Introduction to IOT
Unit-1 (AIDS-309/AIML-309)

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AGENDA

Actuators

Part:3B

Agenda

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- Features of Actuators
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- Challenges of Employing Actuators in IoT:
- Few Examples of Actuators in IoT
- Key difference between Sensors & Actuators
- Basis of the hardware design needed to build useful circuits using basic sensors and actuators

Brief Glimpse of Sensors

- A sensor is a device that detects changes and events in a physical environment.
- It may convert physical parameters like humidity, pressure, temperature, heat, motion, etc., into electrical signals.
- This signal can be converted into a human-readable display and sent across a network for additional processing.
- Active sensors and passive sensors are the two primary types of sensors.
- Active sensors necessitate a power supply, whereas passive sensors don't require a power supply.

Features of Sensors

- A sensor could be either active or passive.
- Active sensors necessitate a power source, but passive doesn't necessitate a power source.
- It is a device that monitors and measures changes in the environment.
- It is responsible for converting physical quantities into electrical signals.
- It is connected to a system's input.
- It generates an electrical signal as its output.

Actuators

- 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.

What are Actuators?

- A device that changes electrical signals into mechanical work is known as an actuator.
- It is used to cause movement or a change in the surroundings. For instance, a fan is utilized to lower the temperature, and a servo motor is utilized to change position, among other things.
- Actuators are connected to a system's output. It receives an electrical signal as input and produces mechanical movement as output.
- It receives input or instruction from a system or a signal conditioning device and outputs it to the environment.

What are Actuators?

- The actuator is dependent on the sensor data.
- The sensor sends data to a signal condition unit, which analyzes the data or information and transmits commands to the actuator depending on that data.
- A "temperature control system" is an instance of an actuator system in which a temperature sensor manages the temperature.
- If the temperature surpasses a specific limit, the device instructs the fan to increase its speed and decrease the temperature.

Actuators

- An actuator is a device that converts energy into motion.
- It receives a control signal and uses it to move or control a mechanism or system.
- Actuators are essential components in various systems and devices, playing a crucial role in controlling physical processes in response to electrical, hydraulic, or pneumatic inputs.
- **Definition:** Devices that convert energy into mechanical motion.
- **Purpose:** Used to move or control mechanisms or systems.

Actuators

- **Energy Sources:** Can be powered by electrical, hydraulic, pneumatic, thermal, magnetic, or mechanical energy.
- **Types of Motion:**
  - Linear (straight-line motion).
  - Rotary (rotational motion).
- **Control Input:** Operate based on control signals, which can be digital or analog.
- **Applications:** Found in various systems, including robotics, industrial machinery, automotive systems, and household devices.

Features of Actuators

- The actuator assists in managing the environment based on sensor readings.
- A device that converts electrical signals into mechanical movement is known as an actuator.
- It requires an additional power source to function.
- It receives an electrical signal as input.
- It is connected to a system's output.
- It produces mechanical work.

Types of Actuators

1. Manual Actuator

This type of actuator is manually operated via gears, levers, and wheels, among other things. They do not need a power source because they are powered by human action.

2. Spring Actuator

It has a loaded spring that is triggered and released to generate mechanical work. It may be triggered in several ways.

Types of Actuators

3. Hydraulic Actuator

Hydraulic actuators generate pressure by compressing fluid in a cylinder, allowing mechanical movement.

4. Electric Actuators

These actuators require power to function. It utilizes an electric motor to produce movement. They are quick and effective.

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.

Types of Actuators

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.

Types of Actuators

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.

Types of Actuators

4. 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.

5. 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.

Different Classes of Actuators

1. Electric Actuators:

- DC Motors: Used for continuous rotation and precise speed control.
- AC Motors: Common in industrial applications for high power and efficiency.
- Stepper Motors: Provide precise control over movement and positioning.
- Solenoids: Create linear motion and are often used in locking mechanisms.

2. Hydraulic Actuators:

- Use pressurized hydraulic fluid to create motion.
- Known for generating high force and are commonly used in heavy machinery.
- Examples include hydraulic cylinders and hydraulic motors.

Different Classes of Actuators

3. Pneumatic Actuators:

Use compressed air to produce motion.

Widely used in automation and industrial applications for their speed and reliability.

Examples include pneumatic cylinders and pneumatic motors.

4. Thermal and Magnetic Actuators:

Thermal Actuators: Rely on temperature changes to induce motion, often used in thermostats and other temperature-sensitive devices.

Magnetic Actuators: Utilize magnetic fields to create motion, such as in magnetic levitation systems.

Different Classes of Actuators

5. Mechanical Actuators:

Convert manual input into mechanical movement.

Examples include gears, pulleys, levers, and cams.

6. Piezoelectric Actuators:

Use piezoelectric materials that change shape when an electric field is applied.

Ideal for precision applications such as in micro-positioning devices.

Challenges of Employing Actuators in IoT:

- **Compatibility:** Actuators may not be interoperable with all IoT devices and systems, limiting their efficacy in some applications.
- **Precision:** Actuators may not always be capable of providing the precise level of control required for certain applications, such as those requiring high levels of accuracy or repeatability.
- **Power Consumption:** Actuators can consume a substantial amount of power, which can be a problem in IoT systems that rely on battery power or have restricted power supplies.
- **Maintenance:** Actuators require routine maintenance to guarantee good operation, which can be time–consuming and costly.
- **Cost:** Actuators can be expensive, which can make them unsuitable for some applications.

Few Examples of Actuators in IoT

- **Smart Home Systems:** Actuators are an important part of smart home systems. They let customers remotely operate various equipment such as lights, heating systems, and security systems. A smart thermostat, for example, can use temperature sensors to change the temperature in a home, and an actuator can activate the heating or cooling system as needed.
- **Industrial Automation:** Actuators are frequently employed in industrial automation to control machines and other systems. Hydraulic actuators, for example, might be used to control the movement of robotic arms in a factory, while electric actuators could be used to regulate the position of a conveyor belt.

Few Examples of Actuators in IoT

- **Agriculture:** Actuators are rapidly being employed to automate numerous processes in agriculture, such as irrigation and harvesting. An actuator, for example, can control the flow of water in an irrigation system or the position of a robotic arm used to harvest crops.
- **Healthcare:** Actuators are employed in a variety of healthcare applications, including prostheses and medical equipment. An actuator, for example, can regulate the movement of a prosthetic limb or the location of a surgical tool during treatment.

Key difference between Sensors & Actuators

- A sensor is a device that detects changes or events in the environment and transmits that data to other electronic devices. In contrast, an actuator is a machine component that moves and controls mechanisms.
- Electrical signals are generated via sensors. On the other hand, an actuator produces energy in the form of heat or motion.
- The sensor is placed at the input port to receive input. In contrast, the actuator is located at the output port.

Key difference between Sensors & Actuators

- There is some example of sensors that utilize sensors, including Magnetometer, cameras, microphones, etc. In contrast, actuators are employed in LEDs, loudspeakers, motor controllers, lasers, etc.
- Sensors are utilized to measure physical quantities. On the other hand, the actuator is utilized to measure the discrete and continuous process parameters.
- The sensor takes input from the environment. In contrast, the actuator receives input from the system's output conditioning unit.

	Sensors	Actuators
Definition	It is a device that detects changes or events in the environment and transmits that data to another electronic system.	It is a machine component that moves and controls mechanisms.
Basic	It converts the physical properties of their environment into electrical signals for the system.	It converts the system's electrical signals into various physical characteristics for their environments.
Type of Output	Electrical signals are generated via sensors.	It generates energy in the form of heat or motion.
Source of Input	It receives input from the environment.	It receives input from the system's output conditioning unit.

Feature	Sensors	Actuators
Placement	These are placed at a system's input port.	These are placed at a system's output port.
Output Generation	It produces output for the input conditioning unit of a system.	It produces output for their environment.
Examples	Sensors include biosensors, motion sensors, image sensors, and chemical sensors.	Actuators include electric motors, comb drives, stepper motors, and hydraulic cylinders.

Basis of hardware design needed to build useful circuits using basic sensors and actuators

Designing hardware circuits using basic sensors and actuators involves a clear understanding of the components, how they interact, and how to process and control signals.

Here are the fundamental principles for such designs:

1. Understanding Sensors and Actuators:

Sensors: Devices that detect physical conditions (e.g., temperature, light, pressure) and convert them into electrical signals.

Examples:

- Temperature Sensors: Thermistors, RTDs.
- Light Sensors: Photodiodes, LDRs (Light Dependent Resistors).
- Motion Sensors: PIR (Passive Infrared) sensors, accelerometers.
- Pressure Sensors: Piezoelectric sensors, strain gauges.
- Actuators: Devices that convert electrical signals into physical action (e.g., movement, light, sound).

Examples:

- Motors: DC motors, stepper motors, servos.
- LEDs: Light-emitting diodes for visual indicators.
- Relays: Electromagnetic switches for controlling higher power circuits.
- Speakers/Buzzers: For sound output.

2. Signal Conditioning:

- Amplification: Sensors often produce low-level signals that need to be amplified for further processing. Operational amplifiers (op-amps) are commonly used.
- Filtering: To remove noise from sensor signals, use low-pass, high-pass, or band-pass filters depending on the application.
- Analog-to-Digital Conversion (ADC): Sensors often provide analog outputs, so an ADC is required to convert these signals into digital form for microcontrollers.
- Level Shifting: Adjusting voltage levels to match the input requirements of other circuit elements, especially when interfacing with microcontrollers.

3. Power Management:

- Power Supply Design: Ensure that both sensors and actuators receive a stable and suitable power supply.
- Voltage Regulation: Use voltage regulators to maintain a constant voltage level, crucial for sensitive sensors.
- Battery Management: For battery-powered systems, consider low-power design techniques to prolong battery life, such as using sleep modes or reducing duty cycles.

4. Interfacing Sensors:

- Direct Connection: Simple sensors like switches or LDRs can be directly connected to microcontroller inputs with appropriate pull-up or pull-down resistors.
- Wheatstone Bridge: Used for precision measurement in sensors like strain gauges, which detect small changes in resistance.
- Communication Protocols: Some sensors use digital communication protocols like I2C, SPI, or UART, which require proper interfacing and communication management in the circuit design.

5. Interfacing Actuators:

- Transistor/MOSFET Switches: Used to drive actuators that require more current than a microcontroller can provide. Transistors can act as switches to control the actuator.
- H-Bridge Circuits: Used to control the direction of DC motors, allowing them to rotate in both directions.
- Relays: Allow a low-power circuit to control a higher power circuit, essential for actuating devices like motors or lights.
- PWM (Pulse Width Modulation): Used to control the speed of motors or brightness of LEDs by varying the duty cycle of the signal.

7. Safety Considerations:

- Overcurrent Protection: Use fuses, resettable fuses, or current limiters to protect components from excessive current.
- Isolation: For circuits involving high voltages or currents, use optocouplers or transformers to isolate sensitive components.
- Debouncing: For mechanical sensors like switches, implement debouncing circuits (either in hardware with capacitors or in software) to prevent false triggering.

8. Prototyping and Testing:

- Breadboarding: Allows for quick prototyping and testing of circuits before final implementation.
- Simulation Tools: Use software like Proteus, TinkerCAD, or LTSpice to simulate the behavior of your circuit before building it.
- Testing Tools: Oscilloscopes, multimeters, and logic analyzers are essential for debugging and verifying circuit performance.

9. Environmental Considerations:

- Temperature Tolerance: Ensure that components are rated for the environmental conditions they will face.
- Protection Against Humidity and Dust: Use enclosures or conformal coatings to protect the circuit.
- Electromagnetic Interference (EMI): Design to minimize interference, especially in noisy environments, by using proper grounding and shielding techniques.

10. Documentation and Planning:

- Circuit Schematics: Document your circuit design with clear schematics showing connections and components.
- Bill of Materials (BOM): Prepare a BOM listing all components, their specifications, and suppliers.
- Testing Procedures: Define clear testing procedures to verify that your circuit works as intended under all expected conditions.

THANK YOU