ENGINEER BEING

RTD (Resistance Temperature Detector)

Define different sensors used for measuring temperature. 10M 2021-22

$\{T \uparrow R \uparrow\}$

The RTD stands for Resistance Temperature Detector. The RTD is defined as the resistor which is used for measuring the temperature.

The resistance of the conductor change with temperature and this property of conductors is used in the RTD for measuring the temperature.

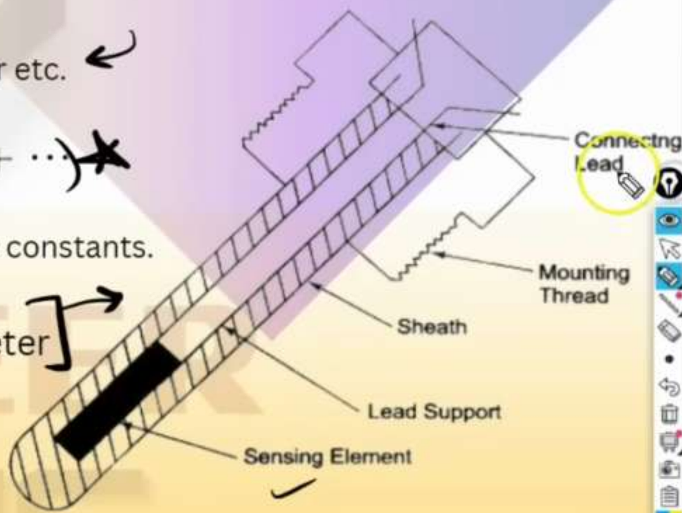
(+ve)

The RTD is made of pure metals like platinum, nickel, copper etc.

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

Where, Ro= resistance at temperature T=0 and α1, α2, α3... are constants.

Industrial platinum resistance thermometer

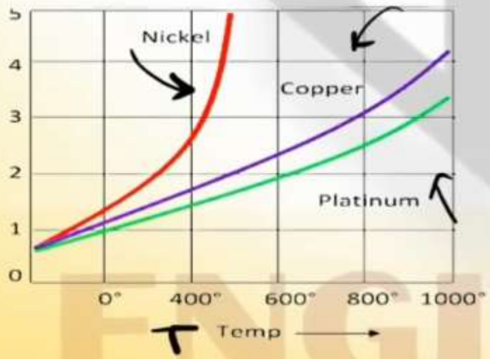


$\{T\uparrow \quad R\uparrow\}$ $\{\rho\uparrow\}$

The requirements of conductor material to be used in these thermometers are :

1) The change in resistance of material per unit change in temperature should be as large as possible.
2) The material should have a high value of resistivity so that a minimum volume of material is used for the construction of RTD.
3) The resistance of the materials should have a continuous and stable relationship with temperature

R/R_0



Characteristics of materials used for resistance thermometers

{RTD}

{Pt.}

high stability

withstand high temp.

2. Thermistors *

(semiconductor)
(-ve)
T↑ R↓

It is a temperature sensitive device

The thermistor is made of the semiconductor material that means their resistance lies between the conductor and the insulator.

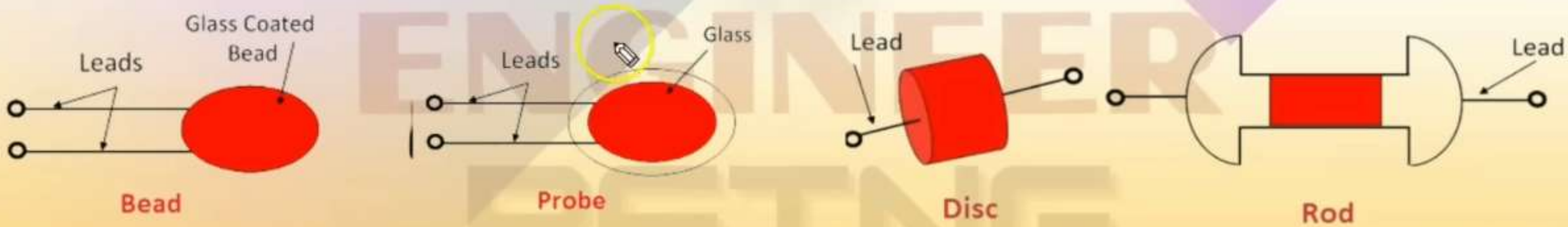
Types of Thermistors

The thermistor is classified into types:

Negative temperature coefficient and the positive temperature coefficient thermistor.

Construction of Thermistors

The thermistor is made with the sintered mixture of metallic oxides like manganese, cobalt, nickel, copper, iron, uranium, etc. It is available in the form of the bead,rod and disc.



The relation between the absolute temperature and the resistance of the thermistor is

$$\left\{ R_{T1} = R_{T2}\, exp\left[\beta\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right] \right\}$$

T↑ R↓

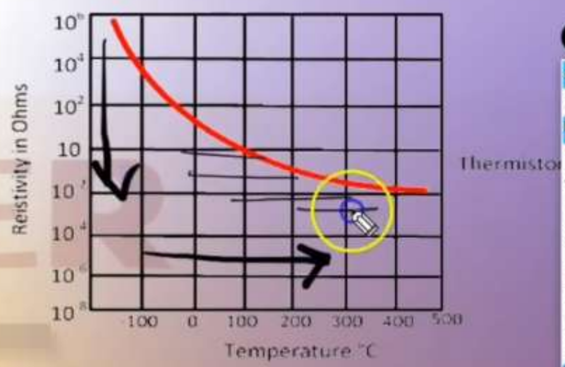
Where,

RT1 – Resistance of the thermistor at absolute temperature T1 in Kelvin.

RT2 – Resistance of the thermistor at absolute temperature T2 in Kelvin.

β – a constant depending on the material of thermistor

The graph shows that the thermistor has a negative temperature coefficient, i.e., the temperature is inversely proportional to the resistance. The resistance of the thermistor changes from 10^-5 to 10^-2 at the temperature between -100C to 400C.



ENGINEER BEING

3. Thermocouple {emf}

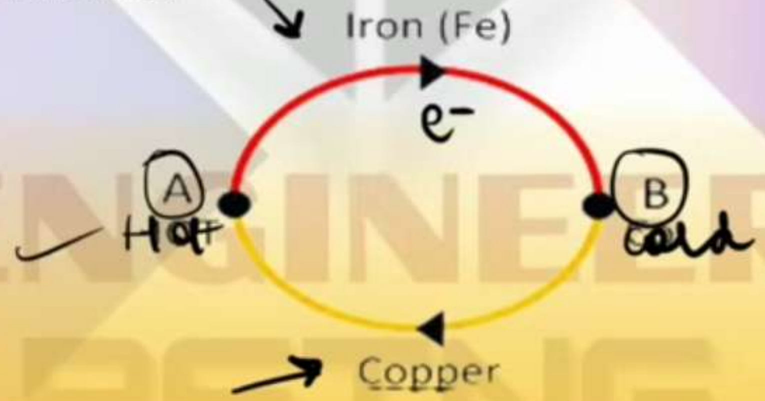
RTD Thermistor

It is a type of sensor used for measuring the temperature in the form of an electric current or the EMF.

Working Principle of Thermocouple

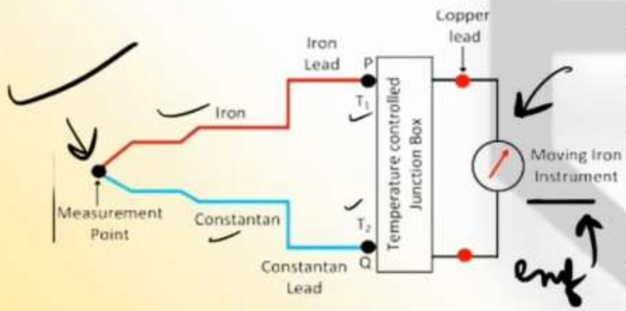
- The working principle of the thermocouple depends on **See back effect.**

Seebeck Effect – The Seebeck effect occurs between two different metals. When the heat provides to any one of the metal, the electrons start flowing from hot metal to cold metal. Thus, direct current induces in the circuit



Working of Thermocouple

The circuit consists two dissimilar metals. These metals are joined together in such a manner that they are creating two junctions. The metals are bounded to the junction through welding.



Let the P and Q are the two junctions of the thermocouples. The T1 and T2 are the temperatures at the junctions. As the temperature of the junctions is different from each other, the EMF generates in the circuit.
If the temperatures of the junction become unequal, the potential difference induces in the circuit. The magnitude of the EMF induces in the circuit depends on the types of material used for making the thermocouple. The total current flowing through the circuit is measured through the measuring devices

The EMF induces in the thermocouple circuit is given by the equation $E = a\,\Delta\theta$

$$\boxed{E = a(\Delta\theta) + \cancel{b(\Delta\theta)^2}}$$

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

Δθ – temperature difference between the hot thermocouple junction and the reference thermocouple junction. a, b – constants

Popular Thermocouples Types

Thermocouple type	Overall range	Typical accuracy*	Comments
Type B (Platinum / Rhodium)	100 to 1800	5 °C (at 1000°C)	Suited for high temperature measurements. Unusually, type B thermocouples give the same output at 0 °C and 42 °C. This makes them useless below 50 °C.
Type E (Chromel / Constantan)	-200 to 900	1.7 °C	Type E has a high output (68 µV/°C) which makes it well suited to low temperature (cryogenic) use. Another property is that it is non-magnetic.
Type J (Iron / Constantan)	-40 to 760	2.2 °C	Limited range makes type J less popular than type K. J types should not be used above 760°C as an abrupt magnetic transformation will cause permanent decalibration.
Type K (Chromel / Alumel)	-200 to 1300	2.2 °C	Type K is the 'general purpose' thermocouple. It is low cost and popular. Sensitivity is approx 41 µV/ °C. Use type K unless you have a good reason not to.

Advantages of Thermocouple

1) The thermocouple is cheaper than the other temperature-measuring devices.
2) The thermocouple has a fast response time.
3) It has a wide temperature range

Disadvantages of the Thermocouples

1) The thermocouple has low accuracy.
2) The recalibration of the thermocouple is difficult.

Application of Thermocouple

➢ In Industry, thermocouples are used for measuring temperatures of industrial furnaces.

➢ In Medical, extremely small size thermocouple probes are used for measuring internal body temperature.

➢ Using extension leads and compensating cables, long transmission distances for temperature measurement are possible.

{$\vec{B}$ → emf}

Hall Effect Transducers

[one form energy → electrical form]

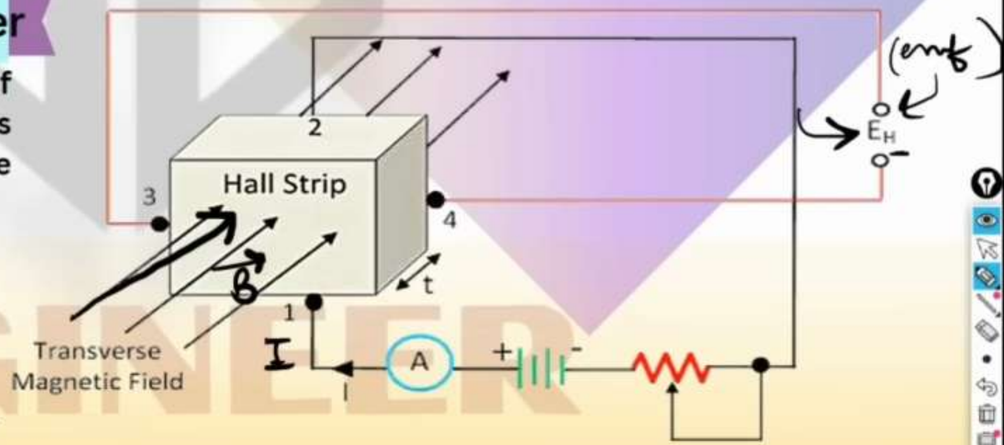
The hall effect element is a type of transducer used for measuring the magnetic field by converting it into an emf.

The transducer converts the magnetic field into an electric quantity which is easily measured by the analogue and digital meters.

hall voltage (emf)

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 output voltage is,

$$\boxed{E_H = K_H I B/t}$$

where,

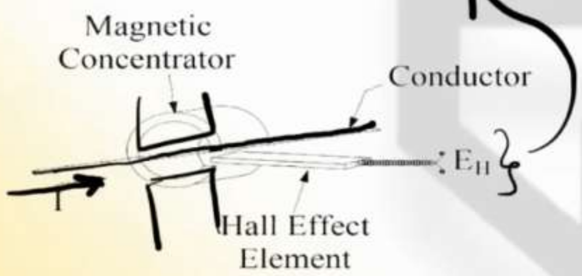
$$K_H - Hall\ effect\ coefficient\ ;\ \frac{V-m}{A-Wbm^{-2}}$$

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

The I is the current in ampere and the B is the flux densities in Wb/m²

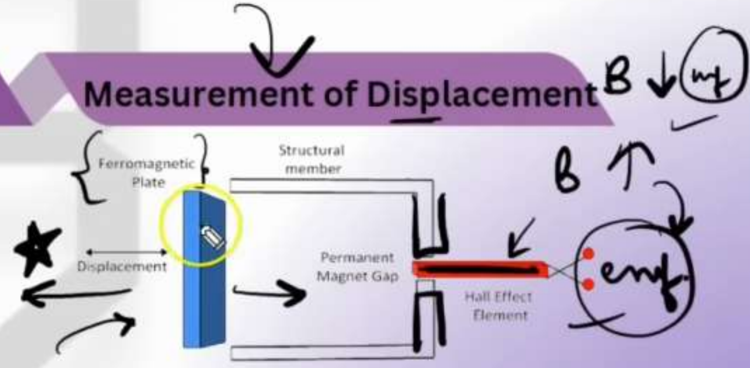
Applications of Hall Effect Transducer

Measurement of Current



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.

Measurement of Displacement



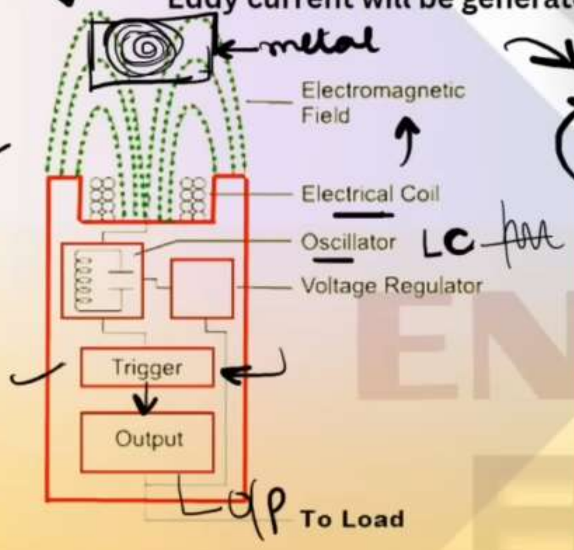
Measurement of Displacement Using Hall Efect Transducer

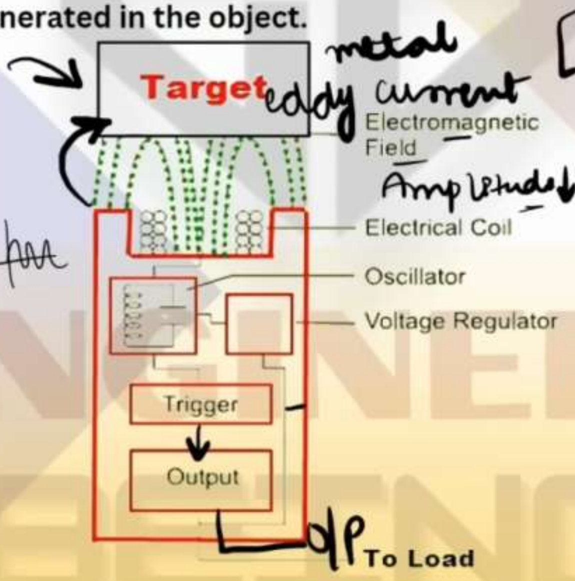
The Hall effect element measures the displacement of the structural element. For example – Consider the ferromagnetic structure which has a permanent magnet. The hall effect transducer placed between the poles of the permanent magnet. The magnetic field strength across the hall effect element changes by changing the position of the ferromagnetic field

1. Inductive proximity sensor

1. The inductive proximity sensor circuit is used for detecting the metal objects.
2. Inductive proximity sensors has four major components: coil, oscillator, trigger and output.
3. Inductive Proximity sensor work on the principle of Faraday law of induction which states that when an electrically conducting object is placed in a time varying magnetic field and electric current called Eddy current will be generated in the object.

Explain the working of Inductive type Proximity sensors 10M 2020-21 or Define different types of Proximity sensors 10M 2021-22





When the oscillating coil is supplied with AC ,the varying magnetic field is generated. When the target object reaches to the to this electromagnetic field, some of the electromagnetic energy is transferred to the object and eddy the current will be generated in the coil which reduces the intensity of magnetic field. this reduces amplitude of EM field and trigger circuit senses the change and output is generated.

Proximity Sensor Circuit 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

{metal object} *

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 sensor

A capacitive sensor acts like a simple Parallel Plate Capacitor.

They are of 2 types : Dielectric type and Conductive type.

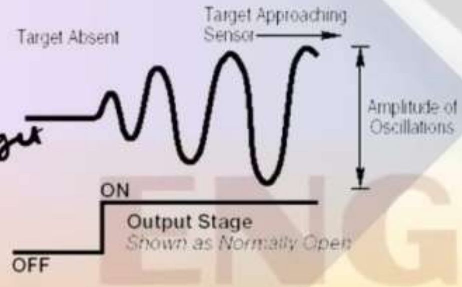
metallic / non metallic

1. Dielectric Type can detect any target that has dielectric constant greater than air. When a target with capacitance greater than air comes near sensor, the C increases, Amplitude of oscillator increases and output is generated.

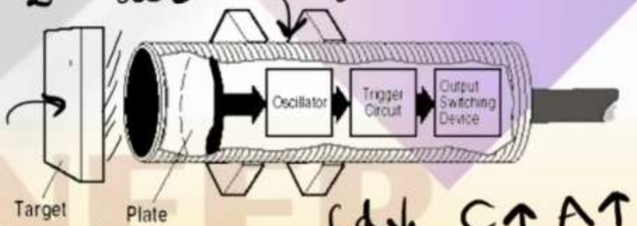
2. In conductive Type, A metal plate in the sensing face of the sensor is electrically connected to an internal oscillator circuit and the target to be sensed acts as the second plate of the capacitor. Unlike an inductive sensor that produces an electromagnetic field a capacitive sensor produces an electrostatic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

$C = \frac{A \epsilon_0 k}{d}$ $\{ C \propto \frac{1}{d} \}$

(oscillator)



C↑ A↑ Target → O/P



2nd air

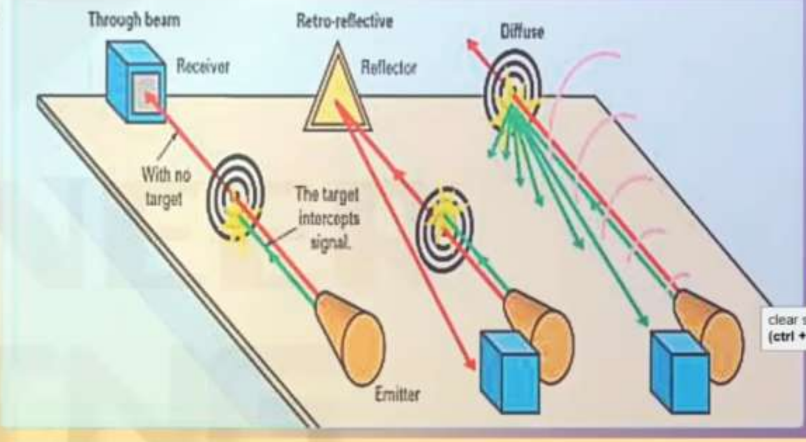
{d↓ C↑ A↑ → O/P}

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.

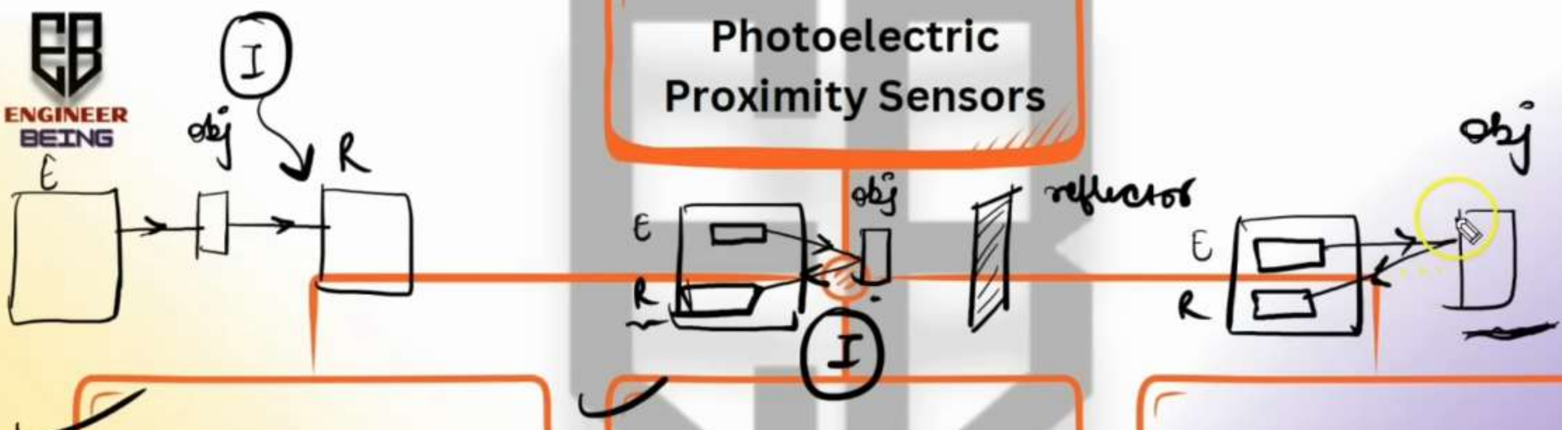
3. Photoelectric Proximity Sensors

- Photoelectric sensor consists of emitter and receiver. **Emitter for emitting the light and receiver for receiving the light.**
- Emitter converts electrical signal to light energy and emits a beam of either visible light or infrared light, **LED used as emitter**
- when light reflected by the sensing object it changes the amount of light that arrives at the receiver
- receiver detects change in the light and convert it into elctrical output usually **photodiode is used as receiver**. Detection circuit verifies light was emitted by its own emitter and sends signal to op circuit indicating that object is detected.

1. **Through-beam**
2. **Retro-reflective**
3. **Diffuse**



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.

Retro-reflective

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.

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.

ENGINEER BEING

Concept of Thermal Imaging

room

Temp.

(IR)

heat

IR → heat → electrical signal → camera → Img

Thermal imaging is a technology that captures the thermal energy emitted by objects and converts it into an image. This image shows the temperature distribution of objects, allowing us to see the heat emitted by objects in the scene.

A thermal camera is used to detect the long-wave **infrared radiation emitted by objects, which is converted into an electrical signal.** This signal is then processed by the camera to produce a thermal image.

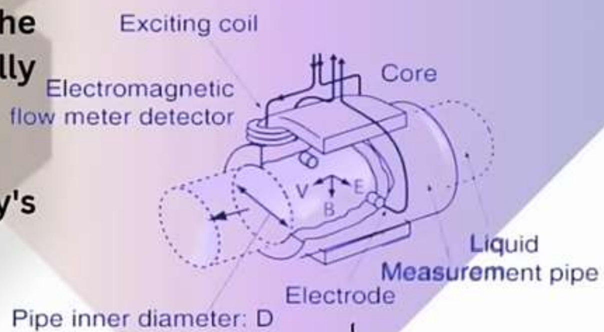
Thermal imaging cameras have a lens that focuses the incoming infrared radiation onto a **detector array**, typically made up of hundreds or thousands of individual detectors.

The electrical signals from the detectors are then processed to produce a thermal image, which is usually **color-coded to show different temperatures**.

2. Electromagnetic flow meter

liquid (conductive)
(v)

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

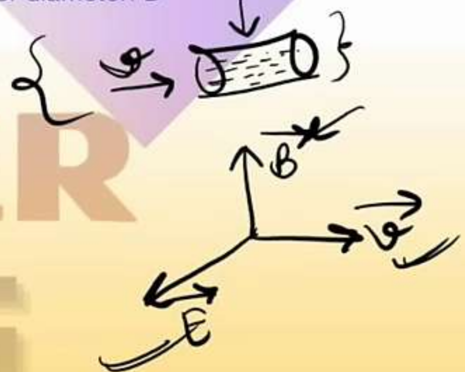


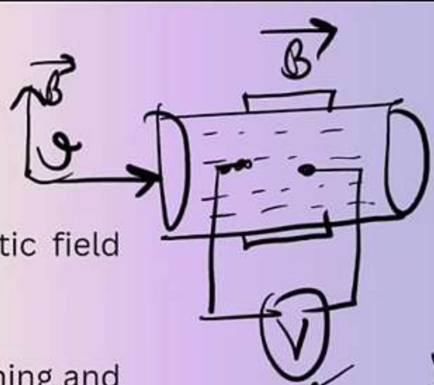
Electromagnetic flow meters detect flow by using Faraday's Law of induction.

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

$$\boxed{E = Blv}$$





$(E = Blv)$

(Emf)

$(V \propto$ flow rate$)$

The basic components of an EMF include a flow sensor, a magnetic field generator, and an electronic measuring system.

The flow sensor typically consists of a pipe with a non-conductive lining and two electrodes that are positioned on the outside of the pipe.

When a magnetic field is applied to the liquid in the pipe, the flow velocity of the liquid induces a voltage across the electrodes proportional to the flow rate.

The induced voltage is then measured by the electronic measuring system and used to calculate the flow rate.

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Advantages

- No restrictions to flow.
- No pressure loss.
- No moving parts.
- Good resistance to erosion.

ρ P

- Independent of viscosity, density, pressure and turbulence.
- Good accuracy.
- Bi-directional.
- Large range of flow rates and diameters.

Disadvantages

- Expensive.
- Limited to conductive liquids.

2. Ultrasonic flowmeter

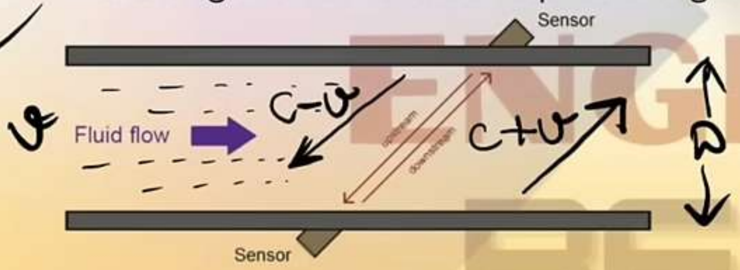
(Sound waves)

There are two main types of ultrasonic flowmeters: transit-time flowmeters and Doppler flowmeters.

Δt

1. Transit-time flowmeters:

This type of ultrasonic flowmeter uses the difference in the travel time of ultrasonic waves sent in the direction of fluid flow and against fluid flow to determine the fluid velocity. The difference in travel time is proportional to the fluid velocity, and this information can be used to calculate the flow rate. Transit-time flowmeters are most commonly used for measuring the flow of clean liquids and gases in pipelines.



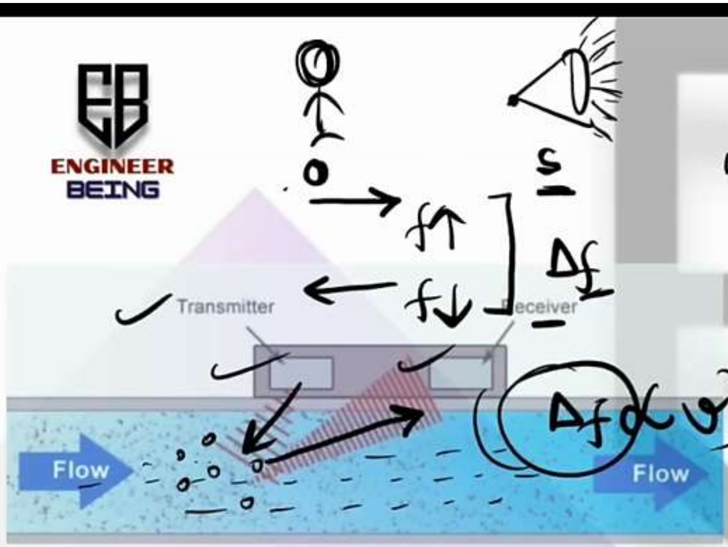
$$t_d = \frac{D}{c+v} \qquad t_u = \frac{D}{c-v}$$

$$\Delta t = t_u - t_d = \frac{D}{c-v} - \frac{D}{c+v}$$

$$D\left(\frac{c+v-c+v}{c^2-v^2}\right)$$

$$\boxed{\Delta t = \frac{2Dv}{c^2}}$$

Δf



$\Delta f \propto v$

$$\Delta f = \frac{2 v f \cos\theta}{c}$$

Doppler flowmeters:

- This type of ultrasonic flowmeter uses the Doppler effect to measure the velocity of fluid flow.
- Doppler ultrasonic flow meter uses a transducer to admit an ultrasonic beam into the stream of fluid flowing through a pipe.
- In order for a doppler flow meter to operate there must be solid particles or air bubbles moving through the stream that will reflect the ultrasonic beam .
- The motion of particles shifts the frequency of the beam which is received by a second transducer the frequency shift is linearly proportional to the flow rate .

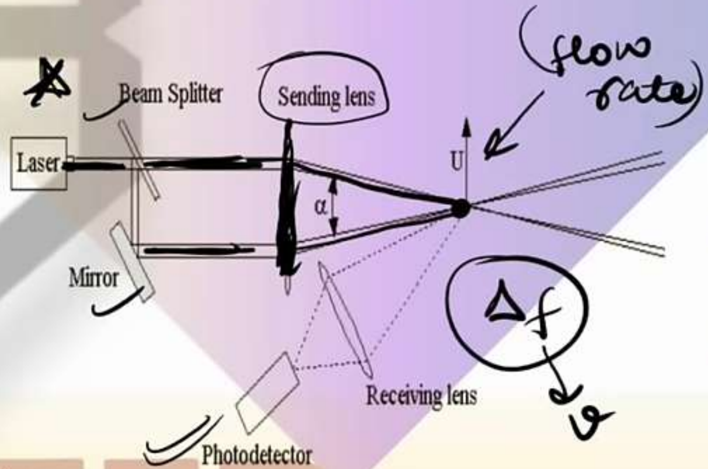
One advantage of ultrasonic flow sensors is that they are non-invasive. This makes them suitable for measuring the flow of fluids that are hazardous, corrosive, or otherwise difficult to access directly.

3. Laser Doppler Velocimetry (LDV)

(Light Amplification by Stimulated Emission of Radiation)

- **Laser Doppler Velocimetry (LDV) is a type of laser-based flow measurement technique that uses laser light to measure the velocity of a fluid.**

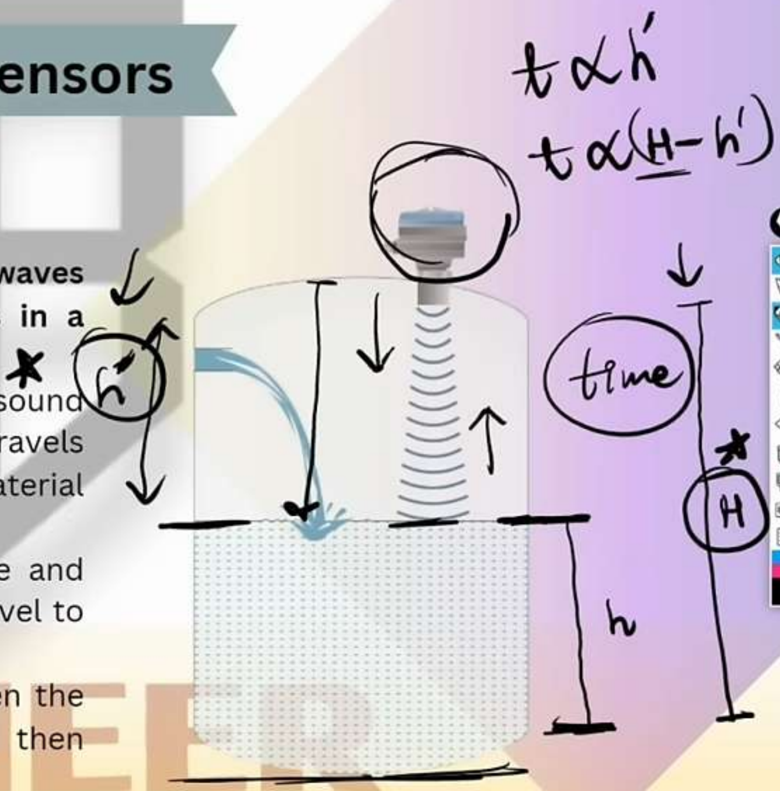
- The laser beam is first split into two parallel beams of equal intensity by a mirror and beam splitter. Both the beams pass through the converging lens and focuses the beam at a point in the flow. The small fluid volume where the two beam intersect is the measurement volume where the velocity is measured.



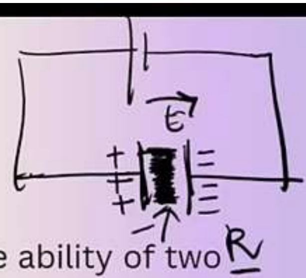
Finally, the frequency information of a scattered and unscattered laser light collected through the receiving lens and photodetector and is converted to voltage signal. Subsequently flow velocities calculated.

1. Ultrasonic level sensors

- **Ultrasonic level sensors are devices that use sound waves to measure the level of liquid or solid materials in a container or tank.**
- These sensors work by emitting a high-frequency sound wave, typically in the range of 20 to 200 kHz, that travels through the air and reflects off the surface of the material being measured.
- The sensor then detects the reflected sound wave and calculates the time it took for the sound wave to travel to and from the material's surface.
- This time is used to determine the distance between the sensor and the surface of the material, which is then converted into a level measurement.



2. Capacitive level sensors

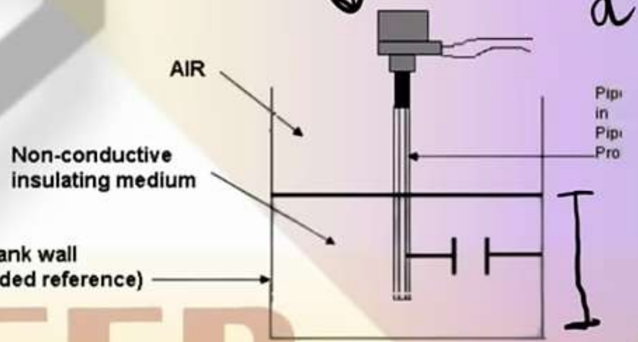


Capacitive level sensors work based on **the principle of capacitance**, which is the ability of two conductive surfaces to store an electric charge. In a capacitive level sensor, one of the conductive surfaces is the probe, and the other surface is the tank or container wall.

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

When the tank is empty, the capacitance between the probe and the tank wall is very low, but as the level of the liquid or solid inside the tank rises, the capacitance increases.

The change in capacitance is detected by an electronic circuit in the sensor, which converts it into a signal that can be used to determine the level of the material in the tank.



level = 0 $C\downarrow$

liquid level $\uparrow$ $C\uparrow$

(level) $\uparrow$ $\boxed{C \propto k}$

Level Measurement can be divided into three categories

(C∝k)

Measurement of non-conductive material

For measuring level of non conducting liquids, bare probe arrangement is used as liquid resistance is sufficiently high to make it dielectric. Since the electrode and tank are fixed in place, the distance (d) is constant, capacitance is directly proportional to the level of the material acting as dielectric

Measurement of conductive material

In conducting liquids, the probe plates are insulated using thin coating of glass or plastic to avoid short circuiting. The conductive material acts as the ground plate of the capacitor.

Non-contact measurement

In Proximity level measurement is the area of the capacitance plates is fixed, but distance between plates varies.

Proximity level measurement does not produce a linear output and are used when the level varies by several inches.

Advantages

- Relatively inexpensive
- Versatile
- Reliable
- Requires minimal maintenance
- Contains no moving parts
- Easy to install and can be adapted easily for different size of vessels
- Good range of measurement, from few cm to about 100 m
- Simple to use
- Easy to clean
- Can be designed for high temperature and pressure applications.

Disadvantages

$\rho \downarrow$ $\quad$ $K \downarrow$ $\quad$ C

- Light density materials under 20 lb/ft3 and materials with particle sizes exceeding 1/2 in. in diameter can be a problem due to their very low dielectric constants (caused by the large amount of air space between particles).

Applications of Capacitive Level Sensor

Capacitive level sensors are widely used in various industries and applications, where they are preferred over other types of level sensors because they are non-invasive, accurate, and reliable. Some common applications of capacitive level sensors include:

- Chemical processing

- Food and beverage

- Pharmaceuticals

- Water treatment

- Automotive