



Introduction to Sensors

Sensor Fundamentals

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| Definition: A sensor is a device that detects and responds to some type of input from the physical environment. |
| Transduction: Sensors convert a physical quantity (e.g., temperature, pressure, light) into an electrical signal (e.g., voltage, current). |
| Key Characteristics: <ul style="list-style-type: none"> Sensitivity: The smallest change in input that a sensor can detect. Accuracy: How close the sensor's reading is to the actual value. Precision: The repeatability of a sensor's readings. Resolution: The smallest increment a sensor can measure. |
| Common Output Signals: <ul style="list-style-type: none"> Voltage: 0-5V, 0-10V Current: 4-20mA Digital: I2C, SPI, UART |
| Calibration: The process of adjusting a sensor's output to match known standards, improving accuracy. |
| Response Time: The time it takes for a sensor to respond to a change in the input signal. |
| Drift: Gradual change in sensor output over time, even with a constant input. |

Sensor Categories

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| Physical Sensors | Measure physical properties like temperature, pressure, acceleration, etc. |
| Chemical Sensors | Detect specific substances in gases or liquids (e.g., gas sensors, pH sensors). |
| Optical Sensors | Detect light or other electromagnetic radiation (e.g., photodiodes, light sensors). |
| Biosensors | Detect biological substances (e.g., glucose sensors). |
| Acoustic Sensors | Detect sound waves or vibrations (e.g., microphones, ultrasonic sensors). |
| Image Sensors | Capture visual information (e.g., cameras). |

Temperature Sensors

Thermocouples

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| Principle: | Seebeck effect - a temperature difference creates a voltage. |
| Types: | Type K (Chromel-Alumel), Type J (Iron-Constantan), Type T (Copper-Constantan). |
| Range: | -200°C to +1350°C (depending on type). |
| Pros: | Wide temperature range, rugged. |
| Cons: | Low sensitivity, requires cold junction compensation. |
| Applications: | Industrial temperature monitoring, furnaces, ovens. |

Resistance Temperature Detectors (RTDs)

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| Principle: | Resistance changes with temperature. |
| Types: | Pt100, Pt1000 (Platinum RTDs are common). |
| Range: | -200°C to +850°C. |
| Pros: | High accuracy and stability. |
| Cons: | Slower response time, more expensive than thermocouples. |
| Applications: | Precision temperature measurements, HVAC systems. |

Thermistors

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| Principle: | Semiconductor device with resistance highly dependent on temperature. |
| Types: | NTC (Negative Temperature Coefficient), PTC (Positive Temperature Coefficient). |
| Range: | -100°C to +300°C. |
| Pros: | High sensitivity, low cost. |
| Cons: | Non-linear response, less stable than RTDs. |
| Applications: | Temperature compensation, over-current protection. |

Pressure Sensors

Strain Gauge Pressure Sensors

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| Principle: | Strain gauges measure the deformation of a diaphragm caused by pressure. |
| Types: | Bonded, unbonded, piezoresistive. |
| Range: | Varies widely depending on the design. |
| Pros: | Good accuracy, robust. |
| Cons: | Can be temperature sensitive, requires signal conditioning. |
| Applications: | Industrial pressure monitoring, automotive pressure sensors. |

Capacitive Pressure Sensors

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| Principle: | Pressure changes the distance between capacitor plates, altering capacitance. |
| Range: | Typically low to medium pressure ranges. |
| Pros: | High sensitivity, low power consumption. |
| Cons: | Sensitive to temperature changes, complex signal conditioning. |
| Applications: | Medical devices, consumer electronics. |
| Types: | Differential, absolute, gauge. |

Piezoresistive Pressure Sensors

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| Principle: | Change in resistance of a semiconductor material due to applied pressure. |
| Range: | Wide range of pressure measurements. |
| Pros: | High sensitivity, small size. |
| Cons: | Temperature sensitivity, non-linearity. |
| Applications: | Automotive, industrial control, medical devices. |
| Types: | Silicon, polysilicon. |

Light Sensors

Photodiodes

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| Principle: | Semiconductor diode that generates current when exposed to light. |
| Types: | PIN, avalanche. |
| Range: | UV to IR spectrum. |
| Pros: | Fast response, high sensitivity. |
| Cons: | Temperature sensitive, requires amplification. |
| Applications: | Light detection, optical communication. |

Phototransistors

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| Principle: | Light controls the current flow between collector and emitter. |
| Range: | Visible light spectrum. |
| Pros: | Higher gain than photodiodes. |
| Cons: | Slower response time, temperature sensitivity. |
| Applications: | Light-activated switches, object detection. |
| Types: | NPN, PNP. |

Light Dependent Resistors (LDRs)

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| Principle: | Resistance decreases as light intensity increases. |
| Range: | Visible light spectrum. |
| Pros: | Simple, low cost. |
| Cons: | Slow response time, non-linear, less accurate. |
| Applications: | Street lights, camera light meters. |
| Materials: | Cadmium sulfide (CdS), others. |