Measurement of Temperature Using Thermistor

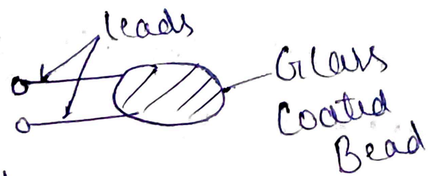
Thermistor

Thermal + Resistor

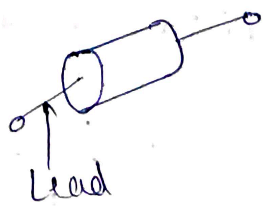
* Thermistor is a special type of resistor whose resistance changes with the change in temperature
* Thermistor have a negative temperature coefficient of resistance
* 1°c rise in temperature
  5% decrease in resistance
* Thermistors are used for precision temperature measurement, control and compensation.
* Temperature range → -60°c to 15°c
  → also used in -ve temp.
* Thermistors are highly sensitive but have a non-linear characteristics of resistance versus temperature.

Construction:

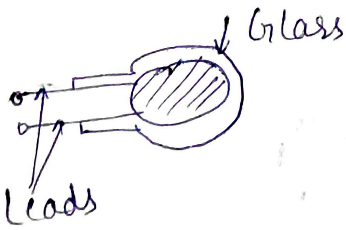
* Manganese, nickel, cobalt, copper, iron and uranium
* Various sizes and shapes → beads, rods, discs



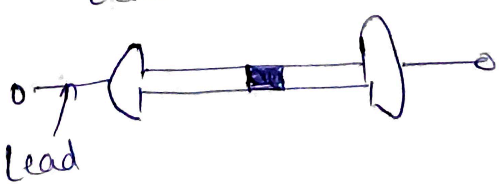
(i) → Bead



(ii) Probe



(iii) → Disc



iv) Rod

1) Bead → Smallest in size
diameter of 0.015 mm to 1.25 mm

2) Glass probes → diameter of 2.5 mm
length varies from 6mm to 50 mm.

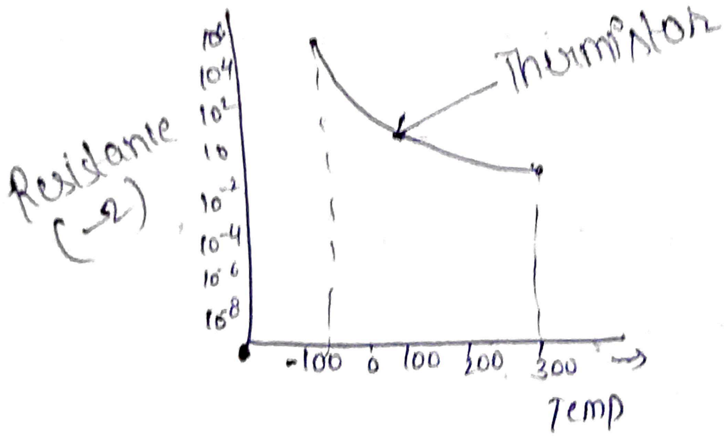
3) Disc → made by pressing material under high pressure in to cylindrical shapes with diameter 2.5 mm to 25 mm

4) Rod → 1.25, 2.75 and 4.25 mm in diameter

Characteristics of Thermistors:-

1. Resistance - temperature
2. Voltage - current
3. Current - Time

Resistance - temperature Characteristics :-

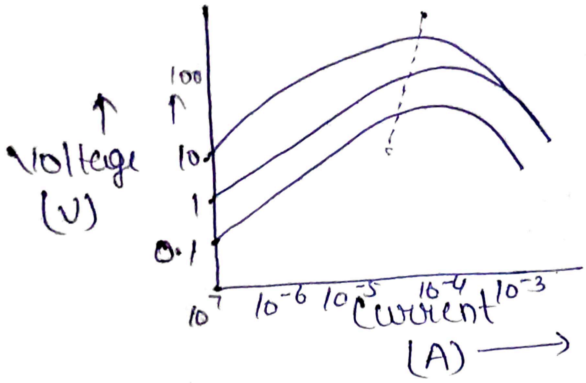


* The mathematical expression for the relationship b/w the resistance of a thermistor and temperature is →

$$\boxed{R_{T_1} = R_{T_2} \exp\left[\beta\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right]}$$

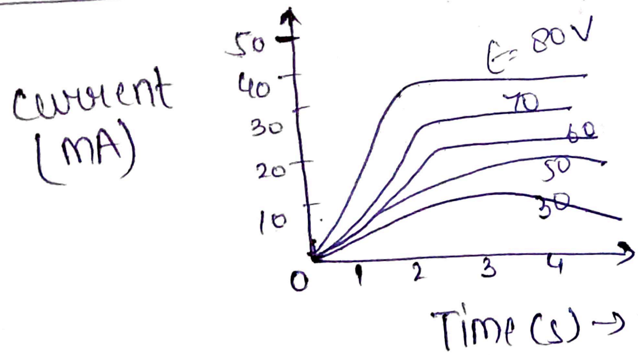
R_{T_1} = resistance of thermistor at temp T_1
R_{T_2} = " " " " T_2
β = constant depending upon the material of thermistor

2. Voltage - current characteristics



* The voltage drop a thermistor increase with increasing current until it reaches a peak value.
* After peak value, the voltage drop decreases with increase in current ↳ negative resistance characteristics

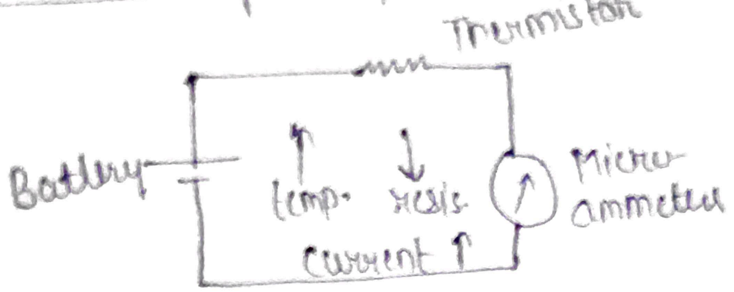
3) Current - Time Characteristics :-



* The time delay to reach maximum current is a function of applied voltage.
* When the heating effect occurs in a thermistor, a certain finite time is required for the thermistor to heat and the current to build up to a maximum steady state value.

Applications of Thermistors

1) Measurement of Temperature



2) Control of Temperature :-
Thermistor are used along with a relay.

3) Temp Compensation →

4) Measurement of power at high frequencies

5) measurement of thermal conductivity

6) " of level, flow, pressure

7) vacuum measurements

8) providing time delay.

Advantages

* compact, rugged, and inexpensive
* good stability, highly sensitive
* response time is fast
* not affected by environmental conditions
  → electric fields.
*

Disadvantage

→ Non linearity in resistance vs temp. characteristics
→ Unsuitable for wide temperature range

Measurement of Temperature Using Thermocouple 13.1

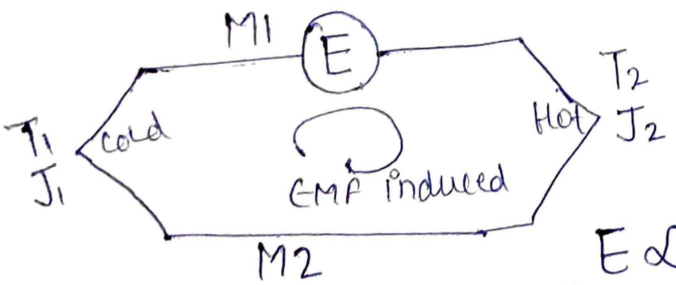
Thermocouple– It is a device made up of two different metals connected end-to-end and is used to measure unknown temperature.

→ The principle its working is based on the phenomenon of *thermoelectric effect

Thermoelectric Effect

* When two metals having different work functions are connected end-to-end, an emf is induced within the circuit which is proportional to the difference b/w the temperature b/w the two junctions.

* This emf is due to the diffusion of charge carriers from the metal having low work function to the metal having higher work function.
  ↳ it is a energy that is used to eject electron from a metal



$E \propto \Delta T$

if there is a temp. diff.

$T_1 \neq T_2$

$\Delta\theta = T_1 - T_2$

$$E = a(\Delta\theta) + b(\Delta\theta)^2$$

* where, a and b are the constant and $\Delta\theta$ is the temprature difference in °C
* a is usually much greater than b, hence b is neglected

This implies

$$E = a(\Delta\theta) \quad \text{or}$$

$$\Delta\theta = \frac{E}{a}$$

Resistance Temperature Detector

Principle:- Resistance of conductors change with respect to the change in temperature

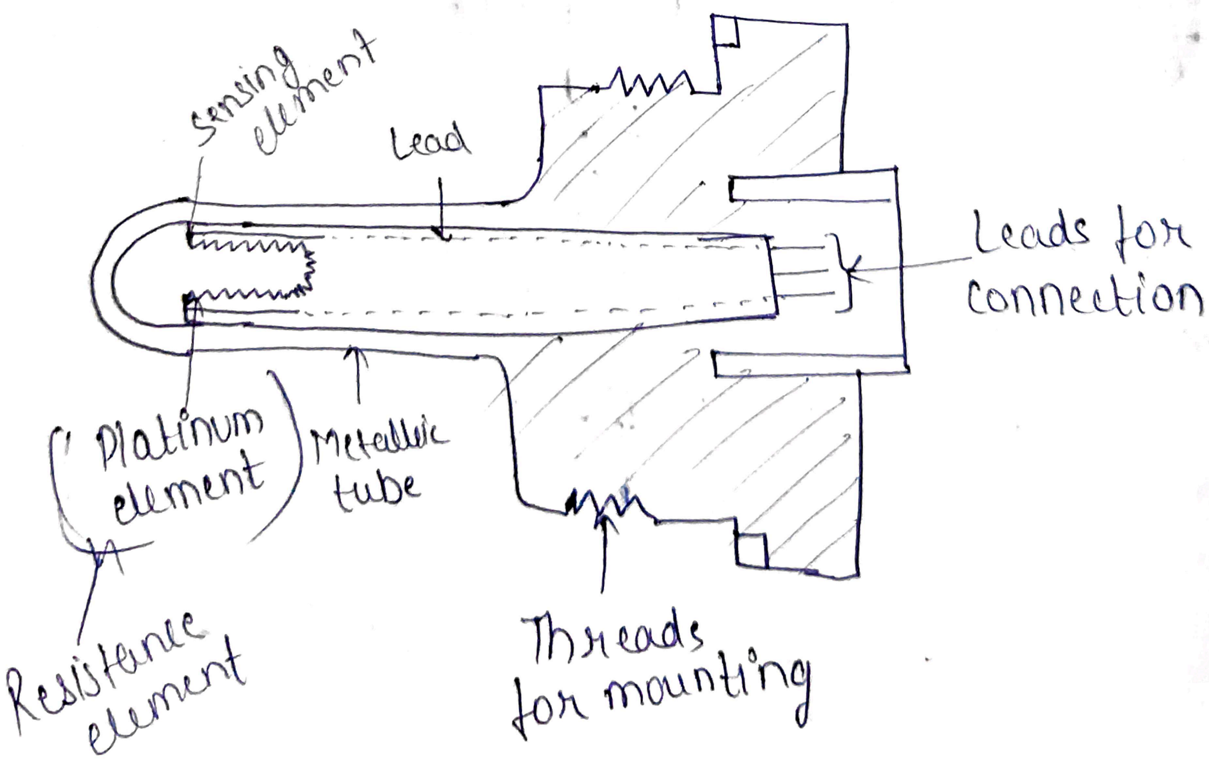
$$R = R_0 (1 + \alpha T)$$

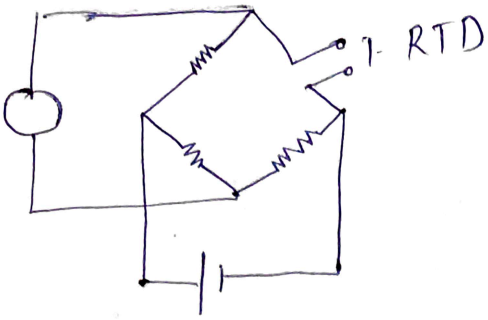
→ for PT100
$R_0 = 100\ \Omega$
$\alpha \rightarrow$ temp. coeff
$\alpha = 0.00385/$
$T =$ Temp°

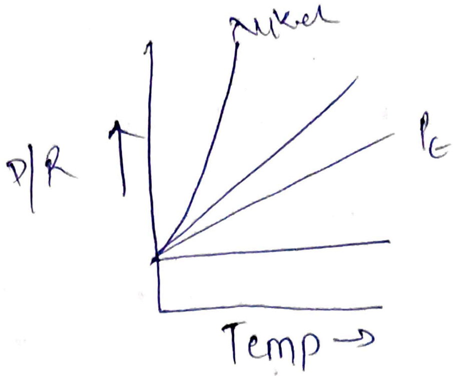
* Conductors have positive temp. cofficient
* Material should have high resistivity
* High accuracy
* For platinum RTD →

$(-182.96°C - 630.74°C)$
oxygen point   antionary point

⇒ platinum is specially suited

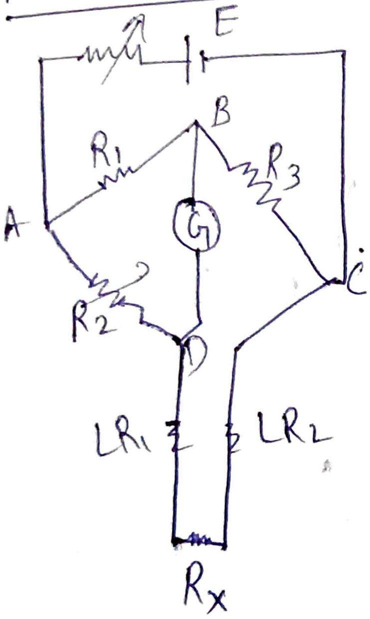




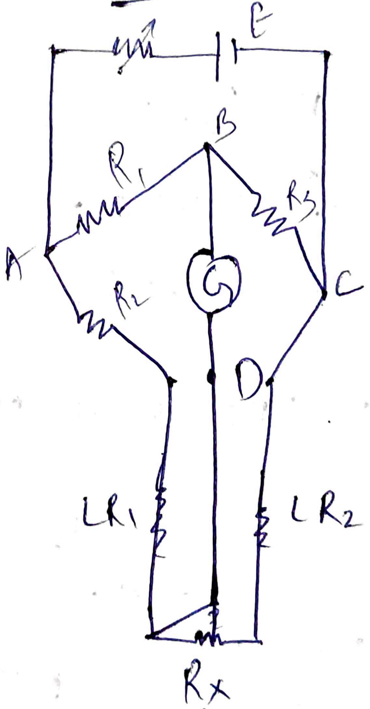


→ also called Electrical resistance thermometers
→ made up of conductors
→ Use 3-wire RTD because of temp. compensation

Two wire RTD



Three wire RTD



Bridge circuit digg.

Increase in temp. in 2-wire RTD → temp compensation

↓

RTD = unknown

$$R = R_0(1+\alpha T)$$

$R = R_0(1)$ (when Temp = 0°C)

$R = 100\Omega$

α → resistance temp. co-efficient

Measurement of Position using Hall effect sensors

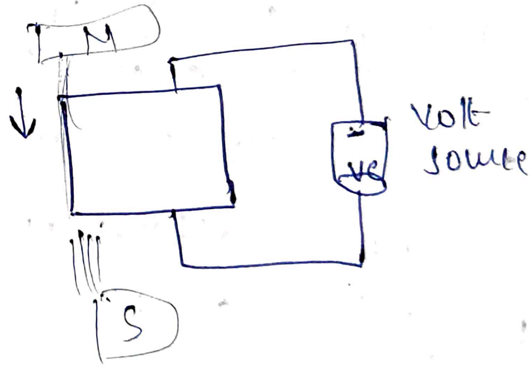
Hall effect

Voltage generate by magnetic field

- Hall effect sensor is a linear transducer that is used to measure magnitude of magnetic field
- This type of sensor sense the presence of magnetic field and hall voltage generates
  and by the help of measured hall voltage we measure the quantity of magnetic flux density
  hall effect
  hall voltage

---

* To understand hall effect we take metallic strip or plate that connected to voltage source
- we know that current flows from +ve terminal to -ve term and electrons flow from -ve to +ve terminal
- when this metallic plate placed in magnetic field



- suppose upper north pole of the magnet & below the metal plate south pole magnet is placed.
- so here magnetic field lines will be from north pole to south pole
- here magnetic field lines remains perpendicular to the circulating current from the plate
- under this condition from lorentz law external force acts on the moving force
- as a result here negative charge (e) deviated from the actual path

states that magnetic field exerts the force on moving ionic current

<u>means</u>

when charge moves in the magnetic field the external force exerted on the moving charge

$$F = q(E + V \times B)$$

F = force
q → charge
V → velocity
B → magnetic field
E → external electric field

---

* As a result now potential difference will be create b/w both point due to higher potential and lower potential
* when we connect the voltmeter b/w both point then we will get a small amount of voltage value and this voltage is known as (hall voltage)
* this hall voltage is directly proportional to the magnitude of the magnetic field.
* so by the help of measured hall voltage we calculate the magnitude of the magnetic field or flux density
* Thus, a hall effect sensor sense the magnitude of magnetic field.

$$E_h = \frac{K_h \cdot iB}{t}$$

K_h → hall effect coefficient
i = current amp
B = flux density wb/m^2
t = thickness of strip metal
E_h = hall voltage

Applications of Hall effect sensors

1. Measurement of Displacement
2. The Hall effect transducer can be used as a magnetic to electric transducer.
3. Measurement of current

- Proximity sensors are sensors that Detect movement or presence of an objects without making physical contact with the objects and converts the information captured into an electrical signal.
- Devices such as limit switches detect an object by physically contacting it, but proximity sensors detect the presence of an object, without touching it.
- As these sensors are non-contact sensors they do not cause any damage to the object.
- Proximity sensors do not use any type of physical moving parts, instead they allow signals to transmit through them, when something that is being monitored comes in close proximity of the sensing area.
- There are many types of proximity sensors and they each sense the presence of an object in their own distint ways.
- Two most commonly used proximity sensors are
  - Capacitive proximity Sensor
  - Inductive proximity sensors

Capacitive Proximity Sensors

Working principle of Capacitive Proximity Sensors

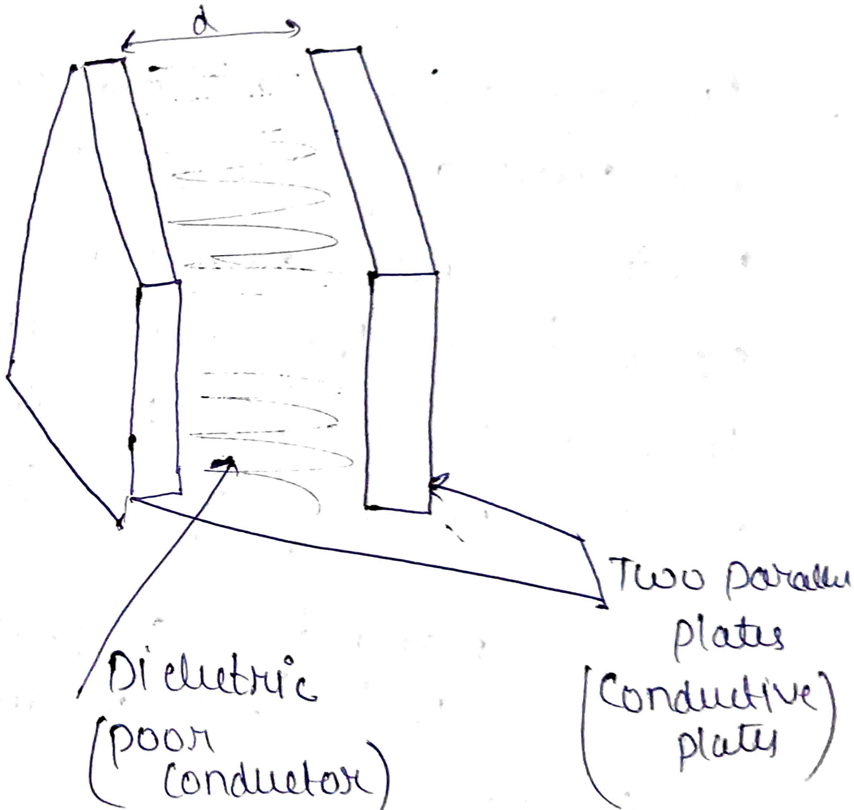
→ Capacitive proximity sensor is based on the principle of a parallel Plate Capacitor. Parallel plate capacitor consist of two parallel plates, that are seperated by a dielectric material which is a poor conductor of electricity such plastic, glass etc

→ The two parallel plates are conductive and they are usually made of Aluminium, tantalum or other metals.

Capacitance

$$C = \frac{A * e}{d}$$

d = distance
A = area
e → dielectric



→ A typical plate has equal amount of +ve and -ve charged particles which means it is electrically neutral

→ If we connect a power source or a battery to the capacitor, a large no° of electrons start moving from the negative terminal of the battery through the conductor wire

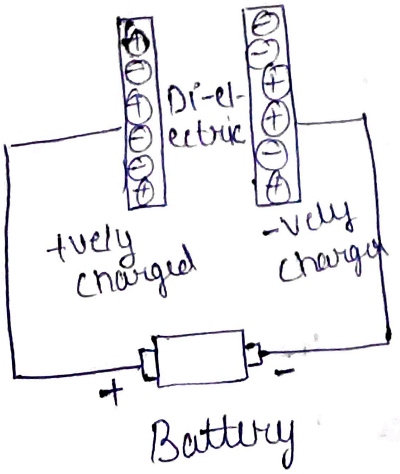
→ When these electrons reach the right side plate of the capacitor, the dielectric material will strongly oppose the movement of electrons from the right side plate to left side plate.

→ As a result, no of electrons that is the -ve charge carriers on the right side plate of the capacitor will be higher than the number of protons, that is the positive charge carriers.

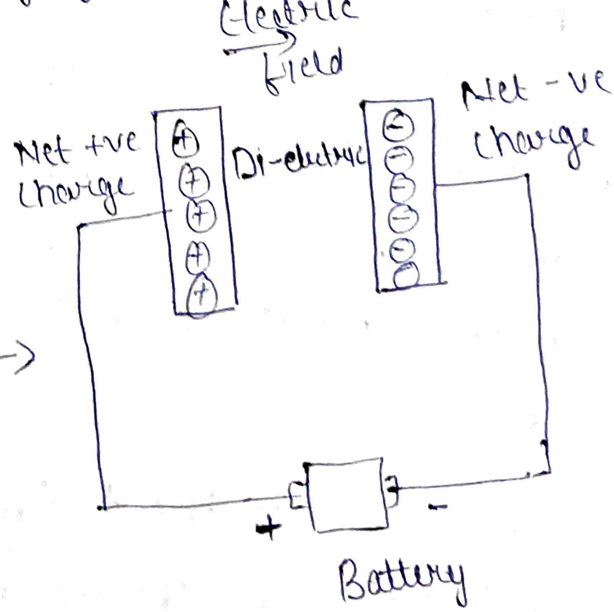
→ Due to this, the right side plate of the capacitor becomes negatively charged, at the same time the electrons on the left side plate experience a strong attractive force from the positive terminal of the battery.

→ As a result the electrons leave from left side plate and will be attracted towards the positive terminal of the battery.

→ Due to this, the no of protons will be higher than the no of electrons in the left side plate and as a result the left side plate of the capacitor becomes positively charged. This is how the charging of capacitor takes place.



→



→ Now, the right side plate has now develop a net negative charge, and the left side plate has developed an equal net +ve charge. This creates an electric field with an attractive force between them which holds the charge of the capacitor.

→ The ability of a capacitor to store electric charge when a voltage is applied is called capacitance. Quantity measuring the ability of a dielectric material to store charge is called Dielectric Constant.

→ The capacitance of a capacitor is directly proportional to the dielectric constant of the material b/w the two plates and inversely proportional to the distance between the two plates.

Inductive Proximity Sensors

→ Inductive proximity sensors are used to detect metal targets. An inductive proximity sensors has four main components.

The first one is the coil

The coil generates necessary electromagnetic field a cup shaped magnetic core holds the coil. This core is necessary to concentrate the coil's magnetic field on the front area of the sensor.

The second part is oscillator The oscillator is generally an LC oscillator. It produces radio frequency which help to generate an electromagnetic field.

The third part is the trigger circuit The trigger circuit senses the change in amplitude of oscillation and gives the signal to the output circuit.

The last part is the output circuit - The o/p circuit has a transistor after receiving the signal the transistor after receiving the signal, the transistor switches on and gives an output.

Coil → Oscillator → Trigger → Output

Working principle of Inductive Proximity Sensors

Inductive proximity Sensors Operate on the basis of Faraday's Law of Inductance

→ According to Faraday's law of induction when an electrically conducting object is placed in a magnetic field then an Electric current called Eddy current will be generated in the object.

→ According to lenz's law, The Eddy current creates a magnetic field in a conductor and this Eddy current magnetic field opposes the magnetic field which created it.

Working of Inductive Proximity Sensors

The proximity sensor is installed in the area where we need to sense the presence of an electrically conductive target object. When the sensing coil in the oscillation circuit is supplied with an alternating current, a changing magnetic field is created around the coil.

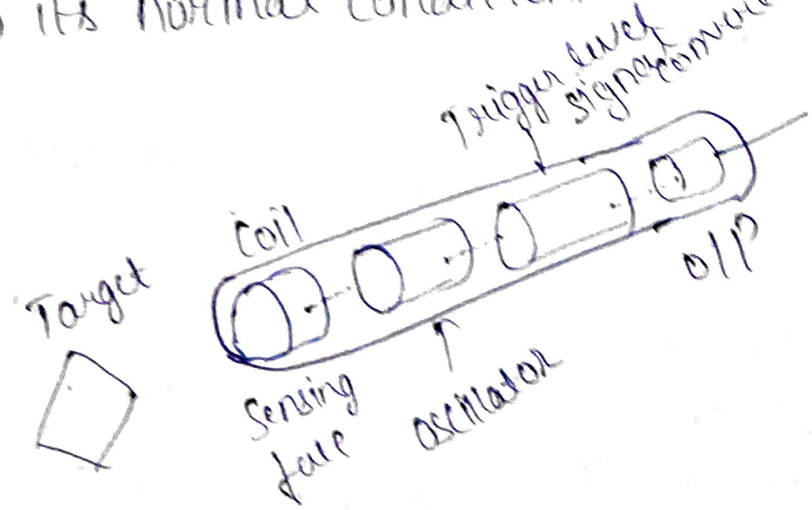
When the target object enters this electromagnetic field

Some of the electromagnetic energy is transferred to the object according to Faraday's law of induction, an electric current called Eddy current will be generated in the object. This Eddy current produce another magnetic field called Eddy current magnetic field and opposes the magnetic field of the coil, the intensity of the magnetic field of coil reduces.

As the target comes very close to the sensor the eddy current increases, decreasing the amplitude of electro-magnetic field.

The trigger circuit monitors the amplitude and when the amplitude goes below a predetermined level, the output state of the sensor switches from its normal condition.

As the target moves away from the sensor the amplitude of the electromagnetic field increases and at a predetermined level the trigger switches the o/p state of the sensor back to its normal condition.



Level Sensors

A level sensor is a device or instrument that is designed to monitor, maintain and measure the liquid or solids levels. Once the liquid is detected, the sensor converts it in to an electric signal. Level sensors are used primarily in the manufacturing and automotive industries

Types of Level Sensors

There are mainly two types of level sensors:

1. Point level sensor or measurement
2. Continuous level sensors or measurement

→ Point level measurement indicates when a product is present at a certain point and

→ Continuous level measuring indicates the continuous level of a product as it rises and fall.

The point level sensors or measuring instruments are:-

→ Capacitance Level sensors

→ Optical level sensors

→ Conductivity level sensors

→ Vibrating level sensors

→ float switch Level sensors

The continuous level sensors or measuring instruments are:

→ Ultrasonic Level Sensors

→ Radar (Microwave) level sensors

Capacitive level Measurement

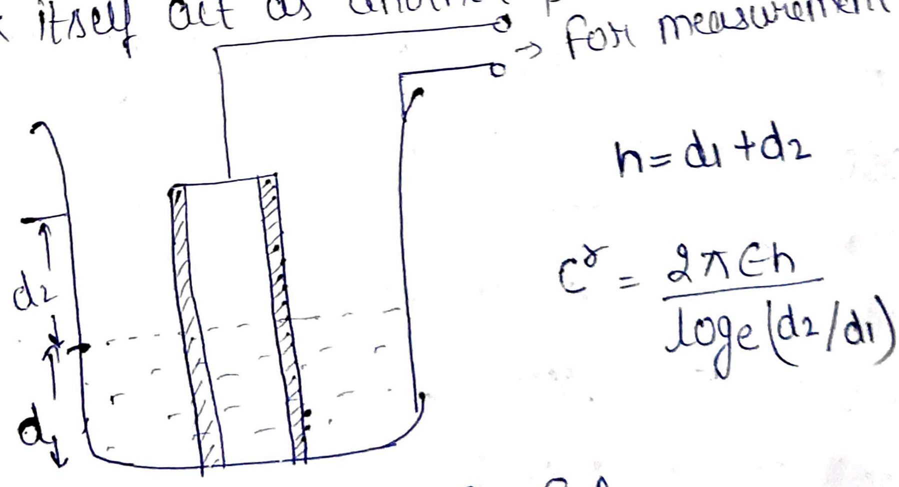
→ Capacitance b/w the two parallel plates:

$$C = \frac{\varepsilon_0 A}{d}$$

→ Three major parameters that can be utilized
- * Change in dielectric constant
- * Change in Area
- * Change in Distance

→ Based on the type of liquid, the capacitive level sensors are divided in to:
- * For non conducting / Insulating fluid
- * For conducting fluid

1. Variable Area Method : Construction
- * A circular conducting rod is placed in between the tank.
- * This rod act as one plate of the circular capacitor
- * The tank itself act as another plate.

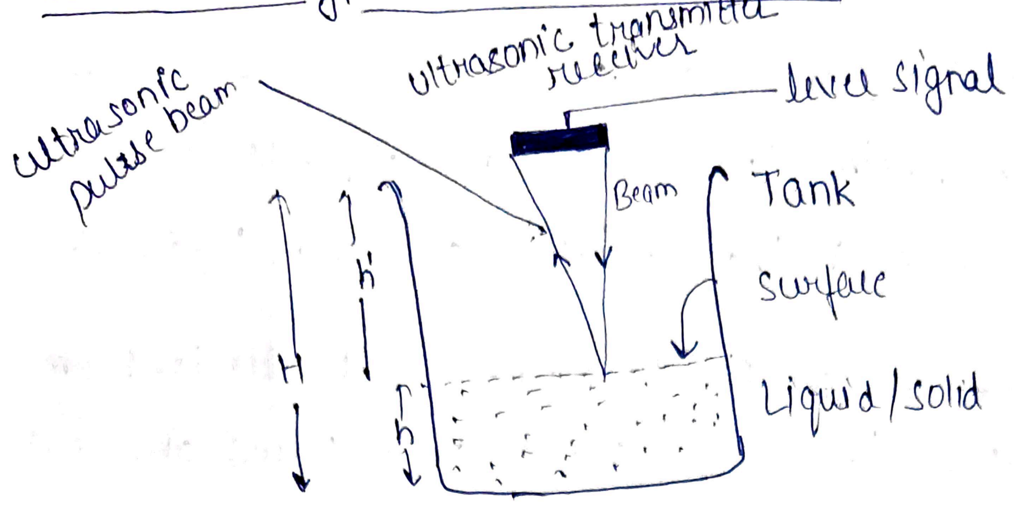


$$h = d_1 + d_2$$

$$C^{r} = \frac{2\pi \varepsilon h}{\log_e (d_2/d_1)}$$

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

Ultrasonic Type Level Measurement



Time taken by beam

$$t \propto h'(H-h)$$

* Ultrasonic wave - 20k Hz - 200kHz

* level sensor is located at the top of the tank.
* Sends the sound waves in the form of bursts in downward direction
* As soon as the waves hits the surface of the fluid, sound echoes get reflected and returned back to the sound
* Time taken by sound waves to return back is directly proportional to the distance b/w the sensor and the fluid.
* Time duration is measured by the sensor → calculate the level of the liquid in the tank.

Features :

* Sensors uses frequencies in tens of KHz range, transit time are ~ 6ms/m. Speed of sound depends on mixture of gases in the headspace and their temperature.
* Heavy foam is found on the surface of the liquid. Foam is to be avoided because it work as a sound absorbent.
* Excessive surface turbulence can result in fluctuations in measurements.
* Good level measurement requires that reflected echo returns back in a straight line to the sensor.

Advantages

1. Ultrasonic level sensors are contactless type & can be used to measure level of hot, corrossive and boiling liquids.
2. require less maintenance
3. mounted at the top of vessel due to which they are less likely to offer leakage problems.

Disadvantages

* cannot be suitably applied in all fields since use of ultrasonic level sensors include few damages.
* Many factors influence the returned echo signal back to sensor like
  1. Heavy vapors
  2. foam
  3. Materials like powders
  4. Noise & temperature.