INDIAN INSTITUTE OF TECHNOLOGY, KANPUR

LAB-MANUAL

Experiment No.:-1

STUDY OF TEMPERATURE TRANSDUCERS

(TRANSDUCERS AND INSTRUMENTATION LAB)

VIRTUAL LAB

Experiment No.:-1

Aim: **-** To study the Temperature Transducers.

A) To study the R.T.D. Temperature Transducer.
B) To study the Thermistor Temperature Transducer.
C) To study the Thermocouple Temperature Transducer.

Apparatus Requirement: -

- Personal computer
- Lab view 2009 Runtime engine
- Internet facility (for online experiment and for offline experiment just download the executable file from the experiment download link given in website)

Introduction: -

A sensor is a device that produces a measurable response to a change in a physical condition, such as temperature or thermal conductivity or to a change in chemical concentration. Sensors are particularly useful for measurements of temperature such as in industrial process control. Here in this experiment we are dealing with temperature sensors mainly. Several temperature sensing techniques are currently in widespread usage. The most common of these are RTDs, Thermocouples and Thermistor. The right one for our application depends on the required temperature range, linearity, accuracy, cost, features, and ease of designing the necessary support circuitry.

Each temperature sensor has its own unique properties and dependence on temperature according to their types and materials used to make them.

Aim: - A) To study the R.T.D. Temperature Transducer.

Apparatus Requirement: -

- Personal computer
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Theory: -

Resistance Temperature Detector (R.T.D.) as the name implies, are sensors used to measure temperature by correlating the resistance of the R.T.D. element with temperature. Most R.T.D. element consist of a length of fine coiled wire wrapped around a ceramic or glass core. The element is usually quite fragile, so it is often placed inside a sheathed probe to protect it. The R.T.D. element is made from a pure material whose resistance at various temperatures has been documented. The material has a predictable change in resistance as the temperature changes; this is predictable change that is used to determine temperature.
R.T.D. is commonly categorized by their nominal resistance at 0 °C. Typical nominal resistance values for platinum thin-film R.T.Ds include 100 Ω and 1000 Ω. The relationship between resistance and temperature is very nearly linear and follows the equation.

Formula Used: -

For $<0\,^0C$ $$\mathbf{R_T = R_0\,[1 + AT + BT^2 + CT^3\,(T - 100)]}$$

For $>0\,^0C$ $$\mathbf{R_T = R_0\,[1 + AT + BT^2]}$$

Where,

R_T = Resistance at temperature T^0C
R_0 = Nominal resistance
A, B and C = Constants used to scale the RTD
T= Temperature in ^0C (Actual Temperature)

Constant coefficients for different standard: -

Table: 1 Callendar-Van Dusen Coefficients Corresponding to Common RTDs

Standard Temperature	Coefficient (α)	A	B	C*
DIN 43760	0.003850	3.9080×10^{-3}	-5.8019×10^{-7}	-4.2735×10^{-12}
American	0.003911	3.9692×10^{-3}	-5.8495×10^{-7}	-4.2325×10^{-12}
ITS-90	0.003926	3.9848×10^{-3}	-5.870×10^{-7}	-4.0000×10^{-12}

* For temperatures below 0° C only; C = 0.0 for temperatures above 0° C.

To use an R.T.D. a small voltage is passed through the element and then measured by Wheatstone bridge as shown in figure: 1.

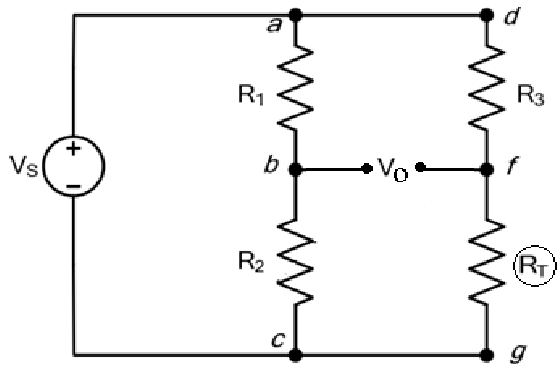


Figure: 1 Wheatstone bridge

The Resistance having some voltage and the voltage drop across R_T can be Calculate by Wheatstone bridge-

Bridge at Balance condition – $V_0 = 0(\text{Volt})$

Bridge at Unbalanced condition –

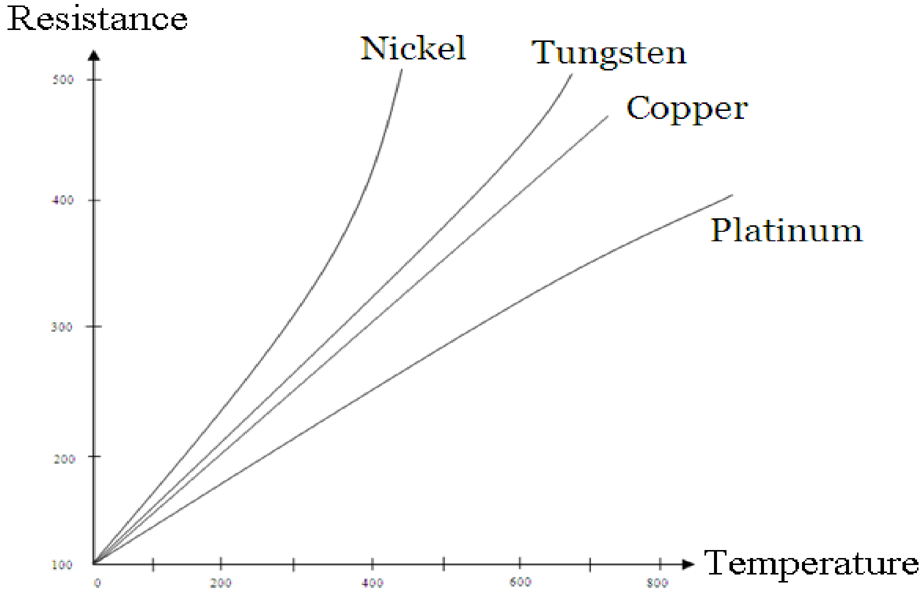
$$V_0 = \left[\left\{ \frac{R_2}{R_1 + R_2} \right\} - \left\{ \frac{R_T}{R_3 + R_T} \right\} \right] \times V_S$$

Where,

R1, R2, R3and R_T = Resistance in Ω

V = Voltage in (volt)

V_S = Source voltage (volt)



Temperature Vs Resistance for different metals

Procedure: -

- Select the experiment,(Study of Temperature Transducers)
- Now if you opted for R.T.D. Temperature Transducer
  1) Click on START tab to ON the burner.
  2) Select desired type of Wire and Length of the wire used for long distance R.T.D.
  3) Initial Vessel`s Temperature at Room Temperature.
  4) Now increase the temperature of vessel using Burner knob.
  5) Evaluate the temperature of vessel by R.T.D.
  6) The graph is showing the relation between Actual Temperature versus Measured Temperature.
  7) Click on STOP tab to stop experiment.

Observational table: -

Sr. No.	Actual Temperature(‘C)	Measured Temperature (‘C)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Plot the graph between Actual Temperature and Measured Temperature.

Result: - The relation between Actual versus Measured Temperature is shown in graph.

Precaution: -

- Follow instructions carefully.
- For fetching correct value, wait until the process gets complete.
- Runtime engine should be properly installed.

Aim: - **B)** To study the Thermistor Temperature Transducer.

Apparatus Requirement: -

- Personal computer
- Lab view 2009 Runtime engine
- Internet facility (for online experiment and for offline experiment just download the executable file from the experiment download link given in website)

Theory:-

Thermistor, a thermally sensitive resistor, it is a solid semiconducting material. Unlike metals, Thermistor respond inversely to temperature, i.e., their resistance decreases as the temperature increases. The Thermistor is usually composed of oxides of manganese, nickel, cobalt, copper and several other nonmetals. Thermistor are widely used as inrush current limiters, temperature sensors, self-resetting over current protectors, and self-regulating heating elements.

Formula used:-

$$R_T = R_{T_o} \exp\left[\beta\left(\frac{1}{T} - \frac{1}{T_o}\right)\right]$$

Where,

R_{T0} = Resistance at a reference Temperature (T_0)
β = Constant, for characteristic of the material (3500^0k to 4500^0k)
T_0= Reference temperature

For accurate temperature measurements, the resistance/temperature curve of the device must be described in more detail. The "Steinhart-Hart" equation is a widely used third-order approximation:

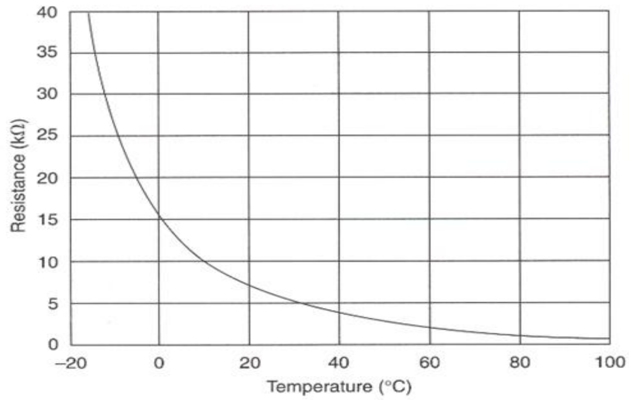
$$T = \frac{1}{A + B\ln(R) + C\ln^3(R)}$$

Where,

A, B & C = Steinhart-Hart Constant
R = Resistance (Ω)
T = Temperature ^{0}C

Steinhart-Hart Constant for different Temperature Range: -

Temperature Range(^{0}C)	**Coefficients for Steinhart-Hart Equation**		
	A	**B**	**C**
-50 to 0	1.43911E-3	2.6930E-4	1.6534E-7
0 to 50	1.44058E-3	2.6907E-4	1.6619E-7
50 to 125	1.44032E-3	2.6904E-4	1.6794E-7



Temperature Vs Resistance Graph

Procedure: -

- Select the experiment,(Study of Temperature Transducers)
- Now if you opted for Thermistor Temperature Transducer
    1) Click on START tab to ON the burner.
    2) Initial Vessel`s Temperature at Room Temperature.
    3) Now increase the temperature of vessel using Burner knob.
    4) Evaluate the temperature of vessel by Thermistor.
    5) The graph is showing the relation between Actual Temperature versus Measured Temperature.
    6) Click on STOP tab to stop experiment.

Observational table: -

Sr. No.	Actual Temperature(K)	Measured Temperature (K)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Plot the graph between Actual Temperature and Measured Temperature.

Result: - The relation between Actual versus Measured Temperature is shown in graph.

Precaution: -

- Follow instructions carefully.
- For fetching correct value, wait until the process gets complete.
- Runtime engine should be properly installed.

Aim: - C) To study the Thermocouple Temperature Transducer.

Apparatus Requirement: -

- Personal computer
- Lab view 2009 Runtime engine
- Internet facility (for online experiment and for offline experiment just download the executable file from the experiment download link given in website)

Theory: -

A thermocouple circuit is formed when two dissimilar metals are joined at both ends and there is a difference in temperature between the two ends. This difference in temperature creates a small Voltage is formed within the circuit. This voltage or EMF (electro motive force) is usually measured in the 1/1000th of a volt (mill volt) and is called the Seeback effect.

Formula Used: -

$$E = c(T_1 - T_2) + k(T_1^2 - T_2^2)$$

Where,

C and k = Seeback constant coefficient of the thermocouple

T_1 = Temperature of the 'hot' junction

T_2 = Temperature of the 'cold' or 'reference' junction

Relation between Temperature and Seeback coefficient: -

Thermocouple output voltages are highly nonlinear. The Seeback coefficient can vary by a factor of three or more over the operating temperature range of some thermocouples, you must approximate the thermocouple voltage Vs temperature curve using polynomials.

$$T = a_0 + a_1 V + a_2 V^2 + a_3 V^3 + ... + a_n V^n$$

Where,

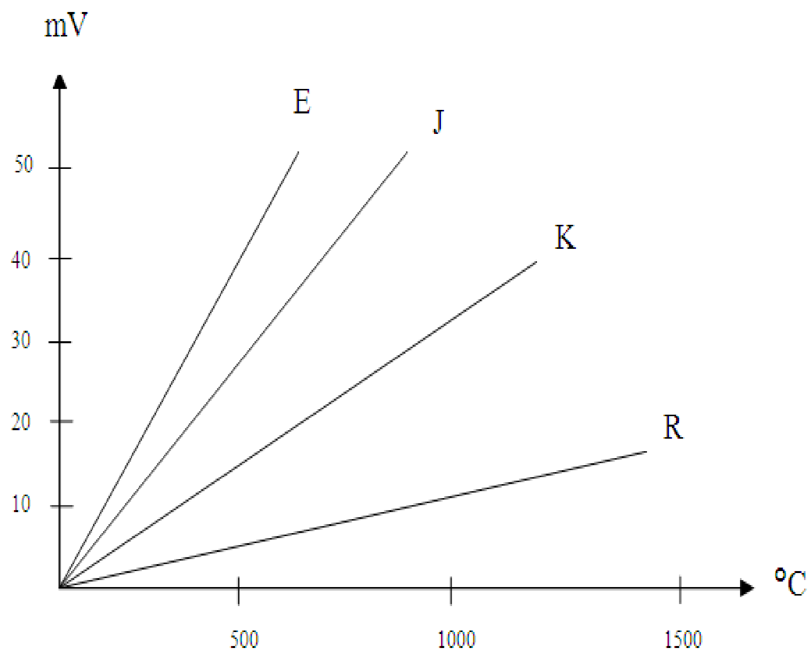
a_0, a_1, a_2, $a_{3...}$= Constant Coefficient for different type of thermocouple

V =Seeback coefficient (emf)

Types of Thermocouple: -

There are different recognized thermocouple types available. Each type has different useful temperature ranges as well as different recommended applications. Thermocouple composition, color codes, and manufacturing specifications are-

Type ANSI Symbol	**Materials**	**Temperature Range (°C)**	**Seeback Coefficient µ V/° C**	**Error +/- (°C)**
T	Copper- Constantan	-270 to 400	38.74 at 0° C	2.2
J	Iron-Constantan	0 to 750	50.37 at 0° C	2.2
E	Chromel- Constantan	-270 to 1000	58.70 at 0° C	1
K	Chromel- Nickel	-270 to 1372	39.48 at 0° C	2.2
R	Platinum- Rhodium	-50 to 1768	11.35 at 600° C	1.5
S	Platinum-Rhodium/Platinum	- 50 to 1768	10.19 at 600° C	1.5



Ideal Graph between Temperature Vs Voltage

<u>Procedure:</u> -

- Select the experiment,(Study of Temperature Transducers)
- Now if you opted for Thermocouple Temperature Transducer

1) Click on START tab to ON the burner.
2) Select desired type of Thermocouple.
3) Initial Vessel`s Temperature at Room Temperature.
4) Now increase the temperature of vessel using Burner knob.
5) Evaluate the temperature of vessel by Thermocouple.
6) The graph is showing the relation between Actual Temperature versus Measured Temperature.
7) Click on STOP tab to stop experiment.

Observational table: -

Sr. No.	Actual Temperature('C)	Measured Temperature ('C)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Plot the graph between Actual Temperature and Measured Temperature.

Result: - The relation between Actual versus Measured Temperature is shown in graph.

Precaution: -

- Follow instructions carefully.
- For fetching correct value, wait until the process gets complete.
- Runtime engine should be properly installed.