UNIT-II

MEASUREMENT OF TEMPERATURE USING THERMISTOR:

- It is also known as "thermal resistors" and it is used to sense temperature.
- Thermistors are generally composed of semi-conductor materials.
- In thermistor small change in temperature produces large change in resistance.
- There are two types of thermistors i.e., positive temperature co-efficient and negative temperature coefficient.
- In positive temperature coefficient value of resistance increase with increase in temperature.
- Most thermistors have a negative coefficient of temperature resistance *i.e.*, their resistance decreases with increase of temperature. The negative temperature coefficient of resistance can be as large as several percent per degree Celsius. This allows the thermistor circuits to detect very small changes in temperature which could not be observed with an RTD or a thermocouple.
- In some case the resistance of thermistor at room temperature may decrease as much as 5 percent for each 1°C rise in temperature. This high sensitivity to temperature changes makes thermistors extremely useful for precision temperature measurements control and compensation.
- The resistance of thermistors ranges from 0.5 Ω to 0.75 MΩ. Thermistor is a highly sensitive device.

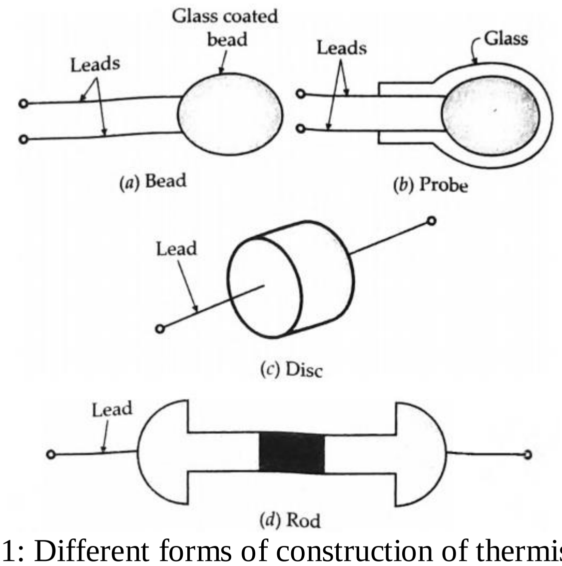


Fig. 1: Different forms of construction of thermistors.

- Thermistors are composed of sintered mixture of metallic oxides such as manganese, nickel, cobalt, copper, iron and uranium. They are available in variety of sizes and shapes.
- The thermistors may be in the form of beads, rods and discs. Some of the commercial forms are shown in Fig. 1.

- A thermistor in the form of a bead is smallest in size and the bead may have a diameter of 0.015 mm to 1.25 mm. Beads may be sealed in the tips of solid glass rods to form probes which may be easier to mount than the beads. Glass probes have a diameter of about 2.5 mm and a length which varies from 6 mm to 50 mm. It is used when measurement of temperature of liquids is required.
- Discs are made by pressing material under high pressure into cylindrical flat shapes with diameters ranging from 2.5 mm to 25 mm. It is used when high power dissipation is required.
- Rod type thermistor has capability of high-power handling.
- The resistance temperature characteristics of a typical thermistor are given in Fig. 2. The resistance temperature characteristics of Fig. 2 shows that a thermistor has a very high negative temperature co-efficient of resistance, making it an ideal temperature transducer.

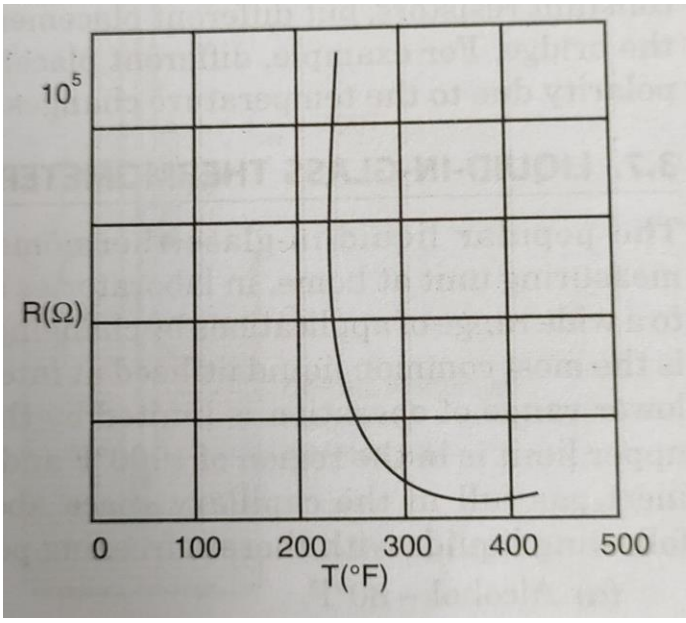


Fig. 2: Resistance-temperature characteristics of a typical thermistor

- The characteristics of thermistors are no doubt non-linear but a linear approximation of the resistance-temperature curve can be obtained over a small range of temperature. Thus, for a limited range of temperature, the resistance of a thermistor varies as given by

$$R_\theta = R_{\theta o}(1 + \alpha_{\theta o}\Delta\theta)$$

Where,

$\alpha_{\theta o}$ is temperature co-efficient,

$\Delta\theta$ is change in temperature in ^oK,

$R_{\theta o}$ is resistance at particular temperature.

Advantages

- Thermistors are compact, rugged and inexpensive.
- Thermistors when properly aged, have good stability.
- The response time of thermistors can vary from a fraction of a second to minutes, depending on the size of the detecting mass and thermal capacity of the thermistor.
- The upper operating limit of temperature for thermistors is dependent on physical changes in the material or solder used in attaching the electrical connections and is usually 400°C or less. The lower temperature limit of temperature is normally determined by the resistance reaching such a high value that it cannot be measured by standard methods.
- Thermistors can be installed at a distance from their associated measuring circuits if elements of high resistance are used such that the resistance of leads (even though the leads may be very long) is negligible. This way the resistance of leads does not affect the readings and hence errors on this count are negligible.

Disadvantages

- It is more fragile
- It is not suitable for large temperature range.

Application of thermistor:

- Measurement of temperature
- Control of temperature
- Temperature compensator

THERMOCOUPLE SENSOR:

- A thermocouple is a sensor for measuring temperature.
- Basically, it is a direct conversion of temperature difference to electrical voltage.
- The working principle of thermocouple is based on Seebeck effect.
- Seebeck effect states that when two wires made from dissimilar metals are joined at two ends to form a loop, and if the two junctions are maintained at different temperatures, a voltage develops in the circuit.
- The pair of metal wires forming the electrical circuit is known as a thermocouple.

Construction and working principle of thermocouple

- A pair of two dissimilar metals that are in physical contact with each other form a thermocouple. These metals may be twisted, screwed, peened, clamped or welded together. The most commonly used method for fabricating is to weld the metals together.
- Thermocouple measures wide ranges of temperature and are rugged, therefore, thermocouples are very often used in industry.

- Fig. 3 shows a thermocouple made from two different kind of metals.
- The wires are joined at the ends which form two junctions known as a measuring junction and a reference junction.
- If measuring junction is heated, it produces a voltage greater than the voltage across the reference junction. The difference in two voltages is measured. The voltmeter reading is calibrated to its corresponding temperature.
- Since the thermo-electric emf depends upon the difference in temperature between the hot junction and the reference junction, the temperature of the latter should remain absolutely constant in order that the calibration holds good and there are no errors on account of change in ambient temperature. The temperature of the reference junction is controlled for this purpose. The reference junction temperature is usually 0°C.
- Thermocouples are used for measurement of temperature up-to 1400°C.
- In industrial applications the choice of materials used to make up a thermocouple depends upon the temperature range to be measured, the kind of atmosphere to which the material will be exposed, to output emf and its stability, mechanical strength, and the accuracy required in measurements.

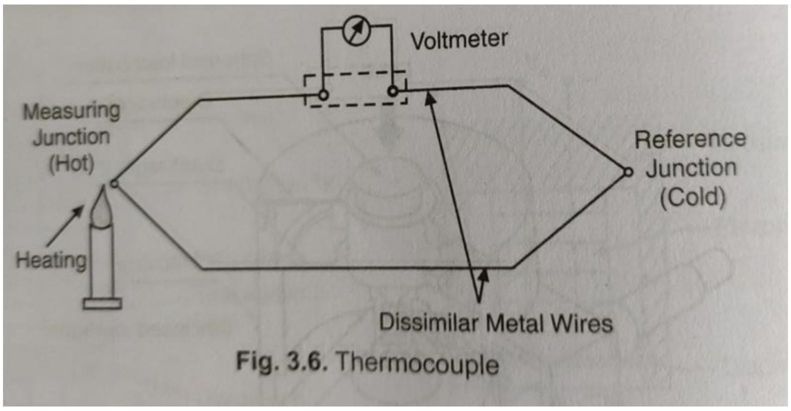


Fig. 3: Thermocouple

- **Thermocouple materials are divided into *two* categories:**
  - Rare metal types using platinum, rhodium, etc. are more durable and can withstand with higher temperatures.
  - Base metal type are comparatively cheaper and have robust construction.

- Several combinations of dissimilar metals make good thermocouples for industrial use. These combinations apart from having linear response and high sensitivity, should be physically strong to withstand high temperatures, rapid temperature changes, and the effect of corrosive and reducing atmospheres.

Advantage of thermocouple:

- Small in size
- Cheaper than RTD
- Speed of response is good
- Rugged in construction
- It has wide range of temperature

Disadvantages of thermocouple:

- Accuracy is less than RTD
- Need periodical checking

Applications

- Stoves, furnaces, pizza oven, etc.

RESISTANCE TEMPERATURE DETECTOR (RTD)

- Resistance temperature detector (RTD) also called resistance thermometer uses the resistance of electrical conductor_for measuring the temperature.

- The resistance of the conductor varies with the temperature. This property of the conductor is used for measuring the temperature.

- The main function of the RTD is to give a positive change in resistance with temperature.

- The metal has a high-temperature coefficient that means their temperature increases with the increase in temperature.

- RTD elements are commonly specified according to their resistance in ohms at zero degree Celsius (0°C). The most common RTD specification is 100 Ω which means that at 0°C, the RTD element should have 100 Ω of resistance.

Material used in resistance temperature detector

- The resistance thermometer uses a sensitive element made of extremely pure metals like platinum, copper or nickel.

- The resistance of the metal is directly proportional to the temperature. Mostly, platinum is used in resistance thermometer. The platinum has high stability, and it can withstand high temperature.

The requirements of a conductor material to be used in RTDs are:

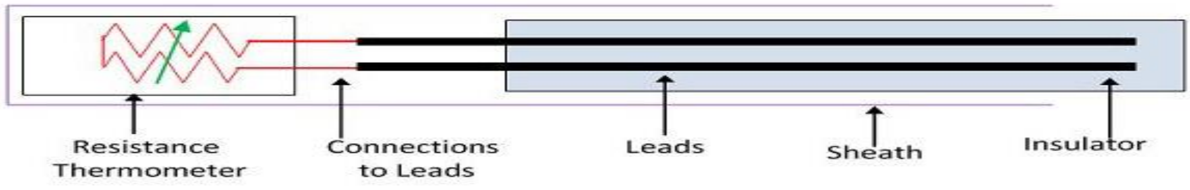
- The change in resistance of material per unit change in temperature should be as large as possible.

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

Construction of RTD

- The resistance thermometer is placed inside the protective tube for providing the protection against damage.

- The resistive element is formed by placing the platinum wire on the ceramic bobbin. This resistance element is placed inside the tube which is made up of stainless steel or copper steel.



Resistance Thermometer

- The lead wire is used for connecting the resistance element with the external lead. The lead wire is covered by the insulated tube which protects it from short circuit. The ceramic material is used as an insulator for high-temperature material and for low-temperature fibre or glass is used.

Operation of Resistance Thermometer

The tip of the resistance thermometer is placed near the measurand heat source. The heat is uniformly distributed across the resistive element. The changes in the resistance vary the temperature of the element. The final resistance is measured. RTD normally uses a wheat stone bridge measurement circuit to compensate for the lead wire resistance. The below mention equations measure the variation in temperature.

$$R_\theta = R_{\theta_0}(1 + a_{\theta_0}\Delta\theta)$$

Where

R_θ – approximation resistance at θºC
$R_{\theta 0}$ – approximation resistance at θ_0ºC
$\Delta\theta$ – $\theta - \theta_0$ change in temperature ºC

$\alpha_{\theta 0}$ – resistance temperature coefficient at θ_0ºC

Advantages:

- The RTD can be easily installed and replaced.
- It is available in wide range.
- The RTD can be used to measure differential temperature.
- They are suitable for remote indication.
- Stability maintained over long period of time.
- No necessity of temperature compensation.

Disadvantages:

- It is affected by shock and vibration.
- Bridge circuit is needed with power supply.
- Slower response time than a thermocouple.
- Large bulb size.
- Higher Initial cost.
- Sensitivity is low.

Applications

- Power electronics
- Aerospace
- Military, etc.

CONCEPT OF THERMAL IMAGING:

- Thermal imaging is a method of using infrared radiation and thermal energy to gather information about objects, in order to formulate images of them, even in low visibility environments.
- It’s a type of technology that has built up a broad range of uses over the years. In particular, it’s an effective form of night-vision technology, with the capability to work in the total absence of any light (since it doesn’t rely on visible light), and can even work in smoke, fog, smog and haze.

How does thermal imaging work?

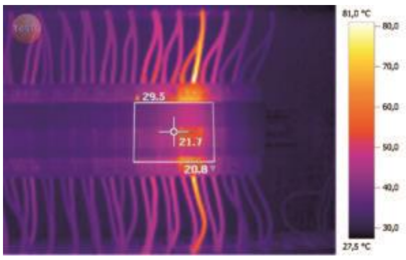
- Thermal imaging is based upon the science of infrared energy (otherwise known as “heat”), which is emitted from all objects. This energy from an object is also referred to as the “heat signature”, and the quantity of radiation emitted tends to be proportional to the overall heat of the object.

- Thermal cameras or thermal imagers are sophisticated devices comprised of a sensitive heat sensor with the capacity to pick up minute differences in temperature. As they gather the infrared radiation from objects in a particular environment, they can start to map out an image based on the differences and inflexions of the temperature measurements.
- In general, thermal images are grayscale: with white representing heat, black representing colder regions, and various shades of grey indicating gradients of temperatures between the two. However, newer models of thermal imaging cameras actually add colour to the images they produce, in order to help users better identify distinct objects more clearly – using colours such as orange, blue, yellow, red and purple.

Applications of thermal imaging

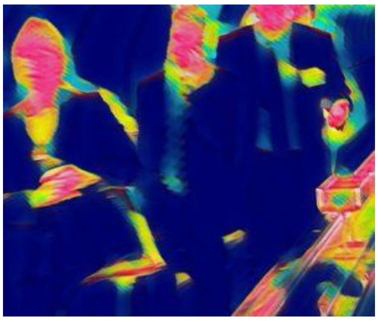
Tracing the origins of thermal imaging, it’s believed to have its beginnings in the Korean War, being used for military purposes such as scouting and night combat missions. Since then, its uses have expanded far and wide, across different disciplines and for a variety of practical applications.

- **Electrical maintenance** uses for thermal imaging are extensive. For example, power line technicians use thermal imaging to locate and pinpoint joints and parts that are at risk of overheating as they’re already emitting more heat than the stronger sections. They can also help spot loose connections or devices that are starting to fail.

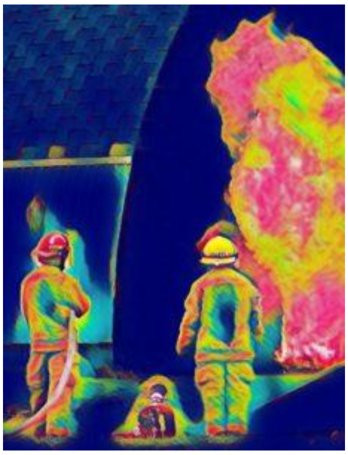


- **Plumbers** use thermal imagers to inspect sites of possible leaks, mainly through walls and pipes. Since the devices can be used at a distance, they’re ideal for finding potential problems in equipment that is either hard to reach or might otherwise pose safety issues to workers.

- **Healthcare and medicine** also have practical uses, such as to spot fevers and temperature anomalies. This has proven to be especially important in airports where these thermal imaging cameras can quickly and accurately scan all incoming or outgoing passengers for higher temperatures, which was crucial during recent outbreaks of diseases like SARS and Ebola. Additionally, thermal imagers have been proven to help diagnose a range of disorders associated with the neck, back and limbs, as well as circulatory problems.



- **Fire-fighters** use thermal imaging to help them see through smoke, particularly in rescue missions when they're searching for people in an otherwise obscured and dangerous environment. They also use thermal cameras for rapid identification of spot fires, so they can intervene before they spread.



MEASUREMENT OF POSITION USING HALL EFFECT SENSORS:

- The principle of working of a Hall Effect Transducer is that if a strip of conducting material carries a current in the presence of a transverse magnetic field as shown in Fig. 5, a difference of potential is produced between the opposite edges of the conductor. The magnitude of the voltage depends upon the current, the strength of magnetic field and the property of the conductor called *Hall Effect.*
- The Hall effect is present in metals and semiconductors in varying amounts, depending upon the densities and mobilities of carriers.

Working Principle

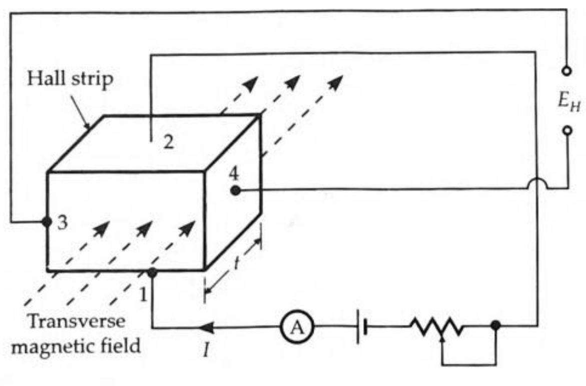


Fig. 5: Hall effect elements

- Let us consider Fig. 5, current is passed through leads 1 and 2 of the strip. The output leads connected to edges 3 and 4 are at the same potential when there is no transverse magnetic field passing through the strip.
- When a transverse magnetic field passes through the strip, an output voltage appears across the output leads. This voltage is proportional to the current and the field strength.

The output voltage is:

$$E_H = \frac{K_H I B}{t}$$

Where

K_H is hall-effect constant, t is the thickness of strip; m, I is current in Ampere and B is flux density in Wb/m^2. Thus, the voltage produced may be used for measurement of either the current / or the magnetic field strength *B*.

- The Hall effect element can be used for the measurement of the position or displacement of a structural element *i.e.,* it can serve as an indirect acting position displacement or proximity transducer in cases where a change of geometry of a magnetic structure causes a change of magnetic field strength.
- An example is shown in Fig. 6 which shows a ferro-magnetic structure having a permanent magnet. The Hall effect transducer is located-in the gap, adjacent to the permanent magnet. The field strength produced by the permanent magnet in the gap, where the Hall effect element is located, is varied by changing the position of a ferro-magnetic plate.
- The voltage output of the Hall effect transducer is proportional to the field strength in the gap which is a function of the position of the ferromagnetic plate from the

structure *i.e.*, the displacement. The method permits measurements of displacement down to 0.025 mm

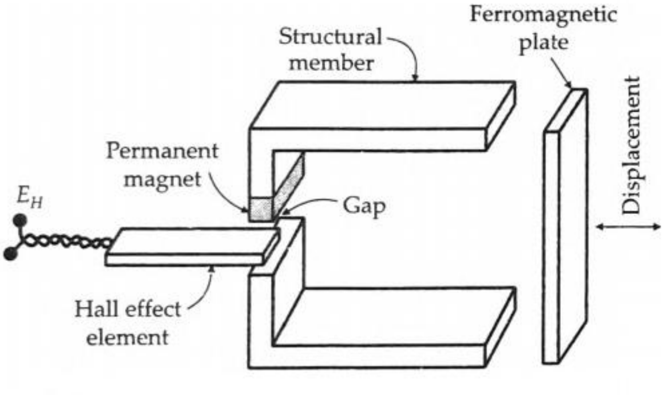
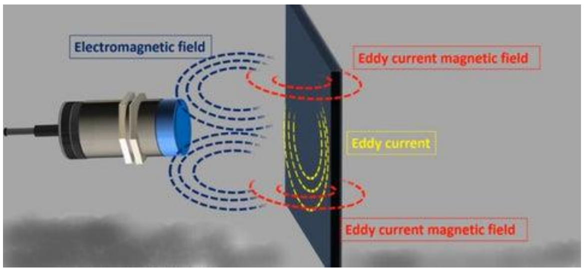


Fig. 6: Measurement of position/displacement using hall effect sensor.

PROXIMITY SENSOR:

- Proximity sensors are designed to detect without contacting the detecting object.
- It has the ability to convert the observed object's movement and presence information into electrical impulses.
- When the object comes in to its sensing area an electrical signal gets generated and this helps to detect the object.
- Proximity sensors are commonly used in industrial application. They are also used in vehicles for detecting the physical closeness of other vehicles as well as for parking-assist function.
- There are many types of proximity sensor like inductive, capacitive, ultrasonic, etc.
- Most commonly used proximity sensors are inductive and capacitive.

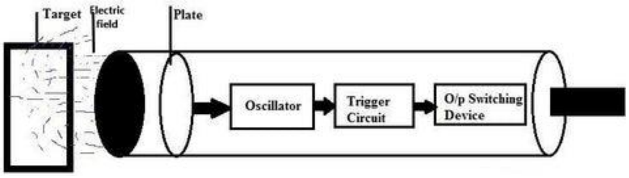
Inductive proximity sensor:



- This type of sensor has a wire wound around typically an iron core, an alternating current is applied to the coil which generates a magnetic field around it.
- This magnetic field gives rise to an eddy current in the electrical conductor.
- These eddy currents then generate an eddy current magnetic field that opposes the electromagnetic field from the sensor.

- When the target is taken close to the sensor the electromagnetic field from the sensor gets reduced, which decreases the amplitude of the electromagnetic field.
- When it decreases beyond the threshold trigger circuit activates the output. This help to identity that object has come into the desired vicinity of the sensor.
- Inductive proximity sensors are used for metal detectors, traffic lights, car washes, and a host of automated industrial processes.
- Inductive proximity sensors enable the detection, without contact, of metal objects at distances of up to 60 mm.

Capacitive proximity sensor:



- Its work on the principle of varying capacitance. So, as the capacitance changes corresponding output signal generated also changes.
- As we know, a typical capacitor is composed of two plates separated by an insulator, also known as a dielectric. The insulating dielectric can be of different types of material, including ceramic, paper, plastic, or even air.
- Within the capacitive proximity sensor is one plate of a capacitor – the target serves as the other plate.
- The air gap between the sensor and the target functions as the dielectric.
- The plate that is internal to the sensor is connected to an oscillator circuit that is used to generate an electrostatic field.
- In the absence of the target, the oscillator circuit does not trigger.
- As the target approaches the sensor, the oscillation amplitude increases, as the sensor detects the target it causes a change in the amount of charge that can be stored on the internal plate, which changes that capacitance value.
- Once the oscillations exceed a threshold, a trigger is set that generates an output signal from the sensor that indicates that the target has approached within the set activation range.
- The capacitive proximity sensors can detect both metallic and non-metallic targets, and their ideal usage is for liquid level control and for sensing granulated materials.
- A typical sensing range for capacitive proximity sensors is from a few millimeters up to about 25 mm and some sensors have an extended range up to 50 mm.

Advantages of proximity sensor:

- It is capable of detecting metals as well as nonmetals.
- Good stability.
- High speed and High switching rate.

- Operates in harsh environmental conditions.
- Low cost and power consumption.

Use or Proximity sensor as accelerometer and vibration sensor

Accelerometer

The phone uses an accelerometer to detect any tilt in the phone to the side and change the display orientation accordingly. Accelerometers detect movement in three dimensions. A proximity sensor uses some kind of wave to detect the presence of nearby objects without touching them. For example, automatic doors and some other everyday applications.

Vibration sensor

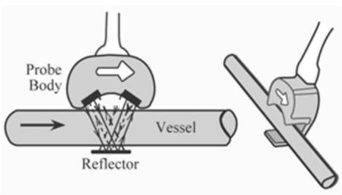
The vibration sensor is also called a piezoelectric sensor. These sensors are flexible devices used for measuring various processes. This sensor uses the piezoelectric effect while measuring the changes within acceleration, pressure, temperature, force otherwise strain by changing to an electrical charge. This sensor is also used for deciding fragrances within the air by immediately measuring capacitance as well as quality.

Ultrasonic Flow Meter-

- An ultrasonic flow meter can be defined as, a meter that is used to measure flow or liquid velocity by using ultrasonic waves.
- This flow meter requires tiny particles or air bubbles within the liquid flow.
- These meters are suitable in the applications of wastewater. So, this type of flow meter is ideal for the applications wherever low maintenance are required.

Working Principle

- An ultrasonic flow meter consists of transmitter, receiver, pipe and reflector.
- The working principle of ultrasonic flow meter is, it uses sound waves to resolve the velocity of a liquid within a pipe.
- There are two conditions in the pipe like no flow and flowing.
- In the first condition (no flow), the frequencies of ultrasonic waves are transmitted into a pipe and reflected wave's frequency is similar. So, there is no frequency shift.
- In the second condition (flowing), the reflected wave's frequency is dissimilar because of the Doppler Effect. So, there is frequency change



- Whenever the liquid flows in the pipe quickly, then the frequency shift can be increased linearly.
- The transmitter processes the signals from the wave & its reflections determine the flow rate.

- Transit time meters transmit & receive ultrasonic waves in both the directions within the pipe.

- The process is described mathematically by following expression :

$$f_t - f_r = \frac{2f_t \cos\theta}{c} \times V$$

where, f_t = Transmitter frequency .
f_r = Receiver frequency.
θ = Angle between flow direction and transmitter/receiver waves.
c = Speed of sound in liquid.
V = Velocity of particles of liquid .

- Thus, the unknown parameter v (flow rate) can be determined.

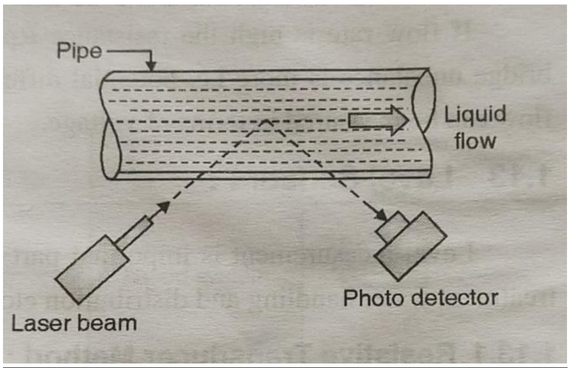
Advantages of Ultrasonic Flow Meter

- It does not block the path of liquid flow.
- The flow of liquid is bidirectional
- It is appropriate for huge quality flow measurement
- It is handy to fit and maintain
- There are no moving parts, pressure loss
- High accuracy

Disadvantages of Ultrasonic Flow Meter

- It is expensive.
- Design of this meter is complex.
- These meters are complicated as compared with other meters; thus, it requires specialist for maintaining and repairing these meters
- It cannot measure cement or concrete pipes one they rusted.
- It doesn't work once the pipe contains holes.

Laser Flow Sensor-



- The Laser Flow sensor measures flow rate of any liquid in open channels.
- The LaserFlow is ideal for a broad range of wastewater monitoring applications.
- It makes use of LASER beams measuring flow rate of any liquid.
- The laser beams used in laser flow meter are in the range of 390-750 nm wavelength.
- A suitable transmitting optics focuses laser beams on to the flow.

- Due to this, straight fringes are generated and these reflect light back to the photo detector.
- The reflected light intensity varies as per the flow rate.
- The photo detector output also changes as power the flow rate.
- Thus, the flow rate can be measured in terms of electrical signal.

Advantages:

- Non-contacting measurement.
- Very high frequency response.

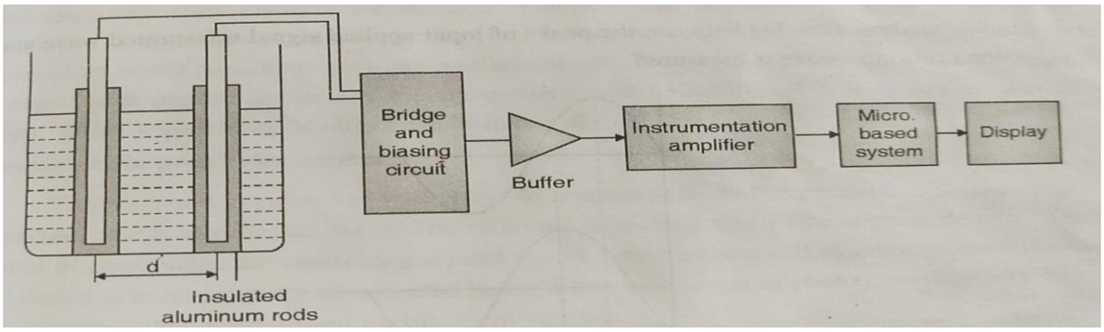
Disadvantages:

- Sufficient transparency is required between the laser source, the target surface, and the photodetector (receiver).
- Accuracy is highly dependent on alignment of emitted and reflected beams.
- Expensive

LEVEL SENSORS

A level sensor is device that is designed to monitor, maintain and measure liquid (and sometimes solid) levels. Once the liquid level is detected, the sensor converts the perceived data into an electric signal.

Capacitive method for level measurement



- This method is used to measure level of liquid.
- Two insulated aluminium rods (act as two parallel plates of a capacitor) which are kept at fixed placed close to each other in a tank separated by a distance ‘d’.
- As we know,

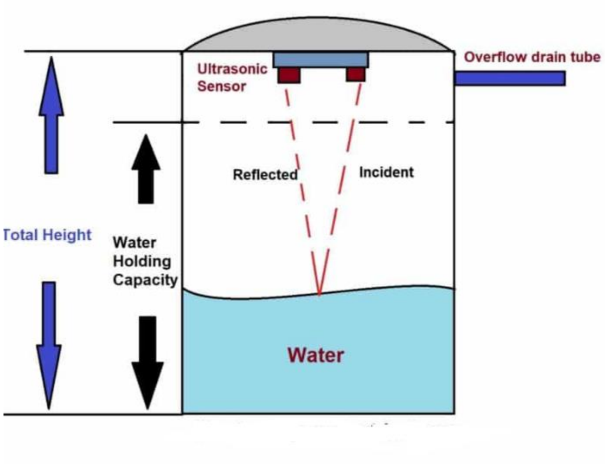
$$C = \frac{\epsilon A}{d}$$

Where,

C – Capacitance in Farads (F)
ε – dielectric constant
A-Overlapping area of two plates
d- distance between two plates

- As the liquid level changes then dielectric constant (ε) is also changed.
- Since, capacitance is directly proportional to height of liquid in a tank (dielectric constant ε) so capacitance value will also be changed.
- This arrangement is applied to bias and connected in a De-Sauty's bridge.
- The electrical output corresponding to value of capacitance is buffered and then applied to instrumentation amplifier.
- The output of amplifier is given to data acquisition system for processing.
- The display unit is connected to microcontroller-based system for showing the output.
- The capacitance value depends upon height of the liquid dielectric between the plates.
- The higher the liquid level, the greater is the capacitance. The lesser the liquid level, the smaller is the capacitance.

Ultrasonic Method



- An ultrasonic transmitter receiver can be mounted on the top of tank for measurement of level of either solids or liquids.
- The beam is projected downwards by the transmitter and is reflected back by the surface of the solid or 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 between transmitting and receiving a pressure pulse is proportional to the distance between the ultrasonic set and surface of the contents of the tank.
- As the level in the tank is more, the distance will be less and accordingly the time will be less. The time is then the measure of level of liquid in the tank.