Introduction to Biomedical Sensors

Second Stage

Biomedical Transducers and Sensors

Lecture No. 1&2

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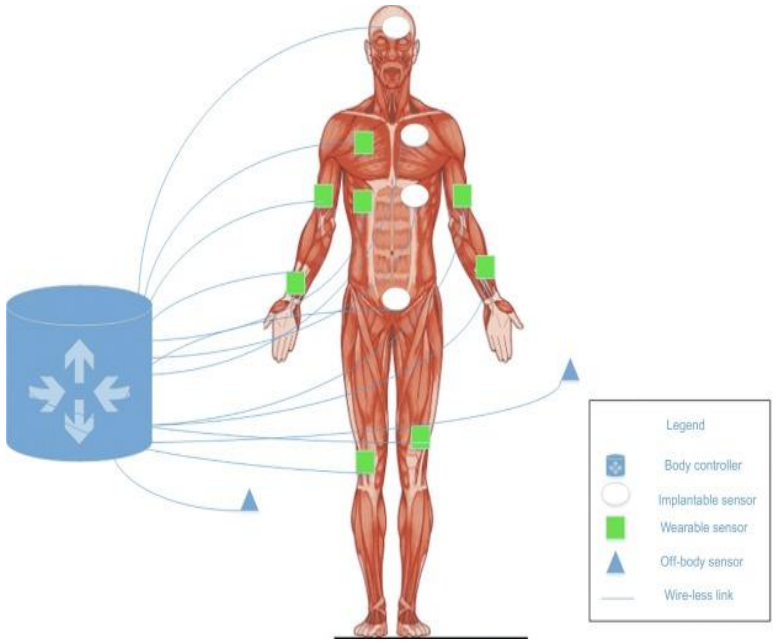
Introduction and General Concepts

A **Biomedical Sensor** is a device that detects, measures, and converts a biological or physiological parameter into a measurable electrical signal. These sensors play a crucial role in modern healthcare, diagnostics, monitoring, and medical research.

Examples of Biomedical Parameters

- Body temperature
- Blood pressure
- Heart rate
- Blood glucose level
- Oxygen saturation (SpO_2)
- Brain activity (EEG)



Basic Sensor System Structure

A biomedical sensing system typically consists of:

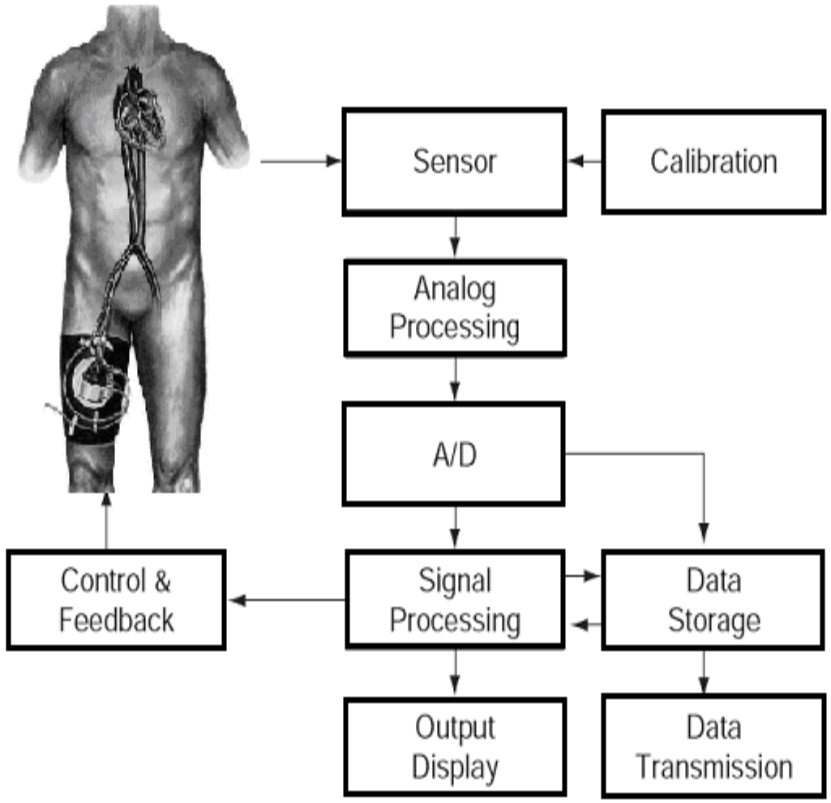
1.Measurand (biological quantity being measured)

2.Sensor (Sensing Element)

3.Signal Conditioning Unit

4.Data Processing Unit

5.Display or Storage System



Terminology Related to Sensors

Understanding basic sensor terminology is essential:

- **Measurand**: The physical or biological quantity to be measured.
- **Sensor**: The primary sensing element that responds to the measurand.
- **Transducer**: Converts one form of energy into another (usually physical → electrical).
- **Sensitivity**: Change in output per unit change in input.
- **Range**: Minimum and maximum values the sensor can measure.
- **Resolution**: Smallest detectable change in input.
- **Accuracy**: Closeness of measured value to the true value.
- **Precision**: Repeatability of measurements.
- **Drift**: Gradual change in sensor output over time.

Classification of Biomedical Sensors

Biomedical sensors can be classified in several ways:

A. Based on Measurand

- **Physical Sensors**: Temperature, pressure, motion
- **Chemical Sensors**: pH sensors, gas sensors
- **Biological Sensors (Biosensors)**: Enzyme sensors, immunosensors, DNA sensors

B. Based on Transduction Principle

- **Resistive Sensors** (e.g., strain gauges)
- **Capacitive Sensors**
- **Piezoelectric Sensors**
- **Optical Sensors**
- **Electrochemical Sensors**

C. Based on Invasiveness

- **Invasive Sensors**: Implanted inside the body
- **Non-Invasive Sensors**: External measurements (e.g., pulse oximeter)
- **Minimally Invasive Sensors**

Sensor Calibration

Definition:

Calibration is the process of comparing a sensor's output with a known reference standard and adjusting it to improve accuracy.

Purpose of Calibration:

- Reduce measurement errors
- Improve accuracy and reliability
- Ensure consistency across measurements

Calibration Procedure:

1. Apply a known input (reference)
2. Measure sensor output
3. Compare output with standard
4. Adjust sensor parameters if needed

Types of Calibration

1. Static Calibration

Static Characteristics of Sensors: Static characteristics describe sensor behavior under steady-state conditions. Key Static Characteristics is :

- **Accuracy**
- **Precision**
- **Sensitivity**
- **Linearity**
- **Resolution**
- **Hysteresis**
- **Repeatability**

2. Dynamic Calibration

Dynamic Characteristics of Sensors: Dynamic characteristics describe sensor behavior when the measurand changes with time. **Important Dynamic Parameters :**

- **Response Time**
- **Time Constant**
- **Rise Time**
- **Settling Time**
- **Bandwidth**
- **Frequency Response**

Errors in Biomedical Sensors

Types of Errors

- **Systematic Errors**: Consistent and predictable
- **Random Errors**: Due to noise and environmental effects
- **Gross Errors**: Human or equipment mistakes

Sources of Errors

- Environmental conditions
- Aging of components
- Improper calibration
- Electrical noise

Measurement Uncertainty

Definition : Uncertainty represents the range within which the true value of a measurement is expected to lie.

Causes of Uncertainty

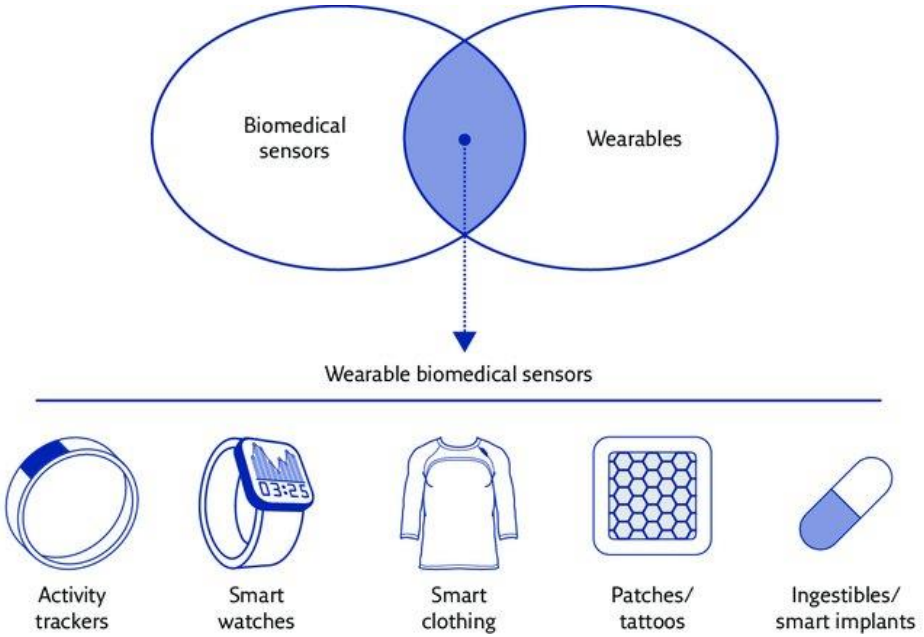
- Instrument limitations
- Calibration errors
- Environmental influences
- Operator variability

Importance

- Essential in clinical decision-making
- Helps evaluate reliability of measurements
- Required in medical standards and regulations

Applications of Biomedical Sensors

- ❖Patient monitoring systems
- ❖Wearable health devices
- ❖Diagnostic equipment
- ❖Medical imaging
- ❖Rehabilitation engineering



Conclusion

Biomedical sensors are fundamental components in modern healthcare systems.

Understanding their principles, characteristics, calibration, and sources of error is essential for accurate and reliable medical measurements.

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