Operating limits and tolerances of platinum resistance thermometers per EN 60751: 2008

General information

Temperature is a measurement for the thermal state of a material - so a measurement of the average kinetic energy of its molecules. A close thermal contact between two bodies is needed in order that these bodies adopt the same temperature (temperature equalisation). The body to be measured should be coupled as closely as possible to the temperature sensor system.

The most established temperature measurement methods are based on material or body properties that change depending on the temperature. One of the most-used methods is the measurement with a resistance thermometer.

This document outlines the recurrent concepts and technologies that apply to all resistance thermometers produced by WIKA.

Standard version
If there are no additional specifications or customer requirements, we will recommend this selection, or we will select this option when offering or producing the thermometer.

Sensor technology

The electrical resistance of a resistance thermometer's sensor changes with the temperature. As the resistance increases when temperature is raised, we refer to it as PTC (**P**ositive **T**emperature **C**oefficient).
Pt100 or Pt1000 measuring resistors are normally used for industrial applications. The exact characteristics of these measuring resistors, and the thermometers based on them, are defined in EN 60751: 2008 [1]. The most important characteristics are described in this document.

Resistance basic values at 0 °C

Designation	Basic value in Ω
Pt100	100
Pt1000	1,000

Bold: Standard version

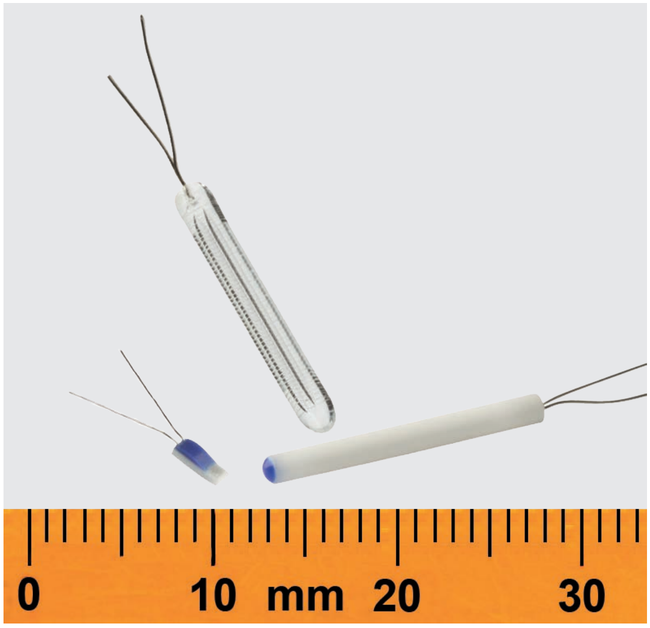


Fig. left: Thin-film measuring resistor
Fig. centre: Glass measuring resistor
Fig. right: Ceramic measuring resistor

1) IEC 60751: 2008 = EN 60751: 2008 = DIN EN 60751: 2009

Measuring resistor designs

Those measuring resistors used in thermometers can be wire-wound measuring resistors (W = Wire-**W**ound) or thin-film resistors (F = Thin-**F**ilm).

Thin-film measuring resistors (F)

(Standard version)

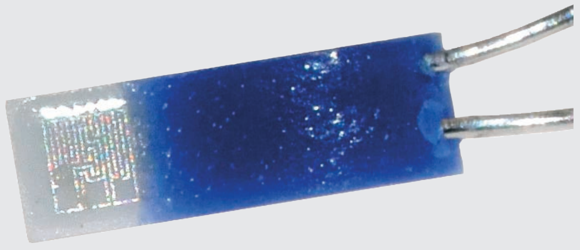
For thin-film measuring resistors, a very thin platinum film is applied to a ceramic carrier plate. Then, connecting wires are attached. Finally, the platinum film and the connecting wire connection are sealed against external effects by a layer of glass.

The thin-film measuring resistor is characterised by

- Temperature range: -50 ... +500 °C [1)]
- High vibration resistance
- Very small size
- Good price/performance ratio

Thin-film measuring resistors are the standard design unless the temperature range or an explicit customer request exclude them.

Thin-film measuring resistor



Wire-wound measuring resistors (W)

In this design, a very thin platinum wire is encased within a round protective body. This design has been well-established for decades and is accepted worldwide.
Two subtypes are available that differ in the choice of insulating material.

- **Glass measuring resistor**
  The bifilar wire of the glass measuring resistor is fused within a glass body.

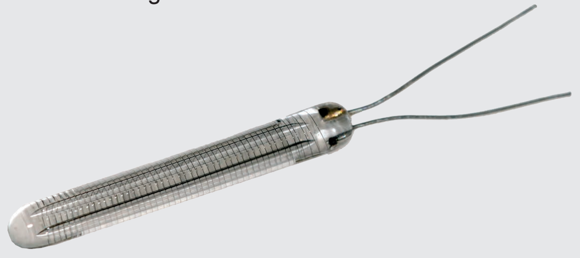
  The glass measuring resistor is characterised by
  - Temperature range: -200 ... +400 °C [1)]
  - High vibration resistance

- **Ceramic measuring resistor**
  The platinum wire of a ceramic measuring resistor is spiral-wound and located in a cylindrical cavity in the protective body.

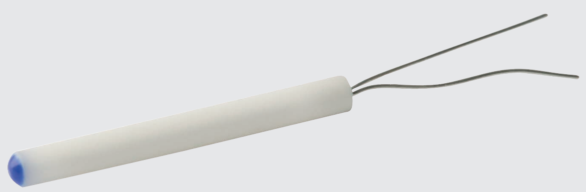
  The ceramic measuring resistor is characterised by
  - Temperature range: -200 ... +600 °C [1)]
  - Limited vibration resistance

1) The specifications apply to class B, see also table on page 4

Glass measuring resistor

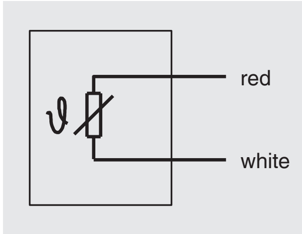


Ceramic measuring resistor



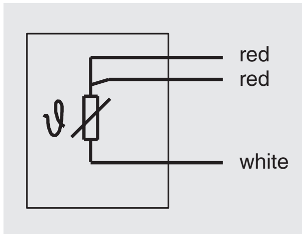
Sensor connection methods

- **2-wire connection**
  The lead resistance to the sensor is recorded as an error in the measurement. For this reason, this connection type is not advisable when using Pt100 measuring resistors for tolerance classes A and AA, since the electrical resistance of the connecting cables and their own temperature dependency are fully included in the measuring result and thus falsify it.



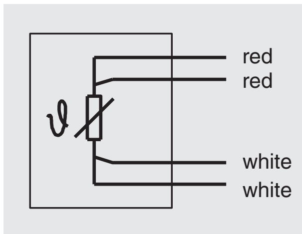
  Applications
  - Connecting cables up to 250 mm
  - Standard when using Pt1000 measuring resistors

- **3-wire connection (standard version)**
  The influence of the lead resistance is compensated as far as possible. The maximum length of the connecting cable depends on the conductor cross-section and the compensation options of the evaluation electronics (transmitter, display, controller or process control system).



  Applications
  - Connecting cables up to approx. 30 m

- **4-wire connection**
  The influence of the connecting cable on the measuring result is completely eliminated since any possible asymmetries in the connecting cable's lead resistance are also compensated.
  The maximum length of the connecting cable depends on the conductor cross-section and the compensation options of the evaluation electronics (transmitter, display, controller or process control system). A 4-wire connection can also be used as a 2-wire or 3-wire connection by disconnecting the unnecessary conductors.



  Applications
  - Laboratory technology
  - Calibration technology
  - Tolerance class A or AA
  - Connecting cables up to 1,000 m

Dual sensors

In the standard version a single sensor is fitted.
The combination of black and yellow is reserved for an optional second measuring resistor. For certain combinations (e.g. small diameter) dual sensors are not possible for technical reasons.

Relationship between temperature and resistance

For each temperature there is exactly one resistance value. This clear relationship can be described by mathematical formulae.

For the temperature range -200 ... 0 °C the following applies, irrespective of the resistor design:

$$R_t = R_0 [1 + At + Bt^2 + C (t - 100 °C) \cdot t^3]$$

For the temperature range 0 ... 600 °C the following applies:

$$R_t = R_0 [1 + At + Bt^2]$$

Legend:
t = Temperature in °C
R_t = Resistance in ohms at the measured temperature
R_0 = Resistance in ohms at t = 0 °C (e.g. 100 ohms)

For the calculation, the following constants apply

$A = 3.9083 \cdot 10^{-3}$ (°C^{-1})
$B = -5.7750 \cdot 10^{-7}$ (°C^{-2})
$C = -4.1830 \cdot 10^{-12}$ (°C^{-4})

Operating limits and tolerance classes

Both measuring resistor versions (wire-wound/thin-film) differ in the possible tolerances at the operating temperatures.

Class	Temperature range in °C		Tolerance value
	Wire-wound (W)	Thin-film (F)	
B	**-196 … +600**	**-50 … +500**	**±(0.30 + 0.0050 | t |) 1)**
A	-100 … +450	-30 … +300	±(0.15 + 0.0020 | t |) 1)
AA	-50 … +250	0 … 150	±(0.10 + 0.0017 | t |) 1)

1) | t | is the numerical value of the temperature in °C irrespective of the sign.

Bold: Standard version

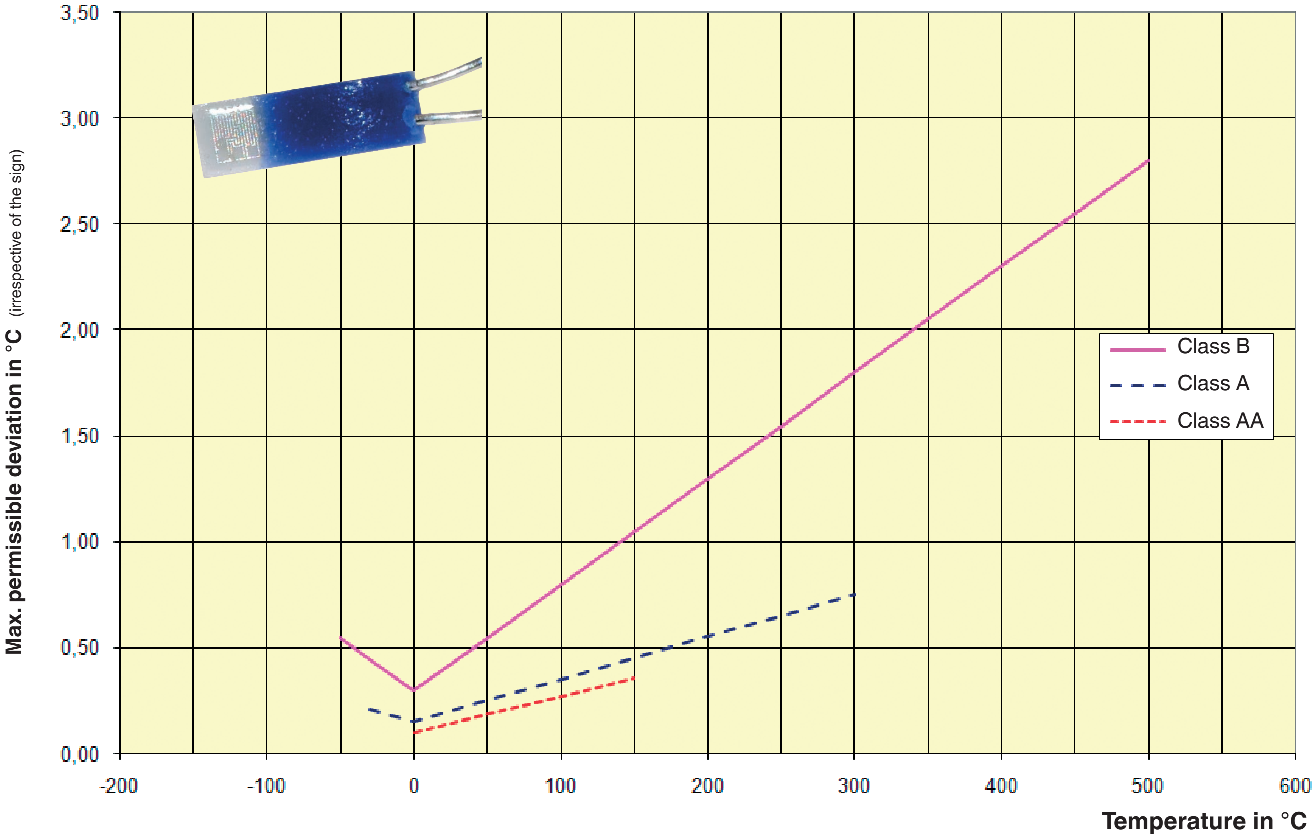
Under certain conditions, thermometers/measuring inserts with built-in measuring resistors can be operated in a temperature range outside the temperature range of the specified class.

The following must be observed regarding the compliance with the tolerance class:
With standard instruments, the class A specified before can no longer be confirmed if the thermometer or measuring insert was operated above or below the class A temperature range. The dwell time is not relevant here.

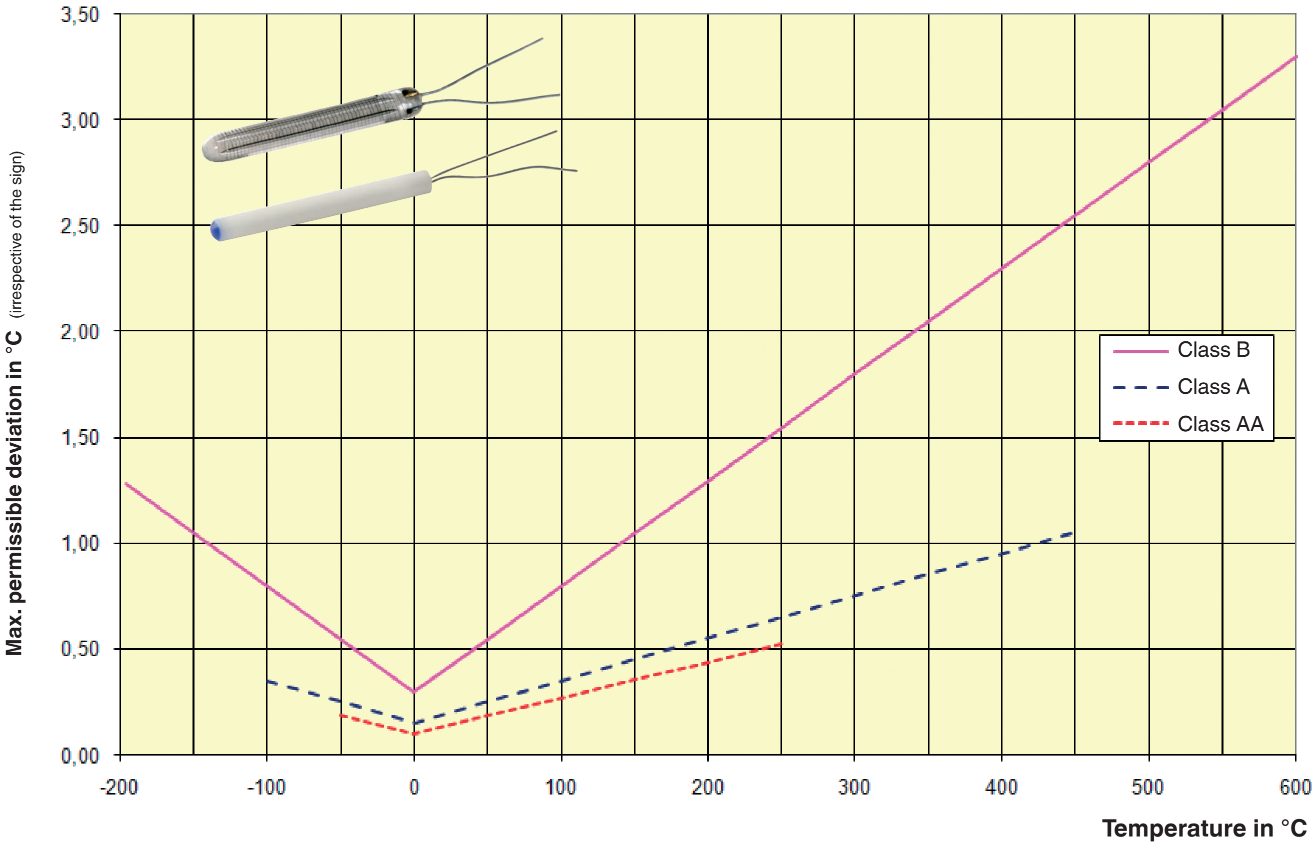
Even if the temperature is in the range of class A again, the tolerance class of the measuring resistor is no longer defined.

Resistance values and tolerance values with selected temperatures (Pt100)

Tolerance value EN 60751: 2008 for resistance thermometers with film measuring resistors



Tolerance value EN 60751: 2008 for resistance thermometers with wire-wound measuring resistors



Temperature values and tolerance values with selected resistance values (Pt100)

Resistance value in Ω	Temperature value in °C (ITS 90)		
	Tolerance class B	Tolerance class A	Tolerance class AA
50	-126.07 ... -124.22	-125.55 ... -124.75	-125.46 ... -124.83
80	-51.32 ... -50.22	-51.02 ... -50.52	-50.96 ... -50.58
100	-0.30 ... +0.30	-0.15 ... +0.15	-0.10 ... +0.10
110	25.26 ... 26.11	25.48 ... 25.89	25.54 ... 25.83
150	129.50 ... 131.40	130.04 ... 130.86	130.13 ... 130.77
200	264.72 ... 267.98	265.67 ... 267.03	265.80 ... 266.90
300	554.60 ... 560.78	556.42 ... 558.95	556.64 ... 558.74

This table can be used to check the evaluation electronics, e.g. by means of a decade resistor:
This means if the sensor or the measuring resistor is simulated by a decade resistor, the evaluation electronics must display a temperature value within the limit values specified above.

Resistance values and tolerance values with selected temperatures (Pt100)

Temperature in °C (ITS 90)	Resistance value in Ω		
	Tolerance class B	Tolerance class A	Tolerance class AA
-196	19.69 ... 20.80	-	-
-100	59.93 ... 60.58	60.11 ... 60.40	-
-50	80.09 ... 80.52	80.21 ... 80.41	80.23 ... 80.38
-30	88.04 ... 88.40	88.14 ... 88.30	88.16 ... 88.28
0	99.88 ... 100.12	99.94 ... 100.06	99.96 ... 100.04
20	107.64 ... 107.95	107.72 ... 107.87	107.74 ... 107.85
100	138.20 ... 138.81	138.37 ... 138.64	138.40 ... 138.61
150	156.93 ... 157.72	157.16 ... 157.49	157.91 ... 157.64
250	193.54 ... 194.66	193.86 ... 194.33	193.91 ... 194.29
300	211.41 ... 212.69	211.78 ... 212.32	-
450	263.31 ... 265.04	263.82 ... 264.53	-
500	280.04 ... 281.91	-	-
600	312.65 ... 314.77	-	-

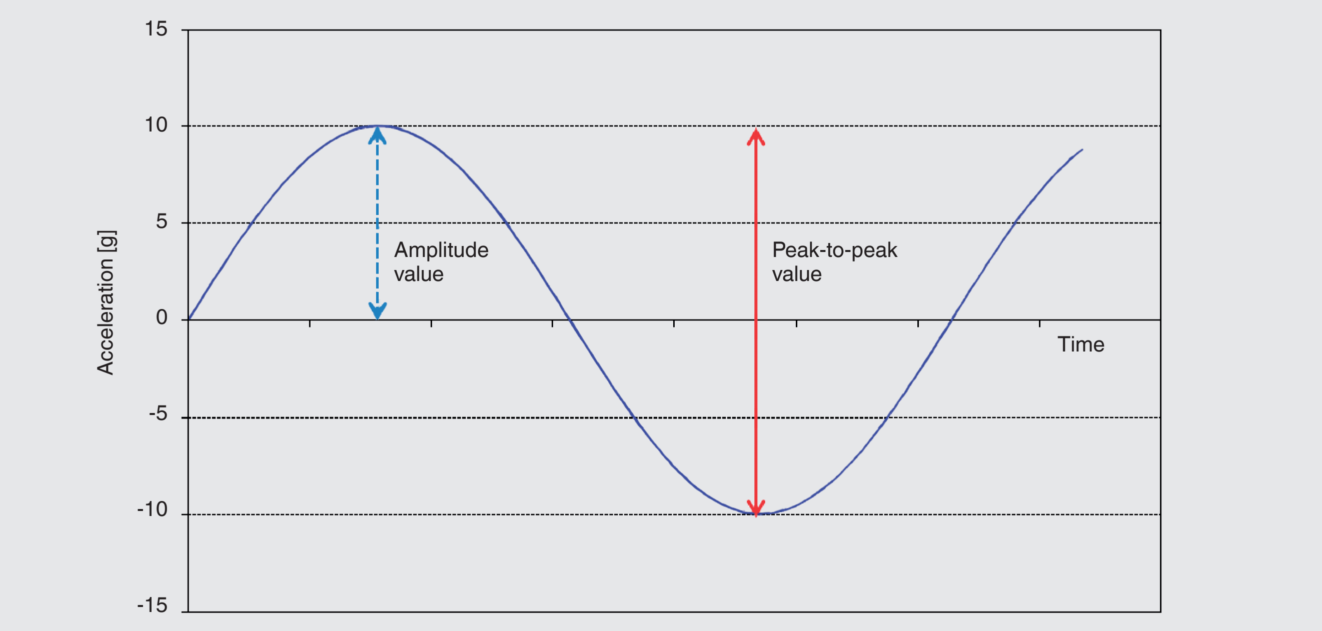
This table represents the calibration process with predefined temperatures.

This means if a temperature standard is available, the resistance value of the test item must lie within the limits specified above.

Vibration resistance of resistance thermometers

In accordance with EN 60751, the design of a resistance thermometer can be influenced by vibration-induced accelerations that can be up to 3 g (30 m/s²) and occur in a frequency range from 10 … 500 Hz.

The vibration resistance data listed in the data sheets of the electrical thermometers from WIKA refer to the "peak-to-peak" value.



Version	Required vibration resistance per EN 60751: 2008 in g [1)] (peak-to-peak)	Determined vibration resistance WIKA per IEC/EN 60751 in g [1)] (peak-to-peak)
Standard	3	6
Vibration resistant (optional, thin-film measuring resistor)	-	20
Highly vibration resistant (special construction, thin-film measuring resistor)	-	50

1) 9.81 m/s²

Measuring resistor		Vibration resistance (peak-to-peak)					
		Ø 3 mm (MI cable)			Ø 6 mm (MI cable)		
		6 g	20 g	50 g	6 g	20 g	50 g
Thin-film (F)	1 x Pt100 / 1 x Pt1000	x	x	x	x	x	x
	2 x Pt100 / 2 x Pt1000	x	x	-	x	x	x
Thin-film, face-sensitive (FS)	1 x Pt100 / 1 x Pt1000	x	-	-	x	-	-
Wire-wound (W)	1 x Pt100 / 1 x Pt1000	x	-	-	x	-	-
	2 x Pt100 / 2 x Pt1000	x	-	-	x	-	-

The vibration resistance data listed in the data sheets of the electrical thermometers from WIKA only refer to the sensor tip.

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