UNIT NO:-02

RTD:- (Resistance Temperature Detector OR Resistance thermometer)

The resistance of a conductor changes when it's temp. is changed. This property is Utilized for measurement of temp.

The variation of resistance R with temp. T(°K) can be represented by the following relationship for most of the metal as

$$R = R_0(1 + \alpha_1 T + \alpha_2 T^2 + \cdots + \alpha_n T^n + \cdots)$$

R_0 = Resistance at temp $T = 0$

α_1, α_2 and α_n are Constants

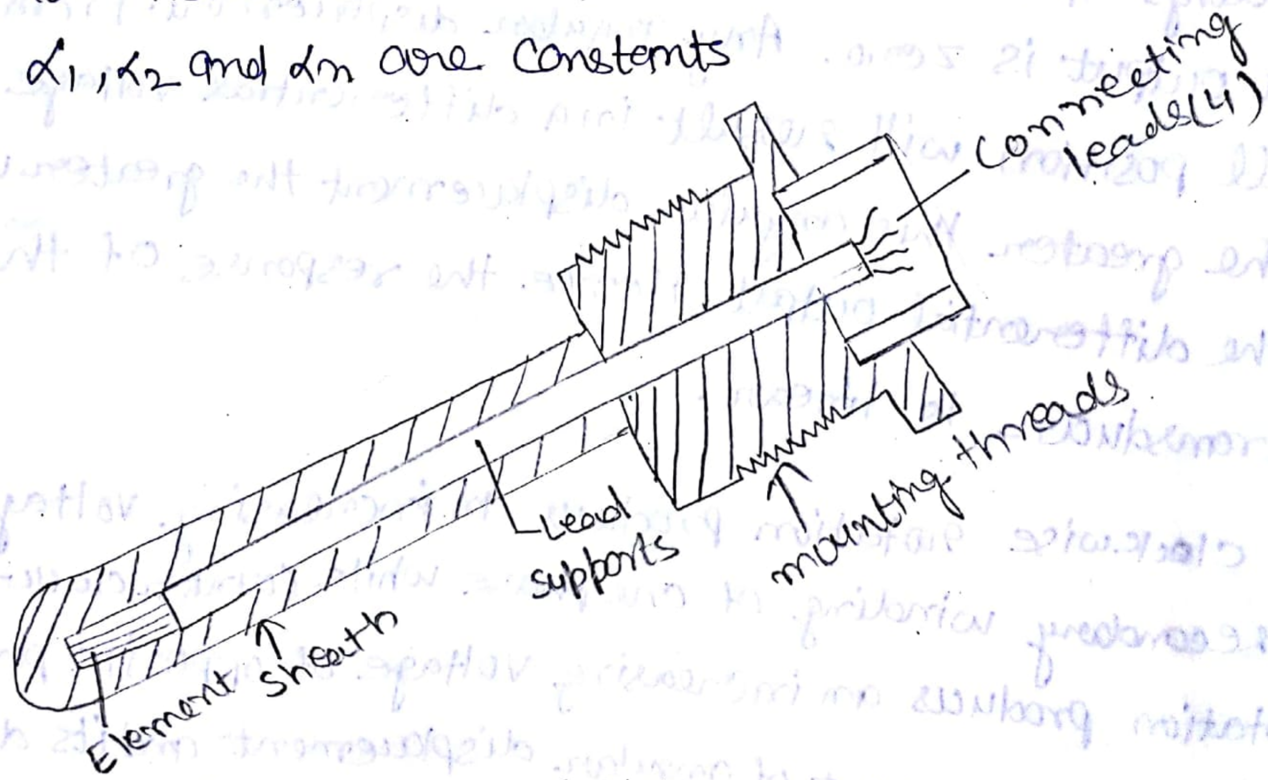


fig: Industrial Platinum resistance thermometer

The resistance thermometer uses the change in electrical resistance of conductor to determine the temperature.

13

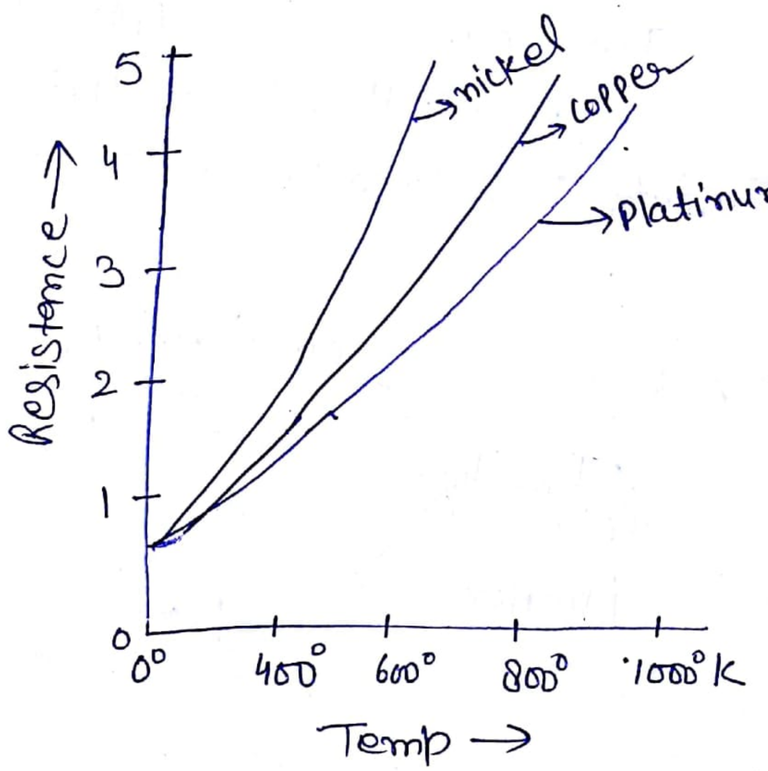
Platinum is especially suited for this purpose, as it can withstand high temp. while maintaining excellent stability. All metals produce a positive change in resistance with temp. RTD have positive temp. coefficient.

The requirement of a conductor material to be used in RTDs are

(i) The change in resistance of material per unit change in temp. should be as large as possible.

(ii) The material should have a high value of resistivity so that minimum volume of material is used for the construction of RTD.

(iii) The resistance of materials should have a continuous and stable relationship with temp.



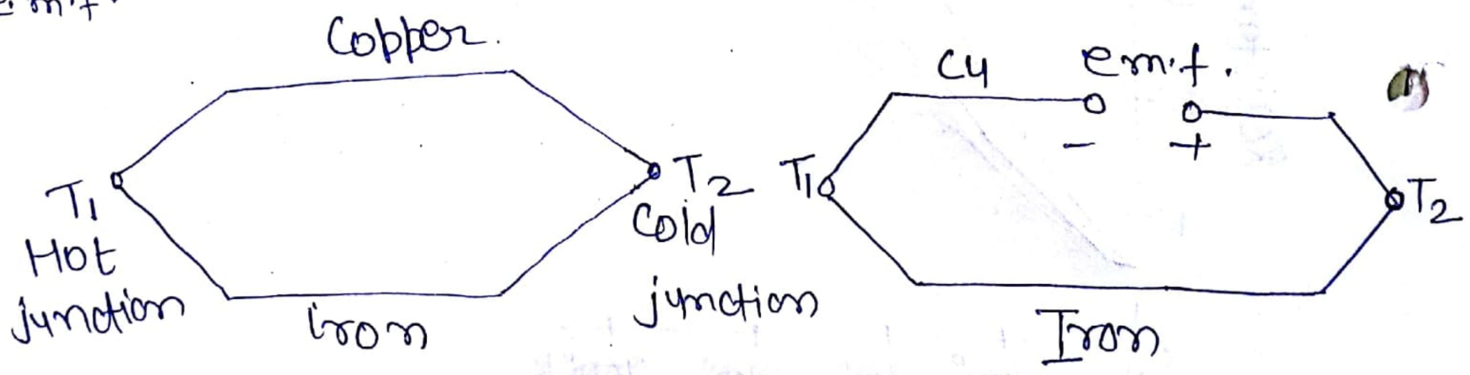
Characteristics of materials used for resistance Thermometers.

The most common RTDs are made of either platinum, nickel or nickel alloys. The nickel wires are used over a limited temp. range. For measurement integrity, platinum is the obvious choice.

Thermocouple:- Thermocouple is used for temperature measurement in which changes in temp. are directly converted into an electrical signal. It is a self regulating transducer and works on the principle of thermoelectric or seebeck effect.

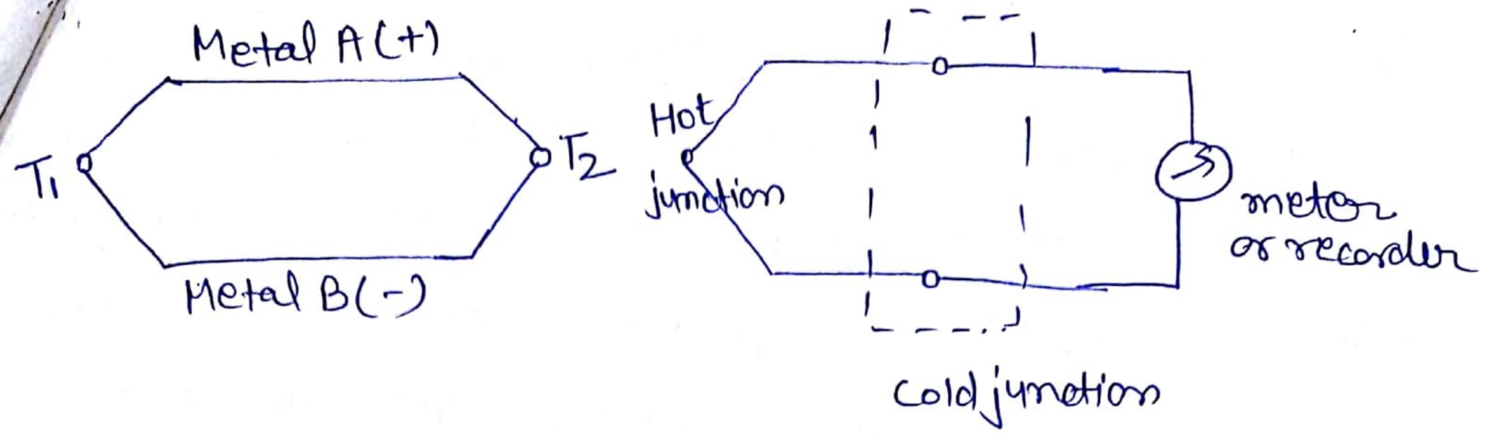
In 1821, the great scientist Prof Seebeck discovered that if the two wires of different metals are joined together forming closed ckt and if the two junctions formed are at different temps, an electric current flows around a closed ckt. This is called seebeck effect.

He also observed that, if two metals used are copper and iron, then the current flows from copper to iron at hot junction and from Iron to copper at cold junction. If the copper wire is cut, the e.m.f appears across the open ckt. This e.m.f is commonly known as seebeck e.m.f.



Construction! -

Thermocouple is made up of two wires of dissimilar metals joined together to form two junctions.



Out of two junctions T_1 & T_2 is kept at constant reference temp. Haence it is refered as cold junction. while the temp. changes to be measured are subjected to the junction T_1 which is refored as hot junction.

When the hot junction temp. is greater as compared to the cold junction, e.m.f is generated due to the temp. gradient The magnitude of the e.m.f generated depends on the material used for the wires and temp. difference b/w the two junctions. Generally a meter or recorder is used to measure e.m.f.

$$E = a(T_1 - T_2) + b(T_1 - T_2)^2$$

Where a & b are constants whose value depend upon the material used

$\Delta\theta$ = difference of temperatures of hot & cold junctions in °C
$= T_1 - T_2$

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

b is very small compare to a

$$E = a\Delta\theta$$

Deflection $\theta \propto E$

$\Delta\theta \propto I^2R$

$\theta = K_2E$

$\Delta\theta = K_1I^2R$

$\theta = K_2a\Delta\theta$

$\theta = K_2aK_1I^2R$

$\theta = K_3I^2 \quad K_3 = K_1K_2aR$

$$\boxed{\theta \propto I^2}$$

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Thermistors:- Thermistor is a contraction of a term "thermal resistors". Thermistors are generally composed of semi-conductor materials. Most thermistors have a negative coefficient of temp. resistance i.e. their resistance decreases with increase of temp. The negative temp. coefficient of resistance can be as large as several percent per degree celsius.

This high sensitivity to temp. changes makes thermistors extremely useful for precision temp. measurements control and compensation. Thermistors are widely used in applications which involve measurements in the range of $-60°C$ to $15°C$. The resistance of thermistors ranges from 0.5Ω to $0.75 M\Omega$. Thermistor is a highly sensitive device.

The mathematical expression for the relationship b/w the resistance of a thermister and absolute temp. of thermister is

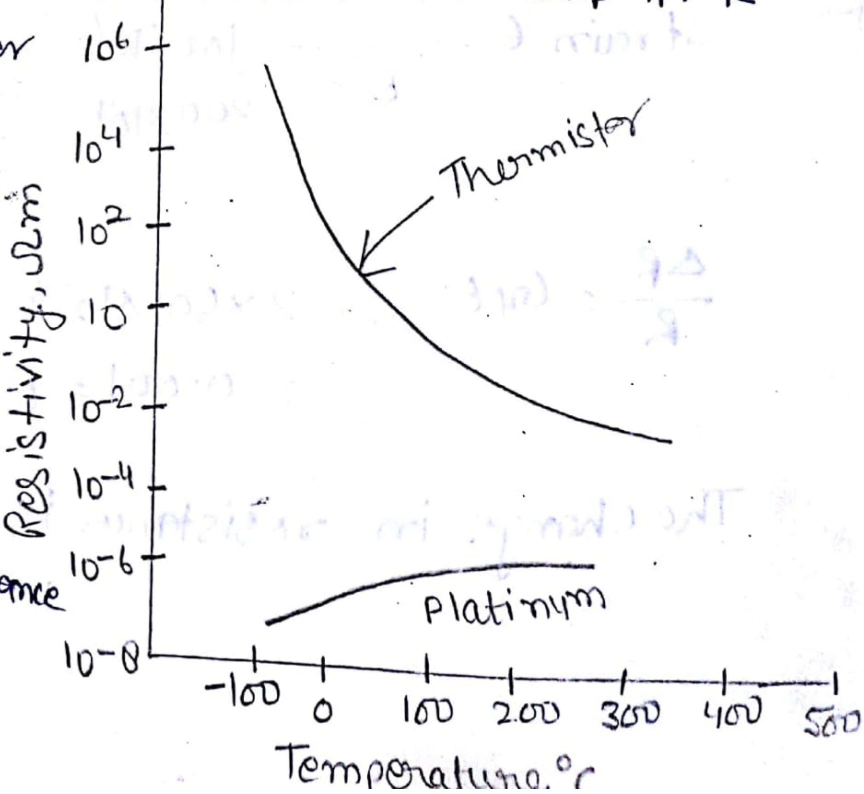
$$\boxed{R_{T_1} = R_{T_2} \exp\left[\beta\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right]}$$

where R_{T_1} = resistance of the thermistor at absolute temp. T_1; °K

R_{T_2} = resistance of thermister at absolute temp T_2; °K

β = a constant depending upon the material of thermistor.

The resistance temperature characteristics show that a thermistor has a very high -ve temp. coefficient of resistance making it an ideal temp. transducer.



Hall Effect Transducers

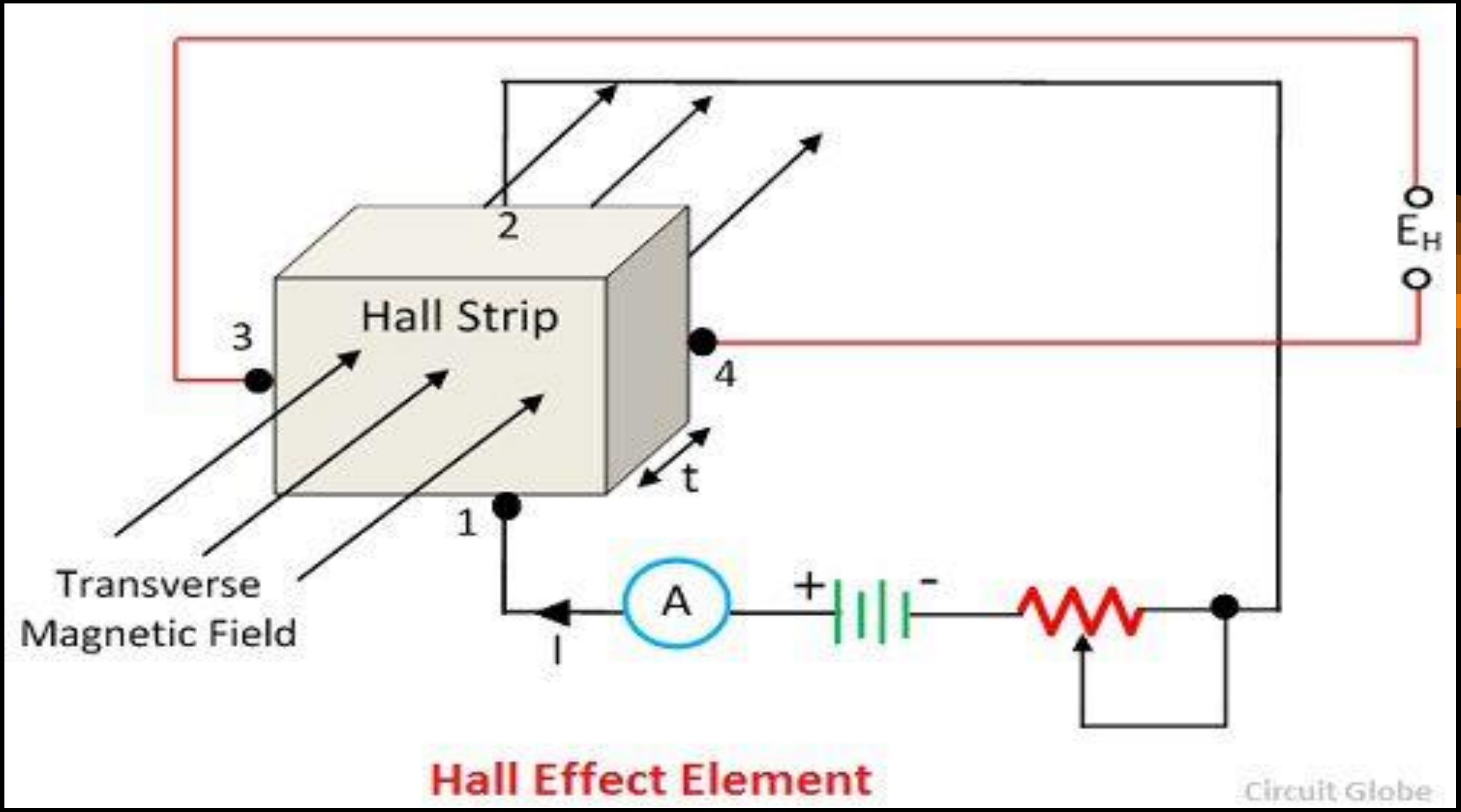
The hall effect element is a type of transducer used for measuring the magnetic field by converting it into an emf. The direct measurement of the magnetic field is not possible. Thus the Hall Effect Transducer is used. The transducer converts the magnetic field into an electric quantity which is easily measured by the analogue and digital meters.

Principle of Hall Effect Transducer

The principle of hall effect transducer is that if the current carrying strip of the conductor is placed in a transverse magnetic field, then the EMF develops on the edge of the conductor. The magnitude of the develop voltage depends on the density of flux, and this property of a conductor is called the Hall effect. The Hall effect element is mainly used for magnetic measurement and for sensing the current.

The metal and the semiconductor has the property of hall effect which depends on the densities and the mobility of the electrons.

Consider the hall effect element shown in the figure below. The current supply through the lead 1 and 2 and the output is obtained from the strip 3 and 4. The lead 3 and 4 are at same potential when no field is applied across the strip.



When the magnetic field is applied to the strip, the output voltage develops across the output leads 3 and 4. The develops voltage is directly proportional to the strength of the material.

The output voltage is,

$$E_H = K_H IB/t$$

where,

$$K_H - Hall\,effect\,coefficient\,;\frac{V-m}{A-Wbm^{-2}}$$

$$t - thickness\,of\,Strip\,;m$$

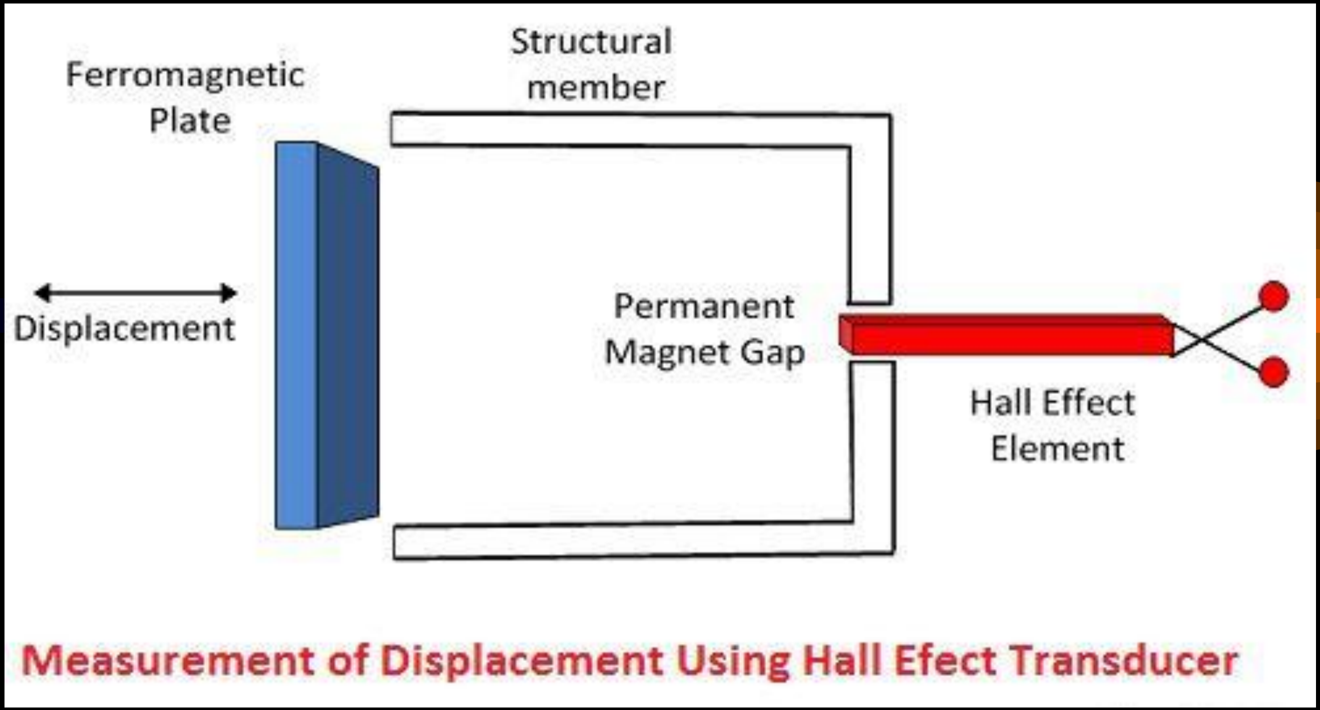
The I is the current in ampere and the B is the flux densities in Wb/m^2

The current and magnetic field strength both can be measured with the help of the output voltages. The hall effect EMF is very small in conductors because of which it is difficult to measure. But semiconductors like germanium produces large EMF which is easily measured by the moving coil instrument.

Applications of Hall Effect Transducer

1) **Magnetic to Electric Transducer** – The Hall effect element is used for converting the magnetic flux into an electric transducer. The magnetic fields are measured by placing the semiconductor material in the measurand magnetic field. The voltage develops at the end of the semiconductor strips, and this voltage is directly proportional to the magnetic field density. The Hall Effect transducer requires small space and also gives the continuous signal concerning the magnetic field strength. The only disadvantage of the transducer is that it is highly sensitive to temperature and thus calibration requires in each case.

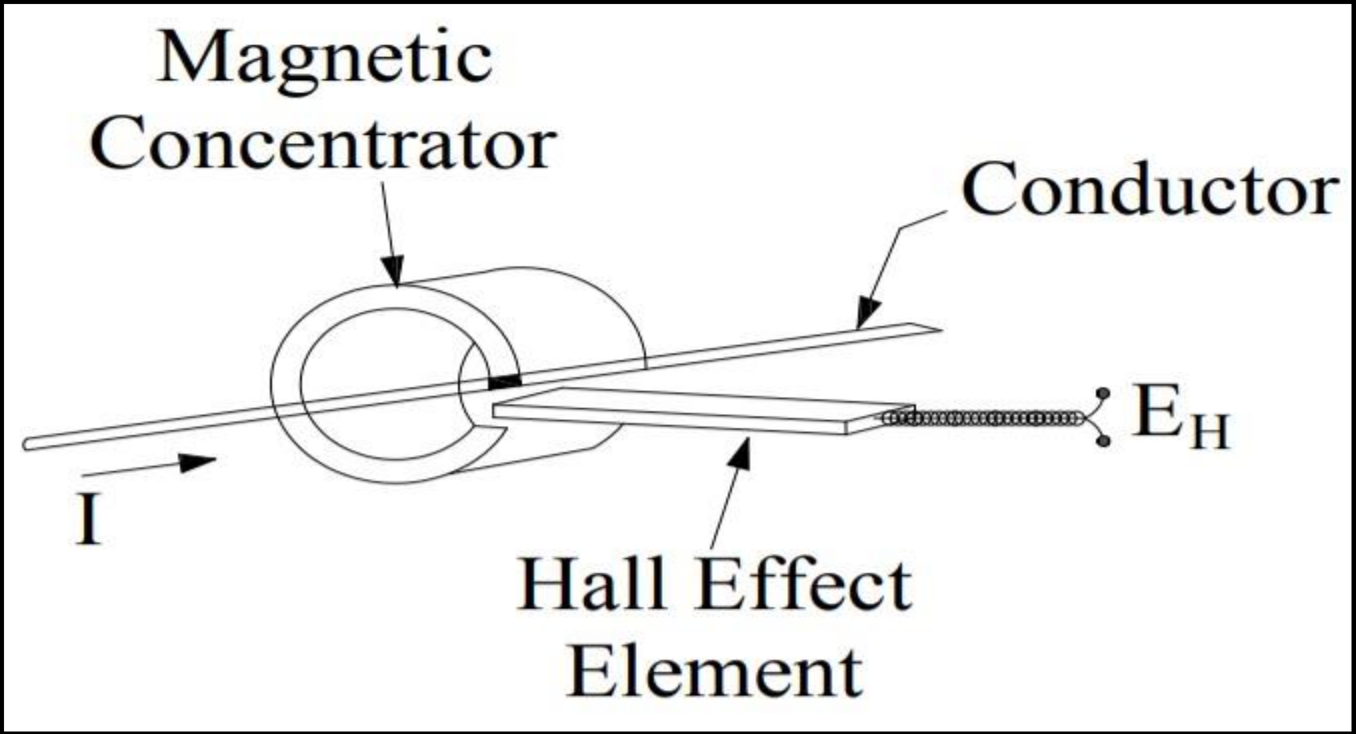
2) **Measurement of Displacement** – The Hall effect element measures the displacement of the structural element.**For example** – Consider the ferromagnetic structure which has a permanent magnet.



The hall effect transducer placed between the poles of the permanent magnet. The magnetic field strength across the hall effect element changes by changing the position of the ferromagnetic field.

3) **<u>Measurement of Current</u>** – The hall effect transducer is also used for measuring the current without any physical connection between the conductor circuit and meter.

The AC or DC is applied across the conductor for developing the magnetic field. The strength of the magnetic field is directly proportional to the applied current. The magnetic field develops the emf across the strips. And this EMF depends on the strength of the conductor.



4) **<u>Measurement of Power –</u>** The hall effect transducer is used for measuring the power of the conductor. The current is applied across the conductor, which develops the magnetic field. The intensity of the field depends on the current. The magnetic field induces the voltage across the strip. The output voltage of the multiplier is proportional to the power of the transducer.

Proximity Sensor

A proximity sensor is an electronic sensor that can detect the presence of objects within its vicinity without any actual physical contact. In order to sense objects, the proximity sensor radiates or emits a beam of electromagnetic radiation, usually in the form of infrared light, and senses the reflection in order to determine the object's proximity or distance from the sensor.

Proximity sensors are commonly used in industrial applications. They are also used in vehicles for detecting the proximity of other vehicles relative to one's own car, as well as for parking-assist functions.

some of the types of proximity sensors:

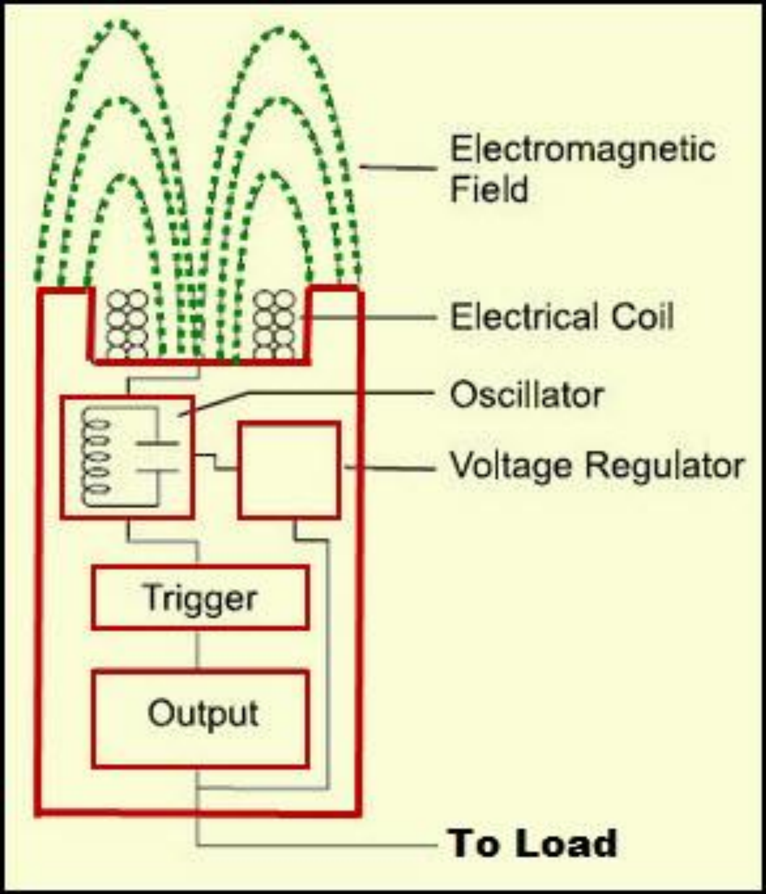
- Inductive
- Capacitive
- Photoelectric
- Magnetic
- Infrared
- Ultrasonic

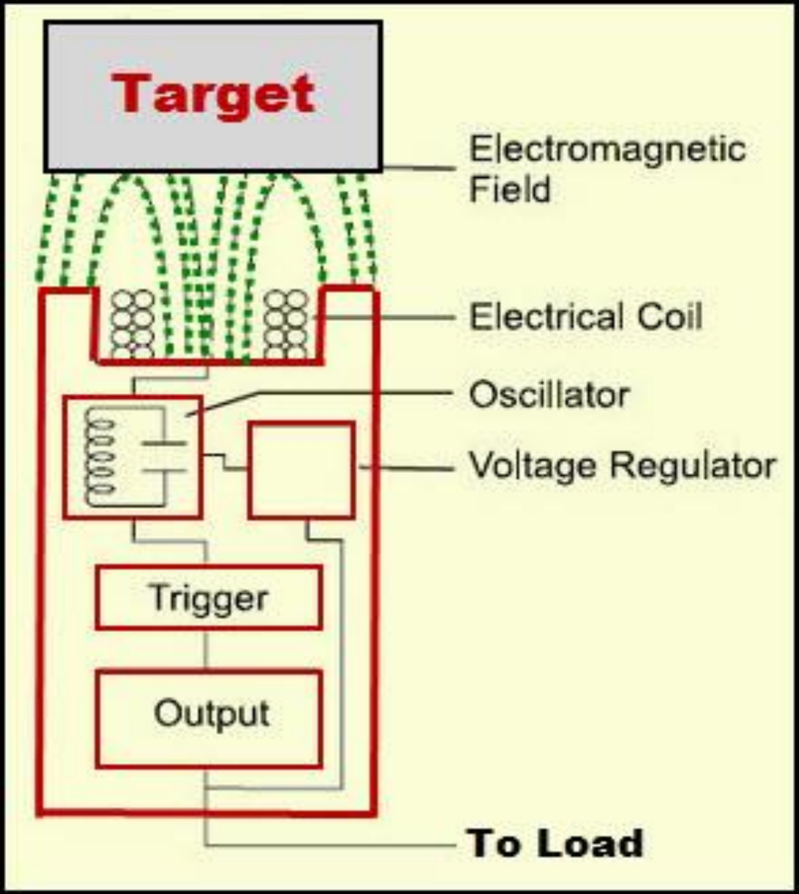
Inductive proximity sensor

<u>Inductive proximity sensors working principle</u>

The inductive proximity sensor circuit is used for detecting the metal objects and the circuit doesn’t detect any objects other than metals. Proximity sensor circuit diagram represents the field produced by the coil, which is generated by providing a power supply. Whenever, this field is disturbed by detecting any metal object (as a metal object enters this field), then an eddy current will be generated that circulates within the target.

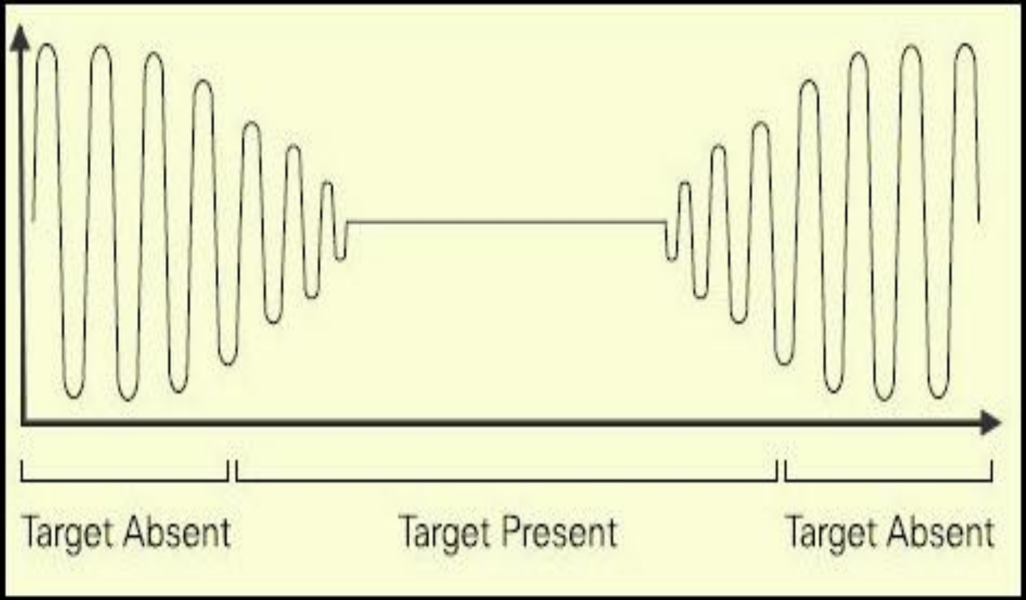
Due to this, load will be caused on the sensor that decreases the electromagnetic field amplitude. If the metal object (called as target) is moved towards the proximity sensor, then the eddy current will increase accordingly. Thus, the load on the oscillator will increase, which decreases the field amplitude.

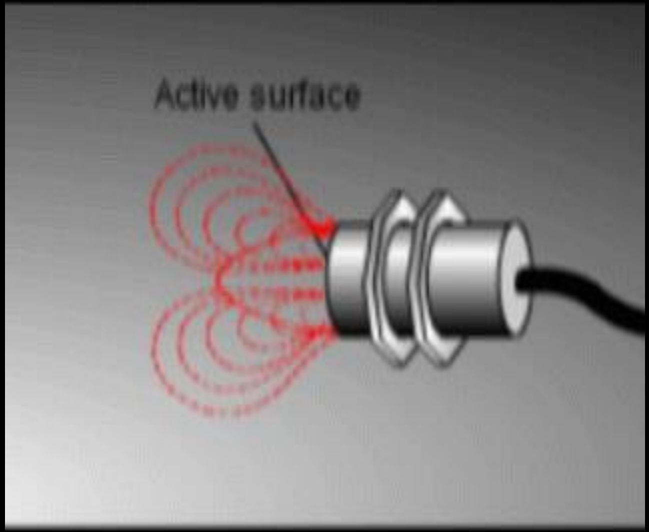

Electromagnetic Field
Electrical Coil
Oscillator
Voltage Regulator
Trigger
Output
To Load


Target
Electromagnetic Field
Electrical Coil
Oscillator
Voltage Regulator
Trigger
Output
To Load

The trigger block in the proximity sensor circuit is used to monitor the amplitude of the oscillator and at particular levels (predetermined levels) the trigger circuit switches on or off the sensor (which is in its normal condition). If the metal object or target is moved away from the proximity sensor, then the amplitude of the oscillator will increase.

The waveform of for the inductive proximity sensor oscillator in the presence of the target and in the absence of the target can be represented as shown in the above figure.





Proximity Sensor Circuit Operating Voltages

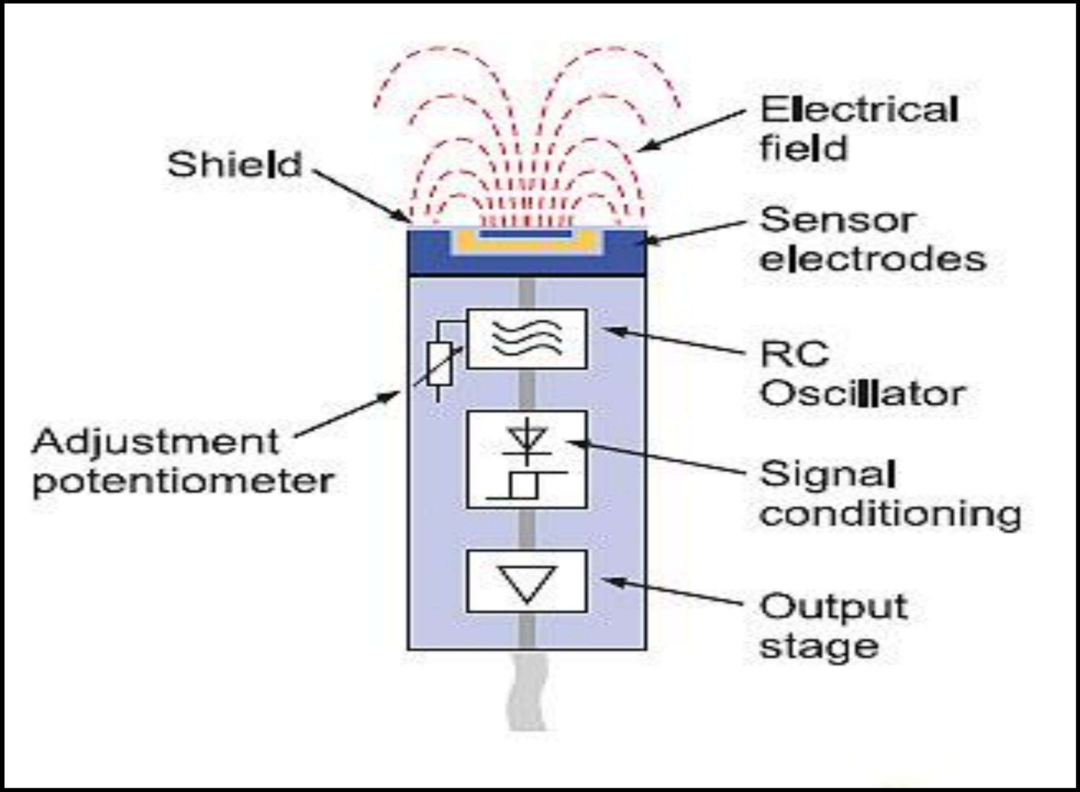
Nowadays, inductive proximity sensors are available with different operating voltages. These inductive proximity sensors are available in AC, DC, and AC/DC modes (universal modes). The operating range of the proximity sensor circuits is from 10V to 250V DC and 20V to 265V AC.

Applications

Common applications of inductive sensors include metal detectors, car washes, and a host of automated industrial processes. Because the sensor does not require physical contact it is particularly useful for applications where access presents challenges. The sensing range is rarely greater than 6 cm, however, and it has no directionality.

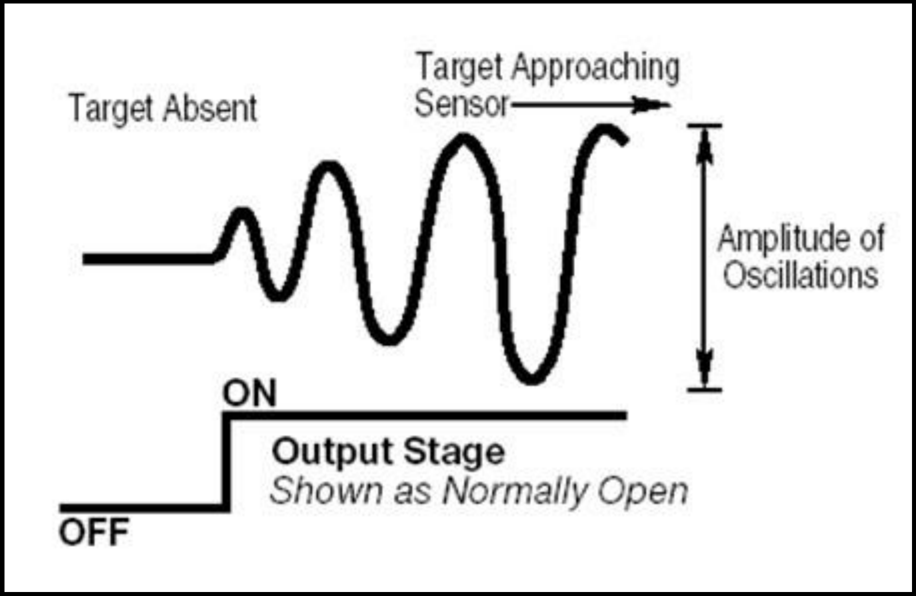
Capacitive proximity sensors

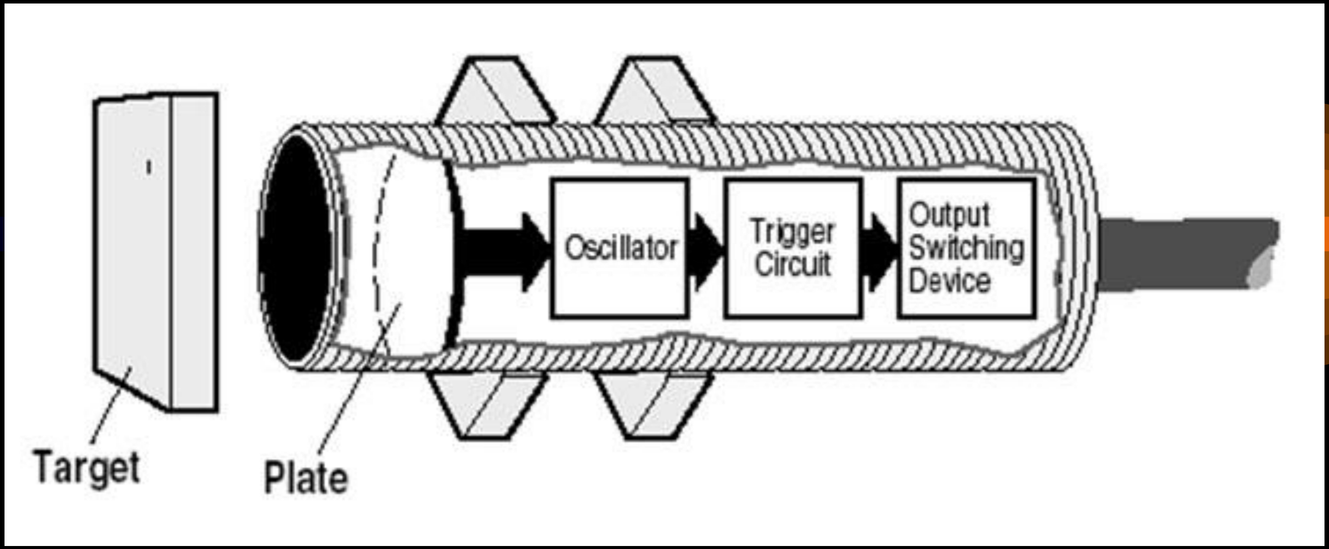
A capacitive sensor acts like a simple capacitor. A metal plate in the sensing face of the sensor is electrically connected to an internal oscillator circuit and the target to be sensed acts as the second plate of the capacitor. Unlike an inductive sensor that produces an electromagnetic field a capacitive sensor produces an electrostatic field.



As the target approaches the sensors face the oscillations increase until they reach a threshold level and activate the output.

Capacitive sensors have the ability to adjust the sensitivity or the threshold level of the oscillator. The sensitivity adjustment can be made by adjusting a potentiometer, using an integral teach pushbutton or remotely by using a teach wire. If the sensor does not have an adjustment method then the sensor must physically be moved for sensing the target correctly. Increasing the sensitivity causes a greater operating distance to the target. Large increases in sensitivity can cause the sensor to be influenced by temperature, humidity, and dirt.



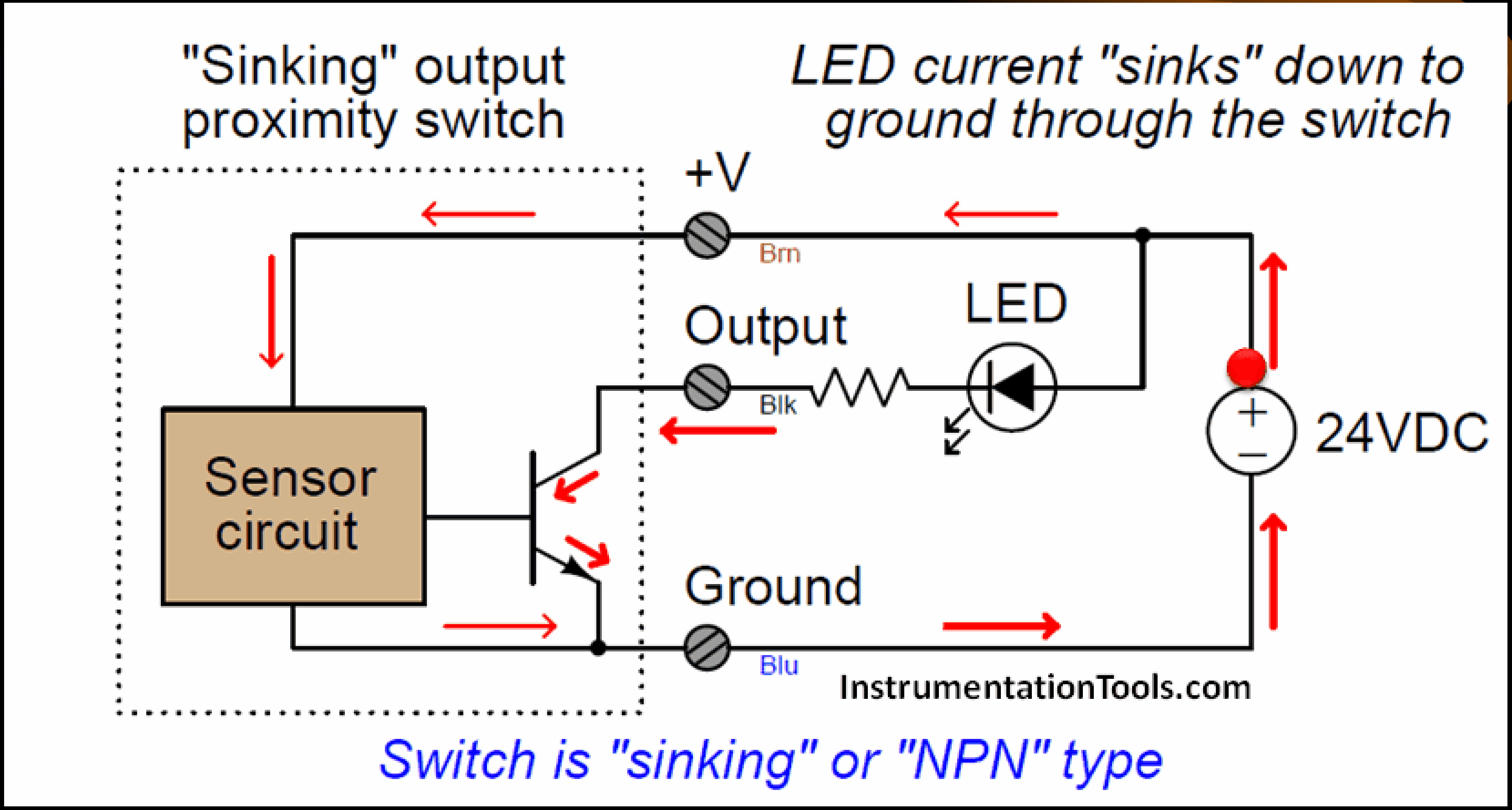

Oscillator
Trigger Circuit
Output Switching Device
Target
Plate

There are two categories of targets that capacitive sensors can detect the first being conductive and the second is non-conductive. Conductive targets include metal, water, blood, acids, bases, and salt water. These targets have a greater capacitance and a targets dielectric strength is immaterial.

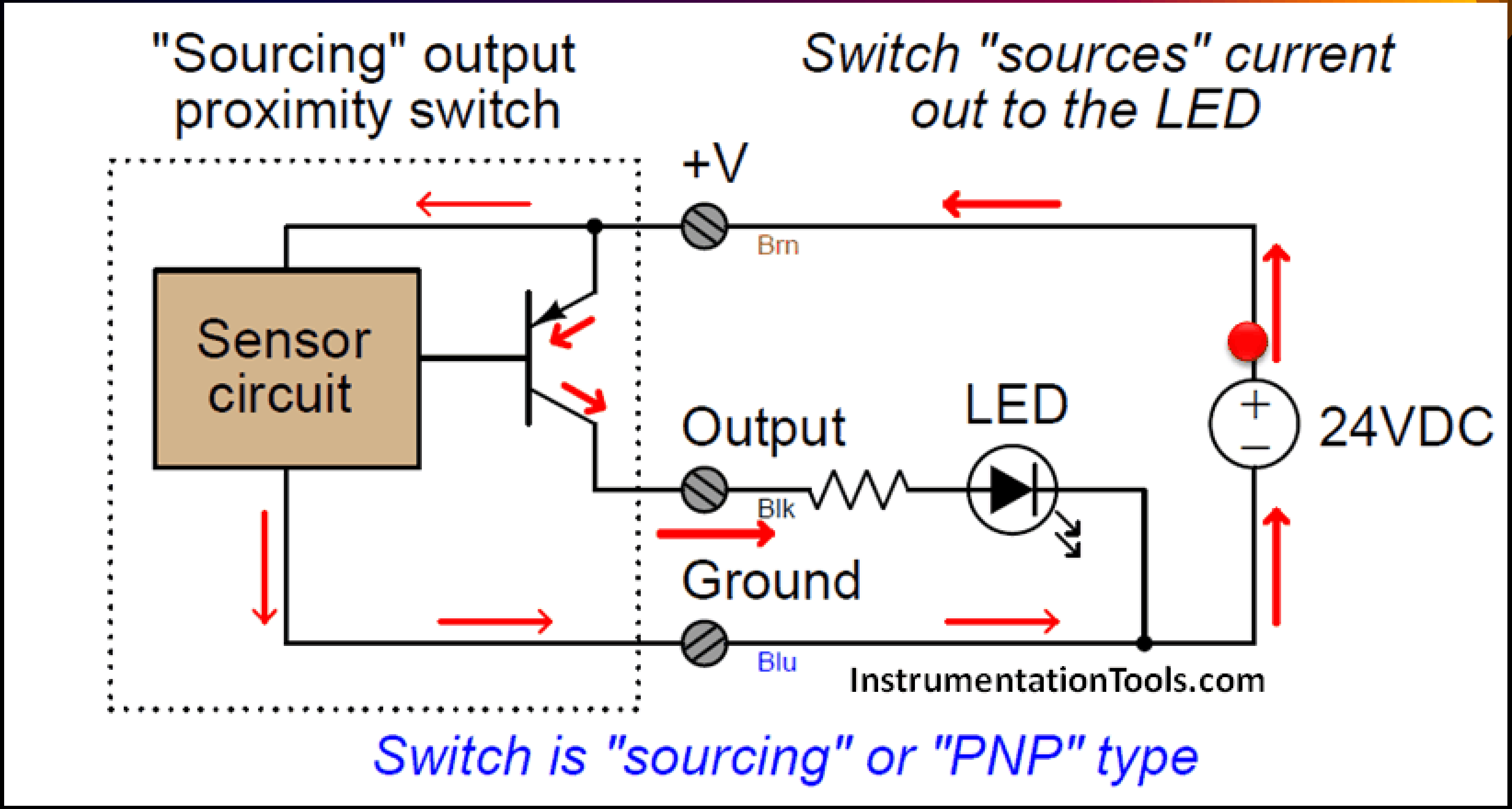
The non-conductive target category acts like an insulator to the sensors electrode. Materials with a high dielectric constant will have a longer sensing distance.

A typical sensing range for capacitive proximity sensors is from a few millimeters up to about 1 inch. (or 25 mm), and some sensors have an extended range up to 2 inch.

Proximity Switch NPN Type



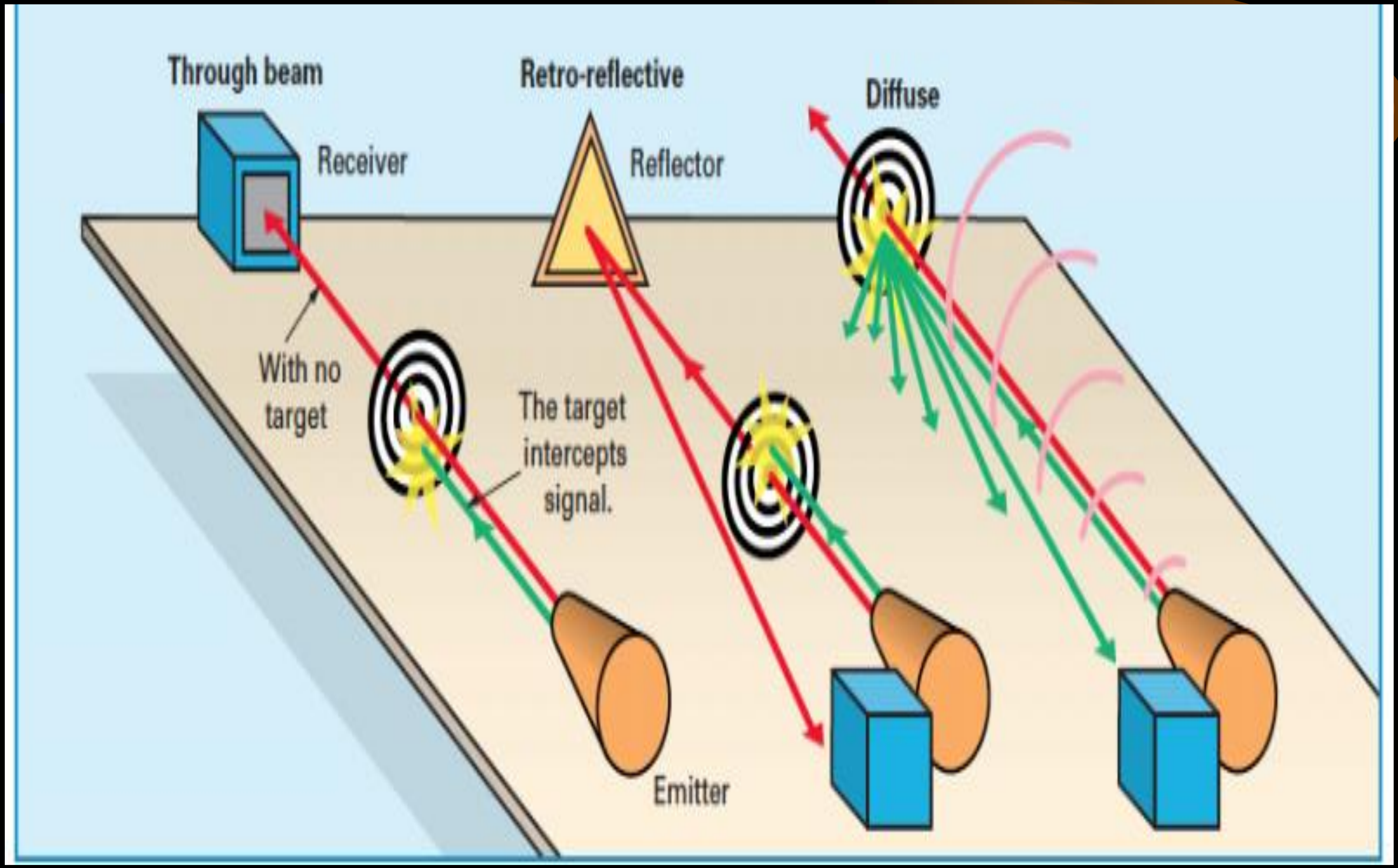
Proximity Switch PNP Type



Photoelectric Proximity Sensors

Photoelectric sensors are so versatile that they solve the bulk of problems put to industrial sensing. They detect targets less than 1 mm in diameter, or from 60 m away. All photoelectric sensors consist of a few of basic components: each has an emitter light source (Light Emitting Diode, laser diode), a photodiode or phototransistor receiver to detect emitted light, and supporting electronics designed to amplify the receiver signal. The emitter, sometimes called the sender, transmits a beam of either visible or infrared light to the detecting receiver.
Identifying their output is thus made easy; darkon and light-on classifications refer to light reception and sensor output activity. If output is produced when no light is received, the sensor is dark-on. Output from light received, and it’s light-on.

Photoelectric Proximity Sensors



Through-beam

Separate emitter and receiver units are required for a thru-beam sensor. The units are aligned in a way that the greatest possible amount of pulsed light from the transmitter reaches the receiver. An object (target) placed in the path of the light beam blocks the light to the receiver, causing the receiver's output to change state. When the target no longer blocks the light path the receiver's output returns to its normal state. Thru-beam is suitable for detection of opaque objects. It cannot be used to detect transparent objects. In addition, vibration can cause alignment problems.

Despite its reliability, through-beam is the least popular photoelectric setup. The purchase, installation, and alignment of the emitter and receiver in two opposing locations, which may be quite a distance apart, are costly and laborious. The maximum sensing range is 300 feet.

Retro-reflective

Reflective and retroreflective scan are two names for the same Retroreflective Scan technique. The emitter and receiver are in one unit. Light from the emitter is transmitted in a straight line to a reflector and returns to the receiver. A normal or a corner-cube reflector can be used. When a target blocks the light path the output of the sensor changes state. When the target no longer blocks the light path the sensor returns to its normal state. The maximum sensing range is 35 feet.

Retroreflective scan sensors may not be able to detect shiny and Shiny Objects objects. Shiny objects reflect light back to the sensor. The sensor is unable to differentiate between light reflected from a shiny object and light reflected from a reflector.

Diffuse

The emitter and receiver are in one unit. Light from the emitter strikes the target and the reflected light is diffused from the surface at all angles. If the receiver receives enough reflected light the output will switch states. When no light is reflected back to the receiver the output returns to its original state. In diffuse scanning the emitter is placed perpendicular to the target. The receiver will be at some angle in order to receive some of the scattered (diffuse) reflection. Only a small amount of light will reach the receiver, therefore, this technique has an effective range of about 40”.

Use of proximity sensor as

- Accelerometer and
- Vibration sensor

Electromagnetic flow meter

Electromagnetic flow meters are particularly suitable for the flow measurements of slurries, sludge and any electrically conducting liquid.

Electromagnetic flow meters detect flow by using Faraday's Law of induction.

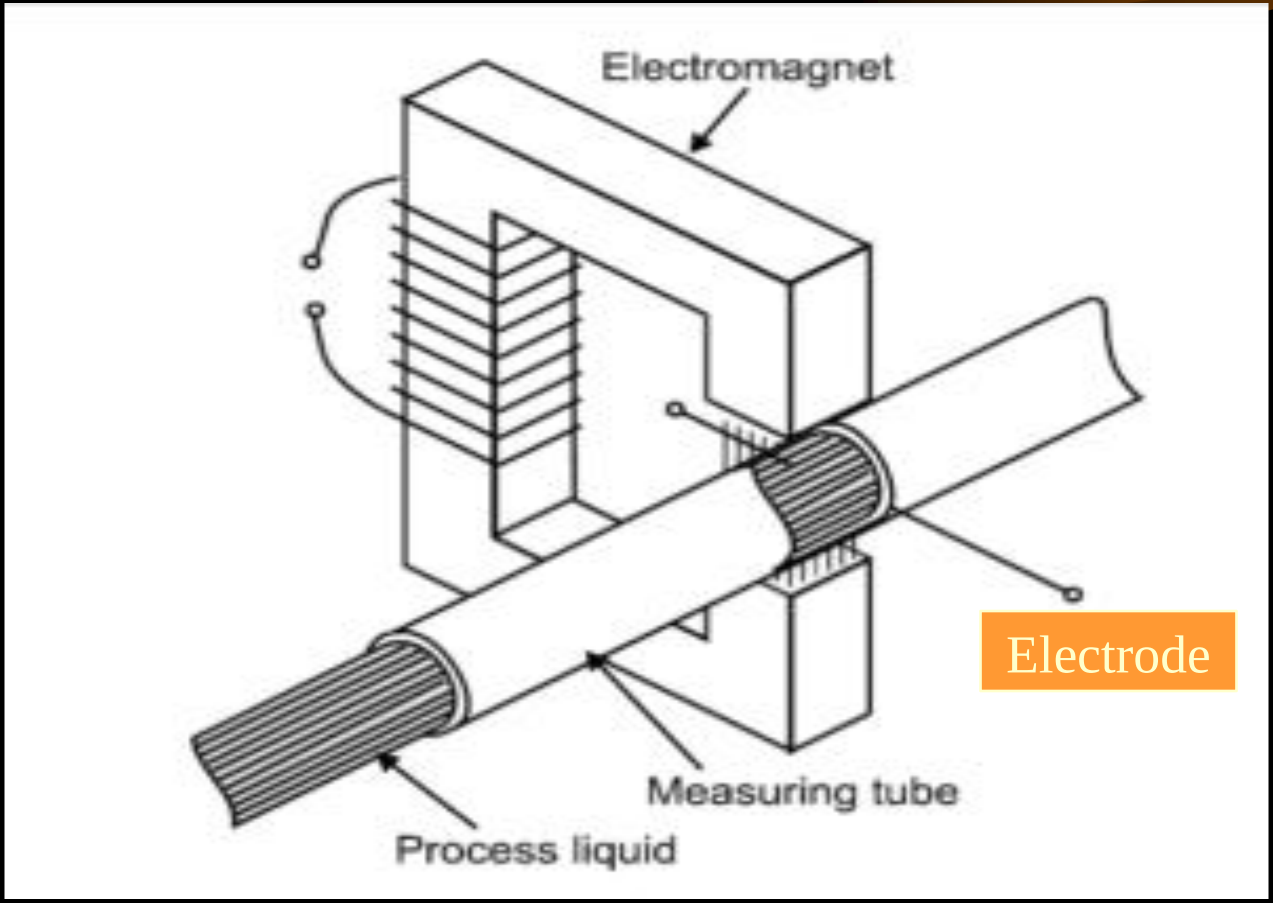
Faraday’s law of induction:

This law state that if a conductor of length **l**(m) is moving with a velocity **v**, perpendicular to a magnetic field of flux density **B** (Tesla), then the induced voltage **E**, across the end of the conductor can be expressed by

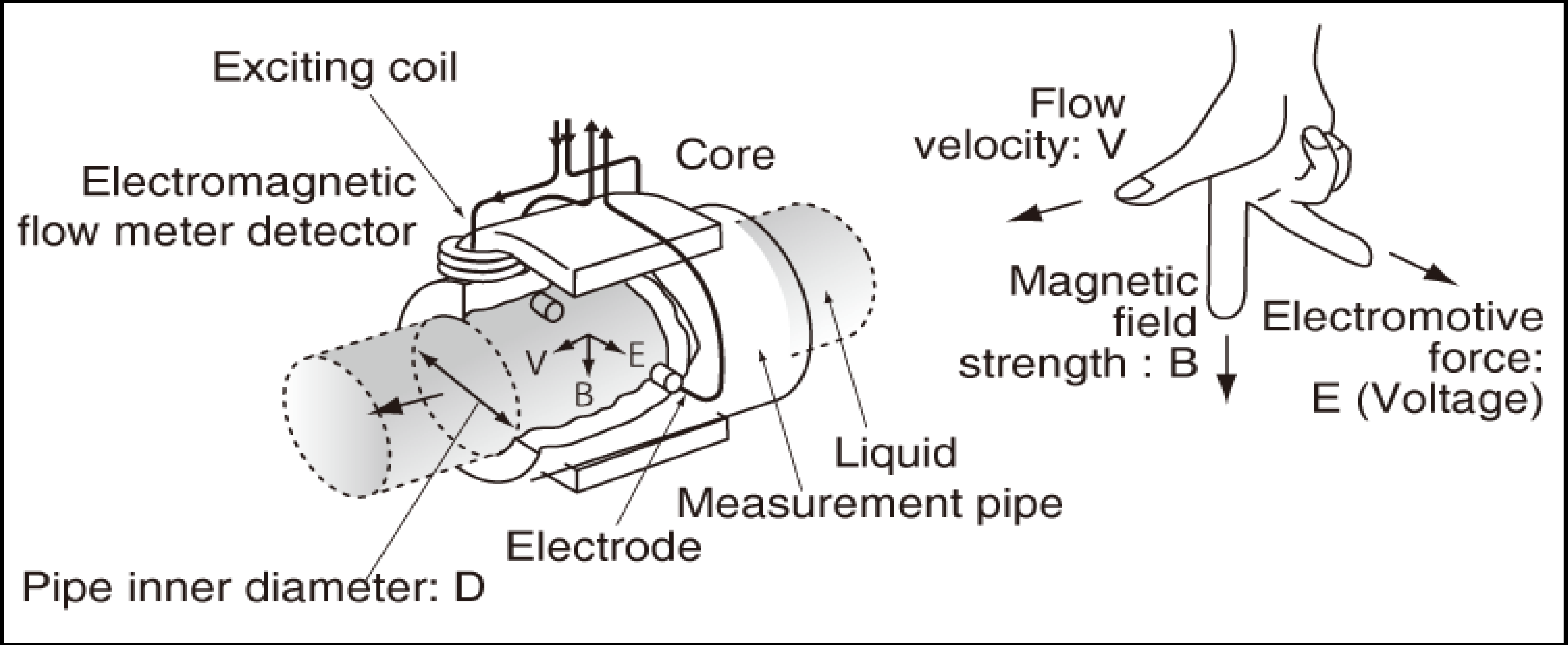
$$\mathbf{E = Blv}$$

Electromagnetic flowmeter uses Faraday's law of electromagnetic induction to determine the flow of a liquid through a pipeline. The magnetic flow meters are also known as magmeters.

Electrically conductive process fluid is passed through a magnetic field induced by coils that are positioned around a section of pipe.



The process fluid is electrically insulated from the pipe with a suitable lining, in the case of a metal pipe, so that the generated voltage is not dissipated through the pipeline. The electrodes are located in the pipe and a voltage is generated across these electrodes that are directly proportional to the average velocity of the liquid passing through the magnetic field.



The coils are energised with ac power or pulsed dc voltage, so consequently the magnetic field and resultant induced voltage respond accordingly. The generated voltage is protected from interference, amplified and converted into a dc current signal by the transmitter.

The magnetic flowmeter measures volume rate at the flowing temperature independent of the effects of viscosity, density, pressure or turbulence.

Advantages:

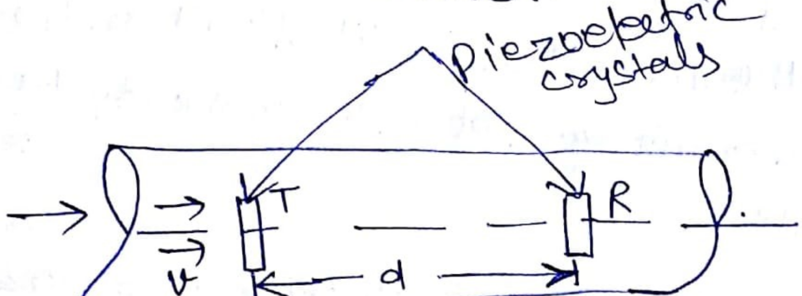
- No restrictions to flow.
- No pressure loss.
- No moving parts.
- Good resistance to erosion.
- Independent of viscosity, density, pressure and turbulence.
- Good accuracy.
- Bi-directional.
- Large range of flow rates and diameters

Disadvantages:

- Expensive.
- Most require a full pipeline.
- Limited to conductive liquids.

Ultrasonic flow meter:- It is a type of flow meter that measures the velocity of a fluid with ultrasound to calculate volume flow. Using ultrasonic transducer, the flow meter can measure the avg. velocity along the path of emitted beam.

Ultrasonic transducer for flow rate consist of two piezoelectric crystals in the liquid or gas separated by a distance. One of crystal acts as a transmitter and the other as a receiver.



The transmitter emits an Ultrasonic pulse which is received at the receiver a time Δt later.

The transit time in the direction of flow is

$$\Delta t_1 = \frac{d}{C+v}$$

d = distance b/w transmitter & receiver; m
C = Velocity of sound propagation in medium
v = linear velocity of flow, m/s

When the signal is travelling in the opposite direction against the flow

$$\Delta t_2 = \frac{d}{C+v}$$

Similarly a Sinusoidal signal of freq f Hz travelling in the flow direction has a phase shift (13)

$$\Delta\phi_1 = \frac{2\pi f d}{C+V} \text{ rad}$$

that travelling against the direction of flow has a phase shift of

$$\Delta\phi_2 = \frac{2\pi f d}{C-V} \text{ rad}$$

A system which can be used external to the pipe carrying the liquid. T and R are respectively transmitting and receiving crystals. They are either pressed to the exterior of pipe or are immersed in the liquid so that the signal is transmitted through the liquid.

The difference in transit times is

$$\Delta t = \Delta t_2 - \Delta t_1 = \frac{d}{C-V} - \frac{d}{C+V}$$

$$= \frac{2dV}{C^2 - V^2}$$

$C >> V$

$$\Delta t \approx \frac{2dV}{C^2}$$

Hence, time Δt is linearly proportional to flow velocity v. This system, though gives a linear relationship, is subjected to an error on account of uncertainty of the value of c

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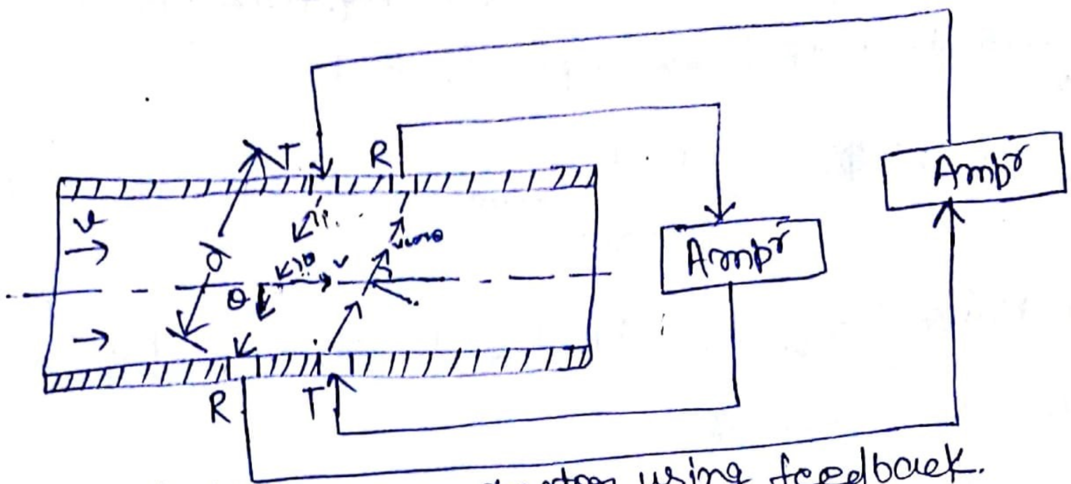

Ultrasonic meter using feedback.

Two self excited oscillating systems because of using the received pulses to trigger the transmitted pulses in feedback arrangement. The pulse repetition freq in the forward propagating loop is $1/\Delta t_1$ while that in the backward loop is $1/\Delta t_2$

$$\Delta t_1 = \frac{d}{c + v\cos\theta}$$

$$f_1 = \frac{c + v\cos\theta}{d}$$

$$\Delta t_2 = \frac{d}{c - v\cos\theta}$$

$$f_2 = \frac{c - v\cos\theta}{d}$$

difference in freq.

$$\Delta f = f_1 - f_2 = \frac{2v\cos\theta}{d}$$

The o/p is independent of c. Also the o/p is linearly proportional to the flow velocity v. The advantage are that there is no obstruction to the flow, they are insensitive to variations in viscosity, density & temp.

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Doppler Effect

Doppler Effect refers to the change in wave frequency during the relative motion between a wave source and its observer. It was discovered by Christian Johann Doppler.

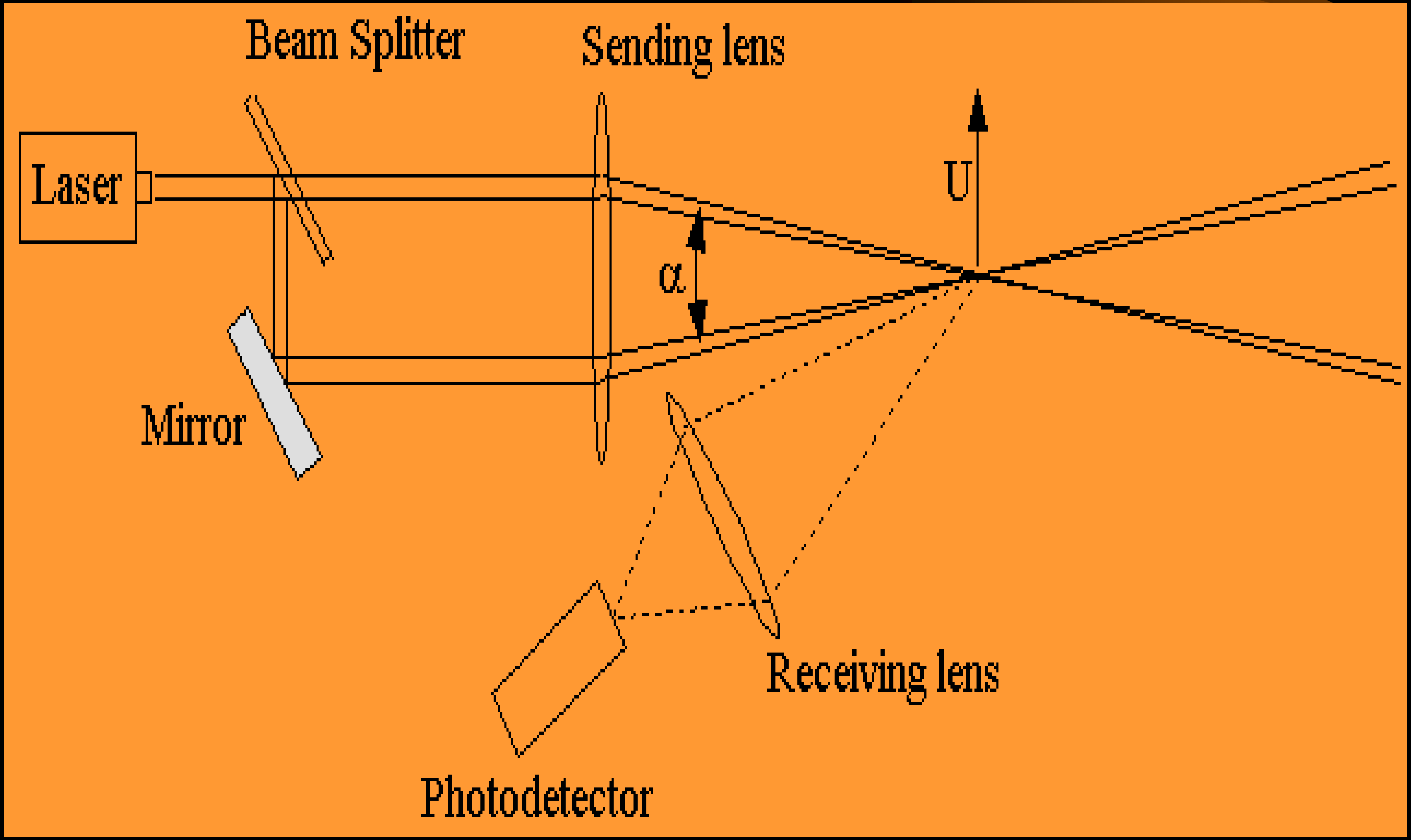
Doppler Effect works on both light and sound objects. For instance, when a sound object moves towards you, the frequency of the sound waves increases, leading to a higher pitch. Conversely, if it moves away from you, the frequency of the sound waves decreases and the pitch comes down. There are various applications of Doppler Effect.

- Sirens
- Astronomy
- Radars
- Medical imaging and blood flow management
- Flow management
- Velocity profile management
- Satellite communication
- Audio
- Vibration measurement

Laser Doppler Velocimetry

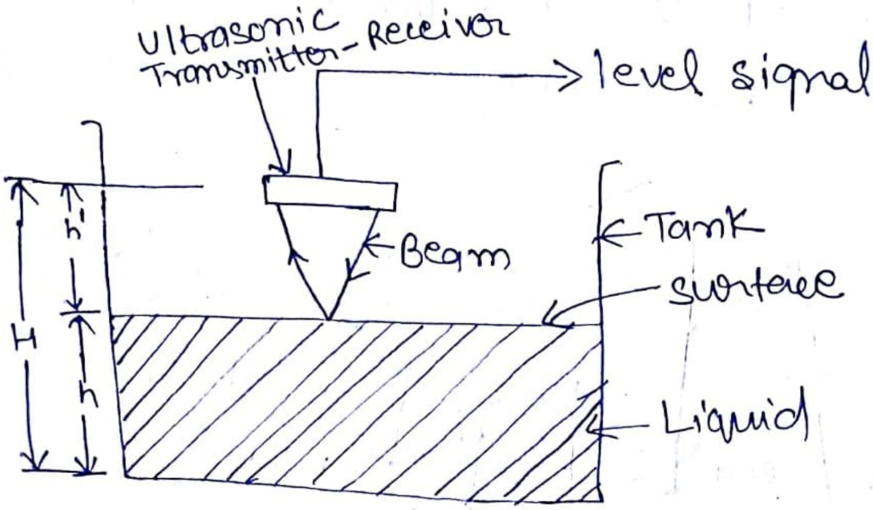
It is also termed as Laser Velocimetry (LV) or Laser Doppler Anemometry (LDA). It is used to measure the fluid velocities by detecting frequency shift of laser light that has been scattered by small particles moving with the fluid. The operating principle of LDV is based on sending a highly coherent monochromatic light beam towards a fluid particle. The monochromatic light beam has same wavelengths and all the waves are in phase. The light reflected from the fluid particle wave will have different frequencies and the change in frequency of reflected radiation due to *Doppler effect* is the measure of fluid velocity. A basic configuration of a LDV setup is shown in Fig. The laser power source is normally a helium-neon/argon-ion laser with a power output of 10mW to 20W. The laser beam is first split into two parallel beams of equal intensity by a mirror and beam-splitters. Both the beams pass through a converging lens that focuses the beams at a point in the flow. The small fluid volume where the two beams intersect is the measurement volume where the velocity is measured. Typically, it has a dimension of 0.1mm diameter and 0.5mm long.

Finally, the frequency information of scattered and unscattered laser light collected through receiving lens and photo-detector, is converted to voltage signal. Subsequently, flow velocity (U) is calculated.



Measurement of liquid level:—

(i) Ultrasonic Method:—



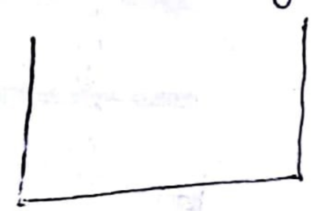
An Ultrasonic transmitter receiver can be mounted on the top of tank for measurement of level of either soids or liquids. The beam is projected downwards by the transmitter and is reflected by the surface of liquid contained in the tank. The beam is received by the receiver. The time taken by the beam is a measure of the distance travelled by the beam. Therefore, the time 't' b/w transmitting and receiving a pressure pulse is proportional to the distance h' b/w the Ultrasonic set and surface of the contents of the tank

$\boxed{t \propto h' \propto (H-h)}$ $h = H - h'$

Capacitive Methods:-

① Variable Area Method:- The variable area capacitor transducer is used for measurement of levels of both solids and liquids. The electrical conducting container containing the materials is used as one connection point of the transducer. The other point is a metal rod completely covered by insulating material inside the container. The insulating material acts as the dielectric medium and the capacitance varies linearly with the height of the material.

$$C = \frac{2\pi \epsilon h}{\log_e (d_2/d_1)} \; F$$



where ϵ = permittivity of the insulator F/m,

d_1 = diameter of the metal rod; m

d_2 = external diameter of insulater

h = height of material

The container should be earthed to avoid any danger of electric shock to the personnel and to prevent any errors due to external metallic objects.

② Capacitive Voltage Divider Method:- The conductivity of liquid is high its surface can be used as one electrode of a capacitor. The other electrode is a fixed reference plate parallel to the surface of the liquid. This uses an auxiliary electrode P_1 placed at a fixed distance above the reference electrode P_2.

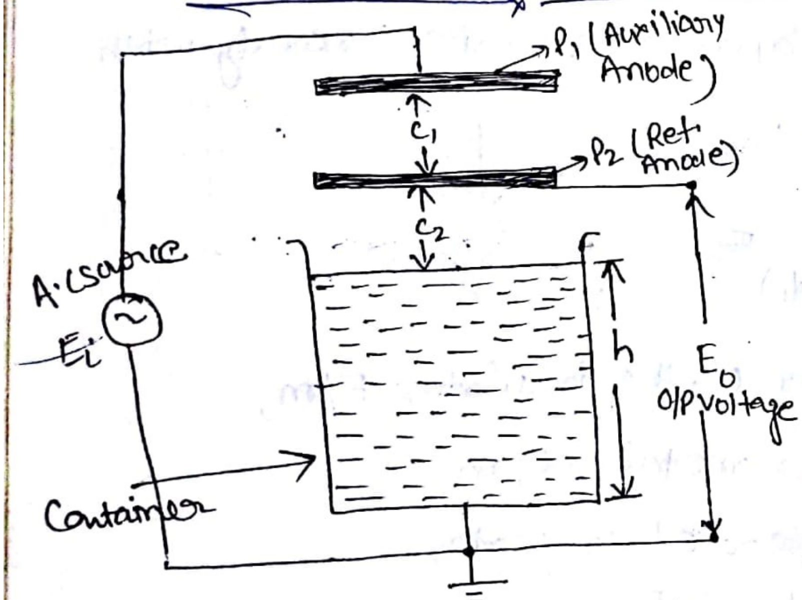
The two electrodes P_1 and P_2 are electrically insulated each other. An a.c voltage is applied b/w the liquid, the electrode P_1

Potential of electrode P_2 with respect to earth $E_0 = E_i \cdot \frac{C_1}{C_1 + C_2}$

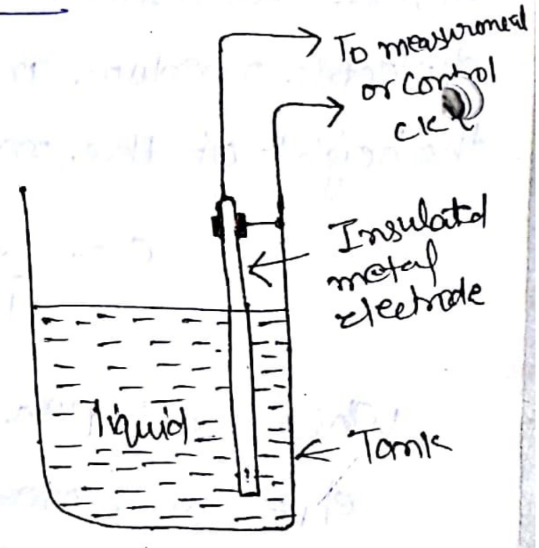
Capacitance C_2 is inversely proportional to the distance b/w the liquid surface and P_2. Thus the O/P voltage decreases with rise of liquid level and therefore the relationship b/w them is non-linear.

$$C_2 = \frac{\epsilon A}{d}$$

③ Variable Dielectric Constant Method:-



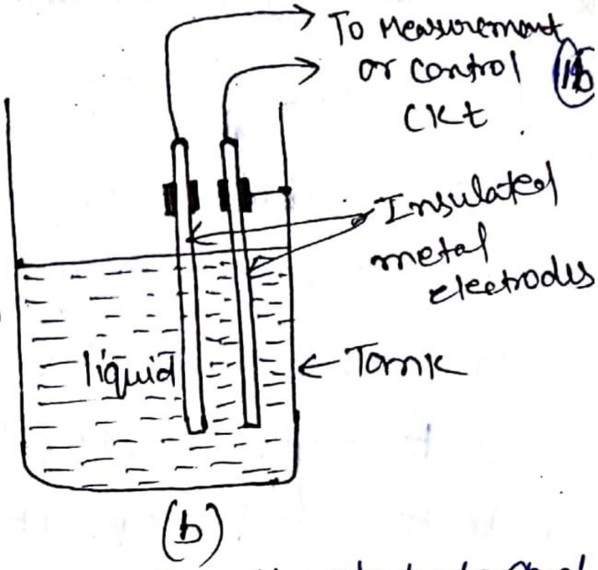
Capacitive voltage divider method for measurement of level of high conductivity liquid



Measurement of liquid level using capacitive Transducer

(9)

a liquid is non conducting it can be used as a dielectric in a capacitor. The measurement of liquid level for non conducting liquids are explained below



(b)

An insulated electrode firmly fixed near and parallel to the metal wall of the tank. If the liquid is non-conductive, the electrode and the tank wall from the plates of a parallel plate capacitor with the liquid in b/w them acting as the dielectric. If the liquid is conductive the rod and the liquid form the plates of the capacitor, and the insulation b/w. them is the dielectric.

The capacitance of this capacitor depends among other factors upon the hieght of the dielectric b/w the plates. The greater the height, the greater the capacitance. The lesser the height the smaller is the capacitance. Thus, the capacitance is α to the height of the liquid in the tank.

Where the tank is not of metal, two parallel insulated rods (electrodes), kept at a fixed distance apart are used. The two rods act as two plates of a parallel plate of capacitor. The higher the liquid level; the greater is the capacitance.

Concept of thermal Imaging:→

Thermal imaging is a method of improving visibility of objects in a dark environment by detecting the objects infrared radiation and Creating an image based on that information.

Thermal imaging, near-infrared illumination, lowlight imaging and are the three most commonly used night vision technologies. Unlike the other two methods, thermal imaging works in environments without any ambient light. Like near-infrared illumination, thermal imaging can penetrate obscurants such as smoke, fog & haze.

working:— All objects emit infrared energy (heat) as a function of their temperature. The infrared energy emitted by an object is known as its heat signature. In general, the hotter an object is, the more radiation it emits. A thermal imager (also known as thermal camera) is essentially a heat sensor that is capable of detecting tiny differences in temperature. The device collects the infrared radiation from objects in the scene & creates an electronic image based on information about the temperature differences. Because objects are rarely precisely the same temp. as other objects around them, a thermal camera can detect them and they will appear as distinct in a thermal image.

Scanned by CamScanner

Concept Of Thermal Imaging →

Thermal imaging concept is used in thermal Image Camera

In thermal Image camera there are 3 main components

1. Main lense (Germanium lense)

Germanium lense is used to pass Infrared light because Germanium Material bandgap (0.7ev) is greater than incoming light energy

* Filter is used to passes only IR light

2. IR sensor:- IR sensor used to sense Infrared light

Indium Gallium Arsenide (InGaAs), Indium phosphate (InP) materials are used in IR sensor

3. Image Processing Unit:- From IR sensor Unit current passes towards image processing unit then image will be displayed.

There are two types of thermal imaging camera

Types:-

1. Uncooled:-
   - No cooling is required
   - Image sensor works on normal temperature
   - Low sensitivity.
   - work on short distance

   uses → Small projects, Equipment functioning

2. Cooled:-
   - Cyrogenic cooling is required for cooling of sensor
   - Highly sensitive to measure 0.1°C temp variation
   - work on 300M distance.
   - costly compare to uncooled

   uses → Military, Industry, Law & Enforcement