ROHINI COLLEGE OF ENGINEERING & TECHNOLOGY
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DEPARTMENT OF BIOMEDICAL ENGINEERING

III Semester- BM3301 SENSORS AND MEASUREMENTS

UNIT - 2

2.5 Thermistor Characteristics

2.5 Thermistors:

- Thermistor is a contraction of a term "**thermal resistors**".
- Thermistors are generally composed of **semi-conductor materials**.
- Although positive temperature co-efficient of units (which exhibit an increase in the value of resistance with increase in temperature) are available, most thermistors have a **negative coefficient of temperature resistance** i.e. their resistance decreases with increase of temperature.
- The negative temperature coefficient of resistance can be as large as several percent per degree Celsius.
- This allows the thermistor circuits to **detect very small changes** in temperature which could not be observed with an RTD or a thermocouple. In some cases, the resistance of thermistor at room temperature may decrease as much as 5 percent for each 1°C rise in temperature.
- This high sensitivity to temperature changes makes thermistors extremely useful for **precision temperature measurements** control and compensation.
- Thermistors are widely used in applications which involve measurements in the range of **- 60°C to 15°C**. The resistance of thermistors ranges from **0.5 Ω to 0.75 MΩ.**
- Thermistor is a **highly sensitive** device.
- The thermistor exhibits a highly **nonlinear characteristic** of resistance versus temperature.

2.5.1 Construction of Thermistors :

- The thermistor consists of a **metal tube, leads, and temperature sensing** element.
- The **temperature sensing element** is the main part of the thermistor, which senses temperature variations enclosed in a metal tube.
- The sensing element is basically a **thermal resistor** made with sintering (pressing) mixtures of metallic oxides like copper, nickel, cobalt, iron, manganese, and uranium.
- The sensing element is covered with an **insulating material** before enclosing it with the metal tube.
- **Two leads** are connected to the temperature sensing element and are brought out of the metal tube.
- The other end of the two leads is connected to one of the **arms of the bridge** circuit (generally Wheatstone bridge is used) which measures the resistance of the temperature sensing element.
- The commercial thermistors are made in the form of **beads, probes, discs**, **and rods** in a variety of sizes as shown in Figure 1.
- Thermistors are highly sensitive to temperature variations, which makes them suitable for **precise temperature** measurements.
- They are used for measuring temperatures ranging from **-100°C to +300°C.**

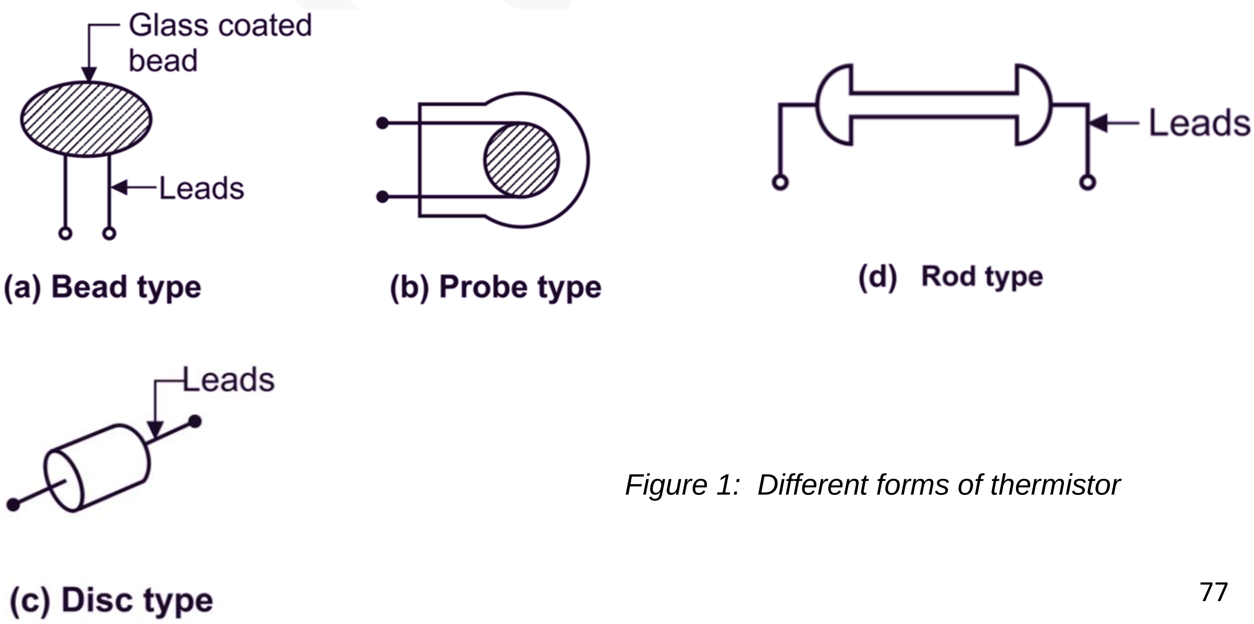

Figure 1: Different forms of thermistor

- A thermistor in the form of a bead is smallest in size and the bead may have a diameter of 0.015 mm to 1.25 mm.
- Beads may be sealed in the tips of solid glass rods to form probes which may be easier to mount than the beads.
- Glass probes have a diameter of about 2.5 mm and a length which varies from 6 mm to 50 mm.
- Discs are made by pressing material under high pressure into cylindrical flat shapes with diameters ranging from 2.5 mm to 25 mm.

2.5.2 Characteristics of Thermistor:

Three important characteristics of thermistor make them extremely useful in measurement and control applications. These are :

- the resistance-temperature characteristics.
- the voltage-current characteristics.
- A the current-time characteristics.

2.5.3 Resistance-Temperature Characteristics of Thermistors:

The mathematical expression for the relationship between the resistance of a thermistor and absolute temperature of thermistor is :

$$R_{T_1} = R_{T_2} \exp\left[\beta\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

where R_{T_1}= resistance of the thermistor at absolute temperature; T_1° K

R_{T_2} = resistance of the thermistor at absolute temperature T_2° K and

β = a constant depending upon the material of thermistor,
typically, 3500 to 4500 °K

The resistance temperature characteristics of a typical thermistor are given in *Figure 2*

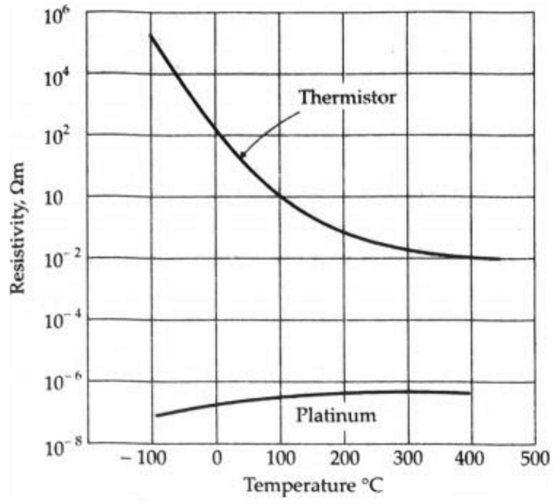

Figure 2. *Resistance-temperature characteristics of a typical thermistor and platinum*

The resistance temperature characteristics of Figure 2 shows that a thermistor has a very high negative temperature co-efficient of resistance, making it an ideal temperature transducer.

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The characteristics of thermistors are no doubt non-linear but a linear approximation of the resistance-temperature curve can be obtained over a small range of temperature. Thus, for a limited range of temperature, the resistance of a thermistor varies as given by Eqn. 2.

$$R_\theta = R_{\theta_0}[1 + \alpha_{\theta_0} \Delta\theta] \quad \text{...} \quad (2)$$

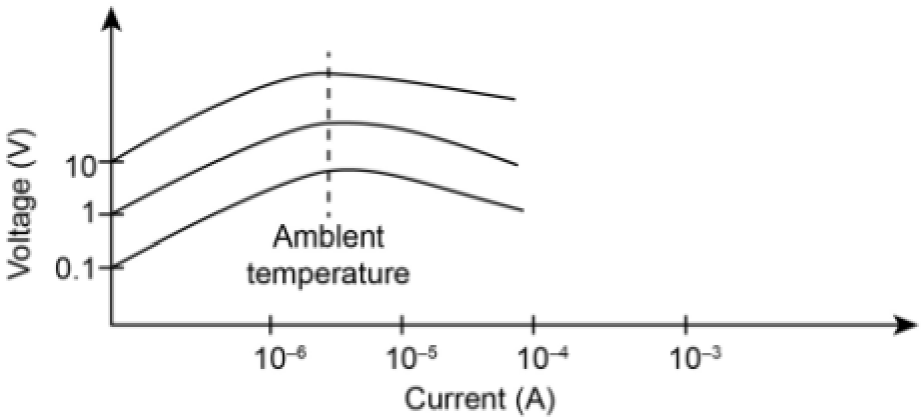
A thermistor exhibits a negative resistance temperature co-efficient which is typically about 0.05/°C. Another relationship that can be conveniently used for resistance-temperature curve of thermistors is:

$$R_T = aR_0 \exp(b/T) \quad \text{................................} \quad (3)$$

where, R_T, R_0= resistance of thermistor at temperature T°K and ice point respectively.

2.5.4 Voltage-Current Characteristics of Thermistors:

These characteristics are shown in Figure 3. Figure 3 shows that the voltage drop across a thermistor increases with increasing current until it reaches a peak value beyond which the voltage drop decreases as the current increases. In this portion of the curve, the thermistor exhibits a negative resistance characteristic.



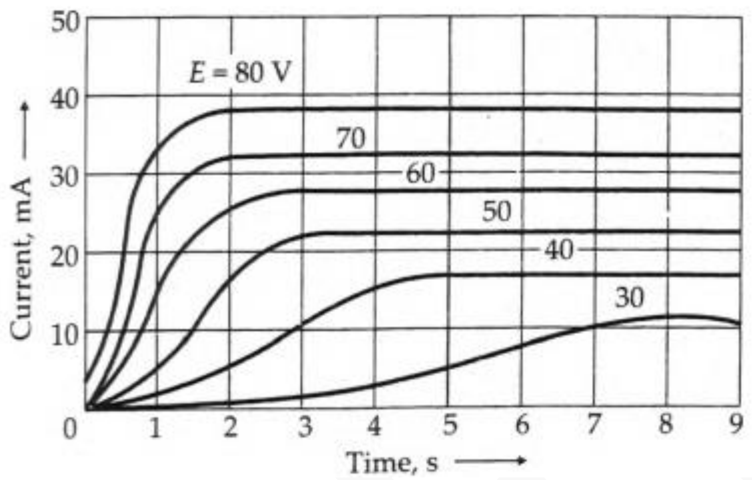
Voltage Vs. Current characteristics

Figure 3 *Voltage-current characteristics of thermistors.*

If a very small voltage is applied to the thermistor, the resulting small current does not produce sufficient heat to raise the temperature of the thermistor above ambient. Under this condition, Ohm's law is followed and the current is proportional to the applied voltage. Larger currents, at larger applied voltages, produce enough heat to raise the thermistor temperature above the ambient temperature and its resistance then decreases. As a result, more current is then drawn and the resistance decreases further. The current continues to increase until the heat dissipation of the thermistor equals the power supplied to it. Therefore, under any fixed ambient conditions, the resistance of a thermistor is largely a function of the power being dissipated within itself, provided that there is enough power available to raise its temperature above ambient.

Under such operating conditions, the temperature of the thermistor may rise 100°C or 200°C and its resistance may drop to one-thousandth of its value at low current. This characteristic of self-heat provides an entirely new field of uses for the thermistor. In the self-heat state, the thermistor is sensitive to anything that changes the rate at which heat is conduced away from it. It can so be used to measure flow, pressure, liquid level, composition of gases, etc. If, on the other hand, the rate of heat removal is fixed, then the thermistor is sensitive to power input and can be used for voltage or power-level control.

2.5.5 Current Time Characteristics of Thermistor:



When we increase the applied voltage then the time delay also increases to reach the maximum current, and when decreasing the voltage level then the time delay to reach the maximum current is also decreasing, this happens because of the heating effect. At the low voltage, the thermistor produces low heat and at lower heat the resistance is high.

2.5.6 Advantages of Thermistors:

1. Temperature Sensitivity
2. Rapid Response
3. Small Size
4. Wide Temperature Range
5. Cost-Effective compared to other temperature sensor
6. Simple Circuitry
7. Good Long-term Stability:

2.5.7 Disadvantages of Thermistors:

1. Non-Linearity

2. Limited Operating Range
3. Self-Heating Effect
4. Fragility if subjected to excessive mechanical stress
5. To achieve accurate temperature measurements, thermistors often require calibration
6. Sensitivity to Environmental Factors

2.5.8 Medical Applications of Thermistors

1. Thermistors are commonly used in medical devices to measure **body temperature**. They can be incorporated into oral, rectal, or ear
2. Thermistors are used in **neonatal incubators** and warming devices to maintain a stable and precise temperature.
3. Thermistors are employed in devices that **warm blood** and intravenous fluids before they are administered to patients.
4. Thermistors are utilized in **magnetic resonance imaging** (MRI) machines to monitor and control the temperature of the equipment.
5. Thermistors play a role in monitoring and regulating the temperature of air and gases delivered to patients through **ventilators**.
6. Thermistors are employed to monitor and ensure the proper temperature during the transportation and storage of temperature-sensitive **medications and vaccines.**