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EUROPEAN STANDARD
NORME EUROPÉENNE
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December 2013

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Supersedes EN 60584-1:1995, EN 60584-2:1993

English version

**Thermocouples -
Part 1: EMF specifications and tolerances
(IEC 60584-1:2013)**

Couples thermoélectriques -
Partie 1: Spécifications et tolérances en
matière de FEM
(CEI 60584-1:2013)

Thermoelemente -
Teil 1: Thermospannungen und
Grenzabweichungen
(IEC 60584-1:2013)

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This European Standard was approved by CENELEC on 2013-10-02. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B - 1000 Brussels

Foreword

The text of document 65B/873/FDIS, future edition 3 of IEC 60584-1, prepared by SC 65B "Measurement and control devices" of IEC/TC 65 "Industrial-process measurement, control and automation" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60584-1:2013.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2014-07-02
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2016-10-02

This document supersedes EN 60584-1:1995 and EN 60584-2:1993.

EN 60584-1:2013 includes the following significant technical changes with respect to EN 60584-1:1995 and EN 60584-2:1993:

- a) EN 60584-1:1995 and EN 60584-2:1993 have been merged;
- b) the standard is now explicitly based on the reference polynomials which express thermocouple EMF as functions of temperature. The tables derived from the polynomials are given in Annex A;
- c) inverse polynomials expressing temperature as functions of EMF are given in Annex B, but inverse tables are not given;
- d) the range of the polynomial relating the EMF of Type K thermocouples is restricted to 1 300 °C;
- e) values of the Seebeck coefficients are given at intervals of 10 °C;
- f) thermoelectric data (EMF and Seebeck coefficients) are given at the fixed points of the ITS-90;
- g) some guidance is given in Annex C regarding the upper temperature limits and environmental conditions of use for each thermocouple type.

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Endorsement notice

The text of the International Standard IEC 60584-1:2013 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60584-1:1995	NOTE	Harmonized as EN 60584-1:1995 (not modified).
IEC 60584-2:1982	NOTE	Harmonized as EN 60584-2:1993 (not modified).
IEC 60584-3:2007	NOTE	Harmonized as EN 60584-3:2008 (not modified).
IEC 61515	NOTE	Harmonized as EN 61515.



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CONTENTS

FOREWORD.....	4
INTRODUCTION.....	6
1 Scope.....	7
2 Terms and definitions.....	7
3 Thermocouple designations.....	8
4 EMF – Temperature reference functions.....	9
5 Thermocouple tolerances.....	14
6 Thermoelectric values at the fixed points of the ITS-90.....	15
Annex A (informative) Tables for EMF as a function of temperature.....	17
Annex B (informative) Inverse polynomial functions.....	57
Annex C (informative) Guidance on the selection of thermocouples.....	64
Bibliography.....	68
Table 1 – Thermocouple types.....	9
Table 2 – Type R reference function.....	10
Table 3 – Type S reference function.....	11
Table 4 – Type B reference function.....	11
Table 5 – Type J reference function.....	11
Table 6 – Type T reference function.....	12
Table 7 – Type E reference function.....	12
Table 8 – Type K reference function.....	13
Table 9 – Type N reference function.....	13
Table 10 – Type C reference function.....	14
Table 11 – Type A reference function.....	14
Table 12 – Thermocouple tolerances.....	15
Table 13 – EMF and Seebeck coefficients of the thermocouples at the fixed points of the ITS-90 (EMF: upper row, Seebeck coefficient: lower row).....	16
Table A.1 – Type R: Platinum - 13 % rhodium / platinum (1 of 5).....	17
Table A.2 – Type S: Platinum-10 % rhodium / platinum (1 of 5).....	21
Table A.3 – Type B: Platinum-30 % rhodium / platinum-6 % rhodium (1 of 4).....	26
Table A.4 – Type J: Iron / copper-nickel (1 of 4).....	30
Table A.5 – Type T: Copper / copper-nickel (1 of 2).....	34
Table A.6 – Type E: Nickel-chromium / copper-nickel (1 of 3).....	36
Table A.7 – Type K: Nickel-chromium / nickel-aluminium (1 of 4).....	39
Table A.8 – Type N: Nickel-chromium-silicon / nickel-silicon (1 of 4).....	43
Table A.9 – Type C: Tungsten-5 % rhenium / tungsten-26 % rhenium (1 of 5).....	47
Table A.10 – Type A: Tungsten-5 % rhenium / tungsten-20 % rhenium (1 of 5).....	52
Table B.1 – Type R Inverse function coefficients.....	58
Table B.2 – Type S Inverse function coefficients.....	59
Table B.3 – Type B Inverse function coefficients.....	59
Table B.4 – Type J Inverse function coefficients.....	60
Table B.5 – Type T Inverse function coefficients.....	60

Table B.6 – Type E Inverse function coefficients	61
Table B.7 – Type K Inverse function coefficients	61
Table B.8 – Type N Inverse function coefficients	62
Table B.9 – Type C Inverse function coefficients	62
Table B.10 – Type A Inverse function coefficients	63
Table C.1 – Recommended maximum temperature of use, t_{\max} / °C	64
Table C.2 – Environmental recommendations and limitations of the conductors	66
Table C.3 – Neutron irradiation effects	67

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SIST EN 60584-1:2014

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

THERMOCOUPLES –

Part 1: EMF specifications and tolerances

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60584-1 has been prepared by sub-committee 65B: Measurement and control devices, of IEC technical committee 65: Industrial-process measurement, control and automation.

This third edition cancels and replaces the second edition published in 1995. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) IEC 60584-1:1995 and IEC 60584-2:1982 have been merged;
- b) the standard is now explicitly based on the reference polynomials which express thermocouple EMF as functions of temperature. The tables derived from the polynomials are given in Annex A;
- c) inverse polynomials expressing temperature as functions of EMF are given in Annex B, but inverse tables are not given;

- d) the range of the polynomial relating the EMF of Type K thermocouples is restricted to 1 300 °C;
- e) values of the Seebeck coefficients are given at intervals of 10 °C;
- f) thermoelectric data (EMF and Seebeck coefficients) are given at the fixed points of the ITS-90;
- g) some guidance is given in Annex C regarding the upper temperature limits and environmental conditions of use for each thermocouple type.

The text of this standard is based on the following documents:

FDIS	Report on voting
65B/873/FDIS	65B/888/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 60584 series, under the general title *Thermocouples* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition or
- amended.

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INTRODUCTION

This International Standard relates the electromotive force (hereafter abbreviated as EMF) generated by the designated thermocouple types to temperature, based upon the International Temperature Scale of 1990 (ITS-90).

The reference polynomials for Types R, S, B, J, T, E, K and N are those used in the previous edition of this standard, IEC 60584-1:1995¹. They were originally produced by the National Institute of Standards and Technology of the USA and published in NIST Monograph 175, 1993.

The major revision of this version is standardization of two kinds of tungsten-rhenium thermocouple, designated Type C and Type A. Both of them have been used in industry for a long time. Temperature versus EMF relationships for Type C and Type A are those published in the ASTM E230/E230-M12 and GOST R 8.585-2001 standards, respectively.

This edition merges two parts of the former IEC 60584 series, IEC 60584-1:1995 (*Reference tables*) and IEC 60584-2:1982 (*Tolerances*) and supersedes both standards. IEC 60584-3:2007 remains valid.

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¹ See Bibliography.

THERMOCOUPLES –

Part 1: EMF specifications and tolerances

1 Scope

This part of IEC 60584 specifies reference functions and tolerances for letter-designated thermocouples (Types R, S, B, J, T, E, K, N, C and A). Temperatures are expressed in degrees Celsius based on the International Temperature Scale of 1990, ITS-90 (symbol t_{90}), and the EMF (symbol E) is in microvolts.

The reference functions are polynomials which express the EMF, E in μV , as a function of temperature t_{90} in $^{\circ}\text{C}$ with the thermocouple reference junctions at 0°C . Values of EMF at intervals of 1°C are tabulated in Annex A.

For convenience of calculating temperatures, inverse functions are given in Annex B which express temperature as functions of EMF within stated accuracies.

This International Standard specifies the tolerances for thermocouples manufactured in accordance with this standard. The tolerance values are for thermocouples manufactured from wires, normally in the diameter range 0,13 mm to 3,2 mm, as delivered to the user and do not allow for calibration drift during use.

Annex C gives guidance on the selection of thermocouples with regard to temperature range and environmental conditions.

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2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1

thermoelectric effect

Seebeck effect

production of an electromotive force (EMF) due to a temperature gradient along a conductor

2.2

Seebeck coefficient of a thermocouple

change in EMF of a thermocouple combination per unit of temperature change, being the first derivative of EMF with respect to temperature.

Note 1 to entry: The Seebeck coefficient dE/dt_{90} , is expressed in $\mu\text{V}/^{\circ}\text{C}$.

2.3

thermocouple

pair of conductors of dissimilar materials joined at one end and forming part of an arrangement using the thermoelectric effect for temperature measurement

2.4

measuring junction

junction of the thermocouple subjected to the temperature to be measured

2.5

reference junction

junction of the thermocouple at a known (reference) temperature

Note 1 to entry: For the specified EMFs of this standard, the reference temperature is 0 °C.

2.6

tolerance

maximum initial permissible deviation from the EMF specification of this standard

Note 1 to entry: The tolerance is expressed as the temperature equivalent in degrees Celsius Celsius (°C).

3 Thermocouple designations

When a thermocouple is identified by the materials of its conductors, the positive conductor shall be listed first, thus: 'positive conductor / negative conductor'.

The positive conductor is the conductor having a positive electric potential with respect to the other conductor when the measuring junction is at a higher temperature than the reference junction.

Table 1 lists the thermocouple types for which EMFs are specified in this standard. Each letter designation of the table identifies the EMF-temperature reference function in the Tables 2 to 11. The designation may be applied to any thermocouple conforming to the relevant function within the stated tolerances specified in Clause 5, regardless of its composition.

Conformity with alloy specification listed in this clause does not guarantee conformity with the EMF-temperature relationship of this standard.

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Table 1 – Thermocouple types

Letter designation	Elements and nominal alloy compositions by weight	
	Positive conductor	Negative conductor
R	Platinum – 13 % rhodium	Platinum
S	Platinum – 10 % rhodium	Platinum
B	Platinum – 30 % rhodium	Platinum – 6 % rhodium
J	Iron	Copper – nickel
T	Copper	Copper – nickel
E	Nickel – chromium	Copper – nickel
K	Nickel – chromium	Nickel – aluminium
N	Nickel – chromium - silicon	Nickel – silicon
C	Tungsten – 5 % rhenium	Tungsten – 26 % rhenium
A	Tungsten – 5 % rhenium	Tungsten – 20 % rhenium

NOTE

- Standard alloy compositions have not been established for base metal thermocouple alloys except Type N, but it should be noted that the compositions are not so critical as the matching of the positive and negative conductor. In particular, the negative conductor of Type J, Type E and Type T thermocouples are generally not interchangeable with each other. Likewise positive conductors of Type C and A are not necessary interchangeable.
- For Type N thermocouple the following composition (percentages of total by weight) is recommended in order to obtain the desired properties like good stability and oxidation resistance.

Positive conductor (known as Nicrosil): 13,7% to 14,7 % Cr%, 1,2 to 1,6 % Si, less than 0,15 % Fe, less than 0,05 % C, less than 0,01 % Mg, balance Ni.

Negative conductor (known as Nisil): less than 0,021% Cr, 4,2% to 4,6% Si, less than 0,15 % Fe, less than 0,05 % C, 0,0 5% to 0,2 % Mg, balance Ni.

4 EMF – Temperature reference functions

The temperature and EMF relationships of this standard are defined by reference functions which give EMF, $E/\mu\text{V}$, as a function of the temperature, $t_{90}/^{\circ}\text{C}$, with a reference temperature of 0°C .

The reference function of polynomial form for each type of thermocouple, except for Type K in the temperature range from 0°C to $1\,300^{\circ}\text{C}$, is defined by the following equation.

$$E = \sum_{i=0}^n a_i \times (t_{90})^i \quad (1)$$

where

E is EMF, expressed in microvolts (μV);

t_{90} is ITS-90 temperature, expressed in degrees Celsius ($^{\circ}\text{C}$);

a_i is the i^{th} coefficient of the polynomial;

n is the order of the polynomial.

The values of a_i and n are dependent on the type of thermocouple and temperature range. Those for each thermocouple are given in the Tables 2 to 11.

For the Type K in the temperature range from 0 °C to 1 300 °C, the reference function is defined by the following equation.

$$E = \sum_{i=0}^n a_i \times (t_{90})^i + c_0 \times \exp[c_1 \times (t_{90} - 126,968 6)^2] \quad (2)$$

where

E is EMF, expressed in microvolts (μV);

t_{90} is ITS-90 temperature, expressed in degrees Celsius ($^{\circ}\text{C}$);

a_i is the i^{th} coefficient of the polynomial;

n is the order of the polynomial;

c_0, c_1 are constants given in Table 8.

Values of EMF are tabulated at intervals of 1 °C in Annex A.

Annex B gives inverse functions relating temperature to EMF within stated accuracies.

NOTE 1 Depending on the processing power available, rounding errors may arise in the calculations using these polynomials. This can be avoided by using the technique of nested multiplication. Thus, form the product $a_n t$, add $a_{(n-1)}$, multiply the result by t , etc, continuing through the series, finally adding a_0 to obtain the result:

$$E = (..((a_n \cdot t_{90} + a_{(n-1)}) \cdot t_{90} + a_{(n-2)}) \cdot t_{90} + \dots + a_1) \cdot t_{90} + a_0$$

Table 2 – Type R reference function

SIST EN 60584-1:2014

Polynomial coefficient	Temperature range		
	-50 °C to 1 064,18 °C ($n = 9$)	1 064,18 °C to 1 664,5 °C ($n = 5$)	1 664,5 °C to 1 768,1 °C ($n = 4$)
a_0	0,000 000 000 00 $\times 10^0$	2,951 579 253 16 $\times 10^3$	1,522 321 182 09 $\times 10^5$
a_1	5,289 617 297 65 $\times 10^0$	-2,520 612 513 32 $\times 10^0$	-2,688 198 885 45 $\times 10^2$
a_2	1,391 665 897 82 $\times 10^{-2}$	1,595 645 018 65 $\times 10^{-2}$	1,712 802 804 71 $\times 10^{-1}$
a_3	-2,388 556 930 17 $\times 10^{-5}$	-7,640 859 475 76 $\times 10^{-6}$	-3,458 957 064 53 $\times 10^{-5}$
a_4	3,569 160 010 63 $\times 10^{-8}$	2,053 052 910 24 $\times 10^{-9}$	-9,346 339 710 46 $\times 10^{-12}$
a_5	-4,623 476 662 98 $\times 10^{-11}$	-2,933 596 681 73 $\times 10^{-13}$	-
a_6	5,007 774 410 34 $\times 10^{-14}$	-	-
a_7	-3,731 058 861 91 $\times 10^{-17}$	-	-
a_8	1,577 164 823 67 $\times 10^{-20}$	-	-
a_9	-2,810 386 252 51 $\times 10^{-24}$	-	-

Table 3 – Type S reference function

Polynomial coefficient	Temperature range		
	-50 °C to 1 064,18 °C (n = 8)	1 064,18 °C to 1 664,5 °C (n = 4)	1 664,5 °C to 1 768,1 °C (n = 4)
a ₀	0,000 000 000 00 × 10 ⁰	1,329 004 440 85 × 10 ³	1,466 282 326 36 × 10 ⁵
a ₁	5,403 133 086 31 × 10 ⁰	3,345 093 113 44 × 10 ⁰	-2,584 305 167 52 × 10 ²
a ₂	1,259 342 897 40 × 10 ⁻²	6,548 051 928 18 × 10 ⁻³	1,636 935 746 41 × 10 ⁻¹
a ₃	-2,324 779 686 89 × 10 ⁻⁵	-1,648 562 592 09 × 10 ⁻⁶	-3,304 390 469 87 × 10 ⁻⁵
a ₄	3,220 288 230 36 × 10 ⁻⁸	1,299 896 051 74 × 10 ⁻¹¹	-9,432 236 906 12 × 10 ⁻¹²
a ₅	-3,314 651 963 89 × 10 ⁻¹¹	-	-
a ₆	2,557 442 517 86 × 10 ⁻¹⁴	-	-
a ₇	-1,250 688 713 93 × 10 ⁻¹⁷	-	-
a ₈	2,714 431 761 45 × 10 ⁻²¹	-	-

Table 4 – Type B reference function

Polynomial coefficient	Temperature range	
	0 °C to 630,615 °C (n = 6)	630,615 °C to 1 820 °C (n = 8)
a ₀	0,000 000 000 00 × 10 ⁰	-3,893 816 862 1 × 10 ³
a ₁	-2,465 081 834 6 × 10 ⁻¹	2,857 174 747 0 × 10 ¹
a ₂	5,904 042 117 1 × 10 ⁻³	-8,488 510 478 5 × 10 ⁻²
a ₃	-1,325 793 163 6 × 10 ⁻⁶	1,578 528 016 4 × 10 ⁻⁴
a ₄	1,566 829 190 1 × 10 ⁻⁹	-1,683 534 486 4 × 10 ⁻⁷
a ₅	-1,694 452 924 0 × 10 ⁻¹²	1,110 979 401 3 × 10 ⁻¹⁰
a ₆	6,299 034 709 4 × 10 ⁻¹⁶	-4,451 543 103 3 × 10 ⁻¹⁴
a ₇	-	9,897 564 082 1 × 10 ⁻¹⁸
a ₈	-	-9,379 133 028 9 × 10 ⁻²²

Table 5 – Type J reference function

Polynomial coefficient	Temperature range	
	-210 °C to 760 °C (n = 8)	760 °C to 1 200 °C (n = 5)
a ₀	0,000 000 000 0 × 10 ⁰	2,964 562 568 1 × 10 ⁵
a ₁	5,038 118 781 5 × 10 ¹	-1,497 612 778 6 × 10 ³
a ₂	3,047 583 693 0 × 10 ⁻²	3,178 710 392 4 × 10 ⁰
a ₃	-8,568 106 572 0 × 10 ⁻⁵	-3,184 768 670 1 × 10 ⁻³
a ₄	1,322 819 529 5 × 10 ⁻⁷	1,572 081 900 4 × 10 ⁻⁶
a ₅	-1,705 295 833 7 × 10 ⁻¹⁰	-3,069 136 905 6 × 10 ⁻¹⁰
a ₆	2,094 809 069 7 × 10 ⁻¹³	-
a ₇	-1,253 839 533 6 × 10 ⁻¹⁶	-
a ₈	1,563 172 569 7 × 10 ⁻²⁰	-

The specified function for Type J (Table 5) extends up to 1 200 °C; however, it should be noted that when a Type J thermocouple has been used above 760 °C, its performance below 760 °C may not conform to the lower part of the function within specified tolerances.