1.2 Introduction to Biomedical Sensors

What is a Biomedical Sensor?

- Any instrumentation system can be described as having three fundamental components:
- a sensor,
- a signal processor,
- and a display and/or storage device.
- Although all these components of the instrumentation system are important, the sensor serves a special function in that it interfaces the instrument with the system being measured.
- In the case of biomedical instrumentation, a biomedical sensor is the interface between the electronic instrument and the biological system.

Important Concerns

1. There are some general concerns that are important for any sensor in an instrumentation system interface function especially for biomedical sensors:
2. The sensor can affect the system, for that sensors must be designed to minimize their interaction with the biological host. It is important that the presence of the sensor does not affect the variable being measured in the vicinity of the sensor via interaction between the sensor and the biologic system. This may change the quantity being sensed in the vicinity.
3. The biological system can affect the performance of the sensor. The foreign body reaction might cause the host's system to attempt to break down the materials of the sensor in order to remove it. This may, in fact, degrade the sensor package so that it can no longer perform in an adequate manner. So the material of package must be proper.

4. Sensors that are implanted in the body are not accessible for calibration. Thus, they must have extremely stable characteristics so that frequent calibrations are not necessary.

Classification of Biomedical Sensors

Biomedical sensors can be **classified** according to how they are used with respect to the biological system:

1. ***Noninvasive biomedical sensors*** *do not even contact the* biological system being measured. Sensors of radiant heat or sound energy coming from an organism are examples of noncontacting sensors. Noninvasive sensors can also be placed on the body surface like Skin surface thermometers, biopotential electrodes, and strain gauges placed on the skin.

2. ***Indwelling sensors (minimally invasive sensors) :****are those that* can be placed into a natural body cavity that communicates with the outside. Examples: oral–rectal thermometers, intrauterine pressure transducers, and stomach pH sensors.

3. ***Invasive sensors:*** *are those that need to be surgically placed and* that require some tissue damage associated with their installation.

We can also classify sensors in terms of the **quantities** that they measure:

1. ***Physical sensors:*** are used in measuring physical quantities *such* as displacement, pressure, and flow.

2.***Chemical sensors:*** are used to determine the concentration of chemical substances within the host. A sub-group of the chemical sensors that are concerned with sensing the presence and the concentration of biochemical materials in the host.

3. ***Bio-analytical sensors or biosensors:*** used to measure some internal quantities like enzymes.

4.***Bio-analytical Sensors:*** A special class of sensors of biological molecules has evolved in recent years. These bioanalytical sensors take advantage of one of the following biochemical reactions:

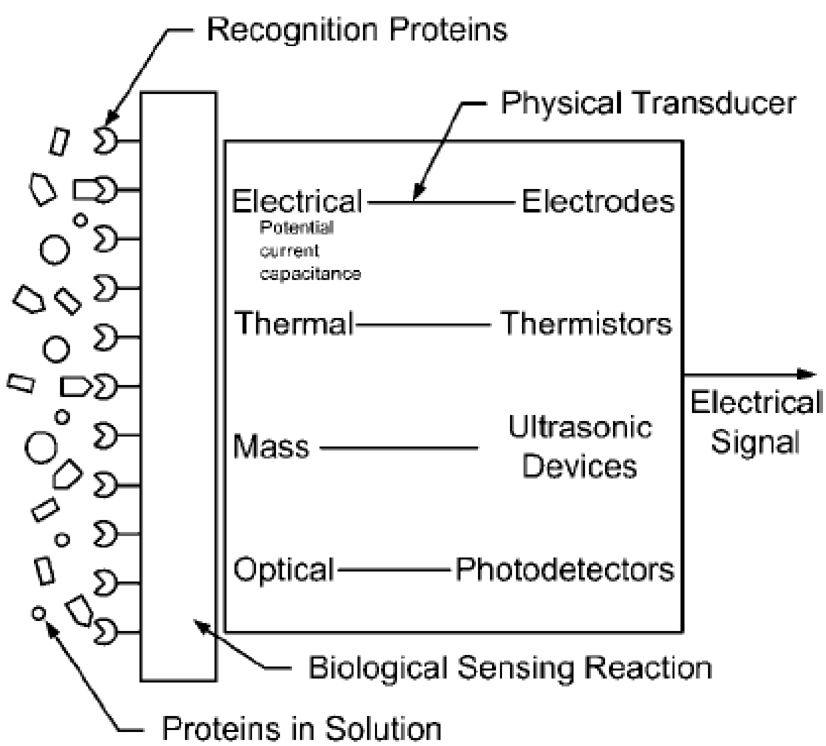
i. enzyme–substrate.

ii. antigen–antibody.

iii. ligand–receptor.

- The advantage of using these reactions in a sensor is that they are highly specific to a particular biological molecule, and sensors with high **sensitivity and selectivity** can be developed based upon these reactions.

- The basic structure of a bio-analytical sensor;



Physical Sensors

- Physical variables measured include temperature, strain, force, pressure, displacement, position, velocity, acceleration, optical radiation, sound, flow rate, viscosity, and electromagnetic fields.

Temperature Sensors:

- Temperature is an important parameter in many control systems, most familiarly in environmental control systems. Several distinctly different transduction mechanisms have been employed to measure temperature.
- The mercury thermometer is a temperature sensor which produces a non electronic output signal. The most commonly used electrical signal generating temperature sensors are thermocouples, thermestors, and resistance thermometers.

Thermocouples:

- Thermocouples employ the Seebeck effect, which occurs at the junction of two dissimilar conductors. A voltage difference is generated between the hot and cold ends of the two conductors due to the differences in the energy distribution of electrons at the two different temperatures. The voltage magnitude generated depends on the properties of the conductor, e.g., conductivity and work function, such that a difference voltage will be measured between the cold ends of two different conductors. The voltage changes fairly linearly with temperature over a given range, depending on the choice of conductors.
- To **minimize measurement error,** the cool end of the couple must be kept at a constant temperature and the voltmeter must have high input impedance. A commonly used thermocouple is made of copper and constantan wires.
- A thermocouple is an ‘‘auto-generator,’’ i.e., it produces a usable output signal, in this case electronic, directly in response to the measurand without the need for auxiliary power.

Resistance thermometer:

- The resistance thermometer relies on the increase in resistance of a metal wire with increasing temperature.
- As the electrons in the metal gain thermal energy, they move about more rapidly and undergo more frequent collisions with each other and the atomic nuclei. These scattering events reduce the mobility of the electrons, and since resistance is inversely proportional to mobility, the resistance

increases.

- Resistance thermometers typically consist of a coil of thin metal wire. Platinum wire gives the largest linear range of operation. The resistance thermometer is a **‘‘modulator’’** or passive transducer. In order to determine the resistance change, a constant current is supplied and the corresponding voltage is measured (or vice versa).

- A measure of **the sensitivity** of a resistance thermometer is its temperature coefficient of resistance (TCR).

Thermistors:

- Thermistors are resistive elements made of semiconductor materials and have a negative temperature coefficient of resistance. The mechanism governing the resistance change of a thermistor is the increase in the number of conducting electrons with increasing temperature, due to thermal generation, i.e., the electrons that are the least tightly bound to the nucleus (valence electrons) gain sufficient thermal energy to break away (enter the conduction band) and become influenced by external fields.

- Thermistors are measured in the same manner as resistance thermometers, but thermistors have up to 100 times higher TCR values.

Displacement and Force Sensors:

- Many types of forces can be sensed by the displacements they create.

- For example, the force due to acceleration of a mass at the end of a spring will cause the spring to stretch and the mass to move. Its displacement from the zero acceleration position is governed by the force generated by the acceleration ($F = m \cdot a$) and by the restoring force of the spring.

- Another example is the displacement of the center of a deformable membrane due to **a difference in pressure across it.**

- Both of these examples require multiple transduction mechanisms to produce an electronic output: **a**

- **primary mechanism** which converts force to displacement (mechanical to mechanical) and then **an intermediate mechanism** to convert displacement to an electrical signal (mechanical to electrical).

Applications Of Biomedical Sensors:

- Biomedical research:
- One of the application fields of the biomedical sensors is using them in continuous biomedical research. So, these sensors can be used to improve the quality of the biomedical product).
- Patient care applications:

Sensors are used as a part of instruments that carry out patient monitoring by making measurements such as blood pressure, oxygen saturation, body temperature and ECG.

- Specimen analysis:
- This can include analyses that can be carried out by the patients themselves in their homes such as it is done with home blood glucose analyzers.
- Sensors also are a part of large, multi- component, automatic blood analyzers used in the central clinical laboratories of medical centers.