R.N.G.P.I.T, Bardoli

Electrical Engineering Department

Subject: EMMI

Prepared By:

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- Experience: 13 Years.

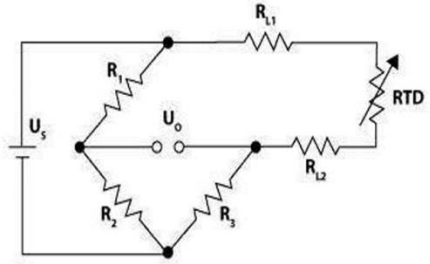
CH: Transducer & Sensors

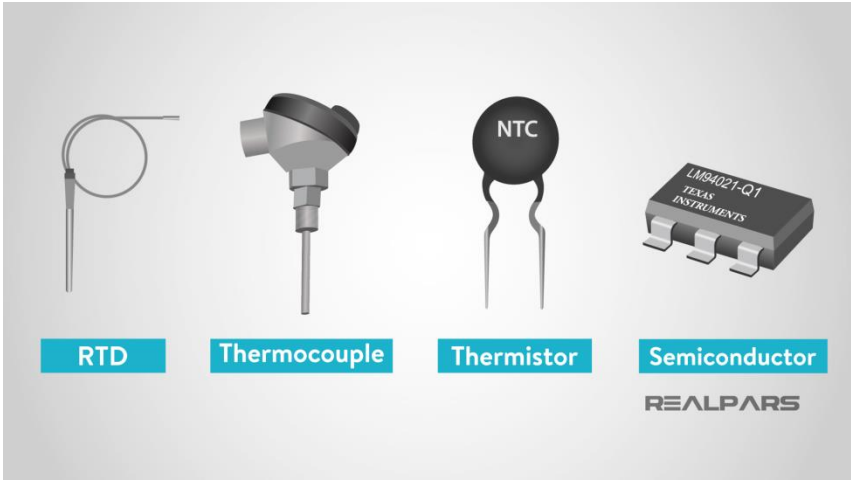
- This Lecture contain

- transducers for measurement of temperature ((Thermocouple and RTD)
- Hall Effect transducer
- Sensors – basic concept – Speed and position sensors

standard deviation, Bar diagram, Histogram.	
Transducers and Sensors : Definition, different types of transducers, criteria for selection, general characteristics and dynamic characteristics, transducers for measurement of temperature ((Thermocouple and RTD), transducers for measurement of pressure, strain, transducers for measurement of displacement, speed, torque, Hall Effect transducer Sensors – basic concept – Speed and position sensors	**10**

- Resistance Temperature Detector or RTD:
- A Resistance Temperature Detector (also known as a Resistance Thermometer or RTD) is an electronic device used to determine the temperature by measuring the resistance of an electrical wire. This wire is referred to as a temperature sensor. If we want to measure temperature with high accuracy, an RTD is the ideal solution, as it has good linear characteristics over a wide range of temperatures. Other common electronics devices used to measure temperature include a thermocouple or a thermistor.





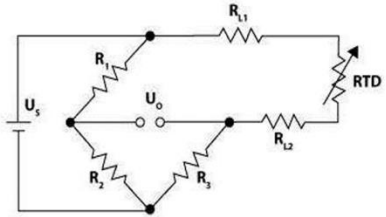
- *Resistance Temperature Detector or RTD:*
- *The variation of resistance of the metal with the variation of the temperature is given as:*

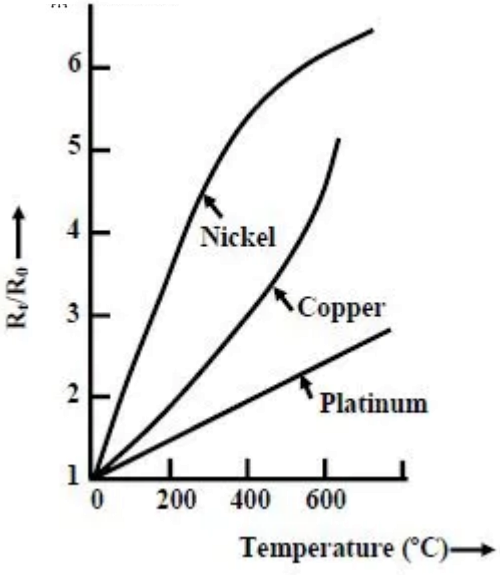
$$R_t = R_0\left[1+\alpha(t-t_0)+\beta(t-t_0)^2+\ldots\right]$$

- *Where, R_t and R_0 are the resistance values at t°C and t_0°C temperatures. α and β are the constants depends on the metals.*
- *This expression is for huge range of temperature. For small range of temperature, the expression can be,*

- *In RTD devices; Copper, Nickel and Platinum are widely used metals. These three metals are having different resistance variations with respective to the temperature variations. That is called resistance-temperature characteristics.*

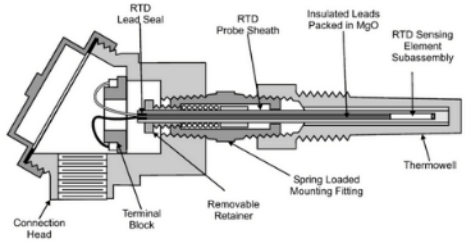
$$R_t = R_0\left[1+\alpha(t-t_0)\right]$$

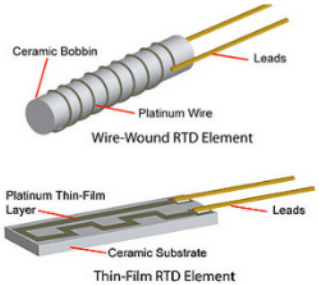




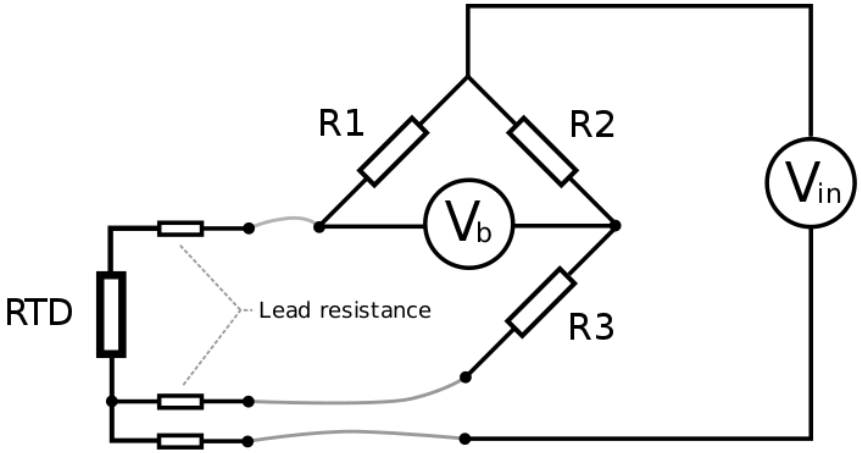
- Construction of RTD:
- The construction is typically such that the wire is wound on a form (in a coil) on notched mica cross frame to achieve small size, improving the thermal conductivity to decrease the response time and a high rate of heat transfer is obtained. In the industrial RTD's, the coil is protected by a stainless steel sheath or a protective tube.

- So that, the physical strain is negligible as the wire expands and increase the length of wire with the temperature change. If the strain on the wire is increasing, then the tension increases. Due to that, the resistance of the wire will change which is undesirable. So, we don't want to change the resistance of wire by any other unwanted changes except the temperature changes.





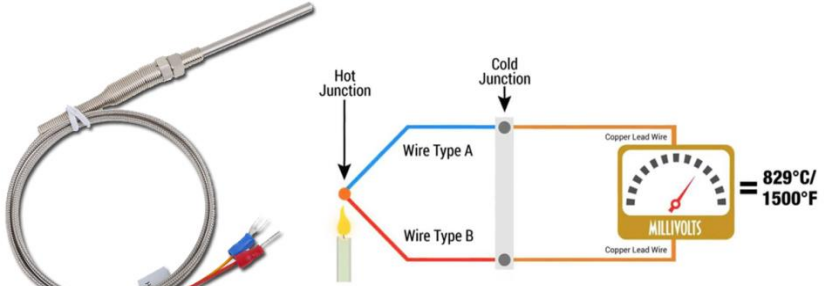
- *Working of RTD:*
- *RTD value is measured by using a bridge circuit. By supplying the constant electric current to the bridge circuit and measuring the resulting voltage drop across the resistor, the RTD resistance can be calculated. Thereby, the temperature can be also determined. This temperature is determined by converting the RTD resistance value using a calibration expression.*
- *In the RTD resistance, there will be an I2R power dissipation by the device itself that causes a slight heating effect. This is called as self-heating in RTD. This may also cause an erroneous reading. Thus, the electric current through the RTD resistance must be kept sufficiently low and constant to avoid self-heating.*

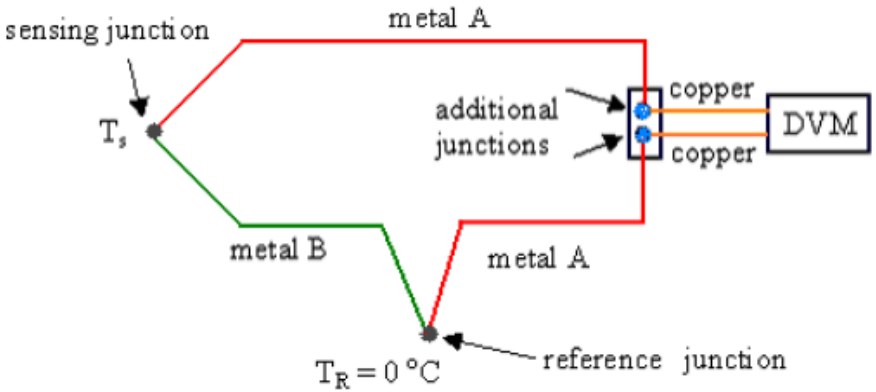


- Thermocouple:
- The thermocouple is the sensor used to measure temperature.
- The thermocouple are made with two wires of different metal, joined together at one end to form a junction. Thermocouples output in millivolts.
- The working principle of thermocouple is based on "SEEBACK EFFECT"

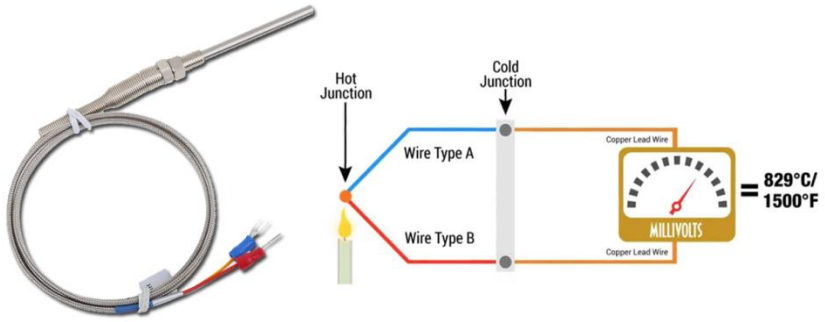
- Thermocouple:
- In 1821, German physicist Thomas Johann Seebeck found that a magnetic field is produced when two different metals are connected at one end and create a temperature difference between two ends.
- He observed that due to the magnetic field the voltage is induced by the thermoelectric effect. However, this voltage is very small (in terms of mV) and depends on the type of metal used in the thermocouple.

- Thermocouple Working :
- A thermocouple consists of two plates of different metals. Both plates are connected at one end and make a junction.
- The junction is placed on the element or surface where we want to measure the temperature. This junction is known as a hot junction. And the second end of the plate is kept at a lower temperature (room temperature). This junction is known as cold junction or reference junction.
- According to the Seebeck effect, the temperature difference between the two different metals induces the potential differences between two points of the thermocouple plates.





- *Thermocouple Working :*
- *If the circuit is closed, a very small amount of current will flow through the circuit. A voltmeter is connected in the circuit. The voltage measured by the voltmeter is a function of a temperature difference between two junctions.*
- *Hence, by measuring the voltage, we can calculate the temperature of the hot junction.*
- *According to different types of combinations of alloys, the thermocouples are available in different types. The type of thermocouple is chosen according to the application, cost, availability, stability, chemical properties, output, and temperature ranges.*

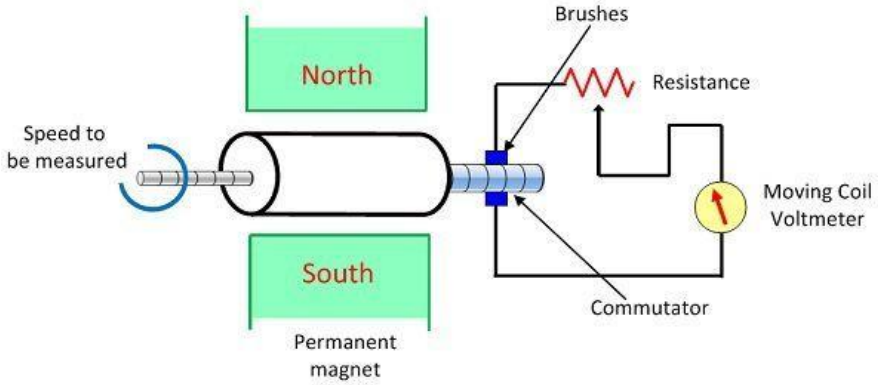


Type	**Positive wire** *characteristic*	**Negative wire** *characteristic*	**Plug**	**Temp. range**
T	Copper (blue) *yellow colored*	Constantan (red) *silver colored*	Blue	-300 to 700 ^{o}F
J	Iron (white) *magnetic, rusty?*	Constantan (red) *non-magnetic*	Black	32 to 1400 ^{o}F
E	Chromel (violet) *shiny finish*	Constantan (red) *dull finish*	Violet	32 to 1600 ^{o}F
K	Chromel (yellow) *non-magnetic*	Alumel (red) *magnetic*	Yellow	32 to 2300 ^{o}F
N	Nicrosil (orange)	Nisil (red)	Orange	32 to 2300 ^{o}F
S	Pt90% - Rh10% (black)	Platinum (red)	Green	32 to 2700 ^{o}F
B	Pt70% - Rh30% (grey)	Pt94% - Rh6% (red)	Grey	32 to 3380 ^{o}F

- Thermocouple Advantage :
- The thermocouple type of instruments accurately indicates the root mean square value of current and voltages irrespective of the waveform. There is a wide varieties of range of thermocouple instruments are available in the market.
- Thermocouple type of instruments give very accurate reading even at high frequency, thus these types of instruments are completely free from frequency errors.
- The measurement of quantity under these instruments is not affected by stray magnetic fields.
- These instruments are known for their high sensitivity.
- Usually for measuring the low value of current bridge type of arrangement is used i.e. ranging from 0.5 Amperes to 20 Amperes while for measuring the higher value of current heater element is required to retain accuracy.
- Thermocouple Disadvantage :
- Instead of many advantages these type of instruments posses one disadvantage, The over load capacity of thermocouple type of instrument is small, even fuse is not able to the heater wire because heater wire may burn out before the fuse blows out.

- Thermocouple Application :
- It is used to monitor the temperature in the steel and iron industries. For, this type of application, type B, S, R, and K thermocouples are used in the electric arc furnace.
- The principle of a thermocouple is used to measure the intensity of incident radiation (especially visible and infrared light). This instrument is known as a thermopile radiation sensor.
- It is used in the temperature sensors in thermostats to measure the temperature of the office, showrooms, and homes.
- The thermocouple is used to detect the pilot flame in the appliances that used to generate heat from gas like a water heater.
- To test the current capacity, it is installed to monitor the temperature while testing the thermal stability of switchgear equipment.
- The number of thermocouples is installed in the chemical production plant and petroleum refineries to measure and monitor temperature at a different stage of the plant.

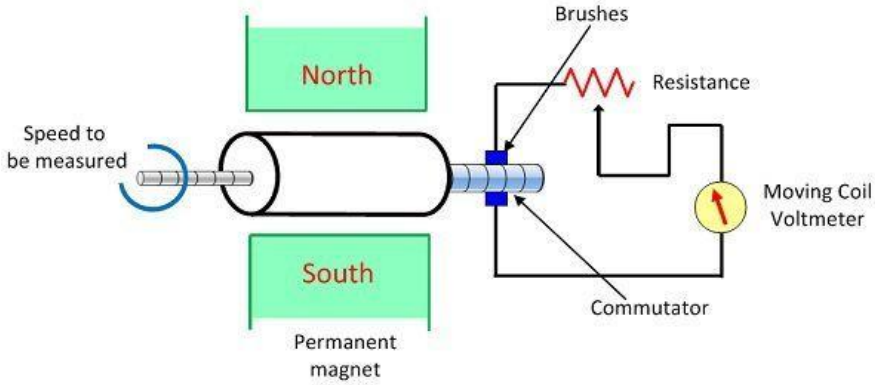
- *Electrical Tachometer:*
- *The tachometer use for measuring the rotational speed or angular velocity of the machine which is coupled to it. It works on the principle of relative motion between the magnetic field and shaft of the coupled device. The relative motion induces the EMF in the coil which is placed between the constant magnetic field of the permanent magnet. The develops EMF is directly proportional to the speed of the shaft.*
- *Mechanical and electrical are the two types of the tachometer. The mechanical tachometer measures the speed of shaft regarding revolution per minutes.*
- *The electrical tachometer converts the angular velocity into an electrical voltage. The electrical tachometer has more advantages over the mechanical tachometer. Thus it is mostly used for measuring the rotational speed of the shaft.*



DC Tachometer Generator

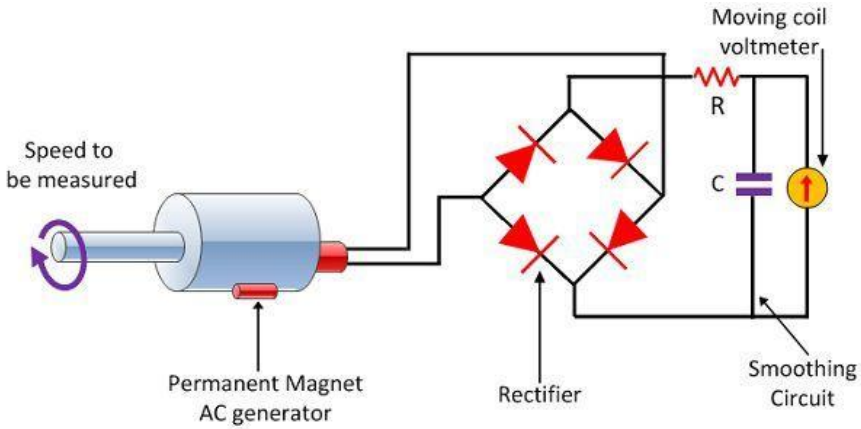
- *Electrical Tachometer:*
- *Depends on the natures of the induced voltage the electrical tachometer is categorized into two types.*
- *(1)AC Tachometer Generator*
- *(2)DC Tachometer Generator*
- *DC Tachometer Generator: Permanent magnet, armature, commutator, brushes, variable resistor, and the moving coil voltmeter are the main parts of the DC tachometer generator. The machine whose speed is to be measured is coupled with the shaft of the DC tachometer generator.*

- *The DC tachometer works on the principle that when the closed conductor moves in the magnetic field, EMF induces in the conductor. The magnitude of the induces emf depends on the flux link with the conductor and the speed of the shaft.*

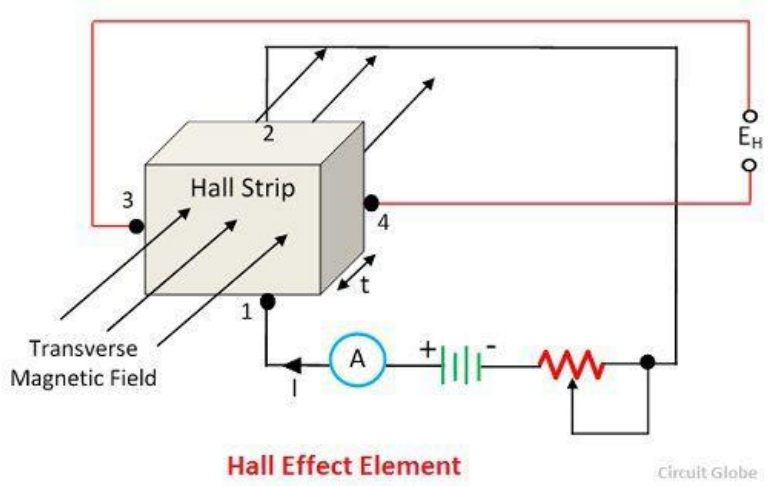


DC Tachometer Generator

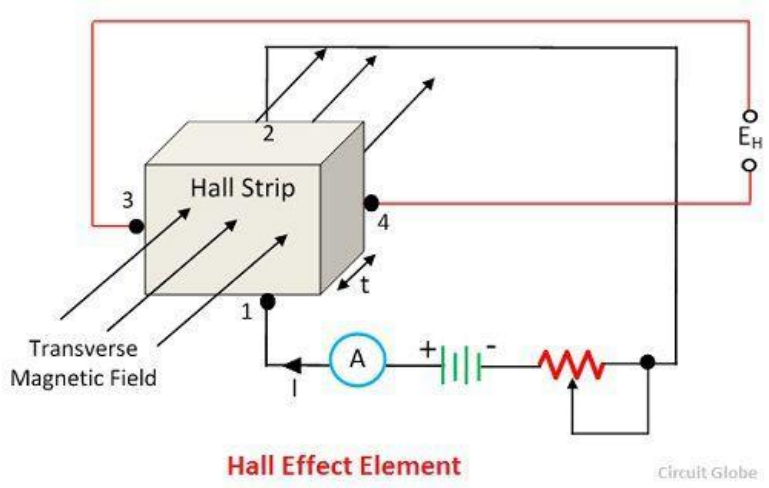
- Electrical Tachometer:
- AC Tachometer Generator
- The DC tachometer generator uses the commutator and brushes which have many disadvantages. The AC tachometer generator designs for reducing the problems. The AC tachometer has stationary armature and rotating magnetic field. Thus, the commutator and brushes are absent in AC tachometer generator.
- The rotating magnetic field induces the EMF in the stationary coil of the stator. The amplitude and frequency of the induced emf are equivalent to the speed of the shaft. Thus, either amplitude or frequency is used for measuring the angular velocity.
- The below mention circuit is used for measuring the speed of the rotor by considering the amplitude of the induced voltage. The induces voltages are rectified and then passes to the capacitor filter for smoothening the ripples of rectified voltages.



- *Hall Effect Transducer:*
- *The hall effect element is a type of transducer used for measuring the magnetic field by converting it into an emf. The direct measurement of the magnetic field is not possible. Thus the Hall Effect Transducer is used. The transducer converts the magnetic field into an electric quantity which is easily measured by the analogue and digital meters.*
- *The principle of hall effect transducer is that if the current carrying strip of the conductor is placed in a transverse magnetic field, then the EMF develops on the edge of the conductor. The magnitude of the develop voltage depends on the density of flux, and this property of a conductor is called the Hall effect. The Hall effect element is mainly used for magnetic measurement and for sensing the current.*

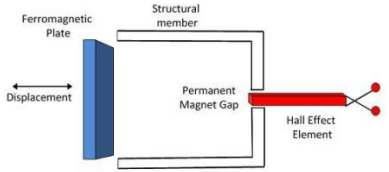


- *Hall Effect Transducer:*
- *The metal and the semiconductor has the property of hall effect which depends on the densities and the mobility of the electrons.*
- *Consider the hall effect element shown in the figure below. The current supply through the lead 1 and 2 and the output is obtained from the strip 3 and 4. The lead 3 and 4 are at same potential when no field is applied across the strip.*
- *When the magnetic field is applied to the strip, the output voltage develops across the output leads 3 and 4. The develops voltage is directly proportional to the strength of the material.*



- *The output voltage is,* $E_H = K_H IB / t$
- *where,* K_H*=hall-effect-coefficient, t thickness, I is the current in ampere and the B is the flux densities in Wb/m2*

- Hall Effect Transducer:
- The current and magnetic field strength both can be measured with the help of the output voltages. The hall effect EMF is very small in conductors because of which it is difficult to measure. But semiconductors like germanium produces large EMF which is easily measured by the moving coil instrument.
- Application:
- Magnetic to Electric Transducer – The Hall effect element is used for converting the magnetic flux into an electric transducer. The magnetic fields are measured by placing the semiconductor material in the measurand magnetic field. The voltage develops at the end of the semiconductor strips, and this voltage is directly proportional to the magnetic field density.
- The Hall Effect transducer requires small space and also gives the continuous signal concerning the magnetic field strength. The only disadvantage of the transducer is that it is highly sensitive to temperature and thus calibration requires in each case.
- Measurement of Displacement – The Hall effect element measures the displacement of the structural element. For example – Consider the ferromagnetic structure which has a permanent magnet.

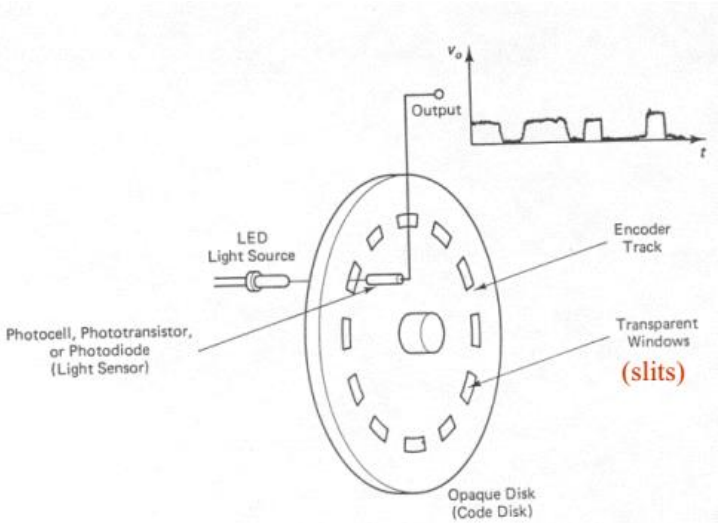


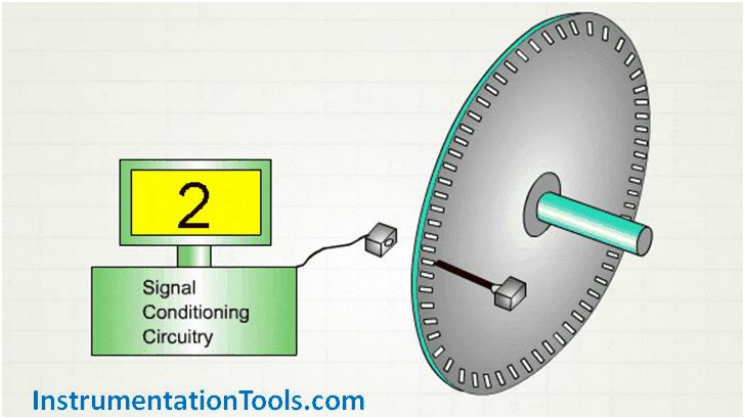
Measurement of Displacement Using Hall Efect Transducer

- The hall effect transducer placed between the poles of the permanent magnet. The magnetic field strength across the hall effect element changes by changing the position of the ferromagnetic field.
- Measurement of Current – The hall effect transducer is also used for measuring the current without any physical connection between the conductor circuit and meter.
- The AC or DC is applied across the conductor for developing the magnetic field. The strength of the magnetic field is directly proportional to the applied current. The magnetic field develops the emf across the strips. And this EMF depends on the strength of the conductor.
- Measurement of Power – The hall effect transducer is used for measuring the power of the conductor. The current is applied across the conductor, which develops the magnetic field. The intensity of the field depends on the current. The magnetic field induces the voltage across the strip. The output voltage of the multiplier is proportional to the power of the transducer.

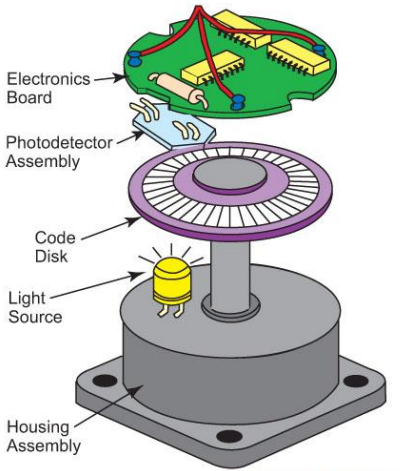
- *Optical Encoders for speed and position measurement:*
- *Any transducer that generates a coded reading of a measurement can be termed an encoder*
- *Shaft Encoders are digital transducers that are used for measuring angular displacements and velocities.*
- *Shaft Encoders can be classified into two categories:*
- *Incremental Encoders*
- *Absolute Encoders*

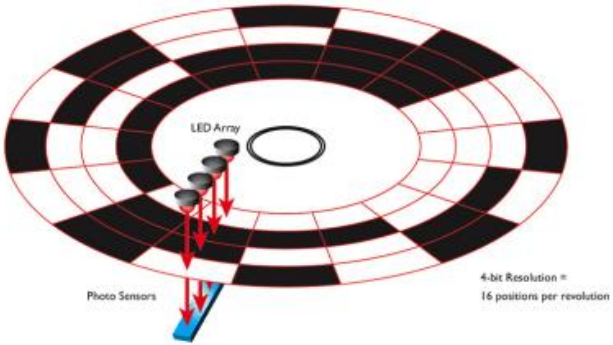
- *Incremental Encoders :*
- *Output is a pulse signal that is generated when the transducer disk rotates as a result of the motion that is being measured.*
- *By counting pulses or by timing the pulse width using a clock signal, both angular displacement and angular velocity can be determined.*
- *Displacement, however, is obtained with respect to some reference point on the disk, as indicated by a reference pulse (index pulse) generated at that location on the disk. The index pulse count determines the number of full revolutions.*



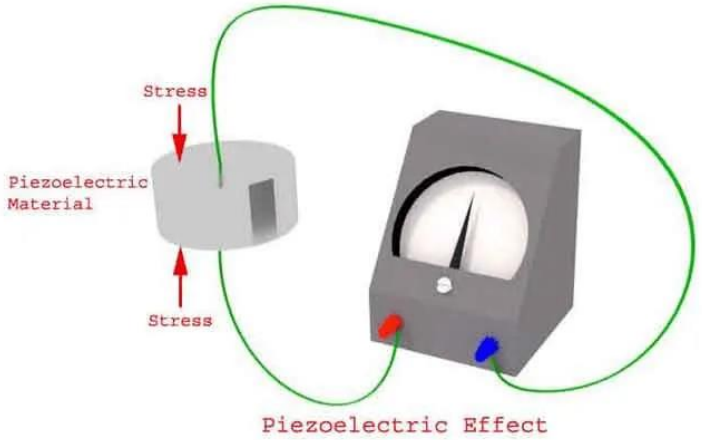


- Absolute Encoders :
- An absolute encoder has many pulse tracks on its transducer disk.
- When the disk of an absolute encoder rotates, several pulse trains – equal in number to the tracks on the disk are generated simultaneously.
- At a given instant, the magnitude of each pulse signal will have one of two signal levels (i.e., a binary state) as determined by a level detector. This signal level corresponds to a binary digit (0 or 1). Hence, the set of pulse trains gives an encoded binary number at any instant.





- Piezo Electric Transducer:
- A piezoelectric transducer (also known as a piezoelectric sensor) is a device that uses the piezoelectric effect to measure changes in acceleration, pressure, strain, temperature or force by converting this energy into an electrical charge.
- The piezoelectric material is one kind of transducers. When we squeeze this piezoelectric material or apply any force or pressure, the transducer converts this energy into voltage. This voltage is a function of the force or pressure applied to it.



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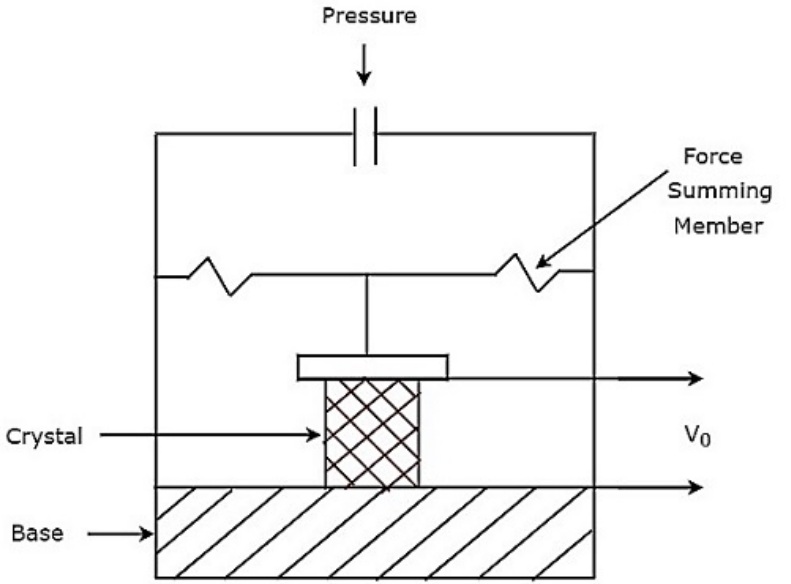

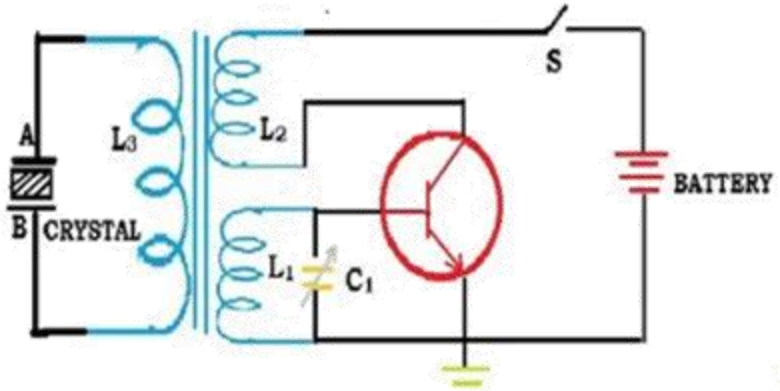

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