temperature humidity CO_2 level flow position

Design Manual

SENSIT

extend your senses

Motto: Temperature is the fourth most frequently measured physical quantity after time, weight and dimension.

Dear users of this Design and User Manual,

You have received a document that originated from the need to preserve in writing the experience with the application and operation of resistance temperature sensors made by SENSIT s.r.o. (hereinafter Sensit) and to provide users with guidance and direction for their applications. The first edition of this Design Manual was later filled with not only more experience but also information most frequently requested by customers. We are delighted that the increasing number of users of the Design Manual also comes with feedback in the form of suggestions and requests for its expansion, especially of its theoretical aspect. Information contained in this Design Manual can be of great help especially for new designers or assembling companies when choosing the suitable type of temperature sensing element and subsequently the temperature sensor during project design and implementation. This information may also be useful to those who have heard about temperature measurement and want to learn the means by which this physical quantity is most frequently measured and what to pay attention to when measuring it.

Consequently, the Design Manual is now not only a summary of experience, rules and principles of temperature sensor application, but also information that can be successfully used for teaching in third stage schools.

The terminology of this manual strives to strictly observe EN 60751, valid from 1 June 2009. (The previous standard, IEC 751, expired on 1 August 2011). In cases where it is customary to use different terms or relationships, these are stated as well.

The management of SENSIT s.r.o. will be grateful for any substantive comments on this Design Manual. All acceptable contributions will be included in the next edition or discussed further. Please contact us at obchod@sensit.cz with the subject "Design Manual".

Content

A bit of theory will not kill anyone

(this chapter can be skipped)

Temperature is one of the 7 base quantities of the International System of Units (SI). Temperature is also one of the state quantities that describe the state of a system. If a system is in the equilibrium state, it can be said that the temperature is the measure of the internal energy of the system (energy of the oscillating movement of atoms, energy of the movement of free electrons). In a non-equilibrium system, the temperature is the measure of the internal energy at the point of measurement. A temperature scale had to be established for the temperature quantity. The basis of the temperature scale is the thermodynamic temperature T measured in kelvin (K). Although temperature may seem infinite, it has certain limits (depending on the system to which it applies). The bottom limit is the so-called absolute zero, which was taken as the starting point – zero on the Kelvin thermodynamic scale. It is a state where any movement of elementary particles in the system ceases, the system has zero internal energy. The thermodynamic temperature is determined according to certain dependencies: State equations of ideal gas, the Carnot cycle efficiency and the Planck's radiation law. One kelvin is then defined as the 273.16th part of the difference between the thermodynamic temperature zero (absolute zero) and the temperature of the triple point of water (in the phase diagram, the triple point of water indicates the temperature and pressure at which the three phases of water (solid – ice, liquid – water and gas – saturated water vapour) coexist in equilibrium). Apart from thermodynamic temperature **T**, there is also Celsius temperature **t** expressed in degrees Celsius (°C), which is much more frequently used in practice. The relationship between thermodynamic and Celsius temperature is expressed by the following equations:

$$T\ (K) = T_0 + t = 273.16 + t\ (°C)$$
$$t\ (°C) = T - T_0 = T\ (K) - 273.16$$

If the difference of two temperatures is 1 K, it is also exactly 1 °C.

Anglo-Saxon countries still commonly use the Fahrenheit temperature scale, whose unit is 1 degree Fahrenheit (°F). Its relationship to the Celsius scale is expressed by the following equations:

$$t\ (°F) = 1.8 \cdot t\ (°C) + 32$$

$$t\ (°C) = (t\ (°F) - 32) / 1.8$$

Keep in mind the definition that if the heat flow between two objects in contact is equal to zero, both objects have the same temperature. Conversely, if two objects in contact have the same temperature, the heat flow between them is equal to zero – the objects are in thermal equilibrium. This must be taken into account especially when measuring the temperature of surfaces, both planar and concave.

Heat, as a kind of energy, spreads (transfers) in three ways:

1. Conduction
2. Convection
3. Radiation.

The heat transfer through conduction and convection can only take place in a material environment and its principle is to transfer the oscillating kinetic energy of atoms between the matter atoms until the internal energies are balanced – the kinetic energy of the oscillating atoms is the same.

Unlike conduction and convection, heat transfer by radiation can also occur in an immaterial environment (in vacuum), because energy is transmitted by electromagnetic waves in the infrared range. The origin of electromagnetic waves is in the internal structure of atoms of a substance that radiates heat. Heat-excited electrons of individual atoms move from higher (high-energy) orbitals to lower (low-energy) orbitals, while radiating the difference in energy potential of individual orbitals in the form of electromagnetic (in this case infrared) radiation. By radiating infrared energy, the radiating object cools down, while the object receiving infrared radiation absorbs the energy and warms up. An object is in thermal equilibrium if the amount of radiated thermal energy is equal to the amount of absorbed thermal energy.

Note: any object that has a higher temperature than absolute zero is a source of infrared radiation.

Temperature is one of several quantities that cannot be measured directly, but only by means of other physical quantities. Temperature measurement is indirect measurement.

The properties of various objects vary if their temperature varies: increasing the temperature increases the volume of liquids, increases the length of a metal rod, increases the resistance of a metal wire, decreases the resistance of some semi-conductive substances, increases the pressure of enclosed gas. All these properties are used to design instruments that show the level of temperature. These temperature meters are called **thermometers**, although they should be called *temperature meters* because they measure temperature and not heat. This historic inconsistency will probably never be corrected, so temperature meters are called thermometers and heat meters are called heat meters or calorimeters.

Thermometers are usually compact instruments unlike thermometer devices that consist of a temperature sensor and auxiliary (evaluation) components.

Thermometers or temperature sensors utilize the following physical principles for their function, including a clear temperature dependence:

- Volumetric expansion of liquids, gases and solids. For solids, only one dimension is used in a specific geometric arrangement – length. In this case, we are talking about
- linear expansion of solids
- Change of electrical resistance of metals and semiconductors
- Thermoelectric effect
- Change of the resonant frequency of crystals
- Change of the parameters of the fibre Bragg grating
- Selective light scattering and refractive index in liquid crystals
- Change of the pressure of saturated vapour
- Heat radiation

The most accurate metrological method of temperature measurement, which is also a very technically demanding and time-consuming method, is gas thermometry, which is based on the state equation for constant volume. For this reason, the International Practical Temperature Scale was established in 1927, which is labelled ITS-90 after the last modification in 1990. ITS-90 is a temperature scale based on 17 fixed empirically determined and defined points that correspond to equilibrium state between the phases of selected chemical elements and water.

The following chapters will address temperature measurement by elements using the physical principle of varying electrical resistance of metal and semiconductors depending on temperature and change of thermoelectric voltage on temperature.

Basic division of Sensit temperature sensors

Resistance temperature sensors utilize the dependence of the change of metal and semiconductor resistance on temperature and currently belong to the most widely used temperature measurement devices. They are widely used in all industries, e.g. engineering, automotive, chemical, heating, when using non-traditional forms of energy, in the food industry, etc. They are also used, for example, as standards for calibrating other types of sensors or thermometers. Their main advantages include stability, accuracy and signal shape. An indispensable advantage of resistance temperature sensors is the ability to electronically process and archive data.

Resistance temperature sensors utilize the dependence of electrical resistance of materials on temperature. They are usually made of pure metal materials, such as platinum, nickel, copper or their alloys. In these materials, the change of resistance and temperature is directly proportional and approximately quadratic. Semiconductor and special resistance sensors are different. In the case of NTC thermistors, for example, the dependence is inversely proportional and approximately hyperbolic – the resistance decreases with increasing temperature unlike PTC thermistors, so-called posistors. The resistance of a posistor first slightly decreases, above the Curie temperature it sharply rises by about 3 orders of magnitude and then decreases again slightly. The narrow area of the sharp increase of electrical resistance, which is one of the characteristics of a posistor, can be influenced by the chemical composition of the input material, thus creating, for example, a set of elements with a graded point of sharp increase in resistance (typically per 10 °C). The dependence curve in the entire temperature range of the posistor can have one to three inflection points. Due to their steep temperature dependence, posistors are also used as resettable thermal fuses. Other applications include switching circuits with semiconductor elements or two-state sensors in control systems at the winding of electric motors, transformers or heating of power components.

The thermoelectric phenomenon (the occurrence of electromotive voltage during the contact of two different metals and its dependence on temperature) is utilized by thermoelectric temperature sensors called thermocouples.

Thermocouples are the second most widely used temperature sensors for temperature measurement after resistance temperature sensors and practically the only elements for contact measurement of temperatures above 800 °C. The contact (joint) of two different metal conductors creates a potential difference proportional to the joint temperature. When closing the circuit by connecting the other ends of the conductors and then disconnecting one of the conductors, the thermoelectric voltage between the ends of this disconnected conductor will be proportional to the temperature difference between the two joints. Its value depends on the materials of the individual conductors. A thermocouple thus represents a generator of voltage, whose value depends on the material from which it is made and on the temperature difference between the two joints, one of which is the *measuring* joint and one is the *comparing* joint. For the correct function of the thermocouple as a gauge, it is essential that the temperature of the comparing joint is constant or known (the parasitic effect of the thermoelectric voltage of this joint is compensated).

Historical development of thermocouples has resulted in several metal pairs currently used in practice. The technical parameters and conditions of use are covered by ČSN EN 60 584 standards (May 2014). The types, designation and temperature ranges of thermocouples are listed in Table 1.

	Conductor composition		Note

Designation according to EN 60 584	Positive conductor	Negative conductor	Measuring range [°C]	
R	PtRh13	Pt	-50 to +1768	Platinum-platinum rhodium 13
S	PtRh10	Pt	-50 to +1768	Platinum-platinum rhodium 10
B	PtRh30	PtRh6	0 to +1820	Platinum rhodium-platinum rhodium
J	Fe	CuNi	-210 to +1200	Iron-constantan
T	Cu	CuNi	-270 to +400	Copper-constantan
E	NiCr	CuNi	-270 to +1000	Chromel-constantan
K	NiCr	NiAl	-270 to +1300	Chromel-alumel
N	NiCrSi	NiSi	-270 to +1300	Nicrosil-nisil
C	WRe5	WRe26	0 to +2315	Tungsten; Rhenium
A	WRe5	WRe20	0 to 2500	Tungsten; Rhenium

Tab. 1 – Types, designation and temperature ranges of thermocouples

Temperature ranges

The temperature range of each temperature sensor is given by the intersection of temperature ranges of the temperature chip, materials used for the installation (solder, sealing compounds, filling material, insulating material, spacer, etc.) and the supply cable (connector).

Sensing element type	Temperature range (°C)	note
platinum	-200 to +900	
nickel	-70 to + 250	
copper	-50 to +150	
NTC	-50 to 150	Typical range. Special thermistor up to 400 or 600
KTY	-55 to +125	
Dallas	-10 to +85	
thermocouple K	-270 to 1300	
thermocouple J	-210 to 1200	
thermocouple S	-50 to 1768	
thermocouple C	0 to 2315	
thermocouple A	0 to 2500	

Tab. 2 – temperature ranges of individual temperature sensing (measuring) elements

Insulation type (working name)	Temperature resistance (°C)	note
PVC	-30 /+70	
extruded PVC	-40 /+105	
silicone	-60 /+180	
silicone – Teflon	-60 /+200	
PTFE	-180 /+260	
LTG glass braid	-50 /+400	

Tab. 3 – Temperature resistance of cables according to the insulation type

Terminology

(in alphabetical order)

The **Curie point** or **Curie temperature** (T_c) is a characteristic feature of ferromagnetic, ferroelectric and piezoelectric substances described by French physicist Pierre Curie. Above the Curie temperature, the substance loses its ferromagnetic, ferroelectric or piezoelectric properties. This feature is used by posistors – PTC thermistors.

The response time $\tau0.5$ ($\tau0.9$) – the sensor time constant – indicates the time in which the input signal reaches 50 % (90 %) of the final value (steady state) in the case of a temperature jump. It depends on the dimensions, material and weight of the sensor and on the environment in which the temperature is measured (e.g. water, air) and its flow rate. The response time for temperature sensors of two different housing diameters is shown in Fig 1.

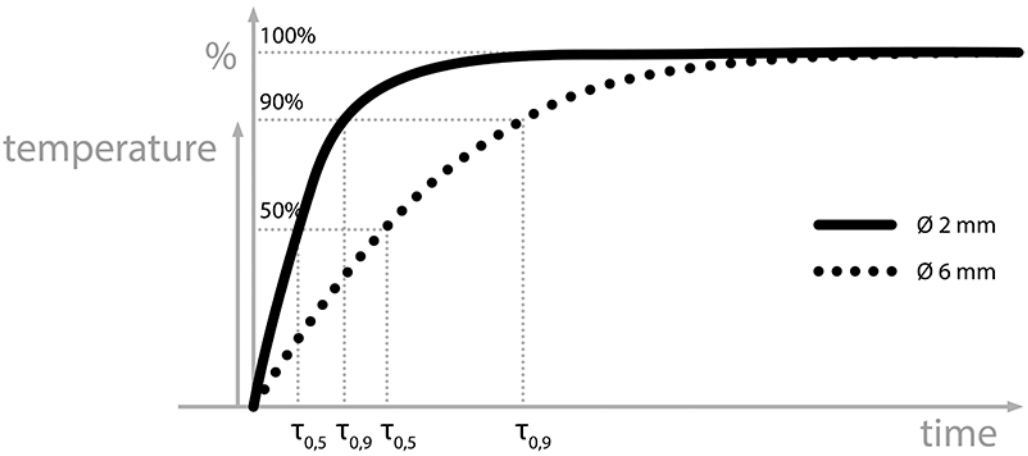


Fig. 1 – Graphical representation of the term “response time”

Electromagnetic compatibility (**EMC**) is a property of an electronic device (transducer, switch, temperature indicator) based on the fact that it does not influence other electronic devices, including itself, with its electromagnetic field and that it resists the effects of the electromagnetic fields of other devices. It is therefore divided into two subcategories: how such a device disturbs its surroundings and how the surroundings disturb the device.

Standard – in general: the standard of a measuring unit or scale of a certain quantity is a gauge for the implementation and maintenance of the unit or scale and its transfer to less accurate gauges.

Temperature sensor hysteresis – property of resistance temperature sensors, where values of electrical resistance measured at evenly increasing temperature from temperature t_1 to temperature t_2 are different from values of electrical resistance measured at evenly decreasing temperature from temperature t_2 to temperature t_1 (t_1; t_2 define the measuring range of the sensor).

Absolute error – **Δ** – difference between the real value and the measured value, which depends on many factors, some of which cannot be minimized.

Relative error – **δ** – ratio of the absolute error to the measured value. It represents the absolute error relative to the unit of the measured quantity. If multiplied by 100, it represents an error in %.

A **systematic error** distorts the measurement result in a certain way and on a regular basis, which primarily leads to values permanently higher or permanently lower than the correct value. Systematic errors may be caused by the measurement methods used, the measuring instruments used or the people carrying out the measurements (so-called personal error).

Example: Temperature measurement by contact temperature sensors is affected by a considerable systematic error. The measured value is lower than the real value and there is an indirect proportion between the measurement error and the diameter of the pipe to which the temperature sensor is attached.

An **inflection point** is a point on a curve at which the curvature changes its sign from positive to negative and vice versa (the curve changes from concave to convex and vice versa).

ITS 90 – International Temperature Scale. It defines the unit of thermodynamic temperature (**T**) – kelvin **[K]** as 1/273.16 of the thermodynamic temperature of the triple point of water. At the same time, it defines temperature (**t**) in degrees Celsius **[°C]** as

$$t\,[°C] = T[K] - 273.15$$

It also defines other 16 empirically determined temperature points that correspond to equilibrium states between the phases (solid, liquid, gas) of selected elements (H_2, He, Ne, O_2, Ar, Hg, Ga, In, Sn, Zn, Al, Ag, Au, Cu).

Insulation resistance is electrical resistance measured between any parts of an electrical circuit (temperature sensing element, supply cables) and the housing, at a defined temperature and with a specified measuring voltage (AC or DC).

Joule heat – is generated by the passage of electric current and is proportional to the second power of this current. It causes self-heating of the temperature sensing element and positive systematic measurement error.

Compensation line – interconnects the thermocouple and the measuring instrument and its branches are made of different materials (metal alloys) than the thermocouple branches. The branches of the compensation line do not create another (parasitic) thermocouple on the connections with the thermocouple branches. It is used in cases where the thermocouple branch material is expensive and the use of an *extension line* would increase the application costs. The temperature of the connections of the compensation line with the thermocouple must not exceed 200 °C and the electrical resistance of the compensation line must not exceed 100 ohms.

Metal temperature sensing element – resistance temperature sensing element that measures temperature using the dependence of the electrical resistance of the metal on temperature . The metal can be platinum, nickel or copper and the sensing element can be wire-wound or thin-film.

Wire-wound metal temperature sensing element – is made of a thin metal wire (Pt, Ni or Cu) of a given electrical resistance, which is evenly wound onto a ceramic cylinder and then fixed and passivated with a ceramic layer. A less common design is a thin wire wound into a spiral that is inserted into a ceramic capillary.

Thin-film metal temperature sensing element – see Temperature (resistance) chip.

Metal resistance temperature sensor – resistance sensor with a metal temperature sensing element.

The **critical temperature of a technological process** is a temperature value, the observance of which has a significant impact on the process quality and therefore on the quality of the final product.

Cryogenic temperature – generally temperature below the freezing point. The division and terminology of the cryogenic temperature are ambiguous. In cryotechnology, the Kelvin scale is used more often than the Celsius scale. Normal cryogenic temperatures up to 120 K (-150 °C), low cryogenic temperatures from 120 K to 5 K (-268 °C), very low cryogenic temperatures from 5 K to 1 K (-272 °C).

MGO – see Mineral insulated resistance temperature sensor

Measurement uncertainty is the parameter related to the measurement result and characterizes the range of values that can be rationally assigned to the measured quantity.

The causes (sources) of measurement uncertainties are influences that in some way affect the uncertainty of unambiguous determination of the measurement result and shift the measured value away from the actual value. Generally, the most common causes of uncertainties are: imperfect or incomplete definition of the measured quantity; wrong choice of the evaluation device; wrong choice of the measurement location/samples; wrong measurement procedure; rounding; linearisation; approximation; interpolation; extrapolation; unknown or uncompensated environmental influences; failure to maintain the same conditions in repeated measurements; subjective influences of the operator and, last but not least, the inaccuracy of the standards and reference materials.

When measuring temperature, measurement uncertainties are mainly affected by the following factors: *response time, self-heating of the temperature sensing element*, mechanical stress (vibration, pressure, bending of the sensor), ambient temperature, heat radiation from the measured sample, *insulation resistance of the sensor* and its possible change, disturbing electric and magnetic fields (induced voltage), mechanical connection of unsuitable materials (parasitic thermoelectric voltages), thermal stress, deviations from the specified installation method (depth of immersion) and, last but not least, radioactive radiation with possible influence on the structure and properties of the mechanical layers of the temperature sensor.

Nickel resistance temperature sensor – resistance temperature sensor with a nickel temperature sensing element.

Resistance temperature sensing element – part of a temperature sensor used to sense temperature. It consists of a material with a defined dependence of electrical resistance on temperature and outlets. Sometimes it is also called a measuring element, measuring resistor (EN 60 751) or measuring sensor. For the purposes of this manual, we will stick to the term **sensing element**.

Mineral insulated resistance temperature sensor – lead-in wires with a temperature chip are pressed with powder ceramic insulation (MgO) into a thin-walled metal tube made of austenitic steel. The diameter of a mineral insulated resistance temperature sensor is 1.5 mm to 6 mm, the temperature range is up to 600 °C. This type of temperature sensor is sometimes (illogically and incorrectly) called MGO (the design is similar to a mineral insulated thermocouple – see Fig. 2).

Resistance temperature sensor – a unit consisting of a resistance temperature sensing element, internal wiring with insulation, a stem tube (stem) and a head or connecting line. It is also called a resistance thermometer.

Optical temperature sensor – a so-called Bragg grating is created at the desired location of the structure of a glass (optical) fibre. The optical fibre extends due to temperature, which changes the parameters of the Bragg grating. The evaluation unit sends a light beam into the optical fibre with an optical temperature sensor. A narrow part of the light spectrum is reflected back from the Bragg grating to the device. Changing the parameters of the Bragg grating also changes the value of the wavelength of the reflected light beam. The change of the wavelength of the light reflected from the Bragg grating is proportional to the temperature at its location. This type of temperature sensor allows the measurement of temperature at different points of the optical fibre simultaneously. The condition is that every fibre measuring point contains a Bragg grating with different parameters and that the evaluation device can process data in a cascade way. Due to the high cost of the optical temperature sensor and evaluator assembly compared to other sensor types, optical temperature sensors can be used where other types of sensors cannot be physically applied or where their use is economically disadvantageous. The primary circuits of nuclear power plants, plants and equipment with high electromagnetic disturbance, specific line structures (bridges, special roads), deep wells for heat pumps and, last but not least, some medical branches.

Platinum resistance temperature sensor – resistance temperature sensor with a platinum temperature sensing element.

Housing – metal (plastic) part of a temperature sensor protecting the *temperature sensing element* and the *internal wiring* from mechanical damage and external influences.

A **posistor** (PTC thermistor) is a temperature-dependent resistor distinguished by a negative-positive temperature characteristic with a significant increase of resistance (by up to 5 orders of magnitude) in a specific narrow temperature interval, which is characteristic for all types of posistors. See page 15.

Extension line – used to connect a thermocouple to a measuring instrument, made of the same materials as the thermocouple branches. If the material of the thermocouple branches is expensive, the extension line is usually replaced with a *compensation line*. An extension line should have an electrical resistance of up to 100 ohms.

Real probe – commercial name for very fast resistance temperature sensors, where the temperature chip is soldered to the bottom of a stem with a diameter of 6 mm. There is therefore only a 0.2mm thick stainless steel layer between the temperature chip and the measured medium.

Self-heating of a temperature sensing element – the passage of measuring current **I** through measuring resistance **R** creates electrical power $\mathbf{P = I^2 R}$, which completely changes to Joule heat. This increases the temperature of the temperature chip itself and affects the measurement with a positive systematic error.

Specified gauge – gauge specified by the Ministry of Industry and Trade Decree No. 345/2002 Coll. for type approval and mandatory verification with respect to its significance. In the case of temperature sensors, these include paired temperature sensors for the billing measurement of heat consumption (charges, tariffs, taxes), temperature sensors having an irreplaceable influence on processes related to environmental protection, occupational safety or protection of other public interests protected by special legislation (HACCAP – temperature sensors measuring *critical temperatures* during food processing – baking temperature, pasteurisation temperature) and temperature sensors in sterilizers (sterilization temperature, health protection).

Stem – metal part of a head temperature sensor protecting the sensing element and the internal wiring from mechanical damage and external influences.

Mean time to failure (MTTF) – statistical value used to quantify the reliability of a product. It is expressed in hours in the format $\mathbf{a.bc \times 10^y}$ h. For a product set (set of temperature sensors), for which we know the time from deployment to failure, the MTTF is calculated as the average of these times.

Temperature resistance sensing element – see Resistance temperature sensing element.

Temperature (resistance) chip – electronic component – metal resistance path of 100, 200, 500, 1000 or 10000 ohms created on a miniature ceramic plate using vacuum deposition of a thin metal layer (Pt, Ni, Cu), photolithography, laser alignment of electrical resistance, splitting of a ceramic pad, point welding of lead-in wires, passivation of the overall structure against external influences and final dimensioning.

Temperature coefficient α – determines the slope of the curve expressing the dependence of the resistance of a resistance temperature sensing element on temperature. The basic resistance at 0 °C $\mathbf{R_0}$ and temperature coefficient **α** are the main characteristics of every sensing element.

Thermistor – temperature-dependent resistor made by press-forming a mixture of metals with semiconductor properties (Fe_2O_3, TiO_2, CuO_2, NiO, etc.) at high temperature into the shape of a bead or disc with two outlets. A thermistor referred to as NTC is characterized by a negative temperature dependence – the electrical resistance decreases with increasing temperature. The basic NTC parameters are electrical resistance at 25 °C and the **β** coefficient, which characterizes the slope of the curve of the dependence of electrical resistance on temperature.

Thermocouple temperature sensor (thermocouple) – sensor consisting of two conductors of a specific composition isolated from each other and connected (welded) at the end into a ball. It uses the physical principle of creating an electrical potential at the point of contact of two different metals whose value is temperature-dependent. It measures the difference of the so-called thermoelectric voltage formed between the joints of the two metals on the "hot" and "cold" end. This thermoelectric voltage is proportional to the temperature difference between the "hot" and "cold" joint and is in the order of mV.

Mineral insulated thermocouple – characterized by a configuration where both thermocouple branches are pressed with powder ceramic insulation into a thin-walled metal tube. The cross section of a mineral insulated thermocouple is shown in Fig. 2.

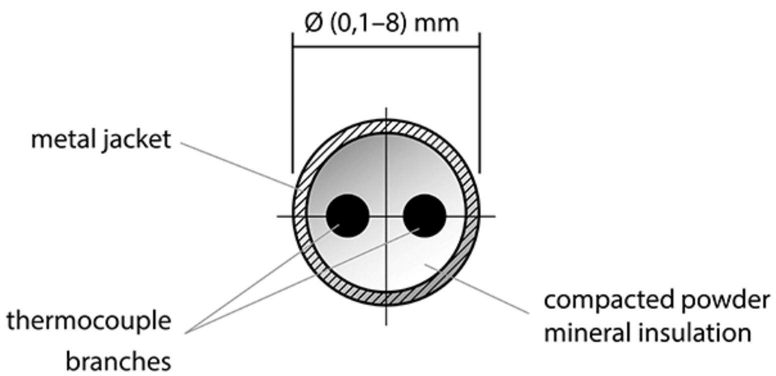


Fig. 2 – cross section of a mineral insulated thermocouple

The thin-wall jacket is made of austenitic steel or (for high temperatures) Inconel. The pressed powder insulation is usually MgO or Al_2O_3. Mineral insulated thermocouples are supplied with an insulated end, grounded end or with a bare measuring end.

Type test – verification of the specified technical parameters of a given type of product, in this case a temperature sensor. The type test is performed by the manufacturer (testing – metrological – laboratory) and its output is a type test report. The type test is carried out before placing a new type of temperature sensor in the market. A repeated type test may be performed after a change of materials or components having a major impact on the properties of the temperature sensor.

Internal wiring – conductors connecting the resistance temperature sensing element to a terminal block or connector located in the sensor head or to a cable in the case of cable temperature sensors – Fig. 3.

Fig. 3 – Internal wiring

Basic resistance R_0 – resistance of a sensing element (sensor) at 0 °C (or at 0.01 °C in the case of standards and accurate thermometers).

The **dependence of resistance R on temperature** – is characteristic for every resistance temperature sensor. Typical courses of the dependence of resistance on temperature for various types of resistance sensing elements are shown in Fig. 4.

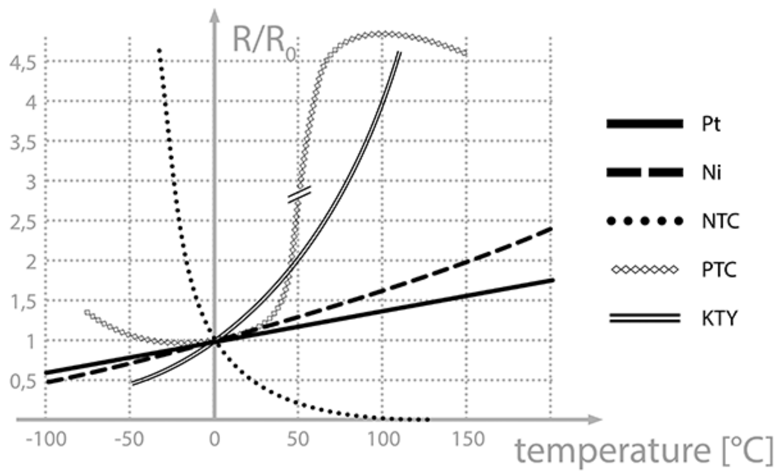


Fig. 4 – Courses of the dependence of the ratio of resistance R to R_0 on temperature for various types of resistance temperature sensors.

Note: The curve for PTC actually has the upper bend at the R/R_0 value up to 5 orders of magnitude higher than on this diagram, i.e. at a value of up to 450,000.

Division of resistance temperature sensors

Resistance temperature sensors can be divided according to various criteria. This manual only states the most used criteria.

1) **According to the type of resistive material of the sensing element**

With sensing elements made of metal materials - Pt, Ni, Cu

With sensing elements made of semiconductor materials - NTC, PTC thermistors

- monocrystalline Si, Ge

2) **According to the temperature range**

For the area of:	- low temperatures	-200 °C to 100 °C
	- room temperatures	-30 °C to 100 °C
	- lower-middle temperatures	-50 °C to 650 °C
	- higher-middle temperatures	0 °C to 1000 °C

3) **According to the accuracy class and use**

Accurate	- standard
	- laboratory
Industrial	- working
	- operational

4) **According to the connection method**

Cable	- free end
	- connector
Head	- gland and terminal block
	- connector

5) **According to application**

Indoors
Outdoors
In a thermowell
Contact
Threaded
Smooth stem
Bayonet mount
Right-angled
Mineral insulated (deformable)

Wiring of resistance temperature sensors

a. **2-wire** – used for common measurement at shorter distances.

b. **3-wire** – compensates for the influence of the change of the resistance of the supply conductors up to their length of about 100 m. Its advantage is the possibility of measuring the resistance of the internal wiring during operation.

c. **4-wire connection** – the measuring resistor in this case is fitted with two current and two voltage wires. The sensor measures the voltage drop at the measuring resistor fed by constant current. The resistance of the internal wiring is completely excluded. It is used for accurate measurements.

d. **2 x 2-wire connection** – it is used for common measurement at shorter distances if two measuring resistors have to be placed in one sensor stem. Measuring resistors do not have to be generally identical.

The types of connection of resistance temperature sensors are shown in Fig. 5.

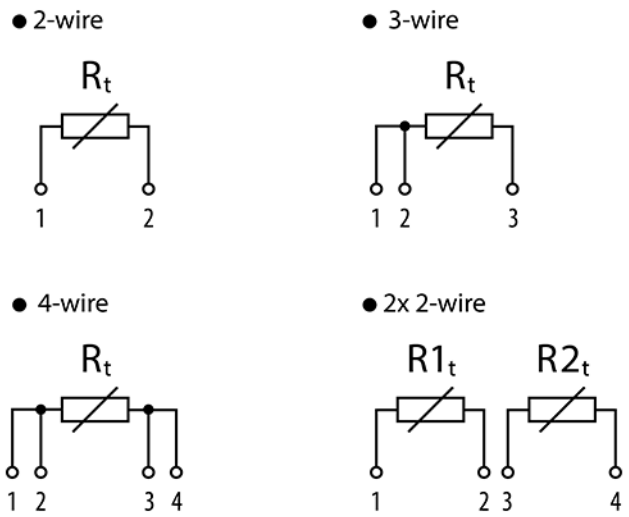


Fig. 5 – Types of connection of resistance temperature sensors

The connection method and the internal wiring material affect the measurement error. The effect of the internal wiring can be reduced by the use of resistance temperature sensors with higher resistances of the sensing element (e.g. 500 Ω, 1000 Ω ...). Accurate measurements fundamentally require the 4-wire connection.

In technical literature, leaflets, etc., the 2-wire, 3-wire and 4-wire connections are abbreviated to **2w**, **3w** and **4w**.

There are other (custom) options available (depending on the sensor type) – **2 x 3-wire** and **2 x 4-wire** connection.

Design of temperature sensing elements

Wire-wound sensing elements

Wire-wound sensing elements are made of a platinum wire with a diameter of 0.007 to 0.05 mm

a) wound into a spiral, which is inserted in cylindrical openings of a ceramic body and appropriately fixed inside. These sensing elements have the hysteresis effect minimized at the expense of vibration resistance. Currently, they are mainly used as superior standards in metal stems filled with air or a mixture of helium and oxygen and hermetically sealed (direct contact with the atmosphere causes an increase of measurement uncertainty mainly due to hydrogen and carbon oxide).

b) bifilarily wound on a ceramic body and covered with ceramic enamel or wound on a glass body and covered with glass solder. These sensing elements are protected against vibration at the expense of hysteresis. The use of these wire-wound sensing elements rapidly drops at the expense of film sensing elements that have smaller dimensions and a shorter time constant, making them significantly more economical.

Wire-wound sensing elements are produced with R_0 values equal to 100 Ω or 500 Ω. The outlets of these sensing elements are wired with a usual diameter of 0.3 or 0.35 mm and length of 10 to 30 mm. The electrical resistance of the outlets is included in the overall resistance of the sensing element, so the length of the outlets cannot be shortened.

Note: For 2nd degree standards, the following values are used: Pt 100; $\alpha=1.3925.10^{-3}$ °C^{-1} (Pt 100/39252), Pt 100; $\alpha=1.3920.10^{-3}$ °C^{-1} (Pt 100/3950) or Pt 100; $\alpha=1.3850.10^{-3}$ °C^{-1} (Pt 100/3850). Standards must meet the requirements of ITS 90.

Film sensing elements

The base of film sensing elements is a ceramic pad made of corundum ceramics (Al_2O_3) with an active metal layer. One ceramic pad of 100 x 100 mm can be turned into 500 or more sensing elements at once. According to the active metal layer deposition technology, we distinguish:

a) the older, thick-film technology, which consists in applying an active layer in the form of a paste on a pad by screen printing. This is followed by burning of the screen printing (thermal stabilization) layer, laser setting of the base value of resistance R_0 = 100, 500, or 1000 Ω, passivation of the active layer and cutting into individual sensing elements. Up to this point, the manufacturing operations are performed with whole ceramic pads and are called bulk operations. After cutting the ceramic pad into individual chips, individual operations take place – fixing of outlets and primary packaging.

b) the newer (approx. since 1988), thin-film technology. In this case, screen printing of the active metal layer is replaced by vacuum deposition (steaming, sputtering) of platinum, nickel or copper with subsequent formation of the final structure by photolithography. The basic (rough) setting of resistance R_0 is given by the topology of the resistance meander and thickness of the deposited layer. The exact setting of resistance R_0 (adjustment) is performed by burning the resistance path with a laser (trimming operation – the electrical resistance of the active metal layer after the photolithography operation is lower than R_0. Using a laser beam, active material is cut off from the so-called adjustment zone, which increases resistance. This operation lasts until R0 is achieved. The final operations are multilayer passivation of the active layer, cutting of the ceramic pad into strips, contacting of outlets, their fixing with glass solder and cutting of strips into individual chips. This technology enables the production of chips with an electrical resistance of R_0 = 50; 100; 200; 500; 1000; 2000; 5000; 10000 or 20000 Ω and dimensions of 2 x 10; 2 x 5; 2.3 x 2 as well as 0.3 x 0.8 mm . In most current applications, thin-film metal resistance sensing elements are replaced with wire-wound resistance sensing elements. Since the thin-film technology is taken from the production of integrated circuits, resistance sensing elements produced by this process have been named temperature chips. Samples of temperature chips produced by the thin-film technology are shown in Fig. 6.

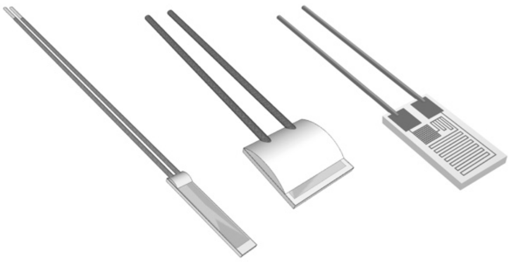
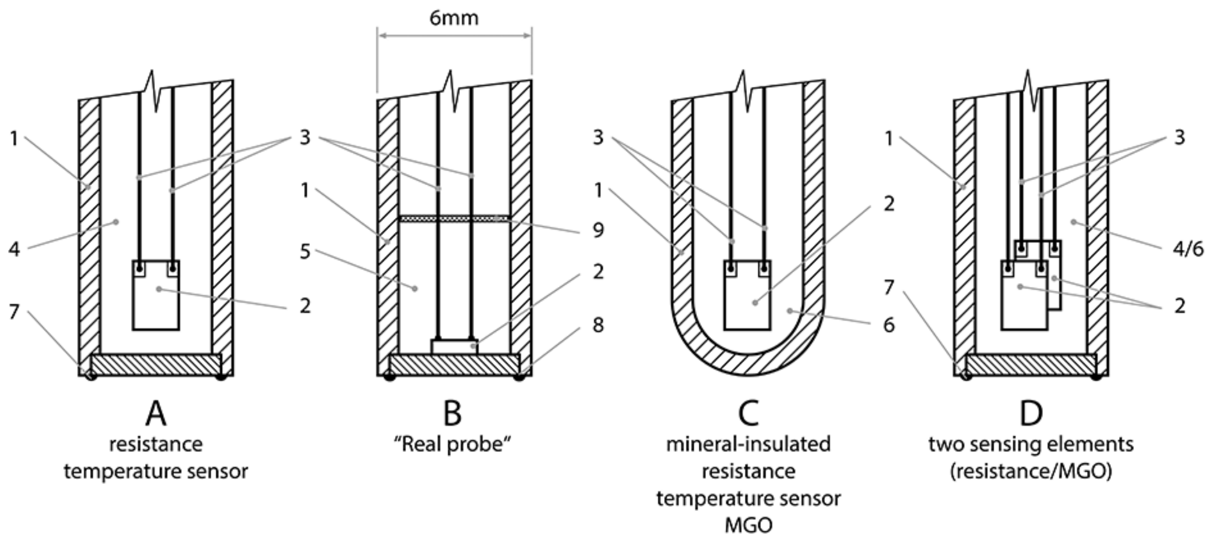


Fig. 6 – Samples of temperature chips, on the right without passivation to visualize the structure

The design of resistance temperature sensors with temperature resistance chips

Because the temperature resistance chip is a subtle electronic component, it is protected against mechanical damage by a metal housing so that the chip is as close as possible to the housing surface that comes into direct contact with the measured medium. The installation method and the materials used have a major impact on the time constant parameter. The best and fastest transfer of heat from the measured medium through the housing wall to the temperature chip and fixation of the temperature chip in the housing is achieved by using suitable sealing compounds (position A in Fig. 7) or thermally conductive inert ceramic powder Al_2O_3 or MgO. Powder MgO is used as a fixation and heat conducting material for the production of mineral insulated temperature sensors, which are now consequently called MGO (position C in Fig. 7).



Legend: 1 – metal housing wall; 2 – temperature resistance chip; 3 – lead-in wires; 4 – heat conducting sealing compound; 5 – air; 6 – MgO; 7 – plasma weld; 8 – laser weld; 9 – insulating spacer

Fig. 7 – The design of resistance temperature sensors with temperature resistance chips.

At this point, attention must be drawn to the unsuitability of the installation of MGO temperature sensors or temperature sensors filled with ceramic powder on equipment that vibrates or is subjected to mechanical shocks. Ceramic powder is an abrasive and it is only a matter of time when its abrasive effects first break the passivation and finally the thin active conductive layer of the temperature sensor.

At present, the latest technology of installing temperature chips in a metal housing is shown in position B in Fig. 7 and has the working name "real probe". The temperature chip is provided in the mass production process with a metal layer on the underside, which allows the temperature chip to be soldered to a metal disc with a thickness of 0.2 mm. The disc is then laser-welded to a metal tube to form its bottom. The space above the soldered chip is filled with air in order to minimize the heat capacity of the sensor. There is only an insulating spacer attached at a certain distance from the chip, securing the correct position of the lead-in wires. "Real probe" resistance temperature sensors have one order of magnitude lower time constant than sensors produced by the current procedures (position A in Fig. 7).

PTC thermistors

(**posistors**) are temperature-dependent resistors produced by press-forming polycrystalline ferroelectric ceramics (barium titanate $BaTiO_3$) at high temperature and pressure into a bead or disc and fitted with two outlets. They are distinguished by a negative temperature characteristic with a significant increase in resistance (up to 5 orders of magnitude) in a specific narrow temperature interval, which is given for each type of posistor – see Fig. 8. For this reason, you may come across the term "limiting PTC thermistors". The posistor characteristic can have 1 to 3 *inflection points*.

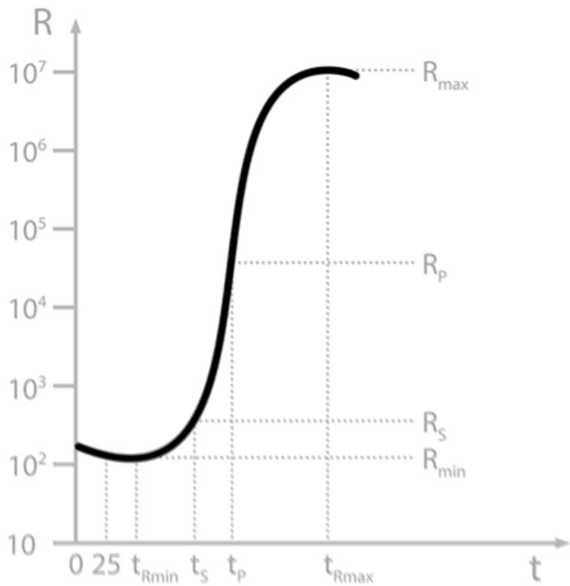


Fig. 8 – Diagram of the dependence of posistor electrical resistance on temperature

NTC thermistors

NTC thermistors are non-linear resistance semiconductor temperature sensing elements with a large negative temperature coefficient. Unlike metal sensing elements, a thermistor is defined by the value of electrical resistance at 25 °C – R_{25} and temperature coefficient β, which is calculated from the values of two absolute temperatures T_1 and T_2 and two corresponding electrical resistances R_1 a R_2 according to the following formula

$$\beta_{t1/t2} = T_1 T_2 / (T_2 - T_1) * \ln (R_1 / R_2)$$

where $\mathbf{t_1}$ = T_1 – 273 and is set to 25 °C
and $\mathbf{t_2}$ = T_2 – 273 and is usually 85 °C or 100 °C.

Thermistor manufacturers indicate either $\boldsymbol{\beta}_{25/85}$ or $\boldsymbol{\beta}_{25/100}$.

NTC thermistors are mainly used in applications with room temperatures that require a measurement accuracy of only 1 %, 3 % or 5 %, with high pressure on the price of the resulting product.

Semiconductor monocrystalline resistance sensing elements

Sensing elements with a monocrystalline structure include, for example, silicon and germanium sensors (very low temperature area). These sensing elements utilize the dependence of the mobility of the free electrical charge carriers in the crystal lattice on temperature. Changing the speed of their movement also changes the crystal resistivity. The base value of the monocrystal resistance is dependent on the amount of additives.

Silicon resistance temperature sensing elements are made of doped monocrystalline silicon, which is connected through contact surfaces to the wire outlets. Temperature dependence of resistance with a positive temperature coefficientα:

$$\mathbf{R_T = R_{25}(1+a*\Delta T+b*\Delta T^2).}$$

They are supplied in standard diode housings. Their advantage is a low price. A certain disadvantage is their temperature range of -50 to +125 °C.

Thermocouples

Thermocouple temperature sensors use the Seebeck effect, where thermoelectric voltage is generated in a simple electrical circuit formed by conductors of two different metals and is proportional to the temperature difference between the measuring and the reference (cold) end. According to the metals used, we divide thermocouples into base metal thermocouples and rare metal thermocouples. The designation, composition and properties of basic thermocouples are defined by EN 60584. In practice, we can rarely come across thermocouples according to other standards.

Typical features:

- short response time;
- very good temperature stability over a wide range of temperatures;
- suitable for high and very high temperatures;
- small size;
- resistance to vibration and temperature shocks;
- the resulting properties are determined by the observance of the exact composition of the metals used;
- generally lower accuracy compared to platinum resistance sensing elements;
- more complex evaluation – we have to also evaluate the temperature of the reference (cold) ends;
- connection to the measuring device must be made through special cables (compensation or extension line) or a special connector for the given type of thermocouple;
- it ages quickly when used near the upper temperature limit, which results in a system measurement error.

Design with wire thermocouples

They consist of two insulated wires. The operational properties of these thermocouples are given by the insulation design and material. The insulation is usually made of plastics (e.g. PVC, PE, silicone, FEP, PTFE,...), glass fibre braid, enamel, ceramic capillary, etc. Figure 9 shows various designs of the measuring end of a thermocouple with plastic insulation.

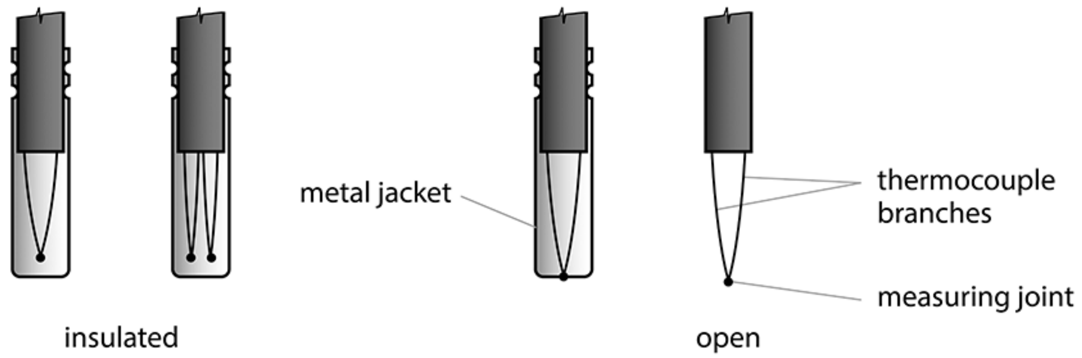


Fig. 9 – Various designs of the measuring end of a thermocouple

Design with mineral insulated thermocouples

They use the design where thermocouple wires are placed in compacted ceramic Al_2O_3 or MgO powder. The housings are usually made of heat-stabilized stainless steel or nickel-based materials, e.g. Inconel 600. The advantage of this design is the high range of measured temperatures and very high mechanical and chemical resistance. Another substantial benefit of mineral insulated thermocouples is their spatial formability and shape stability. Typical designs of the ends of mineral insulated thermocouples are shown in Fig. 10.

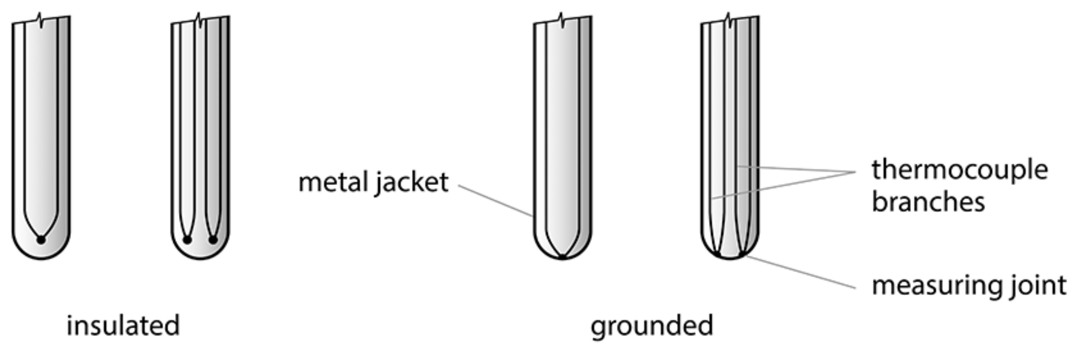


Fig. 10 – Typical designs of the ends of mineral insulated thermocouples

Both these designs allow the implementation of simple as well as multiple thermocouples for a wide range of applications.

Properties of temperature sensors

Resistance temperature sensor hysteresis – property of resistance temperature sensors, where values of electrical resistance measured at evenly increasing temperature from temperature t_1 to temperature t_2 are different from values of electrical resistance measured at evenly decreasing temperature from temperature t_2 to temperature t_1 (t_1; t_2 define the measuring range of the sensor). The term "hysteresis" is represented by Fig. 11.

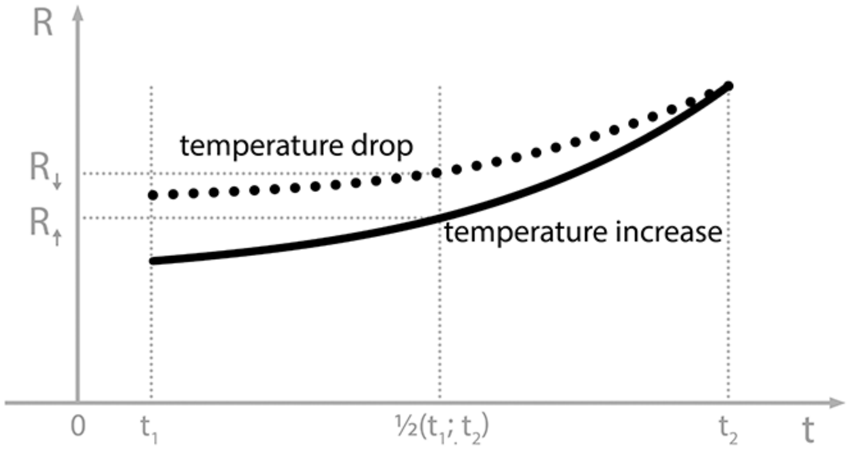


Fig. 11 – Hysteresis of the temperature characteristic (difference highlighted for clarity)

In type tests, the temperature sensor hysteresis value is measured as an absolute value of the difference of electrical resistances

$$\Delta R = |R_{\uparrow} - R_{\downarrow}|$$

in the middle of the defined temperature interval (t_1; t_2). The change of temperature **Δt** corresponding to the difference of **ΔR** in the middle of the defined temperature interval must not depart from the interval of the accuracy class at this temperature.

Hysteresis is caused by the sensitivity of metals to pressure conditions. Metals react to pressure, tension or bending by changing their electrical resistance. Every metal reacts differently, platinum is more sensitive to these changes than nickel.

A temperature resistance chip is a set of several materials: a basic ceramic pad (ceramic substrate) with a thickness of about 500 μm, active metal layer (Pt, Ni, Cu) with a thickness of 1 μm, lead-in metal wires with a diameter of 250–350 μm, passivation layer with a thickness of about 5 μm and glass fixation wall providing resistance of the connection of the lead-in wires to the active metal layer against mechanical stress. The thermal expansion is different for each material, which results in the internal stress of the whole system. The stress of a temperature resistance chip set is different for a specific temperature at an increasing temperature and at a decreasing temperature, even after sufficient temperature stabilization. Stress affects the electrical resistance of the active metal layer. Stress in a temperature resistance chip is minimized by annealing at a temperature of about 800 °C.

The error caused by the hysteresis of a temperature resistance chip does not exceed 50 mK (0.05 °C) in the case of platinum and 9 mK (0.009 °C) in the case of nickel and is at the resolution limit of measuring devices.

Installation into various metal housings using materials for the fixation of temperature resistance chips and provision of fast heat transfer from the housing to the chip increases the total stress on the active metal layer of the temperature chip. It also increases the error caused by hysteresis. The error caused by hysteresis in the middle of the defined temperature interval must not depart from the range of the accuracy class at this temperature.

Self-heating of a resistance sensing element – the passage of measuring current **I** through measuring resistance **R** creates electrical power **$P = I^2 R$**, which completely changes to Joule heat. This increases the temperature of the temperature chip itself and affects the measurement with a positive systematic error. The error is proportional to the second power of the measuring current – see Fig. 12. The maximum value of the measuring current is therefore set so that the error caused by it is lower than ¼ of the tolerance value of the sensing element. Apart from the value of the measuring current, the error caused by self-heating of the sensing element also depends on the size of the chip, the technology of installation into the housing, which significantly affects the dissipation of Joule heat into the immediate vicinity of the temperature chip, and on the measured area itself. Self-heating is also minimized by pulse temperature measurement, where the nominal measuring current is applied to the sensor only for a short time so that Joule heat disperses in the surrounding material.

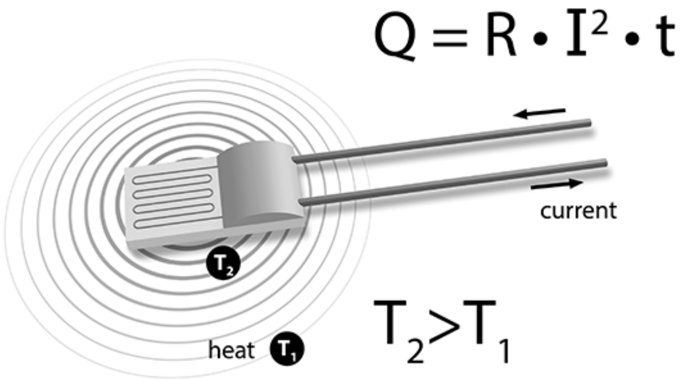


Fig. 12 – Self-heating of a temperature sensing element

Manufacturers of temperature sensing elements present in their materials the values of the maximum measuring current that must not be exceeded in order to prevent distortion of the measurement results. For example, the recommended value of the measuring current for the Pt 100 sensing element is 0.8 mA for Class B, which under normal operating conditions means an error of less than 0.05 °C. In the case of manufacturers stating 5 to 10 mA, the error may increase up to 2 °C. Higher values of the measuring current not only cause a system measurement error due to self-heating, but also decrease the service life of the temperature sensor itself.

The measurement error depending on the value of the measuring current is calculated as follows:

$$\Delta t = S \cdot RI^2$$

where R is resistance [kΩ], I is the measuring current [mA] and S is the self-heating coefficient [°C/mW]. This coefficient is different for different environments and different types of sensing elements.

Temperature coefficient α – is defined as the mean relative change of resistance to degree Celsius between temperatures 0 to 100 °C. It is given in [°C-1] – for example Pt 100; α= 3.850·10-3 °C-1 – or under the designation TCR in [ppm/°C] with Pt 100/3850. Temperature coefficient **α** determines the slope of the curve expressing the dependence of the resistance of a resistance temperature sensing element on temperature – see Fig. 13.

The basic resistance **R_0** and temperature coefficient α are the main characteristics of every temperature sensing element.

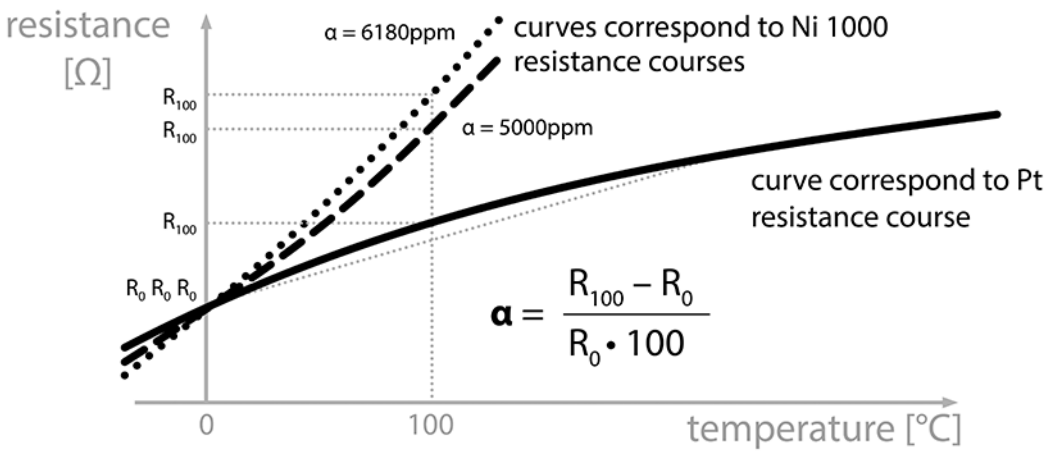


Fig. 13 – Courses of the dependencies of electrical resistance on temperature and the calculation of **α**

Platinum sensing element accuracy – platinum temperature sensing elements are supplied in various accuracy classes (tolerance classes) according to EN 60751. The classification depends on the deviations of the sensing element resistance from the nominal values given by the ideal curve. Sensing elements with a higher accuracy class (e.g. classes AA and A for platinum sensing elements) are used for accurate measurements, for inspection measurement and for the production of operating standards. Normal operating applications usually utilize sensors with a lower accuracy class (e.g. B for platinum sensing elements). Each accuracy class has an equation that characterizes it as well as determines the size of the tolerance field. This field must contain the values of the electrical resistance of the temperature sensing element of the given accuracy.

The tolerance values of platinum resistance sensing elements are expressed by the following equations:

Accuracy class AA: **Δt = ± (0.10+0.0017∗│t│)** in a temperature range of **-50 to +250 °C**

Accuracy class A: **Δt = ± (0.15+0.002∗│t│)** in a temperature range of **-100 to +450 °C**

Accuracy class B: **Δt = ± (0.30+0.005∗│t│)** in a temperature range of **-196 to +600 °C**

Accuracy class C: **Δt = ± (0.60+0.01∗│t│)** in a temperature range of **-196 to +600 °C**

Where │t│is the absolute value of temperature in °C (regardless of the sign). In practice, the AA accuracy class is sometimes called 1/3 DIN or 1/3 B. The tolerance fields for individual accuracy classes are shown in Fig. 14.

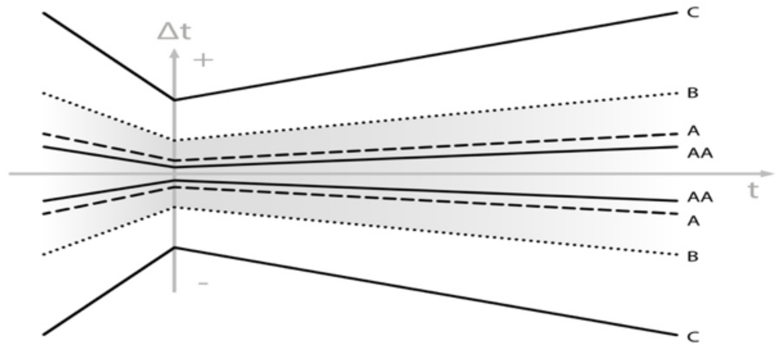


Fig. 14 – Tolerance fields for individual accuracy classes

Certain special applications (e.g. in medicine) require the accuracy of 1/10 B (1/10 DIN or also Premium Grade) with a tolerance band defined as follows

Accuracy class 1/10B: $\Delta t = \pm (0.03+0.0005 * |t|)$

This relationship is not supported by EN 60751.

Important note: Although EN 60751 and the above equations apply to "Industrial platinum resistance thermometers and platinum temperature sensors", the same principles also apply to nickel temperature sensing elements.

Temperature sensor reliability

The term **Reliability**, which went through complex historical development, not just content-wise, is defined in IEC 50 (191) as follows: Reliability is a generic term used to describe the availability and the factors that affect it: failure rate, maintainability and maintenance support (so far the term reliability has represented the failure rate). It is clear that such reliability cannot be measured or quantified and expressed by any numerical indicator. However, it is different for its sub-factors (failure rate, maintainability and maintenance support) that can be assessed using specific indicators. Reference (1) states that, in the broadest sense, reliability is also perceived as a science of correct or incorrect product function. Science that examines the conditions for the correct (required) function or conditions of malfunction, the possibilities of influencing them, prediction (estimation of the future course), verification and measurement.

The reliability of each product is now also understood as an integral part of the characteristics, collectively called quality. Besides reliability, quality includes technical functionality, safety, economy, environmental friendliness, aesthetics.

Considering the purpose and scope of this design and user manual, this paragraph is limited only to the description of the parameters and activities performed with temperature sensors with respect to the reliability in the strict sense of the word, i.e. the **failure rate**, by Sensit.

Bathtub curve – expresses the dependence of the failure rate on time. The **x** axis represents logarithmic time, the **y** axis represents the failure rate in units. The curve consists of 3 parts that give it a characteristic shape of a bathtub – see Fig. 15.

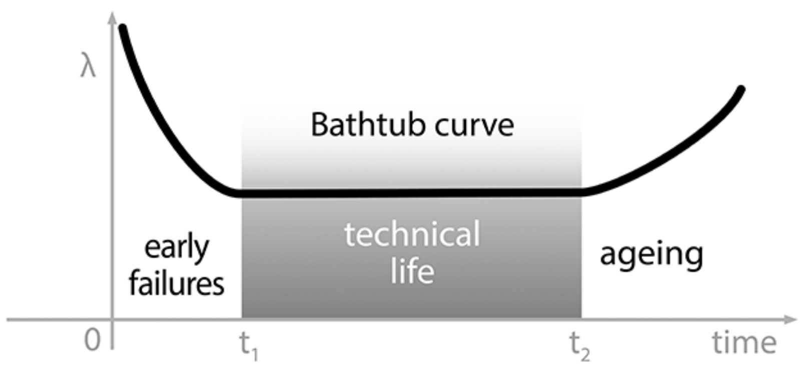


Fig. 15 – Bathtub curve

The first part is a decreasing failure rate, called "infant mortality". Failures are caused by cold joints, narrowed conductor paths on PCBs and chips (interruptions) or short circuits between wires. The second part represents a constant failure rate consisting of random phenomena. The third part is characterized by increasing failure rate resulting from wear and tear, ageing and end of life.

Sensit, as the only manufacturer of temperature sensors in the Czech Republic, uses the so-called “accelerated ageing” process to remove the first part of the bathtub curve. The process consists in exposing sensors to 9–11 temperature cycles in a temperature cycling chamber in the following temperature intervals:
(-10 to +75 °C); (-10 to +120 °C) or (0 to 180 °C). Cycling, which takes place during the night, is part of the production process, followed by final calibration, output inspection and packaging. This ensures that early failures that would occur in the first days of deployment at the customer site are detected and contained by the manufacturer and will not reach the customer.

The term “failure rate” can be quantified by several indicators used in the reliability field. These are: probability of fault-free operation ($R_{(t1, t2)}$), failure intensity ($\lambda_{(t)}$), mean time to failure (MTTF), meat time between failures (MTBF) and failure flow parameter ($z_{(t)}$). Since most types of temperature sensors are irreparable or their repair is not cost-efficient, Sensit evaluates the failure rate parameter using the **mean time to failure – MTTF**.

Minimum depth of immersion of a temperature sensor When immersing a temperature sensor in a liquid (no matter if in a pipe or a container), there is a heat flow between the measuring end and the part of the sensor with ambient temperature. This cools down the measuring end and causes an error of the temperature sensor. EN 60751, Chapter 6.5.8 Minimum immersion depth says: “A thermometer must be immersed in water at a temperature of at least 85 °C to the same depth as that used for determining the tolerance class and with the thermometer terminals close to ambient temperatures. The thermometer is then gradually pulled out of the medium if the resistance does not change by a value corresponding to a temperature change of 0.1 °C. This immersion depth must be declared as the minimum immersion depth.”

Experience shows that the minimum immersion depth of a stem temperature sensor should be 10 times the stem diameter. I.e. 60 mm for a stem diameter of 6 mm. If a temperature sensor is inserted in a thermowell with a diameter of 10 mm, the minimum immersion length should be 100 mm. In order to implement this requirement also for small-diameter pipes (≤ 50 mm), either skew welded-on pieces are used, sensors for direct installation into pipes with a stem of Ø 4 or 3 mm (without thermowells) or installation in an elbow. See Fig. 20.

Operating pressure Thermowells and stems of Sensit temperature sensors with diameters of 12, 10, 8 and 6 mm meet the requirements of Government Decree No. 26/2003 Coll., as amended, for the temperature range of -30 to +200 °C and were certified as part of pressure equipment for a maximum static pressure of PN 63 (6.3 MPa; 63 bar). Stems with a diameter of 4 mm were certified as part of pressure equipment for a maximum static pressure of PN 25 (2.5 MPa; 25 bar). The certification of stems with diameters of 3 and 2 mm is being prepared.

Flow rate in piping The maximum flow rate of the measured medium (air and water vapour /water) for thermowells and stems of specified lengths and diameters is shown in Tab. 4.

thermowell length L2 (mm) thermowell diameter (mm)	up to 60	60 to 100	100 to 160	160 to 220	220 to 400
Ø6 and Ø8	20/2.0	15/1.5	8.0/1.0	2.5/0.6	0.6/0.3
Ø10 and Ø12	35/3.5	30/3.0	15/2.0	5.0/1.2	1.6/0.8

Table 4 – Maximum flow rates in m/s for air and water vapour/water

Temperature transducers for a defined output signal

Transducers are electronic circuits that convert the change of resistance of a resistance temperature sensor or change of thermoelectric voltage of a thermocouple at the transducer input to a standardized value of current or voltage at the output. We are then talking about *temperature-current transducers* or *temperature-voltage transducers*.

Transducers allow the transmission of temperature information to locations tens of meters away from the measurement point and convert the low level of the input signal to a level required for the input of evaluation equipment. They linearize the temperature sensor characteristic, suppress disturbing signals and, last but not least, loads the resistance sensing element with small current, reducing the systematic error caused by self-heating of the sensing element. Transducers with a thermocouple output provide temperature stabilization of the comparing (cold) joint.

The standardized and most commonly used outputs of a temperature-current transducer are 4–20 mA and 0–20 mA.

The standardized and most commonly used outputs of a temperature-voltage transducer are 0–10 V, 0–5 V, 0–3V.

The transducer's output interval requires a defined input temperature interval. From the time where electronic temperature-current and temperature-voltage transducers were manufactured using discrete components, the most commonly used temperature intervals were established, which corresponded with the output current or voltage intervals for a predefined temperature sensor.

Temperature intervals with specified limit values of the outputs of temperature-current or temperature-voltage transducers are as follows: -30 °C to +60 °C; 0 °C to +35 °C; 0 °C to +100 °C; 0 °C to +150 °C; 0 °C to +250 °C and 0 °C to +400 °C.

Sensit offers deliveries of transducers with custom intervals. The most often requested custom ranges are -50 °C to +50 °C and 0 °C to 200 °C.

Nowadays, when temperature-current and temperature-voltage transducers are made of programmable integrated circuits (microprocessors), users set the required input (according to the temperature sensor type) and output themselves. Microprocessors contain equations of the characteristics of individual temperature sensing elements, so the output signal is ideally linearized.

There are also transducers that convert temperature information from a temperature sending element to a digital RS485 or Ethernet signal. Such transducers differ in the types of data processing and transmission protocols, e.g. ASCII, Arion, ModBus, ProfiBus, HART, CAN, Modus TCP, etc.

Transducers are supplied in two variants. Either as part of head temperature sensors (the transducer is located in the head of the temperature sensor) or separately with the corresponding terminals for connecting the temperature sensor, power supply and output. In most cases, the housing is standardized with possible DIN rail installation.

Tables of the dependences of values of the input current or voltage on individual input temperature values for specific temperature intervals are presented in the table part of this manual.

Digital integrated temperature sensing elements

The development of microelectronics has caused a significant shift in the digitization of analogue processes over the past 20 years. Temperature measurement is no exception. It is therefore necessary to mention at least two integrated circuits that have become commonly available temperature sensors with digital output. They are most commonly enclosed in a TO 92 transistor housing, but also in a TO 18 housing or SOT 223 for installation on a PCB. The type of housing significantly affects some technical parameters. The temperature range of these integrated sensing elements is -55 °C to +125 °C and is determined by physical laws.

Dallas DS18B20 / DS18S20

This integrated circuit is a digital temperature sensing elements, for which the manufacturer guarantees an accuracy of 0.5 °C in a temperature range of -10 °C to +85 °C. For communication with a control and evaluation unit (MCU), the sensing element is connected via a single-wire serial interface called the 1-Wire bus and designated DQ. For the power supply, two more wires are required, which are designated GND and VDD. The VDD DC supply voltage may range from 3.3 V to 5.5 V. In addition to temperature measurement, DS18B20 functions as a digital thermostat, whose lower and upper limits can be programmed and stored in the internal memory. When reading the measured value, there are bits that indicate reaching the set limits.

Every DS18B20 sensing element is assigned its own unique 64-bit ID number, which is used to address a particular sensing element in the MCU. The ID number, together with the unique protocol, allows the connection of several sensing elements to one DQ data conductor. The maximum number of sensing elements is limited by the size of the available MCU memory, which must store 64-bit ID numbers.

The principle of connecting multiple DS18B20 sensing elements using 1-Wire is shown in Fig. 16.

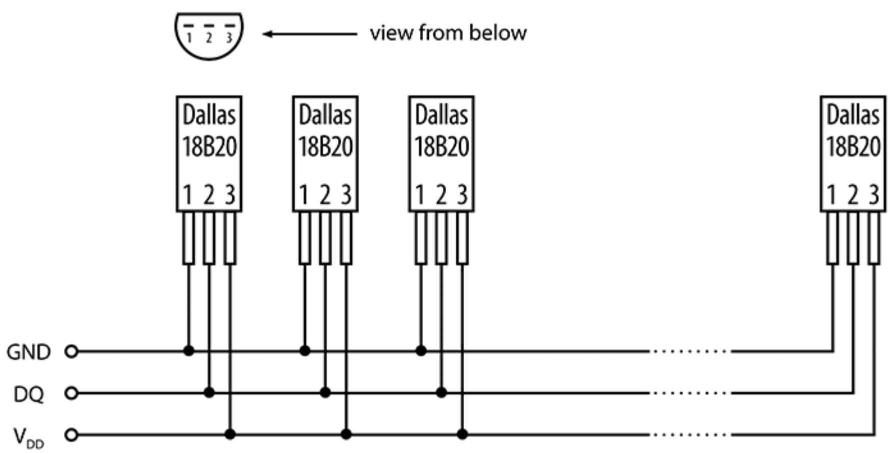


Fig. 16 – Method of connecting multiple DS18B20 sensing elements to the 1-Wire bus

SMT 160-30; SMT 172

Integrated circuit with a temperature sensing function. The output is a rectangular signal at a frequency of 1–4 kHz, whose duty cycle (DC) varies linearly with temperature. Temperature is evaluated by the MCU.

The duty cycle is explained in Fig. 17. The duty cycle is the ratio of the duration of pulse level 1 to the total pulse duration and is dimensionless.

The dependence of the DC on temperature is expressed as follows:

$$DC = 0.32 + 0.0047 \times \mathbf{T}$$

where **T** is temperature in °C.

When the DC is known, temperature is calculated as follows:

$$\mathbf{T} = 212.77 \times DC - 68.085$$

The DC is calculated as the arithmetic mean of 8 consecutive duty cycles.

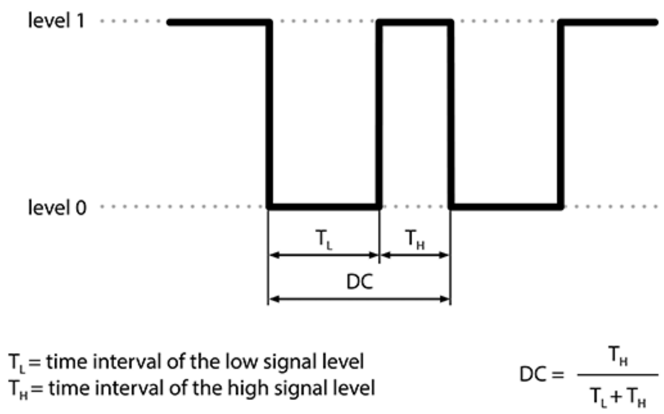


Fig. 17 – Calculation of the DC of a rectangular signal

Calibration of temperature sensors

Calibration is a set of actions that determine the relationship between the sensor being calibrated and a standard in specified conditions. This process compares the values of electrical resistance R of the sensor being calibrated with the R_e values of the standard at one, two, three or more temperatures. The change of temperature **Δt** corresponding to the difference of **ΔR = (R_e – R)** at a given temperature must not depart from the interval of the accuracy class at the measured temperature.

The best uncertainty of the Sensit calibration laboratory is 0.05 °C. The calibration uncertainty is mostly affected by the design of the sensor being calibrated, the possibility of its immersion in the medium and the temperature at which the calibration is performed.

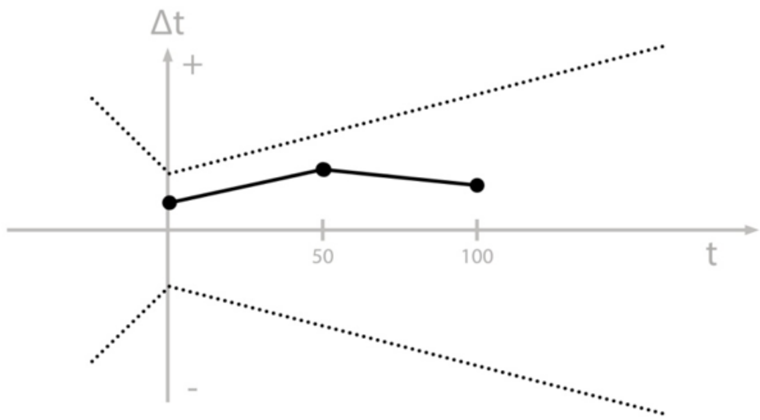


Fig. 18 – Example of temperature sensor calibration at three points

Each sensor goes through output measurement. Calibration is performed at customer request. The output of a calibration is a calibration sheet. Calibration is usually performed at three points. The number of points and the calibration points are set by the gauge user. Three and more points are calibrated where it is necessary to know the real temperature characteristic of the temperature sensor in the whole temperature interval given by the lower and upper temperature of the required calibration – see Fig. 18. Three (and more) points set by calibration can interpose the curve of the dependency of electrical resistance on temperature for that particular temperature sensor being calibrated. Note: Calibration at one or two points is not entirely suitable, because the user does not have enough information about the sensor and work with the measured values is suboptimal.

Failures of resistance temperature sensors

There are 4 types of possible resistance temperature sensor failures:

1. Increased electrical resistance

- can be caused by corrosion of lead-in wires due to humidity, which in turn may lead to interruption of the measuring circuit
- corrosion of the thermal chip conductor path caused by high temperature or humidity, which also leads to interruption of the measuring circuit. This primarily applies to Ni and Cu sensors.
- electromigration when using supply voltage and/or current above the specified value. In the electric (and thermal) field of the thermal chip, atoms of the active layer metal migrate from a warmer point to a colder point and from a point with a higher electric potential to a point with a lower electric potential. The point from which atoms migrate reduces its cross-section, which locally increases the electrical resistance and the temperature of the sensing element

(self-heating). Temperature measurement becomes entirely biased – it shows indefinably higher values. The metal atom migration exponentially increases until the sensor and the entire circuit are completely interrupted. This applies to all metal sensors.

- Connector corrosion – increase of the total resistance by the transient resistance at the connector. This usually does not cause circuit interruption. It is also manifested by a random fluctuation of the resistance value and therefore a fluctuation of the measured value.

2. Open sensor circuit
   – for the above reasons, where complete interruption of the circuit is preceded by gradually and indefinably increasing electrical resistance of the temperature sensor.
- Mechanically interrupted lead-in wire by twisting, cutting, tearing, etc.
3. Decreased electrical resistance is usually caused by moisture penetration and precipitation in the area of the cable connection to the chip outlets, which creates parallel resistance. This phenomenon is a precursor to the subsequent increase of resistance and ultimately total destruction by corrosion.
4. Short circuit of the temperature sensor. Short circuits of temperature sensors are mainly caused by
   - breaking the primary and secondary insulation of both conductors by a metal object
   - twisting the supply cable

There are 3 types of possible thermocouple failures:

1. Decrease of the thermoelectric voltage by age or long-term exposure to the upper limit temperature. This failure can be detected by inspection measurement. It is always detected during thermocouple recalibration.
2. Chaotically changing thermoelectric voltage. This failure is caused by mechanical interruption of the thermoelectric joint of the two thermocouple branches
3. Zero thermoelectric voltage. The thermoelectric circuit was either interrupted or short-circuited.

Failures of sensors with an active 4–20mA output:

1. The measuring current is lower than 3.5 mA – the temperature chip branch is short-circuited
2. The measuring current is higher than 23 mA – the temperature chip branch is interrupted
3. The measuring current chaotically changes its value in a range section – the temperature sensing element exhibits instability for any of the above reasons
4. The measuring current is zero – electronics defect, the power supply is not connected or is defective

Failures of sensors with an active 0–10V output:

1. The output voltage is permanently 0 V – the temperature sensing element input is short-circuited
2. The output voltage is higher than 14 V – the temperature sensing element input is interrupted
3. The output voltage chaotically changes its value in a section of its range – the temperature sensing element exhibits instability for any of the above reasons

Installation, operation and maintenance of temperature sensors

1. Work regulations

- Persons installing the sensor must observe laws, regulations and technical standards related to occupational safety.
- During the installation, observe the installation regulations and user manuals of the products.
- Wiring must be carried out by workers qualified at least according to Section 5 of Decree No. 50/1978 Coll., as amended.

2. General rules

- When designing and installing, take into account the properties of the sensor's surroundings (ambient temperature and humidity range, possibility of splashing water, explosive environment, chemically aggressive environment, flow of the measured medium, vibration and shocks, sunlight, electromagnetic interference). Examples: A sensor for measuring the outdoor temperature should be placed on the northern wall. Beware of cellar windows and ventilation holes that let out warm air.
- When designing and installing, always ask and answer how accurately temperature shall be measured and what time constant is required. The sufficient accuracy for temperature measurement of flue gases is ±5 °C, for temperature measurement of an incubator heating pad ± 0.02 °C. Temperature measurement in the transmission of a wind turbine suffices with a temperature sensor time constant of $\tau_{0.5}$ = 180 s; temperature measurement of blood in a patient's artery requires $\tau_{0.5}$ = 1 s.
- When designing and installing, choose the sensor location to minimize the possibility of their mechanical damage as well as personal injury. Place sensors so that they are readily accessible for potential inspection and servicing. If it is required for inspection and servicing reasons, use a disconnectable cable.
- To transmit the signal from the temperature sensor to a larger distance (for Pt 100 above 2 m, for Pt 1000 and Ni 1000 above 10 m), use a transducer according to the input of the control or displaying unit.
- When designing, take into account the properties of the sensor (measuring range, ingress protection, measurement error, accuracy class, maximum measuring current of the sensing element, time constant).
- Sensors generally cannot be used to measure the temperature of objects under voltage. If this is required, the application must be consulted with the sensor manufacturer.
- Sensors must be properly attached. The supply cables must not be mechanically stressed and must be protected against damage.
- Choose the operating position of sensors so that there is no accumulation of liquids around the entrance of the supply cable into the sensor (the bushing must not face upwards).
- The length of the supply cable at the sensor must be chosen so that handling of this cable is easy and safe.
- Observe the electrical and mechanical properties of the supply cable specified by the manufacturer (conductor cross-section, cable outer diameter, cable shielding) in the technical documentation (e.g. in the product's user manual).
- The sensor's supply cable should not be routed in the vicinity of conductors or equipment with a disturbing electromagnetic field (high voltage lines, inductive load, pulse and frequency converters, frequency-controlled motors, unshielded transformers).
- In areas with strong electromagnetic interference (industrial halls, etc.), it is advisable to use shielded cables with grounded shielding. When both cable ends are grounded,

they must have the same electric potential. Otherwise, large equalizing currents may flow through the shielding. In practice, only one end is grounded.

- Check if the wires of the supply cables are properly fastened in the terminal block by **slightly** pulling the wires.
- Do not install sensors in areas exposed to sunlight or near heat or cold sources (unless these sources are to be measured by the sensors).
- When measuring the temperature of a surface or object where the temperature sensor is located just under the surface, the measurement results are affected by a system error caused by heat dissipation from the measured point through the sensor housing and supply cables. The size of the error is directly dependent on the difference of the temperature of the measured surface or object and the ambient temperature and on the sensor design. In addition, when measuring the surface temperature of piping, the size of the measurement error is inversely proportional to the pipe diameter. Consequence: The requirement for the calibration of contact temperature sensors is unjustified.
- In order to reduce the error caused by the heat dissipation from the measured object outside the temperature sensor and/or to reduce the time constant of the measured object-temperature sensor system, so-called thermal compounds are applied between the measured object and the temperature sensor. Thermal compounds are usually made of silicone grease as a binder and fine metal dust (Fe, Cu, Al) or metal oxide dust as a filler, whose task is to improve heat transfer. **Attention!** Applying thermal compounds on vibrating systems may cause abrasion of the surface of the temperature sensor housing and subsequent destruction. **Attention!** When applying a thermal compound in gearbox thermowells, some gearbox designs may lead to the contamination of the gearbox oil with the thermal compound and subsequent seizure of bearings!!! The use of thermal compounds to measure the temperature of gearboxes is **unjustified** and can be elegantly avoided by the use of a bayonet mount and the shape of the sensor end.
- **ATTENTION when measuring temperature in cold water tanks** (air-conditioning unit rooms). These applications **ALWAYS** require temperature sensors with heads inserted in thermowells!!! Explanation: The sub-ambient temperature at the front of the thermowell results in precipitation of water, which flows down and, due to the physical phenomenon called capillary rise, enters the space between the inner wall of the thermowell and the stem of the sensor. The precipitated water completely fills this space. If there is only a cable temperature sensor inserted in the thermowell instead of a metal sensor stem with a head, it is completely submerged in water. It is only a matter of time when the water penetrates the steel housing of the sensor and at the first moment causes a leakage between the sensor leads (which results in erroneous measurement). After a certain, unpredictable time, it causes corrosive interruption of the conductors of the sensing element itself and thus the destruction of the whole cable temperature sensor.
- When installing a temperature sensor on a room wall using a mounting box, to which cabling is routed in a protective plastic hose (so-called “goose neck”), the end of the protective hose containing the cable should be sealed with expanding foam. There are known cases where air flow through this protective hose affected temperature measurement in the room by a sensor located on a mounting box so that the heating control was therefore non-functional.
- **Attention!** The connection of temperature sensor with an active (current, voltage, frequency, digital) output must always be carried out **when the power is off**!

- Pay attention when handling excess cable length. Keep in mind that an excess cable coiled into a circle acts like a coil, i.e. impedance entering the electrical circuit. During pulse measurement, this impedance first creates voltage at the terminals of the sensing element and when voltage in the pulse mode drops to zero, current starts flowing through the circuit. As a result, the evaluator does not measure and the temperature sensor appears to be interrupted. Solution: If the installed temperature sensor is not to be applied elsewhere, shorten the supply cable to the minimum required length. For two-wire connection, keep in mind the effect of the resistance of the lead-in wires on the measurement result. Decide when this change may be ignored and when it is necessary to perform a correction in the evaluation unit. Otherwise, route the excess length of the cable so that it does not create impedance (loops).

3. Sensors with a head

- Sensors must be hermetically sealed (tightened bushings, screwed-on lid).
- Sensor stems must not be mechanically stressed. Sensors should be ideally attached using plastic or metal holders supplied as accessories.
- Temperature near the sensor head listed in the technical documentation must not be exceeded, not even for a short time (unless specified otherwise).
- Indoor sensors should not be placed in areas with minimum air flow or areas where temperature is greatly influenced (niches, outer walls, wall shared with an unheated room, chimney wall, near the door, sunlit areas).
- Indoor sensors with a current output must only be installed in the position specified in the technical documentation.

4. Cable sensors

- The temperature range listed in the technical documentation must not be exceeded, not even for a short time (unless specified otherwise).
- Sensor housings must not be mechanically stressed.
- The supply cable must be properly mechanically attached.
- When choosing a cable temperature sensor, ask the manufacturer if the chosen type is suitable for your application.
- Cable sensors for the measurement of, for example, flue gases are not designed for humid environments (a heat-resistant cable with glass insulation is hygroscopic, glass fibre insulation is able to hold in moisture that causes corrosion of the lead-in wires as well as the connection between the wires and the sensing element).
- Inappropriate miniaturization of a temperature sensor can affect the measurement accuracy (heat dissipation from the measured point through the supply cable).
- Do not use cable temperature sensors in thermowells on cold water tanks (see general rules above)!

5. Recommended methods of installing thermowells, weld-on pieces and temperature sensors in piping

- General principles for the installation of temperature sensors in piping are given in EN 1434-2 Heat meters – Part 2: Constructional requirements. This standard contains recommended installation procedures for weld-on pieces, thermowells and temperature sensors for various pipe diameters and flow rates. Even though the standard is intended for heat meters, the installation recommendations given here are generally applicable.
- Observance of these principles leads to the required accuracy and reproducibility of measurements.

- Thermowells and temperature sensors should not be installed in areas where the homogeneity of the measured medium is not guaranteed, in areas of turbulent flow – behind bends, in areas with varying cross-section, etc.

The methods of installation of thermowells in piping by welding are shown in the following figure – Fig. 19.

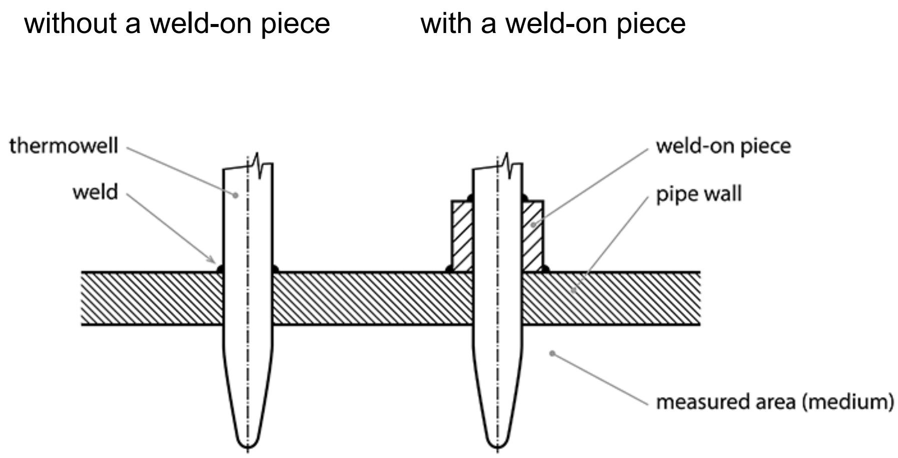


Fig. 19 – Installation of thermowells on piping

- The methods of installation of straight and oblique weld-on pieces according to CSN 1434-2 are shown in Fig. 20.

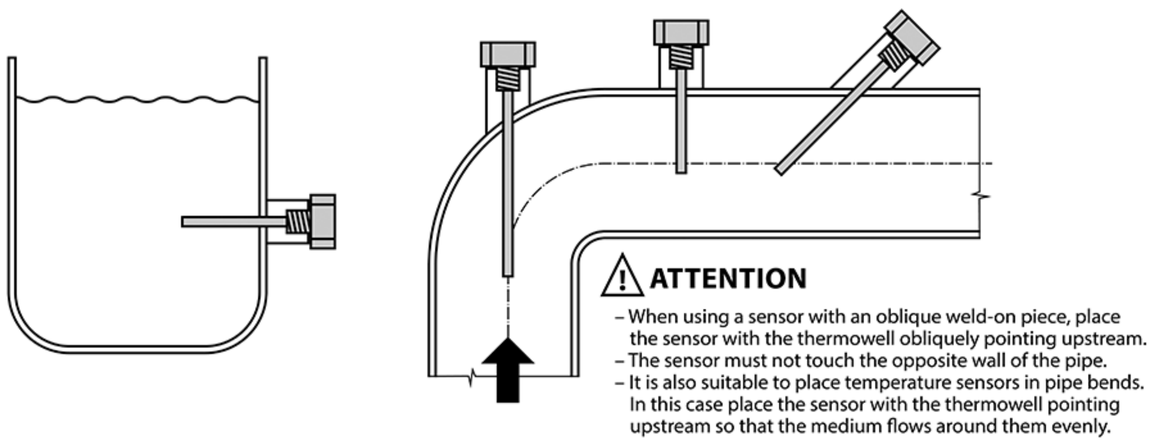


Fig. 20 – Examples of the installation of straight and oblique weld-on pieces

6. Putting into operation

After the installation and connection of the sensor to the electrical circuit (transducer, measuring and control circuit), the device is ready for operation.

7. Attendance and maintenance

During operation, sensors do not require any attendance or maintenance.

When connecting a sensor to an evaluation unit, it is possible that the system may not work or does not work as expected. There are simple procedures to examine the error:
– the system does not work, it does not show any temperature. Is the evaluator connected to a power supply of the specified voltage? Is the temperature sensor correctly connected? This is important to check especially in the case of 3-wire or 4-wire connection. If the wiring is OK, disconnect the temperature sensor from the system and measure it with an ohmmeter. Again, pay extra attention in the case of 3-wire and 4-wire connection. If the measured value of resistance of the temperature sensor is zero or in megaohms, the sensor is defective and must be returned (if it is under warranty) or disposed of in an environmentally-friendly way and a new sensor should be ordered. If it shows a resistance value equal to the table value for temperature measured in another way, the sensor is OK and the fault is in the evaluation device.
– the system shows temperature that does not correspond to reality. Is the temperature sensor correctly connected? This is important to check especially in the case of 3-wire or 4-wire connection. If the wiring is OK and it is not an **indoor temperature sensor**, remove the temperature sensor from the thermowell or release it and immerse its whole metal part for at least 10 minutes in crushed ice. Stir the crushed ice occasionally. The greater the weight of the sensor, the longer the immersion time should be. If the ohmmeter shows a sensor resistance value close to the table value of the given type of sensor for 0 °C, it is still too early to tell if the temperature sensor is OK. Now prepare a pot of boiling water and place the temperature sensor in it. Only if after about 5 minutes the ohmmeter shows a resistance value of the temperature sensor close to the table value for 95 °C to 100 °C (an error may result from the water boiling at a lower temperature than 100 °C – the boiling point depends on the air pressure), it is possible to state that the temperature sensor is OK and the fault has to be searched in the evaluation part of the system. Otherwise, the temperature sensor is defective and must be returned (if it is under warranty) or disposed of in an environmentally-friendly way and a new sensor should be ordered.
Preparation of crushed ice: wrap pieces of ice (obtained e.g. from a refrigerator – approx ¼ kg) in cloth and crush into pea-sized or smaller pieces. Put the crushed ice into a container and add the coldest possible water to ½ of the height of the crushed ice. Allow the mixture to stabilize for 10 minutes while stirring occasionally. Then put the sensor into it.

8. Repairs

Warranty and post-warranty repairs are performed by the manufacturer. Send products for repairs in the original or equivalent packaging. In order for the warranty repair to be admitted, the product must be provided with the warranty card and undamaged identification plate.

9. Keep in mid the general experience

- The feeling of thermal comfort in a room does not depend only on the room temperature. It is also affected by the relative humidity and air flow.
- Women have the feeling of thermal comfort “set” differently from men. Women can perceive a temperature drop gradient of 0.1 °C/h.
- Two identical commercial thermometers in the same location never show the same temperature.

Ingress protection ratings (IP code)

This chapter is included for quick orientation in the IP ratings and is based on EN 60 529.

IP code arrangement: **IP XY AH** where:

The first letters of the IP code mean **I**nternational **P**rotection.
X = the first characteristic digit from 0 to 6 or the letter X indicates the degree of protection against contact with live parts and from the ingress of solid foreign objects.

Y = the second characteristic digit from 0 to 8 or the letter X indicates the degree of protection against water
A = optional additional letter; see EN 60 529
H = optional supplementary letter; see EN 60 529

Meaning of the first characteristic digit:

Digit	Description of protection against contact	Description of protection against the ingress of solid foreign objects
0	Not protected	Not protected
1	Protected against the contact of dangerous parts with the back of a hand.	Protected against the ingress of solid foreign objects with a diameter of 50 mm and larger
2	Protected against the contact of dangerous parts with a finger.	Protected against the ingress of solid foreign objects with a diameter of 12.5 mm and larger
3	Protected against the contact of dangerous parts with a tool.	Protected against the ingress of solid foreign objects with a diameter of 2.5 mm and larger
4	Protected against the contact of dangerous parts with a wire.	Protected against the ingress of solid foreign objects with a diameter of 1.0 mm and larger
5	Protected against the contact of dangerous parts with a wire.	Protected against dust. Possible ingress of an amount of dust that does not endanger the safety and proper operation of the device
6	Protected against the contact of dangerous parts with a wire.	Dust-tight

Meaning of the second characteristic digit (see Chapter 14 of EN 60529):

Digit	Description of protection against water	Definition
0	Not protected	-
1	Protected against vertically falling water drops	Vertically falling water drops must not have any harmful effects
2	Protected against vertically falling water drops when tilted at 15 °	Vertically falling water drops must not have any harmful effects if the enclosure is tilted at an angle of 15 ° to either side of the perpendicular.
3	Protected against spraying water (rain)	Water sprayed at any angle up to 60 ° must not have any harmful effects
4	Protected against splashing water	Water splashing from any direction must not have any harmful effects
5	Protected against water jets	Water projected by nozzles from any direction against the enclosure must not have any harmful effects
6	Protected against powerful water jets	Water projected in powerful jets from any direction against the enclosure must not have any harmful effects
7	Protected against the effects of temporary immersion in water	Under defined pressure and time conditions, the quantity of water that enters the enclosure when temporary immersed does not have harmful effects
8	Protected against the effects of continuous immersion in water	Under conditions agreed between the manufacturer and the customer, which must be stricter than the conditions specified for the characteristic digit 7, the quantity of water that enters the enclosure when continuously immersed must not have harmful effects. 1)
9	Protected against high-pressure, high-temperature water jets	High-pressure, high-temperature water projected by nozzles from any direction against the enclosure must not have any harmful effects Note: this level can be also designated **IP X9 K** according to DIN40050-9, where **K** means high water temperature (above 80 °C).

1) Note: Unless otherwise agreed with the customer, the ingress protection of Sensit temperature sensors of up to IP67 is specified by the manufacturer. The guarantee of IP 68 and IP 69 protection must be supported by tests in an accredited laboratory and is part of type tests.

Temperature sensor specification

If a potential buyer of a temperature sensor is not sure what type of temperature sensor from the Sensit catalogue they need, they should know if it is a head or cable temperature sensor, and it is always important to know and express the requirements for the sensor application.

Sensors with a head

- According to the use: indoors, outdoors, in piping, air conditioning, contact
- Plastic or metal head
- Type of sensing element – Pt 100, Pt 1000, Ni 1000/5000, Ni 1000/6180
- Output signal – 4–20 mA, 0–10 V – here it is necessary to specify the temperature range
- Stem length – 70, 120, 180 mm...
- Stem type – smooth, with a screw union...
- Connection – 2-, 3- and 4-wire
- Accuracy class
- Special requirements – special standards, shock resistance, non-flammability, etc.
- Calibration requirement – at how many and what temperatures

Sensors with a cable:

- Cable type – according to the application temperature, shielded, non-shielded, 2w, 3w or 4w
- Housing type – material and design
- Housing length and material, thread type
- Type of sensing element – Pt 100, Pt 1000, Ni 1000/5000, Ni 1000/6180...
- Accuracy class
- Cable length and termination
- Special requirements – special standards, shock resistance, non-flammability, etc.
- Calibration requirement – at how many and what temperatures

Standard temperature sensors may be modified – the customer can request a change of any parameter listed as standard. It is mostly the stem length, screw union dimension, installation of two identical or different types of sensing element in one stem or housing, cable length or its termination.

If the customer requests a replacement for a temperature sensor of a different manufacturer (**replacement**) or temperature sensor according to their own specification (**custom sensor**), for the assessment of production possibilities and subsequent provision of the most accurate offer, they should provide the following information:

- Send a sample of the temperature sensor, preferably functional or non-functional with information about the type of the sensing element
- Send a sketch (even by hand) or drawing or reference to the required sensor in any literature
- Description of the sensor location, the temperature range, whose temperature it measures, the highest temperature it must endure.

- Requirement for the type of sensing element
- Description of the surroundings of the sensor and the cabling itself (outdoors, acidic environment, high temperature, rapid temperature changes, vibrations, shocks, etc.) required ingress protection (IP).
- How accurately should it measure, how far the temperature sensor will be from the evaluation unit.
- Special requirements (compliance with special standards, shock resistance, non-flammability, resistance of the environment against electromagnetic disturbance, temperature measurement of an object under voltage, salt water, explosive environment, cryogenic temperatures).
- Required time constant.

If you have any questions or concerns, please contact our sales or technical department by calling +420 571 625 571 or via e-mail: obchod@sensit.cz .

Labelling of Sensit temperature sensors

Sensit temperature sensors are labelled by identification labels located on the heads and, in the case of cable temperature sensors, by identification sleeves. Unless otherwise agreed with the customer, the sleeve is located on the cable about 10 cm from its free end. The identification sleeve is placed on the cable and heat-shrunk so that it cannot move along the cable without force. The meaning of the data on the identification label and identification sleeve is explained in Fig. 21 and 22.

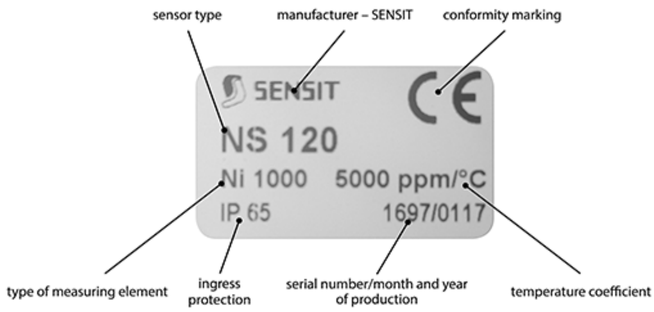


Fig. 21 – Meaning of data on the identification label

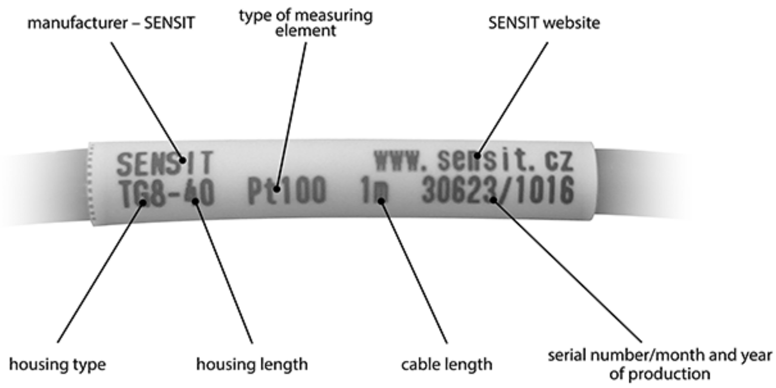
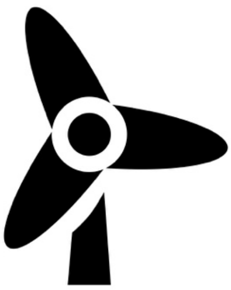
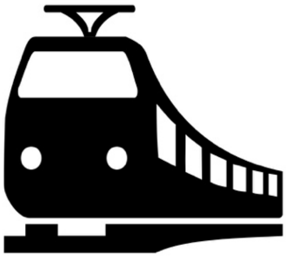


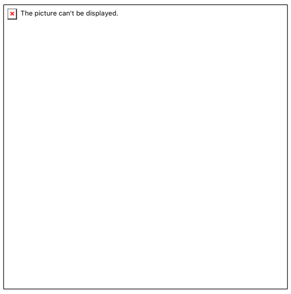
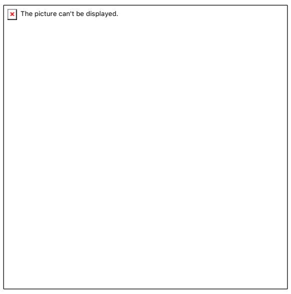
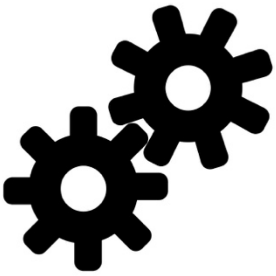
Fig. 22 – Meaning of data on the identification sleeve

Application segments of Sensit resistance temperature sensors

The requirements for the design and properties of resistance temperature sensors vary according to their application in practice. Experience has shown that temperature sensors can be divided according to their application into the following ten segments:

Pictogram	Segment description	Segment characteristics and properties
	Heating industry	Billing measurement of heat consumption – calorimeters. Paired temperature sensors in thermowells or directly in piping for measuring the temperature of the inlet and outlet water; measurement of steam temperature. Measuring range 0 to 180 °C Pt 100, Pt 500, Pt 1000 Compliance with EN 60 751, EN 1434 and Government Decree No. 120/2016 Coll.
	Heating control	Control of heating in residential, office and industrial spaces, control of central heating boilers Temperature sensors for piping, exteriors, interiors, contact sensors, in flues. Measuring ranges -50 °C to 100 °C, for measuring the flue gas temperature in solid fuel boilers up to 800 °C. Pt 100, Pt 1000, Ni 1000, NTC, PTC, DS18B20, thermocouples, etc.
	Air-conditioning	Air conditioning units and systems Temperature, humidity and flow sensors, integrated designs for interiors and AC pipes, outdoor temperature, contact sensors. Measuring ranges -50 °C to 200 °C Pt 100, Pt 1000, Ni 1000, NTC, PTC, DS18B20, thermocouples, etc.
	Renewable energy sources	Heat pumps, wind turbines and small-scale hydropower plants, solar power plants, geothermal wells. Temperature sensors for piping, exteriors, contact sensors, for insertion in metal blocks. Temperature range -50 to 600 °C Pt 100, Pt 1000, Ni 1000, NTC, PTC, DS18B20, thermocouples, etc.

	Rail vehicles	Locomotives, passenger cars, train sets, trams (trolleybuses). Temperature sensors for measuring the temperature of surfaces, metal blocks, air, coolants, oils. Temperature range -50 to 600 °C Pt 100, Pt 1000, Ni 1000, NTC, DS18B20, CAN converters, etc. Shock resistance, electrical safety, EMC, non-flammability, compliance with the requirements of EN 50155, EN 61373, EN 50121-3-2, EN 45545-2 and NFPA 130.
	Rubber and plastics industry	Rubber machines and technologies. Temperature sensors for measuring the temperature of rubber and plastic mixtures, metal blocks, oils, coolants. Temperature range -50 to 1,100 °C Pt 100, Pt 1000, Ni 1000, NTC, PTC, DS18B20, thermocouples, etc. Temperature sensors meet the requirements for a short time constant and resistance to pressure, vibration and abrasion.
	Healthcare and white goods	Neonatal incubators, medical equipment; washing machines, refrigerators, dryers, irons, microwaves, whirlpools, relaxation facilities, cryogenic chambers, autoclaves. Temperature range -200 to 1,100 °C Pt 100, Pt 1000, Ni 1000, NTC, PTC, DS18B20, thermocouples, etc. Miniature dimensions.
	Food industry	Smokehouses, bakery ovens, brewhouses, pasteurizers, convection ovens, dairy plants, meat industry, winemaking, food equipment overhauls, distilleries, sugar factories. Temperature sensors with a CLAMP or MILK flange, cable temperature sensors, stick-in temperature probes and multi-point probes. Temperature range -30 to 300 °C Pt 100, Pt 1000, Ni 1000, NTC, PTC, DS18B20, thermocouples, etc. Use of food steels and materials

	Chemistry, chemical industry	Production of pharmaceuticals, inorganic and organic chemicals, landfill inspection, toiletries, cosmetics. Temperature range -200 to 1,100 °C Pt 100, Pt 1000, Ni 1000, NTC, PTC, DS18B20, thermocouples, etc. Requirements for Zone 2 explosive environment
	Science and research	Collaboration with universities, technical and research centres, Czech Academy of Sciences, laboratories, testing facilities. Temperature range -200 to 1,100 °C Pt 100, Pt 1000, Ni 1000, NTC, PTC, DS18B20, thermocouples, etc. High accuracy up to 1/10B, stability.
	Machines and equipment	The broadest segment in terms of applications Gearboxes, bearings, windings of electric motors, stators, coolants, combustion engine blocks, critical points of technological processes, single-purpose machines and equipment. Cable temperature sensors according to specific requirements. Temperature range -200 to 1,100 °C Pt 100, Pt 1000, Ni 1000, NTC, PTC, DS18B20, thermocouples, etc.
	Custom manufacturing	All applications with one-time production or production in small quantities (in units). E.g.: temperature measurement in a pheasant hatchery, measurement of the temperature profile of a bridge road, temperature profile of ground-water heat pump wells, etc. Cable temperature sensors according to specific requirements. Temperature range -200 to 1,100 °C Pt 100, Pt 1000, Ni 1000, NTC, PTC, DS18B20, thermocouples, etc.

Platinum Resistance Sensors

Temperature sensing elements Pt 100, α = 3.851·10^{-3} °C^{-1}

Basic technical parameters

Sensing element	Thin-film platinum resistor
Maximum range of working temperature	-200 to 800 °C [1)]
Resistance at 0 °C	100 Ω
Long-term resistance stability	0.03 % after 1000 h at t = 400 °C
Recommended / max. direct measuring current	Class A: 0.5 mA / 1.2 mA [2)] Class B: 0.8 mA / 2 mA [2)]

[1)] The real range of working temperature of the sensor is given by the design and production technology of the temperature sensor.
[2)] Applies to a temperature range of -50 to +400 °C

The temperature dependence of the sensing element resistance is expressed as follows:

$R = 100\,(1 + At + Bt^2 + C\,(t-100)\,t^3)$ in a temperature range of -200 to 0 °C

$R = 100\,(1 + At + Bt^2)$ in a temperature range of 0 to 850 °C

where: $A = 3.9083.\ 10^{-3}$ °C^{-1} $B = -5.775.\ 10^{-7}$ °C^{-2} $C = -4.183.\ 10^{-12}$ °C^{-4}

Dependence of resistance on temperature in ohms [Ω]:

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-200	18.52									
-190	22.83	22.40	21.97	21.54	21.11	20.68	20.25	19.82	19.38	18.95
-180	27.10	26.67	26.24	25.82	25.39	24.97	24.54	24.11	23.68	23.25
-170	31.34	30.91	30.49	30.07	29.64	29.22	28.80	28.37	27.95	27.52
-160	35.54	35.12	34.70	34.28	33.86	33.44	33.02	32.60	32.18	31.76
-150	39.72	39.31	38.89	38.47	38.05	37.64	37.22	36.80	36.38	35.96
-140	43.88	43.46	43.05	42.63	42.22	41.80	41.39	40.97	40.56	40.14
-130	48.00	47.59	47.18	46.77	46.36	45.94	45.53	45.12	44.70	44.29
-120	52.11	51.70	51.29	50.88	50.47	50.06	49.65	49.24	48.83	48.42
-110	56.19	55.79	55.38	54.97	54.56	54.15	53.75	53.34	52.93	52.52
-100	60.26	59.85	59.44	59.04	58.63	58.23	57.82	57.41	57.01	56.60
-90	64.30	63.90	63.49	63.09	62.68	62.28	61.88	61.47	61.07	60.66
-80	68.33	67.92	67.52	67.12	66.72	66.31	65.91	65.51	65.11	64.70
-70	72.33	71.93	71.53	71.13	70.73	70.33	69.93	69.53	69.13	68.73
-60	76.33	75.93	75.53	75.13	74.73	74.33	73.93	73.53	73.13	72.73
-50	80.31	79.91	79.51	79.11	78.72	78.32	77.92	77.52	77.12	76.73
-40	84.27	83.87	83.48	83.08	82.69	82.29	81.89	81.50	81.10	80.70
-30	88.22	87.83	87.43	87.04	86.64	86.25	85.85	85.46	85.06	84.67
-20	92.16	91.77	91.37	90.98	90.59	90.19	89.80	89.40	89.01	88.62
-10	96.09	95.69	95.30	94.91	94.52	94.12	93.73	93.34	92.95	92.55
0	100.00	99.61	99.22	98.83	98.44	98.04	97.65	97.26	96.87	96.48

°C	0	1	2	3	4	5	6	7	8	9
0	100.00	100.39	100.78	101.17	101.56	101.95	102.34	102.73	103.12	103.51
10	103.90	104.29	104.68	105.07	105.46	105.85	106.24	106.63	107.02	107.40
20	107.79	108.18	108.57	108.96	109.35	109.73	110.12	110.51	110.90	111.29
30	111.67	112.06	112.45	112.83	113.22	113.61	114.00	114.38	114.77	115.15
40	115.54	115.93	116.31	116.70	117.08	117.47	117.86	118.24	118.63	119.01
50	119.40	119.78	120.17	120.55	120.94	121.32	121.71	122.09	122.47	122.86
60	123.24	123.63	124.01	124.39	124.78	125.16	125.54	125.93	126.31	126.69
70	127.08	127.46	127.84	128.22	128.61	128.99	129.37	129.75	130.13	130.52
80	130.90	131.28	131.66	132.04	132.42	132.80	133.18	133.57	133.95	134.33
90	134.71	135.09	135.47	135.85	136.23	136.61	136.99	137.37	137.75	138.13

100	138.51	138.88	139.26	139.64	140.02	140.40	140.78	141.16	141.54	141.91
110	142.29	142.67	143.05	143.43	143.80	144.18	144.56	144.94	145.31	145.69
120	146.07	146.44	146.82	147.20	147.57	147.95	148.33	148.70	149.08	149.46
130	149.83	150.21	150.58	150.96	151.33	151.71	152.08	152.46	152.83	153.21
140	153.58	153.96	154.33	154.71	155.08	155.46	155.83	156.20	156.58	156.95
150	157.33	157.70	158.07	158.45	158.82	159.19	159.56	159.94	160.31	160.68
160	161.05	161.43	161.80	162.17	162.54	162.91	163.29	163.66	164.03	164.40
170	164.77	165.14	165.51	165.89	166.26	166.63	167.00	167.37	167.74	168.11
180	168.48	168.85	169.22	169.59	169.96	170.33	170.70	171.07	171.43	171.80
190	172.17	172.54	172.91	173.28	173.65	174.02	174.38	174.75	175.12	175.49
200	175.86	176.22	176.59	176.96	177.33	177.69	178.06	178.43	178.79	179.16
210	179.53	179.89	180.26	180.63	180.99	181.36	181.72	182.09	182.46	182.82
220	183.19	183.55	183.92	184.28	184.65	185.01	185.38	185.74	186.11	186.47
230	186.84	187.20	187.56	187.93	188.29	188.66	189.02	189.38	189.75	190.11
240	190.47	190.84	191.20	191.56	191.92	192.29	192.65	193.01	193.37	193.74
250	194.10	194.46	194.82	195.18	195.55	195.91	196.27	196.63	196.99	197.35
260	197.71	198.07	198.43	198.79	199.15	199.51	199.87	200.23	200.59	200.95
270	201.31	201.67	202.03	202.39	202.75	203.11	203.47	203.83	204.19	204.55
280	204.90	205.26	205.62	205.98	206.34	206.70	207.05	207.41	207.77	208.13
290	208.48	208.84	209.20	209.56	209.91	210.27	210.63	210.98	211.34	211.70
300	212.05	212.41	212.76	213.12	213.48	213.83	214.19	214.54	214.90	215.25
310	215.61	215.96	216.32	216.67	217.03	217.38	217.74	218.09	218.44	218.80
320	219.15	219.51	219.86	220.21	220.57	220.92	221.27	221.63	221.98	222.33
330	222.68	223.04	223.39	223.74	224.09	224.45	224.80	225.15	225.50	225.85
340	226.21	226.56	226.91	227.26	227.61	227.96	228.31	228.66	229.02	229.37
350	229.72	230.07	230.42	230.77	231.12	231.47	231.82	232.17	232.52	232.87
360	233.21	233.56	233.91	234.26	234.61	234.96	235.31	235.66	236.00	236.35
370	236.70	237.05	237.40	237.74	238.09	238.44	238.79	239.13	239.48	239.83
380	240.18	240.52	240.87	241.22	241.56	241.91	242.26	242.60	242.95	243.29
390	243.64	243.99	244.33	244.68	245.02	245.37	245.71	246.06	246.40	246.75
400	247.09	247.44	247.78	248.13	248.47	248.81	249.16	249.50	249.85	250.19
410	250.53	250.88	251.22	251.56	251.91	252.25	252.59	252.93	253.28	253.62
420	253.96	254.30	254.65	254.99	255.33	255.67	256.01	256.35	256.70	257.04
430	257.38	257.72	258.06	258.40	258.74	259.08	259.42	259.76	260.10	260.44
440	260.78	261.12	261.46	261.80	262.14	262.48	262.82	263.16	263.50	263.84
450	264.18	264.52	264.86	265.20	265.53	265.87	266.21	266.55	266.89	267.22
460	267.56	267.90	268.24	268.57	268.91	269.25	269.59	269.92	270.26	270.60
470	270.93	271.27	271.61	271.94	272.28	272.61	272.95	273.29	273.62	273.96
480	274.29	274.63	274.96	275.30	275.63	275.97	276.30	276.64	276.97	277.31
490	277.64	277.98	278.31	278.64	278.98	279.31	279.64	279.98	280.31	280.64
500	280.98	281.31	281.64	281.98	282.31	282.64	282.97	283.31	283.64	283.97
510	284.30	284.63	284.97	285.30	285.63	285.96	286.29	286.62	286.95	287.29
520	287.62	287.95	288.28	288.61	288.94	289.27	289.60	289.93	290.26	290.59
530	290.92	291.25	291.58	291.91	292.24	292.56	292.89	293.22	293.55	293.88
540	294.21	294.54	294.86	295.19	295.52	295.85	296.18	296.50	296.83	297.16
550	297.49	297.81	298.14	298.47	298.80	299.12	299.45	299.78	300.10	300.43
560	300.75	301.08	301.41	301.73	302.06	302.38	302.71	303.03	303.36	303.69
570	304.01	304.34	304.66	304.98	305.31	305.63	305.96	306.28	306.61	306.93
580	307.25	307.58	307.90	308.23	308.55	308.87	309.20	309.52	309.84	310.16
590	310.49	310.81	311.13	311.45	311.78	312.10	312.42	312.74	313.06	313.39
600	313.71	314.03	314.35	314.67	314.99	315.31	315.64	315.96	316.28	316.60
610	316.92	317.24	317.56	317.88	318.20	318.52	318.84	319.16	319.48	319.80
620	320.12	320.43	320.75	321.07	321.39	321.71	322.03	322.35	322.67	322.98
630	323.30	323.62	323.94	324.26	324.57	324.89	325.21	325.53	325.84	326.16
640	326.48	326.79	327.11	327.43	327.74	328.06	328.38	328.69	329.01	329.32
650	329.64	329.96	330.27	330.59	330.90	331.22	331.53	331.85	332.16	332.48
660	332.79	333.11	333.42	333.74	334.05	334.36	334.68	334.99	335.30	335.62

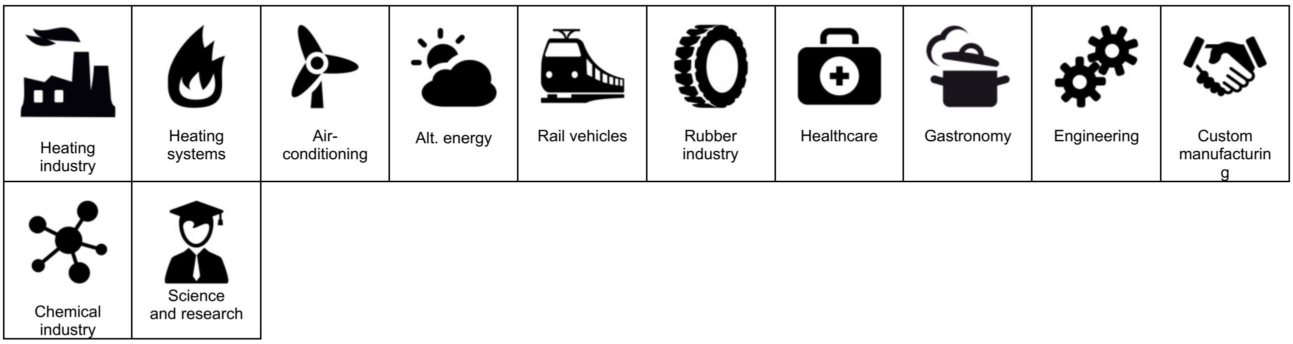
670	335.93	336.25	336.56	336.87	337.18	337.50	337.81	338.12	338.44	338.75
680	339.06	339.37	339.69	340.00	340.31	34062	340.93	341.24	341.56	341.87
690	342.18	342.49	342.80	343.11	343.42	343.73	344.04	344.35	344.66	344.97
700	345.28	345.59	345.90	346.21	346.52	346.83	347.14	347.45	347.76	348.07
710	348.38	348.69	348.99	349.30	349.61	349.92	350.23	350.54	350.84	351.15
720	351.46	351.77	352.08	352.38	352.69	353.00	353.30	353.61	353.92	354.22
730	354.53	354.84	355.14	355.45	355.76	356.06	356.37	356.67	356.98	357.28
740	357.59	357.90	358.20	358.51	358.81	359.12	359.42	359.72	360.03	360.33
750	360.64	360.94	361.25	361.55	361.85	362.16	362.46	362.76	363.07	363.37
760	363.67	363.98	364.28	364.58	364.89	365.19	365.49	365.79	366.10	366.40
770	366.70	367.00	367.30	367.60	367.91	368.21	368.51	368.81	369.11	369.41
780	369.71	370.01	370.31	370.61	370.91	371.21	371.51	371.81	372.11	372.41
790	372.71	373.01	373.31	373.61	373.91	374.21	374.51	374.81	375.11	375.41
800	375.70									

Sensing element accuracy classes

Temperature [°C]	**Resistance [Ω]**	**Class AA**		**Class A**		**Class B**		**Class C**	
		ΔT [°C]	**ΔR [Ω]**	**ΔT [°C]**	**ΔR [Ω]**	**ΔT [°C]**	**ΔR [Ω]**	**ΔT [°C]**	**ΔR [Ω]**
-50	80.31	-	-	-	-	± 0.55	± 0.22	± 1.10	± 0.44
-30	88.22	-	-	± 0.21	± 0.08	± 0.45	± 0.18	± 0.90	± 0.35
0	100.00	± 0.10	± 0.04	± 0.15	± 0.06	± 0.30	± 0.12	± 0.60	± 0.23
25	109.73	± 0.14	± 0.06	± 0.20	± 0.08	± 0.43	± 0.17	± 0.85	± 0.33
100	138.51	± 0.27	± 0.10	± 0.35	± 0.13	± 0.80	± 0.30	± 1.60	± 0.61
150	157.33	± 0.36	± 0.13	± 0.45	± 0.17	± 1.05	± 0.39	± 2.10	± 0.78
200	175.86	-	-	± 0.55	± 0.20	± 1.30	± 0.48	± 2.60	± 0.96
300	212.05	-	-	± 0.75	± 0.27	± 1.80	± 0.64	± 3.60	± 1.28
400	247.09	-	-	-	-	± 2.30	± 0.79	± 4.60	± 1.59
500		-	-	-	-	± 2.80	± 0.93	± 5.60	± 1.87
600		-	-	-	-	-	-	± 6.60	± 2.12

Note: According to EN 60751, the above relationships only apply to temperature intervals given in the table.

Application of sensing elements: Pt 100 sensing elements are the most widely used type of resistance temperature sensing elements. They are most commonly used in measuring and control equipment, the food industry, automotive industry, meteorology, etc. They are supported by most manufacturers in the MaR field. An important area of application is accurate measurement. Pt 100 sensing elements are used in laboratories, for billing measurement and in the production of standards for calibrating other temperature sensors or thermometers.



Temperature sensing elements Pt 100, α = 3.91·10^{-3} °C^{-1}

Basic technical parameters

Sensing element	Thin-film platinum resistor
Maximum range of working temperature	-50 to 400 °C *
Resistance at 0 °C	100 Ω
Long-term resistance stability	0.05 % after 1000 h at 400 °C
Recommended / maximum direct measuring	0.3mA / 1mA

* The real range of working temperature of the sensor is given by the design and technology

Note: Pt 100 temperature sensors with this characteristic are usually part of equipment from Russia or countries of the former Soviet Union. Their properties are described in GOST 6651 - 2009.

The temperature dependence of the sensing element resistance is expressed as follows:

$R = 100 (1 + At + Bt^2 + C (t-100) t^3)$ in a temperature range of -200 to 0 °C

$R = 100 (1 + At + Bt^2)$ in a temperature range of 0 to 850 °C

where: $A = 3.969.\ 10^{-3}$ °C^{-1} $B = -5.841.\ 10^{-7}$ °C^{-2} $C = -4.330.\ 10^{-12}$ °C^{-4}

Dependence of resistance on temperature in ohms [Ω]:

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-50	80.00									
-40	84.03	83.62	83.22	82.82	82.42	82.02	81.61	81.21	80.81	80.40
-30	88.04	87.64	87.24	86.84	86.44	86.03	85.63	85.23	84.83	84.43
-20	92.04	91.64	91.24	90.84	90.44	90.04	89.64	89.24	88.84	88.44
-10	96.03	95.63	95.23	94.83	94.43	94.03	93.63	93.24	92.84	92.44
0	100.00	99.60	99.21	98.81	98.41	98.01	97.62	97.22	96.82	96.42

°C	0	1	2	3	4	5	6	7	8	9
0	100.00	100.40	100.79	101.19	101.59	101.98	102.38	102.78	103.17	103.57
10	103.96	104.36	104.75	105.15	105.55	105.94	106.34	106.73	107.13	107.52
20	107.91	108.31	108.70	109.10	109.49	109.89	110.28	110.67	111.07	111.46
30	111.85	112.25	112.64	113.03	113.43	113.82	114.21	114.61	115.00	115.39
40	115.78	116.17	116.57	116.96	117.35	117.74	118.13	118.53	118.92	119.31
50	119.70	120.09	120.48	120.87	121.26	121.65	122.04	122.43	122.82	123.21
60	123.60	123.99	124.38	124.77	125.16	125.55	125.94	126.33	126.72	127.11
70	127.50	127.89	128.27	128.66	129.05	129.44	129.83	130.21	130.60	130.99
80	131.38	131.77	132.15	132.54	132.93	133.31	133.70	134.09	134.47	134.86
90	135.25	135.63	136.02	136.41	136.79	137.18	137.56	137.95	138.34	138.72
100	139.11	139.49	139.88	140.26	140.65	141.03	141.42	141.80	142.18	142.57
110	142.95	143.34	143.72	144.10	144.49	144.87	145.25	145.64	146.02	146.40
120	146.79	147.17	147.55	147.94	148.32	148.70	149.08	149.46	149.85	150.23
130	150.61	150.99	151.37	151.75	152.14	152.52	152.90	153.28	153.66	154.04
140	154.42	154.80	155.18	155.56	155.94	156.32	156.70	157.08	157.46	157.84
150	158.22	158.60	158.98	159.36	159.74	160.12	160.49	160.87	161.25	161.63
160	162.01	162.39	162.76	163.14	163.52	163.90	164.28	164.65	165.03	165.41
170	165.78	166.16	166.54	166.92	167.29	167.67	168.05	168.42	168.80	169.17
180	169.55	169.93	170.30	170.68	171.05	171.43	171.80	172.18	172.55	172.93
190	173.30	173.68	174.05	174.43	174.80	175.17	175.55	175.92	176.30	176.67
200	177.04	177.42	177.79	178.16	178.54	178.91	179.28	179.66	180.03	180.40
210	180.77	181.15	181.52	181.89	182.26	182.63	183.01	183.38	183.75	184.12
220	184.49	184.86	185.23	185.60	185.97	186.35	186.72	187.09	187.46	187.83

230	188.20	188.57	188.94	189.31	189.68	190.05	190.4	190.78	191.15	191.52
240	191.89	192.26	192.63	193.00	193.37	193.73	194.10	194.47	194.84	195.21
250	195.57	195.94	196.31	196.68	197.04	197.41	197.78	198.15	198.51	198.88
260	199.25	199.61	199.98	200.34	200.71	201.08	201.44	201.81	202.17	202.54
270	202.90	203.27	203.64	204.00	204.37	204.73	205.09	205.46	205.82	206.19
280	206.55	206.92	207.28	207.64	208.01	208.37	208.74	209.10	209.46	209.83
290	210.19	210.55	210.91	211.28	211.64	212.00	212.36	212.73	213.09	213.45
300	213.81	214.17	214.54	214.90	215.26	215.62	215.98	216.34	216.70	217.07
310	217.43	217.79	218.15	218.51	218.87	219.23	219.59	219.95	220.31	220.67
320	221.03	221.39	221.75	222.10	222.46	222.82	223.18	223.54	223.90	224.26
330	224.62	224.97	225.33	225.69	226.05	226.41	226.76	227.12	227.48	227.84
340	228.19	228.55	228.91	229.26	229.62	229.98	230.33	230.69	231.05	231.40
350	231.76	232.12	232.47	232.83	233.18	233.54	233.89	234.25	234.60	234.96
360	235.31	235.67	236.02	236.38	236.73	237.09	237.44	237.80	238.15	238.50
370	238.86	239.21	239.56	239.92	240.27	240.62	240.98	241.33	241.68	242.04
380	242.39	242.74	243.09	243.44	243.80	244.15	244.50	244.85	245.20	245.56
390	245.91	246.26	246.61	246.96	247.31	247.66	248.01	248.36	248.71	249.06
400	249.41									

Sensing element accuracy classes

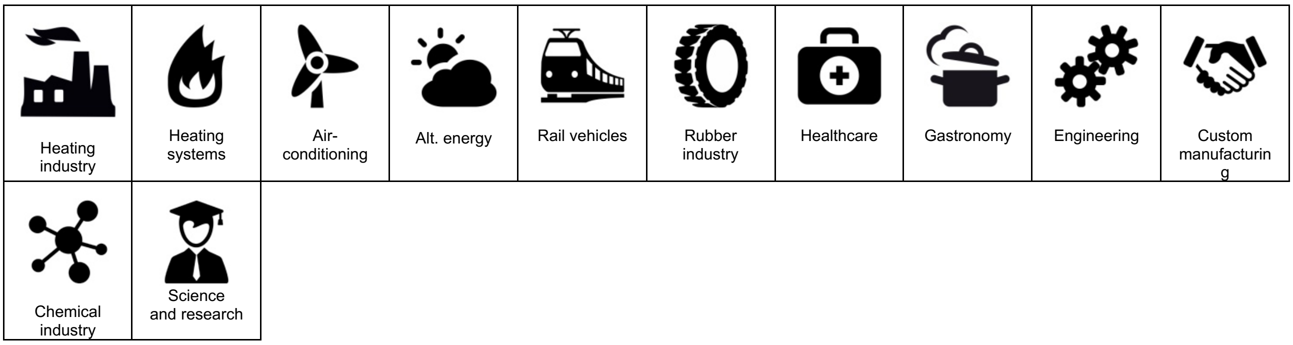
Because EN 60 571 does not apply to Pt 100/3911, it is possible to conclude that even these sensing elements can be classified into two basic accuracy classes expressed as follows:

	for -50°C ≤ t ≤ 400°C
Class A	ΔT = ± (0.15 + 0.002 * | t |) in °C
Class B	ΔT = ± (0.30 + 0.005 * | t |) in °C

* | t | is the absolute value of temperature.

Temperature [°C]	**Resistance [Ω]**	**Class A**		**Class B**	
		ΔT [°C]	**ΔR [Ω]**	**ΔT [°C]**	**ΔR [Ω]**
-50	80.00	± 0.25	± 0.10	± 0.55	± 0.22
0	100.00	± 0.15	± 0.06	± 0.30	± 0.12
100	139.11	± 0.35	± 0.13	± 0.80	± 0.30
200	177.04	± 0.55	± 0.20	± 1.30	± 0.47
400	249.44	± 0.95	± 0.33	± 2.30	± 0.79

Application of sensing elements:



Temperature sensing elements Pt 500, $\alpha = 3.851 \cdot 10^{-3}$ °C^{-1}

Basic technical parameters

Sensing element	Thin-film platinum resistor
Maximum range of working temperature	-200 to 800 °C *
Resistance at 0 °C	500 Ω
Long-term resistance stability	0.03 % after 1000 h at t = 400 °C
Recommended / max. direct measuring current	0.5mA / 1.5mA

[1)] The real range of working temperature of the sensor is given by the design and production technology of the temperature sensor.

The temperature dependence of the sensing element resistance is expressed as follows:

$$R = 500\,(1 + At + Bt^2 + C\,(t-100)\,t^3)$$ in a temperature range of -200 to 0 °C

$$R = 500\,(1 + At + Bt^2)$$ in a temperature range of 0 to 850 °C

where: $A = 3.9083.\ 10^{-3}$ °C^{-1} $B = -5.775.\ 10^{-7}$ °C^{-2} $C = -4.183.\ 10^{-12}$ °C^{-4}

Dependence of resistance on temperature in ohms [Ω]:

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-50	401.53									
-40	421.35	419.37	417.39	415.41	413.43	411.45	409.47	407.49	405.50	403.52
-30	441.11	439.14	437.16	435.19	433.21	431.24	429.26	427.29	425.31	423.33
-20	460.80	458.83	456.87	454.90	452.93	450.96	448.99	447.02	445.05	443.08
-10	480.43	478.47	476.51	474.55	472.58	470.62	468.66	466.69	464.73	462.77
0	500.00	498.05	496.09	494.13	492.18	490.22	488.26	486.31	484.35	482.39

°C	0	1	2	3	4	5	6	7	8	9
0	500.00	501.95	503.91	505.86	507.81	509.76	511.71	513.66	515.61	517.56
10	519.51	521.46	523.41	525.36	527.30	529.25	531.19	533.14	535.08	537.02
20	538.97	540.91	542.85	544.79	546.73	548.67	550.61	552.55	554.49	556.43
30	558.36	560.30	562.24	564.17	566.11	568.04	569.98	571.91	573.84	575.77
40	577.70	579.63	581.56	583.49	585.42	587.35	589.28	591.21	593.13	595.06
50	596.99	598.91	600.84	602.76	604.68	606.60	608.53	610.45	612.37	614.29
60	616.21	618.13	620.05	621.97	623.88	625.80	627.72	629.63	631.55	633.46
70	635.38	637.29	639.20	641.11	643.03	644.94	646.85	648.76	650.67	652.58
80	654.48	656.39	658.30	660.21	662.11	664.02	665.92	667.83	669.73	671.63
90	673.53	675.44	677.34	679.24	681.14	683.04	684.94	686.84	688.73	690.63
100	692.53	694.42	696.32	698.21	700.11	702.00	703.90	705.79	707.68	709.57
110	711.46	713.35	715.24	717.13	719.02	720.91	722.80	724.68	726.57	728.45
120	730.34	732.22	734.11	735.99	737.87	739.76	741.64	743.52	745.40	747.28
130	749.16	751.04	752.92	754.79	756.67	758.55	760.42	762.30	764.17	766.05
140	767.92	769.79	771.67	773.54	775.41	777.28	779.15	781.02	782.89	784.76
150	786.63	788.49	790.36	792.23	794.09	795.96	797.82	799.68	801.55	803.41
160	805.27	807.13	808.99	810.85	812.71	814.57	816.43	818.29	820.15	822.00
170	823.86	825.72	827.57	829.43	831.28	833.13	834.99	836.84	838.69	840.54
180	842.39	844.24	846.09	847.94	849.79	851.64	853.48	855.33	857.17	859.02
190	860.86	862.71	864.55	866.40	868.24	870.08	871.92	873.76	875.60	877.44
200	879.28	881.12	882.96	884.79	886.63	888.47	890.30	892.14	893.97	895.80
210	897.64	899.47	901.30	903.13	904.96	906.79	908.62	910.45	912.28	914.11
220	915.94	917.76	919.59	921.42	923.24	925.07	926.89	928.71	930.54	932.36
230	934.18	936.00	937.82	939.64	941.46	943.28	945.10	946.91	948.73	950.55
240	952.36	954.18	955.99	957.81	959.62	961.43	963.25	965.06	966.87	968.68
250	970.49	972.30	974.11	975.92	977.73	979.53	981.34	983.14	984.95	986.76
260	988.56	990.36	992.17	993.97	995.77	997.57	999.37	1001.17	1002.97	1004.77

270	1006.57	1008.37	1010.17	1011.96	1013.76	1015.55	1017.35	1019.14	1020.94	1022.73
280	1024.52	1026.32	1028.11	1029.90	1031.69	1033.48	1035.27	1037.06	1038.85	1040.63
290	1042.42	1044.21	1045.99	1047.78	1049.56	1051.35	1053.13	1054.91	1056.69	1058.48
300	1060.26	1062.04	1063.82	1065.60	1067.38	1069.15	1070.93	1072.71	1074.49	1076.26
310	1078.04	1079.81	1081.59	1083.36	1085.13	1086.91	1088.68	1090.45	1092.22	1093.99
320	1095.76	1097.53	1099.30	1101.07	1102.83	1104.60	1106.37	1108.13	1109.90	1111.66
330	1113.42	1115.19	1116.95	1118.71	1120.47	1122.24	1124.00	1125.76	1127.51	1129.27
340	1131.03	1132.79	1134.55	1136.30	1138.06	1139.81	1141.57	1143.32	1145.08	1146.83
350	1148.58	1150.33	1152.08	1153.83	1155.58	1157.33	1159.08	1160.83	1162.58	1164.33
360	1166.07	1167.82	1169.56	1171.31	1173.05	1174.80	1176.54	1178.28	1180.02	1181.76
370	1183.51	1185.25	1186.99	1188.72	1190.46	1192.20	1193.94	1195.67	1197.41	1199.15
380	1200.88	1202.62	1204.35	1206.08	1207.82	1209.55	1211.28	1213.01	1214.74	1216.47
390	1218.20	1219.93	1221.66	1223.38	1225.11	1226.84	1228.56	1230.29	1232.01	1233.74
400	1235.46	1237.18	1238.91	1240.63	1242.35	1244.07	1245.79	1247.51	1249.23	1250.94
410	1252.66	1254.38	1256.10	1257.81	1259.53	1261.24	1262.96	1264.67	1266.38	1268.10
420	1269.81	1271.52	1273.23	1274.94	1276.65	1278.36	1280.07	1281.77	1283.48	1285.19
430	1286.89	1288.60	1290.31	1292.01	1293.71	1295.42	1297.12	1298.82	1300.52	1302.22
440	1303.92	1305.62	1307.32	1309.02	1310.72	1312.42	1314.11	1315.81	1317.51	1319.20
450	1320.90	1322.59	1324.28	1325.98	1327.67	1329.36	1331.05	1332.74	1334.43	1336.12
460	1337.81	1339.50	1341.19	1342.87	1344.56	1346.24	1347.93	1349.61	1351.30	1352.98
470	1354.67	1356.35	1358.03	1359.71	1361.39	1363.07	1364.75	1366.43	1368.11	1369.79
480	1371.46	1373.14	1374.82	1376.49	1378.17	1379.84	1381.52	1383.19	1384.86	1386.53
490	1388.20	1389.88	1391.55	1393.22	1394.88	1396.55	1398.22	1399.89	1401.56	1403.22
500	1404.89	1406.55	1408.22	1409.88	1411.54	1413.21	1414.87	1416.53	1418.19	1419.85
510	1421.51	1423.17	1424.83	1426.49	1428.15	1429.80	1431.46	1433.12	1434.77	1436.43
520	1438.08	1439.73	1441.39	1443.04	1444.69	1446.34	1447.99	1449.64	1451.29	1452.94
530	1454.59	1456.24	1457.88	1459.53	1461.18	1462.82	1464.47	1466.11	1467.76	1469.40
540	1471.04	1472.68	1474.32	1475.97	1477.61	1479.25	1480.88	1482.52	1484.16	1485.80
550	1487.44	1489.07	1490.71	1492.34	1493.98	1495.61	1497.24	1498.88	1500.51	1502.14
560	1503.77	1505.40	1507.03	1508.66	1510.29	1511.92	1513.55	1515.17	1516.80	1518.43
570	1520.05	1521.68	1523.30	1524.92	1526.55	1528.17	1529.79	1531.41	1533.03	1534.65
580	1536.27	1537.89	1539.51	1541.13	1542.74	1544.36	1545.98	1547.59	1549.21	1550.82
590	1552.43	1554.05	1555.66	1557.27	1558.88	1560.49	1562.10	1563.71	1565.32	1566.93
600	1568.54									

Sensing element accuracy classes

Temperature [°C]	Resistance [Ω]	Class AA		Class A		Class B		Class C	
		ΔT [°C]	ΔR [Ω]	ΔT [°C]	ΔR [Ω]	ΔT [°C]	ΔR [Ω]	ΔT [°C]	ΔR [Ω]
-50	401.53	-	-	-	-	± 0.55	± 1.09	± 1.10	± 2.18
-30	441.11	-	-	± 0.21	± 0.41	± 0.45	± 0.89	± 0.90	± 1.77
0	500.00	± 0.10	± 0.20	± 0.15	± 0.29	± 0.30	± 0.59	± 0.60	± 1.17
25	548.67	± 0.14	± 0.28	± 0.20	± 0.39	± 0.43	± 0.82	± 0.85	± 1.65
100	692.53	± 0.27	± 0.51	± 0.35	± 0.66	± 0.80	± 1.52	± 1.60	± 3.03
150	786.63	± 0.36	± 0.66	± 0.45	± 0.84	± 1.05	± 1.96	± 2.10	± 3.92
200	879.28	-	-	± 0.55	± 1.01	± 1.30	± 2.39	± 2.60	± 4.78
300	1060.26	-	-	± 0.75	± 1.34	± 1.80	± 3.21	± 3.60	± 6.41
400	1235.46	-	-	-	-	± 2.30	± 3.96	± 4.60	± 7.93
500	1404.89	-	-	-	-	± 2.80	± 4.66	± 5.60	± 9.33
600	1568.54	-	-	-	-	-	-	± 6.60	± 10.61

Note: According to EN 60 751, the above relationships only apply to temperature intervals given in the table.

Application of sensing elements:

 Heating industry	 Heating systems	 Custom manufacturin g

Notes:

Temperature sensing elements Pt 1000, α = 3.851·10^{-3} °C^{-1}

Basic technical parameters

Sensing element	Thin-film platinum resistor
Maximum range of working temperature	-200 to 800 °C 1)
Resistance at 0 °C	1000 Ω
Long-term resistance stability	0.03 % after 1000 h at t = 400 °C
Recommended / maximum direct measuring current	Class A: 0.2 mA / 0.5 mA 2) Class B: 0.3 mA / 0.8 mA 2)

1) The real range of working temperature of the sensor is given by the design and technology.
2) Applies to a temperature range of -50 to +400 °C

The temperature dependence of the sensing element resistance is expressed as follows:

$R = 1000 (1 + At + Bt^2 + C (t-100) t^3)$ in a temperature range of -200 to 0 °C

$R = 1000 (1 + At + Bt^2)$ in a temperature range of 0 to 850 °C

where: A = 3.9083. 10^{-3} °C^{-1} B = -5.775. 10^{-7} °C^{-2} C = -4.183. 10^{-12} °C^{-4}

Dependence of resistance on temperature in ohms [Ω]:

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-200	185.20									
-190	228.25	223.97	219.67	215.38	211.08	206.77	202.47	198.15	193.84	189.52
-180	270.96	266.71	262.45	258.19	253.92	249.65	245.38	241.10	236.82	232.54
-170	313.35	309.13	304.90	300.67	296.43	292.20	287.96	283.71	279.47	275.22
-160	355.43	351.24	347.04	342.84	338.64	334.43	330.22	326.01	321.79	317.57
-150	397.23	393.06	388.89	384.72	380.55	376.37	372.19	368.00	363.82	359.63
-140	438.76	434.62	430.48	426.33	422.18	418.03	413.88	409.72	405.56	401.40
-130	480.05	475.93	471.81	467.69	463.56	459.44	455.31	451.17	447.04	442.90
-120	521.10	517.00	512.91	508.81	504.70	500.60	496.49	492.39	488.28	484.16
-110	561.93	557.86	553.78	549.70	545.62	541.54	537.46	533.37	529.28	525.19
-100	602.56	598.50	594.45	590.39	586.33	582.27	578.21	574.14	570.07	566.00
-90	643.00	638.96	634.92	630.88	626.84	622.80	618.76	614.71	610.66	606.61
-80	683.25	679.24	675.22	671.19	667.17	663.15	659.12	655.09	651.06	647.03
-70	723.35	719.34	715.34	711.34	707.33	703.32	699.31	695.30	691.29	687.27
-60	763.28	759.29	755.30	751.31	747.32	743.33	739.33	735.34	731.34	727.35
-50	803.06	799.09	795.12	791.14	787.17	783.19	779.21	775.23	771.25	767.26
-40	842.71	838.75	834.79	830.83	826.87	822.90	818.94	814.97	811.00	807.03
-30	882.22	878.27	874.32	870.38	866.43	862.48	858.53	854.57	850.62	846.66
-20	921.60	917.67	913.73	909.80	905.86	901.92	897.98	894.04	890.10	886.16
-10	960.86	956.94	953.02	949.09	945.17	941.24	937.32	933.39	929.46	925.53
0	1000.00	996.09	992.18	988.27	984.36	980.44	976.53	972.61	968.70	964.78

°C	0	1	2	3	4	5	6	7	8	9
0	1000.00	1003.91	1007.81	1011.72	1015.62	1019.53	1023.43	1027.33	1031.23	1035.13
10	1039.03	1042.92	1046.82	1050.71	1054.60	1058.49	1062.38	1066.27	1070.16	1074.05
20	1077.94	1081.82	1085.70	1089.59	1093.47	1097.35	1101.23	1105.10	1108.98	1112.86
30	1116.73	1120.60	1124.47	1128.35	1132.21	1136.08	1139.95	1143.82	1147.68	1151.55
40	1155.41	1159.27	1163.13	1166.99	1170.85	1174.70	1178.56	1182.41	1186.27	1190.12
50	1193.97	1197.82	1201.67	1205.52	1209.36	1213.21	1217.05	1220.90	1224.74	1228.58
60	1232.42	1236.26	1240.09	1243.93	1247.77	1251.60	1255.43	1259.26	1263.09	1266.92
70	1270.75	1274.58	1278.40	1282.23	1286.05	1289.87	1293.70	1297.52	1301.33	1305.15
80	1308.97	1312.78	1316.60	1320.41	1324.22	1328.03	1331.84	1335.65	1339.46	1343.26
90	1347.07	1350.87	1354.68	1358.48	1362.28	1366.08	1369.87	1373.67	1377.47	1381.26
100	1385.06	1388.85	1392.64	1396.43	1400.22	1404.00	1407.79	1411.58	1415.36	1419.14

110	1422.93	1426.71	1430.49	1434.26	1438.04	1441.82	1445.59	1449.37	1453.14	1456.91
120	1460.68	1464.45	1468.22	1471.98	1475.75	1479.51	1483.28	1487.04	1490.80	1494.56
130	1498.32	1502.08	1505.83	1509.59	1513.34	1517.10	1520.85	1524.60	1528.35	1532.10
140	1535.84	1539.59	1543.33	1547.08	1550.82	1554.56	1558.30	1562.04	1565.78	1569.52
150	1573.25	1576.99	1580.72	1584.45	1588.18	1591.91	1595.64	1599.37	1603.09	1606.82
160	1610.54	1614.27	1617.99	1621.71	1625.43	1629.15	1632.86	1636.58	1640.30	1644.01
170	1647.72	1651.43	1655.14	1658.85	1662.56	1666.27	1669.97	1673.68	1677.38	1681.08
180	1684.78	1688.48	1692.18	1695.88	1699.58	1703.27	1706.96	1710.66	1714.35	1718.04
190	1721.73	1725.42	1729.10	1732.79	1736.48	1740.16	1743.84	1747.52	1751.20	1754.88
200	1758.56	1762.24	1765.91	1769.59	1773.26	1776.93	1780.60	1784.27	1787.94	1791.61
210	1795.28	1798.94	1802.60	1806.27	1809.93	1813.59	1817.25	1820.91	1824.56	1828.22
220	1831.88	1835.53	1839.18	1842.83	1846.48	1850.13	1853.78	1857.43	1861.07	1864.72
230	1868.36	1872.00	1875.64	1879.28	1882.92	1886.56	1890.19	1893.83	1897.46	1901.10
240	1904.73	1908.36	1911.99	1915.62	1919.24	1922.87	1926.49	1930.12	1933.74	1937.36
250	1940.98	1944.60	1948.22	1951.83	1955.45	1959.06	1962.68	1966.29	1969.90	1973.51
260	1977.12	1980.73	1984.33	1987.94	1991.54	1995.14	1998.75	2002.35	2005.95	2009.54
270	2013.14	2016.74	2020.33	2023.93	2027.52	2031.11	2034.70	2038.29	2041.88	2045.46
280	2049.05	2052.63	2056.22	2059.80	2063.38	2066.96	2070.54	2074.11	2077.69	2081.27
290	2084.84	2088.41	2091.98	2095.55	2099.12	2102.69	2106.26	2109.82	2113.39	2116.95
300	2120.52	2124.08	2127.64	2131.20	2134.75	2138.31	2141.87	2145.42	2148.97	2152.52
310	2156.08	2159.62	2163.17	2166.72	2170.27	2173.81	2177.36	2180.90	2184.44	2187.98
320	2191.52	2195.06	2198.60	2202.13	2205.67	2209.20	2212.73	2216.26	2219.79	2223.32
330	2226.85	2230.38	2233.90	2237.43	2240.95	2244.47	2247.99	2251.51	2255.03	2258.55
340	2262.06	2265.58	2269.09	2272.60	2276.12	2279.63	2283.14	2286.64	2290.15	2293.66
350	2297.16	2300.66	2304.17	2307.67	2311.17	2314.67	2318.16	2321.66	2325.16	2328.65
360	2332.14	2335.64	2339.13	2342.62	2346.10	2349.59	2353.08	2356.56	2360.05	2363.53
370	2367.01	2370.49	2373.97	2377.45	2380.93	2384.40	2387.88	2391.35	2394.82	2398.29
380	2401.76	2405.23	2408.70	2412.17	2415.63	2419.10	2422.56	2426.02	2429.48	2432.94
390	2436.40	2439.86	2443.31	2446.77	2450.22	2453.67	2457.13	2460.58	2464.03	2467.47
400	2470.92	2474.37	2477.81	2481.25	2484.70	2488.14	2491.58	2495.02	2498.45	2501.89
410	2505.33	2508.76	2512.19	2515.62	2519.06	2522.48	2525.91	2529.34	2532.77	2536.19
420	2539.62	2543.04	2546.46	2549.88	2553.30	2556.72	2560.13	2563.55	2566.96	2570.38
430	2573.79	2577.20	2580.61	2584.02	2587.43	2590.83	2594.24	2597.64	2601.05	2604.45
440	2607.85	2611.25	2614.65	2618.04	2621.44	2624.83	2628.23	2631.62	2635.01	2638.40
450	2641.79	2645.18	2648.57	2651.95	2655.34	2658.72	2662.10	2665.48	2668.86	2672.24
460	2675.62	2679.00	2682.37	2685.74	2689.12	2692.49	2695.86	2699.23	2702.60	2705.97
470	2709.33	2712.70	2716.06	2719.42	2722.78	2726.14	2729.50	2732.86	2736.22	2739.57
480	2742.93	2746.28	2749.63	2752.98	2756.33	2759.68	2763.03	2766.38	2769.72	2773.07
490	2776.41	2779.75	2783.09	2786.43	2789.77	2793.11	2796.44	2799.78	2803.11	2806.44
500	2809.78	2813.11	2816.43	2819.76	2823.09	2826.41	2829.74	2833.06	2836.38	2839.71
510	2843.03	2846.34	2849.66	2852.98	2856.29	2859.61	2862.92	2866.23	2869.54	2872.85
520	2876.16	2879.47	2882.77	2886.08	2889.38	2892.68	2895.99	2899.29	2902.58	2905.88
530	2909.18	2912.47	2915.77	2919.06	2922.35	2925.65	2928.94	2932.22	2935.51	2938.80
540	2942.08	2945.37	2948.65	2951.93	2955.21	2958.49	2961.77	2965.05	2968.32	2971.60
550	2974.87	2978.14	2981.42	2984.69	2987.95	2991.22	2994.49	2997.75	3001.02	3004.28
560	3007.54	3010.80	3014.06	3017.32	3020.58	3023.84	3027.09	3030.35	3033.60	3036.85
570	3040.10	3043.35	3046.60	3049.85	3053.09	3056.34	3059.58	3062.82	3066.06	3069.30
580	3072.54	3075.78	3079.02	3082.25	3085.49	3088.72	3091.95	3095.18	3098.41	3101.64
590	3104.87	3108.10	3111.32	3114.54	3117.77	3120.99	3124.21	3127.43	3130.65	3133.86
600	3137.08	3140.29	3143.51	3146.72	3149.93	3153.14	3156.35	3159.56	3162.77	3165.97
610	3169.18	3172.38	3175.58	3178.78	3181.98	3186.18	3188.38	3191.57	3194.77	3197.96
620	3201.15	3204.35	3207.54	3210.73	3213.91	3217.10	3220.29	3223.47	3226.66	3229.84
630	3233.02	3236.20	3239.38	3242.56	3245.73	3248.91	3252.08	3255.26	3258.43	3261.60
640	3264.77	3267.94	3271.10	3274.27	3277.44	3280.60	3283.76	3286.92	3290.08	3293.24
650	3296.40	3299.56	3302.71	3305.87	3309.02	3312.17	3315.33	3318.48	3321.62	3324.77
660	3327.92	3331.06	3334.21	3337.35	3340.49	3343.63	3346.77	3349.91	3353.05	3356.19
670	3359.32	3362.46	3365.59	3368.72	3371.85	3374.98	3378.11	3381.23	338436	3387.48

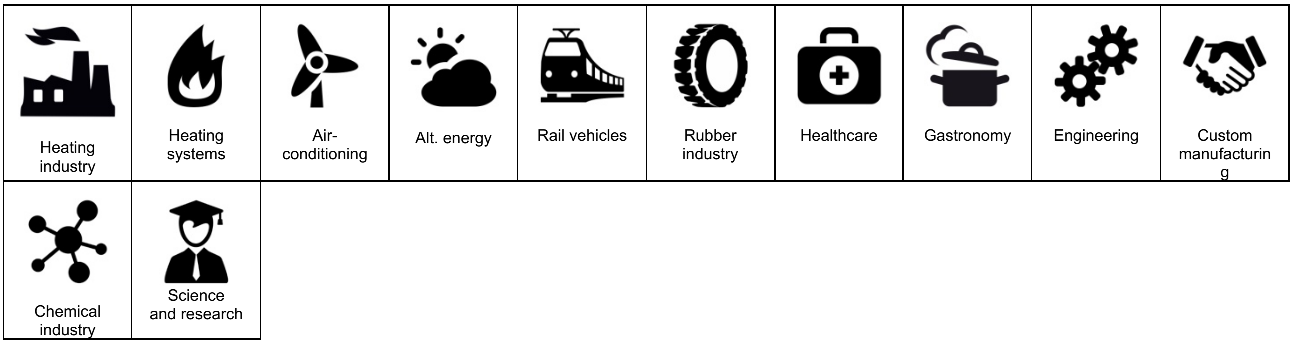
680	3390.61	3393.73	3396.85	3399.97	3403.09	3406.21	3409.32	3412.44	3415.55	3418.67
690	3421.78	3424.89	3428.00	3431.11	3434.22	3437.32	3440.43	3443.53	3446.63	3449.73
700	3452.83	3455.93	3459.03	3462.13	3465.22	3468.32	3471.41	3474.51	3477.60	3480.69
710	3483.78	3486.86	3489.95	3493.03	3496.12	3499.20	3502.28	3505.36	3508.44	3511.52
720	3514.60	3517.68	3520.75	3523.82	3526.90	3529.97	3533.04	3536.11	3539.18	3542.24
730	3545.31	3548.37	3551.44	3554.50	3557.56	3560.62	3563.68	3566.74	3569.79	3572.85
740	3575.90	3578.96	3582.01	3585.06	3588.11	3591.16	3594.20	3597.25	3600.29	3603.34
750	3606.38	3609.42	3612.46	3615.50	3618.54	3621.58	3624.61	3627.65	3630.68	3633.71
760	3636.74	3639.77	3642.80	3645.83	3648.86	3651.88	3654.91	3657.93	3660.95	3663.97
770	3666.99	3670.01	3673.03	3676.04	3679.06	3682.07	3685.08	3688.10	3691.11	3694.11
780	3697.12	3700.13	3703.14	3706.14	3709.14	3712.15	3715.15	3718.15	3721.15	3724.14
790	3727.14	3730.13	3733.13	3736.12	3739.11	3742.10	3745.09	3748.08	3751.07	3754.06
800	3757.04									

Sensing element accuracy classes

Temperature [°C]	Resistance [Ω]	Class AA		Class A		Class B		Class C	
		ΔT [°C]	ΔR [Ω]	ΔT [°C]	ΔR [Ω]	ΔT [°C]	ΔR [Ω]	ΔT [°C]	ΔR [Ω]
-50	803.06	-	-	-	-	± 0.55	± 2.18	± 1.10	± 4.36
-30	882.22	-	-	± 0.21	± 0.83	± 0.45	± 1.77	± 0.90	± 3.55
0	1000.00	± 0.10	± 0.39	± 0.15	± 0.59	± 0.30	± 1.17	± 0.60	± 2.34
25	1097.35	± 0.14	± 0.55	± 0.20	± 0.78	± 0.43	± 1.65	± 0.85	± 3.30
100	1385.06	± 0.27	± 1.02	± 0.35	± 1.33	± 0.80	± 3.03	± 1.60	± 6.07
150	1573.25	± 0.36	± 1.33	± 0.45	± 1.68	± 1.05	± 3.92	± 2.10	± 7.84
200	1758.56	-	-	± 0.55	± 2.02	± 1.30	± 4.78	± 2.60	± 9.56
300	2120.52	-	-	± 0.75	± 2.67	± 1.80	± 6.41	± 3.60	± 12.82
400	2470.92	-	-	-	-	± 2.30	± 7.93	± 4.60	± 15.85
500	2809.78	-	-	-	-	± 2.80	± 9.33	± 5.60	± 18.65
600	3137.08	-	-	-	-	-	-	± 6.60	± 21.22

Note: According to EN 60 751, the above relationships only apply to temperature intervals given in the table.

Application of sensing elements:



Nickel Resistance Sensors

Temperature sensing elements Ni 891

Basic technical parameters

Sensing element	Thin-film nickel resistor
Working temperature range	-50 to 200 °C *
Resistance at 0 °C	891.1 Ω
Long-term resistance stability	0.1 % after 1000 h at 150 °C
Recommended / maximum direct measuring current	0.3 mA / 1 mA

* The real range of working temperature of the sensor is given by the design and technology

The temperature dependence of the sensing element resistance in the temperature range of -50 to 200 °C is expressed as follows:

$$R = 891.05945(1 + At + Bt^2 + Ct^3)$$

where: $A = 5.64742.\ 10^{-3}\ °C^{-1}$
$B = 6.69504.\ 10^{-6}\ °C^{-2}$
$C = 5.68816.\ 10^{-9}\ °C^{-3}$

Dependence of resistance on temperature in ohms [Ω]:

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-50	653.7									
-40	699.0	694.4	689.9	685.3	680.8	676.2	671.7	667.2	662.7	658.2
-30	745.3	740.6	736.0	731.3	726.7	722.0	717.4	712.8	708.2	703.6
-20	792.8	788.0	783.2	778.4	773.7	768.9	764.2	759.4	754.7	750.0
-10	841.3	836.4	831.5	826.6	821.8	816.9	812.1	807.2	802.4	797.6
0	891.1	886.0	881.0	876.0	871.0	866.0	861.1	856.1	851.2	846.2

°C	0	1	2	3	4	5	6	7	8	9
0	891.1	896.1	901.1	906.2	911.3	916.4	921.5	926.6	931.7	936.8
10	942.0	947.1	952.3	957.5	962.7	967.9	973.1	978.4	983.6	988.9
20	994.1	999.4	1004.7	1010.0	1015.3	1020.7	1026.0	1031.4	1036.7	1042.1
30	1047.5	1052.9	1058.4	1063.8	1069.2	1047.7	1080.2	1085.7	1091.2	1096.7
40	1102.2	1107.8	1113.3	1118.9	1124.5	1130.1	1135.7	1141.3	1146.9	1152.6
50	1158.2	1163.9	1169.6	1175.3	1181.0	1186.7	1192.5	1198.2	1204.0	1209.8
60	1215.6	1221.4	1227.2	1233.0	1238.9	1244.7	1250.6	1256.5	1262.4	1268.3
70	1274.3	1280.2	1286.2	1292.2	1298.2	1304.2	1310.2	1316.2	1322.3	1328.3
80	1334.4	1340.5	1346.6	1352.7	1358.9	1365.0	1371.2	1377.4	1383.5	1389.8
90	1396.0	1402.2	1408.5	1414.7	1421.0	1427.3	1433.6	1439.9	1446.3	1452.6
100	1459.0	1465.4	1471.8	1478.2	1484.6	1491.1	1497.5	1504.0	1510.5	1517.0
110	1523.5	1530.1	1536.6	1543.2	1549.8	1556.4	1563.0	1569.6	1576.3	1582.9
120	1589.6	1596.3	1603.0	1609.7	1616.4	1623.2	1630.0	1636.7	1643.6	1650.4
130	1657.2	1664.0	1670.9	1677.8	1684.7	1691.6	1698.5	1705.5	1712.4	1719.4
140	1726.4	1733.4	1740.4	1747.5	1754.5	1761.6	1768.7	1775.8	1782.9	1790.1
150	1797.2	1804.4	1811.6	1818.8	1826.0	1833.2	1840.5	1847.8	1855.1	1862.4
160	1869.7	1877.0	1884.4	1891.8	1899.1	1906.6	1914.0	1921.4	1928.9	1936.3
170	1943.8	1951.3	1958.9	1966.4	1974.0	1981.6	1989.1	1996.8	2004.4	2012.0
180	2019.7	2027.4	2035.1	2042.8	2050.5	2058.3	2066.0	2073.8	2081.6	2089.5
190	2097.3	2105.2	2113.0	2120.9	2128.8	2136.8	2144.7	2152.7	2160.7	2168.7
200	2176.7									

Sensing element accuracy classes

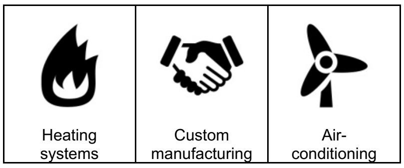
Sensing elements are manufactured in accuracy classes A and B, expressed as follows:

	for - 50 °C ≤ t < 0 °C	**for 0 °C ≤ t ≤ 200 °C**
Class A	ΔT = ± (0.2 + 0.014 * | t |) in °C	ΔT = ± (0.2 + 0.0035 * t) in °C
Class B	ΔT = ± (0.4 + 0.028 * | t |) in °C	ΔT = ± (0.4 + 0.0070 * t) in °C

* | t | is the absolute value of temperature

Temperature [°C]	**Resistance [Ω]**	**Class A**		**Class B**	
		ΔT [°C]	**ΔR [Ω]**	**ΔT [°C]**	**ΔR [Ω]**
-30	745.3	± 0.62	± 2.91	± 1.24	± 5.83
0	891.1	± 0.20	± 1.00	± 0.40	± 2.00
50	1158.2	± 0.38	± 2.14	± 0.75	± 4.28
100	1459.0	± 0.55	± 3.52	± 1.10	± 7.04
150	1797.2	± 0.73	± 5.26	± 1.45	± 10.52
200	2176.7	± 0.90	± 7.20	± 1.80	± 14.40

Application of sensing elements:



Temperature sensing element Ni 1000, α = 5.000·10⁻³ °C⁻¹

Basic technical parameters

Sensing element	Thin-film nickel resistor
Working temperature range	-60 °C to 250 °C *
Resistance at 0 °C	1000 Ω
Long-term resistance stability	0.1% after 1000 h at t = 250 °C
Recommended / maximum direct measuring current	Class A: 0.2 mA / 0.5 mA Class B: 0.3 mA / 0.8 mA

*The real range of working temperature of the sensor is given by the design and technology.

The temperature dependence of the sensing element resistance in the temperature range of -60 to 250 °C is expressed as follows:

$$\mathbf{R = 1000\,(1 + At + Bt^2 + Ct^3)}$$

where: $A = 4.427.\ 10^{-3}\ °C^{-1}$ $B = 5.172.\ 10^{-6}\ °C^{-2}$ $C = 5.585.\ 10^{-9}\ °C^{-3}$

Dependence of resistance on temperature in ohms [Ω]:

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-60	751.8									
-50	790.9	786.9	783.0	779.1	775.1	771.2	767.3	763.4	759.5	755.7
-40	830.8	826.8	822.8	818.8	814.7	810.7	806.8	802.8	798.8	794.8
-30	871.7	867.6	863.4	859.3	855.2	851.2	847.1	843.0	838.9	834.9
-20	913.5	909.3	905.0	900.8	896.7	892.5	888.3	884.1	880.0	875.8
-10	956.2	951.9	947.6	943.3	939.0	934.7	930.5	926.2	922.0	917.7
0	1000.0	995.6	991.2	986.8	982.4	978.0	973.6	969.3	964.9	960.6

°C	0	1	2	3	4	5	6	7	8	9
0	1000.0	1004.4	1008.9	1013.3	1017.8	1022.3	1026.7	1031.2	1035.7	1040.3
10	1044.8	1049.3	1053.9	1058.4	1063.0	1067.6	1072.2	1076.8	1081.4	1086.0
20	1090.7	1095.3	1100.0	1104.6	1109.3	1114.0	1118.7	1123.4	1128.1	1132.9
30	1137.6	1142.4	1147.1	1151.9	1156.7	1161.5	1166.3	1171.2	1176.0	1180.9
40	1185.7	1190.6	1195.5	1200.4	1205.3	1210.2	1215.1	1220.1	1225.0	1230.0
50	1235.0	1240.0	1245.0	1250.0	1255.0	1260.1	1265.1	1270.2	1275.3	1280.3
60	1285.4	1290.6	1295.7	1300.8	1306.0	1311.1	1316.3	1321.5	1326.7	1331.9
70	1337.1	1342.4	1347.6	1352.9	1358.2	1363.5	1368.8	1374.1	1379.4	1384.8
80	1390.1	1395.5	1400.9	1406.3	1411.7	1417.1	1422.5	1428.0	1433.4	1438.9
90	1444.4	1449.9	1455.4	1460.9	1466.5	1472.0	1477.6	1483.2	1488.8	1494.4
100	1500.0	1505.6	1511.3	1517.0	1522.6	1528.3	1534.0	1539.7	1545.5	1551.2
110	1557.0	1562.8	1568.5	1574.4	1580.2	1586.0	1591.8	1597.7	1603.6	1609.5
120	1615.4	1621.3	1627.2	1633.2	1639.1	1645.1	1651.1	1657.1	1663.1	1669.1
130	1675.2	1681.2	1687.3	1693.4	1699.5	1705.6	1711.8	1717.9	1724.1	1730.3
140	1736.5	1742.7	1748.9	1755.2	1761.4	1767.7	1774.0	1780.3	1786.6	1792.9
150	1799.3	1805.6	1812.0	1818.4	1824.8	1831.2	1837.7	1844.1	1850.6	1857.1
160	1863.6	1870.1	1876.7	1883.2	1889.8	1896.4	1902.9	1909.6	1916.2	1922.8
170	1929.5	1936.2	1942.9	1949.6	1956.3	1963.0	1969.8	1976.6	1983.4	1990.2
180	1997.0	2003.8	2010.7	2017.6	2024.5	2031.4	2038.3	2045.2	2052.2	2059.2
190	2066.1	2073.2	2080.2	2087.2	2094.3	2101.3	2108.4	2115.5	2122.7	2129.8
200	2137.0	2144.1	2151.3	2158.5	2165.8	2173.0	2180.3	2187.5	2194.8	2202.1
210	2209.5	2216.8	2224.2	2231.6	2239.0	2246.4	2253.8	2261.3	2268.7	2276.2
220	2283.7	2291.3	2298.8	2306.4	2313.9	2321.5	2329.1	2336.8	2344.4	2352.1
230	2359.8	2367.5	2375.2	2382.9	2390.7	2398.5	2406.2	2414.1	2421.9	2429.7
240	2437.6	2445.5	2453.4	2461.3	2469.2	2477.2	2485.2	2493.2	2501.2	2509.2
250	2517.3									

Sensing element accuracy classes

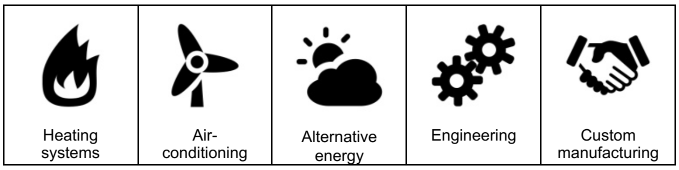
Sensing elements are manufactured in two basic accuracy classes with tolerance fields expressed as follows:

	for - 60 °C ≤ t < 0 °C	**for 0 °C ≤ t ≤ 250 °C**
Class A	ΔT = ± (0.2 + 0.014 * | t |) in °C	ΔT = ± (0.2 + 0.0035 * t) in °C
Class B	ΔT = ± (0.4 + 0.028 | t |) in °C	ΔT = ± (0.4 + 0.0070 * t) in °C

| t | is the absolute value of temperature in °C

Temperature [°C]	**Resistance [Ω]**	**Class A**		**Class B**	
		ΔT [°C]	**ΔR [Ω]**	**ΔT [°C]**	**ΔR [Ω]**
-30	871.7	± 0.62	± 2.54	± 1.24	± 5.08
0	1000.0	± 0.20	± 0.88	± 0.40	± 1.76
25	1114.0	± 0.29	± 1.35	± 0.58	± 2.70
50	1235.0	± 0.38	± 1.87	± 0.75	± 3.75
100	1500.0	± 0.55	± 3.08	± 1.10	± 6.16
150	1799.3	± 0.73	± 4.57	± 1.45	± 9.14
200	2137.0	± 0.90	± 6.39	± 1.80	± 12.78
250	2517.3	± 1.08	± 8.71	± 2.15	± 17.42

Application of sensing elements:



Temperature sensing element Ni 1000, α = 6.18·10^{-3} °C^{-1}

Basic technical parameters

Sensing element	Thin-film nickel resistor
Working temperature range	-60 °C to 250 °C *
Resistance at 0 °C	1000 Ω
Long-term resistance stability	0.1% after 1000 h at t = 250 °C
Recommended / maximum direct measuring current	Class A: 0.2 mA / 0.5 mA Class B: 0.3 mA / 0.8 mA

* The real range of working temperature of the sensor is given by the design and technology.

The temperature dependence of the sensing element resistance in the temperature range of -60 to 250 °C is expressed as follows:

$$R = 1000\,(1 + At + Bt^2 + Ct^4 + Dt^6)$$

where: $A = 5.485.\ 10^{-3}\ °C^{-1}$ $C = 2.805.\ 10^{-11}\ °C^{-4}$
$B = 6.650.\ 10^{-6}\ °C^{-2}$ $D = -2.00.\ 10^{-17}\ °C^{-6}$

Dependence of resistance on temperature in ohms [Ω]:

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-60	695.2									
-50	742.6	737.8	733.0	728.2	723.4	718.7	714.0	709.3	704.6	699.9
-40	791.3	786.4	781.4	776.5	771.6	766.8	761.9	757.0	752.2	747.4
-30	841.5	836.4	831.3	826.3	821.2	816.2	811.2	806.2	801.2	796.3
-20	893.0	887.8	882.6	877.4	872.2	867.0	861.9	856.8	851.7	846.5
-10	945.8	940.5	935.1	929.8	924.5	919.2	913.9	908.7	903.4	898.2
0	1000.0	994.5	989.1	983.6	978.2	972.7	967.3	961.9	956.5	951.2

°C	0	1	2	3	4	5	6	7	8	9
0	1000.0	1005.5	1011.0	1016.5	1022.0	1027.6	1033.1	1038.7	1044.3	1049.9
10	1055.5	1061.1	1066.8	1072.4	1078.1	1083.8	1089.5	1095.2	1100.9	1106.6
20	1112.4	1118.1	1123.9	1129.7	1135.5	1141.3	1147.1	1153.0	1158.8	1164.7
30	1170.6	1176.5	1182.4	1188.3	1194.2	1200.2	1206.1	1212.1	1218.1	1224.1
40	1230.1	1236.1	1242.2	1248.2	1254.3	1260.4	1266.5	1272.6	1278.8	1284.9
50	1291.1	1297.2	1303.4	1309.6	1315.8	1322.0	1328.3	1334.5	1340.8	1347.1
60	1353.4	1359.7	1366.0	1372.4	1378.7	1385.1	1391.5	1397.9	1404.3	1410.8
70	1417.2	1423.7	1430.1	1436.6	1443.1	1449.7	1456.2	1462.8	1469.3	1475.9
80	1482.5	1489.1	1495.7	1502.4	1509.1	1515.7	1522.4	1529.1	1535.9	1542.6
90	1549.3	1556.1	1562.9	1569.7	1576.5	1583.4	1590.2	1597.1	1604.0	1610.9
100	1617.8	1624.7	1631.7	1638.6	1645.6	1652.6	1659.6	1666.7	1673.7	1680.8
110	1687.9	1695.0	1702.1	1709.3	1716.4	1723.6	1730.8	1738.0	1745.2	1752.5
120	1759.7	1767.0	1774.3	1781.6	1788.9	1796.3	1803.7	1811.1	1818.5	1825.9
130	1833.3	1840.8	1848.3	1855.8	1863.3	1870.9	1878.4	1886.0	1893.6	1901.2
140	1908.9	1916.5	1924.2	1931.9	1939.6	1947.4	1955.1	1962.9	1970.7	1978.5
150	1986.3	1994.2	2002.1	2010.0	2017.9	2025.9	2033.8	2041.8	2049.8	2057.8
160	2065.9	2074.0	2082.1	2090.2	2098.3	2106.5	2114.6	2122.8	2131.1	2139.3
170	2147.6	2155.9	2164.2	2172.5	2180.9	2189.3	2197.7	2206.1	2214.6	2223.0
180	2231.5	2240.0	2248.6	2257.2	2265.8	2274.4	2283.0	2291.7	2300.4	2309.1
190	2317.8	2326.6	2335.4	2344.2	2353.0	2361.9	2370.8	2379.7	2388.6	2397.6
200	2406.6	2415.6	2424.7	2433.7	2442.8	2451.9	2461.1	2470.3	2479.5	2488.7
210	2498.0	2507.2	2516.5	2525.9	2535.2	2544.6	2554.0	2563.5	2573.0	2582.5
220	2592.0	2601.6	2611.1	2620.8	2630.4	2640.1	2649.8	2659.5	2669.3	2679.1
230	2688.9	2698.7	2708.6	2718.5	2728.4	2738.4	2748.4	2758.4	2768.5	2778.6
240	2788.7	2798.8	2809.0	2819.2	2829.5	2839.7	2850.0	2860.4	2870.7	2881.1
250	2891.6									

Sensing element accuracy classes

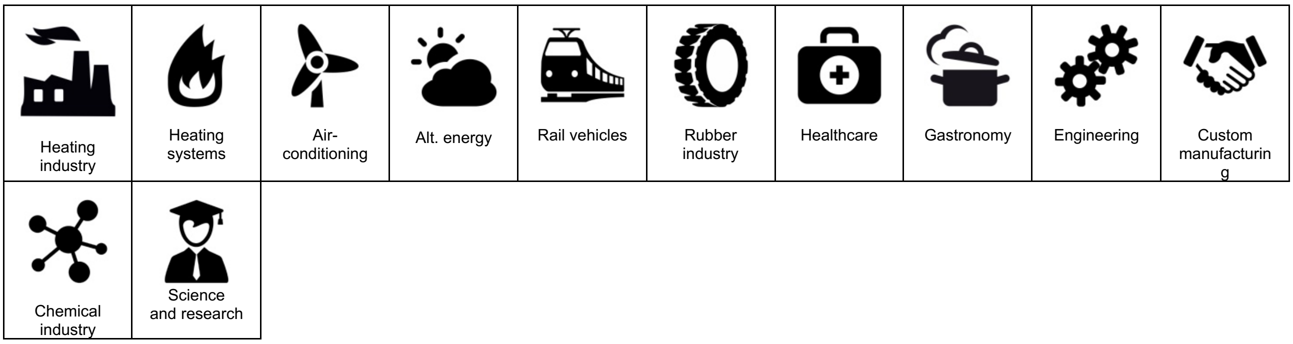
Sensing elements are manufactured in two basic accuracy classes with tolerance fields expressed as follows:

	for t = -60 °C to 0 °C	for t = 0 °C to 250 °C
Class A	ΔT = ± (0.2 + 0.014 * | t |) in °C	ΔT = ± (0.2 + 0.0035 * t) in °C
Class B	ΔT = ± (0.4 + 0.028 | t |) in °C	ΔT = ± (0.4 + 0.0070 * t) in °C

| t | is the absolute value of temperature

Temperature [°C]	Resistance [Ω]	Class A		Class B	
		ΔT [°C]	ΔR [Ω]	ΔT [°C]	ΔR [Ω]
-30	841.5	± 0.62	± 3.16	± 1.24	± 6.32
0	1000.0	± 0.20	± 1.10	± 0.40	± 2.20
25	1141.3	± 0.29	± 1.67	± 0.58	± 3.34
50	1291.1	± 0.38	± 2.29	± 0.75	± 4.58
100	1617.8	± 0.55	± 3.79	± 1.10	± 7.59
150	1986.3	± 0.73	± 5.73	± 1.45	± 11.46
200	2406.6	± 0.90	± 8.10	± 1.80	± 16.20
250	2891.6	± 1.08	± 11.29	± 2.15	± 22.58

Application of sensing elements:



Temperature sensing elements Ni 2226

Basic technical parameters

Sensing element	Thin-film nickel resistor
Working temperature range	-30 °C to 150 °C *
Resistance at 0 °C	2226 Ω
Long-term resistance stability	0.1 % after 1000 h at t = 150 °C
Recommended / maximum direct measuring current	0.2mA / 0.7mA
Note: This is a characteristic of sensors designated **T1** (Staefa Control, later Siemens. They are no longer produced or offered by these companies.)	

* The real range of working temperature of the temperature sensor is given by the design and technology.

The temperature dependence of the sensing element resistance in the temperature range of -30 to 150 °C is expressed as follows:

$$\mathbf{R = 2226\ (1 + At + Bt^2 + Ct^3 + Dt^4)}$$

where: $A = 4.476.\ 10^{-3}\ °C^{-1}$ $C = 2.906.\ 10^{-9}\ °C^{-3}$

$B = 3.6496.\ 10^{-6}\ °C^{-2}$ $D = 3.140.\ 10^{-12}\ °C^{-4}$

Dependence of resistance on temperature in ohms [Ω]:

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-30	1934.2									
-20	2029.9	2020.3	2010.7	2001.1	1991.5	1981.9	1972.3	1962.8	1953.3	1943.7
-10	2127.2	2117.4	2107.6	2097.8	2088.1	2078.4	2068.6	2058.9	2049.3	2039.6
0	2226.0	2216.0	2206.1	2196.2	2186.3	2176.4	2166.5	2156.7	2146.8	2137.0

°C	0	1	2	3	4	5	6	7	8	9
0	2226.0	2236.0	2246.0	2256.0	2266.0	2276.0	2286.1	2296.1	2306.2	2316.3
10	2326.5	2336.6	2346.7	2356.9	2367.1	2377.3	2387.5	2397.8	2408.0	2418.3
20	2428.6	2438.9	2449.2	2459.5	2469.9	2480.3	2490.7	2501.1	2511.5	2521.9
30	2532.4	2542.9	2553.4	2563.9	2574.4	2585.0	2595.5	2606.1	2616.7	2627.3
40	2638.0	2648.6	2659.3	2670.0	2680.7	2691.4	2702.2	2712.9	2723.7	2734.5
50	2745.3	2756.2	2767.0	2777.9	2788.8	2799.7	2810.6	2821.6	2832.6	2843.5
60	2854.5	2865.6	2876.6	2887.7	2898.8	2909.9	2921.0	2932.1	2943.3	2954.4
70	2965.6	2976.9	2988.1	2999.3	3010.6	3021.9	3033.2	3044.6	3055.9	3067.3
80	3078.7	3090.1	3101.5	3113.0	3124.4	3135.9	3147.4	3159.0	3170.5	3182.1
90	3193.7	3205.3	3216.9	3228.6	3240.3	3252.0	3263.7	3275.4	3287.2	3299.0
100	3310.8	3322.6	3334.4	3346.3	3358.2	3370.1	3382.0	3394.0	3405.9	3417.9
110	3429.9	3442.0	3454.0	3466.1	3478.2	3490.3	3502.5	3514.6	3526.8	3539.0
120	3551.2	3563.5	3575.8	3588.1	3600.4	3612.7	3625.1	3637.5	3649.9	3662.3
130	3674.8	3687.2	3699.7	3712.3	3724.8	3737.4	3750.0	3762.6	3775.2	3787.9
140	3800.6	3813.3	3826.0	3838.8	3851.5	3864.3	3877.2	3890.0	3902.9	3915.8
150	3928.7									

Sensing element accuracy classes

Sensing elements are manufactured in accuracy class B, expressed as follows:

for - 30°C ≤ t < 0°C	for 0 °C ≤ t ≤ 50 °C	for 50 °C< t ≤ 100 °C
ΔT = ± (0.7 + 0.063 * | t |) in °C	ΔT = ± 0.7 °C	ΔT = ± (0.7 + 0.038 * (t- 50)) in °C

| t | is the absolute value of temperature

Temperature	Resistance	Class B	
[°C]	[Ω]	ΔT [°C]	ΔR [Ω]
-20	2029.9	± 1.96	± 19.01
0	2226.0	± 0.70	± 7.00
25	2480.3	± 0.70	± 7.28
50	2745.3	± 0.70	± 7.63
70	2965.6	± 1.46	± 16.50
100	3310.8	± 2.60	± 30.68

Application of sensing elements: Previously, temperature sensors with this characteristic were used by Staefa Control, which was purchased in 1997 by the SIEMENS Group and in fact ceased to exist. Nowadays, they can be found under the designation **T1**. They are used as sensing elements for sensors for exteriors, interiors, piping, thermostats, etc. They are currently not used in new constructions and Sensit s.r.o. offers them as spare parts.

Notes:

Semiconductors Resistance Sensors

Temperature sensing elements KTY 81/xyz

Basic technical parameters

Sensing element	Silicon semiconductor resistor
Working temperature range	-55 °C to 150 °C *
Resistance at 25 °C (typical)	KTY81/110: 1000 Ω KTY81/121: 990 Ω KTY81/122: 1010 Ω KTY81/210: 2000 Ω KTY81/220: 2000 Ω
Long-term stability of resistance R_{25}	KTY81/1xx: typically 1.6Ω after 10000 h at t = 150 °C KTY81/2xx: typically 3.2Ω after 10000 h at t = 150 °C
Recommended direct measuring current	0.6 mA to 1 mA
Temperature coefficient at 25 °C (typical)	0.79 % / °C

*The real range of working temperature of the sensor is given by the design and technology.

The temperature dependence of the sensing element resistance is expressed in the temperature range of -55 to 130 °C as follows:

$$\mathbf{R_{KTY} = R_{25}(1 + aT + bT^2)}$$

where: **T = t – 25 °C** (difference between the measured temperature and the reference temperature 25 °C)

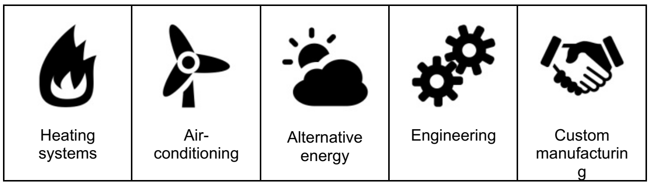
$a = 7.871 \cdot 10^{-3}\ °C^{-1}$, $b = 1.861 \cdot 10^{-5}\ °C^{-2}$

Dependence of the resistance value and tolerance field on temperature:

temperature	KTY81/110				KTY81/121				KTY81/122			
	Resistance [Ω]			ΔT	Resistance [Ω]			ΔT	Resistance [Ω]			ΔT
[°C]	**min.**	**typ.**	**max.**	**[°C]**	**min.**	**typ.**	**max.**	**[°C]**	**min.**	**typ.**	**max.**	**[°C]**
-55	475	490	505	±3.02	471	485	500	±3.02	480	495	510	±3.02
-50	500	515	530	±2.92	495	510	524	±2.92	505	520	535	±2.92
-40	552	567	582	±2.74	547	562	576	±2.74	558	573	588	±2.74
-30	609	624	638	±2.55	603	617	632	±2.55	615	630	645	±2.55
-20	669	684	698	±2.35	662	677	691	±2.35	676	690	705	±2.35
-10	733	747	761	±2.14	726	740	754	±2.14	741	755	769	±2.14
0	802	815	828	±1.91	794	807	820	±1.91	810	823	836	±1.91
10	874	886	898	±1.67	865	877	889	±1.67	883	895	907	±1.67
20	950	961	972	±1.41	941	951	962	±1.41	960	971	982	±1.41
25	990	1000	1010	±1.27	980	990	1000	±1.27	1000	1010	1020	±1.27
30	1029	1040	1051	±1.39	1018	1029	1041	±1.39	1039	1050	1062	±1.39
40	1108	1122	1136	±1.64	1097	1111	1125	±1.64	1120	1134	1148	±1.64
50	1192	1209	1225	±1.91	1180	1196	1213	±1.91	1204	1221	1238	±1.91
60	1278	1299	1319	±2.19	1266	1286	1305	±2.19	1291	1312	1332	±2.19
70	1369	1392	1416	±2.49	1355	1378	1402	±2.49	1382	1406	1430	±2.49
80	1462	1490	1518	±2.80	1447	1475	1502	±2.80	1477	1505	1533	±2.80
90	1559	1591	1623	±3.12	1543	1575	1607	±3.12	1574	1607	1639	±3.12
100	1659	1696	1733	±3.46	1642	1679	1716	±3.46	1676	1713	1750	±3.46
110	1762	1805	1847	±3.83	1745	1786	1828	±3.83	1780	1823	1865	±3.83
120	1967	1915	1963	±4.33	1849	1896	1943	±4.33	1886	1934	1982	±4.33
125	1919	1970	2020	±4.66	1900	1950	2000	±4.66	1938	1989	2041	±4.66
130	1970	2023	2077	±5.07	1950	2003	2056	±5.07	1989	2044	2098	±5.07
140	2065	2124	2184	±6.28	2044	2103	2162	±6.28	2085	2146	2206	±6.28
150	2145	2211	2277	±8.55	2124	2189	2254	±8.55	2167	2233	2299	±8.55

temperature	KTY81/210				KTY81/220			
	Resistance [Ω]			ΔT	Resistance [Ω]			ΔT
[°C]	min.	typ.	max.	[°C]	min.	typ.	max.	[°C]
-55	951	980	1009	±3.02	941	980	1019	±4.02
-50	1000	1030	1059	±2.92	990	1030	1070	±3.94
-40	1105	1135	1165	±2.74	1094	1135	1176	±3.78
-30	1218	1247	1277	±2.55	1205	1247	1289	±3.62
-20	1338	1367	1396	±2.35	1325	1367	1410	±3.45
-10	1467	1495	1523	±2.14	1452	1495	1538	±3.27
0	1603	1630	1656	±1.91	1587	1630	1673	±3.08
10	1748	1772	1797	±1.67	1730	1772	1814	±2.88
20	1901	1922	1944	±1.41	1881	1922	1963	±2.66
25	1980	2000	2020	±1.27	1960	2000	2040	±2.54
30	2057	2080	2102	±1.39	2036	2080	2123	±2.68
40	2217	2245	2272	±1.64	2194	2245	2295	±2.97
50	2383	2417	2451	±1.91	2359	2417	2475	±3.28
60	2557	2597	2637	±2.19	2531	2597	2663	±3.61
70	2737	2785	2832	±2.49	2709	2785	2860	±3.94
80	2924	2980	3035	±2.80	2894	2980	3065	±4.30
90	3118	3182	3246	±3.12	3086	3182	3278	±4.66
100	3318	3392	3466	±3.46	3284	3392	3500	±5.05
110	3523	3607	3691	±3.93	3487	3607	3728	±5.61
120	3722	3817	3912	±4.70	3683	3817	3950	±6.59
125	3815	3915	4016	±5.26	3775	3915	4055	±7.31
130	3901	4008	4114	±6.00	3861	4008	4154	±8.27
140	4049	4166	4283	±8.45	4008	4166	4325	±11.46
150	4153	4280	4407	±14.63	4110	4280	4450	±19.56

Application of sensing elements:



Temperature sensing element NTC 1k0; $B_{25/85}$ = 3528

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-40 to 125 °C *
Resistance at 25 °C	1 kΩ
Coefficient $\beta_{25/85}$	3528 ± 0.5%
Coefficient $\beta_{25/100}$	3564 ± 0.5%
Long-term resistance stability	≤ 3 % after 1000 h at 85 °C **
Recommended / maximum DC input	0.5 mW / 2 mW
Sensor tolerance	±5 % ***

* The real range of working temperature of the sensor is given by the design of the sensing element and the production technology.
** These parameters depend on the specific type and design of the thermistor.
*** The thermistor electrical resistance tolerance at a temperature of 25 °C is rated by the manufacturer into groups ±2 %, ±3 % or ±5%.

Dependence of resistance in Ω on temperature

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-40	**23342**									
-30	**13018**	13882	14745	15609	16472	**17336**	18537	19738	20940	22141
-20	**7569**	8031	8492	8954	9415	**9877**	10505	11133	11762	12390
-10	**4569**	4826	5083	5341	5598	**5855**	6198	6541	6883	7226
0	**2854**	3002	3151	3299	3448	**3596**	3791	3985	4180	4374

°C	0	1	2	3	4	5	6	7	8	9
0	**2854**	2740	2625	2511	2396	**2282**	2193	2104	2016	1927
10	**1838**	1769	1699	1630	1560	**1491**	1436	1381	1327	1272
20	**1217**	1174	1130	1087	1043	**1000**	965	931	896	861
30	**826.6**	798.7	770.9	743.0	715.2	**687.3**	664.8	642.2	619.7	597.1
40	**574.6**	556.2	537.8	519.5	501.1	**482.7**	467.6	452.6	437.5	422.5
50	**407.4**	395.0	382.5	370.1	357.6	**345.2**	334.9	324.6	314.3	304.0
60	**293.7**	285.1	276.5	268.0	259.4	**250.8**	243.6	236.4	229.3	222.1
70	**214.9**	208.9	202.8	196.8	190.7	**184.7**	179.6	147.5	169.5	164.4
80	**159.3**	155.0	150.7	146.3	142.0	**137.7**	134.0	130.4	126.7	123.1
90	**119.4**	116.3	113.2	110.1	107.0	**103.8**	101.1	98.5	95.8	93.1
100	**90.45**	88.16	85.87	83.58	81.29	**79.00**	77.03	75.06	73.09	71.12
110	**69.15**	67.45	65.75	64.06	62.36	**60.66**	59.19	57.72	56.26	54.79
120	**53.32**	52.05	50.78	49.50	48.23	**46.96**	45.85	44.85	43.64	42.54
130	**41.43**	40.47	39.51	38.55	37.59	**36.63**	35.79	34.95	34.11	33.27
140	**32.43**	31.70	30.97	30.23	29.50	**28.77**	28.13	27.49	26.84	26.20
150	**25.56**									

Note: The resistance values in bold are taken from the table of the manufacturer of the bead thermistor, the other values are calculated by linear interpolation, with the error caused by calculation being one order of magnitude lower than the tolerance specified by the manufacturer.

Temperature sensing element NTC 2k0; $B_{25/85}$ = 3552

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-55 to 155 °C *
Resistance at 25 °C	2 kΩ
Coefficient $\beta_{25/85}$	3552 ± 1%
Coefficient $\beta_{25/100}$	3560 ± 1%
Long-term resistance stability	≤ 3 % after 1000 h at 85 °C **
Recommended / maximum DC input	0.5 mW / 2 mW
Sensor tolerance	±5 % ***

* The real range of working temperature of the sensor is given by the design of the sensing element and the production technology.
** These parameters depend on the specific type and design of the thermistor.
*** The thermistor electrical resistance tolerance at a temperature of 25 °C is rated by the manufacturer into groups ±1%, ±3 % or ±5%.

Dependence of resistance in Ω on temperature

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-50	**78635**					**106210**				
-40	**44060**	46978	49896	52814	55732	**58650**	62647	66644	70641	74638
-30	**25392**	26980	28568	30156	31744	**33333**	35478	37623	39769	41914
-20	**15034**	15917	16800	17683	18566	**19450**	20638	21826	23015	24203
-10	**9137**	9643	10150	10657	11164	**11671**	12343	13016	13688	14361
0	**5733**	6028	6323	6619	6914	**7210**	7595	7980	8366	8751

°C	0	1	2	3	4	5	6	7	8	9
0	**5733**	5502	5272	5041	4811	**4581**	4402	4223	4045	3866
10	**3688**	3547	3406	3265	3124	**2984**	2873	2762	2652	2541
20	**2431**	2344	2258	2172	2086	**2000**	1920	1840	1760	1680
30	**1660**	1602	1545	1487	1430	**1373**	1326	1280	1234	1188
40	**1142**	1105	1069	1032	996.6	**960.3**	930.4	900.5	870.6	840.7
50	**810.9**	785.4	759.9	734.4	708.9	**683.4**	662.5	641.6	620.7	599.8
60	**579.0**	562.0	545.1	528.1	511.2	**494.3**	480.1	466.0	451.9	437.8
70	**423.7**	411.7	399.7	387.8	375.8	**363.9**	353.8	343.7	333.7	323.6
80	**313.6**	305.2	296.8	288.5	280.1	**271.8**	264.7	257.6	250.5	243.4
90	**236.4**	230.4	224.5	218.6	212.7	**206.8**	201.7	196.6	191.6	186.5
100	**181.5**	177.0	172.6	168.1	163.7	**159.3**	155.4	151.6	147.8	144.0
110	**140.2**	136.9	133.6	130.3	127.0	**123.8**	120.9	118.1	115.2	112.4
120	**109.6**	107.1	104.7	102.2	99.84	**97.41**	95.29	93.17	91.06	88.94
130	**86.83**	84.95	83.07	81.19	79.31	**77.44**	75.79	74.15	72.51	70.87
140	**69.23**	67.80	66.37	64.95	63.52	**62.10**	60.84	59.58	58.33	57.07
150	**55.82**	54.73	53.64	52.56	51.47	**50.39**				

Note: The resistance values **in bold** are taken from the table of the manufacturer of the bead thermistor, the other values are calculated by linear interpolation, with the error caused by calculation being one order of magnitude lower than the tolerance specified by the manufacturer.

Temperature sensing element NTC 2k0; $B_{25/85}$ = 3625

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-50 to 150 °C *
Resistance at 25 °C	2 kΩ
Coefficient $\beta_{25/85}$	3625 ± 1%
Coefficient $\beta_{25/100}$	3636 ± 1%
Long-term resistance stability	≤ 3 % after 1000 h at 85 °C **
Recommended / maximum DC input	0.5 mW / 2 mW
Sensor tolerance	±5 % ***

* The real range of working temperature of the sensor is given by the design of the sensing element and the production technology.
** These parameters depend on the specific type and design of the thermistor.
*** The thermistor electrical resistance tolerance at a temperature of 25 °C is rated by the manufacturer into groups ±1%, ±3 % or ±5%.

Dependence of resistance in Ω on temperature

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-50	**88480**									
-40	**47760**	51140	54520	57900	61280	**64660**	69424	74188	78952	83716
-30	**26820**	28580	30340	32100	33860	**35620**	38048	40476	42904	45332
-20	**15628**	16578	17528	18479	19429	**20380**	21668	22956	24244	25532
-10	**9414**	9947	10480	11013	11546	**12080**	12789	13499	14208	14918
0	**5846**	6155	6464	6773	7082	**7392**	7796	8200	8605	9009

°C	0	1	2	3	4	5	6	7	8	9
0	**5846**	5608	5370	5133	4895	**4658**	4473	4288	4103	3918
10	**3734**	3590	3446	3302	3158	**3014**	2900	2787	2647	2561
20	**2448**	2358	2268	2179	2089	**2000**	1928	1857	1786	1714
30	**1643**	1586	1529	1471	1414	**1357**	1311	1265	1219	1173
40	**1127**	1090	1053	1015	978.6	**941.4**	911.0	880.6	850.3	819.9
50	**789.6**	764.8	740.0	715.2	690.4	**665.6**	645	624.8	604.4	584.0
60	**563.6**	546.7	529.8	512.9	496.0	**479.2**	465.2	451.2	437.2	423.2
70	**409.2**	397.5	385.8	374.1	362.4	**350.8**	341.0	331.2	321.5	311.7
80	**302.0**	293.8	285.6	277.4	269.2	**261.0**	254.0	247.0	240.1	233.1
90	**226.2**	220.3	214.4	208.6	202.7	**196.9**	191.9	186.9	181.9	176.9
100	**171.9**	167.6	163.4	159.1	154.8	**150.6**	146.9	143.3	139.6	136.0
110	**132.3**	129.2	126.0	122.9	119.8	**116.6**	117.9	119.2	120.5	121.8
120	**123.1**	116.8	110.4	104.1	97.80	**91.46**	89.43	87.40	85.37	83.34
130	**81.32**	79.55	77.79	74.02	74.26	**75.50**	70.96	69.42	67.88	66.34
140	**64.80**	63.45	62.10	60.75	59.40	**58.06**	56.88	55.70	54.52	53.34
150	**52.16**									

Note: The resistance values **in bold** are taken from the table of the manufacturer of the bead thermistor, the other values are calculated by linear interpolation, with the error caused by calculation being one order of magnitude lower than the tolerance specified by the manufacturer.

Temperature sensing element NTC 2k7; $B_{25/85}$ = 3977

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-40 to 125 °C *
Resistance at 25 °C	2.7 kΩ
Coefficient $\beta_{25/85}$	3977 ± 1%
Coefficient $\beta_{25/100}$	3994 ± 1%
Long-term resistance stability	≤ 3 % after 1000 h at 85 °C **
Recommended / maximum DC input	0.5 mW / 2 mW
Sensor tolerance	±2% ***

* The real range of working temperature of the sensor is given by the design of the sensing element and the production technology.
** These parameters depend on the specific type and design of the thermistor.
*** The thermistor electrical resistance tolerance at a temperature of 25 °C is rated by the manufacturer into groups ±2 %, ±3 % or ±5%.

Dependence of resistance in Ω on temperature

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-40	**89655**									
-30	**47304**	50797	54291	57785	61279	**64773**	69749	74725	79702	84678
-20	**26017**	27795	29573	31351	33129	**34907**	37386	39865	42345	44824
-10	**14862**	15804	16747	17689	18632	**19575**	20836	22151	23440	24728
0	**8790**	9308	9826	10345	10863	**11382**	12078	12774	13470	14166

°C	0	1	2	3	4	5	6	7	8	9
0	**8790**	8400	8010	7620	7230	**6841**	6545	6250	5955	5660
10	**5365**	5139	4914	4689	4464	**4239**	4065	3892	3718	3545
20	**3372**	3237	3103	2968	2834	**2700**	2595	2490	2385	2280
30	**2176**	2093	2011	1928	1846	**1764**	1699	1634	1569	1504
40	**1439**	1387	1335	1283	1231	**1180**	1138	1097	1056	1014
50	**973.4**	940.1	906.8	873.5	840.2	**806.9**	779.9	753.0	726.1	699.2
60	**672.3**	650.4	628.5	606.6	584.7	**562.8**	544.9	527.0	509.1	491.2
70	**473.3**	458.6	443.9	429.2	414.5	**399.8**	387.6	375.5	363.4	351.3
80	**339.2**	329.1	319.1	309.0	299.0	**289.0**	280.6	272.2	263.9	255.5
90	**247.2**	240.2	233.2	226.2	219.2	**212.2**	206.3	200.4	194.6	188.7
100	**182.9**	177.9	173.0	168.0	163.1	**158.2**	154.0	149.8	145.6	141.4
110	**137.2**	133.6	130.1	126.5	123.0	**119.5**	116.4	113.4	110.4	107.4
120	**104.4**	101.8	99.22	96.63	94.04	**91.46**	89.24	87.02	84.81	82.59
130	**80.38**	78.42	76.56	74.65	72.74	**70.84**	69.19	67.55	65.90	64.26
140	**62.62**	61.19	59.76	58.34	56.91	**55.49**	54.25	53.01	51.78	50.54
150	**49.31**									

Note: The resistance values **in bold** are taken from the table of the manufacturer of the bead thermistor, the other values are calculated by linear interpolation, with the error caused by calculation being one order of magnitude lower than the tolerance specified by the manufacturer.

Temperature sensing element NTC 3k0; $B_{25/85}$ = 3960

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-40 to 125 °C *
Resistance at 25 °C	3 kΩ
Coefficient $\beta_{25/85}$	3956 ± 1%
Coefficient $\beta_{25/100}$	3966 ± 1%
Long-term resistance stability	≤ 3 % after 1000 h at 85 °C **
Recommended / maximum DC input	0.5 mW / 2 mW
Sensor tolerance	±1% ***

* The real range of working temperature of the sensor is given by the design of the sensing element and the production technology.
** These parameters depend on the specific type and design of the thermistor.
*** The thermistor electrical resistance tolerance at a temperature of 25 °C is rated by the manufacturer into groups ±2 %, ±3 % or ±5%.

Dependence of resistance in Ω on temperature

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-40	**105840**									
-30	**54840**	59022	63204	67386	71568	**75750**	81768	87786	93804	99822
-20	**29751**	31834	33918	36002	38086	**40170**	43104	46038	48972	51906
-10	**16815**	17903	18991	20080	21168	**22257**	23755	25254	26753	28252
0	**9867**	10458	11050	11641	12233	**12825**	13623	14421	15219	16017

°C	0	1	2	3	4	5	6	7	8	9
0	**9867**	9424	8982	8540	8098	**7656**	7323	6990	6657	6324
10	**5991**	5737	5483	5229	4975	**4722**	4527	4333	4138	3944
20	**3750**	3600	3450	3300	3150	**3000**	2883	2766	2649	2532
30	**2415**	2324	2232	2141	2049	**1958**	1885	1813	1741	1669
40	**1596**	1539	1482	1424	1367	**1310**	1264	1218	1172	1126
50	**1081**	1044	1007	970.6	933.8	**897.0**	867.1	837.3	807.5	777.7
60	**747.9**	723.7	699.5	675.3	651.1	**627.0**	607.2	587.4	567.6	547.8
70	**528.0**	511.7	495.4	479.2	462.9	**446.7**	433.3	419.9	406.5	393.1
80	**379.8**	368.7	357.6	346.5	335.4	**324.3**	315.0	305.7	296.4	287.1
90	**277.8**	270.1	262.3	254.6	246.8	**239.1**	232.5	226.0	219.5	213.0
100	**206.5**	201.0	195.5	190.0	184.5	**179.0**	174.4	169.7	165.1	160.4
110	**155.8**	151.8	147.9	143.9	140.0	**136.0**	132.6	129.3	125.9	122.5
120	**119.1**	116.2	113.4	110.5	107.6	**104.7**	102.2	99.76	97.27	94.79
130	**92.31**	90.17	88.03	85.90	83.76	**81.63**	79.77	77.92	76.06	74.21
140	**72.36**	70.75	69.15	67.55	65.95	**64.35**	62.95	61.55	60.15	58.75
150	**57.36**									

Note: The resistance values in bold are taken from the table of the manufacturer of the bead thermistor, the other values are calculated by linear interpolation, with the error caused by calculation being one order of magnitude lower than the tolerance specified by the manufacturer.

Temperature sensing element NTC 3k0; $B_{25/85}$ = 3974

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-40 to 125 °C *
Resistance at 25 °C	3 kΩ
Coefficient $\beta_{25/85}$	3974 ± 1%
Coefficient $\beta_{25/100}$	3988 ± 1%
Long-term resistance stability	≤ 3 % after 1000 h at 85 °C **
Recommended / maximum DC input	0.5 mW / 2 mW
Sensor tolerance	±1% ***

* The real range of working temperature of the sensor is given by the design of the sensing element and the production technology.
** These parameters depend on the specific type and design of the thermistor.
*** The thermistor electrical resistance tolerance at a temperature of 25 °C is rated by the manufacturer into groups ±1 %, ±2 %, ±3 % or ±5 %.

Dependence of resistance in Ω on temperature

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-40	**100950**									
-30	**53100**	57035	60970	64906	68841	**72777**	78411	84086	89680	95315
-20	**29121**	31119	33117	35115	37113	**39111**	41908	44706	47504	50302
-10	**16599**	17655	18711	19767	20823	**21879**	23327	24775	26224	27672
0	**9795**	10375	10955	11535	12115	**12695**	13475	14256	15037	15818

°C	0	1	2	3	4	5	6	7	8	9
0	**9795**	9359	8923	8487	8051	**7616**	7286	6957	6628	6299
10	**5970**	5718	5466	5215	4963	**4712**	4519	4326	4133	3940
20	**3747**	3597	3448	3298	3149	**3000**	2883	2766	2650	2533
30	**2417**	2325	2233	2142	2050	**1959**	1886	1814	1742	1670
40	**1598**	1540	1483	1425	1368	**1311**	1265	1219	1173	1127
50	**1081**	1043	1006	969.9	932.9	**895.9**	866.0	836.1	806.2	776.3
60	**746.4**	722.1	697.8	673.5	649.2	**624.9**	605.0	585.1	565.3	545.4
70	**525.6**	509.3	493.1	476.8	460.6	**444.4**	431.0	417.6	404.2	390.8
80	**377.4**	366.2	355.1	343.9	332.8	**321.7**	312.4	303.1	293.8	284.5
90	**275.3**	267.5	259.8	252.0	244.3	**236.6**	230.0	223.5	217.0	210.5
100	**204.0**	198.5	193.0	187.5	182.0	**176.6**	171.9	167.3	162.6	158.0
110	**153.4**	149.4	145.4	141.5	137.5	**133.6**	130.2	126.8	123.5	120.1
120	**116.8**	113.9	111.0	108.2	105.3	**102.5**	100.0	97.60	95.16	92.71
130	**90.27**	88.14	86.01	83.88	81.75	**79.63**	77.79	75.95	74.11	72.27
140	**70.44**	68.85	67.26	65.67	64.08	**62.50**	61.11	59.73	58.35	56.97
150	**55.59**									

Note: The resistance values in bold are taken from the table of the manufacturer of the bead thermistor, the other values are calculated by linear interpolation, with the error caused by calculation being one order of magnitude lower than the tolerance specified by the manufacturer.

Temperature sensing element NTC 3k3; $B_{25/85}$ = 2880

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-40 to 150 °C *
Resistance at 25 °C	3.3 kΩ
Coefficient $\beta_{25/85}$	2880 ± 1%
Coefficient $\beta_{25/100}$	2882 ± 1%
Long-term resistance stability	≤ 3 % after 1000 h at 85 °C **
Recommended / maximum DC input	0.5 W at 55 °C
Sensor tolerance	±5 % ***

* The real range of working temperature of the sensor is given by the design of the sensing element and the production technology.
** These parameters depend on the specific type and design of the thermistor.
*** The thermistor electrical resistance tolerance at a temperature of 25 °C is rated by the manufacturer into groups ±2 %, ±3 % or ±5%.

Dependence of resistance in Ω on temperature

°C	**0**	**-1**	**-2**	**-3**	**-4**	**-5**	**-6**	**-7**	**-8**	**-9**
-40	**45000**									
-30	**27840**	29322	30804	32286	33768	**35250**	37200	39150	41100	43050
-20	**17780**	18656	19532	20408	21284	**22160**	23296	24432	25568	26704
-10	**11690**	12226	12762	13298	13834	**14370**	15052	15734	16416	17098
0	**7904**	8239	8575	8910	9246	**9582**	10003	10425	10846	11268

°C	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	**7904**	7635	7366	7097	6828	**6560**	6343	6127	5911	5695
10	**5479**	5303	5128	4952	4777	**4602**	4458	4315	4172	4029
20	**3886**	3768	3651	3534	3417	**3300**	3203	3106	3009	2912
30	**2816**	2735	2655	2575	2495	**2415**	2348	2281	2214	2147
40	**2081**	2025	1969	1913	1857	**1801**	1754	1707	1660	1613
50	**1566**	1526	1486	1446	1406	**1367**	1333	1299	1265	1231
60	**1198**	1169	1140	1111	1082	**1054**	1029	1004	980.0	955.4
70	**930.8**	909.6	888.4	867.2	846.0	**824.8**	806.5	788.2	769.9	751.6
80	**733.4**	717.5	701.7	685.8	670.0	**654.2**	640.4	626.6	612.9	599.1
90	**585.4**	573.4	561.4	549.4	537.4	**525.5**	515.0	504.5	494.0	483.5
100	**473.0**	463.8	454.6	445.4	436.2	**427.0**	418.9	410	402.7	394.6
110	**386.5**	379.3	372.2	365.0	357.9	**350.8**	344.4	338.1	331.8	325.5
120	**319.2**	313.5	307.9	302.3	296.7	**291.1**	286.1	281.1	276.1	271.1
130	**266.1**	261.6	257.1	252.7	248.2	**243.8**	239.8	235.8	231.8	227.8
140	**223.8**	220.2	216.6	213.0	209.4	**205.9**	202.7	199.5	196.3	193.1
150	**189.9**									

Note: The resistance values in bold are taken from the table of the manufacturer of the bead thermistor, the other values are calculated by linear interpolation, with the error caused by calculation being one order of magnitude lower than the tolerance specified by the manufacturer.

Temperature sensing element NTC 4k7; $B_{25/85}$ = 3977

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-40 to 150 °C *
Resistance at 25 °C	4.7 kΩ
Coefficient $\beta_{25/85}$	3977 ± 1%
Coefficient $\beta_{25/100}$	3994 ± 1%
Long-term resistance stability	≤ 3 % after 1000 h at 85 °C **
Recommended / maximum DC input	0.5 mW / 2 mW
Sensor tolerance	±5 % ***

* The real range of working temperature of the sensor is given by the design of the sensing element and the production technology.
** These parameters depend on the specific type and design of the thermistor.
*** The thermistor electrical resistance tolerance at a temperature of 25 °C is rated by the manufacturer into groups ±2 %, ±3 % or ±5%.

Dependence of resistance in Ω on temperature

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-40	**156084**									
-30	**82344**	88425	94507	100589	106671	**112753**	121419	130085	138751	147417
-20	**45288**	48383	51478	54574	57669	**60765**	65080	69396	73712	78028
-10	**25872**	27512	29153	30793	32434	**34075**	36317	38560	40802	43045
0	**15300**	16202	17105	18008	18911	**19814**	21025	22237	23448	24660

°C	0	1	2	3	4	5	6	7	8	9
0	**15300**	14621.8	13943.6	13265.4	12587.2	**11909**	11395.2	10881.4	10367.6	9853.8
10	**9340**	8947.6	8555.2	8162.8	7770.4	**7378**	7076.2	6774.4	6472.6	6170.8
20	**5869**	5635.2	5401.4	5167.6	4933.8	**4700**	4517.6	4335.2	4152.8	3970.4
30	**3788**	3644.6	3501.2	3357.8	3214.4	**3071**	2957.8	2844.6	2731.4	2618.2
40	**2505**	2415	2325	2235	2145	**2055**	1982.8	1910.6	1838.4	1766.2
50	**1694**	1636.2	1578.4	1520.6	1462.8	**1405**	1358	1311	1264	1217
60	**1170**	1131.94	1093.88	1055.82	1017.76	**979.7**	948.54	917.38	886.22	855.06
70	**823.9**	798.32	772.74	747.16	721.58	**696**	674.9	653.8	632.7	611.6
80	**590.5**	573	555.5	538	520.5	**503**	488.44	473.88	459.32	444.76
90	**430.2**	418.04	405.88	393.72	381.56	**369.4**	359.18	348.96	338.74	328.52
100	**318.3**	309.7	301.1	292.5	283.9	**275.3**	268.02	260.74	253.46	246.18
110	**238.9**	232.72	226.54	220.36	214.18	**208**	202.74	197.48	192.22	186.96
120	**181.7**	177.2	172.7	168.2	163.7	**159.2**	155.34	151.48	147.62	143.76
130	**139.9**	136.58	133.26	129.94	126.62	**123.3**	120.44	117.58	114.72	111.86
140	**109**	106.52	104.04	101.56	99.08	**96.6**	94.448	92.296	90.144	87.992
150	**85.84**									

Note: The resistance values in bold are taken from the table of the manufacturer of the bead thermistor, the other values are calculated by linear interpolation, with the error caused by calculation being one order of magnitude lower than the tolerance specified by the manufacturer.

Temperature sensing element NTC 5k0; $B_{25/85}$ = 3480

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-55 to 155 °C *
Resistance at 25 °C	5.0 kΩ
Coefficient $β_{25/85}$	3480 ± 1%
Coefficient $β_{25/100}$	3497 ± 1%
Long-term resistance stability	≤ 3 % after 1000 h at 85 °C **
Recommended / maximum DC input	0.5 mW / 2 mW
Sensor tolerance	±5 % ***

* The real range of working temperature of the sensor is given by the design of the sensing element and the production technology.
** These parameters depend on the specific type and design of the thermistor.
*** The thermistor electrical resistance tolerance at a temperature of 25 °C is rated by the manufacturer into groups ±2 %, ±3 % or ±5%.

Dependence of resistance in Ω on temperature

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-50	**189950**	203952	217954	231956	245958	**259960**				
-40	**104800**	111910	119020	126130	133240	**140350**	150270	160190	170110	180030
-30	**60186**	63958	67729	71501	75272	**79044**	84195	89346	94498	99649
-20	**35834**	37916	39997	42079	44160	**46242**	49031	51820	54608	57397
-10	**22043**	23234	24424	25615	26805	**27996**	29564	31131	32699	34266
0	**13968**	14671	15375	16078	16782	**17485**	18397	19308	20220	21131

°C	0	1	2	3	4	5	6	7	8	9
0	**13968**	13421	12874	12328	11781	**11234**	10806	10378	9950	9522
10	**9094**	8757	8419	8082	7744	**7407**	7139	6871	6604	6336
20	**6068**	5854	5641	5427	5214	**5000**	4828	4657	4485	4314
30	**4142**	4004	3865	3727	3588	**3450**	3337	3225	3112	3000
40	**2887**	2795	2703	2612	2520	**2428**	2353	2277	2202	2126
50	**2051**	1989	1927	1865	1803	**1741**	1689.6	1638.2	1586.8	1535.4
60	**1484**	1441	1398	1356	1313	**1270**	1234	1198	1163	1127
70	**1091**	1061	1031	1001	970.8	**940.8**	915.5	890.2	865.0	839.7
80	**814.4**	793.0	771.6	750.3	728.9	**707.5**	689.4	671.2	653.1	634.9
90	**616.8**	601.3	585.8	570.4	554.9	**539.4**	526.2	513.0	499.7	486.5
100	**473.3**	462.0	450.6	439.3	427.9	**416.6**	406.8	397.0	387.3	377.5
110	**367.7**	359.3	350.9	342.4	334.0	**325.6**	318.3	311.0	303.6	296.3
120	**289.0**	282.7	276.3	270.0	263.6	**257.3**	251.8	246.3	240.7	235.2
130	**229.7**	224.9	220.0	215.2	210.3	**205.5**	201.3	197.1	192.8	188.6
140	**184.4**	180.7	177.0	173.2	169.5	**165.8**	162.5	159.2	156.0	152.7
150	**149.4**	146.5	143.6	140.8	137.9	**135.0**				

Note: The resistance values **in bold** are taken from the table of the manufacturer of the bead thermistor, the other values are calculated by linear interpolation, with the error caused by calculation being one order of magnitude lower than the tolerance specified by the manufacturer.

Temperature sensing element NTC 5k0; $B_{25/85}$ = 3988

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-55 to 150 °C *
Resistance at 25 °C	5.0 kΩ
Coefficient $\beta_{25/85}$	3977 ± 1%
Coefficient $\beta_{25/100}$	3994 ± 1%
Long-term resistance stability	≤ 3 % after 1000 h at 85 °C **
Recommended / maximum DC input	0.5 mW / 2 mW
Sensor tolerance	±5 % ***

* The real range of working temperature of the sensor is given by the design of the sensing element and the production technology.
** These parameters depend on the specific type and design of the thermistor.
*** The thermistor electrical resistance tolerance at a temperature of 25 °C is rated by the manufacturer into groups ±2 %, ±3 % or ±5%.

Dependence of resistance in Ω on temperature

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-50	**335050**	364344	393638	422932	452226	**481520**				
-40	**168250**	181768	195286	208804	222322	**235840**	255682	275524	295366	315208
-30	**88500**	95060	101620	108180	114740	**121300**	130690	140080	149470	158860
-20	**48535**	51865	55195	58525	61855	**65185**	69848	74511	79174	83837
-10	**27665**	29425	31185	32945	34705	**36465**	38879	41293	43707	46121
0	**16325**	17297	18269	19241	20213	**21185**	22481	23777	25073	26369

°C	0	1	2	3	4	5	6	7	8	9
0	**16325**	15599	14873	14146	13420	**12694**	12145	11596	11048	10499
10	**9950**	9531	9112	8692	8273	**7854**	7532	7214	6889	6567
20	**6245**	5996	5747	5498	5249	**5000**	4806	4612	4417	4223
30	**4029**	3876	3724	3571	3419	**3266**	3146	3025	2905	2784
40	**2664**	2568	2472	2376	2280	**2184**	2108	2031	1955	1878
50	**1802**	1740	1678	1617	1555	**1493**	1443	1393	1344	1294
60	**1244**	1204	1163	1123	1082	**1042**	1009	975.6	942.4	909.2
70	**876**	848.9	821.9	794.8	767.8	**740.7**	718.4	696.0	673.7	651.3
80	**629**	610.4	591.9	573.3	554.8	**536.2**	520.7	505.2	489.8	474.3
90	**458.8**	445.9	433.0	420.1	407.2	**394.3**	383.4	372.6	361.7	350.9
100	**340.0**	330.9	321.7	312.6	303.4	**294.3**	286.6	278.8	271.1	263.3
110	**255.6**	249.0	242.4	235.9	229.3	**222.7**	217.1	211.5	205.9	200.3
120	**194.7**	189.9	185.2	180.4	175.7	**170.9**	166.8	162.7	158.7	154.6
130	**150.5**	146.9	143.4	139.8	136.3	**132.7**	129.6	126.6	123.5	120.5
140	**117.4**	114.8	112.1	109.5	106.8	**104.2**	101.9	99.58	97.27	94.96
150	**92.65**									

Note: The resistance values **in bold** are taken from the table of the manufacturer of the bead thermistor, the other values are calculated by linear interpolation, with the error caused by calculation being one order of magnitude lower than the tolerance specified by the manufacturer.

Temperature sensing element NTC 6k8; $B_{25/85}$ = 3977

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-40 to 150 °C *
Resistance at 25 °C	6.8 kΩ
Coefficient $\beta_{25/85}$	3977 ± 1%
Coefficient $\beta_{25/100}$	3994 ± 1%
Long-term resistance stability	≤ 3 % after 1000 h at 85 °C **
Recommended / maximum DC input	0.5 mW / 2 mW
Sensor tolerance	±5 % ***

* The real range of working temperature of the sensor is given by the design of the sensing element and the production technology.
** These parameters depend on the specific type and design of the thermistor.
*** The thermistor electrical resistance tolerance at a temperature of 25 °C is rated by the manufacturer into groups ±2 %, ±3 % or ±5%.

Dependence of resistance in Ω on temperature

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-40	**225824**									
-30	**119136**	127935	136734	145533	154332	**163132**	175670	188208	200747	213285
-20	**65524**	70002	74480	78958	83436	**87915**	94159	100403	106647	112891
-10	**37431**	39804	42178	44552	46926	**49300**	52544	55789	59034	62279
0	**22137**	23443	24749	26055	27361	**28667**	30419	32172	33925	35678

°C	0	1	2	3	4	5	6	7	8	9
0	**22137**	21155	20174	19192	18211	**17230**	16486	15743	14999	14256
10	**13513**	12945	12377	11810	11242	**10675**	10238	9801	9365	8928
20	**8492**	8153	7815	7476	7138	**6800**	6536	6272	6008	5744
30	**5480**	5273	5066	4858	4651	**4444**	4280	4116	3952	3788
40	**3624**	3494	3364	3233	3103	**2973**	2869	2765	2660	2556
50	**2452**	2368	2284	2200	2116	**2032**	1964	1896	1829	1761
60	**1693**	163	1583	1527	1472	**1417**	1372	1327	1282	1237
70	**1192**	1155	1118	1081	1044	**1007**	976.5	945.9	915.4	884.8
80	**854.3**	829.0	803.7	778.4	753.1	**727.8**	706.7	685.7	664.6	643.6
90	**622.5**	604.9	587.3	569.7	552.1	**534.5**	519.7	504.9	490.2	475.4
100	**460.6**	448.1	435.7	423.2	410.8	**398.3**	387.8	377.3	366.7	356.2
110	**345.7**	336.8	327.8	318.9	309.9	**301.0**	293.4	285.8	278.1	270.5
120	**262.9**	256.4	249.9	243.3	236.8	**230.3**	224.7	219.1	213.6	208.0
130	**202.4**	197.6	192.8	188.0	183.2	**178.4**	174.3	170.1	166.0	161.8
140	**157.7**	154.1	150.5	147.0	143.4	**139.8**	136.7	133.6	130.4	127.3
150	**124.2**									

Note: The resistance values **in bold** are taken from the table of the manufacturer of the bead thermistor, the other values are calculated by linear interpolation, with the error caused by calculation being one order of magnitude lower than the tolerance specified by the manufacturer.

Temperature sensing element NTC 10k; $B_{25/85}$ = 3435

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-40 to 125 °C *
Resistance at 25 °C	10 kΩ
Coefficient $\beta_{25/85}$	3435 ± 1%
Coefficient $\beta_{25/100}$	3478 ± 1%
Long-term resistance stability	≤ 3 % after 1000 h at 85 °C **
Recommended / maximum DC input	0.5 mW / 2 mW
Sensor tolerance	± 0.5 °C for t = 25 °C ** ± 1.0 °C for t = 0 to 70 °C **

* The real range of working temperature of the sensor is given by the design and technology.
** These parameters depend on the specific type and design of the thermistor.

Dependence of resistance in kΩ on temperature

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-40	**210.514**									
-30	**121.737**	128.421	135.513	143.038	151.025	**159.505**	168.510	178.075	188.237	199.036
-20	**72.503**	76.257	80.230	84.435	88.886	**93.600**	98.593	103.884	109.491	115.434
-10	**44.476**	46.642	48.928	51.340	53.888	**56.578**	59.420	62.423	65.598	68.954
0	**28.081**	29.366	30.717	32.140	33.638	**35.216**	36.878	38.630	40.476	42.423

°C	0	1	2	3	4	5	6	7	8	9
0	**28.081**	26.861	25.700	24.596	23.547	**22.548**	21.597	20.691	19.829	19.008
10	**18.226**	17.480	16.770	16.092	15.445	**14.829**	14.240	13.678	13.142	12.630
20	**12.141**	11.673	11.226	10.799	10.391	**10.000**	9.626	9.269	8.926	8.599
30	**8.285**	7.984	7.696	7.420	7.156	**6.902**	6.659	6.426	6.202	5.987
40	**5.781**	5.583	5.393	5.211	5.035	**4.867**	4.705	4.549	4.399	4.255
50	**4.117**	3.984	3.855	3.732	3.613	**3.499**	3.388	3.282	3.180	3.081
60	**2.986**	2.895	2.806	2.721	2.639	**2.560**	2.483	2.409	2.338	2.269
70	**2.203**	2.138	2.076	2.016	1.958	**1.902**	1.848	1.796	1.745	1.696
80	**1.649**	1.603	1.558	1.515	1.474	**1.434**	1.395	1.357	1.320	1.285
90	**1.250**	1.217	1.185	1.154	1.123	**1.094**	1.065	1.038	1.011	0.985
100	**0.959**	0.935	0.911	0.888	0.866	**0.844**	0.823	0.802	0.782	0.763
110	**0.744**	0.725	0.707	0.690	0.673	**0.657**	0.641	0.625	0.610	0.596
120	**0.581**	0.567	0.554	0.541	0.528	**0.516**				

Note 1: The resistance values **in bold** are taken from the table of the manufacturer of the bead thermistor, the other values are calculated by linear interpolation, with the error caused by calculation being one order of magnitude lower than the tolerance specified by the manufacturer.
Note 2: this type of sensing element is interchangeable with sensor NTC 10k; $\beta_{25/85}$ = 3455 with a tolerance of ± 1%

Temperature sensing element NTC 10k; $B_{25/85}$ = 3977

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-40 to 125 °C *
Resistance at 25 °C	10 kΩ
Coefficient $\beta_{25/85}$	3977 ± 1%
Coefficient $\beta_{25/100}$	3994 ± 1%
Long-term resistance stability	≤ 3 % after 1000 h at 85 °C **
Recommended / maximum DC input	0.5 mW / 2 mW
Sensor tolerance	± 0.5 °C for t = 25 °C ** ± 1.0 °C for t = 0 to 70 °C **

* The real range of working temperature of the sensor is given by the design and technology.
** These parameters depend on the specific type and design of the thermistor.

Dependence of resistance in kΩ on temperature

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-40	**334.202**									
-30	**177.797**	189.085	201.158	214.077	227.905	**242.710**	258.566	275.554	293.759	313.275
-20	**97.923**	103.781	110.026	116.687	123.795	**131.380**	139.479	148.128	157.368	167.242
-10	**55.805**	58.944	62.280	65.827	69.599	**73.612**	77.883	82.430	87.271	92.428
0	**32.869**	34.605	36.445	38.396	40.463	**42.655**	44.981	47.449	50.069	52.850

°C	0	1	2	3	4	5	6	7	8	9
0	**32.869**	31.229	29.680	28.217	26.834	**25.527**	24.291	23.122	22.015	20.968
10	**19.977**	19.038	18.149	17.306	16.507	**15.750**	15.032	14.350	13.703	13.090
20	**12.507**	11.953	11.427	10.927	10.452	**10.000**	9.570	9.161	8.772	8.402
30	**8.049**	7.713	7.393	7.088	6.798	**6.521**	6.256	6.004	5.764	5.534
40	**5.315**	5.106	4.906	4.715	4.533	**4.358**	4.191	4.032	3.879	3.733
50	**3.594**	3.460	3.332	3.210	3.092	**2.980**	2.872	2.768	2.669	2.574
60	**2.483**	2.396	2.312	2.231	2.154	**2.080**	2.009	1.940	1.874	1.811
70	**1.750**	1.692	1.636	1.582	1.530	**1.480**	1.431	1.385	1.340	1.298
80	**1.256**	1.216	1.178	1.141	1.105	**1.071**	1.038	1.006	0.975	0.945
90	**0.916**	0.889	0.862	0.836	0.811	**0.787**	0.764	0.741	0.720	0.699
100	**0.678**	0.659	0.640	0.622	0.604	**0.587**	0.570	0.554	0.539	0.524
110	**0.509**	0.495	0.481	0.468	0.455	**0.443**	0.431	0.419	0.408	0.397
120	**0.386**	0.376	0.366	0.357	0.347	**0.338**				

Note: The resistance values in bold are taken from the table of the manufacturer of the bead thermistor, the other values are calculated by linear interpolation, with the error caused by calculation being one order of magnitude lower than the tolerance specified by the manufacturer.

Temperature sensing element NTC 12k; $B_{25/85}$ = 3740

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-40 to 125 °C *
Resistance at 25 °C	12 kΩ
Coefficient $\beta_{25/85}$	3740 ± 1%
Coefficient $\beta_{25/100}$	3760 ± 1%
Long-term resistance stability	≤ 3 % after 1000 h at 85 °C **
Recommended / maximum DC input	0.5 mW / 5mW
Sensor tolerance	±5 % ***

* The real range of working temperature of the sensor is given by the design of the sensing element and the production technology.
** These parameters depend on the specific type and design of the thermistor.
*** The thermistor electrical resistance tolerance at a temperature of 25 °C is rated by the manufacturer into groups ±1%, ±3 % or ±5%.

Dependence of resistance in Ω on temperature

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-40	**309400**									
-30	**171800**	183340	194880	206420	217960	**229500**	245480	261460	277440	293420
-20	**98980**	105144	111308	117472	123636	**129800**	245480	261460	277440	293420
-10	**58880**	62308	65736	69164	72592	**76020**	138200	146600	155000	163400
0	**36130**	38094	40058	42022	43986	**45950**	80612	85204	89796	94388

°C	0	1	2	3	4	5	6	7	8	9
0	**36130**	34624	33118	31612	30106	**28600**	27440	26280	25120	23960
10	**22800**	21900	21000	20100	19200	**18300**	17594	16888	16182	15476
20	**14770**	14216	13662	13108	12554	**12000**	11560.8	11121.6	10682.4	10243.2
30	**9804**	9454	9104	8754	8404	**8054**	7773.6	7493.2	7212.8	6932.4
40	**6652**	6426	6200	5974	5748	**5522**	5339	5156	4973	4790
50	**4607**	4458	4309	4160	4011	**3862**	3740	3618	3496	3374
60	**3252**	3152	3052	2951	2851	**2751**	2668	2585	2503	2420
70	**2337**	2268	2199	2131	2062	**1993**	1936	1879	1821	1764
80	**1707**	1659	1611	1563	1515	**1467**	1427	1387	1346	1306
90	**1266**	1232	1198	1164	1130	**1096**	1067	1038	1010	980.8
100	**952.0**	927.6	903.2	878.8	854.4	**830.0**	809.2	788.4	767.6	746.8
110	**726.0**	708.2	690.4	672.6	654.8	**637.0**	621.6	606.2	590.8	575.4
120	**560.0**	547.0	534.0	521.0	508.0	**495.0**				

Note: The resistance values **in bold** are taken from the table of the manufacturer of the bead thermistor, the other values are calculated by linear interpolation, with the error caused by calculation being one order of magnitude lower than the tolerance specified by the manufacturer.

Temperature sensing element NTC 20k; $B_{25/85}$ = 4263

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-50 °C to 150°C *
Resistance at 25 °C	20 kΩ
Coefficient $\beta_{25/85}$	4263 ± 1%
Coefficient $\beta_{25/100}$	4285 ± 1%
Long-term resistance stability	0.03 % after 8760 h at t = 70 °C
Recommended / maximum DC input	0.05mW / 1mW
Sensor tolerance for 0 °C ≤ T ≤ 70 °C	± 1.0 °C

*The real range of working temperature of the sensor is given by the design and technology.

The temperature dependence of the sensing element resistance is expressed as follows:

$$\mathbf{T = [A + B * \ln R_T + C * (\ln R_T)^3]^{-1}}$$

where: A = $1.152085338392319 * 10^{-3}$, B = $2.13146276927388 * 10^{-4}$,

C = $9.372336566006315 * 10^{-8}$

Dependence of resistance in Ω on temperature

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-50	1666770									
-40	813620	872257	935550	1003900	1077750	1157590	1243930	1337350	1438490	1548050
-30	415717	443730	473829	506185	540982	578420	618719	662117	708873	759271
-20	221452	235430	250387	266397	283541	301909	321594	342700	365340	389635
-10	122556	129815	137552	145802	154602	163993	174018	184723	196160	208383
0	70242	74152	78305	82717	87407	92394	97698	103342	109348	115744

°C	0	1	2	3	4	5	6	7	8	9
0	70242	66560	63090	59821	56739	53832	51090	48503	46060	43754
10	41576	39517	37572	35733	33994	32348	30792	29318	27922	26601
20	25349	24162	23038	21971	20960	20000	19090	18225	17404	16625
30	15884	15181	14512	13876	13271	12695	12148	11627	11131	10659
40	10209	9780	9372	8982	8611	8257	7920	7597	7290	6997
50	6716	6449	6193	5949	5716	5493	5280	5076	4881	4694
60	4516	4345	4182	4025	3875	3732	3594	3462	3336	3215
70	3098	2987	2880	2778	2679	2585	2494	2407	2323	2243
80	2166	2092	2021	1952	1886	1823	1762	1704	1647	1593
90	1541	1491	1442	1396	1351	1308	1266	1226	1187	1150
100	1114	1080	1046	1014	983.0	953.1	924.1	896.2	869.3	843.3
110	818.1	793.9	770.5	747.8	726.0	704.8	684.4	664.7	645.6	627.1
120	609.3	592.0	575.4	559.2	543.6	528.5	513.8	499.7	486.0	472.7
130	459.9	447.4	435.4	423.7	412.4	401.4	390.8	380.5	370.5	360.8
140	351.4	342.3	333.5	324.9	316.4	308.6	300.8	293.2	285.8	278.7
150	271.7									

Application of sensing elements: These sensing elements are used by Honeywell on their older control systems. They can be often found as part of thermostats, digital thermometers, in testing equipment, in healthcare and in Honeywell computer technology.

Temperature sensing element NTC 22k; $B_{25/85}$ = 3740

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-40 to 150 °C *
Resistance at 25 °C	22 kΩ
Coefficient $\beta_{25/85}$	3740 ± 1%
Coefficient $\beta_{25/100}$	3760 ± 1%
Long-term resistance stability	≤ 3 % after 1000 h at 85 °C **
Recommended / maximum DC input	0.5 mW / 2 mW
Sensor tolerance	±5 % ***

* The real range of working temperature of the sensor is given by the design of the sensing element and the production technology.
** These parameters depend on the specific type and design of the thermistor.
*** The thermistor electrical resistance tolerance at a temperature of 25 °C is rated by the manufacturer into groups ±2 %, ±3 % or ±5%.

Dependence of resistance in kΩ on temperature

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-40	**567.2**									
-30	**315.0**	336.2	357.3	378.5	399.6	**420.8**	450.1	479.4	508.6	537.9
-20	**181.4**	192.7	204.0	215.4	226.7	**238.0**	253.4	268.8	284.2	299.6
-10	**107.9**	114.2	120.5	126.8	133.1	**139.4**	147.8	156.2	164.6	173.0
0	**66.24**	69.84	73.44	77.05	80.65	**84.25**	88.98	93.71	98.44	103.2

°C	0	1	2	3	4	5	6	7	8	9
0	**66.24**	63.48	60.72	57.97	55.21	**52.45**	50.32	48.19	46.07	43.94
10	**41.81**	40.16	38.51	36.85	35.20	**33.55**	32.26	30.96	29.67	28.37
20	**27.08**	26.06	25.05	24.03	23.02	**22.00**	21.19	20.39	19.58	18.78
30	**17.97**	17.33	16.69	16.05	15.41	**14.77**	14.26	13.74	13.23	12.71
40	**12.20**	11.78	11.37	10.95	10.54	**10.12**	9.785	9.451	9.116	8.782
50	**8.447**	8.174	7.901	7.627	7.354	**7.081**	6.857	6.634	6.410	6.187
60	**5.963**	5.779	5.595	5.412	5.228	**5.044**	4.892	4.740	4.588	4.436
70	**4.284**	4.158	4.032	3.906	3.780	**3.654**	3.549	3.444	3.339	3.234
80	**3.129**	3.041	2.953	2.866	2.778	**2.690**	2.616	2.542	2.469	2.395
90	**2.321**	2.259	2.197	2.134	2.072	**2.010**	1.957	1.904	1.852	1.799
100	**1.746**	1.701	1.656	1.612	1.567	**1.522**	1.484	1.446	1.407	1.369
110	**1.331**	1.298	1.266	1.233	1.201	**1.168**	1.140	1.112	1.083	1.055
120	**1.027**	1.003	0.9788	0.9547	0.9306	**0.9065**	0.8856	0.8648	0.8439	0.8231
130	**0.8022**	0.7841	0.7660	0.7479	0.7298	**0.7117**	0.6960	0.6803	0.6646	0.6489
140	**0.6332**	0.6195	0.6058	0.5921	0.5784	**0.5647**	0.5527	0.5408	0.5288	0.5169
150	**0.5049**									

Note: The resistance values **in bold** are taken from the table of the manufacturer of the bead thermistor, the other values are calculated by linear interpolation, with the error caused by calculation being one order of magnitude lower than the tolerance specified by the manufacturer.

Temperature sensing element NTC 68k; $B_{25/85}$ = 4190

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-40 to 125 °C *
Resistance at 25 °C	68 kΩ
Coefficient $\beta_{25/85}$	4190 ± 1%
Coefficient $\beta_{25/100}$	4215 ± 1%
Long-term resistance stability	≤ 3 % after 1000 h at 85 °C **
Recommended / maximum DC input	0.5 mW / 2 mW
Sensor tolerance	±5 % ***

* The real range of working temperature of the sensor is given by the design of the sensing element and the production technology.
** These parameters depend on the specific type and design of the thermistor.
*** The thermistor electrical resistance tolerance at a temperature of 25 °C is rated by the manufacturer into groups ±2%, ±3%, ±5% or 10%.

Dependence of resistance in kΩ on temperature

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-40	**2493**									
-30	**1303**	1401	1499	1598	1696	**1794**	1934	2074	2213	2353
-20	**708.0**	757.6	807.3	856.9	906.6	**956.2**	1026	1095	1164	1234
-10	**398.5**	424.6	450.7	476.7	502.8	**528.9**	564.7	600.5	636.4	672.2
0	**231.8**	246.0	260.2	274.4	288.6	**302.8**	321.9	341.1	360.2	379.0

°C	0	1	2	3	4	5	6	7	8	9
0	**231.8**	221.2	210.6	200.1	189.5	**178.9**	170.9	162.9	155.0	147.0
10	**139.0**	133.0	126.9	120.9	114.8	**108.8**	104.2	99.58	94.96	90.35
20	**85.74**	82.19	78.64	75.10	71.55	**68.00**	65.25	62.51	59.76	57.02
30	**54.27**	52.13	49.99	47.85	45.71	**43.57**	41.89	40.22	38.54	36.87
40	**35.19**	33.87	32.54	31.22	29.89	**28.57**	27.52	26.47	25.43	24.38
50	**23.33**	22.49	21.66	20.82	19.99	**19.15**	18.48	17.81	17.13	16.46
60	**15.79**	15.25	14.71	14.17	13.63	**13.09**	12.65	12.21	11.78	11.34
70	**10.90**	10.54	10.19	9.828	9.471	**9.114**	8.822	8.530	8.239	7.947
80	**7.655**	7.415	7.176	6.936	6.697	**6.457**	6.259	6.062	5.864	5.667
90	**5.469**	5.305	5.141	4.977	4.813	**4.649**	4.513	4.377	4.240	4.104
100	**3.968**	3.854	3.740	3.627	3.513	**3.399**	3.303	3.208	3.112	3.017
110	**2.921**	2.841	2.760	2.680	2.599	**2.519**	2.451	2.383	2.316	2.248
120	**2.180**	2.122	2.065	2.007	1.950	**1.892**				

Note: The resistance values **in bold** are taken from the table of the manufacturer of the bead thermistor, the other values are calculated by linear interpolation, with the error caused by calculation being one order of magnitude lower than the tolerance specified by the manufacturer.

Temperature sensing element NTC 100k; $B_{25/85}$ = 4190

Basic technical parameters

Sensing element	Bead NTC thermistor
Working temperature range	-40 to 125 °C *
Resistance at 25 °C	100 kΩ
Coefficient $\beta_{25/85}$	4190 ± 1%
Coefficient $\beta_{25/100}$	4215 ± 1%
Long-term resistance stability	≤ 3 % after 1000 h at 85 °C **
Recommended / maximum DC input	0.5 mW / 2 mW
Sensor tolerance	±5 % ***

* The real range of working temperature of a temperature sensor with an NTC element is given by the design of the sensing element and the production technology.
** These parameters depend on the specific type and design of the thermistor.
*** The thermistor electrical resistance tolerance at a temperature of 25 °C is rated by the manufacturer into groups ±2%, ±3%, ±5% or 10%.

Dependence of resistance in kΩ on temperature

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-40	**3666**									
-30	**1917**	2061	2205	2350	2494	**2638**	2844	3049	3255	3460
-20	**1041**	1114	1187	1260	1333	**1406**	1508	1610	1713	1815
-10	**586.1**	624.5	662.8	701.2	739.5	**777.9**	830.5	883.1	935.8	988.4
0	**340.9**	361.8	382.7	403.5	424.4	**445.3**	473.5	501.6	529.8	557.9

°C	0	1	2	3	4	5	6	7	8	9
0	**340.9**	325.3	309.8	294.2	278.7	**263.1**	251.4	239.6	227.9	216.1
10	**204.4**	195.5	186.6	177.8	168.9	**160.0**	153.2	146.4	139.7	132.9
20	**126.1**	120.9	115.7	110.4	105.2	**100.0**	95.96	91.92	87.89	83.85
30	**79.81**	76.66	73.52	70.37	67.23	**64.08**	61.61	59.14	56.68	54.21
40	**51.74**	49.80	47.85	45.91	43.96	**42.02**	40.48	38.94	37.39	35.85
50	**34.31**	33.08	31.85	30.62	29.39	**28.16**	27.17	26.18	25.20	24.21
60	**23.22**	22.43	21.63	20.84	20.04	**19.25**	18.61	17.96	17.32	16.67
70	**16.03**	15.50	14.98	14.45	13.93	**13.40**	12.97	12.54	12.12	11.69
80	**11.26**	10.91	10.55	10.20	9.849	**9.496**	9.205	8.914	8.624	8.333
90	**8.042**	7.801	7.560	7.319	7.078	**6.837**	6.637	6.436	6.236	6.035
100	**5.835**	5.668	5.500	5.333	5.165	**4.998**	4.858	4.717	4.577	4.436
110	**4.296**	4.178	4.060	3.941	3.823	**3.705**	3.605	3.505	3.406	3.306
120	**3.206**	3.121	3.037	2.952	2.868	**2.783**				

Note: The resistance values **in bold** are taken from the table of the manufacturer of the bead thermistor, the other values are calculated by linear interpolation, with the error caused by calculation being one order of magnitude lower than the tolerance specified by the manufacturer.

Type J thermocouple sensors

Basic technical parameters

Sensing element	Type J thermocouple
Maximum range of working temperature	-40 to +750 °C *
Reference voltage at 0 °C	0.00 μV

* The real range of working temperature of the sensor is given by the design and technology

Principle:

A change of the temperature of the measured environment results in a defined change of the measuring thermocouple voltage. The change of voltage is defined by the following equation according to EN 60584-1:

$$\mathbf{U = \sum_{i=1}^{n} a_i \, (t_{90})^i \quad \mu V}$$ in a temperature range of -210 to +760 °C

where
$a_1 = 5.038\,118\,7815 \times 10^{1}$ $a_5 = -1.705\,295\,8337 \times 10^{-10}$
$a_2 = 3.047\,583\,6930 \times 10^{-2}$ $a_6 = 2.094\,809\,0697 \times 10^{-13}$
$a_3 = -8.568\,106\,5720 \times 10^{-5}$ $a_7 = -1.253\,839\,5336 \times 10^{-16}$
$a_4 = 1.322\,819\,5295 \times 10^{-7}$ $a_8 = 1.563\,172\,5697 \times 10^{-20}$

$$\mathbf{U = \sum_{i=1}^{n} a_i \, (t_{90})^i \quad \mu V}$$ in a temperature range of +760 to 1200 °C

where
$a_0 = 2.964\,562\,5681 \times 10^{5}$ $a_3 = -3.184\,768\,6701 \times 10^{-3}$
$a_1 = -1.497\,612\,7786 \times 10^{3}$ $a_4 = 1.572\,081\,9004 \times 10^{-6}$
$a_2 = 3.178\,710\,3924$ $a_5 = -3.069\,136\,9056 \times 10^{-10}$

Dependence of voltage in mV on temperature:

°C	0	-10	-20	-30	-40	-50	-60	-70	-80	-90
-200	-7.890	-8.095								
-100	-4.633	-5.037	-5.426	-5.801	-6.159	-6.500	-6.821	-7.123	-7.403	-7.659
0	0.000	-0.501	-0.995	-1.482	-1.961	-2.431	-2.893	-3.344	-3.786	-4.215

°C	0	10	20	30	40	50	60	70	80	90
0	0.000	0.507	1.019	1.537	2.059	2.585	3.116	3.650	4.187	4.726
100	5.269	5.814	6.360	6.909	7.459	8.010	8.562	9.115	9.669	10.224
200	10.779	11.334	11.889	12.445	13.000	13.555	14.110	14.665	15.219	15.773
300	16.327	16.881	17.434	17.986	18.538	19.090	19.642	20.194	20.745	21.297
400	21.848	22.400	22.952	23.504	24.057	24.610	25.164	25.720	26.276	26.834
500	27.393	27.953	28.516	29.080	29.647	30.216	30.788	31.362	31.939	32.519
600	33.102	33.689	34.279	34.873	35.470	36.071	36.675	37.284	37.896	38.512
700	39.132	39.755	40.382	41.012	41.645	42.281	42.919	43.559	44.203	44.848
800	45.494	46.141	46.786	47.431	48.074	48.715	49.353	49.989	50.622	51.251
900	51.877	52.500	53.119	53.735	54.347	54.956	55.561	56.164	56.763	57.360
1000	57.953	58.545	59.134	59.721	60.307	60.890	61.473	62.054	62.634	63.214
1100	63.792	64.370	64.948	65.525	66.102	66.679	67.255	67.831	68.406	68.980
1200	69.553									

The temperature dependence of voltage on temperature with 1 degree Celsius increments is shown in EN 60584-1.

Tolerance classes of accuracy:

Tolerance classes for J thermocouples are defined by EN 60584-2.

Thermocouple designation	Tolerance class	Permissible deviations (°C)	
J	1	± 1.5 °C ± 0.004 * | t |	for temperatures of -40 to +375 °C for temperatures of +375 to +750 °C
	2	± 2.5°C ± 0.0075 * | t |	for temperatures of -40 to +333°C for temperatures of +333 to +750 °C

Sensit temperature sensors based on J thermocouples

Currently only cable (standard and custom) temperature sensors are produced with these sensing elements.

Note: *An overview of cable (standard and custom) temperature sensors can be found at www.sensit.cz or in the Sensit catalogue.*

Type K thermocouple sensors

Basic technical parameters

Sensing element	Type K thermocouple
Maximum range of working temperature	-200 to 1200 °C *
Reference voltage at 0 °C	0.00 μV

* The real range of working temperature of the sensor is given by the design and technology

Principle:

A change of the temperature of the measured environment results in a defined change of the measuring thermocouple voltage. The change of voltage is defined by the following equation according to EN 60584-1:

$$U = \sum_{i=1}^{n} a_i (t_{90})^i \quad \mu V$$ in a temperature range of -270 to 0 °C

where
a_1 = 3.945 012 8025 x 10^{1}
a_2 = 2.362 237 3598 x 10^{-2}
a_3 = -3.285 890 6784 x 10^{-4}
a_4 = -4.990 482 8777 x 10^{-6}
a_5 = -6.750 905 9173 x 10^{-8}
a_6 = -5.741 032 7428 x 10^{-10}
a_7 = -3.108 887 2894 x 10^{-12}
a_8 = -1.045 160 9365 x 10^{-14}
a_9 = -1.988 926 6878 x 10^{-17}
a_{10} = -1.632 269 7486 x 10^{-20}

$$U = b_0 + \sum_{i=1}^{n} b_i (t_{90})^i + c_0 \exp[c_1(t_{90} - 126,9686)^2] \quad \mu V$$ in a temperature range of 0 to 1372 °C

where
b_0 = -1.760 041 3686 x 10^{1}
b_1 = 3.892 120 4975 x 10^{1}
b_2 = 1.855 877 0032 x 10^{-2}
b_3 = -9.945 759 2874 x 10^{-5}
b_4 = 3.184 094 5719 x 10^{-7}
b_5 = -5.607 284 4889 x 10^{-10}
b_6 = -3.108 887 2894 x 10^{-12}
b_7 = -1.045 160 9365 x 10^{-14}
b_8 = -1.988 926 6878 x 10^{-17}
b_9 = -1.632 269 7486 x 10^{-20}
c_0 = 1.185 976 x 10^{2}
c_1 = -1.183 432 x 10^{-4}

Dependence of voltage in mV on temperature:

°C	0	-10	-20	-30	-40	-50	-60	-70	-80	-90
-200	-5.891	-6.035	-6.158	-6.262	-6.344	-6.404	-6.441	-6.458		
-100	-3.554	-3.852	-4.138	-4.411	-4.669	-4.913	-5.141	-5.354	-5.550	-5.730
0	0.000	-0.392	-0.778	-1.156	-1.527	-1.889	-2.243	-2.587	-2.920	-3.243

°C	0	10	20	30	40	50	60	70	80	90
0	0.000	0.397	0.798	1.203	1.612	2.023	2.436	2.851	3.267	3.682
100	4.096	4.509	4.920	5.328	5.735	6.138	6.540	6.941	7.340	7.739
200	8.138	8.539	8.940	9.343	9.747	10.153	10.561	10.971	11.382	11.795
300	12.209	12.624	13.040	13.457	13.874	14.293	14.713	15.133	15.554	15.975
400	16.397	16.820	17.243	17.667	18.091	18.516	18.941	19.366	19.792	20.218
500	20.644	21.071	21.497	21.924	22.350	22.776	23.203	23.629	24.055	24.480
600	24.905	25.330	25.755	26.179	26.602	27.025	27.447	27.869	28.289	28.710
700	29.129	29.548	29.965	30.382	30.798	31.213	31.628	32.041	32.453	32.865
800	33.275	33.685	34.093	34.501	34.908	35.313	35.718	36.121	36.524	36.925
900	37.326	37.725	38.124	38.522	38.918	39.314	39.708	40.101	40.494	40.885
1000	41.276	41.665	42.053	42.440	42.826	43.211	43.595	43.978	44.359	44.740
1100	45.119	45.497	45.873	46.249	46.623	46.995	47.367	47.737	48.105	48.473
1200	48.838	49.202	49.565	49.926	50.286	50.644	51.000	51.355	51.708	52.060
1300	52.410	52.759	53.106	53.451	53.795	54.138	54.479	54.819		

The temperature dependence of voltage on temperature with 1 degree Celsius increments is shown in EN 60584-1.

Tolerance classes of accuracy

Tolerance classes for K thermocouples are defined by EN 60584-2.

Thermocouple designation	Tolerance class	Permissible deviations (°C)	
K	1	± 1.5 °C ± 0.004 * | t | °C	for temperatures of -40 to +375 °C for temperatures of +375 to +1000
	2	± 2.5 °C ± 0.0075 * | t | °C	for temperatures of +40 to +333 °C for temperatures of +333 to +1200
	3	± 2.5 °C ± 0.015 * | t |	for temperatures of -167 to +40 °C for temperatures of -200 to -167 °C

Sensit temperature sensors based on K thermocouples

Currently only cable (standard and custom) temperature sensors are produced with these sensing elements.

Note: *An overview of cable (standard and custom) temperature sensors can be found at www.sensit.cz or in the Sensit catalogue.*

Unified signal 4–20 mA (temperature-current transducers)

Temperature range -30 to 60 °C

°C	0	1	2	3	4	5	6	7	8	9
-30	4.000	4.178	4.356	4.533	4.711	4.889	5.067	5.244	5.422	5.600
-20	5.778	5.956	6.133	6.311	6.489	6.667	6.844	7.022	7.200	7.378
-10	7.556	7.733	7.911	8.089	8.267	8.444	8.622	8.800	8.978	9.156
0	9.333	9.511	9.689	9.867	10.044	10.222	10.400	10.578	10.756	10.933
10	11.111	11.289	11.467	11.644	11.822	12.000	12.178	12.356	12.533	12.711
20	12.889	13.067	13.244	13.422	13.600	13.778	13.956	14.133	14.311	14.489
30	14.667	14.844	15.022	15.200	15.378	15.556	15.733	15.911	16.089	16.267
40	16.444	16.622	16.800	16.978	17.156	17.333	17.511	17.689	17.867	18.044
50	18.222	18.400	18.578	18.756	18.933	19.111	19.289	19.467	19.644	19.822
60	20.000									

Temperature range: 0 to 35 °C

°C	0	1	2	3	4	5	6	7	8	9
0	4.000	4.457	4.914	5.371	5.829	6.286	6.743	7.200	7.657	8.114
10	8.571	9.029	9.486	9.943	10.400	10.857	11.314	11.771	12.229	12.686
20	13.143	13.600	14.057	14.514	14.971	15.429	15.886	16.343	16.800	17.257
30	17.714	18.171	18.629	19.086	19.543	20.000				

Temperature range: 0 to 100 °C

°C	0	1	2	3	4	5	6	7	8	9
0	4.000	4.160	4.320	4.480	4.640	4.800	4.960	5.120	5.280	5.440
10	5.600	5.760	5.920	6.080	6.240	6.400	6.560	6.720	6.880	7.040
20	7.200	7.360	7.520	7.680	7.840	8.000	8.160	8.320	8.480	8.640
30	8.800	8.960	9.120	9.280	9.440	9.600	9.760	9.920	10.080	10.240
40	10.400	10.560	10.720	10.880	11.040	11.200	11.360	11.520	11.680	11.840
50	12.000	12.160	12.320	12.480	12.640	12.800	12.960	13.120	13.280	13.440
60	13.600	13.760	13.920	14.080	14.240	14.400	14.560	14.720	14.880	15.040
70	15.200	15.360	15.520	15.680	15.840	16.000	16.160	16.320	16.480	16.640
80	16.800	16.960	17.120	17.280	17.440	17.600	17.760	17.920	18.080	18.240
90	18.400	18.560	18.720	18.880	19.040	19.200	19.360	19.520	19.680	19.840
100	20.000									

Temperature range: 0 to 150 °C

°C	0	1	2	3	4	5	6	7	8	9
0	4.000	4.107	4.213	4.320	4.427	4.533	4.640	4.747	4.853	4.960
10	5.067	5.173	5.280	5.387	5.493	5.600	5.707	5.813	5.920	6.027
20	6.133	6.240	6.347	6.453	6.560	6.667	6.773	6.880	6.987	7.093
30	7.200	7.307	7.413	7.520	7.627	7.733	7.840	7.947	8.053	8.160
40	8.267	8.373	8.480	8.587	8.693	8.800	8.907	9.013	9.120	9.227
50	9.333	9.440	9.547	9.653	9.760	9.867	9.973	10.080	10.187	10.293
60	10.400	10.507	10.613	10.720	10.827	10.933	11.040	11.147	11.253	11.360
70	11.467	11.573	11.680	11.787	11.893	12.000	12.107	12.213	12.320	12.427
80	12.533	12.640	12.747	12.853	12.960	13.067	13.173	13.280	13.387	13.493
90	13.600	13.707	13.813	13.920	14.027	14.133	14.240	14.347	14.453	14.560
100	14.667	14.773	14.880	14.987	15.093	15.200	15.307	15.413	15.520	15.627
110	15.733	15.840	15.947	16.053	16.160	16.267	16.373	16.480	16.587	16.693
120	16.800	16.907	17.013	17.120	17.227	17.333	17.440	17.547	17.653	17.760
130	17.867	17.973	18.080	18.187	18.293	18.400	18.507	18.613	18.720	18.827
140	18.933	19.040	9.467	19.253	19.360	19.467	19.573	19.680	19.787	19.893
150	20.000									

Temperature range: 0 to 200 °C

°C	0	1	2	3	4	5	6	7	8	9
0	4.000	4.080	4.160	4.240	4.320	4.400	4.480	4.560	4.640	4.720
10	4.800	4.880	4.960	5.040	5.120	5.200	5.280	5.360	5.440	5.520
20	5.600	5.680	5.760	5.840	5.920	6.000	6.080	6.160	6.240	6.320
30	6.400	6.480	6.560	6.640	6.720	6.800	6.880	6.960	7.040	7.120
40	7.200	7.280	7.360	7.440	7.520	7.600	7.680	7.760	7.840	7.920
50	8.000	8.080	8.160	8.240	8.320	8.400	8.480	8.560	8.640	8.720
60	8.800	8.880	8.960	9.040	9.120	9.200	9.280	9.360	9.440	9.520
70	9.600	9.680	9.760	9.840	9.920	10.000	10.080	10.160	10.240	10.320
80	10.400	10.480	10.560	10.640	10.720	10.800	10.880	10.960	11.040	11.120
90	11.200	11.280	11.360	11.440	11.520	11.600	11.680	11.760	11.840	11.920
100	12.000	12.080	12.160	12.240	12.320	12.400	12.480	12.560	12.640	12.720
110	12.800	12.880	12.960	13.040	13.120	13.200	13.280	13.360	13.440	13.520
120	13.600	13.680	13.760	13.840	13.920	14.000	14.080	14.160	14.240	14.320
130	14.400	14.480	14.560	14.640	14.720	14.800	14.880	14.960	15.040	15.120
140	15.200	15.280	15.360	15.440	15.520	15.600	15.680	15.760	15.840	15.920
150	16.000	16.080	16.160	16.240	16.320	16.400	16.480	16.560	16.640	16.720
160	16.800	16.880	16.960	17.040	17.120	17.200	17.280	17.360	17.440	17.520
170	17.600	17.680	17.760	17.840	17.920	18.000	18.080	18.160	18.240	18.320
180	18.400	18.480	18.560	18.640	18.720	18.800	18.880	18.960	19.040	19.120
190	19.200	19.280	19.360	19.440	19.520	19.600	19.680	19.760	19.840	19.920
200	20.000									

Temperature range: 0 to 250 °C

°C	0	1	2	3	4	5	6	7	8	9
0	4.000	4.064	4.128	4.192	4.256	4.320	4.384	4.448	4.512	4.576
10	4.640	4.704	4.768	4.832	4.896	4.960	5.024	5.088	5.152	5.216
20	5.280	5.344	5.408	5.472	5.536	5.600	5.664	5.728	5.792	5.856
30	5.920	5.984	6.048	6.112	6.176	6.240	6.304	6.368	6.432	6.496
40	6.560	6.624	6.688	6.752	6.816	6.880	6.944	7.008	7.072	7.136
50	7.200	7.264	7.328	7.392	7.456	7.520	7.584	7.648	7.712	7.776
60	7.840	7.904	7.968	8.032	8.096	8.160	8.224	8.288	8.352	8.416
70	8.480	8.544	8.608	8.672	8.736	8.800	8.864	8.928	8.992	9.056
80	9.120	9.184	9.248	9.312	9.376	9.440	9.504	9.568	9.632	9.696
90	9.760	9.824	9.888	9.952	10.016	10.080	10.144	10.208	10.272	10.336
100	10.400	10.464	10.528	10.592	10.656	10.720	10.784	10.848	10.912	10.976
110	11.040	11.104	11.168	11.232	11.296	11.360	11.424	11.488	11.552	11.616
120	11.680	11.744	11.808	11.872	11.936	12.000	12.064	12.128	12.192	12.256
130	12.320	12.384	12.448	12.512	12.576	12.640	12.704	12.768	12.832	12.896
140	12.960	13.024	13.088	13.152	13.216	13.280	13.344	13.408	13.472	13.536
150	13.600	13.664	13.728	13.792	13.856	13.920	13.984	14.048	14.112	14.176
160	14.240	14.304	14.368	14.432	14.496	14.560	14.624	14.688	14.752	14.816
170	14.880	14.944	15.008	15.072	15.136	15.200	15.264	15.328	15.392	15.456
180	15.520	15.584	15.648	15.712	15.776	15.840	15.904	15.968	16.032	16.096
190	16.160	16.224	16.288	16.352	16.416	16.480	16.544	16.608	16.672	16.736
200	16.800	16.864	16.928	16.992	17.056	17.120	17.184	17.248	17.312	17.376
210	17.440	17.504	17.568	17.632	17.696	17.760	17.824	17.888	17.952	18.016
220	18.080	18.144	18.208	18.272	18.336	18.400	18.464	18.528	18.592	18.656
230	18.720	18.784	18.848	18.912	18.976	19.040	19.104	19.168	19.232	19.296
240	19.360	19.424	19.488	19.552	19.616	19.680	19.744	19.808	19.872	19.936
250	20.000									

Temperature range: 0 to 400 °C

°C	0	1	2	3	4	5	6	7	8	9
0	4.000	4.040	4.080	4.120	4.160	4.200	4.240	4.280	4.320	4.360
10	4.400	4.440	4.480	4.520	4.560	4.600	4.640	4.680	4.720	4.760
20	4.800	4.840	4.880	4.920	4.960	5.000	5.040	5.080	5.120	5.160
30	5.200	5.240	5.280	5.320	5.360	5.400	5.440	5.480	5.520	5.560
40	5.600	5.640	5.680	5.720	5.760	5.800	5.840	5.880	5.920	5.960
50	6.000	6.040	6.080	6.120	6.160	6.200	6.240	6.280	6.320	6.360
60	6.400	6.440	6.480	6.520	6.560	6.600	6.640	6.680	6.720	6.760
70	6.800	6.840	6.880	6.920	6.960	7.000	7.040	7.080	7.120	7.160
80	7.200	7.240	7.280	7.320	7.360	7.400	7.440	7.480	7.520	7.560
90	7.600	7.640	7.680	7.720	7.760	7.800	7.840	7.880	7.920	7.960
100	8.000	8.040	8.080	8.120	8.160	8.200	8.240	8.280	8.320	8.360
110	8.400	8.440	8.480	8.520	8.560	8.600	8.640	8.680	8.720	8.760
120	8.800	8.840	8.880	8.920	8.960	9.000	9.040	9.080	9.120	9.160
130	9.200	9.240	9.280	9.320	9.360	9.400	9.440	9.480	9.520	9.560
140	9.600	9.640	9.680	9.720	9.760	9.800	9.840	9.880	9.920	9.960
150	10.000	10.040	10.080	10.120	10.160	10.200	10.240	10.280	10.320	10.360
160	10.400	10.440	10.480	10.520	10.560	10.600	10.640	10.680	10.720	10.760
170	10.800	10.840	10.880	10.920	10.960	11.000	11.040	11.080	11.120	11.160
180	11.200	11.240	11.280	11.320	11.360	11.400	11.440	11.480	11.520	11.560
190	11.600	11.640	11.680	11.720	11.760	11.800	11.840	11.880	11.920	11.960
200	12.000	12.040	12.080	12.120	12.160	12.200	12.240	12.280	12.320	12.360
210	12.400	12.440	12.480	12.520	12.560	12.600	12.640	12.680	12.720	12.760
220	12.800	12.840	12.880	12.920	12.960	13.000	13.040	13.080	13.120	13.160
230	13.200	13.240	13.280	13.320	13.360	13.400	13.440	13.480	13.520	13.560
240	13.600	13.640	13.680	13.720	13.760	13.800	13.840	13.880	13.920	13.960
250	14.000	14.040	14.080	14.120	14.160	14.200	14.240	14.280	14.320	14.360
260	14.400	14.440	14.480	14.520	14.560	14.600	14.640	14.680	14.720	14.760
270	14.800	14.840	14.880	14.920	14.960	15.000	15.040	15.080	15.120	15.160
280	15.200	15.240	15.280	15.320	15.360	15.400	15.440	15.480	15.520	15.560
290	15.600	15.640	15.680	15.720	15.760	15.800	15.840	15.880	15.920	15.960
300	16.000	16.040	16.080	16.120	16.160	16.200	16.240	16.280	16.320	16.360
310	16.400	16.440	16.480	16.520	16.560	16.600	16.640	16.680	16.720	16.760
320	16.800	16.840	16.880	16.920	16.960	17.000	17.040	17.080	17.120	17.160
330	17.200	17.240	17.280	17.320	17.360	17.400	17.440	17.480	17.520	17.560
340	17.600	17.640	17.680	17.720	17.760	17.800	17.840	17.880	17.920	17.960
350	18.000	18.040	18.080	18.120	18.160	18.200	18.240	18.280	18.320	18.360
360	18.400	18.440	18.480	18.520	18.560	18.600	18.640	18.680	18.720	18.760
370	18.800	18.840	18.880	18.920	18.960	19.000	19.040	19.080	19.120	19.160
380	19.200	19.240	19.280	19.320	19.360	19.400	19.440	19.480	19.520	19.560
390	19.600	19.640	19.680	19.720	19.760	19.800	19.840	19.880	19.920	19.960
400	20.000									

Temperature range: -50 to 50 °C

°C	0	1	2	3	4	5	6	7	8	9
-50	4.000	4.160	4.320	4.480	4.640	4.800	4.960	5.120	5.280	5.440
-40	5.600	5.760	5.920	6.080	6.240	6.400	6.560	6.720	6.880	7.040
-30	7.200	7.360	7.520	7.680	7.840	8.000	8.160	8.320	8.480	8.640
-20	8.800	8.960	9.120	9.280	9.440	9.600	9.760	9.920	10.080	10.240
-10	10.400	10.560	10.720	10.880	11.040	11.200	11.360	11.520	11.680	11.840
0	12.000	12.160	12.320	12.480	12.640	12.800	12.960	13.120	13.280	13.440
10	13.600	13.760	13.920	14.080	14.240	14.400	14.560	14.720	14.880	15.040
20	15.200	15.360	15.520	15.680	15.840	16.000	16.160	16.320	16.480	16.640
30	16.800	16.960	17.120	17.280	17.440	17.600	17.760	17.920	18.080	18.240
40	18.400	18.560	18.720	18.880	19.040	19.200	19.360	19.520	19.680	19.840
50	20.000									

Unified signal 0–10 V (temperature-voltage transducers)

Temperature range: -30 to 60 °C

°C	0	1	2	3	4	5	6	7	8	9
-30	0.000	0.111	0.222	0.333	0.444	0.556	0.667	0.778	0.889	1.000
-20	1.111	1.222	1.333	1.444	1.556	1.667	1.778	1.889	2.000	2.111
-10	2.222	2.333	2.444	2.556	2.667	2.778	2.889	3.000	3.111	3.222
0	3.333	3.444	3.556	3.667	3.778	3.889	4.000	4.111	4.222	4.333
10	4.444	4.556	4.667	4.778	4.889	5.000	5.111	5.222	5.333	5.444
20	5.556	5.667	5.778	5.889	6.000	6.111	6.222	6.333	6.444	6.556
30	6.667	6.778	6.889	7.000	7.111	7.222	7.333	7.444	7.556	7.667
40	7.778	7.889	8.000	8.111	8.222	8.333	8.444	8.556	8.667	8.778
50	8.889	9.000	9.111	9.222	9.333	9.444	9.556	9.667	9.778	9.889
60	10.000									

Temperature range: 0 to 35 °C

°C	0	1	2	3	4	5	6	7	8	9
0	0.000	0.286	0.571	0.857	1.143	1.429	1.714	2.000	2.286	2.571
10	2.857	3.143	3.429	3.714	4.000	4.286	4.571	4.857	5.143	5.429
20	5.714	6.000	6.286	6.571	6.857	7.143	7.429	7.714	8.000	8.286
30	8.571	8.857	9.143	9.429	9.714	10.000				

Temperature range: 0 to 100 °C

°C	0	1	2	3	4	5	6	7	8	9
0	0.000	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900
10	1.000	1.100	1.200	1.300	1.400	1.500	1.600	1.700	1.800	1.900
20	2.000	2.100	2.200	2.300	2.400	2.500	2.600	2.700	2.800	2.900
30	3.000	3.100	3.200	3.300	3.400	3.500	3.600	3.700	3.800	3.900
40	4.000	4.100	4.200	4.300	4.400	4.500	4.600	4.700	4.800	4.900
50	5.000	5.100	5.200	5.300	5.400	5.500	5.600	5.700	5.800	5.900
60	6.000	6.100	6.200	6.300	6.400	6.500	6.600	6.700	6.800	6.900
70	7.000	7.100	7.200	7.300	7.400	7.500	7.600	7.700	7.800	7.900
80	8.000	8.100	8.200	8.300	8.400	8.500	8.600	8.700	8.800	8.900
90	9.000	9.100	9.200	9.300	9.400	9.500	9.600	9.700	9.800	9.900
100	10.000									

Temperature range: 0 to 150 °C

°C	0	1	2	3	4	5	6	7	8	9
0	0.000	0.067	0.133	0.200	0.267	0.333	0.400	0.467	0.533	0.600
10	0.667	0.733	0.800	0.867	0.933	1.000	1.067	1.133	1.200	1.267
20	1.333	1.400	1.467	1.533	1.600	1.667	1.733	1.800	1.867	1.933
30	2.000	2.067	2.133	2.200	2.267	2.333	2.400	2.467	2.533	2.600
40	2.667	2.733	2.800	2.867	2.933	3.000	3.067	3.133	3.200	3.267
50	3.333	3.400	3.467	3.533	3.600	3.667	3.733	3.800	3.867	3.933
60	4.000	4.067	4.133	4.200	4.267	4.333	4.400	4.467	4.533	4.600
70	4.667	4.733	4.800	4.867	4.933	5.000	5.067	5.133	5.200	5.267
80	5.333	5.400	5.467	5.533	5.600	5.667	5.733	5.800	5.867	5.933
90	6.000	6.067	6.133	6.200	6.267	6.333	6.400	6.467	6.533	6.600
100	6.667	6.733	6.800	6.867	6.933	7.000	7.067	7.133	7.200	7.267
110	7.333	7.400	7.467	7.533	7.600	7.667	7.733	7.800	7.867	7.933
120	8.000	8.067	8.133	8.200	8.267	8.333	8.400	8.467	8.533	8.600
130	8.667	8.733	8.800	8.867	8.933	9.000	9.067	9.133	9.200	9.267
140	9.333	9.400	9.467	9.533	9.600	9.667	9.733	9.800	9.867	9.933
150	10.000									

Temperature range: 0 to 250 °C

°C	0	1	2	3	4	5	6	7	8	9
0	0.000	0.040	0.080	0.120	0.160	0.200	0.240	0.280	0.320	0.360
10	0.400	0.440	0.480	0.520	0.560	0.600	0.640	0.680	0.720	0.760
20	0.800	0.840	0.880	0.920	0.960	1.000	1.040	1.080	1.120	1.160
30	1.200	1.240	1.280	1.320	1.360	1.400	1.440	1.480	1.520	1.560
40	1.600	1.640	1.680	1.720	1.760	1.800	1.840	1.880	1.920	1.960
50	2.000	2.040	2.080	2.120	2.160	2.200	2.240	2.280	2.320	2.360
60	2.400	2.440	2.480	2.520	2.560	2.600	2.640	2.680	2.720	2.760
70	2.800	2.840	2.880	2.920	2.960	3.000	3.040	3.080	3.120	3.160
80	3.200	3.240	3.280	3.320	3.360	3.400	3.440	3.480	3.520	3.560
90	3.600	3.640	3.680	3.720	3.760	3.800	3.840	3.880	3.920	3.960
100	4.000	4.040	4.080	4.120	4.160	4.200	4.240	4.280	4.320	4.360
110	4.400	4.440	4.480	4.520	4.560	4.600	4.640	4.680	4.720	4.760
120	4.800	4.840	4.880	4.920	4.960	5.000	5.040	5.080	5.120	5.160
130	5.200	5.240	5.280	5.320	5.360	5.400	5.440	5.480	5.520	5.560
140	5.600	5.640	5.680	5.720	5.760	5.800	5.840	5.880	5.920	5.960
150	6.000	6.040	6.080	6.120	6.160	6.200	6.240	6.280	6.320	6.360
160	6.400	6.440	6.480	6.520	6.560	6.600	6.640	6.680	6.720	6.760
170	6.800	6.840	6.880	6.920	6.960	7.000	7.040	7.080	7.120	7.160
180	7.200	7.240	7.280	7.320	7.360	7.400	7.440	7.480	7.520	7.560
190	7.600	7.640	7.680	7.720	7.760	7.800	7.840	7.880	7.920	7.960
200	8.000	8.040	8.080	8.120	8.160	8.200	8.240	8.280	8.320	8.360
210	8.400	8.440	8.480	8.520	8.560	8.600	8.640	8.680	8.720	8.760
220	8.800	8.840	8.880	8.920	8.960	9.000	9.040	9.080	9.120	9.160
230	9.200	9.240	9.280	9.320	9.360	9.400	9.440	9.480	9.520	9.560
240	9.600	9.640	9.680	9.720	9.760	9.800	9.840	9.880	9.920	9.960
250	10.000									

Frequently asked questions

- *Why is measurement by a nickel temperature sensor limited to 250 °C despite being a metal?*

Compared to platinum, nickel is a highly corrosive element. That means that contact with oxygen creates nickel(II) oxide (NiO), which has substantially different physical properties than pure nickel. For this reason, the thin nickel layer on nickel temperature chips is relatively complexly protected by so-called passivation layers against direct contact with air oxygen. The passivation properties of these layers, however, are temperature-dependent. With increasing temperature, their passivation abilities decrease so that, at temperatures above 250 °C, they become partially permeable to air oxygen, the measuring nickel layer relatively rapidly oxidizes and the temperature sensor deteriorates.

- *Why do nickel temperature sensors age and how does ageing affect the measurement result?*

The answer follows on the previous question. Passivation layers on nickel temperature sensing elements are never absolutely impermeable to air oxygen, which results in slow gradual oxidation of the nickel layer. We say that the Ni sensing element ages, the value of its resistance gradually increases and, after a certain time (sufficiently long due to the service life of the evaluation equipment), the nickel temperature sensor shows a positive absolute error. It indicates a higher temperature value than the real value. The ageing rate of a nickel temperature sensor is higher the higher is the maximum measured temperature or the longer the sensor is permanently exposed to temperatures near the upper limit of the temperature range. For measured temperatures up to 150 °C, the absolute measurement error due to ageing of the nickel layer can be disregarded. The ageing rate (speed), given what has been said above, depends mainly on the quality of the passivation of the nickel layer, which varies not only between manufacturers, but also within a single manufacturer, depending on the specific type of nickel chip or even the batch of a single specific type.

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