

Usage limitations and accuracy of platinum resistance thermometers (DIN EN 60 751:2009) in industrial applications

WIKA Data Sheet IN 00.17

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 respect to the temperature. If the resistance increases when temperature is raised, we refer to it as PTC (Positive Temperature Coefficient).

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 DIN EN 60 751 (2009-05). The most important characteristics are described in this document.

Basic values for resistance at 0 °C

Designation	Basic value in Ω
Pt100	100
Pt1000	1000

Bold: standard version

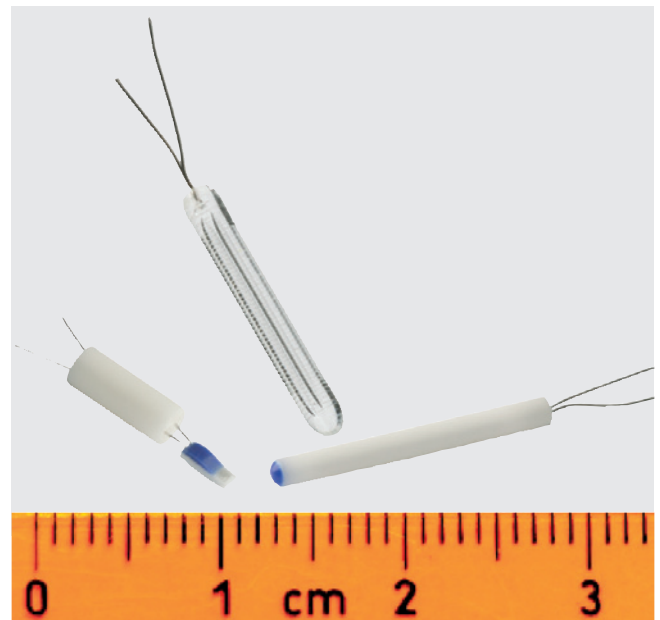


Fig. left: Thin-film resistor
Fig. center: Glass resistor
Fig. right: Ceramic resistor

Measuring resistor designs

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

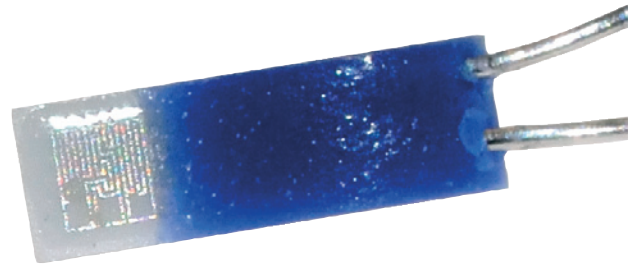
Thin film resistors (F) (standard design)

For thin-film resistors, a very thin platinum film is applied to a ceramic carrier plate. Following this connecting wires are attached. Finally, the platinum film and the connecting wire connection are sealed against external effects by a layer of glass. Thin-film resistors are characterised by their very small size and high vibration resistance.

The thin film resistor is characterised by

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

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



Thin-film resistor

Wire-wound resistors (W)

For these designs, a thin platinum wire is encased within a round protective body. This design has proven itself over the decades and is accepted throughout the world. Two subtypes are available that differ in the choice of insulating material.

Glass resistor

The bifilar wire of the glass resistor is fused within a glass body.

The glass resistor is characterised by

- Temperature range: -200 ... +400 °C *
- High vibration resistance



Glass resistor

Ceramic resistor

The platinum wire of the ceramic resistor is spiral-wound and located in a round cavity in the protective body.

The ceramic resistor is characterised by

- Temperature range: -200 ... +600 °C *
- Limited vibration resistance



Ceramic resistor

* The specifications apply to Cass B, see table on Page 4.

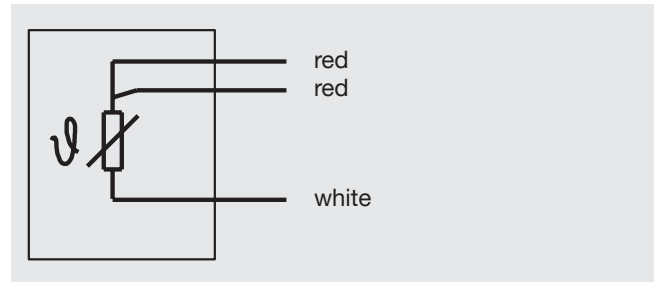
Sensor connection methods

3-wire connection (standard design)

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

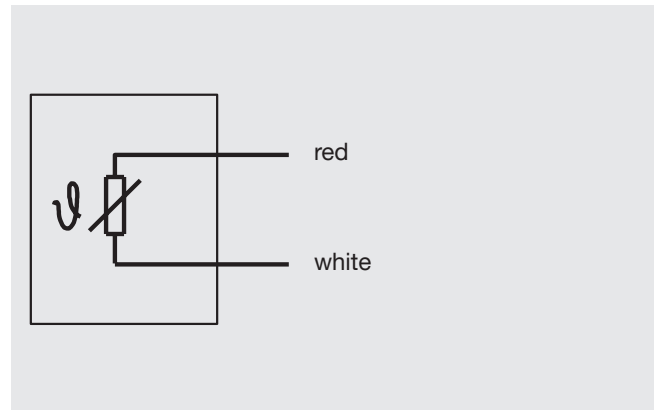


2-wire connection

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 accuracy classes A and AA, since the electrical resistance of the connecting cables and their own temperature dependency are fully included in the measurement result and thus falsify it.

Applications

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



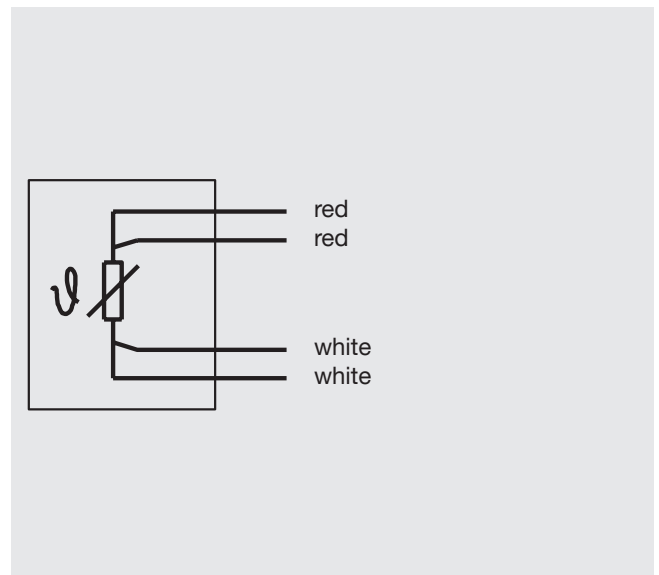
4-wire connection

The influence of the connecting cable on the result of measurement is completely eliminated since any possible asymmetries in the connecting cable's lead resistances are also compensated.

The maximum length of the connecting cable depends on the conductor cross section and on the compensation options of the electronic evaluation (transmitter, display, controller or distributed control system). A 4-wire connection can also be used as 2-wire or 3-wire connection by disconnecting the unnecessary conductors.

Applications

- Laboratory technology
- Calibration technology
- Accuracy Class A or AA
- Connecting cables up to approx. 1000 m



Dual sensors

In the standard design 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.

Relation between temperature and resistance

For each temperature there is an exact resistance value. This clear relation can be described with mathematical formulas.

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

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

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 Ohm)

The following constants apply for the calculation:

$$A = 3.9083 \cdot 10^{-3} \text{ (}^\circ\text{C}^{-1}\text{)}$$

$$B = -5.7750 \cdot 10^{-7} \text{ (}^\circ\text{C}^{-2}\text{)}$$

$$C = -4.1830 \cdot 10^{-12} \text{ (}^\circ\text{C}^{-4}\text{)}$$

Usage limitation and accuracy classes

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

Class	Temperature range		Limiting deviation	
	Wire-wound (W)	Thin-film (F)		
AA	°C	-50 ... +250	0 ... 150	$\pm (0.10 + 0.0017 t)^1$
A	°C	-100 ... +450	-30 ... +300	$\pm (0.15 + 0.0020 t)^1$
B	°C	-196 ... +600	-50 ... +500	$\pm (0.30 + 0.0050 t)^1$

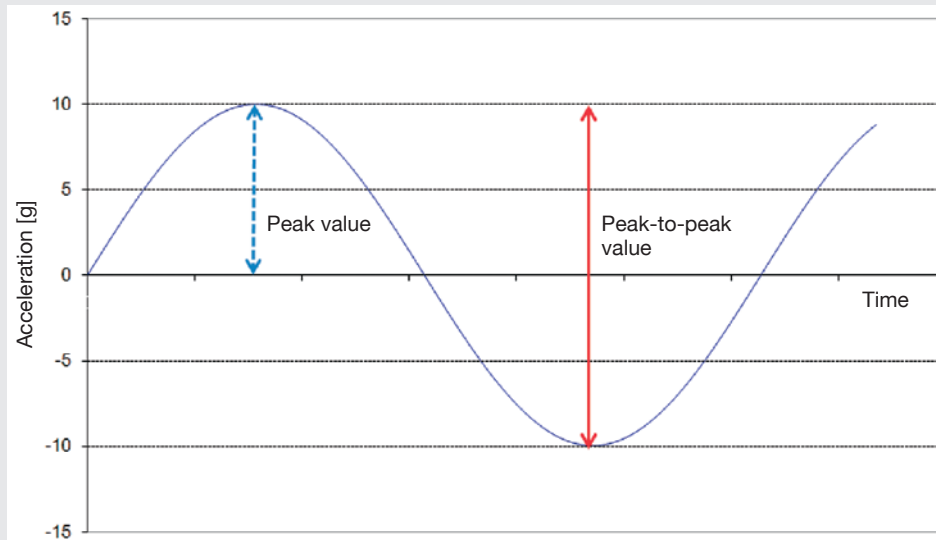
1) | t | is the value of the temperature in °C without consideration of the sign

Bold: Standard version

Vibration resistance of resistance thermometers

In accordance with DIN EN 60 751, the design of a resistance thermometer can be influenced by vibration-induced accelerations that can be up to 30 m/s² and occur in a frequency range from 10 to 500 Hz. The standard refers to the peak-to-peak value (see DIN EN 60 751 Edition 1996).

In order to guarantee the comparability of pressure and temperature measuring instruments, WIKA tests all designs under the same test conditions. Since every other standard (e.g. IEC 60 068 Environmental tests) refers to the peak value of vibrations, WIKA also tests the thermometers in this way. The specifications determined this way can be converted using a factor of 2 into specifications conforming to DIN EN 60 751.



Design	Determined vibration resistance Peak value in [g]*	Vibration resistance in accordance with DIN EN 60 751 in [g]*
Standard	3	6
Vibration resistant	10	20
Special structures	To 25	50

* = 9.81 m/s²

Bold: standard version

If the frequency is known and constant, the acceleration, speed and deflection can be calculated from each other.

The frequency of the vibration is used to calculate the „angular frequency“:

$$\omega = 2 \pi f$$

If the peak value of the vibration, A, is given, the following applies to the maximum speed V_{max} :

$$V_{max} = \frac{A}{\omega}$$

This can be used to determine the deflection from the reference line x_{max} :

$$x_{max} = \frac{V_{max}}{\omega}$$

The space required for the vibration, i.e. the difference between the deflections, can be shown as the peak-to-peak value of the deflection:

$$x_{s2s} = 2 x_{max}$$

Legend:

ω = Angular frequency in 1/sec

A = Peak value, i.e. maximum value of the acceleration, in m/sec²

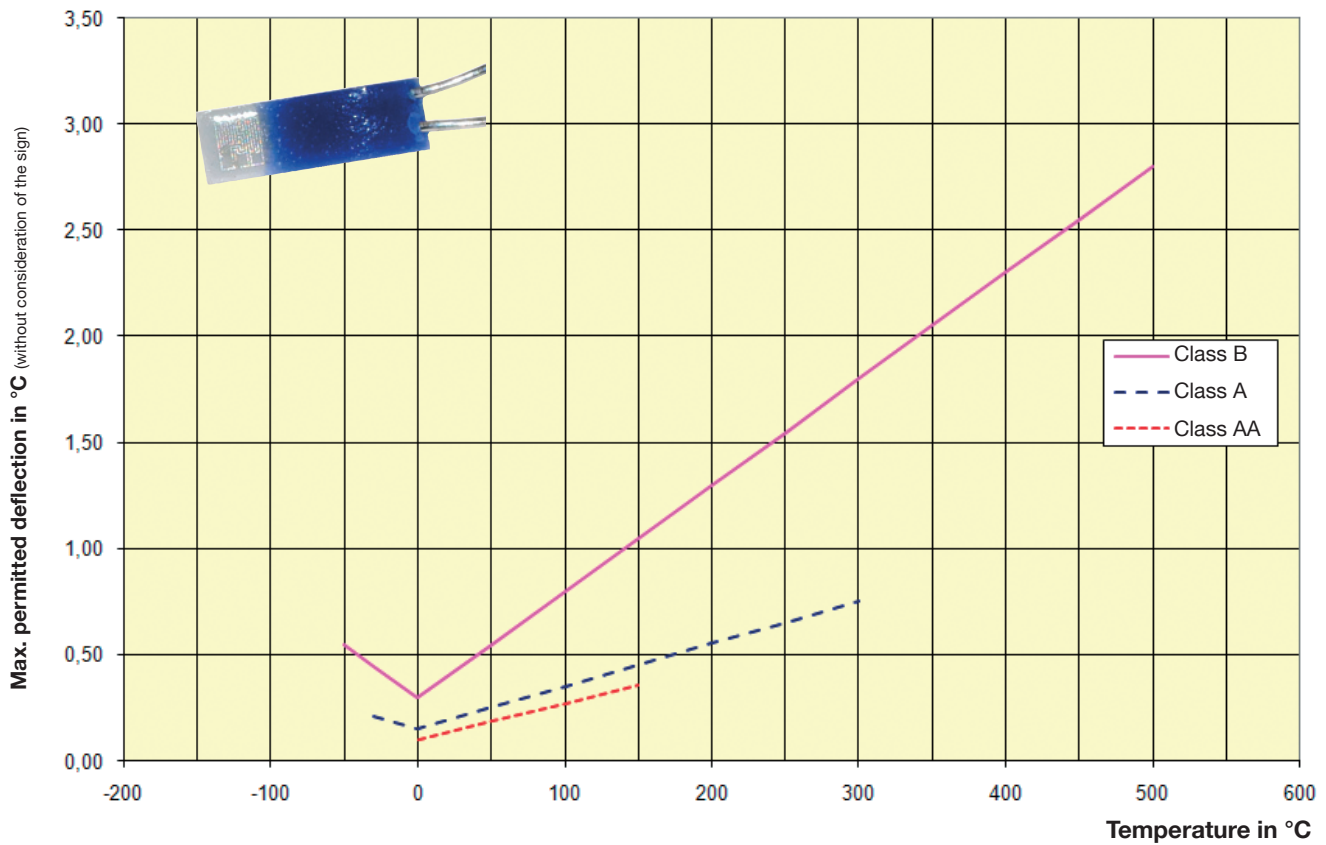
V_{max} = Maximum value of the speed during vibration, in m/sec

x_{max} = Maximum deflection from the rest position in one direction, in m

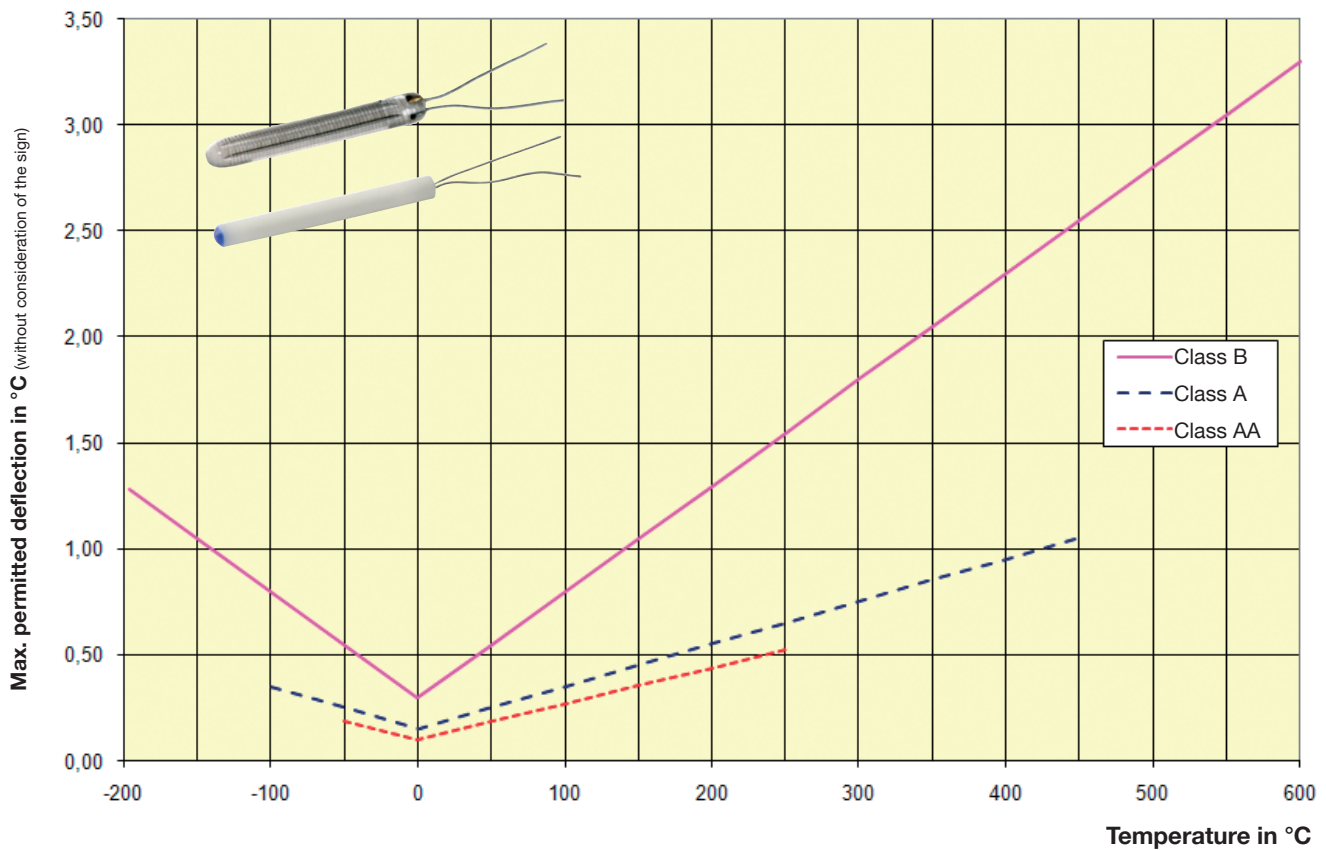
x_{S2S} = Peak-to-peak value of the deflection, i.e. difference between the two extreme values of the deflection, in m

Limiting deviations for calibration and maintenance

Limiting deviation DIN IEC 60 751 for resistance thermometers with film resistors



Limiting deviation DIN IEC 60751 for resistance thermometers with wire-wound resistors



Temperature values and limiting deviations with selected resistance values (Pt100)

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

This table can be used to check the evaluation electronics, e.g. by means of a decade resistor:

So 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 limiting deviations with selected temperatures (Pt100)

Temperature in °C (ITS 90)	Resistance value in Ohm		
	Accuracy Class AA	Accuracy Class A	Accuracy Class B
-196	20.06 ... 20.43	20.01 ... 20.48	19.69 ... 20.80
-100	60.15 ... 60.37	60.11 ... 60.40	59.93 ... 60.58
-50	80.23 ... 80.38	80.21 ... 80.41	80.09 ... 80.52
-30	88.16 ... 88.28	88.14 ... 88.30	88.04 ... 88.40
0	99.96 ... 100.04	99.94 ... 100.06	99.88 ... 100.12
20	107.74 ... 107.85	107.72 ... 107.87	107.64 ... 107.95
100	138.40 ... 138.61	138.37 ... 138.64	138.20 ... 138.81
150	157.91 ... 157.64	157.16 ... 157.49	156.93 ... 157.72
250	193.91 ... 194.29	193.86 ... 194.33	193.54 ... 194.66
300	211.83 ... 212.27	211.78 ... 212.32	211.41 ... 212.69
450	263.89 ... 264.47	263.82 ... 264.53	263.31 ... 265.04
500	280.66 ... 281.29	280.59 ... 281.36	280.04 ... 281.91
600	313.35 ... 314.07	313.27 ... 314.14	312.65 ... 314.77

This table represents the calibration process with predefined temperatures.

So if a temperature standard is available, the resistance value of the test piece must lie within the limits specified above.

Specifications and dimensions given in this leaflet represent the state of engineering at the time of printing.
Modifications may take place and materials specified may be replaced by others without prior notice.



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