Sensors and Instrumentation

Unit - 1

Sensors:- An element that senses a Variation in input energy to produce Variation in another or same.

Or.

A tool which is provide usable output in response to specified measurand.

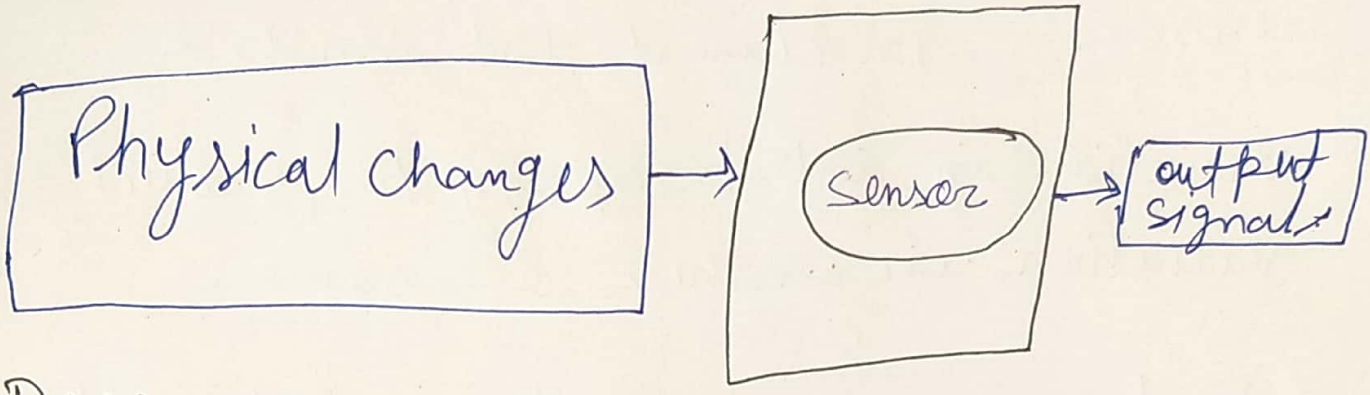
they can be
- a element
- a device
- a circuit.

① Thermometer (degree)
② Scale (Pounds)
③ Ruler
④ measuring tape.

Sensor → Comparision with standards → NIST → calibrate.

(National Institute of Standards and Technology
Authorized by → US Department of Commerce)

Working of Sensor



~~Difference between Sensor & Transducer~~

- ~~The main diffe~~

Types of Sensor :-

1. - Digital sensor
2. - Analog sensor.

Digital sensor :- A digital sensor is an electronic or electrochemical sensor, where data is digitally converted and transmitted. Sensors are often used for analytical measurements,

eg. the measurement of Chemical and Physical properties of liquids.

~~Types~~ Types of Digital Sensor.

1- IR Sensors
2- PIR Sensors / Motion Sensor
3- ~~Sensitive~~ Ultrasonic distance sensor.

Analog Sensor:- Analog sensors are the devices that Produce analog output in correspondance to the quality being calculated. These sensors are also observe the change in external factor such as light intensity, speed of the wind, and solar radiation, and others. The output ranges between 0V to 05V.

Types of Analog Sensor

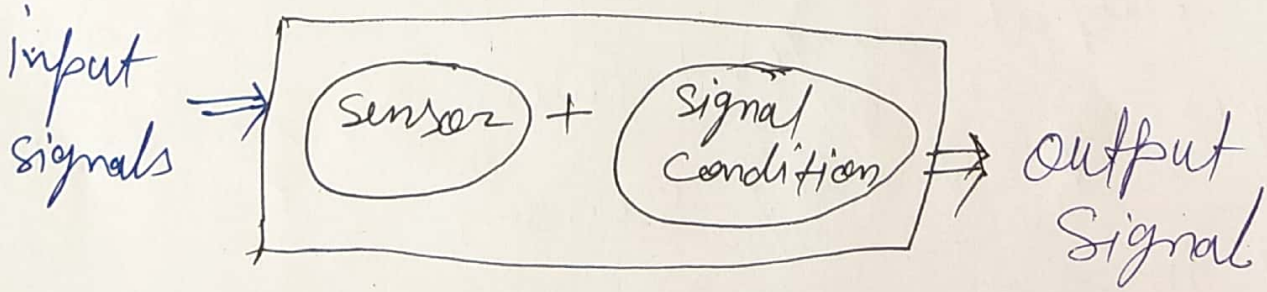
1. LM-35 Temprature Sensor
2. Light Intensity Sensor or LDR
3. ~~Dy~~

Transducer :-

A Transducer can measure similar qualities to a sensor but will convert the signal from one physical form to another meaning their input and output signals are not the same as each other. Transducers are sometimes referred to as energy converters.

Types of Transducer :-

(1) - Input Transducer
(2) - Output Transducer.



Transducer.

input transducer :- An input transducer takes a form of energy and converts it into an electrical signal.

output transducer :- An output transducer take electricity and convert form of energy.

Example :- A light bulb takes electricity and converts it to light, or a motor converting electricity to motion.

~~Sensor / transducer specifications :-~~ Transducer or measurement system

~~Difference between Sensor & Transducer :-~~

Difference between Sensor & Transducer:-

The main difference between a sensor and a transducer is the output signal. Both a sensor and a transducer are used to sense a change within the environment. They are surrounded by or an object they are attached to, but a sensor will give output in the same format and a transducer will convert the measurement into an electrical signal.

Principle of Sensor:- Every sensor has different principle of operation, based on the type of Physical quantity it is measuring. The idea is to create a change in the property/properties of sensor (such as resistance, density, shape, temprature etc) as a function of the Physical Quantity under measurement.

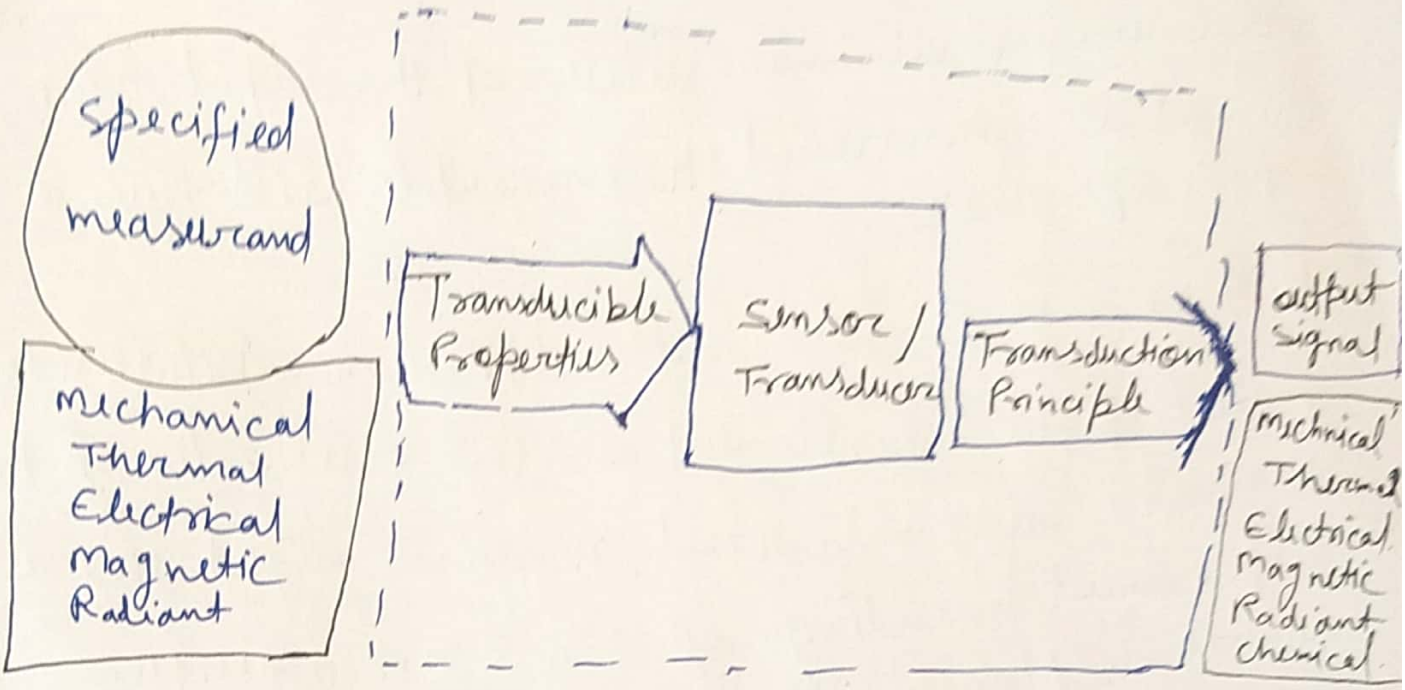


fig :- Sensors definitions and Principles.

Sensor / Transducer specifications :- Sensor specifications inform the user to the about deviations from the ideal behaviour of the sensors. Various specifications of a sensor/transducer system is given below-

1- Range :- The range of a sensor indicates the limits between which the input can vary.
for Example :- A thermocouple for the measurement of temperature might have a range of 25-225°c.

2- Span:- The span is difference between the maximum and minimum values of the input. Thus, the above-mentioned thermocouple will have a span of 200°c.

3- Error:- Error is the difference between the result of the measurement and the true value of the quantity being measured. A sensor might give a displacement reading of 29.8 mm, when the actual displacement had been 30 mm, then the error is -0.2 mm.

4- Accuracy:- The accuracy defines the closeness of the agreement between the actual measurment result and a true value of the measurand. It is ~~often~~ often expressed as a percentage of the full range output or full-scale deflection.

Example:- A piezoelectric transducer used to evaluate dynamic pressure phenomena associated with explosions, pulsations, or dynamic pressure conditions in ~~these~~ motors, rocket engines, compressors, and other pressurized device is capable to detect pressures between 0.1 and 10,000 psig (0.7 KPa to 70 MPa).

if it is specified with the accuracy of about ±1% full scale, then the reading given can be expected to be within ± 0.7 MPa.

5. Sensitivity:- Sensitivity of a sensor is defined as the ratio of change in output value of a sensor to the per unit change in input value that causes the output change.

for Example:- A General purpose thermocouple may have a sensitivity of 41 μV/°C.

6:- Nonlinearity:- The nonlinearity indicates the maximum deviations of the actual measured curve of a sensor from the ideal curve. Linearity is often specified in terms of percentage of ~~nonlinearity~~ nonlinearity, which is defined as

$$\text{Nonlinearity}(\%) = \frac{\text{Maximum deviation input}}{\text{Maximum full scale input.}}$$

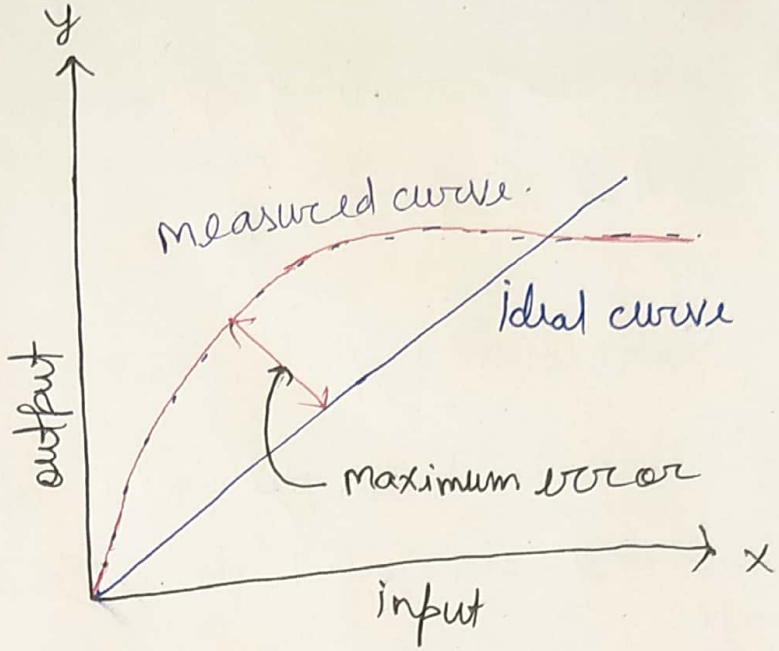


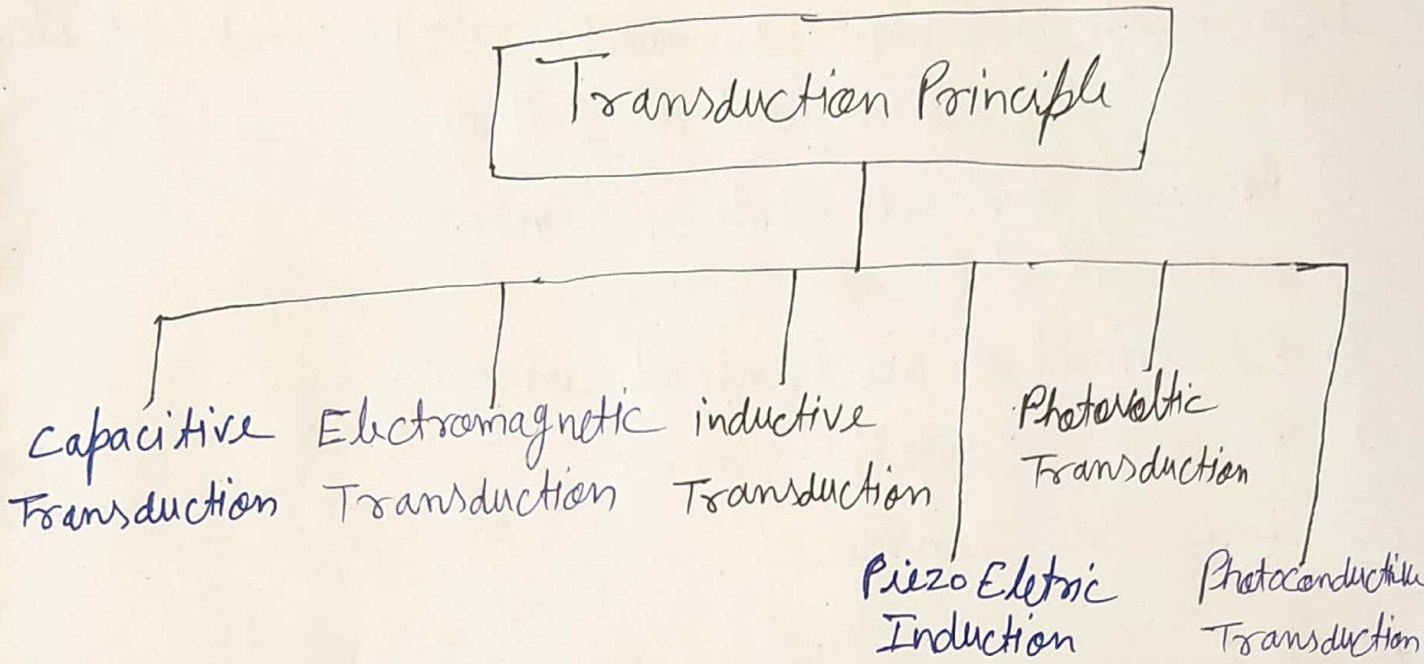
fig :- Non-linearity error.

7- Resolution :- Resolution is the smallest detectable incremental change of input parameter that can be detected in the output signal. Resolution can be expressed either as a proportion of the full scale reading or in absolute terms.

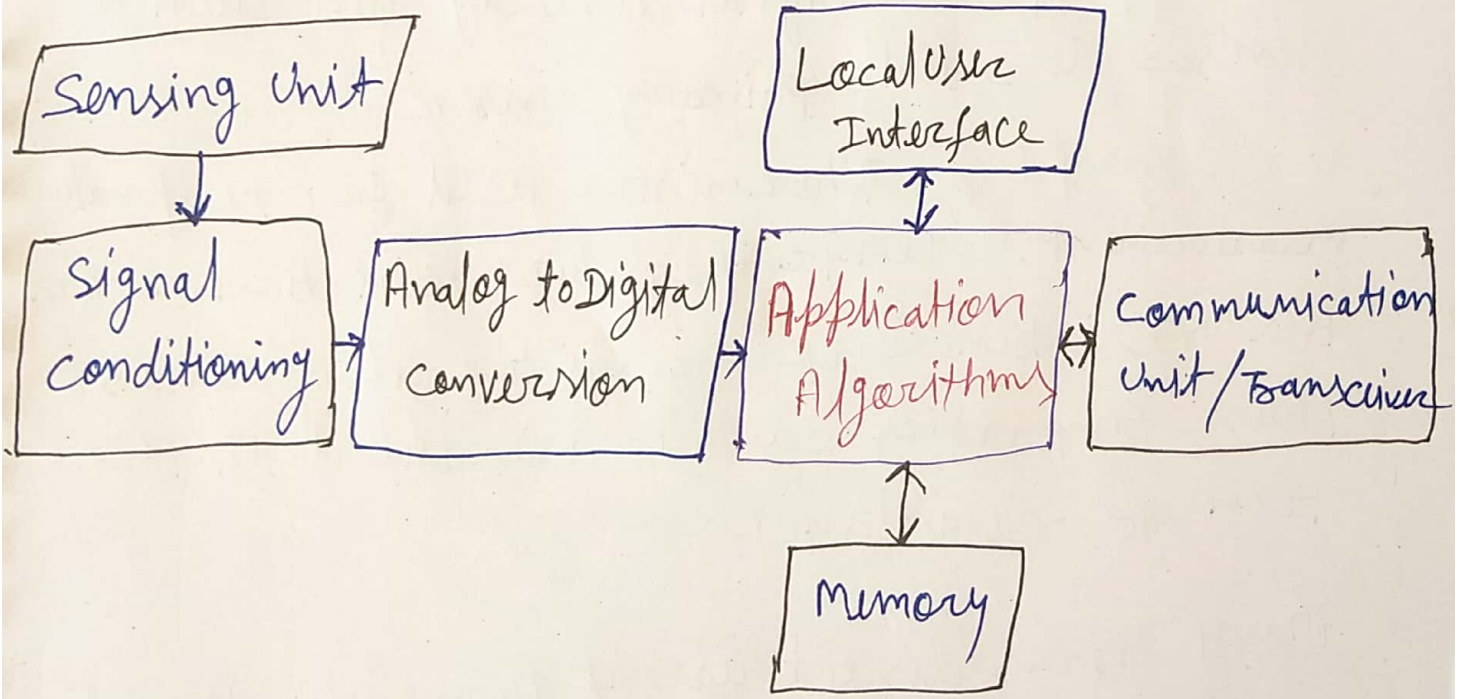
Example :- If a LVDT sensor measures a displacement up to 20 mm and it provides an output as a number between 1 and 100 then the resolution of the sensor device is 0.2 mm.

Transduction Principle :- Transduction is taking energy from one form and transferring it into another and Quantifying that energy change

or energy input. As one can see there are a number of measurands that can be quantified via a variety of transduction techniques.



Block Diagram for Sensing Process



Classification of Sensors :- A sensor can be classified according to environmental variables like heat, pressure, humidity, range, movement etc. Sensors are classified as follows :

1. Primary and secondary sensor.
2. Active and Passive sensor.
3. Electrical & mechanical sensor.
4. Analog & Digital sensor.
5. Inverse sensor.

(1) Primary and Secondary Sensor :- When the input signal is directly sensed by sensor and converted into appropriate signal directly then such a sensor is called a primary sensor.

For example :- Thermistor used for temprature measurement. when temperature variation occurs, the resistance of thermistor also varies. Thus, temprature can be measured in the term of resistance.

Many times direct use of primary sensor is not possible. So secondary sensor are used along with primary sensor. In such case, the input signal is first sensed by a

Primary sensor and it is given as the input to other sensor for conversion.

For Example:- In case of pressure measurement, bellows act as primary sensor. So pressure is applied to bellows and displacement is produce which is transferred to LVDT core. The LVDT produces output signal (voltage) as per the displacement.

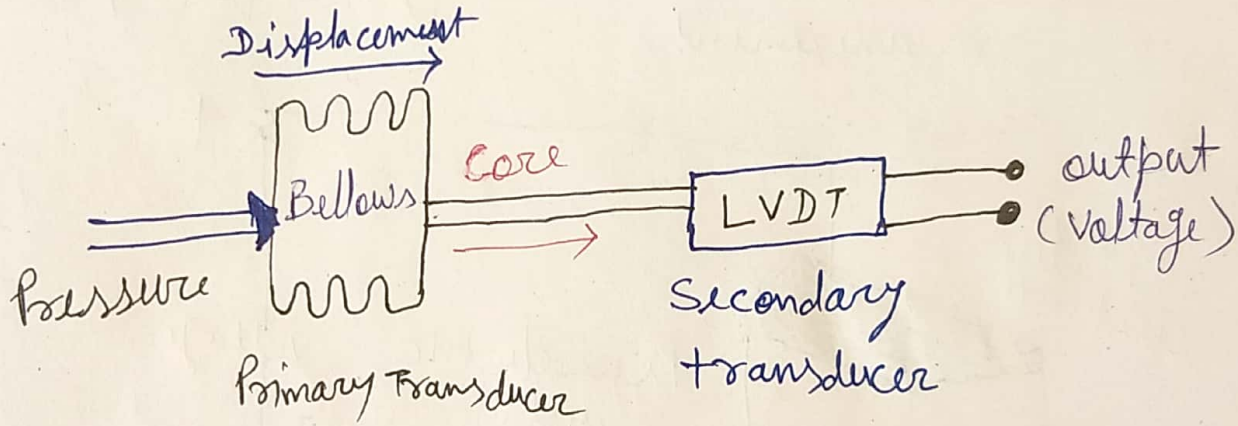


fig:- Secondary Sensor.

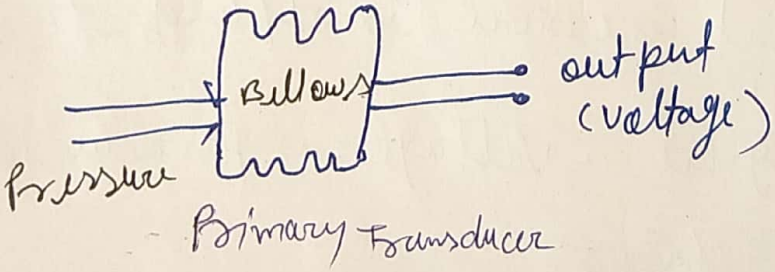


fig:- Primary Sensor.

What is LVDT :- (Linear Variable differential transformer)

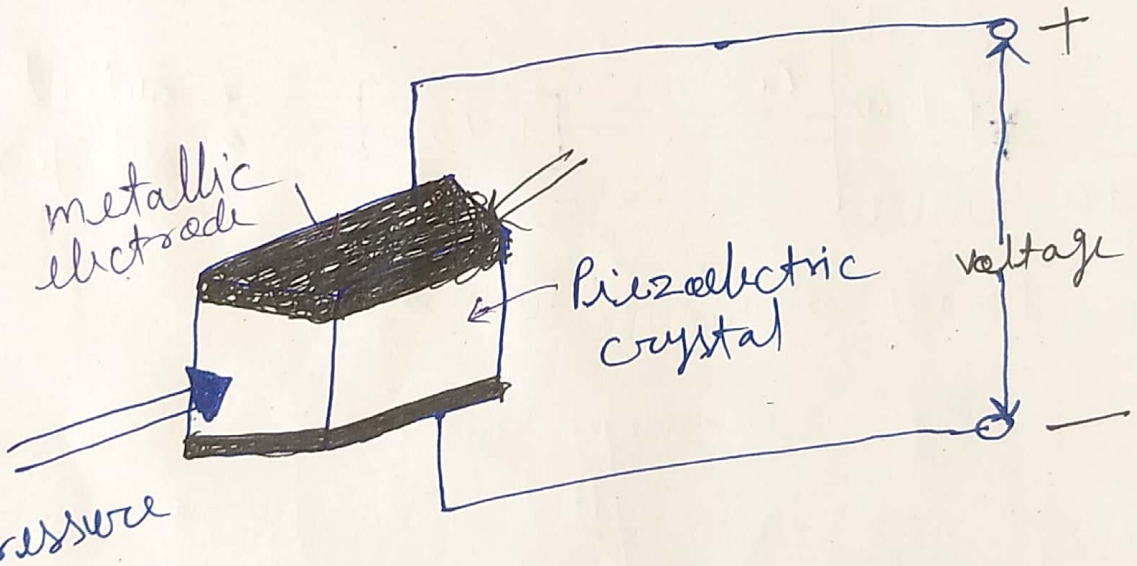
It is a Type of electrical transformer used to measuring linear displacement.

~~Rotary Variable Transfor :-~~

(2)

Active & Passive Sensor :- Active sensor are those which do not require any external Power input for their functioning.

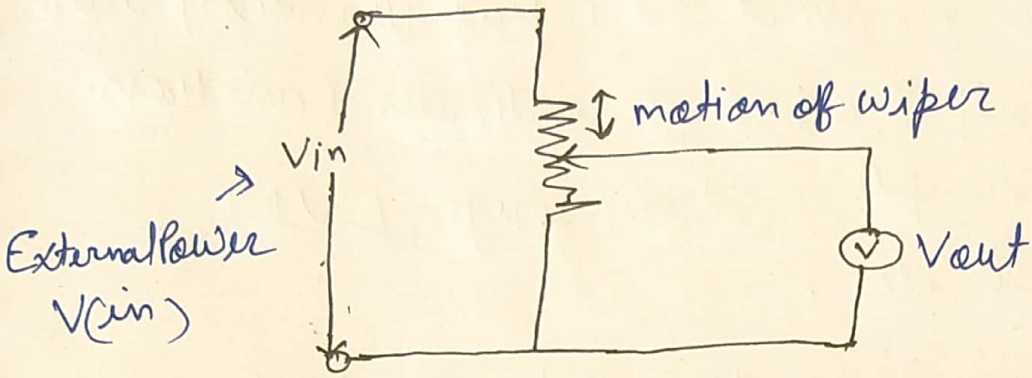
for Example :- A piezoelectric crystal for pressure measurement.



When differential Pressure is applied to the piezoelectric crystal, a voltage is produced across the two faces.

Passive Sensor are those which require external power input for their functioning. These are also known as externally powered Sensors.

Examples of passive sensors are resistive, inductive and capacitive sensor.



Consider application of potential divider used for displacement measurement.

(3) Electrical and Mechanical Sensor :-

Electrical Sensor :- It is a device which converts a physical quantity into electrical signal. The electrical signal obtained is very convenient to handle and process. So electrical sensor are most popular.

Example :- Ultrasonic sensor, PIR Sensor etc.

Mechanical Sensor :- There are many mechnical quantites which are to be masured in pratical world. These mainly force, pressure, displacement, flow rate and many more. Most of the mechanical sensor convert

applied force into displacement.

(4) Analog & Digital Sensor :- The sensor are classified on the basis of nature of output signal i.e. analog and digital.

- Analog sensors convert the input quantity into an analog output which is continous function of time. for Example :- strain gauge, LVDT, thermocouple etc.

- Digital sensors convert input signal to the output signal in the form of pulse or 0 and 1. This make use of Analog to Digital converter (ADC).

(5) Inverse sensor :- Broadly it can be said that, sensor is a device which converts non-electrical quantity into electrical quantity.

- An inverse sensor is defined as a device which convert electrical Quantity into a non electrical Quantity. Example.

The Analogue ammeter and the voltmeter convert the current into a displacement. The Oscilloscope is used for converting the electrical signal into a physical displacement.

Sensor Selection Criteria:- The following parameters need to be keep in mind while selecting a sensor for application.

1- Variables measured and application.
2- Dynamic range
3- Required Resolution and sensitivity.
4- Required accuracy and precision.
5- Environmental conditions.
6- Power available for sensing.
7- Availability.
8- Cost
9- Size and available space.
10- Ease of use.
11- Ease of maintenance.
12- Required signal processing.

Characteristics of the sensor / Transducer:-

1- Accuracy
2- Precision
3- Range
4- Resolution.
5- Sensitivity
6- Minimum detectable signal
7- Linearity.

① Accuracy :- It is the closeness with which the measured value approaches to the true value.

$$\%\text{Error}(E_r) = \frac{X_T - X_m}{X_T} \times 100$$

$$\text{Accuracy} = 1 - E_r$$

where $X_T \rightarrow$ True value

$X_m \rightarrow$ Measured value.

Example 1

A meter reads 127.50V and the true value of the voltage is 127.43V. Determine:

(a) Static Error

(b) Static correction for this instrument.

Solvⁿ

(a) Measured value $A_m = 127.50V$.

True value $A_T = 127.43V$

Static Error $= \delta A = A_m - A_T$

$= 127.50 - 127.43$

$= 0.07V$ Ans.

(b) Static correction $\delta c = \delta A$

$= -0.07V$ Ans

Example 2 A thermometer reads 95.45°c and the static correction given in the correction curve is −0.08°c. Determine the true value of the temperature.

Solvn

Measured value $A_m = 95.45°c$

correction curve $\delta c = -0.08°c$

True value of the temperature $A_t = A_m + \delta c$

$= 95.45 - 0.08$

$= 95.37°c$ Ans

(2) Precision:- It is a degree of reproducibility of the measured value.

$$P = |X_m - X_A|$$

where X_A is average of all reading.

Example:- A set of independent current measurements were recorded as 10.03, 10.10, 10.11 and 10.08A. Calculate (a) Average current (b) range of the error.

Solvn:-

(a) Average current $I_{av} = \frac{I_1 + I_2 + I_3 + I_4}{4}$

$= \frac{10.03 + 10.10 + 10.11 + 10.08}{4}$

$= 10.08 A.$ Ans

(b) Maximum value of current $I_{max} = 10.11$ A.

$$\text{Range} = I_{max} - I_{av}$$
$$= 10.11 - 10.08 = 0.03 \text{ A}.$$

minimum value of current $I_{min} = 10.03$ A.

$$\text{Range} = I_{av} - I_{min}$$
$$= 10.08 - 10.03$$
$$= 0.05 \text{ A}.$$

Therefore average range of error $= \pm \frac{0.3 + 0.5}{2}$

$$= \pm 0.04 \text{ A. Ans}$$

(3) Resolution :- The smallest change in the input that would produce a detectable change in the output

$$\%R = \frac{\Delta X}{X_{max} - X_{min}} \times 100$$

Example :- A moving coil voltmeter has a uniform scale with 100 divisions, the full scale reading is 200 V and 1/10 of scale division can be estimated with a fair degree of certainty. Determine the resolution of the instrument is volt.

Solvn :-

$$1 \text{ Scale division} = \frac{200}{100} = 2\,V$$

$$\text{Resolution} = \frac{1}{10} \text{ scale division} = \frac{1}{10} \times 2 = 0.2\,V$$

(4) **Sensitivity :-** It is the ratio of incremental change in output to incremental change in input.

$$S = \frac{\Delta y}{\Delta x}$$

where Δy is change in output and Δx change in input.

(5) **Range :-** It is the difference between the maximum and minimum value that can be measured by the instruments.

$$\text{Range} = R_{max} - R_{min}$$

(6) **Minimum detectable Signal :-** It is the minimum value of measurand which can be detected by the instruments.