

Instrumentation and process control.

Unit 01 :- Basic Instrumentation System and characteristics.

Unit 02 :- Transducers.

Unit 03 :- Signal Conditioning and data transmission.

Unit 04 :- Measurement of Non-Electrical quantities.

Unit 05 :- Basic Control System.

Unit 01

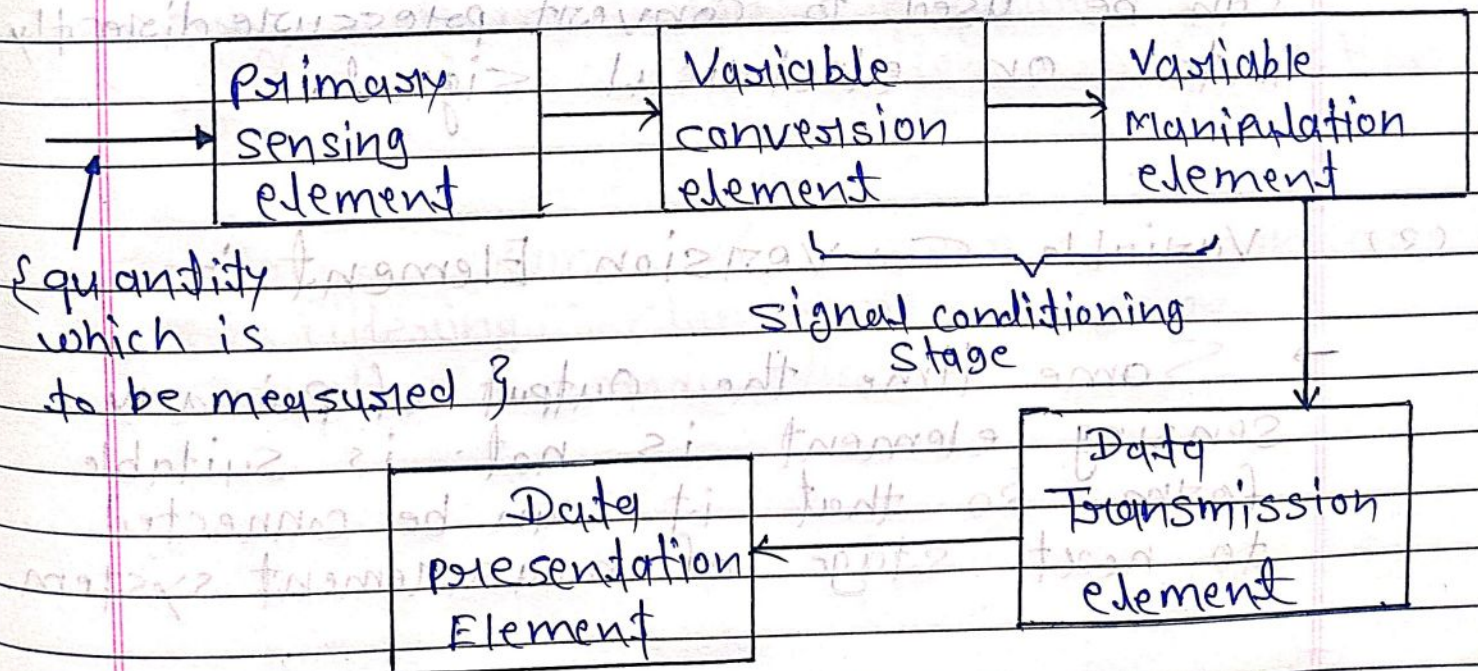
Basic Instrumentation System and Characteristics,

1.1 Need of Instrumentation :-

→ In power plants and in power industries, integrating, recording, controlling and Alarming various process parameters like flow pressure, temperature, level density etc.

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1.2 Block diagram of generating instrumentation.



Block diagram of generated:

(1) Primary Sensing Element :-

- The primary Sensing Element is the first block of generalised measurement system.
- The quantity which is to be measured is applied to primary sensing element.
- Generally transducers are used as a primary sensing element.
- The main function of primary sensing element is to be convert quantity to be measured into an equivalent electrical signal.
- For example a piezoelectric transducers can be used to convert pressure directly into an electrical signal.

(2) Variable Conversion Element :-

- Same time the output of primary sensing element is not suitable to next stage of measurement system.

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→ For example the output of primary sensing element is analog while the next stage of measurement system requires a digital output so here we use analog to digital converter as a variable conversion element.

(3). Variable manipulation Elements :-

→ Variable manipulation elements perform many linear and non-linear function to be the signal to bring it in a suitable form so that it can be connected to the next stage of measurement system.

→ Some example of non-linear function are amplification, integration, differentiation, addition, subtraction etc.

→ Some example of linear function are filtering, clamping, clipping, sampling, modulation.

(4) Data Transmission Element :-

→ Data transmission element are used when data presentation system and primary sensing element are far separated from each other.

(5) Data Presentation System :-

→ When we get data.

→ Computers, Projector etc.

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1.3. Characteristic of instrumentation system. :-

→ There are two type of characteristic :-

(a) Static characteristic

(b) Dynamic c/s

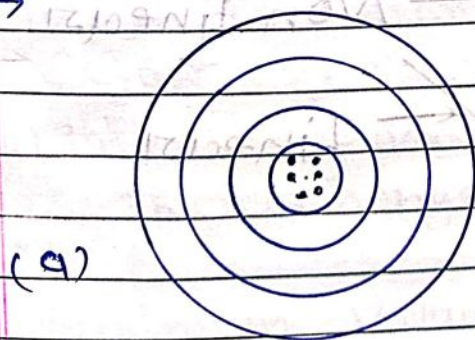
(a) Static c/s :-

The set of criteria defined for the instrument which are used to measure the quantities which are slowly varying with the time or mostly constant.

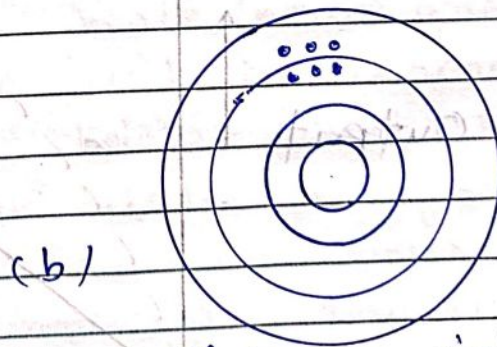
→ Some static c/s are accuracy, precision, sensitivity, linearity, Deadzone, static error, threshold etc.

★ (i) Accuracy and Precision :-

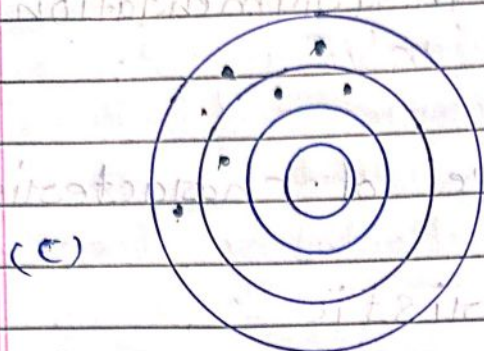
→



High accuracy
High precision



High precision
Low accuracy



(c)

Less accuracy
Less precision.



(d)

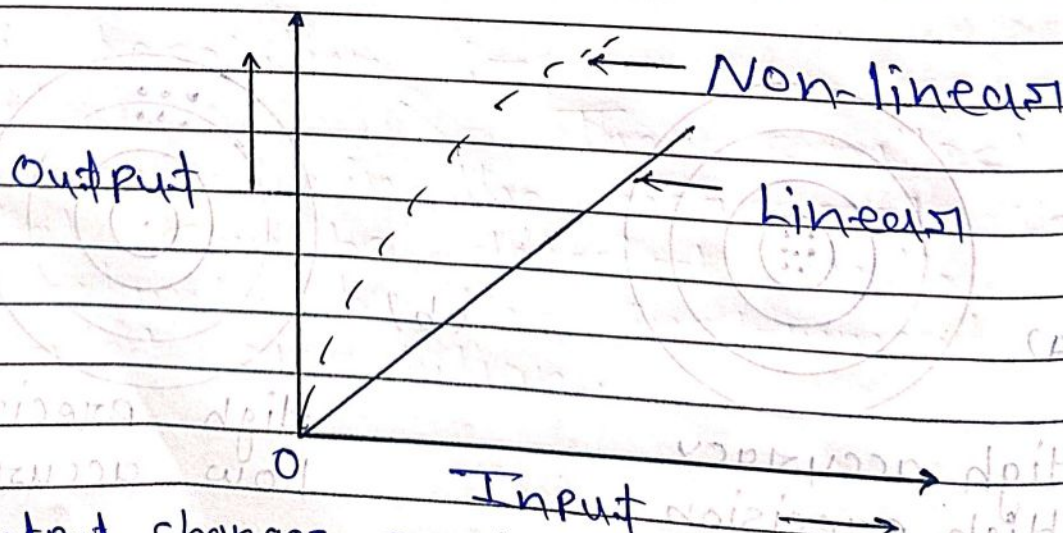
Not Accuracy
Not precision

→ Accuracy is the closeness of the measurement to a static value, while precision is the closeness of measurement to each other.

★

(ii) Linearity :-

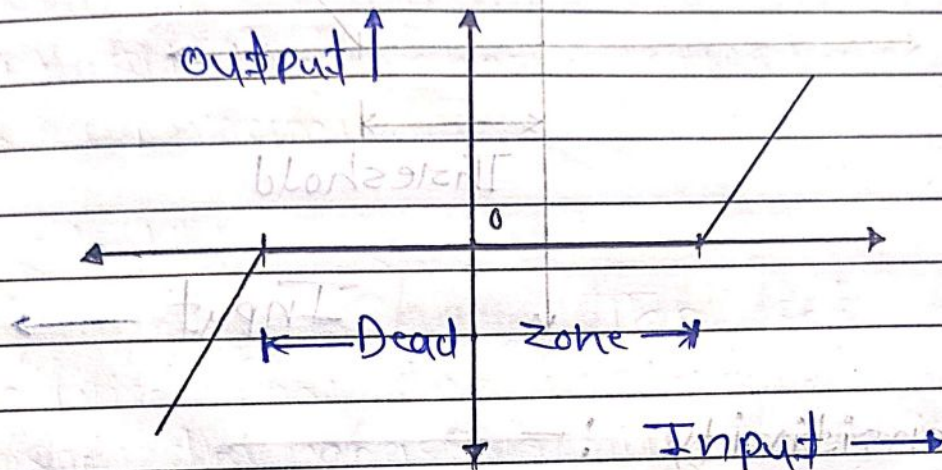
The linearity is defined as the ability to reproduce the input characteristics symmetrically & linearly.



→ Output changes proportional to input change
(Output $\propto$ Input).

(iii) Dead zone :-

It is the largest change of input quantity for which there is no output.

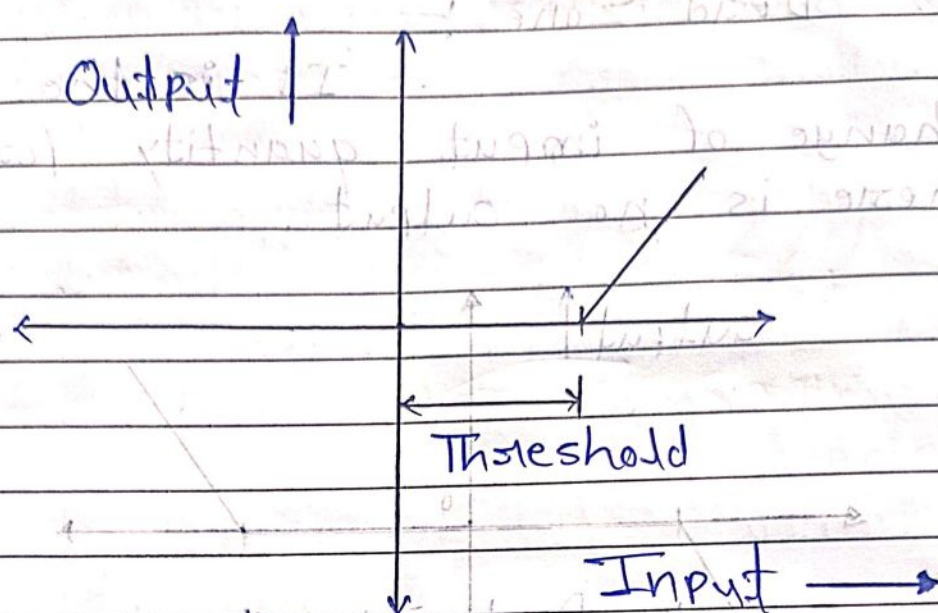


★ (iv) Static Error :-

It is the deviation from the true value to the measured value. (Static error = True value - measured value.)

★ (v) Threshold :-

If the instrument input is increased very gradually from zero there will be some minimum value below which no output change can detect. This minimum value defines as the threshold of the instrument.



★ (vi) Sensitivity :-

It is the ratio of change in output with respect to change in input.

$$\text{Sensitivity} = \frac{\text{change in output}}{\text{change in input}}$$

★ (vii) Resolution :-

The smallest increment in the measured value that can be detected with certainty by the instrument is called resolution.

(viii) Stability :-

The ability of an instrument to retain its performance throughout its specified storage life and operating life is called as stability.

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(b) Dynamic Characteristics :-

→ The set of criteria defined for the instruments which change rapidly with time, is called dynamic characteristics.

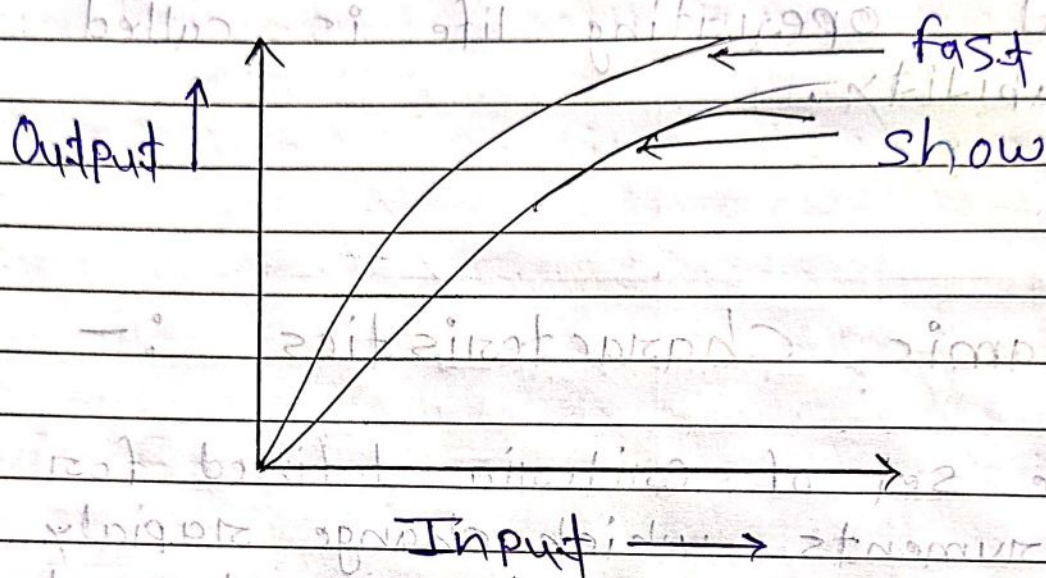
→ Response time & fidelity are the desirable c/s but lag and dynamic error are undesirable c/s of the instruments.

→ Speed of response or response time, fidelity, lag, dynamic error are the dynamic c/s of the instruments.

(a) Speed of response :-

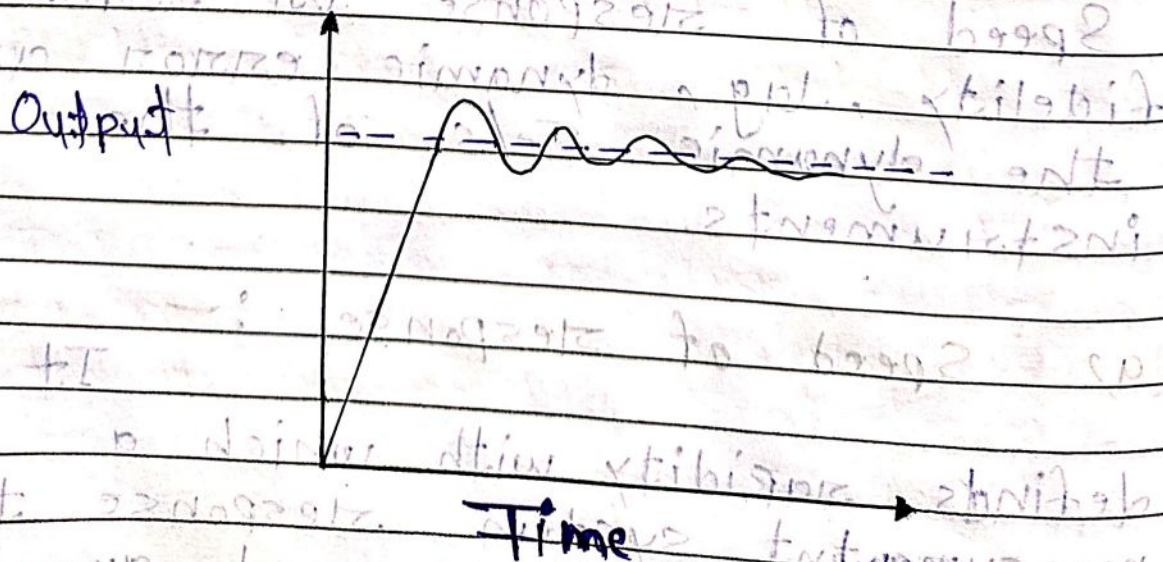
It is defined as rapidity with which a measurement system response to change in the measured quantity.

→ It shows how active or fast the instruments.



(b) Lag / Measuring Lag :-

→ It is the retardation or delay in the response of measurement system to change in the measured quantity.

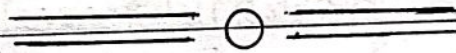


(C) Dynamic Error :-

→ The dynamic error is the difference between the true value of quantity changing with the time & the value indicated by the instruments.

Fidelity :-

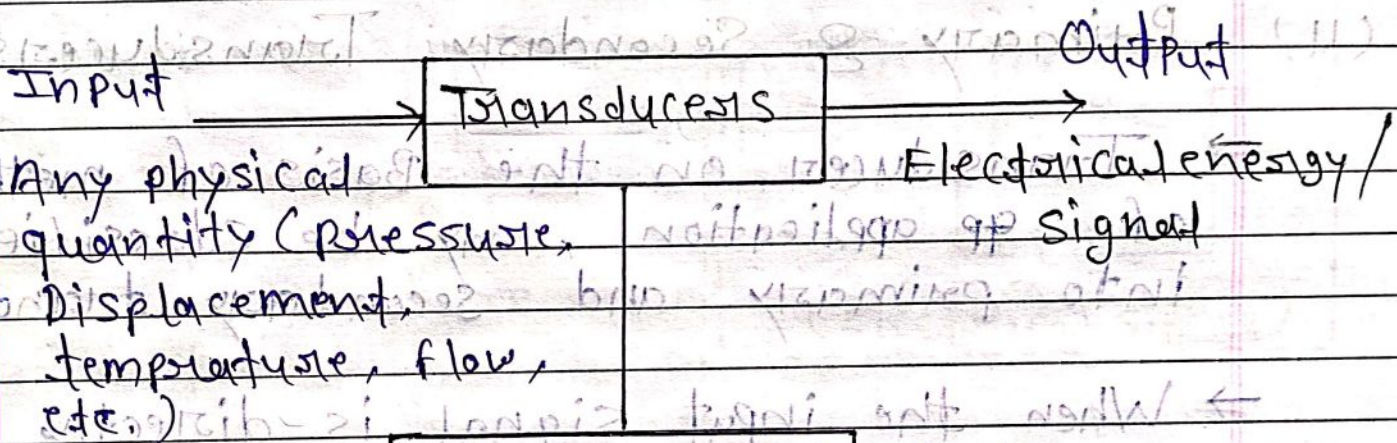
It is defined as the degree of closeness with which the system indicates or records, the signal which is impressed upon it.



Unit - 02

Transducers

Transducers :- A transducer is device which convert any physical quantity like (pressure, distance, temperature, flow, Displacement etc) in to an electrical signal / energy.



Sensor

Transduction

* सभी Input को Sensing कर भी सकता है और नहीं भी करता है यह Transducer में होता भी है और नहीं भी होता है।

Non electrical to electrical Conversion

Classification of Transducers :-

(i) On the basis of transduction.

(ii) Primary & Secondary Transducers.

(iii) Active & passive Transducers.

(iv) Inverse Transducers.

(II) Primary & Secondary Transducers :-

→ Transducer, on the basis of method of application, may be classified into primary and secondary transducers.

→ When the input signal is directly sensed by the transducer and physical phenomenon is converted into the electrical form directly then such a transducer is called the primary transducer.

→ For example, in case of pressure measurement, Bourdon tube is primary sensor / Transducer, which converts pressure first into displacement, and then the displacement is converted into an

9.1 Output Voltage by an LVDT. In this case LVDT is secondary transducer.

primary transducer Secondary transducer

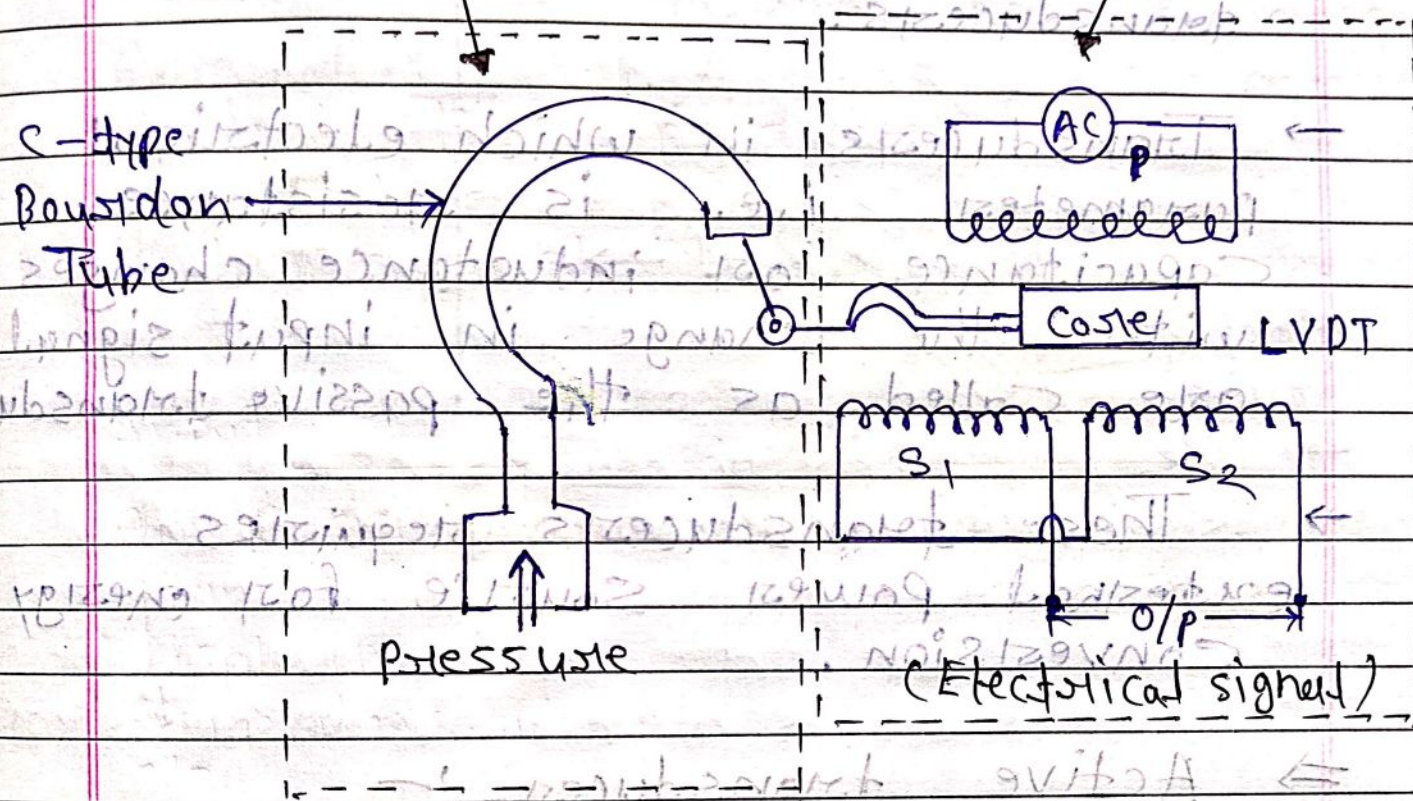


Fig.:- Pressure measurement using Bourdon Tube and LVDT.

(iii) Active & Passive Transducers :-

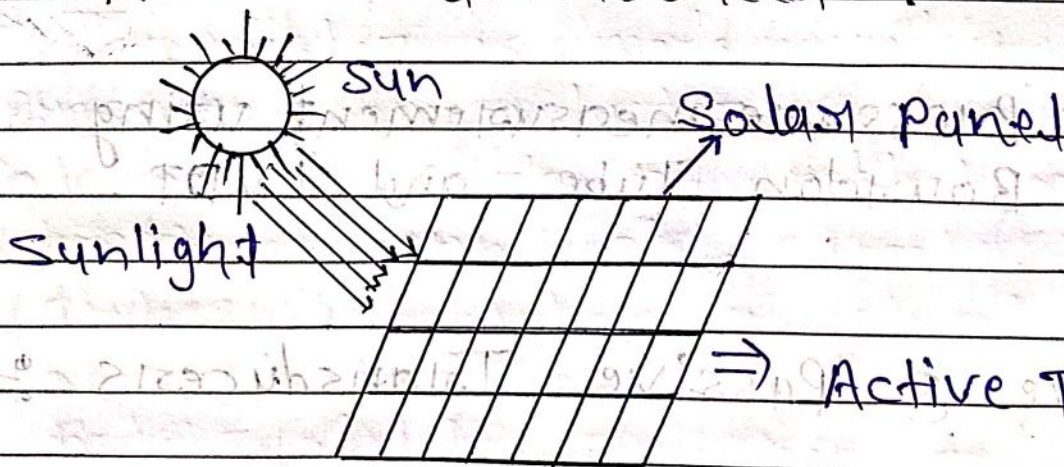
→ Transducer on the basis of method of energy conversion may be classified into active and passive transducer.

→ Self generating type transducers i.e. the transducers which develop their output in the form of electrical voltage or current without any external source are called as active transducers.

→ Transducers in which electrical parameters i.e. is resistance, capacitance or inductance changes with the change in input signal are called as the passive transducers.

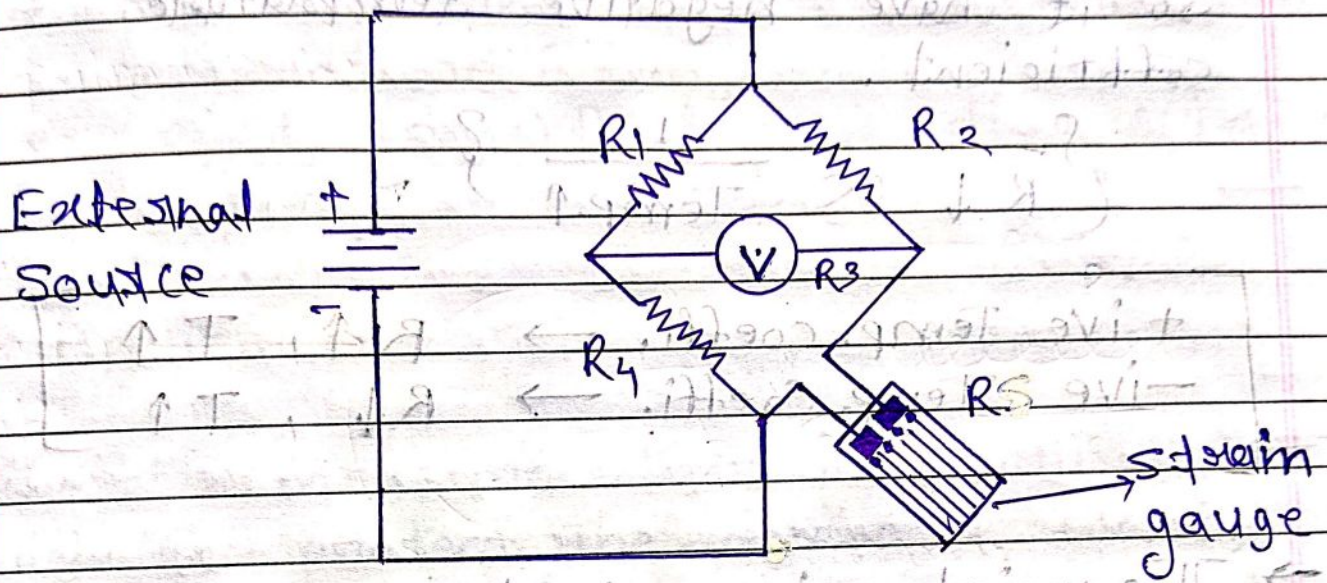
→ These transducers requires external power source for energy conversion.

⇒ Active transducer :-

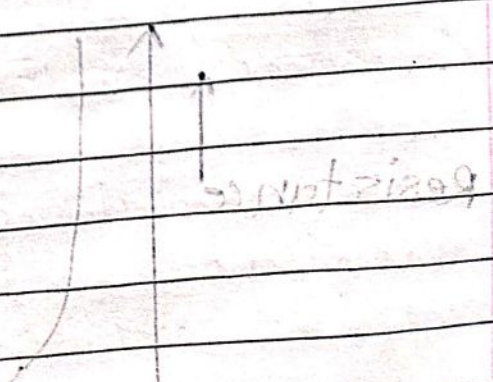


Sunlight → Electrical energy / signal.

⇒ Passive Transducers :-



Passive Transducers



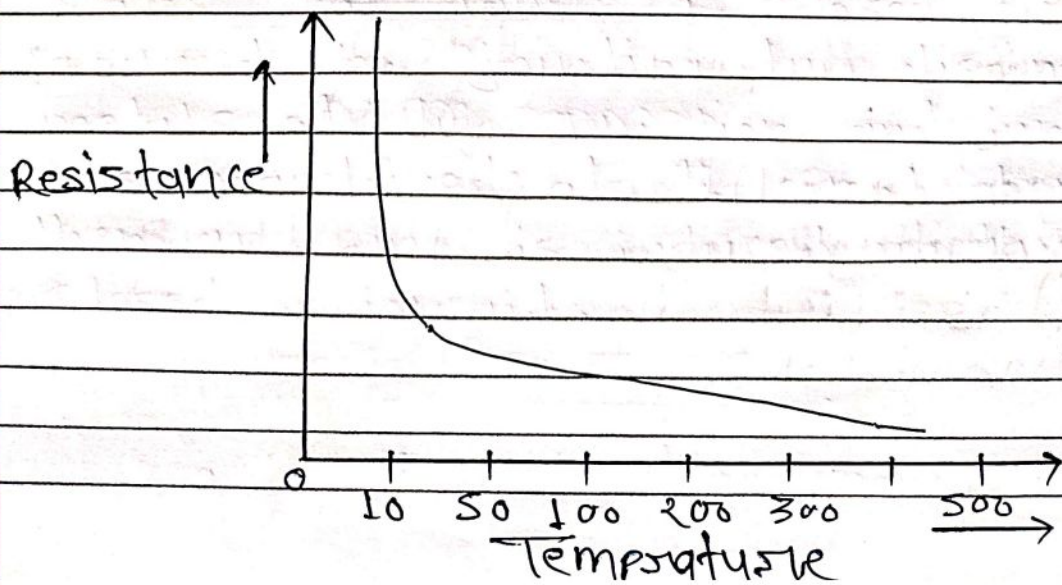
Thermistor :-

Most of the thermistors are made up of semiconductor device, So it have negative temperature coefficient.

$$\left\{ R \propto \frac{1}{\text{Temp.}} \right\}$$

+ive Temp. Coeffi.	→	$R \uparrow, T \uparrow$
-ive Temp. Coeffi.	→	$R \downarrow, T \uparrow$

- Thermistor is a heat sensing device resistance changes rapidly with temperature.
- Thermistor is a non-linear resistor.
- Thermistor is made under high pressure semiconductor ceramic mixture of metal oxide of nickel, cobalt, copper, iron etc.

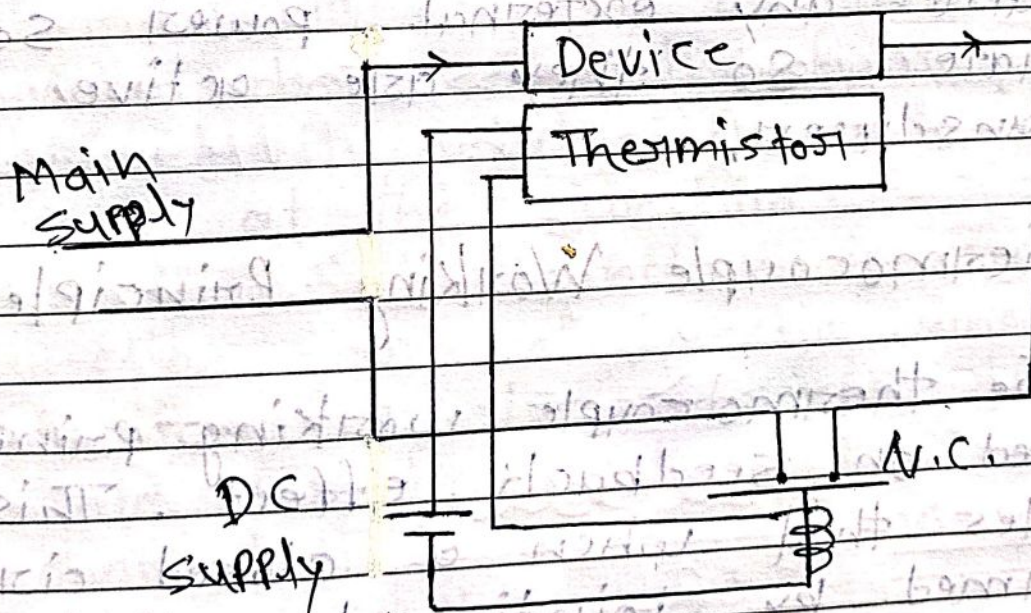


⇒ Advantage :-

- Small size and low cost.
- Fast response over narrow temperature range.
- Good sensitivity in the NTC region.

⇒ Application :-

- (i) To measure the temperature.
- (ii) To protect the device (circuit) from high temperature.



Thermocouple :-

Thermocouples are the temperature sensors which are extensively used for the measurement of temperature variations.

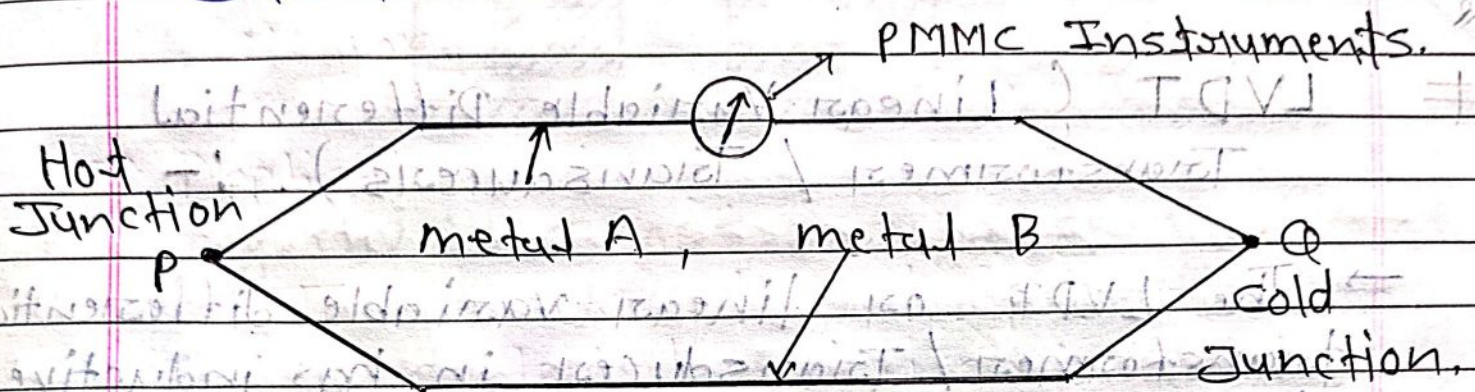
→ They sense the temperature is further measured by other instruments after sensing it.

→ As they convert a non-Electrical quantity (temperature) into voltage (electrical quantity). So they are transducers also since they do not require any external power source to operate. So they are active transducers.

⇒ Thermocouple Working Principle :-

→ The thermocouple working principle is based on Seebeck effect. This effect states that when a closed circuit is formed by joining two dissimilar metals at two junctions and junctions are maintained at different temperatures then an EMF is induced in this closed circuit.

→ The amount of induced emf is different for different metal combination and is proportional to temperature differences of the junction.



→ A circuit diagram of thermocouple is shown above. In the figure, two dissimilar metals 'A' and 'B' are joined at the junction 'P' and 'Q'. Here the 'P' junction is measuring junction or hot junction whereas the junction 'Q' is reference junction or cold junction and a PMMC instrument is connected to measure the emf in the order millivolts.

→ When both the junction are at same temperature, emf generated at both junction will be same, No. current will flow through the circuit and there will be no deflection in the meter.

→ When both the junction are at different temperatures, a current will flow through the meter and the meter will show the deflection.

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LVDT (Linear Variable Differential Transformer / Transducers) :-

→ The LVDT or linear variable differential transformer / Transducer is an inductive transducer that converts linear motion (displacement) into an electrical signal.

→ The output across secondary of this transformer is the differential thus it is called so.

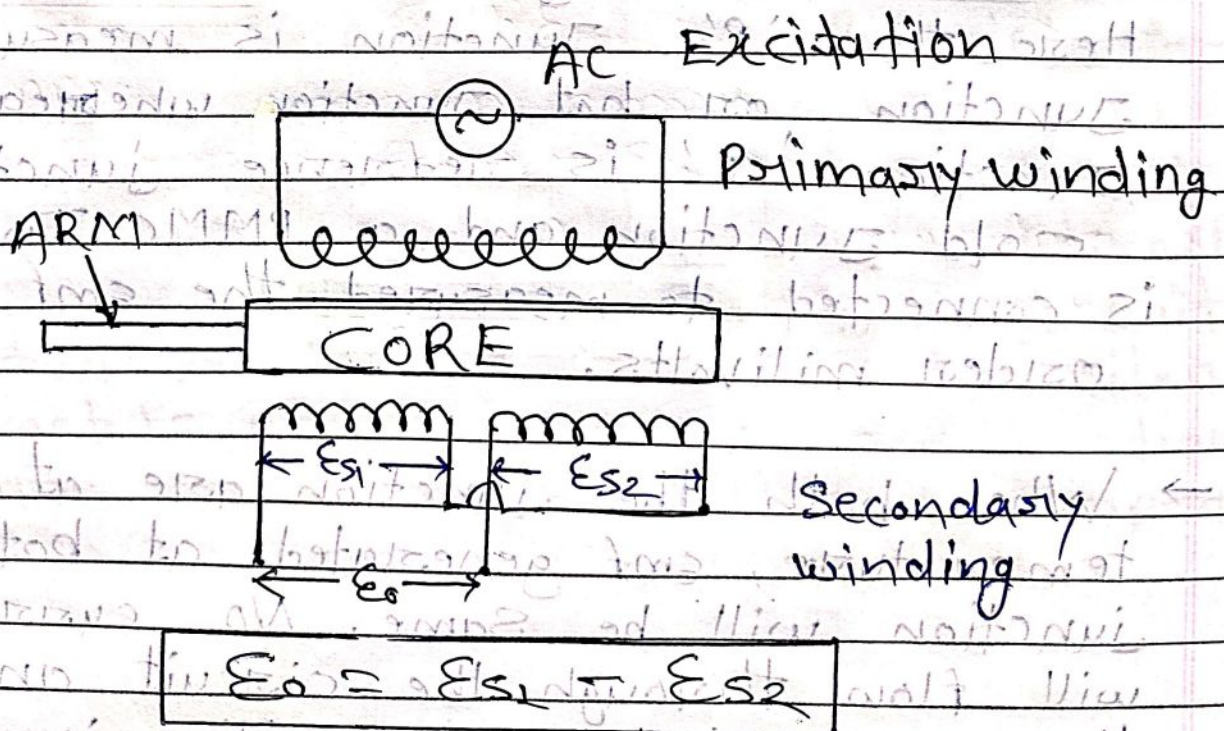


fig (a) :- Circuit diagram of LVDT.

Secondary winding (S_1)

ARM

Primary winding

Secondary winding (S_2)

CORE

fig. (b) :- CROSS SECTIONAL VIEW of LVDT

Construction :-

→ The transformer consist of a primary winding 'P' and Secondary winding S_1 & S_2 , wound on a cylindrical formers.

→ Both the secondary winding have equal number of turns and we place them on either side of primary winding.

→ The primary winding is connected to an AC source which produces flux in the air gap and voltages are induced in Secondary winding.

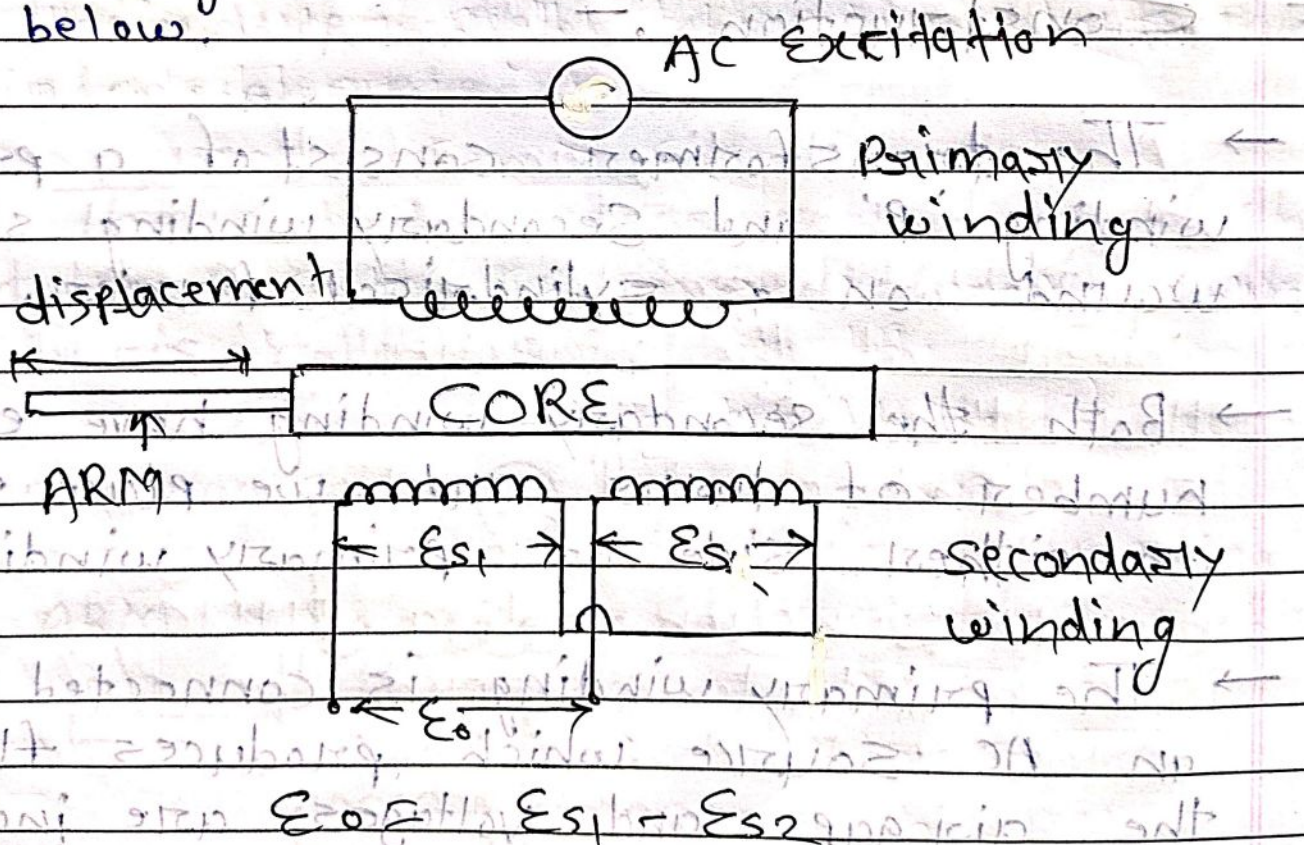
→ A moveable iron core is placed in side the formers and displacement to be measured is connected to the iron core.

Primary winding

→ The both of the secondary windings are connected in such a way that resulted output is the difference between the voltages of two windings.

Working :-

→ Now three cases arises according to the location of core which explains the working of LVDT are discussed below.



★ Case - I :- Null Position

When the core is at Null position (for No displacement) then flux linking with both the secondary winding is equal. So the induced emf is equal both windings. So the value of $E_{\text{output}} (E_o)$ is zero as E_1 & E_2 are equal. So it shows that no displacement took place.

$$E_1 = E_2$$
$$E_o = E_1 - E_2 = 0$$

★ Case - II :- upword position (↑) / Left position (←)

→ When the core is moved to upword / Left of null position, in this case the flux linking with secondary winding S_1 is more as compared to flux linking with S_2 . Due to this E_1 will be more as that of E_2 .

→ Due to this output voltage (E_{out}) is positive (+), It shows the core moved upword / left direction to Null position

$$E_1 > E_2$$

$$E_o = E_1 - E_2 = + \text{ve Value.}$$

★ Case - III :- Downward Position (✓) / Right position (→)

→ When the core is moved to downward / Right of null position, in this case the flux linking with secondary windings S_2 is more as compared to flux linking with S_1 . Due to this E_2 will be more as that of E_1 .

→ Due to this output voltage (E_{out}) is Negative. It shows the core moved downward / Right direction to null position.

$$E_{S1} > E_{S2}$$

$E_{S1} - E_{S2}$ is -ive value

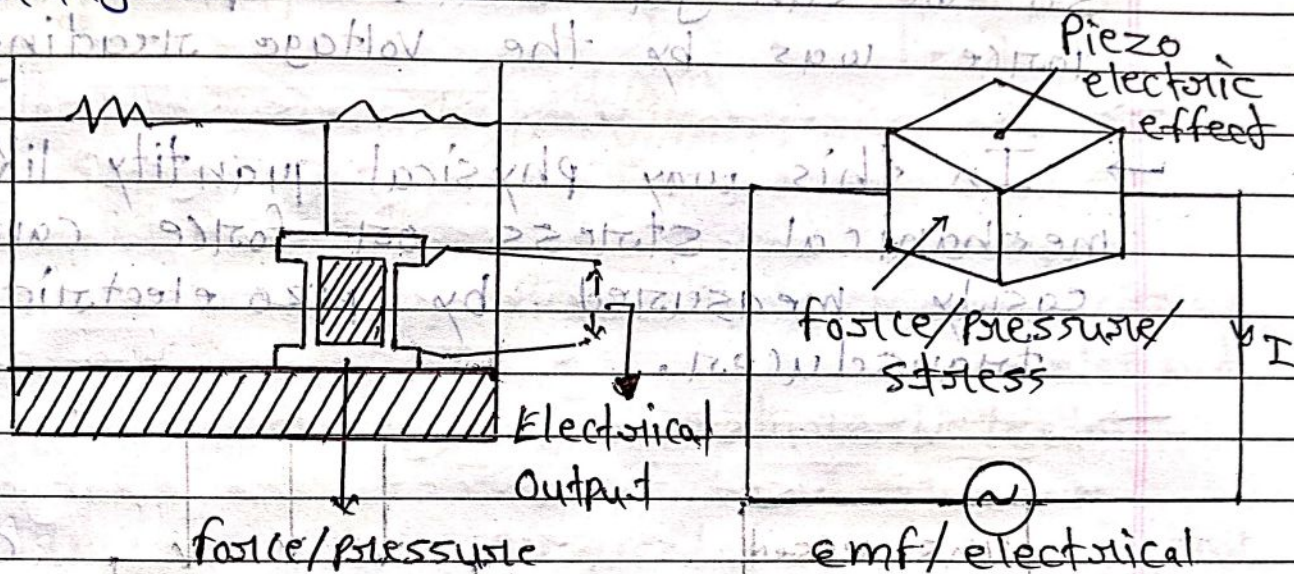
(E_{out} - ive value)

$$= 0 \quad = 0$$

→ Due to this output voltage (E_{out}) is positive / left direction to null position.

Piezoelectric Transducer :-

→ A Piezoelectric transducer is a device that uses piezo electric effect to measure change in acceleration, pressure, stress or force by converting this energy into an electrical energy/charge.



Physical quantity → Electrical signal.

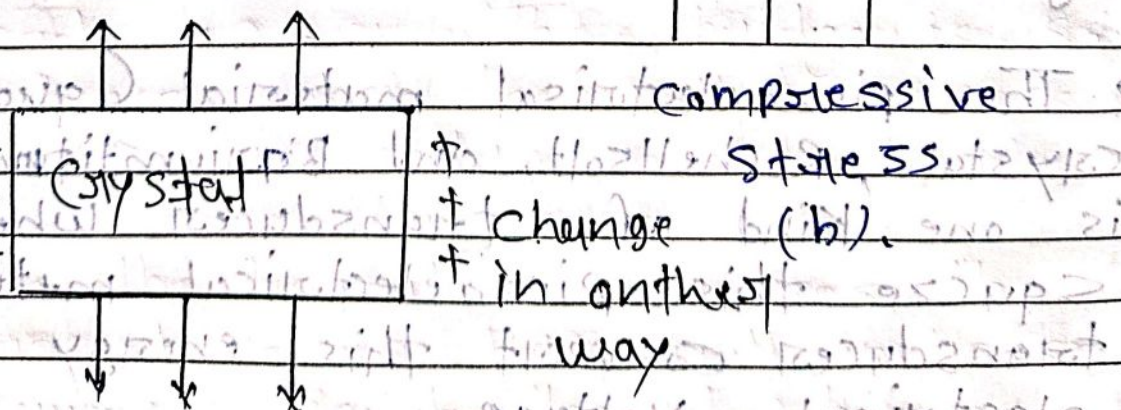
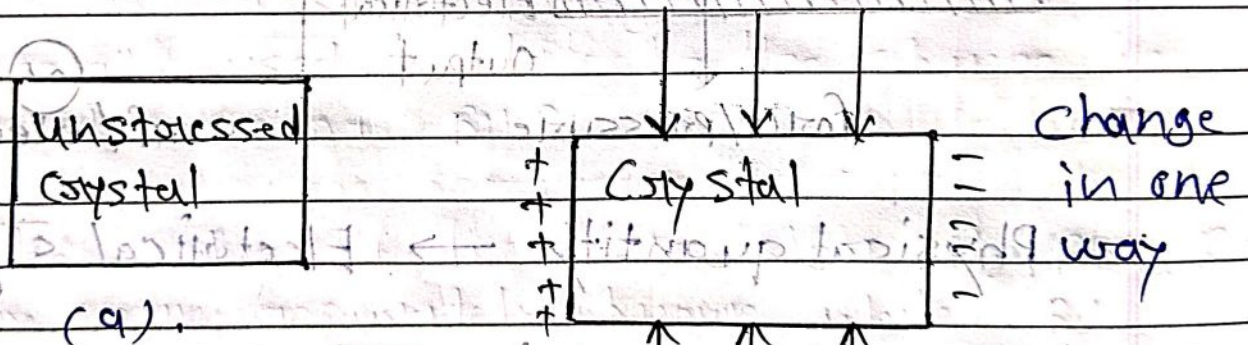
Fig. :- Piezo electric Transducer.

→ The piezoelectrical material (quartz, crystal, Rochell salt, and Barium titanate) is one kind of a transducer when we squeeze this piezoelectrical material transducer convert this energy into electrical voltage.

→ This voltage is a function of force or pressure applied on it. This voltage is easily measured by the voltage measuring instruments.

→ Since this voltage will be a function of an force or pressure applied to it. So we can get what the pressure or force was by the voltage reading.

→ In this way physical quantity like mechanical stress or force can be easily measured by piezoelectric transducers.



Tensile force
(c).

RTD (Resistance temperature Detector) :-

→ RTD stands for resistance temperature detector (RTD) is also called as resistance thermometer.

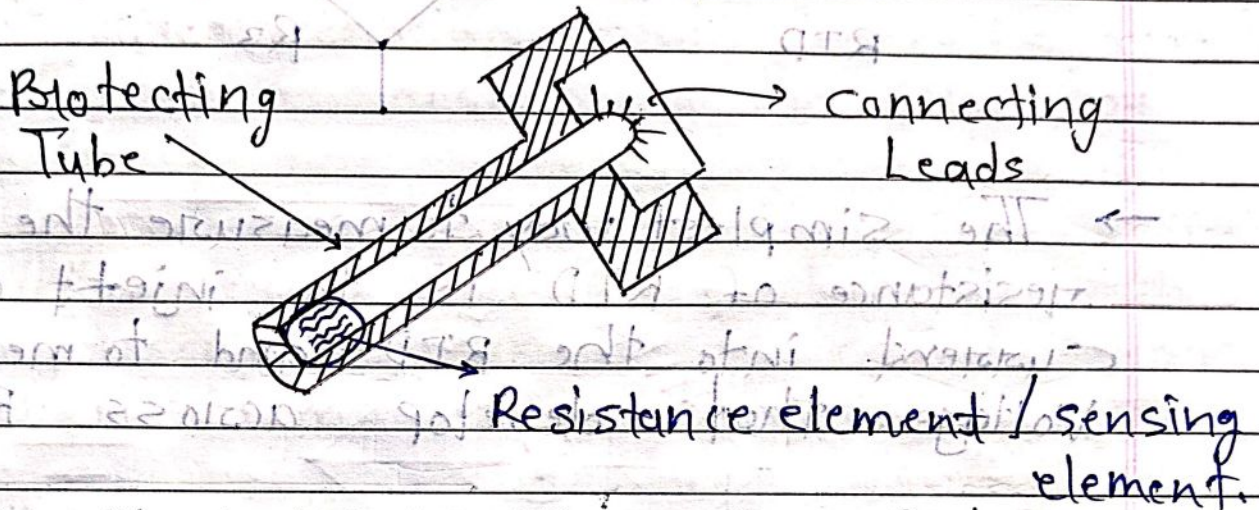
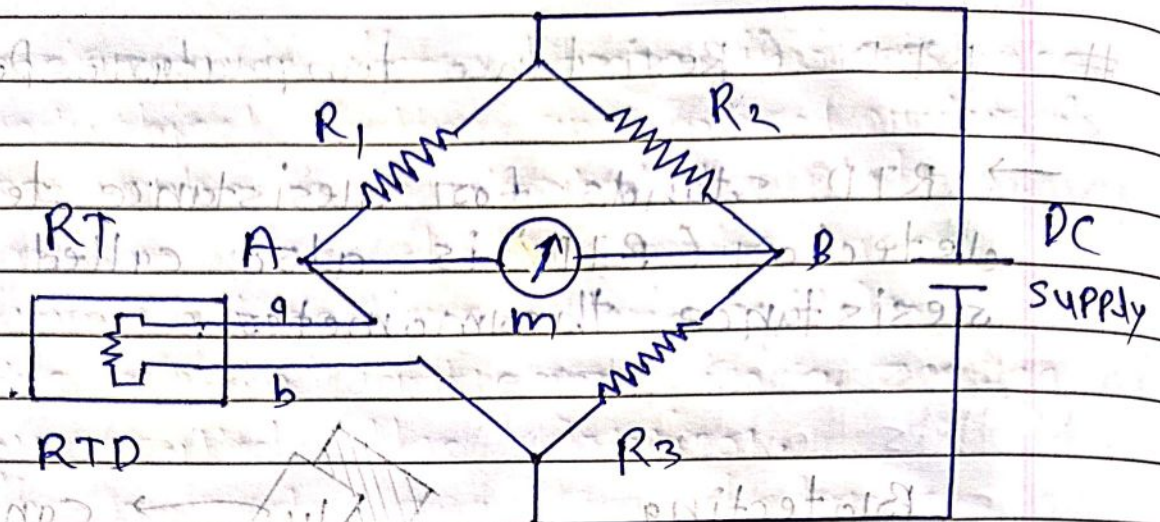


Fig. :- Resistance Temperature Detector.

→ RTD are commonly used to accurately and quickly measure the temperature of applications. This device can be constructed using various materials such as platinum, Nickel, Copper, Nickel iron, etc.

→ The working of the RTD is based on the resistance - temperature relationship of the material used for its construction. The amount of change seen in the resistance value of the material caused due to per degree rise in temperature is measured and the sensor is calibrated accordingly.



→ The simplest way to measure the resistance of RTD is to inject constant current into the RTD and to measure voltage that develop across RTD.

→ A Wheatstone bridge circuit is generally used to detect the change in resistance of RTD.

→ The value of fixed resistors R_1 , R_2 & R_3 are very accurately known while RTD is sent the resistance of RTD with lead a & b. The bridge is said to be balanced when the voltage across point A & B is zero.

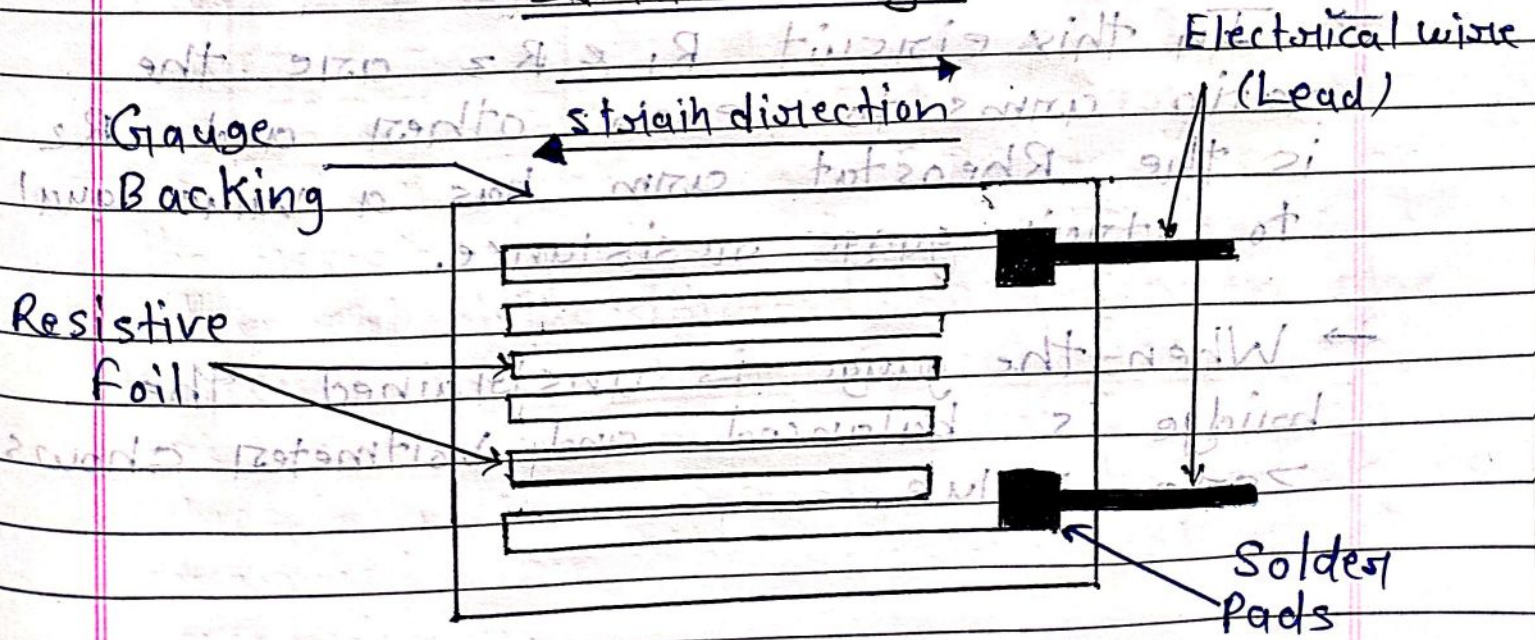
→ As the temperature increases the resistance of RTD will increase causing the bridge to become unbalanced and meter M may be calibrated in temperature vs. voltage & current.

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Strain Gauge :-

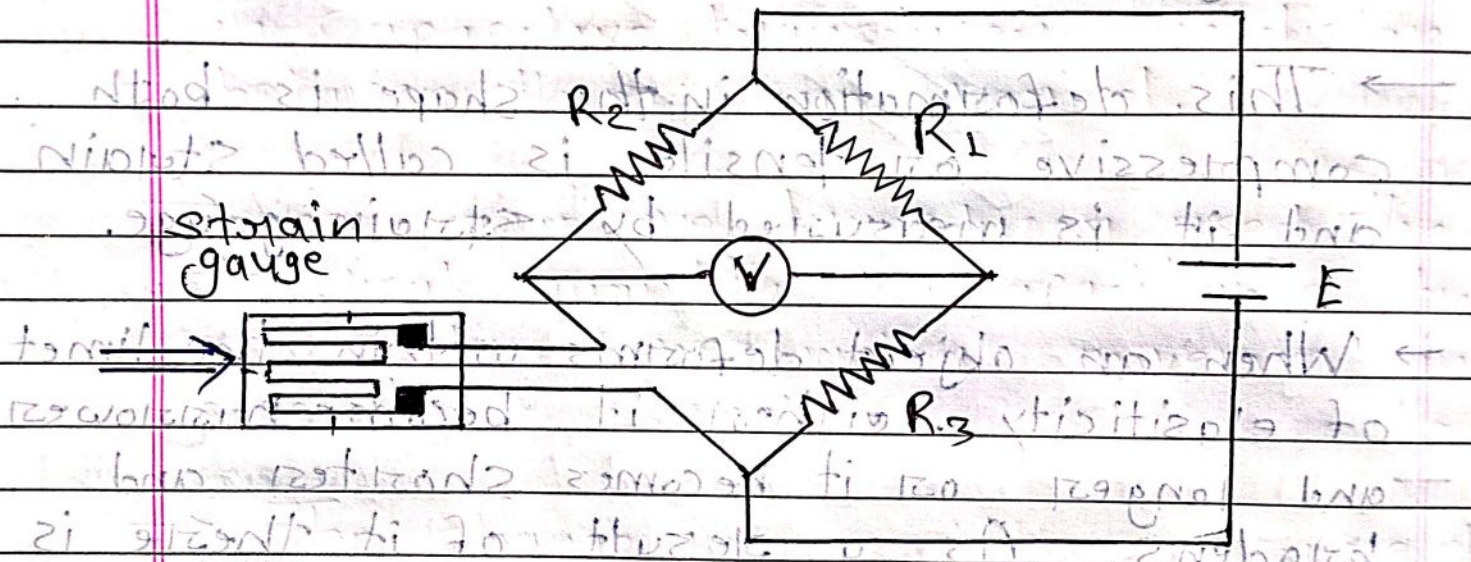
- A strain gauge is a Resistor used to measure strain on an object.
- When a external force is applied on an object, due to which there is a deformation occurs in the shape of the object.
- This deformation in the shape is both compressive or tensile is called strain and it is measured by strain gauge.
- When an object deforms within the limit of elasticity, either it become narrower and longer or it becomes shorter and broadens. As a result of it there is a change in resistance end to end.

Strain Gauge



→ By measuring the change in resistance of an object, the amount of induced stress can be calculated.

→ Strain gauge has a long thin metallic strip stretched in a zigzag pattern called the cassities.



→ In this circuit R_1 & R_3 are the ratio arms to each other and R_2 is the Rheostat arm has a value equal to strain gauge resistance.

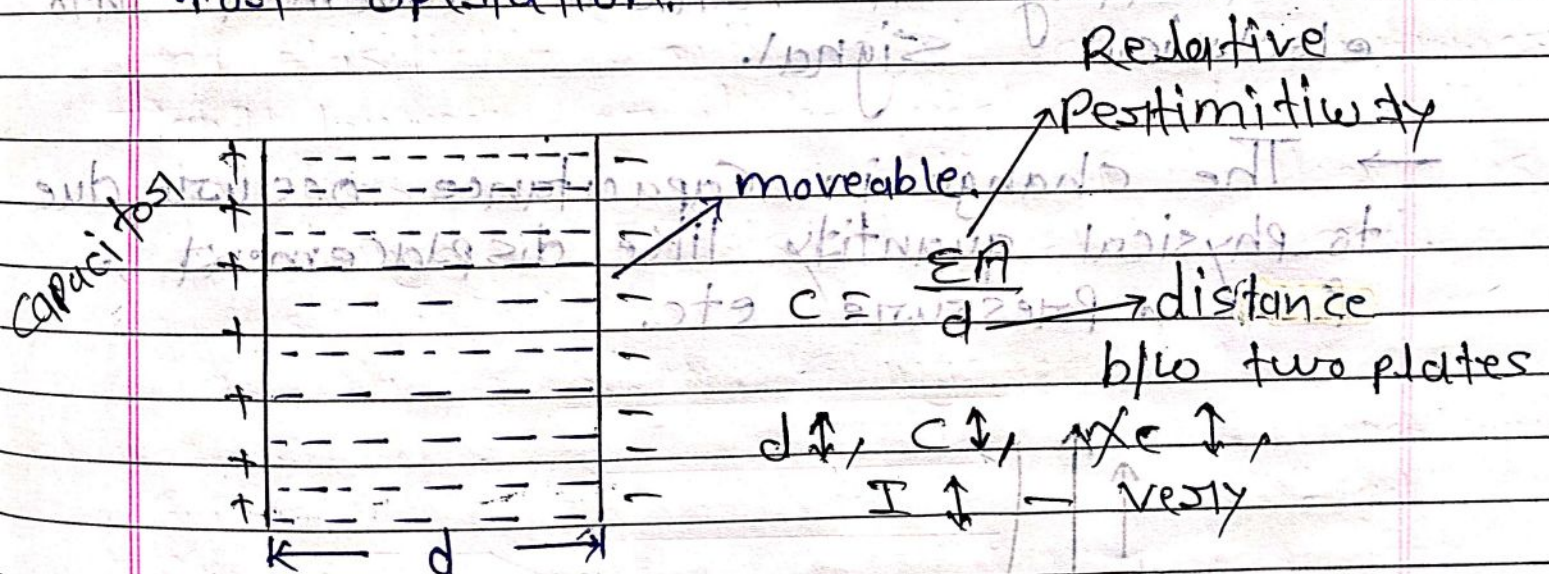
→ When the gauge is unstained the bridge is balanced and Voltmeter shows zero value.

→ As there is a change in resistance of strain gauge, the bridge gets unbalanced and producing an indication at the voltmeter.

Capacitive Transducers :-

→ The Capacitive transducer is used for measuring the displacement, pressure and other physical quantity.

→ It is a passive transducer that means it requires external power for operation.



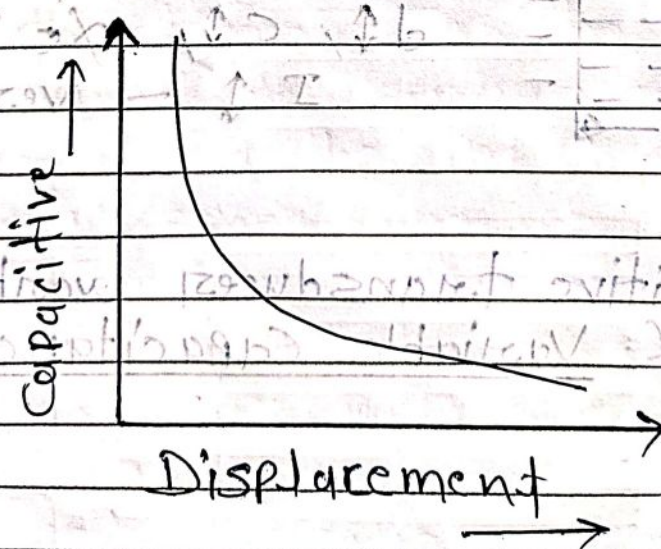
→ The Capacitive transducers work on the principle of Variable Capacitance.

→ The capacitance of capacitive transducer change because of reason like overlapping of plates, change in the distance between the plates and dielectric medium which is either air, liquid, gas etc,

→ In the normal capacitor distance between two plates are fixed, but in capacitive transducer the distance between them is varied.

→ The capacitive transducer used the electrical quantity of capacitance by converting mechanical movement into electrical signal.

→ The change in capacitance occurs due to physical quantity like displacement, force, pressure etc.



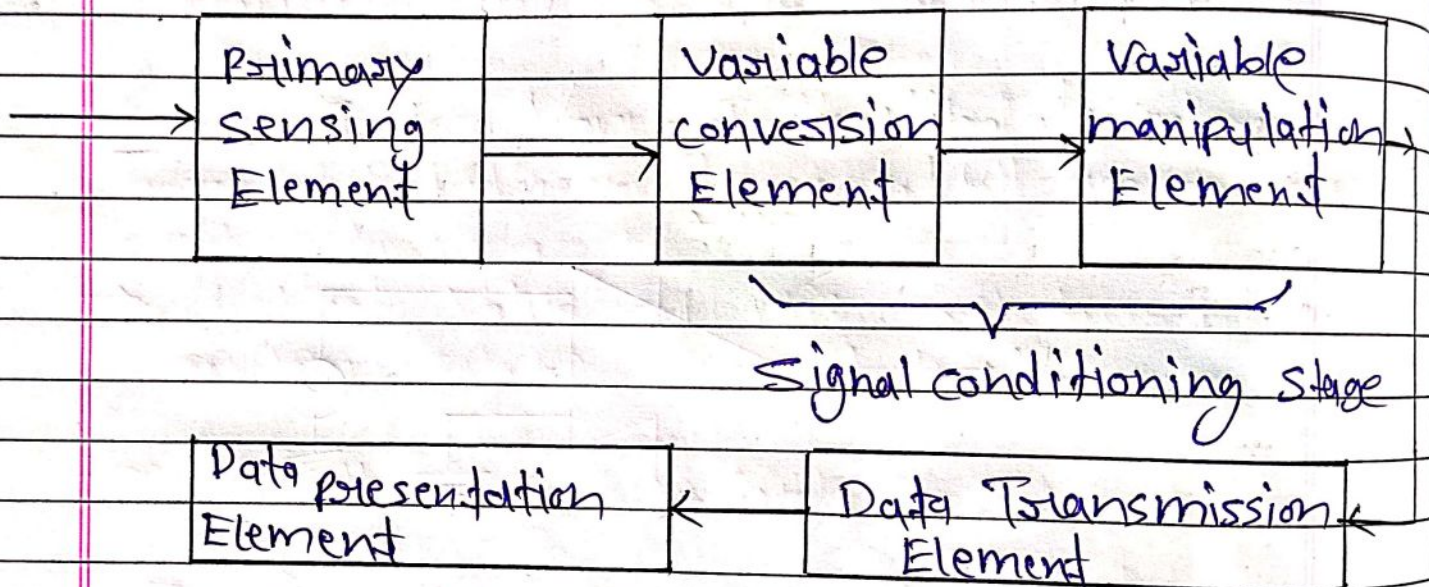
Bourdon Tube :-

Unit - 03.

Signal Conditioning & Data Transmission

Signal conditioning :-

⇒ Block diagram of Instrumentation System :-



→ In electronics and signal processing signal conditioning is the manipulation of analog signal in such a way that it meets requirement of the next stage for further processing.

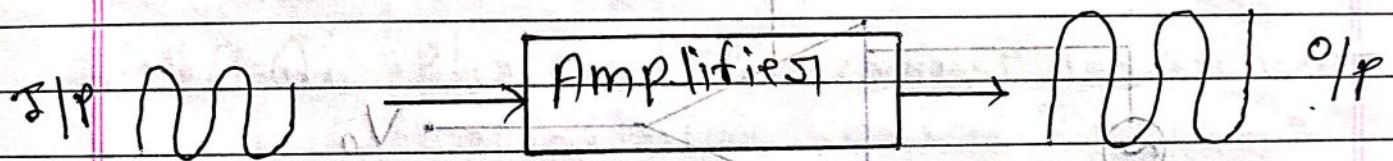
Purpose :-

The purpose is to amplify and convert this signal into an easy to read and compatible form for machine can tool.

⇒ Basic Work of Signal Conditioning :-

- Addition
- Subtraction
- Amplification
- Modulation
- Demodulation
- Filtering
- Clamping
- Clipping

OPAMP (Operational Amplifier) :-



→ An opamp is a high gain amplifier used to perform variety of functions:-

addition, subtraction, Amplification, modulation, Demodulation, filtering, clamping, clipping.

⇒ It has 4 terminal.

- Non-Inverting terminal
- Inverting terminal.
- Supply terminal.
- Output terminal

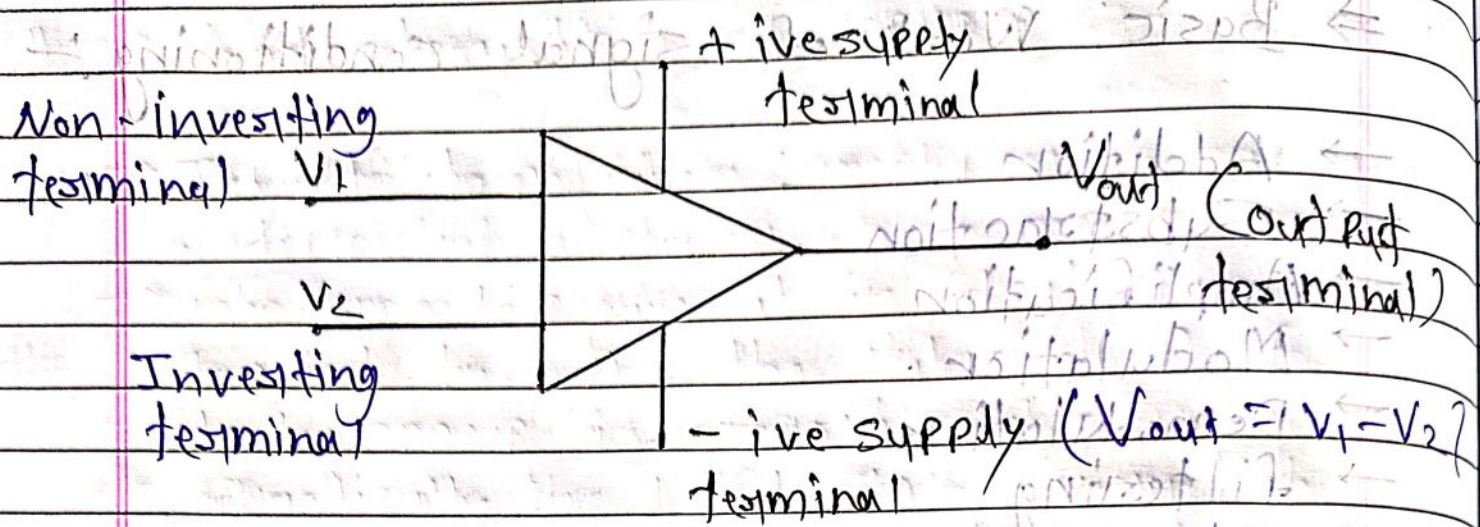
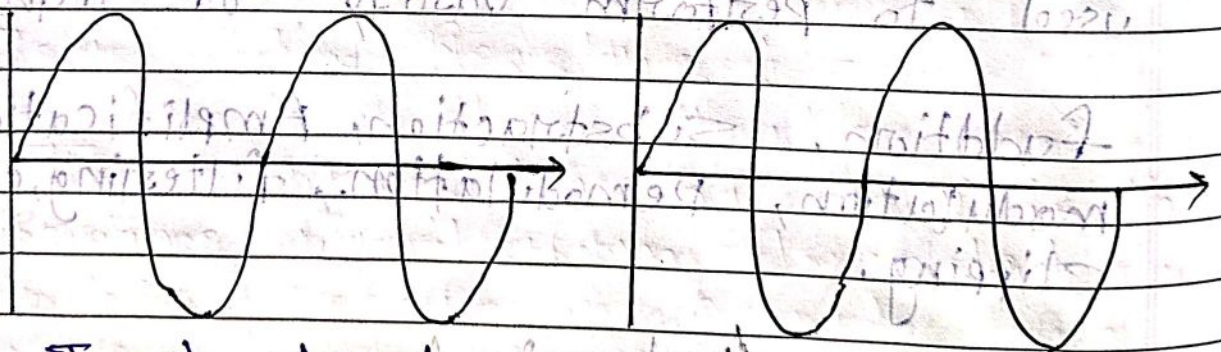
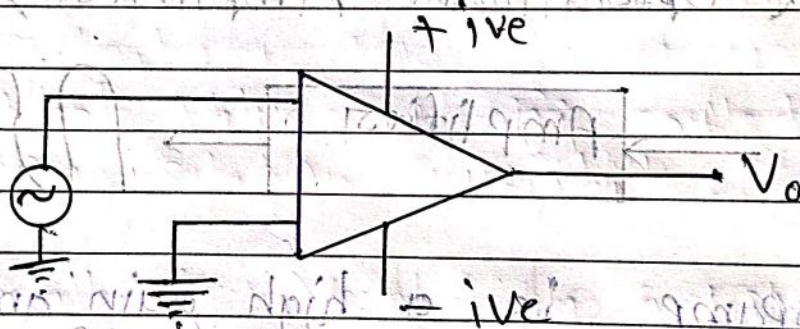


Fig :- OPAMP (Operational Amplifier)

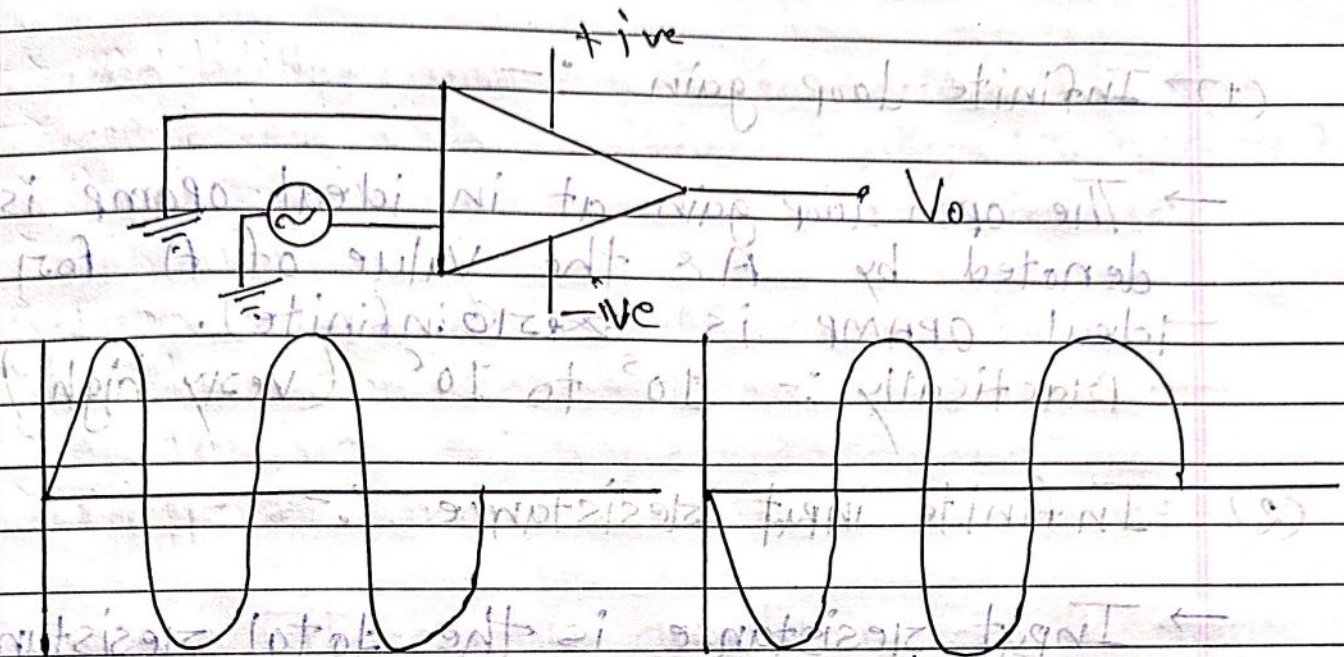
Case - I :- Non-Inverting terminal.



(a) Input signal (b) Output signal

0° Phase displacement
(difference)

Case - II

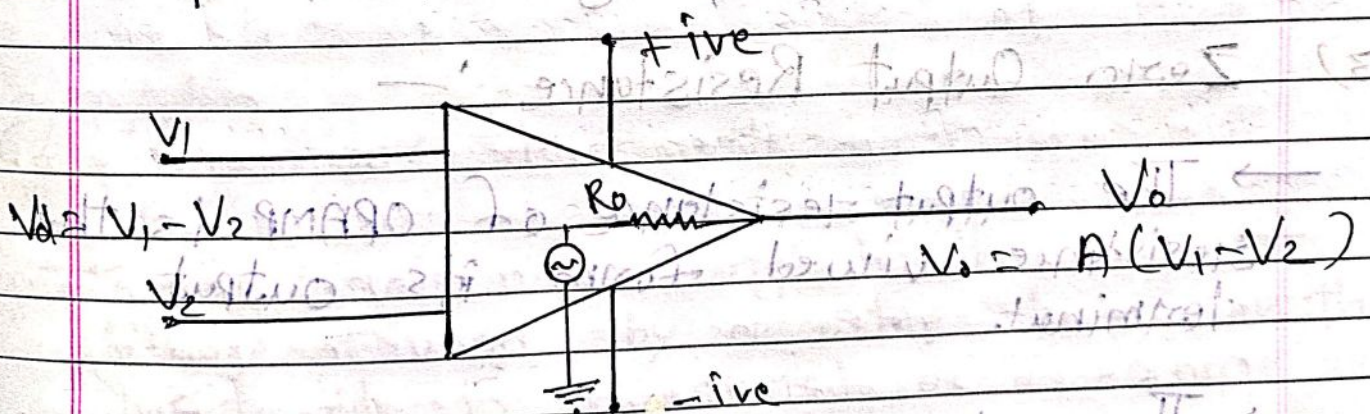


(a) I/P signal

(b) O/P signal

180° Phase displacement (difference)

⇒ Equivalent Circuit of OPAMP:-



V_d = differential voltage.

R_i = Input Resistance.

R_o = output Resistance.

A = open loop gain.

Characteristics of OPAMP :-

(1) Infinite loop gain :-

→ The open loop gain at in ideal opamp is denoted by A & the value of A for ideal OPAMP is ∞ (infinite).

Practically :- 10^5 to 10^6 (very high)

(2) Infinite input resistance :-

→ Input resistance is the total resistance measured between the input terminal of OPAMP.

→ The value of R_i of an ideal OPAMP is ∞ (infinite)

Practically :- Very high ($1\text{ M}\Omega$)

(3) Zero Output Resistance :-

→ The output resistance of OPAMP is the resistance viewed from its output terminal.

→ The output resistance of an ideal OPAMP is zero.

(4) Zero offset Voltage:-

→ The Voltage which is produced at the output when both input Voltage ($V_1 = V_2 = 0$) are zero, is called offset Voltage.

→ For an ideal OPAMP, offset Voltage is zero.

(5) Infinite Bandwidth:-

→ Bandwidth of an amplifier is the range of frequency over which all the signal frequency are amplified almost equally.

→ The bandwidth of an ideal OPAMP is ∞ . So it can amplify frequency signal from 0 to ∞ Hz.

(6) Infinite Slew rate:-

→ The rate of change in the output Voltage caused by a step change on the input is measured as a Voltage change in a given time. $\left\{ S.R = \frac{V}{t} \right\}$

→ The slew rate of an ideal OPAMP is ∞ (infinite).

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Instrumentation Amplifier :-

- An instrumentation amplifier is basically a differential amplifier which meets certain requirements.
- In many industrial and consumer applications the measurement and control of quantities such as temperature, pressure, humidity etc. is required.
- A Transducer is used to convert these quantities into an Electrical signal first and output of transducer is then applied to an amplifier called is instrumentation amplifier.
- This instrumentation amplifier is used to amplify this low level output signal from Transducer such that it can drive the indicator or display.
- Reason behind using of instrumentation amplifier because it provide "high CMRR" (Common mode Rejection Ratio) and high input impedance and low output impedance.

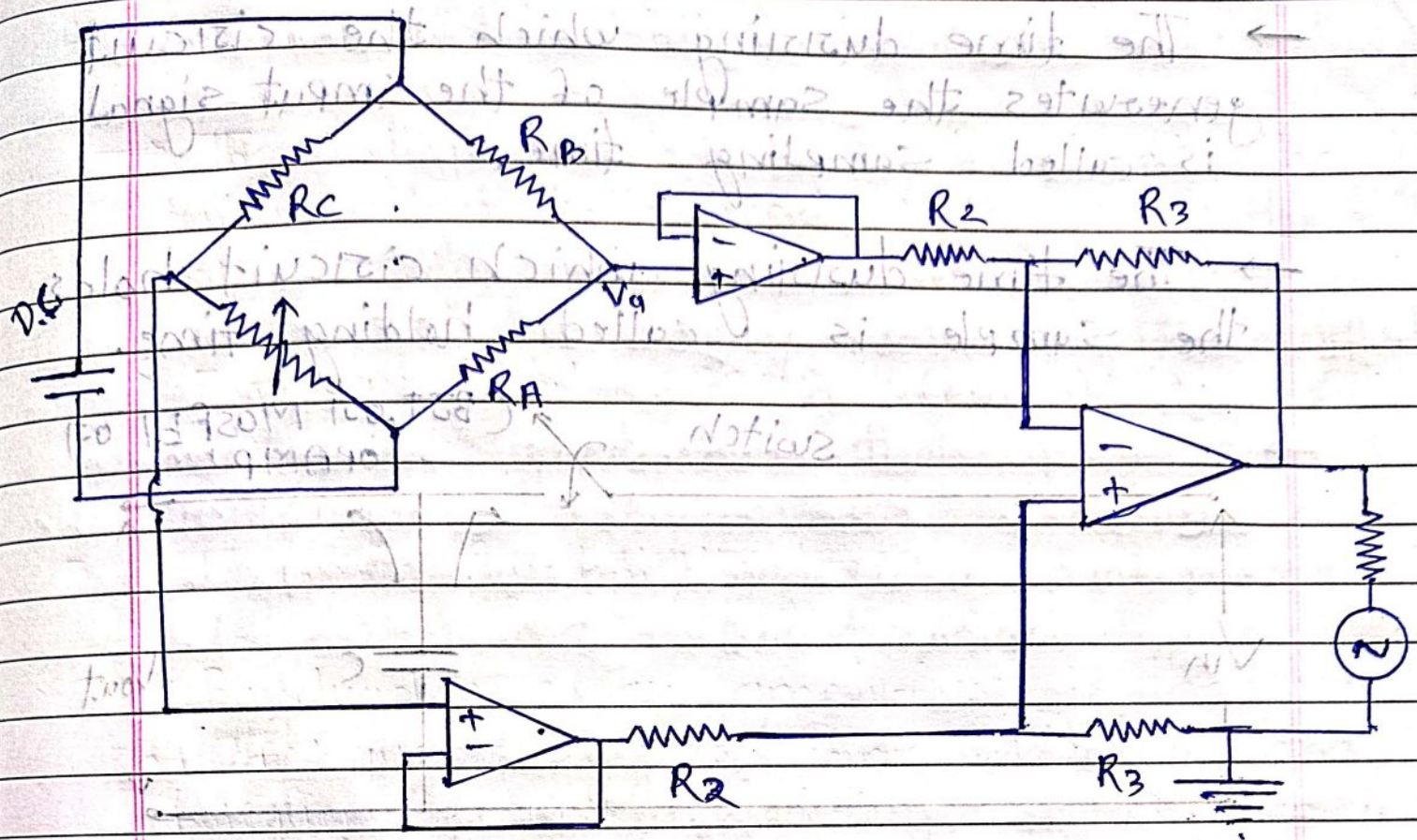
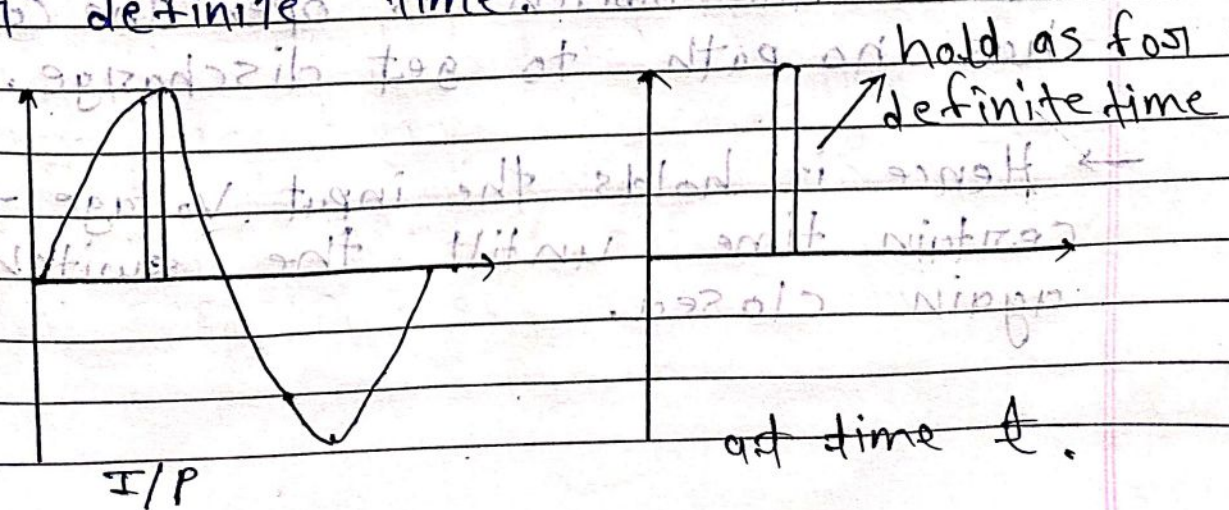


Fig. 1 Instrumentation Amplifier.

Sample and Hold Circuit :-

→ In sample and hold circuit is an electronic circuit which creates the sample of voltage given to it as input and after this it holds these sample for definite time.



→ The time during which the circuit generates the sample of the input signal is called sampling time.

→ The time during which circuit holds the sample is called holding time.

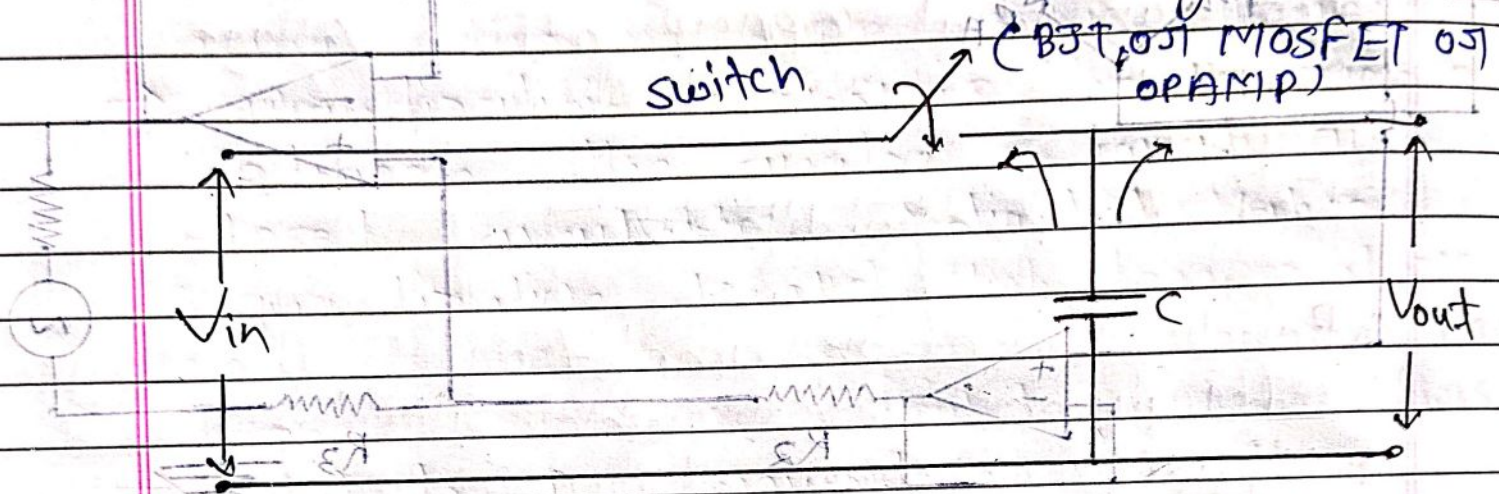


fig. 1 Sample and hold Circuit

→ The Sample and Hold circuit consist of a combination of switch and a capacitor such that when switch is closed then the capacitor charges to the given input voltage.

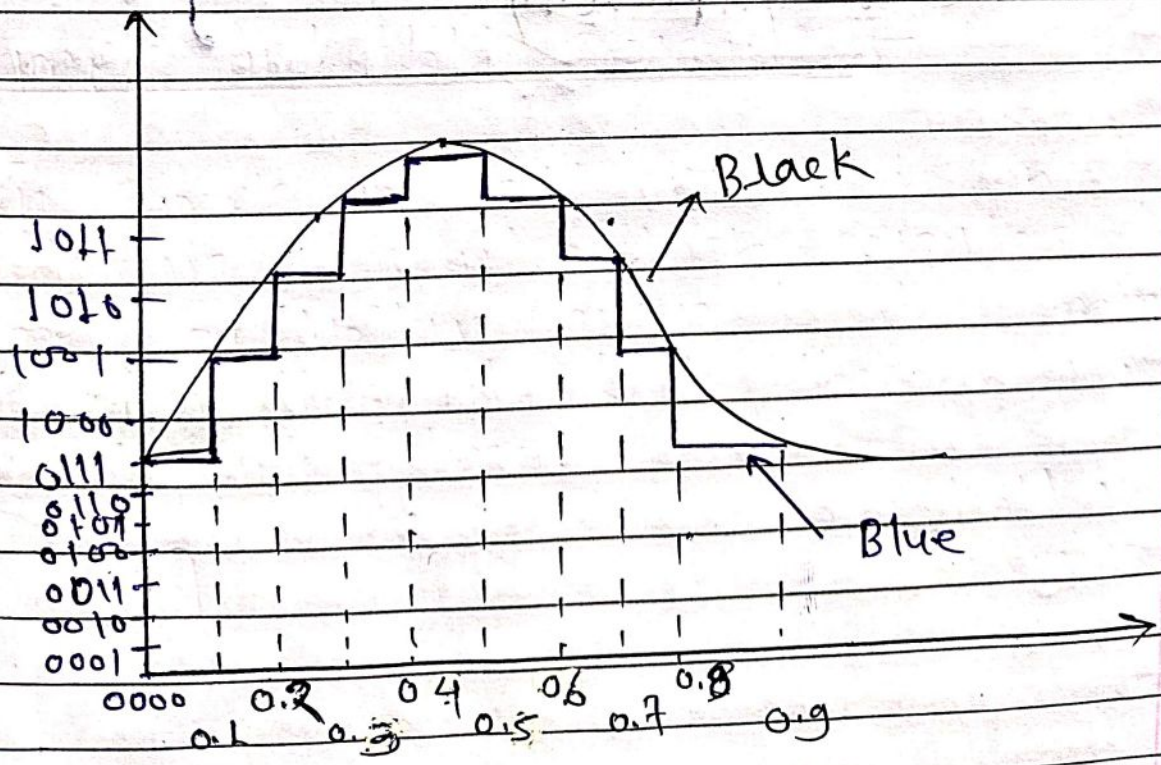
→ When the switch is open the capacitor has no path to get discharge.

→ Hence it holds the input voltage for a certain time until the switch is again closed.

Quantization :-

→ The digitization of analog signals involves the rounding off of the value which are approximately equal to analog value. The method sampling chooses a few points of analog signal and then these points are joined to round off value to a nearest stabilized value such process is called as Quantization.

→ The quantizing of an analog signal is done by discretizing the signal with a number of quantization levels.

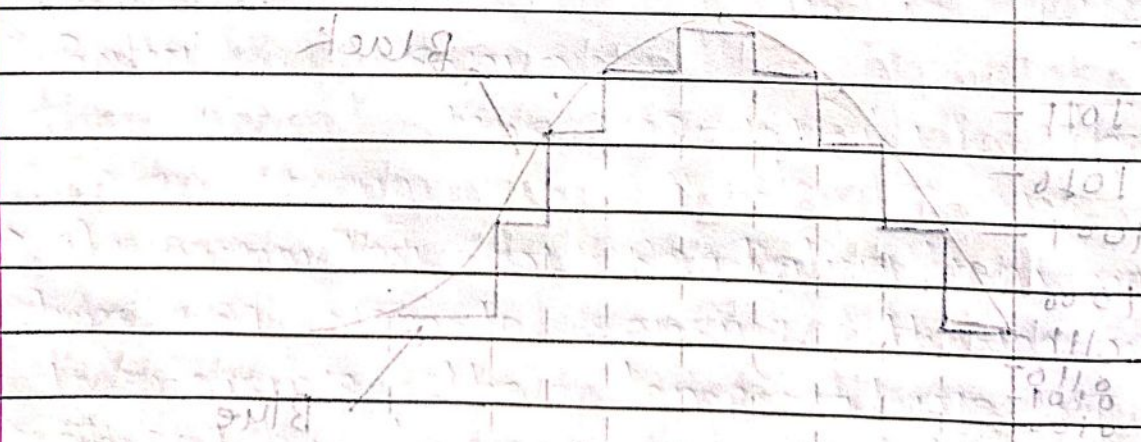


The blackline represent analog signal while the black line represent the quantized signal.

Quantization Error :-

→ quantization error is the difference between the analog signal and the closest available digital value. (quantization level).

- ⇒ A to D Converter
 - D to A Converter
 - Multiplexer
 - De-Multiplexer
- } Last Season.

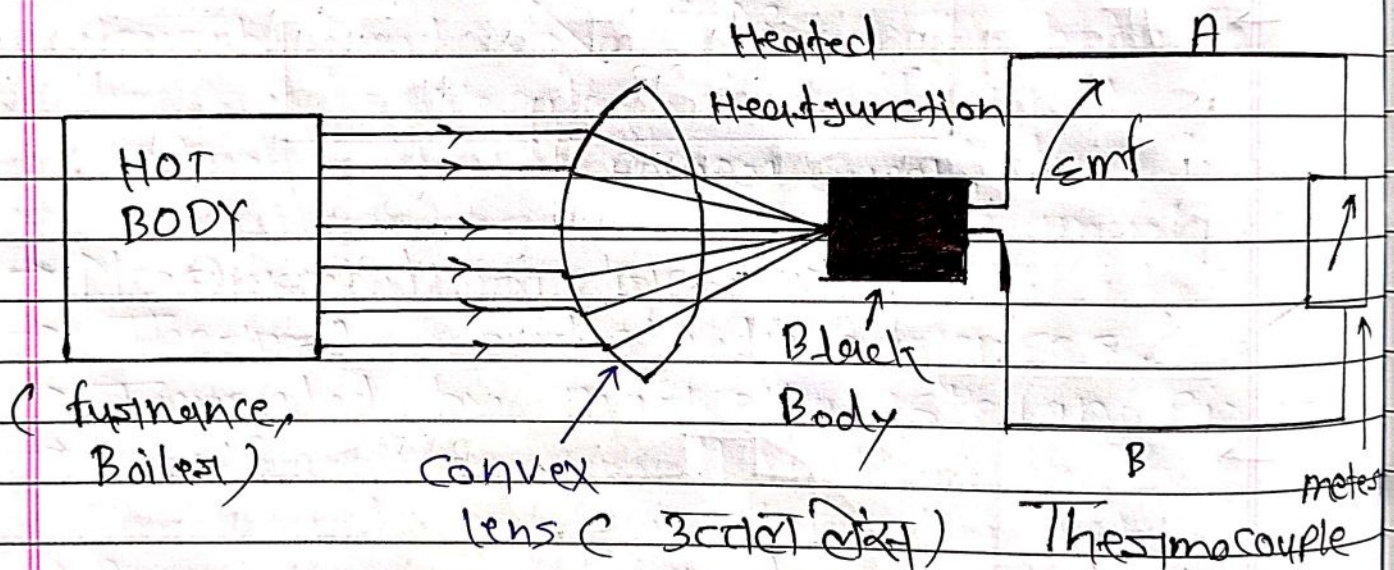


Unit - 04

Measurement of Non-Electrical quantities.

4.1 Measurement of Temperature — using, Thermocouple, RTD, Thermistor and Pyrometer.

Pyrometer :- (Fire / High temperature)



→ A Pyrometer or Radiation thermometer is a type of remote sensing thermometer used to measure the temperature of distant object.

→ A pyrometer is a device that is used for non-contact temperature measurement temperature range from

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700°C - 4000°C

→ A Non. contact temperature measurement is essential in all types of industries and some industrial process for melting, heating and drying.

→ Pyrometer works by detecting infrared radiation it consist of a convex lens to focus the IR radiation on to a detector which converts the IR radiation into an electrical signal.

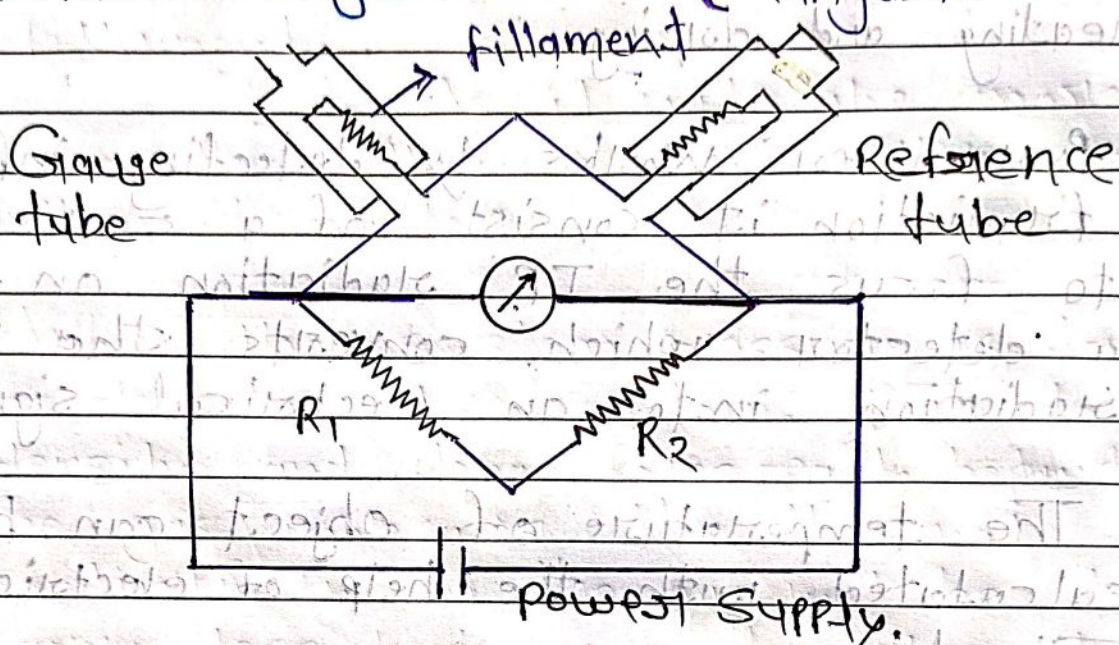
→ The temperature of object can be calculated with the help of electrical signal.

→ In a black body a thermocouple is present with the help of thermocouple a heat is converted into an electrical signal.

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4.2 Measurement of pressure — using LVDT, Strain Gauge and Capacitive Transducer, Pirani Gauge.

Pirani Gauge :- (Tungsten, Nickel)



- Measurement of pressure
- Thermal conductivity of gases.
- Invented by Marcello Stefano Pirani
- 50°C

→ Pirani Gauge is a device used to measure pressure especially in vacuum system.

→ It is based on a hot metal wire that is suspended in a tube and exposed to gas pressure media. These hot metal wire are made up of thin, tungsten, nickel, or platinum wire.

→ It work by measuring the change in thermal conductivity and used this measurement to obtain the pressure of the system.

→ This gauge is suitable for measuring pressure in very low pressure in the range from 0.1 pascal to 100 pascals.

→ First, the power supply is supplied to the pirani wheat stone bridge.

→ The filament in the gauge tube and reference tube begins to heat up. The filament in both tubes will be heated to about 50°C.

→ The gas tubes are open to the system and the reference tube are closed.

→ The Pirani gauge is placed in the system on which to measure the pressure.

→ As soon as the gas tube is open, gas molecules from the system will enter the gauge tube and collide with the hot filament.

→ Then the gas molecules that collide with the filament will receive heat from the filament and escape from the gauge tube.

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→ The heat exerted by the gas molecules will depend on the environmental pressure. If the pressure is high, the density of the gas will be highest and will carry a greater amount of heat from the filament.

As it will take more heat from the filament, it will cool the filament faster.

→ When the system pressure is low, the gas density will also be low. Due to low density and long free path between the gas molecules, the thermal conductivity of the gas will be low and carry less heat from the filament. So the filament will slowly cool down compared to high pressure.

→ So we can say that the thermal conductivity of gas depends on its pressure. The filament wire is maintained at a constant temperature which is 50°C . Therefore, the voltage required to maintain the temperature from voltage requirement we can calculate the pressure of the system.

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4.3 Measurement of Speed — using Tachometer, Stroboscope.

Tachometer :—

→ An instrument used for measurement of angular velocity of shaft either by registering the total number of revolution during the period of contact or directly by indicating the number of revolution per minute (RPM).

⇒ Types :—

(I) Mechanical Tachometer

- (a) Revolution Counter
- (b) Hand speed Indicator
- (c) Tachoscope
- (d) Centrifugal Tachometer.

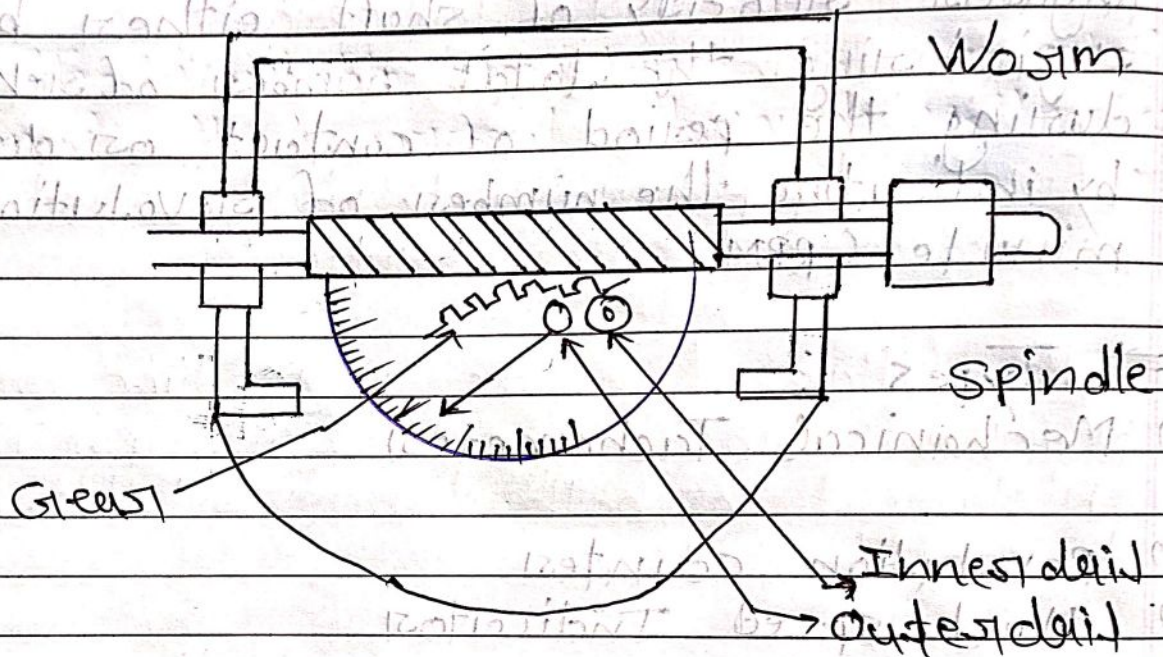
(II) Electrical Tachometer.

- | | |
|-----------------------------|---------------------|
| (a) Tachogeneration | } Contact types |
| (b) Eddy current Tachometer | |
| (c) Magnetic pickup | } Non-contact types |
| (d) photo electric | |
| (E) Capacitive | |

(III) Digital Tachometer

(IV) STROBOSCOPE

1 (a) Revolution Counter :-



→ Revolution Counter is used to measure an average speed in stead of instant speed.

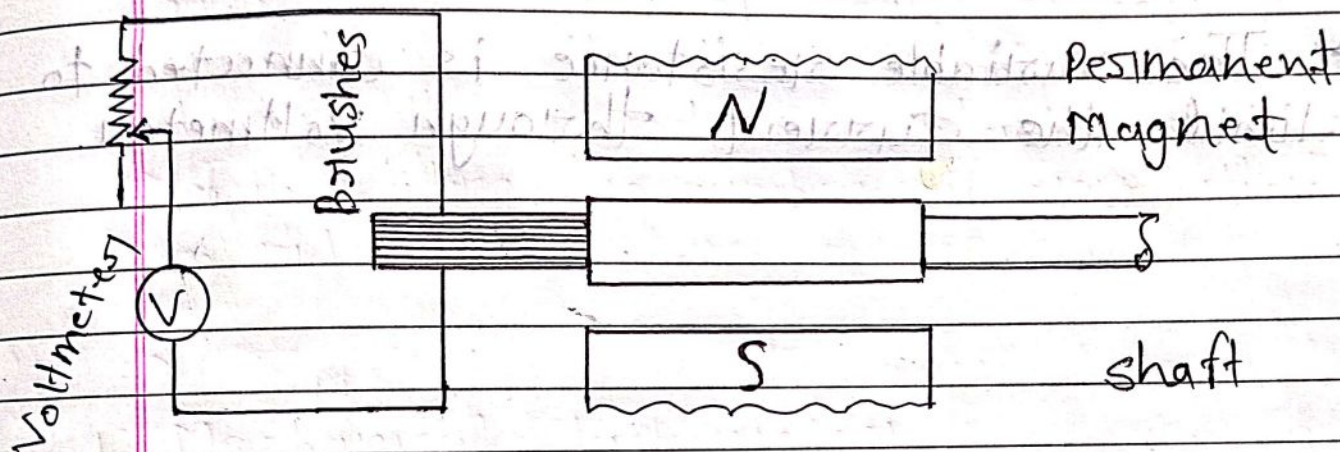
→ It consist of Worm & gear that is usually attached to a Spindle to a spindle. It has two dials an inner dial and Outer dial.

→ The outer dial represent the revolution of spindle & Inner dial represent time.

→ These are limited to low speed ranging from 200 to 3000 rpm.

DC Tachogenerator :-

Variable st.



→ In DC generator the emf generation depends upon the two factors (a) field excitation (b) Speed.

→ If for the field permanent magnet pole piece are used, then generated voltage depends only on speed.

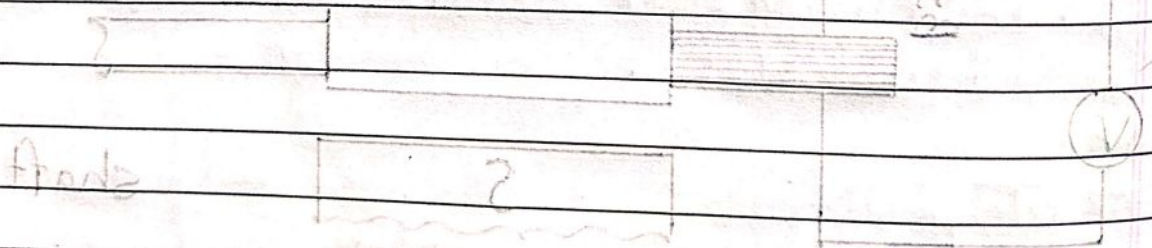
$$E_g = \frac{\phi Z N P}{60 A}, \quad E_g \propto \phi N, \quad \phi \text{ is constant,}$$

then, $E_g \propto N$

→ Hence the speed of shaft can be calculated by measuring the generated emf.

→ A Voltmeter is connected across the brushes to measure generated voltage.

→ The variable resistance is connected to limit the current through voltmeter.



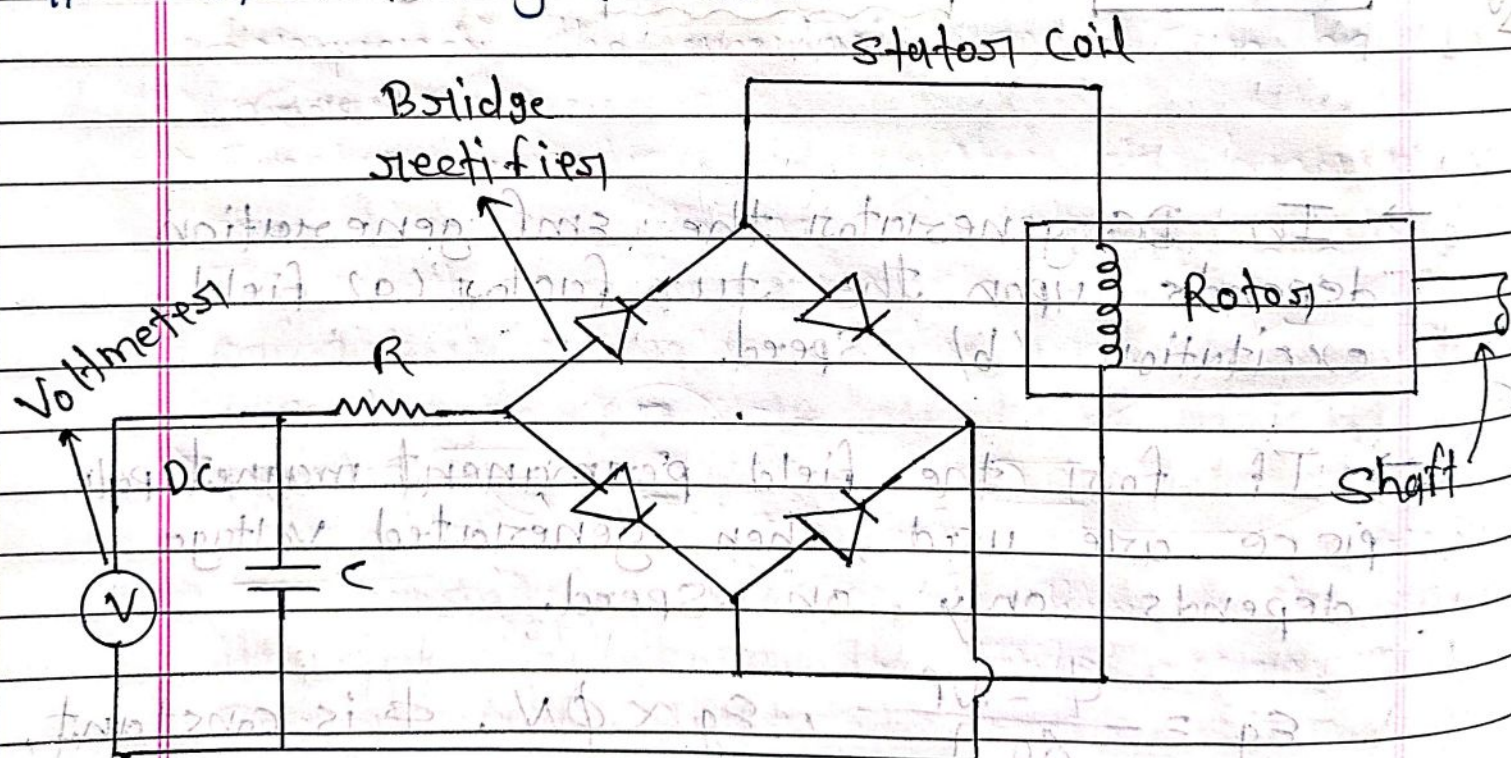
→ Hence the speed of shaft can be calculated by measuring the generated emf.

→ A Voltmeter is connected across the brushes to measure generated voltage.

→ The variable resistance is connected to limit the current through voltmeter.

Speed

AC Tachogenerator :-



→ The inherent demerit associated with DC tachogenerator due to brushes and commutator are eliminated in AC tachogenerator.

→ It consists of like an alternator a stationary armature conductor a stator and rotating field (Rotor).

→ The alternating emf induced in the stationary coil is rectified and the DC voltage is measured with the help of Voltmeter.

STROBOSCOPE

→ A stroboscope or strobe is an instrument that works on the phenomenon of stroboscopic effect.

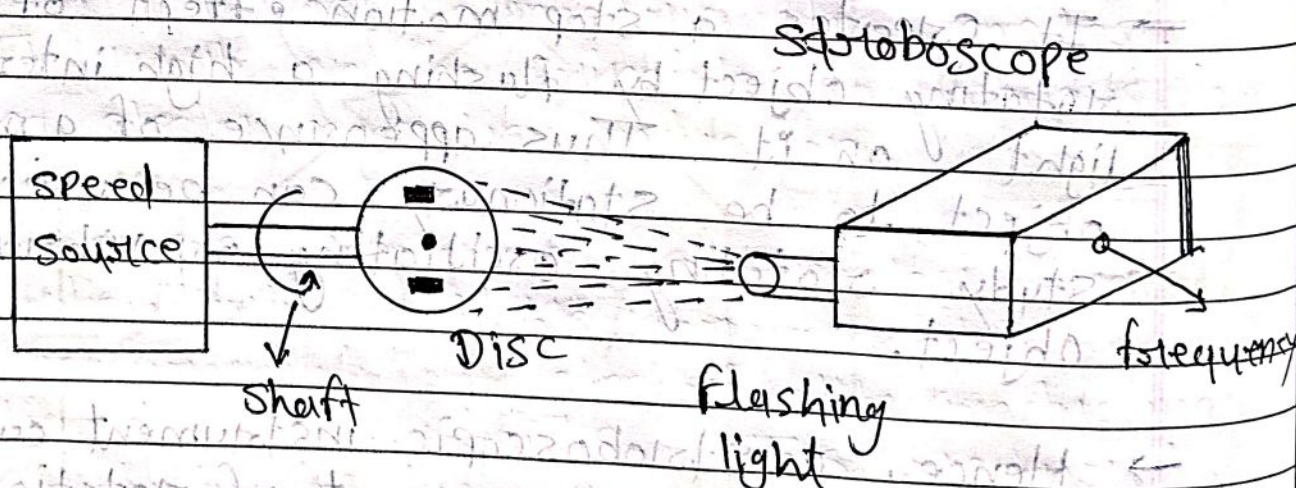
→ It creates a stop motion effect of a rotating object by flashing a high intensity light on it. Thus appearance of a moving object to be stationary can be used to study rotating oscillating or vibrating object.

→ Hence, a stroboscopic instrument can be used for the measurement of rotational speed or rotary motion or angular velocity of a motor or any rotating object. Angular speed or angular velocity between 600 to 20,000 RPM can be measured with the help of a stroboscope tachometer.

→ A stroboscope tachometer used a variable frequency flashing light called stroboscopy.

→ It consists of a flashing light of variable frequency in which the flashing frequency of the stroboscope light can be adjusted.

→ A variable frequency oscillator is employed to control the flashing frequency of the light by adjusting the oscillator frequency the angular speed can be measured.



→ In order to measure the angular velocity of a disk with distinctive marks is mounted on the rotating shaft whose angular velocity is to be measured.

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The stroboscope is provided with a neon gas discharge bulb. The stroboscope is adjusted such that the light flashing directly on the reference works.

→ The frequency of these flashes is varied and adjustment knob until the reference mark on the disc appears to be stationary.

→ This occurs of these flashes is very

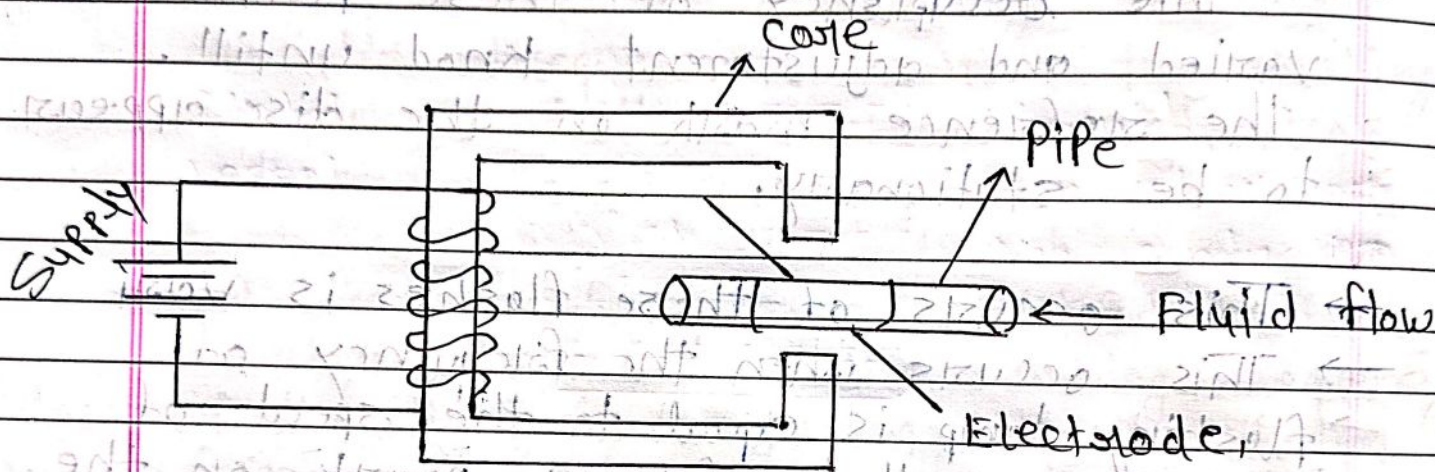
→ This occurs when the frequency of flashing lamp is equal to the speed of rotation of the reference mark on the disc. Thus the frequency of flashing light of stroboscope gives the angular velocity or speed when calibration in terms of speed.

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4.4. Measurement of flow - using electromagnetic

pic-up, turbine flow meter.

Electromagnetic Flow Meter :-



→ Electromagnetic flow meter also known as mag flow or Volumetric flow meter. It work on the principle of Faradays law of electromagnetic induction.

→ The electromagnetic flow meter are particularly suitable for the flow measurement of electrically conducting liquid or fluids. This required conductivity typically ranges from 3 to 10 microsiemen.

→ The unique design of magnetic flow meters allows them to take their reading without the need for any moving parts.

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→ A magnetic flow meter operates based on the magnetic field it generates, which is used to measure the flow rate of a conductive liquid. As the flow speed increases the voltage produced by the fluid also increases.

→ The principle behind a magnetic flow meter is stated in Faraday's law, which states that the voltage E is directly proportional to the flow velocity of the liquid (V), the magnetic field strength (B) and the length of conductor (L).

$$E \propto B L V$$

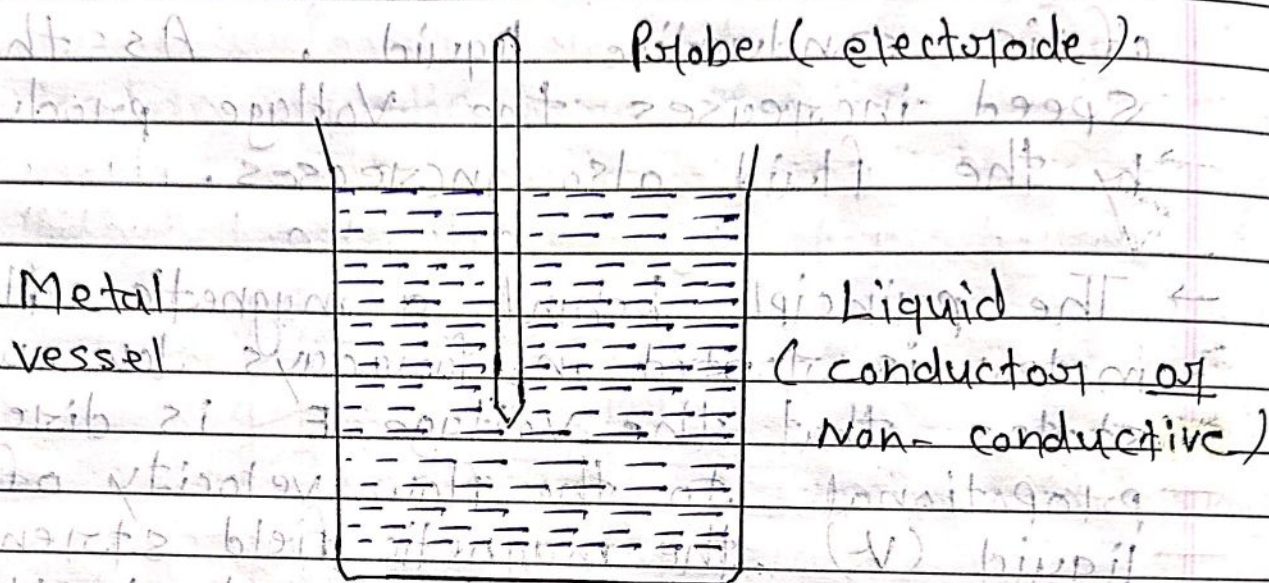
Where, B , and L are constant

then,

$$E \propto V$$

→ In this way with the help generated voltage we can measure the velocity of electrically conductive fluid/liquid.

Measurement of liquid level using Capacitive transducer.



- Capacitance level transducers are used for a wide variety of solids, aqueous and organic liquid and slurries.
- The principle of Capacitive level measurement is based on change of capacitance.
- An insulated electrode acts as one plate of capacitor and tank wall act as the other plate.
- The capacitance depends on the fluid level. An empty tank has a lower capacitance while a filled tank has a higher capacitance.

→ A simple capacitor consist of two electrode plate separated by an insulator. Such as solid, liquid or gas. This insulator is also called as dielectric.

→ Value of C depends on electric used, area of plate and also distance between the plates.

$$C = \frac{\epsilon A}{d}$$

ϵ = Permittivity of dielectric.

A = Area of plate

d = Distance between plates.

→ When the level in the tank drops, the dielectric constant drops causing a drop in capacitance readings while when the level in the tank rises, the dielectric constant increase causing a rise in capacitance reading. In this way with the help of capacitance reading the level can be calculated.

→ For measurement of level of non-conducting liquid pure electrode is used while for conducting liquid an insulated electrode is used.

Displacement :- measures amount by which the object has moved.

Position :- measures position of the same object with respect to reference position.

Proximity :- Tells whether object has moved within some particular distance or not.

* Proximity Sensor / Transducer :-

→ A Proximity sensor is a sensor able to detect the presence of near by object, without any physical contact.

→ A Proximity sensor often emits and electro magnetic field or beam of electro magnetic radiation (Infrared) and looks for changes in the field.

→ The object beam sensed is often referred to as the proximity sensor target.

→ Different proximity sensor targets different sensor.

→ For example, a Capacitive proximity sensor might be suitable for a plastic target an inductive proximity sensor always requires a metal target.

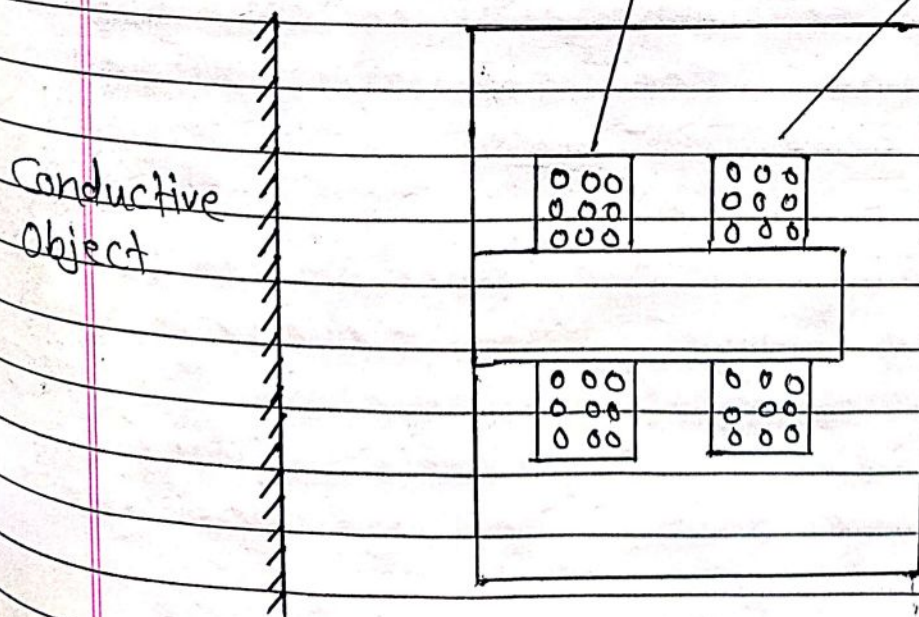
Types of Proximity Sensor :-

(i) Eddy current proximity sensor (Metal target / Conductive target)
(ii) Inductive proximity sensor

(iii) Capacitive proximity sensor (Non-conductive / Plastic target).

(1) Eddy Current Proximity Sensor :-

sensor coil Reference coil



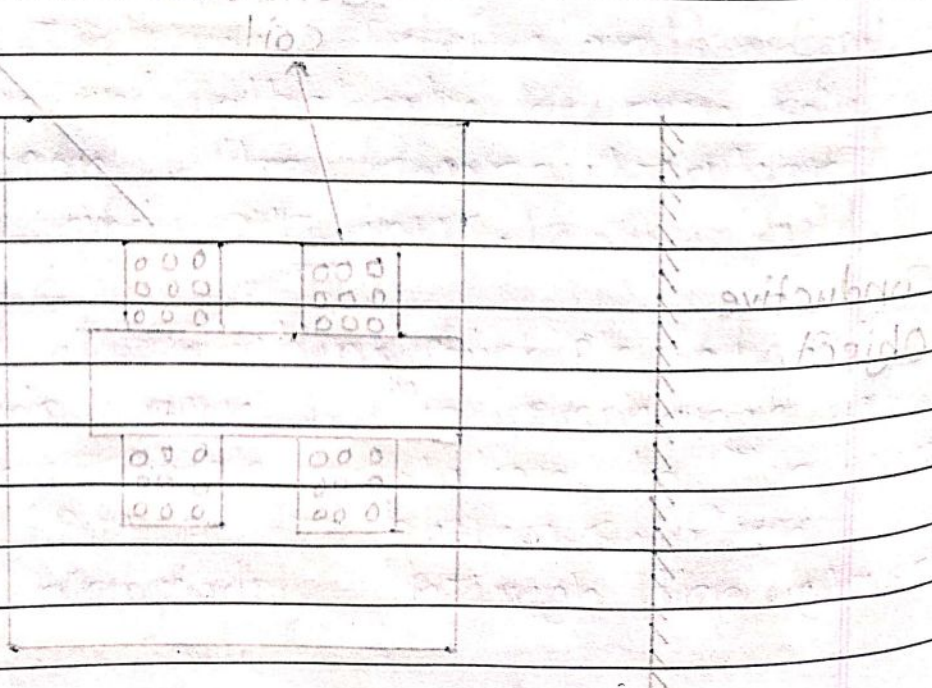
→ Eddy current proximity sensor are used to detect non-magnetic but conductive material.

→ When an alternating current is passed through this coil, an alternating magnetic field of the coil, then eddy current are induced in the object due to magnetic field.

→ These eddy current creates their own magnetic field, which distorts the magnetic field responsible for their generation.

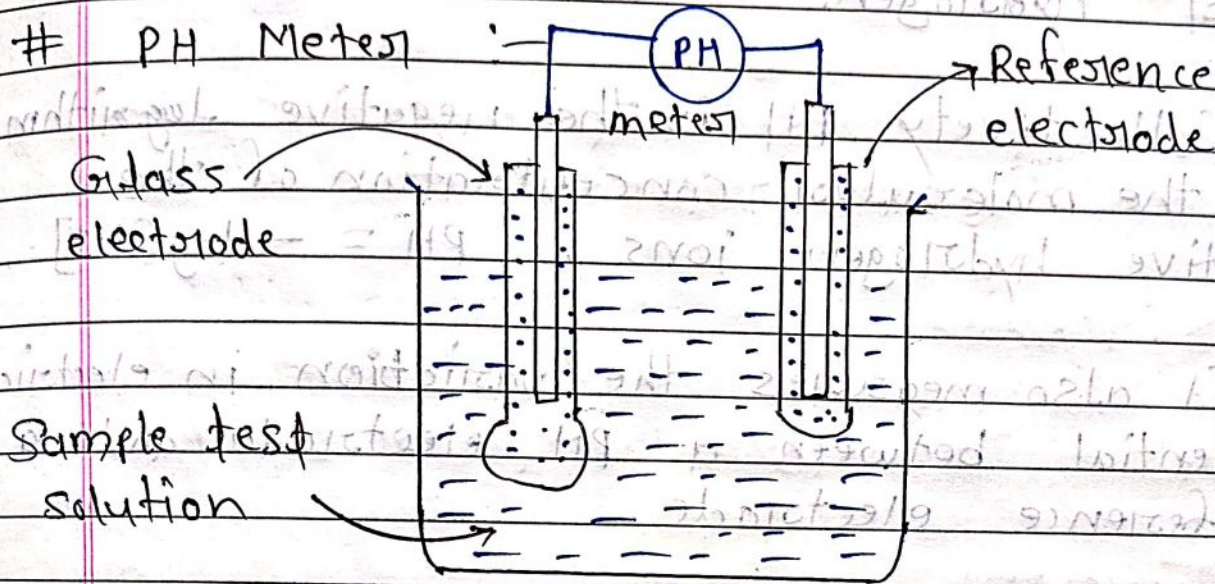
→ As a result, impedance of the coil, changes and so the amplitude of alternating current also changes.

→ Due to the change in current position can be identified.



Material Analysis - Measurement of pH, Humidity, types of Hygrometer.

PH Meter



$P = \text{Negative logarithm}$

$H = \text{Hydrogen ion}$

Acidic ←

Neutral

→ Base

$$[PH = -\log[H^+]]$$

→ A PH meter is an electrical instrument that is used to determine the acidity or alkalinity of the solution.

→ It is also known as a PH analyzer, PH monitor or Potentiometer.

→ PH is the concentration of hydrogen ions in the solution.

→ The word PH is acquired from 'P' the scientific figure for negative logarithm and 'H' the chemical symbol for Hydrogen.

→ Collectively PH is the negative logarithm of the molecular concentration of the active hydrogen ions ; $PH = -\log[H^+]$.

→ It also measures the variation in electrical potential between a PH electrode and a reference electrode.

→ A solution containing more H^+ ions remains acidic while the solution containing more OH^- ions remains alkaline.

→ PH Value of solution ranges from 1 to 14.

→ The acidity and alkalinity of any solution depends upon the concentration of H^+ and OH^- ions.

→ The overall working principle of PH meter depends upon the exchange of ions from sample solution to the inner solution. (PH = 7, buffer solution) of glass electrode through the glass membrane.

Unit - 05

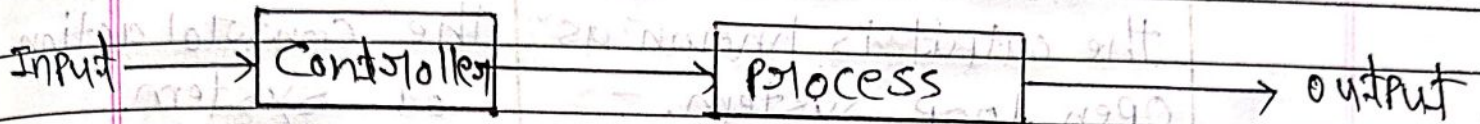
Basic Control system

1. open loop & closed loop control system & Block diagram representation.
2. S. Domain
3. Laplace Transform in power system.
4. Transfer Function.
5. Zeros & Poles.
6. Stability
7. Proportion, Integral, Derivative Controller

Imp

open loop & closed loop control system:-
Block diagram representation.

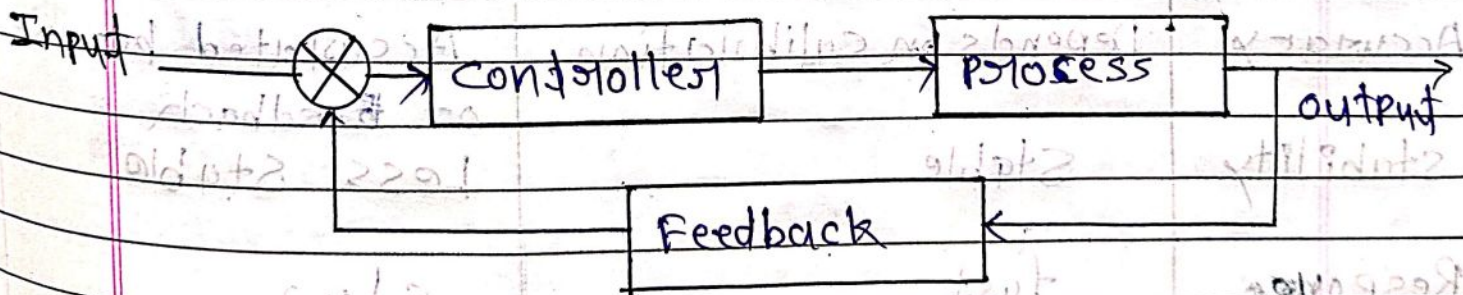
⇒ Open loop control system:-



→ A system that uses a predetermined set of instructions to determine its behaviour without any feedback from the system.

→ This means that the system doesn't adjust its behaviour based on changes in the environment.

⇒ Close loop control system:-



→ A system that used feedback from the system being controlled to adjust its behaviour.

In a close loop system the output is measured and compared to a desired reference value and any difference is used to adjust the control action.

Based on	Open loop System	Close loop system
Defination →	The system whose control action is free the output is known as Open loop system.	The close loop, the output depend on the control action of system.
Other Name	Non-feedback system	Feedback system
Components	Controller and controlled process	Amplifier, controller, controlled process and feedback.
Consturction	Simple	Complex
Reliability	Non-Reliable	Reliable
Accuracy	Depends on calibration	Accurate because of feedback
Stability	Stable	Less Stable
Response	fast	slow
Example	Traffic light, immersion rod, Automatic washing machine etc.	Air conditioner, Refrigerator, speed and pressure control system etc.

S Domain :-

→ The variable s in the s domain represents complex frequency which includes both real and imaginary components, allowing for a comprehensive analysis of system dynamics.

→ This transformation allows engineers to work with simpler algebraic expressions rather than complex differential equations making it easier to analyze system behaviours.

$$(s = \sigma + j\omega)$$

Real part of frequency $\rightarrow \sigma$

Imaginary part of frequency $\rightarrow j\omega$

Complex frequency $\rightarrow s$

Imp

Laplace Transform in power system :-

⇒ Objective :- To convert time domain function into frequency domain.

⇒ Definition :- Let $f(t)$ be a function of t defined for $0 \leq t \leq \infty$ then Laplace transform of $f(t)$ is denoted by $L[f(t)]$ or $f(s)$ is defined by

$$L[f(t)] = f(s) = \int_0^{\infty} e^{-st} f(t) dt$$

Page:
 Date:
 Domain:
 $f(t) = 1$

$$f(s) = \int_0^{\infty} e^{-st} (1) dt$$

$$= \int_0^{\infty} e^{-st} dt = \left[\frac{e^{-st}}{-s} \right]_0^{\infty}$$

$$= \left[\frac{e^{-\infty}}{-s} - \frac{e^{-s \cdot 0}}{-s} \right]$$

$$= \left[\frac{0}{-s} - \frac{1}{-s} \right] = \left[0 + \frac{1}{s} \right]$$

$$= \frac{1}{s}$$

Real part of $f(s)$ is $\frac{1}{s}$ with $\sigma = 2$

$\Rightarrow$ Some Laplace transform

(1) $L(1) = \frac{1}{s}$

(2) $L\{e^{at}\} = \frac{1}{s-a}$

(3) $L(t^n) = \frac{n!}{s^{n+1}}$

(4) $L\{\sin at\} = \frac{a}{s^2 + a^2}$

(5) $L\{\cos at\} = \frac{s}{s^2 + a^2}$

(6) $L(\sinh at) = \frac{a}{s^2 - a^2}$

(7) $L(\cosh at) = \frac{s}{s^2 - a^2}$

#

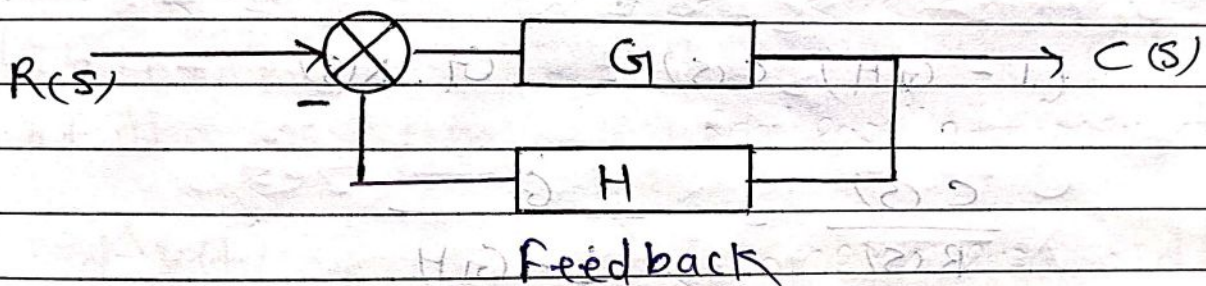
Transfer Function :-

→ Transfer function of a control system is the ratio of Laplace transform of output to Laplace transform of input,

$$\text{i.e. Transfer function} = \frac{\text{L.T of output}}{\text{L.T of input}}$$

with zero initial condition

⇒ Negative feedback :-



$$C(s) = G[R(s) - H \cdot C(s)]$$

$$C(s) = G \cdot R(s) - GH \cdot C(s)$$

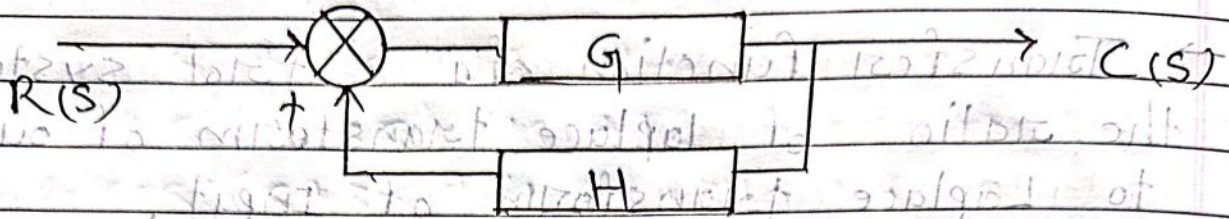
$$C(s) + GH \cdot C(s) = G \cdot R(s)$$

$$C(s) (1 + GH) = G \cdot R(s)$$

$$\frac{C(s)}{R(s)} = \frac{G}{1 + GH}$$

$$\text{+ve Transfer function} = \frac{G}{1 + GH}$$

⇒ positive Feedback :-



$$C(s) = G [R(s) + H \cdot C(s)]$$

$$C(s) = G \cdot R(s) + G \cdot H \cdot C(s)$$

$$C(s) - G \cdot H \cdot C(s) = G \cdot R(s)$$

$$(1 - GH) C(s) = G \cdot R(s)$$

$$\frac{C(s)}{R(s)} = \frac{G}{1 - GH}$$

[-ve. Transfer function] $\frac{G}{1 - GH}$

$$(1 - GH) C(s) = G \cdot R(s)$$

$$C(s) = \frac{G \cdot R(s)}{1 - GH}$$

$$1 - GH = 1 + GH$$

Zeros & Poles :-

⇒ Zeros :- zero of a transfer function are the frequencies (value of s) for which the numerator of the transfer function becomes zero.

⇒ Poles :- Poles of a transfer function are the frequencies (value of s) for which the denominator of the transfer function becomes zero.

* For example :- Find the transfer function of the system given by :-

$$\frac{d^2 y(t)}{dt^2} + 7 \frac{dy(t)}{dt} + 12 y(t) = \frac{d x(t)}{dt} + 2 x(t)$$

→ $x(t)$ is the input & $y(t)$ is the output.

Taking Laplace on the both side

$$s^2 y(s) + 7s y(s) + 12 y(s) = s x(s) + 2 x(s)$$

$$(s^2 + 7s + 12) y(s) = (s + 2) x(s)$$

$$\frac{y(s)}{x(s)} = \frac{s + 2}{s^2 + 7s + 12}$$

$$\left[\text{Transfer function} = \frac{s + 2}{s^2 + 7s + 12} \right]$$

$$T.F = \frac{s+2}{s^2+7s+12}$$

$$\begin{aligned} & \frac{s^2+7s+12}{s^2+3s+4s+12} \\ & \frac{s(s+3)+4(s+3)}{(s+3)(s+4)} \end{aligned}$$

$$T.F = \frac{(s+2)}{(s+3)(s+4)}$$

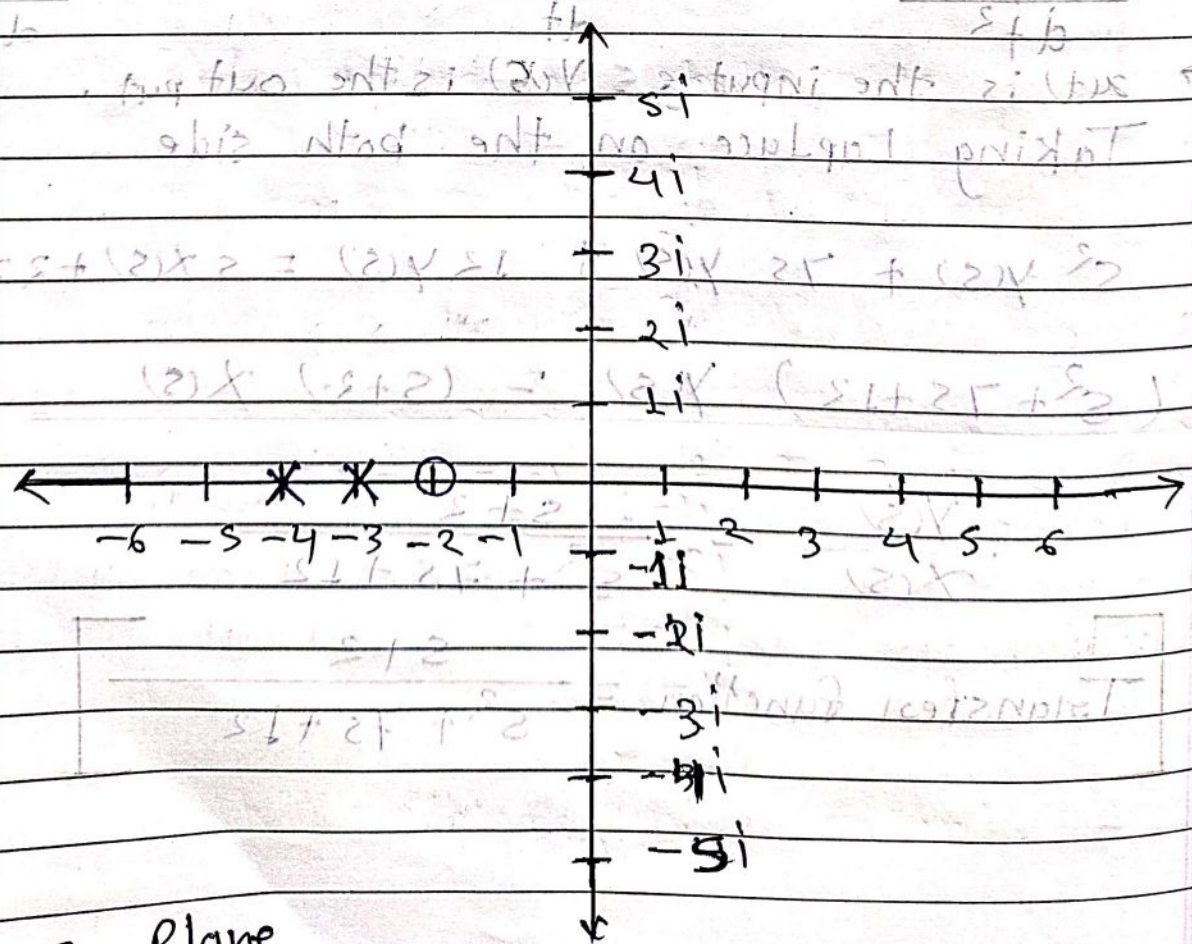
zeros: $s+2=0 \Rightarrow s=-2$

poles: $s+3=0, s=-3$

$s+4=0, s=-4$

$\circ \rightarrow$ Circle $\rightarrow$ zero

$\times \rightarrow$ poles



$\rightarrow$ s-plane

Q. ① T.f. $\equiv \frac{(2s+6)(s+2)}{s(s+1)(s+4)}$

Zeros :- ① $2s + 6 = 0$

$$s = \frac{-6}{2} = -3$$

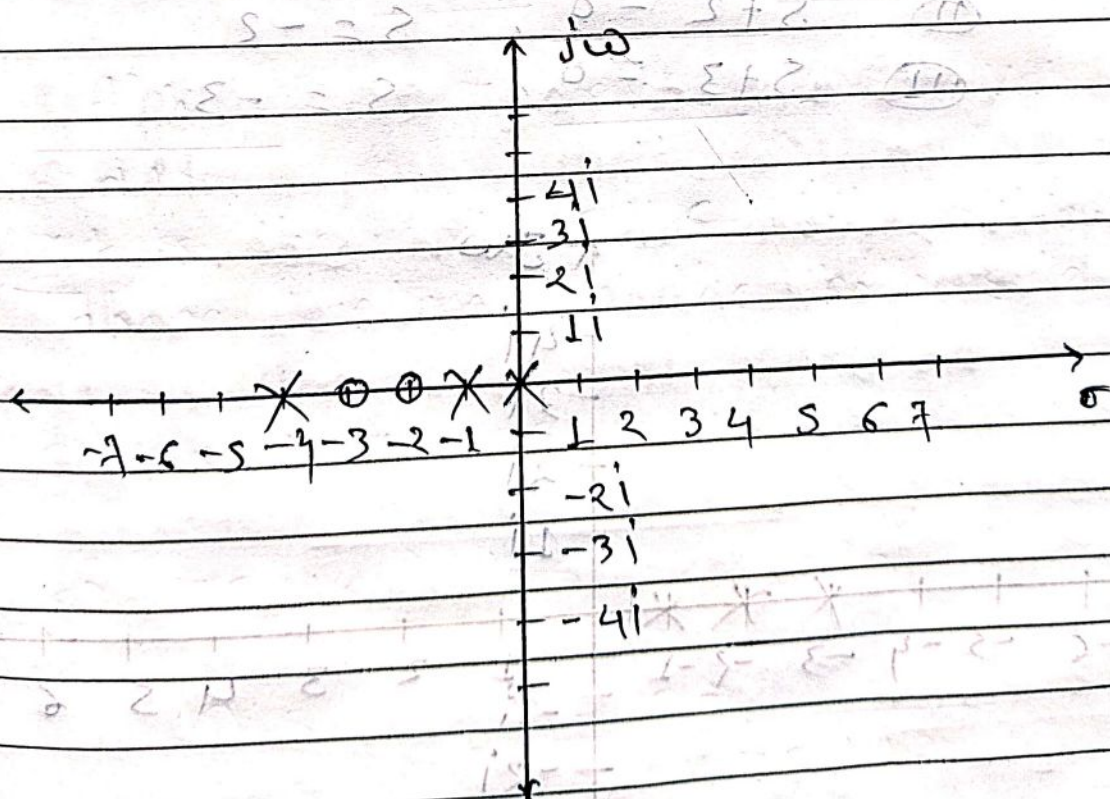
Zeros :- ② $s + 2 = 0$

$$s = -2$$

Poles :- ① $s = 0$

② $s + 1 = 0$, $s = -1$

③ $s + 4 = 0$, $s = -4$



s-plane

① T.f. = $\frac{6(s+1)}{s^3 + 6s^2 + 11s + 6}$

⇒ Zeros :- not

⇒ Poles :- $s^3 + 6s^2 + 11s + 6 = 0$

$$s^2(s+1) + 5s(s+1) + 6(s+1) = 0$$

$$(s+1)(s^2 + 5s + 6) = 0$$

$$(s+1)(s^2 + 2s + 3s + 6) = 0$$

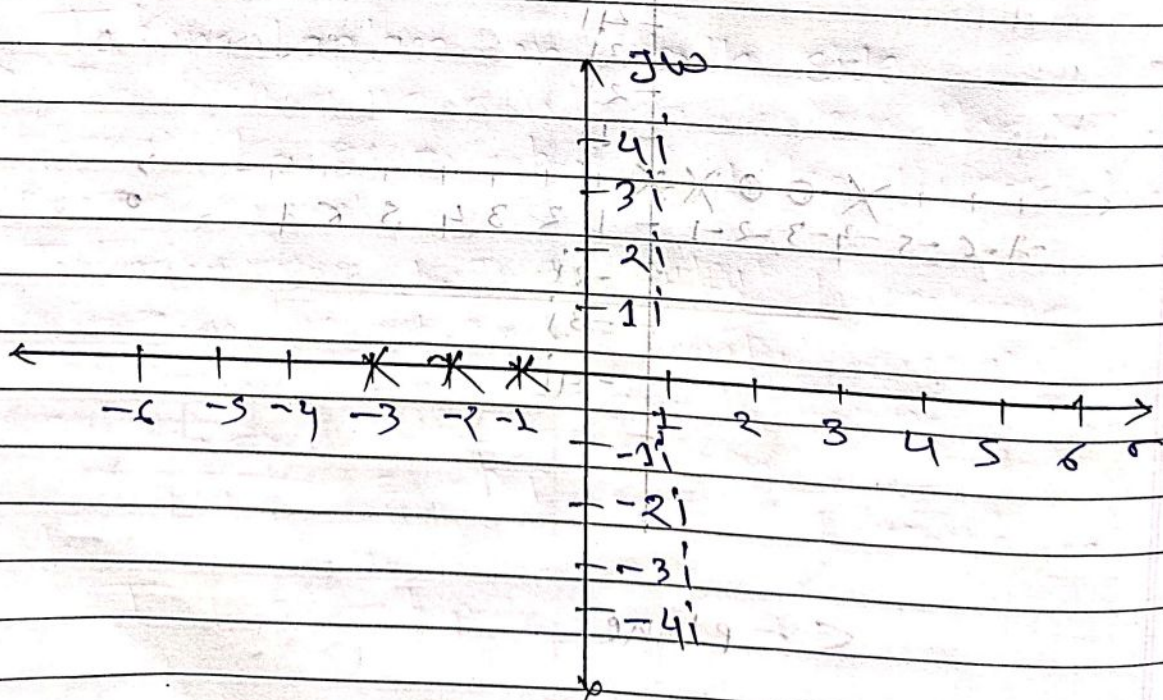
$$(s+1)[s(s+2) + 3(s+2)] = 0$$

$$(s+1)(s+2)(s+3) = 0$$

Poles :- ① $s+1 = 0$, $s = -1$

② $s+2 = 0$, $s = -2$

③ $s+3 = 0$, $s = -3$



S-plane

Stability :- Stability of the system depends upon poles.

→ If the poles are located in the left half of S -plane, then the system is stable.

→ As poles approach to origin, the stability decreases.

→ When poles are (non-repeated) location on the imaginary axis then the system is marginally stable.

→ As poles are located on imaginary axis are repeated then the system is unstable.

→ If poles are located in the right half of S -plane, then the system is unstable.

→ The pole which are close to origin are called dominant poles.

Imp

Proportional Controller :-

→ In proportional control system the actuating signal is proportional to the error signal.

→ The error signal being difference between the reference input signal and feedback signal, obtained from the output of the system.

$$\left[\begin{array}{l} \text{Actuating} \\ \text{Signal} \end{array} = \text{Reference signal} - \text{Feedback} \right]$$

$$\text{Let, } C_a(t) \propto E(t)$$

Taking Laplace on both side

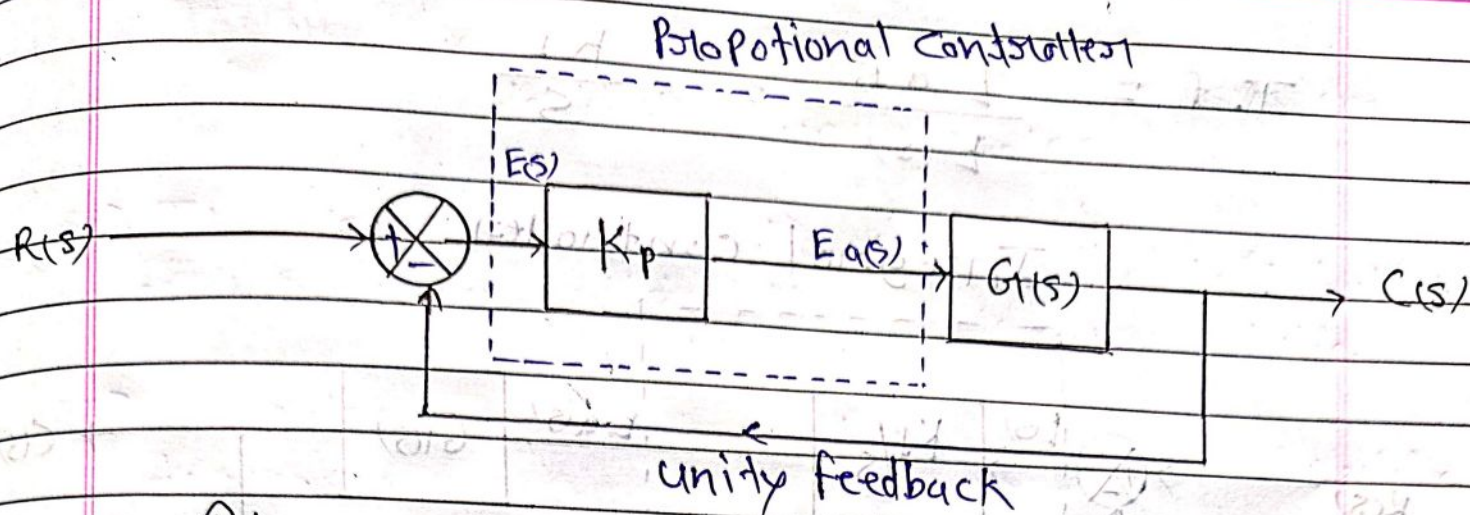
$$E_a(s) = K_p E(s)$$

Transfer function = $\frac{\text{L.T. of output}}{\text{L.T. of input}}$

$$\frac{E_a(s)}{E(s)} = K_p$$

$$T.F = K_p$$

$$[\therefore K_p = \text{Proportional Constant}]$$



Block diagram of Proportional Controller.

Imp #

Integral Controller :-

→ In integral control system the actuating signal is proportional to the integration of error signal.

→ The error signal being difference between the reference input signal and feedback signal obtained from the output of the system.

Let,

$$C_{act}(t) \propto \int e(t) dt$$

$$C_{act}(t) = K_I \int e(t) dt$$

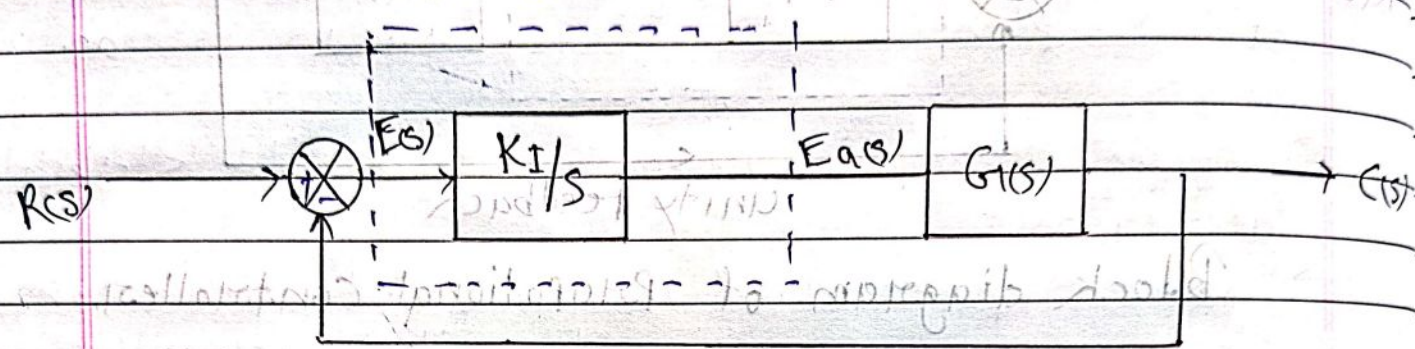
Taking Laplace on both side

$$E_a(s) = \frac{K_I}{s} E(s)$$

$$\frac{E_a(s)}{E(s)} = \frac{K_I}{s}$$

$$T.f = \frac{E a(s)}{E(s)} = \frac{K_I}{s}$$

Integral controller



unity Feedback

$K_I = \text{Integral constant}$

Integral Controller with Unity Feedback

Derivative Controller :-

→ In Derivative control system the actuating signal is proportional to the differentiation error signal.

The error signal being difference between the reference input signal and feedback signal obtained from the output of the system.

Let, (actuating signal) $\downarrow$ (Error signal) $\downarrow$

$$C_a(t) \propto \frac{d}{dt} C_e(t)$$

$$C_a(t) = K_D \frac{d}{dt} e(t)$$

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Taking Laplace on both side.

$$E_a(s) = (s \cdot K_D) E(s)$$

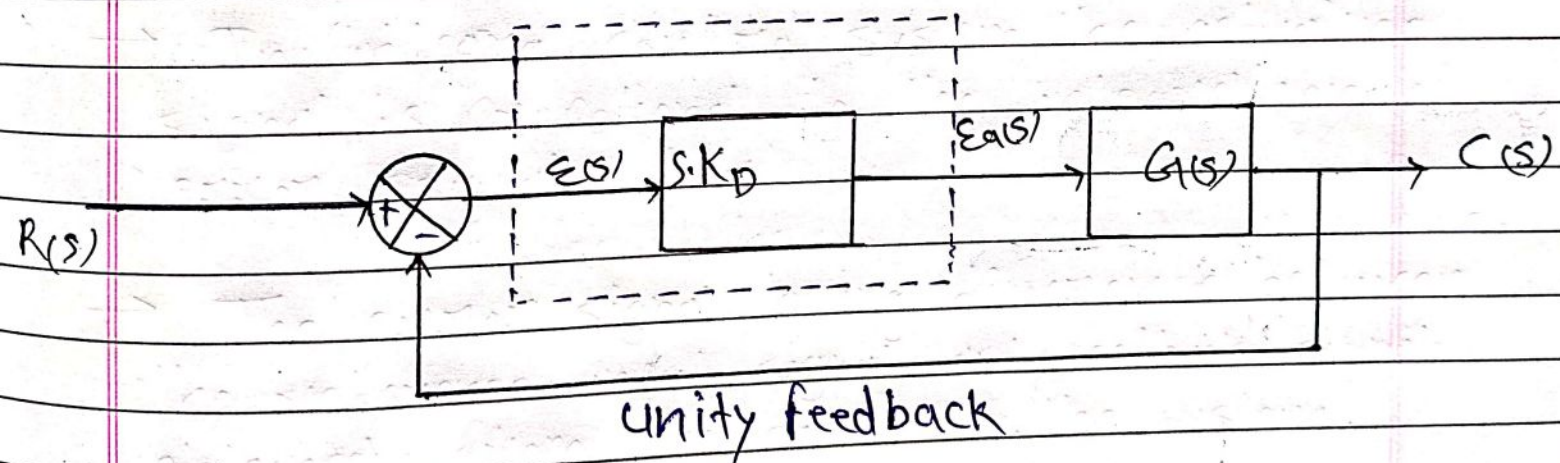
(output) (input)

$$\text{Transfer function} = \frac{\text{L.T. of output}}{\text{L.T. of input}}$$

$$T.F = \frac{E_a(s)}{E(s)} = s \cdot K_D$$

[K_D = Derivative Constant]

Derivative Controller



Derivative Controller with unity Feedback.