

# UNIT II

## Thermal Sensors

### **Introduction to Thermal Sensors**

#### **Definition**

Thermal sensors measure temperature or temperature-related physical quantities.

#### **Functions**

Temperature measurement

Process monitoring

Industrial control

Scientific research

#### **Applications**

Power plants

Medical equipment

Aerospace

Electronics

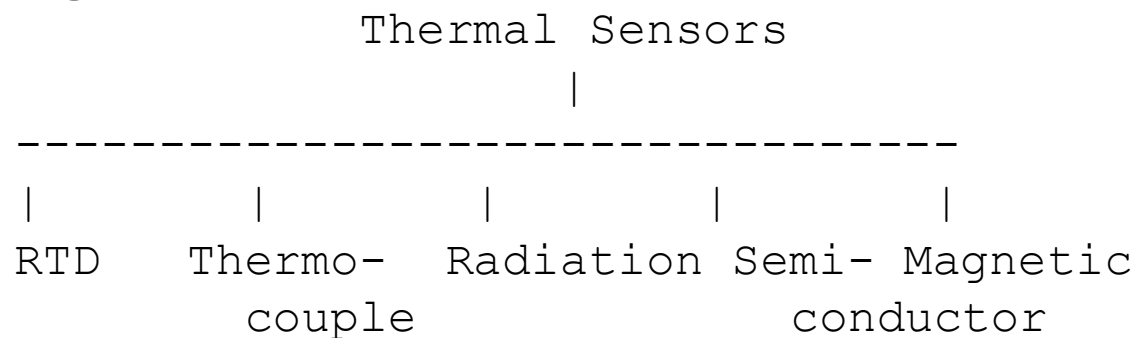
#### **Diagram**

Heat Source → Thermal Sensor → Signal Conditioning → Display

## Classification of Thermal Sensors Categories

1. Expansion Thermometers
2. Resistance Thermometers
3. Thermoelectric Sensors
4. Radiation Sensors
5. Semiconductor Sensors
6. Magnetic Thermometers
7. Nuclear Thermometers

### Diagram



## Gas Thermometric Sensors

### Principle

Based on pressure-temperature relation of gases.

### Equation

$$PV = nRt$$

P is pressure; V is volume; n is amount of gas; T is temperature.

### Features

High accuracy

Standard temperature reference

### Applications

Calibration laboratories

### Diagram

Gas Bulb

|

Capillary Tube

|

Pressure Gauge

## Working of Gas Thermometer

### Operation

- Gas enclosed in bulb
- Temperature change alters pressure
- Pressure indicates temperature

### Advantages

- Accurate
- Stable

### Diagram

Heat → Gas Expansion → Pressure Increase → Temperature Reading

## Thermal Expansion Type Thermometric Sensors

### Principle

Materials expand when heated.

### Types

Liquid-in-glass thermometer

Bimetallic thermometer

### Equation

$$\Delta L = \alpha L \Delta T$$

### Diagram

Cold    Hot

|=====| → |=====|

## Bimetallic Thermometer

### Construction

Two metals bonded together.

### Working

Different expansion rates cause bending.

### Applications

- Ovens
- HVAC systems

### Diagram

Metal A

=====

Metal B

=====

Heating → Curvature

## Acoustic Temperature Sensor

### Principle

Speed of sound varies with temperature.

### Formula

$$v = \sqrt{\gamma RT}$$

### Features

- Non-contact
- High-temperature measurements

### Diagram

Transmitter → Sound Wave → Receiver

## Dielectric Constant Thermo Sensors

### Principle

Dielectric constant changes with temperature.

### Characteristics

- Fast response
- High sensitivity

### Diagram

Temperature Change



Dielectric Constant Change



Capacitance Change

## Refractive Index Thermo Sensors

### Principle

Temperature affects refractive index.

### Applications

- Fiber optic sensing
- Chemical industries

### Diagram

Light Source



Optical Fiber



Detector

# Helium Low Temperature Thermometer

## Principle

Uses helium properties at cryogenic temperatures.

## Range

-1 K to 30 K

## Applications

- Space research
- Superconductivity studies

## Diagram

Cryogenic Chamber



Helium Sensor



Readout

## Nuclear Thermometer

### Principle

Based on nuclear energy level populations.

### Features

- Ultra-low temperature measurement

### Applications

- Physics laboratories

### Diagram

Atomic Nuclei



Energy Transition



Temperature

## Magnetic Thermometer

### Principle

Magnetic susceptibility changes with temperature.

### Equation

$$\chi = \frac{C}{T}$$

### Diagram

Magnetic Material



Magnetization Change



Temperature

## Resistance Change Type Sensors

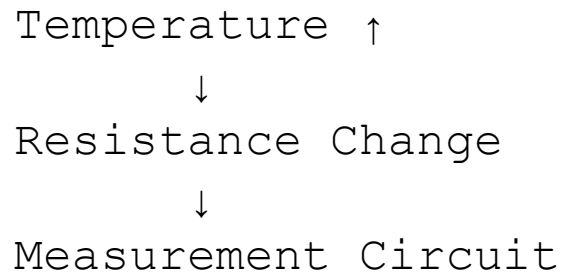
### Principle

Electrical resistance varies with temperature.

### Types

- RTD
- Thermistor

### Diagram



# Resistance Temperature Detector (RTD)

## Material

- Platinum
- Nickel

## Advantages

- Accurate
- Stable

## Diagram

Pt Coil



Bridge Circuit



Display

## Thermistors

### Types

- NTC
- PTC

### Characteristics

- High sensitivity
- Fast response

### Diagram

Temperature



Thermistor



Resistance Variation

## Thermo-EMF Sensors (Thermocouples)

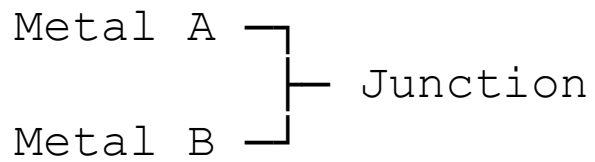
### Principle

Seebeck Effect

### Working

Voltage generated by temperature difference.

### Diagram



$\Delta T \rightarrow$  Voltage

## Junction Semiconductor Sensors

### Principle

PN junction voltage varies with temperature.

### Examples

- LM35
- AD590

### Diagram

PN Junction



Voltage Output



Temperature

## Thermal Radiation Sensors

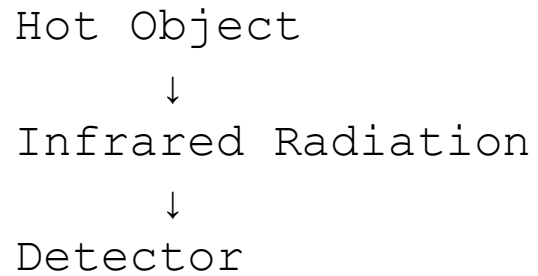
### Principle

Measure emitted thermal radiation.

### Types

- Pyrometers
- Infrared Sensors

### Diagram



## Quartz Crystal Thermoelectric Sensors

### Principle

Quartz resonance frequency varies with temperature.

### Features

- High precision
- Excellent stability

### Diagram

Quartz Crystal



Frequency Shift



Temperature

## **NQR Thermometry**

### **Nuclear Quadrupole Resonance**

#### **Principle**

Resonance frequency depends on temperature.

#### **Applications**

- Cryogenic measurements

#### **Diagram**

RF Signal



NQR Resonance



Temperature

## **Spectroscopic Thermometry**

### **Principle**

Temperature determined from spectral lines.

### **Applications**

- Combustion monitoring
- Plasma diagnostics

### **Diagram**

Hot Gas



Spectrometer



Spectrum Analysis

## Noise Thermometry

### Principle

Based on Johnson-Nyquist noise.

### Equation

$$V_n = \sqrt{4kTRB}$$

### Advantages

- Calibration-free
- High accuracy

### Diagram

Resistor



Thermal Noise



Amplifier

## Heat Flux Sensors

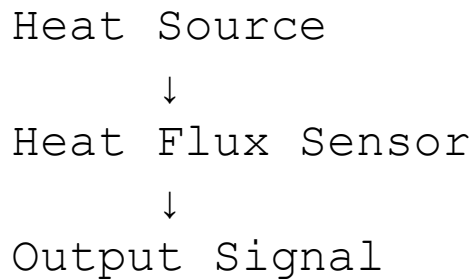
### Principle

Measure heat transfer rate.

### Applications

- Thermal insulation testing
- Aerospace

### Diagram



## Comparison of Thermal Sensors

Sensor	Accuracy	Range	Response
RTD	High	Medium	Medium
Thermistor	Very High	Low	Fast
Thermocouple	Medium	Very High	Fast
Radiation Sensor	Medium	Very High	Very Fast

## Applications and Conclusion

### Applications

- Industrial automation
- Biomedical systems
- Aerospace
- Environmental monitoring
- Scientific research

### Conclusion

- Thermal sensors are essential for temperature measurement.
- Different sensors are selected based on range, accuracy, and response time.

### Final Diagram

Thermal Sensors



Measurement



Control



Automation

## Magnetic Sensors and Transducers

### Topics Covered:

- Introduction
- Sensor Principles
- Magneto-Resistive Sensors
- Anisotropic Magneto-Resistive (AMR) Sensors
- Semiconductor Magnetoresistors
- Hall Effect Sensors
- Inductance & Eddy Current Sensors
- Angular/Rotary Movement Transducers
- Synchros

**Image:** Magnetic field lines around a magnet.