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Construction and application of temperature sensors

Temperature-dependent resistance

The variation of the electrical resistance of metals with temperature is very often employed for the electrical measurement of temperature. Since electrical resistance increases with rising temperature, we speak of a positive temperature coefficient or **PTC**, for example in the case of platinum temperature sensors.

In order to use this effect for measuring temperature, the metal has to vary its electrical resistance with temperature in a reproducible manner. The characteristic properties of the metal must not change during operation, as this would result in measurement errors. The temperature coefficient should as far as possible be independent of temperature, pressure and chemical effects.

Standardized platinum temperature sensors

Platinum has become firmly established as a resistance material in industrial instrumentation. It has the advantage that it is highly resistant to corrosion, is relatively easy to work (especially in wire manufacture), is available in a very pure state and exhibits good reproducibility of its electrical properties. To ensure universal interchangeability, these properties are defined in the EN 60 751 standard.

The electrical resistance and the permissible tolerances with varying temperatures are laid down in this standard.

Additional definitions cover the nominal value of the temperature sensor and the temperature range. The calculation distinguishes between the temperature ranges -200 to 0°C and 0 to 850°C.

The range -200 to 0°C is covered by a third-order polynomial:

$$R(t) = R_0(1 + A \times t + B \times t^2 + C \times (t - 100°C) \times t^3)$$

A second-order polynomial applies to the range 0 to 850°C.

$$R(t) = R_0(1 + A \times t + B \times t^2)$$

The coefficients have the values below:

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

The term R_0 is referred to as the **nominal value** and represents the resistance at 0°C.

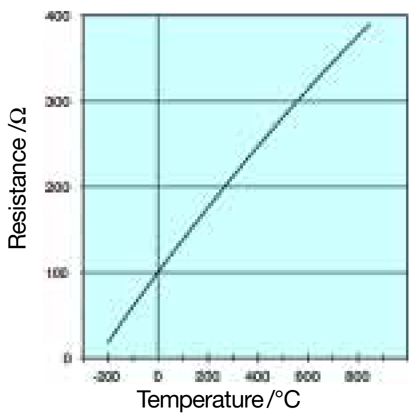

Fig. 1: Pt100 characteristic

According to EN 60 751, the nominal value is 100.000Ω at 0°C. We therefore refer to it as a Pt100 temperature sensor.

Temperature sensors with nominal values of 500 and 1000Ω are also available. Their advantage lies in their higher sensitivity, which means that their resistance varies more strongly with temperature.

The resistance change in the temperature range up to 100°C is approximately:
0.4Ω/°C for Pt100 temperature sensors
2.0Ω/°C for Pt500 temperature sensors
4.0Ω/°C for Pt1000 temperature sensors

As an additional parameter, the standard defines a mean temperature coefficient between 0°C and 100°C. It represents the average change in resistance, referred to the nominal value at 0°C:

$$\alpha = \frac{R_{100} - R_0}{R_0 \times 100°C} = 3.850 \times 10^{-3} °C^{-1}$$

R_0 or R_{100} are the resistance values for the temperatures 0°C or 100°C.

Calculating the temperature from the resistance

In its application as a thermometer, the resistance of the temperature sensor is used to calculate the corresponding temperature. The formulae above represent the variation of the electrical resistance with temperature.

For temperatures above 0°C it is possible to derive an explicit expression from the characteristic according to EN 60 751:

$$t = \frac{-R_0 \times A + [(R_0 \times A)^2 - 4 \times R_0 \times B \times (R_0 - R)]^{1/2}}{2 \times R_0 \times B}$$

R = measured resistance in Ω
t = calculated temperature in °C
R_0, A, B = parameters to EN 60 751

Tolerances

The standard distinguishes between two tolerance classes:

Class A: Δt = ± (0.15 + 0.002 x ltl)
Class B: Δt = ± (0.30 + 0.005 x ltl)

t = temperature in °C (without sign)

The formula for calculating the tolerance ΔR in Ω at a temperature t > 0°C is:

$$\Delta R = R_0(A + 2 \times B \times t) \times \Delta t$$

For t < 0°C:

$$\Delta R = R_0(A + 2 \times B \times t - 300°C \times C \times t^2 + 4 \times C \times t^3) \times \Delta t$$

The tolerance class A applies to temperatures from -200 to +600°C.

Tolerance class B covers the entire definition range of -200 to +850°C.

Extended tolerance classes

It is frequently found that the two tolerance classes cited in the standard do not sufficiently cover particular requirements. Based on the standard tolerances, **JUMO** has defined additional classes in order to meet the most variegated market requirements.

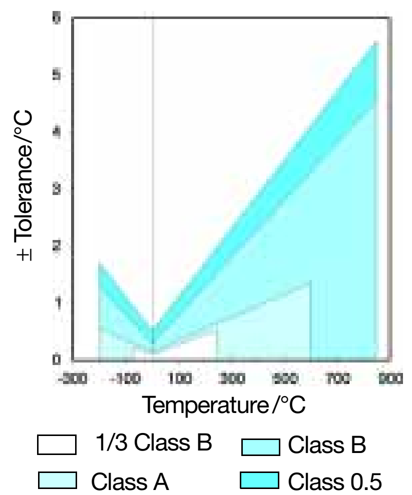

Fig. 2: Tolerance variation at different temperatures

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Tolerance class	Temperature range	Tolerance in °C	Tolerance at	
			t = 0°C	t = 100°C
1/3 Class B	- 70 to +250°C	± (0.10 °C + 0.0017 x Itl)	± 0.10°C	± 0.27°C
Class A	-200 to +600°C	± (0.15°C + 0.0020 x Itl)	± 0.15°C	± 0.35°C
Class B	-200 to +850°C	± (0.30°C + 0.0050 x Itl)	± 0.30°C	± 0.80°C
Class 0.5	-200 to +850°C	± (0.50°C + 0.0060 x Itl)	± 0.50°C	± 1.10°C

Table 1: Tolerance classes

Itl = temperature in °C without sign

Construction

Essentially, there are two different styles: wire temperature sensors in glass, ceramic or foil, and thin-film temperature sensors.

Platinum-glass temperature sensors Type PG

This style incorporates two platinum wires that are wound on a glass carrier to form a bifilar winding (two wires in a loop). The winding is fused into the glass and provided with connecting wires.

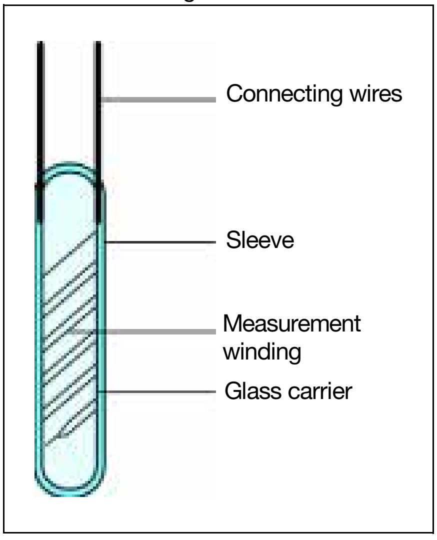

Fig. 3: Construction of platinum-glass temperature sensors

After the platinum winding has been calibrated, a sleeve is pushed over the glass carrier and both are then fused together, which firmly seals in the winding. The platinum wire used has a diameter of 17 to 30µm, depending on the style. The glass is accurately matched to the expansion coefficient of the platinum wire.

The dimensions of the sensor can vary in length from 8 to 55mm and in diameter from 0.9 to 4.9mm.

In addition to the versions with a nominal value of 100Ω, temperature sensors with 500 and 1000Ω are also available. Temperature sensors of this construction are resistant to shock and vibration and can, thanks to their excellent chemical resistance, be used directly in the medium. Styles with a glass extension and twin measurement windings can also be supplied. The operating temperature covers the range from -200 to +400°C.

Laboratory resistance thermometers

A glass tube is fused to the end of a platinum-glass temperature sensor PGL series. The end of the glass tube can be finished to suit a particular application and can additionally be provided with a ground joint.

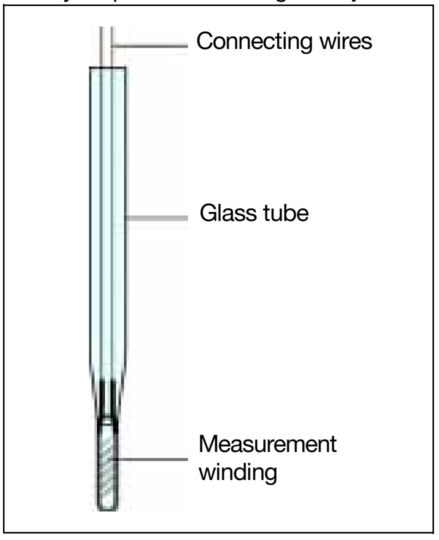

Fig. 4: Construction of platinum-glass temperature sensors with glass tube

The electrical connection of the resistance thermometer is made via a connector system (e.g. LEMOSA), or directly through the connecting wires in 2-wire, 3-wire or 4-wire circuit. The laboratory resistance thermometer can be built into a metal protection tube to protect the glass tube and the sensor from mechanical damage. The protection tube is perforated in the region of the temperature sensor, to ensure the direct contact between the sensor and the medium.

Platinum-ceramic temperature sensors Type PK

A ceramic tube has either two or four bores; a calibrated platinum coil with connecting wires is inserted into each of these bores. They are filled with alumina powder to fix the winding and to improve the heat transfer. After calibration, the two ends of the ceramic body are closed with glass seals, which also secure the connecting wires in position.

The diameter of this temperature sensor style ranges from 0.9 to 4.9mm, its overall length from 6 to 30mm.

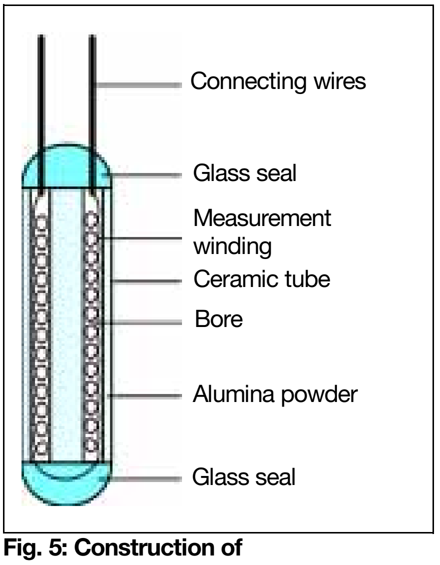

Fig. 5: Construction of platinum-ceramic temperature sensors

The internal construction of these temperature sensors prevents permanent changes in resistance, which may occur in other styles due to strong temperature fluctuations or shock-like temperature changes. In a dry environment, these sensors can also be used without a protective fitting.

The operating temperature ranges from - 200 to +800°C.

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Platinum-foil temperature sensors Type PF

This foil temperature sensor incorporates a platinum measurement winding which is embedded between two polyimide foils. Two nickel tapes are taken out to form the connections. The temperature sensor has a small thickness of only about 0.3mm. It is mainly used for temperature measurement on flat or curved surfaces.

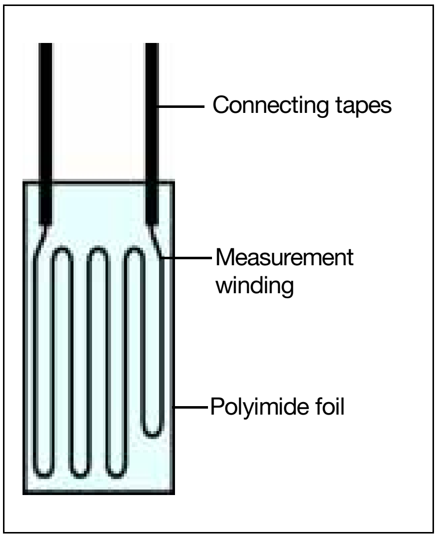

Fig. 6: Construction of platinum-foil temperature sensors

Thanks to its low intrinsic mass and its relatively large surface area, this flexible temperature sensor achieves a fast response with measurements on pipes, radiators and tools, for example. The operating temperature ranges from -80 to +180°C.

Platinum-chip temperature sensors Type PCA with connecting wires

In these temperature sensors, the active part is a platinum layer of zig-zag shape, which is placed on a ceramic substrate and provided with metal connecting wires. The track structure is covered with a glass layer as a protection against external effects, and for insulation. The operating temperatures depend on the particular version and range from -50 to +600°C. Dimensions from 2.0 x 2.5mm up to 2.0 x 10mm are possible. Excellent response is ensured by its small size and low mass. Compared with glass and ceramic temperature sensors, high nominal values up to 1000Ω can be produced, combined with extremely small size.

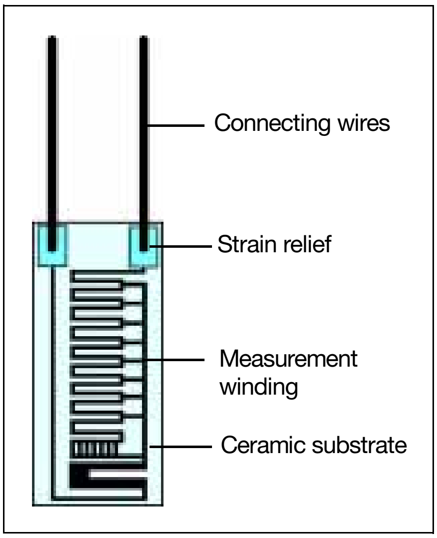

Fig. 7: Construction of platinum-chip temperature sensors with connecting wires

Thin-film temperature sensors combine the favorable properties of a platinum sensor, such as interchangeability, long-term stability, reproducibility and large temperature range, with the advantages of large-scale manufacture.

Platinum-chip temperature sensors Type PCR in cylindrical style

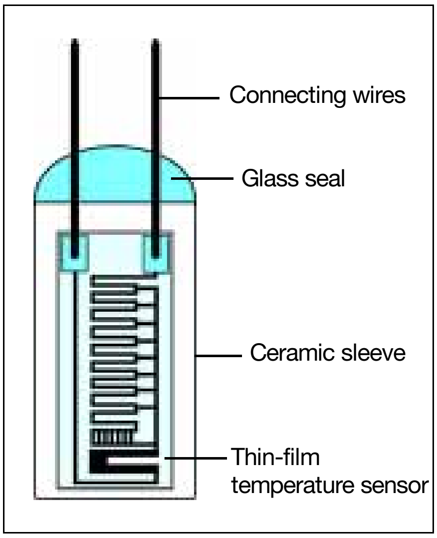

Fig. 8: Construction of platinum-chip temperature sensors in cylindrical style

A platinum-chip temperature sensor is inserted in a ceramic sleeve open at one end, which is then hermetically sealed with a glass seal. Platinum-chip temperature sensors in cylindrical style can be readily fitted into protection tubes and are largely insensitive to shock and vibration. The ceramic sleeve also protects the temperature sensor from external effects and provides high mechanical strength. Cylindrical-style temperature sensors are a low-cost alternative to wire-wound styles. The temperature range covers -50 to +300°C.

Platinum-chip temperature sensors Type PCS, SMD style

Like other SMD components, the platinum SMD temperature sensor has solder connections at both ends. The size 1206 [3216] and the electro-tinned wrap-around contact ensure insertion-friendly use on circuit boards.

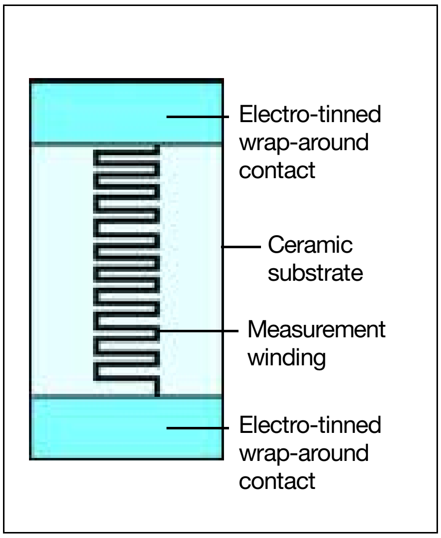

Fig. 9: Construction of platinum-chip temperature sensors, SMD style

Compared to styles incorporating connecting wires, the SMD temperature sensor is particularly rugged and intended essentially for automatic insertion in large-scale production. Its favorable characteristics as a platinum temperature sensor, such as standard nominal values of 100 or 500Ω to EN specification, high long-term stability, interchangeability without recalibration and excellent reproducibility of the electrical properties, ensure universal application. It is used for surface and environmental temperature measurement on circuit boards, as well as for temperature compensation.

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Notes on application

Measurement details

All temperature sensor are tested before shipment and selected according to tolerance class. During these measurements, the temperature sensors, including the connecting wires, are at the particular test temperature. Contact with the connecting wires is made 2 mm from the open end of the wires, using a 4-wire circuit. If temperature sensors are fabricated further, it must be noted that, when using 2-wire circuit, any change in the length of the connecting wires will alter the electrical resistance. In a few cases, this may lead to the device falling outside the tolerance limits.

Self-heating

The output signal of a temperature sensor can only be measured by passing a current through the sensor. This measurement current produces a power loss and therefore heats up the sensor, which results in an increased temperature indication. Self-heating depends on various factors, including the extent to which the heat generated can be dissipated via the medium to be measured.

Because of the relationship for electrical power, $P = R \cdot I^2$, the effect also depends on the nominal resistance of the temperature sensor: for the same measurement current, a Pt1000 temperature sensor heats up 10 times as much as a Pt100.

The advantage of a higher sensitivity is therefore counterbalanced by an increase in self-heating. If one permits a temperature increase of 0.1°C in flowing water, the current for wire-wound ceramic temperature sensors varies between 3 and 50mA, depending on the size; it is about 1mA in the case of thin-film sensors.

In stationary air, the permissible current is reduced by a factor of about 50. Since the temperature sensors are usually built into protective fittings, the self-heating effect is modified. The permitted current lies roughly between the extreme values mentioned above, depending on the heat transfer, thermal conduction and thermal capacity of the fitting.

Thermometer manufacturers often specify a self-heat coefficient that is a measure for the temperature increase through a defined power loss in the sensor. Such calorimetric measurements are carried out under defined conditions (in water at $0.5 m / sec^{-1}$, in air at $2 m / sec^{-1}$); however, the information is rather theoretical and serves only as a comparison between the different designs. In most cases, the measurement current is set to 1mA by the instrument manufacturer, since this value is considered to be practically useful and produces no appreciable self-heating.

For example, if a Pt100 temperature sensor is put in a closed and fully insulated container with $10 cm^3$ air, this measurement current of 1 milliampere will increase the air temperature by 39°C after one hour.
With flowing gases or liquids, the effect is less pronounced, because of the much greater heat dissipation.

Because of the differences in measurement conditions, the self-heating effect has to be measured on site. The temperature is measured at varying currents. The self-heat coefficient E is given by:

$$E = \Delta t / (R \times I^2)$$

where Δt = (indicated temperature) - (temperature of the medium), R = resistance of the temperature sensor, I = measurement current

The self-heat coefficient can be used to determine the maximum current if an error Δt is permitted.

$$I = (\Delta t / E \times R)^{1/2}$$

Sensor response

If a sensor is subjected to a sudden change in temperature, then a certain amount of time will pass before it has accepted the new temperature. This time depends on the construction of the sensor and the local conditions, such as flow velocity and medium. The specifications in this catalogue are based on measurements in circulating water with a flow velocity of 0.4m/sec. The response times for other media can be determined by using the heat transfer coefficient to VDI/VDE 3522. Diagram 10 shows the typical shape of the response curve (transfer function).
It serves to determine the times when the sensor has reached 50 or 90% of the end value.

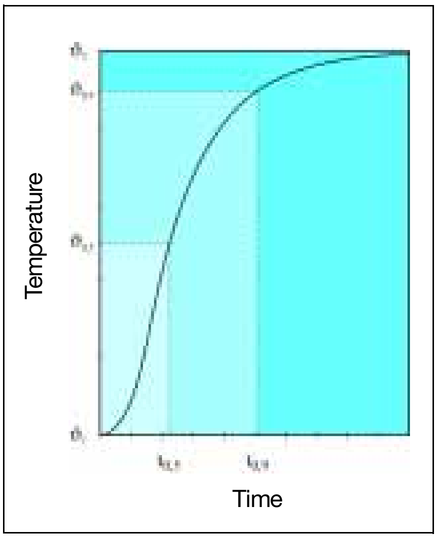

Fig. 10: Transfer function

The transfer function, i.e. the variations of the measurement following a step change in temperature at the temperature sensor, provides the necessary information.

To determine the transfer function, the temperature sensor is exposed to a flow of warm water or air.
Two times (settling times) characterize the transfer function:

- **Half-value time $t_{0.5}$**
  It indicates the time taken by the measurement to reach 50% of the final value, and the
- **90% time $t_{0.9}$**
  when 90% of the final value has been reached.

A time τ, which is required to reach 63.2% of the final value, is not given because of possible confusion with the time constant of an exponential function. The heat transfer function of virtually all temperature sensors deviates markedly from such a function.

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Reference values to EN 60 751 (ITS 90)

in Ohm for Pt100 temperature sensors in 1°C steps

°C	-0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-200	18.520	-	-	-	-	-	-	-	-	-
-190	22.825	22.397	21.967	21.538	21.108	20.677	20.247	19.815	19.384	18.952
-180	27.096	26.671	26.245	25.819	25.392	24.965	24.538	24.110	23.682	23.254
-170	31.335	30.913	30.490	30.067	29.643	29.220	28.796	28.371	27.947	27.552
-160	35.543	35.124	34.704	34.284	33.864	33.443	33.022	32.601	32.179	31.757
-150	39.723	39.306	38.889	38.472	38.055	37.637	37.219	36.800	36.382	35.963
-140	43.876	43.462	43.048	42.633	42.218	41.803	41.388	40.972	40.556	40.140
-130	48.005	47.593	47.181	46.769	46.356	45.944	45.531	45.117	44.704	44.290
-120	52.110	51.700	51.291	50.881	50.470	50.060	49.649	49.239	48.828	48.416
-110	56.193	55.786	55.378	54.970	54.562	54.154	53.746	53.337	52.928	52.519
-100	60.256	59.850	59.445	59.039	58.633	58.227	57.821	57.414	57.007	56.600
- 90	64.300	63.896	63.492	63.088	62.684	62.280	61.876	61.471	61.066	60.661
- 80	68.325	67.924	67.552	67.120	66.717	66.315	65.912	65.509	65.106	64.703
- 70	72.335	71.934	71.534	71.134	70.733	70.332	69.931	69.530	69.129	68.727
- 60	76.328	75.929	75.530	75.131	74.732	74.333	73.934	73.534	73.134	72.735
- 50	80.306	79.909	79.512	79.114	78.717	78.319	77.921	77.523	77.125	76.726
- 40	84.271	83.875	83.479	82.083	82.687	82.290	81.894	81.497	81.100	80.703
- 30	88.222	87.827	87.432	87.038	86.643	86.248	85.853	85.457	85.062	84.666
- 20	92.160	91.767	91.373	90.980	90.586	90.192	89.798	89.404	89.010	88.616
- 10	96.086	95.694	95.302	94.909	94.517	94.124	93.732	93.339	92.946	92.553
0	100.000	99.609	99.218	98.827	98.436	98.044	97.653	97.261	96.870	96.478

°C	0	1	2	3	4	5	6	7	8	9
0	100.000	100.391	100.781	101.172	101.562	101.953	102.343	102.733	103.123	103.513
10	103.903	104.292	104.682	105.071	105.460	105.849	106.238	106.627	107.016	107.405
20	107.794	108.182	108.570	108.959	109.347	109.735	110.123	110.510	110.898	111.286
30	111.673	112.060	112.447	112.835	113.221	113.608	113.995	114.382	114.768	115.155
40	115.541	115.927	116.313	116.699	117.085	117.470	117.856	118.241	118.627	119.012
50	119.397	119.782	120.167	120.552	120.936	121.321	121.705	122.090	122.474	122.858
60	123.242	123.626	124.009	124.393	124.777	125.160	125.543	125.926	126.309	126.692
70	127.075	127.458	127.840	128.223	128.605	128.987	129.370	129.752	130.133	130.515
80	130.897	131.278	131.660	132.041	132.422	132.803	133.184	133.565	133.946	134.326
90	134.707	135.087	135.468	135.848	136.228	136.608	136.987	137.367	137.747	138.126
100	138.506	138.885	139.264	139.643	140.022	140.400	140.779	141.158	141.536	141.914
110	142.293	142.671	143.049	143.426	143.804	144.182	144.559	144.937	145.314	145.691
120	146.068	146.445	146.822	147.198	147.575	147.951	148.328	148.704	149.080	149.456
130	149.832	150.208	150.583	150.959	151.334	151.710	152.085	152.460	152.865	153.210
140	153.584	153.959	154.333	154.708	155.082	155.456	155.830	156.204	156.578	156.952
150	157.325	157.699	158.072	158.445	158.818	159.191	159.564	159.937	160.309	160.682
160	161.054	161.427	161.799	162.171	162.543	162.915	163.286	163.658	164.030	164.401
170	164.772	165.143	165.514	165.885	166.256	166.627	166.997	167.368	167.738	168.108
180	168.478	168.848	169.218	169.588	169.958	170.327	170.696	171.066	171.435	171.804
190	172.173	172.542	172.910	173.279	173.648	174.016	174.384	174.752	175.120	175.488
200	175.856	176.224	176.591	176.959	177.326	177.693	178.060	178.427	178.794	179.161
210	179.528	179.894	180.260	180.627	180.993	181.359	181.725	182.091	182.456	182.822
220	183.188	183.553	183.918	184.283	184.648	185.013	185.378	185.743	186.107	186.472
230	186.836	187.200	187.564	187.928	188.292	188.656	189.019	189.383	189.746	190.110
240	190.473	190.836	191.199	191.562	191.924	192.287	192.649	193.012	193.374	193.736
250	194.098	194.460	194.822	195.183	195.545	195.906	196.268	196.629	196.990	197.351
260	197.712	198.073	198.433	198.794	199.154	199.514	199.875	200.235	200.595	200.954
270	201.314	201.674	202.033	202.393	202.752	203.111	203.470	203.829	204.188	204.546
280	204.905	205.263	205.622	205.980	206.338	206.696	207.054	207.411	207.769	208.127
290	208.484	208.841	209.198	209.555	209.912	210.269	210.626	210.982	211.339	211.695
300	212.052	212.408	212.764	213.120	213.475	213.831	214.187	214.542	214.897	215.252

The reference values have been calculated according to the International Temperature Scale ITS 90.
(For Pt500 or Pt1000 temperature sensors, the reference values have to be multiplied by 5 or 10 respectively).

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Reference values to EN 60 751 (ITS 90)

in Ohm for Pt100 temperature sensors in 1°C steps

°C	0	1	2	3	4	5	6	7	8	9
310	215.608	215.962	216.317	216.672	217.027	217.381	217.736	218.090	218.444	218.798
320	219.152	219.506	219.860	220.213	220.567	220.920	221.273	221.626	221.979	222.332
330	222.685	223.038	223.390	223.743	224.095	224.447	224.799	225.151	225.503	225.855
340	226.206	226.558	226.909	227.260	227.612	227.963	228.314	228.664	229.015	229.366
350	229.716	230.066	230.417	230.767	231.117	231.467	231.816	232.166	232.516	232.865
360	233.214	233.564	233.913	234.262	234.610	234.959	235.308	235.656	236.005	236.353
370	236.701	237.049	237.397	237.745	238.093	238.440	238.788	239.135	239.482	239.829
380	240.176	240.523	240.870	241.217	241.563	241.910	242.256	242.602	242.948	243.294
390	243.640	243.986	244.331	244.677	245.022	245.367	245.713	246.058	246.403	246.747
400	247.092	247.437	247.781	248.125	248.470	248.814	249.158	249.502	249.845	250.189
410	250.533	250.876	251.219	251.562	251.906	252.248	252.591	252.934	253.277	253.619
420	253.962	254.304	254.646	254.988	255.330	255.672	256.013	256.355	256.696	257.038
430	257.379	257.720	258.061	258.402	258.743	259.083	259.424	259.764	260.105	260.445
440	260.785	261.125	261.465	261.804	262.144	262.483	262.823	263.162	263.501	263.840
450	264.179	264.518	264.857	265.195	265.534	265.872	266.210	266.548	266.886	267.224
460	267.562	267.900	268.237	268.574	268.912	269.249	269.586	269.923	270.260	270.597
470	270.933	271.270	271.606	271.942	272.278	272.614	272.950	273.286	273.622	273.957
480	274.293	274.628	274.963	275.298	275.633	275.968	276.303	276.638	276.972	277.307
490	277.641	277.975	278.309	278.643	278.977	279.311	279.644	279.978	280.311	280.644
500	280.978	281.311	281.643	281.976	282.309	282.641	282.974	283.306	283.638	283.971
510	284.303	284.634	284.966	285.298	285.629	285.961	286.292	286.623	286.954	287.285
520	287.616	287.947	288.277	288.608	288.938	289.268	289.599	289.929	290.258	290.588
530	290.918	291.247	291.577	291.906	292.235	292.565	292.894	293.222	293.551	293.880
540	294.208	294.537	294.865	295.193	295.521	295.849	296.177	296.505	296.832	297.160
550	297.487	297.814	298.142	298.469	298.795	299.122	299.449	299.775	300.102	300.428
560	300.754	301.080	301.406	301.732	302.058	302.384	302.709	303.035	303.360	303.685
570	304.010	304.335	304.660	304.985	305.309	305.634	305.958	306.282	306.606	306.930
580	307.254	307.578	307.902	308.225	308.549	308.872	309.195	309.518	309.841	310.164
590	310.487	310.810	311.132	311.454	311.777	312.099	312.421	312.743	313.065	313.386
600	313.708	314.029	314.351	314.672	314.993	315.314	315.635	315.956	316.277	316.597
610	316.918	317.238	317.558	317.878	318.198	318.518	318.838	319.157	319.477	319.796
620	320.116	320.435	320.754	321.073	321.391	321.710	322.029	322.347	322.666	322.984
630	323.302	323.620	323.938	324.256	324.573	324.891	325.208	325.526	325.843	326.160
640	326.477	326.794	327.110	327.427	327.744	328.060	328.376	328.692	329.008	329.324
650	329.640	329.956	330.271	330.587	330.902	331.217	331.533	331.848	332.162	332.477
660	332.792	333.106	333.421	333.735	334.049	334.363	334.677	334.991	335.305	335.619
670	335.932	336.246	336.559	336.872	337.185	337.498	337.811	338.123	338.436	338.748
680	339.061	339.373	339.685	339.997	340.309	340.621	340.932	341.244	341.555	341.867
690	342.178	342.489	342.800	343.111	343.422	343.732	344.043	344.353	344.663	344.973
700	345.284	345.593	345.903	346.213	346.522	346.832	347.141	347.451	347.760	348.069
710	348.378	348.686	348.995	349.303	349.612	349.920	350.228	350.536	350.844	351.152
720	351.460	351.768	352.075	352.382	352.690	352.997	353.304	353.611	353.918	354.224
730	354.531	354.837	355.144	355.450	355.756	256.062	356.368	356.674	356.979	357.285
740	357.590	357.896	358.201	358.506	358.811	359.116	359.420	359.725	360.029	360.334
750	360.638	360.942	361.246	361.550	361.854	362.158	362.461	362.765	363.068	363.371
760	363.674	363.977	364.280	364.583	364.886	365.188	365.491	365.793	366.095	366.397
770	366.699	367.001	367.303	367.604	367.906	368.207	368.508	368.810	369.111	369.412
780	369.712	370.013	370.314	370.614	370.914	371.215	371.515	371.815	372.115	372.414
790	372.714	373.013	373.313	373.612	373.911	374.210	374.509	374.808	375.107	375.406
800	375.704	376.002	376.301	376.599	376.897	377.195	377.493	377.790	378.088	378.385
810	378.683	378.980	379.277	379.574	379.871	380.167	380.464	380.761	381.057	381.353
820	381.650	381.946	382.242	382.537	382.833	383.129	383.424	383.720	384.015	384.310
830	384.605	384.900	385.195	385.489	385.784	386.078	386.373	386.667	386.961	387.255
840	387.549	387.843	388.136	388.430	388.723	389.016	389.310	389.603	389.896	390.188
850	390.481	-	-	-	-	-	-	-	-	-

The reference values have been calculated according to the International Temperature Scale ITS 90.
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Electrical Temperature Measurement

with Thermocouples and Resistance Thermometers

D. Weber and M. Nau

Electrical temperature sensors have become indispensable components in modern automation, domestic engineering and production technology. As a result of the rapid expansion of automation during recent years, they have become firmly established in industrial engineering.

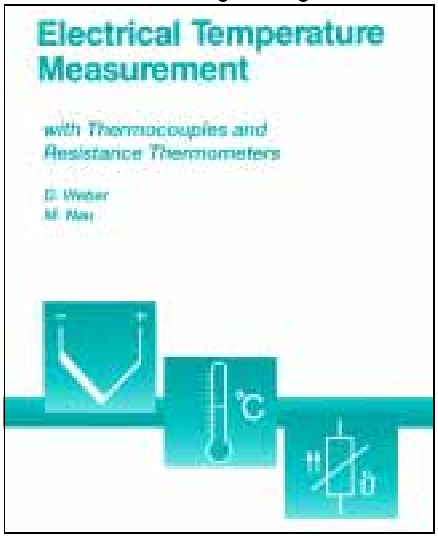

Fig. 11: Publication
Electrical Temperature Measurement with Thermocouples and Resistance Thermometers

In view of this large spectrum of products available for temperature measurement, it is becoming ever more important for the user to select the one suitable for his application.

On 128 pages this publication deals with the theoretical fundamentals of electrical temperature measurement, the practical construction of temperature sensors, their standardization, electrical connection and types of construction.

In addition, it describes in detail the different fittings for electrical thermometers, their classification according to DIN standards, and the great variety of applications. An extensive section of tables for voltage and resistance series according to DIN and EN makes this book a valuable guide, both for the experienced practical engineer and for the novice in the field of electrical temperature measurement.

To be ordered under Sales No. 90/00085081, price 15 DM net.
Schools, institutes and universities are asked to make bulk orders, because of the high handling costs.

Control Engineering

A guide for beginners

F. Blasinger

On 137 pages this publication covers the essential principles of measurement and control engineering. It offers the reader an opportunity to become familiar with the different types and applications of electronic controllers, assists in selecting the one most suitable for a particular application from the large number of different models, and ensures that it is adjusted correctly.

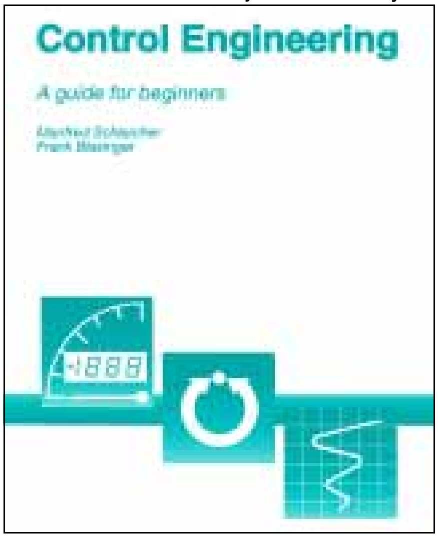

Fig. 12: Publication
Control Engineering

Mathematics has been avoided where possible, and the emphasis has been placed on practical control principles.

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German Calibration Service (DKD) at JUCHHEIM

Certification laboratory for temperature

Raised quality expectations, improved measurement technology and, of course, quality assurance systems, such as ISO 9000, make increasing demands on the documentation of processes and the monitoring of measuring devices.
In addition, there are increasing calls from customers for high product quality standards. Particularly stringent demands arise from the ISO 9001/9004 standard “Test devices monitoring”. This provides the legal basis for obliging suppliers and manufacturers (of products that are subject to processes where temperature is relevant) to check testing devices which can affect the product quality, before use or at certain intervals. Generally, this is done by calibrating or adjusting with certified devices. Because of the high demand for calibrated instruments and the large number of instruments to be calibrated, the state laboratories have insufficient capacity. The industry has therefore established and supports special calibration laboratories which are linked to the German Calibration Service (DKD) and subordinate to the Physikalisch-Technische-Bundesanstalt (PTB).

The certification laboratory of the German Calibration Service at JUMO has carried out calibration certification for temperature since 1992. This service provides fast and economical certification for everyone.
DKD calibration certificates can be issued for resistance thermometers, thermocouples, measurement sets, data loggers and temperature block calibrators within the range -80 to +1100°C. The traceability of the reference standard is the central issue here. All DKD calibration certificates are recognized as documents of traceability, without any further specifications. In addition, calibrated precision platinum resistance thermometers or complete measurement sets with indicator in a service case can be obtained.