

# IoT Unit–2: Sensors and Actuators

## RGPV IMPORTANT QUESTIONS WITH EASY AND DETAILED ANSWERS

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### 1. Sensor Node

#### Introduction

Sensor node IoT system ka basic building block hota hai. Ye environment se data collect karta hai aur network/cloud ko send karta hai.

#### Definition

**A sensor node is a small electronic device in an IoT network that senses physical data, processes it and communicates it to other nodes or cloud.**

#### Why It Is Needed

Sensor node real-world information ko digital form me convert karta hai. Iske bina IoT system environment ko समझ नहीं सकता.

#### Easy Explanation

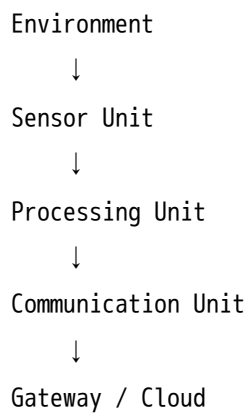
Sensor node ko mini IoT device समझो. Isme sensor, processor, memory, battery aur communication module hota hai.

#### Step-by-Step Working

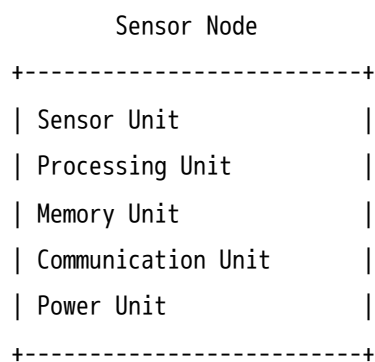
1. Sensor physical quantity detect karta hai.

2. Signal processing unit data ko process karta hai.
3. Microcontroller decision leta hai.
4. Communication unit data send karta hai.
5. Power unit device ko energy provide karta hai.

## Flow of Process



## Diagram



## Real-Life Analogy

Sensor node human body ke sense organ + brain + mouth jaisa hai. Sense organ data leta hai, brain process karta hai, mouth information send karta hai.

## **Advantages**

- Real-time data collection
- Small size
- Low cost
- Wireless communication possible
- Automation support

## **Disadvantages**

- Limited battery life
- Limited memory
- Limited processing power
- Security risk
- Range limitation

## **Applications**

- Smart agriculture
- Healthcare monitoring
- Smart home
- Military surveillance
- Industrial monitoring

## **Important Keywords**

**Sensor Unit, Processing Unit, Communication Unit, Power Unit, Wireless Sensor Network**

## **Conclusion**

Sensor node IoT network ka basic component hai jo sensing, processing and communication perform karta hai.

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## 2. Sensor Features

### Introduction

Sensor features sensor ki quality aur performance batate hain. Good sensor accurate, fast, stable aur sensitive hona chahiye.

### Definition

**Sensor features are performance characteristics that describe how accurately and efficiently a sensor measures physical quantities.**

### Important Sensor Features

Feature	Easy Meaning
Accuracy	Actual value ke close reading
Precision	Same reading baar-baar milna
Sensitivity	Small change detect karna
Resolution	Smallest measurable change
Range	Minimum to maximum measurable value
Response Time	Kitni fast reading deta hai
Linearity	Output input ke proportion me
Stability	Long time tak correct working

### Why It Is Needed

Sensor choose karte time features check karna important hota hai. Wrong sensor se wrong data aur wrong decision ho sakta hai.

## Easy Explanation

Example: Temperature sensor agar  $25^{\circ}\text{C}$  ko  $25.1^{\circ}\text{C}$  show kare to accurate hai. Agar baar-baar same value de to precise hai.

## Diagram

Sensor Features

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Accuracy | Precision | Sensitivity | Resolution | Range

## Real-Life Analogy

Jaise exam me topper answer accurate, clear aur consistent hota hai, waise good sensor accurate, precise aur stable hota hai.

## Advantages

- Correct measurement
- Better IoT decisions
- Reliable monitoring
- High system performance

## Disadvantages

- High quality sensors costly hote hain
- Calibration required hoti hai
- Har sensor every environment me suitable nahi hota

## Applications

- Medical devices
- Smart meters
- Weather stations
- Industrial automation

## **Important Keywords**

**Accuracy, Precision, Sensitivity, Resolution, Range, Response Time, Stability**

## **Conclusion**

Sensor features help in selecting suitable sensor for IoT applications.

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# **3. Actuator Types**

## **Introduction**

Actuator IoT system ka action component hota hai. Sensor data detect karta hai, actuator action perform karta hai.

## **Definition**

**An actuator is a device that converts electrical control signals into physical action or movement.**

## **Why It Is Needed**

IoT system me sirf data collect karna enough nahi hota. System ko action bhi perform karna hota hai, jaise motor ON karna, valve open karna, door lock karna.

## **Easy Explanation**

Sensor = Detects

Controller = Decides

Actuator = Acts

## Step-by-Step Working

1. Sensor data collect karta hai.
2. Controller data analyze karta hai.
3. Controller actuator ko signal bhejta hai.
4. Actuator physical action perform karta hai.

## Flow of Process

Sensor → Controller → Actuator → Physical Action

## Diagram

Temperature Sensor → Controller → Fan Motor  
↓  
Fan ON

## Types of Actuators

Actuator Type	Energy Source	Example
Hydraulic	Liquid pressure	JCB machine
Pneumatic	Compressed air	Air brake
Electrical	Electricity	Motor, relay

Actuator Type	Energy Source	Example
Thermal	Heat energy	Thermostat
Magnetic	Magnetic field	Solenoid
Mechanical	Mechanical force	Gear system
Soft Actuator	Flexible material	Soft robot

## Real-Life Analogy

Human muscles actuator jaisi hoti hain. Brain signal deta hai aur muscles movement karti hain.

## Advantages

- Automation possible
- Remote control
- Fast response
- Useful in robots and machines

## Disadvantages

- Power required
- Maintenance needed
- Mechanical wear and tear
- Some actuators costly

## Applications

- Robotics
- Smart home
- Industrial automation
- Medical devices
- Vehicle systems

## Important Keywords

**Control Signal, Physical Action, Motor, Relay, Hydraulic, Pneumatic, Electrical Actuator**

## Conclusion

Actuator IoT system ko real-world action perform karne ki ability deta hai.

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# 4. Analog vs Digital Sensors

## Introduction

Sensors output ke basis par analog aur digital type me divide kiye jaate hain.

## Definition

**Analog Sensor:** A sensor that gives continuous output signal.

**Digital Sensor:** A sensor that gives discrete digital output signal.

## Why It Is Needed

Different IoT systems me different output required hota hai. Isliye analog aur digital sensors ka selection important hai.

## Easy Explanation

Analog sensor smooth continuous value deta hai. Digital sensor fixed digital value deta hai, usually 0/1 or digital data.


## Comparison Table

Basis	Analog Sensor	Digital Sensor
Output	Continuous	Discrete
Signal Type	Voltage/current	Binary/digital data

Basis	Analog Sensor	Digital Sensor
Accuracy	Less compared to digital	More accurate
Noise Effect	More affected	Less affected
Cost	Usually low	Usually high
Example	LDR, LM35	DHT11, DS18B20
Interface	ADC needed	Direct microcontroller input

## Diagram

Analog Output:

Smooth wave 

Digital Output:

0 1 0 1 1 0

## Real-Life Analogy

Analog clock hands continuously move karte hain. Digital clock numbers me exact time show karti hai.

## Advantages

### Analog Sensor

- Simple
- Cheap
- Easy to use

### Digital Sensor

- Accurate
- Noise resistant

- Easy microcontroller interface

## Disadvantages

### Analog Sensor

- Noise affected
- ADC required
- Accuracy low ho sakti hai

### Digital Sensor

- Costly
- Circuit complex

## Which is Better and Why?

IoT applications me **digital sensors better** hote hain because microcontrollers digital data easily read karte hain and noise effect kam hota hai. But low-cost simple applications me analog sensors useful hain.

## Important Keywords

**Continuous Signal, Discrete Signal, ADC, Binary Output, Noise Resistance**

## Conclusion

Analog sensors continuous output dete hain, while digital sensors discrete and more reliable output dete hain.

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# 5. Sensor Errors

## Introduction

Sensor always 100% correct reading nahi deta. Actual value aur measured value ke difference ko sensor error kehte hain.

## Definition

**Sensor error is the difference between actual value of a physical quantity and value measured by the sensor.**

## Why It Is Needed

Sensor errors ko samajhna important hai because wrong sensor reading se wrong IoT decision ho sakta hai.

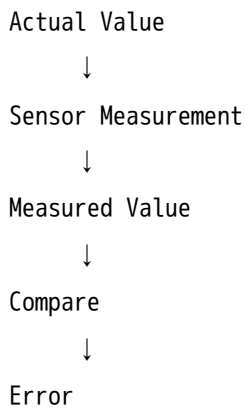
## Types of Sensor Errors

Error Type	Easy Meaning
Bias Error	Constant fixed error
Drift Error	Time ke saath output change
Hysteresis Error	Same input par different output
Quantization Error	Digital conversion approximation error
Calibration Error	Improper setting error
Noise Error	External disturbance error

## Step-by-Step Explanation

1. Actual environment value hoti hai.
2. Sensor value measure karta hai.
3. Measured value actual se different ho sakti hai.
4. Difference error hota hai.
5. Calibration se error reduce kiya ja sakta hai.

## Flow



## Example

Actual temperature = 30°C

Sensor reading = 32°C

Error = 2°C

## Advantages of Error Analysis

- Sensor accuracy improve hoti hai
- Calibration easy hoti hai
- Reliable IoT system banta hai

## Disadvantages

- Error correction complex ho sakta hai
- High accuracy sensors costly hote hain

## Applications

- Medical IoT
- Industrial IoT
- Weather monitoring
- Smart meters

## Important Keywords

**Bias, Drift, Hysteresis, Quantization, Calibration, Noise, Accuracy**

## Conclusion

Sensor errors affect measurement quality. Reliable IoT system ke liye sensor error analysis important hai.

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# 6. Scalar vs Vector Sensors

## Introduction

Sensors measured quantity ke nature ke basis par scalar aur vector sensors me divide hote hain.

## Definition

**Scalar Sensor:** Sensor that measures only magnitude of a quantity.

**Vector Sensor:** Sensor that measures both magnitude and direction of a quantity.

## Easy Explanation

Magnitude ka matlab value. Direction ka matlab kis side me.

Example:

- Temperature = 30°C only value → scalar
- Velocity = 20 m/s east direction → vector

## Comparison Table

Basis	Scalar Sensor	Vector Sensor
Measures	Magnitude only	Magnitude + direction

Basis	Scalar Sensor	Vector Sensor
Output	Single value	Multi-dimensional value
Complexity	Simple	Complex
Example	Temperature sensor	Accelerometer
Application	Weather monitoring	Motion tracking

## Diagram

Scalar:

Temperature = 30°C

Vector:

Acceleration = 5 m/s<sup>2</sup> → Direction X-axis

## Real-Life Analogy

Weight machine scalar value deta hai. Compass direction deta hai, so vector-type sensing karta hai.

## Advantages

### Scalar Sensor

- Simple
- Low cost
- Easy to process

### Vector Sensor

- Direction information
- Motion tracking useful
- More detailed data

## **Disadvantages**

### **Scalar Sensor**

- Direction information nahi deta

### **Vector Sensor**

- Complex
- Costly
- More processing required

## **Which is Better and Why?**

Simple measurements ke liye scalar sensor better hai. Motion, direction, robotics and navigation ke liye vector sensor better hai.

## **Important Keywords**

**Magnitude, Direction, Scalar Quantity, Vector Quantity, Accelerometer, Gyroscope**

## **Conclusion**

Scalar sensors only value measure karte hain, while vector sensors value ke saath direction bhi measure karte hain.

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# **7. Soft Actuators**

## **Introduction**

Soft actuators flexible materials se bane hote hain. Ye traditional hard actuators se different hote hain.

## Definition

**Soft actuators are flexible actuators made from soft materials that can bend, stretch or deform to produce motion.**

## Why It Is Needed

Traditional actuators rigid hote hain. Soft actuators delicate tasks ke liye useful hote hain, jaise medical robots and artificial muscles.

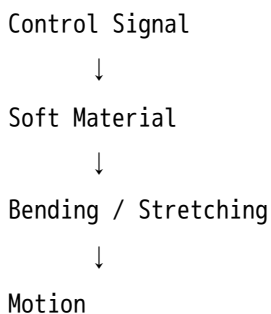
## Easy Explanation

Soft actuator rubber-like material ka hota hai jo air, electricity, heat ya magnetic field se shape change karta hai.

## Step-by-Step Working

1. Control signal diya jata hai.
2. Soft material energy receive karta hai.
3. Material expand, bend ya contract karta hai.
4. Motion generate hoti hai.

## Flow



# Diagram

Before Signal: [ Straight Soft Material ]

After Signal: [ Curved / Bent Material ]

## Real-Life Analogy

Human muscles soft actuator jaisi hoti hain. Signal milne par muscle contract/relax hoti hai.

## Advantages

- Flexible
- Safe for humans
- Lightweight
- Useful in medical robotics
- Can handle delicate objects

## Disadvantages

- Less force compared to hydraulic actuator
- Control difficult
- Material durability issue

## Applications

- Soft robotics
- Artificial muscles
- Medical devices
- Prosthetic limbs
- Wearable devices

## **Important Keywords**

**Flexible Material, Soft Robotics, Artificial Muscles, Bending, Stretching, Human-Safe Actuation**

## **Conclusion**

Soft actuators flexible and safe motion provide karte hain, especially medical and soft robotics applications me.

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# **8. Sensor Resolution**

## **Introduction**

Sensor resolution batata hai ki sensor smallest change ko detect kar sakta hai ya nahi.

## **Definition**

**Sensor resolution is the smallest change in input quantity that a sensor can detect and measure.**

## **Why It Is Needed**

High resolution sensor detailed measurement deta hai. Low resolution sensor small changes ignore kar sakta hai.

## **Easy Explanation**

Agar temperature sensor  $1^{\circ}\text{C}$  change detect karta hai, resolution low hai. Agar  $0.1^{\circ}\text{C}$  change detect karta hai, resolution high hai.

## **Step-by-Step Understanding**

1. Physical value change hoti hai.
2. Sensor us change ko detect karta hai.
3. Agar change sensor ke resolution se small hai, sensor detect nahi karega.
4. Agar change resolution ke equal ya bada hai, sensor detect karega.

## Diagram

Low Resolution:

$25^{\circ}\text{C} \rightarrow 26^{\circ}\text{C} \rightarrow 27^{\circ}\text{C}$

High Resolution:

$25.0^{\circ}\text{C} \rightarrow 25.1^{\circ}\text{C} \rightarrow 25.2^{\circ}\text{C}$

## Real-Life Analogy

Normal ruler mm tak measure karta hai. Vernier caliper usse chhota measurement detect kar sakta hai. Vernier ki resolution better hoti hai.

## Advantages

- Detailed measurement
- Better accuracy
- Useful in medical and industrial systems

## Disadvantages

- High cost
- More data processing
- Sensitive to noise

## Applications

- Medical sensors
- Precision instruments
- Industrial control
- Scientific measurement

## Important Keywords

**Smallest Detectable Change, Measurement Detail, High Resolution, Precision**

## Conclusion

Sensor resolution determines how small a change a sensor can detect. High resolution improves measurement quality.

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# 9. Quantization Error

## Introduction

Quantization error digital sensors and ADC systems me hota hai. Jab continuous analog signal ko digital value me convert kiya jata hai, approximation error create hota hai.

## Definition

**Quantization error is the difference between actual analog value and nearest digital value after conversion.**

## Why It Is Needed

IoT systems me sensor data digital form me process hota hai. Conversion ke time error samajhna important hai.

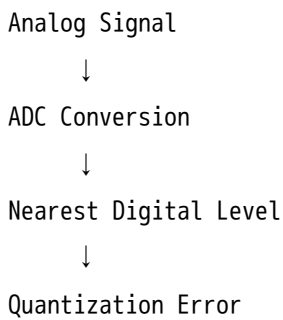
## Easy Explanation

Analog value smooth hoti hai, but digital system fixed steps me value store karta hai. Is rounding difference ko quantization error bolte hain.

## Step-by-Step Working

1. Sensor analog signal generate karta hai.
2. ADC analog value ko digital value me convert karta hai.
3. Digital system nearest level choose karta hai.
4. Actual value aur selected level me difference hota hai.
5. Ye difference quantization error hota hai.

## Flow



## Diagram

Actual Value:	2.36 V
Digital Level:	2.40 V
Error:	0.04 V

## Real-Life Analogy

Agar marks 89.6 hain aur system round karke 90 kar de, to 0.4 ka rounding difference quantization error jaisa hai.

## Advantages of Understanding It

- ADC selection better hota hai
- Accuracy improve kar sakte hain
- Error correction possible hoti hai

## Disadvantages

- Digital conversion me unavoidable
- Low resolution ADC me error zyada hota hai
- Precision affect hoti hai

## Applications

- ADC systems
- Digital sensors
- Signal processing
- IoT data acquisition

## Important Keywords

**ADC, Analog Signal, Digital Level, Approximation, Rounding Error, Quantization Step**

## Conclusion

Quantization error analog-to-digital conversion ka natural error hai. High resolution ADC use karke ise reduce kiya ja sakta hai.



## Comparison Table: Sensor vs Actuator

Basis	Sensor	Actuator
Function	Detects physical quantity	Performs physical action
Input	Physical quantity	Electrical signal
Output	Electrical signal/data	Motion/action
Example	Temperature sensor	Motor
Role in IoT	Data collection	Control/action

## Which is Better and Why?

Dono ka role different hai. Sensor बिना actuator system action नहीं ले सकता, actuator बिना sensor system environment नहीं समझ सकता. IoT me dono equally important hain.



## Comparison Table: Analog vs Digital

### Sensors

Basis	Analog Sensor	Digital Sensor
Output	Continuous	Discrete
Noise	More affected	Less affected
Accuracy	Lower	Higher
Cost	Low	High
Example	LDR	DHT11
IoT Use	Simple systems	Smart systems



## Comparison Table: Hydraulic vs

### Pneumatic vs Electrical Actuator

Basis	Hydraulic	Pneumatic	Electrical
Energy	Liquid pressure	Compressed air	Electricity

<b>Basis</b>	<b>Hydraulic</b>	<b>Pneumatic</b>	<b>Electrical</b>
Force	Very high	Medium	Low to medium
Speed	Medium	Fast	Fast
Cleanliness	Leakage issue	Clean	Clean
Example	Crane	Air brake	Motor

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## **Most Important 7-Mark Questions**

1. Explain sensor node with diagram.
  2. Explain components and challenges of sensor node.
  3. Explain sensor features.
  4. Differentiate between analog and digital sensors.
  5. Differentiate between scalar and vector sensors.
  6. Explain sensor errors.
  7. Explain sensor resolution.
  8. Explain actuator and its types.
  9. Explain soft actuators.
  10. Explain quantization error.
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## **Most Important 14-Mark Questions**

1. Explain sensor node architecture, components and challenges in detail.
  2. Explain sensor features, resolution and sensor errors.
  3. Explain analog, digital, scalar and vector sensors with comparison.
  4. Explain actuator and various actuator types with applications.
  5. Explain sensor errors: bias, drift, hysteresis and quantization error.
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## **PYQ-Based Expected Questions**

## Very High Probability

- ✓ Sensor Node
- ✓ Sensor Features
- ✓ Actuator Types
- ✓ Analog vs Digital Sensors

## High Probability

- ✓ Sensor Errors
- ✓ Scalar vs Vector Sensors
- ✓ Soft Actuators

## Medium Probability

- ✓ Sensor Resolution
- ✓ Quantization Error

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# One-Night Revision Notes

Topic	Quick Revision
Sensor Node	Senses + processes + communicates
Sensor Feature	Performance quality
Resolution	Smallest detectable change
Bias	Constant error
Drift	Error changes with time
Hysteresis	Same input, different output
Quantization	Digital rounding error
Actuator	Electrical signal to physical action
Soft Actuator	Flexible actuator
Scalar	Magnitude only

Topic	Quick Revision
Vector	Magnitude + direction

## Smart Study Plan

### 2-Hour Plan

Time	Topic
25 min	Sensor Node
20 min	Sensor Features
20 min	Sensor Errors
20 min	Analog vs Digital
20 min	Actuator Types
15 min	Scalar/Vector + Soft Actuator

### 5-Hour Plan

Time	Topic
1 hour	Sensor Node + Challenges
1 hour	Sensor Features + Resolution
1 hour	Sensor Errors
1 hour	Sensor Classes
1 hour	Actuator Types + Revision

## Memory Tricks

### Sensor Node Components

#### SPCMP

- S = Sensor

- P = Processor
- C = Communication
- M = Memory
- P = Power

## **Sensor Features**

### **ARPRS**

- A = Accuracy
- R = Resolution
- P = Precision
- R = Response Time
- S = Sensitivity

## **Sensor Errors**

### **BDHQ**

- B = Bias
- D = Drift
- H = Hysteresis
- Q = Quantization

## **Actuator Types**

### **HPETMS**

- H = Hydraulic
  - P = Pneumatic
  - E = Electrical
  - T = Thermal
  - M = Mechanical
  - S = Soft
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# Topper Answer Writing Tips

For 7 marks:

Definition



Diagram



Working



Advantages



Applications



Conclusion

For 14 marks:

Introduction



Definition



Types / Components



Detailed Explanation



Diagram



Comparison Table



Advantages



Disadvantages



Applications

↓

Conclusion

## **Keywords to Underline**

**Sensor Node, Accuracy, Resolution, Bias, Drift, Hysteresis, Quantization Error, Actuator, Hydraulic, Pneumatic, Electrical, Soft Actuator**

Final tip: सबसे पहले **Sensor Node + Sensor Features + Actuator Types + Analog vs Digital Sensors** पढ़ो. Unit-2 में यही सबसे scoring topics हैं.