Module II: Sensors and Transduction Principles

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1. Introduction to Sensors

A **sensor** is a device that detects or measures a physical property and converts it into a signal which can be read or further processed—usually electrical.

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2. Transduction Principles

Transduction is the process of converting one form of energy into another. In sensors, this typically means converting:

- **Physical quantities** (like force, pressure, or temperature)
  → into
- **Electrical signals** (voltage, current, resistance, etc.)

Common transduction methods:

- Piezoelectric
- Electromagnetic
- Resistive
- Capacitive
- Inductive
- Optical

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3. Sensor Characteristics

- **Sensitivity**: Output signal change per unit input change
- **Accuracy**: Closeness of output to actual value
- **Range**: Minimum and maximum values measurable

- **Resolution**: Smallest detectable input change
- **Precision**: Repeatability of output for same input
- **Linearity**: Proportionality between input and output
- **Drift**: Deviation in output over time

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4. Noise in Sensors

Sources of noise may include:

- Electrical interference
- Thermal noise
- Quantization error in ADCs
- Environmental disturbances (vibration, temperature)

Noise management: Shielding, grounding, filtering, and signal conditioning.

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5. Common Engineering Sensors

Measurement	Typical Sensors
Proximity	Inductive, capacitive, ultrasonic, IR sensors
Force	Strain gauges, load cells, piezoelectric sensors
Velocity	Tachometers, optical encoders, Hall-effect sensors
Temperature	Thermocouples, RTDs, thermistors
Pressure	Piezoelectric sensors, MEMS pressure sensors
Displacement	LVDT, potentiometers, laser displacement sensors

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6. Signal Conditioning

Before feeding sensor output to a controller, **signal conditioning** is necessary.
This includes:

- Amplification
- Filtering
- Isolation
- Analog-to-Digital Conversion (ADC)
- Linearization

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7. Sensor Selection Criteria

To select an appropriate sensor:

- Define the **measurand** (what you're measuring)
- Determine **range**, **environment**, and **required accuracy**
- Consider **power supply**, **cost**, and **interface compatibility**
- Evaluate **durability**, **size**, and **response time**

Summary of Key Terms

- **Transducer**: Device converting one form of energy to another
- **Sensor**: A type of transducer specifically used to sense physical properties
- **Actuator**: Performs actions based on sensor data