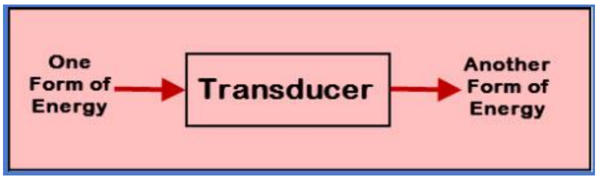
Transducers

• A transducer is an electrical device which is used to convert one form of energy into another form.



Types of Electrical Transducers

Mainly, the electrical transducers can be classified into the following **two types**.

- Active Transducers
- Passive Transducers

Basic requirements of the Electrical transducer

- Repeatability

  When the same input signal is applied to the transducer at different times under the same environmental conditions, it should give identical output signals.

- Linearity

  The transducers should have linear input-output characteristics.

- Ruggedness

  The transducer circuit should have overload protection so that it will withstand overloads.

- High stability and reliability

  The transducers output signal should not get affected by environmental variations(disturbances) like temperature, vibration etc. It should give minimum error in measurements.

Basic requirements of the Electrical transducer

- Good dynamic response

  In real-time applications, the input signal will vary with time (ie, the input signal is dynamic in nature). The transducer should respond as quick as possible for any change in the input signal.

- Convenient instrumentation

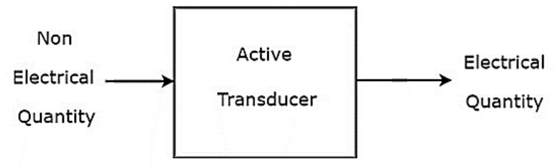
  The transducers output signal should be measured either directly or after suitable amplification.

- Mechanical characteristics

  When the transducer is subjected to various mechanical strains during working conditions, its performance should not degrade. It should withstand the mechanical strains.

Active Transducers

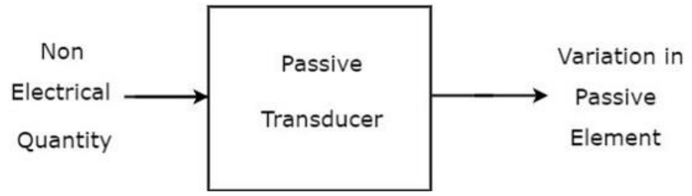
- **Active transducers** are those which do not require any power source for their operation. They work on the energy conversion principle. They produce an electrical signal proportional to the input (physical quantity). For example, a thermocouple is an **active transducer**



- **Examples**
  - Piezo Electric Transducer - it produces an electrical quantity which is equivalent to the pressure input.
  - Photo Electric Transducer - it produces an electrical quantity which is equivalent to the illumination of light input
  - Thermo Electric Transducer - it produces an electrical quantity which is equivalent to temperature input.

Passive Transducers

- The transducer, which can’t produce the electrical quantities such as voltage and current is known as **passive transducer**.
- But, it produces the variation in one of passive elements like resistor (R), inductor (L) and capacitor (C).
- Passive transducer requires external power supply.



- **Examples**
  - Resistive Transducer
  - Inductive Transducer
  - Capacitive Transducer

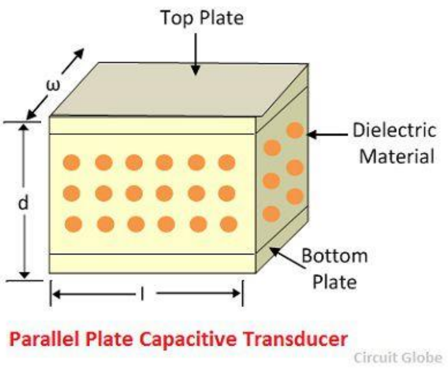
Displacement Transducer

- A Displacement Transducer is an electromechanical device used to convert mechanical motion or vibrations, specifically rectilinear motion, into a variable electrical current, voltage or electric signals, and the reverse.

  - Capacitive Transducer
  - Inductive
  - Variable Inductance
  - Linear Variable Differential Transformer

Capacitive Transducer

- The capacitive transducer is used for measuring the displacement, pressure and other physical quantities.
- It is a passive transducer that means it requires external power for operation.
- The capacitive transducer works on the principle of variable capacitances.



Parallel Plate Capacitive Transducer

Capacitive Transducer

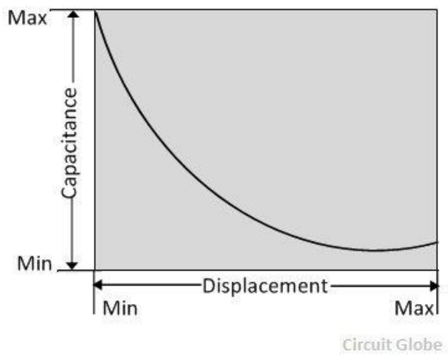
- The capacitive transducer contains two parallel metal plates.
- These plates are separated by the dielectric medium which is either air, material, gas or liquid.
- In the normal capacitor the distance between the plates are fixed, but in capacitive transducer the distance between them are varied.

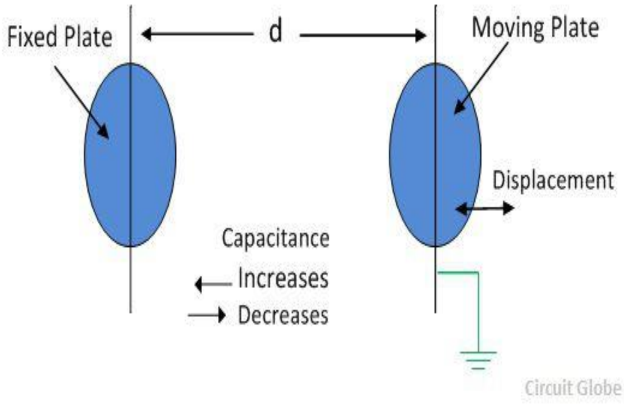
where,

A – overlapping area of plates in m^2
d – the distance between two plates in meter
ε – permittivity of the medium in F/m
ε_r – relative permittivity
ε_0 – the permittivity of free space

$$C = \varepsilon A/d$$

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





- The capacitance of the transducer is inversely proportional to the distance between the plates.
- The one plate of the transducer is fixed, and the other is movable.
- The displacement which is to be measured links to the movable plates.
- The capacitance is inversely proportional to the distance because of which the capacitor shows the nonlinear response.
- Such type of transducer is used for measuring the small displacement.

Advantage of Capacitive Transducer

- It requires an external force for operation and hence very useful for small systems.
- The capacitive transducer is very sensitive.
- It gives good frequency response because of which it is used for the dynamic study.
- The transducer has high input impedance hence they have a small loading effect.
- It requires small output power for operation.

Disadvantages of capacitive Transducer

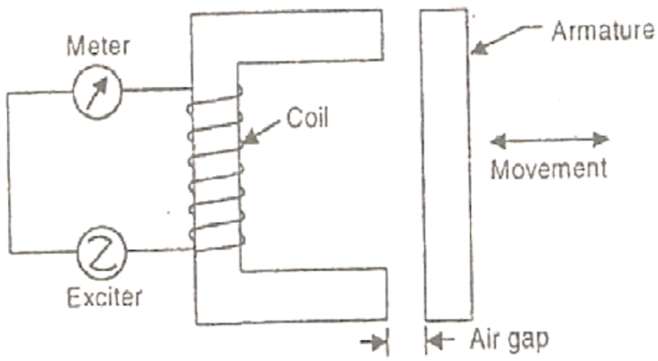
- The metallic parts of the transducers require insulation.
- The frame of the capacitor requires earthing for reducing the effect of the stray magnetic field.
- Sometimes the transducer shows the nonlinear behaviours because of the edge effect which is controlled by using the guard ring.
- The cable connecting across the transducer causes an error.

Uses of Capacitive Transducer

- The capacitive transducer uses for measurement of both the linear and angular displacement. It is extremely sensitive and used for the measurement of very small distance.
- It is used for the measurement of the force and pressures. The force or pressure, which is to be measured is first converted into a displacement, and then the displacement changes the capacitances of the transducer.
- It is used as a pressure transducer in some cases, where the dielectric constant of the transducer changes with the pressure.
- The humidity in gases is measured through the capacitive transducer.
- The transducer uses the mechanical modifier for measuring the volume, density, weight etc.

Variable Reluctance Transducer

- Magnetic circuit reactance may be changed by affecting a change in the air gap (reluctance type)
  - In variable reluctance type transducer, the change in inductance may be calibrated in terms of movement of armature.
  - Used for measurement of dynamic quantities such as pressure, force, displacement, acceleration, angular position, etc.



$L = N^2 / R = N^2 / Ri + Ra$

N : number of turns

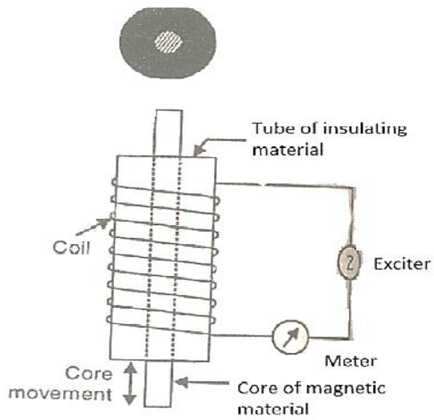
R : reluctance of coil

Ri : reluctance of iron path

Ra : reluctance of air gap

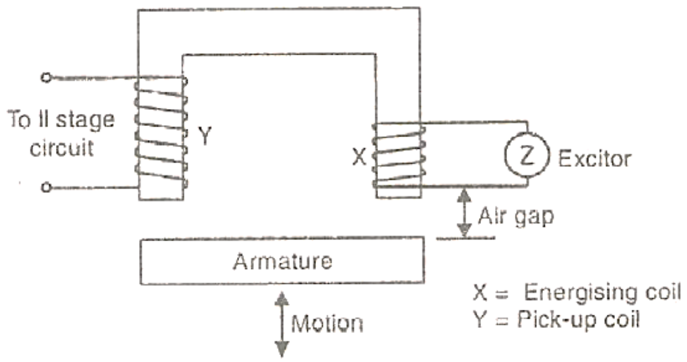
Variable Permeance type Transducer

- The inductance of coil is changed by varying the core material.
- When the coil on insulating tube is energized and the core enters the solenoid cell, the inductance of the coil increases in proportion to the amount of metal within the coil.
- Used for measurement of displacement, strain, force, etc.



Mutual Inductance Transducer

- A change in the position of armature by a mechanical input changes the air gap.
- This causes a change in output from coil Y, which may be used as measure of the displacement of mechanical input.



Self Inductance Transducer

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

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

Where,

- N = number of turns.
- R = reluctance of the magnetic circuit.

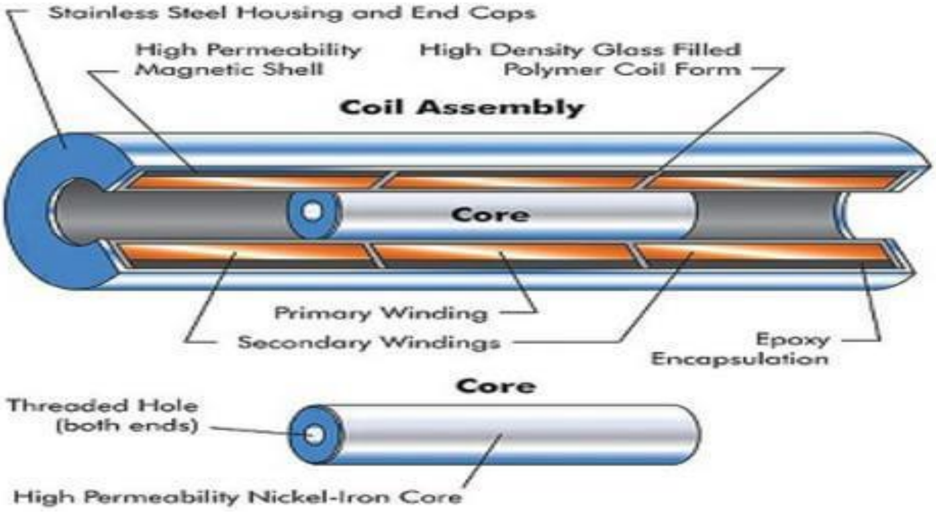
Where, μ = effective permeability of the medium in and around the coil.

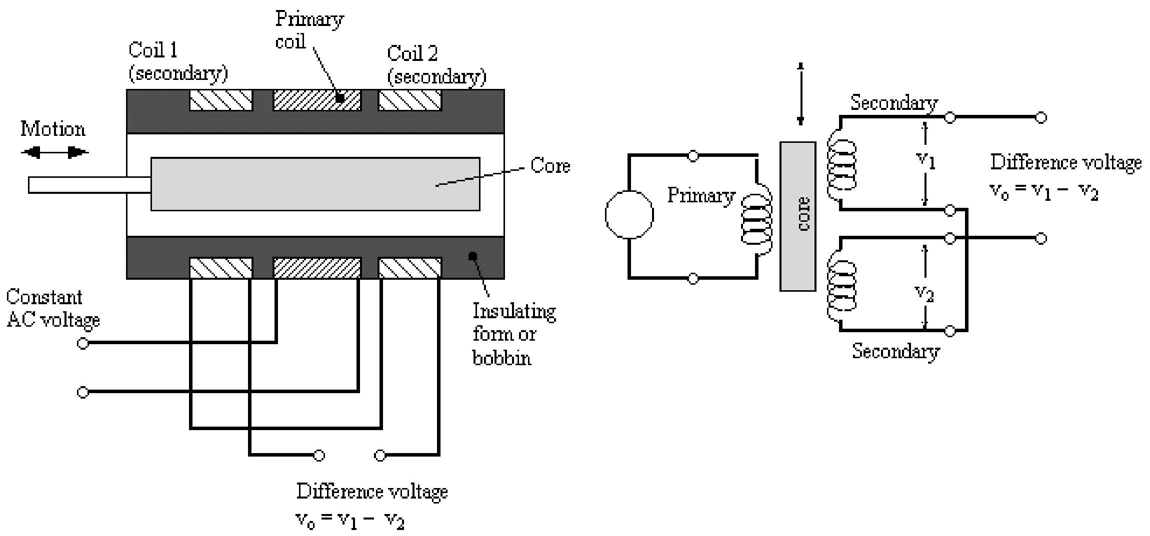
$$L = N^2 \mu G$$

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

Linear Variable Differential Transformer (LVDT)

- It converts the rectangular movement of an object to the equivalent electrical signal. LVDT is used to calculate displacement and works on the transformer principle.



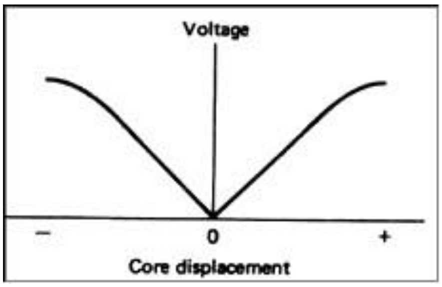

Primary
coil
Coil 1
(secondary)
Coil 2
(secondary)
Motion
Core
Constant
AC voltage
Insulating
form or
bobbin
Difference voltage
$v_o = v_1 - v_2$
Secondary
Primary
core
v_1
Difference voltage
$v_o = v_1 - v_2$
v_2
Secondary

(a) (b)

Construction:

- LVDT consists of a cylindrical former where it is surrounded by one primary winding in the centre of the former and the two secondary windings at the sides.
- The number of turns in both the secondary windings are equal, but they are opposite to each other, i.e., if the left secondary windings is in the clockwise direction, the right secondary windings will be in the anti-clockwise direction, hence the net output voltages will be the difference in voltages between the two secondary coil.
- Esteem iron core is placed in the centre

- **Case-1: Core is at NULL position**
  - The flux linkage of both the secondary winding S_1 & S_2 will be same- NULL position. This means $E_{s1} = E_{s2}$ and hence net output voltage E_0 of LVDT = 0.
- **Case-2: Core is moved left to the NULL position:**
  - When core of LVDT is moved to the left of the NULL position 'O' the flux linkage of secondary winding S_1 will become more than that of winding S_2. This means the emf induced in winding S_1 will be more than S_2. Hence $E_{s1} > E_{s2}$ and net output voltage $E_0 = (E_{s1} – E_{s2})$ = Positive.
- **Case-3: Core is moved right to the NULL position**
  - The emf induced in secondary winding S_2 will be more than that of S_1. This means $E_{s2} > E_{s1}$ and hence net output voltage $E_0 = (E_{s1} – E_{s2})$ = negative.



Application

- LVDT is used in those applications where displacement ranging from fraction of a mm to few cm. As a primary transducer, it converts the mechanical displacement into electrical signal.
- Acting as a secondary transducer, it is sued for measurement of force, pressure, weight etc.

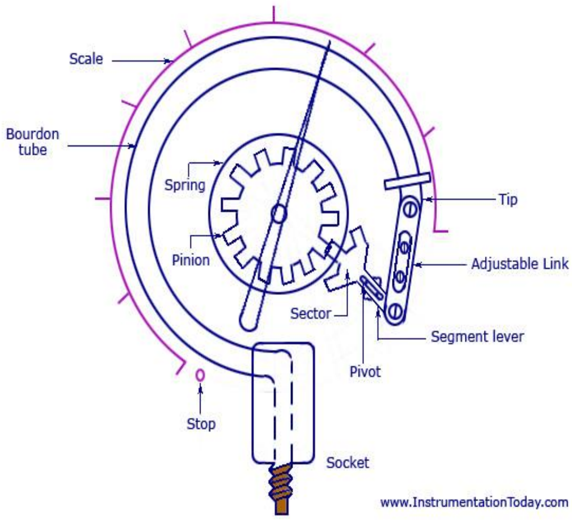
Pressure Transducers

- A **pressure transducer**, often called a **pressure transmitter**, is a transducer that converts pressure into an analog electrical signal.
- Pressure transducers are generally available with three types of electrical output;
  - millivolt
  - amplified voltage
  - 4-20mA.

Bourdon Tube

- Bourdon Tubes are known for its very high range of differential **pressure measurement**.
- The device was invented by Eugene Bourdon in the year 1849.
- The basic idea behind the device is that, cross-sectional tubing when deformed in any way will tend to regain its circular form under the action of pressure.
- The bourdon pressure gauges used today have a slight elliptical cross-section and the tube is generally bent into a C-shape or arc length of about 27 degrees.

Bourdon Tube



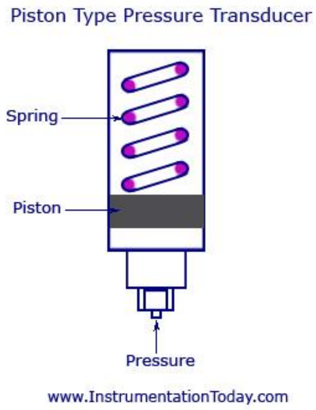
Bourdon Tube Pressure Gauge

- The pressure input is given to a socket which is soldered to the tube at the base.
- The other end or free end of the device is sealed by a tip.
- This tip is connected to a segmental lever through an adjustable length link.
- The lever length may also be adjustable.
- The segmental lever is suitably pivoted and the spindle holds the pointer.
- A hair spring is sometimes used to fasten the spindle of the frame of the instrument to provide necessary tension for proper meshing of the gear teeth and thereby freeing the system from the backlash.

Bourdon Tube

- As the fluid pressure enters the bourdon tube, it tries to be reformed and because of a free tip available, this action causes the tip to travel in free space and the tube unwinds.
- The simultaneous actions of bending and tension due to the internal pressure make a non-linear movement of the free tip.
- This travel is suitable guided and amplified for the measurement of the internal pressure.
- But the main requirement of the device is that whenever the same pressure is applied, the movement of the tip should be the same and on withdrawal of the pressure the tip should return to the initial point.
- A lot of compound stresses originate in the tube as soon as the pressure is applied.
- This makes the travel of the tip to be non-linear in nature. If the tip travel is considerably small, the stresses can be considered to produce a linear motion that is parallel to the axis of the link.

Piston type pressure Transducer

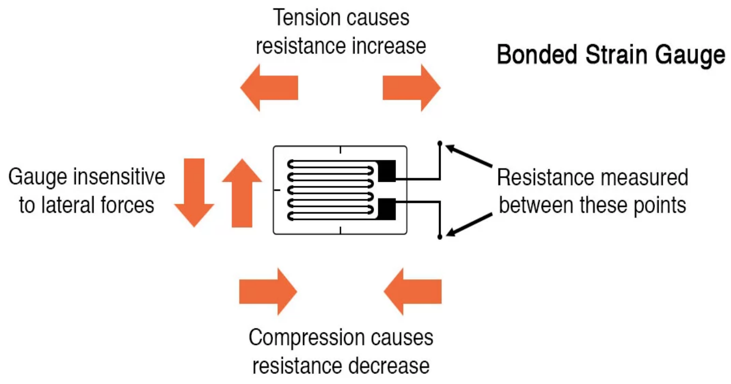


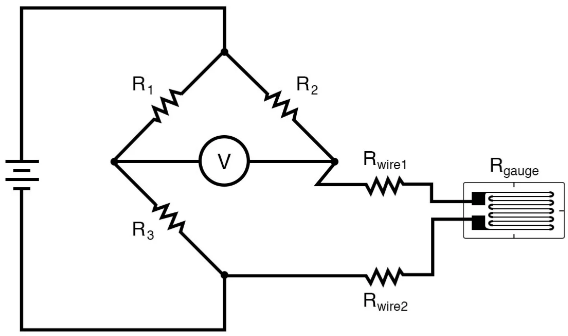
- The input pressure is given to the piston.
- This moves the piston accordingly and causes the spring to be compressed.
- The piston position will be directly proportional to the amount of input pressure exerted.
- A meter is placed outside the piston and spring arrangement, which indicates the amount of pressure exerted.
- As the device has the ability to withstand shock, sudden pressure changes, and vibrations, it is commonly used in hydraulic applications.

Strain Gauge

- There are some materials whose resistance changes when strain is applied to them or when they are stretched and this change in resistance can be measured easily.
- For applying the strain you need force, thus the change in resistance of the material can be calibrated to measure the applied force.
- Thus the devices whose resistance changes due to applied strain or applied force are called as the strain gauges.

Bonded Strain Gauge





Bonded Strain Gauge

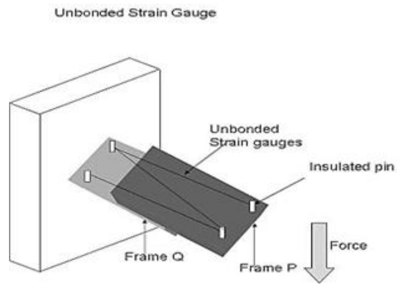
- If a strip of conductive metal is stretched, it will become skinnier and longer, both changes resulting in an increase of electrical resistance end-to-end.
- Conversely, if a strip of conductive metal is placed under compressive force it will broaden and shorten.
- If these stresses are kept within the elastic limit of the metal strip the strip can be used as a measuring element for physical force, the amount of applied force inferred from measuring its resistance.

Unbonded Strain Gauge

- These strain gauges are not directly bonded (that is, pasted) onto the surface of the structure under study.
- Hence they are termed as unbonded strain gauges.
- The arrangement of an unbonded strain gauges consists of the following.
- Two frames P and Q carrying rigidly fixed insulated pins as shown in diagram.
- These two frames can move relative with respect to each other and they are held together by a spring loaded mechanism.
- A fine wire resistance strain gauge is stretched around the insulated pins.
- The strain gauge is connected to a wheat stone bridge.

Unbonded Strain Gauge

- When a force is applied on the structure under study (frames P & Q), frames P moves relative to frame Q, and due to this strain gauge will change in length and cross section.
- That is, the strain gauge is strained.
- This strain changes the resistance of the strain gauge and this change in resistance of the strain gauge is measured using a wheat stone bridge.
- This change in resistance when calibrated becomes a measure of the applied force and change in dimensions of the structure under study.



Applications of Strain Gauge

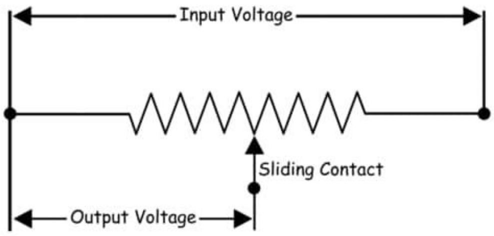
- Residual stress
- Vibration measurement
- Torque measurement
- Bending and deflection measurement
- Compression and tension measurement
- Strain measurement

Potentiometer

- A **potentiometer** (also known as a **pot** or **potmeter**) is defined as a 3 terminal variable resistor in which the resistance is manually varied to control the flow of electric current.
- A potentiometer acts as an adjustable voltage divider.
- A potentiometer is a passive electronic component. Potentiometers work by varying the position of a sliding contact across a uniform resistance.

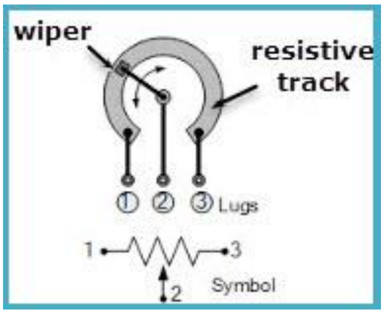
Potentiometer

- In a potentiometer, the entire input voltage is applied across the whole length of the resistor, and the output voltage is the voltage drop between the fixed and sliding contact.
- A potentiometer has the two terminals of the input source fixed to the end of the resistor.
- To adjust the output voltage the sliding contact gets moved along the resistor on the output side.

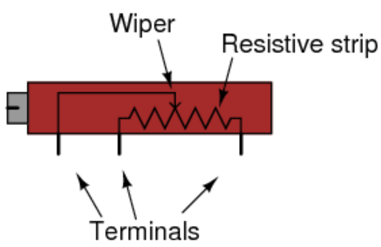


Potentiometer Types

- There are two main types of potentiometers:
  - Rotary potentiometer
  - Linear potentiometer
- Although the basic constructional features of these potentiometers vary, the working principle of both of these types of potentiometers is the same.



Linear potentiometer construction



Applications of Potentiometer

- The three main applications of a potentiometer are:
  - Comparing the emf of a battery cell with a standard cell
  - Measuring the internal resistance of a battery cell
  - Measuring the voltage across a branch of a circuit

Accelerometers

- Accelerometers are Micro-Electro-Mechanical Sensors (MEMS).
- An **accelerometer** is an electromechanical device used to measure acceleration forces.
- Such forces may be static, like the continuous force of gravity or, as is the case with many mobile devices, dynamic to sense movement or vibrations.
- Acceleration is the measurement of the change in velocity, or speed divided by time.

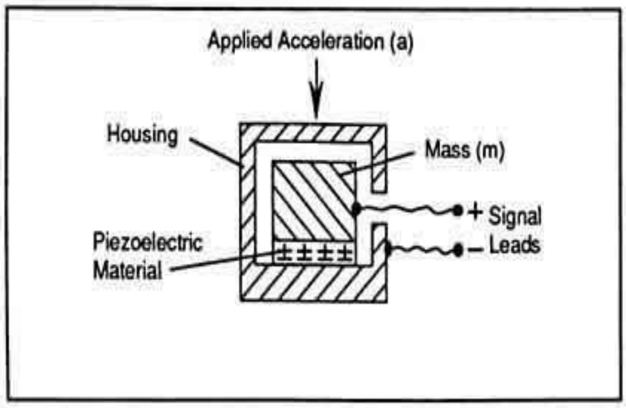
Types of Accelerometer

- Two very common types utilize capacitive sensing and the piezoelectric effect to sense the displacement of the mass proportional to the applied acceleration.

Capacitive Accelerometer

- Accelerometers that implement capacitive sensing output a voltage dependent on the distance between two planar surfaces.
- One or both of these “plates” are charged with an electrical current.
- Changing the gap between the plates changes the electrical capacity of the system, which can be measured as a voltage output.
- This method of sensing is known for its high accuracy and stability.
- Capacitive accelerometers are also less prone to noise and variation with temperature, typically dissipate less power

Piezoelectric Accelerometer



Piezoelectric sensing of acceleration is natural, as acceleration is directly proportional to force. When certain types of crystal are compressed, charges of opposite polarity accumulate on opposite sides of the crystal. This is known as the piezoelectric effect. In a piezoelectric accelerometer, charge accumulates on the crystal and is translated and amplified into either an output current or voltage.

Electromagnetic Flow Meters

- Electromagnetic Flow Meters are based on FARADAY'S LAW INDUCTION.
- These meters are also called as Magflow or Electromagnetic Flow Meters.
- A magnetic field is applied to the metering tube, which results in a potential difference proportional to the flow velocity perpendicular to the flux lines.
- The physical principle at work is electromagnetic induction and mathematically defined as

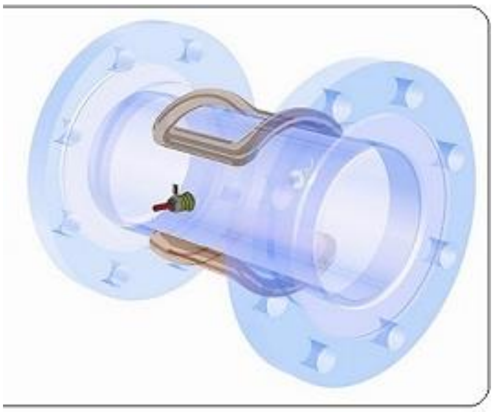
$$E=k*B*D*V.$$

where,

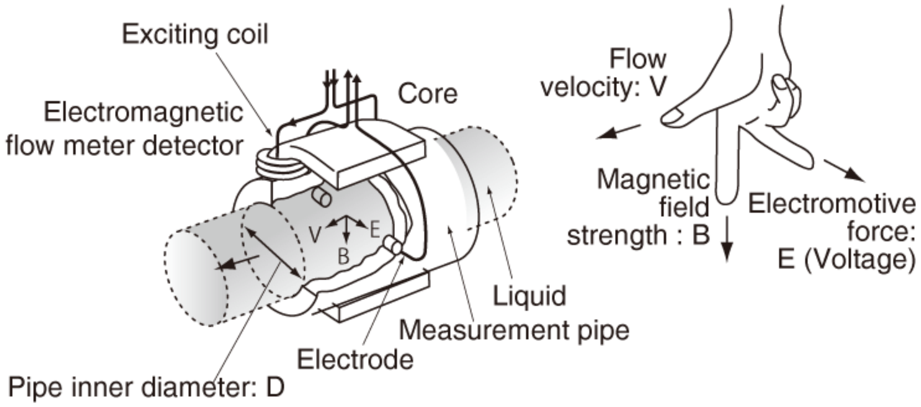
E=Induced Voltage (Linear with velocity), k=Proportionality Constant,

B=Magnetic Field Strength (Coil Inductance), D=Distance between electrodes

V=Velocity of process fluids.



- The induced voltage (E) is directly proportional to the velocity (V) of the fluid moving through the magnetic field (B).
- The induced voltage is carried to the transmitter through the electrode circuit.
- The transmitter then converts this voltage into a quantifiable flow velocity.
- The volumetric flow rate of the fluid is calculated using this known velocity along with the area of the pipe.



Chemical Transducers

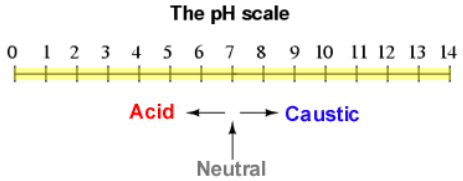
- Converts chemical energy to electrical energy.
- pH is the numeric representation of gram-equivalent per litre of hydrogen ion concentration in any solution.
- It varies between 0 to14. It is the logarithmic measurement of moles of hydrogen ions per litre of solution.
- The solutions having pH value between 0 to 7 are acidic solutions with large concentration of hydrogen ions whereas solutions having pH value between 8 to 14 are basic solutions with small hydrogen concentration.
- The solutions having pH value of 7 are neutral solutions. Measuring the pH gives the measure of alkalinity or acidity of a solution.

Ways to measure pH of a solution

- Using indicator strip which when placed in a solution, changes its color accordingly. The strip is then taken out and its color is matched with a color on the color chart to decide the corresponding pH value.
- Using a pH indicator fluid where the unknown solution is added to the fluid and the changed color of the fluid is matched with a already available color on the color wheel to decide the pH value.
- Using a pH sensor where a probe can be simply inserted inside the solution and pH reading can be done.

pH Sensor

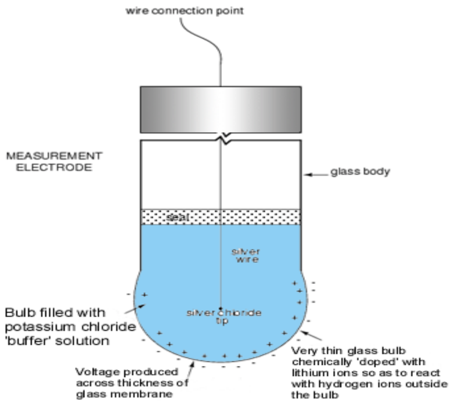
- pH is the numeric representation of gram-equivalent per liter of hydrogen ion concentration in any solution. It varies between 0 to14.

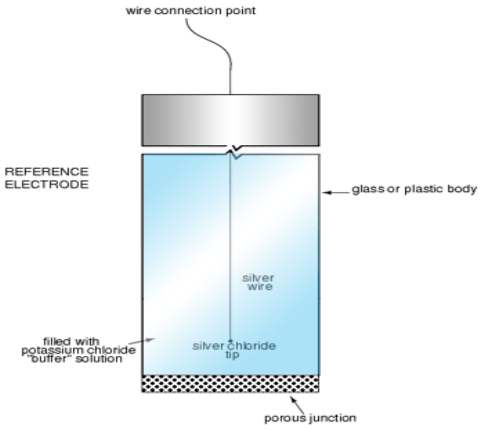


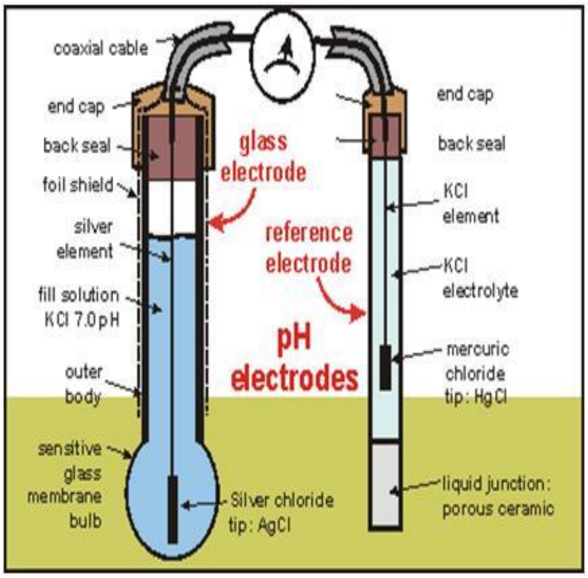
Working Principle of pH Meter

- pH meter basically works on the fact that interface of two liquids produces a electric potential which can be measured.
- In other words when a liquid inside an enclosure made of glass is placed inside a solution other than that liquid, there exists an electrochemical potential between the two liquids.

- **pH electrode**
  - It is constructed of special glass to create the ion-selective barrier needed to screen out hydrogen ions from all the other ions floating around in the solution.
  - This glass is chemically doped with lithium ions, which is what makes it react electrochemically to hydrogen ions.
- **Reference electrode**
  - It is made from a chemical solution of neutral (7) pH buffer solution (usually potassium chloride) allowed to exchange ions with the process solution through a porous separator







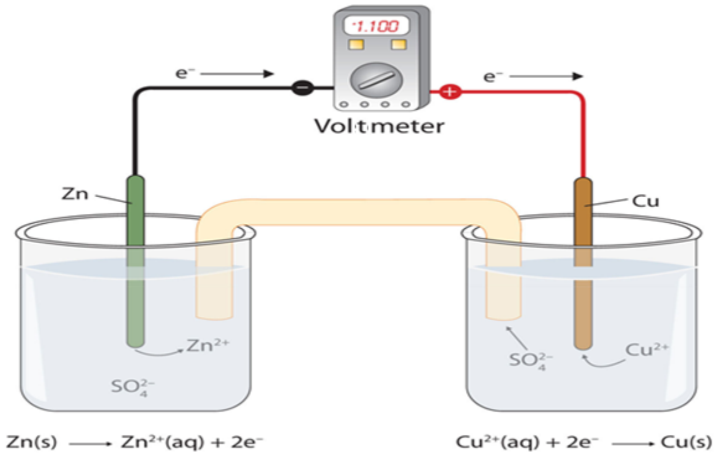
- The electrode is placed inside the beaker filled with a solution whose pH is to be measured.
- The glass bulb welded at the end of the measurement electrode consists of lithium ions doped to it which makes it act as an ion selective barrier and allows the hydrogen ions from the unknown solution to migrate through the barrier and interacts with the glass, developing an electrochemical potential related to the hydrogen ion concentration.
- The measurement electrode potential thus changes with the hydrogen ion concentration.
- On the other hand, the reference electrode potential doesn't change with the hydrogen ion concentration and provides a stable potential against which the measuring electrode is compared.
- It consists of a neutral solution which is allowed to exchange ions with the unknown solution through a porous separator, thus forming low resistance connection to complete the whole circuit.
- The potential difference between the two electrodes gives a direct measurement of the hydrogen ion concentration or pH of the system

Electro galvanic Sensor

- A galvanic cell is a type of electrochemical cell.
- It is used to supply electric current by making the transfer of electrons through a redox reaction.
- These reactions are used to convert the chemical energy into electrical energy.
- Galvanic cell utilizes the ability to separate the flow of electrons in the process of oxidization and reduction, causing a half reaction and connecting each with a wire so that a path can be formed for the flow of electrons through such wire.
- This flow of electrons is essentially called a current.

Working of Galvanic Cells

• A galvanic cell can be made out of any two metals. These two metals can form the anode and the cathode if left in contact with each other.
• Since these two metals will be placed in two separate containers and would be connected by a conducting wire, an electric current would be formed, which would transfer all electrons from one metal to another.



Advantages of Galvanic Cells

Advantages of the use of fuel cells include:

- high energy conversion efficiency
- modular design, different sizes available
- low chemical pollution
- fuel flexibility
- co-generation capability by using heat produced
- quiet operation
- unlimited run time while fuel is supplied
- no need to be recharged
- low maintenance due to lack of moving parts
- low running costs
- lower weight and volume than conventional batteries for electric-powered vehicles
- potential to power portable devices for longer times than conventional batteries.

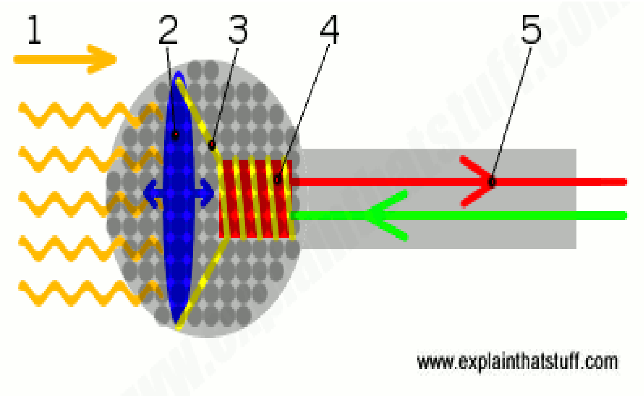
Electroacoustic Transducers

Electro acoustic Transducers

- An electro acoustic transducer may convert electrical signals to acoustic signals or vice versa.
- **earphone**, **earpiece**, **headphone**, **phone** -
- **loudspeaker**,
- **microphone**, **mike**
- They serve two principal purposes.
  - First, they are used for converting music or speech into electric signals which are transmitted or processed in some manner and then reproduced.
  - Second, they serve as measuring instruments, converting acoustic signals into electric currents which are processed and displayed.

Microphone

- When you speak, **sound waves** created by your voice carry energy toward the microphone
- Inside the microphone, the **diaphragm** moves back and forth when the sound waves hit it.
- The **coil**, attached to the diaphragm, moves back and forth as well.
- The **permanent magnet** produces a magnetic field that cuts through the coil.
- As the coil moves back and forth through the magnetic field, an electric current flows through it.
- The **electric current** flows out from the microphone to an amplifier or sound recording device.



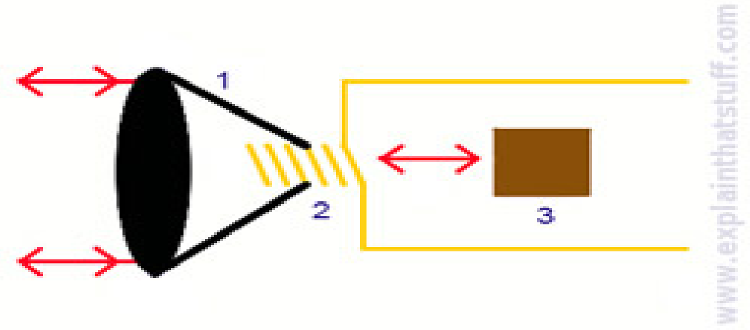
1 – Sound Waves
2 – Diaphragm
3 – Coil
4 – Permanent Magnet
5 – Electric Current

Loudspeaker

- The purpose of a loudspeaker is to convert an electrical signal into sound waves.
- In order to translate an electrical signal into an audible sound, speakers contain an electromagnet: a metal coil which creates a magnetic field when an electric current flows through it.
- Inside a speaker, an electromagnet is placed in front of a permanent magnet.
- The permanent magnet is fixed firmly into position whereas the electromagnet is mobile. As pulses of electricity pass through the coil of the electromagnet, the direction of its magnetic field is rapidly changed.
- The electromagnet is attached to a cone made of a flexible material such as paper or plastic which amplifies these vibrations, pumping sound waves into the surrounding air and towards your ears.

Loudspeaker

- When an electrical signal is applied to the voice coil, a magnetic field is created by the electric current in the voice coil, making it a variable electromagnet.
- The coil and the driver's magnetic system interact, generating a mechanical force that causes the coil (and thus, the attached cone) to move back and forth, accelerating and reproducing sound under the control of the applied electrical signal coming from the amplifier.



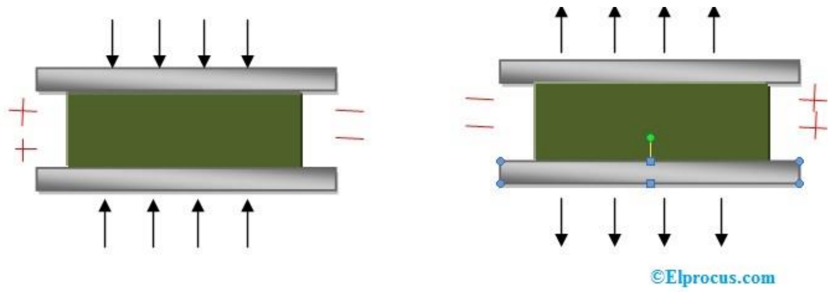
Inside a speaker:
1. Cone
2. Electromagnet (Voice coil)
3. Permanent magnet

Piezoelectric Transducer

- The Piezoelectric transducer is an **electroacoustic transducer** use for **conversion** of **pressure** or mechanical stress into an alternating **electrical force.**
- It is used for measuring the physical quantity like force, pressure, stress, etc., which is directly not possible to measure.
- The piezoelectric transducer uses the piezoelectric material which has a special property, i.e. the material induces voltage when the pressure or stress applied to it.
- The material which shows such property is known as the electro-resistive element.
- Piezoelectric Effect
  - If a varying potential is applied to a piezoelectric transducer, it will change the dimension of the material or deform it.
  - This effect is known as the piezoelectric effect.

Piezoelectric Transducer Working

- **Piezoelectric Transducer** works with the principle of piezoelectricity.
- The faces of piezoelectric material, usual quartz, is coated with a thin layer of conducting material such as silver.
- When stress has applied the ions in the material move towards one of the conducting surface while moving away from the other.
- This results in the generation of charge.
- This charge is used for calibration of stress.
- The polarity of the produced charge depends upon the direction of the applied stress.



Piezoelectric Transducer Formula

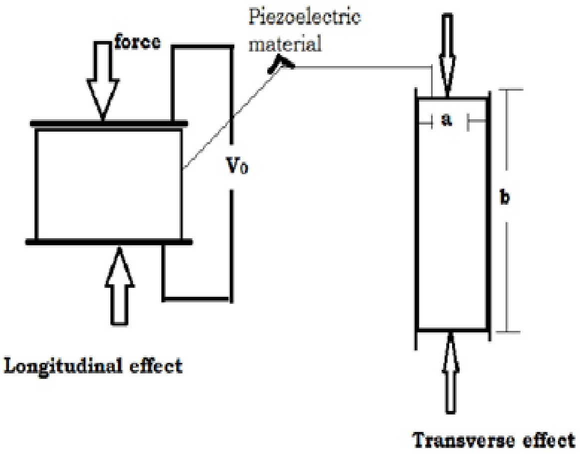
- The orientation of the crystal also effects the amount of voltage generated.
- Crystal in a transducer can be arranged in **longitudinal position** or **transverse position**.
- In the longitudinal effect, the charge generated is given by

Q = F * d

Where
- F is the applied force
- d is the piezoelectric coefficient of the crystal.

- In the transverse effect, the charge generated is given by

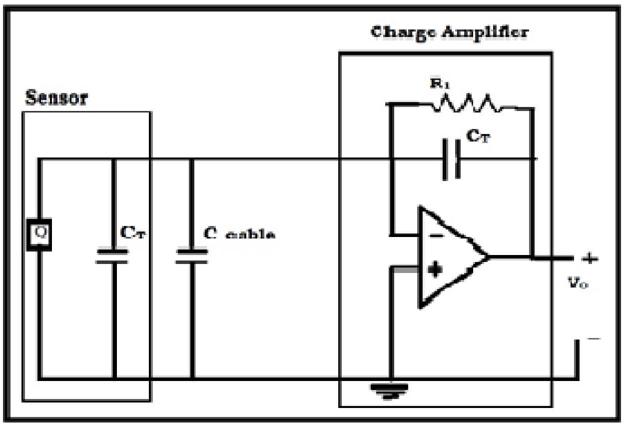
Q = F * d * (b/a)



Transverse effect :
The applied stress is perpendicular to the direction of the resultant electric field

Piezoelectric Transducer Circuit

- Here quartz crystal coated with silver is used as a sensor to generate a voltage when stress is applied on it.
- A charge amplifier is used to measure the produced charge without dissipation.
- To draw very low current the resistance R1 is very high.
- So in a piezoelectric transducer when mechanical stress is applied a proportional electric voltage is generated which is amplified using charge amplifier and used for calibration of applied stress.



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Piezoelectric Transducer Applications

- They are used in **seismographs** to measure vibrations in rockets.
- In strain gauges to measure force, stress, vibrations etc…
- Used by automotive industries to measure detonations in engines.
- These are used in **ultrasonic imaging** in medical applications.

Advantages & Disadvantages

Advantages

- These are active transducer i.e. they don't require external power for working and are therefore self-generating.
- The high-frequency response of these transducers makes a good choice for various applications.

Limitations

- Temperature and environmental conditions can affect the behaviour of the transducer.
- They can only measure changing pressure hence they are useless while measuring static parameters.

SONAR

- Sound Navigation And Ranging (SONAR).
- SONAR is a technique that uses sound waves to map or locate objects in the surrounding environment.
- Principle
  - First, emit a cluster of sound waves in the direction of an object.
  - While a few waves will bounce off it, the remaining waves will be reflected back in the direction of the emitter.
  - With the knowledge of the speed of sound and the time that passed before the wave was retrieved, an adroit receiver can calculate the object's distance from the emitter.
  - While Sonar can be implemented in the open air, it is known to be more effective in water.
  - This is because sound waves tend to travel longer distances in water.

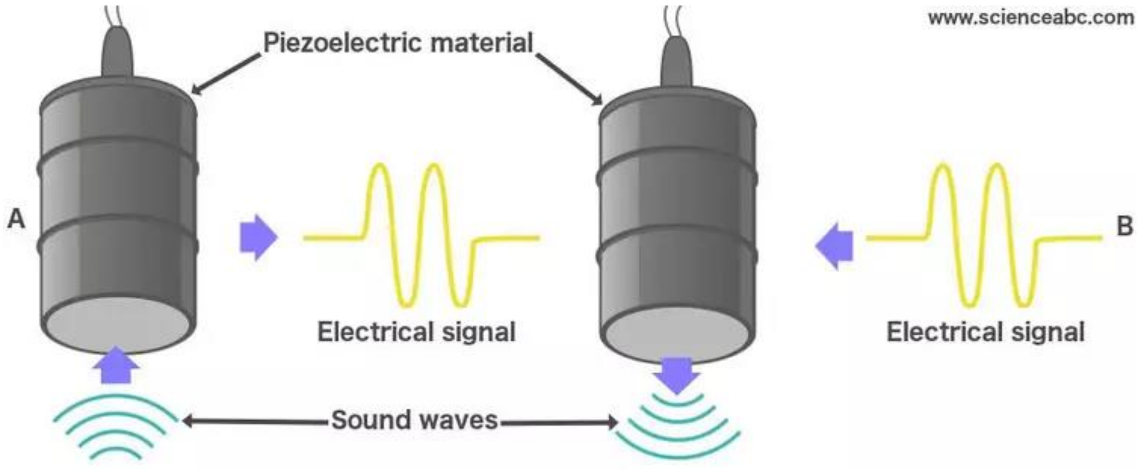
Active and Passive SONAR

- Active SONAR :
  - a technique that utilizes a receiver as well as a transmitter.

- Passive SONAR :
  - a technique that does not require its own transmitter

- Applications :
  - Warfare Submarines
  - Medical applications.

SONAR



www.scienceabc.com
Piezoelectric material
A
Electrical signal
Electrical signal
B
Sound waves

SONAR

- The transmitters are mostly piezoelectric materials, materials that wobble and distort when subjected to an electric current.
- The production of sound from these distortions is analogous to the vibration of a diaphragm in your speaker.
- Conversely, piezoelectric materials produce an electric current when subjected to distortion, a property that convinced us to simultaneously employ them as receivers.
- However, because the reflected waves are waves scattered by an object, one can reasonably conclude that their intensity is diminished compared to the original, incident sound waves.
- The low intensity of the received waves renders images murky or not suitably bright.
- The quality of an image, therefore, depends not only on the capabilities of the machine, but also the aspects of the object and the terrain in which the mechanism is implemented.

Ultrasonic Transducers

- An ultrasonic transducer is a device used to convert some other type of energy into an ultrasonic vibration.

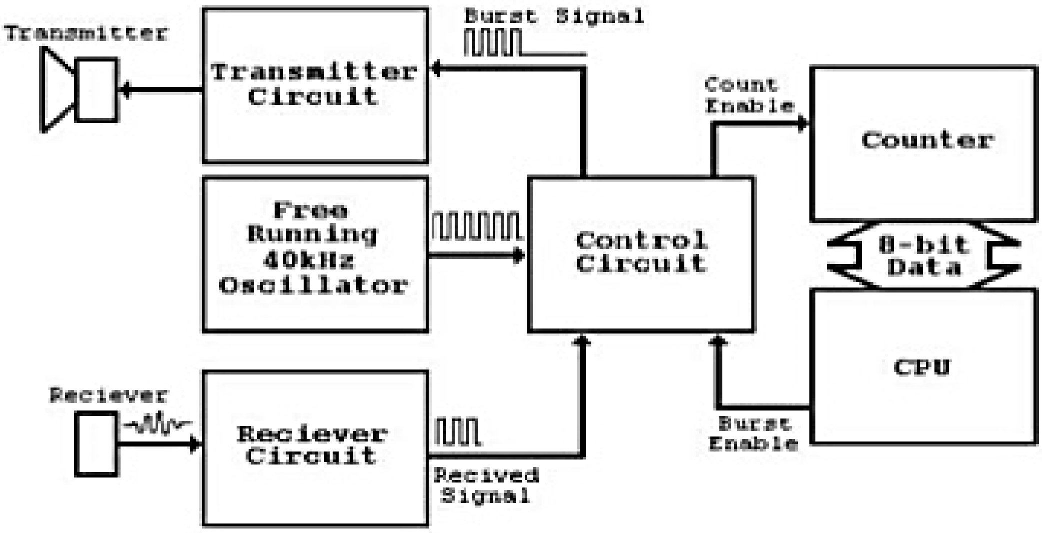
Working Principle:

- When an electrical pulse of high voltage is applied to the ultrasonic transducer it vibrates across a specific spectrum of frequencies and generates a burst of sound waves.
- Whenever any obstacle comes ahead of the ultrasonic sensor the sound waves will reflect back in the form of echo and generates an electric pulse.
- It calculates the time taken between sending sound waves and receiving echo.
- The echo patterns will be compared with the patterns of sound waves to determine detected signal's condition.

$$W = CT$$

W = Wave length
C = Velocity of sound in a medium
T=Time Period

Ultrasonic Transducers



APPLICATIONS :

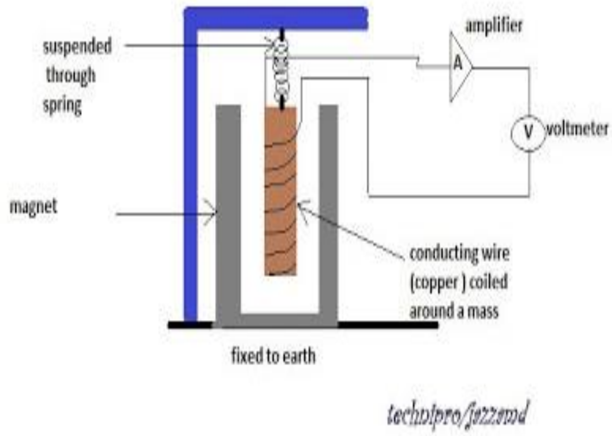
- Used to measure the Liquid Levels.
- Used to measure the obstacle distance
- This system used in automotive parking sensors and obstacle warning systems.
- Used in terrain monitoring robots
- This systems could be deployed in tanks, dams or other water bodies

Geophones

- A **geophone** is a device that converts ground movement (velocity) into voltage, which may be recorded at a recording station.
- The deviation of this measured voltage from the base line is called the seismic response and is analysed for structure of the earth.
- Geophones are used in reflection seismology to record the energy waves reflected by the subsurface geology.

Geophones

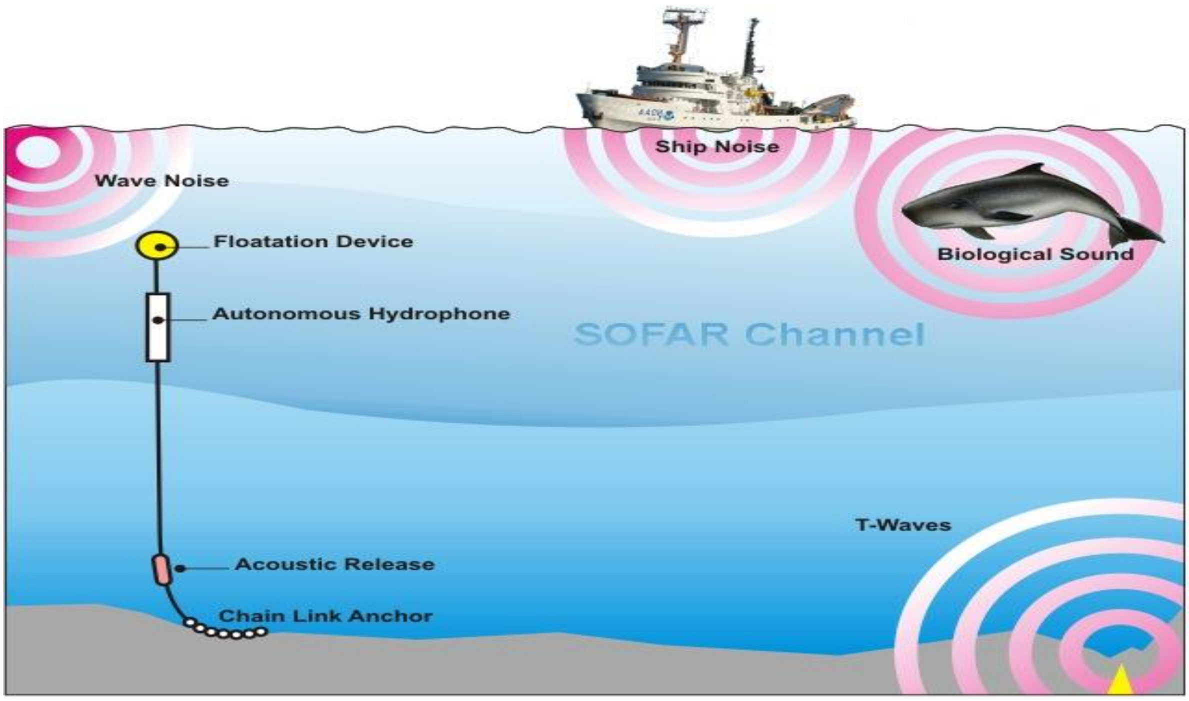
- The active element is a block (a mass) nonconducting, whirled by a copper or any good conducting wire.
- Active element is suspended using a spring in region enclosed by magnet.
- This magnet is fixed to the earth using a long spine fixed to it to attach firmly to ground.
- When the ground moves the entire configuration moves except the mass which is freely suspended due to inertia.
- Hence we get relative motion between the magnet and the coil and hence output voltage is generated which is proportional to the ground velocity since the magnetic flux changes at a rate equal to the ground velocity.
- The output can be further amplified to and the setup can be made more precise since even small variations can be recorded.
- Due to electrical output it is easy to store the data or to process it to any other form.



Hydrophones

- **Hydrophone is a** device for converting sound waves into electrical signals, similar in operation to a microphone but used primarily for detecting sound waves from an underwater source, such as a submarine.
- Most hydrophones are based on a piezoelectric transducer that generates an electric potential when subjected to a pressure change, such as a sound wave.
- While a hydrophone can detect sound waves in the air, it is not as sensitive with airborne sounds because of its acoustic impedance is designed specifically for sound detection in water.

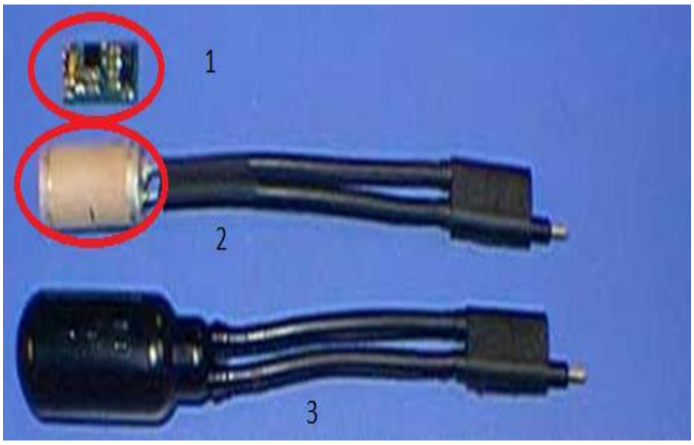
Hydrophones



Hydrophones

- A typical hydrophone has a transducer. This transducer is crucial for converting the incoming sound waves into an electrical voltage.
- The transducers are packed together in a tube with oil, which aids the collection of pressure waves entering the hydrophone.
- Pre-amplifiers are often used to enhance the electrical signal and limit the potential of noise contamination from additional components to the hydrophone.

Hydrophones



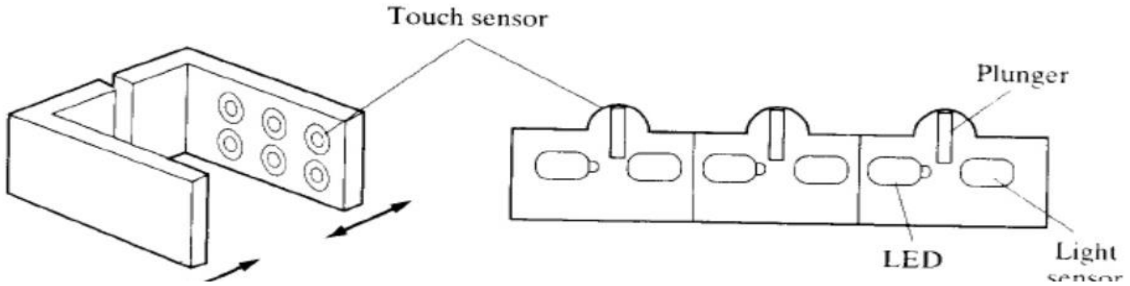
- 1 - preamplifier.
- 2 - The preamplifier is housed inside the ceramic element.
- 3 - The final product that is encapsulated in urethane.

Tactile Transducer

- 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 a capability of detecting the stimuli resulting from the mechanical simulation, pain, and temperature.
    - The kinesthetic touch receives sensor inputs from the receptors present inside the muscles, tendons and joints.
- Tactile Sensor – Cutaneous sense

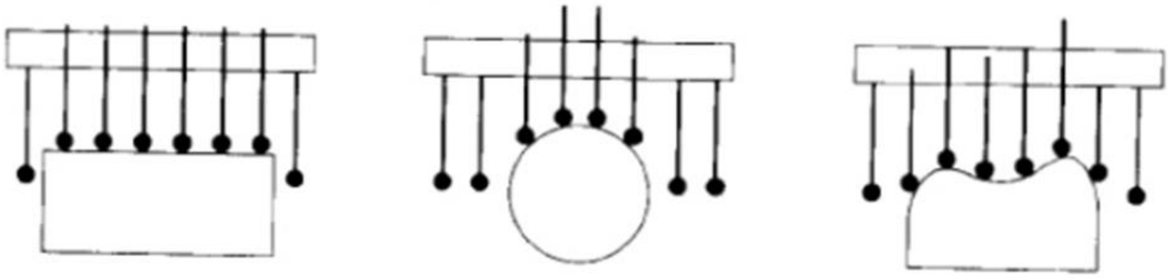
Tactile Transducer

- In this design, an array of six touch sensors is arranged on each side of a tactile sensor.
- Each touch sensor is made up of a plunger, an LED and a light sensor.
- As the tactile sensor closes and the plunger moves in or out, it blocks the light from the LED projecting onto the light sensor.
- The output of the light sensor is then proportional to the displacement of the plunger.



Tactile Transducer

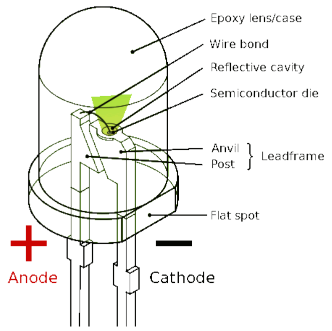
- As the tactile sensor comes in contact with an object, depending on the shape and size of the object, different touch sensors react differently at a different sequence.
- This information is then used by the controller to determine the size and the shape of the object.

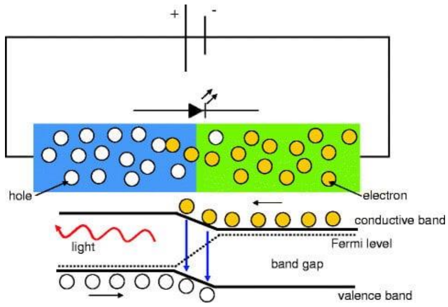


Electrooptical Transducer

LED (Light Emitting Diode)

- An LED is just like a normal p n junction diode, but with light-emitting properties.
- Like an ordinary diode, the LED diode works when it is forward biased.
- In this case, the n-type semiconductor is heavily doped than the p-type forming the p-n junction.
- When it is forward biased, the potential barrier gets reduced and the electrons and holes combine at the depletion layer (or active layer), light or photons are emitted or radiated in all directions.

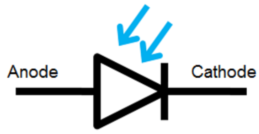




- Some of the materials used in LEDs are:
  - Aluminium Gallium Arsenide(AlGaAs) – infrared.
  - Gallium Arsenic Phosphide(GaAsP) – red, orange, yellow.
  - Aluminium Gallium Phosphide(AlGaP) – green.
  - Indium gallium nitride (InGaN) – blue, blue-green, near UV.
  - Zinc Selenide(ZnSe) – blue.
- **Applications of LEDs**
- Electronic displays such as OLEDs, micro-LEDs, quantum dots etc.
- As an LED indicator.
- In remote controls.
- Lightings.
- Opto-isolators.

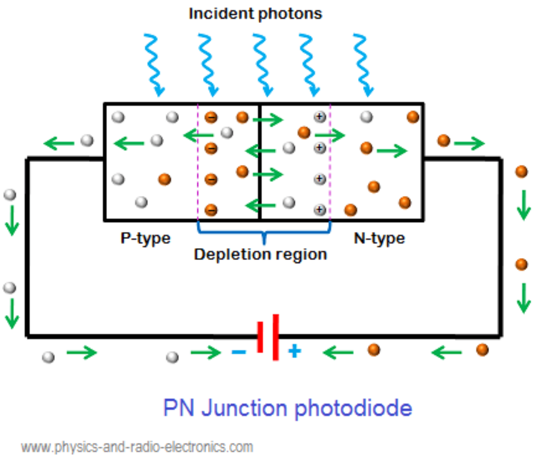
Photodiode

- A photodiode is a p-n junction is a device that consumes light energy to generate electric current. It is also referred as photo-detector, photo-sensor, or light detector.
- Photodiodes are specially designed to operate in reverse bias condition.
- Photodiode is very sensitive to light so when light or photons falls on the photodiode it easily converts light into electric current.
- A normal p-n junction diode allows a small amount of electric current under reverse bias condition. To increase the electric current under reverse bias condition, we need to generate more minority carriers
- External light energy is supplied to the p-n junction photodiode, the valence electrons in the depletion region gains energy.

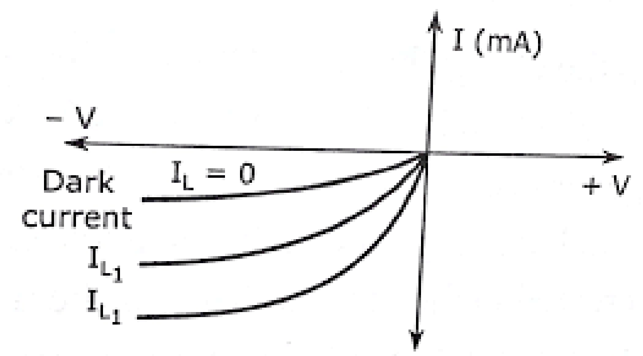


Photodiode symbol

- If the light energy applied to the photodiode is greater the band-gap of semiconductor material, the valence electrons gain enough energy and break bonding with the parent atom.
- The mechanism of generating electron-hole pair by using light energy is known as the inner photoelectric effect.
- The minority carriers in the depletion region experience force due to the depletion region electric field and the external electric field.
- As a result, free electrons move towards the n region.



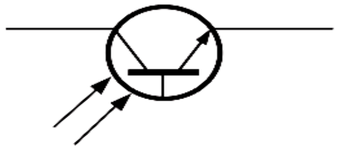
- When no light is applied to the reverse bias photodiode, it carries a small reverse current due to external voltage.
- This small electric current under the absence of light is called dark current. It is denoted by I $_{\lambda}$.



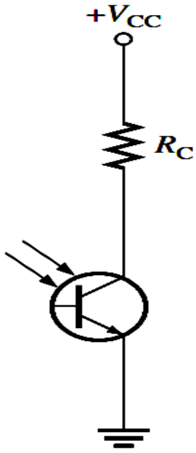
(b) I - V characteristic

Phototransistor

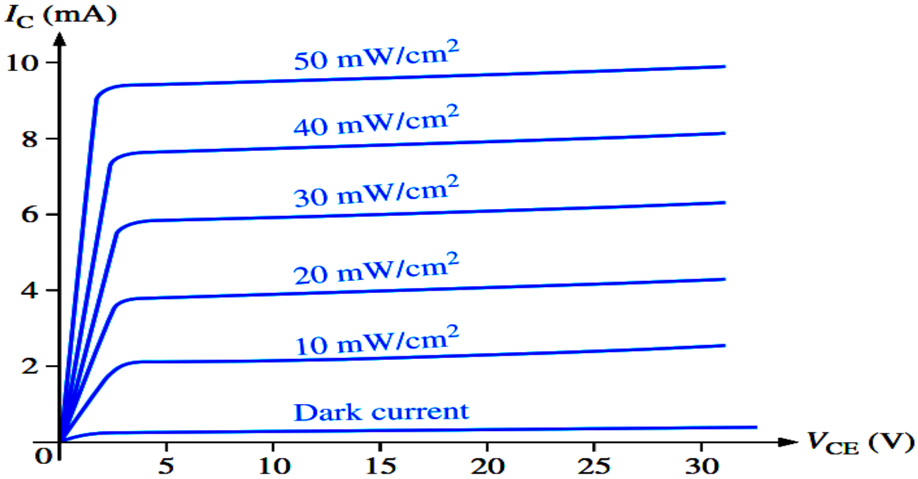
- A phototransistor is similar to a regular BJT except that the base current is produced and controlled by light instead of a voltage source.
- The phototransistor effectively converts light energy to an electrical signal.
- In a phototransistor the base current is produced when light strikes the photosensitive semiconductor base region.
- The collector-base pn junction is exposed to incident light through a lens opening in the transistor package.
- When there is no incident light, there is only a small thermally generated collector-to-emitter leakage current, I_{CEO}; this dark current is typically in the nA range.
- When light strikes the collector-base pn junction, a base current, $I\lambda$, is produced that is directly proportional to the light intensity.
- This action produces a collector current that increases with $I\lambda$. Except for the way base current is generated, the phototransistor behaves as a conventional BJT.



Phototransistor circuit



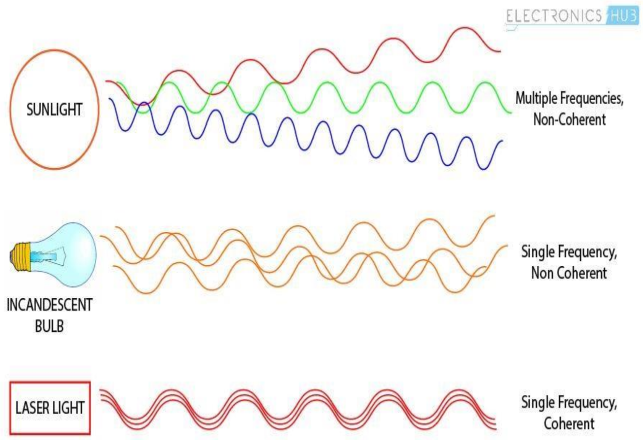
Phototransistor collector characteristic curves



- Phototransistors are not sensitive to all light but only to light within a certain range of wavelengths. They are most sensitive to particular wavelengths in the red and infrared part of the spectrum.

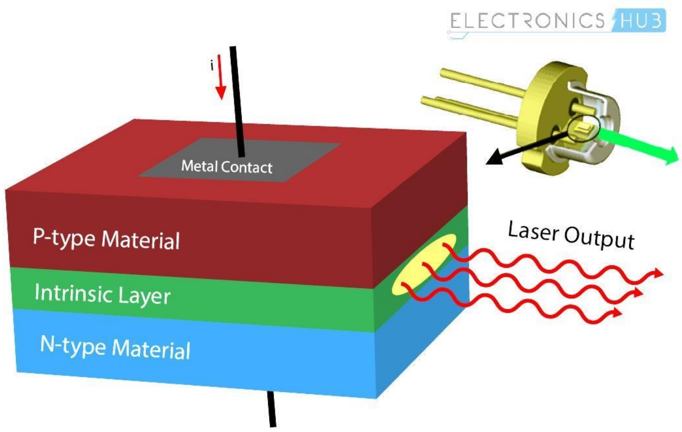
LASER Diode

- A Laser Diode is a semiconductor device similar to a light-emitting diode (LED).
- It uses p-n junction to emit coherent light in which all the waves are at the same frequency and phase.
- This coherent light is produced by the laser diode using a process termed as “Light Amplification by Stimulated Emission of Radiation”, which is abbreviated as LASER.
- And since a p-n junction is used to produce laser light, this device is named as a laser diode.



LASER Diode

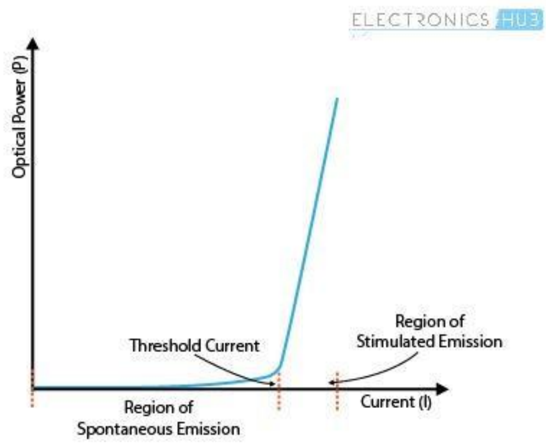
- The input terminals are connected to a metal plates which are sandwiched to the n-type and p-type layers.
- This type of laser diode is also called as a "Homojunction Laser Diode".
- The intrinsic region between the p-type and n-type material is used to increase the volume of active region, so that more number of holes and electrons can accumulate at the junction.
- This allows more number of electrons to recombine with holes at any instant of time, resulting in better output power.
- The laser light is emitted from the elliptical region. This beam from the laser diode can be further focused using an optical lens.
- This entire PIN diode (P-type, Intrinsic, N-Type) arrangement is enclosed normally in a metal casing.



LASER DIODE CONSTRUCTION

LASER Diode Characteristics

- As we increase the current flow to the laser diode, the optical power of output light gradually increases up to a certain threshold.
- Until this point, most of the light emitted is due to spontaneous emission.
- Above this threshold current, the process of stimulated emission increases.
- This causes the power of output light to increase a lot even for smaller increases in input current.
- The output optical power also depends on temperature and it reduces with decrease in temperature.



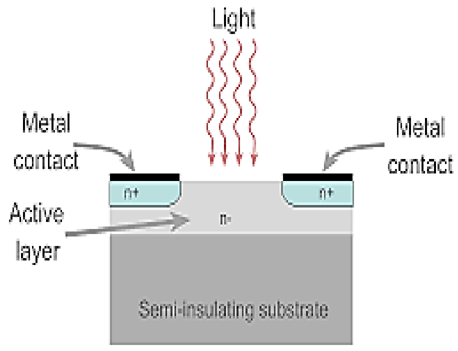
LASER DIODE P-I GRAPH

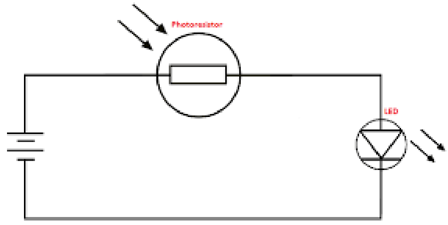
Photoresistor

- The name photoresistor is the combination of words: photon (light particles) and resistor.
- A photoresistor is a type of resistor whose resistance decreases when the intensity of light increases.
- Photoresistors are also sometimes referred as LDR (Light Dependent Resistor), semiconductor photoresistor, photoconductor, or photocell. Photoresistor changes its resistance only when it is exposed to light.

Photoresistor

- When the light falls on the photoresistor, some of the valence electron absorbs energy from the light and breaks the bonding with the atoms.
- The valence electrons, which break the bonding with the atoms, are called free electrons.
- When the light energy applied to the photoresistor increases, the number of charge carriers generated in the photoresistor also increases.
- As a result, the electric current flowing through the photoresistor increases.
- Increase in electric current means decrease in resistance.
- Thus, the resistance of the photoresistor decreases when the intensity of applied light increases.





Basic Photoresistor Circuit

Photoresistor

Applications of photoresistors

- Photoresistors are used in streetlights to control when the light should turn on and when the light should turn off.
- When the surrounding light falls on the photo resistor, it causes the streetlight to turnoff.
- When there is no light, the photoresistor causes the street light to turn on. This reduces the wastage of electricity.
- They are also used in various devices such as alarm devices, solar street lamps, night-lights, and clock radios.

Advantages of photoresistor

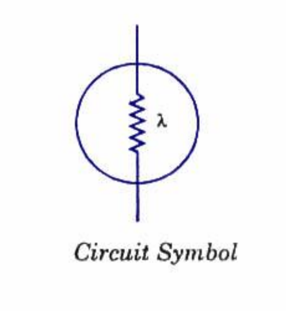
- Small in size
- Low cost
- It is easy to carry from one place to another place.

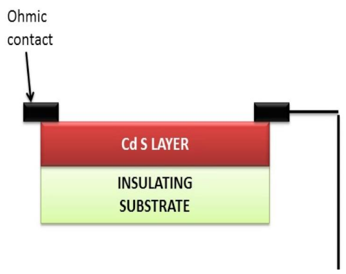
Disadvantages of photoresistor

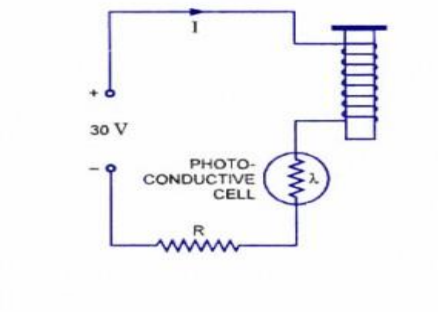
- The accuracy of photoresistor is very low

Photoconductive Cell

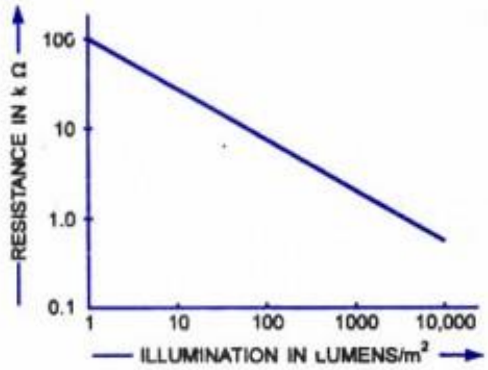
- **The photoconductive cell** is a two terminal semiconductor device whose terminal resistance will vary (linearly) with the intensity of the incident light.
- The essential elements of a photoconductive cell are the ceramic substrate, a layer of photoconductive material, metallic electrodes to connect the device into a circuit and a moisture resistant enclosure.







Photoconductive Cell



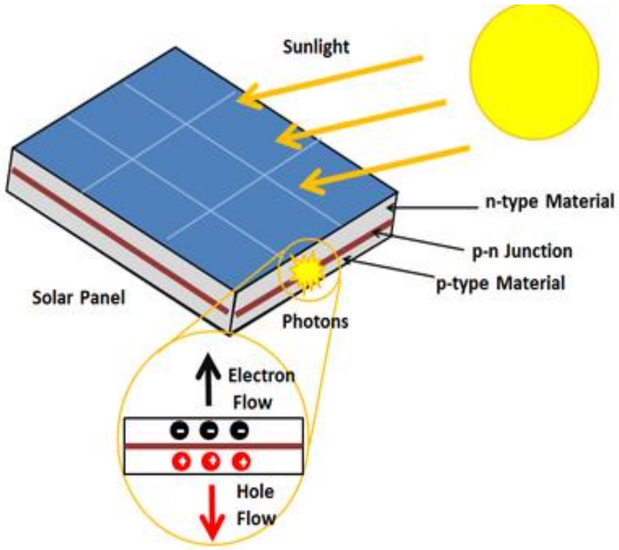
Illumination Characteristic of a Typical Photoconductive Cell

- The illumination characteristics of a typical photoconductive cell are shown from which it is obvious that when the cell is not illuminated its resistance may be more than 1 00 kilo ohms.
- This resistance is called the *dark resistance.*
- When the cell is illuminated, the resistance may fall to a few hun-dred ohms.

Photovoltaic Cell (Solar Cell)

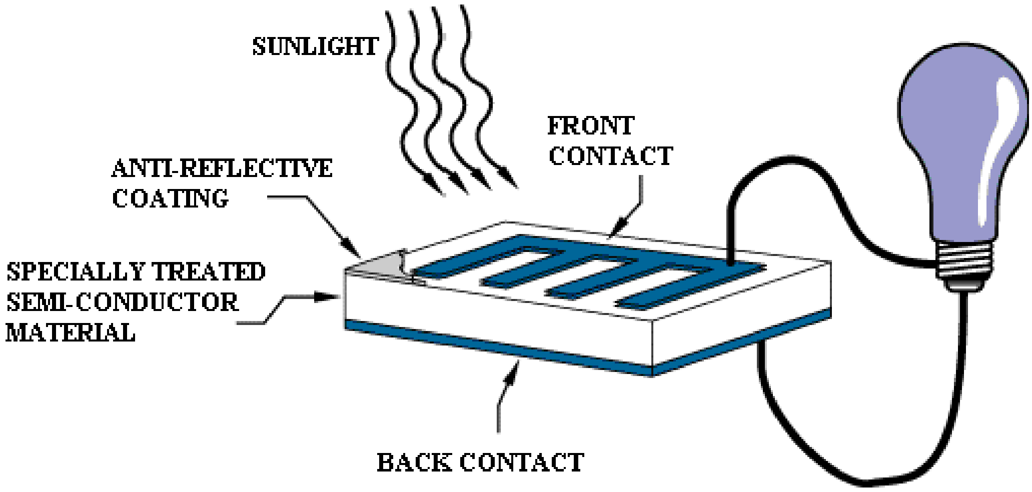
- A photovoltaic cell (PV cell) is a specialized semiconductor diode that converts visible light into direct current (DC).
- Some PV cells can also convert infrared (IR) or ultraviolet (UV) radiation into DC electricity.
- The **photovoltaic effect** is a process that generates voltage or electric current in a **photovoltaic cell** when it is exposed to sunlight.
- These solar cells are composed of two different types of semiconductors—a p-type and an n-type—that are joined together to create a **p-n junction**.

Photovoltaic Cell (Solar Cell)



- When light of a suitable wavelength is incident on these cells, energy from the photon is transferred to an electron of the semiconducting material, causing it to jump to a higher energy state known as the conduction band.
- In their excited state in the conduction band, these electrons are free to move through the material, and it is this motion of the electron that creates an electric current in the cell.

Photovoltaic Cell

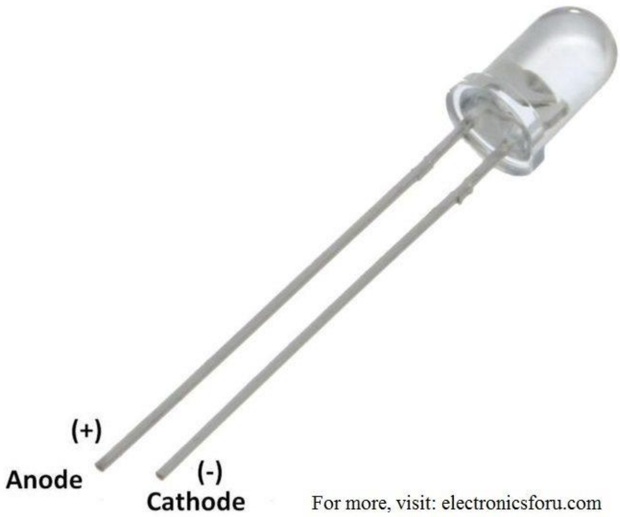


Infrared Emitters

- An IR LED (infrared light emitting diode) is a solid state lighting (SSL) device that emits light in the infrared range of the electromagnetic radiation spectrum.
- IR LEDs allow for cheap, efficient production of infrared light, which is electromagnetic radiation in the 700 nm to 1mm range.
- The appearance of IR LED is same as a common LED.
- Since the human eye cannot see the infrared radiations, it is not possible for a person to identify if an IR LED is working.
- The massive use of IR LEDs in remote controls and safety alarm systems has drastically reduced the pricing of IR diodes in the market.

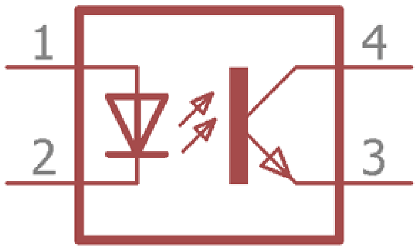
Infrared LED

- An IR LED is a type of diode or simple semiconductor.
- Electric current is allowed to flow in only one direction in diodes.
- As the current flows, electrons move from one part of the diode and recombine with holes on another part.
- In order to recombine with the holes, the electrons must shed energy in the form of photons, which produce light.

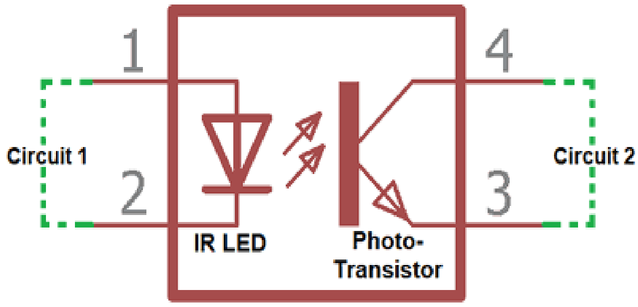


Optocoupler

- **Opto-coupler** is an electronic component that transfers electrical signals between two isolated circuits.
- **Optocoupler also called Opto-isolator, photo coupler or optical isolator.**
- Often in circuits, especially low voltage or highly noise sensitive circuits, Optocoupler is used to isolate circuitry to prevent electrical collision chances or to exclude unwanted noises.



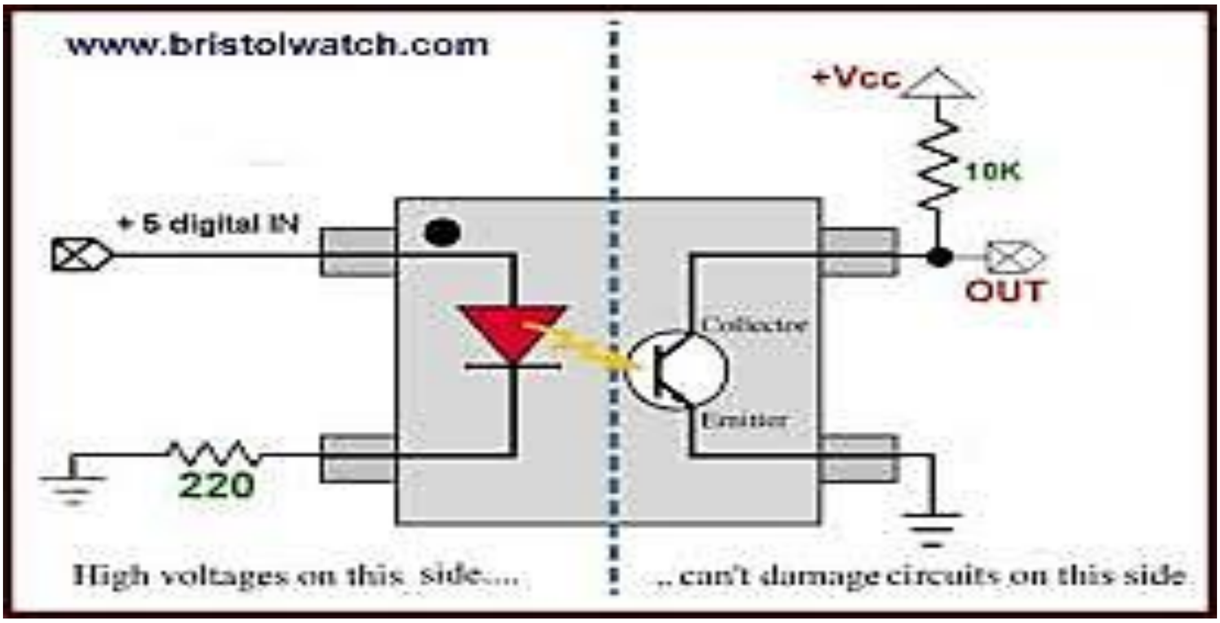
Optocoupler



Opto-coupler

- On the left side pin 1 and pin 2 are exposed, it is a **LED (Light Emitting Diode),** the LED emit **infrared light** to the **photosensitive transistor** on the right side.
- The photo-transistor switches the output circuitry by its collector and emitter, same as typical BJT transistors.
- Intensity of the LED directly controls the photo-transistor.
- Since the LED can be controlled by a different circuitry and the photo transistor can control different circuitry so two independent circuits can be controlled by Optocoupler.

Optocoupler



Types of Optocouplers

Depending on the use there are mainly four types of optocouplers are available.

- Opto-coupler which use **Photo Transistor**.
- Opto-coupler which use **Photo Darlington Transistor**.
- Opto-coupler which use **Photo TRIAC**.
- Opto-coupler which use **Photo SCR**.

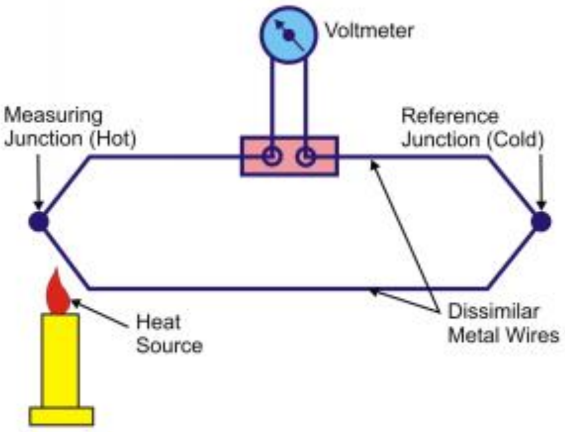
Thermocouple

- A Thermocouple is a sensor used to measure temperature.
- Thermocouples consist of two wire legs made from different metals. The wires legs are welded together at one end, creating a junction.
- This junction is where the temperature is measured. When the junction experiences a change in temperature, a voltage is created.
- The voltage can then be interpreted using thermocouple reference tables to calculate the temperature.

See beck-effect

- This type of effect occurs among two dissimilar metals. When the heat offers to any one of the metal wire, then the flow of electrons supplies from hot metal wire to cold metal wire. Therefore, direct current stimulates in the circuit.

Thermocouple



- This circuit can be built with two different metals, and that are coupled together by generating two junctions.
- The two metals are surrounded to the connection through welding.
- When the temperature of the junction is dissimilar from each other, then the electromagnetic force generates in the circuit.

Advantages & Disadvantages of Thermocouple

Advantages

- Accuracy is high
- It is Robust and can be used in environments like harsh as well as high vibration.
- Thermal reaction is fast
- The operating range of temperature is wide.
- Wide operating temperature range
- Cost is low and extremely consistent

Disadvantages

- It has low-accuracy.
- The thermocouple recalibration is hard

Applications

- temperature measurement for kilns, gas turbine exhaust, diesel engines, and other industrial processes.
- Thermocouples are also used in homes, offices and businesses as the temperature sensors in thermostats, and also as flame sensors in safety devices for gas-powered appliances.

Thermistor

- A **thermistor** (or **thermal resistor**) is defined as a type of resistor whose electrical resistance varies with changes in temperature.
- Although all resistors' resistance will fluctuate slightly with temperature, a thermistor is particularly sensitive to temperature changes.
- The working principle of a thermistor is that its resistance is dependent on its temperature.
- We can measure the resistance of a thermistor using an ohmmeter.

There are two types of thermistors:

- Negative Temperature Coefficient (NTC) Thermistor
- Positive Temperature Coefficient (PTC) Thermistor

Thermistor

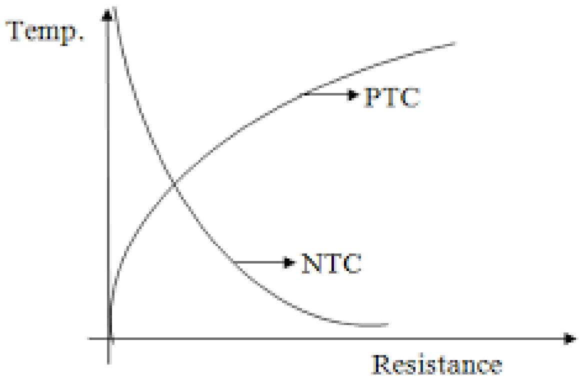
NTC Thermistor

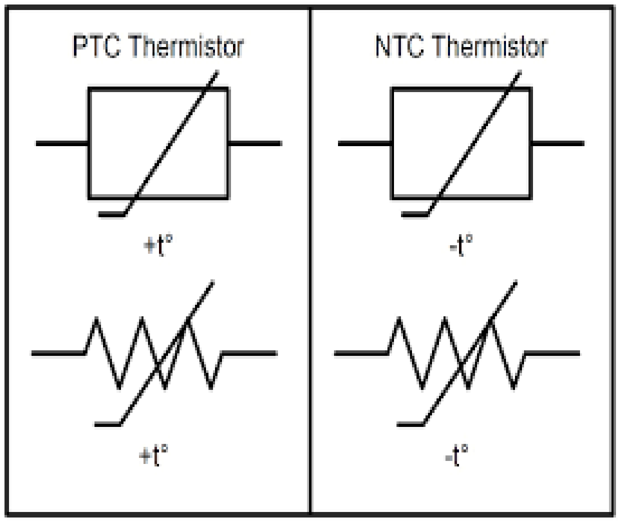
- In an NTC thermistor, when the temperature increases, resistance decreases.
- And when temperature decreases, resistance increases.
- Hence in an NTC thermistor temperature and resistance are inversely proportional.
- These are the most common type of thermistor.

PTC Thermistor

- A PTC thermistor has the reverse relationship between temperature and resistance.
- When temperature increases, the resistance increases. And when temperature decreases, resistance decreases.
- Hence in a PTC thermistor temperature and resistance directly proportional.

Thermistor


Temp.
PTC
NTC
Resistance


PTC Thermistor
+t°
+t°
NTC Thermistor
-t°
-t°

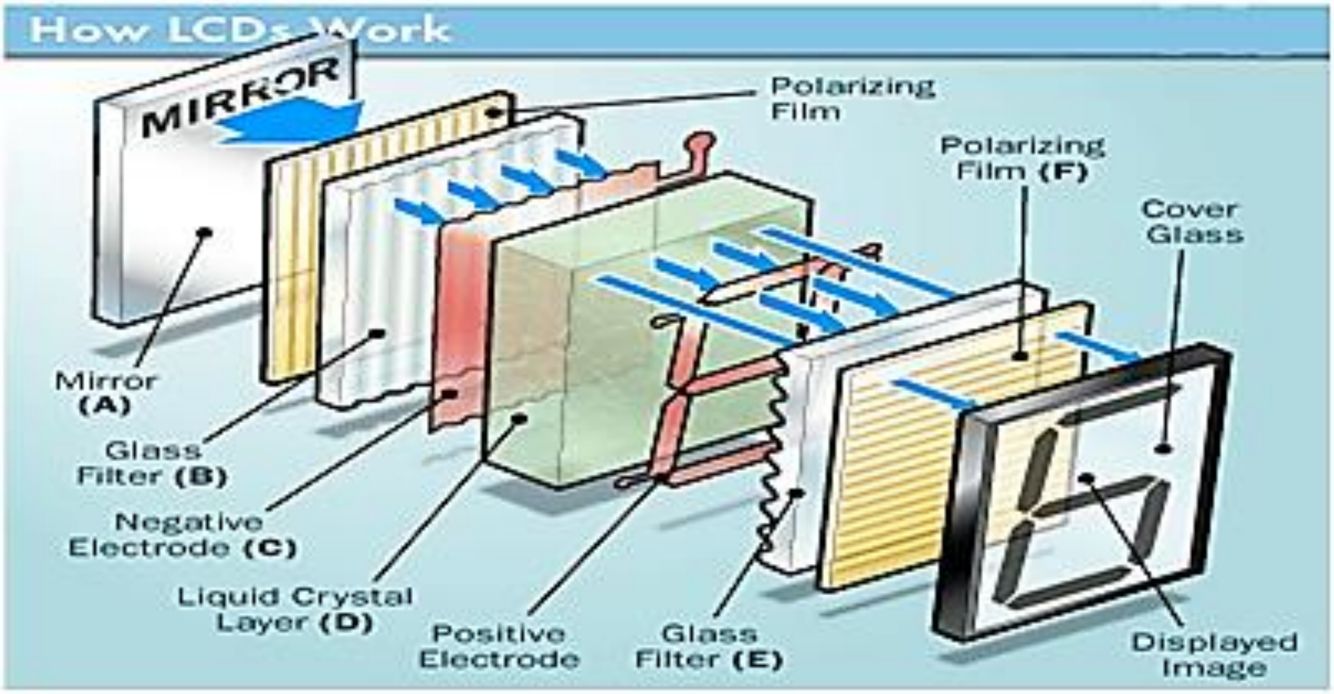
Applications of Thermistors

- Digital thermometers (thermostats)
- Automotive applications (to measure oil and coolant temperatures in cars & trucks)
- Household appliances (like microwaves, fridges, and ovens)
- Circuit protection (i.e. surge protection)
- Rechargeable batteries (ensure the correct battery temperature is maintained)
- To measure the thermal conductivity of electrical materials
- Temperature compensation (i.e. maintain resistance to compensate for effects caused by changes in temperature in another part of the circuit)
- Used in wheatstone bridge circuits

LCD

- A liquid crystal display or LCD draws its definition from its name itself. It is combination of two states of matter, the solid and the liquid.
- LCD uses a liquid crystal to produce a visible image. Liquid crystal displays are super-thin technology display screen that are generally used in laptop computer screen, TVs, cell phones and portable video games.
- LCD's technologies allow displays to be much thinner when compared to cathode ray tube (CRT) technology.

LCD


How LCDs Work
MIRROR
Polarizing Film
Polarizing Film (F)
Cover Glass
Mirror (A)
Glass Filter (B)
Negative Electrode (C)
Liquid Crystal Layer (D)
Positive Electrode
Glass Filter (E)
Displayed Image

LCD

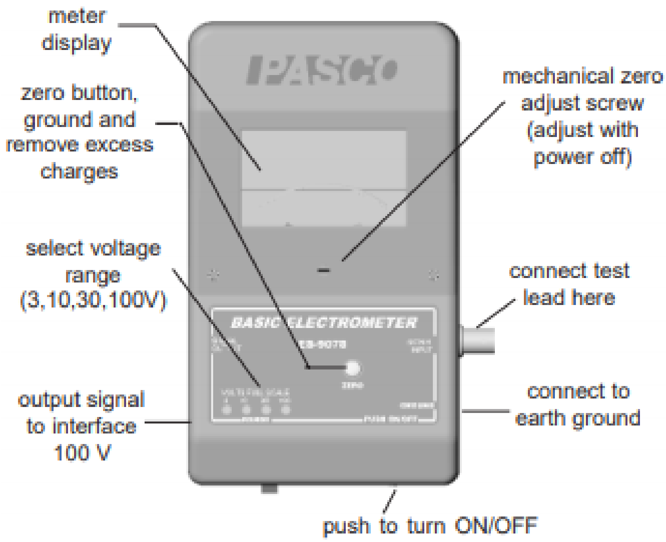
- The principle behind the LCD’s is that when an electrical current is applied to the liquid crystal molecule, the molecule tends to untwist.
- This causes the angle of light which is passing through the molecule of the polarized glass to chnge and also cause a change in the angle of the top polarizing filter.
- As a result a little light is allowed to pass the polarized glass through a particular area of the LCD.
- Thus that particular area will become dark compared to other.
- The LCD works on the principle of blocking light.
- While constructing the LCD’s, a reflected mirror is arranged at the back. An electrode plane is made of indium-tin oxide which is kept on top and a polarized glass with a polarizing film is also added on the bottom of the device.
- The complete region of the LCD has to be enclosed by a common electrode and above it should be the liquid crystal matter.

LCD

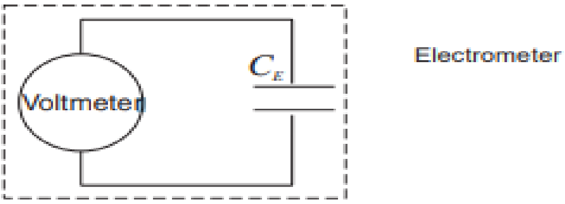
- Next comes to the second piece of glass with an electrode in the form of the rectangle on the bottom and, on top, another polarizing film.
- It must be considered that both the pieces are kept at right angles.
- When there is no current, the light passes through the front of the LCD it will be reflected by the mirror and bounced back.
- As the electrode is connected to a battery the current from it will cause the liquid crystals between the common-plane electrode and the electrode shaped like a rectangle to untwist.
- Thus the light is blocked from passing through. That particular rectangular area appears blank.

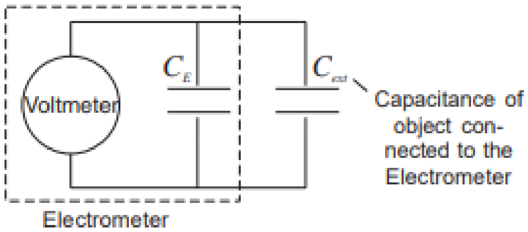
Electrometer

- An electrometer is an electrical instrument for measuring electric charge or electrical potential difference.



Electrometer



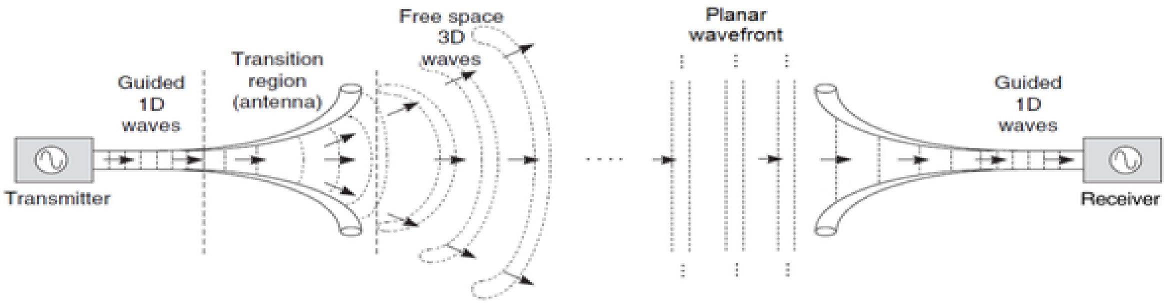


- The electrometer can be thought of as an infinite impedance voltmeter in parallel with a capacitor, C_E.
- C_E represents the internal capacitance of the electrometer.
- When a charged object is placed across the electrometer leads, a voltage V displays on the meter.
- If the value C_E is known, the value of the charge can be calculated as $Q = C_E V$.
- The capacitance of the electrometer alone is around 27 pF.
- However, if the sampled object adds significant capacitance, then $Q = (C + C_E)V$

Antenna

- An antenna is a specialized transducer that converts radio-frequency (RF) fields into alternating current (AC) or vice-versa.
- At frequencies below 3 GHz, many different types of antennas are used.
- Antennas demonstrate a property known as reciprocity, which means that an antenna will maintain the same characteristics regardless if it is transmitting or receiving.
- There are two basic types:
  - the receiving antenna, which intercepts RF energy and delivers AC to electronic equipment
  - the transmitting antenna, which is fed with AC from electronic equipment and generates an RF field.

Antenna

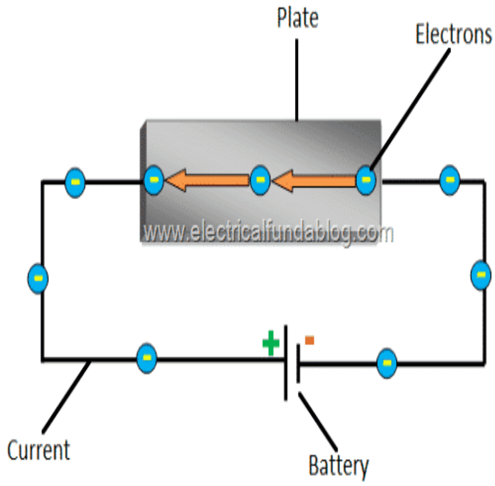


- Fundamentally, from Maxwell's equations, Electromagnetic waves are generated by accelerating electric currents and conductors carry those currents.
- The EM waves that are generated then propagate through space.
- The goal of antenna design is to ensure that the conversion between current and radiation occurs as efficiently as possible and that power is transmitted or received with desired characteristics.

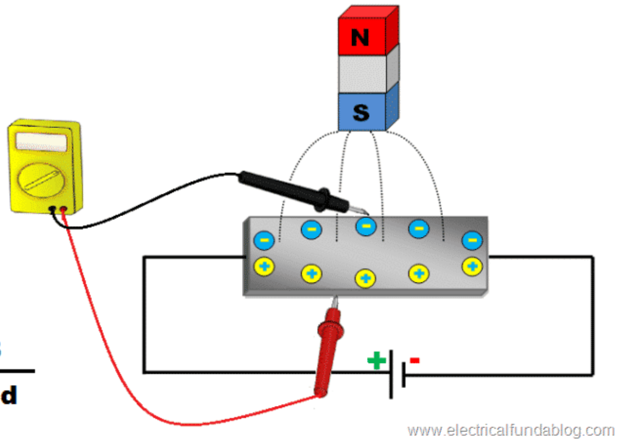
Hall Effect

- Hall Effect Principle says that when a conductor or semiconductor with current flowing in one direction is introduced perpendicular to a magnetic field a voltage could be measured at right angles to the current path.
- The effect of getting a measurable voltage, as told above, is called the Hall Effect.
- When a conductor is connected to a battery, the charge carriers are in motion, they will produce a magnetic field.
- Now when you place a magnet near the plate, its magnetic field will distort the magnetic field of the charge carriers.
- This will upset the straight flow of the charge carriers. The force which upsets the direction of flow of charge carriers is known as Lorentz force.
- Due to the distortion in the magnetic field of the charge carriers, the negative charged electrons will be deflected to one side of the plate and positive charged holes to the other side.
- That is why a potential difference (also called as Hall Voltage) will generate between both sides of the plate which can be measured using a meter.

Hall Effect



$$V_H = \frac{I\,B}{q\,n\,d}$$

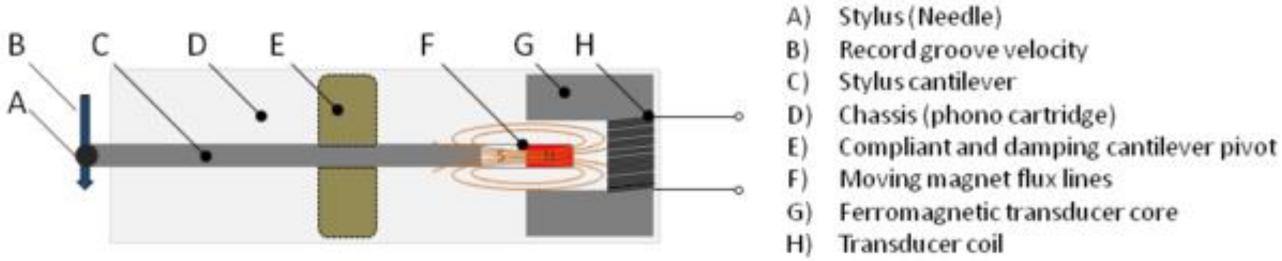


I – Current flowing through the Sensor
B – Magnetic Field Strength
q – Charge
n – number of charge carriers per unit volume
d – Thickness of the Sensor

Magnetic Cartridge

- A **magnetic cartridge**, more commonly called a **phonograph cartridge** or **phono cartridge** or (colloquially) a **pickup**, is an electromechanical transducer that is used to play records on a turntable.
- The basic principle of phonograph sound reproduction stems from a small diameter diamond needle follows a groove cut into the surface of a record.
- The resulting needle velocity is mechanically coupled to one element of an electrical coil transducer to produce an electrical current.

Magnetic Cartridge

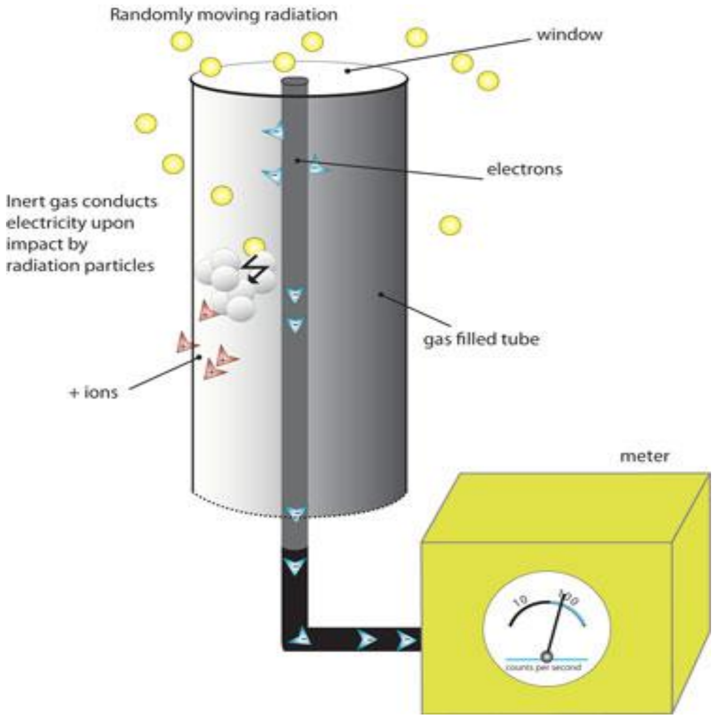


- The cartridge contains a removable or permanently mounted stylus, the tip - usually a gemstone, such as diamond or sapphire - of which makes physical contact with the record's groove.
- As the stylus tracks the serrated groove, it vibrates a cantilever on which is mounted a permanent magnet which moves between the magnetic fields of sets of electromagnetic coils in the cartridge.
- The shifting magnetic fields generate an electrical current in the coils.
- The electrical signal generated by the cartridge can be amplified and then converted into sound by a loudspeaker.

Geiger Muller Tubes

- Geiger counter is also called as Geiger tube.
- This instrument is actually used for detecting and measuring ionizing radiation like alpha particles, beta particles, and gamma rays.
- A Geiger-Müller counter can count individual particles at rates up to about 10,000 per second and is used widely in medicine and in prospecting for radioactive ores.
- The unit for measuring radioactive emissions is the becquerel (Bq). The Bq indicates the number of decays per second.

Geiger Muller Tubes

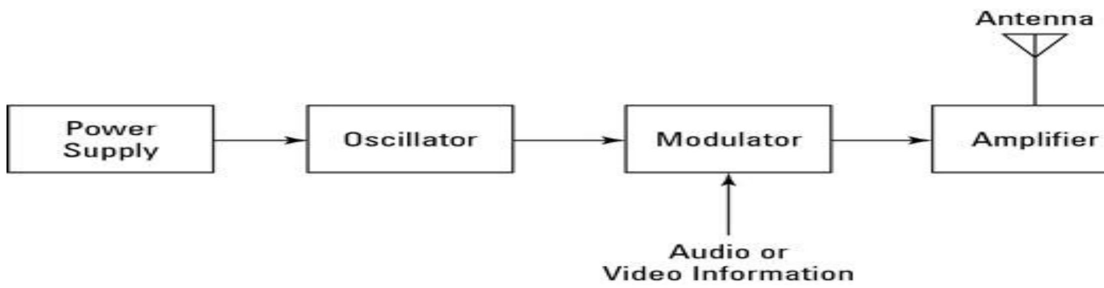


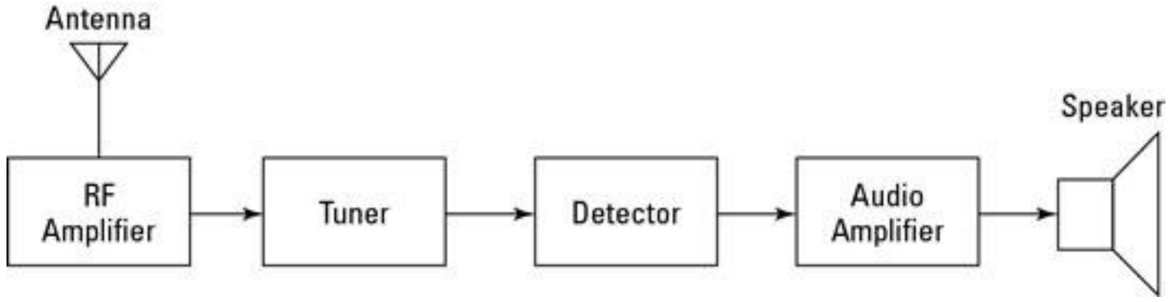
- The counter consists of a tube filled with an inert gas that becomes conductive of electricity when it is impacted by a high-energy particle.
- When a Geiger counter is exposed to ionizing radiation, the particles penetrate the tube and collide with the gas, releasing more electrons.
- Positive ions exit the tube and the negatively charged electrons become attracted to a high-voltage middle wire.
- When the number of electrons that build up around the wire reaches a threshold, it creates an electric current.
- This causes the temporary closing of a switch and generates an electric pulse that is registered on a meter

Radio Transmitter & Receiver

- A radio transmitter consists of several elements that work together to generate radio waves that contain useful information such as audio, video, or digital data.
- **Power supply:** Provides the necessary electrical power to operate the transmitter.
- **Oscillator:** Creates alternating current at the frequency on which the transmitter will transmit. The oscillator usually generates a sine wave, which is referred to as a *carrier wave.*
- **Modulator:** Adds useful information to the carrier wave. There are two main ways to add this information. The first, called amplitude modulation or AM, makes slight increases or decreases to the intensity of the carrier wave. The second, called frequency modulation or FM, makes slight increases or decreases the frequency of the carrier wave.
- **Amplifier:** Amplifies the modulated carrier wave to increase its power. The more powerful the amplifier, the more powerful the broadcast.
- **Antenna:** Converts the amplified signal to radio waves.

Radio Transmitter & Receiver





Radio Transmitter & Receiver

- Radio receiver is the opposite of a radio transmitter. It uses an antenna to capture radio waves, processes those waves to extract only those waves that are vibrating at the desired frequency, extracts the audio signals that were added to those waves, amplifies the audio signals, and finally plays them on a speaker.
- **Antenna:** Captures the radio waves. Typically, the antenna is simply a length of wire. When this wire is exposed to radio waves, the waves induce a very small alternating current in the antenna.
- **RF amplifier:** A sensitive amplifier that amplifies the very weak radio frequency (RF) signal from the antenna so that the signal can be processed by the tuner.
- **Tuner:** A circuit that can extract signals of a particular frequency from a mix of signals of different frequencies. On its own, the antenna captures radio waves of all frequencies and sends them to the RF amplifier, which dutifully amplifies them all.
- **Detector:** Responsible for separating the audio information from the carrier wave. For AM signals, this can be done with a diode that just rectifies the alternating current signal. What’s left after the diode has its way with the alternating current signal is a direct current signal that can be fed to an audio amplifier circuit. For FM signals, the detector circuit is a little more complicated.
- **Audio amplifier:** This component’s job is to amplify the weak signal that comes from the detector so that it can be heard. This can be done using a simple transistor amplifier circuit.