Unit-1 Intro-- To Sensors and Actuators

* **Sensor** : A sensor is a device that detects and responds to some input from the physical enviroment. is called sensor.
  -> The input can be light, heat, motion, moisture, pressure etc.

* **Types of sensors**

1. **Active sensors** : The sensors which requires an external power source(or) signal to work is active sensors.

2 **passive sensors** : The sensors which ~~requires~~ do not require external power source(or) signal to work is called passive sensors.

3 **Temperature sensors** : The sensors which are designed for measureing the degree of coolness and hotness in a object is called temperature sensors.

4 pressure sensors : The sensors which are designed to measure the pressure in gases or) liquids is called pressure sensors.

5 strain sensor : The sensors which are designed to measure strain on the object by measureing change in the resistance that occurs when object is stretched or) compressed is called strain sensor.

* General characteristics of sensors

-> sensor characteristics are mainly classified into two types.

1. static characteristics

- Sensitivity
- Resolution
- Linearity
- Range
- selectivity.

2. Dynamic characteristics

- Hysteresis
- Temperature
- Frequency
- Noise
- saturation
- Mechanical variables.

* Materials used and their fabrication process

* 6 Deposition

- chemical vapour deposition

Def: chemical vapour deposition (CVD) is a process that can be used to create solid materials for sensors and other applications.

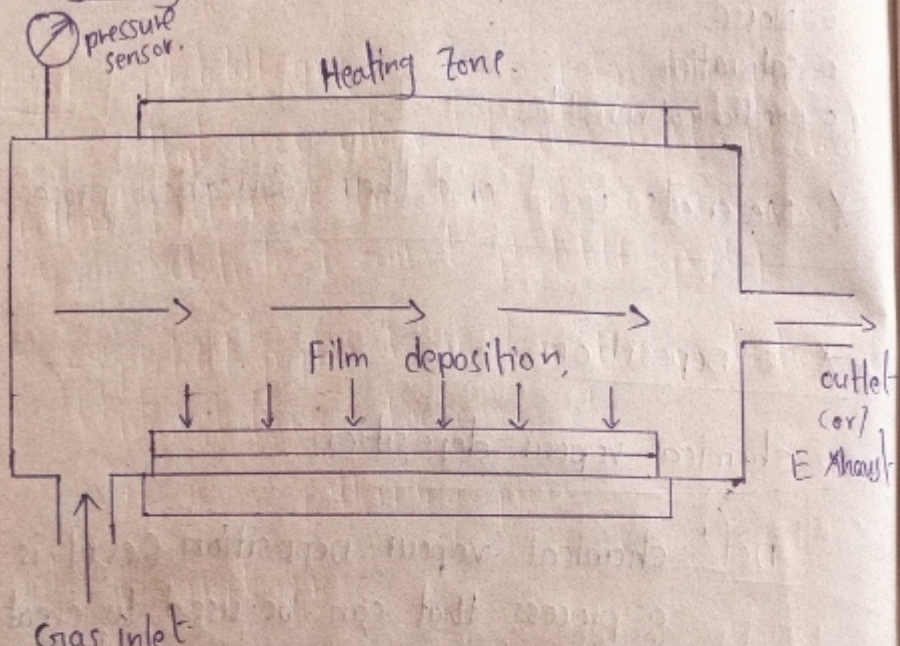
-> CVD: chemical vapour deposition.

-> chemical reactions transform gaseous molecules into a solid material, in the form of thin film on the surface of the substance.

-> Here films are formed by two reactions

- Homogenous reaction
- Heterogenous reactions

Diagram



-> Above diagram shows schematic diagram of chemical vapour deposition (CVD).

-> Diagram consist of gas inlet, Heating zone, pressure sensor, Exhaust, film deposition etc.

-> CVD is used to preparation of single crystal metal oxides - ferrites, garnites etc.

parameters

-> No electric current (or) feilds required.

-> operates in the range of few Torr.

process

-> Mass transport of reactants
-> Gias phase reactions
-> Adsorption
-> surface reactions
-> surface migration.
-> In corporation.
-> desorption by products.
-> Transport of by-products towards the outlet.

Advantages

-> High deposition
-> cover 3D structures
-> Requires low vaccum.

Disadvantages

-> High operating temperature
-> precursors are toxic.

Applications

-> used in the semiconductor industry
-> Microfabrication.
-> nanowires.

* photolithography

Def: photolithography is a fabrication process that uses ultraviolet (UV) light to create patterns ~~patterned~~ thin films for sensors on a substrate, is called photolithography.

-> photolithography is used in the production of microelectronics, biosensors etc.

-> It is a patterning process.

photolithography process

1. **Apply photoresist:** A light-sensitive polymer is called photoresist is coated on substrate, usually a silicon.

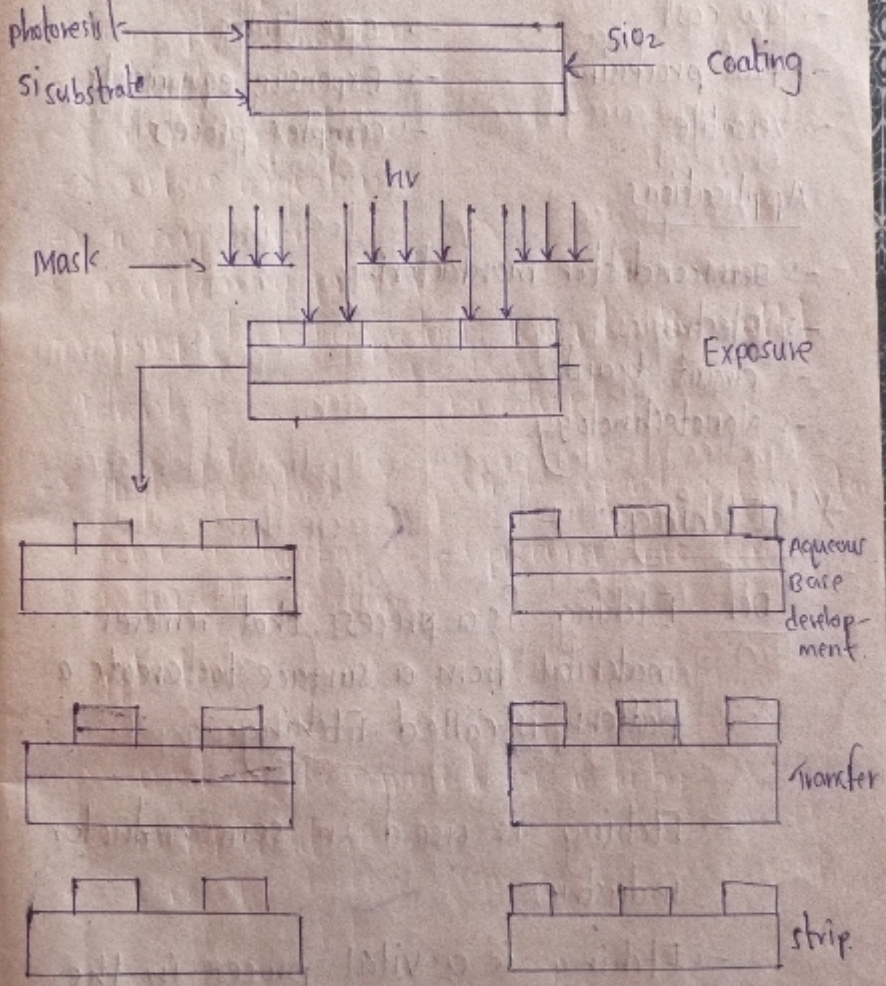
2. **Exposure to light:** The coated substrate is exposed to light, here light source is UV light, through photo mask.

3. **Develop:** The exposed areas of the substrate are developed, removing photoresist.

4. **Etch:** The exposed areas are etched away

5. **Remove Remaining photoresist:** The remaining photo resist is removed.

process diagram



-> steps in photolithography

1. substrate cleaning
2. photoresist cleaning
3. soft Bake
4. mask alignment
5. Exposure
6. post-exposure Bake
7. Development
8. Hard Bake
9. Etching
10. photo-resist stripping

Advantages

-> low cost
-> Fast processing
-> versatile.

Disadvantages

-> size limits
-> Expensive equipments
-> complex process.

Applications

-> semiconductor manfacturing
-> Electronics
-> circuit boards
-> Nanotechnology

* Etching : E

Def Etching is a process, that removes material from a surface to create a pattern is called Etching.

-> Etching is used in semiconductor industries.
-> Etching is a vital process in the fabrication of ICs.
-> Etching is of two types
  o Dry etching
  o wet etching.

1. Dry Etching

Dry etching refers to the removal of materials, typically a masked pattern of semiconductor material.

(or)

Dry etching is the process of removing substrate materials by gaseous etchents without wet chemicals or/. is called dry etching.

-> In dry etching gases are used as etchants
-> Dry etching types
  o plasma etching.
  o. Reactive ion etching.
  o ion milling.

2 wet etching : wet etching is a process that uses a liquid to remove material from a surface. is called wet etching.

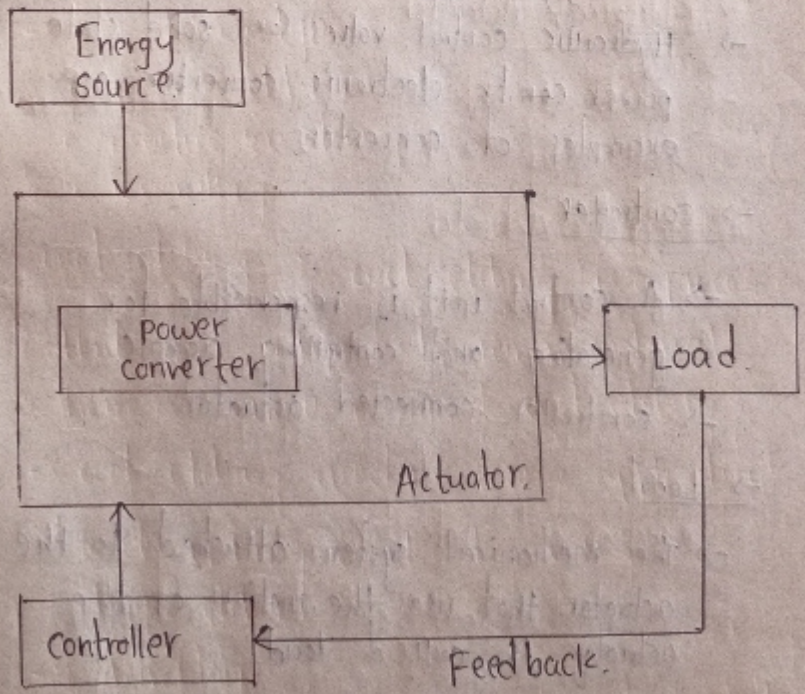
-> wet etching used in many applications
-> wet etching works by using a liquid etchant.
-> Advantages
  o High selectivity
  o. controllable etch rate
  o. High repeatability.

Dry etching	wet etching
-> Etching done at plasma phase.	-> Etching done at liquid phase.
-> uses gaseous phase chemicals.	-> uses liquid phase chemicals.
-> more precise	-> less precise
-> more cost	-> less cost
-> more operating parameters	-> less operating parameters.
-> Applicable for size less than 2um.	-> Applicable for size more than 2um.
-> It is safe.	-> It is not safe.
-> ~~Hi~~ low selectivity	-> High selectivity
-> low throughput	-> High throughput

* Functional block diagram of Actuators

Actuator : An Actuator is a component of a machine that produces force, torque, (or) displacement usually in a controlled way, when electrical, hydraulic input is given is called actuator.

Functional diagram



Typically, an actuator consist of:-

-> Energy source

-> Energy source provides the ability to do work.

-> Actuators draws electrical (or) mechanical energy from external.

-> Energy can be regulated (or) unregulated.

-> power converter

-> Energy source is attached to actuator.

-> Hydraulic control valves (or) solid state power ~~conty~~ electronic converters are examples of converters.

-> controller :

-> A control unit is responsible for generating and controlling signals.

-> controller connected actuator.

-> Load

-> The mechanical system attached to the actuator, that uses the motion of the actuator is called load.

-> load o/p connected to controller is called feedback.

Types of Actuators

Actuator : An actuator is a device used to move (or) control a body in a linear (or) rotational by applying a control signal is called Actuator.

classification

o According to type of motion

1. Linear actuator : A Linear actuator moves a body in a linear direction.
   -> They provide push-pull motion

2. Rotary actuator : A Rotary actuator moves a body in a circular motion. is called Rotary actuator.

o According to type of power used.

1. Hydraulic Actuator : They utilize hydraulic power generated by a pump to create mechanical action.

-> Hydraulic actuator consist of cylinder and piston.
-> They use fluid.

2. pneumatic Actuators

-> pneumatic actuator utilizes vaccum or/ compressed air to create mechanical action.
-> From this actuators we get considerable amount of force with small pressure change.
-> They use air or/ vaccum.

3. Electrical Actuator

-> Electrical actuators have applications in automation systems.

4. Magnetic Actuator:

-> They utilize magnetic effect to generate mechanical ~~motion~~ action.
-> They use magnetic effect.

5 Mechanical Actuator

-> A mechanical actuator works by converting one type of motion into another by utilizing gears, pulley etc.

* Simple Applications of Actuators

-> Different types of actuators have a lot of different applications.

1. In Automation
   - packaging
   - label scanning & printing
   - control solar panel direction.

2. In Automobiles
   - car Bonnet control.
   - Throttle control
   - Door Locking
   - window control.

3. In medical Industry
   - ventilators
   - patient handling

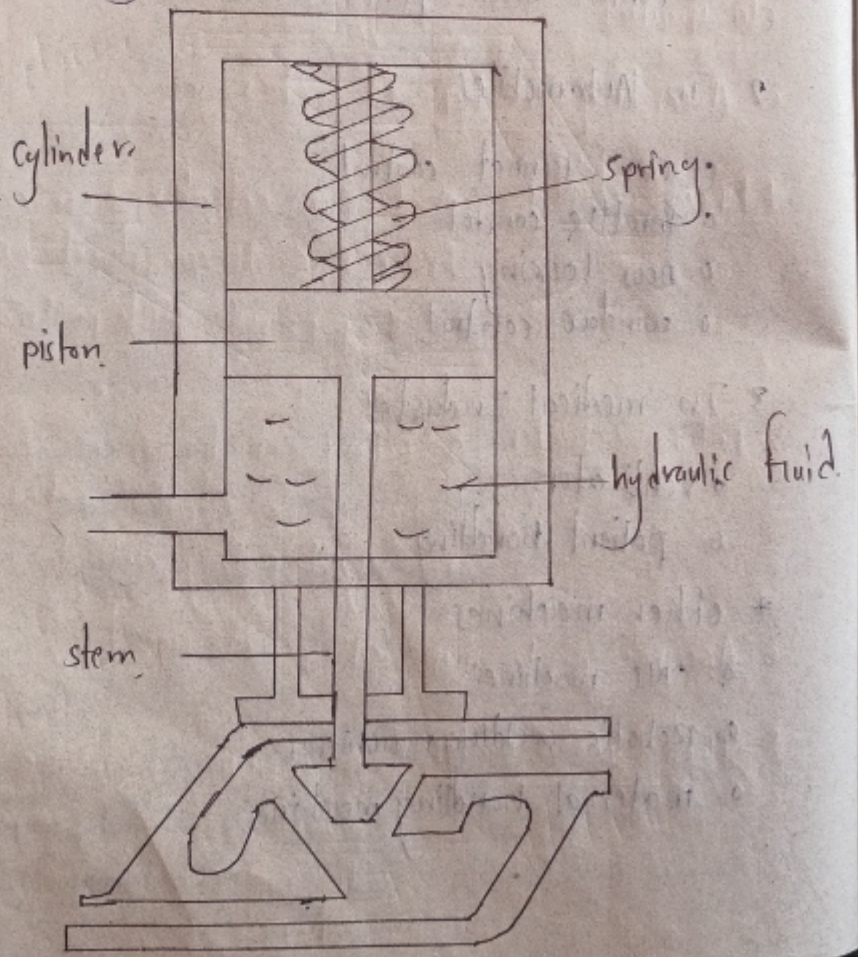
4. other machines
   - CNC machines
   - Robotic welding machines
   - material handling machines.

Types of actuators and working

1. Hydraulic Actuator.

They utilize hydraulic power generated by a pump to create mechanical action is called hydraulic actuator.

-> It consist of cylinder and piston
-> They use fluid



-> Block diagram show hydraulic actuator.
-> Hydraulic actuator consist of spring, hydraulic fluid, piston, cylinder, stem etc.
-> when a large amount of force is required to operate a valve, hydraulic actuators are used.
-> Hydraulic actuators come in many designs.
-> piston types are most commonly used actuators
-> As hydraulic pressure increases, the valve continuous to open.
-> The principle of operation of a hydraulic actuator is same as pneumatic actuator.

Advantages

-> very powerful
-> Efficient
-> Heavy-duty applications
-> low cost
-> simple design

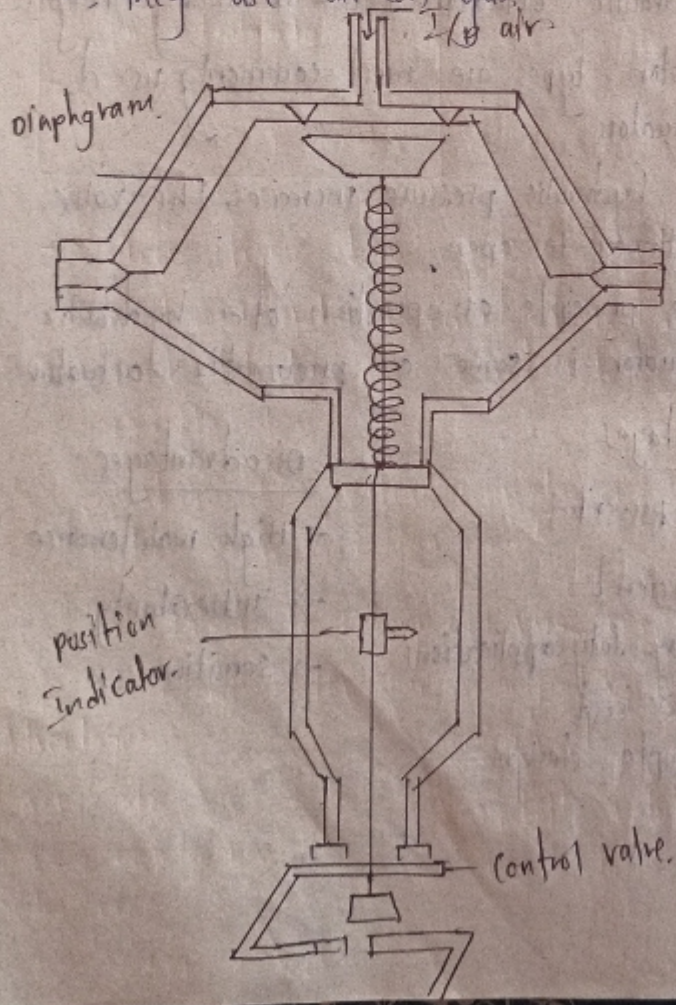
Disadvantages

-> High maintenance
-> Inflexibility.
-> sensitive

2. Pneumatic Actuator : pneumatic Actuator is a mechanical device that converts compressed air (or) gas into mechanical action is called pneumatic Actuator.

-> pneumatic actuators are also know air cylinders, air actuators.

-> They use air (or) gas.



-> Block diagram shows pneumatic actuator.

-> pneumatic actuator consist of I/p air, Diaphgram, position indicator, control valve etc

-> pneumatic actuators use compressed air to drive piston (or) gear.

-> pneumatic actuators are used in many industries, aviation, railway applications.

-> Advantages

-> Reliable
-> Efficient
-> Safe.
-> Din't require ignition (or) electricity.

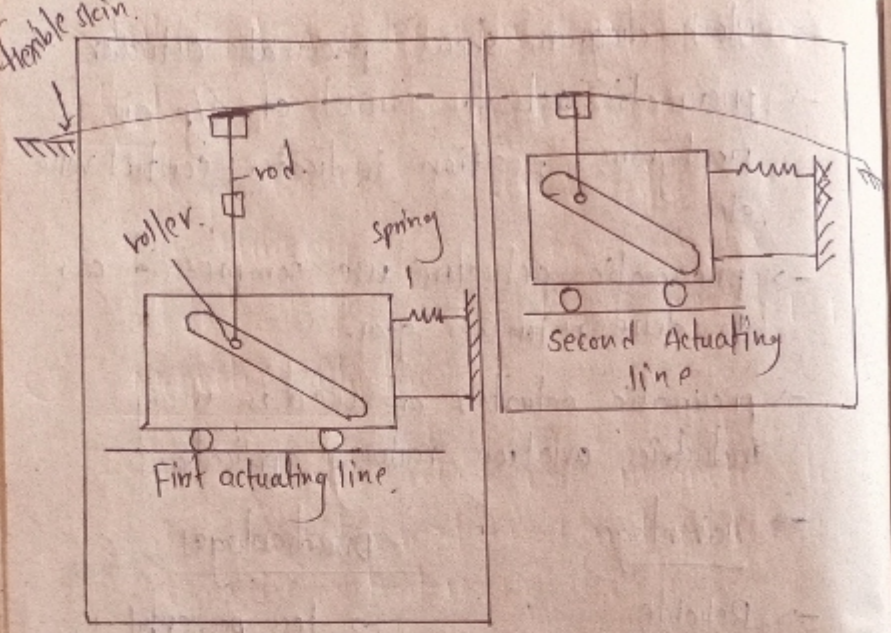
Disadvantages

-> less powerful
-> short lifespan
-> more maintenance.

3. Mehanical Actuator : Mechanical Actuator utilizes magnetic effect to generate mechanical Action is called Mechanical Actuator.

-> They use magnetic effect.

-> Diagram.



-> Above figure shows mechanical Actuator.

-> Mechanical Actuator consist of rod, roller, spring, First Actuating line, second Actuating line, flexible skin.

-> Mechanical actuator converts one form of motion into another form.

-> Ex: Linear to Rotary (or) vice versa.

-> It is used for increasing torque.

Advantages

-> very safe.
-> Easy maintenance.
-> less noise
-> low energy consumption.

Disadvantages

-> unstable nature.
-> need trained persons.

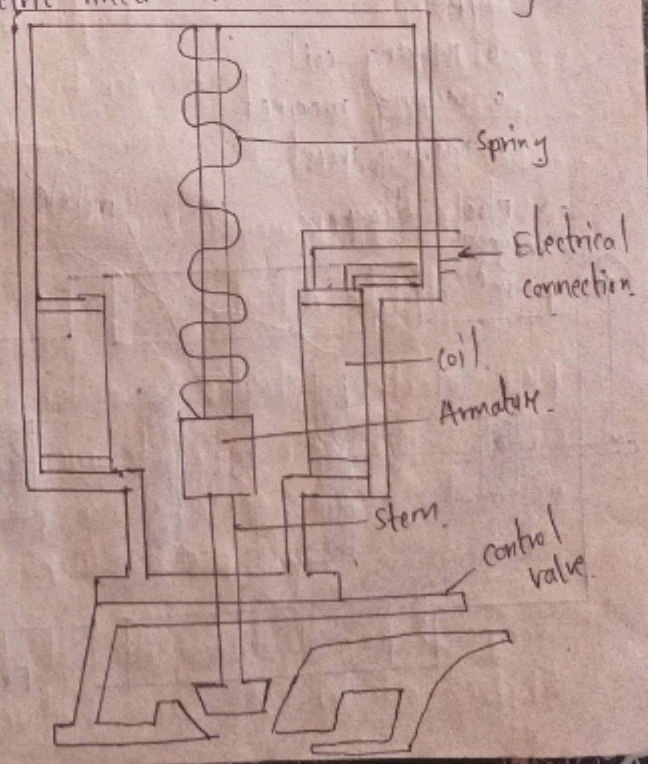
④ Electric Actuator

-> An electric actuator is a mechanical device used to convert electric energy into kinetic energy in either single linear (or) rotary motion is called Electric actuator.

-> Electric actuator is a Electromechanical device.

-> These are driven by either Ac (or) DC motor.

-> Types.
o Electric linear actuator o Electric rotary actuator



-> voltage having b/w 12V - 24V.

Advantages

-> High precision
-> More efficiency
-> Easy to design

Disadvantages

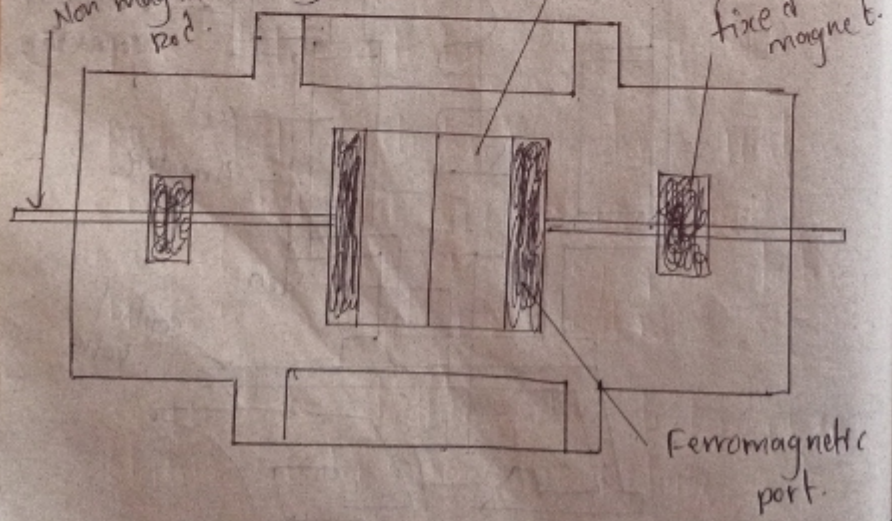
-> High cost
-> More complex
-> Require trained people

(5) Magnetic Actuator

-> The Actuators which uses magnetic effect to generate mechanical motion is called magnetic Actuators

-> Types
- Moving coil
- Moving magnet
- Moving iron

-> Block diagram,



-> Above diagram shows Magnetic Actuator.

-> Magnetic Actuator consist of Non-Magnetic rod, mobile magnet, fixed magnet, ferro magnetic part, etc.

-> Magnetic actuator works on the principle of lorentz force equation

$$F = q(E + V + B)$$

Advantages

-> low power consumption
-> High o/p force.
-> High precision

Disadvantages

-> High cost.
-> Magnetic field cannot be turned off

(6) Electro-Magnetic Actuators

-> An electro-magnetic Actuator is a device that converts electrical energy into mechanical energy, & vice-versa using interaction b/w electric and magnetic fields is called E.M Actuators.

-> They are used in many industries

-> They are efficient and robust.

-> The fundamental laws governing governing:
- Faradays law
- Bio-savart's law.
- lorentz force law.

-> Electromagnetic actuators are used in motors, machinary etc.

-> Mechanical switch is used to control this actuator.

Advantages

-> ~~High o/p~~
-> ~~sensitive~~
-> ~~more complex~~
-> Reliable, robust
-> low voltage required

disadvantages

-> High heat o/p
-> sensitive
-> More complex

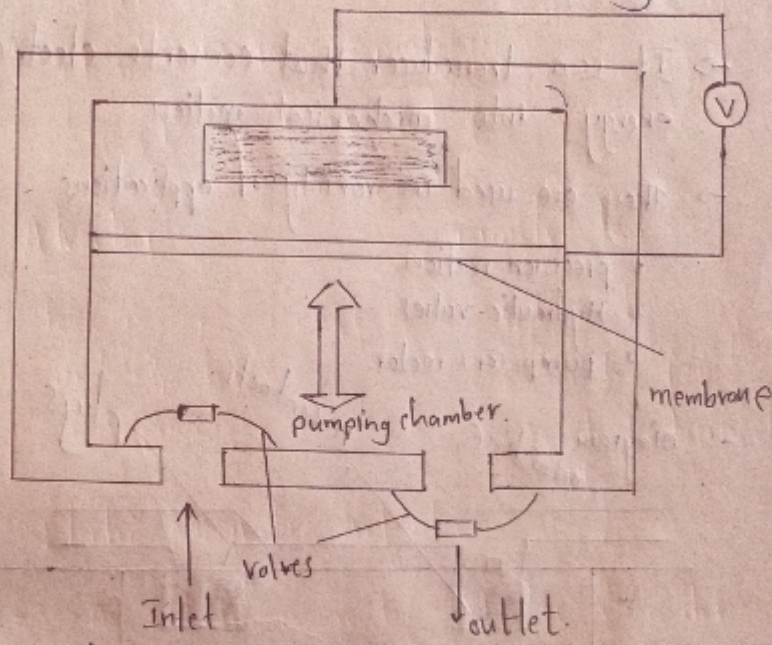
(7) piezo-electric Actuators

piezo electric actuator is a device that converts electrical energy into mechanical movement (or) vice versa, using piezo-electric effect is called p.e actuator.

-> compared to electromagnetic actuators, piezo electric actuator have more features,

-> This actuator made up of ~~mate~~ piezo-electric materials such as quartz, ceramics.

-> The Important specifications
- Force
- displacement
- operating voltage.



-- Block diagram shows piezo-electric actuator.

-> It consist of valves, inlet, outlet, pumping chamber, membrane, voltage source etc

Advantages

-> simple design
-> quick response
-> High efficiency

disadvantages

-> High voltage required
-> sensitive.

8. piezo-resistive Actuator

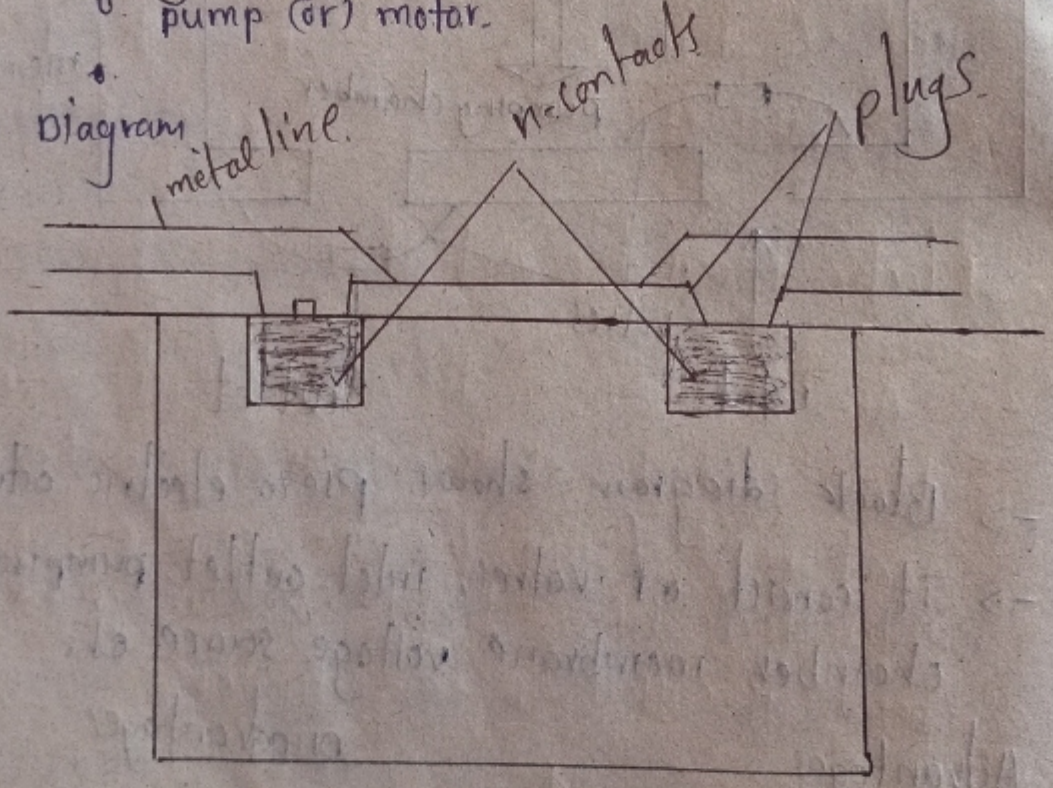
-> piezo-resistive actuator is a device that uses the piezo-resistive effect to generate mechanical motion (or) action is called piezo-resistive actuator.

-> It is a transducer, that converts electrical energy into mechanical motion.

-> They are used in variety of applications.

- precision motion
- Hydraulic valves
- pump (or) motor.

-> Diagram



-> Diagram shows piezo resistive Actuator.

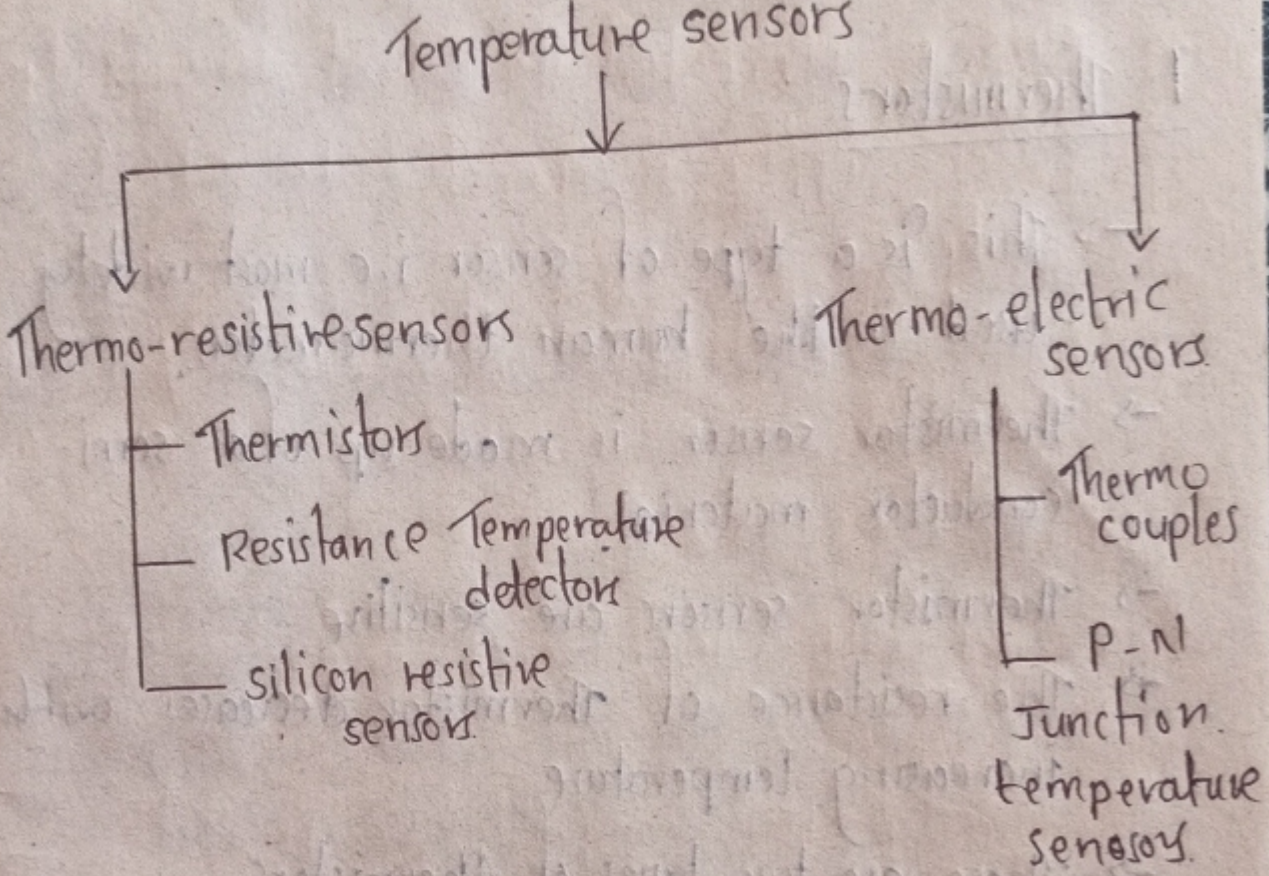
Advantages

-> High speed
-> low power consumption

Disadvantages

-> sensitive.
-> easily prone to damage.

Unit - II



Temperature sensors: The sensors which are designed for measuring degree of coolness (or) hotness in a object is called temperature sensors.

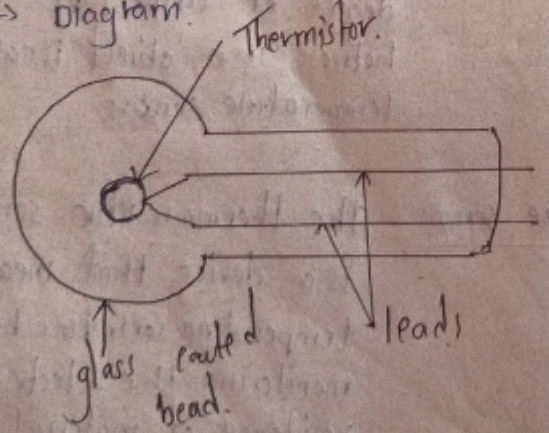
Thermoresistive sensor The thermo resistive sensor is a device that measures temperature (or) flow by monitering the electrical resistance of material that changes with temperature

-> Thermo resistive sensors are classified into 3 types.

1. Thermistors :-

-> This is a type of sensor i.e most widely used in the human thermometer.
-> Thermistor sensor is made up of a semi-conductor material.
-> Thermistor sensors are sensitive.
-> The resistance of Thermistor decreases with increasing temperature.
-> There are two types of thermistors.
  - +ve temperature coefficient Thermistor.
  - -ve " " "

-> Diagram



-> Above figure shows schematic diagram of Thermistor.

Advantages

-> It is fast.
-> More accurate.
-> Good stability.

disadvantage

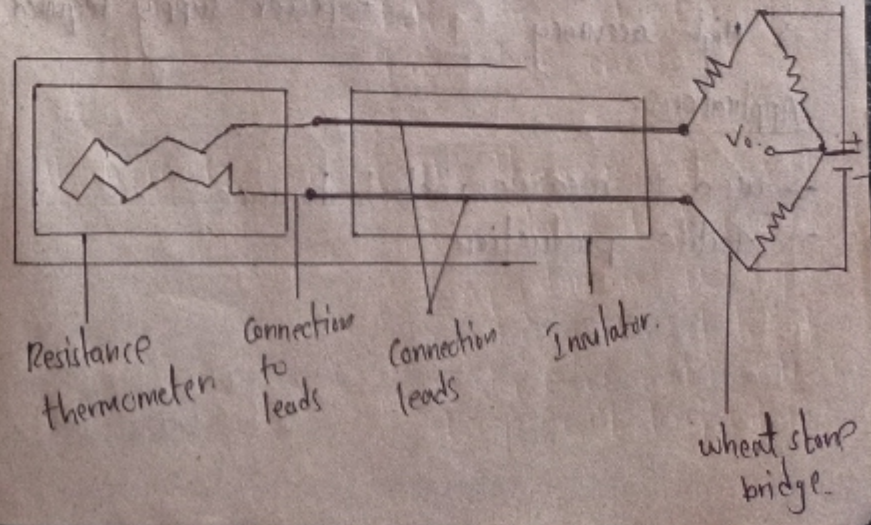
-> Non-linear behaviour.
-> power supply required.

Applications

-> used to measure thermal conductivity
-> used in time delay circuits.

2. Resistance Temperature Detectors (RDTs)

-> RDT's - stands for Resistance temperature detectors (RDTs)
-> RDT's are generally made up of metals like platinum, ceramics. etc
-> construction of RDTs



-> Above diagram shows construction of RDT's.
-> RDT is connected to wheat stone bridge.
-> power supply is connected to wheat-stone bridge.
-> small amount of current continuously passes to coil.

-> $R_t = R_0(1+\alpha T)$
- R_t is the resistance of temperature $T(°C)$
- R_0 " " " " " $0(°C)$
- α is the temperature coefficient.

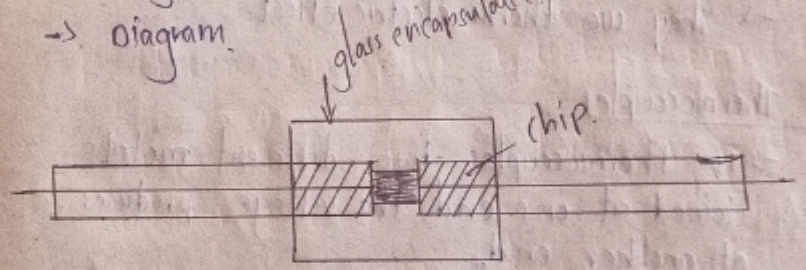
Advantages
-> High temperatures can be measured.
-> High accuracy

Disadvantages
-> Big size
-> power supply required.

Applications
-> used to measure metal furnace
-> Textile production

3 Silicon Resistive sensors

-> silicon resistive sensor is also called as diode temperature sensor.
-> It is made as small chip with two electrodes.
-> It is based on the principle of forward voltage drop.
-> Diagram.



-> Above figure shows silicon resistive sensor.
-> It consist of glass encapsulated and chip with two electrodes
-> It is of two types
-> Temperature Range $-45°C$ to $+85°C$.
-> Resistance Range - 1kΩ to 25°C

Advantages
-> High accuracy and stability
-> small size & low cost.

Disadvantages
-> Non-linear.
-> Heat is generated.

Applications
-> used in: smartphones, tatpo laptops, medical, spacecraft etc

Thermo electric sensors :

These are type of sensors that generates electrical voltage directly is called Thermo electric sensors.

(or)

These are devices that convert temperature differences into electrical voltage is called Thermo electric sensors.

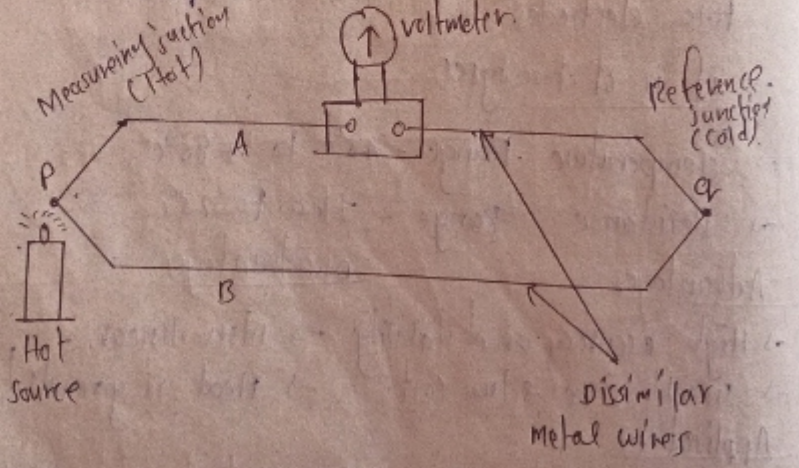
-> They use thermo electric effect.

1. Thermocouples :

-> In thermocouples two different metals joined at one end, the voltage produces at another end.

-> Thermocouples works on the principle of seebeck effect.

-> output is at milli volts.



-> Above figure shows thermocouple sensor.

-> It consist of Hot source, Hot end, cold end, voltmeter, dissimilar metal wires, etc.

-> The two wires are called +ve and -ve legs of thermocouple.

~~Applications~~

-> High temperature range (-200°C - 2500°C)

-> low cost.

-> compact size.

Applications

-> Industrial Applications

-> Medical Applications

-> consumer products

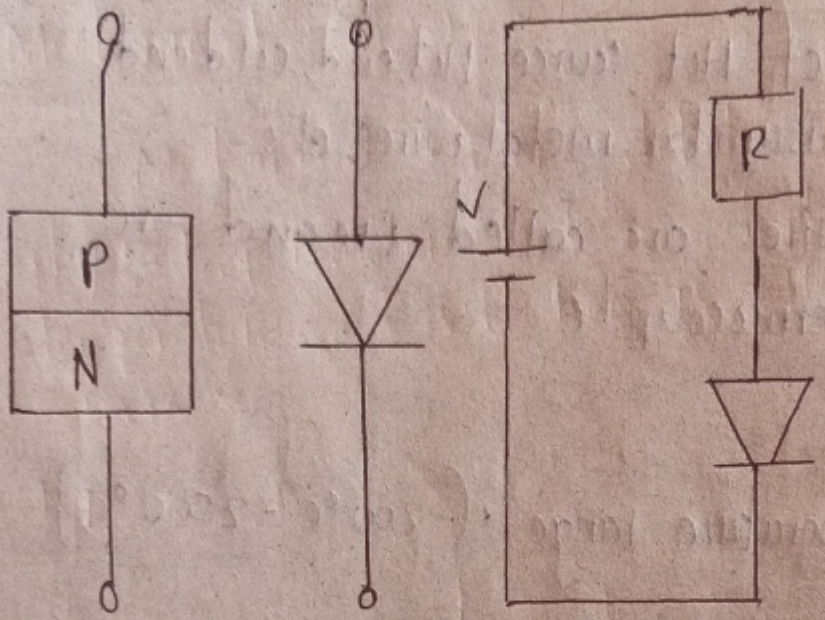
-> ~~paper~~ Environmental monitering.

2. P-N Junction temperature sensors

-> These utilizes the temperature dependent voltage characteristics of a p-N junction diode to measure temperature is called p-NJTS.

-> It is also known as Junction temperature sensor.

-> Below figure shows construction of PN-junction sensor.



→ The max temperature range is -55°C - 150°C

→ These sensors operate at 10-100μA current

Applications

→ used in electronic devices & circuits.

→ used in industries.

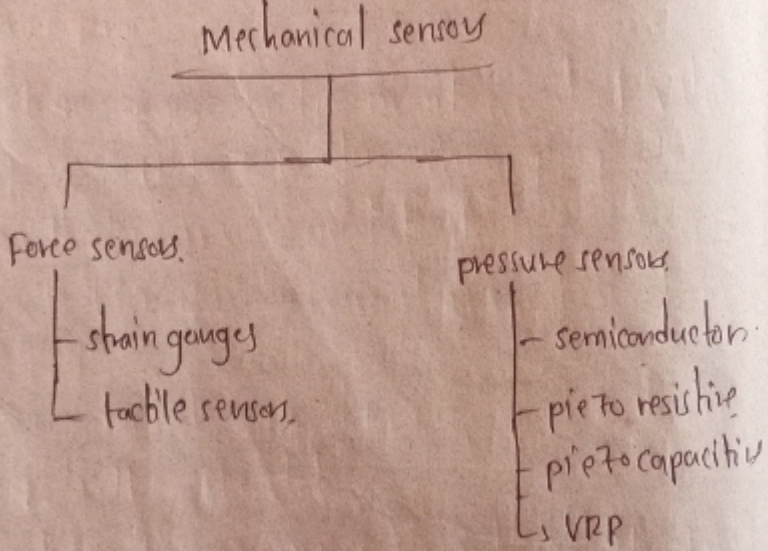
→ utilized in aircraft systems.

→ used for temperature control.

Mechanical sensors :

Mechanical sensors detects changes in physical parameters such as displacement, pressure, temperature and vibration is called mechanical sensors

Types



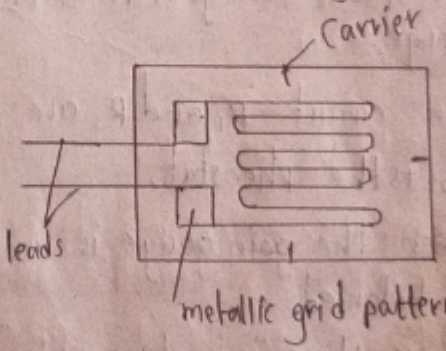
Force Sensor : Force sensor is a transducer that converts any input signal into an electrical o/p signal.

* strain guage

strain guage is a device that measures the strain of an object when force is applied, by change in electrical resistance is called strain guage.

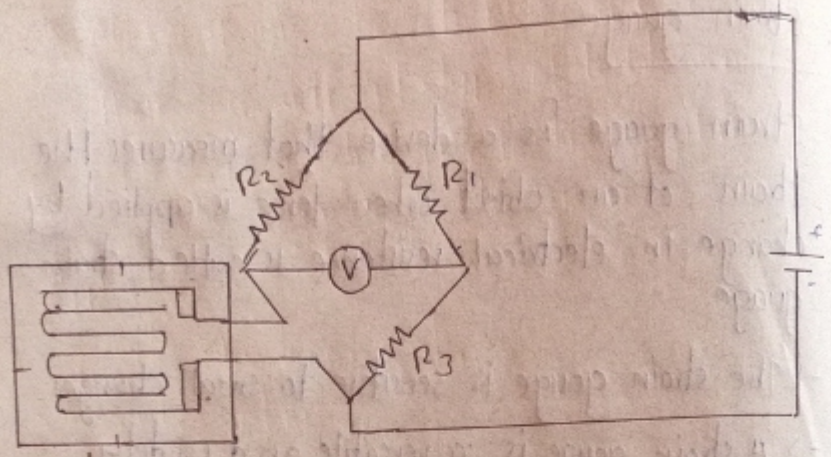
-> The strain gauge is sensitive to small changes
-> A strain gauge is a versatile and widely used sensing device
-> strain gauges are used in wide range of applications.
-> The principle behind strain gauge is converting mechanical strain into electrical signal

-> symbol



strain gauge Bridge circuit

-> The strain gauge is a part of bridge circuit.
-> strain gauge bridge circuit shown in below figure



Strain gauge.

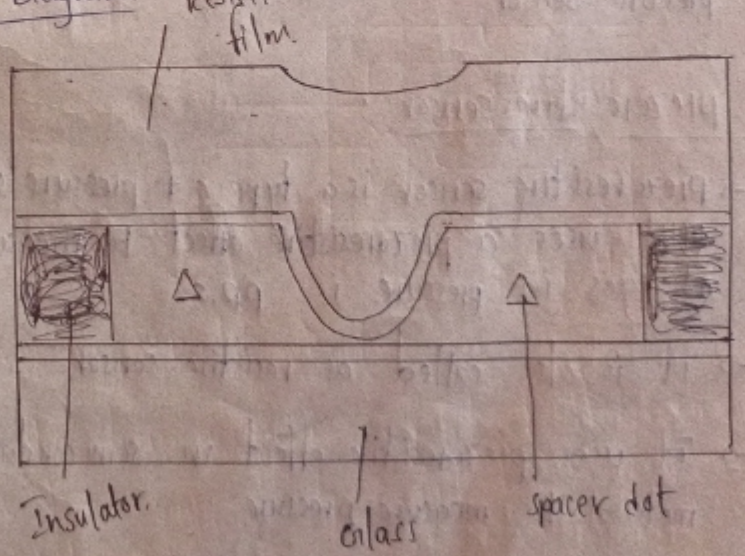
-> strain gauge bridge circuit consist of voltmeter, power supply, 3 resistors, strain gauge, etc.
-> voltmeter provide accurate strain.
-> wheatstone bridge circuit is used in strain gauge.
-> In circuit R_1 and R_3 are equal each other.
-> R_2 is the Rheostat.
-> when the ~~gain~~ gauge is unstrained, the bridge is balanced.
-> when there is a change in resistance of gauge, the bridge is unbalanced.
-> The o/p voltage from bridge can be amplified further by differential amplifier.

Uses

-> used in mechanical Engineering development.
-> used to measure to stress.

* Tactile sensors

-> A tactile sensor is nothing but a touch sensor.
-> It provides information about the object which has made contact with the sensor.
-> The information can be in the form of shape of object, size of object.
-> This sensor is sensitive to the touch
-> Diagram



-> Above figure shows tactile sensor.
-> There are different types of tactile sensors optical, piezoelectric, piezoresistive capacitive magnetic, dynamic. tactile sensors.

Applications

-> used in touch screen devices
-> security systems
-> Biometric. etc.

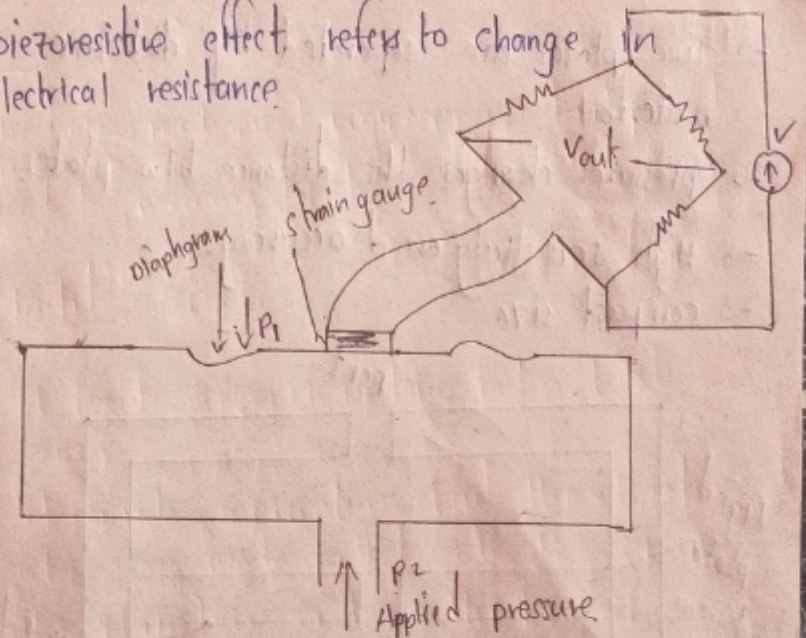
* Pressure sensors

-> pressure sensor is a device that measures the pressure of a fluid (liquid or) gas) and converts it into electrical signal is called pressure sensor.

1. piezoresistive sensor :

-> piezoresistive sensor is a type of pressure sensor that uses a piezoresistive effect to measure changes in pressure. is. PR.S.
-> It is also called as resistive sensor.
-> It uses piezoresistive effect in semiconductor material to measure pressure.

-> piezoresistive effect refers to change in electrical resistance



-> Above diagram show piezoresistive sensor
-> It is highly sensitivity
-> Low power consumption

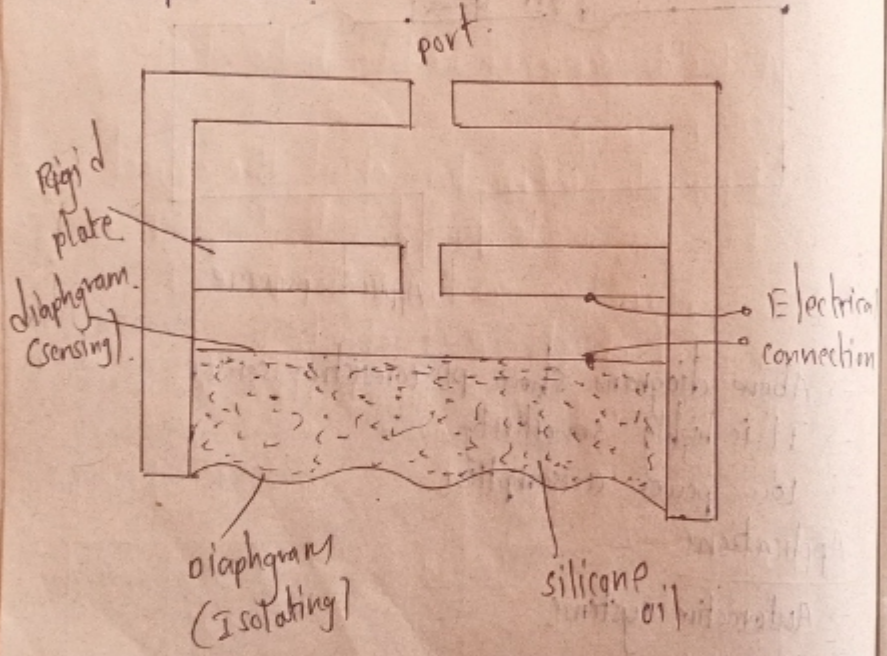
Applications

-> Automotive systems
-> Aerospace
-> Medical devices

2 Capacitive sensors

Capacitive pressure sensors measure pressure by detecting changes in capacitance b/w two electrodes is called C.S
-> It works by using two parallel conducting plates, one of which act as diaphgram

-> Two plates are separated by dielectric material.
-> pressure changes the distance b/w plates.
-> High sensitivity and accuracy.
-> compact size.



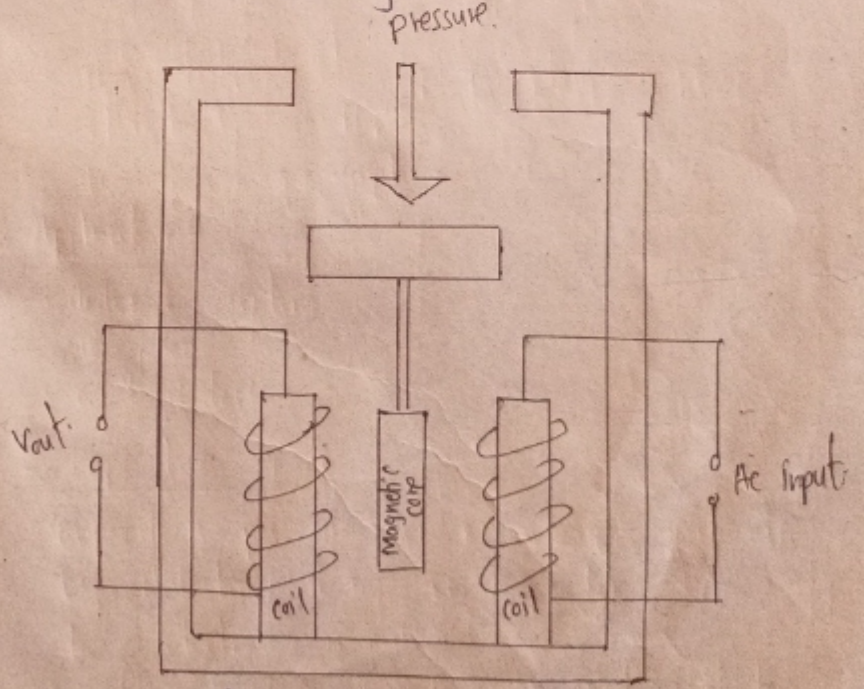
-> Diagram shows capacitive pressure sensor.

Applications

-> Industries
-> Automotive systems
-> Aerospace
-> Medical devices

3. VRP sensor

-> VRP- variable reluctance pressure sensor.
-> A VRP sensor measures pressure by detecting changes in magnetic reluctance
-> It works on the principle of variable reluctance.
-> It is also called as VRP Transducer.
-> It is also used to measure rotational ~~pr~~ speed, position etc.
-> This VRP sensor converts detected reluctance into electrical signal.



-> Diagram shows VRP sensor.

Applications

- Industries
- Automotive systems
- Aerospace
- Medical devices

Unit-3

* Acoustic sensors : Acoustic sensors are devices designed to detect and measure sound waves (or) Acoustic signals in the surrounding environment is called Acoustic sensors

-> These sensors converts sound waves into electrical signals.

-> These sensors generate a signal by moving diaphgram.

-> Types of Acoustic sensors.

- ultrasonic sensors
- Microphones
- piezo-electric resonators.

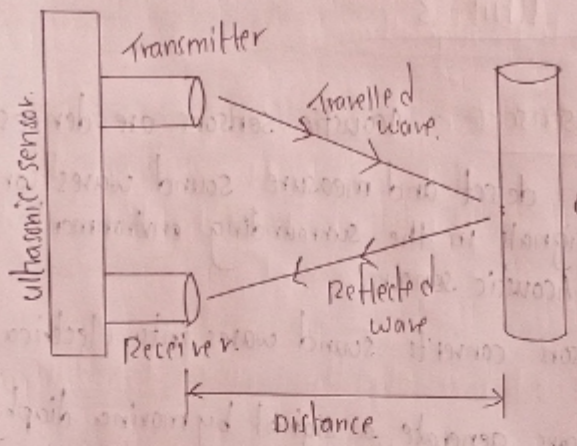
1. Ultrasonic sensors :-

Def: It is a electronic instrument that measures the distance to an object using ultrasonic sound waves. is called ultrasonic sensor.

-> An ultrasonic sensor has 2 parts.

- A Transmitter that sends out a signal that human cannot hear.
- A Receiver the receives signal after it has bounced back by nearer objects.

Working -s. Diagramatic representation.



-> Above Block diagram shows working of ultrasonic sensor.
-> Block diagram consist of ultrasonic sensor, object, transmitter, Receiver, etc.
-> Transmitter sends ultrasonic waves two towards objects.
-> wave blw transmitter and object is Travelled wave
-> This travelled waves Reflected back to receiver from object.
-> The wave blw Receiver and object is Reflected wave and converts into electric signals.
-> If object is close to sensor, the signal comes quickly
-> If object is far away from sensor, then signal takes long time to come back.
-> Distance = speed of sound x Time of high pulse/2
-> This sensor can measure upto 21 mts

Applications:

-> used in air traffic control
-> used in robotics
-> used in parking Technology.

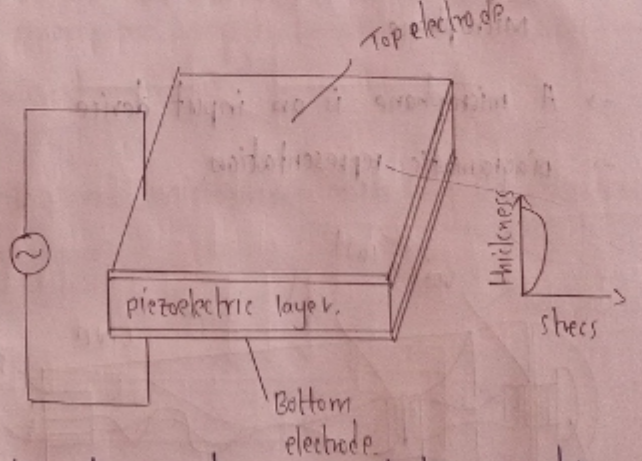
(2) piezo-electric Resonator:

Def: A piezo-electric Resonator is a electronic component that can act as sensor (or) be used in electronic oscillators and filters.

-> piezo-electric resonators are used in electronic oscillators and filters.
-> It is used in DC-DC converter.
-> It is sensitive to changes in pressure, temperature

Working

-> Diagramatic representation.



-> Above block diagram shows piezo-electric resonator.
-> Block diagram consist of piezoelatric layer, Top & bottom electrodes, power supply. etc

-> piezo electric layer placed blw Top and Bottom electrodes
-> when mechanical stress is applied to this material, it causes deformation, which results in separation of +ve and -ve charges.
-> The electrodes are used to collect this charges.
-> To make this resonator resonate, an alternating current voltage is applied to the electrodes.

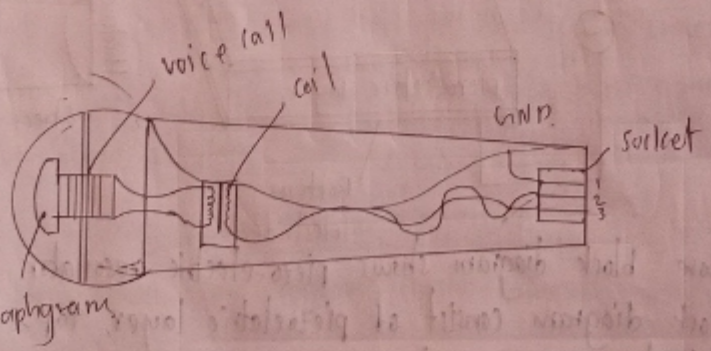
Applications

-> used in crystal oscillators.
-> used in medical science.
-> used for distance measurement.
-> used in gas lighters.

3. Microphones

-> Def A microphone is a device for converting sound waves into electrical energy, which can be amplified, transmitted, or recorded. is called Microphone.

-> A microphone is an input device.
-> diagramatic representation.



-> Above diagram shows structure of microphone.
-> structure of microphone consist of diaphgram, socket, GND, coil, voice coil etc.

o principle : Microphone operates onto the principle of acoustic-to electric transduction.

-> A diag diaphgram is attached to coil of wire.
-> when sound waves hit diaphgram, it moves back and forth.
-> The most commonly used microphones are dynamic and condensor microphones.
-> It is used for voice recording.
-> It is also used for computer gaming.

Applications

-> used in speech recognition.
-> used in smartphones, headsets, laptops etc.

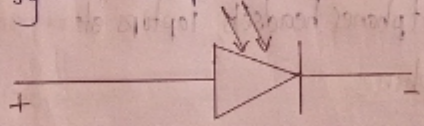
Types of microphones

o omnidirectional microphone
o uni-directional "
o Bi- " "
o cross-talk "
o clip-on "

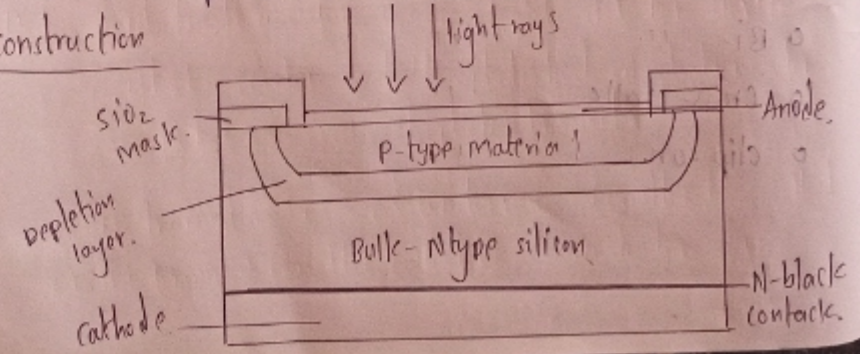
Optical sensors

Def: An optical sensor is a device that converts light into electrical signals and measures Intensity, wavelength, polarization, phase is called optical sensor.

- **photodiode**: A photodiode is a type of light detector, which is used to convert light into ~~Eurren~~ electrical signal is called photodiode.
  - -> photodiode is a P-N junction diode.
  - -> photodiode is also called as photo-detector (or) photo-sensor.
  - -> sometimes photodiodes are look like an light emitting diodes.
  - -> The symbol of photodiode



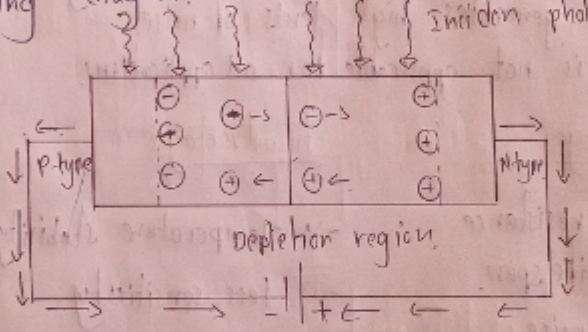
- **principle**: photodiode works on the principle of photoelectric effect.
- **construction**



-> Above diagram shows construction of photodiode.
-> This is diode is made up of two semiconductors.
  - P-type.
  - N-type.
-> photodiode construction consist of sio2 mask, anode, cathode, p-type material, Bulk-N-type silicon, light rays, N-block contact etc.

Working

-> The working principle of photodiode is photoelectric effect.
-> working diagram



-> Therefore holes moves towards anode and electrons moves towards cathode.
-> It is a P-N junction device.
-> Depletion region is in blw p-layer and N-layer.

Types of photodiode

- **PN photodiode**
  - -> PN photodiode is the first developed PN type diode.
  - -> It has advanced performance.

-> used in wide applications
-> This diode is qurte small and sensitive.

o PIN photodiode

-> PIN photodiode most commonly used photodiode.
-> PIN is more powerful than PN photodiode.
-> It has wide intrinsic area blw N and P regions.

o Avalanche photodiode

-> This kind of diode is used in low light areas.
-> It generates high levels of noise.
-> It is not applicable for all applications.

Advantages

-> less resistance.
-> long life span.
-> less noise.
-> low weights.

Disadvantages

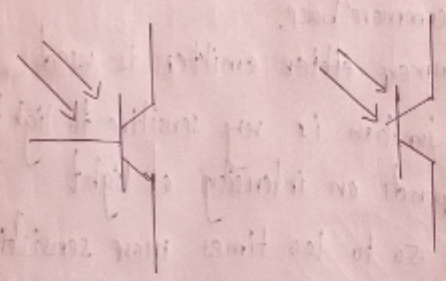
-> Temperature stability is poor.
-> less sensitivity
-> Active area is small.

✱ photo transistors

Def: photo-transistor is a light detector device which combines both photodiode and transistor amplifier is called photo-transistor.

-> photo-transistor is either a tri-terminal (emitter, base, collector) or bi-terminal (emitter, collector) semiconductor device.

-> symbol of photo transistor

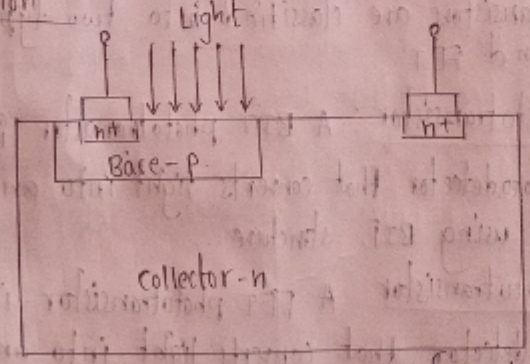


fig; Tri-terminal photo transistor. Bi-terminal photo transistor.

-> photo transistors are used to detect light pulses, and convert them into electrical signals.
-> photo transistors are operated by light.
-> photo transistor have large gain, low cost, and used in many applications.
-> It is capable of converting light energy into electric energy.

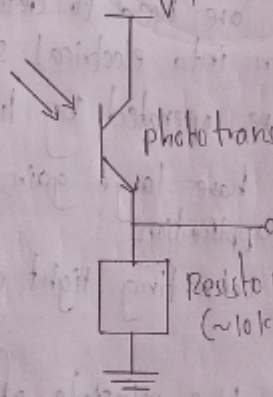
Principle It works the principle of photoelectric effect.

Construction



-> Above figure shows construction of photo transistor.
-> photo transistor is bi-polar transistor.
-> It is available in both P-N-P and N-P-N types.

-> It have different configurations like common emitter, common collector, common base.
-> But generally common ~~eitter~~ emitter is used.
-> The collector base junction is very sensitive to light.
-> It's working depends on intensity of light.
-> phototransistor is 50 to 100 times more sensitive than photodiode.
-> phototransistor circuit.



o Types of phototransistor.

-> phototransistors are classified into two types namely BJT and FET.

BJT phototransistor: A BJT phototransistor is a type of photodetector that converts light into an electrical signal using BJT structure.

FET phototransistor: A FET phototransistor is a type of photodetector that converts light into an electrical signal using FET structure.

Advantages

-> produces high current than photodiodes.
-> inexpensive.
-> Fast.

Disadvantages

-> Handling voltages over 1000 volts.
-> do not allow electrons freely.

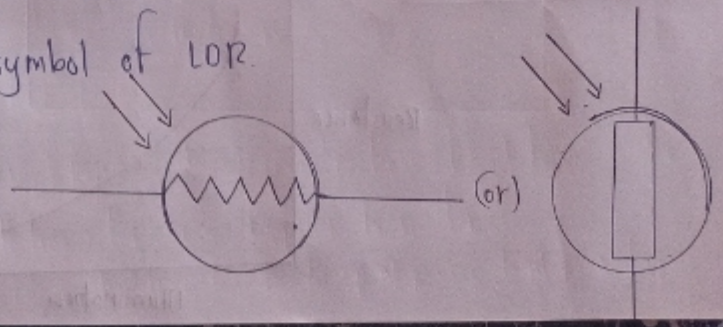
Applications

-> punch card readers.
-> CD players.

* photo-resistor based sensors (or) Light dependent Resistor

Def: A Light dependent resistor (or) photoresistor is a light controlled variable resistor, it's resistance changes with the light intensity that falls on it is called Light dependent resistor.

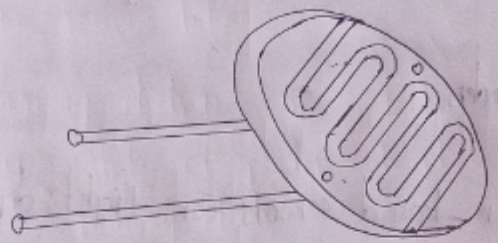
-> The resistance value will be dropped when light level increases.
-> The LDR's are made up of semiconductor materials, having high resistance like cadmium sulphide, lead sulphide, lead selenide etc.
-> LDR's are non-linear devices.
-> symbol of LDR



working:

-> The working principle of LDR is photoconductivity.

-> Typical LDR



-> Above figure shows light dependent resistor.

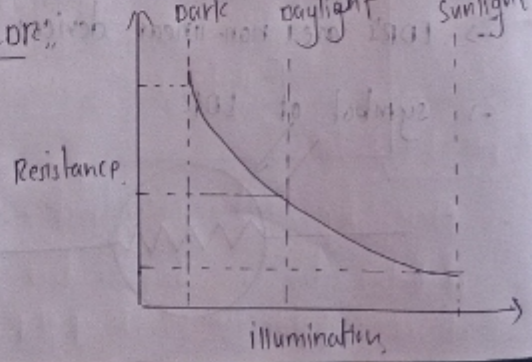
-> photoconductivity is an optical phenomenon in which material conductivity reduces when light is absorbed by the material.

-> when light falls on LDR, the electrons in the valence band are excited to the conduction band.

-> photons in the incident light have energy this energy helps to electrons for jumping valence band to conduction band.

-> The result is more current is flowing.

o Characteristics of LDR:



Applications

- o Barcode scanners
- o Automatic lights in street light systems
- o Light intensity meters

-X photomultiplier

Def photo multiplier is a highly sensitive photodetector that converts low-level light signals into electrical signals through amplification is called photomultiplier.

-> photomultipliers also called as photomultipliers (or) photomultiplier tubes.

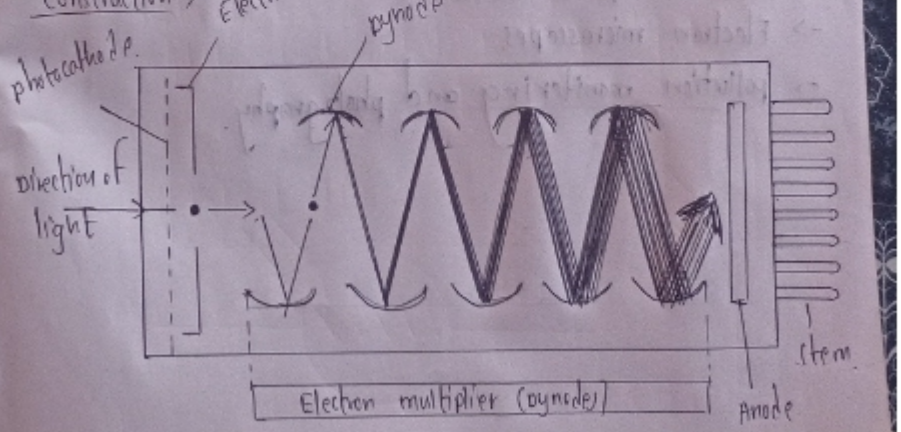
-> This is a device that converts incident photons into electrical signal.

-> photomultipliers are most sensitive among all light sensors.

working principle

-> photomultipler works on the principle of photoelectric effect and secondary emission.

construction:



-> Above diagram shows construction of photomultiplier,

-> construction of photomultiplier consist of photocathode, anode, dynode, stem, electrode, vaccum etc.

-> The entire assembley of photomultiplier is housed inside the vaccum tube.

-> primary electrons: The electrons emitted after the strike of photons to photocathode are called primary electrons.

secondary electrons: The electrons ejected from the dynode D by the fall of primary electrons on it are called secondary electrons.

-> photocathode converts the photons to a photoelectrons.

-> A photomultiplier will produce a small current even without incident photons is called dark current.

Applications

-> used in spectrometers.

-> Electron microscopes,

-> pollution monitering and photography.

Unit - 4

* Motors as Actuators:

-> Motors are electrical Actuators that convert electrical energy into mechanical energy and producing rotational (or) linear motion.

1 Linear motor:

-> A Linear motor is an electromagnetic device that produces Linear motion.

-> Here Linear means straight line.

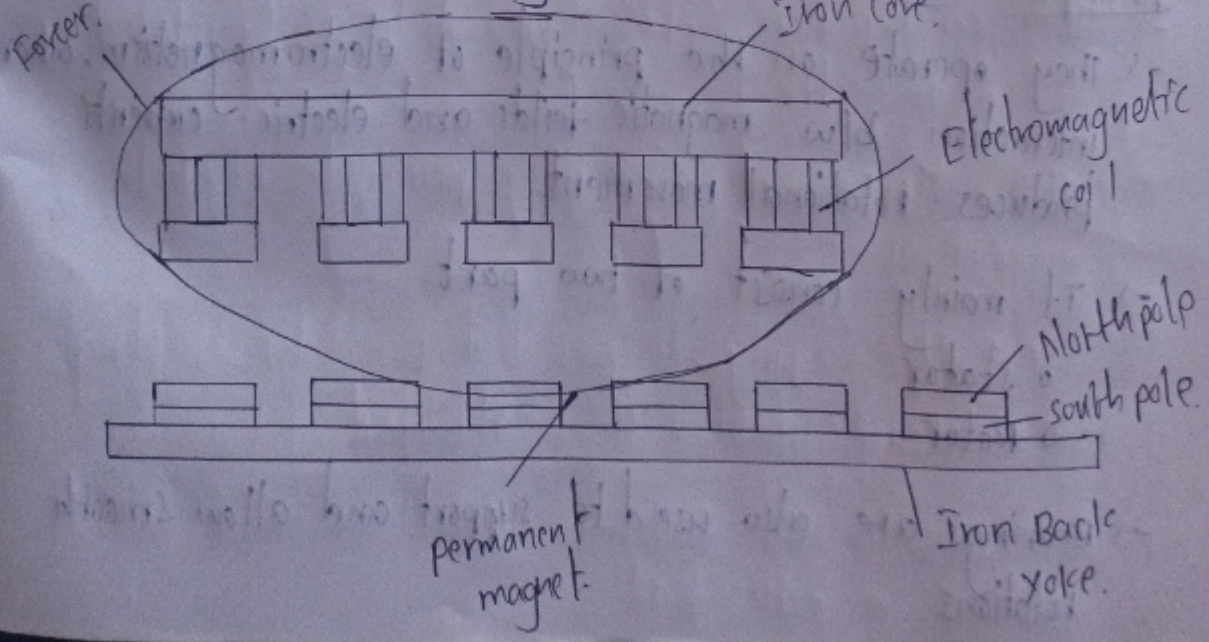
principle

-> Linear motors works on the principle of interaction b/w magnetic feilds and electric currents.

-> Linear motors mainly consist of two parts.

- o stator (stationary part)
- o mover (moving part).

-> stator contains series of coils arranged in a line, mover contains permanent magnet (or) set of coils.



working

-> Above diagram shows Linear motor.
-> Linear motor consist of Forcer, Iron core electromagnetic coil, North pole, south pole, Iron Back yoke, permanent magnet.
-> when electric cunent is applied to the coils, they create magnetic feild.
-> The interaction blw magnetic feilds generates a force.
-> This force pushes (or) pulls the mover.
-> By varying the cunent, the speed and direction of Linear motor can be controlled.

Applications

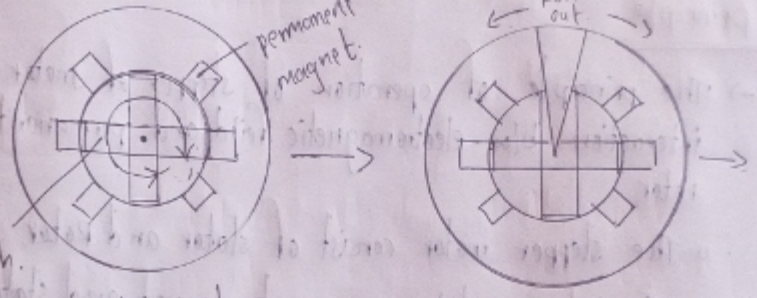
-> used in CNC machines.
-> " " semiconductor manfacturing.
-> " " 3rd printing
-> " " medical devices.

2. Rotational motors

-> Rotational motors are electromechanical devices that convert electrical energy into mechanical motion and results rotational movement, is called Rotational motors.

principle

-> They operate on the principle of electromagnetism, wher interaction blw magnetic feilds and electric cunents produces rotational movement.
-> It mainly consist of two part.
  - stator.
  - Rotor.
-> Bearings are also used to support and allow smooth rotations.



Rotary motor

working

-> when Direct current (DC) is applied to the motor, it passes through the Rotor.
-> The direction of cunent of creates magnetic feild
-> As long as cunent is supplied to the motor, the rotor will continue to rotate.
-> converting electrical energy into mechanical energy.
-> Applications

-> Motors are used in mixers, blenders, other kitchen applians ces.
-> used in electric cars, scooters, bycycles.

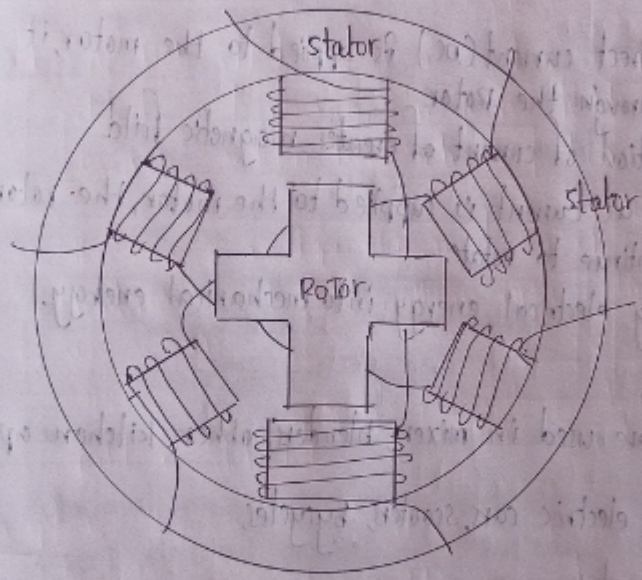
3 stepping motor

-> A stepping motor is a type of electric motor that divides a full rotation into number of equal ~~parts~~ steps, is called stepping motor.
-> It converts electrical pulses into mechanical rotation.
-> stepping motors are of two types
  - permanent magnet stepper motor.
  - Hybrid stepper motor.

Principle

-> The principle of operation of stepper of motor is interaction blw electromagnetic feild and permanent magnet rotor.

- o The stepper motor consist of stator and Rotor.
- o. The rotor contains permanent magnet and stator contains coils.



working

-> The construction of a stepper motor fairly related to a DC Motor.

-> The stepper motor working principle is Electro-magnetism.

-> once the supply is provided to stator winding the magnetic feild will be developed.

-> Now rotor in the motor will start to move with rotating magnetic feild.

Applications

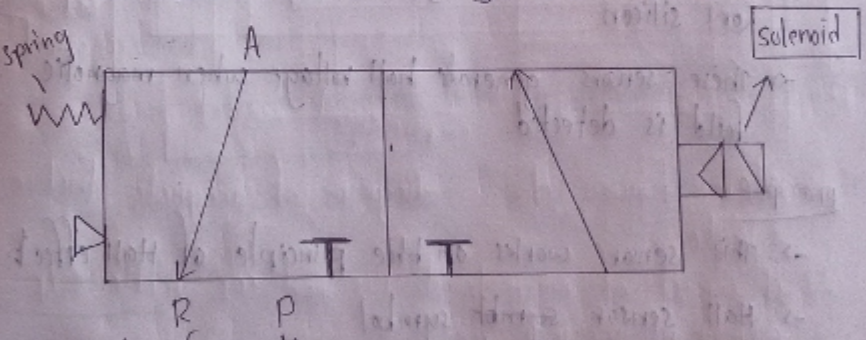
-> Industrial machines
-> Medical.
-> Electronics.
-> security.

* Magnetic valves;

Def Magnetic valves are electromechanical devices used to control the flow of liquids (or) gases in a system is called magnetic valves.

-> Magnetic valves are also called as solenoid valves.

-> They consist of coil of wire wound around a hallow core called solenoid, which generates magnetic feild.



principle of operation

-> working principle of magnetic valve is electromagnetism.

-> magnetic valve works by using an electromagnetic valve coil. to open (or) close valve.

-> when the magnetic coil energized, a magnetic feild builds up.

-> This magnetic feild pulls a plunger

-> This plunger lifted (or) lowered to open (or) close valve.

Applications

-> Fluid control.
-> water management.
-> steam control.
-> gas control.

X Hall effect sensors

Def A Hall effect sensor is a transducer that detects and measures magnetic feilds by converting magnetic information into an electrical signal.

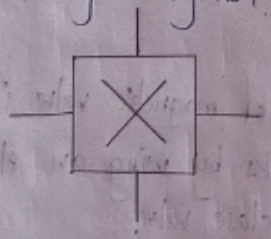
-> This sensor is typically made up of a semiconductor material such as galliuna arsenide, indium arsenide, (or) silicon.

-> These sensors generate hall voltage when magnetic feild is detected.

principle

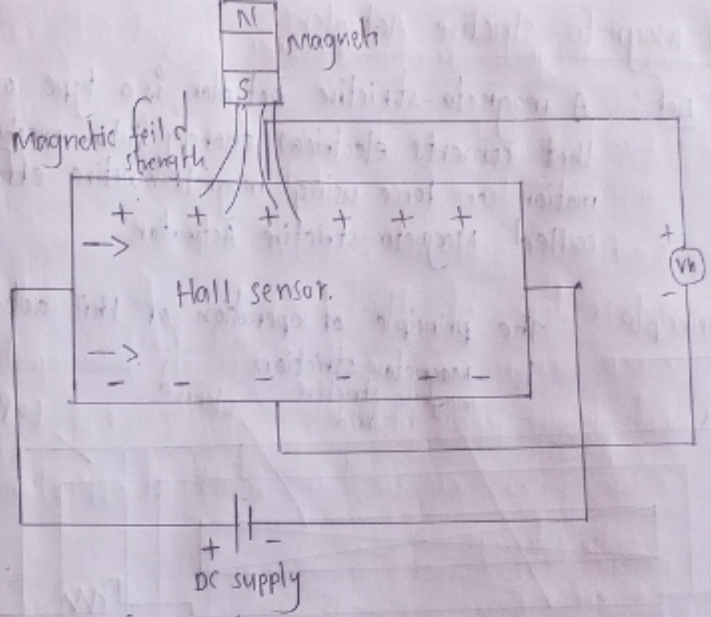
-> This sensor works on the principle of Hall effect.

-> Hall sensor ~~symbol~~ symbol



working

-> Hall-effect sensors made with thin p-type semiconductor materials.



-> Above figure shows Hall sensor working.
-> Hall effect sensor consist of Hall sensor, DC supply, Magnet, voltage source, etc
-> when external magnetic feild ~~is~~ is introduced perpendicular to the hall plate.
-> Due to this Hall voltage develops across the hall plate

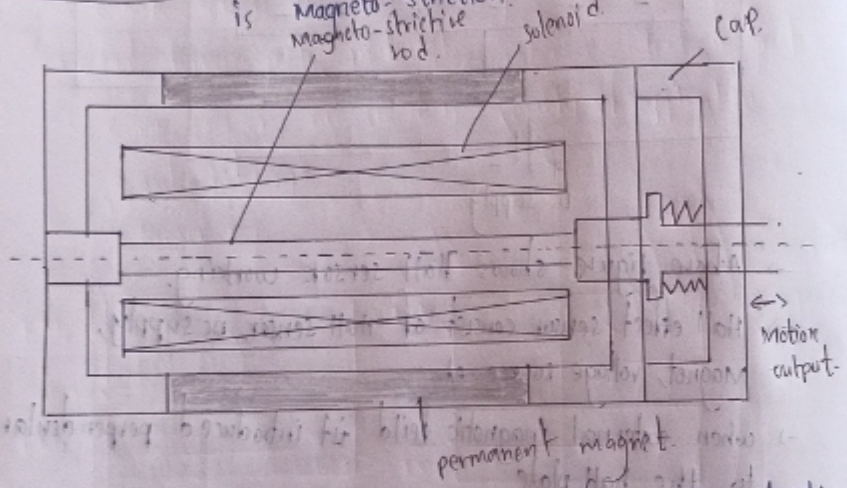
Applications,

-> used for measuring fluid level in a container.
-> " " " displacement
-> door locks and Ignition systems.

* Magneto-strictive Actuators

Def: A magneto-strictive actuator is a type of device that converts electrical energy into mechanical motion (or) force using magneto-strictive effect is called Magneto-strictive Actuator.

principle: The principle of operation of this actuator is Magneto-striction.



-> Above figure shows diagram of magneto-strictive Actuator.
-> It consist of magneto-strictive rod, cap, motion o/p permanent magnet.
-> It is surrounded by coil of wire

working
-> when an electric current passes through the coil of wire, it generates magnetic field ~~around~~
-> The generated magnetic field cause to change shape of magnetostrictive Actuator.
-> It results deformation.
-> If magnetostrictive material changes its shape (or) length it creates mechanical movement

Applications
-> Robotics
-> optical systems
-> used in mirrors
-> used in machinary.

* Magneto-Resistive sensor:

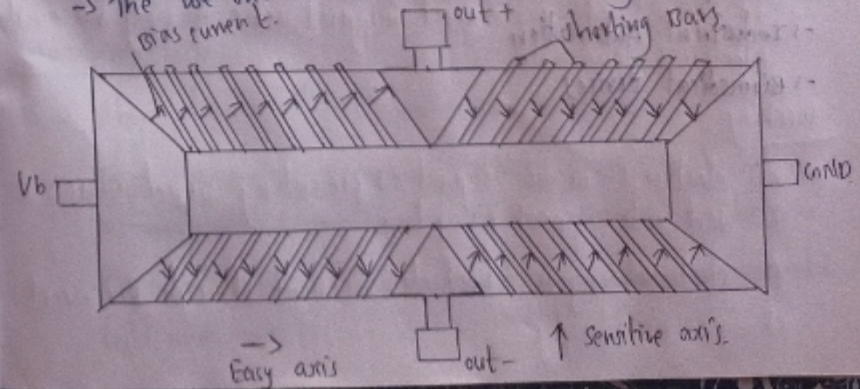
Def Magneto-resistive sensors are devices used to detect and measure magnetic fields. is called MRS.

principle: Magneto-resistive sensor works one the principle of magneto-resistance.

-> There are different types of magneto-resistive sensors, but mainly two types

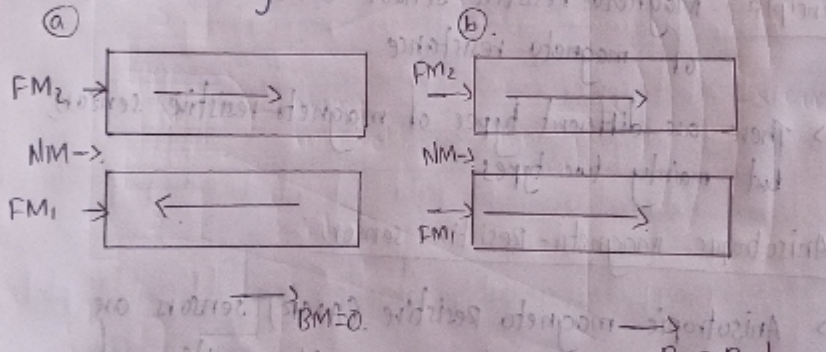
o Anisotropic Magneto-Resistive sensors:

-> Anisotropic magneto Resistive (AMR) sensors are magnetic sensors that measure the position of rotating and moving elements
-> The use the characteristics of ferromagnetic materials.



○ Giant magneto-resistive (GMR) sensor

-> Giant magneto-resistive sensor (GMR) is a device that measures changes in electrical resistance.
-> GMR is a quantum mechanical effect.
-> The resistance of device proportional to magnetic field.
-> GMR sensors uses multiple layers of ferromagnetic and non-ferromagnetic materials.
-> GMR sensors are used in variety of applications.
  ○ Data storage
  ○ Biosensing.



Applications

-> security systems
-> Aerospace
-> Industrial Automation
-> Biomedical devices.

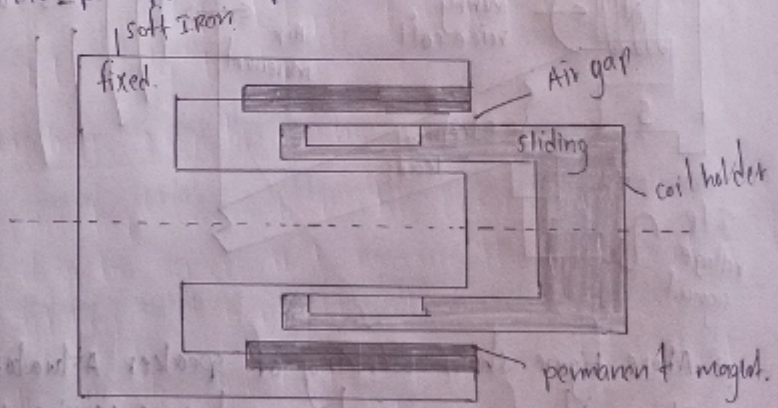
* Voice coil Actuators

Def: A voice coil Actuator (VCA) is a linear motor that uses permanent magnetic field and an electric current to create force that moves a coil. is called VCA.

-> A voice coil is a linear actuator.
-> voice coils were developed for loud speakers, for converting electrical energy into sound wave.
-> It uses diaphgram.
-> Loud speakers used to create a louder voice.

principle

-> The principle of operation of VCA is Lorentz forces.



working

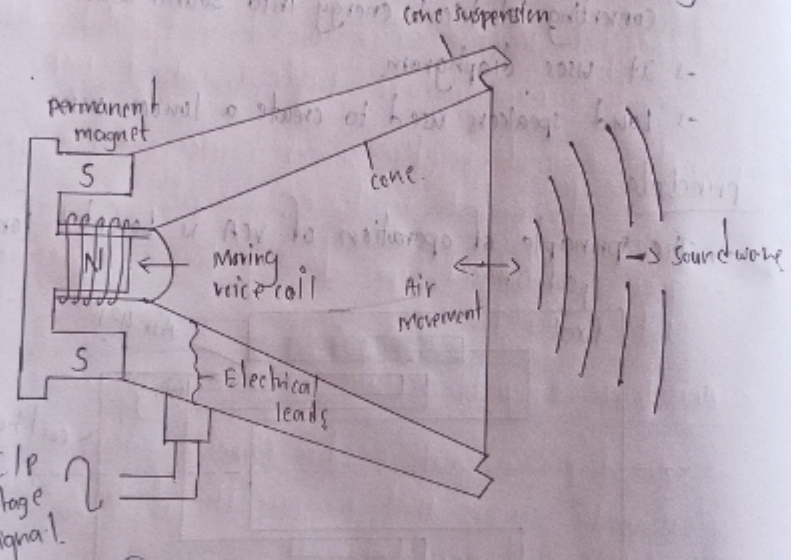
-> Above figure shows voice coil Actuator.
-> If a conductor carrying electric current is placed in a magnetic field, then force is generated on the wire.
-> The Lorentz force is proportional is product of magnetic field and current.

-> The diaphgram converts electric current into sound energy.

* Speaker Actuator

Def Speaker Actuator is a device that converts electrical signals into sound waves and allowing us to hear sound is called speaker Actuator.

principle The principle of operation is electromagnetism.



-> Above figure shows working of speaker Actuator
-> It consist of permanent magnet, cone, moving voice coil, Electrical leads, etc.

working

-> An electrical audio signal, representing sound waves is fed into speaker system.
-> As electrical signal fluctuates, current through voice coil changes accordingly.
-> The interaction blw changing magnetic field and fixed magnetic field causes voice coil to move.
-> As the diaphgram moves back and forth, it pushes and pulls so surrounding air.
-> final result is sound waves produces.

Applications

-> Telecommunications
-> security
-> voice communication applications.
-> large speakers, etc.

* Inductive sensor

An inductive sensor is a device that uses the principle of electromagnetic induction to detect (or) measure objects is called inductive sensor.

-> It is of two types.

- Linear variable differential Transformer/ Transducer (LVDT)
- Rotary variable differential Transformer/ Transducer (RVDT)

Unit-5

* chemical sensors

Def chemical sensors detect and measure chemical properties of substances in gases, liquids, solids is called chemical sensors.

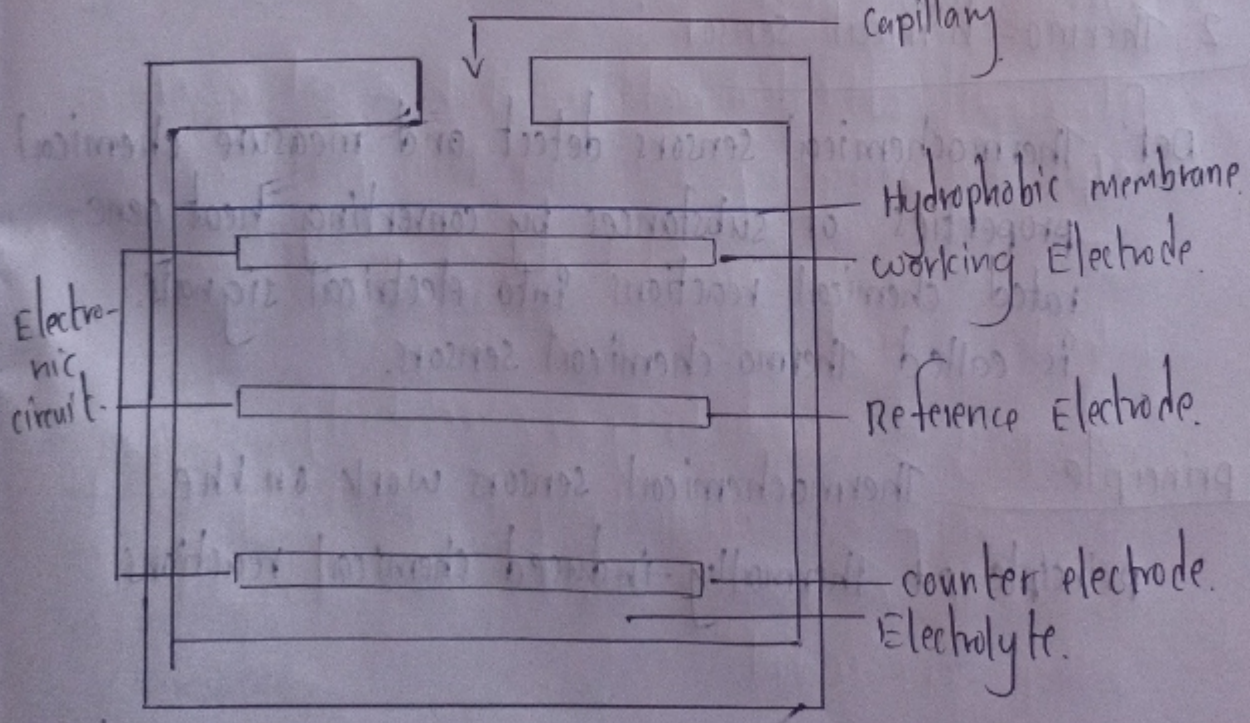
-> chemical sensor is a analyzer

-> chemical sensor mainly consist of two functional parts:

- The receptor
- The transducer

1. Electro-chemical sensor : An Electrochemical sensor is a device that detects and measures chemical properties of substances by converting chemical reactions into electrical signals.

principle Electrochemical sensor works on the principle of electrochemical reactions.



-> Above figure shows Electro-chemical sensor.
-> It consist of working,- Reference- counter Electrodes, capillary, Electronic circuit, Hydrophobic membrane, Electrolyte.
-> Electrodes are made up of metals like gold and platinum.
-> Electrochemical reactions takes place in working electrode.
-> counter electrode completes the circuit by allowing the flow of current b/w working and Reference electrodes.
-> working electrode either donates or accepts electrons.
-> Electrons generated during reaction, flow to external circuit through counter electrode.

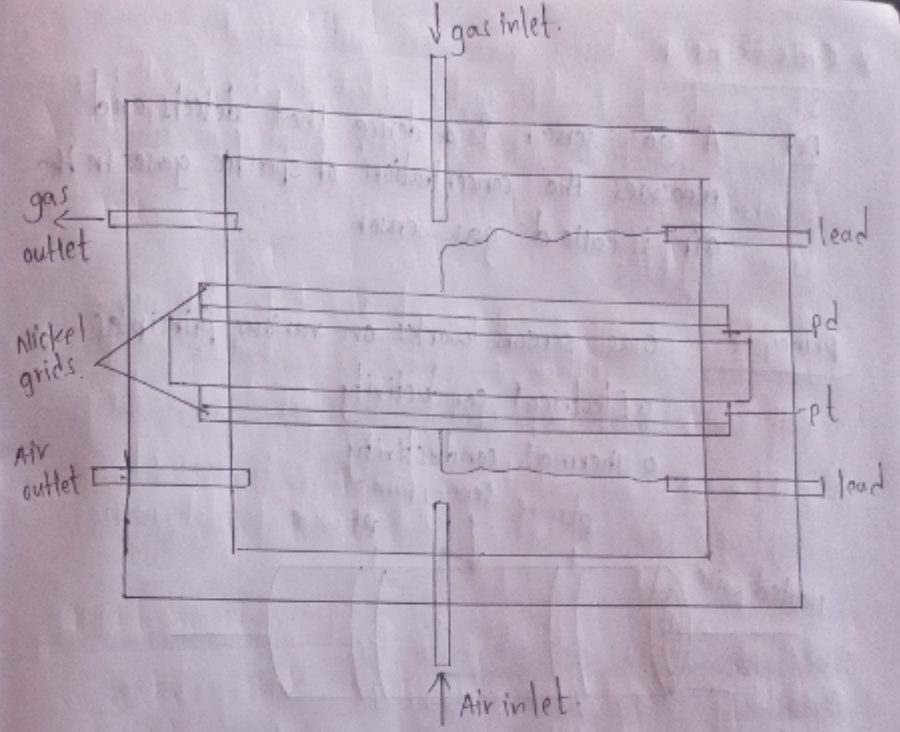
Applications

-> Industries.
-> Enviromental monitering.
-> medical.

2. Thermo-chemical sensor :

Def: Thermochemical sensors detect and measure chemical properties of substances by converting heat-generated chemical reactions into electrical signals. is called Thermo-chemical sensors.

principle Thermochemical sensors work on the principle of Thermally-induced chemical reactions.



-> Above figure shows Thermo-chemical sensor.
-> It consist of gas inlet, gas outlet, air inlet, air outlet, leads, pd, pt etc.
-> Electrodes are made up of gold, platinum etc.
-> This sensor is used in gas detection.
-> The sensing element is heated to a specific temperature.
-> The sensor measures relevant changes and converts them into a electrical signal.

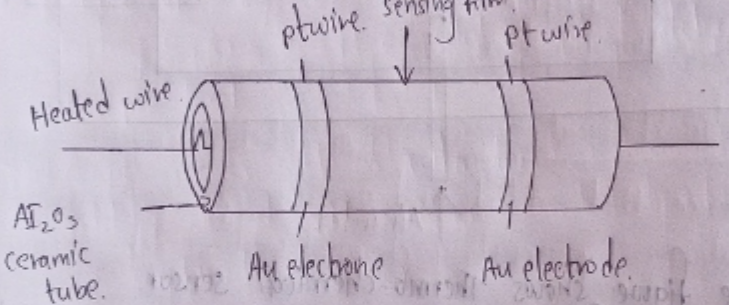
Applications

-> Industries
-> medical.
-> Aerospace.
-> Enviromental monitering.

X Gas sensor

Def: A gas sensor is a device that detects and measures the concentration of specific gases in the air is called gas sensor.

Principle: Gas sensors works on various principles
- Electrical conductivity
- Thermal conductivity



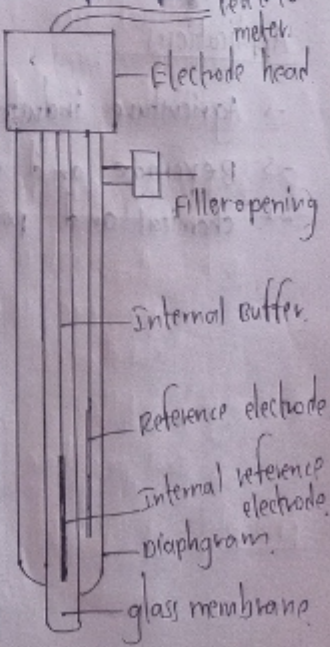
-> Above figure shows structure of gas sensor
-> It consist of Au electrodes, pt wire, sensing film, heated wire, Al_2O_3 ceramic tube.
-> It consist of 6 terminals, in which 4 act as I/p (or) o/p, and remaining 2 are for heating the coil.
-> when sensor is exposed to target gas, the gas molecules interact with semiconductors surface.
-> changing its conductivity (or) resistivity.
-> The change in conductivity (or) resistivity converts this into a readable output. in the form of voltage (or) current
-> Based on this voltage value, type and concentration of the gas can be estimated.
-> Types:
- optical gas sensor
- Electrochemical gas sensor
- Infrared gas sensor

Applications:
-> Industrial safety
-> Environment monitoring
-> Aerospace
-> smart homes

4. PH sensor

Def: A PH sensor is a device that measures the acidity (or) alkalinity of a solution, typically in the range of 0-14 pH units is called pH sensor.

Principle: pH sensor works on various principles.
- Ion exchange
- FET Technology
- Electrochemical reactions



-> Above figure shows ~~gas~~ sen pH sensor.
-> It consist of Lead to meter, Electrode head, filler opening, Reference electrode, internal buffer, diaphgram, glass membrane etc
-> PH = -log [H+]
-> A pH sensor is a equipment used to determine whether a solution is acidic or/ alkaline.
-> PH sensor made up of two electrodes.
-> It works by detecting the concentration of hydrogen ions in the solutions, which determines it's pH level.
-> A pH sensor act as voltmeter.
-> widely used pH sensors
  - o combination sensor,
  - o differential pH sensor.

Applications

-> Agriculture industries.
-> Beverage and food industries.
-> chemical and paramedical industries.

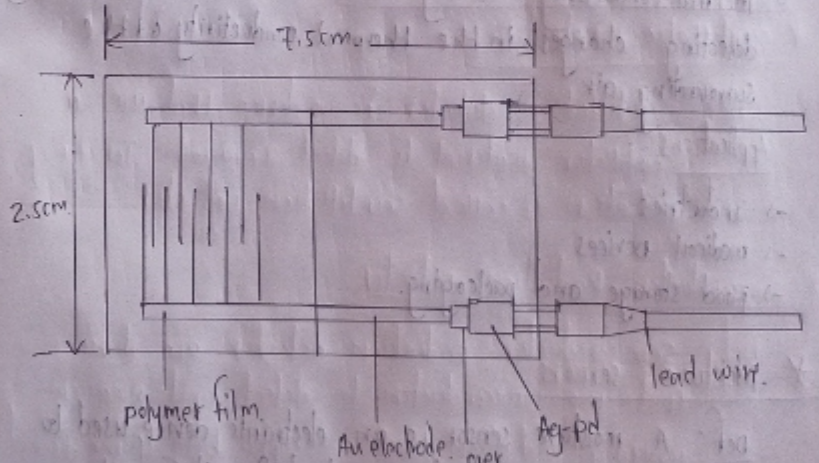
X Humidity sensor

Def A Humidity sensor is a device that measures the amount of moisture in the air is called Humidity sensor.

principle Humidity sensors works on various principles.

- o Capacitance changes with Humidity
- o Resistance " "
- o Thermal conductivity " "

-> It is used to measure amount of water vapour present in air.



-> Here Above figure shows humidity sensor.
-> It consists of polymer film, Au electrode, over coat, Ag-pd, lead wire etc.
-> Humidity sensors are very important devices.
-> Technically it is used to measure humidity of the atmosphere.

-> Humidity can be measured in two methods.

- Absolute Humidity (AH)
- Relative Humidity (RH)

-> AH = m/v.

- Capacitive Humidity sensor: It measures humidity by detecting changes in capacitance of the surrounding air
- Resistive Humidity sensor: A resistive humidity sensor measures humidity by detecting changes in resistance in the hygroscopic material.
- Thermal conductivity humidity sensor: It measures humidity by detecting changes in the thermal conductivity of the surrounding air.

Applications:

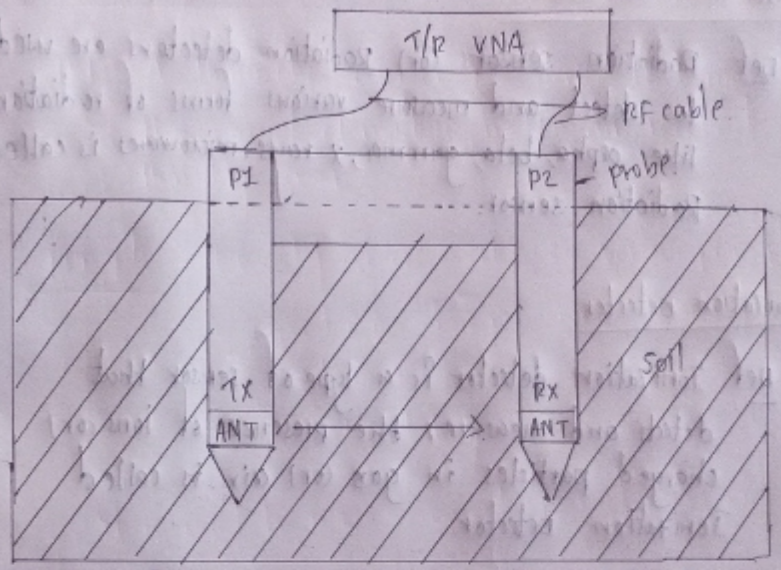
-> Industries
-> medical devices
-> Food storage and packaging.

* Moisture sensors

Def: A moisture sensor is an electronic device, used to measure the moisture content in soil, (or) other substances.

-> moisture sensors are widely used to measure the soil moisture.

principle: It works on the principle of change in resistance (or) conductivity.



-> Above figure shows moisture sensor construction.
-> It consist of T/R VNA, RF cable, probe soil, Tx, Rx. etc.
-> It consists of two probes, i.e metallic rods. that are inserted into the soil.
-> when the soil is dry it has high resistance, causing less conductivity between the probes.
-> It requires low power consumption.
-> It is difficult to design.
-> It has fast response time.
-> It has accurate measurements.
-> Types of moisture sensors.
  - Resistive moisture sensors.
  - capacitive " "
  - Thermal conductivity " "
  - Infrared " "

Applications

-> Agriculture.
-> construction.
-> Textile industry.
-> Environmental monitoring.

* Radiation sensors

Def Radiation sensors (or) Radiation detectors are used to detect and measure various forms of radiation like alpha, beta, gamma, x-rays, microwaves is called Radiation sensor.

* Ionization detector

Def Ionization detector is a type of sensor that detects and measures the presence of ions (or) charged particles in gas (or) air is called Ionization detector.

* Scintillation detector

Def scintillation detector is a device that uses a scintillator material to detect ~~Ionizati~~ Ionizing radiation is called scintillation detector.

* Semiconductor Radiation detector

Def: Semiconductor radiation detectors are devices that use semiconductors to detect and measure ionizing radiation such as alpha, beta, gamma and x-rays is called SRD.

* Grieger muller counter

Def A grieger muller counter is a device used for detecting and measuring ionizing radiation is called grieger muller counter.

* Microwave sensor :

Microwave sensor is a device that utilize microwave radiation to detect and measure various characteristics of an object (or) environment is called microwave sensor.

- It is of three types
  - Reflection microwave sensor.
  - Resonant microwave sensor.
  - Transmission microwave sensor.