CHAPTER 4

MEASURING DEVICES
(SENSOR & TRANSDUCER)
ACTIVE TRANSDUCER
ACTIVE TRANSDUCER

- Also known as self generating transducer.
- Do not require an external power and they produce an analog voltage or current when stimulated by some physical form or energy.

Examples:
- RTD
- THERMISTOR
- THERMOCOUPLE
RTD

- RTD is a Resistance Temperature Detector.
- RTD are temperature sensors that are based on the principles; metal resistance increasing with temperature.
- RTD are made of materials whose resistance changes in accordance with temperature.
- It is commonly employ platinum, nickel as resistance wires elements whose resistance varies with temperature.

A commercial Thermo Works RTD probe
RTD CONT’D
## RTD CONT’D

<table>
<thead>
<tr>
<th>Type of RTD</th>
<th>Temperature Range °C</th>
<th>Resistance Coefficient Alpha (α) Ω/°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platinum</td>
<td>-184 to 815</td>
<td>0.0039</td>
</tr>
<tr>
<td>Nickel</td>
<td>-73 to 149</td>
<td>0.0067</td>
</tr>
<tr>
<td>Copper</td>
<td>-51 to 149</td>
<td>0.0042</td>
</tr>
<tr>
<td>Tungsten</td>
<td>-73 to 276</td>
<td>0.0045</td>
</tr>
</tbody>
</table>

A table for RTD that shows the type of material, temperature range, and the amount of resistance per °C

Nickel and copper wire are less expensive and easier to manufacture than platinum. They are often used in low-range industrial applications.
The relationship between temperature and resistance of conductor in the temperature range near 0°C can be calculated from the equation:

\[ R_t = R_{\text{ref}} \left( 1 + \alpha \Delta T \right) \]

- \( R_t \): Resistance of the conductor at \( T_0 \)°C
- \( R_{\text{ref}} \): Resistance at the reference temperature usually 0°C/20°C
- \( \alpha \): Temperature coefficient of resistance
- \( \Delta T \): Difference between operating & reference temperature
What is the resistance of a platinum RTD at 70°C if the resistance at 20°C is 135Ω and if \( \alpha_{70^\circ C} = 0.00392 \)
What is the resistance of a platinum RTD at 70°C if the resistance at 20°C is 135Ω and if $\alpha_{70°C} = 0.00392$
SOLUTION
A platinum resistance thermometer has a resistance of 150Ω at 20°C. Calculate its resistance at 50°C ($\alpha_{70°C} = 0.00392$)
SOLUTION
Thermistor or thermal resistors are semiconductors devices that behave as resistors with a usually negative high temperature coefficient of resistance.

This means that their resistance decreases as their temperature rises.

It is made by sintering mixtures of metallic oxide, such as oxide manganese, nickel, cobalt, copper and uranium.

They are available in a wide variety of shapes and sizes. Their wide range characteristics also permit them to be used in limiting and regulation circuits as time delay.

Thermistor are much smaller and cheaper. It gives a fast output response to temperature changes but they have lower measurement sensitivity compared to RTD.
THERMISTOR CONT’D

Typical thermistor configurations

Electrical symbol of a thermistor
The temperature-resistance characteristics of a thermistor is of exponential type and is given by:

\[ R_T = R_o e^{\beta \left( \frac{1}{T} - \frac{1}{T_o} \right)} \]

- \( R_o \) = resistance at the reference temperature \( T_o \) (Kelvin)
- \( R_T \) = resistance at the measured temperature \( T \) (Kelvin)
- \( \beta \) = experimentally determined constant for the given thermistor material.

\( 0^\circ C = 273 \text{ K} \)
Relationship between R and T (°F)

R decreases as the T increases
EXAMPLE 3

For a certain thermistor, $\beta=3140\text{K}$ and the resistance at 27°C is known to be $1050\Omega$. The thermistor is used for temperature measurement and the resistance measured is $2330\Omega$. Find the measured temperature.
SOLUTION
The circuit below is to be used for temperature measurement. The thermistor is a 4-kΩ type identified in (Figure in slide No 9). The meter is a 50-mA ammeter with a resistance of 3Ω, \( R_c \) is set to 17Ω, and the power supply \( V_T \) is 15V. What will the meter reading at 150°F be?
EXAMPLE 5

At room temperature (25°C), the voltmeter in the figure below gives a reading of 2 V. The temperature of a material is measured using the thermistor and the voltmeter now gives a reading of 4 V. If given that $V_T$ is 20 V, $\beta$ is 4000K, $R_c$ is 1kΩ and the internal resistance of the voltmeter is 100Ω, what is the temperature of the measured material?
SOLUTION
Thermocouple normally used to convert temperature to voltage.

The construction of thermocouple is shown below:

Temperature being measured

Basic construction of thermocouple

Connecting leads

Depends on

Material (wire)

Temperature Difference
It consists of a pair of conductor from different type of materials.

Both conductors are connected on one side to give a close loop where the temperature is measured.

This side is called the hot junction or sensing junction. The hot junction (sensing junction) is placed in or on the material being tasted.

The other side where both conductors are opened is called the cold junction. It is connected to the voltage-measuring equipment. This side is maintained in hot and cold junction gives the magnitude of voltage, V.
Made – diff. metals or metal alloys covering a wide range of temperatures (-270°C → 2700°C)

Output Voltage of the Thermocouple, $V_o$

\[ V_o = c(T_1 - T_2) + k(T_1^2 - T_2^2) \]

$c$(mV/°C) and $k$(mV/°C²) = constants of the thermocouple materials

$T_1$ = the temperature of the ‘hot’ junction

$T_2$ = the temperature of the ‘cold’ or ‘reference’ junction
THERMOCOUPLE CONT’D

(a) Uninsulated
(b) Insulated

(c) Probe assembly
(d) Thermocouple well (protection high)
During experiments with a copper-constantan thermocouple it was found that $c = 3.75 \times 10^{-2} \text{ mV/}^\circ\text{C}$ and $k = 4.5 \times 10^{-5} \text{ mV/}^\circ\text{C}^2$. If $T_1=100^\circ\text{C}$ and the cold junction $T_2$ is kept in ice, compute the output voltage.
SOLUTION
END OF PART 2