

**DEPARTMENT OF INFORMATION TECHNOLOGY & COMPUTER
ENGINEERING**



LECTURE NOTES

SUBJECT: INTRODUCTION TO IOT

BRANCH: 5TH SEM, IT

FACULTY NAME: DR. ANITARANI BRAHMA

Jharsuguda Engineering School, Jharsuguda

Department of Information Technology

Vision:

To focus on development of skilled and confident personalities of today and tomorrow by using cutting edge technology in the department of Information Technology to accept need based challenges with a sense of social responsibilities.

Mission:

- **M1:** To impart quality education by implementing state-of-the-art teaching-learning methods to enrich the academic competency, credibility and integrity of the students.
- **M2:** To implement the educational program in our department from fundamental engineering to recent technology as per emerging trends in the field of Information Technology.
- **M3:** To facilitate a conducive ambience and infrastructure to develop professional skills and nurture innovation in students.
- **M4:** To inculcate sensitivity towards society, respect for environment and promote high standards of ethics.

LEARNING OUTCOMES:

After completing this course, student will be able to:

- Explain Core IoT Concepts, including architecture, components, and communication models.
- Identify IoT Ecosystem Elements, such as sensors, actuators, microcontrollers, communication protocols, and cloud platforms.
- Integrate Hardware Components like Arduino, Raspberry Pi, sensors, and actuators for IoT projects.
- Analyze Sensor Data from IoT devices.
- Identify Common Security Threats in IoT ecosystems, including data breaches, device hijacking, and network vulnerabilities.

Course Outcome

CO1:

CO2:

CO3:

CO4:

CO5:

CHAPTER-1

Introduction to IOT

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Definition and significance of IoT :

Introduction

The Internet of Things (IoT) is one of the most important technological developments of the 21st century. It connects physical objects to the Internet, enabling them to collect, exchange, and process data automatically. IoT combines sensors, communication technologies, computing systems, and software applications to create intelligent environments that improve efficiency, productivity, and quality of life.

Today, IoT is widely used in homes, industries, healthcare, agriculture, transportation, and smart cities, making it a key component of digital transformation.

Definition of IoT

The **Internet of Things (IoT)** is a network of physical devices (things) embedded with sensors, software, processors, and communication technologies that enable them to collect, exchange, and process data over the internet.

The **Internet of Things (IoT)** refers to a network of physical devices, vehicles, appliances, sensors, and other objects embedded with electronics, software, sensors, and communication capabilities that enable them to connect and exchange data over the Internet.

According to the concept of IoT, everyday objects can communicate with each other and with centralized systems without requiring continuous human intervention.

Simple Definition

"IoT is a system in which physical objects are connected to the Internet and can collect, share, and act upon data."

Example

A smart air conditioner can measure room temperature using sensors, send the data to a cloud platform, and automatically adjust cooling settings based on user preferences.

Key Characteristics of IoT

a) Connectivity

IoT devices are connected through communication technologies such as Wi-Fi, Bluetooth, Zigbee, LoRaWAN, and cellular networks.

b) Sensing

Sensors collect information from the surrounding environment, such as temperature, humidity, pressure, motion, and light.

c) Intelligence

IoT systems analyze collected data and make intelligent decisions automatically.

d) Automation

Many tasks can be performed automatically without human intervention.

e) Real-Time Data Processing

IoT systems continuously monitor and process data to provide immediate responses.

f) Scalability

Millions of devices can be connected and managed simultaneously.

g) Interoperability

Different devices and platforms can communicate and work together effectively.

Components of IoT

An IoT system typically consists of the following components:

1. Sensors

Devices that collect data from the environment.

Examples:

- Temperature sensors
- Humidity sensors
- Motion sensors
- Pressure sensors

Connectivity

Communication networks used to transmit data.

Examples:

- Wi-Fi
- Bluetooth
- Zigbee
- LoRaWAN
- Cellular Networks (4G/5G)

Data Processing

Collected data is processed locally or in cloud servers to generate useful information.

4. User Interface

Allows users to monitor and control IoT devices through mobile applications, dashboards, or web interfaces.

Significance of IoT

IoT has transformed the way people interact with technology and the physical world. Its significance can be understood through the following aspects:

1. Improved Automation

IoT enables automatic monitoring and control of devices.

Examples:

- Smart lighting systems
- Automatic irrigation systems
- Smart thermostats

Benefits:

- Reduced human effort
- Increased efficiency

- Better resource utilization
-

2.Real-Time Monitoring

IoT allows continuous monitoring of equipment, environments, and processes.

Examples:

- Health monitoring wearables
- Industrial machine monitoring
- Environmental monitoring systems

Benefits:

- Immediate detection of abnormalities
 - Faster response to problems
 - Increased reliability
-

3.Better Decision Making

IoT devices generate large amounts of data that can be analyzed to support decision-making.

Examples:

- Traffic management systems
- Smart farming applications
- Business analytics platforms

Benefits:

- Accurate predictions
 - Improved planning
 - Enhanced productivity
-

4.Cost Reduction

Organizations can reduce operational costs through automation and predictive maintenance.

Examples:

- Energy-efficient buildings
- Predictive maintenance in industries
- Automated inventory management

Benefits:

- Lower maintenance costs
 - Reduced downtime
 - Increased profitability
-

5.Enhanced Healthcare

IoT has revolutionized healthcare through remote patient monitoring and smart medical devices.

Examples:

- Smart watches
- Heart-rate monitors
- Remote diagnostic systems

Benefits:

- Continuous health monitoring
 - Early disease detection
 - Improved patient care
-

6.Smart Cities Development

IoT is a key technology for developing smart cities.

Applications:

- Smart traffic management
- Smart parking systems
- Smart waste management
- Smart street lighting

Benefits:

- Improved public services
- Reduced congestion
- Efficient resource utilization

7. Industrial Transformation

Industrial IoT (IIoT) enables intelligent manufacturing and Industry 4.0.

Applications:

- Machine monitoring
- Quality control
- Predictive maintenance
- Supply chain management

Benefits:

- Increased productivity
 - Reduced downtime
 - Better product quality
-

Applications of IoT

Smart Homes

- Smart lighting
- Smart locks
- Smart appliances

Healthcare

- Remote patient monitoring
- Wearable devices
- Telemedicine

Agriculture

- Precision farming
- Soil monitoring
- Automated irrigation

Transportation

- Connected vehicles
- Fleet management
- Traffic monitoring

Industry

- Smart manufacturing
- Asset tracking
- Process automation

Advantages of IoT

1. Automation of tasks
2. Improved efficiency
3. Better resource management
4. Real-time monitoring
5. Enhanced decision making
6. Reduced operational costs
7. Improved customer experience

Challenges of IoT

1. Security vulnerabilities
2. Privacy concerns
3. Interoperability issues
4. High implementation cost
5. Network dependency
6. Data management challenges
7. Power consumption issues

Historical Evolution of IoT

The evolution of IoT can be divided into several phases based on technological advancements.

Phase I: Early Foundations (1960s–1980s)

Development of Embedded Systems

The roots of IoT can be traced back to the development of embedded systems and microprocessors.

Key Developments:

- Introduction of microcontrollers and microprocessors.
- Development of programmable logic controllers (PLCs).
- Growth of industrial automation systems.
- Emergence of computer networking technologies.

Significance

During this phase, machines could perform automated tasks but lacked Internet connectivity.

Example:

- Automated manufacturing systems in industries.
-

Phase II: Emergence of Networking Technologies (1980s–1990s)

Machine-to-Machine (M2M) Communication

The concept of devices communicating with each other began to emerge.

Key Technologies:

- Local Area Networks (LANs)
- Ethernet
- Wireless communication technologies

RFID Technology

Radio Frequency Identification (RFID) became an important milestone.

RFID Features:

- Wireless identification of objects.
- Tracking and inventory management.
- Supply chain monitoring.

Example

Retail companies started using RFID tags to monitor inventory and logistics.

Phase III: Birth of the Internet of Things Concept (1999)

Coining of the Term "Internet of Things"

The term **Internet of Things (IoT)** was first introduced by:

Kevin Ashton

While working at Procter & Gamble, Ashton proposed using RFID technology to connect physical objects to the Internet.

Importance

This marked the beginning of the IoT era and introduced the vision of connecting everyday objects to digital networks.

Phase IV: Expansion of Wireless and Internet Technologies (2000–2010)

During this period, the Internet became widely available, and wireless technologies matured.

Major Developments

Wireless Communication

- Wi-Fi
- Bluetooth
- Zigbee

Sensor Technology

- Miniaturized sensors

- Low-power electronics
- Wireless sensor networks

Mobile Computing

- Smartphones
- Mobile applications
- GPS technology

Impact

Devices could now:

- Collect data
- Transmit information
- Be remotely monitored and controlled

Example

Smart home systems began to appear, enabling remote control of lights and appliances.

Phase V: Cloud Computing and Big Data Era (2010–2020)

Cloud Computing Revolution

Cloud platforms transformed IoT by providing:

- Large-scale data storage
- Remote device management
- Data analytics capabilities
- Scalability

Big Data Analytics

IoT devices generated enormous amounts of data, leading to:

- Predictive analytics
- Real-time monitoring
- Business intelligence

Growth of Smart Applications

Smart Homes

- Smart thermostats

- Smart security systems

Smart Cities

- Traffic management
- Smart parking

Healthcare

- Wearable devices
- Remote patient monitoring

Industrial IoT (IIoT)

Manufacturing industries adopted IoT for:

- Predictive maintenance
 - Process optimization
 - Quality control
-

Phase VI: AI-Driven IoT and Industry 4.0 (2020–Present)

Artificial Intelligence Integration

Modern IoT systems increasingly integrate:

- Machine Learning (ML)
- Artificial Intelligence (AI)
- Deep Learning

Edge Computing

Data processing is performed closer to devices, reducing:

- Latency
- Bandwidth consumption
- Response time

5G Connectivity

5G networks provide:

- Ultra-low latency
- High-speed communication
- Massive device connectivity

Examples

- Autonomous vehicles
- Smart factories
- Intelligent healthcare systems
- AI-powered surveillance systems

Future Prospects of IoT

The future of IoT is highly promising due to rapid advancements in communication, computing, and artificial intelligence.

1 Smart Cities

IoT will play a central role in developing smart cities.

Applications:

- Smart traffic control
- Intelligent transportation
- Smart energy grids
- Waste management systems
- Smart street lighting

Benefits:

- Reduced congestion
 - Lower energy consumption
 - Improved public services
-

2 Smart Healthcare

Future healthcare systems will rely heavily on IoT.

Applications:

- Continuous patient monitoring
- AI-assisted diagnosis
- Remote surgeries
- Smart medical devices

Benefits:

- Early disease detection
 - Reduced healthcare costs
 - Improved patient outcomes
-

3 Industrial IoT (IIoT)

Future industries will use connected machines and intelligent automation.

Applications:

- Digital twins
- Predictive maintenance
- Robotics
- Smart manufacturing

Benefits:

- Higher productivity
 - Reduced downtime
 - Better quality control
-

4 Autonomous Vehicles

IoT will support:

- Vehicle-to-Vehicle (V2V) communication
- Vehicle-to-Infrastructure (V2I) communication
- Smart traffic systems

Benefits:

- Increased road safety
 - Reduced accidents
 - Efficient transportation
-

5 Agriculture 4.0

Future agriculture will become highly data-driven.

Applications:

- Smart irrigation
- Crop monitoring
- Precision farming
- Livestock tracking

Benefits:

- Increased productivity
 - Reduced water usage
 - Sustainable farming
-

6 Artificial Intelligence and IoT (AIoT)

The convergence of AI and IoT, known as **AIoT**, will enable:

- Self-learning systems
- Intelligent automation
- Predictive decision-making
- Autonomous operations

Examples:

- Smart robots
 - Intelligent factories
 - Personalized healthcare systems
-

7 Edge Computing and Fog Computing

Future IoT systems will increasingly process data near the source.

Advantages:

- Faster response time
 - Reduced cloud dependency
 - Enhanced security
 - Lower network congestion
-

8 Green IoT

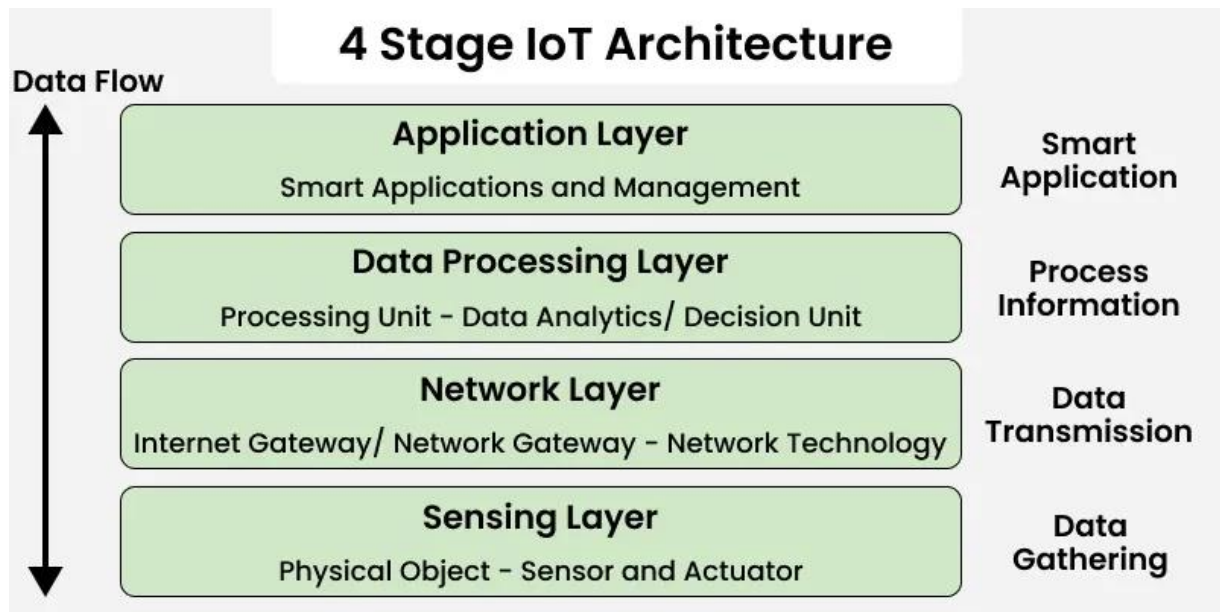
Future IoT development will focus on sustainability.

Objectives:

- Energy-efficient devices
- Renewable energy integration
- Reduced carbon footprint
- Environment-friendly technologies

Layering Architecture of Internet of Things (IoT)

- The IoT architecture acts as the foundation for all connected devices and applications.
- Each layer has a distinct role, from sensing real-world data to delivering intelligent actions.
- A clear structure ensures scalability, security and smooth device communication.
- The architecture of [Internet of Things](#) consists of four different layers i.e. Sensing Layer, Network Layer, Data processing Layer and Application Layer.



1. Sensing Layer

This is the bottom-most layer responsible for detecting physical conditions from the environment.

Functions

- Collects raw data such as temperature, humidity, motion, sound or pressure.
- Senses changes in the surroundings through embedded components.

- Initiates actions using actuators when required.

Components

- Sensors like humidity, gas, infrared, ultrasonic
- Actuators like motors, switches, valves
- Microcontrollers and RFID tags

Communication: Transfers sensed data to the network layer via wired or wireless links.

2. Network Layer

This layer provides connectivity and communication between IoT devices and cloud systems.

Functions

- Transmits collected sensor data to processing platforms securely.
- Supports device-to-device and device-to-server communication.
- Handles addressing, routing and data forwarding.

Technologies

- Wi-Fi, Bluetooth, Zigbee, LoRaWAN
- Ethernet and satellite networks
- Supporting Devices
- Routers and switches

3. Data Processing Layer

This layer analyzes, filters and interprets data received from network devices.

Functions

- Cleans and formats raw sensor data for meaningful insights.
- Applies analytics to detect patterns or abnormalities.
- Stores data for historical analysis or reporting.

Components

- IoT cloud platforms
- Data lakes and warehouses
- Stream processing and machine learning engines

Output

- Predictive alerts and reports
- Anomaly detection signals
- Decision rules for automation

4. Application Layer

This top-most layer interacts directly with end users and business systems.

Functions

- Provides interfaces to monitor and control IoT devices remotely.
- Displays visual analytics through dashboards and charts.
- Triggers automated actions based on processed insights.

Components

- Mobile applications
- Web dashboards and portals
- Visualization and alerting tools

Capabilities

- Remote device management
- Real-time condition monitoring
- Integration with enterprise applications

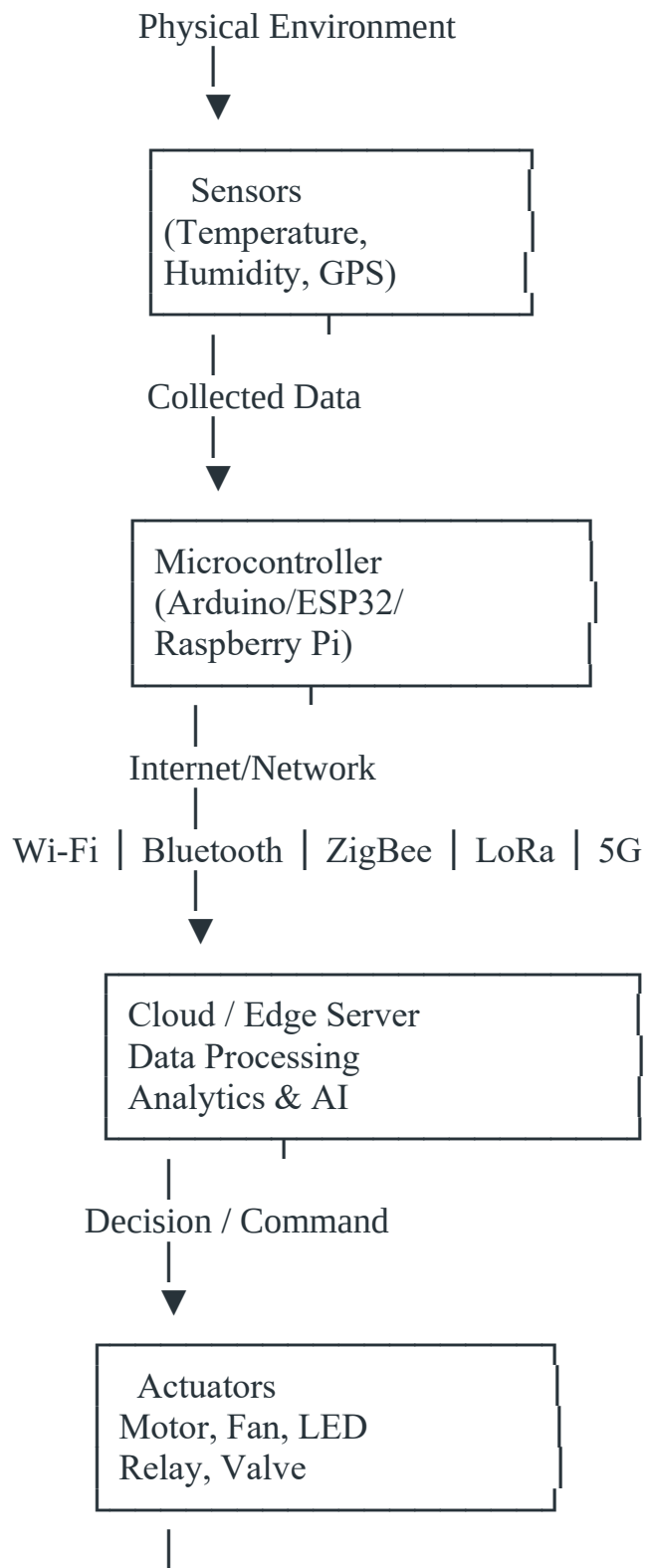
Basic Architecture of IOT:

The **Internet of Things (IoT)** is a network of physical devices (things) embedded with sensors, software, processors, and communication technologies that enable them to collect, exchange, and process data over the internet.

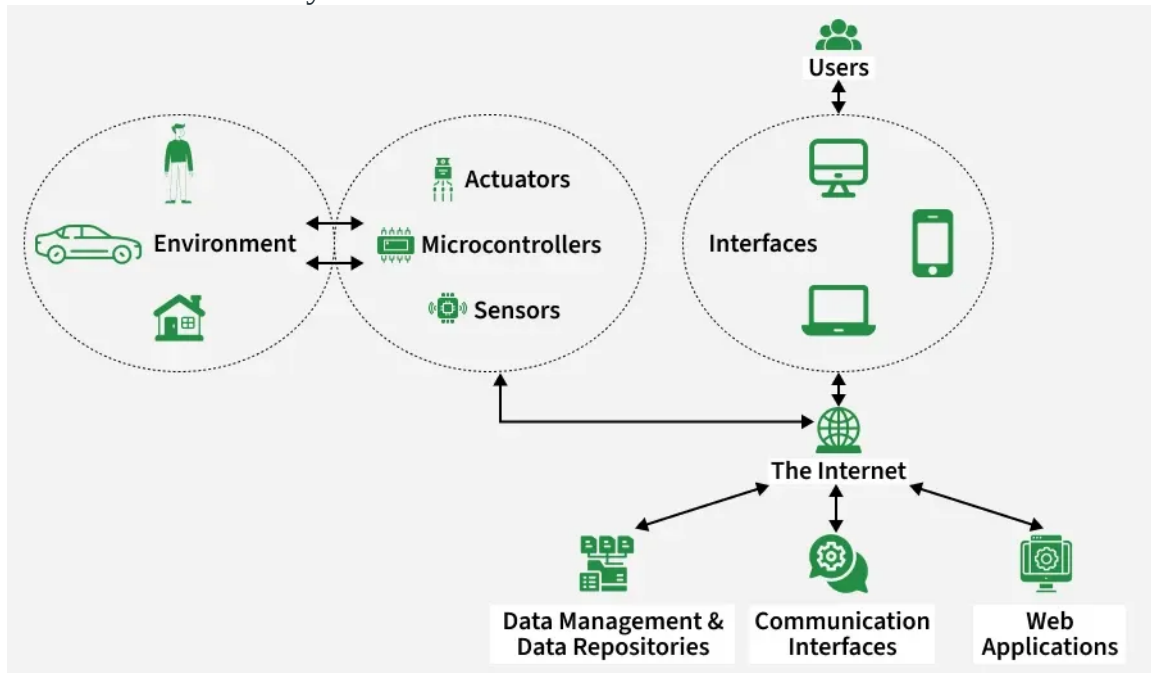
Components of IoT System

An IoT system is built using multiple interconnected components that work together to sense data, process it, transmit it over networks, and present useful information to users or trigger actions automatically.

- **IoT Devices (Things):** Physical objects such as appliances, machines, vehicles, or wearables that sense data from the environment or perform actions.
- **Sensors and Actuators:** Sensors collect environmental data like temperature, motion, or light, while actuators convert digital signals into physical actions.
- **Embedded Processing Units:** Microcontrollers or microprocessors that process sensor data, execute control logic, and manage device operations.
- **Connectivity Modules:** Enable devices to communicate over networks using technologies such as Wi-Fi, Bluetooth, cellular networks, or LPWAN.
- **IoT Gateways:** Aggregate data from multiple devices, perform protocol translation, and securely transmit data to cloud or edge platforms.
- **Cloud / Edge Computing:** Cloud platforms store and analyze large IoT data, while edge computing processes data near the source to reduce latency.
- **User Interface and Applications:** Dashboards, mobile apps, or web interfaces that allow users to monitor data, control devices, and receive alerts.



Action in Physical World



1. Sensors:

A **sensor** is an electronic device that detects changes in the physical environment and converts them into electrical signals.

Sensors are the **input devices** of an IoT system.

Functions of Sensors

- Measure physical quantities
- Convert physical signals into electrical signals
- Send data to the controller
- Enable automatic monitoring

Common Types of Sensors

Sensor	Measures	Example Application
Temperature Sensor	Temperature	Weather Station
Humidity Sensor	Moisture	Smart Agriculture
Light Sensor (LDR)	Light Intensity	Automatic Street Lights
Motion Sensor (PIR)	Human Movement	Security Systems
Gas Sensor	Smoke/Gas	Fire Detection

Sensor	Measures	Example Application
Pressure Sensor	Pressure	Industrial Monitoring
GPS Sensor	Location	Vehicle Tracking
Ultrasonic Sensor	Distance	Parking System

Characteristics of Good Sensors

- High accuracy
- Fast response
- Reliability
- Low power consumption
- Long lifespan
- Low maintenance

2.Actuators:

An **actuator** is an output device that converts electrical signals into physical action.

It receives commands from the controller after data processing.

Functions

- Perform mechanical actions
- Control electrical devices
- Respond automatically to sensor data

Types of Actuator:

Actuator	Action
Motor	Rotates objects
Servo Motor	Controls angle
Relay	Switches appliances
Solenoid Valve	Opens or closes valves
LED	Visual indication
Buzzer	Sound alert
Fan	Cooling
Pump	Moves liquids

Actuator

E.g. If a temperature sensor detects **40°C**, the controller activates a **fan** using a relay.

Action

Sensor Vs Actuator:

Sensor	Actuator
Input Device	Output Device
Detects changes	Performs action
Produces data	Uses commands
Examples: Temperature, Gas, Motion	Motor, Relay, Fan

3. Connectivity:

Connectivity is the communication medium through which IoT devices exchange information with cloud servers or other devices.

Without connectivity, IoT devices cannot communicate.

Common Communication Technologies

A. Wi-Fi

- High speed
- Medium range
- Internet access
- Used in smart homes

Advantages

- Fast
- Easy installation

Disadvantages

- Higher power consumption

B. Bluetooth

- Short range
- Low power

- Device-to-device communication

Applications

- Smart watches
 - Wireless headphones
 - Health monitoring
-

C. ZigBee

- Low power
- Medium range
- Mesh networking

Applications

- Smart lighting
 - Home automation
 - Industrial IoT
-

D. LoRa

- Very long range
- Very low power
- Low data rate

Applications

- Smart agriculture
 - Environmental monitoring
 - Smart cities
-

E. Cellular Networks (4G/5G)

- Wide coverage
- High speed
- Suitable for mobile IoT

Applications

- Connected vehicles

- Smart transportation
- Remote monitoring

4. Data Processing

Data processing is the stage where collected sensor data is analyzed to make intelligent decisions.

Processing may occur:

- Inside the device (Edge Computing)
- In the Cloud
- At Fog Nodes

Steps in Data Processing

Step 1: Data Collection

Sensors continuously collect information.

Example:

Temperature = 32°C

Humidity = 70%

Step 2: Data Transmission

Data is transmitted through communication networks.

Example:

ESP32 → Wi-Fi → Cloud

Step 3: Data Storage

Information is stored in:

- Cloud databases

- Local servers
 - Edge devices
-

Step 4: Data Analysis

Algorithms analyze the received information.

Examples:

- Pattern recognition
 - Machine learning
 - Threshold detection
-

Step 5: Decision Making

Rules determine appropriate actions.

Example:

IF Temperature > 35°C

THEN Turn ON Fan

Step 6: Action

Commands are sent to actuators.

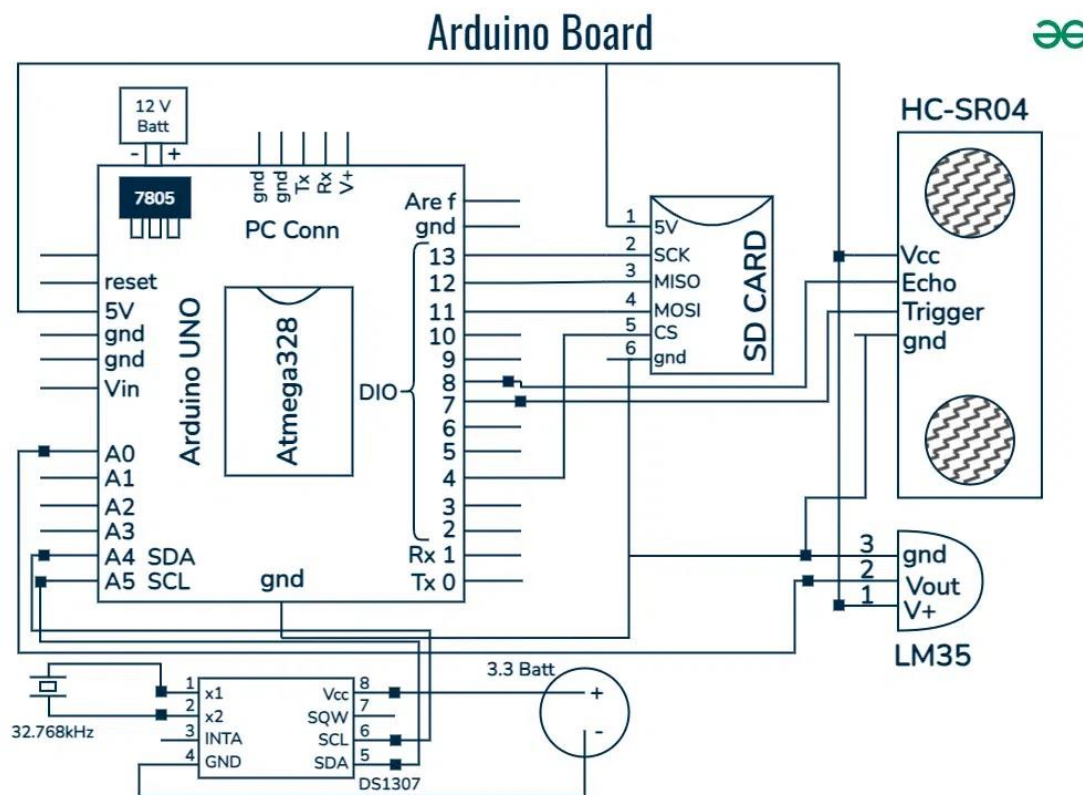
Example:

Fan starts automatically.

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What is Arduino?

- [Arduino](#) is an open-source, cross-platform, very simple hardware and software environment intended for interactive projects.
- It is a microcontroller-based development electronic board having—a computer in one chip—besides a development environment within which one writes, compiles, and ultimately downloads code onto the microcontroller.
- It provides digital, analog, power, and communication pins for connecting external devices.
- The **Arduino Uno** has **14 digital I/O pins**, **6 analog input pins**, power pins, and communication pins.



The Arduino Uno board has:

- 14 digital I/O pins
- 6 analog input pins
- 4 power pins
- 1 reset pin
- 1 ICSP header
- **Digital Pins (0–13):** Used for standard input/output. Pins 0 (RX) and 1 (TX) are reserved for serial communication.
. Pins 3, 5, 6, 9, 10, and 11 support Pulse Width Modulation (PWM) for motor control and LED dimming.
- **Analog Input Pins (A0–A5):** Measure varying voltages (0–5V) using a 10-bit Analog-to-Digital Converter, mapping values from 0 to 1023.
- **Power Pins:**
 - **5V and 3.3V:** Provide regulated voltage outputs to power external sensors.
 - **GND (Ground):** Completes electrical circuits.
 - **Vin:** Connects an external power supply (7–12V recommended) to the board.

To configure or control these pins, the standard Arduino IDE functions:

- `pinMode(pin, mode)`: Defines pin behavior as `INPUT` or `OUTPUT`.
- `digitalWrite(pin, state)`: Sends a `HIGH` (5V) or `LOW` (0V) to an output pin.
- `analogRead(pin)`: Reads the value of an analog input

Advantages of Arduino

- **User Friendly:** [Arduino IDE](#) is so user-friendly that even a complete beginner finds it very easy to learn.
- **Above all:** Open-source, Arduino has an enormous community providing a huge number of tutorials, libraries, and other resources.
- **variety of shields:** There exist a variety of shields that can give extended capabilities to an Arduino for wireless, motor control, and even Internet connectivity.

- **Economical:** Arduino boards are much cheaper in price than most other microcontrollers or development boards.
- **Platform Independent:** The Arduino Software runs on Windows, Mac OS X and Linux.

Disadvantages of Arduino

- **Limited Computational Power:** The processing and memory resources of the Arduino boards are actually quite limited, so they cannot be used for higher operations, such as an operating system workable through intensive computation.
- **Absence of Multitasking:** Arduino boards are fundamentally designed for single-task execution, signifying their inability to manage several tasks concurrently.
- **Connectivity is limited:** While shields can absolutely extend the connective selection, the basic model of an Arduino does have its features lacking, such as Wi-Fi and Ethernet.

Raspberry Pi

The Raspberry Pi is a low-cost, small-sized, single-board computer developed by the Raspberry Pi Foundation.

Raspberry Pi is a complete computer with an installed [operating system](#)—a form of Linux on most versions.

It does all tasks that would normally be performed on a regular desktop; it browses the internet, it plays videos, and it runs software programs.

Advantages of Raspberry Pi

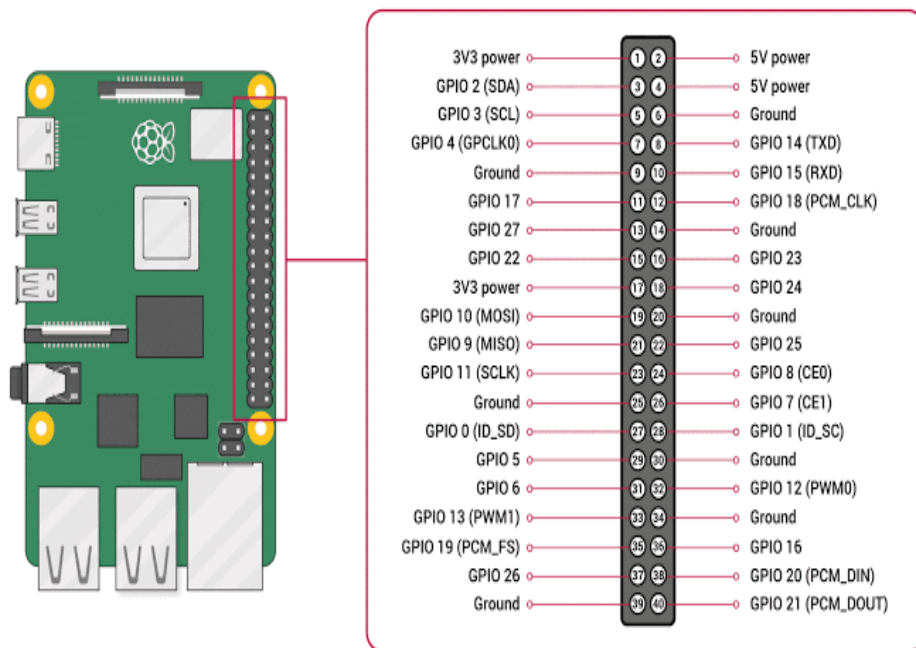
- **Full-Fledged Computer:** Raspberry Pi is running on a full-fledged operating system, which can perform tasks like running a desktop computer, including multitasking.
- **Versatile:** Means that the Raspberry Pi is useful for a wide range of uses — from simple projects like home automation to complex applications in artificial intelligence and machine learning.
- **Extensive Connectivity:** Raspberry Pi has numerous options for connectivity, such as HDMI, USB, [Ethernet](#), Wi-Fi, and Bluetooth, making the system ideal for networked projects.
- **Strong Community Support:** Besides Arduino, the Raspberry Pi is also developed on a Dynamite-sized community that boasts very active forums, tutorials, and resources.

- **GPIO Pins:** The Raspberry Pi makes it possible to interface with electronic components by the use of General Purpose Input/Output GPIO Pins, this is by far sophisticated compared to Arduino inputs.

Disadvantages of Raspberry Pi

- **Complexity:** Setting up and using the Raspberry Pi is a bit more complicated compared to Arduino, because it requires some knowledge of operating systems and possibly command-line interfaces.
- **High Power Consumption:** The Raspberry Pi has high power consumption compared to an Arduino, which could become a problem for battery-powered projects.
- **Cost:** Raspberry Pi is pretty cheap, though becomes rather expensive with the designing of the SD cards, power supplies, and cases in comparison to Arduino boards.

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Pin	Function	Pin	Function
1	3.3V	2	5V
3	GPIO2 (SDA1 - I2C)	4	5V
5	GPIO3 (SCL1 - I2C)	6	GND
7	GPIO4	8	GPIO14 (TXD - UART)
9	GND	10	GPIO15 (RXD - UART)
11	GPIO17	12	GPIO18 (PWM)
13	GPIO27	14	GND
15	GPIO22	16	GPIO23
17	3.3V	18	GPIO24
19	GPIO10 (MOSI - SPI)	20	GND
21	GPIO9 (MISO - SPI)	22	GPIO25
23	GPIO11 (SCLK - SPI)	24	GPIO8 (CE0 - SPI)
25	GND	26	GPIO7 (CE1 - SPI)
27	GPIO0 (ID_SD)	28	GPIO1 (ID_SC)
29	GPIO5	30	GN
31	GPIO6	32	GPIO12 (PWM)
33	GPIO13 (PWM)	34	GND
35	GPIO19 (PCM_FS/SPI)	36	GPIO16
37	GPIO26	38	GPIO20 (PCM_DIN/SPI)
39	GND	40	GPIO21 (PCM_DOUT/SPI)

Difference between Arduino and Raspberry Pi

S No.	Arduino	Raspberry Pi
1.	In the year 2005, the classrooms of the Interactive Design Institute in Ivrea, Italy, first introduced the Arduino board.	In the year 2012, Eben Upton first introduced the Raspberry Pi device in February.
2.	Control unit of the Arduino is from the At mega family.	The control unit of Raspberry Pi is from the ARM family.
3.	Arduino is based on a microcontroller.	While Raspberry Pi is based on a microprocessor.
4.	It is designed to control the electrical components connected to the circuit board in a system.	While Raspberry Pi computes data and produces valuable outputs, and controls components in a system based on the outcome of its computation.
5.	Arduino boards have a simple hardware and software structure.	While Raspberry Pi boards have a complex architecture of hardware and software.
6.	CPU architecture: 8 bit.	CPU architecture: 64 bit.
7.	It uses very little RAM, 2 kB.	While Raspberry Pi requires more RAM, 1 GB.

S No.	Arduino	Raspberry Pi
8.	It clocks a processing speed of 16 MHz.	While Raspberry Pi clocks a processing speed of 1.4 GHz.
9.	It is cheaper in cost.	While Raspberry Pi is expensive.
10.	It has a higher I/O current drive strength.	While Raspberry Pi has a lower I/O current drive strength.
11.	It consumes about 200 MW of power.	While it consumes about 700 MW of power.
12.	Its logic level is 5V.	Its logic level is 3V.
13.	It does not have internet support.	It has inbuilt Ethernet port and WiFi support.
14.	It has higher current drive strength.	It has lower current drive strength.
15.	Some of the applications of Arduino are traffic light countdown timer , Weighing machines , etc.	Some of the applications of Raspberry Pi are Stop motion cameras , Robot Controllers , Game Servers.
16.	Operating systems are required in Arduino.	Operating System is required in Raspberry Pi.

S No.	Arduino	Raspberry Pi
17.	Two tiny cores Arduino with 32 MHz	Single core and 700 MHz

Software components: Operating systems and Middleware

In an IoT system, **Operating Systems (OS)** manage hardware and execute local tasks, while **Middleware** bridges the gap between devices, networks, and cloud applications. These software components provide the foundational plumbing, data routing, and device security needed for seamless, distributed IoT functionality.

1. IoT Operating Systems (OS)

Unlike traditional desktop environments, IoT devices operate with strict constraints in memory, power, and processing. IoT operating systems handle low-level hardware interactions, task scheduling, and local security.

- **Real-Time Operating Systems (RTOS):** Systems like **FreeRTOS** or **Zephyr** are designed to execute highly deterministic tasks with zero-latency requirements (critical in medical devices or industrial controls).
- **Embedded Linux:** Used on more powerful "gateway" devices (e.g., Raspberry Pi), platforms like **Ubuntu Core** or **OpenWrt** support complex processing, heavy networking, and broad driver compatibility. [
- **Specialized IoT OS:** Systems such as **Contiki** or **TinyOS** are built specifically for extreme low-power, constrained microcontrollers and wireless sensor networks.

2. Middleware

Often referred to as the "software glue" or "plumbing" of IoT, middleware is an intermediate layer that translates protocols, manages device fleets, and aggregates data.

It abstracts the underlying complexities of hardware and networks, allowing developers to focus on application logic.

Core functions of IoT middleware include:

- **Connectivity & Protocol Management:** Facilitates communication across various wireless and wired networks using lightweight IoT protocols such as MQTT, CoAP, and AMQP.
- **Device Management:** Handles device onboarding, remote firmware updates (OTA), and health monitoring.
- **Data Processing & Analytics:** Aggregates, filters, and translates incoming sensor data into usable formats before sending it to enterprise applications.
- **Security & Authentication:** Manages access control, identity verification, and end-to-end data encryption.

Popular deployment types include Edge Middleware (operating locally on gateways to process data before sending to the cloud) and Cloud-Based Platforms like **AWS IoT Core** or **Microsoft Azure IoT Hub**, which provide vast, scalable backend infrastructure.

Short Answer Questions

1. Define a sensor with an example.
2. What is an actuator?
3. List any four IoT communication technologies.
4. What is data processing in IoT?
5. Differentiate between sensors and actuators.

Long Answer Questions

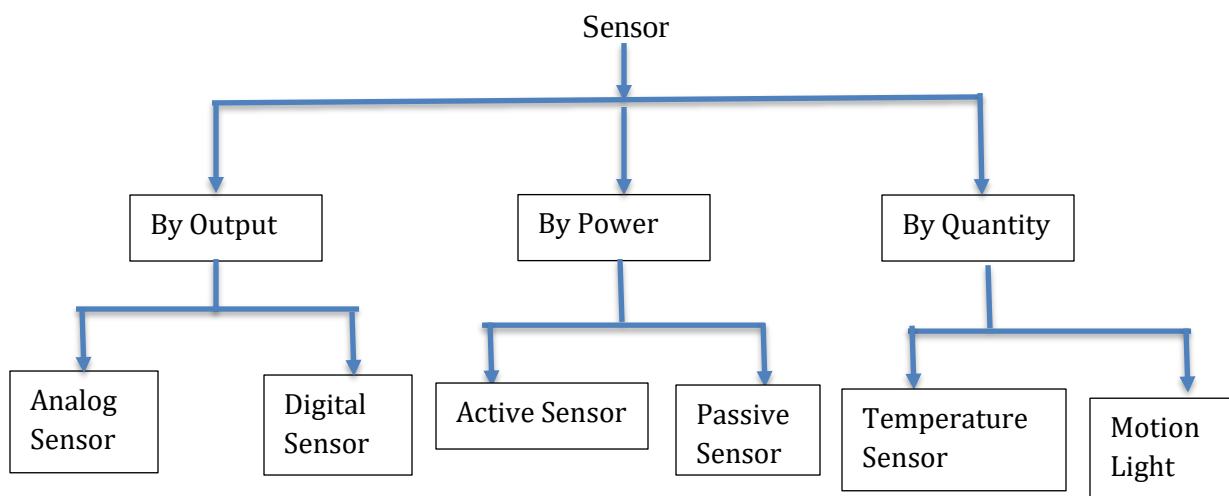
1. Explain the basic architecture of an IoT system with a neat diagram. Describe all its components.
2. Describe the role of sensors, actuators, connectivity, and data processing in IoT.
3. Compare Wi-Fi, Bluetooth, ZigBee, LoRa, and 5G.
4. Explain the complete data flow in an IoT system with an example.
5. Discuss real-world applications of IoT architecture in smart homes, healthcare, agriculture, and industry.

CHAPTER 2

(SENSORS & DATA ACQUISITION)

Introduction: A **sensor** is an electronic device that detects or measures a physical quantity from the surrounding environment and converts it into an electrical signal that can be processed by a controller or computer.

Physical quantities such as **temperature, humidity, light, pressure, motion, sound, gas concentration, and distance** cannot usually be directly understood by a microcontroller. Sensors convert these physical quantities into electrical signals.



Analog Sensors

An **analog sensor** produces a continuously varying output signal corresponding to the measured quantity.

The output may be voltage, current, resistance, etc.

e.g. Thermistor, LDR, Analog temperature/pressure sensor

Digital Sensors

A **digital sensor** produces data in digital form, generally as binary values or through a digital communication interface.

e.g. Digital temperature/humidity/accelerometers/proximity sensor

Active Sensors

An **active sensor** requires an external power source to operate and produce an output.

e.g. Ultrasonic sensor, Radar sensor ,Infrared sensor ,Some pressure sensors.

Passive Sensors

A **passive sensor** does not normally generate its own energy. Instead, its electrical characteristics change in response to an external physical quantity.

e.g. Thermistor, LDR, Strain gauge, RTD

Contact Sensors

A **contact sensor** must physically touch the object or surface being measured or detected.

e.g. Limit switch, Contact temperature sensor, Touch sensor, Mechanical switch

Non-Contact Sensors

A **non-contact sensor** detects an object or physical quantity without requiring direct physical contact.

e.g. Ultrasonic sensor, Infrared sensor, Proximity sensor, Radar sensor ,Optical sensor

Sensor Type	Physical Quantity Measured	Examples
Temperature sensor	Temperature	LM35, DS18B20, thermistor
Humidity sensor	Moisture in air	DHT11, DHT22
Motion sensor	Movement	PIR, microwave sensor
Light sensor	Light intensity	LDR, photodiode
Pressure sensor	Pressure	BMP280, MPX5700
Proximity sensor	Presence/distance of object	IR, ultrasonic
Gas sensor	Gas concentration	MQ-2, MQ-135
Sound sensor	Sound level	Microphone sensor
Accelerometer	Acceleration/tilt	MPU6050
Gyroscope	Angular velocity	MPU6050
Touch sensor	Touch/contact	Capacitive touch sensor
Soil moisture sensor	Soil moisture	Resistive/capacitive sensor

1. Temperature Sensors:

A **temperature sensor** is a device used to measure the temperature of an object or environment and convert it into an electrical signal.

Temperature is generally measured in:

- **Degree Celsius (°C)**
- **Degree Fahrenheit (°F)**
- **Kelvin (K)**

Temperature sensors are widely used in:

Weather monitoring , Air conditioners , Refrigerators, Industrial processes, IoT systems, Medical equipment, Computer systems, Smart homes.

Examples of Temperature Sensors

1. **Thermistor**
2. **LM35**
3. **DS18B20**
4. **Thermocouple**
5. **RTD**
6. **Digital temperature sensors**

Thermistor (Thermal + Resistor):

- It is a temperature-sensitive resistor.
- Its Resistance changes significantly with temperature.

Applications of Thermistors

- Digital thermometers
- Battery temperature monitoring
- Air conditioners
- Refrigerators
- Electronic circuits
- Over-temperature protection
- IoT devices

Thermocouple

A **thermocouple** is a temperature sensor made by joining two different metals.

When the junction is subjected to a temperature difference, a small voltage is generated. This phenomenon is related to the **Seebeck effect**.

Applications

- Furnaces
- Boilers
- Industrial ovens
- Engines
- Manufacturing processes
- High-temperature measurement

Semiconductor or IC Temperature Sensors

Semiconductor temperature sensors are based on the temperature-dependent electrical characteristics of semiconductor devices.

They are commonly available as integrated circuits.

Applications

- Computers
- Microcontrollers
- Electronic equipment
- Battery monitoring
- IoT devices
- Consumer electronics

Digital Temperature Sensors

A **digital temperature sensor** directly provides temperature information in digital form.

The sensor may communicate with a microcontroller using interfaces such as:

- I²C
- SPI
- 1-Wire

A digital sensor can simplify system design because the microcontroller receives temperature data directly rather than having to measure a small analog voltage.

Infrared Temperature Sensor

An **infrared (IR) temperature sensor** measures temperature without requiring direct physical contact with the object.

All objects emit infrared radiation depending on their temperature. An infrared sensor detects this radiation and estimates the object's temperature.

Applications

- Non-contact thermometers
- Industrial inspection
- Medical temperature measurement
- Electrical equipment monitoring
- Moving-object temperature measurement
- Thermal imaging

Humidity Sensor and Its Types

1. Introduction

A **humidity sensor** is an electronic device used to measure the amount of moisture or water vapour present in the surrounding air.

Humidity is an important environmental parameter along with **temperature, pressure, and light**. Humidity sensors are widely used in weather monitoring, agriculture, industrial automation, HVAC systems, smart homes, and IoT applications.

Definition

A humidity sensor is a device that detects and measures the moisture content of air and converts it into an electrical signal that can be measured or processed.

Humidity is generally expressed as **Relative Humidity (RH)** and measured in **percentage (%)**.

For example:

60% RH means that the air contains approximately 60% of the maximum moisture it can hold at that particular temperature.

Relative Humidity

Relative humidity is the ratio of the actual amount of water vapour in the air to the maximum amount of water vapour the air can hold at a particular temperature.

It is expressed as:

$$RH = \frac{\text{Maximum water vapour capacity}}{\text{Actual water vapour}} \times 100$$

For example:

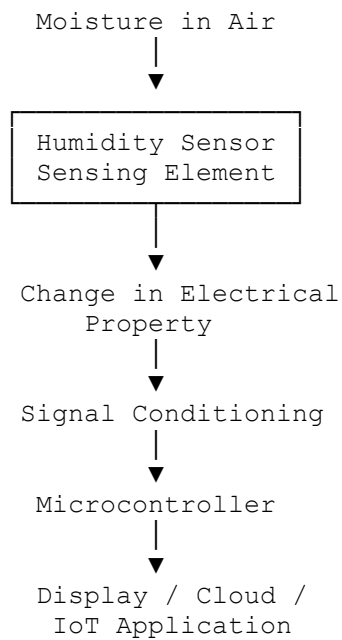
- **20% RH** → relatively dry air

- **50% RH** → moderate humidity
- **80% RH** → highly humid air

3. Basic Working of a Humidity Sensor

A humidity sensor contains a **humidity-sensitive material or element** whose electrical property changes when the amount of moisture in the air changes.

The basic process is:

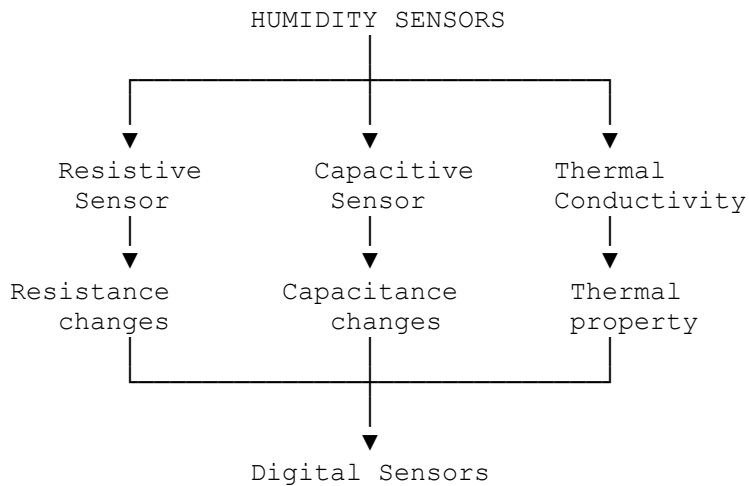


Depending on the type of sensor, humidity may cause a change in:

- Resistance
 - Capacitance
 - Electrical conductivity
 - Frequency
 - Digital output value
-

4. Types of Humidity Sensors

Humidity sensors can be broadly classified into:



The major types are:

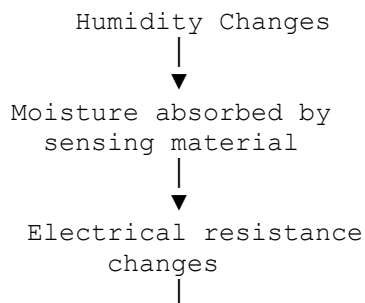
1. **Resistive humidity sensor**
 2. **Capacitive humidity sensor**
 3. **Thermal conductivity humidity sensor**
 4. **Digital humidity sensor**
-

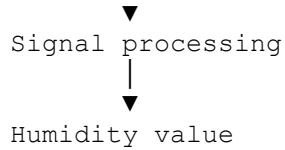
Resistive Humidity Sensor

A **resistive humidity sensor** measures humidity by detecting changes in the electrical resistance of a moisture-sensitive material.

When humidity changes, the conductivity of the sensing material changes, resulting in a change in resistance.

Working Principle





Generally, as moisture increases, the electrical conductivity of the sensing material increases and its resistance changes.

Advantages

- Simple construction
- Low cost
- Small size
- Easy to interface
- Suitable for many applications

Limitations

- Accuracy may be affected by temperature
- Long-term stability can be lower than some capacitive sensors
- Requires calibration

Applications

- Domestic appliances
- Weather monitoring
- Industrial systems
- Air-conditioning systems
- IoT devices

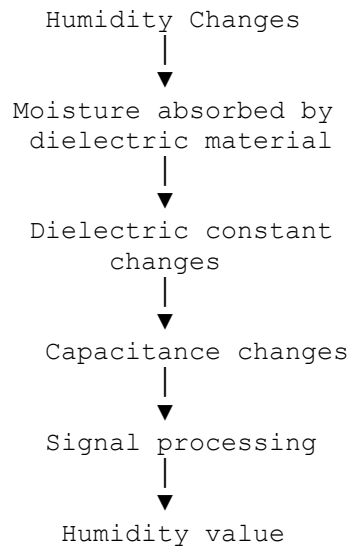
6. Capacitive Humidity Sensor

A **capacitive humidity sensor** measures humidity by detecting a change in capacitance caused by moisture.

It generally consists of two electrodes separated by a humidity-sensitive dielectric material.

When humidity changes, the dielectric properties of the material change, causing the capacitance to change.

Working Principle



Advantages

- Good accuracy
- Good stability
- Suitable for a wide humidity range
- Low power consumption
- Commonly used in digital humidity sensors

Limitations

- Can be more expensive than simple resistive sensors
- Requires suitable signal-conditioning circuitry
- Performance can be affected by contamination

Applications

- Weather stations
 - HVAC systems
 - Industrial automation
 - Medical equipment
 - Smart homes
 - IoT systems
-

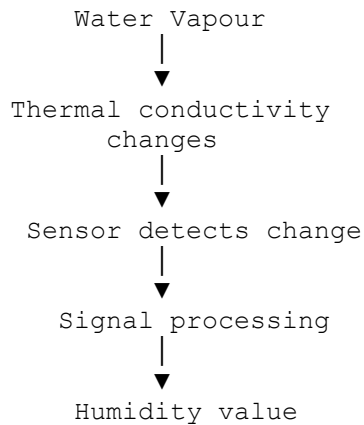
7. Thermal Conductivity Humidity Sensor

A **thermal conductivity humidity sensor** determines humidity by measuring changes in the thermal conductivity of the surrounding gas.

The thermal conductivity of air changes depending on the amount of water vapour present.

The sensor measures this change and calculates the humidity.

Basic Operation



Applications

- Industrial processes
- Drying systems
- Gas analysis
- High-temperature environments
- Industrial monitoring

Advantages

- Useful in certain harsh environments
- Can be used for industrial applications
- Suitable for measuring high humidity in some specialized systems

Limitations

- More complex
- Relatively expensive
- Accuracy depends on gas composition and temperature

8. Digital Humidity Sensors

A **digital humidity sensor** provides humidity information directly in digital form.

Many modern digital sensors measure **both temperature and humidity**.

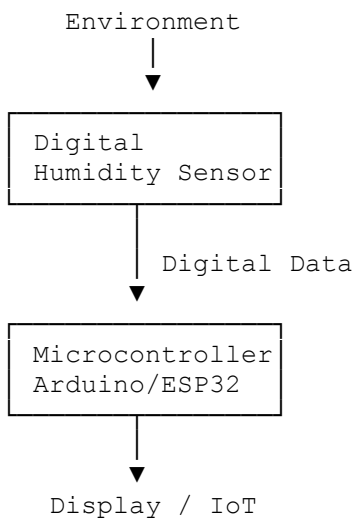
Examples include:

- DHT11
- DHT22
- SHT series sensors

A digital humidity sensor can be connected to a microcontroller such as:

- Arduino
- ESP32
- Raspberry Pi

Basic Connection



Advantages

- Easy to interface
 - Provides digital output
 - Suitable for microcontroller applications
 - Often measures temperature and humidity together
 - Useful for IoT applications
-

9. DHT11 Humidity Sensor

The **DHT11** is a commonly used low-cost digital temperature and humidity sensor for educational and basic IoT projects.

It can measure:

- Temperature

- Relative humidity

The sensor provides digital data to the microcontroller.

Typical Applications

- School/college projects
- Arduino projects
- Smart-home systems
- Environmental monitoring
- Basic IoT applications

Advantages

- Low cost
- Easy to use
- Digital output
- Temperature and humidity measurement in one device

Limitations

- Lower accuracy compared with more advanced sensors
 - Slower response
 - Limited measurement range
-

10. DHT22 Humidity Sensor

The **DHT22** is a more accurate and higher-performance sensor compared with the DHT11.

It also measures:

- Temperature
- Relative humidity

Advantages

- Better accuracy than DHT11
- Wider measurement range
- Digital output
- Suitable for IoT projects

Applications

- Weather monitoring
- Smart agriculture
- Home automation
- Environmental monitoring
- IoT systems

Sensor	Principle	Main Feature
Resistive	Resistance change	Simple and low cost
Capacitive	Capacitance change	Good accuracy and stability
Thermal conductivity	Thermal conductivity change	Industrial applications
DHT11	Digital sensing	Low-cost educational projects
DHT22	Digital sensing	Better accuracy and wider range
SHT series	Capacitive + digital processing	Higher-performance applications

Motion Sensor:

A **motion sensor** is an electronic device used to detect the movement of a person, object, or animal within a particular area.

Motion sensors are widely used in **IoT (Internet of Things)** systems, security systems, automatic lighting, smart homes, industrial automation, and robotics.

A motion sensor generally detects a change in the surrounding environment and converts it into an **electrical signal** that can be processed by a microcontroller such as **Arduino, Raspberry Pi, or ESP32**.

Basic Concept

Movement → Sensor detects change → Electrical signal → Controller processes signal → Action

For example, when a person enters a room, a motion sensor detects the movement and sends a signal to the controller. The controller can then switch ON a light automatically.

2. What is Motion?

Motion is the change in position of an object with respect to time.

A motion sensor does not necessarily detect the position of an object continuously. Instead, it generally detects a **change or movement** in its surroundings.

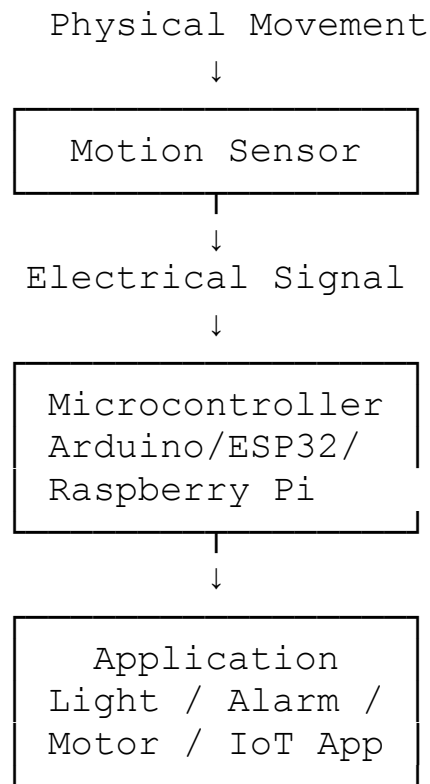
Examples:

- A person walking into a room
 - A vehicle moving on a road
 - An object moving on a conveyor belt
 - A door being opened
 - A robot moving from one location to another
-

3. Motion Sensor

A **motion sensor** is a sensor that detects physical movement in a specified area and produces an electrical output corresponding to the detected movement.

General Block Diagram



4. Types of Motion Sensors

Motion sensors can be classified according to the principle used for detecting movement.

The important types are:

1. **PIR (Passive Infrared) Sensor**
 2. **Ultrasonic Motion Sensor**
 3. **Microwave/Radar Motion Sensor**
 4. **Active Infrared (IR) Sensor**
 5. **Accelerometer**
 6. **Gyroscope**
 7. **Magnetic/Reed Switch Sensor**
-

PIR Sensor

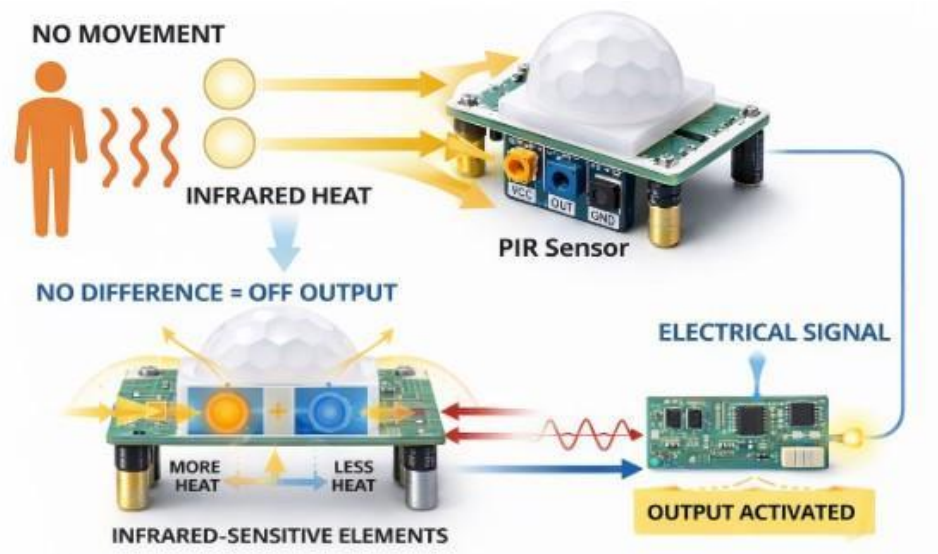
PIR stands for **Passive Infrared**.

A PIR sensor detects movement by sensing changes in **infrared radiation** emitted by objects, especially humans and animals.

All objects having a temperature above absolute zero emit infrared radiation. A human body emits infrared radiation because of its body temperature.

When a person moves across the sensing area, the amount of infrared radiation received by the sensor changes. The PIR sensor detects this change and generates an output signal.





Main Parts of a PIR Sensor

A typical PIR module contains:

- **Pyroelectric sensor**
- **Fresnel lens**
- Signal processing circuit
- Output circuit

- Power supply terminals

Working of PIR Sensor

1. The sensor continuously monitors infrared radiation in its surroundings.
2. A stationary person produces relatively constant infrared radiation.
3. When the person moves, the infrared pattern reaching the sensor changes.
4. The pyroelectric element detects this change.
5. The electronic circuit amplifies and processes the signal.
6. The sensor produces a digital output indicating motion.

PIR Sensor Output

Typically:

- **LOW** → No motion detected
- **HIGH** → Motion detected

However, the exact output behavior depends on the particular module.

Applications

- Automatic lights
 - Burglar alarms
 - Smart home systems
 - Automatic doors
 - Security systems
 - Energy-saving systems
-

Ultrasonic Motion Sensor

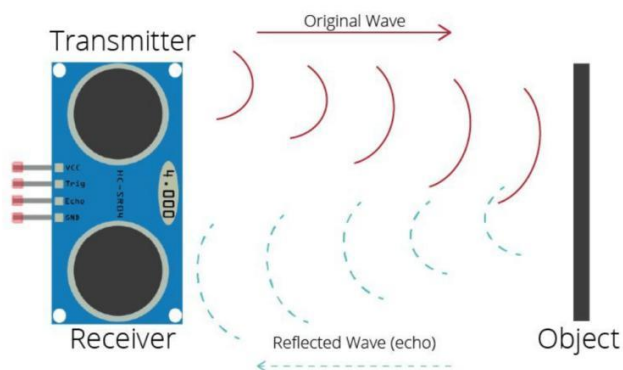
An **ultrasonic sensor** uses high-frequency sound waves to detect objects and measure distance.

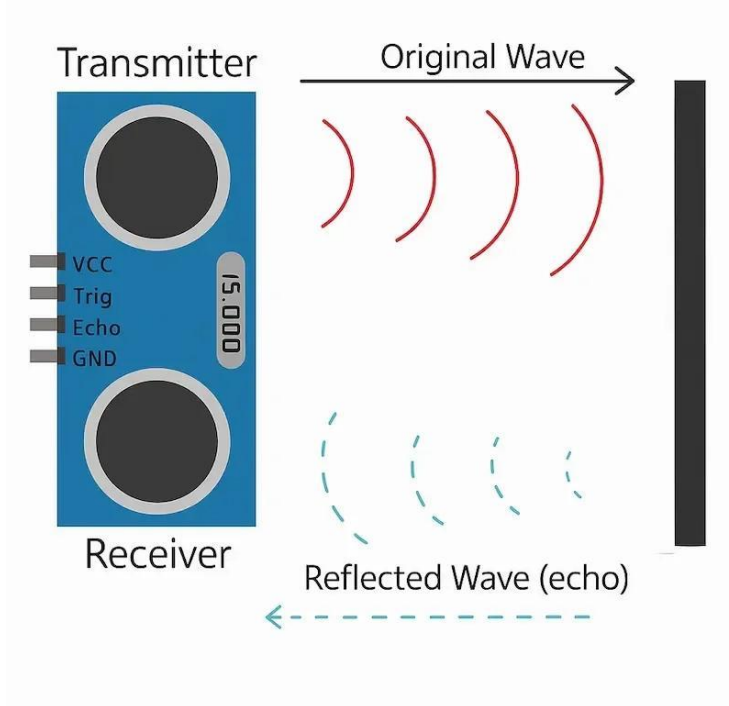
Ultrasonic waves have frequencies greater than **20 kHz**, which is above the normal range of human hearing.

A commonly used module is **HC-SR04**.



Working Principle of Ultrasonic Sensor





Working Principle

The sensor sends an ultrasonic pulse toward an object.

The sound wave travels through the air, hits the object, and returns to the sensor as an echo.

The controller measures the time taken by the sound wave to return.

Distance Calculation

$\text{Distance} = 2 \times \text{Speed of Sound} \times \text{Time}$

The division by 2 is required because the sound travels:

Sensor → Object → Sensor

Applications

- Obstacle detection
- Robot navigation

- Parking systems
 - Automatic doors
 - Distance measurement
 - Industrial automation
-

Microwave/Radar Motion Sensor

A microwave motion sensor uses **electromagnetic waves** to detect movement.

It transmits microwave signals and receives the reflected signals from objects.

When an object moves, the reflected signal changes. This change is used to identify motion.

Doppler Effect

Many radar-based motion sensors use the **Doppler effect**.

When an object moves toward or away from the sensor, the frequency of the reflected wave changes.

The sensor analyzes this frequency change to determine movement.

Advantages

- Can detect movement through some non-metallic materials
- Can cover a relatively large area
- Works in darkness
- Can detect motion at greater distances than many PIR sensors

Applications

- Security systems
- Automatic doors
- Traffic monitoring
- Industrial automation
- Smart lighting

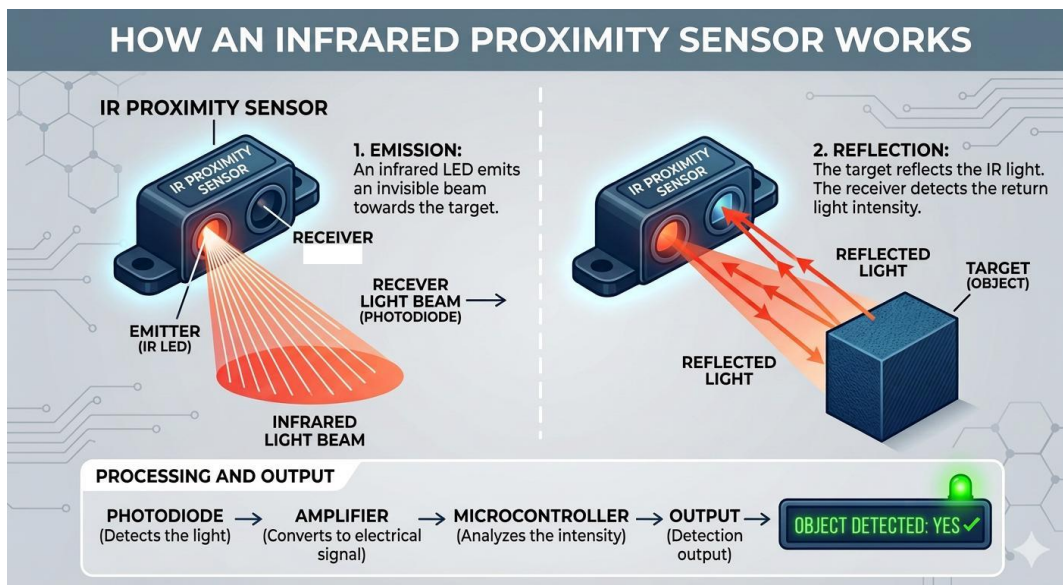
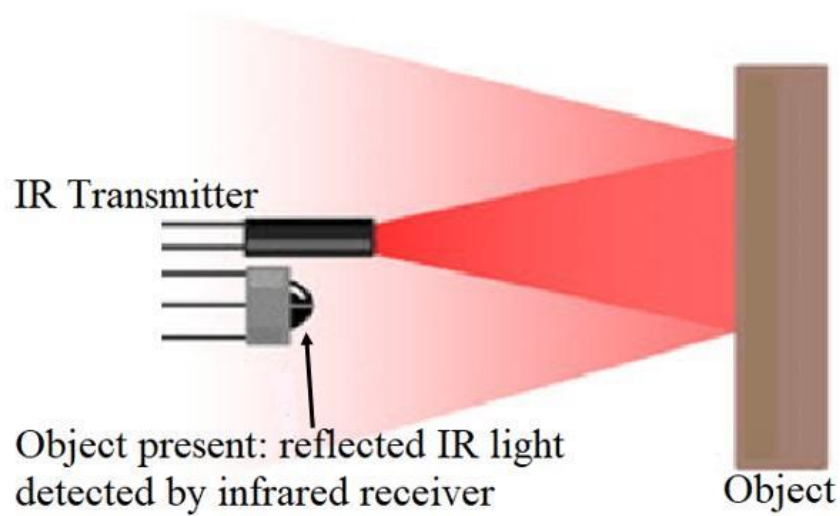
- Vehicle detection

Active Infrared Sensor

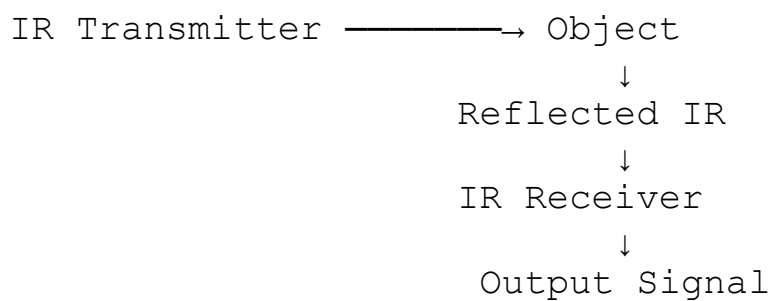
An **active IR sensor** consists of an **IR transmitter** and an **IR receiver**.

The transmitter emits infrared light. When an object comes into the sensing path, the IR radiation is reflected or interrupted, and the receiver detects the change.





Working



Applications

- Obstacle detection
 - Object counting
 - Line-following robots
 - Automatic doors
 - Proximity detection
 - Industrial automation
-

Accelerometer

An **accelerometer** is a sensor used to measure **acceleration**.

Acceleration is the rate of change of velocity.

It can also be used to detect:

- Movement
- Vibration
- Tilt
- Shock
- Orientation changes

Modern accelerometers commonly measure acceleration along three axes:

- **X-axis**
- **Y-axis**
- **Z-axis**

Therefore, they are called **3-axis accelerometers**.

Example

A smartphone uses an accelerometer to detect when the phone is rotated from portrait to landscape orientation.

Applications

- Smartphones
 - Wearable devices
 - Robots
 - Vehicle systems
 - Drone systems
 - Motion detection
 - Vibration monitoring
-

Gyroscope

A **gyroscope** measures **angular velocity**, or the rate at which an object rotates.

It is particularly useful for detecting changes in orientation and rotation.

Modern MEMS gyroscopes commonly measure rotation around three axes:

- Roll
- Pitch
- Yaw

Difference Between Accelerometer and Gyroscope

Accelerometer	Gyroscope
Measures linear acceleration	Measures angular velocity
Detects movement and tilt	Detects rotation
Measures acceleration in m/s^2 or g	Measures angular velocity in $^\circ/\text{s}$ or rad/s
Useful for detecting changes in linear motion	Useful for detecting orientation and rotation

Many systems combine both sensors to obtain more accurate motion information.

Magnetic/Reed Switch Sensor

A **reed switch** is a magnetically operated electrical switch.

It can be used to detect movement of a door, window, or other object.

A typical system contains:

- Reed switch
- Permanent magnet

When the magnet is close to the reed switch, the switch changes its state.

Example: Door Security

Door Closed:

Magnet → Reed Switch → Contact Closed

Door Opened:

Magnet moves away → Contact changes state

Applications

- Door security
- Window alarms
- Home automation
- Position detection
- Industrial equipment

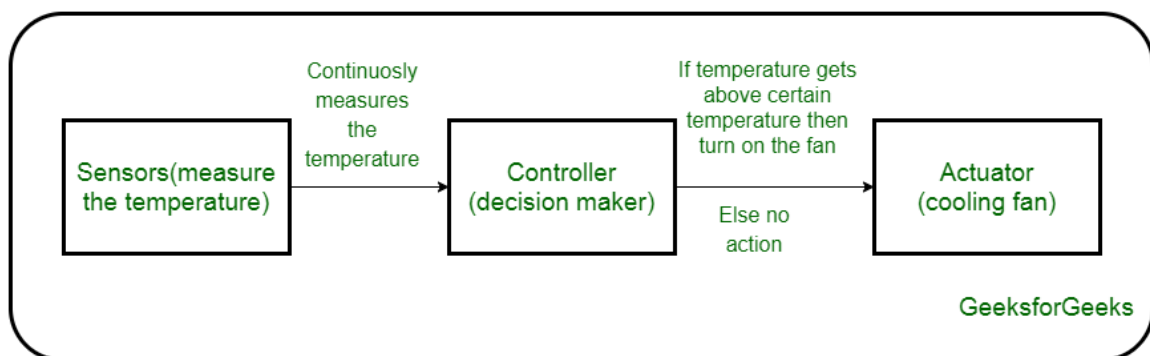
Actuator:

An IoT device is made up of a Physical object (“thing”) + Controller (“brain”) + Sensors + Actuators + Networks (Internet).

An actuator is a machine component or system that moves or controls the mechanism of the system. Sensors in the device sense the environment, then control signals are generated for the actuators according to the actions needed to perform.

A servo motor is an example of an actuator. They are linear or rotatory actuators, can move to a given specified angular or linear position. We can use servo motors for IoT applications and make the motor rotate to 90 degrees, 180 degrees, etc., as per our need.

The following diagram shows what actuators do, the controller directs the actuator based on the sensor data to do the work.



The control system acts upon an environment through the actuator. It requires a source of energy and a control signal. When it receives a control signal, it converts the source of energy to a mechanical operation. On this basis, on which form of energy it uses, it has different types given below.

Types of Actuators :

1. Hydraulic Actuators -

A hydraulic actuator uses hydraulic power to perform a mechanical operation. They are actuated by a cylinder or fluid motor. The mechanical motion is converted to rotary, linear, or oscillatory motion, according to the need of the IoT device. Ex- construction equipment uses hydraulic actuators because hydraulic actuators can generate a large amount of force.

Advantages :

- Hydraulic actuators can produce a large magnitude of force and high speed.
- Used in welding, clamping, etc.
- Used for lowering or raising the vehicles in car transport carriers.

Disadvantages :

- Hydraulic fluid leaks can cause efficiency loss and issues of cleaning.
- It is expensive.
- It requires noise reduction equipment, heat exchangers, and high maintenance systems.

2. Pneumatic Actuators -

A pneumatic actuator uses energy formed by vacuum or compressed air at high pressure to convert into either linear or rotary motion. Example- Used in robotics, use sensors that work like human fingers by using compressed air.

Advantages :

- They are a low-cost option and are used at extreme temperatures where using air is a safer option than chemicals.
- They need low maintenance, are durable, and have a long operational life.
- It is very quick in starting and stopping the motion.

Disadvantages :

- Loss of pressure can make it less efficient.

- The air compressor should be running continuously.
- Air can be polluted, and it needs maintenance.

3. Electrical Actuators -

An electric actuator uses electrical energy, is usually actuated by a motor that converts electrical energy into mechanical torque. An example of an electric actuator is a solenoid based electric bell.

Advantages :

- It has many applications in various industries as it can automate industrial valves.
- It produces less noise and is safe to use since there are no fluid leakages.
- It can be re-programmed and it provides the highest control precision positioning.

Disadvantages :

- It is expensive.
- It depends a lot on environmental conditions.

Other actuators are -

- **Thermal/Magnetic Actuators -**

These are actuated by thermal or mechanical energy. Shape Memory Alloys (SMAs) or Magnetic Shape-Memory Alloys (MSMAs) are used by these actuators. An example of a thermal/magnetic actuator can be a piezo motor using SMA.

- **Mechanical Actuators -**

A mechanical actuator executes movement by converting rotary motion into linear motion. It involves pulleys, chains, gears, rails, and other devices to operate. Example - A crankshaft.

- Soft Actuators
- Shape Memory Polymers

- Light Activated Polymers
- With the expanding world of IoT, sensors and actuators will find more usage in commercial and domestic applications along with the pre-existing use in industry.

Relay:

A relay is an electrically operated switch in the context of electronics and electrical engineering. It is made up of a coil and one or more contact sets. When an electrical current runs through the coil, a magnetic field is created that activates the contacts, allowing them to open or close the circuits. Relays are frequently employed in automotive applications, industrial automation, and control systems to control high-power or high-voltage devices with a lower-power signal.

A simple [electromagnetic](#) switch is a relay that can be used to make or break an electrical connection. Basically, the relay is just like a mechanical switch, but we can control it with an electromagnetic signal instead of manually turning it on or off. It can be of different types, like electromechanical, which is frequently used, or solid-state. Every electromechanical relay consists of an Electromagnet, Switching points, Mechanically moveable contacts, and a spring. Also, the electromagnet is constructed by winding a copper coil on a metal core. The two ends of the coil are connected by two pins of the relay. Two more contacts are present, called switching points to connect high ampere loads and common contacts to connect the switching points. Contacts are known as NO (Normal Open), NC (Normal Closed), and COM (Common) contacts. Someone can use a relay either in an [AC circuit](#) or a [DC circuit](#).

Working of Relay:

Relay works on the basis of the principle of electromagnetic induction.

- Include a magnetic field around the relay, when the electromagnet is applied with some current.
- Can use a switch to apply DC current to the load.
- The copper coil and the iron core act as the electromagnet in the relay.
- Energizing of relay: When the coil is applied with DC current, it starts attracting the contact.
- De-energizing of relay: When the supply is removed it retrieves back to the original position.

Types of Relays

Depending on functionality, structure and application, relays can be classified into different types:

- **Electromagnetic:** Uses an electromagnet to mechanically operate a switch.
- **Electronic:** Relies on solid-state components to switch circuits without moving parts.
- **Latching or Non-Latching:** Latching will be in same state after activation and non-latching returns to its default state when the activating signal is removed.
- **Reed type:** Consists of reed contacts in a sealed glass tube
- **High Voltage:** Designed to handle high voltage applications.
- **Small signal :** Ideal for low voltage and low current applications
- **Time delay & Multi Dimensional:** Delays switching action for a specified period.
- **Thermal:** Operates based on temperature changes.
- **Differential:** Compares two signals or conditions and activates when there's a difference.
- **Distance:** Measures distance or displacement and switches based on proximity.

- **Frequency & Automotive:** Designed for specific frequency ranges.
- **Polarized:** Has a specific polarity for operation.
- **Moving coil:** Uses a coil moving within a magnetic field.
- **Safety & Super vision:** Ensures safe operation and monitors systems for faults
- **Ground fault:** Detects ground faults and interrupts the circuit
- **Rotary:** Uses rotational movement.

Applications of Relay

There are limitless applications of relay, its main function is to control the high voltage circuit (230V AC circuit) with the low voltage(DC voltage) power supply.

- Relays are used in computer circuits in order to perform the mathematical and arithmetic operations in it.
- It used to control the electric motor switches. We need 230V AC supply to turn on an electric motor but in some cases, there can make situation to switch ON the motor with the DC supply voltage, a relay can be used for those cases.
- A Relay is used on Automatic Stabilizers. The set of relays sense the voltage variations and also controls the load circuit with the help of circuit breakers, when the supply voltage is other than rated voltage.
- If there exists more than one circuit in a system, it is used for circuit selection also.
- It is used in Traffic signal controllers, temperature controllers and televisions.

Motor:

Motors convert electrical energy into mechanical energy, essential for powering various devices and machinery. DC motors are used for precise speed control in electronic devices and vehicles. AC motors drive industrial machinery due to their efficiency and durability. Stepper and servo motors offer exact positioning for applications like robotics and CNC machines, demonstrating their critical role in modern technology. In this article, we learn about different types of motors.

What are Motors?

Electric Motors are devices that convert electrical energy into mechanical energy. It helps in functioning as the heart of many machines and appliances. They come in various types, including AC (Alternating Current) and DC (Direct Current) motors, each suited to different applications. Motors drive everything from small fans and household appliances to large industrial machinery and vehicles.

Types of Electric Motors

These are the main types of electric motors:

1. DC Motors (Direct Current Motors)

- Brushed DC Motors
- Brushless DC Motors

2. AC Motors (Alternating Current Motors)

- Induction Motors (Asynchronous Motors)
- Synchronous Motors

3. Specials Types of Motors

- Stepper Motor
- Servo Motor
- Reluctance Motor
- Hysteresis Motor
- Universal Motor
- pneumatic Motor

Motor Type	Key Characteristics	Common Uses
Stepper Motor	It moves in discrete steps for precise control over position and speed.	3D printers, CNC machines, scanners.
Servo Motor	It is capable of precise control of angular or linear position, velocity, and acceleration.	Robotics for accurate joint movement, remote-controlled vehicles, antenna positioning systems.
Reluctance Motor	It operates based on minimizing magnetic resistance in the circuit.	Electric fans, blowers, pump drives.
Hysteresis Motor	It utilizes magnetic hysteresis of rotor material to produce torque.	Sound-sensitive applications like projectors, recording equipment.
Universal Motor	It operates on either AC or DC power; known for high speed and torque.	Portable power tools, household appliances like blenders, vacuum cleaners.
Pneumatic Motor	It is an explosion-proof, offers variable speed control, and provides high starting torque, making them robust and suitable for harsh, hazardous environments.	It is commonly used in handheld industrial tools such as drills and grinders, especially in environments where electrical sparks could pose a risk of explosion.

