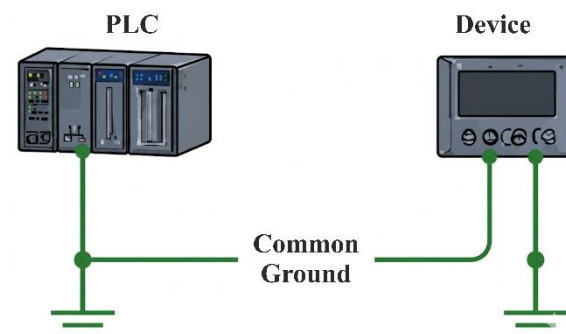


Fig.3.21: Signal Ground

to flow. This can introduce electrical noise, resulting in corrupted data, unstable device behavior, or even physical damage to components.

In industrial environments where electromagnetic interference (EMI) is common, grounding plays an even more critical role. The use of shielded cables with grounding at one end only is a widely recommended approach to reduce noise and maintain data integrity.

Terminal Resistor

Terminal or termination resistors are used in differential communication buses such as RS-485, CAN, and Profibus to prevent signal reflections at the ends of the transmission line. Without proper termination, electrical signals bounce back along the cable, creating interference patterns that can corrupt data packets or cause communication errors. These issues are especially problematic in high-speed networks or systems with long cable runs.

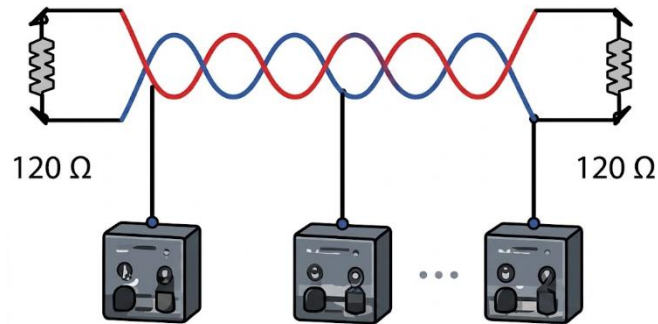


Fig.3.22: Terminal Resistor

By matching the termination resistor to the characteristic impedance of the cable (typically 120 ohms), reflections are absorbed, resulting in cleaner signal transmission. For reliable operation, termination resistors must be placed at both ends of the bus, and the network should not have more than two terminations.

Cable Length

The length of a communication cable affects the speed and integrity of signal transmission. As the cable length increases, signal attenuation i.e. loss of signal strength, also increases. Long cables can introduce delays, degrade voltage levels, and increase susceptibility to external noise, especially if proper shielding and grounding is not implemented. Each communication standard defines maximum permissible cable lengths to ensure optimal performance.

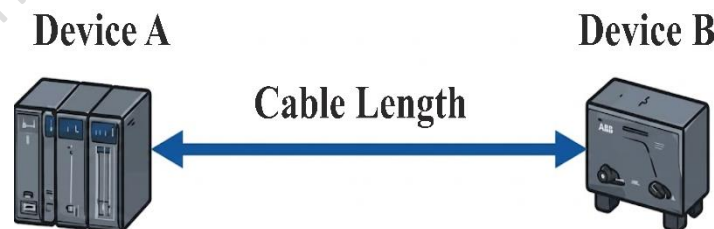


Fig.3.23: Cable Length

For example, standard Ethernet connections using Cat5e or Cat6 cables are limited to 100 meters, whereas RS-485 networks can extend up to 1200 meters under ideal conditions. In cases where long-distance communication is necessary, repeaters or signal boosters may be used to amplify or regenerate the signal.

Baud Rate

Baud rate defines the speed at which data is transmitted between devices in an IIOT network. It is typically measured in bits per second (bps), with common values such as 9600, 19200, 38400, or 115200 bps. In industrial systems, setting the correct baud rate is essential for synchronized communication. A higher baud rate enables faster data transmission but may reduce reliability over longer distances or in electrically noisy environments.

All devices connected within the same communication segment (like RS-485 or Modbus RTU) must be set to the same baud rate. This setting is usually configured through the

device's setup software or user interface, and in some older or compact field devices, via DIP or rotary switches.

Distance

Distance refers to the physical length of the communication cable between devices and is a critical factor in maintaining signal integrity. Longer cable runs are more susceptible to signal degradation, latency, and electromagnetic interference. Different communication protocols support different maximum distances; for example, RS-485 can typically handle up to 1200 meters, while standard Ethernet is limited to 100 meters using Cat5e/Cat6 cables.

Choosing the correct communication protocol and matching it with an appropriate baud rate is essential to maintain reliable communication over longer distances. In cases where the distance exceeds the protocol's limit, repeaters, signal boosters, or fiber optics may be required. Proper shielding, grounding, and adherence to cable specifications are also important to minimize interference and maintain performance.

Station ID

The station ID, also referred to as the device address or node number, uniquely identifies each device on a communication network. This is especially important in multi-drop networks like Modbus RTU, CAN bus, or Profibus, where several devices communicate over the same bus. Assigning a unique station ID to each device prevents communication conflicts and allows the master device or controller to target specific devices for data exchange. Station IDs are usually set during device configuration using software provided by the manufacturer. However, in many industrial devices, especially sensors and simple actuators, the ID is set manually using DIP switches, rotary switches, or configuration pins.

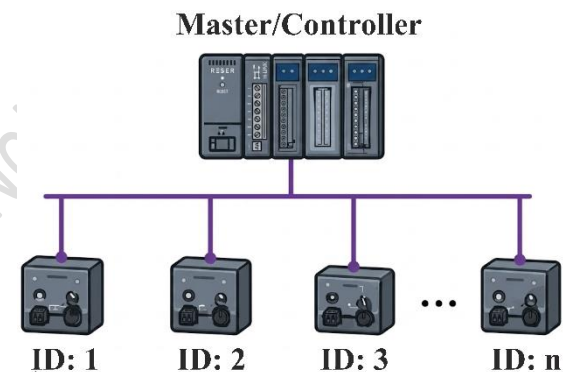


Fig.3.24: Station ID

Station Type

Station type defines the role a device plays in the network, such as a master, slave, sensor, controller, or gateway. Understanding and assigning the correct station type is crucial in IIOT systems where communication is often role-based.



Fig.3.25: Station Type

For instance, in a Modbus RTU setup, the master sends queries while slaves respond. Similarly, in an MQTT-based IIOT network, a device may act as a publisher (sending data) or subscriber (receiving data). These roles determine how devices interact with each other and with cloud or edge computing systems. Station type is typically configured using software tools during the initial setup of the device and may be defined in the device's firmware or control parameters.

PRACTICAL ACTIVITY

ACTIVITY 1: Identify and Match Network Topologies with Their Features

Objective: Identify and recall the key features of network topologies used in IIOT systems.

Instructions:

i) Column A lists topologies. Write the correct options from Column B that matches each feature. Some options may be used more than once.

Column A – Topology	Column B – Feature / Description
1. Star Topology	A. Data travels in a loop; one break can stop communication
2. Bus Topology	B. All devices connect to a central hub or switch
3. Ring Topology	C. Combines two or more topologies for large networks
4. Mesh Topology	D. Each device connects to multiple others – highly fault tolerant
5. Tree Topology	E. Devices are linked along a single shared cable
6. Hybrid Topology	F. Hierarchical structure; a mix of star and bus

Write your answers here:

1. _____ 2. _____ 3. _____ 4. _____ 5. _____ 6. _____

ii) Now apply what you know – choose the correct topology for each situation:

Situation	Best Topology (write the name)
A car workshop has 6 robotic arms all controlled from one central computer.	
A factory floor has sensors along a single assembly line.	

Situation	Best Topology (write the name)
A smart factory uses both robotic arms (star) and conveyor sensors (bus) on the same network.	

ACTIVITY 2: Analyze Communication Signals and Parameters

Objective: Understand how signal and system parameters affect communication quality in IIOT networks.

Part A:

Instructions: - Read each statement and write TRUE or FALSE in the box

Statement	True / False
1. A higher baud rate always means better reliability over long distances.	
2. Terminal resistors are placed at both ends of a bus cable to prevent signal reflections.	
3. All devices on the same RS-485 network can have different baud rates.	
4. A standard Ethernet cable (Cat5e/Cat6) can reliably carry data up to 100 meters.	
5. Signal grounding provides a common electrical reference to reduce noise and interference.	
6. Bending a fiber optic cable sharply will not affect signal transmission.	

Part B:

Instructions: - Complete each sentence using the correct word from the box below.

Word Box: Station ID | 120 ohms | baud rate | RS-485 | 1200 meters | signal ground

- The speed of data transmission in an IIoT network is controlled by the _____.
- The characteristic impedance of a typical communication bus cable is _____.
- A unique address assigned to each device on a Modbus network is called a _____.
- The protocol that can extend communication up to _____ under ideal conditions is RS-485.

5. Providing a common electrical reference to all connected devices in a system is known as _____.

**ACTIVITY 3:
Identify Features and Uses of Industrial Protocols**

Objective: Learn the basic features of common industrial protocols and where they are used.

Instructions: The table below is partially completed. Fill in the missing entries using your textbook. The first row has been completed as an example.

Protocol	Category	Main Feature	Where It Is Used
MODBUS RTU	Fieldbus	Simple serial communication; master-slave	Connecting PLCs, sensors in factories
PROFINET	Industrial Ethernet		Motion control, robotics, Siemens systems
MQTT		Lightweight publish-subscribe; works on low bandwidth	
PROFIBUS	Fieldbus		Process plants and factory automation
OPC UA		Secure, platform-independent; works across different brands	
Wireless HART	Wireless		Remote monitoring in process industries

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. You are setting up a remote IIOT monitoring system in an area with limited bandwidth and frequent delays. Which protocol would you apply to ensure reliable data transmission?
 - a) PROFINET
 - b) MODBUS RTU
 - c) MQTT
 - d) Ether CAT

2. During the installation of a small IIOT network inside a workshop, you need a topology where all devices connect to one central device for easy control. Which topology would you implement?
 - a) Ring
 - b) Mesh
 - c) Star
 - d) Bus

3. A factory needs fast fault detection and easy network management. Which topology would you choose to apply for this requirement?
 - a) Cost-saving installations
 - b) Centralized control and fault detection
 - c) Low-speed networks
 - d) Large-scale process automation

4. While inspecting communication issues in an industrial network, you observe weak signals from a sensor 150 meters away. Which factor should you evaluate first to diagnose attenuation?
 - a) Color of insulation
 - b) Cable length
 - c) Baud rate only
 - d) Cable temperature

5. You are configuring a new production line that uses Siemens PLCs. Which Ethernet-based protocol would you apply to ensure compatibility?
 - a) Profibus
 - b) PROFINET
 - c) CC-Link
 - d) OPC UA

B. Match the following

Column A	Column B
1. MQTT	A. Data travels in a circular path; one failure affects all
2. MODBUS RTU	B. Unique number used in serial protocols like MODBUS RTU
3. Ring Topology	C. Prevents signal reflections in communication cables
4. Station ID	D. Serial communication used in legacy systems

5. Terminal Resistor	E. Publish-subscribe protocol for IIOT cloud communication
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C. Fill in the blanks

1. The Ethernet-based version of PROFIBUS is called _____.
2. A hybrid of star and bus topology is known as _____ topology.
3. For complex data structures and semantic modeling, _____ is the best choice.
4. Providing a common electrical reference point for all devices in a communication system is called _____.
5. Baud rate is measured in _____ per second.

D. Answer the following

1. When setting up an IIOT system in a factory, how would you use communication protocols to ensure that devices exchange data reliably?
2. If you had to choose between MODBUS RTU and OPC UA for a new automation project, how would their differences guide your selection?
3. While designing an IIOT network layout, which two topologies might you consider, and how would you decide when to use each?
4. You are installing communication cables on a shop floor. How would you apply bend-radius precautions to prevent signal loss or cable damage?
5. During troubleshooting, you find unstable readings from connected sensors. How might ground loops be causing this issue, and what steps would you take to fix it?

SESSION 3: IIOT SENSOR AND DEVICE INTEGRATION

IIOT has revolutionized how machines, processes, and people interact in modern industries. Sensors and devices continuously collect and share data, but their true value lies in integration with industrial networks, automation systems, and digital platforms.

Through sensor and device integration, data flows smoothly from the shop floor to controllers, gateways, and cloud systems, enabling real-time monitoring, predictive maintenance, and data-driven decision-making.

By combining smart sensors, communication protocols, and automation tools, IIoT creates a connected ecosystem where every component, from a sensor to a cloud dashboard; works together efficiently. This integration forms the foundation of smart factories, bridging the gap between the physical and digital worlds to drive innovation, reliability, and operational efficiency.

3.10 Practical Analysis of Network Layers in IIOT Systems

While the OSI model defines seven layers, IIOT systems typically use a simplified layered approach that focuses on practical communication and real-world implementation. In an IIOT environment, sensors and devices do not operate in isolation; they communicate through layered networks designed to ensure reliability, interoperability, and security. Each layer performs a specific function in the transmission, processing, and utilization of data.

Understanding and analyzing these layers is essential, as any failure or misconfiguration at a particular layer can lead to data loss, communication delays, reduced performance, or even unsafe industrial operations (Fig.3.26).

- At the Physical Layer, the focus is on the actual medium of communication. This includes copper Ethernet cables, fiber optic connections for long distances or high electromagnetic environments, and wireless technologies such as Wi-Fi, Bluetooth Low Energy (BLE), LoRaWAN, or 5G. Factors such as shielding, grounding, and surge protection must be considered to minimize interference. Even simple issues like cable quality, connector faults, or improper grounding can cause intermittent failures in device communication.
- The Data Link Layer ensures reliable point-to-point or point-to-multipoint communication between devices. In industrial networks, this layer uses standards like Ethernet/IP, PROFINET, EtherCAT, or Modbus RTU. It is also where redundancy protocols such as Rapid Spanning Tree Protocol (RSTP) or Parallel Redundancy Protocol (PRP) are implemented to provide fault tolerance. Correct configuration at this layer prevents problems like packet collisions, delays, and communication bottlenecks.
- The Network Layer is responsible for addressing and routing. Devices are assigned IP addresses, and routers or managed switches handle the flow of data between subnets. This layer ensures that traffic from field devices reaches higher-level systems like SCADA, MES, or the cloud. Network segmentation, VLANs, and firewalls are commonly used here to isolate operational technology (OT) from information technology (IT), improving both performance and cybersecurity.
- The Transport Layer determines how data is delivered. Transmission Control Protocol (TCP) provides reliable, ordered communication, making it suitable for configuration and non-time-critical data. In contrast, User Datagram Protocol (UDP) allows faster, connectionless communication, making it useful for real-time telemetry or control signals where low latency is more important than reliability.

- Finally, the Application Layer defines how information is exchanged between industrial devices and software systems. Common protocols include MQTT for lightweight, publish-subscribe communication; OPC UA for rich, secure, and interoperable data exchange; and Modbus TCP for simple master-slave setups. This layer is where the actual meaning of data such as temperature readings, vibration levels, or motor speed is defined and standardized.

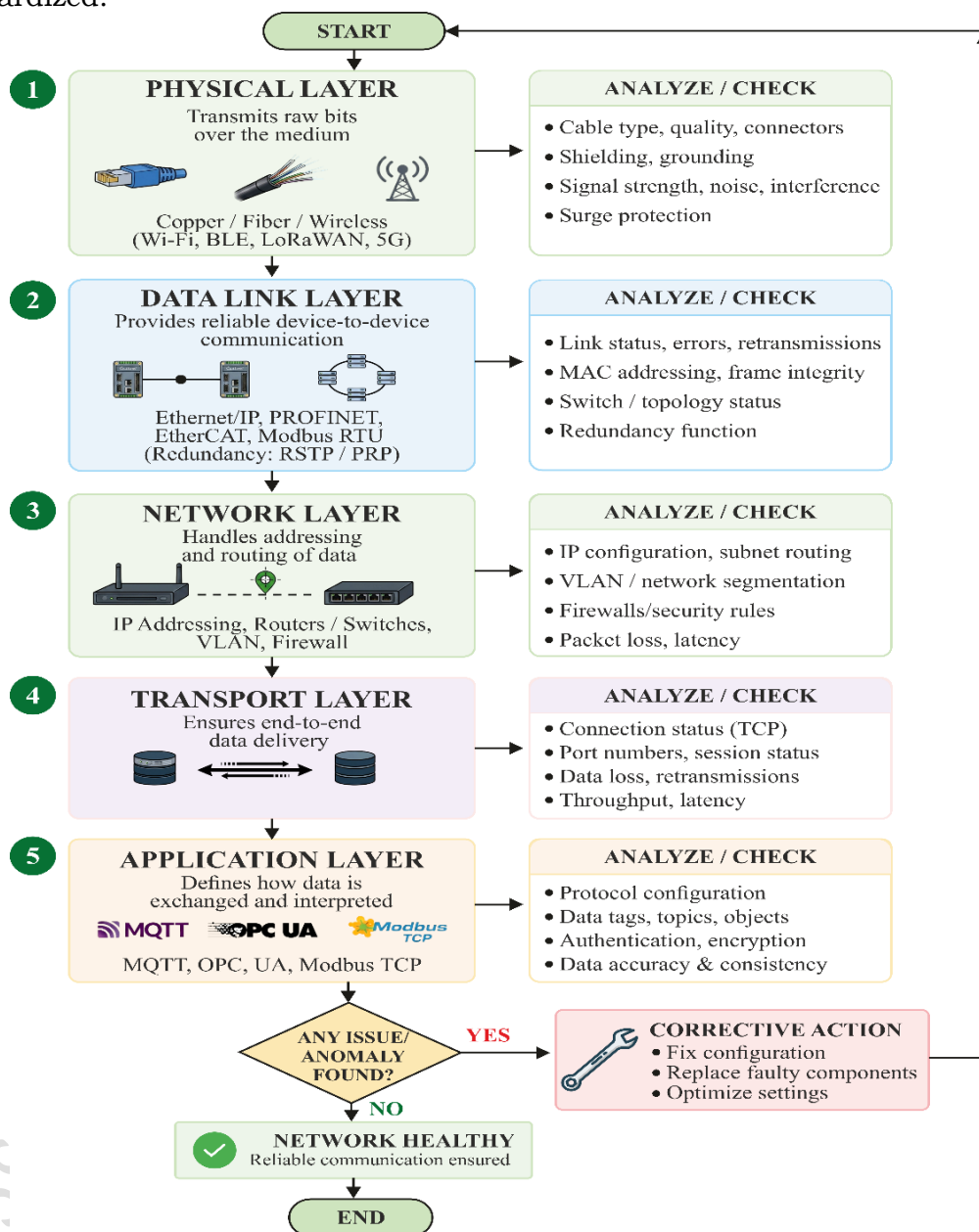


Fig.3.26: Practical Analysis of Network Layers in IIOT Systems

3.11 Integration Using I/O-Link

In earlier days, machines in industries used simple sensors and actuators that were connected with direct wires. These wires could only send very basic information, such as ON/OFF signals. For example, a temperature sensor could only tell if the machine was "too

hot" or "not too hot." This limited communication made it difficult to understand what was really happening inside the machine.

I/O-Link is a modern system that changes this. It is like giving sensors and actuators the ability to “talk” and “listen” just like humans. With I/O-Link, the connection between the machine’s brain (the controller) and its senses (sensors) or hands (actuators) becomes two-way communication. This means:

- A sensor can send detailed data to the controller. For example, a temperature sensor doesn’t just say “hot” or “cold.” It can tell the exact temperature, like 78.5°C.
- A controller can also send instructions back to the sensor. For example, the controller can tell the sensor to change its measuring range (e.g., measure from 0–100°C instead of 0–50°C).

Another amazing feature is that I/O-Link sensors can give extra information about themselves. For example:

- They can share their model number and version automatically (no need to check the manual).
- They can warn if they are getting old or faulty, like saying, “I am working now, but my readings are becoming unstable.”
- They can send diagnostic data, which helps engineers fix problems before the machine actually breaks down. This is called predictive maintenance.

I/O-Link also saves time and money in industries:

- It uses normal 3-wire cables instead of expensive shielded cables. This makes wiring simpler and cheaper.
- It allows automatic setup. When you connect to a new sensor, the system immediately recognizes it and loads the right settings.
- If a sensor is damaged, you can just replace it quickly (hot swap), and it will be ready to use without manual adjustments.
- For industries, this is very powerful because machines must run continuously, and even a few minutes of downtime can cause big financial losses. With I/O-Link, downtime is reduced, and production becomes more reliable.

Comparison between Traditional Wiring and I/O-Link

Table 3.3: Comparison between Traditional Wiring and I/O-Link

Feature / Aspect	Traditional Wiring	I/O-Link
Communication	One-way (sensor → controller)	Two-way (sensor ↔ controller)
Data Type	Only basic signals (e.g., ON/OFF, analog value)	Detailed data (exact values, status, diagnostics)
Extra Information	Not possible	Sensors share ID, health, errors, and warnings
Cables Required	Expensive shielded cables	Simple, low-cost 3-wire cables
Installation	Complex, time-consuming	Easy and faster setup
Device Replacement	Manual reconfiguration needed	Hot swap: Automatic recognition and setup

Maintenance	Reactive (fix after breakdown)	Predictive (detect problems before failure)
Integration with Higher Systems	Limited	Direct connection to PLCs, SCADA, and Cloud
Overall Cost	Higher (due to wiring and manual setup)	Lower (less wiring, faster commissioning)
Usefulness in Smart Factories	Limited	Highly suitable and future-ready

Benefits of Using I/O-Link:

- Faster installation with standard cables.
- Real-time monitoring of sensors and actuators.
- Reduced downtime due to predictive maintenance.
- Easy integration with higher-level systems like MES or SCADA.

Example: Smart Conveyor System in a Factory

A factory has a conveyor belt system that moves products through various stages: inspection, packaging, and sorting. The goal is to monitor product position, detect jams, and adjust speed automatically.

Integration using, I/O-Link:

1. Sensors:

- Photoelectric sensors detect the presence of a product at different points on the conveyor.
- Temperature sensors monitor motor temperature to prevent overheating.
- Proximity sensors detect metal parts in packaging lines.

2. I/O-Link Devices:

- Each sensor is connected to an I/O-Link master instead of being wired directly to the PLC (Programmable Logic Controller).
- I/O-Link enables bi-directional communication; sensors can send data and receive commands for configuration.

3. Data Integration:

- The I/O-Link master sends sensor data to the PLC.
- The PLC processes data and controls actuators (motors, pushers, alarms) based on sensor readings.
- Example: If a product is detected at a sorting point, the PLC activates a pneumatic arm to redirect it.

4. Advanced Features with I/O-Link:

- Sensors can report diagnostics, like signal strength or failure, to the PLC.
- PLC can remotely adjust sensor sensitivity or thresholds without physically touching the device.

- All sensor data can be logged in the factory's IIOT system for predictive maintenance and analytics.

3.12 Connecting Intelligent Devices in Networks

Modern IIOT devices are no longer simple machines; they are smart and intelligent systems. These devices have small built-in computers called microcontrollers, which allow them to collect data, process it, and communicate with other devices. Because of this, they can interact directly with controllers, edge devices, or even cloud platforms.

These smart sensors and actuators can connect in different ways depending on the requirement. In some cases, they use wired connections like industrial Ethernet for fast and reliable communication. In other cases, they use wireless technologies like Wi-Fi for flexibility and easy installation.

In a typical industrial setup, data flows through different levels:

- Devices may send data to PLCs (Programmable Logic Controllers) for quick, real-time control.
- Some data is sent to edge devices, where it is filtered and processed locally to make faster decisions.
- Other data is sent to the cloud, where it is stored, analyzed, and used for reports or long-term planning.

This layered system ensures that data is processed at the most suitable place, either near the machine, at the edge, or in the cloud; making the system more efficient.

These intelligent devices do more than just send real-time readings. They also provide useful information such as:

- Machine health and operating condition
- Energy consumption
- Maintenance alerts (before failure happens)
- Past performance data

This ability helps machines take smart decisions automatically, without always depending on a central system. As a result, industries become more efficient, reliable, and safe.

To ensure that devices from different manufacturers can work together, standard communication protocols like OPC UA, MQTT, and Modbus are used. These act like common languages that allow devices to understand each other.

Security is also a key part of IIOT systems. Only authorized devices are allowed to connect to the network, and regular software updates keep the system protected from threats. Many smart devices also have self-monitoring features, which help detect problems early and reduce downtime and repair costs.

Another important feature is scalability. As factories grow or needs change, new devices can be added easily without disturbing the existing system. Advanced networking features also ensure that data is delivered quickly, reliably, and without delay, even in complex environments (Fig.3.27).

☞ In simple terms, connecting intelligent devices transforms traditional industries into smart, connected, and automated systems, where machines can communicate, cooperate, and make decisions on their own.

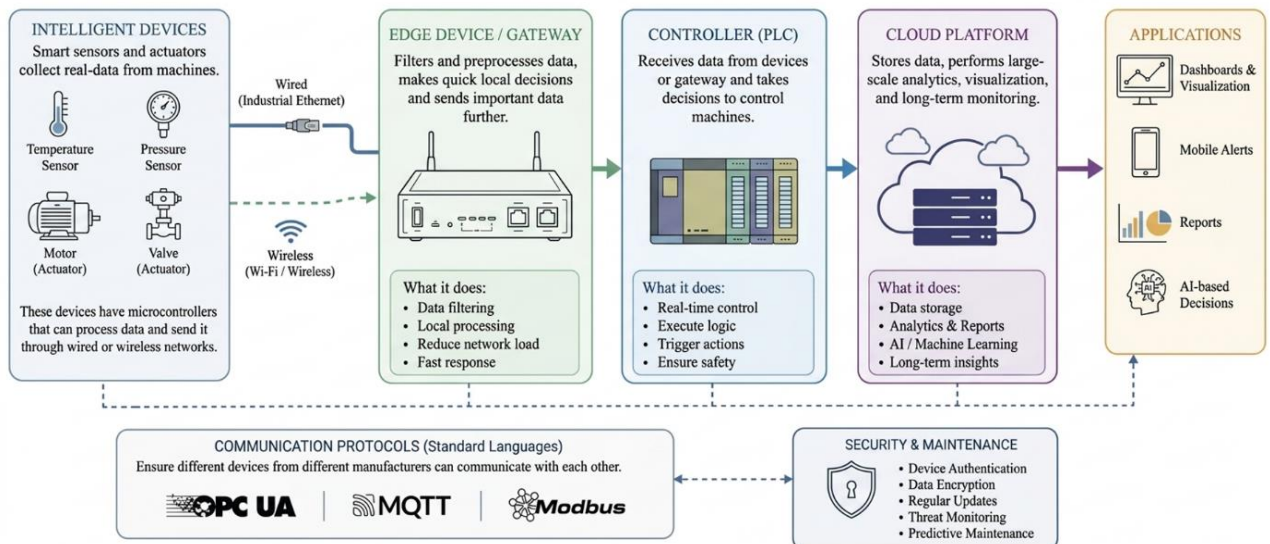


Fig.3.27: Connecting Intelligent Devices in Networks

3.13 Need for automation elements

In an Industrial Internet of Things (IIOT) system, automation elements such as sensors and control devices play a critical role in enabling intelligent, real-time monitoring, data-driven decisions, and optimized industrial operations. These components form the foundation of smart manufacturing by creating a seamless flow of information between machines, processes, and decision-making systems.

Sensors: The Data Collectors

Sensors are essential for capturing real-world physical parameters and converting them into electrical signals that can be processed and transmitted over a network. They enable IIOT systems to monitor various aspects of industrial environments such as:

- Temperature, humidity, and pressure in manufacturing plants
- Vibration and motion in machinery for predictive maintenance
- Speed, level, proximity, and voltage for quality and safety control
- Gas and chemical detection for environment monitoring and worker safety

These sensors continuously provide accurate, real-time data, which is critical for maintaining process stability, ensuring product quality, and avoiding equipment failure.

Control Devices: The Decision Executors

Control devices such as PLCs (Programmable Logic Controllers), DCS (Distributed Control Systems), and microcontrollers act as the "brain" of the system. They receive data from

sensors and execute appropriate actions based on pre-programmed logic or real-time AI analytics. These devices control operations like:

- Starting/stopping motors or conveyors
- Adjusting temperature or flow rate
- Triggering alarms in unsafe conditions
- Managing robotic operations in assembly lines

They ensure the system responds quickly and efficiently to changing conditions, minimizing human intervention and operational delays.

Role in Automation and Integration

Together, sensors and control devices enable closed-loop control, where real-time sensor feedback is used to dynamically adjust processes. This level of automation improves efficiency, consistency, and safety while reducing manual errors, energy consumption, and downtime.

In IIOT, these components are often connected over industrial networks, making it possible to integrate them into centralized monitoring platforms and cloud systems. This leads to enhanced visibility, remote control, historical analysis, and machine learning-driven optimization.

3.14 Integration of Industrial Devices into IIOT Networks Using I/O-Link

In Industrial Internet of Things (IIOT) systems, seamless communication between field devices (like sensors and actuators) and central controllers is essential. I/O Link, a standardized I/O communication technology (IEC 61131-9), plays a crucial role in integrating machines, systems, and robots into different network layers.

A) Role of IO-Link Master

The IO-Link master acts as the bridge between intelligent field devices and higher-level controllers such as PLCs (Programmable Logic Controllers) or industrial PCs. It converts IO-Link communication from smart devices into standard fieldbus or Ethernet protocols like PROFINET, EtherNet/IP, or Modbus TCP.

B) Layered Network Integration (Fig.3.28)

Field Layer: This includes sensors, actuators, and machines. Devices here use I/O Link to send real-time operational data such as temperature, pressure, or motor status to the I/O Link master.

Control Layer: I/O Link masters relay this data to PLCs or controllers that manage operations, trigger responses, or execute logic.

Supervisory Layer: Data from controllers is forwarded to SCADA or MES systems for monitoring, analytics, or process optimization.

Enterprise Layer: Finally, data can be pushed to cloud platforms for long-term storage, analysis, or AI-based decision-making.

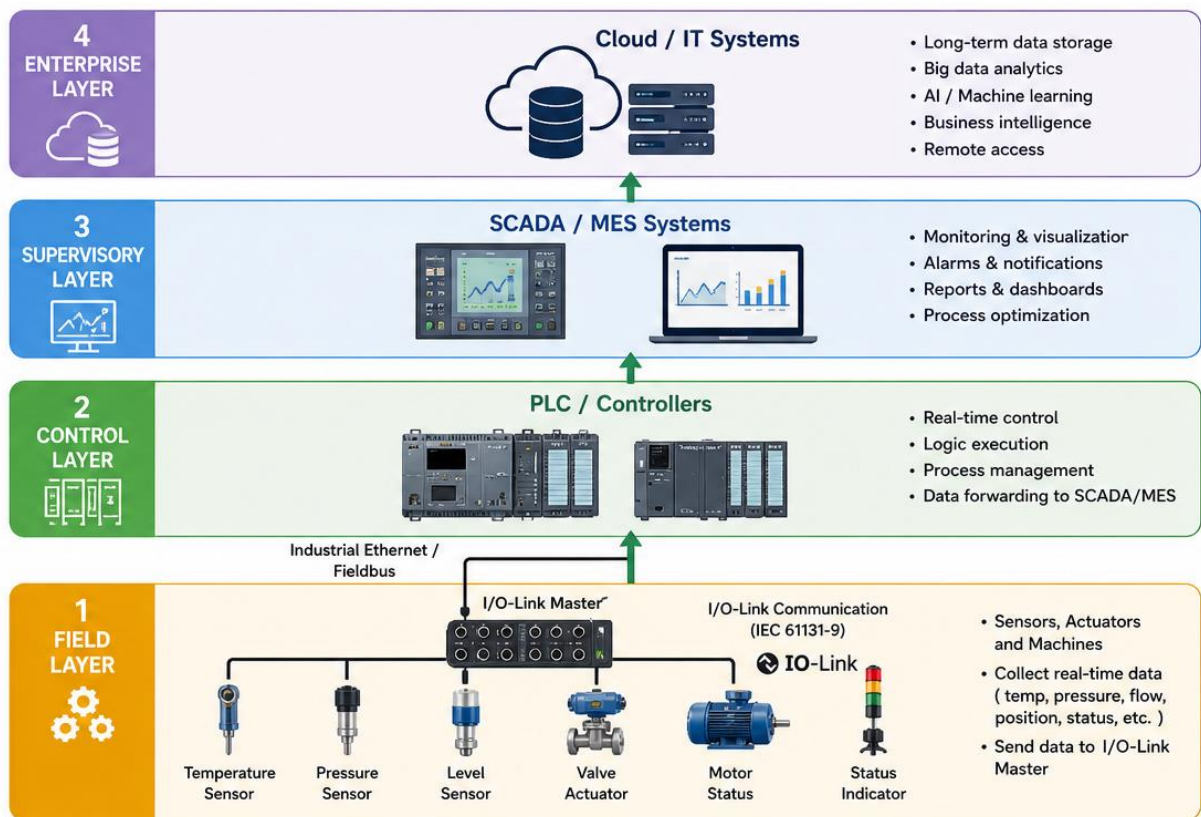


Fig.3.28: Integration of Industrial Devices into IIOT Networks Using I/O-Link Systems

C) Benefits of I/O Link Integration

- Plug-and-play device configuration
- Bidirectional communication for diagnostics and parameter setting
- Reduced wiring complexity
- Easy scalability and maintenance

D) Application in Robots and Automation Systems

I/O Link enables flexible integration of robotic arms, conveyors, and automated machinery into smart manufacturing systems. These systems benefit from real-time diagnostics, remote configuration, and synchronized operation, increasing productivity and minimizing downtime.

PRACTICAL ACTIVITY

ACTIVITY 1:

Identify and Describe Network Layers in IIOT

Objective: Understand the role of each network layer in an IIOT system and identify the appropriate protocol or technology associated with each layer.

Instructions: The five network layers are listed below. Provide a brief description for each column. The Physical Layer has been completed as an example.

Layer in the Network	What does this layer do?	Give one protocol or technology used here	Give one example problem at this layer
Physical Layer	Handles the actual medium – cables, fiber, wireless signals	Ethernet cable, Wi-Fi, Fiber optic	Loose connector or broken cable stops communication
Data Link Layer			
Network Layer			
Transport Layer			
Application Layer			

Think and Answer:

A machine is not sending data because of a cut wire. Which layer should a technician check first? _____

Factory data is reaching a server it should not access. Which layer's settings need to be reviewed? _____

ACTIVITY 2:

I/O-Link vs. Traditional Wiring – Spot The Difference

Objective: Compare I/O-Link technology with traditional wiring and understand the practical benefits.

Instructions: - Read each statement and place a ✓ in the appropriate column: Traditional Wiring, I/O-Link, or Both (if it applies to both).

Statement	Traditional Wiring	I/O-Link
Uses simple 3-wire standard cables		
Communication is one-way only (sensor → controller)		
Sensor can report its own model number and health status		
Requires manual reconfiguration when a device is replaced		
Supports automatic device recognition (hot swap)		
Maintenance is reactive – issues are fixed after breakdown		
Sends detailed data like exact temperature value (e.g., 78.5°C)		

Think and Answer:

A factory manager decides to replace old wired sensors with I/O-Link sensors on their conveyor belt.

Give ONE reason this will reduce machine downtime:

Give ONE reason this will make maintenance easier:

ACTIVITY 3:**Identify Automation Elements and Their Role**

Objective: Recognize the role of sensors and control devices (automation elements) in real IIOT factory scenarios.

Instructions: Read each factory scenario given in the table. Identify the automation element involved and describe its function. The first example has been completed as an example.

Factory Scenario	Automation Element (Sensor / Control Device)	Specific Device Name	What does it do in this scenario?
A motor gets too hot and the system automatically turns on a cooling fan.	Sensor	Temperature Sensor	Detects motor heat and sends the reading to the controller, which activates the fan.
A product reaches the end of a conveyor and the belt automatically stops.			
A gas leak is detected in a paint booth and an alarm goes off immediately.			
A robotic arm adjusts its grip pressure based on the weight of the item it picks up.			
Vibration levels in a motor are tracked daily to predict when it might fail.			

Think and Answer:

- When a sensor sends data to a controller, which then adjusts the machine, this is called:
 - Open-loop control
 - Closed-loop control
 - Manual control
- Which type of maintenance uses sensor data to predict failure before it happens?
 - Reactive maintenance
 - Routine maintenance
 - Predictive maintenance

CHECK YOUR PROGRESS**A. Multiple Choice Questions**

- A machine is not sending data because of a loose cable connection. Which layer of the IIOT network should you check?
 - Network Layer

- b) Physical Layer
c) Application Layer
d) Data Link Layer
2. To connect a smart sensor that can send and receive data with a controller, which technology should be used?
a) Modbus RTU
b) I/O-Link
c) RS-232
d) Wi-Fi
3. A new sensor is connected to a system and starts working automatically without extra setup. Which feature makes this possible?
a) Auto setup (Hot-swap) in I/O-Link
b) Manual wiring
c) Analog calibration
d) Voltage divider
4. In a smart conveyor, sensors detect products and send data to a PLC that controls the motor speed. What concept is applied here?
a) Closed-loop control
b) Manual control
c) Open-loop system
d) Remote control
5. When using sensors from different companies in one IIoT system, what helps them work together?
a) Standard protocols like OPC UA
b) Custom wiring for each
c) Manual data transfer
d) Vendor-specific software

B. Match the following

Column A	Column B
1. I/O-Link	A. Sensors with microcontrollers that can preprocess data
2. Predictive Maintenance	B. Controls motors and machines using sensor inputs
3. PLC (Programmable Logic Controller)	C. Standard protocol for secure industrial communication
4. OPC UA	D. Fixing machines before failure using data warnings
5. Intelligent Devices	E. Allows automatic sensor setup and two-way data flow

C. Fill in the blanks

1. In IIOT systems, _____ devices process data near the source to reduce delay and improve efficiency.
2. The _____ layer ensures that data reaches the correct destination across different networks.

3. I/O-Link enables _____ communication, allowing both data transmission and configuration between devices and controllers.
4. Sensors convert physical parameters like temperature and pressure into _____ signals for processing.
5. Standard protocols like MQTT and OPC UA help ensure _____ between devices from different manufacturers.

D. Answer the following

1. If you are setting up an IIOT system in a factory, how would you decide whether to use wired or wireless communication?
2. If many sensors are sending large data continuously, how would you use edge devices to manage the data efficiently?
3. If your IIOT network is facing security risks, what steps would you take to improve its security?
4. If devices in a system use different protocols (MQTT, OPC UA), how would you ensure they communicate properly?
5. If a sensor is giving incorrect readings during operation, what actions would you take to identify and fix the issue?

SESSION 4: DATA MANAGEMENT, SECURITY AND DOCUMENTATION IN IIOT NETWORKS

3.15 Data Types in Automation Systems

In an industrial automation system that includes robots and smart machines, data is exchanged continuously across a network to ensure efficient and reliable operations. This data is broadly categorized into three types: machine data, process data, and control data. Each type serves a unique purpose and flows between different components like sensors, actuators, controllers, and cloud systems (Fig.3.29).

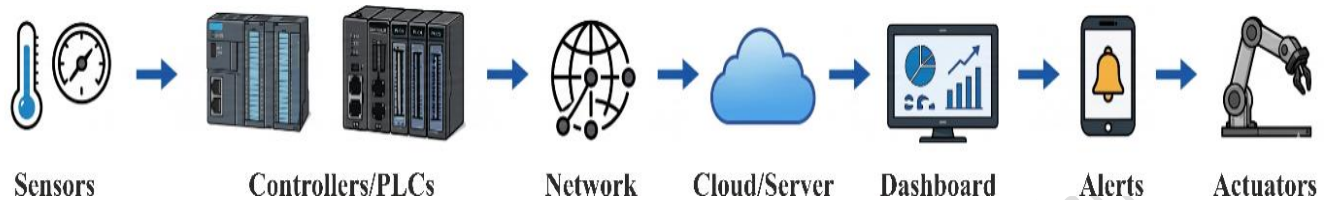


Fig.3.29: Data Flow in Automation System

Have You Ever Wondered?

How does a modern machine 'know' that one of its parts may fail soon?



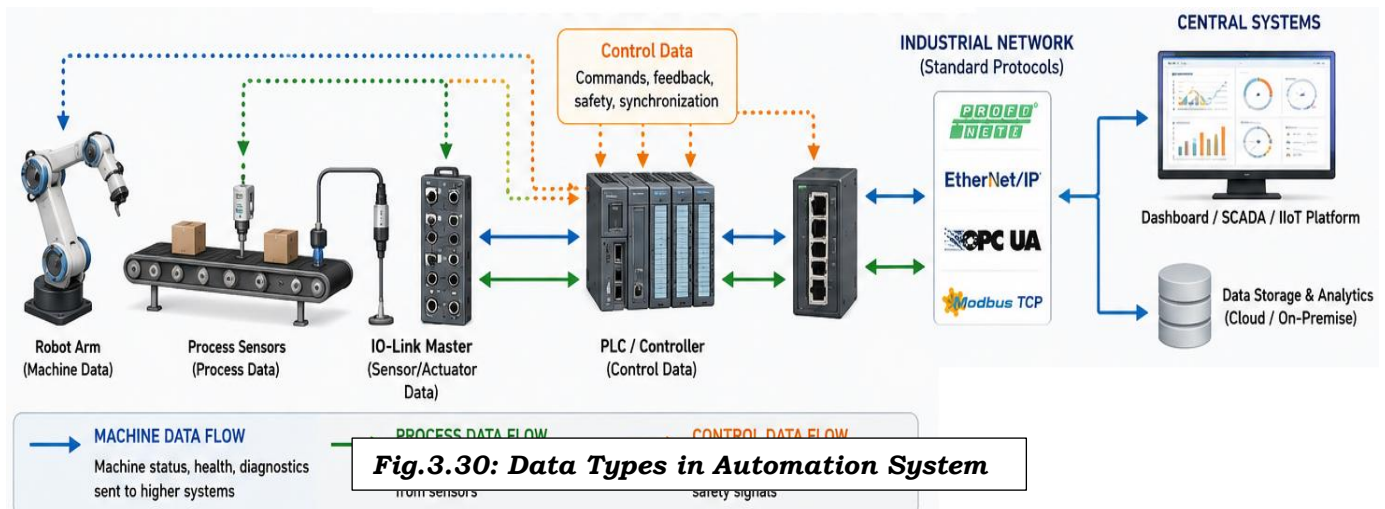
Machine data:

Machine data refers to the information produced by machines about their current operating status and health. For example, a robot arm might generate data such as joint angles, motor temperature, torque, and the number of operation cycles completed. Similarly, a CNC machine could report spindle speed, lubrication levels, or vibration patterns. This type of data is mainly used for monitoring the condition of the equipment, detecting faults early, and planning preventive maintenance. For instance, if a motor reports increasing vibration over time, it may indicate bearing wear, prompting scheduled maintenance before a failure occurs.

Process data: It includes real-time information about the parameters and conditions of the manufacturing or industrial process. This could involve data from sensors monitoring the temperature of a furnace, the pressure in a pipeline, the position of a product on a conveyor, or the flow rate of a liquid in a mixing tank. For example, in a food packaging plant, process data might include the number of units filled, sealing temperature, and the weight of each pack. This data is essential for maintaining quality, optimizing efficiency, and ensuring the process adheres to safety and production standards.

Control data: It involves the instructions and feedback that regulate how machines and systems operate. It consists of command signals from programmable logic controllers (PLCs), robotic controllers, or industrial PCs. For instance, a PLC might send a signal to a robot to pick and place an object or to start and stop a conveyor belt. Control data also includes safety instructions, such as emergency stop signals or interlock feedback from safety doors. Additionally, control data ensures synchronized operation between devices, for example,

coordinating the timing between a filling machine and a capping machine on a bottling line (Fig.3.30).



In a fully integrated industrial network, these three types of data are transmitted over standard communication protocols like PROFINET, EtherNet/IP, OPC UA, or Modbus TCP. For example, a robot might send its machine data to a central dashboard via OPC UA, receive control instructions over PROFINET, and interact with process sensors through an IO-Link master. The combined flow of machine, process, and control data enables smart automation, remote monitoring, real-time analytics, and predictive maintenance—key features of the modern Industrial Internet of Things (IIOT).

Think About It!

What might happen if two machines in a factory do not operate in proper synchronization?



3.16 Methods for Physical Security in IIOT System

Industrial networks that integrate IIOT devices, machines, robots, and automation systems are vulnerable not only to cyber threats but also to physical tampering, damage, and unauthorized access. Physical security safeguards the hardware, infrastructure, and operations. Below are the key methods:

1. Restricted Physical Access

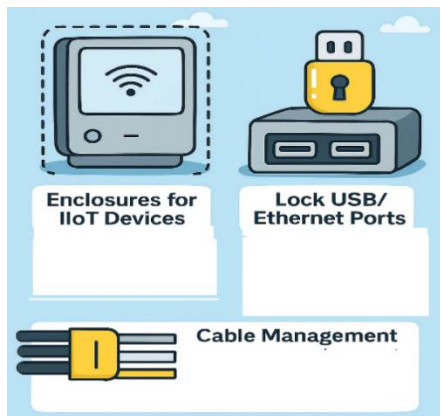


Authorized Personnel Only: Limit entry to control rooms, sensor areas, and robot cells using RFID cards, biometric scanners, or access codes.

Fenced and Locked Areas: Enclose critical equipment in lockable cabinets or secure rooms.

Security Personnel: Use trained guards in high-risk or sensitive zones.

2. Device and Port Protection



Enclosures for IIOT Devices: Install IIOT sensors and controllers in tamper-proof or weather-resistant enclosures.

Lock USB/Ethernet Ports: Prevent unauthorized connections by using physical locks or port blockers on exposed interfaces.

Cable Management: Secure power and communication cables in trays or conduits to avoid tampering or accidental disconnection.

3. Surveillance and Monitoring



CCTV Cameras: Monitor key areas like control panels, robot cells, and gateways.

Remote Viewing: Use IP cameras integrated with IIOT platforms for real-time remote monitoring.

Motion Detectors: Install sensors to detect unauthorized movement in restricted zones.

4. Environmental Safety Systems



Fire Detection and Suppression: Equip control rooms with smoke detectors and automatic fire extinguishing systems.

Climate Control: Maintain optimal temperature and humidity levels for sensitive devices using HVAC systems and environmental sensors.

Vibration/Shock Monitoring: Protect robots and machines with vibration sensors to detect abnormal physical impacts.

5. Power Protection and Backup

- UPS Systems: Ensure uninterrupted power for critical components with backup batteries.
- Redundant Power Supplies: Avoid downtime by having secondary power sources.
- Surge Protectors: Use electrical protection devices to shield hardware from voltage spikes.

Think About It!

What could happen if power suddenly fails during an important industrial operation?



6. Regular Security Audits and Maintenance

- Routine Inspections: Periodically inspect physical infrastructure for signs of wear, damage, or tampering.
- Asset Inventory Management: Keep a detailed log of all IIOT devices, their locations, and access history.
- Training for Staff: Educate employees about physical security protocols and how to report suspicious activity.

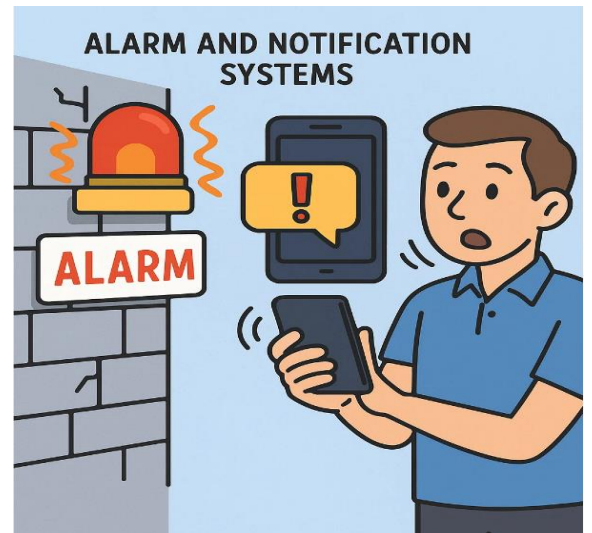
👉 Many industrial accidents happen because small faults are ignored during inspection.

7. Alarm and Notification Systems

Tamper Alarms: Use sensors that trigger alerts if enclosures are opened or devices are moved.

Alarms: Notify security teams when unauthorized access attempts occur.

Emergency Shutdown Mechanisms: Enable manual override or emergency stop features for machines and robots.



8. Signage and Safety Label

Warning Signs: Display clear notices like “Authorized Personnel Only” or “High Voltage Area”.

Identification Labels: Mark all devices, ports, and cables to prevent confusion and misuse.

Instruction Boards: Provide quick-reference guides near control units and robot workstations



3.17 Organisational Trial Run Procedure

A trial run is a structured test phase used to verify that a newly installed or modified IIOT system functions correctly under expected operating conditions before full-scale deployment. In an automotive IIOT (Industrial Internet of Things) system, conducting a trial run is a critical step before full-scale deployment. Organizations follow specific policies and procedures to ensure safety, functionality, reliability, and compliance. Here's a detailed explanation of those organization-specified policies and procedures (Fig.3.31):

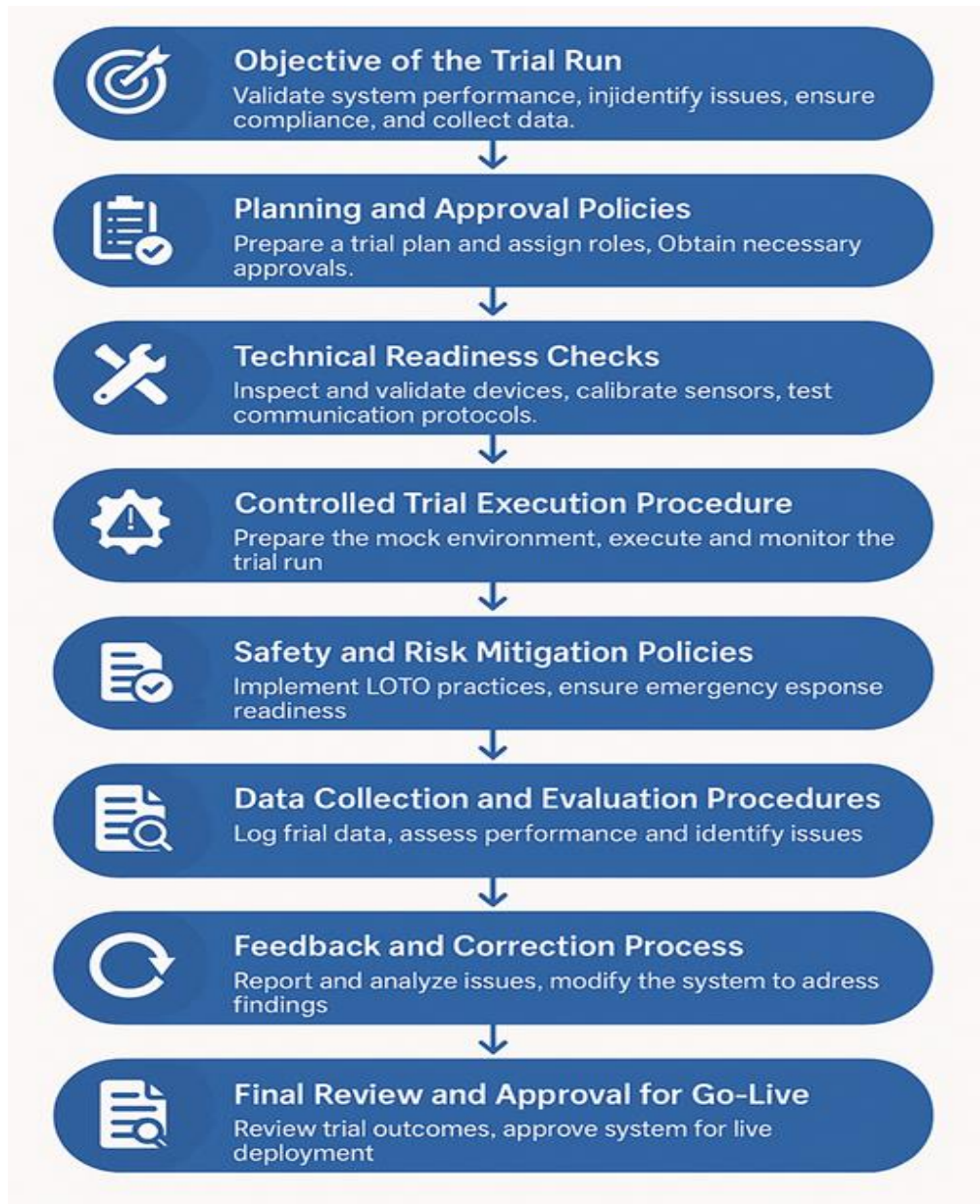


Fig.3.31: Organisational Trial Run Procedure

1. Objective of the Trial Run:

- Validate system performance (e.g., sensors, machines, PLCs, network).
- Identify and resolve technical and safety issues.
- Ensure compliance with functional and safety standards.
- Collect data for evaluation and documentation.

2. Planning and Approval Policies

a. Trial Run Proposal and Approval: A formal trial plan should be prepared before initiating any system testing. This document must clearly define the scope of the trial, including which systems will be tested such as robots, sensors, and actuators. It should

also specify the trial location, expected duration, and all required resources, including tools and technical support personnel. Once the plan is complete, it must be submitted for approval to the project manager, safety officer, and the quality assurance team to ensure that the trial meets all operational, safety, and compliance standards.

b. Defined Roles and Responsibilities: To ensure smooth execution of the trial run, specific roles and responsibilities should be assigned to the team members. Key roles may include a Trial Run Supervisor to oversee the entire process, a Safety In-Charge to monitor compliance with safety protocols, an IIOT System Engineer to manage communication networks and system integration, and a Maintenance Technician to address any hardware or equipment-related issues. Clearly defining these roles helps maintain accountability and improves the efficiency of the trial.

3. Technical Readiness Checks

a. Pre-Trial System Inspection: Before beginning the trial, conduct a thorough inspection of the entire system. This includes checking wiring, grounding, and configuration settings of all devices involved. Sensor calibration must be validated to ensure accurate measurements, and PLC logic and actuator positions should be verified for correct operation. Additionally, ensure that the network topology—whether Star, Ring, or another configuration—has been properly established and tested.

b. Device Communication Testing: Once physical checks are complete, verify that all IIOT communication protocols such as MQTT, OPC UA, and PROFINET are functioning correctly. Ensure that edge devices, cloud gateways, and dashboards are successfully integrated and are exchanging data without errors. This step confirms that the communication framework is ready for real-time system interaction.

4. Controlled Trial Execution Procedure

a. Trial Environment Preparation

The trial should be conducted in a controlled, isolated, or simulated environment to minimize operational risks. Safety precautions such as dummy loads and mechanical guards should be put in place to prevent hazards during initial testing.

b. Live Trial Run Execution: During the live trial, operate the system under standard working conditions. Continuously monitor key performance parameters such as sensor accuracy, actuator response time, signal strength, and network delays. This ensures that the system behaves as expected under real-world loads.

c. Real-Time Monitoring: Use SCADA, HMI, or IIoT dashboards to observe real-time system data, alarms, and alerts. All deviations, response times, and abnormal behaviors must be logged systematically for later analysis.

5. Safety and Risk Mitigation Policies

a. LOTO (Lockout-Tagout) Implementation: Before any setup or modification work begins, ensure that the Lockout-Tagout procedure is strictly followed. All energy sources

should be isolated to prevent accidental start-up and ensure worker safety during preparation.

b. Emergency Response Readiness: Emergency stop buttons, safety interlocks, and protocols must be active and tested before starting the trial. Additionally, assign a dedicated emergency response team to remain on standby throughout the testing period to handle any unexpected incidents.

6.Data Collection and Evaluation Procedures

a. Trial Data Logging: Throughout the trial, collect detailed data from sensors, machines, and the communication network. Any faults, anomalies, or unexpected behaviors should be recorded for evaluation.

b. Performance Assessment: Analyze the collected data to evaluate system performance in terms of accuracy, latency, machine coordination, and network resilience. This assessment helps determine whether the system is ready for further refinement or deployment.

7.Feedback and Correction Process

a. Issue Reporting: Document all identified issues using a TGW (Things Gone Wrong) approach. Conduct root cause analysis for each problem and develop corrective action plans to eliminate or reduce their recurrence.

b. System Modifications: Implement modifications such as adjustments to control logic, wiring, or hardware components based on the findings. All changes should be approved by authorized personnel and properly documented before the next trial.

8.Reporting and Documentation: Prepare a comprehensive Trial Run Report summarizing test results, system behavior, issues encountered, and corrective actions taken. Include clear recommendations for full deployment. All documentation should be maintained for audits, knowledge sharing, and future references.

9.Final Review and Approval for Go-Live: Conduct a final review of the trial outcomes with all stakeholders, including engineering, safety, and quality teams. If the system meets all performance, reliability, and safety requirements, it can be formally approved for go-live deployment.

3.18 Technical Documentation and Records

In the implementation of an Automotive IIOT system, documentation plays a critical role at every phase, from procurement to system deployment and future upgrades. It ensures systematic tracking, quality control, safety compliance, and continuous improvement. The documentation can be broadly categorized into four phases: Procurement, Trial Run, System Modifications, and Records for Future Reference.

A) Procurement Phase

During the procurement phase, the process begins with a **Purchase Requisition (PR)** raised by the technical or production team. This document outlines the required

components—such as IIOT sensors, gateways, PLCs, or cables—along with specifications and quantities. Once the PR is approved, a **Request for Quotation (RFQ)** is sent to multiple vendors, including technical details like voltage, communication protocol, and industrial certifications.

The responses from vendors are evaluated through a Comparative Statement or bid analysis that considers both technical suitability and commercial terms. After finalizing the vendor, a **Purchase Order (PO)** is issued, specifying the item list, pricing, delivery conditions, and payment terms. Upon delivery, a Delivery Note and Invoice are received, and a Goods Inspection Report is prepared to confirm that the received equipment matches the ordered specifications and is free from damage. These documents ensure that the IIOT system components are procured legally, transparently, and traceably.

B) Trial Run Phase

The trial run phase begins with a detailed Trial Run Plan that includes the scope of testing, devices involved (e.g., sensors, robots, controllers), performance expectations, testing schedule, and personnel responsibilities. Prior to initiating the trial, a Technical Checklist is prepared to ensure that all systems—such as wiring, configurations, device settings, and safety controls—are properly installed and ready for operation.

During the trial run, real-time readings and behaviors are recorded using Test Data Sheets. These logs capture sensor responses, machine actuation, and communication stability under working conditions. Engineers prepare a Trial Observation Report to document any irregularities or abnormal operations, while a Safety Checklist ensures compliance with LOTO (Lockout-Tagout), emergency stops, and physical safety barriers. Additionally, SCADA or HMI logs are used to monitor network communication, device health, and alerts. This phase is crucial for validating system readiness before full deployment.

C) System Modification Phase

System modifications are often required based on findings from the trial run. In such cases, a Change Request Form (CRF) is submitted, detailing the need for modification, type of change (hardware/software), and its impact on performance or safety. Once approved through a Change Approval Note, the modification is carried out under supervision.

Any changes made to wiring, network configuration, or programming must be reflected in updated schematics, network diagrams, or control logic documentation. In the case of software or firmware updates, a Firmware/Software Change Log is maintained. This log includes version numbers, date of update, a description of changes, and initials of the responsible engineer. These documents help in ensuring traceability, avoid confusion during audits, and assist in future troubleshooting.

3.19 Records and Documents for Future Reference

To support long-term operational efficiency and future system upgrades, several records are maintained post-trial. One of the most valuable records is the Experience Under

Development Log, which includes real-world insights, troubleshooting steps, integration issues, and lessons learned by engineers during system development. For example, documenting issues like signal interference near motors or cable routing challenges can help prevent repetition in future projects.

During the trial process, not all outcomes are favorable. To document such incidents, a TGW (Things Gone Wrong) log is maintained, capturing all system errors or breakdowns, such as device malfunctions or unstable communication. These records must include Root Cause Analysis (RCA), corrective actions taken, and any preventive measures implemented to avoid recurrence.

Equally important is the TGR (Things Gone Right) record, which highlights successful methods, optimal device placements, robust configurations, or effective grounding practices. These best practices serve as reference points and help standardize approaches in future system designs.

Once the trial is complete, a Final Trial Summary Report is compiled. It summarizes the objectives, data outcomes, observed issues, resolutions, and final recommendations. This report forms the basis for evaluating whether the system is ready for live deployment. Finally, to ensure smooth handover from the development to operational team, Training and Handover Records are created. These include details of personnel trained, topics covered, manuals shared, and acknowledgments signed by users.

These documents can be summarized as phase-wise as follows:

Table 3.4: Phase-Wise Details of Records and Documents

Phase	Documents/Records
Procurement	PR, RFQ, Bid Evaluation, PO, Delivery Note, Invoice, Inspection Report
Trial Run	Trial Plan, Checklist, Test Data, Observation Report, Safety Logs, SCADA Logs
Modifications	Change Request, Approval Note, Updated Drawings, Firmware/Software Logs
Future Reference	Experience Logs, TGW/TGR Logs, Final Trial Report, Training Records, Handover Sheet

PRACTICAL ACTIVITY

ACTIVITY 1:

Design A Smoke Detection System Using Mq-2 Sensor and Arduino Uno

Objectives:

1. Understand the working principle of a smoke sensor
2. Interface an MQ-2 smoke sensor with Arduino
3. Read analog sensor data using Arduino
4. Monitor smoke levels using the Serial Monitor
5. Develop basic fire safety monitoring systems

Components Required:

Component	Quantity
Arduino UNO	1
MQ-2 Smoke Sensor Module	1
Jumper Wires	4
USB Cable	1

Theory

Smoke detection systems are important for fire safety and air quality monitoring. These systems help detect smoke or harmful gases early and trigger alerts to prevent accidents.

In this activity, an MQ-2 Gas and Smoke Sensor Module is interfaced with an Arduino Uno to detect smoke in the environment. The sensor measures the concentration of smoke and gases and sends an analog signal to the Arduino, which displays the values on the Serial Monitor.

Hardware Connection:

MQ-2 Sensor Pin	Arduino Connection
VCC	5V


GND	GND
AO (Analog Output)	A0
DO (Digital Output — Optional)	D2

The AO pin provides analog values (0-1023) based on smoke concentration. Higher values indicate more smoke.

Procedure:

Step 1: Wire the MQ-2 Sensor

Connect VCC → 5V, GND → GND, AO → A0 of Arduino UNO.

 Allow the MQ-2 sensor to warm up for about 30 seconds before taking readings.

Step 2: Connect Arduino to Computer

Plug in the USB cable and open Arduino IDE.

Step 3: Write the Program

Enter the following code:

```
// Arduino Code
int SmokePin = 2;
void setup() {
  Serial.begin(19200);
  pinMode(SmokePin, INPUT);
}
void loop() {
  int smoke = digitalRead(SmokePin);
  if (smoke == LOW) {
    Serial.println("Smoke Detected !");
  } else {
    Serial.println("No Smoke");
  }
  delay(1000);
}
```

Step 4: Upload and Test

1. Select board Arduino UNO and correct COM port
2. Click Upload
3. Open Serial Monitor at baud rate 9600

- Bring a smoke or gas source near the sensor and observe values rising

Output:



Fig.1: No smoke detected in Serial Monitor

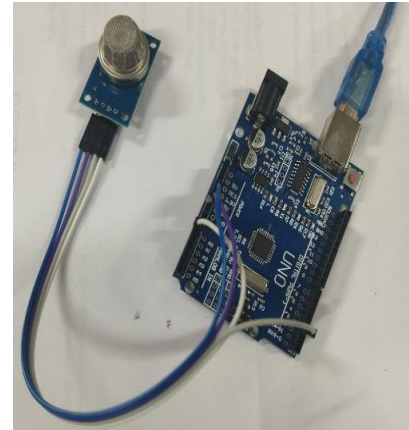


Fig.2: No smoke environment

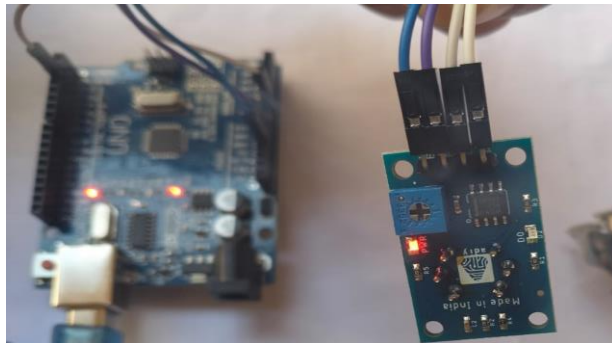


Fig.3: smoke environment

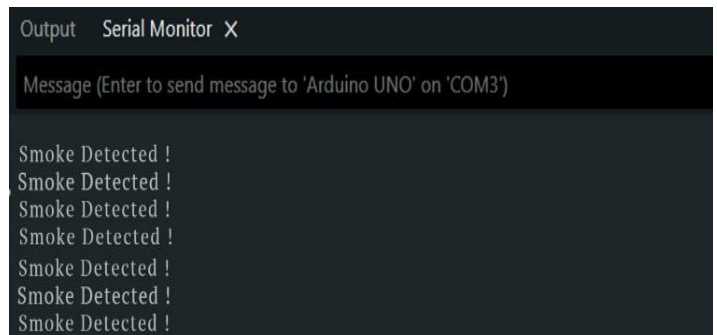


Fig.4: Serial Monitor output: Smoke detected in Serial Monitor

Exercise

Add an LED (on pin D8) to the circuit and modify the code to turn the LED ON when smoke is detected (value > 400) and OFF otherwise.

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. While monitoring a machine, which type of data would you use to control and regulate its operation in real time?
 - a) Spindle speed and motor temperature
 - b) Sensor readings stored in the cloud
 - c) Instructions and feedback regulating machines
 - d) Environmental safety parameters

2. You are designing a dashboard to monitor and control robots in a factory. Which communication protocol would you select for efficient data exchange?
 - a) MQTT
 - b) OPC UA
 - c) HTTP
 - d) RS-232

3. In an industrial setup, how would you prevent unauthorized entry into restricted areas containing critical equipment?
 - a) Software firewalls
 - b) Biometric scanners
 - c) PLC programming
 - d) Modbus encryption

4. Before performing maintenance on a machine, which safety procedure would you apply to ensure the equipment does not start accidentally?
 - a) Log-off Temporary Operator
 - b) Line of Technical Output
 - c) Lockout-Tagout
 - d) Loop Optimization Testing

5. During system testing, where would you record SCADA logs and safety checklists to evaluate system performance?
 - a) Procurement phase
 - b) Trial Run phase
 - c) Modification phase
 - d) Post-deployment phase

B. Match the following

Column A	Column B
1. Control Data	A. Testing phase before full implementation

2. Uninterruptible Power Supply (UPS)	B. Wireless tracking of inventory or personnel
3. TGR (Trial Gone Right)	C. Maintains continuity during power interruptions
4. Trial Run	D. Commands that manage machine operations
5. RFID Tag	E. Trial meets expectations and performance criteria

C. Fill in the blanks

1. In an automation system, _____ data includes information like motor temperature, vibration, and machine health status.
2. _____ data provides real-time information about process parameters such as temperature, pressure, and flow rate.
3. Control data consists of _____ and feedback signals that regulate machine operations.
4. A _____ system ensures uninterrupted power supply to critical IIOT devices during power failures.
5. The LOTO procedure stands for _____ and is used to ensure safety during maintenance.

D. Answer the following

1. During equipment monitoring, how can machine data help in identifying early signs of failure?
2. In a production line, which devices would you select to collect process data and support smooth operation?
3. While setting up an IIOT system, what steps would you take to physically secure machines and network devices?
4. Before starting full-scale production, how can a trial run help in checking system performance and safety?
5. After testing a system which records should be prepared to document results and support future improvements?

MODULE 4**ORGANISATION WORK AND RESOURCES AS
PER HEALTH AND SAFETY STANDARDS****Module Overview**

In today's modern and fast-changing work environment, ensuring the health, safety, and well-being of employees is essential. At the same time, organizations must also protect the environment by adopting responsible and sustainable practices. This module focuses on creating a safe, healthy, and environmentally conscious workplace.

The module covers important aspects such as workplace precautions, first aid techniques, fire safety, evacuation procedures, safe working habits, hazard reporting, hygiene practices, and environmental responsibility. It helps individuals develop the skills required to identify hazards, respond effectively during emergencies, and maintain a secure workplace.

Additionally, the module emphasizes on eco-friendly practices such as waste segregation, e-waste disposal, pollution control, and green workplace initiatives. By following these principles, organizations can build a culture of safety, health, and sustainability for employees, customers, and society.

Learning Outcomes

After completing this module, you will be able to:

- Identify workplace hazards and follow appropriate health and safety precautions to maintain a secure working environment.
- Demonstrate basic first aid, fire safety, and emergency evacuation procedures for effective response during accidents or emergencies.
- Adopt safe working habits and hygiene practices to promote employee health and prevent workplace injuries or illness.
- Report hazards, unsafe conditions, and incidents using proper organizational procedures and safety protocols.
- Apply environmentally responsible practices such as waste segregation, e-waste disposal, pollution control, and green workplace initiatives.

Module Structure

Session 1: Workplace Health and Safety Practices

Session 2: Organisation's Green Practices

SESSION 1: WORKPLACE HEALTH AND SAFETY PRACTICES

4.1 Importance of Workplace Health and Safety

Every employee has the right to work in a safe and secure environment. Therefore, every organization must follow applicable laws, safety standards, and workplace regulations to protect the health and well-being of its employees. A well-defined workplace health and safety policy establishes the required standards for safe working conditions, hazard prevention, and employee welfare.

It is the responsibility of all organizations to ensure that the workplace remains compliant with safety requirements and promotes a culture of prevention and responsibility.

Important safety considerations while establishing a workplace include the following measure:

- Use ergonomic furniture and equipment to reduce bending, twisting, and physical strain.
- Provide mechanical aids or lifting equipment for handling heavy materials.
- Keep appropriate safety equipment available for hazardous tasks.
- Ensure emergency exits are clearly marked, accessible, and easy to use.
- Develop workplace health and safety rules and ensure proper compliance.
- Follow regular safety procedures, inspections, and preventive protocols.

4.2 Precautions to be Taken at Work

Every employee is responsible for following workplace safety rules and developing safe habits. Every employee needs to develop the following habits:

1. Report unsafe conditions immediately to the supervisor.
2. Identify trip, slip, and fall hazards.
3. Inform management about accidents or injuries.
4. Wear suitable Personal Protective Equipment (PPE).
5. Learn how to use safety devices correctly.
6. Avoid actions that may endanger others.
7. Stay alert while working.
8. Know the location of fire extinguishers, first aid kits, and emergency exits

4.3 First Aid Techniques

Accidents, injuries, or sudden illness can happen anytime at home, work, or public places. Immediate care given before professional medical help arrives is called

First Aid. First aid helps to:

- Save life
- Prevent the condition from worsening
- Reduce pain and discomfort
- Support recovery until medical help arrives

4.3.1 First Aid for Cuts and Wounds (Refer Fig.4.1)

- Apply direct pressure using a clean cloth or gauze to stop bleeding.
- Do not remove soaked cloth; place another layer over it.
- Raise the injured limb above heart level if possible.
- Wash hands before and after treatment.
- Use tourniquet only for severe uncontrolled bleeding.

Cleaning the Wound

- Wash with soap and clean lukewarm water.
- Rinse properly.
- Do not use corrosive chemicals such as iodine or hydrogen peroxide directly.

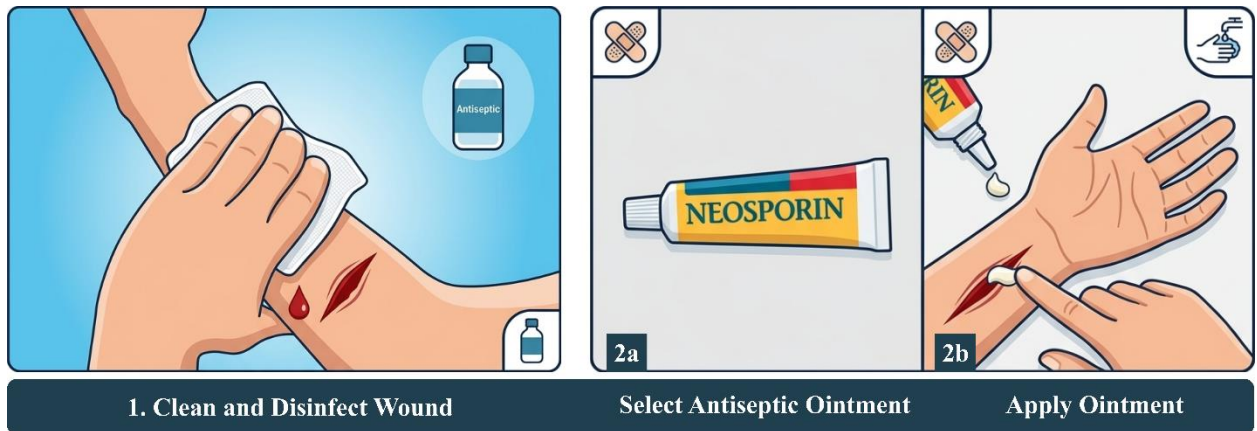


Fig.4.1: First Aid for Cuts and Wounds

Protecting the Wound

- Apply antiseptic cream.
- Cover with sterile dressing.
- Change bandage daily.

Call Emergency Help If:

- Bleeding is severe
- Bleeding continues after 10 minutes pressure
- Deep wound exists
- Chest or abdominal injury occurs

- Internal bleeding suspected

4.3.2 First Aid for Burns

- Place burnt area under cool running water for at least 10 minutes (Fig.4.2).
- Carefully remove loose clothing near burn.
- Do not remove clothing stuck to skin.
- Remove jewellery if possible.
- Keep burn area clean and uncovered if advised.
- Do not break blisters.
- Do not apply oil, cream, or home remedies.



Fig.4.2: First Aid for Burns

4.3.3 First Aid for Fractures

- Do not move protruding bones.
- Cover wound with clean bandage.
- Control bleeding with pressure around wound.
- Support injured part.
- Apply **RICE** method: (Fig.4.3)

- Rest
- Ice
- Compression
- Elevation

- Seek immediate medical help.

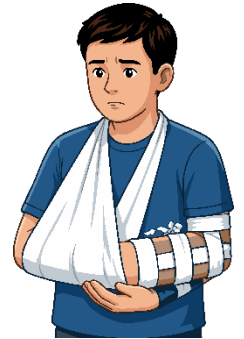


Fig.4.3: First Aid for Fractures

4.3.4 First Aid for Heart Attack / Stroke

Use **FAST** method: (Fig.4.4)

- **F – Face:** Check facial weakness
- **A – Arms:** Can both arms be raised?
- **S – Speech:** Is speech unclear?
- **T – Time:** Call emergency services immediately



Fig.4.4: First Aid for Heart Attack / Stroke

4.3.5 First Aid for Head Injury (Fig.4.5)

- Let the person rest.
- Apply cold compress.
- If vomiting, unconsciousness, or drowsiness occurs, call emergency medical help.



Fig.4.5: First Aid for Head Injury

4.3.6 Chemical Hazards and First Aid

Chemical hazards may enter the body through different routes of exposure.

- Inhalation occurs when harmful gases, fumes, vapors, or dust are breathed in through the nose or mouth, which may affect the lungs and breathing system.
- Skin contact happens when chemicals touch the skin, causing irritation, burns, or absorption into the body.
- Ingestion occurs when hazardous substances are swallowed accidentally through contaminated hands, food, or water, which may cause poisoning or internal harm.

The symptoms, in this case, will be:

- Burning sensation
- Nausea
- Vomiting
- Difficulty breathing
- Stomach pain
- Loss of consciousness

Immediate Actions to be taken as follows:

- Remove victim from hazardous area.
- Remove contaminated clothing.
- Wash affected skin or eyes with water (Fig.4.6)
- Do not induce vomiting unless medically advised.
- Call ambulance immediately.
- Give CPR if breathing stops.



Fig.4.6: Wash affected skin or eyes with water

Preventive measures for the chemical hazards

- Use gloves, masks, goggles, and protective clothing.
- Ensure good ventilation.
- Use insulated tools where required.

4.4 Fire Safety and Evacuation

Fire safety is essential in every workplace to protect people, equipment, and property during emergencies. Proper planning and regular training help ensure quick and safe evacuation during a fire incident.

Essentials for Smooth Evacuation (Refer Fig.4.7)

- Keep all passageways and escape routes clear at all times.
- Install proper and visible exit signage.
- Provide sufficient emergency exits for all occupants.
- Ensure emergency doors open easily from inside.

- Provide emergency lighting in corridors and stairways.
- Conduct regular fire safety training for employees.
- Designate a safe assembly area outside the building.
- Do not use lifts/elevators during fire emergencies.



Fig.4.7: Essentials for Smooth Evacuation

Special Evacuation Support has to be given for the person comes in following categories:

i) For Visually Impaired Persons

- Announce emergency clearly
- Offer arm support

ii) For Hearing Impaired Persons

- Use hand gestures
- Flash lights
- Write directions if needed

iii) For Persons with Mobility Issues

- Assist carefully
- Use sturdy chair or wheelchair if required

- Inform rescue team of their location

Did You Notice?

Emergency exit signs usually glow in the dark so they remain visible even during power failure.



4.5 Importance of Fire Safety Drills

Fire safety drills are essential for preparing employees to respond correctly during real fire emergencies. Regular drills improve awareness, confidence, and coordination, helping people evacuate safely and quickly. Fire drills should be conducted regularly to maintain readiness and ensure workplace safety.

Benefits of Fire Safety Drills

- **Practice Evacuation Procedures:**
Fire drills help employees learn the correct escape routes, assembly points, and evacuation process.
- **Reduce Panic During Emergencies:**
Repeated practice builds confidence and helps people remain calm during an actual fire incident.
- **Check Exit Routes and Alarm Systems:**
Drills help verify that emergency exits, alarms, signage, and lighting are functioning properly.
- **Improve Emergency Response Speed:**
Employees become familiar with procedures, allowing faster and more organized evacuation.
- **Identify Weaknesses in Safety Systems:**
Drills help detect blocked exits, poor coordination, or faulty emergency equipment that need improvement.

4.6 Importance of Safe Working Practices

Safe working practices are essential for maintaining a healthy and productive workplace. Good hygiene habits and responsible behavior help reduce the spread of bacteria, viruses, and other harmful germs. By following cleanliness rules, workers can protect themselves and others from illness.

Healthy Practices

- **Wash hands regularly:** Hand washing with soap helps remove germs and prevents infections.

- Keep workplace clean: Clean floors, desks, and work areas reduce dust, dirt, and contamination.
- Cover coughs and sneezes: Using a tissue or elbow prevents germs from spreading to others.
- Avoid sharing personal items: Do not share bottles, towels, masks, or personal tools.
- Maintain cleanliness of tools and surfaces: Regular cleaning of equipment and commonly touched surfaces improves hygiene and safety.

4.7 Importance of Social Distancing

Social distancing is an important safety practice to reduce the spread of communicable diseases. Many infections spread through close contact, air droplets, touching contaminated surfaces, or shared objects. Maintaining distance and following preventive measures help protect workers, families, and the community. In workplaces, the use of appropriate Personal Protective Equipment (PPE) such as masks, gloves, face shields, gowns, or protective clothing also helps reduce the risk of infection, especially in high-risk areas (Fig.4.8).

Preventive Measures

- Maintain physical distance: Keep a safe distance from others to reduce close-contact transmission.
- Wear face masks when required: Masks help reduce the spread of droplets in crowded or risky areas.
- Stay home if infected: Avoid coming to work when unwell to prevent spreading illness.
- Follow quarantine/isolation guidelines: Follow health instructions if exposed to infection or diagnosed sick.
- Practice hand hygiene: Wash hands regularly or use sanitizer to remove germs.



Fig.4.8: PPE Kit

4.8 Safe Workplace Practices

Every organization should maintain a properly stocked first aid box containing following items:

- Bandages
- Gauze
- Antiseptic solution
- Cotton
- Gloves
- Scissors

- Burn cream
- Adhesive tape
- Pain relief medicines (if approved)



Fig.4.9: First Aid Box Components

4.9 Methods of Reporting Safety Hazards

Every organization follows a standard procedure for reporting hazards, unsafe conditions, and emergencies. Proper reporting helps management take quick corrective action and prevents accidents from becoming more serious. Employees should immediately report any hazard they notice in the workplace.


The 6Cs of Safety Reporting provide guidance for effective communication:

1. Communicate First means reporting the hazard immediately without delay.
2. Communicate Rightly means giving clear and accurate information about the situation.
3. Communicate Credibly means being truthful and honest while reporting.
4. Communicate Empathetically means showing concern for any injured or affected persons.
5. Communicate for Action means informing the correct supervisor or responsible authority so that action can be taken.
6. Communicate Respectfully means maintaining dignity, cooperation, and trust during communication.

4.9.1 Hazard Report Details

A hazard report generally includes important details in the **Worker Section**. The employee should mention their name, designation, date and time of reporting, supervisor's name, location of the hazard, clear description of the hazard, and any suggested solution. These details help in proper identification and quick response.

The **Supervisor Section** of the report includes investigation findings after examining the issue. It may contain the causes of the incident, risks involved, and preventive or corrective actions taken to remove the hazard. Proper documentation helps improve future safety planning (Fig.4.10).



HAZARD REPORT FORM

Report all hazards, unsafe conditions or near-miss incidents immediately.

Report No.:	HRF-2024-0156
Date Reported:	16-May-2024

WORKER SECTION		SUPERVISOR SECTION																
Name of Worker	: Ramesh Kumar	Investigation Findings Visited the area and found water leakage from overhead pipe joint. Floor was wet and slippery.																
Designation	: Machine Operator																	
Date & Time	: 16-May-2024 09:30 AM	Causes of Incident / Hazard <ul style="list-style-type: none"> Pipe joint damaged and leaking. No warning sign placed in the area. Housekeeping not done on time. 																
Supervisor Name	: Sanjay Patel																	
Location	: Production Area - Line 2	<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left; padding: 5px;">Preventive / Corrective Actions Taken</th> <th style="text-align: center; padding: 5px;">Completed</th> <th style="text-align: center; padding: 5px;">Pending</th> </tr> </thead> <tbody> <tr> <td style="padding: 5px;">• Pipe repaired and leakage stopped.</td> <td style="text-align: center;">☑</td> <td style="text-align: center;">☐</td> </tr> <tr> <td style="padding: 5px;">• Floor cleaned and dried.</td> <td style="text-align: center;">☑</td> <td style="text-align: center;">☐</td> </tr> <tr> <td style="padding: 5px;">• "Wet Floor" warning signs installed.</td> <td style="text-align: center;">☑</td> <td style="text-align: center;">☐</td> </tr> <tr> <td style="padding: 5px;">• Instructed housekeeping team for regular checks.</td> <td style="text-align: center;">☑</td> <td style="text-align: center;">☐</td> </tr> </tbody> </table>		Preventive / Corrective Actions Taken	Completed	Pending	• Pipe repaired and leakage stopped.	☑	☐	• Floor cleaned and dried.	☑	☐	• "Wet Floor" warning signs installed.	☑	☐	• Instructed housekeeping team for regular checks.	☑	☐
Preventive / Corrective Actions Taken	Completed			Pending														
• Pipe repaired and leakage stopped.	☑	☐																
• Floor cleaned and dried.	☑	☐																
• "Wet Floor" warning signs installed.	☑	☐																
• Instructed housekeeping team for regular checks.	☑	☐																
Type of Hazard	<input checked="" type="checkbox"/> Physical <input type="checkbox"/> Chemical <input type="checkbox"/> Biological <input type="checkbox"/> Ergonomic <input type="checkbox"/> Electrical <input type="checkbox"/> Other	Additional Remarks / Recommendations Conduct regular inspection of all overhead pipelines. Create awareness among workers to report hazards immediately.																
Hazard Description <i>(What happened or what you observed)</i>	The floor near machine M-12 is wet due to water leakage from the pipe. There is no warning sign in the area. Workers may slip and fall.																	
Suggested Solution	Fix the pipe leakage immediately. Clean and dry the floor. Place "Wet Floor" warning signs.	Supervisor Name: Sanjay Patel Signature:																
Worker Signature:	<i>Ramesh Kumar</i>																	

FOR ACTION BY SAFETY / MANAGEMENT			
Action Taken: Pipeline inspection planned. Housekeeping schedule reviewed. Workers informed.	Action By: Safety Officer	Target Date: 21-May-2024	Status: In Progress

FOLLOW-UP / VERIFICATION		
Verified By: A. Mehta	Date: 21-May-2024	Status: Closed

Note: Timely reporting of hazards helps prevent accidents and protects lives.

Fig.4.10: Sample of Hazard Report

4.10 Occupational Hazards

Occupational hazards are risks or dangers associated with a specific job or work environment. These hazards can affect the health, safety, and well-being of workers if proper precautions are not followed. Different industries face different types of occupational hazards.

Common examples of occupational hazards include the following:

- Noise Exposure-which may damage hearing over time, a
- Chemical Contact- which can cause burns, allergies, or breathing problems.
- Electrical Shock- another serious hazard in workplaces using machinery and power systems.
- Repetitive Strain Injuries- caused by repeated movements or poor posture.
- Heat Exposure- can lead to dehydration, fatigue, or heatstroke in hot environments.
- Slips and Falls -common physical hazards that may cause injuries such as fractures or sprains

PRACTICAL ACTIVITY

ACTIVITY 1:

Hazard Identification in Workplace

Objective: To identify unsafe conditions and hazards in the workplace.

Materials Required: Checklist, pen, notebook, PPE kit.

Procedure:

1. Visit the assigned workplace area.
2. Observe machines, tools, floors, electrical points, and work practices.
3. Identify any unsafe act or unsafe condition.
4. Record the hazards in the checklist.
5. Discuss findings with the supervisor.

ACTIVITY 2:

Filling A Hazard Report Form

Objective: To learn the correct method of reporting hazards.

Materials Required: Sample hazard report form, pen.

Procedure:

1. Observe a simulated hazard situation.
2. Enter worker details in the report form.
3. Mention date, time, location, and hazard description.
4. Suggest corrective actions.
5. Submit the form to the supervisor.

ACTIVITY 3:**Identification of Occupational Hazards**

Objective: To identify occupational hazards related to different jobs.

Materials Required: Charts, workplace pictures, notebook.

Procedure:

1. Show images of different workplaces.
2. Ask students to identify hazards such as noise, heat, chemicals, slips, etc.
3. Write hazards job-wise.
4. Discuss preventive measures.
5. Present findings in class.

ACTIVITY 4:**Practice of First Aid Techniques For Common Injuries**

Objective: To practice first aid techniques for common injuries.

Materials Required: First aid kit, bandages, antiseptic cream, splint, cotton, gauze, props for role-play.

Procedure:

1. Select a specific injury scenario such as a cut, burn, or broken bone.
2. Simulate the injury scenario using props or role-play with a partner.
3. Apply the appropriate first aid technique according to standard guidelines.
4. Check dressing, bandaging, cooling, or immobilization methods used.
5. Evaluate the effectiveness of the first aid provided.

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. A worker notices oil spilled near a machine walkway. What should the worker do first according to workplace safety practices?
 - a) Ignore it and continue work
 - b) Report the unsafe condition immediately to the supervisor
 - c) Wait for cleaning staff at the end of the day
 - d) Cover it with paper only

2. During a fire emergency, an employee on the third floor wants to leave quickly. What is the safest action?
 - a) Use the elevator to save time
 - b) Hide under a desk
 - c) Use the marked emergency exit staircase
 - d) Wait for permission from coworkers

3. A person gets a minor burn from hot equipment in the workshop. What should be done immediately?
 - a) Apply oil on the burn
 - b) Break any blisters formed
 - c) Place the burnt area under cool running water
 - d) Cover it with dirty cloth

4. An employee has cough and fever but still plans to attend office. What is the best action based on social distancing practices?
 - a) Go to work and avoid talking
 - b) Stay home until recovery
 - c) Share medicines with coworkers
 - d) Remove mask while working

5. A worker cuts his hand and bleeding continues after applying pressure for 10 minutes. What should be done next?
 - a) Continue working normally
 - b) Wash with chemical solution only
 - c) Call emergency medical help
 - d) Remove all bandages immediately

B. Match the following

Column A	Column B
1. FAST Method	A. Reduce spread of diseases
2. Fire Drill	B. Heart attack / stroke response

3. Hand Hygiene	C. Prepare for emergency evacuation
4. PPE	D. Personal Protective Equipment
5. Hazard Report	E. Reporting unsafe conditions

C. Fill in the blanks

1. Immediate care given before medical help arrives is called _____.
2. During a fire emergency, employees should use the _____ exit.
3. Wearing gloves, masks, and goggles are examples of _____.
4. The letter “T” in FAST stands for _____ to call emergency services.
5. Unsafe conditions should be reported immediately to the _____.

D. Answer the following

1. A worker is asked to lift a heavy box manually. How would you apply workplace safety practices to complete the task safely?
2. During a routine inspection, you find that the first aid box is missing important items. What steps would you take to ensure readiness for emergencies?
3. A chemical liquid accidentally splashes on a worker’s hand in the laboratory. How would you respond using proper first aid procedures?
4. During a fire drill, some employees are confused about where to assemble outside the building. How would you handle the situation effectively?
5. A staff member complains of wrist pain due to repeated computer work. How would you apply ergonomic practices to reduce the problem?

SESSION 2: ORGANISATION'S GREEN PRACTICES

4.11 Waste Management

Waste management is an important eco-friendly practice adopted by organizations to protect the environment and public health. It includes the proper collection, separation, transportation, treatment, recycling, and disposal of waste materials. Effective waste management helps reduce pollution, save natural resources, and support sustainable development.

Organizations generate different types of waste such as paper waste, plastic waste, food waste, industrial waste, chemical waste, and electronic waste. Proper waste handling ensures that reusable materials are recovered and harmful waste is safely treated.

4.11.1 E-Waste

Electronic waste, commonly known as e-waste, refers to discarded electrical and electronic equipment that is no longer useful, damaged, outdated, or rejected during manufacturing, repair, or refurbishment processes.

With rapid growth in information technology and communication sectors, the use of electronic products such as computers, mobile phones, televisions, printers, refrigerators, and other appliances has increased significantly. Frequent technological upgrades encourage consumers to replace old devices quickly, leading to a large rise in e-waste generation.

E-waste contains valuable materials such as plastics, glass, ceramics, copper, and aluminum. However, it may also contain hazardous substances like lead, mercury, cadmium, and toxic gases, which can harm humans, animals, soil, air, and water if disposed of improperly.

Many authorized companies now collect, process, recycle, and safely dispose of e-waste to reduce environmental damage and recover useful resources.

Categories of Electronic Goods

Electronic goods are commonly grouped into three categories:

- **White Goods:** Household appliances such as refrigerators, washing machines, air conditioners.

- **Brown Goods:** Consumer electronics such as televisions, cameras, audio systems.
- **Grey Goods:** IT and communication devices such as computers, printers, scanners, fax machines.

4.11.2 E-Waste Management Process

A systematic e-waste management process includes the following steps (Refer Fig.4.11)

1. Collection of e-waste from homes, offices, stores, and industries.
2. Safe transportation to authorized recycling or disposal centers.
3. Segregation of different types of electronic waste.
4. Manual or mechanical dismantling of components.
5. Separation of metals, plastics, glass, and circuit boards.
6. Recycling and conversion into raw materials.
7. Supply of recovered materials to manufacturing industries.
8. Safe disposal of hazardous residues.

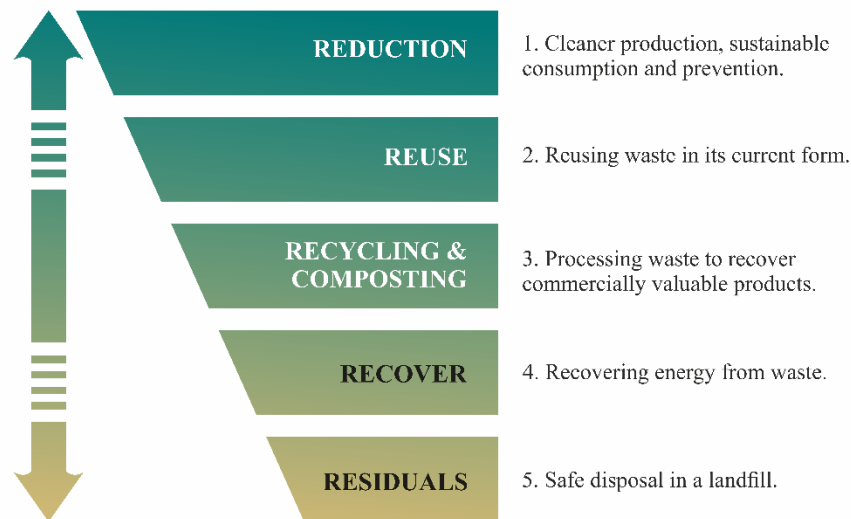


Fig.4.11: E-waste Management Process

4.12 Recyclable and Non-Recyclable Waste

Recyclable Waste

Recyclable waste includes materials that can be processed and reused to make new products. Recycling reduces landfill waste, saves energy, and lowers greenhouse gas emissions. Examples of recyclable waste are:

- Paper
- Cardboard

- Glass
- Plastic containers
- Metals
- Wood
- Textiles
- E-waste

Non-Recyclable Waste

Non-recyclable waste cannot be reused economically or safely. Reducing non-recyclable waste is important for environmental protection. Examples of non-recyclable waste are:

- Shredded paper
- Used diapers
- Sanitary waste
- Certain contaminated packaging
- Aerosol cans
- Bottle caps (in some systems)

4.13 Colour Codes of Waste Collection Bins

To improve waste segregation and make waste disposal more effective, organizations and municipalities use color-coded waste collection bins. These bins help people separate different types of waste at the source, making recycling, composting, and safe disposal easier (Fig.4.12).

Green Bin – Biodegradable / Wet Waste

The green bin is used for biodegradable or organic waste that can decompose naturally. It is used for:

- Food waste
- Fruit and vegetable peels
- Tea leaves and coffee grounds
- Garden waste
- Flowers and other organic waste

Blue Bin – Dry / Recyclable Waste

The blue bin is used for dry waste that can be recycled and reused. Generally, it is used for:

- Paper
- Plastic bottles and wrappers
- Cardboard boxes
- Tetra packs
- Metal cans
- Clean packaging waste



Fig.4.12: Tricolor Waste Bin

Black Bin – Domestic Hazardous Waste

The black bin is used for household waste that may be harmful or unsafe if mixed with regular waste. It is used for:

- Sanitary napkins
- Diapers
- Used bandages
- Batteries
- CFL bulbs
- Expired medicines
- Broken thermometers
- Printer cartridges

4.14 Sources of Waste

Waste is generated from many activities, such as:

Construction Waste – Waste produced during the construction or demolition of buildings and other structures.

• **Commercial Waste** – Waste generated from shops, offices, hotels, and other commercial activities.

• **Household Waste** – Garbage produced in homes, which may include both organic and inorganic waste materials.

• **Medical or Clinical Waste** – Waste generated from hospitals and medical facilities, such as used needles, syringes, surgical waste, blood, and wound dressings.

• **Agricultural Waste** – Waste produced from farming activities, including empty pesticide containers, old silage bags, expired medicines, used tyres, crop residues, and chemical fertilizers.

• **Industrial Waste** – Waste generated from manufacturing and processing industries such as cement plants, chemical factories, textile industries, and power plants.

• **Electronic Waste (E-Waste)** – Discarded or non-working electronic devices such as televisions, computers, and mobile phones. Some e-waste contains harmful substances like lead, mercury, and cadmium, which can damage human health and the environment.

• **Mining Waste** – Waste produced during mining activities. Mining and blasting release harmful gases and significantly disturb the natural environment.

• **Chemical Waste** – Waste materials produced from chemical substances and industrial chemical processes.

- **Radioactive Waste** – Waste generated from nuclear reactors, radioactive material extraction, and atomic explosions.

4.15 Waste Disposal Methods

Organizations use various waste disposal methods depending on waste type.

Incineration – A waste treatment process in which waste is burned in a controlled way to reduce non-combustible materials such as ash and harmful gases.

- **Waste Compaction** – Waste materials are compressed into compact blocks to make storage, transport, and recycling easier.

- **Landfill** – Waste that cannot be recycled or reused is disposed of by spreading it in low-lying land areas.

- **Composting** – A natural process in which microorganisms break down organic waste over time to produce compost.

- **Biogas Generation** – Biodegradable waste is converted into biogas using fungi, bacteria, and other microorganisms in biogas plants.

- **Vermicomposting** – A method of converting organic waste into nutrient-rich manure with the help of earthworms.

4.16 Sources of Pollution

Improper waste disposal contributes to environmental pollution. Pollution is the introduction of harmful substances into the environment, causing damage to living beings and natural systems.

Major sources of pollution include:

- Industries
- Vehicles
- Sewage discharge
- Mining
- Chemicals
- Agricultural runoff
- Open waste dumping

4.17 Types of Pollution (Refer Table 4.1)

Table 4.1: Types of Pollution

Type of Pollution	Details / Pollutants Involved
Air Pollution	Air pollution occurs when harmful solid particles and gases contaminate the atmosphere. Common pollutants include vehicle emissions, industrial smoke, chemical gases, dust, and pollen.
Water Pollution	Water pollution occurs when toxic substances enter water bodies such as rivers, lakes, oceans, and groundwater, making water unsafe for use. Common pollutants include untreated sewage, industrial chemicals, oil spills, and dumped waste.
Soil Pollution	Soil pollution is the presence of harmful chemicals or contaminants in soil at levels that may affect human health or ecosystems. Common sources include heavy metals, fertilizers, pesticides, phosphates, carbonates, sulfates, and nitrates.
Noise Pollution	Noise pollution occurs when unwanted sound from traffic, aircraft, industries, construction, or loudspeakers reaches harmful levels. Underwater noise from ships can also disturb marine life and navigation systems of whales and other species.
Light Pollution	Light pollution is the excessive or misdirected artificial light in the night sky, mainly found in urban areas. It can disturb ecosystems, affect wildlife behavior, and confuse the natural cycle of day and night.

4.18 Organization's Focus on Greening of Jobs

Greening of jobs means designing work practices that protect the environment, conserve resources, and support sustainability. Organizations now focus on:

- Renewable energy use
- Waste reduction
- Pollution control
- Eco-friendly operations
- Sustainable employment practices

4.18.1 ESG

ESG stands for **Environmental, Social, and Governance**. It is a framework used to evaluate how responsibly a business operates. Many organizations are audited for ESG compliance. ESG helps assess how companies manage:

- **Environmental impact:** It measures how business activities affect air, water, land, and natural resources. It also evaluates efforts to reduce pollution and conserve energy.
- **Social responsibility:** It examines how the company contributes to society and supports community welfare. It includes fair treatment of customers, suppliers, and society.

- **Ethical governance:** It checks whether the company follows honest, transparent, and lawful management practices. Strong governance prevents corruption and misuse of power.
- **Employee welfare:** It evaluates workplace safety, fair wages, health benefits, and employee satisfaction. Good welfare practices improve productivity and morale.
- **Human rights:** It ensures that the company respects equality, dignity, and freedom of all people. It also checks for child labour, discrimination, and unfair treatment.
- **Long-term sustainability:** It measures whether the company can grow responsibly while protecting future resources. Sustainable practices support long-term success.

4.18.2 Importance of ESG

- Builds company reputation
- Creates long-term value
- Attracts investors
- Reduces risks
- Improves stakeholder trust
- Encourages sustainable growth

4.18.3 Factors of ESG

Several factors are considered to evaluate how effectively an organization follows its ESG (Environmental, Social, and Governance) policies. Understanding these factors is important for developing a strong and effective ESG policy. These factors are broadly divided into three categories: environmental, social, and governance. Proper knowledge of these areas helps organizations create and implement successful ESG practices.

Environmental

Environmental factors relate to a business's impact on the environment. Examples include:

- Usage of renewable energy
- Effective waste management
- Policies for protecting and preserving the environment

Social

Social factors relate to the people of the organization. How they are treated in the organization is what it focuses on. The major entities are the stakeholders, employees, and customers. Examples include:

- diversity and inclusion
- proper work conditions and labour standards
- relationships with the community

Governance

Governance factors relate to the company policies for effectively running it. They include:

- tax strategies
- structure of the company
- relationship with stakeholders
- payments to the employees and CEO

Each factor plays an important role in determining a company's overall ESG compliance rating. Ignoring any one aspect can negatively affect both the ESG rating and the company's reputation.

Companies should clearly communicate their ESG policies to employees as well as the public. They should also explain the activities and practices they follow to protect the environment, support people and society, and maintain good governance standards.

PRACTICAL ACTIVITY

ACTIVITY 1:

Awareness on Proper E-Waste Disposal

Objective: To raise awareness about proper e-waste disposal and recycling practices.

Materials Required: Posters, pamphlets, old electronic items, collection boxes, record register, marker pens.

Procedure:

1. Conduct a workshop to explain the dangers of improper e-waste disposal and the benefits of recycling.
2. Display informative posters on e-waste management in the workplace.
3. Set up designated collection points for old electronic devices such as mobiles, chargers, and computer parts.
4. Coordinate with certified e-waste recycling companies for safe disposal.
5. Maintain records of collected e-waste and share progress reports.

Activity 2:

Waste Segregation Awareness

Objective: To educate employees about segregation of recyclable and non-recyclable waste.

Materials Required: Waste samples or pictures, pamphlets, labelled bins, chart paper.

Procedure:

1. Distribute educational materials explaining recyclable and non-recyclable waste.
2. Organize a sorting game where employees classify waste items into correct categories.
3. Discuss the importance of waste segregation for recycling and environmental protection.
4. Place clearly labelled bins for recyclable and non-recyclable waste.
5. Encourage employees to follow segregation practices daily.

ACTIVITY 3:**Familiarization With Tricolour Bin System**

Objective: To familiarize employees with the tricolor waste bin system.

Materials Required: Green, blue, and black bins, waste samples, labels, quiz sheets.

Procedure:

1. Conduct an information session explaining the purpose of green, blue, and black bins.
2. Explain which types of waste should be placed in each bin.
3. Organize an interactive quiz to test understanding of bin usage.
4. Check that all bins are properly labelled and placed in suitable locations.
5. Conduct a role-play demonstration of correct waste disposal practices.

CHECK YOUR PROGRESS**A. Multiple Choice Questions**

1. Your office is replacing outdated electronic devices. Which item should be sent for e-waste recycling?
 - a) Banana peel
 - b) Old mobile phone
 - c) Tea leaves
 - d) Garden waste

2. In the cafeteria, leftover food and vegetable peels need to be disposed of correctly. Which bin should be used?
 - a) Blue
 - b) Black
 - c) Green
 - d) Red

3. A housing society wants to convert kitchen waste into useful manure for gardens. Which waste disposal method should be adopted?
 - a) Incineration
 - b) Composting
 - c) Landfill
 - d) Compaction

4. A company wants to improve investor trust, employee welfare, and environmental responsibility. Which framework should it adopt?
 - a) Energy, Safety, Growth
 - b) Environmental, Social, Governance
 - c) Economic, Social, Green
 - d) Ecology, Safety, Governance

5. A city administration wants to reduce harmful pollutants in the atmosphere. Which source should be controlled first?
 - a) Vehicle emissions
 - b) Broken glass
 - c) Food waste
 - d) Cardboard

B. Match the following

Column A	Column B
1. Green Bin	A. Dry recyclable waste
2. Blue Bin	B. Wet biodegradable waste
3. Black Bin	C. Hazardous domestic waste
4. Composting	D. Organic waste to manure
5. ESG	E. Environmental, Social, Governance

C. Fill in the blanks

1. Discarded electrical and electronic devices are called _____.
2. The _____ bin is used for dry recyclable waste.
3. Waste that cannot be reused safely is called _____ waste.
4. _____ pollution is caused by excessive unwanted sound.
5. ESG helps improve long-term company _____.

D. Answer the following

1. A company stores damaged batteries, old wires, and broken keyboards in an open area. How would you organize safe handling and disposal of these materials?

2. During an office event, paper cups, food leftovers, and used tissues are mixed in one dustbin. What waste segregation system would you implement?
3. A manufacturing unit receives complaints about loud machine noise and smoke emissions. What measures would you suggest to control these forms of pollution?
4. An organization wants to improve its ESG score related to environmental factors. What practical actions would you recommend?
5. A school campus plans to start green practices for students and staff. What steps would you suggest for waste management and sustainability?

ANSWER KEY

MODULE 1: Introduction to the Role of an Automotive IIOT Application Technician

Session 1: Overview of Indian Automobile Manufacturing Market

Multiple Choice Questions	Match the following	Fill in the blanks
1. D 2. B 3. C 4. A 5. B	1-C 2-A 3- D 4-E 5-B	1. 7.1 2. 3.9 3. infrastructure 4. electric 5. 35

Session 2: Introduction to the Automotive Industry

Multiple Choice Questions	Match the following	Fill in the blanks
1. D 2. C 3. B 4. A 5. A	1-E 2-D 3-A 4-B 5-C	1. mechanical, electrical, electronic 2. Mechatronics 3. Electronic Control Unit 4. Electric motors, rechargeable batteries 5. electric

Session 3: Introduction to IIOT

Multiple Choice Questions	Match the following	Fill in the blanks
1. C 2. C 3. B 4. C 5. C	1-B 2-E 3- A 4- C	1. real-time 2. Temperature 3. GPS 4. internet 5. gas leaks

	5- D	
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Session 4: Role & Responsibilities of an Automotive IIOT Application Technician

Multiple Choice Questions	Match the following	Fill in the blanks
1. B 2. B 3. B 4. B 5. B	1 – B 2 – A 3 – C 4 – D 5 – E	1. device configuration 2. ring 3. environmental 4. cybersecurity 5. PLC

MODULE 2: Building Blocks of Automotive IIOT

Session 1: Fundamentals of Microcontrollers

Multiple Choice Questions	Match the following	Fill in the blanks
1. B 2. B 3. B 4. B 5. B	1-C 2-A 3- B 4- D 5- E	1. Brain 2. A0 3. ESP8266 4. Arduino IDE 5. physical

Session 2: Automotive IIOT Sensors and Actuators

Multiple Choice Questions	Match the following	Fill in the blanks
1. D 2. B 3. D 4. B 5. A	1-E 2-D 3- A 4- B 5- C	1. physical 2. digital thermometer 3. energy into motion 4. physical contact 5. humidity sensor

Session 3: Interfacing Sensors with Microcontroller

Multiple Choice Questions	Match the following	Fill in the blanks
1. B 2. B	1-B	1. electrical

3. B	2-A	2. analog
4. B	3- C	3. digitalRead()
5. B	4- D	4. 3.3
	5- E	5. storing

MODULE 3: Industrial Network Design and Integration

Session 1: IIOT Network Architecture and Devices

Multiple Choice Questions	Match the following	Fill in the blanks
1. C	1-E	1. Physical Layer
2. B	2-D	2. HMI (Human Machine Interface)
3. B	3- A	3. Data Link Layer
4. C	4- B	4. Edge devices
5. C	5- C	5. Switch

Session 2: Network Topologies and Protocols

Multiple Choice Questions	Match the following	Fill in the blanks
1. C	1-E	1. PROFINET
2. C	2-D	2. Tree
3. B	3- A	3. OPC UA
4. B	4- B	4. signal grounding
5. B	5- C	5. bits

Session 3: IIOT Sensor and Device Integration

Multiple Choice Questions	Match the following	Fill in the blanks
1. B	1-E	1. Edge
2. B	2-D	2. Network
3. A	3- B	3. bidirectional
4. A	4- C	4. electrical
5. A	5- A	5. interoperability

Session 4: Data Management, Security and Documentation in IIOT Networks

Multiple Choice Questions	Match the following	Fill in the blanks
1. C 2. B 3. B 4. C 5. B	1-D 2-C 3- E 4- A 5- B	1. machine 2. process 3. instructions 4. UPS 5. Lockout-Tagout

MODULE 4: Organisation Work and Resources as per Health and Safety Standards

Session 1: Workplace Health and Safety Practices

Multiple Choice Questions	Match the following	Fill in the blanks
1. B 2. C 3. C 4. B 5. C	1 – B 2 – C 3 – A 4 – D 5 – E	1. First Aid 2. emergency 3. PPE 4. Time 5. supervisor

Session 2: Organisation's Green Practices

Multiple Choice Questions	Match the following	Fill in the blanks
6. B 7. C 8. B 9. B 10.A	1-B 2-A 3-C 4-D 5-E	1. e-waste 2. blue 3. non-recyclable 4. Noise 5. sustainability

GLOSSARY

Term	Meaning
Actuator	A device that converts control signals into physical action such as movement, switching, or valve operation.
AGV	Automated Guided Vehicle used for material movement in factories through guided routes.
Alarm	A warning indication generated when a machine or process crosses set limits or detects a fault.
Analytics	The study of collected data to identify patterns, trends, and useful insights.
Bandwidth	The total data carrying capacity of a communication network.
Blind Spot (Connectivity)	An area or condition where devices fail to communicate effectively due to weak signal, faults, or configuration issues.
Cable Tester	A tool used to check cable continuity, wiring faults, and signal quality.
Cloud Computing	Use of remote servers on the internet for storing, processing, and analyzing data.
Cloud Dashboard	Online dashboard used to view machine data, alerts, and reports remotely.
Communication Protocol	Rules that define how data is exchanged between devices.
Connectivity	The ability of devices to establish and maintain communication.
Controller	A device such as PLC or RTU used to control machines and industrial processes.
CRC Error	Cyclic Redundancy Check error indicating corrupted or damaged data transmission.
Dashboard	Graphical interface used to display machine status, alarms, charts, and KPIs.
Data Acquisition	Process of collecting data from sensors, machines, or industrial systems.
Data Logging	Recording operational data for future review and analysis.
DHCP	Dynamic Host Configuration Protocol that automatically assigns IP addresses to devices.
Downtime	Period during which a machine, network, or system is not functioning.
Edge Device	A device located near machines that processes data locally before sending it to the cloud.
Edge Computing	Processing data near the source device to reduce delay and network load.

Emergency Stop	Safety mechanism used to stop a machine immediately during danger or malfunction.
Ethernet	Standard wired networking technology used in industrial communication systems.
Ethernet Switch	Device used to connect multiple Ethernet devices in a local network.
Event Log	Stored record of alarms, faults, and system events with timestamps.
Firmware	Embedded software stored inside a device for controlling its functions.
Firewall	Security system used to block unauthorized network access.
Flow Sensor	Sensor used to measure liquid or gas flow rate in a system.
Gateway	Device that connects different networks and transfers industrial data to cloud platforms.
HMI	Human Machine Interface used by operators to control and monitor machines.
Historical Data	Previously stored operational data used for trend analysis and maintenance planning.
IIOT	Industrial Internet of Things – smart industrial devices connected for monitoring and control.
Interference	Disturbance that weakens communication signals due to noise or overlapping frequencies.
IP Address	Unique numerical address assigned to each device in a network.
I/O Link	Industrial communication standard for connecting smart sensors and actuators.
I/O Link Master	Device that connects I/O Link sensors/actuators with PLCs or networks.
Jitter	Variation in packet timing that affects real-time communication performance.
KPI	Key Performance Indicator used to measure machine or process performance.
Latency	Delay in transmitting data between source and destination.
LiDAR	Light Detection and Ranging technology used to detect distance and objects.
Load Balancing	Distribution of network traffic evenly across multiple devices or paths.
Machine Learning	AI method where systems learn patterns from data for prediction or decision-making.
Maintenance	Activities carried out to keep equipment in proper working condition.
Mesh Topology	Network arrangement where devices are interconnected with multiple paths.
Modbus	Common industrial communication protocol for exchanging data between devices.

MQTT	Lightweight publish-subscribe messaging protocol used in IoT systems.
Network Health Monitoring	Continuous checking of network condition, performance, and connected devices.
Network Mapping	Creating a layout of connected devices, paths, and communication links.
Network Topology	Physical or logical arrangement of devices in a network.
Node	Any connected device in a communication network.
OPC UA	Secure industrial communication protocol for data exchange and interoperability.
Oscilloscope	Instrument used to observe electrical signal waveforms and quality.
Packet Loss	Failure of data packets to reach the destination device.
Ping Test	Basic network test used to check connectivity and response time.
PLC	Programmable Logic Controller used in industrial automation systems.
Predictive Analytics	Use of historical and real-time data to predict future events or failures.
Predictive Maintenance	Maintenance approach based on predicted equipment condition or faults.
Pressure Sensor	Sensor used to measure gas or liquid pressure.
Proactive Analysis	Studying data trends in advance to prevent faults or downtime.
Protocol Analyzer	Tool used to capture and analyze communication data packets.
Proximity Sensor	Sensor that detects nearby objects without physical contact.
QoS	Quality of Service technique used to prioritize critical network traffic.
Real-Time Data	Data received and displayed immediately as events happen.
Remote Control	Ability to operate equipment from a distant location through a network.
Remote Monitoring	Observation of machines and systems from a remote location.
Router	Device that forwards data between different networks.
RTU	Remote Terminal Unit used for remote monitoring and control applications.
SCADA	Supervisory Control and Data Acquisition system used for industrial control and monitoring.
Sensor	Device that detects physical conditions such as temperature, pressure, or motion.
Signal Strength	Quality or power level of a communication signal.
Star Topology	Network arrangement where all devices connect to a central switch or hub.

Subnet Mask	Value used with an IP address to identify network and host portions.
Systematic Troubleshooting	Step-by-step method used to identify and solve faults.
Temperature Probe	Device used to measure temperature directly.
Thermal Camera	Camera used to detect heat patterns and abnormal temperature rise.
Throughput	Actual rate of successful data transfer in a network.
Traffic Analysis	Examination of network data flow to detect congestion or faults.
Trend Graph	Graph showing parameter changes over time.
Troubleshooting	Process of identifying and correcting faults in a system.
Uptime	Total time during which a machine or network remains operational.
Vibration Sensor	Sensor used to monitor vibration levels in rotating machinery.
VLAN	Virtual Local Area Network used to logically divide network sections.
VPN	Virtual Private Network used for secure remote access.
Wear Alarm	Alarm indicating excessive wear or maintenance need in machine components.
Wireshark	Software tool used for packet capture and network analysis.
Wireless Network	Communication network that uses radio signals instead of cables.



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