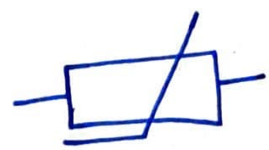
2) **THERMISTOR:-**

★ A thermistor is a device that uses resistance to detect temperature

★ Thermistors can also measure the temperature across the range of $-40 \sim 150 \pm 0.35°C$

★ Thermistors act as a passive component in a circuit

★ They are an accurate, cheap and robust way to measure temperature

★ Symbol for thermistor =>  or 

uses:-

★ Digital thermometers

★ Automotive applications

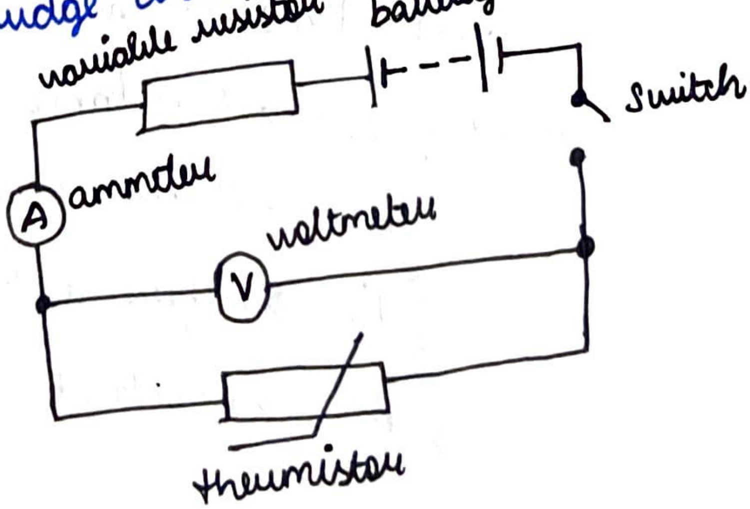
★ Household appliances

★ Circuit protection

★ Rechargeable batteries

★ Temperature Compensation

★ used in wheatstone bridge circuits



Working principle :-

★ 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

★ If we know the exact relationship between how changes in the temperature will affect the resistance of the thermistor - then by measuring the thermistor's resistance we can derive its temperature

2 types

1) NTC Termistor :-

★ Negative Temperature Coefficient

★ When the Temperature increases, resistance decreases

★ And when the Temperature decreases, resistance increases

★ Temperature and Resistance are inversely proportional

★ These are the most common type of thermistor

★ Relationship b/w Temp. and resistance

$$R_T = R_0 e^{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)}$$

where, $R_T \rightarrow$ Resistance at temperature T

$R_0 \rightarrow$ Resistance at temperature T_0 (0°C)

$T_0 \rightarrow$ Reference temperature (25°C)

$\beta \rightarrow$ constant

2) PTC thermistor :-

★ Positive Temperature Coefficient

★ has the reverse relationship b/w temperature and resistance

★ when Temp. ↑ , Resistance ↑

★ when Temp. ↓ , Resistance ↓

★ Temp. & Resistance are inversely proportional

★ Relationship b/w Temp. and Resistance

$$R_T = R_0 (1 + \alpha (T - T_0))$$

$$R_T = R_0 (1 + \alpha (\Delta T))$$

where , R_T = Resistance at Temperature T

R_0 = Resistance at Temperature T_0 (0°C)

T_0 = Reference Temperature (25°C)

α = constant

→ Applications

~~NTC~~	~~PTC~~
~~★ Industrial applications~~	~~★ used in self-regulating heaters~~
~~★ controlling engine temperatures~~	~~used for motor winding protection~~
~~★ Fluid level gauging~~	~~sensing liquid levels~~
~~★ Temperature measurement~~	~~used as thermal switch~~
~~★ inrush current limiting~~	~~measurement & control of temp.~~

Application

NTC	PTC
★ Industrial applications	★ Fuse
★ copy machines	★ Switch
★ Burglar alarms	★ over current protection
★ detectors	★ Temperature sensor
★ AC , Refrigerators	★ Motor starting

→ STRAIN GAUGE GAUGE FACTOR DERIVATION :-

$$\text{Strain} = \frac{\text{change in Dimension}}{\text{original Dimension}} = \frac{\Delta L}{L}$$

$$\text{Resistivity } (R) = \frac{\rho L}{A}$$

$$\frac{dR}{ds} = \frac{d}{ds}\left(\frac{\rho L}{A}\right)$$

$$\frac{d}{ds}(A^{-1}) = -1A^{-1-1}$$
$$= -1A^{-2}$$
$$= -\frac{1}{A^2}$$

$$\frac{dR}{ds} = \frac{\rho}{A}\frac{\partial L}{\partial s} - \frac{\rho L}{A^2}\frac{\partial A}{\partial s} + \frac{L}{A}\frac{\partial \rho}{\partial s}$$

÷ by R ,

$$\frac{1}{R}\cdot\frac{dR}{ds} = \frac{\rho}{AR}\frac{\partial L}{\partial s} - \frac{\rho L}{A^2 R}\frac{\partial A}{\partial s} + \frac{L}{AR}\frac{\partial \rho}{\partial s}$$

$$\frac{1}{R}\cdot\frac{dR}{ds} = \frac{\cancel{\rho}}{\cancel{A}\times\frac{\cancel{\rho}L}{\cancel{A}}}\frac{\partial L}{\partial s} - \frac{\cancel{\rho}\cancel{L}}{A^{\cancel{2}}\cdot\frac{\cancel{\rho}\cancel{L}}{\cancel{A}}}\frac{\partial A}{\partial s} + \frac{\cancel{L}}{\cancel{A}\cdot\frac{\rho\cancel{L}}{\cancel{A}}}\frac{\partial \rho}{\partial s}$$

$$\boxed{\frac{1}{R}\cdot\frac{dR}{ds} = \frac{1}{L}\frac{\partial L}{\partial s} - \frac{1}{A}\frac{\partial A}{\partial s} + \frac{1}{\rho}\frac{\partial \rho}{\partial s}} \rightarrow (1)$$

$$A = \pi r^2$$

$$r = \frac{D}{2}$$

$$\Rightarrow A = \frac{\pi D^2}{4}$$

$$\boxed{\frac{\partial A}{\partial s} = \frac{\pi}{4}\cdot 2D\cdot\frac{\partial D}{\partial s}} \rightarrow (2)$$

Sub ② in ①,

$$\frac{1}{R}\frac{dR}{ds} = \frac{1}{L}\frac{\partial L}{\partial S} - \frac{1}{A}\cdot\frac{\pi}{4}\,2D\,\frac{\partial D}{\partial S} + \frac{1}{\rho}\frac{\partial \rho}{\partial S}$$

$$\frac{1}{R}\frac{dR}{ds} = \frac{1}{L}\frac{\partial L}{\partial S} - \frac{1}{\frac{\cancel{\pi} D^{\cancel{2}}}{\cancel{4}}}\cdot\frac{\cancel{\pi}}{\cancel{4}}\,2\cancel{D}\,\frac{\partial D}{\partial S} + \frac{1}{\rho}\frac{\partial \rho}{\partial S}$$

$$\boxed{\frac{1}{R}\frac{dR}{ds} = \frac{1}{L}\frac{\partial L}{\partial S} - \frac{2}{D}\frac{\partial D}{\partial S} + \frac{1}{\rho}\frac{\partial \rho}{\partial S}} \rightarrow ③$$

Poisson Ratio = $\dfrac{\text{Lateral strain}}{\text{Longitudinal strain}}$

$$\gamma = \frac{\partial A / A}{\partial L / L} \quad \text{(or)} \quad -\frac{\partial A / A}{\partial L / L}$$

$$\gamma = -\frac{\partial D / D}{\partial L / L}$$

$$\boxed{\frac{\partial D}{D} = -\gamma\frac{\partial L}{L}} \rightarrow ④$$

Sub ④ in ③,

$$\boxed{\frac{1}{R}\frac{dR}{ds} = \frac{1}{L}\frac{\partial L}{\partial S} + \frac{2\gamma}{L}\frac{\partial L}{\partial S} + \frac{1}{\rho}\frac{\partial \rho}{\partial S}} \rightarrow ⑤$$

$$\frac{1}{R}\frac{dR}{ds} = \frac{1}{L}\frac{\partial L}{\partial S}\left[1 + 2\gamma\right] + \frac{1}{\rho}\frac{\partial \rho}{\partial S}$$

Gauge Factor $= \dfrac{\Delta R/R}{\Delta L/L}$

$$G_F = \frac{\Delta R/R}{\Delta L/L}$$

$$\frac{\Delta R}{R} = G_F \frac{\Delta L}{L}$$

from (5),

$$\frac{\Delta R}{R} = \frac{\Delta L}{L} + 2\gamma \frac{\Delta L}{L} + \frac{\Delta \rho}{\rho}$$

$\div$ by $\dfrac{\Delta L}{L}$,

$$\frac{\Delta R/R}{\Delta L/L} = \frac{\Delta L/L}{\Delta L/L} + 2\gamma\frac{\Delta L/L}{\Delta L/L} + \frac{\Delta \rho/\rho}{\Delta L/L}$$

$$G_F = 1 + 2\gamma + \frac{\Delta \rho/\rho}{\Delta L/L}$$

ε = strain $= \Delta L/L$

$$G_F = 1 + 2\gamma + \frac{\Delta \rho/\rho}{\varepsilon}$$

$\dfrac{\Delta \rho/\rho}{\varepsilon} \Rightarrow$ very small so it is neglected

$$\boxed{G_F = 1 + 2\gamma}$$

2) SENSORS:-

- A sensor or transducer as a device which provides a usable output in response to a specified measurand.
- Output is defined as an 'electrical quantity' and Measurand - Physical quantity, or condition which is measured.'

- Physical quantity :Temperature, Pressure, force, motion, displacement, humidity, light flow etc.
- Electrical quantity: Change in resistance, inductance, capacitance etc.

CLASSIFICATION BASED ON MEASURANDS:-

- Mechanical :Length, area, volume, force, pressure, acceleration, torque, mass flow, acoustic intensity, and so on ..
- Thermal :Temperature, heat flow, entropy, state of matter.
- Electrical :Charge, current, voltage, resistance, inductance, capacitance, dielectric constant, polarization, frequency, electric field, dipole moment, and so on.
- Magnetic :Field intensity, flux density, permeability, magnetic moment, and so forth.
- Radiant :Intensity, phase, refractive index, reflectance, transmittance, absorbance, wavelength, polarization, and so on.
- Chemical :Concentration, composition, oxidation/reduction potential, reaction rate, pH, and the like.

TECHNOLOGY BASED CLASSIFICATION:

- Conventional sensors are now aptly supported by technologies which have yielded Micro Electro Mechanical Sensors (MEMS), CMOS image sensors, displacement and motion detectors and biosensors.
- Similarly, Coriolis, magnetic and ultrasonic flowmeters, photoelectric, proximity, Hall effect, infrared, integrated circuit (IC), temperature, radar-based level sensors are also relatively modern.

MINIMIZATION OF ERRORS:-

- Gross errors cannot be completely eliminated, but can be minimized by taking proper care in reading and recording of the measurement parameter.
- Instrumental Systematic errors can be avoided by

  a. selecting a suitable instrument for the particular measurement applications

  c. calibrating the instrument against a standard
- Environmental Systematic errors can be avoided by air conditioning, hermetically sealing certain components in the instruments, and using magnetic shields
- Observational Systematic errors can be avoided by concentrating on one particular measurement process at a time. Clearing out the area where the instrument is placed will also help the observer focus
- Random errors can be treated mathematically using laws of probability. The idea is to repeat the measurement to gain high precision.

3)DIFFERENT TYPES OF ERRORS:-

Basically Three types of errors are studied:-

1. Gross Errors
2. Systematic Errors
3. Random Errors

1)GROSS ERROR:-

- Gross Errors mainly covers the human mistakes in reading instruments and recording and calculating measurement results.
- Example:- Due to oversight, The read of Temperature as 31.5°. while the actual reading may be 21.5°.
- Gross Errors may be of any amount and then their mathematical analysis is impossible. Then these are avoided by adopting two means:-

1. Great care is must in reading and recording the data.
2. Two , Three or even more reading should be taken for the quantity under measurement.

2)SYSTEMATIC ERROR:-

a) Instrumental Errors:-

- These errors arises due to three main reasons.

I. Due to inherent shortcoming in the instrument.

Example:- If the spring used in permanent magnet instrument has become weak then instrument will always read high. Errors may caused because of friction , hysteresis , or even gear backlash.

II. Due to misuse of the instruments.

III. Due to Loading effects of instruments.

b) Environmental Errors:-

- These errors are due to conditions external to the measuring Device including conditions in the are surrounding the instrument.
- These may be effects of Temperature, Pressure, Humidity, Dust, Vibrations or of external magnetic or electrostatic fields

c) Observational Errors:-

- There are many sources of observational errors:-
- -- Parallax, i.e. Apparent displacement when the line of vision is not normal to the scale.
- -- Inaccurate estimate of average reading.
- -- Wrong scale reading and wrong recording the data.
- -- Incorrect conversion of units between consecutive reading.

3)RANDOM ERROR:-

- The quantity being measured is affected by many happenings in the universe.
- The errors caused by happening or disturbances about which we are unaware are Random Errors.
- Its also knownas residual Errors.