ROHINI COLLEGE OF ENGINEERING AND TECHNOLOGY
AUTONOMOUS INSTITUTION
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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

VII Semester

AU3008 Sensors and Actuators

UNIT – I - *INTRODUCTION TO MEASUREMENTS AND SENSORS*

1.1 Sensor Functions:

A sensor is a device that detects or measures a physical quantity, such as temperature, pressure, light, or sound, and converts it into a signal that can be interpreted by an electronic system or a human. The primary function of a sensor is to provide information about the state or condition of a physical system or environment. Sensors are essential components in a wide range of applications, including industrial automation, consumer electronics, scientific instrumentation, and medical devices.

Here are some primary functions of sensors:

1. Detection

- **Presence**: Detects the presence or absence of an object (e.g., proximity sensors).
- **Motion**: Senses movement (e.g., motion detectors).

2. Measurement

- **Temperature**: Measures the temperature of an environment or object (e.g., thermocouples, thermistors).
- **Pressure**: Measures the force exerted by a fluid (e.g., barometers, pressure transducers).

- **Light**: Detects the intensity or presence of light (e.g., photodiodes, light-dependent resistors).
- **Distance**: Measures the distance between objects (e.g., ultrasonic sensors, laser rangefinders).
- **Acceleration**: Measures the rate of change of velocity (e.g., accelerometers).
- **Humidity**: Measures the moisture level in the air (e.g., hygrometers).
- **Sound**: Detects and measures sound waves (e.g., microphones).
- **Magnetic Fields**: Measures the strength and direction of magnetic fields (e.g., Hall effect sensors).

3. Conversion

- **Analog to Digital**: Converts physical quantities into digital signals for processing (e.g., analog-to-digital converters).
- **Signal Conditioning**: Enhances or conditions signals for better interpretation (e.g., amplifiers, filters).

4. Control and Automation

- **Feedback Systems**: Provides data for control systems to maintain desired conditions (e.g., thermostats in HVAC systems).
- **Automation**: Triggers actions in automated systems (e.g., sensors in robotics).

5. Safety and Security

- **Smoke and Gas Detection**: Detects hazardous gases or smoke (e.g., carbon monoxide detectors, smoke detectors).
- **Intrusion Detection**: Monitors unauthorized access (e.g., infrared sensors in security systems).

6. Environmental Monitoring

- **Weather Monitoring**: Measures various atmospheric conditions (e.g., anemometers for wind speed, rain gauges).
- **Pollution Monitoring**: Detects pollutants in air or water (e.g., air quality sensors, water quality sensors).

7. Healthcare and Biomedical

- **Vital Signs Monitoring**: Measures physiological parameters (e.g., heart rate monitors, blood glucose sensors).
- **Diagnostic Tools**: Assists in medical diagnostics (e.g., MRI sensors, X-ray detectors).

8. Industrial Applications

- **Process Control**: Monitors and controls manufacturing processes (e.g., level sensors in tanks, flow sensors in pipelines).
- **Quality Control**: Ensures product quality and consistency (e.g., vision sensors for inspection).

9. Consumer Electronics

- **User Interaction**: Enhances user experience (e.g., touch screens, gyroscopes in smartphones).
- **Performance Monitoring**: Monitors device performance and conditions (e.g., battery sensors, thermal sensors).

10. Automotive

- **Vehicle Systems**: Monitors and controls various vehicle functions (e.g., tire pressure sensors, oxygen sensors in exhaust systems).
- **Driver Assistance**: Supports advanced driver-assistance systems (ADAS) (e.g., radar sensors, LIDAR).

Sensors play a crucial role in modern technology, enabling the detection, measurement, and conversion of various physical parameters into actionable data. This data is used in numerous applications across diverse fields, from industrial automation and healthcare to consumer electronics and environmental monitoring.

1.2 Classifications of Sensors

Sensors can be classified based on various criteria, including the type of measured quantity, the principle of operation, the type of output signal, and their application. Here are some common classifications.

1. Based on Measured Quantity

1. **Temperature Sensors**: Thermocouples, thermistors, resistance temperature detectors (RTDs), infrared sensors.
2. **Pressure Sensors**: Barometers, piezoelectric sensors, strain gauge sensors.
3. **Light Sensors**: Photodiodes, light-dependent resistors (LDRs), phototransistors.
4. **Proximity Sensors**: Inductive, capacitive, ultrasonic, infrared.
5. **Motion Sensors**: Accelerometers, gyroscopes, passive infrared (PIR) sensors.
6. **Level Sensors**: Float sensors, ultrasonic level sensors, capacitive level sensors.
7. **Flow Sensors**: Magnetic, ultrasonic, thermal mass flow sensors.
8. **Humidity Sensors**: Hygrometers, capacitive humidity sensors, resistive humidity sensors.
9. **Gas Sensors**: Carbon monoxide sensors, methane sensors, oxygen sensors.

2. Based on Principle of Operation

1. **Electromechanical Sensors**: Strain gauges, piezoelectric sensors.
2. **Optical Sensors**: Photodiodes, phototransistors, fiber optic sensors.
3. **Thermal Sensors**: Thermocouples, thermistors, RTDs.
4. **Magnetic Sensors**: Hall effect sensors, magnetoresistive sensors.
5. **Chemical Sensors**: pH sensors, gas sensors.
6. **Capacitive Sensors**: Proximity sensors, touch sensors.
7. **Inductive Sensors**: Proximity sensors, metal detectors.

3. Based on Output Signal

- **Analog Sensors**: Produce a continuous output signal (e.g., thermocouples, strain gauges).
- **Digital Sensors**: Produce a discrete output signal (e.g., digital temperature sensors, digital pressure sensors).

4. Based on Power Requirement

- **Active Sensors**: Require an external power source to operate (e.g., infrared sensors, ultrasonic sensors).
- **Passive Sensors**: Do not require an external power source and generate output based on the measured quantity (e.g., thermocouples, piezoelectric sensors).

5. Based on Application

- **Environmental Sensors**: Weather sensors, air quality sensors, water quality sensors.
- **Industrial Sensors**: Pressure sensors, level sensors, flow sensors, temperature sensors.
- **Automotive Sensors**: Oxygen sensors, tire pressure sensors, parking sensors, airbag sensors.
- **Medical Sensors**: Blood glucose sensors, heart rate monitors, temperature probes.
- **Consumer Electronics Sensors**: Accelerometers, gyroscopes, ambient light sensors, touch sensors.

6. Based on Sensing Method

- **Contact Sensors**: Require physical contact with the object being measured (e.g., thermocouples, strain gauges).
- **Non-contact Sensors**: Do not require physical contact with the object being measured (e.g., infrared sensors, ultrasonic sensors).

7. Based on Technology

- **MEMS Sensors (Micro-Electro-Mechanical Systems)**: Accelerometers, gyroscopes, pressure sensors.
- **Fiber Optic Sensors**: Used for sensing temperature, pressure, and other physical properties through light transmission in fiber optics.

- **Nanotechnology-based Sensors**: Utilized in advanced applications for detecting minute quantities of substances.

8. Sensors Based on Applications in Automotive Systems

The use of sensors in the automotive industry is not merely an outcome of technological advancements; rather, it is an essential progression toward achieving enhanced performance, increased safety, and increased efficiency in automobiles. There are many sensors in modern cars, and each one has a specific purpose. The crucial roles that sensors play in a variety of automotive applications are explained in the sections that follow:

i. Engine Management and Control

The engine management system's core components are the sensors, they enable peak performance, fuel economy, and emission control:

Fuel/Air Mixture Control: By measuring the amount of oxygen in exhaust gasses through the use of oxygen sensors installed inside the exhaust system, the engine control module is able to modify the fuel-air mixture for the best possible combustion.

Ignition Timing: Crankshaft and camshaft position sensors help establish the engine's phase and speed. This information helps the engine control unit (ECU) to time the spark for combustion exactly.

Cooling System: Temperature sensors monitor the engine's coolant temperature. If the temperature crosses a defined threshold, the ECU can modify the functioning of the cooling fan or communicate a potential overheating issue to the driver.

Turbocharger Control: Pressure sensors are used in turbocharged engines to monitor the boost pressure and ensure that it remains within the safe operating parameters established for the engine.

ii. Safety Systems

Safety is fundamental in vehicle design, and sensors play a critical part in numerous safety-enhancing systems:

Airbag Deployment: Accelerometers detect fast deceleration characteristics of a collision. The sensor alerts the airbag control unit to activate the airbags, which cushion the occupants and lower the possibility of injury in the event of a large accident.

Anti-Lock Braking System (ABS): Wheel speed sensors constantly track the rotational speed of each wheel in the anti-lock braking system (ABS). The ABS adjusts brake pressure to prevent wheel lockup when it senses it is about to happen, preserving steering control.

Traction Control System: This system detects when one or more wheels lose grip by using wheel speed sensors. In order to regain traction, the ECU can then lower engine power or apply brake force to particular wheels.

Collision Sensors: These are particularly crucial for battery electric vehicles (BEVs), as they ensure that all high-voltage parts are deactivated in the event of a collision. This is accomplished via the collision sensor circuit, which modifies the crash signal state that high-voltage components expect in the case of a crash and ensures that any circuits that may have become accessible to persons due to the collision and vehicle damage are de-energized.

iii. Driver-Assistance Systems

As a result of technological improvements, cars now feature a variety of sensors to support and enhance the driving experience:

Parking Assistance: This is provided by ultrasonic sensors installed all around the car to identify nearby obstructions. By giving the driver input regarding the distance to objects, these sensors help make parking in confined places easier to handle.

Lane-Keeping Assistance: Roadside lane markers are detected by optical or infrared sensors. Depending on how sophisticated the system is, it may alert the driver or even take corrective action if it detects an inadvertent lane departure without signaling.

Adaptive Cruise Control: This technology keeps a safe following distance between itself and the car in front of you using radar or LIDAR sensors. The mechanism automatically lowers speed to preserve the predetermined gap if the car in front of it slows down.

Blind Spot Detection: This system lowers the likelihood of side-swiping accidents by alerting drivers to cars in their blind spots, usually through the use of radar or ultrasonic sensors.

Modern cars are essentially a symphony of interconnected systems, each of which contributes to the overall driving experience. As the "eyes and ears" of the car, sensors continuously collect information from its surroundings and internal systems. Advanced control algorithms and this data-rich environment open the door to a safer, more effective, and more pleasurable driving experience.

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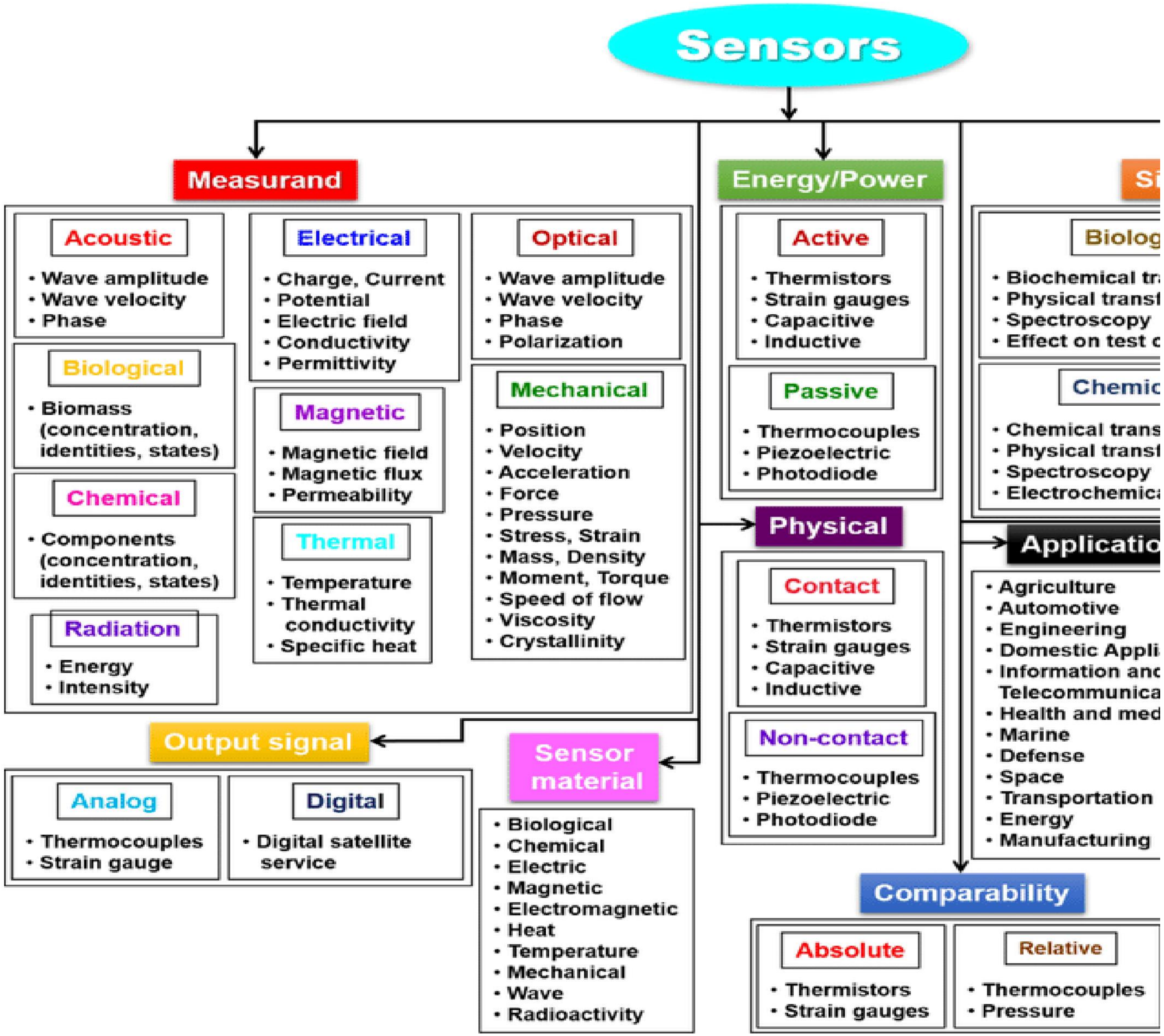
Sensors
Measurand
Acoustic
• Wave amplitude
• Wave velocity
• Phase
Electrical
• Charge, Current
• Potential
• Electric field
• Conductivity
• Permittivity
Optical
• Wave amplitude
• Wave velocity
• Phase
• Polarization
Biological
• Biomass (concentration, identities, states)
Magnetic
• Magnetic field
• Magnetic flux
• Permeability
Mechanical
• Position
• Velocity
• Acceleration
• Force
• Pressure
• Stress, Strain
• Mass, Density
• Moment, Torque
• Speed of flow
• Viscosity
• Crystallinity
Chemical
• Components (concentration, identities, states)
Thermal
• Temperature
• Thermal conductivity
• Specific heat
Radiation
• Energy
• Intensity
Energy/Power
Active
• Thermistors
• Strain gauges
• Capacitive
• Inductive
Passive
• Thermocouples
• Piezoelectric
• Photodiode
Physical
Contact
• Thermistors
• Strain gauges
• Capacitive
• Inductive
Non-contact
• Thermocouples
• Piezoelectric
• Photodiode
Output signal
Analog
• Thermocouples
• Strain gauge
Digital
• Digital satellite service
Sensor material
• Biological
• Chemical
• Electric
• Magnetic
• Electromagnetic
• Heat
• Temperature
• Mechanical
• Wave
• Radioactivity
Biolog
• Biochemical tr
• Physical transf
• Spectroscopy
• Effect on test c
Chemic
• Chemical trans
• Physical transf
• Spectroscopy
• Electrochemica
Applicatio
• Agriculture
• Automotive
• Engineering
• Domestic Appli
• Information and Telecommunica
• Health and med
• Marine
• Defense
• Space
• Transportation
• Energy
• Manufacturing
Comparability
Absolute
• Thermistors
• Strain gauges
Relative
• Thermocouples
• Pressure

Classifications of Sensors:

1. Based on the Type of Input (Stimulus):

a. Mechanical Sensors

- Measure physical quantities like force, pressure, displacement, or vibration.
- Examples: Strain gauges, piezoelectric sensors, accelerometers.

b. Thermal Sensors

- Detect temperature or heat changes.
- Examples: Thermocouples, thermistors, infrared sensors.

c. Optical Sensors

- Detect light or electromagnetic radiation.
- Examples: Photodiodes, phototransistors, laser sensors.

d. Acoustic Sensors

- Measure sound waves or vibrations.
- Examples: Microphones, ultrasonic sensors.

e. Chemical Sensors

- Detect the presence or concentration of specific chemical substances.
- Examples: pH sensors, gas sensors, biosensors.

f. Magnetic Sensors

- Detect magnetic fields.
- Examples: Hall-effect sensors, magnetometers.

g. **Radiation Sensors**

- Measure ionizing radiation levels.
- Examples: Geiger-Müller counters, scintillation detectors.

2. Based on the Output Signal:

a. **Analog Sensors**

- Provide a continuous signal proportional to the measured quantity.
- Examples: Thermocouples, strain gauges.

b. **Digital Sensors**

- Provide a discrete output, often in binary form.
- Examples: Digital temperature sensors, rotary encoders.

3. Based on the Operating Principle:

a. **Resistive Sensors**

- Change in resistance is measured.
- Examples: Thermistors, strain gauges.

b. **Capacitive Sensors**

- Operate based on changes in capacitance.
- Examples: Proximity sensors, humidity sensors.

c. **Inductive Sensors**

- Use changes in inductance for measurement.
- Examples: Inductive proximity sensors, LVDTs (Linear Variable Differential Transformers).

d**. Optical Sensors**

- Rely on the interaction of light.
- Examples: Photodiodes, LIDAR sensors.

e. **Piezoelectric Sensors**

- Generate an electrical signal in response to mechanical stress.
- Examples: Vibration sensors, accelerometers.

4. Based on Power Supply:

a**. Active Sensors**

- Require an external power source to operate.
- Examples: Ultrasonic sensors, radar sensors.

b. **Passive Sensors**

- Operate without an external power source and directly generate output signals.
- Examples: Thermocouples, photovoltaic cells.

5. Based on Application:

a. **Environmental Sensors**

- Measure environmental parameters like temperature, humidity, or air quality.
- Examples: Weather sensors, CO_2 sensors.

b. **Industrial Sensors**

- Used in automation and process control.
- Examples: Proximity sensors, pressure sensors.

c. **Biomedical Sensors**

- Monitor physiological parameters.

- Examples: Heart rate sensors, glucose monitors.

d. **Automotive Sensors**

- Used in vehicle systems for safety and performance.
- Examples: Oxygen sensors, speed sensors.

e. **IoT Sensors**

- Specifically designed for Internet of Things (IoT) applications.
- Examples: Smart temperature sensors, motion detectors.

6**. Based on Sensing Range:**

- Short-range sensors: Proximity sensors, touch sensors.
- Long-range sensors: Radar sensors, ultrasonic sensors.

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