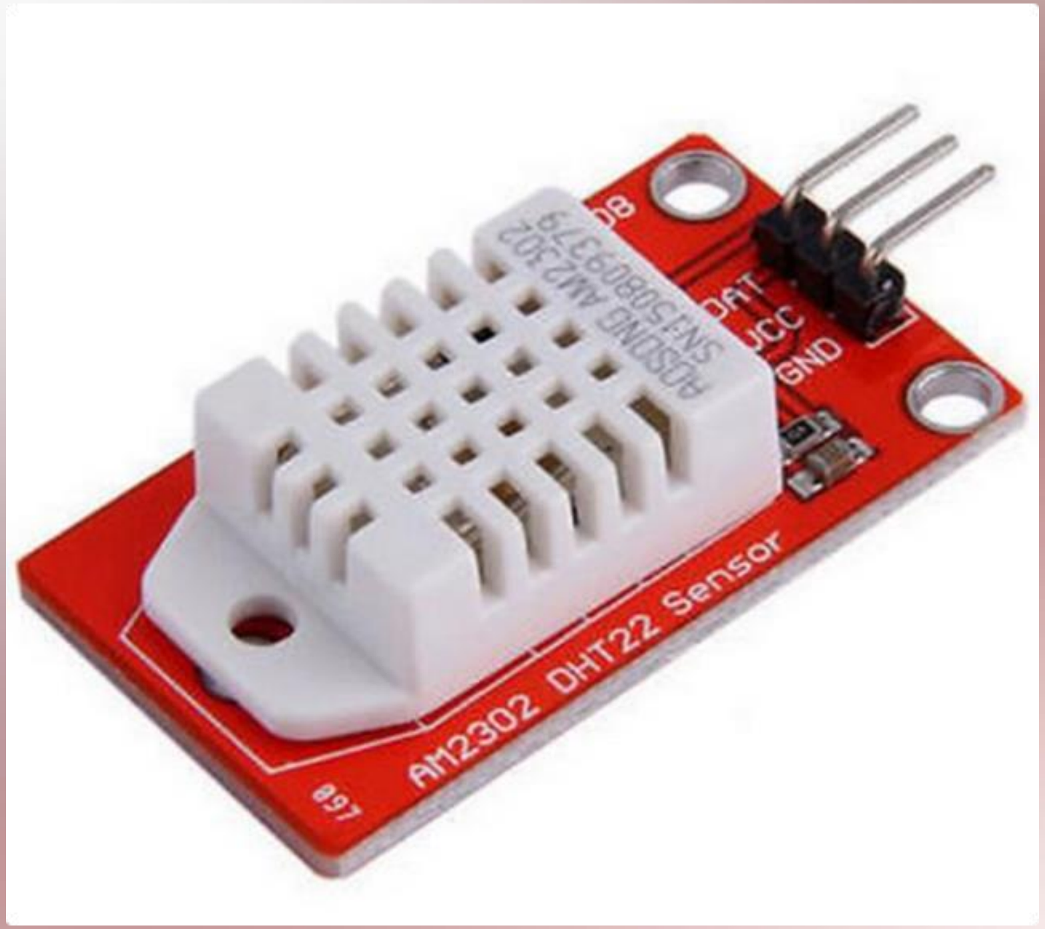


Introduction to Temperature and Humidity Sensors

Temperature and humidity sensors are essential tools for monitoring and controlling environmental conditions in a wide range of applications, from industrial processes to home automation. These sensors measure and report the temperature and moisture content of the surrounding air, providing valuable data for decision-making and optimization.

by Disha Sharma

Types of Temperature Sensors

Thermistors

Thermistors are thermally sensitive resistors that change resistance in response to temperature changes. They are known for their high sensitivity and fast response times.

Resistance Temperature Detectors (RTDs)

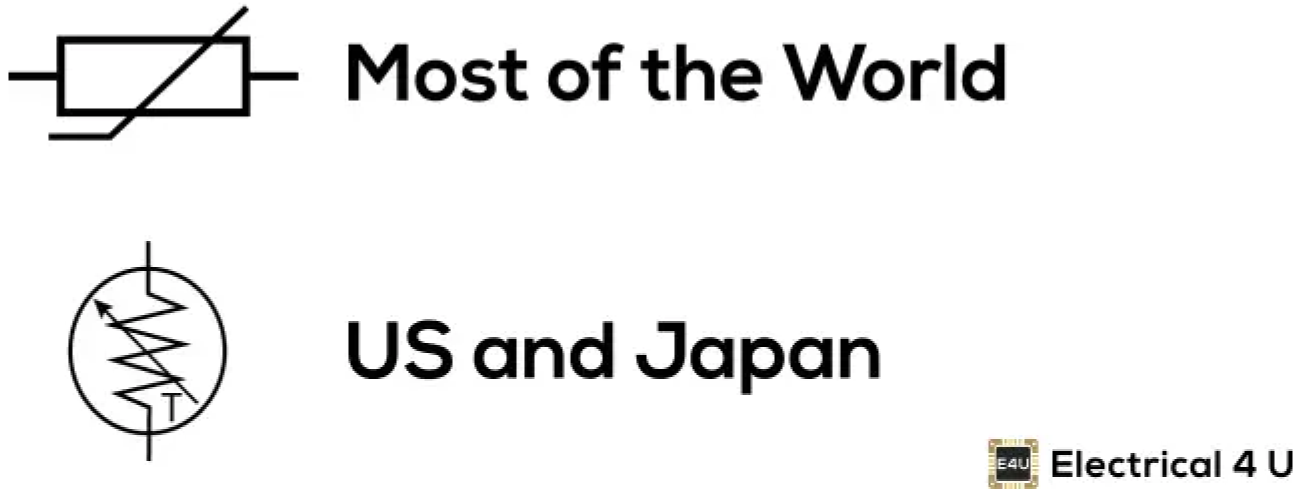
RTDs use the temperature-dependent changes in the electrical resistance of metals, such as platinum, to measure temperature. They offer high accuracy and stability.

Thermocouples

Thermocouples generate a small voltage in response to temperature changes. They are known for their wide temperature range, ruggedness, and low cost.

Thermistor Sensors

- Thermistors are thermally sensitive resistors. In thermistors, the electrical resistance changes according to their temperature. They are made of a combination of two or three metal oxides with zinc oxide among one of them. This combination is inserted in a ceramic base which is an insulator.
- Thermistors are available in two types based on temperature coefficient: positive temperature coefficient (PTC) thermistors and negative temperature coefficient (NTC) thermistors.
- Symbol of thermistor shown below -



NTC Thermistor Sensors

- In an NTC thermistor, resistance decreases as temperature increases, and vice versa. This inverse relationship makes NTC thermistors the most common type.

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

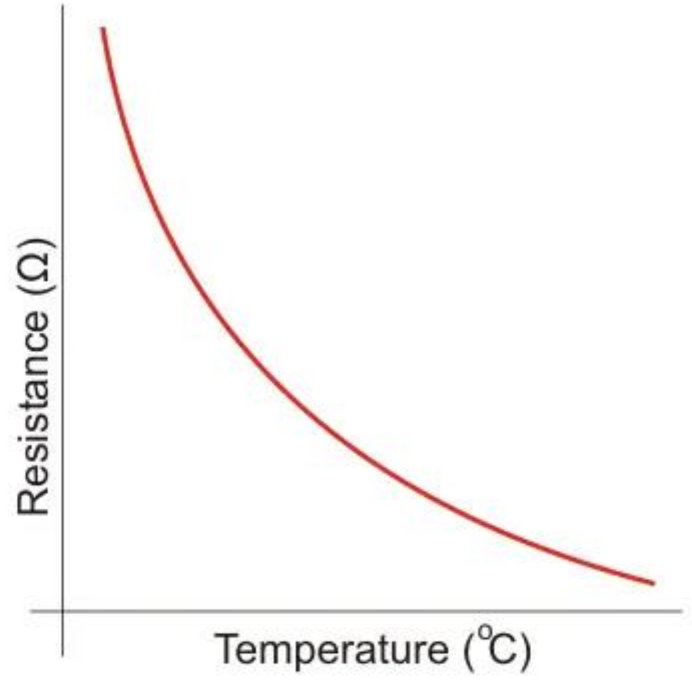
$$R_T = R_0 e^{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)} \qquad (1)$$

Where:

RT is the resistance at temperature T (K)
R0 is the resistance at temperature T0 (K)
T0 is the reference temperature (normally 25oC)
β is a constant, its value is dependent on the characteristics of the material. The nominal value is taken as 4000.

- From the equation (1), we can determine the resistance temperature coefficient, which indicates the thermistor's sensitivity.

$$\alpha_T = \frac{1}{R_T}\frac{dR_T}{dT} = -\frac{\beta}{T^2} \qquad (2)$$



Thermistor Sensors

1. ## High Sensitivity

Thermistors exhibit a large change in resistance for a small change in temperature, making them highly sensitive.

2. ## Fast Response

Thermistors have a relatively fast response time, allowing them to quickly detect temperature changes.

3. ## Nonlinear Characteristics

Thermistor resistance-temperature relationships are nonlinear, requiring specialized calibration and compensation techniques.

4. ## Limited Temperature Range

Thermistors typically have a limited operating temperature range, often from -50°C to 150°C.

Resistance Temperature Detectors (RTDs)

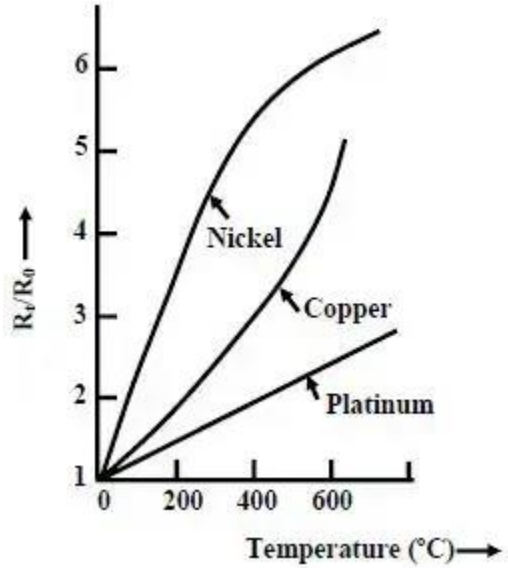
- A **Resistance Temperature Detector** (also known as a **Resistance Thermometer** or **RTD**) is an electronic device used to determine the temperature by measuring the resistance of an electrical wire. This wire is referred to as a temperature sensor.
- The variation of resistance of the metal with the variation of the temperature is given as,

$$R_t = R_0[1 + (t - t_0) + \beta(t - t_0)^2 + \cdots\cdots]$$

Where, R_t and R_0 are the resistance values at t°C and t_0°C temperatures. α and β are the constants depends on the metals.
This expression is for huge range of temperature. For small range of temperature, the expression can be,

$$R_t = R_0[1 + (t - t_0)]$$

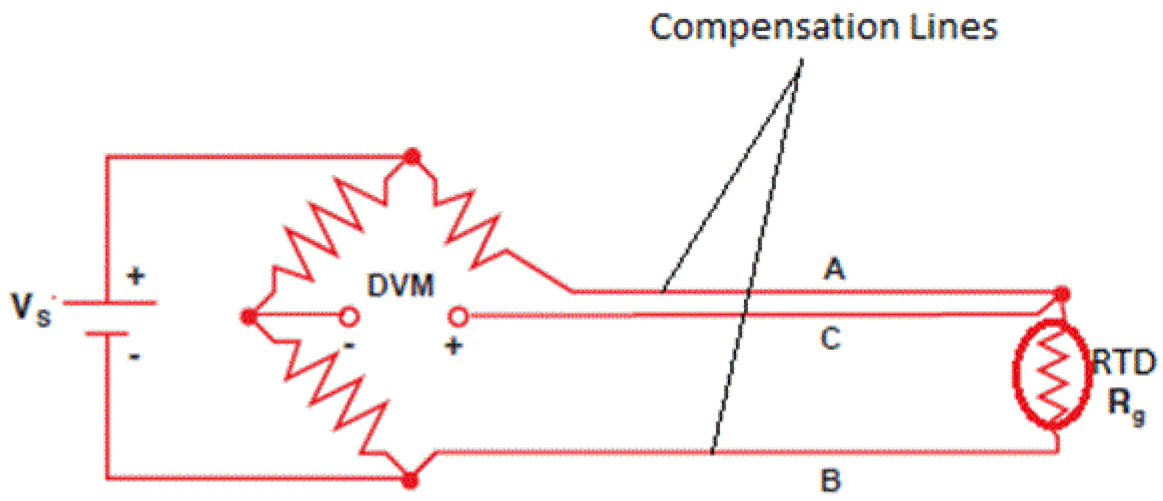
- **RTD** devices commonly use metals like Copper, Nickel, and Platinum. Each metal has unique resistance changes that correspond to temperature variations, known as resistance-temperature characteristics. Platinum has the temperature range of 650°C, and then the Copper and Nickel have 120°C and 300°C respectively.

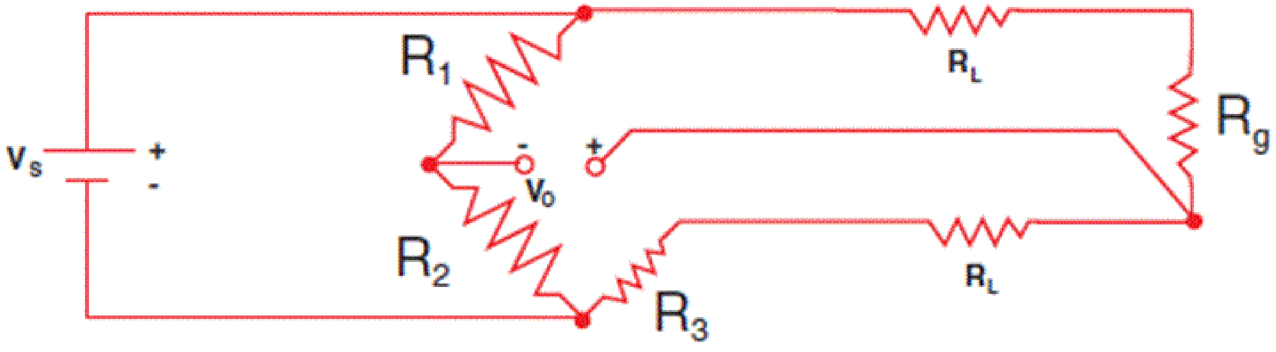


Construction of Resistance Temperature Detectors (RTDs)

- The resistance of an RTD is determined using a bridge circuit, where a constant electric current is supplied and the voltage drop across a resistor is measured to calculate temperature. This temperature is determined by converting the RTD resistance value using a calibration expression.
- In a three-wire RTD, if wires A and B are identical in length and cross-sectional area, their impedance effects neutralize each other. The dummy wire C then serves as a sensing lead to measure voltage drop without carrying current. In these circuits, the output voltage is directly proportional to the temperature. So, we need one calibration equation to find the temperature.
- If we know the values of V_S and V_O, we can find R_g and then we can find the temperature value using calibration equation. Now, assume R_1 = R_2:

$$V_0 = V_S\left(\frac{R_3}{R_3+R_g}\right) - \left(\frac{V_S}{2}\right)$$





Resistance Temperature Detectors (RTDs)

Accurate Measurements

RTDs provide highly accurate temperature measurements due to their linear resistance-temperature relationship.

Wide Temperature Range

RTDs can operate over a wide temperature range, typically from -200°C to 850°C.

Stable and Durable

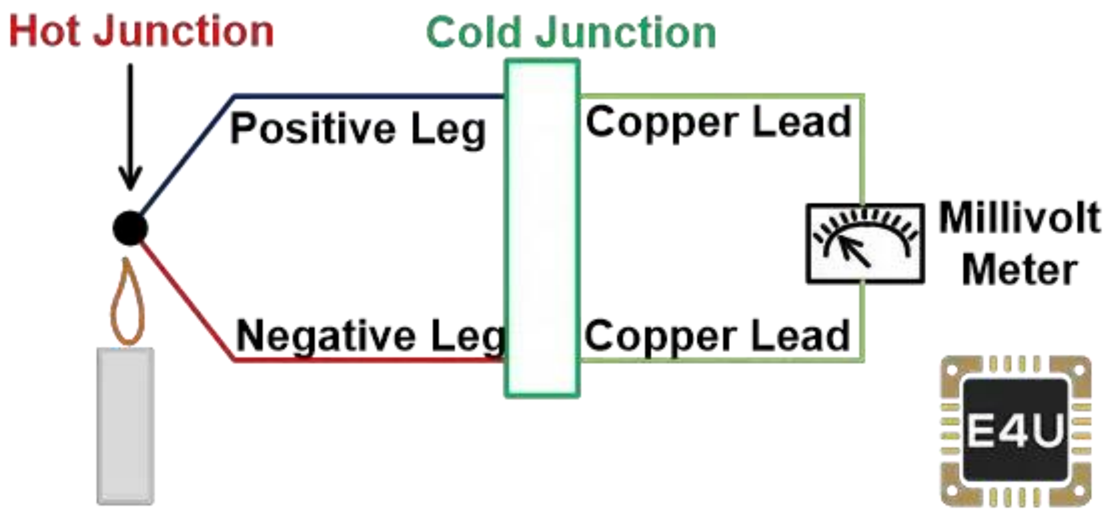
RTDs are known for their long-term stability and durability, making them suitable for industrial applications.

Higher Cost

RTDs generally have a higher cost compared to other temperature sensor technologies.

Thermocouple Sensors

- A thermocouple is a device that converts temperature differences into an electric voltage, based on the principle of the Seeback effect. This effect is the phenomenon of generating an electric voltage due to a temperature difference between two different metals or metal alloys.



- It is a type of sensor that can measure temperature at a specific point or location.
- Thermocouples are widely used in industrial, domestic, commercial, and scientific applications due to their simplicity, durability, low cost, and wide temperature range.

Thermocouple Type	Temperature Range (˚C)				
	Short Term Use	Continuous Use	Class 1 Tolerance	Class 2 Tolerance	Class 3 Tolerance
Type E	-40 to 900	0 to 800	-40 to 800	-40 to 900	-40 to 904
Type J	-180 to 800	0 to 750	-40 to 750	-40 to 750	N/A
Type K	-180 to 1300	0 to 1100	-40 to 1000	-40 to 1200	-180 to 1300
Type N	-270 to 1300	0 to 1100	-40 to 1000	-40 to 1200	-270 to 1304
Type R	-50 to 1700	0 to 1600	0 to 1600	0 to 1600	N/A
Type S	-50 to 1750	0 to 1600	0 to 1600	0 to 1600	N/A
Type T	-250 to 400	-185 to 300	-40 to 350	-40 to 350	-250 to 404
Type B	0 to 1820	200 to 1700	N/A	600 to 1700	4 to 1820

Thermocouple Sensors

1

Thermal Junction

Thermocouples generate a small voltage based on the temperature difference between two dissimilar metal junctions.

2

Reference Junction

The reference junction, typically maintained at a known temperature, provides a reference point for the voltage measurement.

3

Voltage Measurement

The voltage generated by the thermocouple is measured and converted to a temperature value.

Types of Humidity Sensors

Capacitive Sensors

Capacitive sensors measure the change in the dielectric properties of a material in response to changes in humidity.

Resistive Sensors

Resistive sensors measure the change in electrical resistance of a material as a function of humidity levels.

Psychrometric Sensors

Psychrometric sensors use the relationship between temperature and humidity to determine the moisture content in the air.

Capacitive Humidity Sensors

1 **High Sensitivity**

Capacitive sensors exhibit a significant change in capacitance in response to small changes in humidity.

2 **Wide Measurement Range**

Capacitive sensors can accurately measure a broad range of humidity levels, from low to high.

3 **Fast Response**

Capacitive sensors have a relatively fast response time, allowing for quick detection of humidity changes.

4 **Stability and Reliability**

Capacitive sensors are known for their long-term stability and reliability in various environmental conditions.

Resistive Humidity Sensors

Simple Design

Resistive sensors have a simple and cost-effective design, making them suitable for various applications.

Temperature Dependence

Resistive sensors are susceptible to temperature variations, requiring compensation for accurate humidity measurements.

Limited Stability

Resistive sensors may experience drift and degradation over time, affecting their long-term reliability.

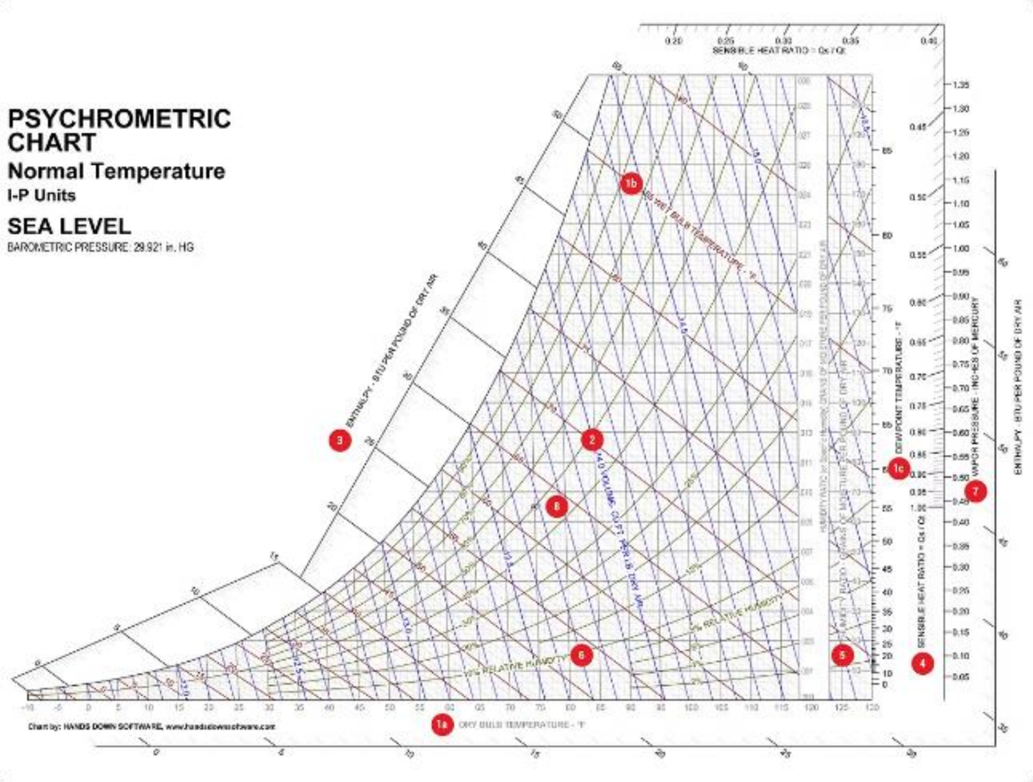
Humidity Exposure

Resistive sensors can be vulnerable to water exposure, which can impact their performance and lifespan.

Psychrometric Humidity Sensors

Wet-Bulb Temperature	Dry-Bulb Temperature	Relative Humidity
The temperature of a moistened surface that is exposed to air flow.	The temperature of the surrounding air.	The ratio of the actual amount of water vapor in the air to the maximum amount that the air can hold at a given temperature.

Psychrometric sensors use the relationship between wet-bulb temperature, dry-bulb temperature, and relative humidity to determine the moisture content in the air.



Applications and Considerations

Industrial Processes

Temperature and humidity sensors are crucial for monitoring and controlling environmental conditions in industrial processes, such as manufacturing, HVAC, and food processing.

Building Automation

These sensors are used in building automation systems to maintain comfortable indoor environments and optimize energy efficiency.

Environmental Monitoring

Temperature and humidity sensors are employed in weather stations, climate research, and environmental monitoring applications to gather data on atmospheric conditions.

Sensor Selection

When choosing temperature and humidity sensors, factors like accuracy, response time, operating range, and environmental compatibility should be considered to ensure optimal performance.