Transducer & Sensors

- A transducer is a device that converts energy from one form to another. Usually a transducer converts a signal in one form of energy to a signal in another.

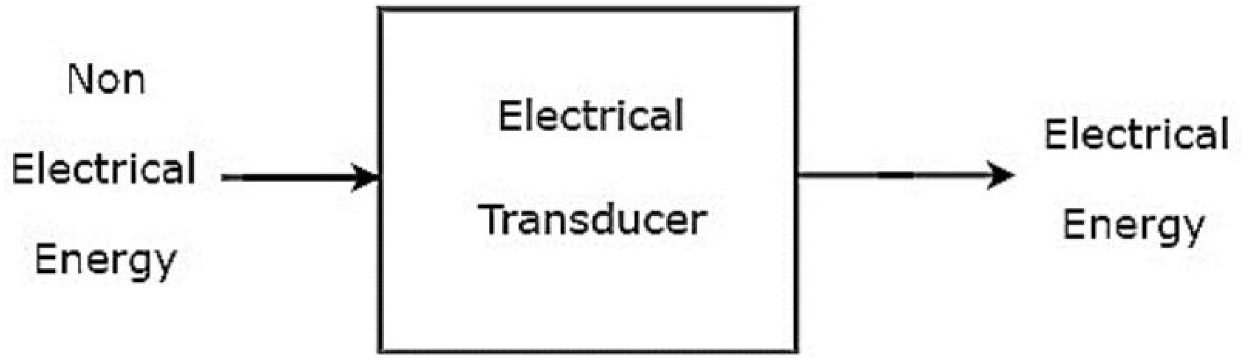
- Transducers are often employed at the boundaries of automation, measurement, and control systems, where electrical signals are converted to and from other physical quantities (energy, force, torque, light, motion, position, etc.).

- The process of converting one form of energy to another is known as transduction.

Transducers

- Generally, medical diagnostic instruments derive their information from sensors, electrodes, or transducers.
- Medical instrumentation relies on analog electrical signals for an input.
- These signals can be acquired directly by biopotential electrodes—for example, in monitoring the electrical signals generated by the heart, muscles or brain, or indirectly by transducers that convert a nonelectrical physical variable such as pressure, flow, or temperature, or biochemical variables, such as partial pressures of gases or ionic concentrations, to an electrical signal.
- Since the process of measuring a biological variable is commonly referred to as sensing, electrodes and transducers are often grouped together and are termed sensors.

Basically, Transducer converts one form of energy into another form of energy. The transducer, which converts non-electrical form of energy into electrical form of energy is known as **electrical transducer**. The **block diagram** of electrical transducer is shown in below figure.



As shown in the figure, electrical transducer will produce an output, which has electrical energy. The output of electrical transducer is equivalent to the input, which has non-electrical energy.

- The **purpose of the transducer** is to convert the biochemical reaction into the form of an optical, electrical, or physical signal that is proportional to the concentration of a specific chemical.

- Depending on the specific needs, some sensors are used primarily in clinical laboratories to measure in vitro physiological quantities such as electrolytes, enzymes, and other biochemical metabolites in blood.

- Other biomedical sensors for measuring pressure, flow, and the concentrations of gases, such as oxygen and carbon dioxide, are used in vivo to follow continuously (monitor) the condition of a patient.

Types of Electrical Transducers

Mainly, the electrical transducers can be classified into the following two types.

- Active Transducers
- Passive Transducers

Now, let us discuss about these two types of transducers briefly.

Active Transducers

- It is the type of transducer device that does not require any exterior power supply for producing output and which is in function to convert physical signals into electric powered signals by means of the ability of itself.

- It is also called self-generating transducer, since it doesn't require any external power supply.
- The transducer, which can produce one of the electrical quantities such as voltage and current is known as active transducer.
- A thermocouple is an instance of an active transducer.

The **block diagram** of active transducer is shown in below figure.

As shown in the figure, active transducer will produce an electrical quantity (or signal), which is equivalent to the non-electrical input quantity (or signal).

Examples

Following are the examples of active transducers.

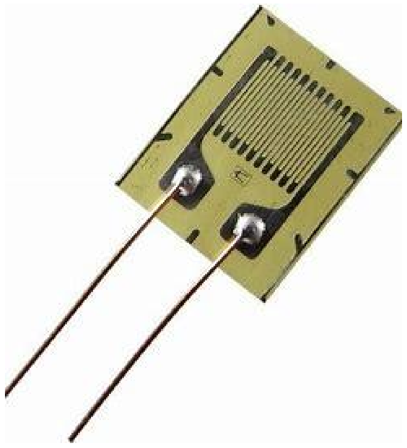
- Piezo Electric Transducer
- Photo Electric Transducer
- Thermo Electric Transducer

- The **Passive transducer** produces a change in some passive electrical quantity, such as capacitance, resistance, or inductance, as a result of stimulation.

- Passive transducers usually require additional electrical energy.
- It is an externally powered transducer and is a type of gadget that is no longer in a position to convert physical signals into electric powered signals through itself,

- It converts signals by means of any other energy source i.e which produces variation when comes in contact with any passive element.

- Example: Strain gauges, capacitive transducers, and thermistors are of passive transducers.
- Its output form relies upon on variant in passive associated.

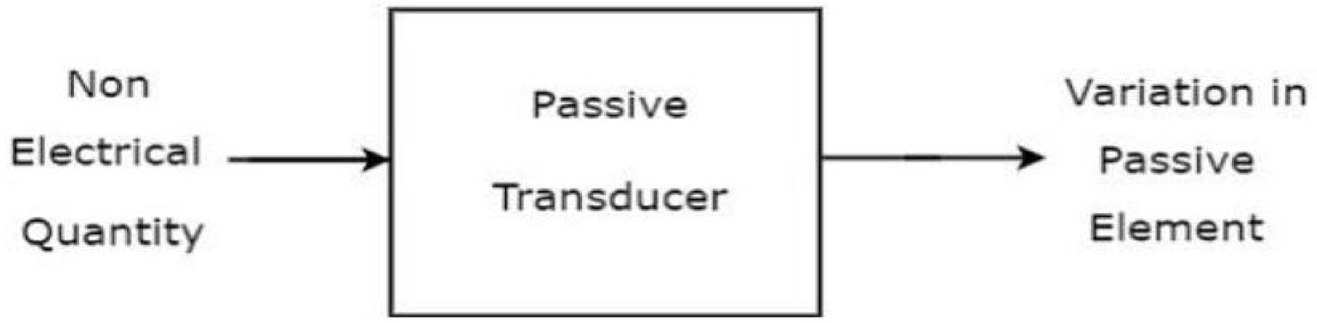


Strain gauges

Passive Transducers

The transducer, which can't produce the electrical quantities such as voltage and current is known as **passive transducer**. But, it produces the variation in one of passive elements like resistor (R), inductor (L) and capacitor (C). Passive transducer requires external power supply.

The **block diagram** of passive transducer is shown in below figure.



- As shown in the figure, passive transducer will produce variation in the passive element in accordance with the variation in the non-electrical input quantity (or signal).

Examples: Following are the examples of passive transducers.

- Resistive Transducer
- Inductive Transducer
- Capacitive Transducer

Difference between Active Transducer and Passive Transducer:

Active Transducer	Passive Transducer
It is kind of transducer which generates output in form of voltage or current, without any exterior power supply.	It is a kind of transducer whose interior parameters include capacitance, resistance, The smallest signals and inductance modified or change when it comes in contact with any passive element.
Its working principle includes drawing energy from measured source.	Its working principle includes drawing power from external sources which results in a change in its physical properties.

It has its own power supply for its functioning.	For its functioning, it requires an external power supply.
It has a much simpler design, unlike Passive Transducer.	It has a design that is complex as compared to an Active Transducer.
Smallest change in pressure that it can be detected in its output is very low, i.e it has a low resolution.	It can detect small changes in output easily and more accurately, i.e. it has a high resolution.

The output of active transducers depends on signal which is used for measurement.	The output of passive transducers depends on signal from the external power supply.
These kinds of transducers are also known as self-generating transducers as they do not need any external power source.	These are also known as externally powered transducers as they need an external power supply to perform tasks.

What is Sensor?

- As per the definition of a sensor, it is a physical device that is useful for measuring the changes in the surroundings after measuring their physical quantities (light, heat, sound, etc.) and transforming them into signals (current, voltage, etc.) that can be easily read by users.
- Sensors provide accurate readings if the calibration is done correctly.
- For instance, mercury present in a thermometer transforms the body temperature change into easily measured reading that can be sighted through a calibrated glass tube; it does so because of its expansion and contraction courtesy temperature changes.

What is Transducer?

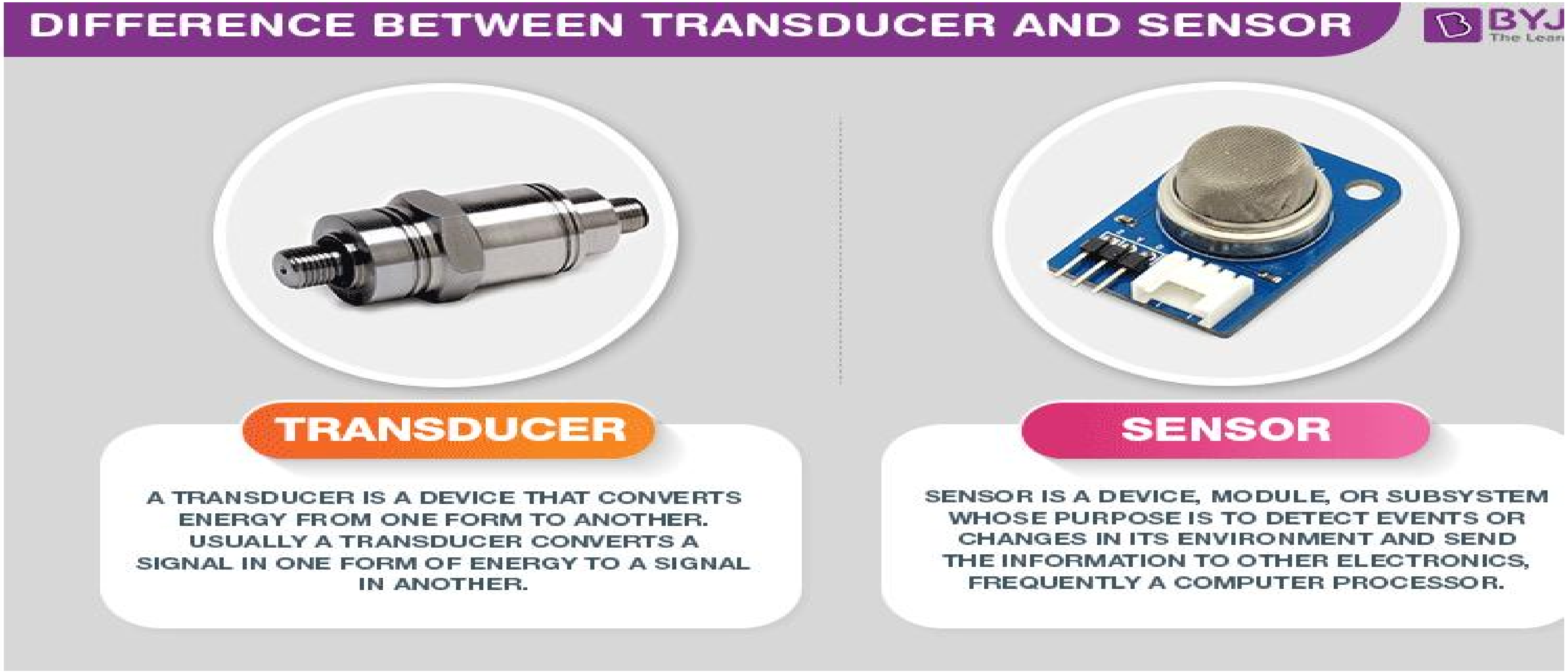
- As per the definition of a transducer, it is a physical device that alters the physical attributes of given non-electrical signals to form an electrical signal that can be measured easily.

- This process of conversion of energy in the transducer is referred to as transduction. Transduction takes two steps to complete; firstly, it senses signals and then strengthens them for the cause of further processing.

Difference Between a Transducer and a Sensor

A sensor is a device that measures a physical quantity. For example, in a mercury thermometer, the mercury simply expands when the temperature rises to give a reading to the user. Here there are no electrical inferences or changes. On the other hand, a transducer measures similar quantities as a sensor but the signal in a transducer is converted from one form to another. This is the reason why transducers are also referred to as energy converters.

Transducers	Sensors
It converts energy from one form to another.	It senses physical quantities and converts it into a readable form.
Cable extension transducer, linear transducer and microphones are some examples of transducers.	Thermistors, pressure switches and motion sensors are some examples of sensors.


DIFFERENCE BETWEEN TRANSDUCER AND SENSOR
TRANSDUCER
A TRANSDUCER IS A DEVICE THAT CONVERTS ENERGY FROM ONE FORM TO ANOTHER. USUALLY A TRANSDUCER CONVERTS A SIGNAL IN ONE FORM OF ENERGY TO A SIGNAL IN ANOTHER.
SENSOR
SENSOR IS A DEVICE, MODULE, OR SUBSYSTEM WHOSE PURPOSE IS TO DETECT EVENTS OR CHANGES IN ITS ENVIRONMENT AND SEND THE INFORMATION TO OTHER ELECTRONICS, FREQUENTLY A COMPUTER PROCESSOR.

Sensor Classifications

- Biomedical sensors are usually classified according to the quantity to be measured and are typically categorized as physical, electrical, or chemical, depending on their specific applications.

- Biosensors, which can be considered a special subclassification of biomedical sensors, are a group of sensors that have two distinct components: a biological recognition element, such as a purified enzyme, antibody, or receptor,

- That functions as a mediator and provides the selectivity that is needed to sense the chemical component (usually referred to as the analyte) of interest, and

- a supporting structure that also acts as a transducer and is in intimate contact with the biological sensing sensed by the biological recognition element into a quantifiable measurement, typically in the element.

Sensor Packaging

- Packaging of certain biomedical sensors, primarily sensors for in vivo applications, is an important consideration during the design, fabrication, and use of the device.

- Obviously, the sensor must be safe and remain functionally reliable.

- In the development of implantable biosensors, an additional key issue is the long operational lifetime and biocompatibility of the sensor.

- Whenever a sensor comes into contact with body fluids, the host itself may affect the function of the sensor, or the sensor may affect the site in which it is implanted.

Sensor Specifications

- To understand sensor performance characteristics, it is important first to understand some of the common terminology associated with sensor specifications.
- Sensitivity: Sensitivity is typically defined as the ratio of output change for a given change in input.
- Range: The range of a sensor corresponds to the minimum and maximum operating limits that the sensor is expected to measure accurately. For example, a temperature sensor; operating range of -200 to +500 ^{0}C.
- Accuracy: Accuracy refers to the difference between the true value and the actual value measured by the sensor.
- Precision: Precision refers to the degree of measurement reproducibility. Very reproducible readings indicate a high precision. Precision should not be confused with accuracy.
- For example, measurements may be highly precise but not necessary accurate.

- Resolution: When the input quantity is increased from some arbitrary nonzero value, the output of a sensor may not change until a certain input increment is exceeded. Accordingly, resolution is defined as the smallest distinguishable input change that can be detected with certainty.

- Reproducibility: Reproducibility describ
- es how close the measurements are when the same input is measured repeatedly over time.
- Offset: Offset refers to the output value when the input is zero,
- Linearity: Linearity is a measure of the maximum deviation of any reading from a straight calibration line.

- Response Time: The response time indicates the time it takes a sensor to reach a certain percent (e.g., 95 percent) of its final steady-state value when the input is changed.
- Drift: Drift refers to the change in sensor reading when the input remains constant.

Advantages of converting a physical quantity into an electrical signal

Here, we have listed the various advantages of converting a physical quantity into an electrical signal:

- Electrical signals are easily transmitted and processed for measurement.
- Electrical signals process less friction error.
- Small power is needed to control the electrical systems.
- Amplification and attenuation of electrical signals are easy.
- The measuring instrument used for measuring the electrical signal is very compact and accurate.

Transducer Efficiency

Transducer efficiency is defined as the ratio of output power in the desired form to the total power input. Mathematically, the ratio is represented as follows:

$$E = \frac{Q}{P}$$

P represents the input in the above ratio, and Q represents the power output in the desired form. The efficiency of the transducer always falls between 0 and 1.

No transducer is 100% efficient; some power is always lost in the conversion process. This loss is manifested in the form of heat. In incandescent lamps of certain wattage, only a few watts are transformed into visible light. Most of the power is dissipated as heat. Due to this, an incandescent lamp is a bad transducer in terms of efficiency.

Applications of Transducer

- A transducer measures load on the engines
- They are used to detect the movement of muscles; this process is known as acceleromyograph.
- Transducers are used in an ultrasound machine.
- The transducers in a speaker convert electrical signals into acoustic sound.
- A transducer is used in the antenna to convert electromagnetic waves into an electrical signal.

temerture trasducer

temerture sensor

temerture trasducer

Electrodes for biophysical sensing
(Biopotential Electrodes)

- Bioelectricity is a naturally occuring phenomenon that aries from the fact that living organism composed of ions in different quantitites.
- Potential difference occurs when the concentration of ions is different between two points. When dealing ioning conduction, it is very complex and non-linear phenomenon.

- Medical Electrodes: The medical electrode transfers the energy of ionic currents in the body into electrical currents that can be amplified, studied, and used to help make diagnoses.

- The porpose of bioelectrodes is to acquire medically significant bioelectric signals, such as ECG, EMG and EEG.

- Bioelectrodes are class of sensors that trnasduce ionic conduction to electronics conduction so that signal can be processed in electronic circuits.

Electrodes for biophysical sensing ....

- Biopotential measurements must be carried out using high-quality electrodes to minimize motion artifacts so that the measured signal is accurate, stable, & undistorted.

- Body fluids are very corrosive to metals, so not all metals are acceptable for biopotential sensing. Furthermore, some materials are toxic to living tissues.

- For implantable applications, relatively strong metal electrodes are used. Example: stainless steel or noble materials such as gold, or various alloys such as platinum-tungsten, titanium-nitride, or iridium-oxide.

- It should not react chemically with tissue electrolytes, thus minimize tissue toxicity.

- Biopotential electrodes are classified either as noninvasive (skin surface) or invasive (e.g., microelectrodes or wire electrodes).

Surface Electrodes (Floating, Metal Plate & Multipoint)

What is a Surface Electrode?

- Surface electrode measures the potential available from the surface of the skin. It senses the signal from heart, brain and nerves.

- Larger surface electrodes sense the ECG signals. Smaller surface electrodes sense the EMG and EEG signals.
- The types of surface electrodes are as follows:

1. Metal Plate Electrodes

- ECG measurement technique uses either rectangular or circular shaped plate electrodes made of nickel, silver or German silver materials.

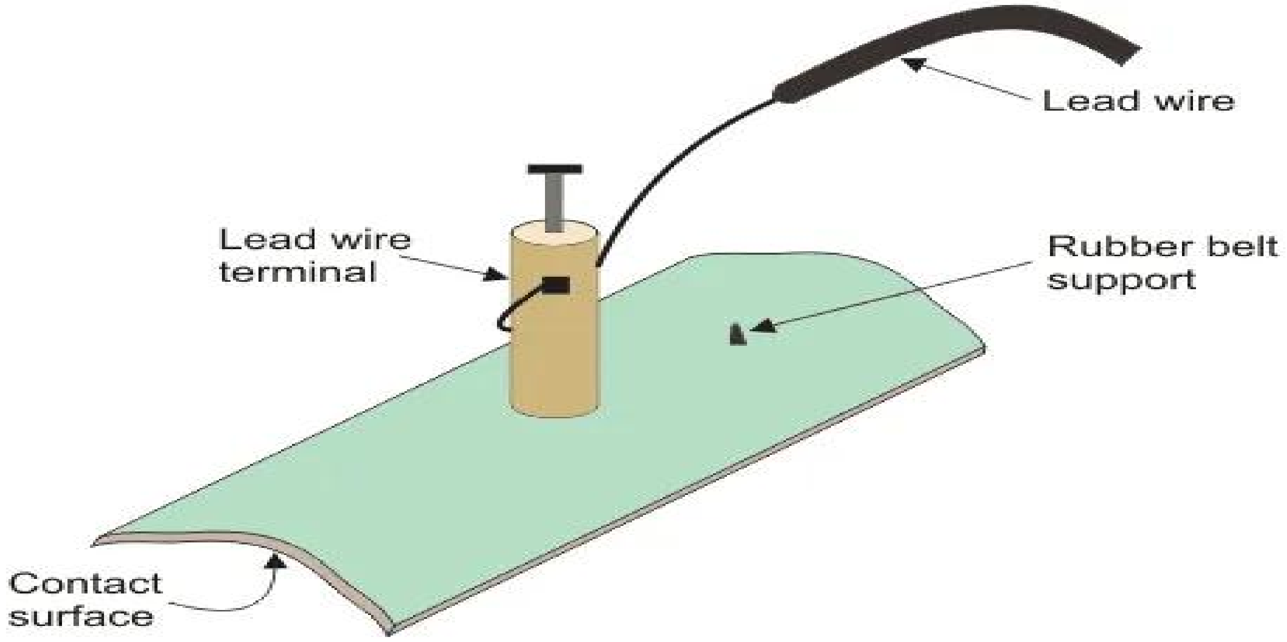
- Electrodes are pasted on the skin using electrolyte paste. The electrode slippage and plate displacement are the two major disadvantages of this electrode type.

- They are very sensitive, leading to measurement errors.

- Since it is suitable for application on four limbs of the body, they called limb electrodes.

- During surgical procedure since patient's legs are immobile, limb electrodes are preferred. Chest electrodes interfere with the surgery, so not used for ECG measurement.

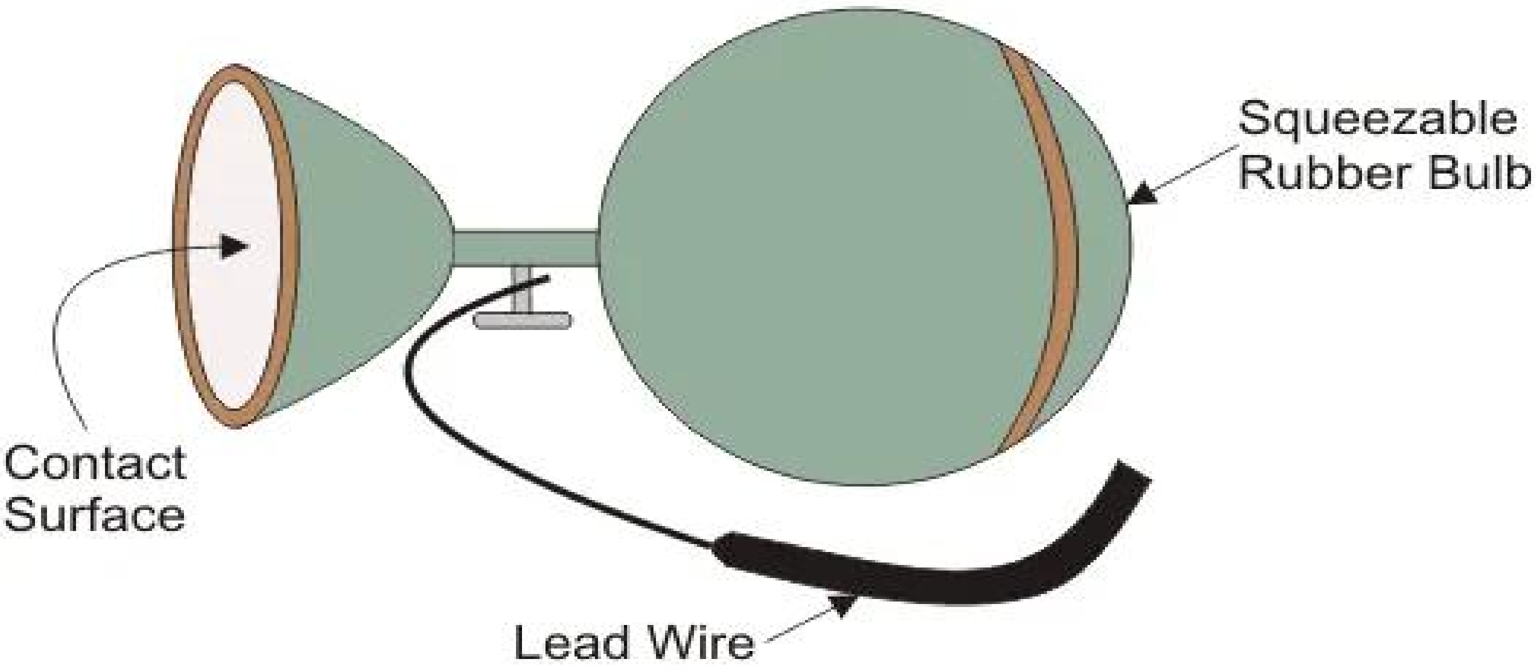
- At the same time for a long-term patient monitoring limb-electrodes are not used.



2. Suction Cup Electrodes

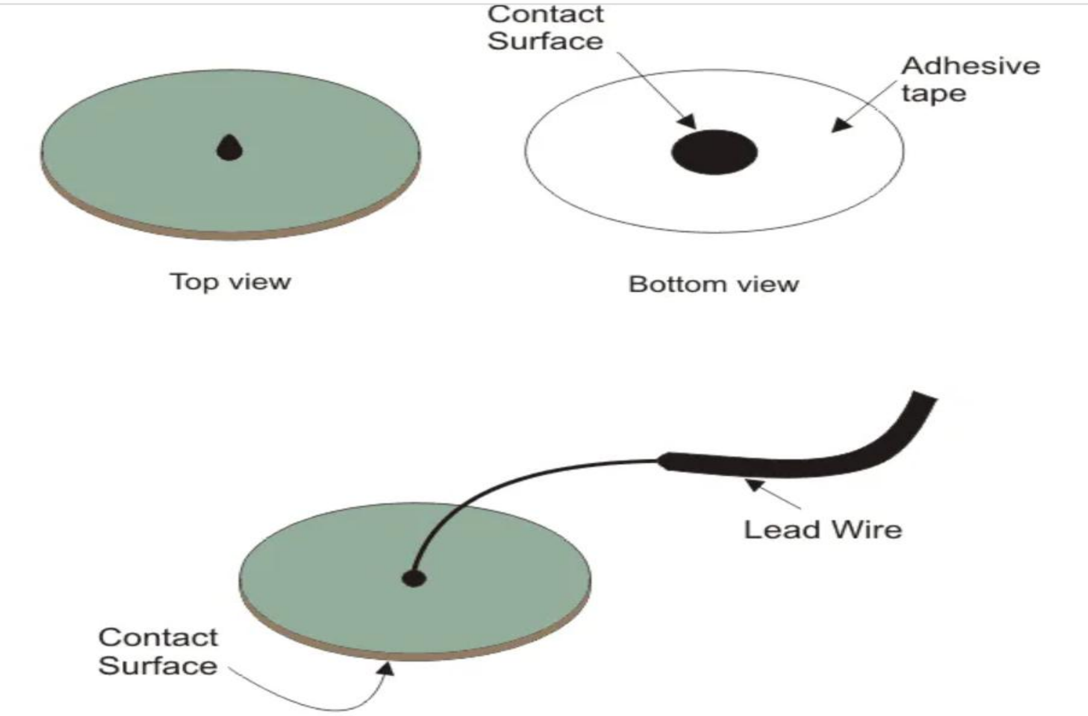
- To measure ECG from various positions on the chest, Suction cup electrodes are used. It suits well to attach electrodes on flat surface of the body and on soft tissue regions. They have a good contact surface.

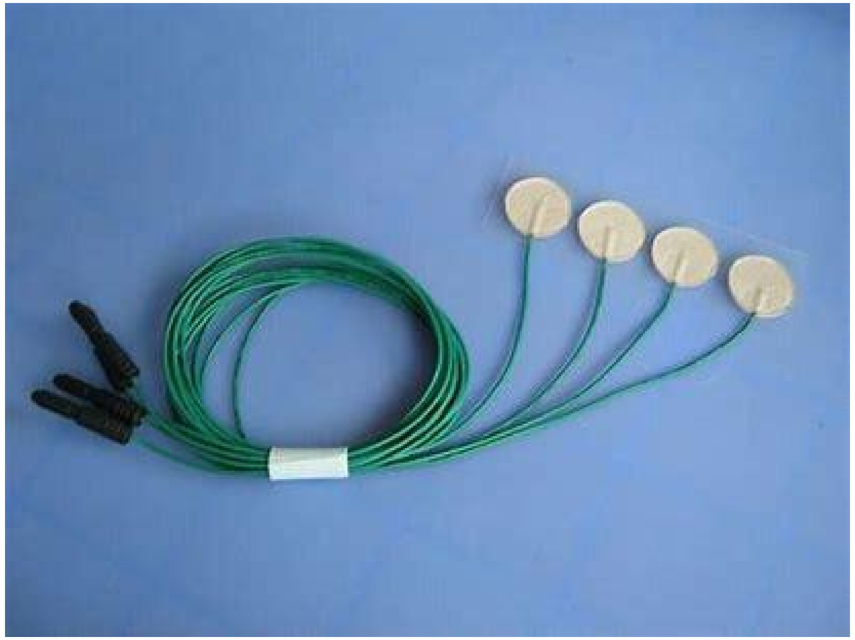
- Physically they are large but the skin contacts only the electrode rim. It has high contact impedance. They have a plastic syringe barrel, suction tube and cables.

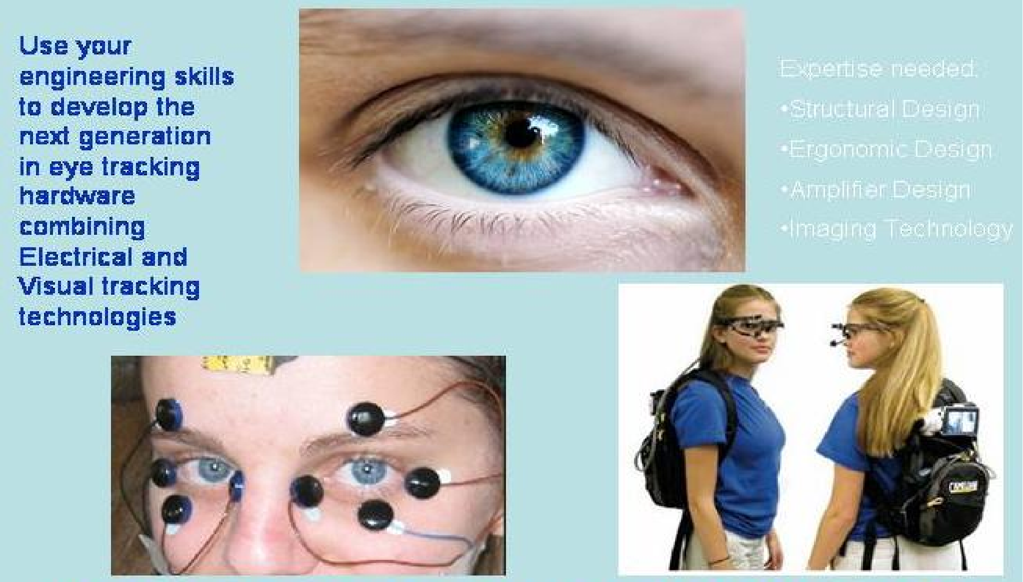


3. Adhesive Type Electrodes

- In the surface electrode, the pressure of surface electrode against the skin squeezes out the electrode paste. To avoid this problem, adhesive electrodes are used.
- It has a lightweight metallic screen, having a pad at behind for placing electrode paste.
- This adhesive backing hold the electrode on place and tight. It also helps to avoid evaporation of electrolyte present in the electrode paste.

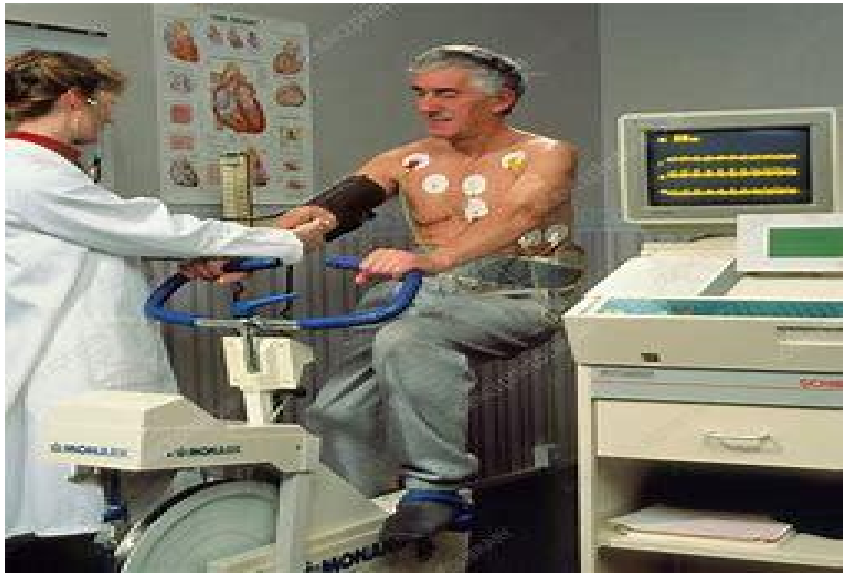





Use your engineering skills to develop the next generation in eye tracking hardware combining Electrical and Visual tracking technologies
Expertise needed:
•Structural Design
•Ergonomic Design
•Amplifier Design
•Imaging Technology

EOG

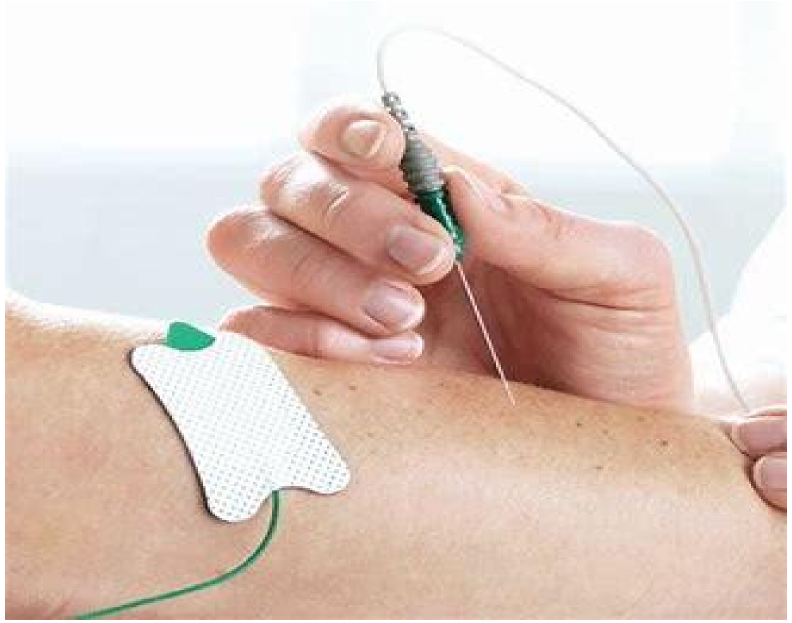

iPad
sEMG Biofeedback FES
| XFT-2003 |
Motion commands
sEMG signals
Real-time stimulation
iPad
Support New iPad
A Revolutionary Innovative Technology— sEMG



ECG

EMG

- Needle electrodes or intramuscular wire electrodes are favored over surface electrodes because they can enter the individual motor units straightaway and evaluate the coming action potentials more precisely.
- The most widely employed needle electrode is the concentric ring needle with a monopolar single electrode.



EEG Electrodes

- Electroencefalography (EEG) is a method to record brain activity throw the capture of electric activation.
- EEG scans are performed by placing EEG sensors – small metal discs also called EEG electrodes – on scalp.
- These electrodes pick up and record the electrical activity in your brain. The collected EEG signals are amplified, digitized, and then sent to a computer or mobile device for storage and data processing.

Brain areas and function

- Passive electrodes are usually made of silver/silver chloride (Ag–AgCl) and many systems typically use electrodes attached to individual wires.
- These electrodes are applied to the scalp using a conductive gel or paste, usually after preparing the scalp area by light abrasion to reduce electrode-scalp impedance.

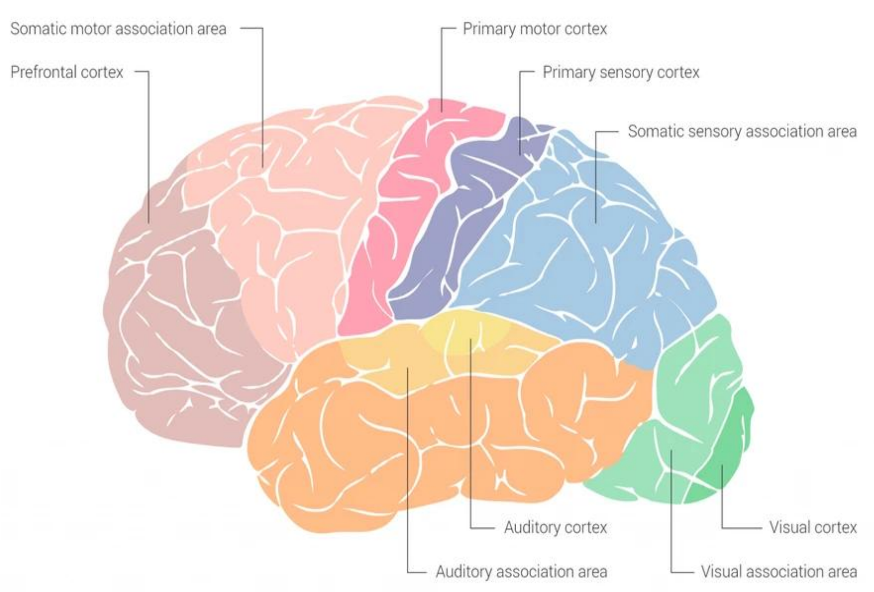
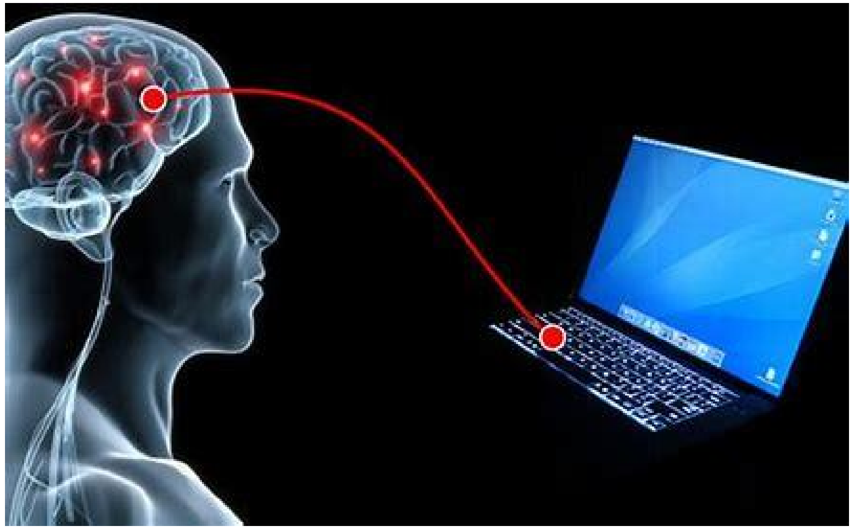


Figure 1. Regions of the cerebral cortex associated with brain functions. Modified from: https://human-memory.net/sensory-cortex/

- A brain–computer interface (BCI), sometimes called a brain–machine interface (BMI), is a direct communication pathway between the brain's electrical activity and an external device, most commonly a computer or robotic limb.



Examples of different types of noninvasive biopotential electrodes used primarily for ECG recording are shown in Figure 10.6. A typical flexible biopotential electrode for ECG recording is composed of certain types of polymers or elastomers that are made electrically conductive by the addition of a fine carbon or metal powder. These electrodes (Figure 10.6a) are available with prepasted AgCl gel for quick and easy application to the skin using a double-sided peel-off adhesive tape.

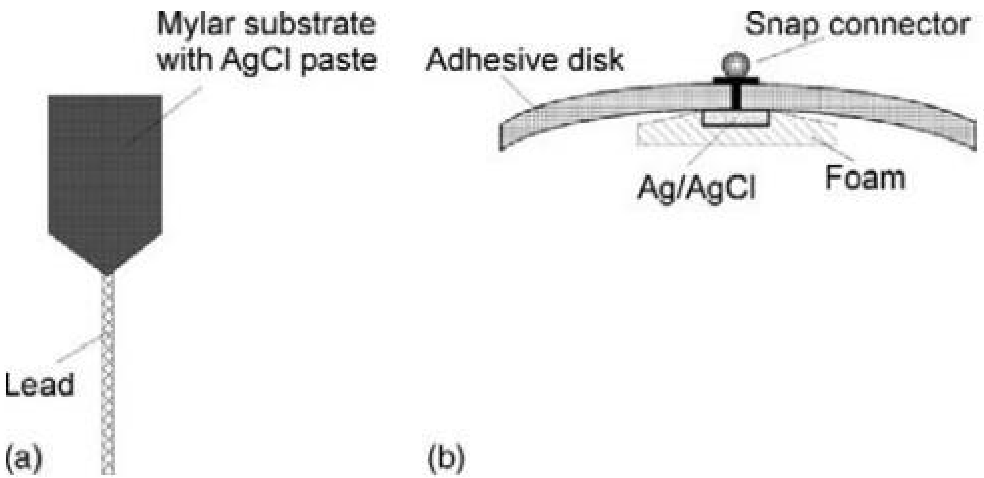


FIGURE 10.6 Biopotential skin surface ECG electrodes: (a) flexible Mylar electrode and (b) disposable snap-type Ag/AgCl electrode.

EMG Electrodes

- A number of different types of biopotential electrodes are used in recording electromyographic (EMG) signals from different muscles in the body.

- The shape and size of the recorded EMG signals depend on the electrical property of these electrodes and the recording location.

- For noninvasive recordings, proper skin preparation, which normally involves cleansing the skin with alcohol or the application of a small amount of an electrolyte paste, helps to minimize the impedance of the skin-electrode interface and improve the quality of the recorded signal considerably.

- The most common electrodes used for surface EMG recording and nerve conduction studies are circular discs, about 1 cm in diameter, that are made of silver or platinum.

EEG Electrodes

- The most commonly used electrodes for recording electroencephalographic signals from
- the brain (EEG) are cup electrodes and subdermal needle electrodes. Cup electrodes are made
- of platinum or tin approximately 5–10 mm in diameter. These cup electrodes are filled with a
- conducting electrolyte gel and can be attached to the scalp with an adhesive tape.
- Recording of electrical potentials from the scalp is difficult because hair and oily skin
- impede good electrical contact. Therefore, clinicians sometimes prefer to use subdermal
- EEG electrodes instead of metal surface electrodes for EEG recording. These are basically
- fine platinum or stainless-steel needle electrodes about 10 mm long

Microelectrodes

- Microelectrodes are biopotential electrodes with an ultrafine tapered tip that can be inserted into individual biological cells.
- These electrodes serve an important role in recording action potentials from single cells and are commonly used in neurophysiological studies.
- The tip of these electrodes must be small with respect to the dimensions of the biological cell to avoid cell damage and at the same time sufficiently strong to penetrate the cell wall.

Figure 10.8 illustrates the construction of three typical types of microelectrodes: glass micro_x0002_pipettes, metal microelectrodes, and solid-state microprobes. In Figure 10.8a, a hollow glass capillary tube, typically 1 mm in diameter, is heated and
softened in the middle inside a small furnace and then quickly pulled apart from both ends.

Brain Computer Interface (BCI): Japanese robot 'wired to monkey's brain