UNIT-2

DISPLACEMENT SENSOR

Variable Resistive Transducer Working and Its Applications

The resistive transducers are also known as resistive sensors or variable resistance transducers. These transducers are most frequently used for calculating different physical quantities like pressure, vibration, temperature, force, and displacement. These transducers work in both primary as well as secondary. But generally, these are used as secondary because the primary transducer's output can work as an input to the resistive transducer. The output which is attained from it is adjusted against the amount of input & it provides the input value directly

The resistive transducer can be defined as; the resistance of a transducer can be changed due to the effects of the environment. Here, the resistance change can be calculated with the help of measuring devices like AC or DC. The main purpose of this transducer is to measure physical quantities such as vibration, displacement, temperature, etc.

he physical quantity measurement is fairly not easy. The physical quantities can be changed by using this transducer into variable resistance. By using the meters, it can be measured easily. The method of difference in resistance is extensively used within industrial applications.

The primary transducer converts the physical quantities to a mechanical signal whereas the secondary transducer converts to an electrical signal directly.The major types of resistive transducer include potentiometers, resistive position transducers, resistive pressure transducers, thermistors, strain gauges, and LDR.

Working of Resistive Transducer

This is the most frequently used transducer to calculate pressure, temperature, force, displacement, vibrations, etc. To understand the working of a resistive transducer, the conductor rod is considered as an example of this transducer.These transducers work on the principle of the length of a conductor which is directly proportional to the conductor's resistance & it is inversely proportional to the conductor's area. So, the denominated length of the conductor is 'L', the area is 'A' and resistance is ‘R’ and the resistivity is ‘ρ’. It is stable for every material which is used in conductor construction.

$$R = \rho L/A$$

From the above equation,

- ‘R’ is the resistance of the conductor.
- ‘A’ is the side view part of the conductor.
- “L’ is the conductor’s length.
- ‘ρ’ – the resistivity of the conductor.

The transducer’s resistance can be changed because of the exterior environmental factors as well as the conductor’s physical properties. The change in resistance can be measured using AC devices or DC devices. This transducer acts like a primary as well as the secondary transducer. A primary transducer is used to change the physical quantity to the mechanical signal whereas a secondary transducer is used to convert a mechanical signal to an electrical signal.

Applications of Resistive Transducer

The applications of resistive transducer include potentiometer, resistance thermometer, strain gauges, thermistor, etc.

- These transducers are mainly used to calculate the temperature in several applications.
- The applications of resistive transducer include potentiometer, resistance thermometer, strain gauges, thermistor, etc.
- These transducers are used to measure displacement.
- The best examples of this transducer are potentiometers like rotator & translation. The resistance of these can be changed with the deviation within their lengths to measure the displacement.
- The semiconductor material’s resistance can be changed when the strain happens on it. This property can be used to measure force, displacement, and pressure, etc.
- The metal’s resistance can be changed due to temperature change. So this property can be used to calculate the temperature.
- The working principle of this is the thermistor materials temperature coefficient can be changed by the temperature. The temperature coefficient of the thermistor is negative which means this is inversely proportional to resistance.

Advantages of Resistive Transducer

The advantages of the resistive transducer include the following.

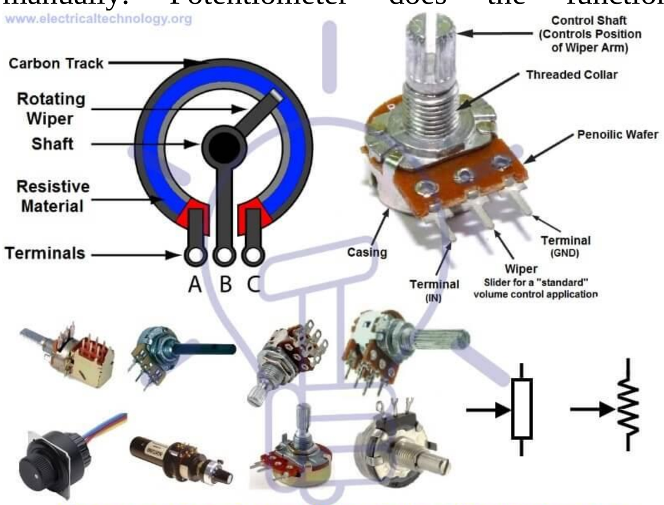
- These transducers give quick responses.
- These are available in different sizes and they have high resistance.
- The voltage otherwise current for both the AC & DC is suitable for calculating variable resistance.
- They are low-cost.
- The operation of these transducers is very easy and used in various applications wherever the necessities are not mostly severe.
- These are used to measure the huge amplitudes of displacement.
- Its electrical efficiency is extremely high and gives adequate output to let control operations.

Disadvantages

- When using these transducers, huge power is necessary to move the sliding contacts. The sliding contacts can exhaust, become uneven and produce noise.

1.1Potentiometers:

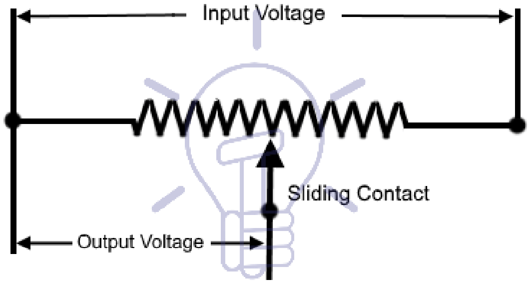
A potentiometer is also called as pot. It is variable resistor that has 3 terminals. Two fixed terminals and one variable terminal. In this device the current flow is controlled by varying the resistance manually. Potentiometer does the function of an adjustable voltage divider.



Construction, Types & Symbols of Potentiometer

How does a Potentiometer work?

Potentiometer is a passive component that works on moving the slider across the full length of the conductor. The input supply voltage is applied to the entire length of the resistor. The output voltage is measured as voltage drop between fixed and movable contact as seen in the figure below. The slider is adjusted manually over the resistive strip to change the resistance value from zero to a higher value. When the resistance changes, the current flowing through circuit changes. Hence according to Ohm's law, the resistive material also changes.



Working of Potentiometer

Assume that two batteries are connected in parallel through galvanometer. Negative ends of both batteries are connected together and similarly both positive ends are connected together. Since both batteries carry same electric potential, there will be no current flowing through galvanometer and its does not show deflection. The pot also works on the same phenomenon.

Types of Potentiometers:

1. Rotary Potentiometer
2. Linear Potentiometer

Rotary Potentiometer:

Adjustable supply voltage can be obtained using rotary potentiometer. A familiar example is volume controller of a radio transistor, in which the amplifier supply is supported by the rotary knob of the pot. The other applications are it is used when the end user needs smooth voltage control.

Linear Potentiometer:

It works same as the rotary potentiometer but the only difference is slider moves linearly on the resistor. The resistor ends are connected across the supply voltage. The two ends of the output circuit are connected to the sliding terminal and resistor terminal

Applications of Potentiometers:

1. Potentiometer as a Voltage Divider:
2. Audio Control
3. Television
4. Transducers
5. Pots as measuring devices:
6. Pots as tuners and calibrators
7. To compare the emf of a battery cell with a standard cell
8. To measure the internal resistance of a battery cell
9. To measure the voltage across a branch of a given circuit.

<u>Strain Gauge:</u>

A <u>strain gauge</u> is a passive <u>transducer</u>, that converts mechanical displacement into the change of resistance. A strain gauge sensor is a thin wafer-like device that can be attached to a variety of materials to measure applied strain. These are used as a fundamental sensor in many types of sensors like pressure sensors, load cells, torque sensors etc.

<u>Strain Gauge Working Principle</u>

The foil type strain gauges (Figure #1) are very common in which a resistive foil is mounted on a backing material. These are available in a variety of shapes and sizes for different applications. The resistance of the foil changes as the material to which the gauge is attached undergoes tension or compression due to change in its length and diameter.

This change in resistance is proportional to the applied strain. As this change in resistance is very small in magnitude so its effect can be only sensed by a Wheatstone bridge. This is the basic *strain gauge working principle*.

10.

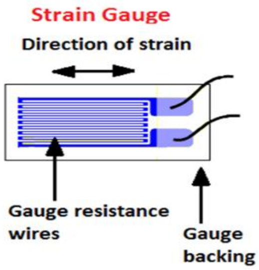


Figure #1

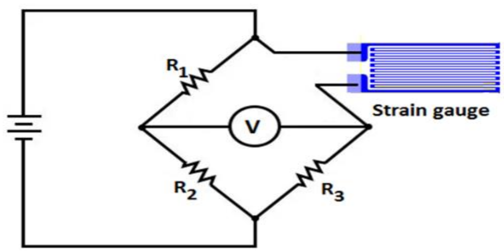


Figure #2

A circuit diagram is shown in Figure #2. In this circuit diagram, a strain gauge is connected into a Wheatstone bridge. This circuit is so designed that when no force is applied to the strain gauge, R1 is equal to R2 and the resistance of the strain gauge is equal to R3. In this condition the Wheatstone bridge is balanced and the voltmeter shows no deflection.

But when strain is applied to the strain gauge, the resistance of the strain gauge sensor changes, the Wheatstone bridge becomes unbalanced, a current flows through the voltmeter. Since the net change in the resistance is proportional to the applied strain, therefore, resultant current flow through the voltmeter is proportional to the applied strain. So, the voltmeter can be calibrated in terms of strain or force.

In the above circuit, we have used only one strain gauge. This is known as 'quarter bridge' circuit. We can also use two strain gauges or even four strain gauges in this circuit. Then this circuit is called 'half bridge' and 'full bridge' respectively. The full bridge circuit provides greater sensitivity and least temperature variation errors.

Gauge Factor of Strain Gauge

The gauge factor of strain gauge is defined as the unit change in resistance per unit change in length.

i.e. gauge factor $Gf = (\Delta R/R)/(\Delta l/l)$

where, R = nominal gauge resistance,

ΔR = change in resistance,

l = length of the specimen in an unstressed condition,

Δl = change in specimen length.

It can be proved mathematically,

Gauge factor, $Gf = 1 + 2v + (\Delta\rho/\rho)/(\Delta L/L)$

If the change in resistivity due to strain is almost negligible, then

gauge factor of strain gauge, $Gf = 1 + 2v$

Where, v is Poisson's ratio. It may be defined as the ratio of strain in the lateral direction to the strain in the axial direction. The Poisson's ratio for most metals lies in the range of 0 to 0.5 and this gives a gauge factor of 2 approximately.

Strain Gauge Transducer Types:

Strain Gauge Transducer Types are three types, namely

1.Wire Strain Gauges

2.Foil Strain Gauge

3.Semiconductor Strain Gauge

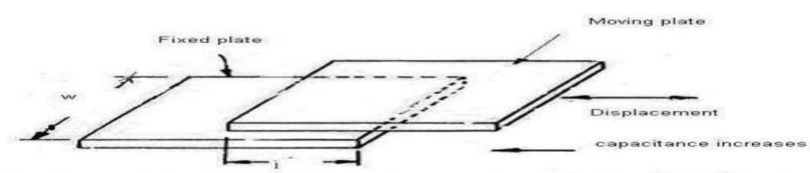
Strain Gauge Applications

Strain gauges are used to determine or verify component or structure stresses, or by manufacturers of load cells, pressure and torque transducers, etc., where they utilize the physical parameter being measured to strain a part of the transducer in a linear way. It converts force, pressure, tension, weight, etc., into a change in electrical resistance which can then be measured.

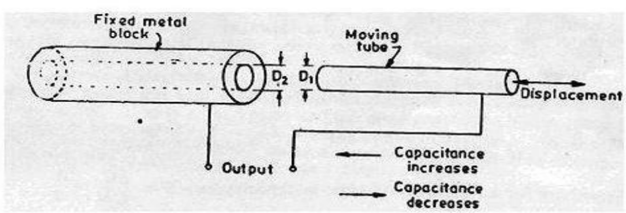
Variable Capacitve Transducer:

The capacitive transducer or sensor is nothing but the capacitor with variable capacitance. The capacitive transducer comprises of two parallel metal plates that are separated by the material such as air, which is called as the dielectric material. In the typical capacitor the distance between the two plates is fixed, but in variable capacitance transducers the distance between the two plates is variable.In the instruments using capacitance transducers the value of the capacitance changes due to change in the value of the input quantity that is to be measured. This change in capacitance can be measured easily and it is calibrated against the input quantity, thus the value if the input quantity can be measured directly.

Capactive Transducer or Capacitive Sensor or Variable Capacitance Transducer



Flat Type of Capactive Transducer



Concentric Type of Capacitive Transducer

Capacitance of the Capacitive Transducers: The capacitance C between the two plates of capacitive transducers is given by:

$$\mathbf{C = \varepsilon_o \times \varepsilon_r \times A/ d}$$

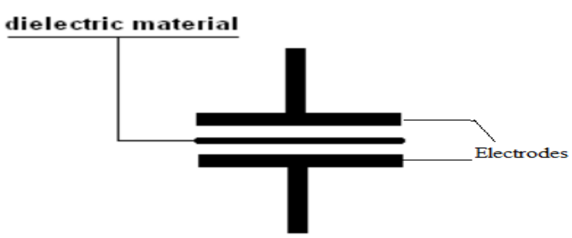
Where C is the capacitance of the capacitor or the variable capacitance transducer

ε_o is the absolute permittivity
ε_r is the relative permittivity
The product of ε_o & ε_r is also called as the dielectric constant of the capacitive transducer.
A is the area of the plates, D is the distance between the plates

It is clear from the above formula that capacitance of the capacitive transducer depends on the area of the plates and the distance between the plates. The capacitance of the capacitive transducer also changes with the dielectric constant of the dielectric material used in it.Thus the capacitance of the variable capacitance transducer can change with the change of the dielectric material, change in the area of the plates and the distance between the plates. Depending on the parameter that changes for the capacitive transducers, they are of three types as mentioned below.

1) **Changing Dielectric Constant type of Capacitive Transducers**

In these capacitive transducer the dielectric material between the two plates changes, due to which the capacitance of the transducer also changes. When the input quantity to be measured changes the value of the dielectric constant also changes so the capacitance of the instrument changes. This capacitance, calibrated against the input quantity, directly gives the value of the quantity to be measured. This principle is used for measurement of level in the hydrogen container, where the change in level of hydrogen between the two plates results in change of the dielectric constant of the capacitance transducer. Apart from level, this principle can also be used.



2) **Changing Area of the Plates of Capacitive Transducers**

The capacitance of the variable capacitance transducer also changes with the area of the two plates. This principle is used in the torquemeter, used for measurement of the torque on the shaft. This comprises of the sleeve that has teeth cut axially and the matching shaft that has similar teeth at its periphery.

3) **Changing Distance between the Plates of Capacitive Transducers**

In these capacitive transducers the distance between the plates is variable, while the area of the plates and the dielectric constant remain constant. This is the most commonly used type of variable capacitance transducer. For measurement of the displacement of the object, one plate of the capacitance transducer is kept fixed, while the other is connected to the object. When the object moves, the plate of the capacitance transducer also moves, this results in change in distance between the two plates and the change in the capacitance. The changed capacitance is measured easily and it calibrated against the input quantity, which is displacement. This principle can also be used to measure pressure, velocity, acceleration etc.

Principle:

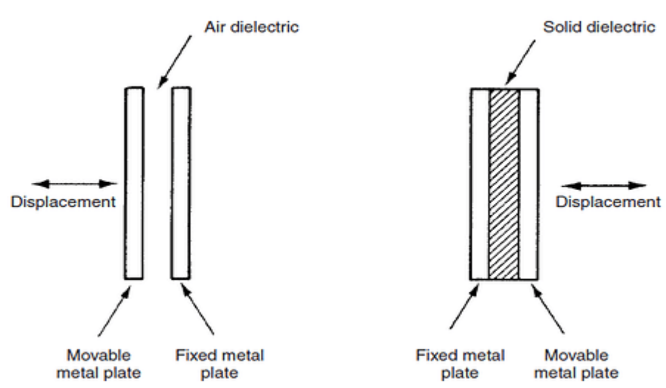
The principle of variable capacitance is used in displacement measuring transducers in various ways. Capacitance is a function of effective area of conductor, the separation between the conductors and the dielectric strength of the material. It is described in the equation below:

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

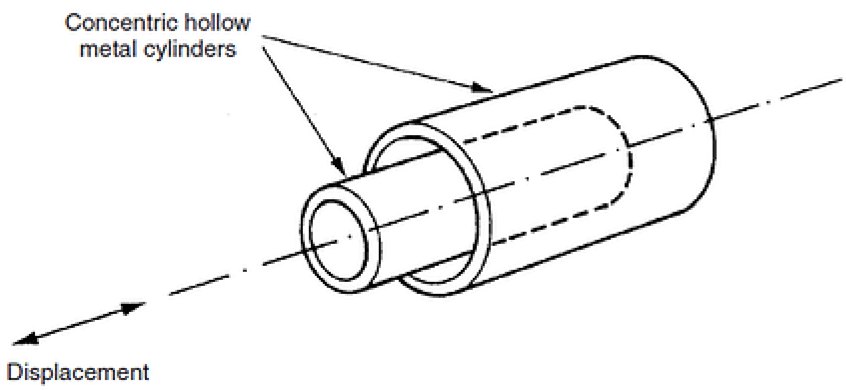
d - Distance between the two parallel electrodes.
ε - Dielectric constant, permittivity, of the dielectric medium
A - Area of the electrode.

Working:

There are three way to change the capacitance, changing in the area, changing the distance between the electrode plates and changing the material between the electrodes thus permittivity changes.

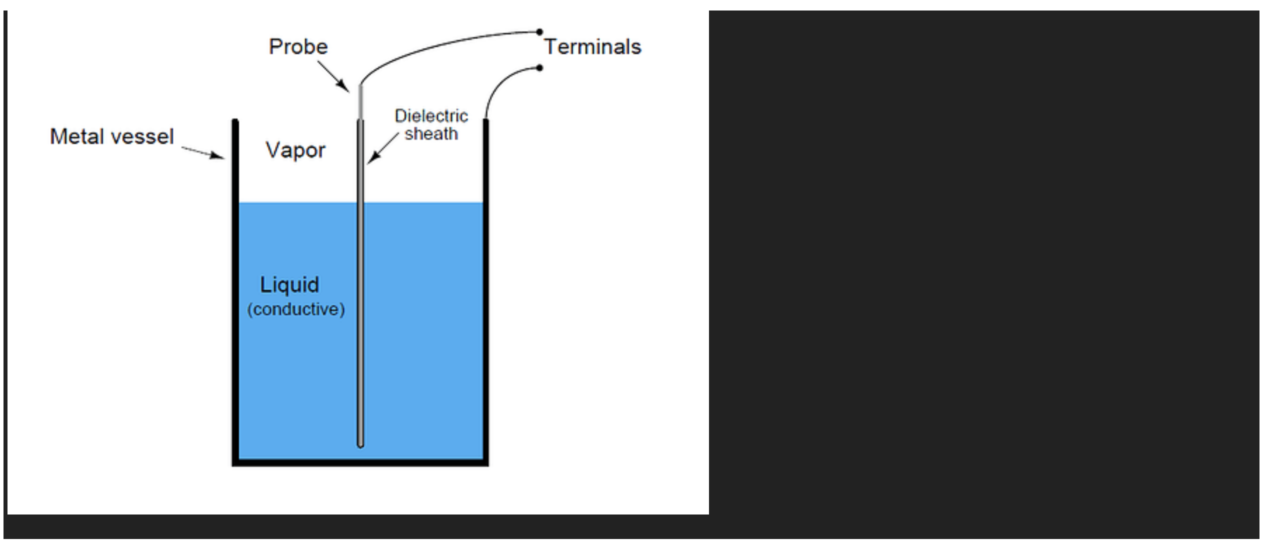


One of the two electrodes is made fixed and the other is made movable for measure displacement. Displacement to be measured is applied to the movable metal plate, as the plate moves the distance between the plates increases and this changes the capacitance measurement. Thus the change in the capacitance will be the function of the displacement of the electrode.



The capacitor plates are formed by two concentric, hollow, metal cylinders. The displacement to be measured is applied to the inner cylinder, which alters the capacitance.

Example: capacitance transducer for Level measurement:



Here both the electrodes are fixed so the distance is constant. One electrode is dipped into the liquid and another one is fixed to the wall of the tank. As the liquid level increases the permittivity changes and thus the capacitance changes.

Advantages:

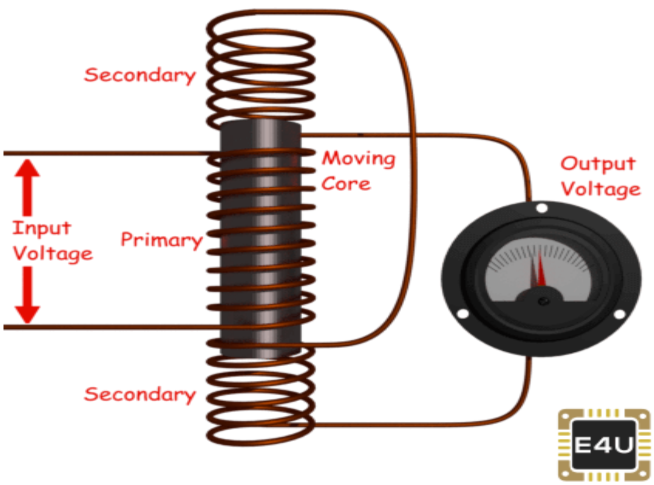
- It produces an accurate frequency response to both static and dynamic measurements
- Negligible loading effects

Disadvantage:

- Accuracy can be affected by change in temperature
- As the lead is lengthy it can cause errors or distortion in signals.

Variable Inductive transducers

Inductive transducers work on the principle of inductance change due to any appreciable change in the quantity to be measured i.e. measured. For example, LVDT, a kind of inductive transducers, measures displacement in terms of voltage difference between its two secondary voltages. Secondary voltages are nothing but the result of induction due to the flux change in the secondary coil with the displacement of the iron bar. Anyway, LVDT is discussed here briefly to explain the **principle of inductive transducer**. LVDT will be explained in another article in more detail. For the time being let's focus on the basic introduction of inductive transducers.



An example of an Inductive Transducer (LVDT)

Now first our motive is to find how the inductive transducers can be made to work. This can be done by changing the flux with the help of measured and this changing flux obviously changes the inductance and this inductance change can be calibrated in terms of measured. Hence inductive transducers use one of the following principles for its working.

1. Change of self inductance
2. Change of mutual inductance
3. Production of eddy current

Change of Self Inductance of Inductive Transducer

$$L = \frac{N^2}{R}$$

We know very well that self inductance of a coil is given by

Where,
N = number of turns.
R = reluctance of the magnetic circuit.
Also we know that reluctance R is given by

$$R = \frac{l}{\mu A}$$

$$L = \frac{N^2 \mu A}{l}$$

Where, μ = effective permeability of the medium in and around the coil.

$$L = N^2 \mu G$$

Where,
G = A/l and called the geometric form factor.
A = area of cross-section of the coil.
l = length of the coil.

So, we can vary self inductance by

- Change in number of turns, N,
- Changing geometric configuration, G,
- Changing permeability

For the sake of understanding we can say that if the displacement is to be measured by the inductive transducers, it should change any of the above parameter for causing in the change in self inductance. Examples are

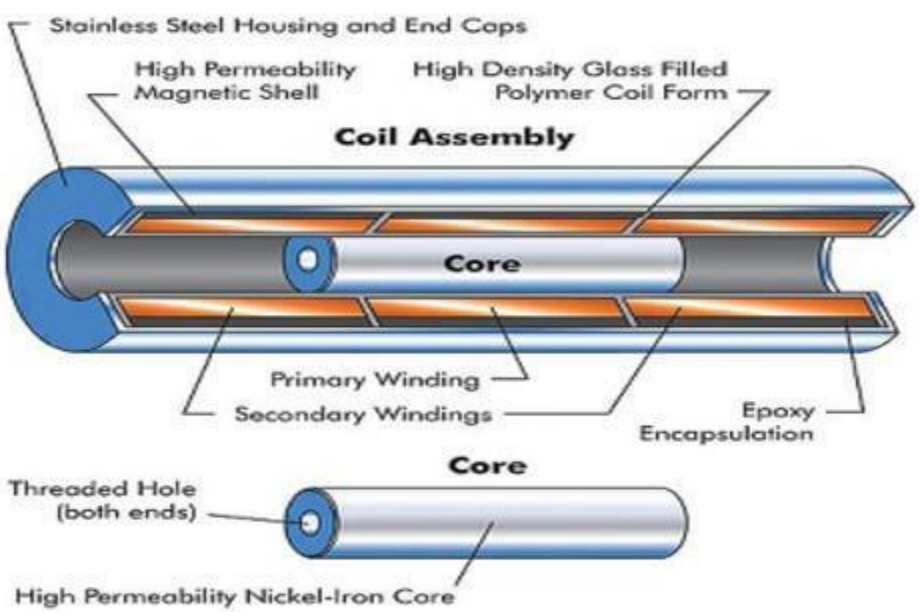
Linear Variable Differential Transformer

The term LVDT or Linear Variable Differential Transformer is a robust, complete linear arrangement transducer and naturally frictionless. They have an endless life cycle when it is used properly. Because AC controlled LVDT does not include any kind of electronics, they intended to work at very low temperatures otherwise up to 650 °C (1200 °F) in insensitive environments.

The applications of LVDTs mainly include automation, power turbines, aircraft, hydraulics, nuclear reactors, satellites, and many more. These types of transducers contain low physical phenomena and outstanding repetition.

The LVDT alters a linear dislocation from a mechanical position into a relative electrical signal including phase and amplitude of the information of direction and distance. The operation of LVDT does not need an electrical bond between the touching parts and coil, but as an alternative depends on the electromagnetic coupling.LVDT is used to calculate displacement and works on the transformer principle.

Linear Variable Differential Transformer



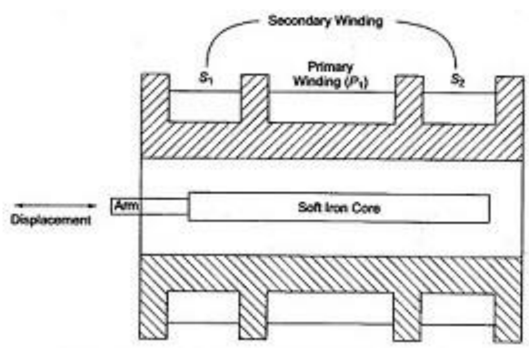
The above LVDT sensor diagram comprises a core as well as a coil assembly. Here, the core is protected by the thing whose location is being calculated, while the coil assembly is increased to a stationary structure. The coil assembly includes three wire wound coils on the hollow shape. The inside coil is the major, which is energized by an AC source. The magnetic flux generated by the main is attached to the two minor coils, making an AC voltage in every coil.

The main benefit of this transducer when we compared with other LVDT types is toughness. As there is no material contact across the sensing component.

Because the machine depends on the combination of magnetic flux, this transducer can have an unlimited resolution. So the minimum fraction of progress can be noticed by an appropriate signal conditioning tool, and the transducer's resolution is exclusively determined by the declaration of the DAS (data acquisition system).

LVDT Construction

LVDT comprises of a cylindrical former, which is bounded by one main winding in the hub of the former and the two minor LVDT windings are wound on the surfaces. The amount of twists in both the minor windings is equivalent, but they are reverse to each other like clockwise direction and anti-clockwise direction.

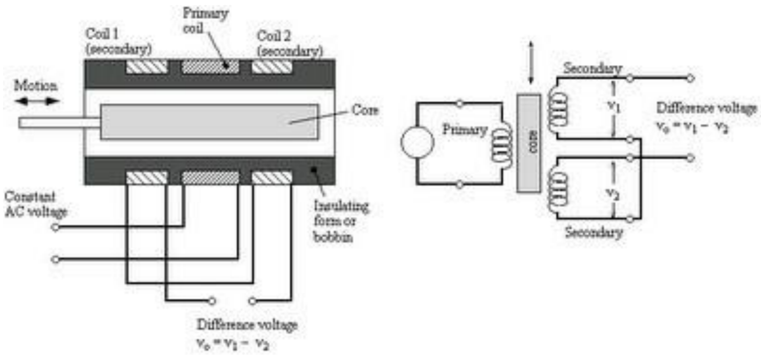


LVDT construction

For this reason, the o/p voltages will be the variation in voltages among the two minor coils. These two coils are denoted with S1 & S2. Esteem iron core is located in the middle of the cylindrical former. The excitation voltage of AC is 5-12V and the operating frequency is given by 50 to 400 HZ.

Working Principle of LVDT

The working principle of the linear variable differential transformer or LVDT working theory is mutual induction. The dislocation is a nonelectrical energy that is changed into an electrical energy. And, how the energy is altered is discussed in detail in the working of an LVDT.



LVDT Working Principle

Working of an LVDT

The working of LVDT circuit diagram can be divided into three cases based on the position of the iron core in the insulated former.

- **In Case-1:** When the core of the LVDT is at the null location, then both the minor windings flux will equal, so the induced e.m.f is similar in the windings. So for no dislocation, the output value (e_{out}) is zero because both the e1 & e2 are equivalent. Thus, it illustrates that no dislocation took place.
- **In Case-2:** When the core of the LVDT is shifted to up to the null point. In this case, the flux involving with minor winding S1 is additional as contrasted to flux connecting with the S 2 winding. Due to this reason, e1 will be added as that of e2. Due to this e_{out} (output voltage) is positive.
- **In Case-3:** When the core of the LVDT is shifted down to the null point, In this case, the amount of e2 will be added as that of e1. Due to this e_{out} output voltage will be negative plus it illustrates the o/p to down on the location point.

Advantages and Disadvantages of LVDT

The LVDT advantages and disadvantages include the following.

- The measurement of the displacement range of LVDT is very high, and it ranges from 1.25 mm -250 mm.
- The LVDT output is very high, and it doesn't require any extension. It owns a high compassion which is normally about 40V/mm.
- When the core travels within a hollow former consequently there is no failure of displacement input while frictional loss so it makes an LVDT as a very precise device.
- LVDT demonstrates a small hysteresis and thus repetition is exceptional in all situations
- The power consumption of the LVDT is very low which is about 1W as evaluated by another type of transducers.
- LVDT changes the linear dislocation into an electrical voltage which is simple to progress.
- LVDT is responsive to move away from magnetic fields, thus it constantly needs a system to keep them from drift magnetic fields.
- It is accomplished that LVDTs are more beneficial as contrasted than any kind of inductive transducer.

- LVDT gets damaged by temperature as well as vibrations.

LVDT Applications

The applications of the LVDT transducer mainly include where dislocations to be calculated that are ranging from a division of mm to only some cms.

- The LVDT sensor works as the main transducer, and that changes dislocation to electrical signal straight.
- This transducer can also work as a secondary transducer.
- LVDT is used to measure the weight, force and also pressure
- Some of these transducers are used to calculate the pressure and load
- LVDT's are mostly used in industries as well as servomechanisms.
- Other applications like power turbines, hydraulics, automation, aircraft, and satellites

RVDT – Rotary Variable Differential Transformer Explained

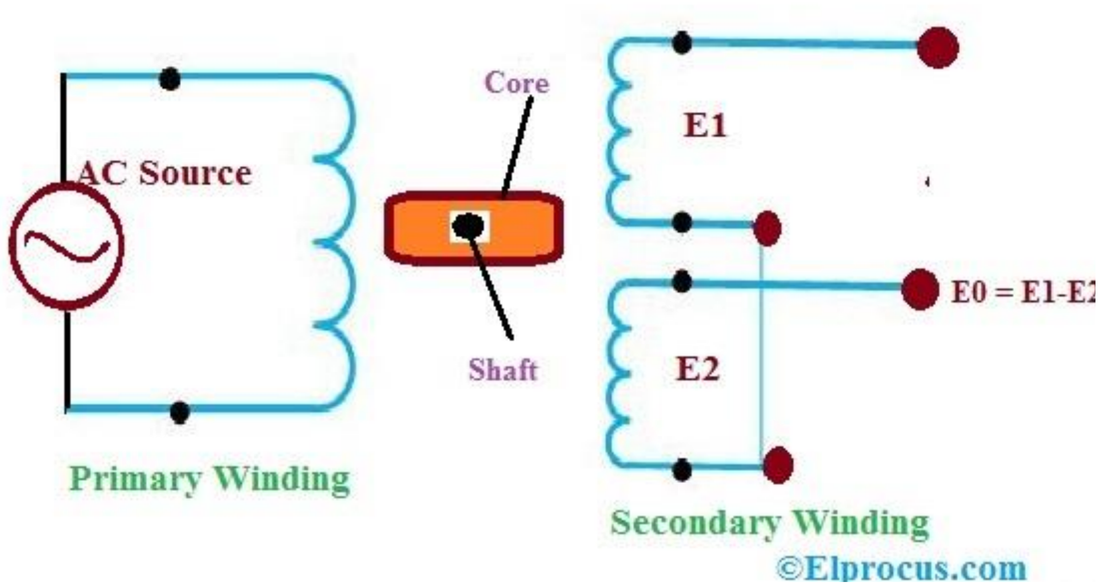
In the previous article, we have discussed an overview of LVDT or Linear Variable Differential Transformer. This article discusses an overview of RVDT, and the **RVDT full form** is Rotary Variable Differential Transformer. The designing of RVDT is same like an LVDT, apart from the design of core. Because, when it turns then the mutual inductance among the two windings of the transformer namely the primary coil and the secondary coils will change linearly by the angular displacement. RVDT's uses brushless, non-contacting equipment for ensuring long-life, consistent, repeatable and position detecting by unlimited resolution. Such performance guarantees precise position sensing under the most intense working conditions.

The RVDT stands for Rotary Variable Differential Transformer. It is one kind of electromechanical transducer used to give the linear o/p which is proportional to the i/p angular displacement. The main function of RVDT is to detect the angular displacement and converts it into an electrical signal. The both the RVDT and LVDT workings are similar, but LVDT employs the flexible iron core for displacement measurement whereas in RVDT employs a cam type core. This core will turn among the two windings of the transformer using the shaft.

Rotary Variable Differential Transformer

RVDT Construction and Its Working

RVDT transducer has two windings similar to a normal transformer such as primary winding and two secondary windings shown in the following **RVDT diagram**. The two windings of the transformer wounded, where the two secondary windings have an equivalent number of windings. These are located on both sides of the primary winding of the transformer. A cam formed a magnetic core which is made with a soft iron is coupled to a shaft. Thus, this core can be twisted among the windings. The construction of both the RVDT and LVDT are similar but the main difference is the shape of the core in transformer windings. This core will turn between the two windings of the transformer due to the shaft.



RVDT Construction

The typical RVDTs are linear over a +40 or -40 degrees, Sensitivity is about 2mV to 3mV per degree of rotation and the input voltage range is 3V RMS at frequency ranges from 400Hz to 20kHz. Based on the movement of the shaft in the transformer, the three conditions will be produced such as

- When the Core is at Null Position
- When the Core Rotates in Clockwise Direction
- When the Core Rotates in Anticlockwise Direction

When the Core is at Null Position

In the first condition, when the shaft is placed at the null position then the induced e.m.f in the secondary windings are similar although reverse in phase. Thus, the differential o/p potential will be zero, and the condition will be E1 = E2, where E0 = E1-E2 =0

When the Core Rotates in Clockwise Direction

In the second condition, when the shaft rotates in the direction of clockwise; more section of the core will enter across the primary winding. Therefore, the induced e.m.f across the primary winding is higher than secondary winding. Hence, the differential o/p potential is positive, and the condition will be E1 > E2, where E0 = E1-E2 = positive.

When the Core Rotates in Anticlockwise Direction

In the third condition, when the shaft rotates in the direction of anticlockwise, more section of the core will be entered across the secondary winding. Thus, the induced e.m.f across the secondary coil is higher than the primary coil. Hence, the differential o/p potential is negative that means 1800 phase shift, and the condition will be E1 < E2, where E0 = E1-E2 = negative.

Advantages of RVDT

- The consistency of RVDT is high
- The exactness of RVDT is high
- The lifespan is long
- The performance is repeatable
- The construction is compact and strong

- Durability
- Low cost
- Easy to handle electronic components
- Resolution is infinite
- Linearity is Excellent
- A wide range of dimension ranges

Disadvantages of RVDT

The contact among the measuring exterior as well as the nozzle is not possible for all time.

- The output of the RVDT is linear (about +40 or -40 degrees), so it restricts the usability.

RVDT Applications

Applications of RVDT

- Fuel Valves as well as Hydraulic
- Modern machine tools
- Controls Cockpit
- Controls Fuel
- Brake with cable systems
- Engines bleed air-systems
- Robotics
- Aircraft and Avionics
- Process Control industry
- Weapon and Torpedo Systems
- Engine fuel control
- Nose wheel steering systems
- Fly by wire systems
- Push reverser
- Actuators for controlling Flight as well as Engine
- Ecological control systems

Variable Reluctance Sensor

The variable reluctance sensor consists of a wire wrapped around a permanent magnet. When the ferromagnetic material such as a flywheel tooth passes the sensor the magnetic field is disrupted. Due to this an AC voltage is generated, the amplitude and frequency of which depends on the speed of the flywheel. Here the polarity of the voltage is not important. The amplitude of this AC voltage also depends on the air gap i.e. the distance between the sensor and the flywheel tooth. The voltage decreases as the air gap increases and the voltage increases as air gap decreases. Since the amplitude depends on the speed and also the air gap, correct setting of the air gap is very important when measuring lower speeds. This AC signal from the sensor can be processed further to obtain the digital output.

The variable Reluctance sensors are called as passive sensors since they don't need external power supply for their operation.

We know very well that self inductance of a coil is given by

Where,
N = number of turns.
R = reluctance of the magnetic circuit.
Also we know that reluctance R is given by

$$R = \frac{l}{\mu A}$$

$$L = \frac{N^2 \mu A}{l}$$

Where, μ = effective permeability of the medium in and around the coil.

$$L = N^2 \mu G$$

Where,
G = A/l and called the geometric form factor.
A = area of cross-section of the coil.
l = length of the coil.

Advantages of Variable reluctance sensor

- They don't need external power supply
- Low cost
- Light weight
- They are robust and can work in harsh environments
- Can work in high temperature and high vibration environment

Disadvantages of Variable reluctance sensor

- Difficult to measure low speeds
- Additional signal processing circuitry required

Applications of Variable reluctance sensor

- Gear tooth speed sensor
- Turbine speed of the jet engine

Hall Effect Sensor

We could not end this discussion on Magnetism without a mention about magnetic sensors and especially the very commonly used **Hall Effect Sensor**.

Magnetic sensors convert magnetic or magnetically encoded information into electrical signals for processing by electronic circuits, and in the **Sensors and Transducers** tutorials we looked at inductive proximity sensors and the LDVT as well as solenoid and relay output actuators.

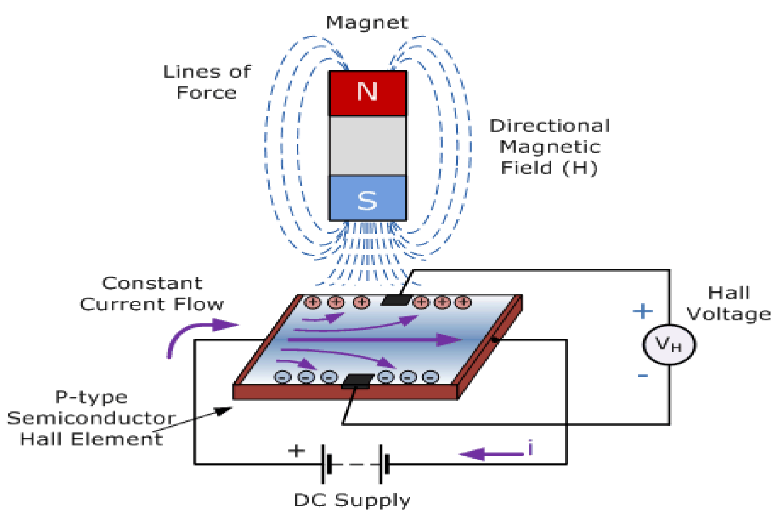
Magnetic sensors are solid state devices that are becoming more and more popular because they can be used in many different types of application such as sensing position, velocity or directional movement. They are also a popular choice of sensor for the electronics designer due to their non-contact wear free operation, their low maintenance, robust design and as sealed hall effect devices are immune to vibration, dust and water.

One of the main uses of magnetic sensors is in automotive systems for the sensing of position, distance and speed. For example, the angular position of the crank shaft for the firing angle of the spark plugs, the position of the car seats and seat belts for air-bag control or wheel speed detection for the anti-lock braking system, (ABS).

Magnetic sensors are designed to respond to a wide range of positive and negative magnetic fields in a variety of different applications and one type of magnet sensor whose output signal is a function of magnetic field density around it is called the Hall Effect Sensor.

Hall Effect Sensors are devices which are activated by an external magnetic field. We know that a magnetic field has two important characteristics flux density, (B) and polarity (North and South Poles). The output signal from a Hall effect sensor is the function of magnetic field density around the device. When the magnetic flux density around the sensor exceeds a certain pre-set threshold, the sensor detects it and generates an output voltage called the **Hall Voltage, V_H**. Consider the diagram below.

Hall Effect Sensor Principles



Hall Effect Sensors consist basically of a thin piece of rectangular p-type semiconductor material such as gallium arsenide (GaAs), indium antimonide (InSb) or indium arsenide (InAs) passing a continuous current through itself. When the device is placed within a magnetic field, the magnetic flux lines exert a force on the semiconductor material which deflects the charge carriers, electrons and holes, to either side of the semiconductor slab. This movement of charge carriers is a result of the magnetic force they experience passing through the semiconductor material.

As these electrons and holes move side wards a potential difference is produced between the two sides of the semiconductor material by the build-up of these charge carriers. Then the movement of electrons through the semiconductor material is affected by the presence of an external magnetic field which is at right angles to it and this effect is greater in a flat rectangular shaped material.

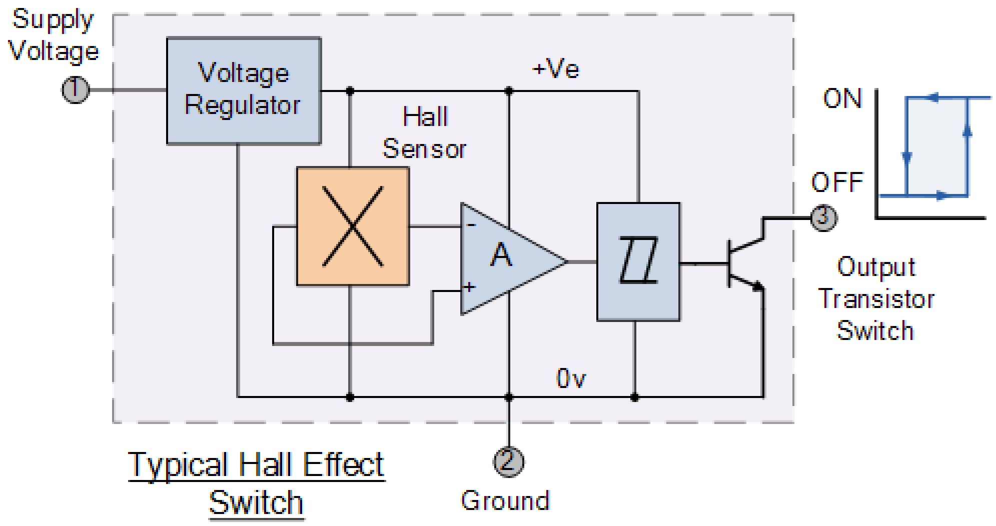
The effect of generating a measurable voltage by using a magnetic field is called the **Hall Effect** after Edwin Hall who discovered it back in the 1870's with the basic physical principle underlying the Hall effect being Lorentz force. To generate a potential difference across the device the magnetic flux lines must be perpendicular, (90^o) to the flow of current and be of the correct polarity, generally a south pole.

The Hall effect provides information regarding the type of magnetic pole and magnitude of the magnetic field. For example, a south pole would cause the device to produce a voltage output while a north pole would have no effect. Generally, Hall Effect sensors and switches are designed to be in the "OFF", (open circuit condition) when there is no magnetic field present. They only turn "ON", (closed circuit condition) when subjected to a magnetic field of sufficient strength and polarity.

Hall Effect Magnetic Sensor

The output voltage, called the Hall voltage, (V_H) of the basic Hall Element is directly proportional to the strength of the magnetic field passing through the semiconductor material (output $\propto$ H). This output voltage can be quite small, only a few microvolts even when subjected to strong magnetic fields so most commercially available Hall effect devices are manufactured with built-in DC amplifiers, logic switching circuits and voltage regulators to improve the sensors sensitivity, hysteresis and output voltage. This also allows the Hall effect sensor to operate over a wider range of power supplies and magnetic field conditions.

The Hall Effect Sensor

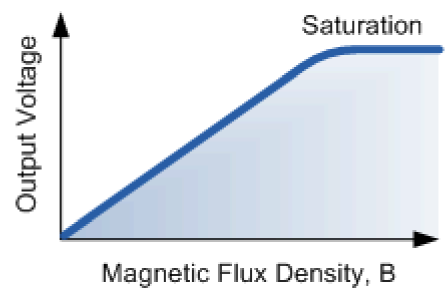


Typical Hall Effect Switch

Hall Effect Sensors are available with either linear or digital outputs. The output signal for linear (analogue) sensors is taken directly from the output of the operational amplifier with the output voltage being directly proportional to the magnetic field passing through the Hall sensor. This output Hall voltage is given as:

$$V_H = R_H \left(\frac{I}{t} \times B \right)$$

- Where:
- V_H is the Hall Voltage in volts
- R_H is the Hall Effect co-efficient
- I is the current flow through the sensor in amps
- t is the thickness of the sensor in mm
- B is the Magnetic Flux density in Teslas



Linear or analogue sensors give a continuous voltage output that increases with a strong magnetic field and decreases with a weak magnetic field. In linear output Hall effect sensors, as the strength of the magnetic field increases the output signal from the amplifier will also increase until it begins to saturate by the limits imposed on it by the power supply. Any additional increase in the magnetic field will have no effect on the output but drive it more into saturation.

Digital output sensors on the other hand have a Schmitt-trigger with built in hysteresis connected to the op-amp. When the magnetic flux passing through the Hall sensor exceeds a pre-set value the output from the device switches quickly between its “OFF” condition to an “ON” condition without any type of contact bounce. This built-in hysteresis eliminates any oscillation of the output signal as the sensor moves in and out of the magnetic field. Then digital output sensors have just two states, “ON” and “OFF”.

There are two basic types of digital Hall effect sensor, **Bipolar** and **Unipolar**. Bipolar sensors require a positive magnetic field (south pole) to operate them and a negative field (north pole) to release them while unipolar sensors require only a single magnetic south pole to both operate and release them as they move in and out of the magnetic field.

Most Hall effect devices can not directly switch large electrical loads as their output drive capabilities are very small around 10 to 20mA. For large current loads an open-collector (current sinking) NPN Transistor is added to the output.

This transistor operates in its saturated region as a NPN sink switch which shorts the output terminal to ground whenever the applied flux density is higher than that of the “ON” pre-set point.

The output switching transistor can be either an open emitter transistor, open collector transistor configuration or both providing a push-pull output type configuration that can sink enough current to directly drive many loads, including relays, motors, LEDs, and lamps.

Applications of Hall Effect Sensor

The applications of Hall Effect Sensors have been represented in two categories for ease of understanding.

- Applications of Analog Hall Effect Sensors
- Applications of Digital Hall Effect Sensors

Applications of Analog Hall Effect Sensors

Analog Hall Effect Sensors are utilized for :

- Direct Current sensing in Clamp meters (also known as Tong Testers).
- Wheel speed detection for the anti-lock braking system, (ABS).
- Motor control devices for protection and indications.
- Sensing the availability of Power supply.
- Motion Sensing.
- Sensing the rate of flow.
- Sensing Diaphragm pressure in Diaphragm pressure gauge.
- Sensing Vibration.
- Sensing Ferrous Metal in Ferrous Metal Detectors.
- Voltage Regulation.

Applications of Digital Hall Effect Sensors

Digital Hall Effect Sensors are utilized for :

- Sensing the angular position of the crank shaft for the firing angle of the spark plugs.
- Sensing the position of the car seats and seat belts for air-bag control .
- Wireless Communications.
- Sensing Pressure.
- Sensing Proximity.
- Sensing rate of flow.
- Sensing position of Valves.
- Sensing position of Lens.

Advantages of Hall Effect Sensors

Hall Effect Sensors have the following advantages:

- They can be used for multiple sensor functions like position sensing, speed sensing as well as for sensing the direction of movement too.
- As they are solid state devices, there is absolutely no wear and tear due to absence of moving parts.
- They are almost maintenance free.
- They are robust.
- They are immune to vibration, dust and water.

Disadvantages of Hall Effect Sensors

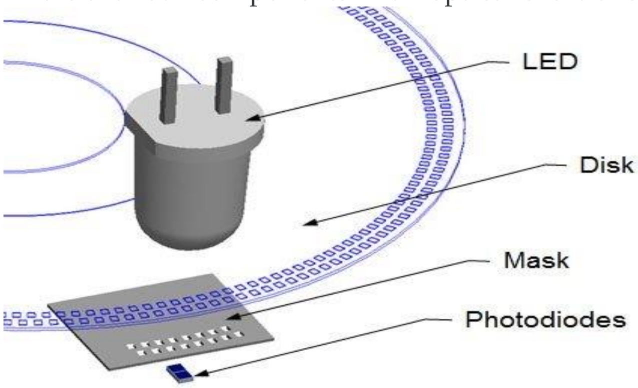
The Hall Effect Sensors have the following disadvantages: –

- They are not capable to measure current flow at a distance more than 10 cm. The only solution to overcome this issue is to use a very strong magnet that can generate a wide magnetic field.
- Accuracy of the measured value is always a concern as external magnetic fields may affect the values.
- High Temperature affects the conductor resistance. This will in turn affect the charge carrier’s mobility and sensitivity of Hall Effect Sensors.

Optical Encoder

An optical encoder is a type of rotary encoder that uses a sensor to identify position change as light passes through a patterned encoder wheel or disk.

There are four components in an optical shaft encoder:

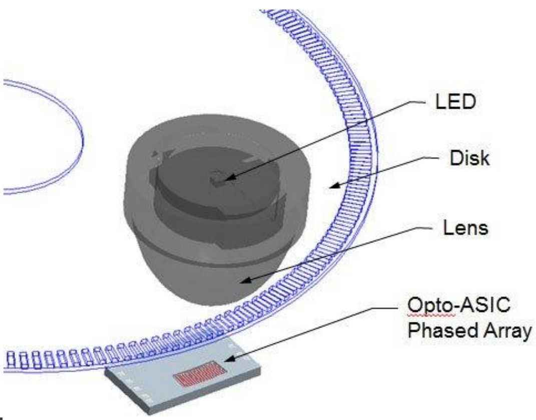


- A light source (an LED light)
- A sensor
- A moveable disk
- A fixed mask

The LED shines through one side of the optical shaft encoder. The encoder wheel or disk has a series of tracks on it, similar to the concentric grooves in an LP. The mask has a corresponding track for every track on the disk of the optical encoder, and small perforations, called windows, are cut along the tracks in the mask. As the disk moves, different windows in the mask are covered or open, showing the movement and position of the optical shaft encoder. Each arc in the rotation indicates a different position and has a different pattern of open/closed windows. The sensor behind the mask identifies the optical encoders' current pattern.

Each sensor represents one single signal for the optical encoder. A track can contain two sensors, which are offset to give two slightly different signals produced at the same time. These offset signals can be used by the optical encoder engine to determine more detailed motion information, like speed. A second track can be used to give an index pulse once per revolution, providing a method to orient the signals.

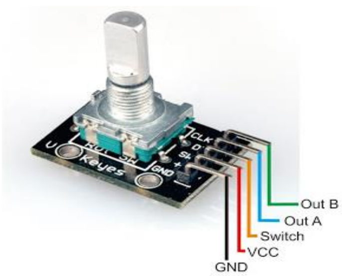
An even more reliable cousin to basic mask optical encoders is phased-array optical rotary encoders.

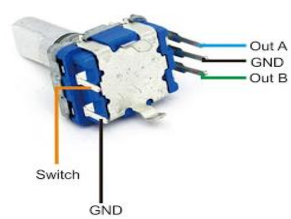


Phased-array optical encoders use multiple signal outputs to average together to create a single signal that is delivered by the engine. These multiple signals that are used by an optical shaft encoder are called the array. By using averages instead of a single reading, phased array-optical encoders have much more stable signals so they can be used in less stable environments, such as mining or heavy manufacturing, where vibrations or shock could affect a traditional mask optical shaft encoder. They require less precision during installation than traditional mask optical encoders.

Applications for Optical Encoders

Optical encoder engines can be amazingly precise, with some designs hitting 4 million counts per revolution. This makes an optical encoder a desirable choice where resolution matters, from office equipment like computer mice and copiers to medical equipment. With phased-array technology, an optical encoder is increasingly able to perform in much tougher environments which require a combination of durability and resolution, like crane operations and automated vehicle guidance.



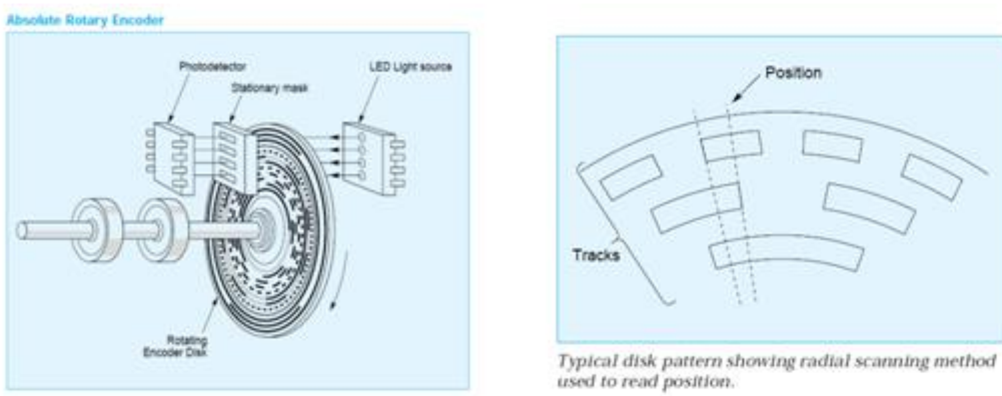


A rotary encoder, also called a shaft encoder, is an electro-mechanical device that converts the angular position or motion of a shaft or axle to analog or digital output signals. There are two main types of rotary encoder: absolute and incremental. The output of an absolute encoder indicates the current shaft position, making it an angle transducer. The output of an incremental encoder provides information about the motion of the shaft, which typically is processed elsewhere into information such as position, speed and distance.Rotary encoders are used in a wide range of applications that require monitoring or control, or both, of mechanical systems, including industrial controls, robotics, photographic lenses, computer input devices such as optomechanical mice and trackballs, controlled stress rheometers, and rotating radar platforms.

Types of Rotary Encoder:

Absolute Encoder:

An absolute encoder maintains position information when power is removed from the encoder. The position of the encoder is available immediately on applying power. The relationship between the encoder value and the physical position of the controlled machinery is set at assembly; the system does not need to return to a calibration point to maintain position accuracy.



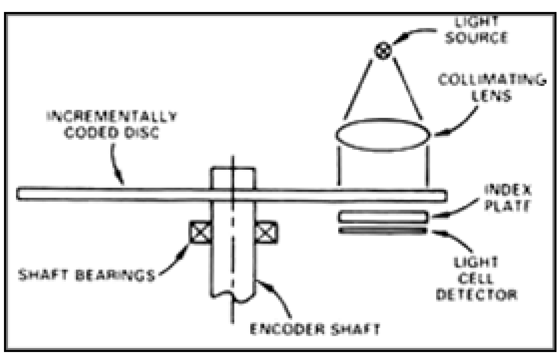
Typical disk pattern showing radial scanning method used to read position.

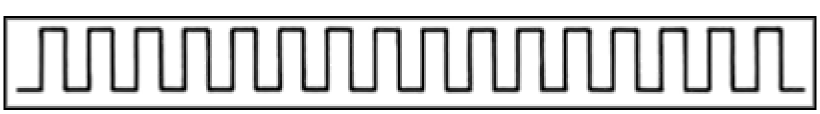
Components of Absolute Encoder

An absolute encoder has multiple code rings with various binary weightings which provide a data word representing the absolute position of the encoder within one revolution. This type of encoder is often referred to as a parallel absolute encoder.

A multi-turn absolute rotary encoder includes additional code wheels and gears. A high-resolution wheel measures the fractional rotation, and lower-resolution geared code wheels record the number of whole revolutions of the shaft.

Incremental Encoder:



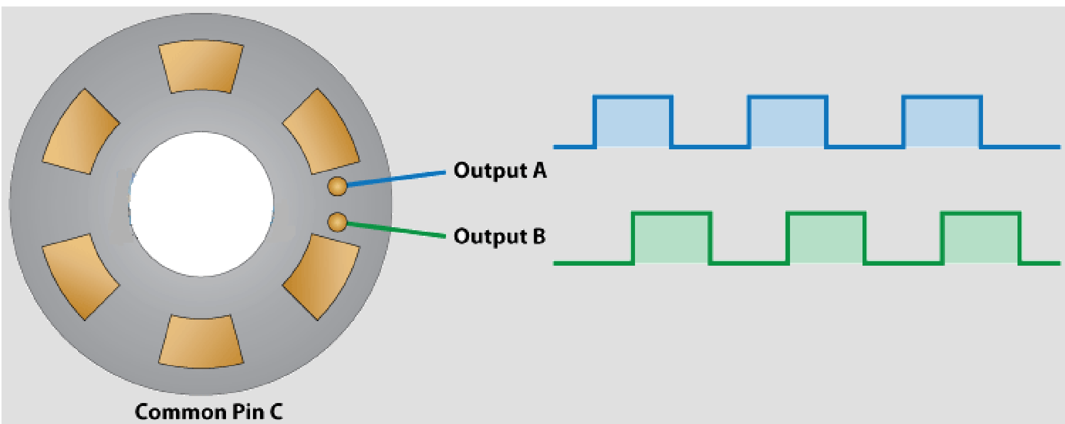


Pulse Train Produced from Incremental Encoder

An incremental encoder will immediately report changes in position, which is an essential capability in some applications. However, it does not report or keep track of absolute position. As a result, the mechanical system monitored by an incremental encoder may have to be moved to a fixed reference point to initialize the position measurement.

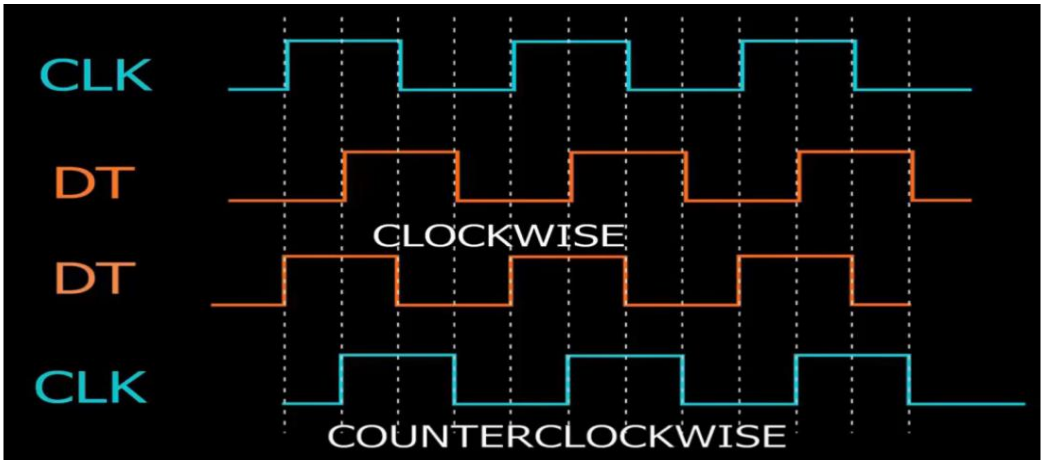
How Rotary Encoder Works?

The encoder has a disk with evenly spaced contact zones that are connected to the common pin C and two other separate contact pins A and B, as illustrated below.



When the disk will start rotating step by step, the pins A and B will start making contact with the common pin and the two square wave output signals will be generated accordingly.

Any of the two outputs can be used for determining the rotated position if we just count the pulses of the signal. However, if we want to determine the rotation direction as well, we need to consider both signals at the same time.



We can notice that the two output signals are displaced at 90 degrees out of phase from each other. If the encoder is rotating clockwise the output A will be ahead of output B.

So if we count the steps each time the signal changes, from High to Low or from Low to High, we can notice at that time the two output signals have opposite values. Vice versa, if the encoder is rotating counter clockwise, the output signals have equal values. So considering this, we can easily program our controller to read the encoder position and the rotation direction.

<u>Applications of Rotary Encoders:</u>

An encoder can be used in applications requiring feedback of position, velocity, distance, etc. The examples listed below illustrate the vast capabilities and implementations of an encoder:

1. Assembly Machines
2. Packaging
3. X and Y Indication Systems
4. Printers
5. Testing Machines
6. CNC Machines
7. Robotics
8. Labeling Machines
9. Medical Equipment
10. Textiles

11. Drilling Machines

12. Motor Feedback

Advantages & Disadvantages of Rotary (optical)Encoders:

Advantages of an Encoder

1. Highly reliable and accurate
2. Low-cost feedback
3. High resolution
4. Integrated electronics
5. Fuses optical and digital technology
6. Can be incorporated into existing applications
7. Compact size

Disadvantages of an Encoder

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

Synchros & its Construction, Working

The term synchro is a generic name for a family of inductive devices which works on the principle of a rotating transformer(Induction motor). The trade names for **synchros** are Selsyn, Autosyn and Telesyn. Basically, they are electro-mechanical devices or electromagnetic transducers which produces an output voltage depending upon the angular position of the rotor.

A synchro system is formed by the interconnection of the devices called the **synchro transmitter** and the **synchro control transformer**. They are also called Synchro pair.
The *synchro* pair measures and compares two angular displacements and its output voltage are approximately linear with an angular difference of the axis of both the shafts. They can be used in the following two ways,

1. To control the angular position of the load from a remote place/long distance.

2.For automatic correction of changes due to the disturbance in the angular position of the load.

The Synchro is a **type of transducer** which **transforms** the **angular position of the shaft** into an **electric signal**. It is used as an **error detector** and as a **rotary position sensor.** The error occurs in the system because of the misalignment of the shaft. The transmitter and the control transformer are the two main parts of the synchro.

Synchros System Types

The synchro system is of two types. They are

1. Control Type Synchro.
2. Torque Transmission Type Synchro.

Torque Transmission Type Synchros

This type of synchros has small output torque, and hence they are used for running the very light load like a pointer. The control type Synchro is used for driving the large loads.

Control Type Synchros System

The controls synchros is used for error detection in positional control systems. Their systems consist two units. They are

1. Synchro Transmitter
2. Synchro receiver

Construction of Synchro Transmitter:

The **constructional features**, electrical circuit and a schematic symbol of *synchro transmitter* are shown in the below figure. The two major parts of the **synchro transmitter** are stator and rotor. The stator is identical to the stator of the three-phase alternator.

It is made of laminated silicon steel and slotted on the inner periphery to accommodate a balanced three-phase winding. The stator winding is the concentric type with the axis of three coils 120° apart. The stator winding is star connected (Y-connection). This basic construction will help you derive the **transfer function of Synchros**.

The rotor is of dumbbell construction with a single winding. The ends of rotor winding are terminated on two slip rings. A single-phase ac excitation voltage is applied to the rotor through slip rings.

Working principle of Synchro Transmitter:

When the rotor is excited by ac voltage, the rotor current flows, and a magnetic field is produced. The rotor magnetic field induces an emf in the stator coils by transformer action. The effective voltage induced in any stator coil depends upon the angular position of the coil's axis with respect to the rotor axis.

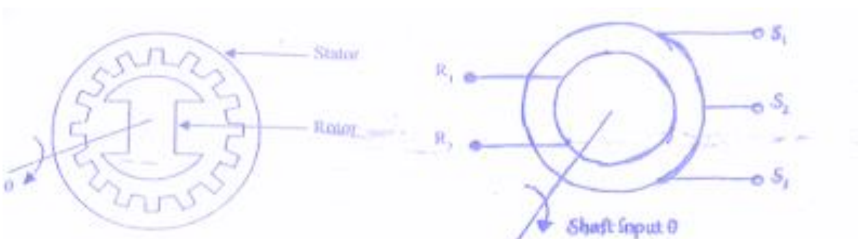
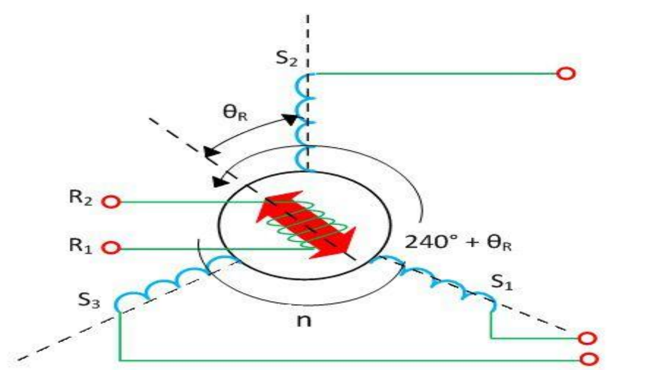


Fig 2.4a : Constructional features   Fig 2.4b : Schematic symbol of a synchro transmitter



Sychro Transmitter

er = Instantaneous value of ac voltage applied to rotor.

es1,es2,es3 = Instantaneous value of emf induced in stator coils S1 ,S2,S3 with respect to neutral respectively.

Er = Maximum value of rotor excitation voltage.

ω = Angular frequency of rotor excitation voltage.

Kt = Turns ratio of stator and rotor windings.

Kc = Coupling coefficient.

θ = Angular displacement of rotor with respect to reference.

Let, the instantaneous value of rotor excitation voltage, er = Er sin ωt

Let the rotor rotates in an anticlockwise direction. When the rotor rotates by an angle,θ EMFs are induced in stator coils. The frequency of induced emf is the same as that of rotor frequency. The magnitude of induced EMFs is proportional to the turns ratio and coupling coefficient. The turns ratio, Kt is a constant, but coupling coefficient, K is a function of rotor angular position.

Induced emf in stator coil = Kt Kc Er sin ωt

Let es2 be reference vector. With reference to the above figure, when $\theta = 0$, the flux linkage of coil S2 is maximum and when $\theta = 90°$, the flux linkage of coil S2 is zero. Hence the flux linkage of coil S2 is a function of $\cos\theta$ (i.e., kc= Kt $\cos\theta$ for coil S2). The flux linkage of coil s3 will be maximum after a rotation of 120° in the anticlockwise direction and that of S1 after a rotation of 240°.

Coupling coefficient,Kc for S2 = K1 $\cos\theta$

Coupling coefficient,Kc for S3 = K1 $\cos(\theta-120°)$

Coupling coefficient,Kc for S1 = K1 $\cos(\theta-240°)$

Hence the EMFs of stator coils with respect to neutral can be expressed as follows.

$es2 = Kt\ K1 \cos\theta\ \ Er \sin\omega t = K\ Er\ \cos\theta \sin\omega t$

$es3 = Kt\ K1 \cos(\theta-120°)\ \ Er \sin\omega t = K\ Er\ \cos(\theta-120°) \sin\omega t$

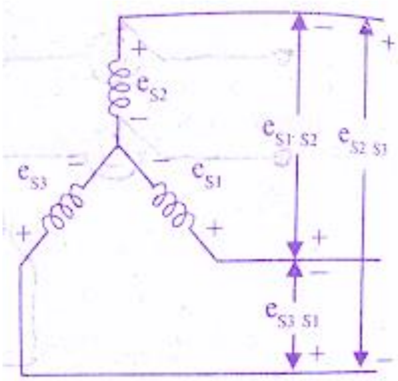
$es1 = Kt\ K1 \cos(\theta-240°)\ \ Er \sin\omega t = K\ Er\ \cos(\theta-240°) \sin\omega t$

With reference to the below figure by Kirchoffs voltage law the coil-to-coil emf can be expressed as ,

$eS1S2 = eS1 - eS2 = \sqrt{3}\ KEr \sin(\theta + 240°)\sin\omega t$

$eS2s3 = eS2 - es3 = \sqrt{3}\ KEr \sin(\theta + 120°)\sin\omega t$

$eS3s1 = eS3 - es1 = \sqrt{3}\ KEr \sin\theta \sin\omega t$



The constructional features, electrical circuit and a schematic symbol of **Synchro Transmitter** are shown in figure-2. The two major parts of **Synchro Transmitters** are stator and rotor.The stators identical to the stator of three phase alternator. It is made of laminated silicon steel and slotted on the inner periphery to accommodate a balance three phase winding. The stator winding is concentric type with the axis of the three coil 120° apart. The stator winding is star connected(Y - connection).
The rotor is of dumb bell construction with a single winding. The ends of the rotor winding are terminated on two slip rings. A single phase AC excitation voltage is applied to the rotor through the slip rings.

Synchros Transmitter – Their construction is similar to the three phase alternator. The stator of the synchros is made of steel for reducing the iron losses. The stator is slotted for housing the three phase windings. The axis of the stator winding is kept 120º apart from each other.

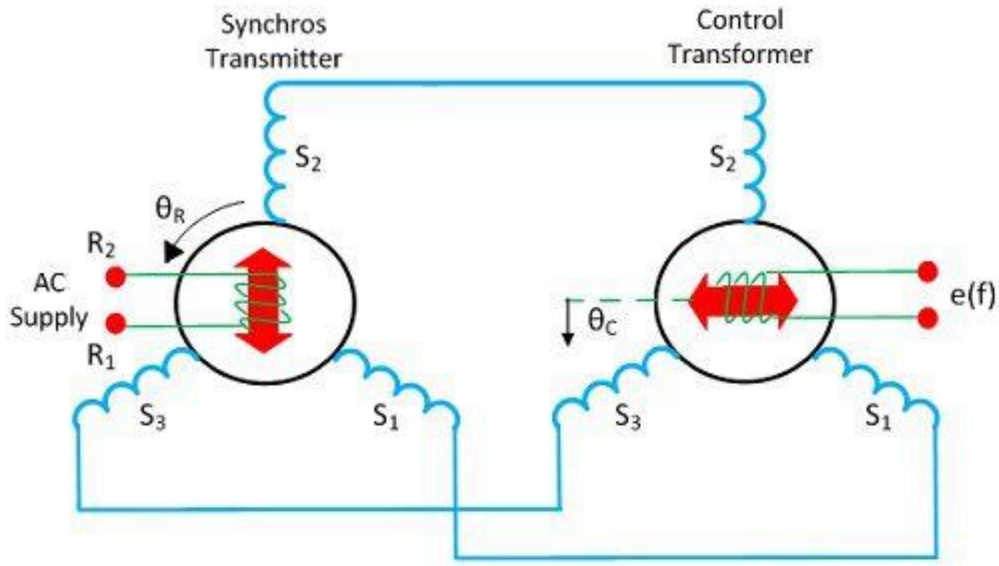
The AC voltage is applied to the rotor of the transmitter and it is expressed as

$$v_r = \sqrt{2} Sin\omega_c t$$

Where V_r – r.ms.value of rotor voltage
ω_c – carrier frequency

The coils of the stator windings are connected in star. The rotor of the synchros is a dumbbell in shape, and a concentric coil is wound on it. The AC voltage is applied to the rotor with the help of slip rings. The constructional feature of the synchros is shown in the figure below.

Consider the voltage is applied to the rotor of the transmitter as shown in the figure



Syncho Error Dectector

Circuit Globe

above.

The voltage applied to the rotor induces the magnetizing current and an alternating flux along its axis. The voltage is induced in the stator winding because of the mutual induction between the rotor and stator flux. The flux linked in the stator winding is equal to the cosine of the angle between the rotor and stator. The voltage is induced in the stator winding.

Let V_{s1}, V_{s2}, V_{s3} be the voltages generated in the stator windings S_1, S_2, and S_3 respectively. The figure below shows the rotor position of the synchro transmitter. The rotor axis makes an angle

$$V_{s1n} = kV_r Sin\omega_c t cos(\theta_R + 120°)$$

$$V_{s2n} = kV_r Sin\omega_c t cos\theta_R$$

$$V_{s1n} = kV_r Sin\omega_c t cos(\theta_R + 240°)$$

θ_r concerning the stator windings S_2.

$$V_{s1s2} = V_{s1n} - V_{s2n}$$

$$V_{s1s2} = \sqrt{3}kV_r Sin(\theta_R + 240°)Sin\omega_c t$$

$$V_{s3s2} = V_{s2n} - V_{s3n}$$

$$V_{s1s2} = \sqrt{3}kV_r Sin(\theta_R + 120°)Sin\omega_c t$$

$$V_{s3s1} = V_{s3n} - V_{s1n}$$

$$V_{s3s1} = kV_r Sin\omega_c t Sin\theta_R$$

The three terminals of the stator windings are

The variation in the stator terminal axis concerning the rotor is shown in the figure below.

$$e(t) = k'V_r Cos(90° - \theta_R + \theta_C)Sin\omega_c t$$

$$e(t) = k'V_r Sin(\theta_R - \theta_C)Sin\omega_c t$$

When the rotor angle becomes zero, the maximum current is produced in the stator windings S_2. The zero position of the rotor is used as a reference for determining the rotor angular position.

The output of the transmitter is given to stator winding of the control transformer which is shown in the above figure.

The current of the same and magnitude flow through the transmitter and control transformer of the synchros. Because of the circulating current, the flux is established between the air gap flux of the control transformer.

The flux axis of the control transformer and the transmitter is aligned in the same position. The voltage generates by the rotor of control transformer is equal to the cosine of the angle between the rotors of the transmitter and the controller. The voltage is given as

$$e(t) = k'V_r Cos\emptyset Sin\omega_c t$$

The figure above shows the output of the synchro error detector which is a modulated signal. The modulating wave above shown the misalignment between the rotor position and the carrier wave.

$$e(t) = (\theta_R - \theta_C)$$

Where K_s is the error detector.

TOUCH OR TACTILE SENSOR

Now-a-days all the modern electronic devices are touch based. These have been used in ATMs, information kiosks, smart mobile devices, vending machines etc. These touch screen devices are developed based on touch sensors.

Touch Sensor Working and Its Appplications

The human body has five sense elements which are used to interact with our surroundings. Machines also need some sensing elements to interact with there surroundings. To make this possible sensor was invented. The invention of the first manmade sensor, thermostat, dates back to 1883. In 1940s infrared sensors were introduced. Today we have sensors that can sense motion, light, humidity, temperature, smoke, etc…Analog and digital both types of sensors are available today. Sensors have brought a revolutionary change in the size and cost of various control systems. One of such sensor which can detect touch is the Touch sensor.

Touch Sensors are the electronic sensors that can detect touch. They operate as a switch when touched. These sensors are used in lamps, touch screens of the mobile, etc… Touch sensors offer an intuitive user interface.

Touch Sensor

Touch sensors are also known as Tactile sensors. These are simple to design, low cost and are produced in large scale. With the advance in technology, these sensors are rapidly replacing the mechanical switches. Based on their functions there are two types of touch sensors- Capacitive sensor and Resistive sensor

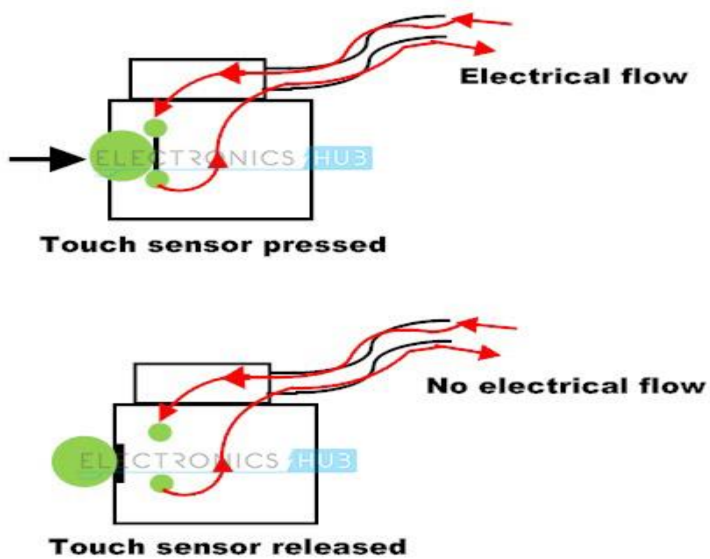
Capacitive sensors work by measuring capacitance and are seen in portable devices. These are durable, robust and attractive with low cost. Resistive sensors don't depend on any electrical properties for operation. These sensors work by measuring the pressure applied to their surface.

Principle of Working

Touch sensors are also called as tactile sensors and are sensitive to touch, force or pressure. They are one of the simplest and useful sensors. The working of a touch sensor is similar to that of a simple switch.

When there is contact with the surface of the touch sensor, the circuit is closed inside the sensor and there is a flow of current. When the contact is released, the circuit is opened and no current flows.

The pictorial representation of working of a touch sensor is shown below.



TOUCH /TACTILE Sensor types

There are various touch sensor types such as 5-wire(or 4-wire) resistive, surface capacitive, projected capacitive, surface acoustic wave and Infrared sensors.

Wire resistive Sensor : In this type of sensor, when user touches screen, two metallic layers make contact. This results into flow of current. The point of contact is determined based on change in the voltage. This type of touch sensors are more affordable but they are damaged with the use of sharp objects.

Surface capacitive Sensor: This sensors are activated with the touch of human skin or a stylus holding an electrical charge. In this type of monitor, a transparent electrode film is placed on top of the glass panel. When exposed finger touches the monitor screen, it reacts to the static electrical capacity of the human body. Some of the charge will get transfer from the screen to the user. The change in capacitance(decreased) is detected by sensors located at the four corners of the screen. This allows the controller to determine the touch point.

Projected capacitive Sensor: This type of touch sensor is similar to surface capacitive type. It offers two merits compare to surface capacitive. It can also be activated with the application of surgical gloves as well as thin cotton gloves. It also detects multiple touch points.

This type of sensor has sheet of glass with embedded transparent electrode films and an IC chip. This create 3 dimentional electrostatic field. When a finger comes in direct contact with the screen, ratios of electrical current will change and hence system will detect touch points.

Surface Acoustic Wave Sensor: SAW touchscreen monitors utilize a series of piezoelectric transducers and receivers. This creates grid of ultrasonic waves on the surface. The other element is placed on the glass referred as reflector. When a panel is touched, portion of the wave is absorbed. This will help receiving transducer to locate the touch point and send this data to the system.

Infrared Sensor: This type of touch screen sensor is based on interruption of light path in an invisible light grid in front of the screen. If an obstacle appears inside the grid matrix. it will interrupt the light beams and will cause reduction in measured photo current in the detectors. Based on these information’s, X-Y co-ordinates can be determined.

Capacitive Touch Sensor

Capacitive touch sensors are widely used in most of the portable devices like mobile phones and MP3 players. Capacitive touch sensors can be found even in home appliances, automotive and industrial applications. The reasons for this development are durability, robustness, attractive product design and cost.

Touch sensors, unlike mechanical devices, do not contain moving parts. Hence, they are more durable than mechanical input devices. Touch sensors are robust as there are no openings for humidity and dust to enter.

The principle of a capacitive touch sensor is explained below.

The simplest form of capacitor can be made with two conductors separated by an insulator. Metal plates can be considered as conductors. The formula of capacitance is shown below.

$C = \varepsilon_0 * \varepsilon_r * A / d$

Where

ε_0 is the permittivity of free space

ε_r is relative permittivity or dielectric constant

A is area of the plates and d is the distance between them.

Capacitance is directly proportional to the area and inversely proportional to the distance.

In capacitive touch sensors, the electrode represents one of the plates of the capacitor. The second plate is represented by two objects: one is the environment of the sensor electrode which forms parasitic capacitor C_0 and the other is a conductive object like human finger which forms touch capacitor C_T.

The sensor electrode is connected to a measurement circuit and the capacitance is measured periodically. The output capacitance will increase if a conductive object touches or approaches the sensor electrode. The measurement circuit will detect the change in the capacitance and converts it into a trigger signal.

The working of a capacitive touch sensor is shown in below figure.

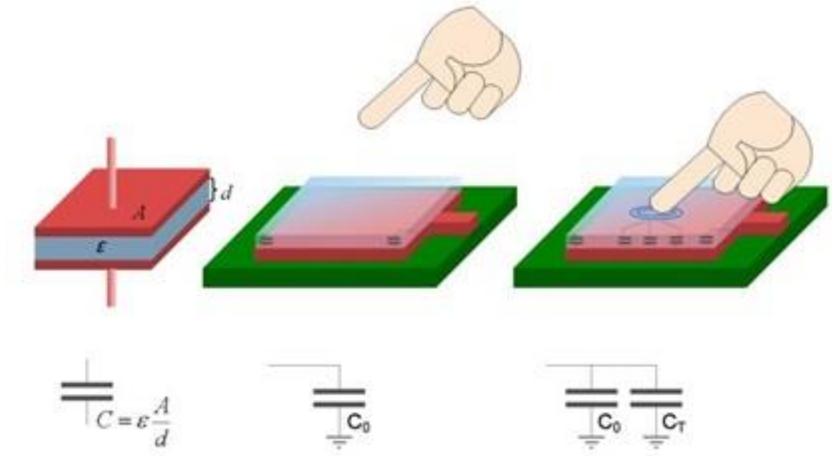


Image Resource Link: www.fujitsu.com/downloads/MICRO/fme/articles/fujitsu-whitepaper-capacitive-touch-sensors.pdf

If the area of the sensor electrode is bigger and the thickness of the cover material is less, the touch capacitance C_T is also big. As a result, the capacitance difference between touching pad and untouched sensor pad is also big. This means that the size of the sensor electrode and covering material will influence the sensitivity of the sensor.

The measurement of capacitance is used in many applications like determining distance, pressure, acceleration, etc. Capacitive Touch sensors are another area of application. There are numerous methods to measure capacitance. Some of them are: amplitude modulation, frequency modulation, time delay measurement, duty cycle, etc.

In case of capacitive touch sensors, presence of a conductive material is enough to trigger the load and do not require any force. Hence, the risk of false or unintended triggers is higher in case of capacitive touch sensors. This problem is more in the presence of moisture or water, which is a good conductor.

The method of measurement of capacitance in touch sensors requires a reference plane located near by the sensing pad. In capacitive touch sensors, a finger trip forms the capacitance between the sensing electrode and reference plane. The skin oils or sweat from human body may cause a false trigger.

To distinguish between intended and false touches, additional sensing pads or software algorithms are used. The best solution is to get rid of reference ground electrode.

There are two types of capacitive touch sensors: surface capacitive sensing and projected capacitive sensing.

In surface capacitive sensing, an insulator is applied with a conductive coating on one side of its surface. On top of this conductive coating, a thin layer of insulator is applied. Current is applied to all the corners of the conductive coating.

When an external conductor like a human finger comes in contact with the surface, a capacitance is formed between them and draws more current from the corners. The current at each corner is measured and their ratio will determine the position of the touch on the surface.

In projected capacitive sensing, the whole surface is not charged, but an X – Y grid of conductive material is placed between two insulating materials. The grid is often made of Copper or Gold on a PCB or Indium Tin Oxide on glass. An IC is used to charge and monitor the grid.

When a charge is pulled by external conducting object like a finger(s) from an area on the grid, the IC calculates the location of the finger on the touch surface. Touch sensors, made of projective capacitive technology can be used to sense a finger that is not touching its surface. They act as near proximity sensors.

Resistive Touch Sensor

Resistive touch sensors are used for a longer time than capacitive solutions as they are simple control circuits. A resistive touch sensor does not depend on the electrical property of capacitance. Hence, resistive touch sensors can accommodate non – conducting materials like stylus and glove wrapped finger.

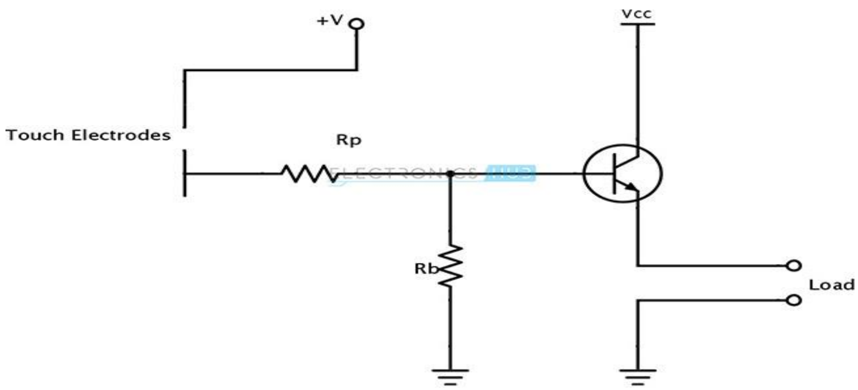
In contrast to capacitive touch sensors which measure the capacitance, resistive touch sensors sense the pressure on the surface.

A resistive touch sensor consists of two conductive layers separated by small spacer dots. The bottom layer is made up of either glass or film and the top layer is made up of film. The conductive material is coated with metallic film generally Indium Tin Oxide and is transparent in nature. A voltage is applied across the surface of the conductor.

When any probe like a finger, stylus pen, pen, etc. is used to apply pressure on the top film of the sensor, it activates the sensor. When ample pressure is applied, the top film flexes inward and makes contact with the bottom film. This results in voltage drop and the point of contact creates a voltage divider network in the X – Y directions.

This voltage and the changes in the voltage are detected by a controller and calculate the position of the touch where the pressure is applied based on the X – Y coordinates of the touch.

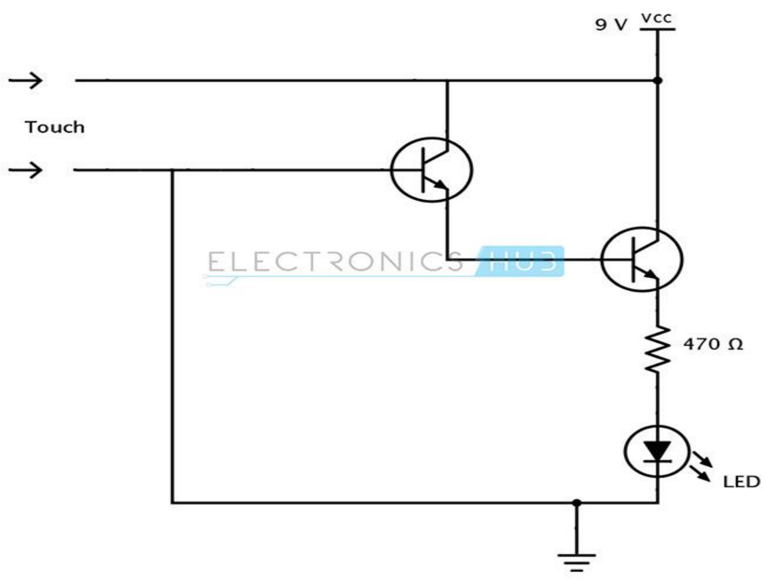
The functioning of a resistive touch sensor can be explained using the following figure.



The resistance of the object touching the electrodes will come into the picture in the working of resistive touch sensors. For example, when finger touches the surface, the small resistance of the finger allows some current to flow through it, completing a circuit. The transistor acts as a switch. The resistor Rp is used to protect the transistor from any possible short circuit of the electrodes. The resistor Rb is used to keep the base at the ground when the circuit is open, i.e. there is no finger.

When both the electrodes are touched, small current flows through the finger and the transistor switches ON, as a result the load becomes active.

A simple resistive touch sensitive circuit is shown below.



It consists of two electrodes, two transistors connected in Darlington configuration, a resistor and an LED. When a finger is placed on the electrodes, the circuit is complete and current amplification takes place. The resistor is used to restrict the amount of the current to the LED.

There are three types of resistive touch sensors: 4 – wire, 5 – wire and 8 – wire.

4 – Wire resistive touch sensor is most cost effective. 5 – Wire resistive touch sensors are most durable. They are similar to 4 – wire sensors except that all the electrodes in this type are on the bottom layer. The top layer in 5 – wire sensors act as a voltage measuring probe. Because of this type of construction, 5 – wire resistive touch sensors allow higher number of actuations.

In 8 – wire resistive touch sensors, each edge of the sensor provides a sensing line. These sensing lines act as a stable voltage gradient for the touch controller. The actual baseline voltage levels at the touch area are reported by these sensing lines to the controller. They are the most accurate type of resistive touch sensors.

Any object like a finger, stylus, pen, gloved finger, etc. are used to apply pressure on resistive touch sensors, they are mostly used in harsh environments. But the response time of resistive touch sensors is less than capacitive touch sensors. Hence, the capacitive touch sensors are slowly replacing them.

Applications

Capacitor sensors are easily available and are of very low cost. These sensors are highly used in mobile phones, iPods, automotive, small home appliances, etc… These are also used for measuring pressure, distance, etc… A drawback of these sensors is that they can give a false alarm.

Resistive touch sensors only work when sufficient pressure is applied. Hence, these sensors are not useful for detecting small contact or pressure. These are used in applications such as musical instruments, keypads, touch-pads, etc.. where a large amount of pressure is applied.

Tactile Sensor in Robotics

The WSG-DSA is a gripper finger that integrates tactile sensing for high-resolution profile feedback during grasping. For sensing purposes, it uses a DSA9205i intelligent tactile transducer. It fits on top of the base jaws of the WSG and is straightly interfaced with the gripper controller through the integrated sensor port within the base jaws so that no external components and cables are needed to include a tactile device to your handling applications. These types of finger sensors detected automatically and parametrized by the WSG. The pressure profile can be used from the inside of the gripper controller by using a powerful scripting interface. This article discusses types of tactile sensors and their working.

A tactile sensor is a device. It measures the coming information in response to the physical interaction with the environment. The sense of touch in humans is generally modeled, i.e. cutaneous sense and the kinesthetic sense. Cutaneous touch has the capability of detecting the stimuli resulting from the mechanical stimulation, pain, and temperature. The kinesthetic touch receives sensor inputs from the receptors present inside the muscles, tendons, and joints.

Tactile Sensor

Types of Tactile Sensors

There are different types of tactile sensors which are given below

- Force/ torque sensor
- Dynamic sensor
- Thermal sensor

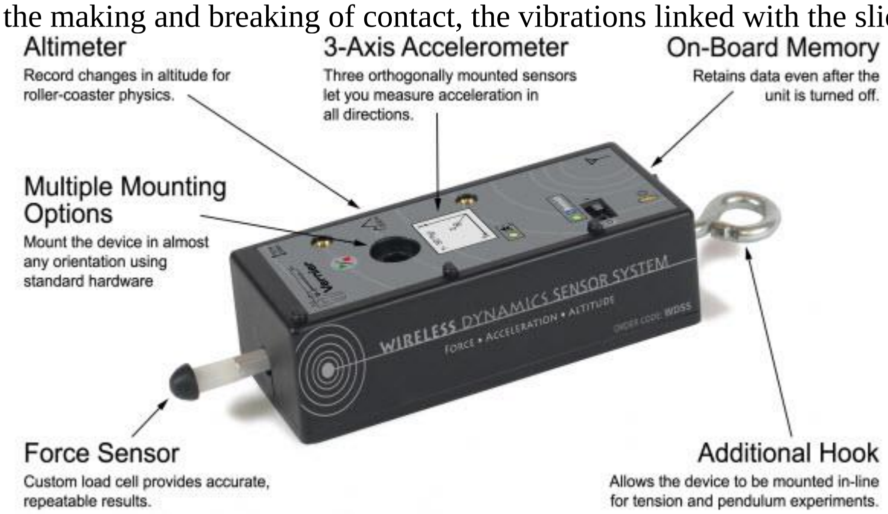
Force/ Torque Sensor

Force/ torque sensors are used in combination with a tactile array to give the information for force control. These types of sensors can sense load anywhere like the distal link of a manipulator and in constrains as a skin sensor. The skin sensor generally provides more accurate force measurement at higher bandwidths. If the manipulator link is defined generally, and the signal point contact is assumed, then the force/ torque sensor can give the information about the contact location of force and moments- it is called as intrinsic tactile sensing. The image of the torque sensor is shown below.

Force or Torque Sensor

Dynamic Sensor

Dynamic sensors are smaller accelerometers at the finger strips or at the skin of the robotic finger. The general function like Pacinian corpuscles in humans and have equally large respective fields; thus one or two skins accelerometer are sufficient for entire finger. These sensors effectively detect the making and breaking of contact, the vibrations linked with the sliding over textured surfaces.



Dynamic Sensor

A stress rate sensor is the second type of dynamic tactile sensor. If the fingertip is sliding at the speed of a few cm/s overall small bumps or pits on a surface, the temporary changes in the skin became important. A piezoelectric polymer such as PVDF produces a charge in response to damage that can be applied to produce a current, which is directly proportional to the range of change.

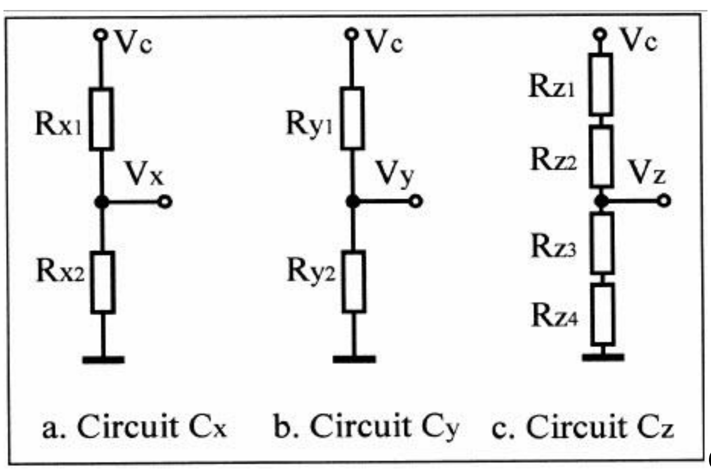
Thermal Sensor

Thermal sensors are important to the human ability to identify the materials of the objects made, but some are used in robotics as well. The thermal sensing involves detecting thermal gradients in the skin, which are correspondent to both the temperature and the thermal conductivity of an object. Robotic thermal sensors are involved in the Peltier junctions in combination with the Thermistors.

Thermal Sensor

Working principle and Circuit Diagram of the Tactile Sensor

The tactile sensors are developed to provide tactile sensing abilities for tele-operational manipulators and intelligent robots. Tactile sensors can identify a normal force applied to the tactile pixels for mesmerizing the force control and the tactile images and to generate object recognition. However, to obtain tactile images and normal forces, the information of tangential is critical for force control and slide prevention, which is mesmerizing to task success – thus the three-dimensional tactile sensors are required.



Circuit Diagram of Tactile Sensor

There are several three-dimensional tactile sensors developed by using the Piezoresistive, capacitive, and optional sensing elements and these tactile sensors are fabricated by the MEMS technology. The integrated sensing elements and the preprocessing circuits are for the compactness but these are too weak and easily broken for most of the applications; and, for an example, the force range of a tactile sensor is only 0.01 N w4x and the other tactile sensors are not provided by the MEMS technology. The below circuit diagram shows a tactile sensor circuit.

The Tactile Sensor in Robotics

The tactile sensor which is used in the NASA robots is given below

- One of the examples directly related to planetary exploration.
- NASA uses these sensors at the international space station for helping humans with repairing/maintenance in the environment
  - NASA has tried many tactile sensors in robotics which are in the initial stage. They have used Force Sensing Resistor, and now quantum tunneling composites are in use
- Multiple load buttons and cells are made a practice to develop tactile sensors are produced by an industrial robot

Tactile Sensor Applications

Tactile sensor applications are used in

- Robotics
- Computer hardware
- Security system
- Touch screen devices on mobile phone
- Computing

Advantages of Tactile Sensor

The advantages of the tactile sensor are given below:

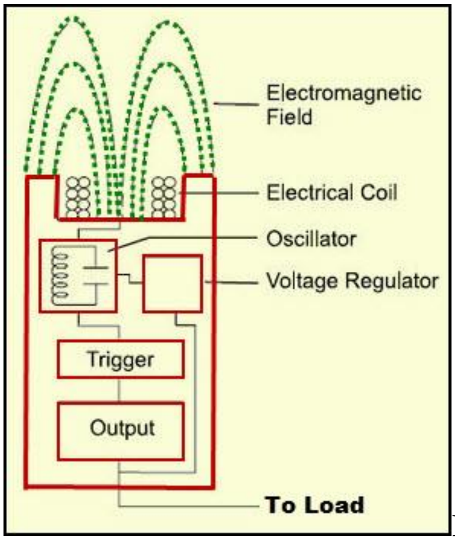
- They offer easy to use tactile sensor solutions
- The tactile sensor has no external components and cables
- Compact extraction
- Verified tactile sensing technology from robotics.

Proximity Sensor

A sensor that can be used for detecting the presence of objects surrounding it without having any physical contact is termed as a proximity sensor. This can be done using the electromagnetic field or electromagnetic radiation beam in which the field or return signal changes in the event of the presence of any object in its surrounding. This object sensed by the proximity sensor is termed as a target.

Thus, if we discuss about different types of targets such as plastic target, metal target, and so on requires different types of proximity sensors such as capacitive proximity sensor or photoelectric proximity sensor, inductive proximity sensor, magnetic proximity sensor and so on. The range in which the proximity sensor is able to detect an object is termed as nominal range. Unlike the other sensors, proximity sensors can last for long life and have very high reliability as there are no mechanical parts as well as no physical contact exists between the sensor and sensed object.

Proximity Sensor Circuit Diagram

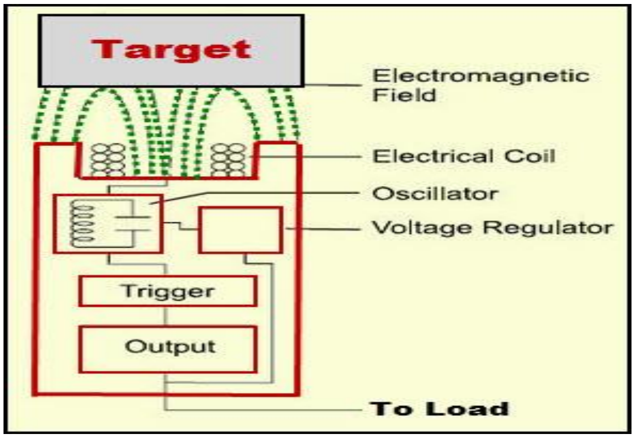


Proximity Sensor Circuit Block Diagram

Let us discuss about the inductive proximity sensor circuit which is most frequently used in many applications. The proximity sensor circuit diagram is shown in the above figure which consists of different blocks such as oscillator block, electrical induction coil, power supply, voltage regulator, etc.

Proximity Sensor Working Principle

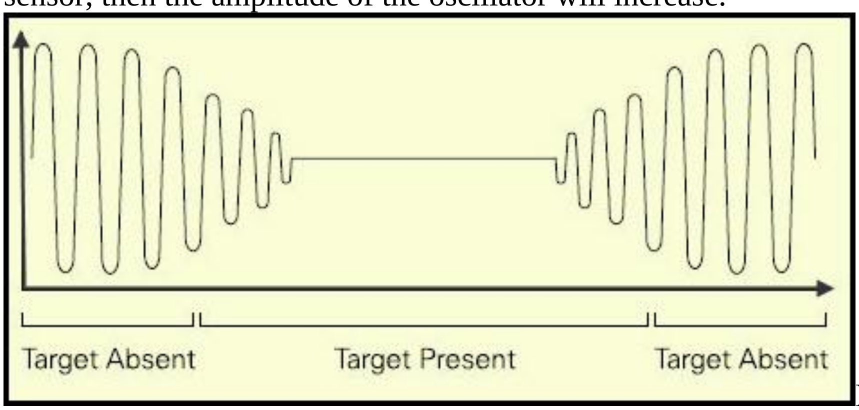
The inductive proximity sensor circuit is used for detecting the metal objects and the circuit doesn't detect any objects other than metals. The above proximity sensor circuit diagram represents the field produced by the coil, which is generated by providing a power supply. Whenever, this field is disturbed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



Proximity Sensor Circuit Diagram when Target is Detected

Due to this, load will be caused on the sensor that decreases the electromagnetic field amplitude. If the metal object (called as target, as we discussed earlier in this article) 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.

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.



Proximity Sensor's Oscillator Waveform

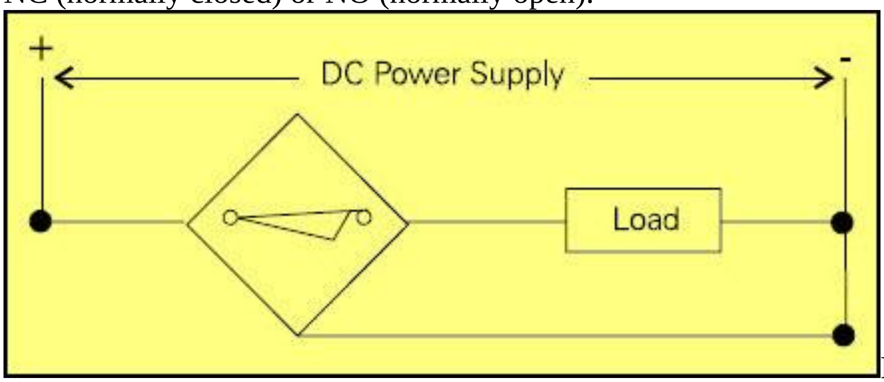
The waveform of for the inductive proximity sensor oscillator in the presence of the target and in the absence of the target can be represented as shown in the above figure.

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 320V DC and 20V to 265V AC.

Proximity Sensor Circuit Wiring

The proximity sensor circuit wiring is done as shown in the below figure. Depending on the transistor condition based on the absence of target, proximity sensor outputs are considered as NC (normally closed) or NO (normally open).

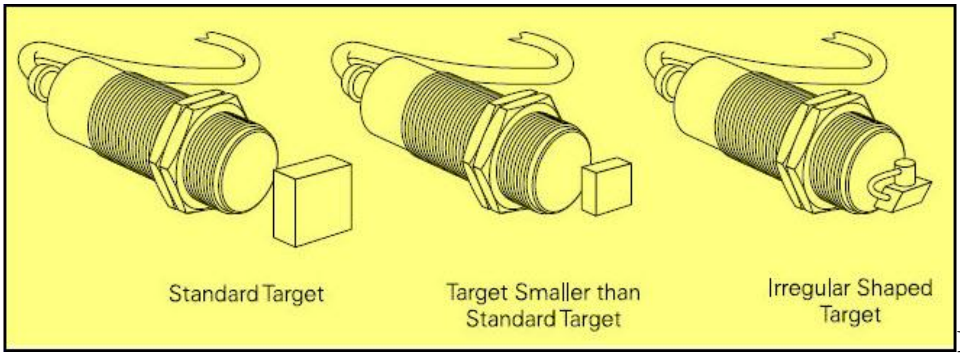


Proximity Sensor Circuit Wiring

If PNP output is low or off while the target is absent, then we can consider the device as normally opened. Similarly, if the PNP output is high or on while the target is absent, then we can consider the device as normally closed.

Proximity Sensor Circuit-Target Size

A flat and smooth surface with a thickness of 1mm and made of mild steel can be considered as standard target. There are various grades in which steel is available and mild steel is made of composition of carbon and iron (higher content). The standard target with shielded sensors will be having sides that are equal to the diameter of sensing face. The sides of the target with unshielded sensors is equal to a greater one among the two, i.e., the diameter of the sensing face or thrice the rated operating range.

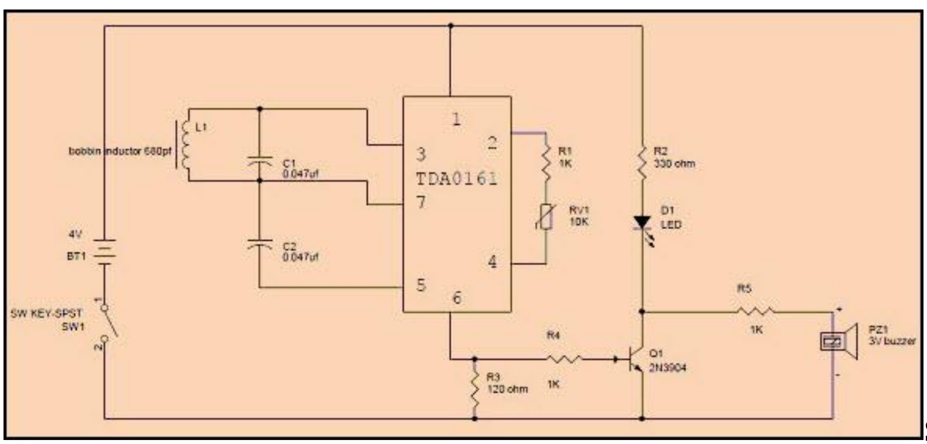


Proximity Sensor Circuit-Target Size

Even though, the size of the target is greater than the standard target, there will be no change in the sensing range. But, if the size of the target becomes less than the standard target or irregular, then the sensing distance will decrease. Thus, we can say that, as small as the size of the target, then the target must be moved closer to the sensing face to get detected.

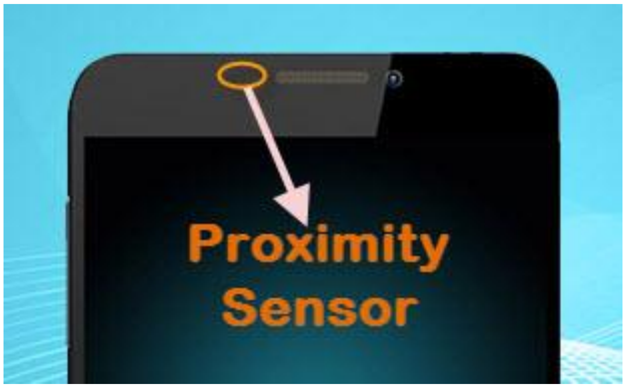
<u>Proximity Sensor Circuit Applications</u>

The proximity sensor circuit can be used for different applications, a few proximity sensor circuit applications are described below:



Simple Metal Detector Circuit

A simple metal detector can be designed using proximity sensor, buzzer, and LC circuit (inductor connected in parallel with capacitor), which are connected as shown in the above circuit diagram. This circuit will make the LED to glow and buzzer to sound whenever it detects metal objects or targets.



Ultrasonic Transducer

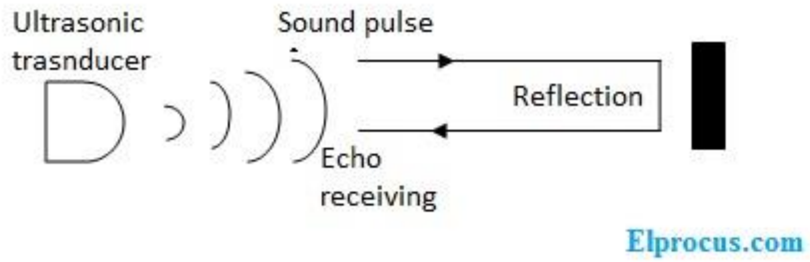
The ultrasonic transducer is one type of sound-related sensor. These transducers send the electrical signals to the object and once the signal strikes the object then it reverts to the transducer. In this process, this transducer measures the distance of the object not by the intensity of the sound. These transducers use ultrasonic waves for the measurement of a few parameters. It has a wide range of applications in various fields. The frequency range of ultrasonic waves is above 20 kHz. These are mainly used in measuring distance applications. The following image indicates the ultrasonic transducer.

ultrasonic-transducer

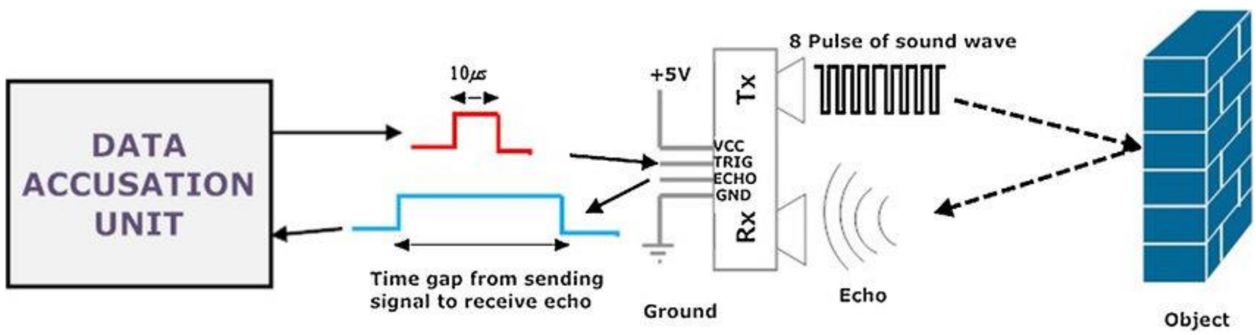
These transducers can be defined as a transducer which is used to convert one type of energy to ultrasonic vibration. By these ultrasonic vibrations, this transducer measures the distance of the object. These are available in two types like active and passive

Ultrasonic Transducer Working Principle

When an electrical signal is applied to this transducer, it vibrates around the specific frequency range and generates a sound wave. These sound waves travel and whenever any obstacle comes, these sound waves will reflect the transducer inform of echo. And at the end of the transducer, this echo converts into an electrical signal. Here, the transducer calculates the time interval between the sending of the sound wave to the receiving the echo signal. The ultrasonic sensor sends the ultrasonic pulse at 40 kHz which travels through the air. These transducers are better than the infrared sensors because these ultrasonic transducer/sensors are not affected by the smoke, black materials, etc. Ultrasonic sensors exhibit excellence in suppressing background interference.



ultrasonic-transducer



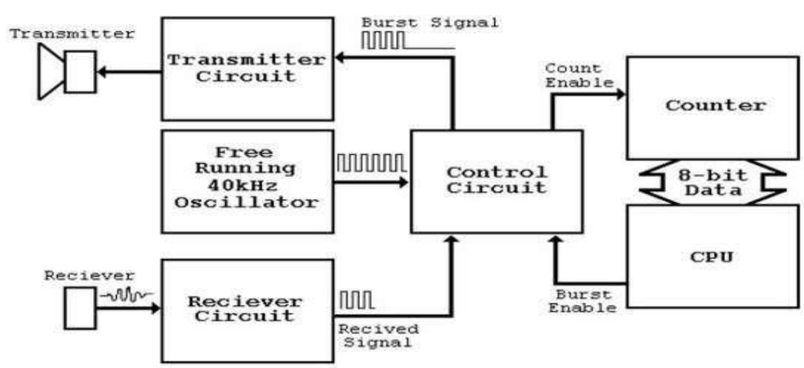
Ultrasonic transducers are mainly used for finding the distance by using ultrasonic waves. The distance can be measured by the following formula.

D = ½ * T * C

Here, D indicates the distance

T indicates the time difference between sending and reception of ultrasonic waves

C is indicating the sonic speed.



Ultras

There are various types of ultrasonic transducers available based on factors like piezoelectric crystal arrangement, footprint, and frequency. They are

Linear Ultrasonic Transducers – In this type of transducers, piezoelectric crystal arrangement is linear.

Standard Ultrasonic Transducers – This type is also called as convex transducers. In this type, the piezoelectric crystal is in a curvy form. For in-depth examinations these are preferable.

Phased Array Ultrasonic Transducers – Phased array transducers have a small footprint and low frequency. (its center frequency is 2 MHz – 7 MHz)

For non-destructive testing, the ultrasonic transducers are again having different types. They contact transducers, angle beam transducers, Delay line transducers, immersion transducers, and dual element transducers.

Ultrasonic Transducer Applications

These transducers have many applications in different fields like industrial, medical, etc. These are having more application because of ultrasonic waves. This helps finds the targets, measure the distance of the objects to the target, to find the position of the object, to calculate the level also the ultrasonic transducers are helpful.

In the medical field, the ultrasonic transducer is having the applications in diagnostic testing, surgical devices while treating cancer, internal organ testing, heart checkups, eyes and uterus checkups ultrasonic transducers are useful.

In the industrial field, ultrasonic transducers have few important applications. By these transducers, they can measure the distance of certain objects to avoid a collision, in production line management, liquid level control, wire break detection, people detection for counting, vehicle detection and many more.

Ultrasonic Transducers Advantages and Disadvantages

- Any system has advantages and a few disadvantages. Here will discuss the advantages of the ultrasonic transducer.
- These ultrasonic transducers can able to measure in any type of material. They can sense all types of materials.
- The ultrasonic transducers are not affected by temperature, water, dust or any.
- In any type of environment, the ultrasonic transducers will work in a good manner.
- It can measure in high sensing distances also.

Disadvantage:

- Ultrasonic transducers are sensitive to temperature variation. This temperature variation may change the ultrasonic reaction.
- It will face problems while reading the reflections from small objects, thin and soft objects.

Optoelectronics

In the scientific context, Optoelectronics deals with the study and application of electronic devices that interacts with light which might be detection of light, its creation, and exploitation for several purposes. This includes Gamma rays, X ray, Ultraviolet, Infrared and visible light.It also encompasses the study, design and manufacture of hardware apparatus that facilitate the conversion of electricity into photon signals.

Optoelectronic devices are primarily transducers i.e. they can convert one energy form to another. These devices produce light by expending electrical energy. They can also detect light and transform light signals to electrical signals for processing by a computer.

Optoelectronics makes use of the quantum mechanical effect of light. This property is used mainly in the materials that are used in the manufacture of semiconductors. Below mentioned are few such effects of light.

Photoelectric or Photovoltaic

Here, the light is directly converted into electricity. Solar cells make the best utilization of this direct conversion effect.

Photoconductivity

A material is made more electronically conductive by this electrical phenomenon. It is achieved by absorbing electromagnetic radiations such as UV light, infrared and visible light. Generally, it is utilized in Charge Coupled Device (CCD) imaging sensors.

Stimulated Emission

In this process, an energized molecule is made to interact with a light photon. This interaction decreases the energy level of photon and results in the liberation or emission of a matching photon. It is then transferred to an electromagnetic field. Quantum cascade lasers and laser diodes make use of this process.

Radiative Recombination

In this approach electron transfer occurs in semiconductors from valence to conducting band. This results in a recombination effect and carrier generation process that produces light. LED's employ this principle for light production.

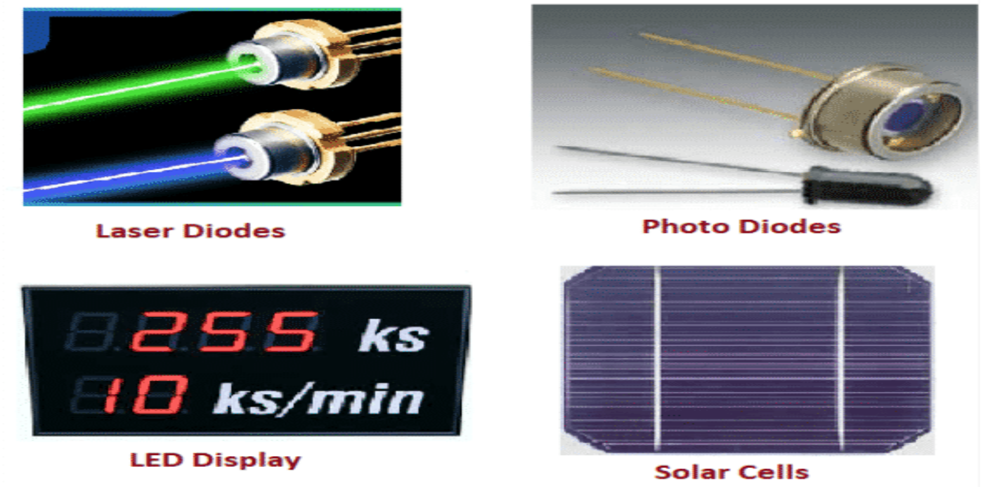


Fig. 2 – Optoelectronic Devices

Working Principle of Optoelectronic Communication System

A typical Optoelectronic Communication System consists of components namely:

- Light Source
- Optical Transmitter
- Photo Coupler
- Optical Fiber, Wave-guide
- Transducer
- Optical Receiver or Detector

Light Source

The light emitted from the source acts as an input to the Optical Transmitter. LEDs and Laser Diodes are used as the light source depending upon the application. They generate input electrical signals for the communication system.

Optical Transmitter

The Optical Transmitter converts the signal received from a Laser Diode or LED to an optical output.

Photo Coupler

The Photo Couplers transfers the electrical signals between two isolated circuits through the transmission channel that may be Optical fiber, wave-guide or free space. It also provides high insulation voltage.

Optical Fiber, Wave-guide

It acts as a transmission medium and guides electromagnetic waves in optical spectrum.

Transducer

Transducer modulates the signal proportional to the incident light and the signal further undergoes coupling through the channel.

Optical Receiver or Detector

Photo-diodes and Photo-transistors are generally used as Optical Detectors. The light detector converts the incident light in to electrical signal and it is further processed or stored to receive information. The electrical signal generated is either a Photo-current or a Photo-voltage.

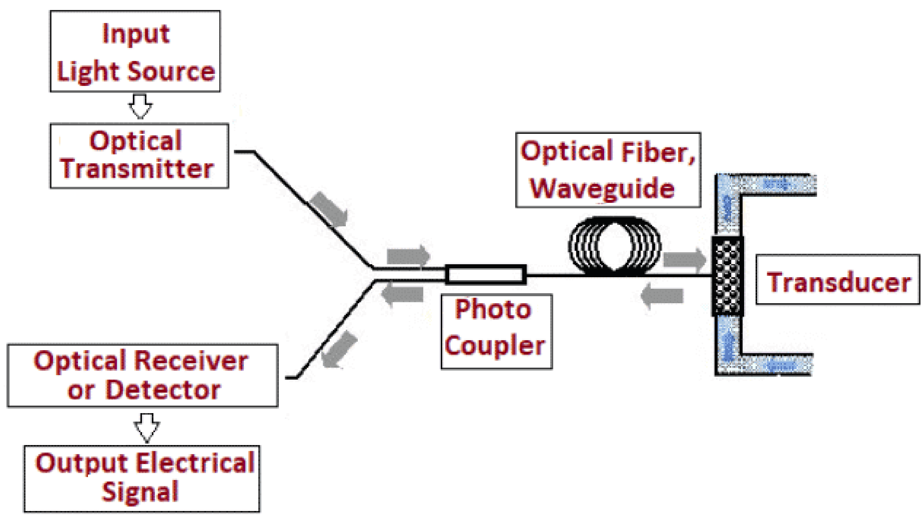


Fig. 3 – Block Diagram of Optoelectronics Communication System

<u>Optoelectronic Devices</u>

An optoelectronic device comprises of various semiconductor alloys that lay on substrates. Different semiconductor layers are deposited sequentially on the substrate during the expansion of multi-quantum well of laser active regions.

These layers are deposited altering between barrier and well regions. Holes and electrons combine in the well region to produce laser light. Barrier regions are used for confining holes and electrons inside the well.

<u>Optoelectronic devices include:</u>

- Information Displays using LED's
- Photo Diodes
- Remote Sensing System
- Solar Cells

We will now look at some of the common Optoelectronic devices used today.

Photo-diodes

This semiconductor light sensor generates electricity or voltage when light touches the junction. The Junction here is an active p-n junction, operated in the reverse bias condition. When an excited photon strikes the photo-diode, electron-hole pairs are created.

Electrons then diffuse into the p-n junction to generate an electric field. This electric field equals the negative voltage found across an unbiased diode. This process is termed as inner photoelectric effect. Photo-diodes can be used in three formats:

- Photo-voltaic: As solar cells
- Forward biased: As LED
- Reverse biased: As photo detector

They are used in different types of circuitry and applications like medical instruments, cameras, communication devices, safety and industrial equipment.

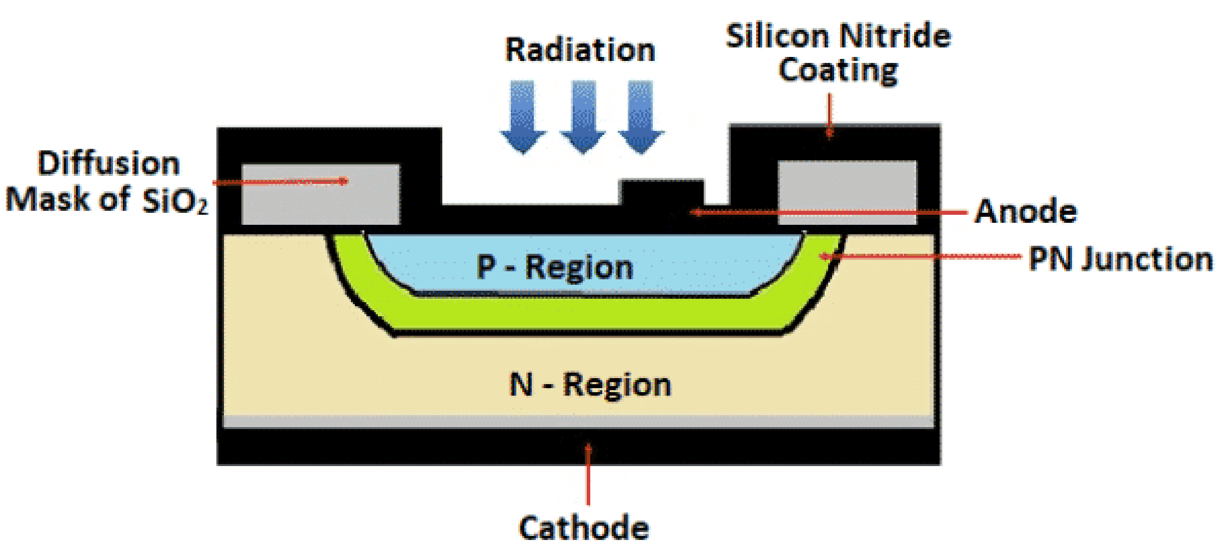


Fig. 4 – Structure of Photo-diode

Solar Cells

This photo-voltaic cell does direct conversion of solar energy into electricity. Sunlight is composed of photons. When these photons collide with the silicon atoms of solar cell, energy transfer takes place from photons to the lose electrons. These high energy electrons then flow into external circuits.

Solar Cells consists of only two layers. The first one is laden with electrons that are always ready to jump to the second layer. The second layer has a few missing electrons and hence can accommodate electrons from the first layer.

Solar Cells are advantageous as it is cost-effective and zero fuel supply. They demand minimal maintenance. They are used in rural electrification, ocean navigation systems and electric power generation in space.

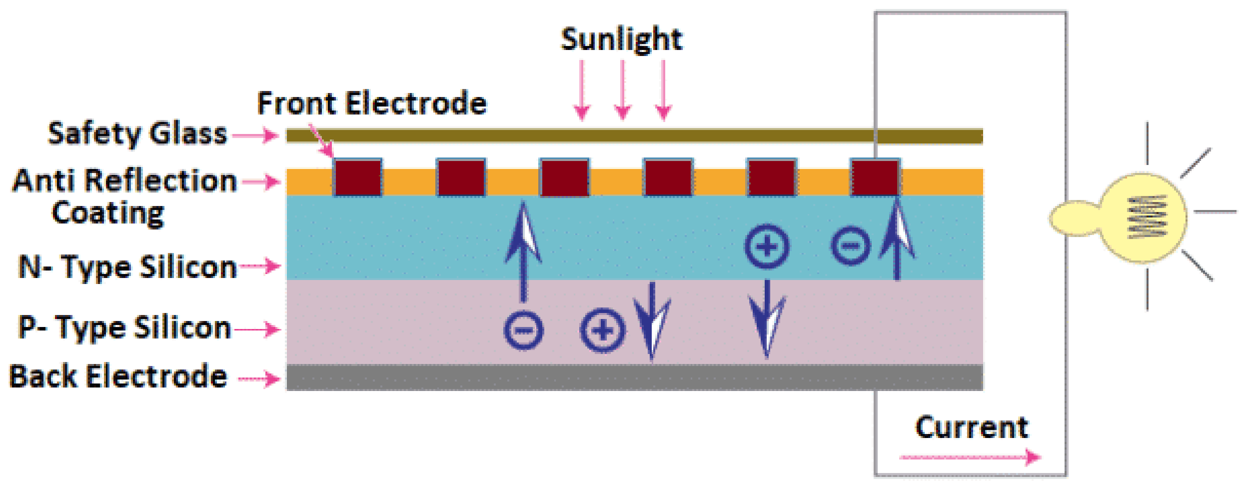


Fig. 5 – Structure of Solar Cell

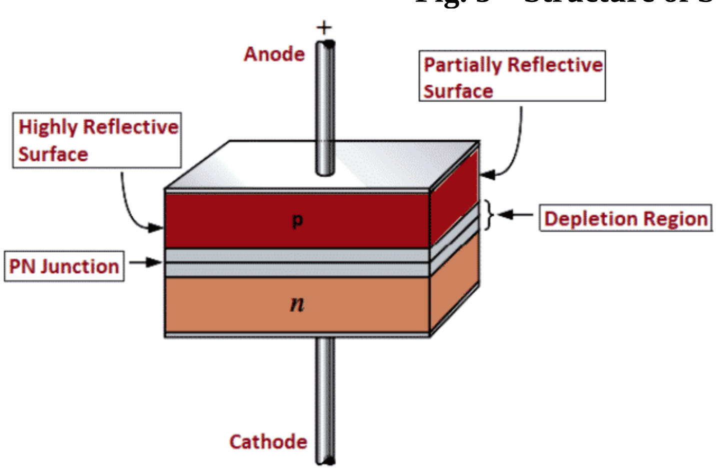


Fig. 6 – Structure of Laser Diode

Applications of Optoelectronics

Optoelectronic semiconductor devices have a major impact on almost all areas of Information Technology. These devices can be classified based on their functional roles like output, input, processing, transmission, memory and others.

Many technologies and physical properties are exploited by applications using Optoelectronics. Several such applications have come to our understanding and control only during the previous decade.

Below mentioned are some of the applications of Optoelectronic devices:

- LED's have revolutionized lighting system and used in areas like computer components, watches, medical devices, fiber optic communication, switches, household appliances, consumer electronics and 7 segment displays
- Solar Cells are used in several solar energy based projects for measurement systems, auto irrigation system, solar power charge controller, Arduino based solar street lights, and sun tracking solar panels
- Optical Fibers are used in telecommunication, fiber lasers, sensors, bio-medicals and other industries
- Laser Diodes find their use in military applications, surgical procedures, optical memories, CD players, local area networks and in electrical projects like RF controlled robotic vehicles

Advantages of Optoelectronics

The advantages of Optoelectronics are:

- Optoelectronics have helped the military and Aerospace industry immensely. The transmitted Over- Air RF links might not reach the intended receivers due to confined spaces, tunnels or in seagoing vessels and to overcome this, they use optical repeaters and fiber optic networks.
- Optoelectronics has given a new dimension in designing satellites of future.
- It provides a high bandwidth for communications.
- The optoelectronic devices consume less power.

Disadvantages of Optoelectronics

The disadvantages of Optoelectronics are:

- The optoelectronic devices are temperature sensitive.
- Coupling requires precise alignment of Optoelectronic components which is complex.

- Integration of Optoelectronic elements on to a substrate is difficult.

Gyroscope Sensor

Gyroscope sensor is a device that can measure and maintain the orientation and angular velocity of an object. These are more advanced than accelerometers. These can measure the tilt and lateral orientation of the object whereas accelerometer can only measure the linear motion.
Gyroscope sensors are also called as Angular Rate Sensor or Angular Velocity Sensors. These sensors are installed in the applications where the orientation of the object is difficult to sense by humans.

A gyroscope is a device that uses Earth's gravity to help determine orientation. Its design consists of a freely-rotating disk called a rotor, mounted onto a spinning axis in the center of a larger and more stable wheel. As the axis turns, the rotor remains stationary to indicate the central gravitational pull, and thus which way is "down."Measured in degrees per second, angular velocity is the change in the rotational angle of the object per unit of time.

Gyroscope Sensor

Gyroscope Sensor Working Principle

Besides sensing the angular velocity, Gyroscope sensors can also measure the motion of the object. For more robust and accurate motion sensing, in consumer electronics Gyroscope sensors are combined with Accelerometer sensors.

Depending on the direction there are three types of angular rate measurements. Yaw- the horizontal rotation on a flat surface when seen the object from above, Pitch- Vertical rotation as seen the object from front, Roll- the horizontal rotation when seen the object from front.

The concept of Coriolis force is used in Gyroscope sensors. In this sensor to measure the angular rate, the rotation rate of the sensor is converted into an electrical signal. Working principle of Gyroscope sensor can be understood by observing the working of Vibration Gyroscope sensor.

This sensor consists of an internal vibrating element made up of crystal material in the shape of a double – T- structure. This structure comprises a stationary part in the center with 'Sensing Arm' attached to it and 'Drive Arm' on both sides.

This double-T-structure is symmetrical. When an alternating vibration electrical field is applied to the drive arms, continuous lateral vibrations are produced. As Drive arms are symmetrical, when one arm moves to left the other moves to the right, thus canceling out the leaking vibrations. This keeps the stationary part at the center and sensing arm remains static.

When the external rotational force is applied to the sensor vertical vibrations are caused on Drive arms. This leads to the vibration of the Drive arms in the upward and downward directions due to which a rotational force acts on the stationary part in the center.

Rotation of the stationary part leads to the vertical vibrations in sensing arms. These vibrations caused in the sensing arm are measured as a change in electrical charge. This change is used to measure the external rotational force applied to the sensor as Angular rotation.

Types

With the advance in technology highly accurate, reliable and miniature devices are being manufactured. More accurate measurements of orientation and movement in a 3D space became possible with the integration of the Gyroscope sensor. Gyroscopes are also available in different sizes with different performances.

Based on their sizes, Gyroscope sensors are divided as small and large-sized. From large to small the hierarchy of Gyroscope sensors can be listed as Ring laser gyroscope, Fiber-optic gyroscope, Fluid gyroscope, and Vibration gyroscope.

Being small and more easy to use Vibration gyroscope is most popular. The accuracy of vibration gyroscope depends upon the stationary element material used in the sensor and structural differences. So, manufacturers are using different materials and structures to increase the accuracy of vibration gyroscope.

Types of Vibration Gyroscope

For Piezoelectrical transducers, materials like crystal and ceramics are used for the stationary part of the sensor. Here for crystal material structures like double-T- structure, Tuning Fork and H-shaped tuning fork are used. When ceramic material is used prismatic or columnar structure is chosen.

Characteristics of the Vibration Gyroscope sensor includes scale factor, temperature-frequency coefficient, compact size, shock resistance, stability and noise characteristics.

Gyroscope Sensor in Mobile

To facilitate a good user experience nowadays smartphones are embedded with various types of sensors. These sensors also provide phone information about its surroundings and also helps in increased battery life.

Steve Jobs was the first to use Gyroscope technology in consumer electronics. Apple iPhone was the first smartphone o have Gyroscope sensor technology. With the help of gyroscope in the smartphone, we can detect motion and gestures with our phones. Smartphones usually have an electronic version of the Vibration Gyroscope sensor.

Gyroscope Sensor Mobile App

Gyroscope Sensor app helps to detect the tilt and orientation of the mobile phone. Gyroscope Sensor app is useful for old smartphones which don’t have a Gyroscope sensor.

An app such as GyroEmu an Xposed module makes use of accelerometer and magnetometer present on the phone to simulate a Gyroscope Sensor. Gyroscope Sensor is mostly used on the smartphone for playing high technology AR games.

Applications

Gyroscope Sensors are used for versatile applications. Ring laser Gyros are used in Aircraft and Source shuttles whereas Fiber optic Gyros are used in racecars and motorboats.

Vibration Gyroscope sensors are used in the car navigation systems, Electronic stability control systems of vehicles, motion sensing for mobile games, camera-shake detection systems in digital cameras, radio-controlled helicopters, Robotic systems, etc…

The main functions of the Gyroscope Sensor for all the applications are Angular velocity sensing, angle sensing, and control mechanisms. Image blurring in cameras can be compensated by using Gyroscope Sensor-based optical image stabilization system.

By understanding their behavior and characteristics developers are designing many efficient and low-cost products such as gesture-based control of the wireless mouse, directional control of wheel-chair, a system to control external devices using gesture commands, etc…