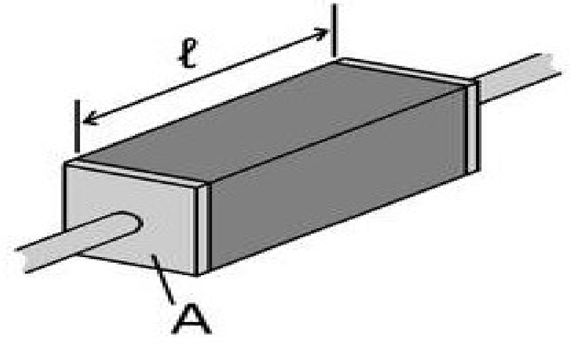
Resistive Transducers

Resistive Transducers

The resistive transducer element works on the principle that the resistance of the element is directly proportional to the length of the conductor and inversely proportional to the area of the conductor.



$$R = \rho L / A$$

Where R – resistance in ohms.

A – cross-section area of the conductor in meter square.

L – Length of the conductor in meter square.

ρ – the resistivity of the conductor in materials in ohm meter.

The resistive transducer converts the physical quantities into variable resistance which is easily measured by the meters.

Applications of Resistive Transducer

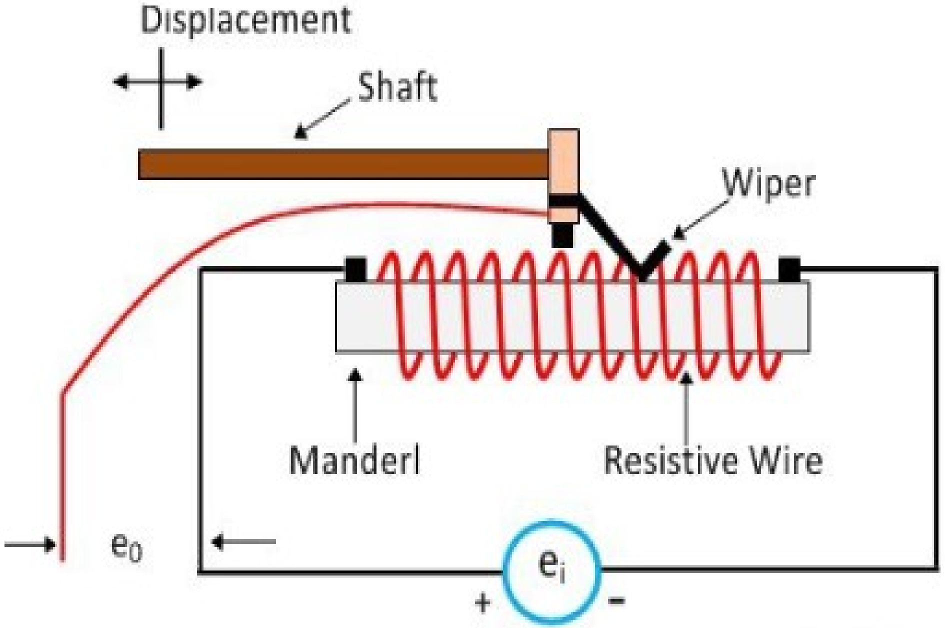
1.Potentiometer – The translation and rotatory potentiometer are the examples of the resistive transducers. The resistance of their conductor varies with the variation in their lengths which is used for the measurement of displacement.

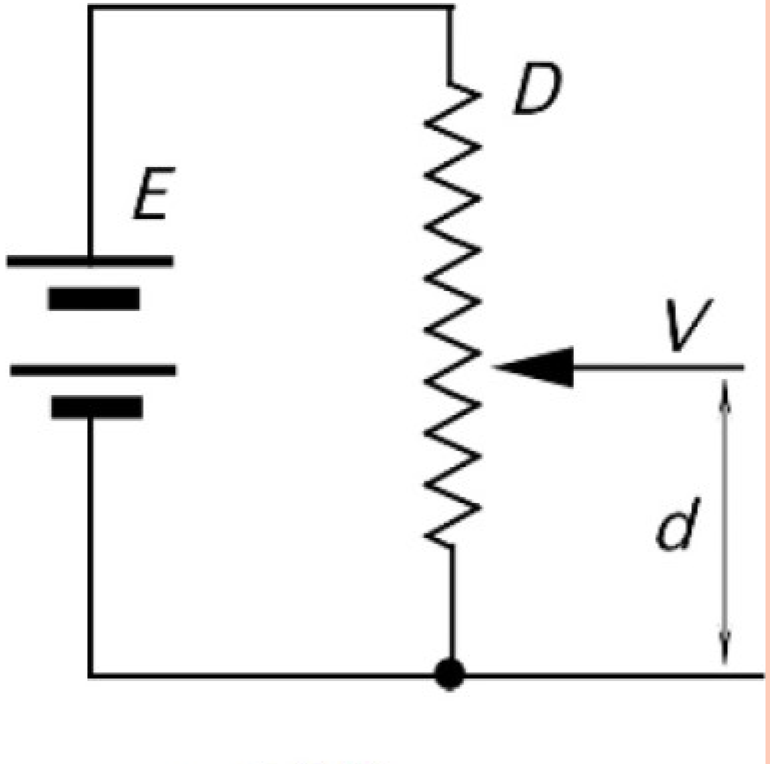
2.Strain gauges –The resistance of their semiconductor material changes when the strain occurs on it. This property of metals is used for the measurement of the pressure, force-displacement etc.

3.Resistance Thermometer – The resistance of the metals changes because of changes in temperature. This property of conductor is used for measuring the temperature.

4.Thermistor – It works on the principle that the temperature coefficient of the thermistor material varies with the temperature. The thermistor has the negative temperature coefficient.

Linear potentiometer





v = E (d/D)

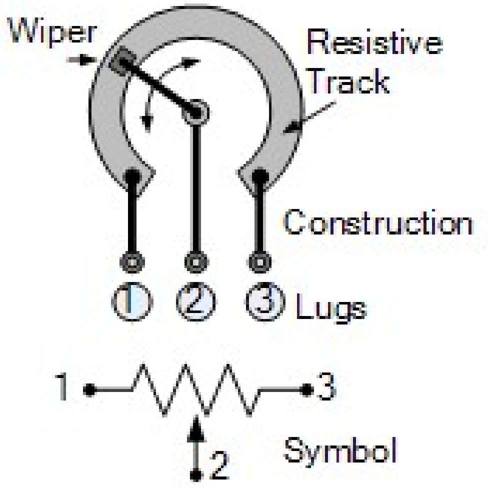
The voltage drop across the wiper of linear potentiometer:

$$V = E\,(d/D)$$

Where, D is full scale displacement, E is voltage across the pot , d is the displacement. Here the output signal is proportional to the excitation voltage applied across the sensor.

ROTARY POTENTIOMETER

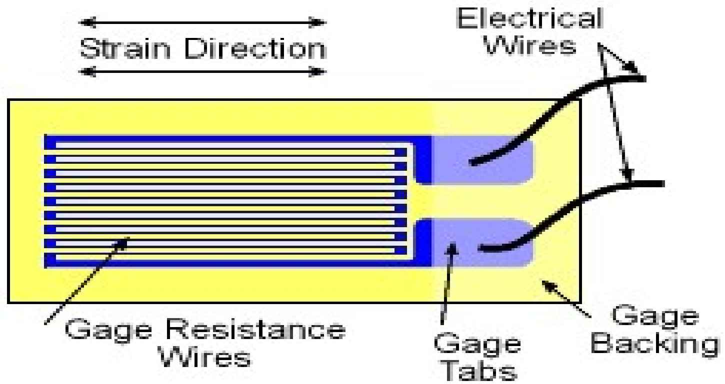
The **potentiometer**, commonly referred to as a "pot", is a three-terminal mechanically operated rotary analogue device which can be found and used in a large variety of electrical and electronic circuits.



They are passive devices, meaning they require a power supply or additional circuitry in order to perform their basic linear or rotary position function.
Variable potentiometers are available in a variety of different mechanical variations allowing for easy adjustment to control a voltage, current, or the biasing and gain control of a circuit to obtain a zero condition.

STRAIN GAUGE

A Strain gauge is a sensor whose resistance varies with applied force; It converts force, pressure, tension, weight, etc., into a change in electrical resistance which can then be measured.



Basic Linear Strain Gage

Strain gages are constructed from a single wire that is wound back and forth. The gage is attached to the surface of an object with wires in the direction where the strain is to be measured.
The electrical resistance in the wires change when they are elongated which results in a change in output voltage when the circuit is connected in a Wheatstone bridge assembly.

Strain gauge with Wheatstone bridge

Figure represents a strain gauge used with a Wheatstone bridge assembly. The three arms of the bridge are normal resistances while to the forth arm strain gauge is connected.

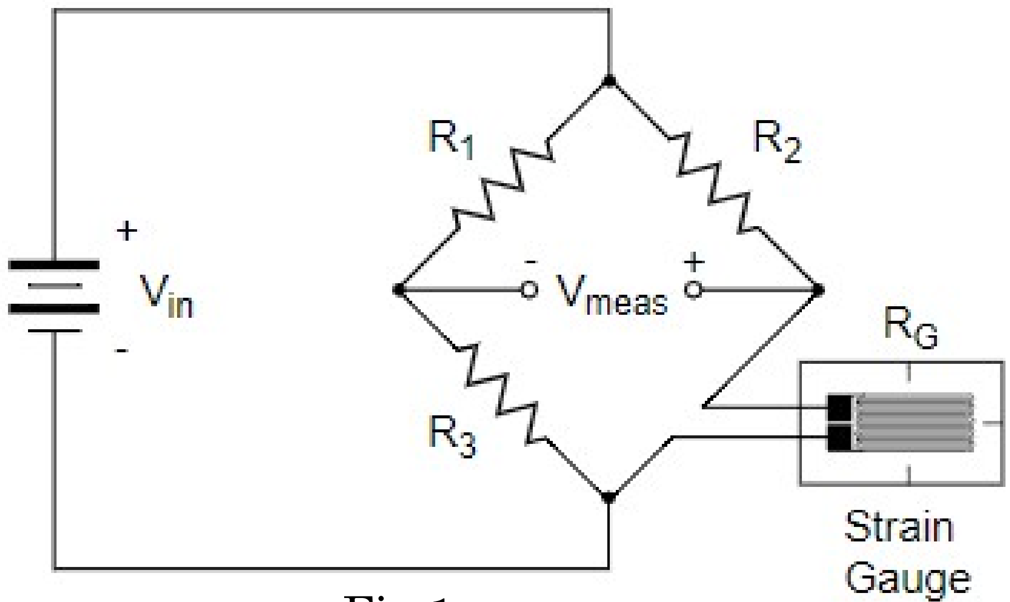
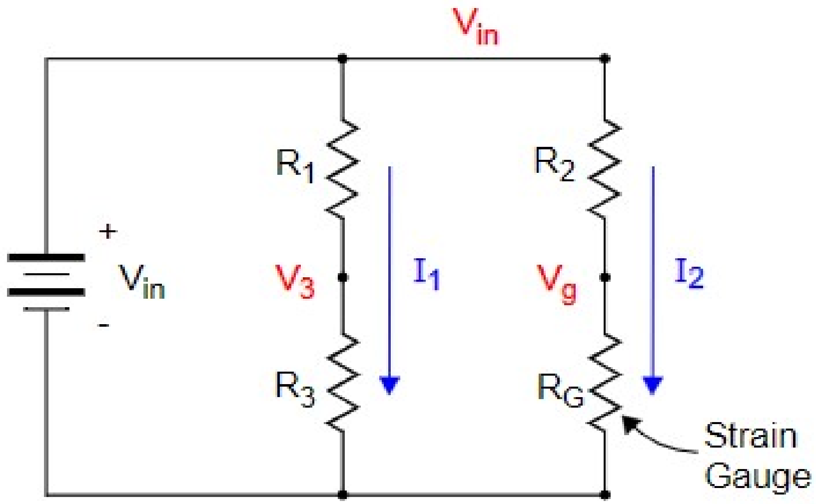


Fig.1

$$V_{meas} = V_{in}\left[\frac{R_G}{R_2 + R_G} - \frac{R_3}{R_1 + R_3}\right]$$

Circuit Analysis

We will analyse the circuit shown in fig. 1 as a voltage sensitive bridge.



$$I_1 = \frac{V_{in}}{R_1 + R_3}$$

$$I_2 = \frac{V_{in}}{R_2 + R_G}$$

$$V_3 = I_1 R_3$$

$$V_3 = V_{in}\frac{R_3}{R_1 + R_3}$$

$$V_g = I_2 R_G$$

$$V_G = V_{in}\frac{R_G}{R_2 + R_G}$$

The voltage across the voltmeter will be V_g-V_3

$$V_{meas} = V_{in}\left[\frac{R_G}{R_2 + R_G} - \frac{R_3}{R_1 + R_3}\right]$$

CONTINUED

The circuit shown in fig. 1 has an output voltage given by:

$$V_{meas} = V_{in}\left[\frac{R_G}{R_2 + R_G} - \frac{R_3}{R_1 + R_3}\right]$$

Let the the gauge's resistance, R_G is defined as the sum of its nominal zero-strain value, R_{Go} plus its change due to strain, ΔR_G

$$R_G = R_{G\,o} + \Delta R_G$$

Therefore the expression for the output voltage becomes:

$$V_{meas} = V_{in}\left[\frac{R_{G,o} + \Delta R_G}{R_2 + R_{G,o} + \Delta R_G} - \frac{R_3}{R_1 + R_3}\right]$$

CONTINUED

If all the resistances are equal then the expression becomes:

$$V_{meas} = V_{in}\left[\frac{R_{G,o} + \Delta R_G}{2R_{G,o} + \Delta R_G} - \frac{1}{2}\right]$$

Solving

$$V_{meas} = V_{in}\left[\frac{\Delta R_G}{4R_{G,o} + 2\Delta R_G}\right]$$

The term ΔR can be dropped from the denominator. Therefore

$$V_{meas} = V_{in}\left[\frac{1}{4R_{G,o}}\right]\Delta R_G$$

Hence V_{meas} is directly proportional to ΔR, hence proportional to strain.

Gauge factor

Gauge factor is defined as the ratio of fractional change in electrical resistance to the fractional change in length (strain):

$$GF = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\epsilon}$$

Relationship between gauge factor and poisson’s ratio

$$G_f = 1 + 2v + \frac{((\Delta\rho/\rho))}{\varepsilon}$$

Example – A resistance wire strain gauge uses a soft iron wire of small diameter. The gauge factor is +4.2. Neglecting the piezo resistive effects, calculate the Poisson's ratio.

Resistance thermometers

Resistance thermometers are a type of transducer used to measure temperature.

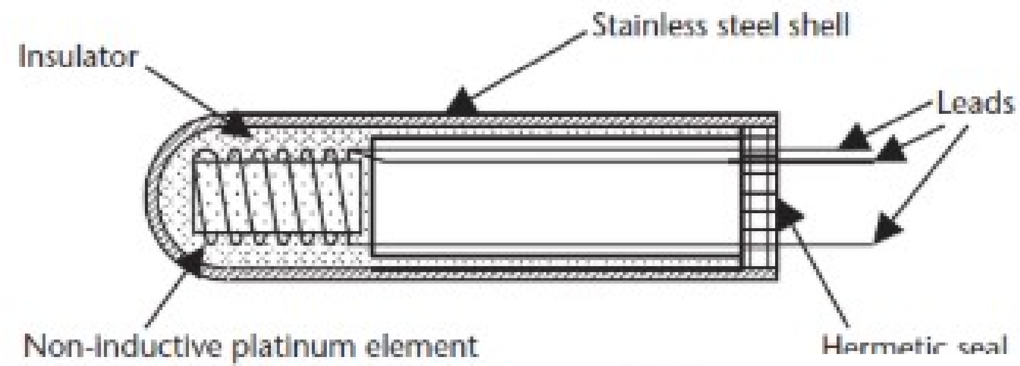
The working principle depends on the change in resistivity of any material when the temperature changes, and this change in the resistivity causes a change of resistance.

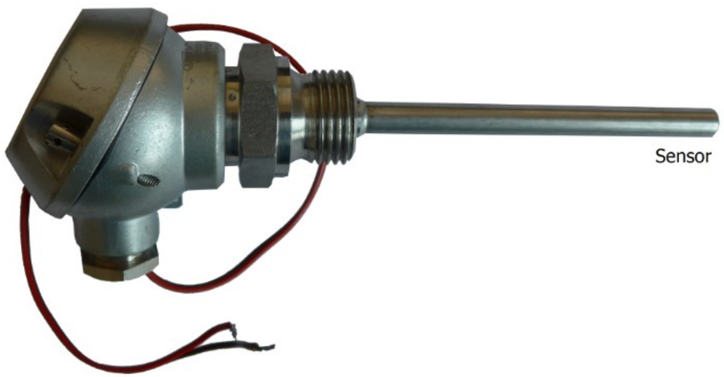
They are also known by a number of different names including Resistance temperature detectors (RTDs), Platinum resistance thermometers (PRTs) or Pt100 sensors.

Resistance thermometers are usually used to measure temperatures between -200 and 500°C.

CONTINUED

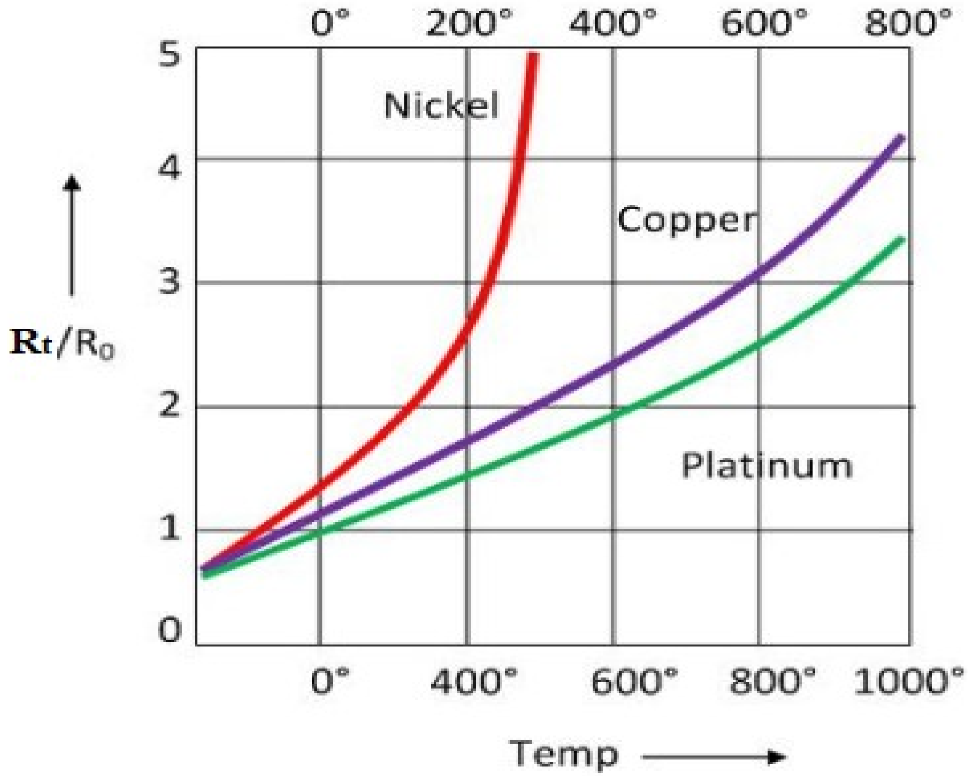
A platinum resistance thermometer consists of a platinum coil that is present inside a cross frame. A common style involves wires wound on glass or ceramic bobbin formers that have similar temperature versus expansion characteristics to that of the platinum wire. The whole arrangement is placed in an evacuated tube which is made of stainless steel.





Characteristics

The resistance versus temperature curve for an RTD with different materials is shown below:



Platinum is preferred among all the elements due to its high linearity than the other elements.

Relationship of Resistance and Temperature in RTDs

Compared to other temperature devices, the output of an RTD is relatively linear with respect to temperature. The temperature coefficient, called alpha (α), differs between RTD curves.

$$\alpha(\Omega/\Omega/°C) = (R_{100} - R_0)/(R_0 * 100° C)$$

Alpha is most commonly defined as the change in RTD resistance from 0 to 100° C, divided by the resistance at 0° C, divided by 100° C

Although the resistance-temperature curve is relatively linear, accurately converting measured resistance to temperature requires curve fitting. The Callendar-Van Dusen equation is commonly used to approximate the RTD curve:

$$R_t = R_0[1 + At + Bt^2 + C(t - 100)^3]$$

Where R_t is the resistance of the RTD at temperature = t, R_0 is the resistance of the RTD at 0° C, A, B, and C are the Callendar-Van Dusen coefficients

THERMISTOR

Thermistor is a two terminal solid state temperature sensing device which acts a bit like an electrical resistor but is highly temperature sensitive. They are constructed using sensitive semiconductor based metal oxides with metallized connecting leads formed into a ceramic disc or bead. Thermistors can be used to produce an analogue output voltage with variations in ambient temperature and as such can be referred to as a transducer.

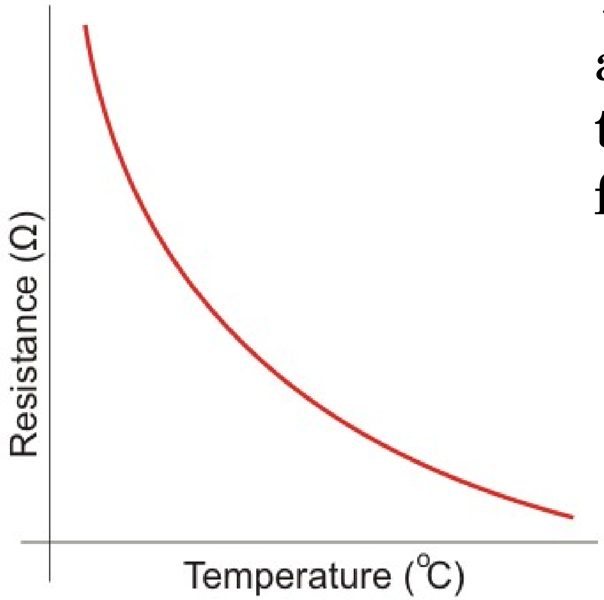
"Thermistor" is a combination of the words THERM-ally sensitive res-ISTOR.

Uses

- Digital thermometers
- To measure oil and coolant temperatures in cars & trucks
- Household appliances (like microwaves, fridges)

CHARACTERISTICS

In an NTC (negative temperature coefficient) thermistor, when the temperature increases, resistance decreases. These are the most common type of thermistor.



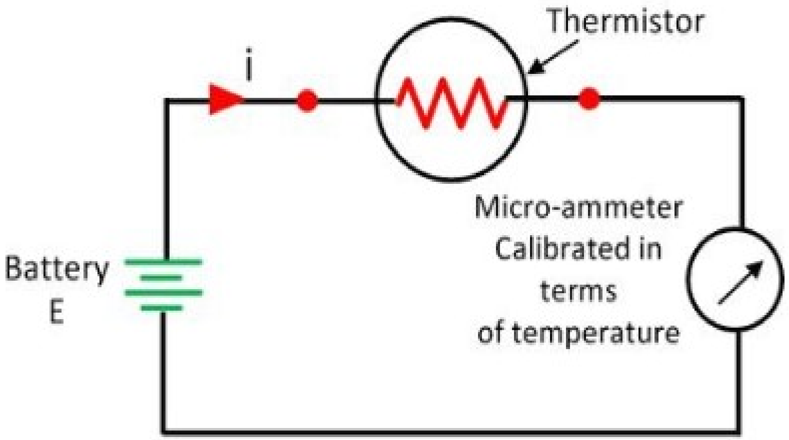
The relationship between resistance and temperature in an NTC thermistor is governed by the following expression:

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

- R_T is the resistance at temperature T (K)
- R_0 is the resistance at temperature T_0 (K)
- T_0 is the reference temperature (normally 25°C)
- β is a constant, its value is dependant on the characteristics of the material.

Thermistor Circuits

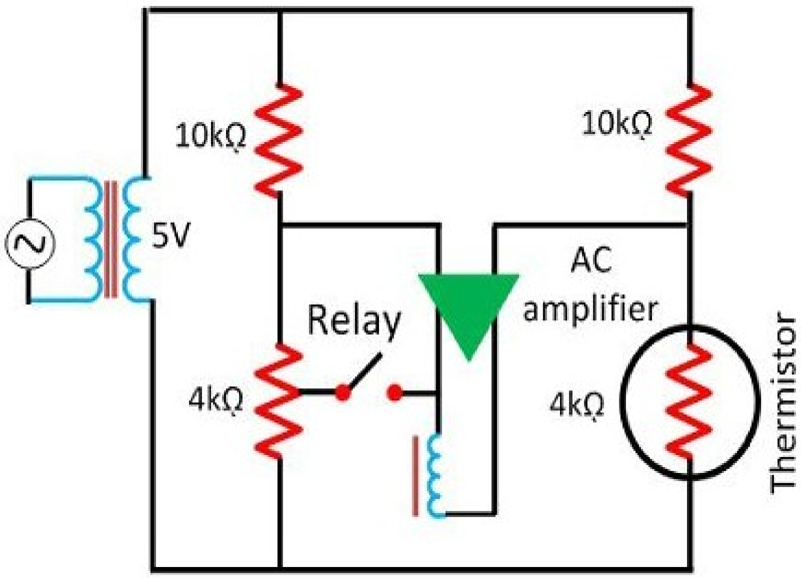
1 Measurement of Temperature



The small change in temperature causes a change in the resistance of thermistor which relatively changes the current of the circuit.

2 Control of Temperature

The unbalance voltage applied to an amplifier, and the output of the amplifier excites the relay. The relay controls the circuit current and generates heat.



RTD VS THERMISTOR

- The main difference between RTDs and thermistors is the material they are made of. While RTD resistors are pure metal, thermistors are made with polymer or ceramic materials.

- **Range:** Unlike RTDs, thermistors can only monitor a smaller range of temperature. While some RTDs can reach 600°C, thermistors can only measure up to 130°C. If the application involves temperatures above 130°C, the only option is the RTD probe.

- **Cost:** Thermistors are quite inexpensive compared with RTDs. If your application temperature matches the available range, thermistors are probably the best option.

- **Sensitivity:** Both thermistors and RTD react to temperature changes with predictable changes in resistance. However, thermistors change resistance by tens of ohm per degree, compared to a smaller number of ohms for RTD sensors. With the appropriate meter, the user can therefore obtain more accurate readings. Thermistor response times are also superior to RTDs, detecting changes in temperature much faster. The sensing area of a thermistor can be as small as a pin head, delivering quicker feedback.

THANK YOU