Unit -V
Miscellaneous Measurement- part II

5.1 Speed Measurement: Define
speed, its units- types
5.1.1 Non-contact type
- Magnetic pickup
- Photo pickup
- Stroboscope
- Optical Encoder

5.1.2 Contact type
- DC tachometer
- AC tachometer

5.2 Position sensor:
Proximity sensor
5.2.1 Types-
inductive , capacitive , photoelectric and ultrasonic type.
5.3 Prepare specification for it

Definition of Speed:

It is defined as the rate at which something moves or operates.
In Industrial processes, speed as a variable refers to the revolution per minute of some rotating equipment.

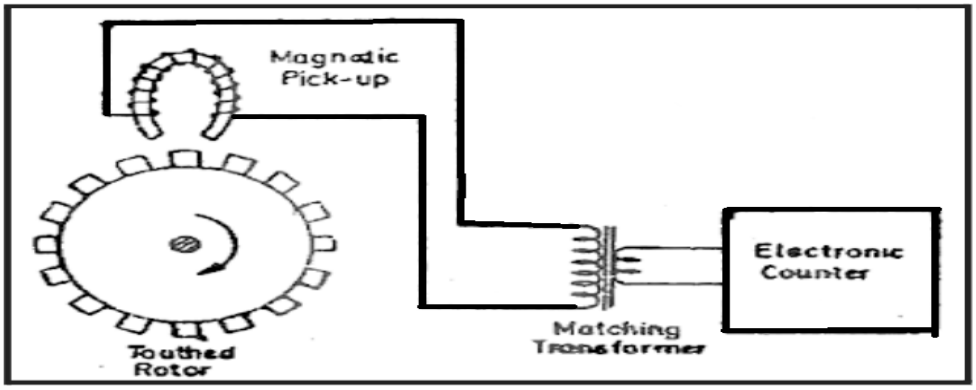
Units:

a) Meter/ second
b) Revolution per minute (RPM)
c) Feet per minute
d) Miles per hour
e) Yard per minute
f) Production unit per unit time

Types of speed Transducers

1) Non-contact type
   - Magnetic pickup
   - Photo pickup
   - Stroboscope
   - Optical Encoder
2) Contact type
   - DC tachometer
   - AC tachometer

Magnetic Pickup Tachometer.



A magnetic pickup consists of a coil wound around a permanent magnetic probe. When a discrete ferromagnetic objects such as gear tooth, turbine rotor blades, slot head discs or shaft are passed through the probe's magnetic field, flux density is modulated, this induces AC voltage in the coil.

Explanation :

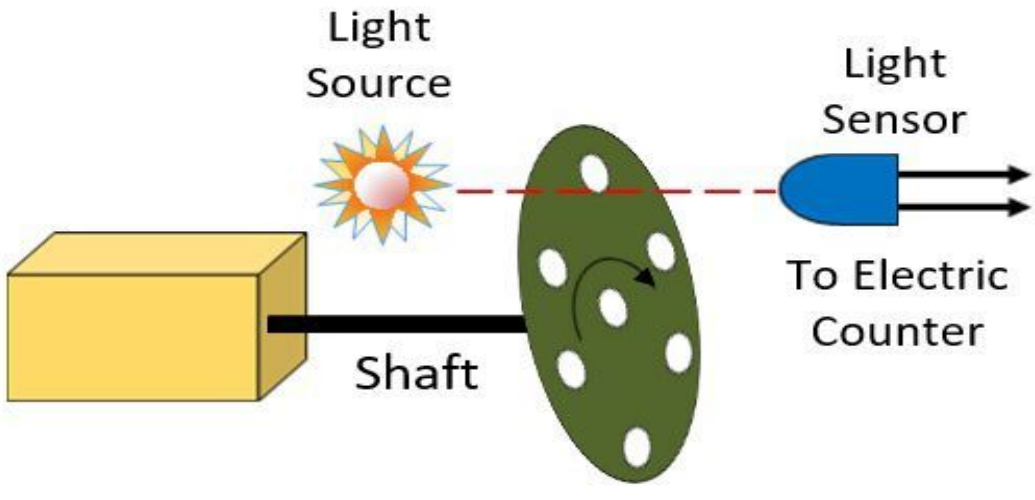
1. It consists of a cylindrical permanent magnet placed behind a soft iron pole piece around which the coil is wound.
2. The magnetic pickup sensor is placed in front of shaft gear made up of ferromagnetic material whose speed is to be measured.
3. As the gear rotates, magnetic flux in the soft iron pole piece becomes high when tooth of ferromagnetic gear comes in front of the magnetic pickup.
4. The flux drops off as the tooth of the gear is passed.
5. Thus the voltage is generated in coil
6. The frequency of the pulses of induced voltage will depend upon the number of teeth of the rotor and speed of rotation .
7. Since the number of teeth is known, the speed of rotation can be determined by measuring the frequency of pulses with an electronic counter.
8. Hence, Speed

$$n = (Pulses\ per\ second/\ Number\ of\ teeth) \quad rps$$
$$n = P/T\ *\ 60\ rpm$$

Advantages of Magnetic Pickup Tachometer.

i) Simple and rugged in construction.
ii) Maintenance free
iii) It is more accurate to measure the speed of discrete ferromagnetic rotating equipment.
iv) It can be used for a type of surface such as rotating, vibrating or moving surface
v) It may be operated under the conditions when oil, grease, water and non-corrosive liquids are present.
vi) Easy to calibrate.

Photoelectric tachometer or photo pickup tachometer.



Explanation:

01. This method of measuring speed of rotation consists of mounting disc on rotating shaft.
02. The disc has a number of equidistant holes on its periphery.
03. At one side of the disc, light source is fixed and at the other side light sensor such as a photodiode or phototransistor is placed.
04. When the opaque portion of the disc lies between the light source and light sensor, photo sensor produces an output pulse.
05. The frequency at which these pulses are produced depend on the number of holes in the disc and speed of the rotating disc. As the number of holes is fixed, then frequency is directly proportional to speed.
    Frequency α Speed.
06. The pulses can be measured by an electronic counter which can be directly calibrated in terms of speed in RPM.

Advantages.

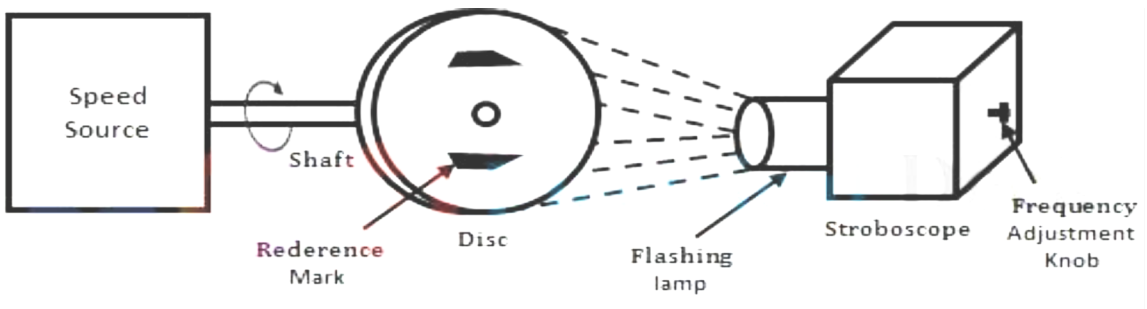
1. The output format is digital hence no conversion of analog to digital is required. Hence more accurate.
2. The pulse amplitude is constant, this simplifies the electronic circuitry.
3. It is a digital instrument with high accuracy.

Disadvantages.

1. Light source must be replaced time to time because life time of light source is 50,000 hours.
2. The accuracy of this method depends on the error represented by 1 pulse.

Stroboscope

A stroboscope is an instrument that works on the phenomenon of stroboscopic effect. It creates a stop motion effect of a rotating object by flashing a high-intensity light on it. This appearance of a moving object to be stationary can be used to study rotating, oscillating or vibrating objects.



Concept:

Stroboscope is a simple, portable manually operated device which may be used for the measurement of periodic or rotatory motion.
Basically the instrument is a source of variable frequency flashing bright light, the flashing frequency is set by the operator.

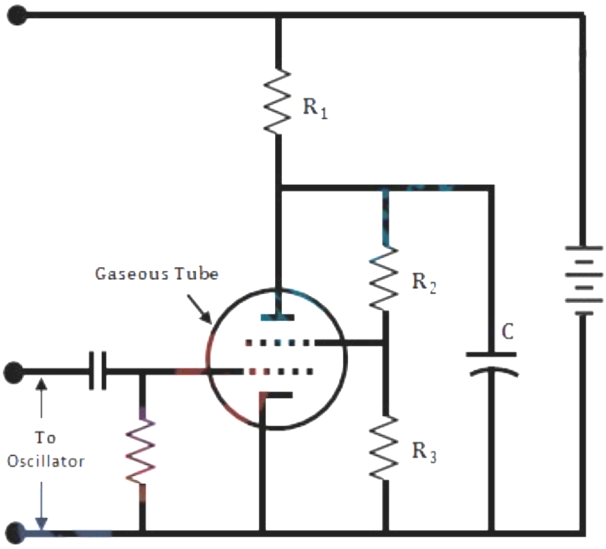
Construction & Working:

1. A distinctive mark is made on the shaft or on a disc attached to the rotating object whose speed is to be measured.
2. A stroboscope is made to flash light directly on the mark.
3. The flashing frequency is adjusted until the mark appears stationary.
4. Under these conditions, speed is equal to flashing frequency.

   FLASHING FREQUENCY α SPEED

5. The scale of the stroboscope is calibrated in terms of speed which can be directly read off.

Strobotron



Stroboscope consists of a source of flashing light whose frequency can be varied and controlled . This source is called a Strobotron.

Strobotron Working:

1. It is a hot cathode gaseous discharge tube.
2. It consists of two electrodes (cathode and anode) and two grids (inner grid and outer grid).

3. The conduction in the discharge tube starts, when the potential of the inner grid is less than or the potential of the outer grid is more than a particular value. (In order to stop the conduction, the anode potential must be made zero.)
4. A variable frequency oscillator is a part of the strobotron circuit and it is connected to the gaseous discharge tube
5. The oscillator supplies a signal which is responsible for the flashing of light.
6. When the strobotron (gaseous tube) receives an oscillating signal from the oscillator, the ionized tube starts flashing. Due to the flashing process, the capacitor C gets discharged. In order to recharge again, capacitor C draws a large amount of current. This leads to a high voltage drop across the resistor R, which in turn leads to a decrease in anode potential.
7. The decrease in anode potential stops the ionization of the gas in the discharge tube and hence the flashing of the light also stops. The flashing of light starts again when it receives the next pulse from the oscillator.
8. By varying the frequency of the oscillator (i.e., oscillating signal) the frequency of the flashing of the light can be varied and thus controlled.
9. The flashing light is used to measure the speed of the rotating object in the stroboscope system.

Advantages.

1. This method requires no special attachment with the shaft.
2. This method imposes no load on the shaft.
3. It is very convenient for laboratory work.

Disadvantages:

1. It is less accurate because of human error.
2. The stroboscope cannot be used in surroundings where the ambient light is above the a certain level.

Applications :

1. It is used for measurement of Speed of rotating objects.
2. It is used for observation of high speed objects.
3. It is used with video cameras to capture precise images.

Commercially available stroboscopes are usually available in the speed range of 600 to 20,000 RPM

Optical encoder

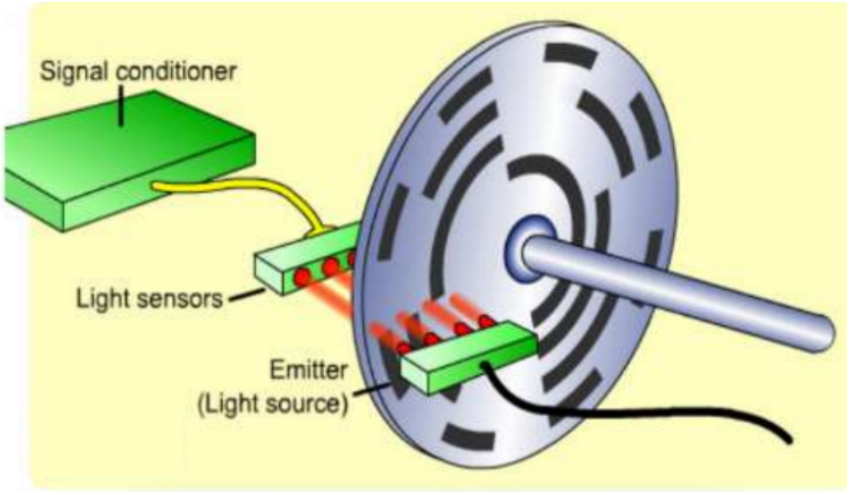
Encoders

Encoders are used to translate rotary or linear motion into a digital signal. Usually this is for the purpose of monitoring or controlling motion parameters such as speed, rate, direction, distance or position.

Applications

1. Cut to length applications
2. Jacks for railroad cars
3. Bottle rotation for label application
4. Printing applications
5. Elevator position applications
6. Automated assembly lines
7. Packaging machines

Absolute optical encoder.



1. An absolute optical encoder contains a disc which is connected to the shaft whose speed is to be measured.
2. The disc is placed between light source and light sensor.
3. As they rotate together, pulses of light from an emitter strike the sensor, every time a slot on the disc aligned between them.
4. Each pulse of light is converted into an electronic pulse by signal conditioner.
5. It is called absolute encoder because it always measures the absolute position that means the actual position is indicated by whatever measurement is made at that particular moment.
6. It is used to measure angular velocity.

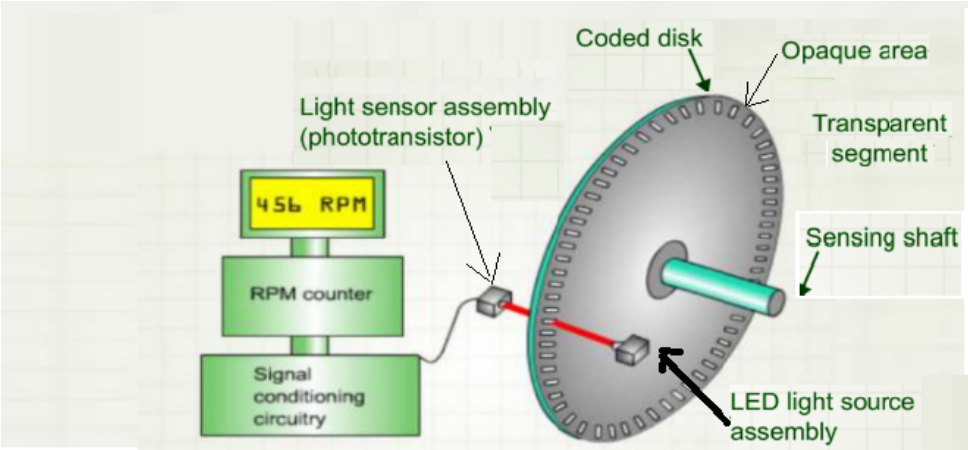
Advantages of an absolute encoder

1. Battery backup is not necessary to avoid data loss.
2. They have different functions like scaling, speed, Fieldbus & preset.
3. Magnetic or optical scan measurement.
4. Once power is lost, it provides continuous position monitoring.
5. The flexibility of programming.
6. Precision control allows use in different applications where functional safety is required.
7. The exact position of a machine can be determined.

Disadvantages of an absolute encoder

1. Complicated to manufacture
2. Expensive

Incremental optical encoder.



1. An incremental encoder is an electromechanical device used to provide feedback signals for speed control application.
2. These feedback signals can provide the following types of signal about rotary or linear mechanisms.
   a) Direction of rotation.
   b) Position.
   c) Speed.
3. A disc is connected to the shaft whose speed is to be measured is placed between light source and sensor.
4. As the disc rotates, pulses of light from the source strike the sensor every time that light is paced to a transparent segment. Each pulse of light is converted into digital signal by a signal conditioning system.
5. The device is called incremental encoder because the pulse it produced are counted one at a time.

6. One track encoders are also called incremental encoders. They are typically used to measure the RPM of a rotating device. Speed can be measured in two ways.
   a) By counting the no. of pulses within a time period.
   b) By measuring the time interval between pulses.

Advantages of an Encoder :

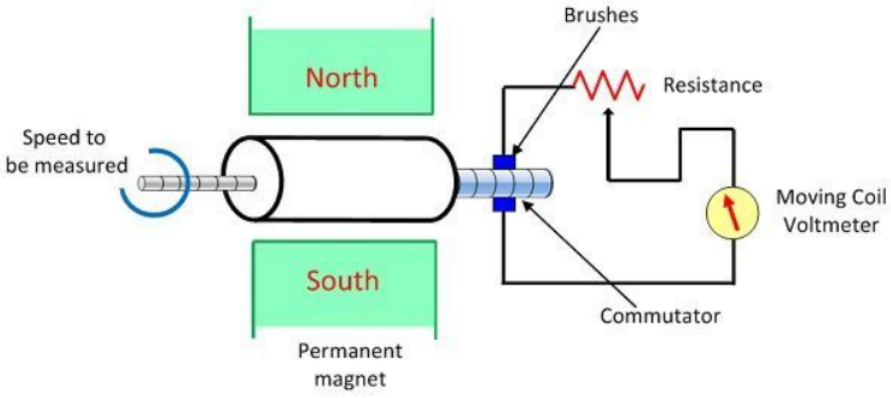
- Highly reliable and accurate
- Low-cost feedback
- High resolution
- Integrated electronics
- Fuses optical and digital technology
- Can be incorporated into existing applications
- Compact size

Disadvantages of an Encoder :

- Subject to magnetic or radio interference (Magnetic Encoders)
- Direct light source interference (Optical Encoders)
- Susceptible to dirt, oil and dust contaminates

Sr. No.	Absolute Encoder	Incremental Encoder
1	Has unique code for each shaft Position which represents the absolute position of the encoder.	It generates an output signal each time the shaft rotates at a certain angle.
2	It only need power when a reading is taken	It needs to be powered on throughout the operation of the device.
3	It costs twice than incremental encoder	less expensive than absolute encoder
4	It doesn't lose the position information when the power is lost	Each time the power is lost, the reading must be reinitialized or the system shows an error.
5	Complex than Incremental encoder	Simple than absolute encoder
6	These encoders are used in different applications where controlling, monitoring is required like diagnostic imaging, surgical robotics, etc.	These are used in applications where velocity & direction information is necessary

DC Tachometer



Construction and Working:

- DC Tachometer generator consists of a small armature which is coupled through a shaft to the machine whose speed to be measured.
- This armature revolves around the field of permanent magnet.
- The EMF generated is proportional to the product of speed and flux.Since flux of the a permanent magnet is constant, the EMF generated is directly proportional to speed.
- The Polarity of output voltage indicates the direction of rotation
- The EMF is measured with help of moving coil voltmeter whose scale is calibrated in terms of speed.
- The function of commutator is conversation of AC to DC and resistance limits the current for the safe operation of PMMC.

Advantages:

i. The direction of rotation directly indicated by the polarity of output voltage.
ii. The output voltage is typically 10mV /rpm and can be measured with normal DC Voltmeter.
iii. The relationship between input (speed) and output (voltage) is linear.

Disadvantages:

i. Brushes and commutators require periodic maintenance.
ii. The input resistance of meter should be very high as compared to the output resistance of generator. This is required to limit the armature current to small value.

The emf induces in the dc tachometer generator is given as

$$E = \frac{\emptyset PN}{60} \times \frac{z}{a}$$

Where, E – generated voltage

Φ – flux per poles in Weber

P- number of poles

N – speed in revolution per minutes

Z – the number of the conductor in armature windings.

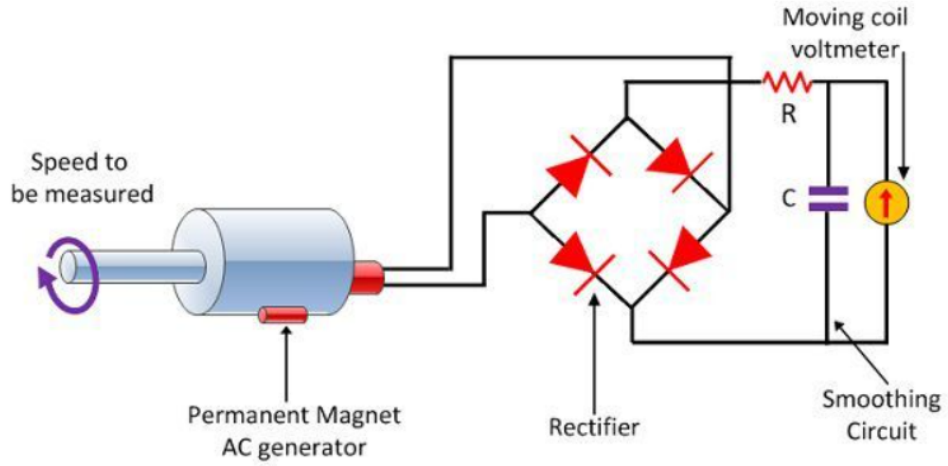
a – number of the parallel path in the armature windings.

$$E \; \alpha \; N$$

$$E = KN$$

$$K = Constant = \frac{\emptyset P}{60} \times \frac{z}{a}$$

AC Tachometer



Construction and Working:

1. The AC tachometer has a stationary armature and rotating magnetic field. Thus, the commutator and brushes are absent in the AC tachometer generator.
2. The coil is wound on the stator and therefore the problems associated with commutator are absent
3. The rotation of the magnet causes an EMF to be induced in the stator coil .
4. The amplitude and frequency of this EMF are both proportional to the speed of rotation . Thus either amplitude or frequency of induced voltage may be used as a measure of rotational speed .
5. When amplitude of the induced voltage is used as a measure of speed the circuit shown above is used. The output voltage of the AC tachometer is rectified and is measured with a permanent magnet moving coil instrument.
   • The speed of this instrument is 500 to 10,000 rpm.

Advantages of AC Tachometer Generator :

1. The amplitude and frequency of voltage induced in stator winding are proportional to speed.
2. The unknown speed can be measured in two ways. One is by measuring the amplitude and the other is by measuring the frequency of the induced voltage.
3. The rectified output voltage can be measured by means of a moving coil voltmeter that contains a uniform scale.
4. The problems of the dc tachometer generator due to the presence of the commutator are absent.
5. The relationship between input (speed) and output (amplitude and frequency of voltage) is linear.

Limitations of AC Tachometer.

- The difficulty with this system is that at low speed the frequency of output voltage is low
- which may not be measured.
- High speed also makes a problem because as speed increases, Frequency increases and
- the impedance of the coil also increases which causes non-linearity.

Compare AC Tachometer with DC Tachometer.

SR No.	AC Tachometer	DC Tachometer
1	Permanent or Electromagnet is used.	Permanent magnet is used.
2	AC input voltage is applied	DC input voltage is applied.
3	Commutators and brushes are absent.	Commutators and brushes are present.
4	Because of the absence of mechanical parts, no maintenance is required.	Periodic maintenance is required.
5	By using extra high resistance, readout instrument (PMMC) reads the true value of speed. Hence linearity exists.	Input resistance of meter should be very high with output resistance of generator. Otherwise non-linearity exists.
6	Extra electronic circuit is needed for AC to DC conversion.	No need of extra electronic circuit for AC to DC conversion.

Write the specification of AC/DC Tachometer. [2 marks]

1. Voltage output.
2. Accuracy.
3. EMF vs Speed Linearity.
4. Shaft Diameter.
5. Temperature Coefficient.
6. Internal Resistance.
7. Maximum Operating Temperature.
8. Frequency at 900 rpm.

Proximity Sensors

A proximity sensor is a sensor able to detect the presence of nearby objects without any physical contact.

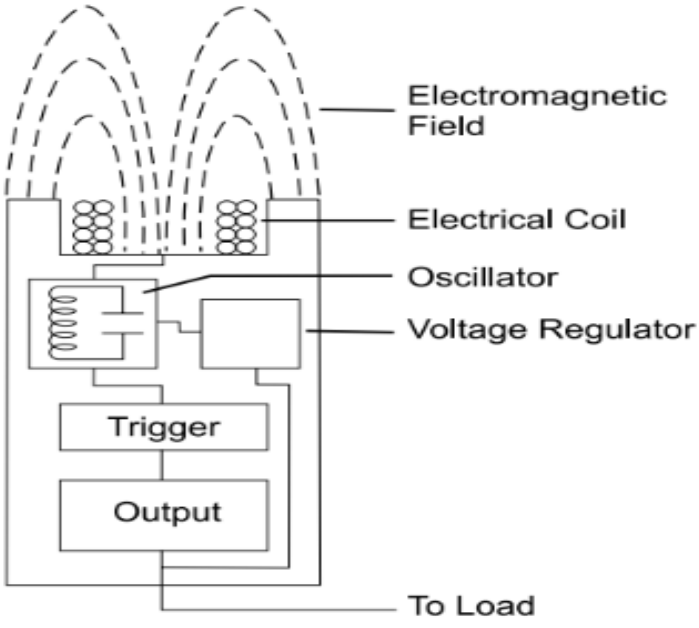
Sensor	Objects	Detected Technology
Inductive	Metal	Electromagnetic Field
Capacitive	Any	Electrostatic Field
Ultrasonic	Any	Sound Waves
Photoelectric	Any	Light

Inductive Proximity Sensors

It is one type of non-contact sensor based on the working principle of a transformer. It is used for position and speed sensing. It uses a coil or inductor for its construction. Hence the name inductive sensor.

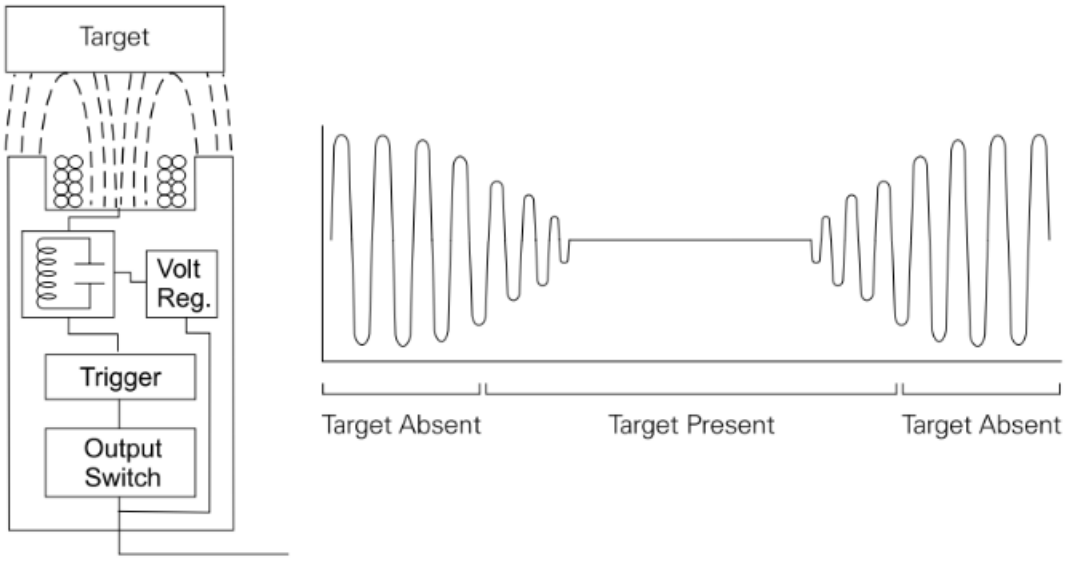
Construction

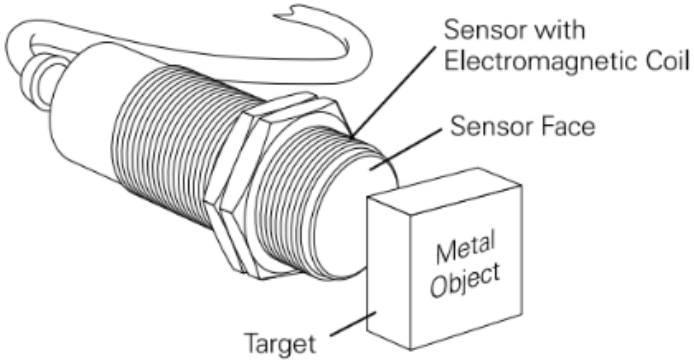
1. Sensor consists of four elements: coil, oscillator, trigger circuit, and an output.
2. The oscillator is an inductive capacitive tuned circuit that creates a radio frequency.
3. The electromagnetic field produced by the oscillator is emitted from the coil away from the face of the sensor.



Working

1. When a metal target enters the field, eddy currents circulate within the target.
2. This causes a load on the sensor, decreasing the amplitude of the electromagnetic field.
3. As the target approaches the sensor the eddy currents increase, increasing the load on the oscillator and further decreasing the amplitude of the field.
4. The trigger circuit monitors the oscillator's amplitude and at a predetermined level switches the output state of the sensor from its normal condition (on or off).
5. As the target moves away from the sensor, the oscillator's amplitude increases.
6. At a predetermined level the trigger switches the output state of the sensor back to its normal condition (on or off).





The sensor incorporates an electromagnetic coil which is used to detect the presence of a conductive metal object. The sensor will ignore the presence of an object if it is not metal.

Advantages of Inductive sensor

1. It can withstand harsh environmental conditions.
2. It has a longer life.
3. It is very easy to install.
4. It has very predictable results and performance.
5. It has a higher switching rate.

Disadvantages of Inductive sensor

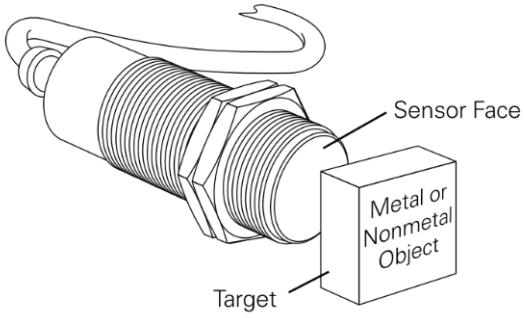
1. The sensing range of an inductive sensor depends on the type of metal being detected, its shape, its size and also coil size used in the design. Due to the above reason, an inductive sensor has distance limitations for sensing.
2. It can detect metallic targets only.

Applications

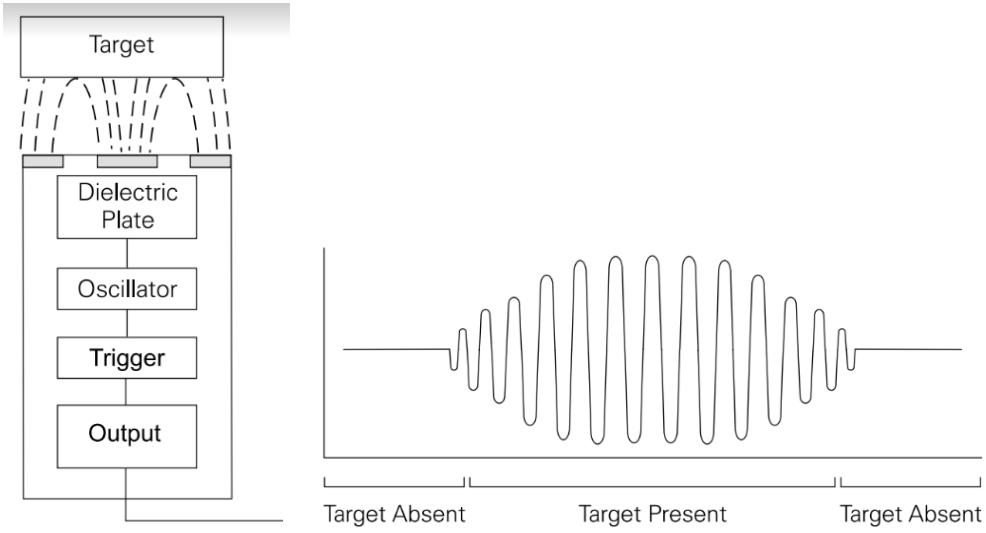
1. Industrial usages
   Production automation machines that count products, product transfers
2. Security usages
   Detection of metal objects, armory, land mines, etc.

Capacitive Proximity Sensors

Capacitive proximity sensors are similar to inductive proximity sensors. The main difference between the two types is that capacitive proximity sensors produce an electrostatic field instead of an electromagnetic field. Capacitive proximity switches will sense metal as well as nonmetallic materials such as paper, glass, liquids, and cloth.



The sensing surface of a capacitive sensor is formed by two concentrically shaped metal electrodes of an unwound capacitor. When an object nears the sensing surface it enters the electrostatic field of the electrodes and changes the capacitance in an oscillator circuit. As a result, the oscillator begins oscillating. The trigger circuit reads the oscillator's amplitude and when it reaches a specific level the output state of the sensor changes. As the target moves away from the sensor the oscillator's amplitude decreases, switching the sensor output back to its original state.



Capacitive sensors depend on the dielectric constant of the target. The larger the dielectric number of a material the easier it is to detect.

Applications

A. Industrial usages
   1. Production automation machines that count products, product transfers
   2. Filling processes, pipelines, inks, etc.
   3. Fluid level, composition, and pressure
B. Moisture control
C. Non-invasive content detection
D. Touch applications

Advantages of Capacitive Proximity Sensors

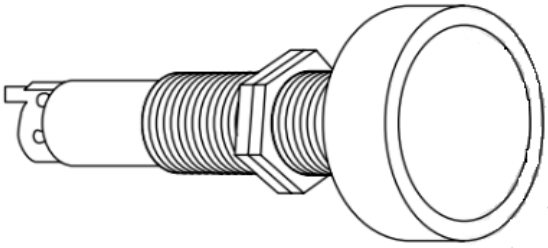
1. Contactless detection
2. A wide array of materials to be detected
3. Able to detect objects through non-metallic walls with its wide sensitivity band
4. Well-suited to be used in an industrial environment
5. Contains potentiometer that allows users to adjust sensor sensitivity, such that only wanted objects will be sensed
6. No moving parts, ensuring a longer service life

Disadvantages of Capacitive Proximity Sensors

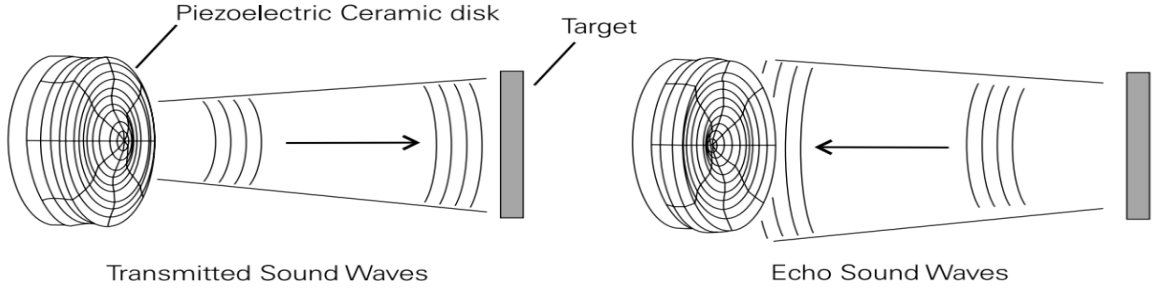
1. Relative low range, though incremental increase from inductive sensors
2. Higher price as compared to inductive sensors

Ultrasonic Proximity Sensors

Ultrasonic proximity sensors use a transducer to send and receive high frequency sound signals. When a target enters the beam the sound is reflected back to the switch, causing it to energize or de-energize the output circuit.



A piezoelectric ceramic disk is mounted on the sensor surface. It can transmit and receive high-frequency pulses. A high- frequency voltage is applied to the disk, causing it to vibrate at the same frequency. The vibrating disk produces high-frequency sound waves. When transmitted pulses strike a sound-reflecting object, echoes are produced. The duration of the reflected pulse is evaluated at the transducer. When the target enters the preset operating range, the output of the switch changes state. When the target leaves the preset operating range, the output returns to its original state.



The time interval between the transmitted signal and the echo is directly proportional to the distance between the object and sensor.

Applications

1. Distance measurement
2. Anemometers for wind speed and direction detection
3. Automation production processes
4. Fluid detection
5. Unmanned aerial vehicles (UAVs) for object monitoring
6. Robotics

Advantages of Ultrasonic Proximity Sensors

1. Contactless detection
2. Not affected by object color and transparency
3. Not affected by external environmental conditions, reliable solution
4. Works well in places with extreme conditions
5. Able to be used in dark environments
6. Low current consumption

Disadvantages of Ultrasonic Proximity Sensors

1. Limited detection range though capable of higher range as compared to inductive and capacitive sensors
2. Doesn't work in a vacuum since ultrasonic sensors operate via sound waves
3. Not able to measure the distance of Soft objects or ones with extreme textures

Photoelectric Proximity Sensors

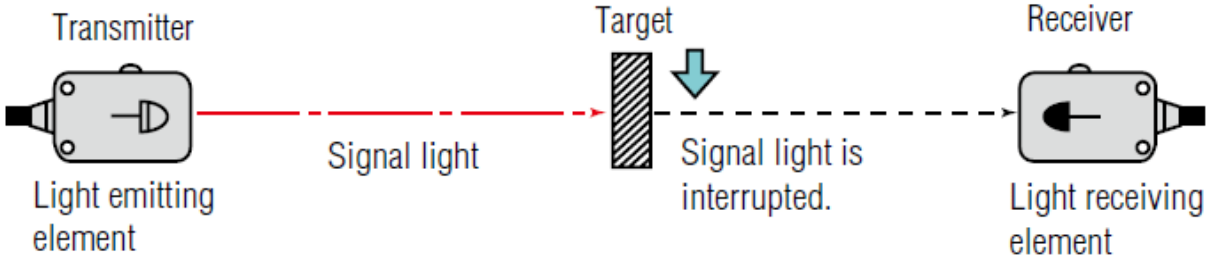
Photoelectric sensors are able to detect both metallic and non-metallic targets.
The main components of this sensor are emitter, detector and associated electronics. Emitter (Light Emitting Diode, laser diode) sends a beam of light. The detector (photodiode or phototransistor) detects emitted light. An associated electronics required to amplify the detected signal.

There are three main sensing methods of the photoelectric proximity sensor

1. Through beam method
2. Retro-reflective method
3. Diffuse or Reflective method

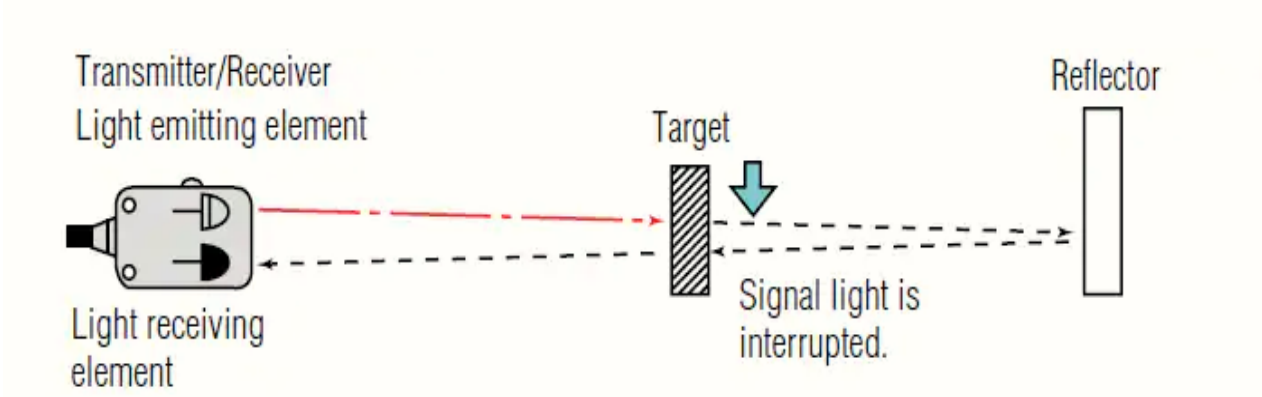
Through beam method

In this type of method, an emitter sends out a beam of light directly in the line-of-sight of the emitter to a receiver. When an object breaks this beam of light, it detects it as a presence. This type of setup requires two components, they are an emitter and a separate detector, which makes it a bit more complex to install and wire. However, the advantage is that it's the most accurate of the sensing methods with the longest sensing range.



Retro-reflective method

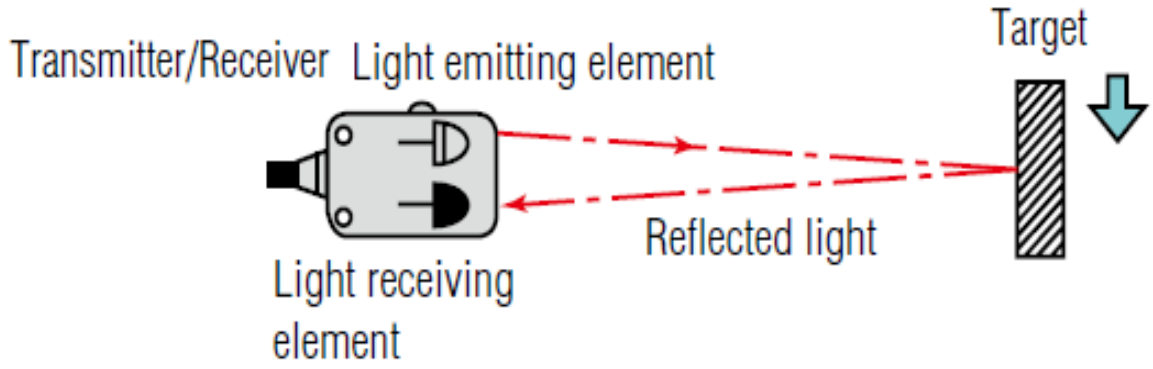
In this method, detection occurs when the light path breaks or disturbs. Both the light emitting and light receiving elements are in the same housing. The light from the emitting element hits the reflector and returns to the light receiving element. When a target is present, the light gets interrupted.



One reason for using a retro-reflective sensor over a through-beam sensor is for the convenience of one wiring location, the opposing side only requires reflector mounting.

Diffuse or Reflective method

As in retro-reflective sensors, emitters and receivers located in the same housing. In this Diffuse method, Both the light emitting and light receiving elements are contained in a single housing. The sensor receives the light reflected from the target.



Diffuse photoelectric sensors are similar in some respects to reflective sensors. This is because like reflective sensors they emit a light beam in the direction of the object to be detected. However, instead of a reflector used to bounce the light back to a detector, the object to be sensed functions as the reflector, bouncing some of the light back to be detected and register an object's presence.

Advantages of Photoelectric Proximity Sensor

1. The sensor senses all kinds of materials.
2. It has longer life, long sensing range and very reliability.
3. Very fast response time and less costly.
4. Diffuse photoelectric sensor detects small objects including color mark and label detection.
5. Most retro-reflective type sensors can detect transparent objects.
6. Through beam type, it can detect long range and it is tolerant of dirty environments.

Disadvantages of Photoelectric Proximity Sensor

1. Over course of time lenses get contaminated.
2. Generally, the sensing range is affected due to color and reflectivity of the target.
3. Through beam type requires transmitter (Tx) and receiver (Rx) at two separate locations
4. Retro reflective type requires a reflector in addition to Tx/Rx. This makes system installation complex

Applications of Photoelectric Proximity Sensor

1. Used in the food and pharmaceutical industries, and in packaging plants.
2. Counting of small objects
3. Detection of colours in the printing and packaging sectors.
4. Monitoring bigger areas for objects with light grids
5. Distance Measurement
6. Logistics and materials handling
7. Automatic doors

Comparison of Proximity sensors

Sr. No.	Parameter	Inductive	Capacitive	Ultrasonic
1	Principle	It uses current induced by magnetic fields to detect nearby metal objects	Base on an electronic principle where an electrical field is produced on the active side	Based on an ultrasonic source and receiver in the same device
2	Material detected	Metallic only	(All material) Metallic and non-metallic objects Including liquid, powders, and granular	All material (Object with simple surfaces)
3	Operating distance	Low:<50mm(Short)	Low:<50mm (Short)	Large:15m (Long)
4	Robustness to vibration	High	High	Low
5	Cost	Low	Medium	High
6	Sensitivity	Any	Humidity & vapors	Air flow & temperature variation
7	Applications	1. Machine- tools, assembly line, automotive industry 2. Detection of metal parts in harsh environments 3. High speed moving parts	1. Final inspection on packaging lines 2. Measurements of the filling level of the liquids or granules through the walls of plastic or glass tanks	1. Passage of objects on conveyor: glass bottles, cardboard Packaging 2. Filling level of liquids in a bottle or of granulates in a plastic injection machine 3. Depth of cavity