

Measuring Temperature - Basics

Definition

Temperature is the main physical quantity which describes the state of a thermodynamic system. The measurement of temperature is based on the fact that all objects - and consequently also temperature sensors - are **exchanging energy** with their surroundings.

There are three ways to exchange energy:

- Conduction
- Connection
- Radiation

For an ideal temperature measurement, the temperature sensor and its surroundings are in **thermal equilibrium**, thus there is no energy transfer to or from the sensor. The temperature of the sensor is equal to the surrounding temperature.

To state the absolute temperature, a **reference value** is necessary.

A scale for temperature can be defined knowing the reference value and the temperature behaviour of the sensor. The Kelvin scale is based on the **absolute minimal temperature** 0 K and the triple state of water 273.16 K. The unit is 1 Kelvin = 1 K.

T is used for absolute temperature measured on Kelvin scale. The **triple state of water** is the temperature where water can exist in all its three states.

Apart from the Kelvin scale, the **Celsius scale** is accepted in Europe. The unit of the Celsius scale is 1°C = 1K. The Celsius scale is shifted by 273.15, with respect to the Kelvin scale. At normal atmospheric pressure of 1013.25 mbar the melting of water is at 273.15 K (resp. 0°C). The symbol for this temperature information is **t**.

All temperature scales (IPTS-68 or TTS) were replaced 1990 by the **International Temperature Scale ITS-90**. On this new Celsius scale the boiling temperature of water (was 100°C) is no point of reference any more. The new boiling temperature of water acc. ITS-90 is already at $t = 99.974^{\circ}\text{C}$ at normal atmospheric pressure.

$$\text{Formula: } t \text{ [}^{\circ}\text{C]} = T - 273.15$$

$$\text{e.g. } 250 \text{ K} = (250 - 273.15)^{\circ}\text{C} = -23.15^{\circ}\text{C}$$

$$T \text{ [K]} = t + 273.15$$

$$\text{e.g. } 50^{\circ}\text{C} = (50 + 273.15) \text{ K} = 323.15 \text{ K}$$

Measuring Methods

The temperature can be measured mechanically or electronically.

Mechanical methods are based e.g. on bimetal, liquid thermometers or gas thermometers. In the **industrial measurement** technology the electronic methods are preferred. These are mainly based on the variation of an electrical resistor as function of temperature. The PTC elements (positive temperature coefficient) are used for thermal protection switches, NTC-elements (negative temperature coefficient) for low accuracy requirements.

For **high accuracy applications** metal resistors are used. The metal employed can be platinum, molybdenum or nickel in form of wire or thin film on a substrate.

E+E temperature transmitters are using **platinum-temperature sensors** with characteristics according **IEC751** and **EN60751**.