Components of Man Instrument System

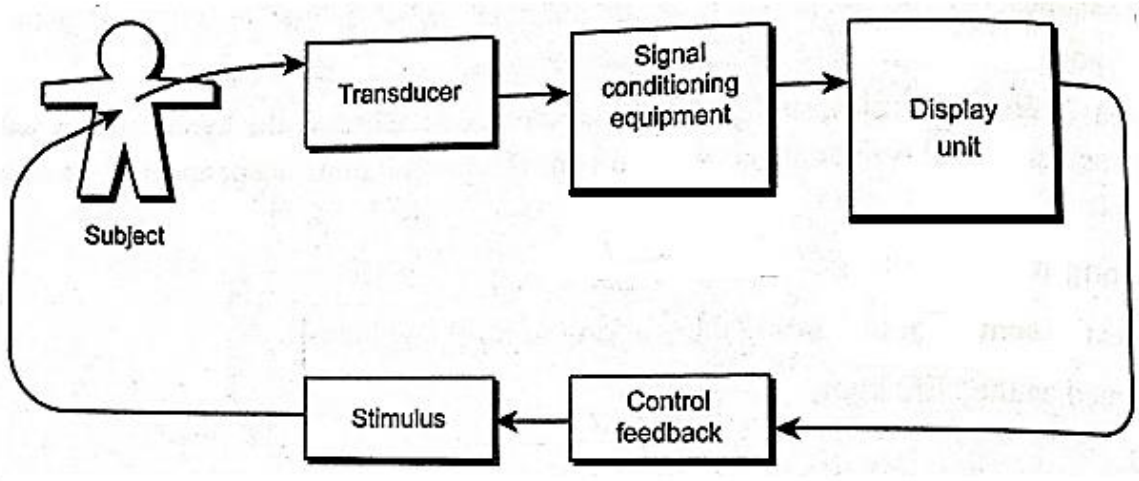
Introduction

A system which includes both the human organism and the instrumentation required for measurement of the human is called as the man instrument system.

Components

i) Subject ii) Transducer iii) Signal Conditioning equipment
iv) Display unit v) Control Feedback vi) Stimulus

Block diagram



Description

Subject

Human being is nothing but the subject. The measurements are made on the subject.

Transducer

The transducer receives the bio signal like temperature, Blood Pressure etc., from the Patient and converts into electrical signal.

S.No	Bio signal	Transducer
1	Temperature	Thermistor
2	Blood pressure	strain gauge
3	Stomach pH	Glass electrode

Signal conditioning equipment

Signal conditioning equipment is also known as Signal Processing equipment. It amplifies the electrical output from the transducer. It also processes the signals

from the transducer to the Display Unit. Signal processing equipment makes the signal suitable to operate the Display Unit.

Display Unit

The output from the Signal Conditioning equipment is displayed in the display unit. It includes graphic pen recorder to record the data. It also used as recording or diagnosis unit. The output can be displayed by using CRT display (or) Digital Signal Oscilloscope.

Control feedback

The Part of the Display Unit is used to control the operation of this system. The output of the Control feedback is connected with stimulus to control the input applied to the subject.

Stimulus

Stimulus is a process of stimulating the subject to response for the required operation.

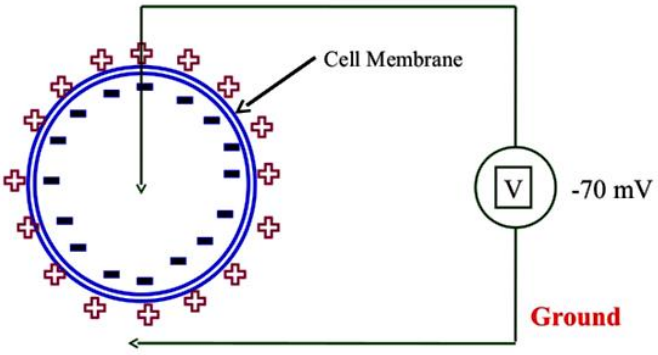
Resting and Action Potential – Generation & Characteristics

Surrounding the cells of the body is the body fluids. These fluids are conductive solutions containing charged atom known as ions. The principal ions are Sodium (Na^+), Potassium (K^+) and Chloride (Cl^-). The cell membrane is semi-permeable. It allows the entry of Potassium (K^+) and Chloride (Cl^-) and blocks the entry of Sodium (Na^+) ions.

Resting Potential

When a cell does not send a signal, it is at "resting state". At resting state, the inside of the cell is negative when compared to outside of the cell. The difference in ion concentration results in the Resting Potential of the cell.

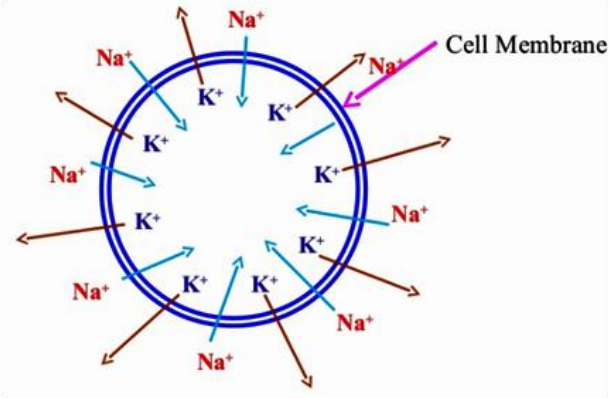
Circuit diagram: Polarized Cell with its Resting Potential



Description:

The value of resting potential is between – 60mV to – 100mV. At the resting state, the cell is polarized.

Depolarization of a cell:



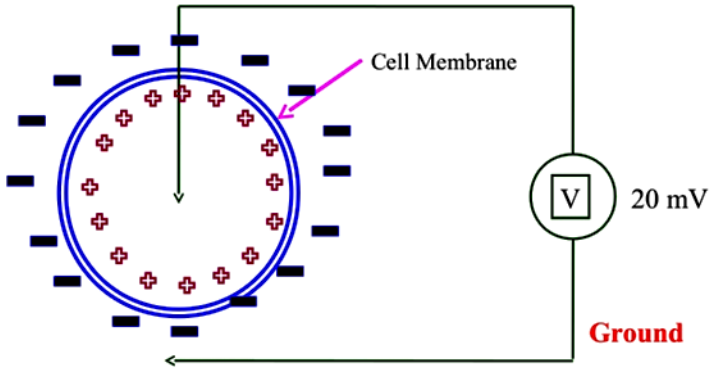
Description:

When the cell membrane is excited by some external energy, the membrane changes its characteristics. It allows the Sodium (Na^+) ions to enter inside the cell. Sodium (Na^+) ions move fastly but Potassium (K^+) ion does not move as fast as Sodium (Na^+) ions. The cell becomes depolarized.

Action Potential:

The Positive potential of the cell membrane during excitation is called as Action Potential.

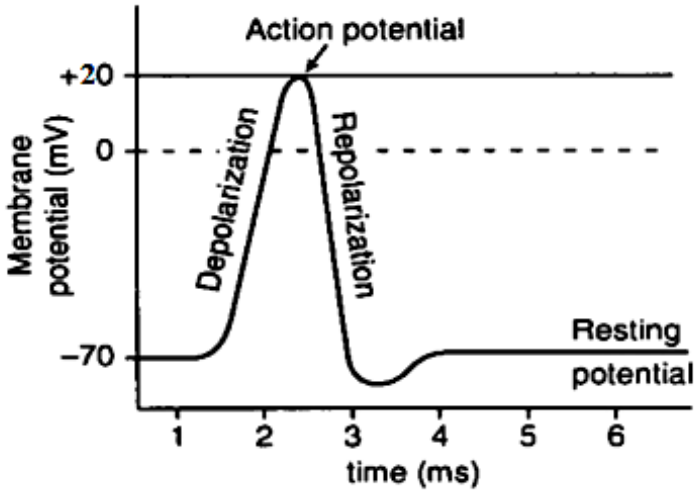
Circuit diagram: Depolarized Cell with its Action Potential



Description:

The cell has Positive on inside and negative on outside. The value of Action potential is between + 20mV. As long as action potential present, the cell is said to be depolarized.

Waveform:



Description:

Depolarization: It is the process of changing from Resting potential to Action Potential

Sodium (Na^+) ion is moved to outside cell by using sodium pump. Therefore the Cell returns to its original position and the Cell is repolarized

Repolarization: It is the process of changing from Action potential to Resting Potential

Cardiovascular systems

Introduction:-

Cardio means Heart and Vascular refers to Blood Vessels. The cardiovascular system consists of the heart, blood vessels, and blood. Its primary function is to transport nutrients and oxygen-rich blood to all parts of the body and to carry deoxygenated blood back to the lungs.

Heart Chambers:-

Heart is used to do the pumping action. It pumps the blood throughout the body. This pumping action is done by contraction of heart muscles that are surrounding the four chambers of heart. The top 2 chambers are called the right atrium and left atrium. The bottom 2 chambers are called the right and left ventricles. Each of these chambers is separated by valves which direct the flow of blood.

Heart Valves:-

Heart valves prevent the backward flow of blood keep blood flowing in one direction.

The four heart valves are:

- Tricuspid valve
- Semilunar valve
- Bicuspid valve (or) Mitral valve
- Aortic valve

Types of blood circulation

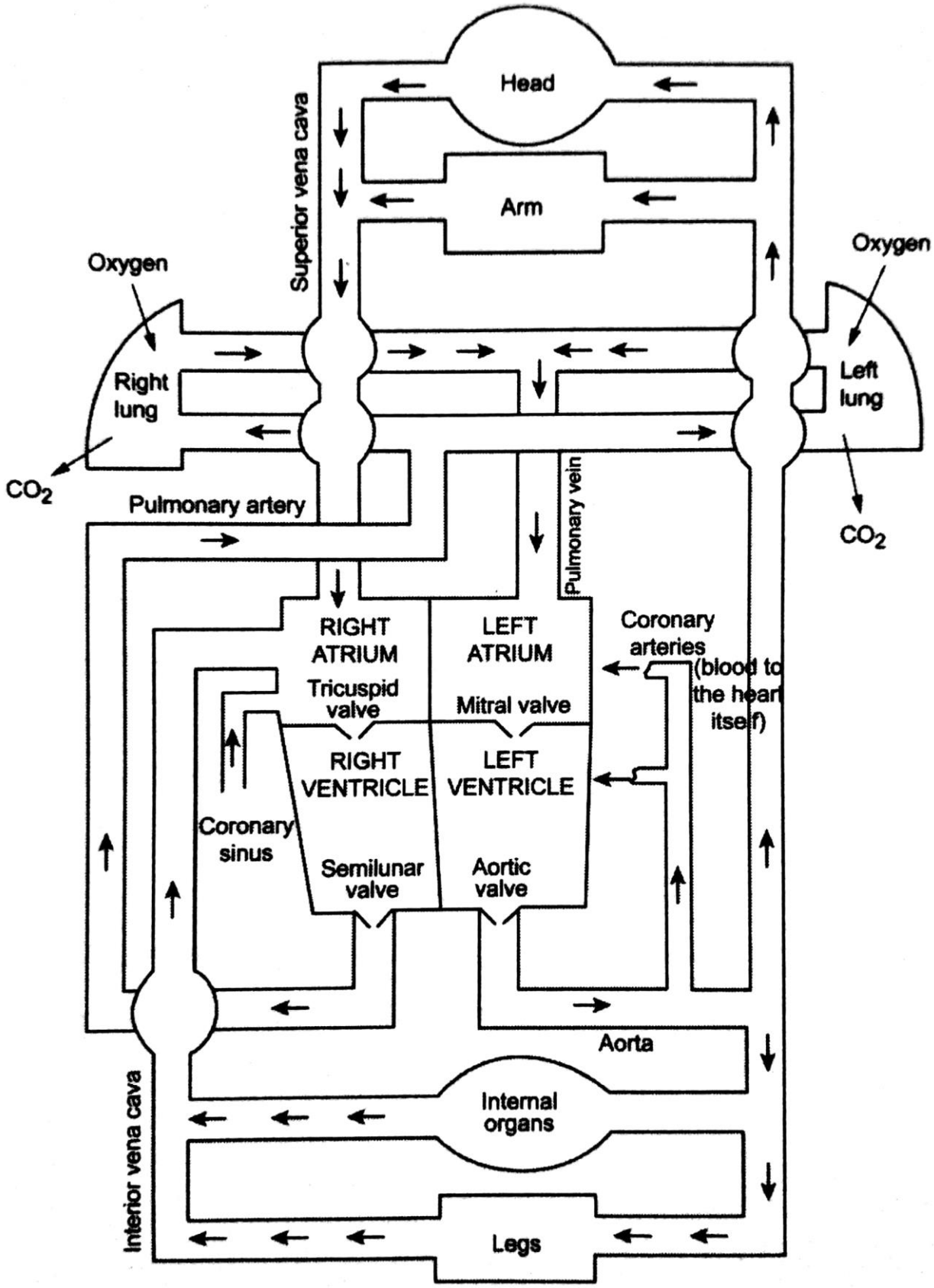
1.Pulmonary circulation

The circulatory path for blood flow through the lungs is known as pulmonary circulation. (i.e) Pulmonary circulation moves blood between the heart and lungs.

2.Systemic circulation

The circulatory path which supplies oxygen (O_2) to the cell of the body is known as systemic circulation. (i.e) Systemic circulation moves blood between the heart and cells of the body.

Cardiovascular System



Description:-

➡ Heart muscles receive the blood from coronary arteries. This coronary arterial system is a branch of systemic circulation.

➡ Coronary sinus collects the blood which is circulated in the heart and it is given to right atrium.

➡Blood enters into the right atrium using inferior vena cava and superior vena cava.

- Inferior vena cava collects blood from the organs of the body and from the legs.
- Superior vena cava collects the blood from head, arms, etc.

➡ If right atrium is filled with the blood, then, contraction occur, so the blood is pumped to right ventricle using tricuspid valve.

➡When right ventricle is filled with the blood, semilunar valve is opened. So, blood is pumped to lungs through pulmonary artery.

➡In lungs, this blood are oxygenated, and then it is given to left atrium through pulmonary vein.

➡ If left atrium is filled with the pure blood (oxygenated blood), blood is pumped to left ventricle through mitral valve (Bicuspid Valve).

➡ When left ventricle is filled with the blood, then aortic valve is opened and blood is pumped to various parts of the body, like head, arms, legs, and various interval organs and coronary arteries.

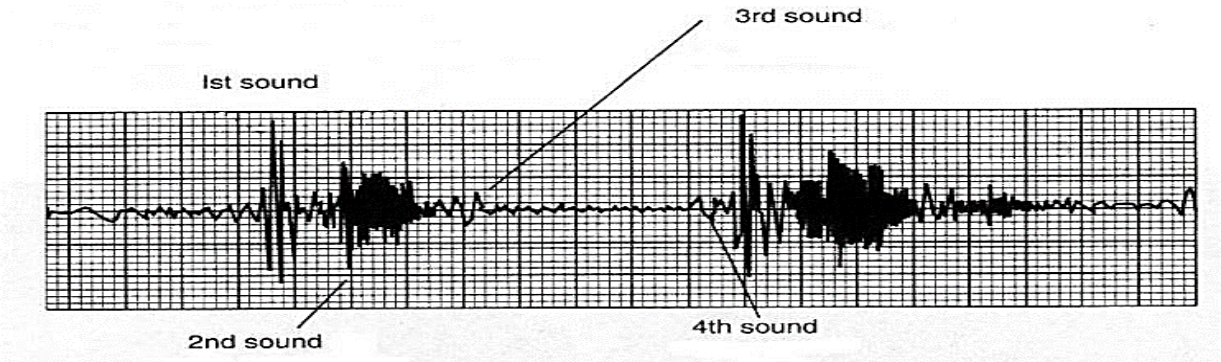
Heart Sounds

Heart sound generated by the beating heart and the resultant flow of blood through it. Four heart sounds can be recorded by phonocardiography. The first and second heart sounds are audible through a stethoscope.

Factors involved in production of heart sounds

- The movement of blood through chambers of heart
- The movement of cardiac muscle
- The movement of valves of the heart

Heart sounds waveform



First Heart Sound (S_1)

First Heart Sound occurs when the tricuspid and bicuspid valve closes. First Heart sound is heard at the beginning of systole. It is referred as LUB. It is generated by the vibration of the blood and the ventricular wall. First Heart Sound is soft and low pitched sound

Second Heart Sound (S_2)

Second Heart Sound occurs when the aortic and semi lunar valve closes. Second Heart sound is heard at the end of systole and the beginning of diastole. It is referred as DUB. It is generated by the vibration of the blood and the aorta. Second Heart Sound is short and high pitched sound

Third Heart Sound (S_3)

Third Heart sound heard at the rapid filling period of the ventricles. It is a short and low pitched sound

Fourth Heart Sound (S_4)

Fourth Heart sound is heard during the terminal phase of ventricular filling (i.e) atrial contraction. It is a short and low pitched sound

Murmur

Murmur has relatively prolonged series of auditory vibrations of varying intensity, frequency, quality, configuration, and duration. It is an abnormal extra heart sound. Murmurs have noisy characteristics and last for longer time. Murmurs are due to the turbulent flow of blood in the heart of large vessels.

Transducer and its Principles

Generally, transducer converts one form of energy into another form of energy. The energy may be electrical, mechanical etc.,

Ex 1- Microphone

Microphone converts sound energy into electrical energy

Transducer is also defined as a device that converts Non- electrical parameters to electrical signals. (i.e) It senses Bio signal such as temperature, heart sound, blood pressure and converts it to electrical signals.

Types of Transducer:-

- Active Transducer
- Passive Transducer

Principles:-

- Energy Conversion Principle - Used in Active Transducer
- Energy Controlling Principle - Used in Passive Transducer

Active Transducer:-

Active transducer operates under Energy Conversion Principle. It is also known as Self generating device. It converts Bio signal like Heart beat, Blood Pressure into an electrical output without using external dc/ac excitation voltage. It doesn't require external power source. It operates in reverse direction.

Types of Active Transducers:-

- Magnetic Induction Transducer
- Piezoelectric Transducer
- Photoelectric Transducer
- Thermoelectric Transducer

Passive Transducers:-

Passive transducer operates under Energy Controlling Principle. It converts Bio signal like Heart beat, Blood Pressure into an electrical output by using external dc/ac excitation voltage. It requires external power source.

Types of Passive Transducers

- Resistive Transducer
- Inductive Transducer
- Capacitive Transducer

Active Transducer

Active transducer operates under Energy Conversion Principle. It is also known as Self generating device. It converts Bio signal like Heartbeat, Blood Pressure into an electrical output without using external dc/ac excitation voltage. It doesn't require external power source. It operates in reverse direction.

Types of Active Transducers:-

- Piezoelectric Transducer
- Photoelectric Transducer

1. Piezo Electric Transducer

Piezoelectric transducers are active transducer which converts pressure into an electrical energy. It is based on piezoelectric effect.

Principle: Piezoelectric effect

When a mechanical force is applied to the crystals, dimensions of the crystal are changed & electric potential appears across crystal. Conversely varying potential is applied to the axis of the crystal, the dimensions are changed & crystal deforms. This phenomenon is called piezoelectric effect.

Piezoelectric material:

The material which exhibits the piezoelectric effect are called Piezo electric material. E.x. Quartz, Rochelle salt & Tourmaline

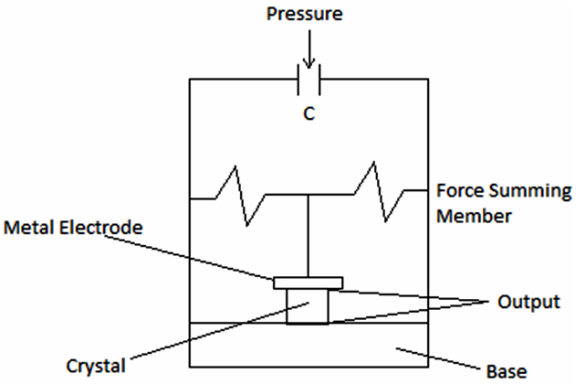
Quartz:

The piezoelectric activity of quartz lies between Rochelle salt & Tourmaline. It is available in natural. Its cost is low.

Construction:

A crystal is placed between base & force summing member. Metal electrodes placed above crystal for measuring output. A design element frequently used for the conversion of physical variables is the force summing member.

Circuit diagram:



Working:

An externally applied pressure, entering the transducer through the pressure port, applies pressure to the top of a crystal. This produces an emf across the crystal proportional to the magnitude of applied pressure.

For a piezoelectric element under pressure, part of energy is converted to an electric potential that appears on opposite faces of crystal, i.e. produces charge on capacitor.

The output voltage is given by

$$V_o = Q/C$$

Where, Q – Generated charge, C – Capacitor

Output voltage (V_o) is of the order of 1 to 30 mv. If is affected by temperature variations.

Merits:

- It doesn't require external power supply.
- It has very good HF response.
- Its construction is very simple.
- Its stability is very good.

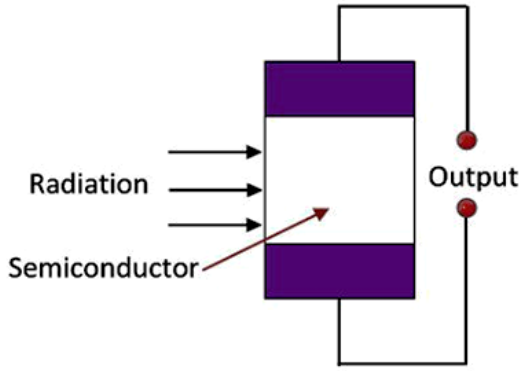
Demerits:

- It can't measure static condition due to temperature variations.
- It requires careful shielding & compensation due to high impedance.

2. Photo Electric Transducer

The photoelectric transducer converts the light energy into electrical energy. The photoelectric transducer uses a photosensitive element, which ejects the electrons when the beam of light absorbs through it.

Principle: Photoelectric Effect



When light or any other radiation of wavelength falls on the metal or semiconductor, it ejects electrons

The absorption of light energises the electrons of the material, and hence the electrons start moving.

Types

➡Photoconductive Cell

➡ Photodiode

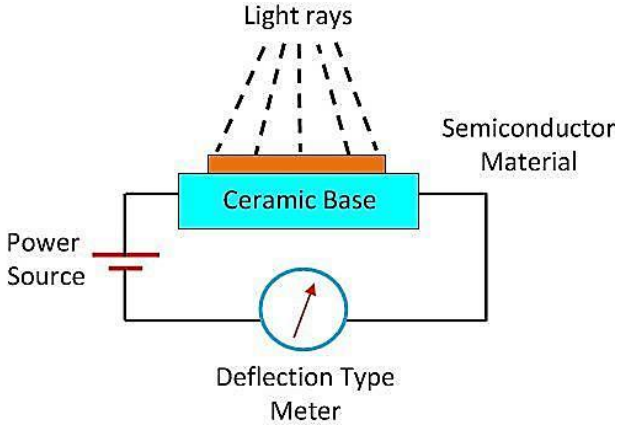
Photoconductive Cell

The photoconductive cell converts the light energy into an electric current. It uses the semiconductor material like cadmium selenide, Ge, Se, as a photo sensing element.

Description:

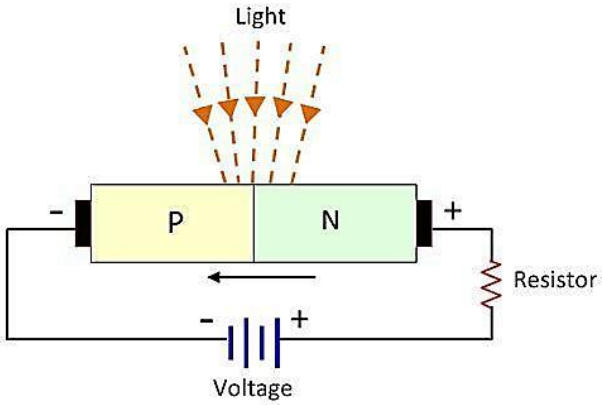
When the beam of light falls on the semiconductor material, their conductivity increases and it works like a closed switch. The current starts flowing into the semiconductor material and deflects the pointer of the meter.

Circuit diagram:



Photodiode

The photodiode is a semiconductor material which converts the light into the current. The electrons of the semiconductor material start moving when the photodiode absorbs the light energy. The response time of the photodiode is very less. It is designed for working in reverse bias.



Passive Transducer

Passive transducer operates under Energy Controlling Principle. It converts Bio signal like Heart beat, Blood Pressure into an electrical output by using external dc/ac excitation voltage. It requires external power source.

Types of Passive Transducers

➡Capacitive Transducer ➡Inductive Transducer

1. Capacitive transducer:

A capacitive transducer is a device that converts physical motion into a change in capacitance.

Principle:

Change in capacitance due to change in the area of conducting plates, the dielectric constant and distance between the plates.

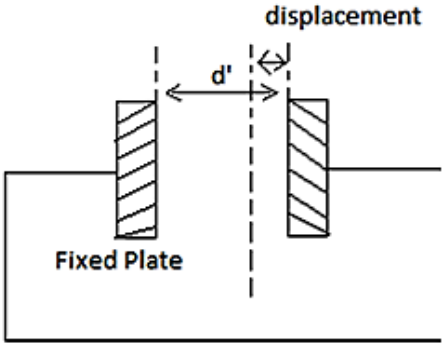
The capacitance of a parallel plate capacitor is given by

$$C = \Sigma_r \Sigma_o A/d$$

Where, A – Area of conducting plates, d – Distance between parallel plates

Σ_0 – Permittivity, Σ_r – Relative permitivity (dielectric constant)

In the capacitance transducers, the variation of capacitance as a function of displacement is achieved by three ways.

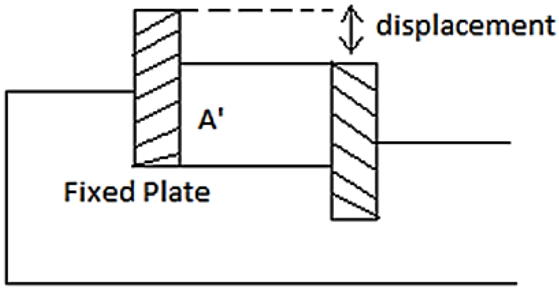


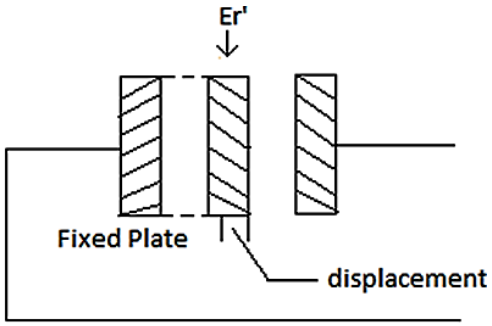
(i) The capacitance (C) is inversely proportional to the distance between parallel plates (d).

i.e. C α 1/d

ii) The capacitance (C) is directly proportional to common plate area (A).

i.e. C





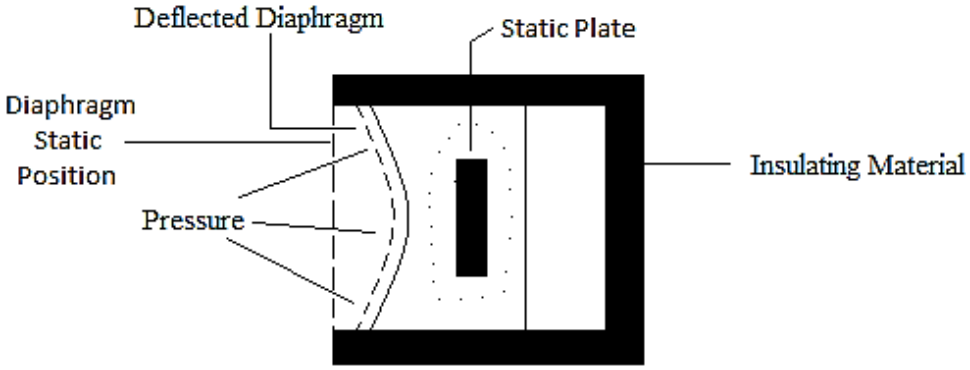
iii) The capacitance (C) is also directly proportional to the dielectric constant (Σ_r).

i.e. C α Σ_r

Capacitive pressure transducer:

Capacitive pressure transducer measures the change in capacitance due to change in distance between the plates.

Circuit diagram:



Construction: In capacitive transducer diaphragm acts as one of the plates of a two plate capacitor while the other plate is fixed. The fixed plate & the diaphragm are separated by a dielectric material.

Working:

When the Pressure is applied to the diaphragm, it changes in position from initial static position. Due to this, the distance of separation between the fixed plate & the diaphragm changes hence the capacitance also changes.

The change in capacitance can be measured by using any simple AC bridge.

Merits:

- It requires small forces only.
- It consumes low power.

- It has high input impedance.
- Capacitance transducer has good frequency response.

Demerits:

- It is a temperature sensitive transducer.
- Proper insulation is required between the metallic paths of the capacitive transducer.

2. Inductive transducer:

An inductive electromechanical transducer is a device that converts physical motion into a change in inductance.

Principle:

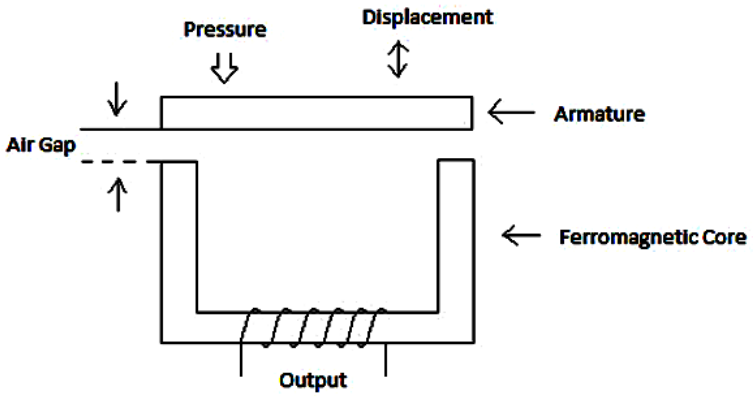
Inductive transducer is based on the principle of change in reluctance, no. of turns in the coil which may produce change in self-inductance (or) Mutual inductance of the transducer.

$$L=N^2 / S$$

Where, N → No. of turns in the coil,

S →Reluctance

Circuit Diagram:



Construction:

A coil is wound on a ferromagnetic core. The armature is also a ferromagnetic material which is movable. The core and armature is separated by an air gap.

Working:

When a pressure is applied to the armature, the air gap is changed there by varying the reluctance of the magnetic circuit (ie) the size of the air gap determines the reluctance of the magnetic circuit. Thus the applied pressure is measured by change of inductance in a coil. The inductive transducer enables static & dynamic measurements. Its drawback is that it has limited frequency.

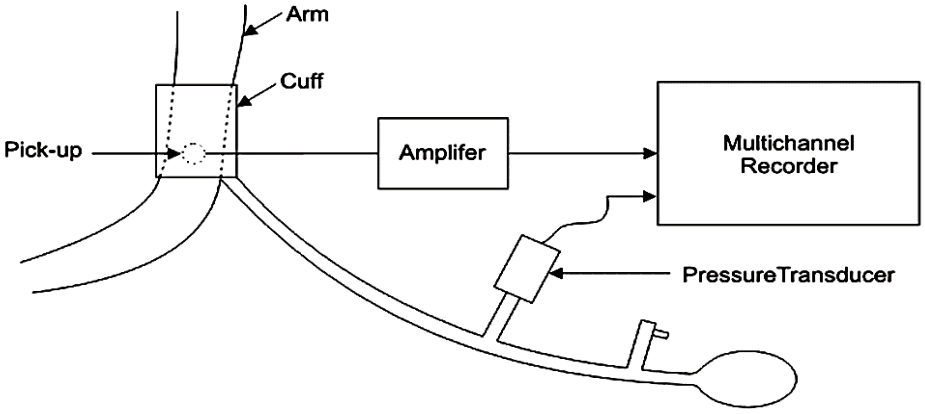
Transducers in Biomedical Applications

1.Piezo Electric Transducer:-

Piezoelectric transducers are active transducer which converts pressure into an electrical energy. It is based on piezoelectric effect.

Applications

- Piezo electric Transducer acts as a pulse sensor to measure the pulse rate of a human.
- Piezo electric crystal microphone measures and records the Heart sounds. Sounds from heart chambers are measured with Catheter-tip piezoelectric transducers.
- Piezo electric transducers are also used to measure Blood flow in Ultrasonic Blood flow meter.
- Rubber cuff is inflated with air. When cuff pressure exceeds systolic pressure, Korotkoff sound is heard and the noted pressure is systolic pressure. A piezoelectric crystal detects the Korotkoff sounds during systolic blood pressure measurement.



- In ultrasonic scanning devices, Piezo electric transducers are used. When an ultrasonic pulse transmits through the human body, it reflects an echo signal of different frequency. The received is displayed on Cathode Ray Oscilloscope.

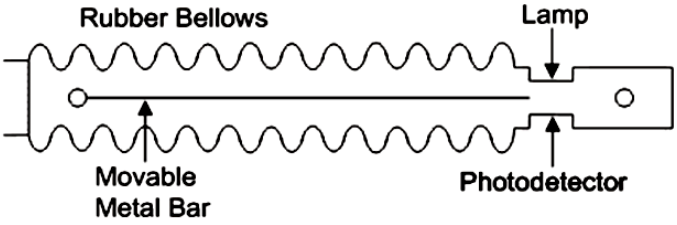
2. Photo Electric Transducer:-

Photo Electric transducer is an active transducer which generates electrical voltage in proportion to the radiation incident on it.

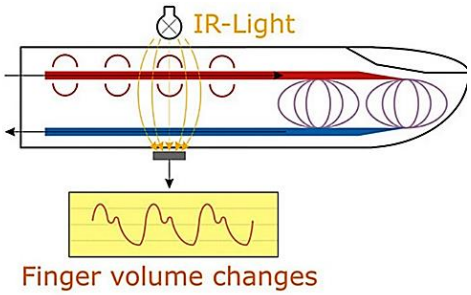
Applications:-

- In Photoelectric plethysmography, silicon photovoltaic cells acts as pulse sensor.

- Circumference of the chest can be measured with photodetector. Wrap the chest with a rubber bellow. Inside the bellows, the movable metal bar is attached. When the chest expands during breathing, the amount of light that falls on the photodiode varies due to the metal bar. Calibrate the obtained result to get the respiratory volume.



- Blood flow change is measured with a Photodetector. A beam of IR-light is directed to the part of the tissue which is to be measured for blood flow. The blood flow modulates the attenuated or reflected light which is recorded. The light that is transmitted is collected with a photodetector.



- Blood pressure can be measured with Photoeletric transducers.

3. Inductive Transducer:-

An Inductive transducer is a device that converts physical motion into a change in Inductance.

Applications:-

- A LVDT acts as a Pressure sensor.
- To measure tremor in patients suffering from Parkinson's disease.

4. Capacitive Transducer:-

A Capacitive transducer is a device that converts physical motion into a change in capacitance.

Applications:-

- Differential capacitive transducers measure blood pressure.
- A capacitance displacement transducer measures chest wall motions
- The transducer is used to record heart sounds