Biomedical Instrumentation (BI)

6TH EE/EEE/ETC

mod - 2 .

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Transducere are devices which Converts one form of energy into anothere. Because of the familiar advantage of electric and electronics method of measurement, it is usual practice to Convert all non-electric Phenomena associated with the Physiological event into electric Quantity. Any Physical Quantity can be converted into a Proportional electrical quantity such as voltage or electric current. This Physical Quantity which is to be measure can be Pressure, Temperature, level, displacement etc. A Number of factor decide the Choice of a particular Transducere to be used for the study of a Specific Phenomena. These factore Include

- The magnitude of quantity to be measured.
- The ordere of accuracy required
- The static or dynamic character of the Process to be studied.
- Economic Consideration.

Classification of Transducere:-

Many Physical, chemical and optical Properties and principle can be applied to construct Transducer for application in medical field.

Based on external Power Source is required or not

Active Transducer:- Active Transducer are those which don't require any Power Source for their operation They produce an electrical Signal Proportional to its Input.

eg:- Thermocouple, PV cell.

Passive Transducer:- This Transducer that required energy to be put into it in order to Translate Change due to the measurement.

eg:- Strain gauge, LVDT.

Based on Quantity to be measured

- Temperature Transducer
- Pressure Transducer
- Displacement Transducer
- Flow Transducer
- Inductive Transducer.

Based on Principle of operation

- Photo-voltaic
- piezoelectric transducer
- chemical
- mutual Induction.
- Hall Effect.

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Performance Characterstics of transducers:-

Characterstic plays an important role in determining The performance of the system. The characterstic of a Transducer is as follows.

A) Static Characterstic
B) Dynamic characterstic.

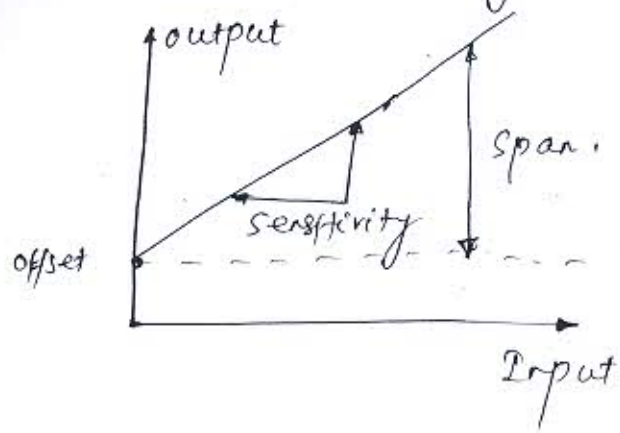
Static Characterstic

Accuracy:- This term describes the algebric difference between the Indicated value and the true value.

Precision:- It refers to the degree of repeatability of a measurement i.e when it is used it gives same output everytime.

Resolution:- The resolution of a transducer indicate smallest measurable input Increment i.e. it is the ability of the sensore to see small difference in reading.

Sensitivity:- The Sensitivity of the sensor is defined as the slope of the output characterstic curve or the minimum input of physical parameter that will create a detectable output change.



Span:- It indicate total operating range of the Transducer

offset:- The offset is defined as the output that will exist when it should be zero. This shown is above fig.

Drift:- Drift indicate change of baseline or of sensitivity with time, Temperature. Drift is basically the change in signal over long period of time.

linearity:- It indicate that output is proportional to to the input

Threshold:- The Threshold of the transducer is the smallest change in the measurand that will result in a measurable change in the transducer output.

Saturation:- Saturation is the region in which output does not change with the increase in input.

Input range:- This is the range between maximum and minimum values applied.

Dynamic Characteristic :-

1. Transfer function.
2. Frequency response :-
3. Response time.
4. Setting time.

DISPLACEMENT, POSITION AND FLOW AND PRESSURE TRANSDUCERS

These Transducer are useful in measuring the size shape and position of the organ and tissues of the body.

Position :- Spatial location of a body or point with respect to a reference point.

Displacement :- vector representing a change in position of a body or point with respect to a reference point. Displacement may be linear or angular.

motion :- Change in position with respect to reference ~~point~~ system.

Displacement Transducer :-

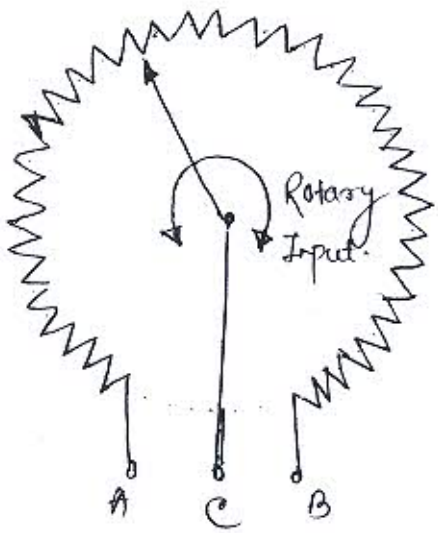
A displacement Transducer is an electromechanical device used to convert mechanical motion or vibration specifically rectilinear motion, into a variable electrical current, voltage or electric signal.

Conversion Principle :-

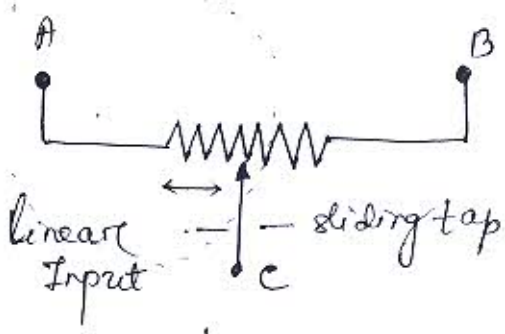
The different Conversion Principle used is

(i) Potentiometric
(ii) Electrostatic or Variable Capacitance.
(iii) Variable Inductance.

Potentiometric Transducer :-



Rotational Displacement



Linear Displacement.

One of the Simplest Transducer for measuring displacement is a Variable resistor. The resistance between two terminals on this device is related to linear or angular displacement of a sliding tap along a resistance element.

Variable Capacitance :-

* When the distance between a pair of metallic Plate forming an electrical capacitance is altered there is a Change in the capacitance according to the relation.

$$C = 0.0885 K \cdot A/d$$

C = Capacitance in microfards.
d = distance between the plate in cm.
A = Area of each identical plate in cm^2
K = dielectric Constant of the medium separating the two plate.

By moving one of the plate with respect to the other. The capacitance will vary inversely with respect to the plate separation. This will give a hyperbolic displacement - capacitance characteristic. if the plate separation is kept constant and area of overlap changes due to displacement capacitance characteristic is linear.

Variable Inductance

Change in inductance can be used to measure displacement by varying three coil parameter given in the following equation

$$L = n^2 G \mu$$

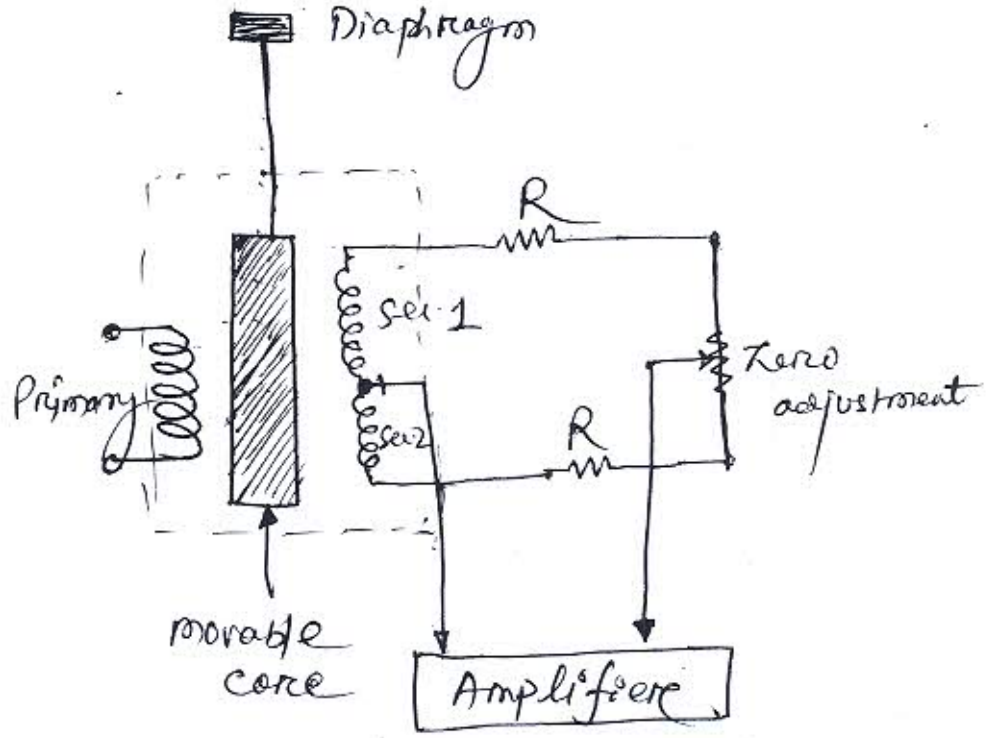
where L = inductance of the coil
n = number of turns in coil.
μ = permeability of the medium.
G = geometrical form factor.

The inductance can be changed either by varying its physical dimension or by changing the permeablity of its magnetic core. The core having a permeablity higher than air can be made to move through the coil in relation to the displacement.

Linear variable differential Transformer (LVDT)

An extremely useful phenomena frequently utilized in designing displacement pickup based on principle of variation in coupling between Transformer winding, when the magnetic core of the transformer is displaced with respect to the position of these two winding

↳ These Transducer can be used for measurement of physiological pressure.



↳ The Central coil is energized or Primary coil connected to a Sinewave oscillator. The two other coil are so connected that their output are so connected that their output are equal in magnitude but opposite in phase.

↳ with the ferromagnetic core symmetrically placed between the coils, and the two secondary coils connected in series, the induced output voltage across them is zero.

↳ When the core is moved, the voltage induced in one of the secondary winding exceeds that induced in the other. A net voltage output then results from the two secondaries.

↳ A simple bridge circuit can be employed to detect the differential signal thus produced

↳ Typical operating excitation of these transducers is 6V at 2.5 KHz. ~~Some~~ Commercial device typically have a sensitivity of 0.5 to 2.0 mV per 0.001 cm displacement for a 1V input. Full scale displacement of 0.001 to 25 cm with a linearity of ± 0.25% are available.

PRESSURE TRANSDUCERS

↳ Pressure is a very valuable parameter in the medical field and therefore many devices have been developed to effect its transduction to measurable electrical signal. The basic principle behind all these pressure to be measured is applied to a flexible diaphragm which get deformed by the action of the pressure exerted on it. This motion of the diaphragm is then measured in terms of an electrical signal.

↳ Diaphragm is a thin flat plate of circular shape attached firmly by its edge to the wall containing vassel. Typical diaphragm material are stainless steel, phosphor bronze and beryllium copper.

↳ The most commonly employed pressure transducer which make use of diaphragm are of following type.

A) capacitive Manometer :- in which the diaphragm form one plate of capacitor.

B) Differential Transformer :- Where the diaphragm is attached to the core of differential Transformer.

c) Strain gauge :- where the strain gauge bridge is attached to diaphragm.

Displacement Transducer can be converted to Pressure Transducer by attaching a diaphragm to the moving member of the Transducer. The following Pressure Transducer are commercial available.

LVDT Pressure Transducer :-

- It is a three coil inductive transducer operated in the differential mode. It consists of a Primary coil and two secondaries coil winding on a cylindrical former.
- The Primary coil is connected to an alternating source whereas the differential output is taken from the two secondary coils.
- A movable iron core is placed inside the former. The core is attached to a small circular elastic diaphragm exposed to measurand.
- When core is symmetrical placed between the coil, The induced output voltage is zero. When the core is moved, The voltage induced in one of secondary

winding exceeds that induced in the other. A net output voltage then results from the two secondaries.

↳ LVDT is run by a constant voltage source to improve linearity of the system.

Piezo-electric Transducers

↳ The piezo-electric effect is a property of natural crystalline substance to develop electric potential along a crystallographic axis in response to the movement of charge as a result of mechanical deformation. Thus piezo-electricity is pressure electricity.

↳ On application of pressure, the charge Q developed along a particular axis is given by

$$Q = dF \text{ Coloumb}$$

d = piezo-electric constant. (C/N)

F = applied force.

↳ The change in voltage can be found by assuming that the system acts like a parallel-plate capacitor and can be written as $E_0 = \frac{Q}{C} = \frac{dF}{C}$

The capacitance between two parallel plate of area 'a' separated by distance 'x' is given by

$$C = \varepsilon \frac{a}{x}$$

ε = dielectric constant

$$E_0 = \frac{dF \cdot x}{\varepsilon a} = g \cdot P \cdot x$$

$$\frac{d}{\varepsilon} = g, \quad \frac{F}{a} = P$$

The principle of operation is that when an asymmetrical crystal lattice is distorted, a charge re-orientation takes place, causing a relative displacement of negative and positive charges. The displaced internal charge induce surface charge of opposite polarity in opposite of crystal.

Application:- Piezo-electric Transducers find numerous application in medical Instrumentation field. They are used in ultrasonic scanner for imaging and blood flow measurement.

STRAIN GAUGE PRESSURE TRANSDUCERS

A Transducer is based upon change in Resistance of a wire produced due to small mechanical displacement. A linear relationship exist between the deformation and electric resistance of a suitably selected gauge over a specified range.

Gauge factor:-

The figure of merit which describe the overall behaviour of the wire under stress is determined from "gauge factor" which is defined as

$$g = \frac{\Delta R/R}{\Delta L/L}$$

where ΔR = Incremental change in Resistance

R = Resistance of unstretched wire.

ΔL = Incremental change in length

L = Unstretched length of wire.

it is advisable to select a material with high gauge factor.

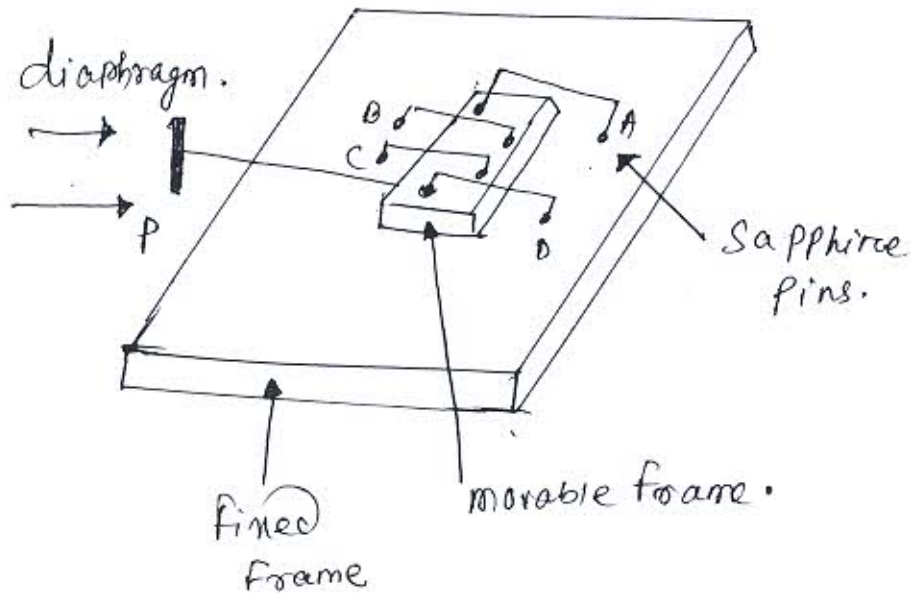
Material	gauge Factor	Temperature coefficient of Resistance (w/w/°c)
Constantan	2.0	2×10^{-6}
Platinum	6.1	3×10^{-3}
Nickel	12.1	6×10^{-3}
Silicon	120	6×10^{-3}

Types of electrical strain gauge:-

There are two types of electrical strain gauge

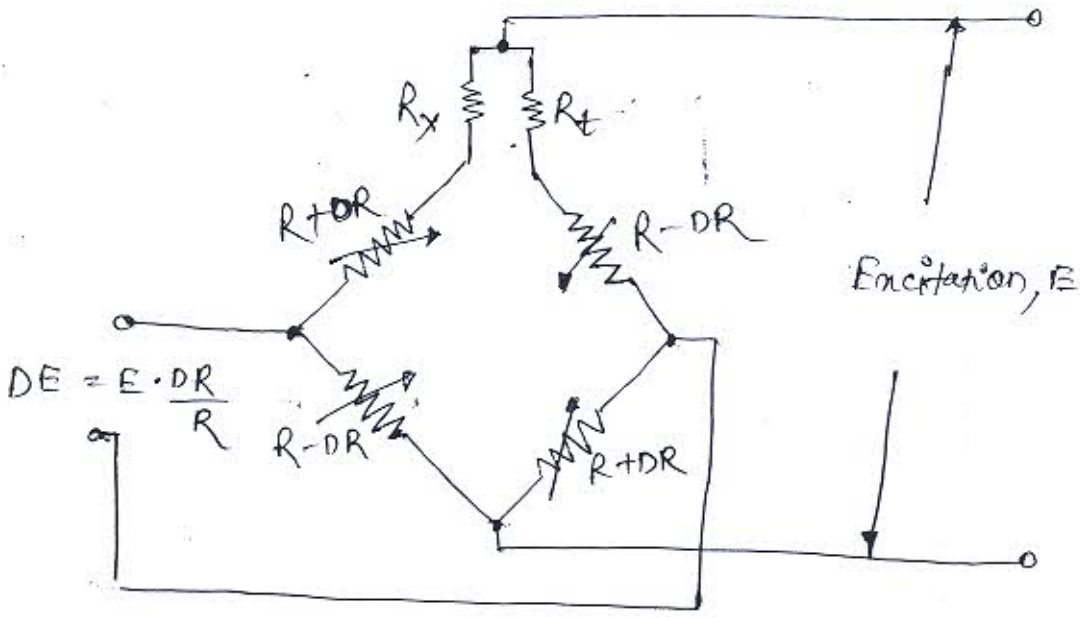
1. unbonded strain gauge.
2. bonded strain gauge.

Unbonded strain gauge:-



Unbonded strain gauge:

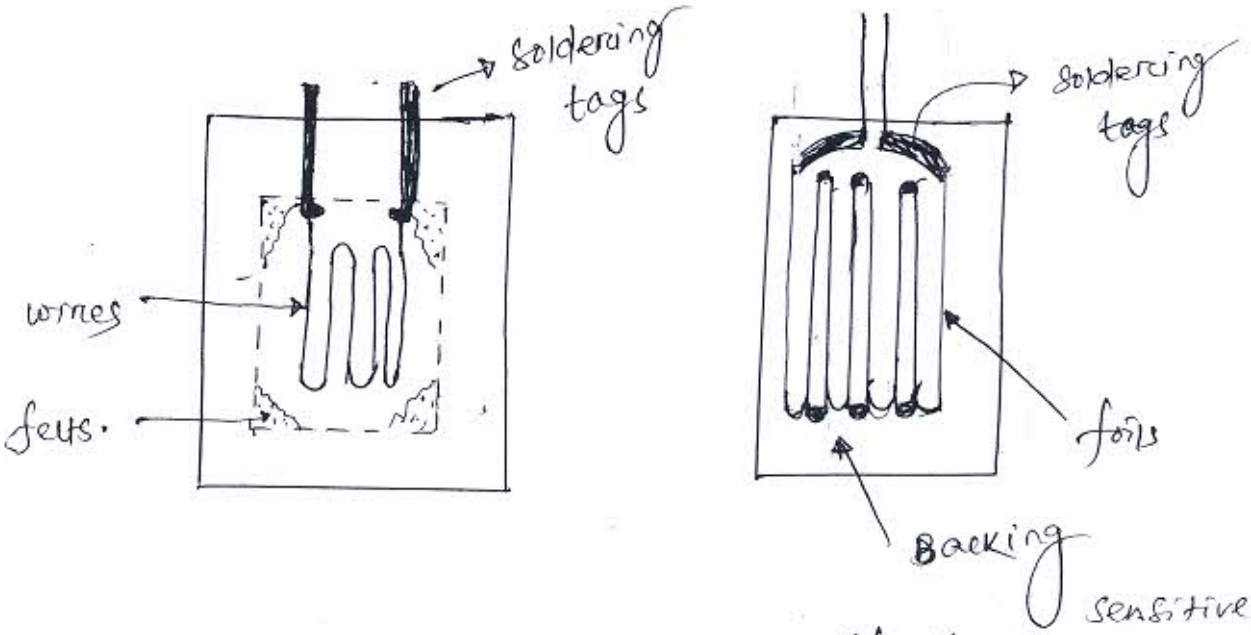
most of the Pressure Transducere for direct measurement of blood Pressure are of unbonded wire strain gauge. The arrangement having outer frame is fixed and inner frame which is connected to the diaphragm upon which pressure acts is movable. The pressure P applied in the direction is shown in the figure. stretch wire B and C and relax wire A and D. These wire form a four arm active Bridge shown below-



The moving frame is mounted on spring which brings it to the central reference position when no pressure is applied to the diaphragm. Zeroing of the bridge can be accomplished by a Resistor R_x connected in series. Similarly a series connected Resistor R_t in the other arm of bridge.

The unbonded strain gauge transducer preferred when low pressure measurement are to be made since hysteresis error are much lesser than would be the case if wire gauge wire bound to the diaphragm. Unbonded strain gauge transducer can be made sufficiently small which are even suitable for mounting at the tip of a cardiac catheter.

Bonded strain gauge :-



The bonded strain gauge consists of strain sensitive gauge which are firmly bonded with an adhesive to the membrane or diaphragm whose movement is to be recorded. The backing material commonly used is paper, bakelized paper or and similar material. For pressure measurement purpose, strain gauge constructed above is attached to a diaphragm.

Silicon - bonded strain gauge :-

In recent years, there has been an increasing tendency to use bonded gauges made from a silicon semiconductor instead of from bonded wire or foil strain gauge. This is because of its higher gauge factor resulting in a greater sensitivity and potential miniaturization.