The most accurate way to measure temperature in the range -259 to 962EC is with platinum wire transducers. The change of resistance with temperature is measured. There is a great number of different models dependent on field of application. Mostly the resistance at 0 EC is 100 ohm (Pt100), but for reference applications 25 ohm is common. There are also higher resistances, and when platinum film is used, 1000 ohm is not unusual.

The wire is usually potted in ceramics or glass. However the potting material contributes to permanent resistance change or hysteresis, when the transducer is temperature cycled. In 25 ohm reference transducer, where the wire is free, the stability is much better, but the transducer is also extremely sensitive to vibration, impacts and blows. The oxidizing air around the wire also improves the stability. Unisystem use Pt100 elements from TDI (Thermal Developments International Ltd) in England. They have an affixing system, which partially supports the wire, and this is a excellent compromise. It can withstand vibration up to 30 g.
Big size of the element means low self heating due to the measuring current, but it also means slow response. The medium size has the lowest prize.

In most European standards, the change of resistance between 0 and 100 EC was 1.3850 times. The new standard IEC 751 has 1.385055. In USA and Japan the value 1.3916 is used. This corresponds to a more pure metal. The new International Temperature Scale from 1990, ITS-90, uses 1.39283 for high purity reference transducers. These are very expensive, minimum 0.5 m long in order to decrease the influence from external temperature. This and extreme sensitivity to mechanical handling make them very impractical to use.

The resistance R of the Pt temperature resistor is assumed to follow:

$$\mathbf{R = R_0(1 + AT + BT^2 + CT^3(T - 100))}.$$

R_0 for Pt100 is 100 ohm. T is the temperature in EC. A, B and C are constants.
According to IEC 751: A = 3.90830×10^{-3}. B = -5.775×10^{-7}. C = 0 for T > 0 EC else -4.183×10^{-12}.

The tolerance at 0 EC of the resistance, 100 ohm, is often given as a ratio of the DIN43760 tolerance 0,12%. Thus e.g. DIN/5 is 0.02%, 0.02 ohm or 0.05 EC. Down to DIN/10 is normally available. TDI specifies the tolerance of A, or change between 0 and 100 EC, within 3 ppm (ppm = 10^{-6}).

Theoretically for our DIN/N transducers thus the accuracy is $(0.3 + T \times 1.2 \times 10^{-3})/N + T \times 0.8 \times 10^{-3}$ EC. However big temperature change adds a hysteresis, which decreases the accuracy.

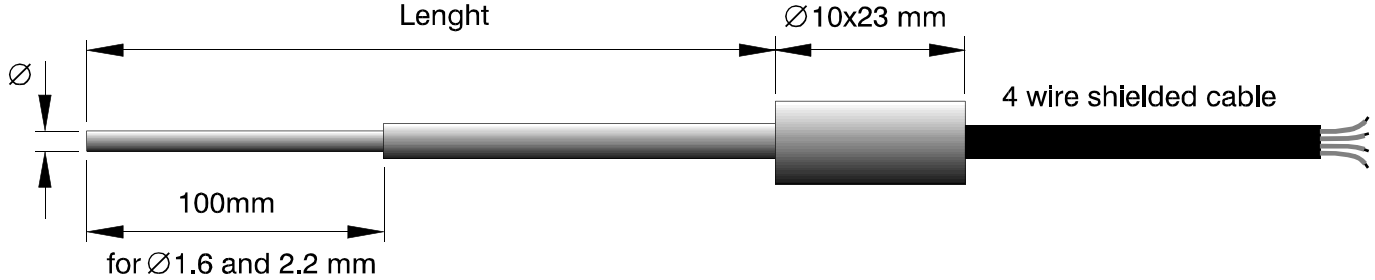
At delivery our temperature meters have been calibrated with precision resistors according to the formula above, and in this case DIN/5 or DIN/10 transducers are suitable to use.

When our U241 series are calibrated with temperature, A, B and the resistance R_0 are calculated and stored. In this case our transducers with the lowest accuracy may be used. C may be changed, but this is hardly necessary.

Standard transducers.

UNI No	Diameter	Length	Wall thickness	Sensing length	Tolerance DIN	Tolerance %
U24410	1.6 mm	200 mm	0.25 mm	12 mm	1/5	0.02 %
U24411	1.6 mm	200 mm	0.25 mm	12 mm	1	0.1 %
U24400	2.2 mm	200 mm	0.25 mm	6 mm	1/5	0.02 %
U24401	2.2 mm	200 mm	0.25 mm	6 mm	1	0.1 %
U14140	3 mm	300 mm	0.5 mm	12 mm	1/5	0.02 %
U14141	3 mm	300 mm	0.5 mm	12 mm	1	0.1 %

Temperature range: -100 to 250 EC.
The resistance in mohm at the melting point of ice, 0 EC with ±0.02 EC accuracy, is specified in a protocol.
The shielded 4 wire cable has the shield connected to the housing of the transducer. Cable length 2m.
We also supply other sizes and special designs with extended temperature range.



Calibration.

Calibration with temperature can be supplied from SP (Swedish National Testing and Research Institute).

As standard, calibration is performed in 3 points with 2 more check points. Further check points can be measured. The price for calibrating more transducers at the same time is very favorable.

There are two levels of reference temperature accuracy, 5 mK or 10 mK (milli Kelvin).

Before the calibration, is it advisable to pre-age the transducer by temperature cycling.

In order to easily and regularly check the stability of the Pt100 transducer, we recommend another one or more calibrated reference transducers, as the cost for this is comparatively low. Then comparisons can be made. A reason for this is, that it seems impossible to get information of or guarantee for the long time stability from the manufacturers. They probably will allege improper mechanical handling or excessive temperature cycling as reason for instability. The reference transducer must be handled very carefully.

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The stability of the instrument can be checked with a high stability resistor. With help of the min and max functions, the deviation can be checked during a longer period.

Unisystem supplies resistors mounted in the standard D-sub connector. The corresponding temperature, according to the proposed formula above, is noted in mK. The long term stability of the resistor is <5 ppm during the first year and within 10 ppm during the next three years, with proper care. The resistance temperature change is <0.3 ppm/EC. 4 ppm corresponds to 1 mK at 100 ohm (0 EC). The standard resistances are 100, 125 and 150 ohm with Unisystem numbers U2426, U2427 and U2428 respectively.

Thermoelectric voltage is created between different metals at different temperature. In order to avoid this influence, AC current is used for the measurement. However this increases the price and decreases the accuracy. In U241 series DC current is used, and proper layout has decreased the thermovoltage below measurable levels and certainly below 0.3µV or 1mK. Well designed Pt100 transducers have similar low thermovoltages. In order to test these, the polarities of the measurement current and signal are switched, and if then the instrument display changes, this corresponds to twice the thermovoltage.

Unisystem can supply such a switch in a well shielded box with standard connectors.

The resistance for industrial Pt-100 transducers according to IEC 751.

-100 EC	-EC	±EC	+EC	+100 EC	+200 EC	+300 EC	+400 EC	+500 EC	+600 EC	+700 EC	+800 EC
60.2558	100.0000	0	100.0000	138.5055	175.8560	212.0515	247.0920	280.9775	313.7080	345.2835	375.7040
56.1930	96.0859	10	103.9025	142.2925	179.5275	215.6075	250.5325	284.3025	316.9175	348.3775	378.6825
52.1098	92.1599	20	107.7935	146.0680	183.1875	219.1520	253.9615	287.6160	320.1155	351.4600	381.6495
48.0048	88.2217	30	111.6729	149.8319	186.8359	222.6849	257.3789	290.9179	323.3019	354.5309	384.6049
43.8764	84.2707	40	115.5408	153.5843	190.4728	226.2063	260.7848	294.2083	326.4768	357.5903	387.5488
39.7232	80.3063	50	119.3971	157.3251	194.0981	229.7161	264.1791	297.4871	329.6401	360.6381	390.4811
35.5433	76.3278	60	123.2419	161.0544	197.7119	233.2144	267.5619	300.7544	332.7919	363.6744	393.4019
31.3350	72.3345	70	127.0751	164.7721	201.3141	236.7011	270.9331	304.0101	335.9321	366.6991	396.3111
27.0964	68.3254	80	130.8968	168.4783	204.9048	240.1763	274.2928	307.2543	339.0608	369.7123	399.2088
22.8255	64.2996	90	134.7069	172.1729	208.4839	243.6399	277.6409	310.4869	342.1779	372.7139	402.0949
18.5201	60.2558	100	138.5055	175.8560	212.0515	247.0920	280.9775	313.7080	345.2835	375.7040	404.9695

The resistance for high purity Pt-100 reference transducers according to ITS-90. Normally Pt-25 is used.

-100 EC	-EC	±EC	+EC	+100 EC	+200 EC	+300 EC	+400 EC	+500 EC	+600 EC	+700 EC	+800 EC
59.4541	99.9960	0	99.9960	139.2773	177.3663	214.2840	250.0441	284.6397	318.0425	350.2195	381.1566
55.3145	96.0014	10	103.9785	143.1395	181.1105	217.9120	253.5564	288.0342	321.3158	353.3690	384.1825
51.1547	91.9946	20	107.9488	146.9898	184.8429	221.5285	257.0570	291.4168	324.5768	356.5060	387.1963
46.9723	87.9754	30	111.9069	150.8282	188.5637	225.1334	260.5460	294.7874	327.8255	359.6306	390.1978
42.7648	83.9436	40	115.8530	154.6548	192.2729	228.7268	264.0233	298.1459	331.0618	362.7428	393.1873
38.5295	79.8986	50	119.7871	158.4695	195.9704	232.3086	267.4889	301.4924	334.2858	365.8427	396.1647
34.2638	75.8400	60	123.7091	162.2724	199.6563	235.8789	270.9427	304.8268	337.4973	368.9301	399.1301
29.9670	71.7670	70	127.6191	166.0635	203.3306	239.4376	274.3847	308.1490	340.6965	372.0052	402.0836
25.6422	67.6790	80	131.5171	169.8429	206.9933	242.9847	277.8149	311.4590	343.8833	375.0679	405.0251
21.3013	63.5751	90	135.4032	173.6105	210.6445	246.5202	281.2332	314.7569	347.0576	378.1184	407.9548
16.9752	59.4541	100	139.2773	177.3663	214.2840	250.0441	284.6397	318.0425	350.2195	381.1566	410.8727

The table above is defined i the range -259,3467 to 0,01 EC by an exponential function of a logarithmic polynomial of 12th degree. I the range 0,01 EC to 961,78 EC a polynomial of 9th degree is used. 0 EC = 273,15 K

The functions satisfies the following fixed points. T = triple point. M = melting point. F = freezing point.

Substance	e-H_2 T	Ne T	O_2 T	Ar T	Hg T	H_2O T
Temp. EC	-259.3467	-248.5939	-218.7916	-189.3442	-38.8344	0.01
Pt-100	0.1190	0.8450	9.1718	21.5860	84.4142	100.0000

Substance	Ga M	In F	Sn F	Zn F	Al F	Ag F
Temp. EC	29.7646	156.5985	231.928	419.527	660.323	961.78
Pt-100	111.8139	160.9802	189.2798	256.8917	337.6009	428.6421

Calibration according to ITS-90.

The functions of ITS-90 are of course not satisfied by the 2nd degree function of U241 series temperature meters. The following table shows examples of calibration points and the maximum deviation in a range around these. The deviation is also given i four other points. It is given i mohm (*R). 0,4 mohm . 1 mK.

The temperatures with index E are some maximum ^{E} or minimum $_{E}$ in the deviation function.

Calibration points EC				Range EC	max ±*R	EC	*R	EC	*R	EC	*R	EC	*R
1	0	64	131	-10 to 142	0.4	-45	+0.5	-24_E	-0.7	155	1.2	190	5.1
2	-7	142	295	-99 to 320	4.7	-130	20.7	-110	-10.4	340	9.7	370	19.3
3	0	195	434	-34 to 632	10.2	-196	+9.9	-181_E	-27.7	-138^E	-5.9	-76_E	-17.1
4	170	260	470	157 to 482	0.8	60	-20.4	120	-5.0	510	-4.3	560	-18.0
5	0	-50	-102	-137 to +7	1.3	-160	-16.0	-145	-4.5	20	-5.0	+40	-13.8

Example 1 is suitable for U2413 with resolution of 0,001 EC and range from -45 to + 198 EC.
Example 2 and 3 may be used for U2411 with resolution of 0,01 EC.
Example 4 indicates that between 157 and 482 EC, ITS-90 is rather well satisfied by a 2nd degree function.
Example 5 indicates that the accuracy is acceptable for negative temperatures when the C-factor is considered.
The deviation increases rapidly with the calibration range.
Outside the calibration range, the deviation often increases rapidly.