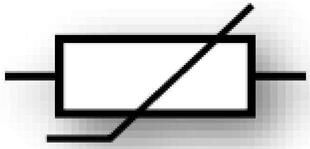
THERMISTORS



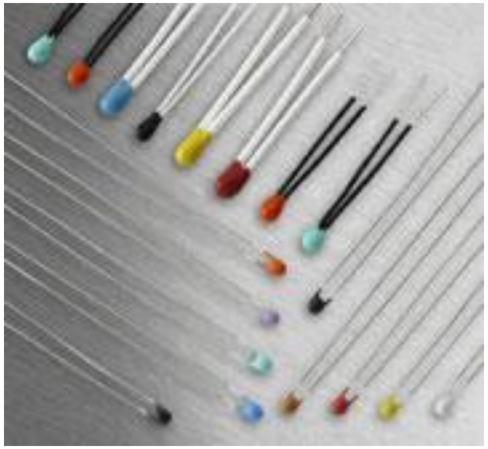
Thermistor symbol

Thermistors

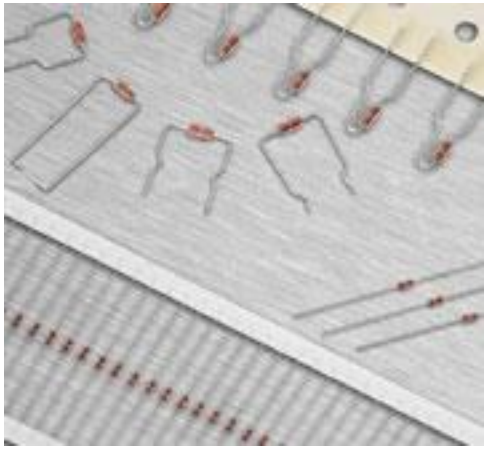
THERMal resISTORS

- A thermistor is a type of resistor used to measure temperature changes,
- It changes its resistance (R) with changing temperature T.

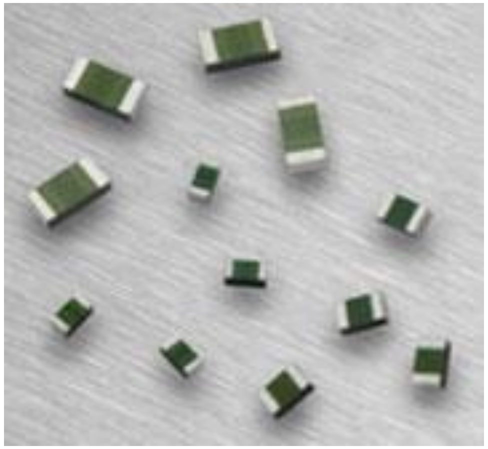
- Thermistor is a combination of the words thermal and resistor.
- The Thermistor was invented by Samuel Ruben in 1930, and has U.S. Patent #2,021,491.



Leads, coated



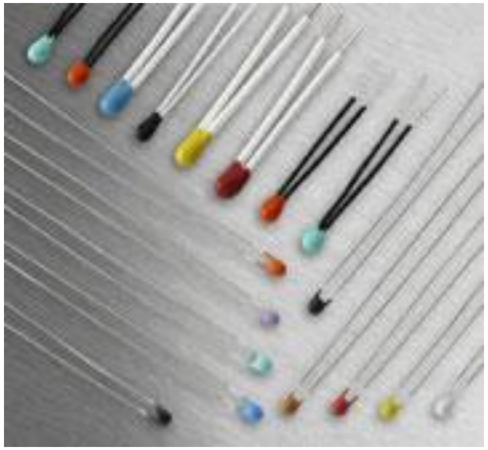
Glass encased



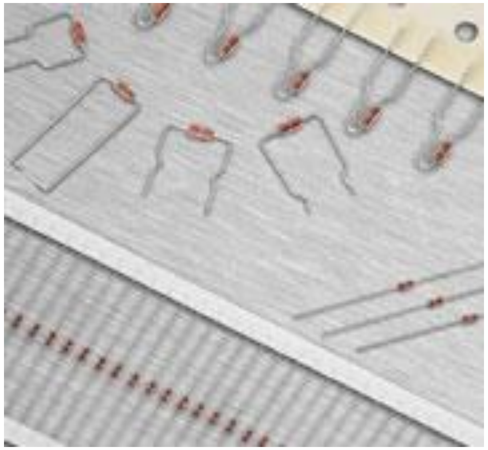
Surface mount

Thermistors
THERMal resISTORS

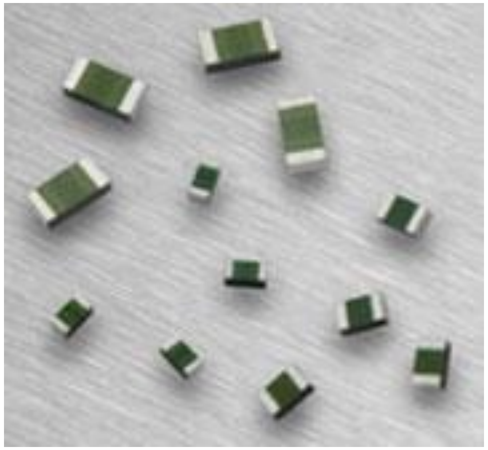
Thermistors are made of semiconductor materials (metallic compounds including oxides such as manganese, copper, cobalt, and nickel, as well as single-crystal semiconductors silicon and germanium).



Leads, coated



Glass encased



Surface mount

Thermistors
THERMal resISTORS

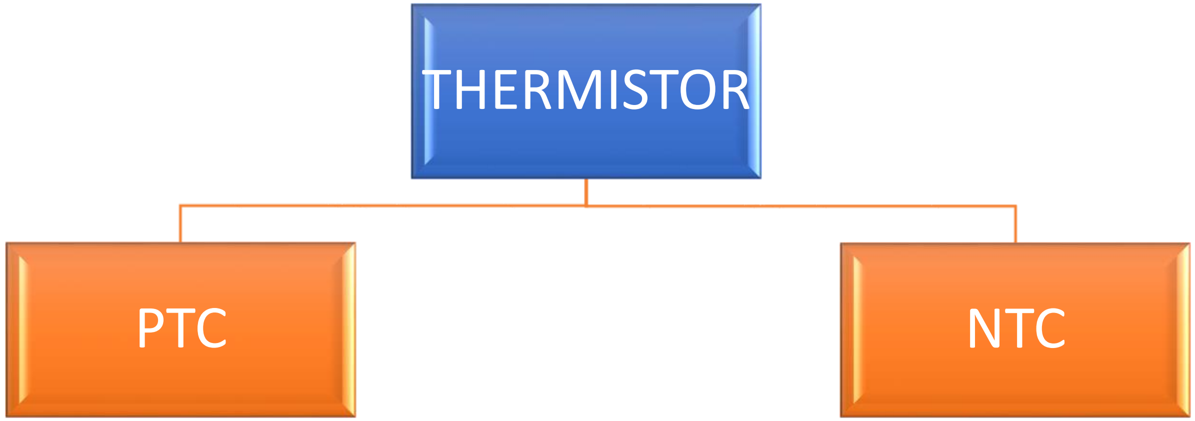
Assume a simple linear relationship between resistance and temperature for the following discussion:

$$\Delta R = k \, \Delta T$$

ΔR = change in resistance

ΔT = change in temperature

k = first-order temperature coefficient of resistance



- **There are two basic types of thermistors** —
  negative temperature coefficient (NTC)
  &
  positive temperature coefficient (PTC).

- NTC thermistors are much more commonly used than PTC thermistors.

- NTC thermistors give a relatively large output (change of resistance) for a small temperature change

Thermistors can be classified into two types depending on the sign of k.

$$\Delta R = k \, \Delta T$$

If k is positive, the resistance increases with increasing temperature, and the device is called a positive temperature coefficient (PTC) thermistor, Posistor.

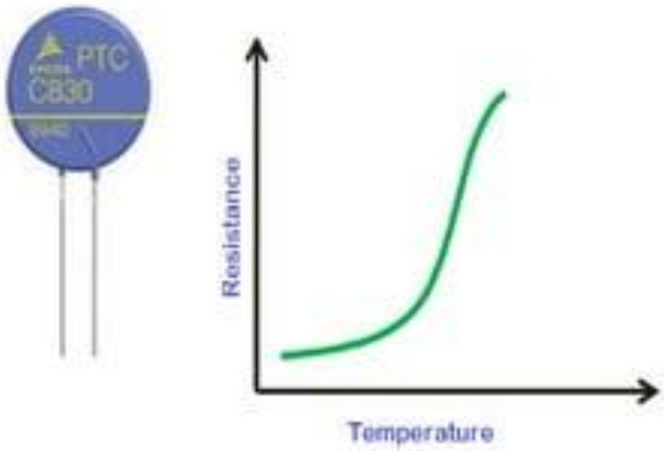
If k is negative, the resistance decreases with increasing temperature, and the device is called a negative temperature coefficient (NTC) thermistor.

THERMAL SENSORS

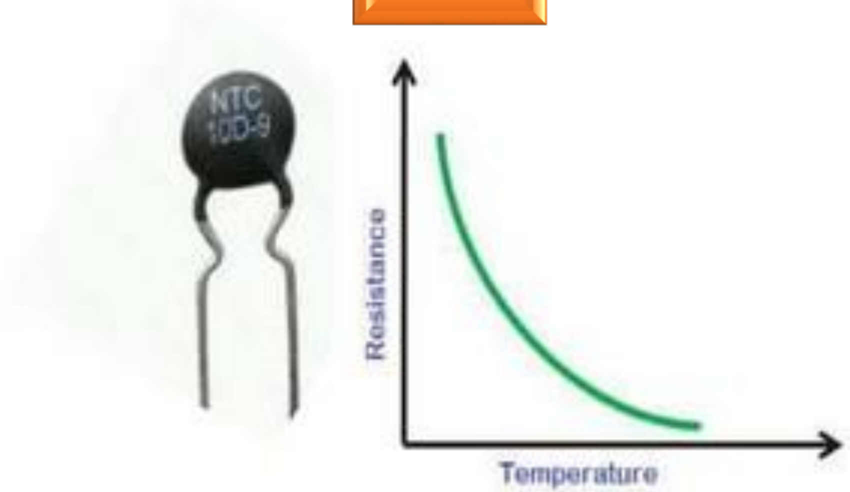
THERMISTOR

PTC

NTC

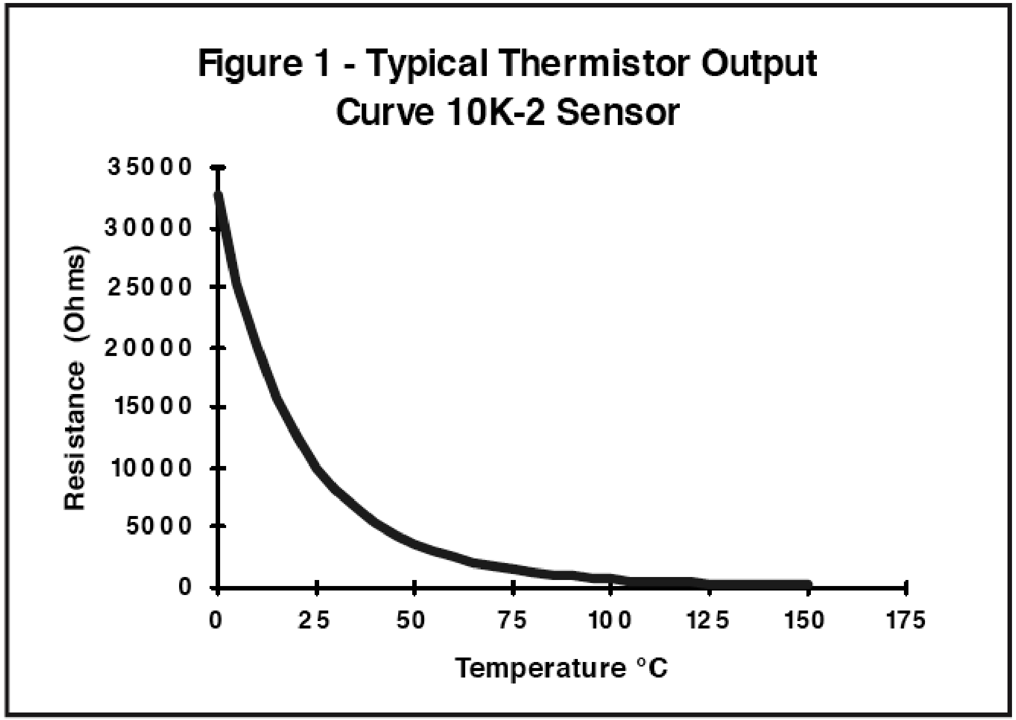


- PTC stands for *Positive Temperature Coefficient*. As temperature rises, resistance increases . This type of thermistor is used in
- Current limiting devices
- Self regulating heaters
- Timer in degaussing coil
- Motors



- NTC stands for *Negative Temperature Coefficient*. As temperature rises, resistance decreases . These are employed in
- Very low temperature thermometer
- Digital Thermostats
- Battery pack monitors
- In-rush protection devices

THERMISTOR



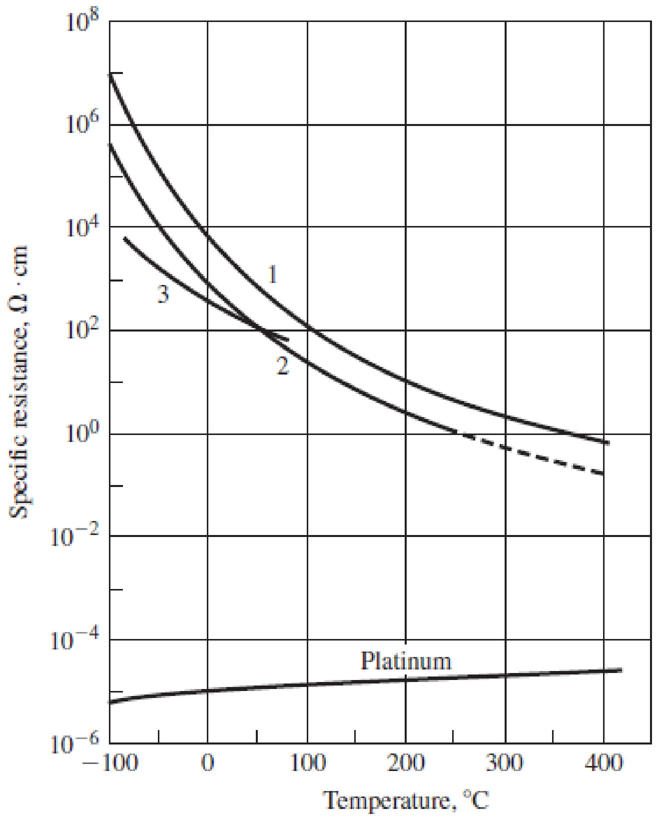
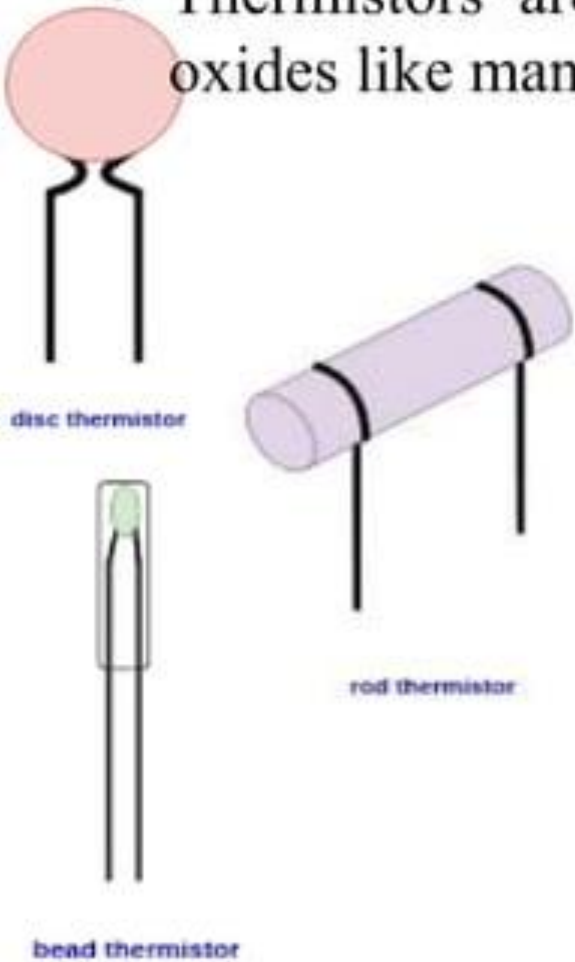
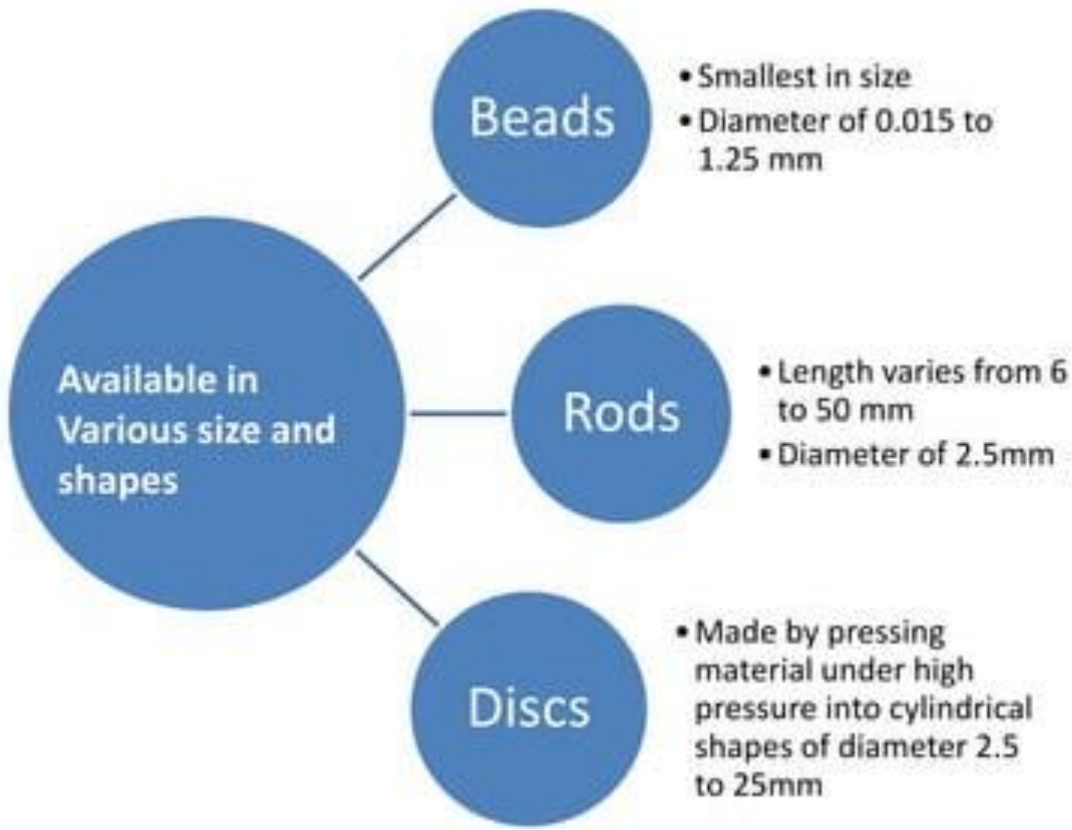


Figure 8.8 Resistivity of three thermistor materials compared with platinum, according to Ref. [1].

Construction :

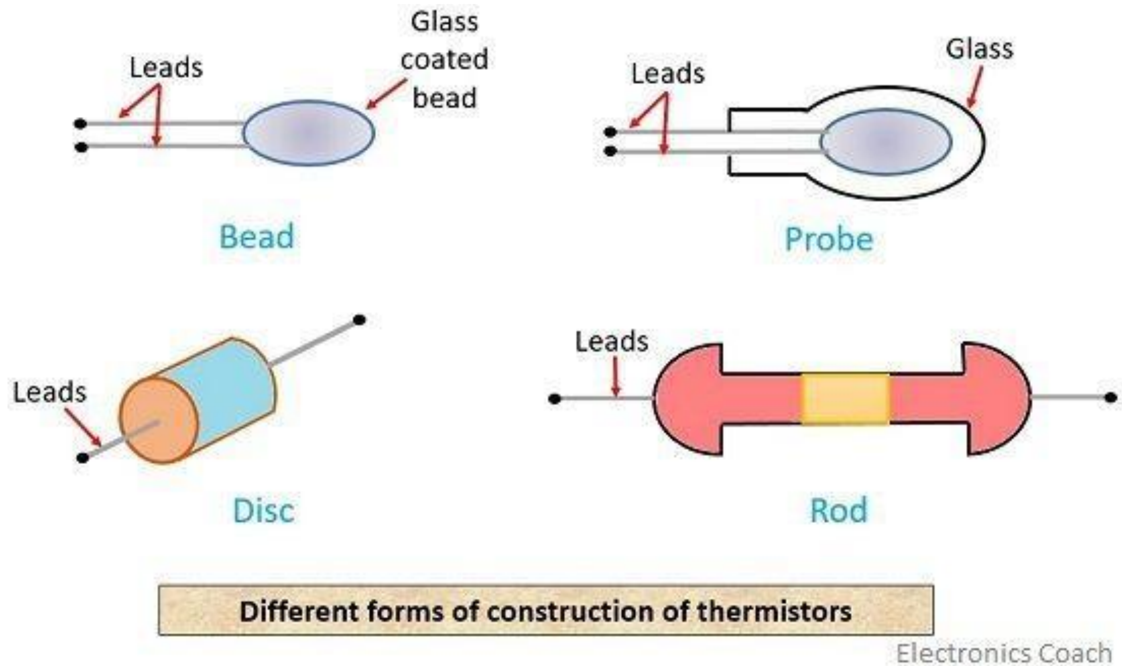
- Thermistors are composed of sintered mixture of metallic oxides like manganese, nickel, cobalt, iron and uranium.





- To make a thermistor, two or more semiconductor powders of metallic oxides are mixed with a binder to form a slurry.
- Small drops of this slurry are formed over the lead wires & dry it on into a sintering furnace.
- During this process, the slurry will shrink onto the lead wires to make an electrical connection.
- This processed metallic oxide is sealed by putting a glass coating on it. This glass coating gives a waterproof property to the thermistors – helping to improve their stability.

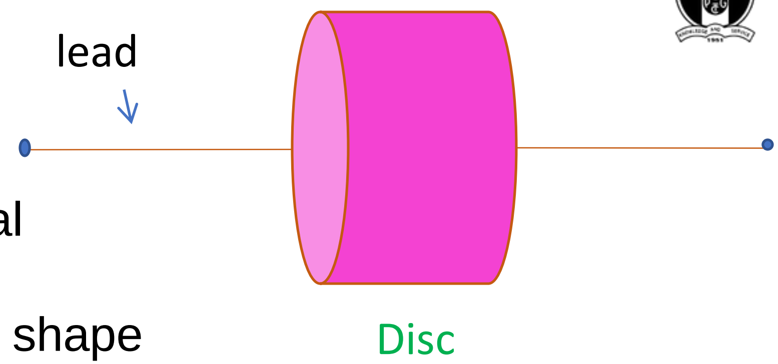
- Thermistors are fabricated in wafer, disk, bead and other shapes



Beads :

- The smallest thermistor
- Diameter of the beads - 0.15 mm to 125 mm
- Beads sealed in the tips of solid glass rods form Probe
- Resistance ranges from 300 Ω to 100 Ω
- Probes measure temperature of the liquids

Disc shaped thermistors :



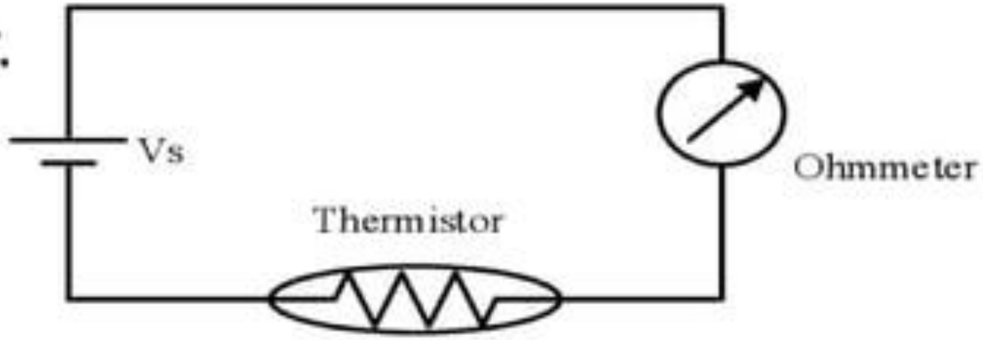
- These are formed by pressing thermistor material
- Under high pressure pressed into flat cylindrical shape
- Disc diameter - 1.25 mm to 25 mm
  thickness - 0.25 mm to 0.75mm
- Resistance of the disc varies from 1 Ω to 0.75 Ω
- These are mainly used for temperature control

Washer shaped Thermistors :

- These are Disc thermistors with a hole at the center
- These are suitable for mounting on a bolt

Working Principle :

- It works by its dependency on-resistance values on the change in temperature which is depending upon the material chosen in the construction of the thermistor
- The value of resistance can be measured by using an ohmmeter. These are connected in series with the battery and the meter.

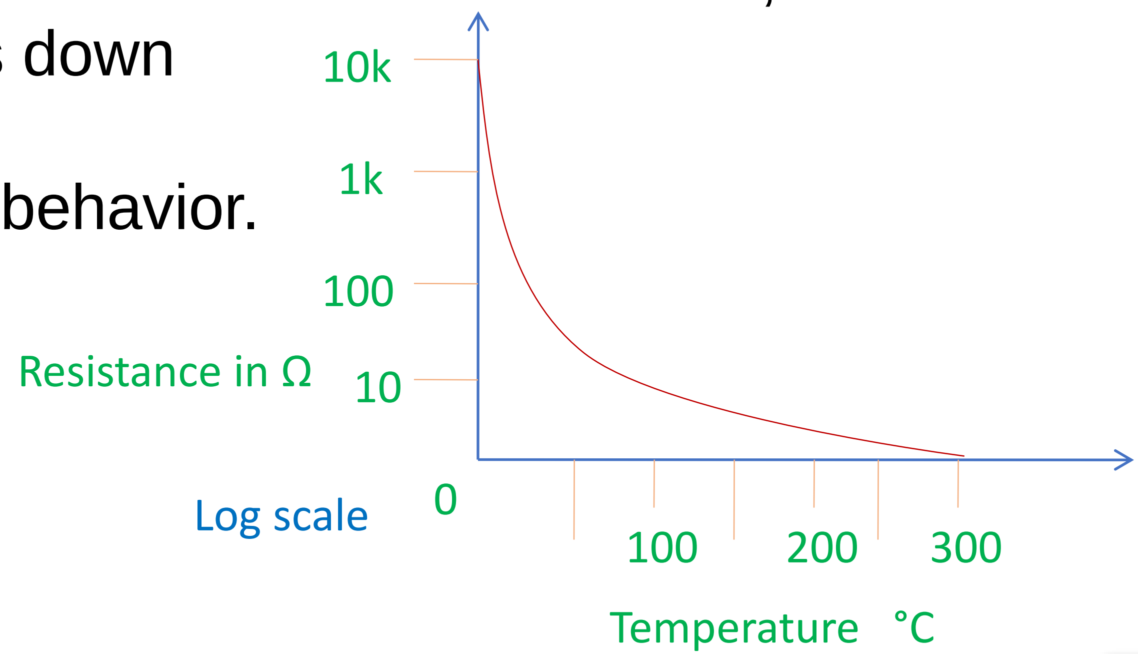


The resistance of NTC thermistors decreases with increasing temperature:

- Under normal temperatures there is an energy barrier to moving electrons from site to site.

- As thermal energy rises with temperature the ability of electrons to surmount this barrier increases, so that resistivity goes down

—hence the NTCR behavior.



- The relation between the temperature and the resistance of the thermistor is mathematically expressed by the equation :

$$R_{T1} = R_{T2} exp\left[\beta\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right]$$

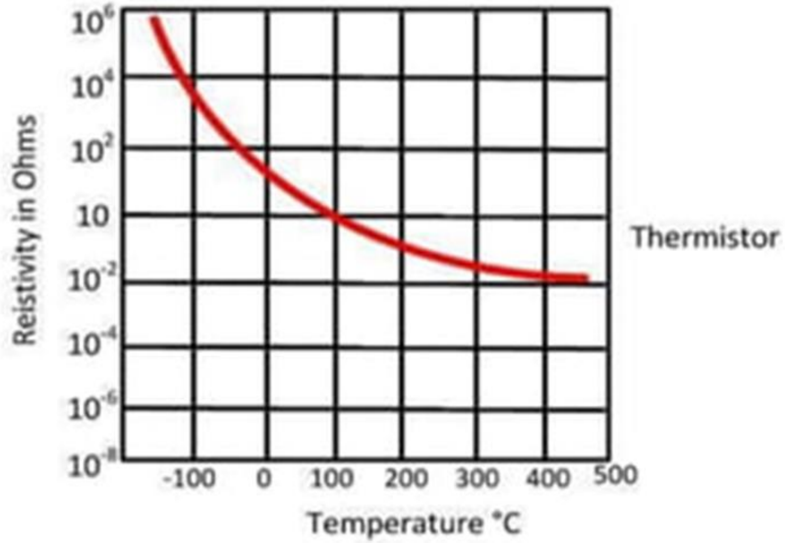
Where,

R_{T1} - Resistance of the thermistor at temperature T_1 in Kelvin.

R_{T2} - Resistance of the thermistor at temperature T_2 in Kelvin.

β -temperature depending on the material of thermistor.

The resistance of the thermistor changes from 10^5 to 10^{-2} at the temperature between -100°C to 400°C.



Applications of Thermistors

PTC type Thermistors :

- Current limiting devices in circuit protection as replacement for fuse
- Heating elements in small temperature controlled ovens

NTC type Thermistors :

- Resistance Thermometer in low temperature measurements of the order of 10 K
- Inrush-current limiting devices in power supply circuits (They present a higher resistance initially which prevents large currents)
- Commonly used in modern digital thermostat to monitor the temperature of battery packs while charging.

Applications:

- Digital thermometers
- Used in Automobiles to determine and record the temperature of the oil and coolant found in the engine.
- Rechargeable battery has a Thermistor built in it, to regulate the temperature and helps the battery not to get burnt.
- Wield as circuit protection element.

Pros	Cons
✓ Compact, rugged and inexpensive ✓ Good stability and high sensitivity ✓ Response time is fast ✓ Not affected by stray magnetic and electric field	x Non-linear output is seen x Not suitable for high temperature measurement x Shielded cables must be used to minimize interference x Self heating

Advantages:

1.Smaller size
2.Large change in resistance for a given temperature
3.Fast response over a narrow temperature range
4.Contact and lead resistance problems not encountered

Limitations:

1.Not suitable over a wide range of temperature
2. Need of shielded cables, filters, etc
(to minimize the interference) due to high resistance
3.Very low excitation current to avoid self-heating

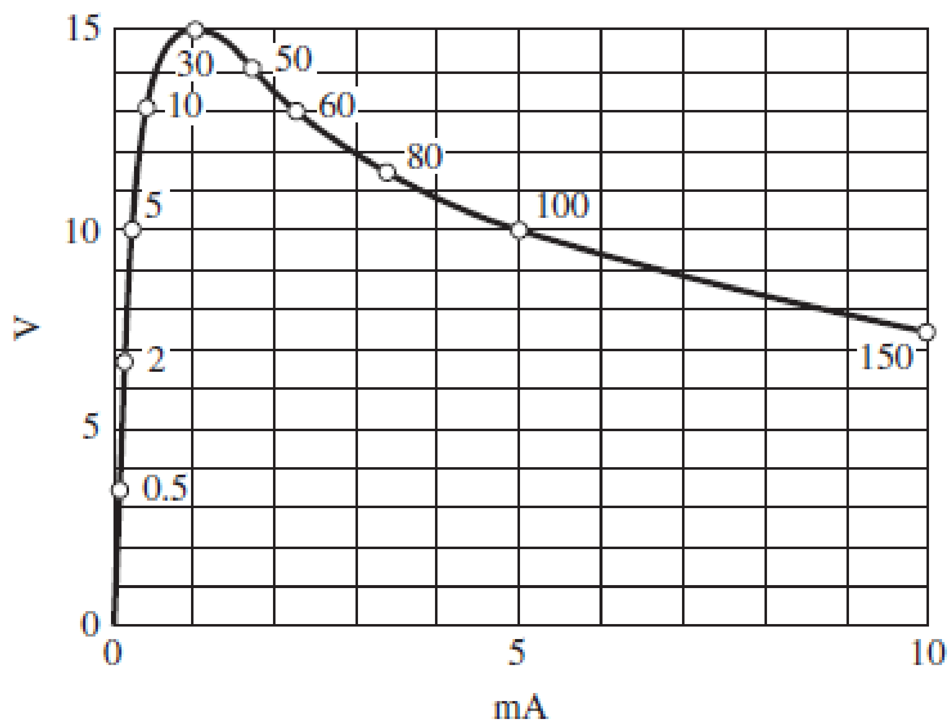


Figure 8.9 Static voltage-current curve for a typical thermistor, according to Ref. [1].

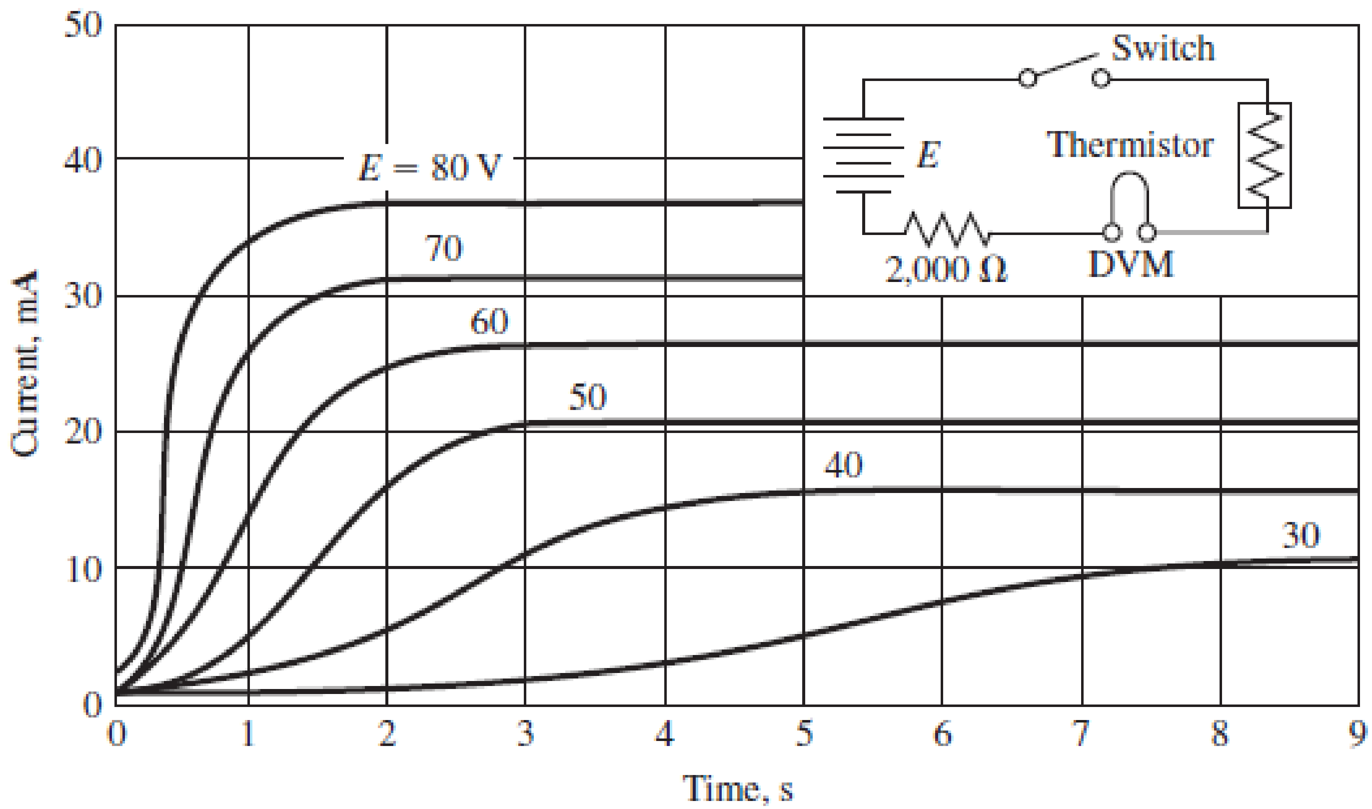


Figure 8.10 Typical set of transient voltage-current curves for a thermistor, according to Ref. [1]. Circuit for measurement is shown in insert.

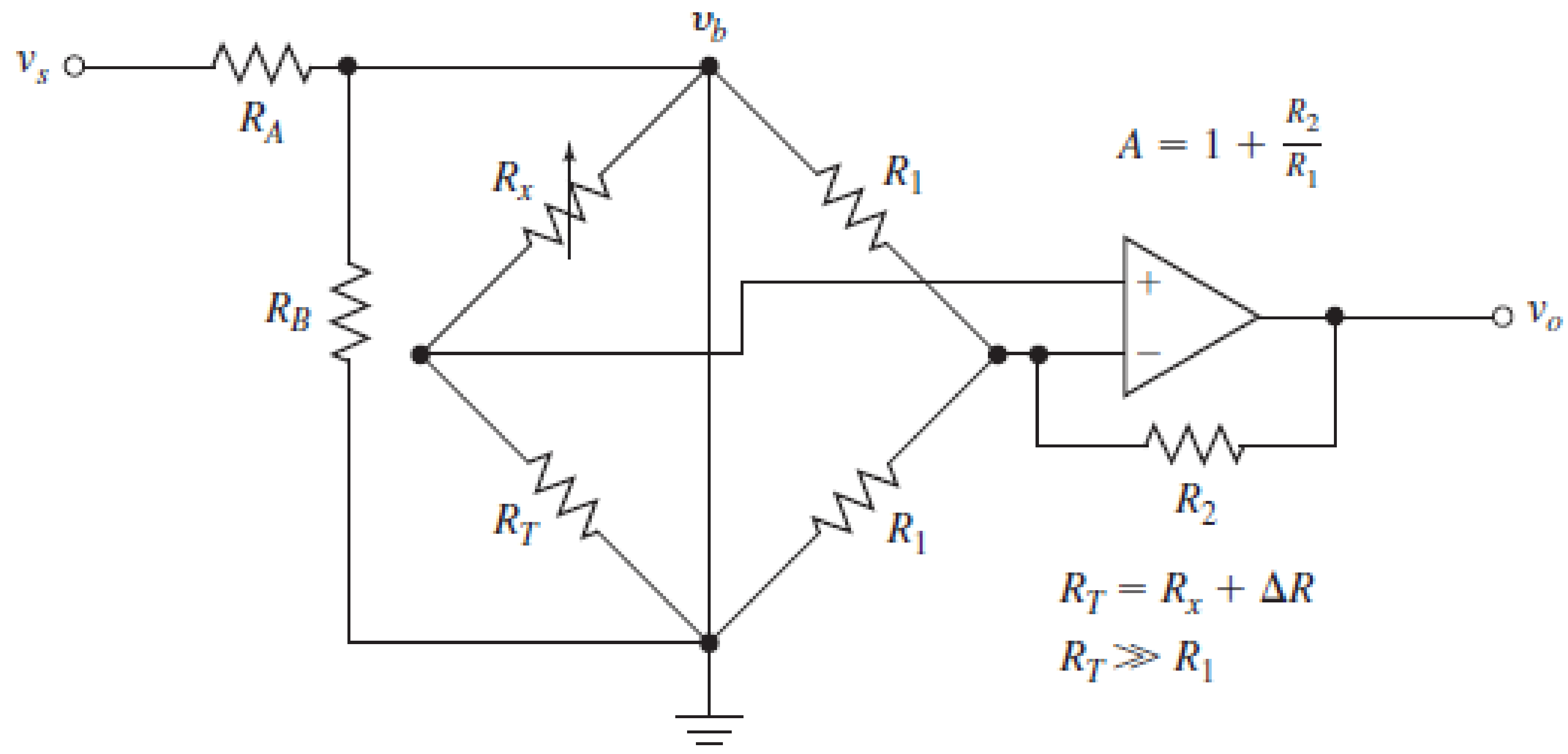


Figure 8.11 Bridge amplifier circuit, according to Ref. [24].

For linear operation we must have $R_T \gg R_1$ and R_B is approximately $R_1/10$. The amplifier voltage gain is $A = 1 + R_2/R_1$. If these conditions are satisfied, the output voltage can be expressed as

$$v_o = \frac{A v_b \alpha \, \Delta T}{4} \qquad \textbf{[8.9]}$$

where α is the temperature coefficient of resistance and ΔT is the temperature difference from balanced conditions, i.e., from $\Delta R = 0$.

Example 8.3 **THERMISTOR SENSITIVITY.** Calculate the temperature sensitivity for thermistor No. 1 in Fig. 8.8 at 100°C. Express the result in ohm-centimeters per degree Celsius. Take $\beta = 4120$ K at 100°C.

Solution

The sensitivity is obtained by differentiating Eq. (8.8).

$$S = \frac{dR}{dT} = R_0 \exp\left[\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)\right]\left(\frac{-\beta}{T^2}\right)$$

We wish to express the result in resistivity units; thus, the resistivity at 100°C is inserted for R_0. Also,

$$T = T_0 = 100^\circ\text{C} = 373\ \text{K}$$

so that

$$S = -\rho_{100^\circ\text{C}}\frac{4120}{(373)^2}$$

$$= -\frac{(110)(4120)}{(373)^2} = -3.26\ \Omega \cdot \text{cm}/^\circ\text{C}$$