Module - I - 5th semester

Sensor's and Transducers

Sub :- SAT

Element of a General Measurement System :-

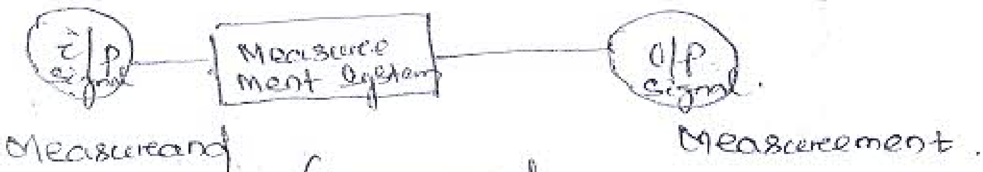
Measurement :- Measurement is a act, or the result of a quantitative comparison between a predetermine standard and an unknown magnitude.

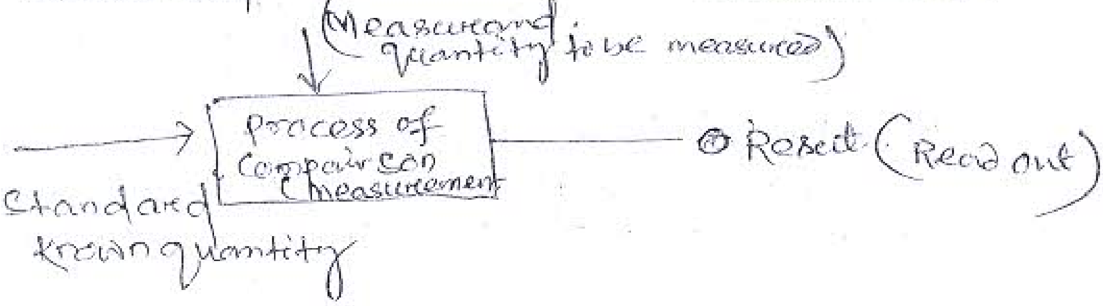
Measurand :- The physical quantity or the characteristic condition which is object of measurement in an Instrumentation system is variously termed as Measurand.

Measurand are two type

→ Fundamental quantity - mass, length & time

→ Derived quantity :- speed, velocity & ~~accelerat~~ acceleration, & pressure.





General Measurement System

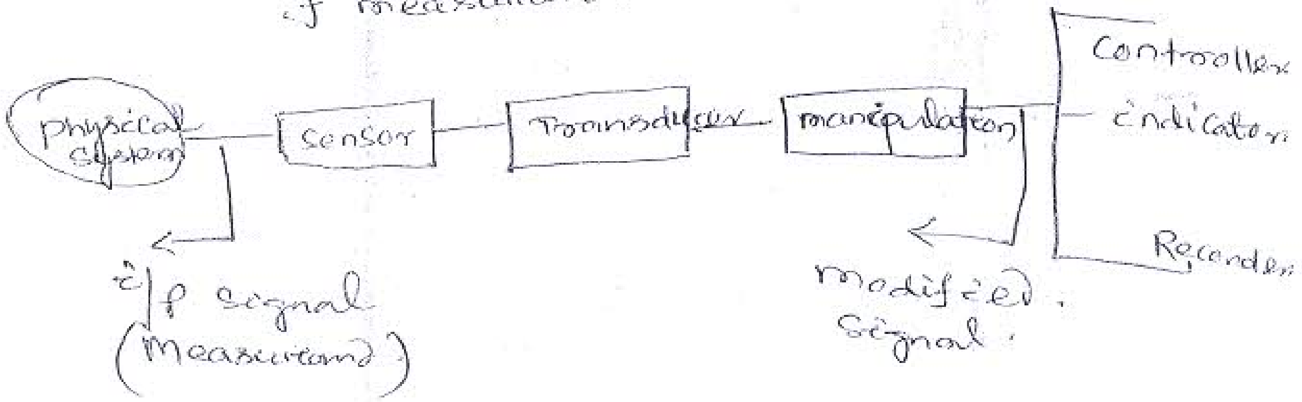
(1) Primary Sensing Element
(2) Variable conversion of Transducer :-
(3) Manupulation Element.
(4) Data transmission Element.
(5) Data presentation element.

(1) Primary Sensing Element :-

→ it is an Element that sensitive to the Measured variable.

→ Sensing Element are sence the condition

State or value of the process variable by extracting a small part of Energy form the measurand and then produces an output which reflect this Condition, State or value of measurand.



Variable Conversion of Transducer Element

This Element converts the signal from one physical form to another without changing the information content of the signal.

Manipulation Element:- This Element operate one signal according to some mathematical rule without changing the physical nature of the variable.

Data Transmission Element:- This element transmits the signal from one location to another without changing its information contents.

Data presentation Element:- This Element provides a display record or indication of the output from the manipulation Element.

Data presentation Element:- This Element provide display the record or indication of the O/P from the manipulate Element.

Static characteristics of INSTRUMENT

The performance of an Instrument is described by means of quantitative qualities terms as characteristics. There are two type of characteristics

(1) Static Characteristics
(2) dynamic characteristics

(1) Static Characteristics:- Static characteristics pertain to a system where the quantities to be measured are ~~constant~~ Constant or vary slowly with time.

(2). Dynamic characteristics: dynamic characteristics pertain to a system where quantities rapidly varying with time is called dynamic characteristics.

Overall performance of an Instrument is judged by semi quantitative Super imposition of the static and dynamic characteristics.

Defination Relating to Measuring Instrument

(1) True value / Actual value :- The actual magnitude of a signal i/p to a measuring system. Which can only be approached and never evaluated is termed as true or actual value.

(2) Indicating Value:- It is the magnitude of a variable indicated by a measuring Instrument.

(3) Sensitivity:- The ratio of O/P Response to i/p responce is called sensitivity.

(4) Range:- The region between the limit within which an Instrument is designed to operate for measuring, indicating or recording a physical quantities is called range of the Instrument.

Accuracy - It may be defined as conformity with or closeness to an accepted standard value

Precision - The degree of agreement within a group of measurement

→ It can be expressed as deviation in measurement

error

Tolerance - It is the range of inaccuracy which can be tolerated in measurement.

Teacher's Signature

Problem:-

A pressure Gauge, which has linear calibration curve, has radius of scale line as 90 mm. and pressure of zero to 60 pascals is displayed over an arc of 300°. Determine the sensitivity of Gauge as ratio of scale length to pressure.

Ans: Full scale deflection = $300^\circ = 300 \times \frac{\pi}{180} = \frac{5\pi}{3}$ r

length of [illegible]le $= \frac{5\pi}{3} \times 90 = 150\pi$ mm.

Sensitivity [illegible] $\frac{\text{scale length}}{\text{Calibration pressure}}$

(G.D.)

Calibration pressure = 60 pascal.

$= \frac{150\pi}{60} = 2.5\pi$ mm/Pa.

(1) A pressure indicator showed a range as 42 bar on a scale range of 0-50 bar. If true value was 41.4 bar, Determine

(1) Static error

(2) Static correction

relative error

$V_m = 42$ bar $\quad V_t = 41.4$ bar

Scale range = 0-50 bar.

Static error, $E_s = V_m - V_t = 42 - 41.4 = 0.6$ bar.

(2) static Correction $= C_s = -E_s = -0.6$ bar

(3) Relative error $E_r = \frac{E_s}{V_t} =$

(1) Static Calibration: It is process by which all the static performance characteristic are obtained in one form to another

Accuracy :- It is the degree of correctness with which a measuring means yield the true value with reference to accepted Engineering standard.

Or It may be defined as conformity with or closeness to an accepted standard value or true value.

Sensitivity :- The ratio of O/P responce to the input response is called sensitivity.

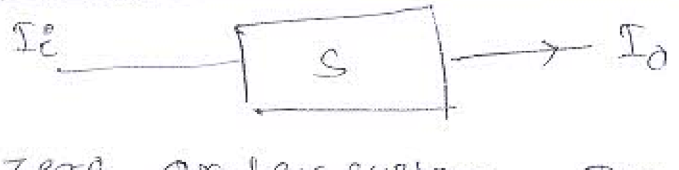
Precision It refers to the degree of agreement within a group of measurement

→ It is usually expressed in term of deviation in measurement.

Tolerance :- It is the range of inaccuracy which can be tolerated in measurement.

Dead Zone :- It is a range within which variable can vary without being detected,

Zero oder measurement system



The zero order system, the O/P is faithfully reproduction of I/P without any distortion or time lag.

$$I_0 = S I_i$$

I_0 → information out of measuring system.

S → sensitivity

I_i → I/P information.

The equation is obtained putting $n=0$,

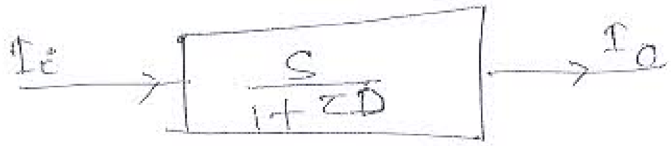
$$A_0 I_0 = B_0 I_i$$

$$I_0 = \frac{B_0 I_i}{A_0} = S I_i$$

Example of zero order system

(1) mechanical lever's.
(2) Amplifier.
(3) potentiometer.

First order measurement system



The behaviour of 1st order system is given by first order differential eqn.

$$A_1 \frac{dI_0}{dt} + A_0 I_0 = B_0 I_i$$

$$\frac{A_1}{A_0}\left(\frac{dI_0}{dt}\right) + I_0 = \frac{B_0}{A_0} I_i$$

$$\tau \frac{dI_0}{dt} + I_0 = S I_i$$

$\tau = \frac{A_1}{A_0}$ – time constant.

$S = \frac{B_0}{A_0}$ – Sensitivity.

Using D-operator, we get.

$$D = \frac{d}{dt}, \quad D^2 = \frac{d^2}{dt^2}$$

Second order Measurement system

(1)

$$I_i \longrightarrow \boxed{\frac{S}{1+\left(\frac{2\nu}{\omega_n}\right)D+\left(\frac{1}{\omega_n^2}\right)D^2}} \longrightarrow I_o$$

$$A_2\left(\frac{d^2 I_o}{dt^2}\right)+A_1\left(\frac{dI_o}{dt}\right)+A_0 I_o = B_0 I_i$$

$$\frac{A_2}{A_0}\left(\frac{d^2 I_o}{dt^2}\right)+\frac{A_1}{A_0}\frac{dI_o}{dt}+\frac{A_0}{A_0}I_o=\frac{B_0}{A_0}I_i$$

$$\Rightarrow \frac{A_2}{A_0}\left(\frac{d^2 I_o}{dt^2}\right)+\frac{A_1}{A_0}\frac{dI_o}{dt}+I_o=\frac{B_0}{A_0}I_i$$

Where

$$\omega_n = \frac{A_0}{A_2} = \text{Undamped Natural frequency (rad/sec)}$$

$$\nu = \frac{A_1}{2\sqrt{A_0 A_2}} \rightarrow \text{damping ratio.}$$

$$S = \frac{B_0}{A_0} - \text{Static Sensitivity or Steady state gain.}$$

$$\frac{1}{\omega_n^2}\left(\frac{d^2 I_o}{dt^2}\right)+\frac{2\nu}{\omega_n}\left(\frac{dI_o}{dt}\right)+I_o = S I_i$$

in term D-operator. we have.

$$\left(\frac{D^2}{\omega_n^2}+\frac{2\nu}{\omega_n}D+1\right)I_o = S I_i$$

$$\boxed{\frac{I_o}{I_i}=\frac{S}{\frac{1}{\omega_n^2}D^2+\frac{2\nu}{\omega_n}D+1}}$$

Example of Second order System

(1) measurement of accⁿ & force.
(2) piezo electric cell.
(3)

A second order system following differential eqⁿ given below

$$\frac{d^2 I_0}{dt^2} + 3\frac{dI_0}{dt} + 30 I_0 = 30 I_i$$

where I_0, I

① Dete

Solⁿ $\frac{1}{\omega_n^2}\frac{d^2 I_0}{dt^2} + \frac{2\nu}{\omega_n}\frac{dI_0}{dt} + I_0 = K I_i$

from eqⁿ ①

$$\frac{1}{30}\frac{d^2 I_0}{dt^2} + \frac{1}{10}\frac{dI_0}{dt} + I_0 = I_i$$

$\omega_n^2 = 30$ $\quad \frac{2\nu}{\omega_n} = \frac{1}{10} = 0.1$ & $K = 1$

$\omega_n = \sqrt{30} = 5.477$

Damping ratio $= \frac{2\nu}{\omega_n} = 0.1$

$\nu = \frac{\omega_n \times 0.1}{2}$

$\nu = \frac{5.477}{2} \times 0.1 = 0.274$

Damping natural frequency

$\omega_d = \omega_n\sqrt{1-\nu^2} = 5.477\sqrt{1-0.274^2}$

$= 5.267$ rad/s

Static sensitivity $K = 1$

time constant $\tau = \frac{1}{\omega_n} = \frac{1}{5.477}$

$= 0.1826$

A Transfer function may have more than one dimension. When the sensor's o/p is influenced by more than one i/p stimuli.

Dynamic error

- It is allso called as measurement error.
- It difference betn the true value of the quantity changing with time and value indicated by measurement system.

→ The max. amount by which the pointer moves beyond the steadystate is called over shoot.

Transfer function of typical sensing element.

An Ideal (Theoretical) o/p - stimulus relationship is characterized by the so-called T/F.

→ The T/F establish establishes Independence betn the Electrical Signal (S) produced by sensor and stimulus s

$$S = f(s)$$

That function may be a simple linear connection or nonlinear dependence (i.e logarithmic, exponential or power function)

→ in many cases the relationship is Undimensional (i.e o/p versus one i/p stimulus)

→ A unidimensional linear relationship is represented by the equation.

$$S = a + bs \quad \text{——— (1)}$$

where a is the Intercept i.e o/p signal at zero i/p signal.

and b is called sensitivity.

Sensor properties Logarithmic function

$$S = a + b \ln s$$

exponential function.

$$S = a e^{ks}$$

power function.

$$S = a_0 + a_1 s^k$$

k - Constant number -