Resistive Sensors and Their Signal Conditioning

Second Stage

Biomedical Transducers and Sensors

Lecture No. 3&4

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2026-2025

Introduction to Resistive Sensors

Resistive sensors are one of the most fundamental types of sensors used in biomedical and engineering applications.

A **Resistive Sensor** is a device in which the measurand causes a change in electrical resistance. The resistance variation is then converted into a measurable voltage or current signal.

Resistive sensors are widely used because they are:

- Simple in construction
- Reliable
- Cost-effective
- Easy to interface with electronic circuits

In biomedical applications, resistive sensors are used in:

- Body temperature measurement
- Blood pressure transducers
- Respiratory monitoring
- Biomechanical strain measurement

Basic Operating Principle of Resistive Sensors

The resistance of a conductor is given by:

$$R = \rho \frac{L}{A}$$

Where:

- R= Resistance
- ρ= Resistivity of material
- L= Length
- A= Cross-sectional area

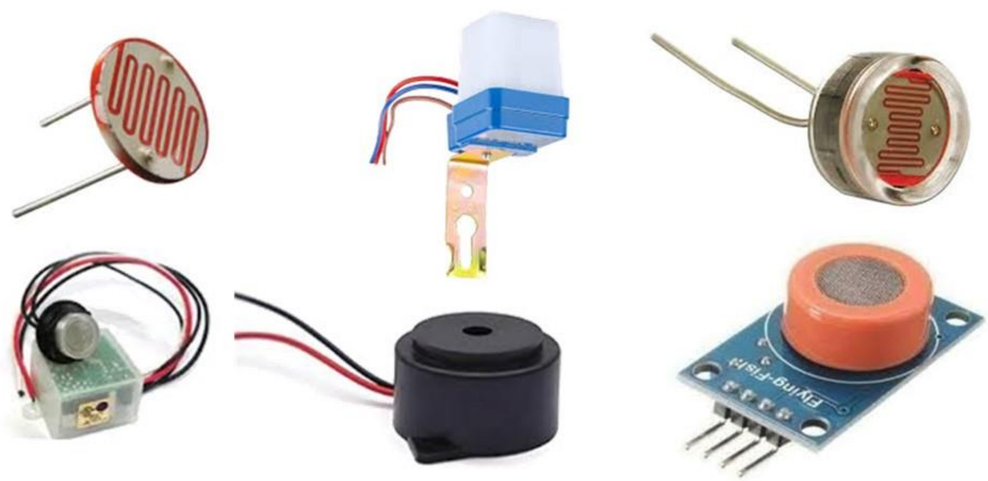
Any physical quantity that changes:

- Resistivity (temperature, light)
- Length (strain)
- Area (mechanical deformation)
- will result in a measurable resistance change.

Types of Resistive Sensors

Resistive sensors used in biomedical and engineering systems include:

1. Potentiometers
2. Strain Gages
3. Resistive Temperature Detectors (RTDs)
4. Thermistors
5. Light Dependent Resistors (LDRs)



Potentiometers

Definition

A **potentiometer** is a three-terminal resistive device used primarily for position or displacement measurement.

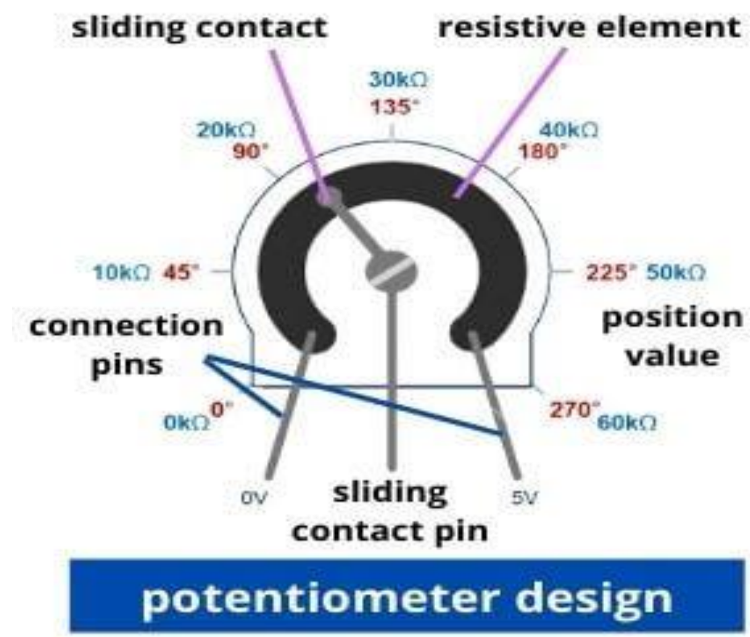
Working Principle : It operates as a voltage divider:

$$V_{out} = V_{in} \times \frac{R_2}{R_1 + R_2}$$

Output voltage is proportional to mechanical displacement.

Applications in Biomedical Engineering

- ❑ Joint angle measurement
- ❑ Rehabilitation devices
- ❑ Position feedback in prosthetics



Strain Gages

Definition

A **strain gage** measures mechanical strain by detecting resistance changes caused by deformation.

Mathematical Relation

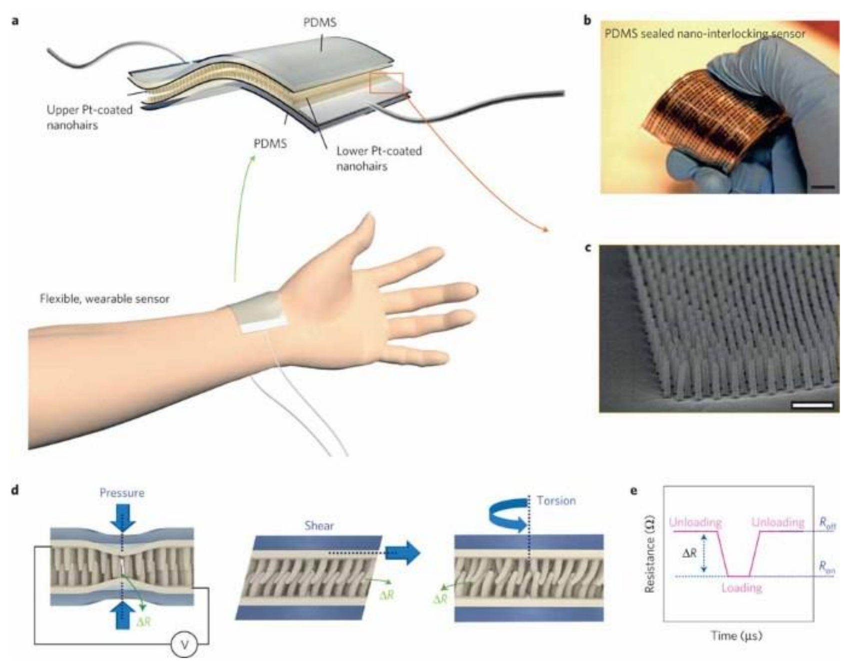
$$\frac{\Delta R}{R} = GF \cdot \varepsilon$$

Where:

- ❑ GF= Gauge factor
- ❑ ε= Strain
- ❑ Typical metallic gauge factor ≈ 2

Biomedical Applications

- ❑ Load cells for patient weight monitoring
- ❑ Blood pressure measurement
- ❑ Respiratory movement detection



Resistive Temperature Detectors (RTDs)

Definition

An RTD is a temperature sensor that uses the predictable resistance change of metals (usually platinum).

Temperature Relation

$$R(T) = R_0(1 + \alpha T)$$

For platinum:

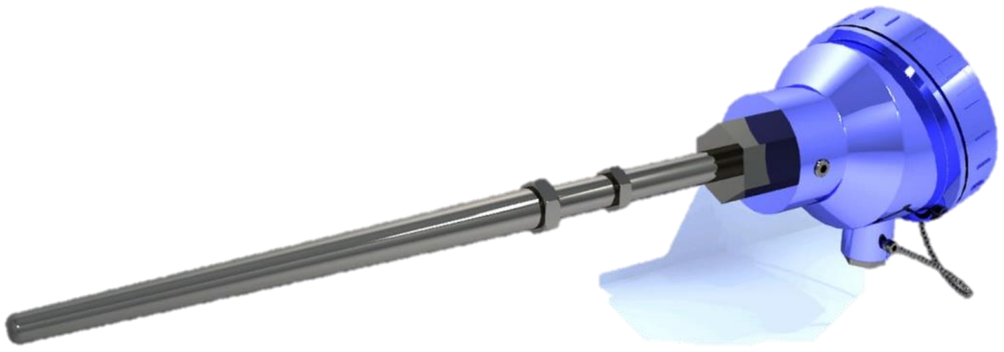
$$\alpha \approx 0.00385/°C$$

Advantages

- ❑ High accuracy
- ❑ Excellent stability
- ❑ Wide temperature range

Biomedical Applications

- ❑ Body temperature monitoring
- ❑ Laboratory instrumentation



Thermistors

Definition

Thermistors are temperature-sensitive semiconductor resistors.

Types:

NTC (Negative Temperature Coefficient)

Resistance decreases as temperature increases.

PTC (Positive Temperature Coefficient)

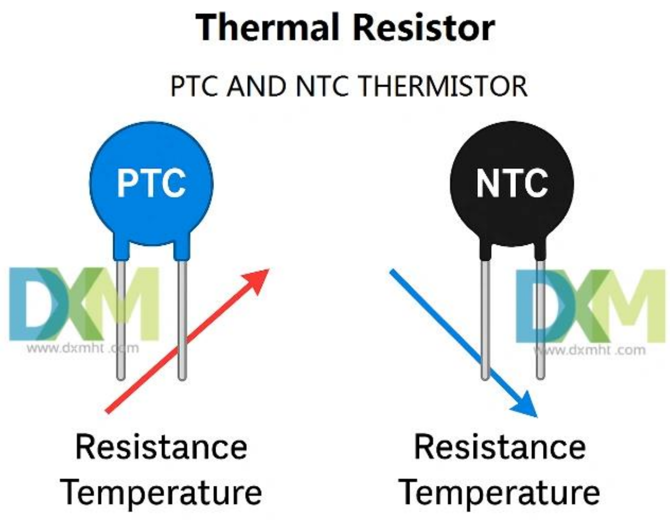
Resistance increases as temperature increases.

Equation (NTC)

$$R(T) = R_0 e^{B\left(\frac{1}{T}-\frac{1}{T_0}\right)}$$

Biomedical Applications

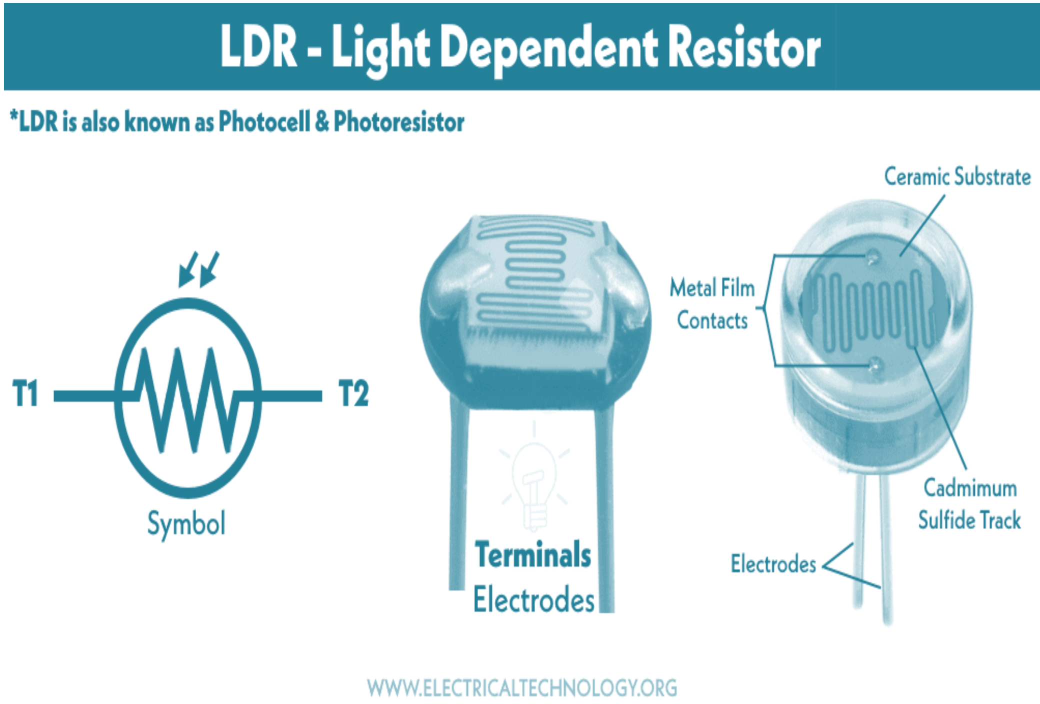
- ❑ Digital thermometers
- ❑ Incubator temperature control
- ❑ Patient monitoring systems



Light Dependent Resistors (LDR)

Definition

An LDR is a photoconductive sensor whose resistance decreases with increasing light intensity.



Characteristics

- ❑ High resistance in darkness
- ❑ Low resistance in light
- ❑ Nonlinear response

Biomedical Applications

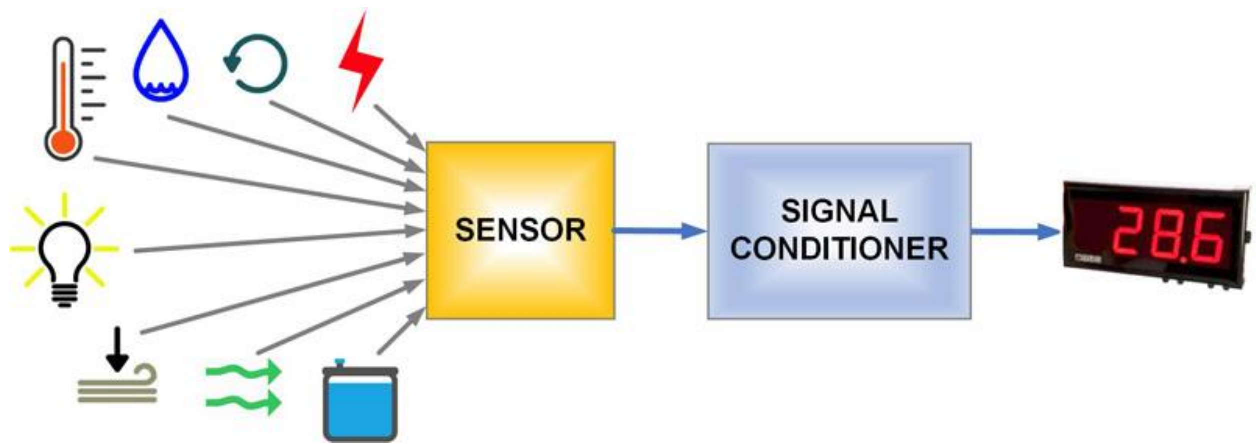
- ❑ Optical pulse sensors
- ❑ Light detection in imaging systems

Signal Conditioning for Resistive Sensors

Raw resistance changes are usually small and require conditioning before processing.

Signal conditioning includes:

1. Excitation
2. Bridge circuits
3. Amplification
4. Filtering
5. Linearization



Excitation Methods

Constant Voltage Excitation

Used in:

- ❑ Potentiometers
- ❑ Wheatstone bridges

Constant Current Excitation

Used in:

- ❑ RTDs
- ❑ Thermistors

Wheatstone Bridge

Used for precise measurement of small resistance changes.

Advantages:

- ❑ Improved sensitivity
- ❑ Temperature compensation
- ❑ Noise reduction

Amplification

Instrumentation amplifiers are preferred due to:

- ❑ High input impedance
- ❑ High CMRR
- ❑ Low noise

Filtering

Low-pass filters remove:

- ❑ Electromagnetic interference
- ❑ High-frequency noise

Linearization

Required for:

- ❑ Thermistors
- ❑ LDRs

Methods:

- ❑ Mathematical compensation
- ❑ Lookup tables
- ❑ Software correction

Comparative Analysis

Sensor	Linearity	Sensitivity	Stability	Cost
Potentiometer	High	Medium	Medium	Low
Strain Gage	High	Low	High	Medium
RTD	High	Medium	Very High	High
Thermistor	Low	Very High	Medium	Low
LDR	Low	Medium	Low	Very Low

Advantages and Limitations

Advantages

- ❑ Simple structure
- ❑ Easy signal processing
- ❑ Cost-effective
- ❑ Reliable

Limitations

- ❑ Temperature drift
- ❑ Nonlinearity (thermistors, LDRs)
- ❑ Mechanical wear (potentiometers)
- ❑ Self-heating effects

Conclusion

- Resistive sensors are essential components in biomedical instrumentation.

- Their accurate utilization depends not only on understanding their physical principles but also on implementing proper signal conditioning techniques.

- Mastering these sensors forms a foundation for advanced biomedical measurement systems.

References

- Sensors and Signal Conditioning, Ramon Pallas-Areny and John G. Webster, John Wiley & Sons, 2001,2nd Edition.
- Biosensors: An Introduction , Eggins, Brian, John Wiley & Sons, 1996,1st Edition