

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Thermistors – Directly heated positive temperature coefficient –
Part 1: Generic specification**

**Thermistances – Coefficient de température positif à chauffage direct –
Partie 1: Spécification générique**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**THERMISTORS – DIRECTLY HEATED POSITIVE
TEMPERATURE COEFFICIENT –****Part 1: Generic specification****FOREWORD**

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IEC 60738-1 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2006 and Amendment 1:2009. This edition constitutes a technical revision.

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

- a) Restructured completely to comply with ISO/IEC Directives; categorization and reorganization of test methods into these categories;
- b) Some wordings, figures and references have been revised.

The text of this International Standard is based on the following documents:

Draft	Report on voting
40/2969/FDIS	40/2977/RVD

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

The language used for the development of this International Standard is English.

A list of all parts in the IEC 60738 series, published under the general title *Thermistors – Directly heated positive temperature coefficient*, can be found on the IEC website.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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THERMISTORS – DIRECTLY HEATED POSITIVE TEMPERATURE COEFFICIENT –

Part 1: Generic specification

1 Scope

This part of IEC 60738 describes terms and methods of test for positive step-function temperature coefficient thermistors, insulated and non-insulated types, typically made from ferro-electric semi-conductor materials.

It establishes standard terms, inspection procedures and methods of test for use in detail specifications for qualification approval and for quality assessment systems for electronic components.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60027 (all parts), *Letter symbols to be used in electrical technology*

IEC 60050 (all parts), *International Electrotechnical Vocabulary (IEV)* (available at www.electropedia.org)

IEC 60062, *Marking codes for resistors and capacitors*

IEC 60068-1:2013, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-1:2007, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-2:2007, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60068-2-6, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-11, *Environmental testing – Part 2-11: Tests – Test Ka: Salt mist*

IEC 60068-2-13, *Environmental testing – Part 2-13: Tests – Test M: Low air pressure*

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*
Amendment 1 (1986)

IEC 60068-2-20, *Environmental testing – Part 2-20: Tests – Test Ta and Tb: Test methods for solderability and resistance to soldering heat of devices with leads*

IEC 60068-2-21, *Environmental testing – Part 2-21: Tests – Test U: Robustness of terminations and integral mounting devices*

IEC 60068-2-27, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60068-2-30, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12-hour cycle)*

IEC 60068-2-58, *Environmental testing – Part 2-58: Tests – Test Td: Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)*

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60294, *Measurement of the dimensions of a cylindrical component with axial terminations*

IEC 60617, *Graphical symbols for diagrams* (available at <http://std.iec.ch/iec60617>)

IEC 60717, *Method for determination of the space required by capacitors and resistors with unidirectional terminations*

IEC 61193-2, *Quality assessment systems – Part 2: Selection and use of sampling plans for inspection of electronic components and packages*

IEC 61249-2-7, *Materials for printed boards and other interconnecting structures – Part 2-7: Reinforced base materials clad and unclad – Epoxide woven E-glass laminated sheet of defined flammability (vertical burning test), copper-clad*

IEC 61760-1, *Surface mounting technology – Part 1: Standard method for the specification of surface mounting components (SMDs)*

ISO 80000-1, *Quantities and units – Part 1: General*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1

type

group of components having similar design features and whose similar manufacturing techniques enable them to be grouped together either for qualification approval or for quality conformance inspection

Note 1 to entry: A type is generally covered by a single detail specification.

Note 2 to entry: Components described in several detail specifications can, in some cases, be considered as belonging to the same type, but they are generally covered by a single detail specification.

3.2

style

variation within a type having specific nominal dimensions and characteristics

3.3 thermistor

thermally sensitive semiconducting resistor which exhibits a significant change in electrical resistance with a change in body temperature

3.4 positive temperature coefficient thermistor

thermistor whose resistance increases with its increasing temperature throughout the useful part of its characteristic

3.5 positive step-function temperature coefficient thermistor PTC

thermistor which shows a step-like increase in its resistance when the increasing temperature reaches a specific value

Note 1 to entry: A PTC thermistor will show secondary effects which are to be considered.

3.6 zero-power resistance R_T

value of the resistance of a PTC thermistor, at a given temperature, under conditions such that the change in resistance due to the internal generation of heat is negligible with respect to the total error of measurement

Note 1 to entry: Any resistance value of a PTC thermistor is dependent on the value and the mode of the applied voltage (AC or DC) and, when an AC source is used, on the frequency (see 3.8 and 3.9).

3.7 nominal zero-power resistance R_n

DC resistance value of a thermistor measured at a specified temperature, preferably at 25 °C, with a power dissipation low enough that any further decrease in power will result only in a negligible change in resistance

Note 1 to entry: Zero-power resistance can also be measured using AC if required by the detail specification.

3.8 voltage dependency

secondary effect exhibiting a decreasing resistance with increasing voltage across the thermistor when measured at a constant body temperature

3.9 frequency dependency

secondary effect exhibiting a substantial decrease of the positive temperature coefficient of the thermistor when the frequency increases

3.10 resistance/temperature characteristic

relationship between the zero-power resistance of a thermistor and the temperature of the thermo-sensitive element when measured under specified reference conditions (see Figure 1)

Note 1 to entry: PTC thermistors can have more than one resistance/temperature characteristic specified. The zero-power resistance of the resistance/temperature characteristics can be measured using a pulse voltage (U_{pulse}) higher than 1,5 V, which is specified in the detail specification. The right curve in Figure 1 shows the typical resistance/temperature characteristic when using the pulse voltage (U_{pulse}).

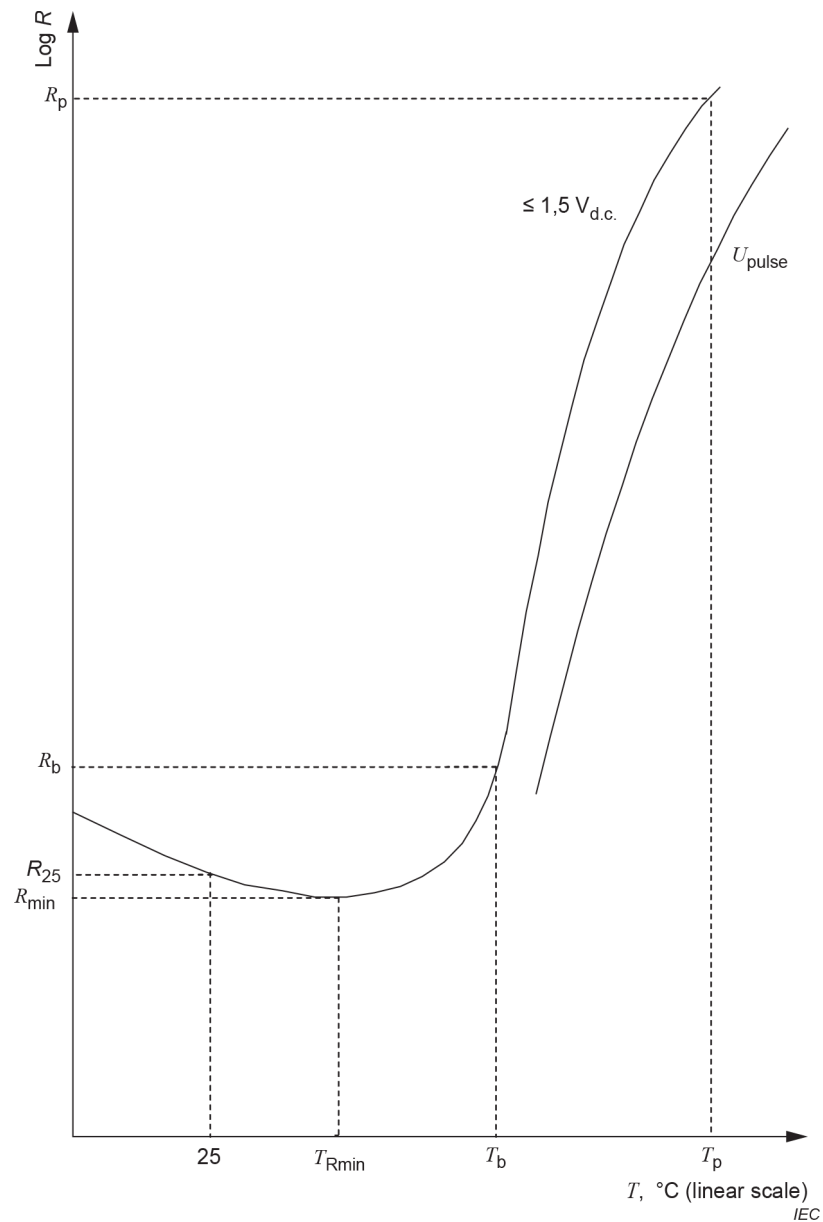


Figure 1 – Typical resistance-temperature characteristic and definitions for PTC thermistors (at zero power)

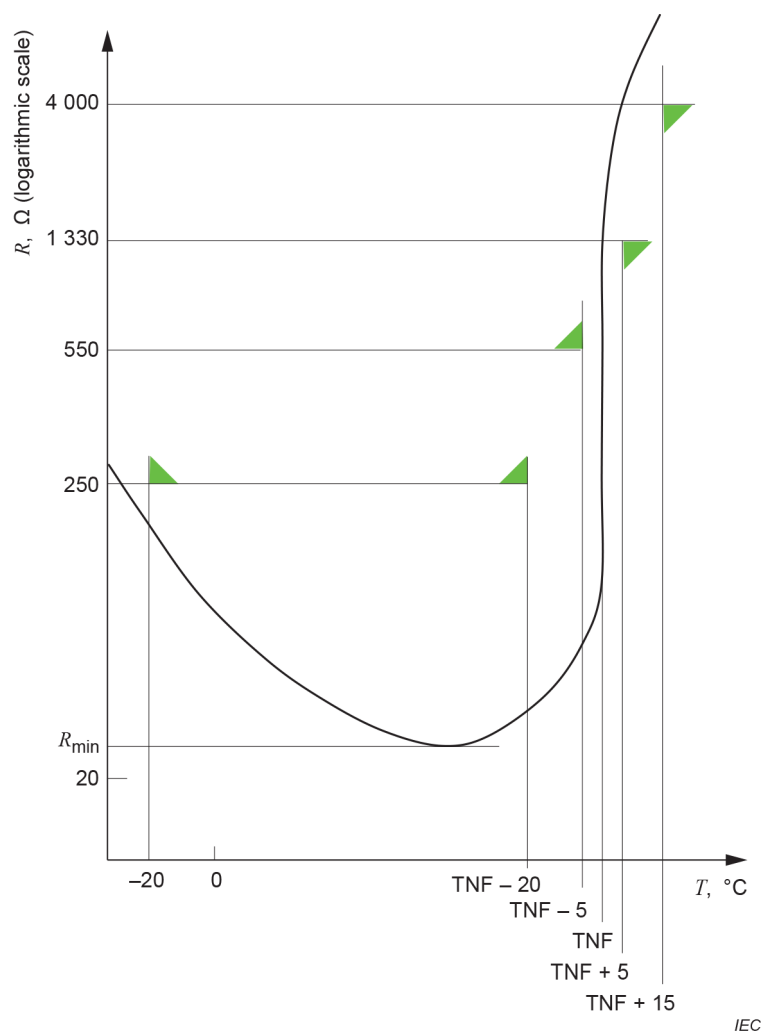
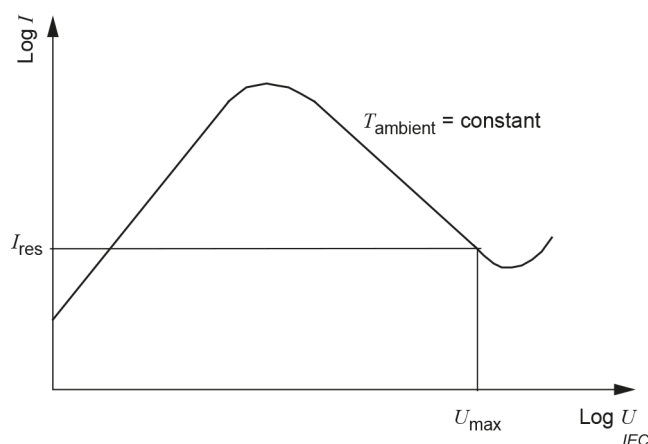


Figure 2 – Typical R-TNF characteristic for PTC thermistors in sensor applications

3.11

current/voltage characteristic

relationship in still air at 25 $^{\circ}\text{C}$ (unless otherwise stated) between the applied voltage (DC or AC) at the thermistor terminations and the current under steady-state conditions (see Figure 3)



NOTE 1 $U_{\max}$ will be specified by the manufacturer.

NOTE 2 The breakdown voltage is the value beyond which the voltage-handling capability of the thermistor no longer exhibits its characteristic property.

Figure 3 – Typical current/voltage characteristic for PTC thermistors

3.12 nominal functioning temperature

T_{NF}

nominal temperature at the steep part of the resistance temperature characteristic at which the system controlled by the thermistor is designed to operate

Note 1 to entry: T_{NF} is exclusively defined for PTC resistors in sensor applications

3.13 switching temperature

T_b

temperature at which the step-like function commences

3.14 minimum resistance

$R_{\min}$

minimum value of the zero-power resistance/temperature characteristic (see Figure 1 and Figure 2)

3.15 resistance at switching temperature

R_b

value of the zero-power resistance corresponding to the switching temperature defined as $R_b = 2 \times R_{\min}$

Note 1 to entry: As an alternative, the definition $R_b = 2 \times R_{25}$ can be used. If this definition is used, this shall be explicitly stated in the detail specification.

3.16 temperature for minimum resistance

$T_{R\min}$

temperature at which $R_{\min}$ occurs

3.17**temperature for pulse-power resistance** **T_p**

temperature, higher than T_b , in the PTC part of the resistance/temperature characteristic for which a minimum value R_p of the zero-power resistance is specified

3.18**pulse-power resistance** **R_p**

resistance at temperature T_p measured at maximum voltage or a voltage specified in the detail specification and given as a minimum value

Note 1 to entry: The measurement should be made under such conditions that a change in resistance due to internal generation of heat is negligible with respect to the total error of measurement. The applied voltage and the characteristics of any pulse used should be given in the detail specification; when applying the maximum voltage, the maximum overload current may not be exceeded

3.19**average temperature coefficient of resistance at a stated voltage** **α_R**

rate of change of resistance with temperature expressed as %/K, calculated from the formula:

$$\alpha_R = \frac{100}{(T_p - T_b)} \times \ln \frac{R_p}{R_b}$$

where T_p exceeds T_b by a minimum of 10 K.

Note 1 to entry: The temperatures T_p and T_b are to be given if applicable and the measurement conditions for R_b and R_p should be the same, unless otherwise specified in the detail specification

Note 2 to entry: The detail specification can specify the measurement of the temperature coefficient of resistance in a narrow temperature range where its value is a maximum, together with a suitable test method.

3.20**upper category temperature****UCT**

maximum ambient temperature at which a thermistor has been designed to operate continuously at zero power

3.21**lower category temperature****LCT**

minimum ambient temperature at which a thermistor has been designed to operate continuously at zero power

3.22**maximum voltage** **U_{max}**

maximum voltage (AC or DC) that can be continuously applied to the thermistor without exceeding the maximum overload current at the inrush

3.23**maximum operating temperature** **T_{A-max}**

maximum ambient temperature at which the thermistor can operate continuously at the maximum voltage without exceeding the maximum overload current

3.24
minimum operating temperature T_{A-min}

Minimum ambient temperature at which the thermistor can operate continuously at the maximum voltage without exceeding the maximum overload current

3.25
isolation voltage

maximum peak voltage that can be applied under continuous operating conditions between any of the thermistor terminations and any conducting surface

Note 1 to entry: Isolation voltage is only applicable to insulated thermistors.

3.26
maximum overload current I_{mo}

value of current (AC or DC) for the operating temperature range, which shall not be exceeded under specified conditions of ambient temperature and voltage

Note 1 to entry: It can be necessary to limit the current through the thermistor using a series resistor R_s .

3.27
residual current I_{res}

value of current (AC or DC) in the thermistor at a specified ambient temperature (preferably 25 °C) under steady-state conditions

Note 1 to entry: The applied voltage is the maximum voltage unless otherwise specified (see Figure 3).

3.28
tripping current I_t

lowest current that will cause the thermistor to trip to a high-resistance condition at a specified temperature (preferably 25 °C) and within a time to be specified in the detail specification

3.29
non-tripping current I_{nt}

maximum current at a specified ambient temperature (preferably 25 °C), which the thermistor will conduct indefinitely in its low-resistance condition

3.30
inrush current I_{in}

current occurring during the transient period from the moment of switching to the steady-state condition

3.31
peak inrush current $I_{in p}$

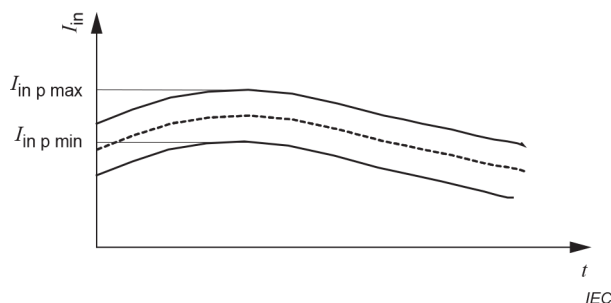
maximum value of current during the transient period (see Figure 4)

3.32
minimum peak inrush current $I_{in p min}$

lowest specified value of the peak of the inrush current

3.33**maximum peak inrush current** $I_{in\ p\ max}$

maximum specified value of the peak inrush current

**Figure 4 – I_{in} against t at U_{dc}** **3.34****peak-to-peak inrush current** $I_{in\ pp}$

value of the inrush current measured between adjacent positive and negative peaks (see Figure 5)

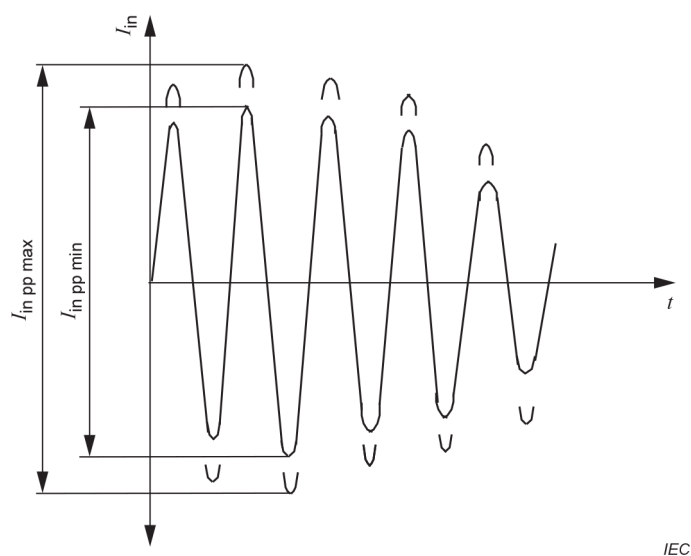
Note 1 to entry: Peak-to-peak inrush current only applies to AC conditions.

3.35**minimum peak-to-peak inrush current** $I_{in\ pp\ min}$

lowest specified value of the peak-to-peak inrush current

3.36**maximum peak-to-peak inrush current** $I_{in\ pp\ max}$

maximum specified value of the peak-to-peak inrush current

**Figure 5 – I_{in} against t at U_{RMS}**

IEC

3.37

peak inrush power

$P_{in\ p}$

peak power ($U \times I_{in\ p}$) measured at the maximum peak value of the current occurring during the transient period from the moment of switching to the steady-state operating condition measured under specified conditions of ambient temperature, voltage and circuit

3.38

maximum peak inrush power

$P_{in\ p\ max.}$

maximum peak power which can occur during the transient period before the thermistor reaches its steady-state operating condition

Note 1 to entry: In the detail specification, it should be specified whether the "0-peak value" or the "RMS value" of the voltage should be taken.

3.39

maximum power

$P_{max.}$

maximum power is the power ($U_{max.} \times I_{res}$) that can be dissipated continuously by the thermistor when the maximum voltage is applied under specified conditions of ambient temperature, circuit and thermal dissipation when thermal equilibrium is obtained

Note 1 to entry: If the power is supplied by an AC source, then the voltage and current should be measured with true RMS meters.

3.40

maximum energy

$E_{max.}$

maximum energy (in J) is the energy ($C_{th.} \times (T_b - T_{amb})$) that can be absorbed by the thermistor during a short transient period without self-heating above its switching temperature (T_b)

Note 1 to entry: The maximum energy is applied under specified conditions of voltage, time, circuit and ambient temperature (preferably 25 °C).

Note 2 to entry: The energy ($C \times U_{max}^2/2$) is supplied by discharging a capacitor of known capacitance C , charged at the PTC U_{max} , completely in the PTC thermistor.

3.41

dissipation factor

δ

quotient (in W/K) of the change in power dissipation in the thermistor and the resultant change of the body temperature under specified ambient conditions (temperature, medium)

3.42

thermal resistance

R_{th}

quotient (in K/W) of the temperature difference between the thermistor and its ambient and the power dissipated by the thermistor under specified ambient conditions (temperature, medium)

Note 1 to entry: Dissipation factor and thermal resistance are mutually reciprocal.

3.43

heat capacity

C_{th}

energy (in J) the thermistor needs to increase its body temperature by 1 K

**3.44
response time** t_a

<ambient temperature change> time, in s, required by a thermistor to change its temperature between two defined conditions when subjected to a change in ambient temperature

**3.45
response time** t_p

<power change> time, in s, required by a thermistor to change its temperature between two defined conditions of power input

**3.46
thermal time constant** τ_a

<constant by ambient temperature change> time required for a thermistor to respond to 63,2 % of an external step change at ambient temperature

Note 1 to entry: The thermal time constant (ideal) for a thermistor is the product of its heat capacity and its thermal resistance.

**3.47
thermal time constant** τ_c

<constant by cooling> time required for a thermistor to cool by 63,2 % of its temperature excess due to electrical heating in still air

Note 1 to entry: The thermal time constant (ideal) for a thermistor is the product of its heat capacity and its thermal resistance.

**3.48
insulated thermistors**

thermistors capable of meeting the requirements of the insulation-resistance and voltage- proof tests when specified in the test schedule

**3.49
surface temperature** T_s

temperature under defined conditions at the boundary layer between two media

**3.50
final surface temperature** T_{sf}

temperature reached under defined conditions when thermal equilibrium is established

4 General requirements**4.1 Units and symbols**

Units, graphical symbols, letter symbols and terminology shall, whenever possible, be taken from the following publications:

- IEC 60027,
- IEC 60050,
- IEC 60617,
- IEC 80000-1.

When further items are required, they shall be derived in accordance with the principles of the documents listed above.

4.2 Preferred values

4.2.1 Climatic categories

The thermistors are classified into climatic categories according to the general rules given in IEC 60068-1:2013, Annex A. The detail specification shall state the appropriate category.

4.2.2 Spacings

The spacings between parts of opposite polarity of a thermistor shall be not less than the applicable values specified in Table 1.

Table 1 – Creepage distances and clearances

Environment	Operating voltage DCV or ACV					
	≤ 32	> 32 and ≤ 50	> 50 and ≤ 300	> 300 and ≤ 600	> 600 and ≤ 800	> 800 and ≤ 1000
Sealed or encapsulated	Exception 1	0,4 mm	0,8 mm	0,8 mm	1,0 mm	1,5 mm
Clean	Exception 1	1,0 mm	1,0 mm	1,0 mm	1,5 mm	2,0 mm
Normal and dirty	Exception 1	1,0 mm	1,5 mm	1,5 mm	2,0 mm	2,5 mm

This applies to both creepage distances and clearances.

Exception 1: as to the creepage distances and clearances for PTC thermistors with a rated operating voltage of less than 32 V, this value meets the intention of these requirements when the thermistor is confirmed to have the maximum voltage specified in the detail specification.

An insulating barrier or liner that is used to provide spacings shall be not less than 0,71 mm.

Exception 2: a barrier or liner that is used in conjunction with at least 50 % of required through-air spacing shall be not less than 0,33 mm in thickness.

Exception 3: a barrier or liner having a thickness of less than that specified above complies with the requirements when it is investigated and found to be rated for the intended conditions of use and found to be mechanically and electrically equivalent to the barrier or liner specified above.

4.3 Marking

4.3.1 General

The following shall be clearly marked on the thermistor in the following order of precedence as space permits.

- Values of the primary characteristics appropriate to the application of the thermistor to be specified in the detail specification. When these values are coded (including colour coding), details shall be given in the detail specification or type designation.
- Manufacturer's name and/or trademark.
- Date of manufacture.
- The number of the detail specification and style.

The package containing the thermistors shall be clearly marked with all the information listed above.

Any additional marking shall be so applied that no confusion can arise.

4.3.2 Coding

Where coding for the date is used, the method shall be selected from those given in IEC 60062.

5 General provisions for measurements and test method

5.1 General

The blank detail specification shall indicate the tests to be carried out, which measurements are to be made before and after each test or subgroup of tests, and the sequence in which they shall be made. The stages of each test shall be carried out in the order written. The measuring conditions shall be the same for initial and final measurements.

If national specifications within any quality assessment system include methods other than those specified in the above specifications, they shall be fully described.

5.2 Standard conditions for testing

5.2.1 Standard atmospheric conditions for testing

Unless otherwise specified, all tests shall be carried out under standard atmospheric conditions for testing as given in 4.3 of IEC 60068-1:2013:

- temperature 15 °C to 35 °C;
- relative humidity 25 % to 75 %;
- air pressure 86 kPa to 106 kPa.

All tests requiring a close control of temperature shall be made with the thermistor immersed in a well-stirred non-conducting, non-corrosive, non-reducing medium maintained at the test temperature. The thermistors shall attain thermal equilibrium before results are recorded.

When measurements are made at a temperature other than the specified temperature, the results shall, where necessary, be corrected to the specified temperature. The ambient temperature during the measurements shall be stated in the test report.

During measurements, the thermistor shall not be exposed to draughts, direct sun rays or other influences likely to cause error.

The tests shall be carried out in the stated order.

5.2.2 Error of measurement

The total error of measurement of power dissipation, temperature tolerance and the tolerance of the measuring equipment shall not exceed 10 % of the tolerance in the detail specification.

5.3 Drying and recovery

5.3.1 Drying

Where drying is called for in the specification, the thermistor shall be conditioned before measurement is made, using Procedure I or Procedure II as called for in the detail specification.

Procedure I

For (24 ± 4) h in an oven at a temperature of (55 ± 2) °C and relative humidity not exceeding 20 %.

Procedure II

For (36 ± 4) h in an oven at (100 ± 5) °C.

The thermistor shall then be allowed to cool in a desiccator using a suitable desiccant, such as activated alumina or silica gel, and shall be kept therein from the time of removal from the oven to the beginning of the specified tests.

5.3.2 Recovery

Where recovery is required, the thermistor shall be stored at standard atmospheric conditions for testing for 1 h to 2 h.

5.3.3 Shock test severities

Test severities given in detail specifications shall be the following:

Test Ea (IEC 60068-2-27)

Pulse shape: Half-sine

Acceleration: 500 m/s^2

Pulse duration: 11 ms

Severity: Three successive shocks in each axis direction per specimen
Separate specimens to be used for each axis (six shocks total per specimen)

5.3.4 Vibration severities

Test severities given in the detail specifications shall be selected from Table 2:

Test Fc (IEC 60068-2-6)

Table 2 – Test severities of vibration

Frequency Hz	Total number of sweep cycles
10 to 55	3×24
10 to 500	3×10
10 to 2 000	3×8

5.4 Mounting (for surface mount thermistors only)

5.4.1 General

An example of a mounting for surface mount thermistors is shown in Figure A.3.

5.4.2 Printed wiring board and land pattern

Surface mount thermistors shall be mounted on a suitable substrate, the method of mounting will depend on the thermistor's construction. The substrate material shall normally be a 1,6 mm thick epoxide woven glass fabric laminated printed board (as defined in IEC 61249-2-7 IEC-EP-GC-CU) or an 0,635 mm alumina substrate and shall not affect the result of any test or measurement. The detail specification shall indicate which material is to be used for the electrical measurements.

The substrate shall have metallized land areas of proper spacing to permit mounting of surface mount thermistors and shall provide electrical connection to the surface mount thermistor terminals. The details shall be specified in the detail specification.

If another method of mounting applies, the method should be clearly described in the detail specification.

5.4.3 Wave soldering method

When the detail specification specifies wave soldering, a suitable glue, details of which can be specified in the detail specification, shall be used to fasten the component to the substrate before soldering is performed.

Small dots of the glue shall be applied between the conductors of the substrate by means of a suitable device securing repeatable results.

The surface mount thermistors shall be placed on the dots using tweezers. To ensure that no glue is applied to the conductors, the surface mount thermistors shall not be moved about.

The substrate with the surface mount thermistors shall be heat-treated in an oven at 100 °C for 15 min.

The substrate shall be soldered in a wave soldering apparatus. The apparatus shall be adjusted to have a pre-heating temperature of 80 °C to 130 °C, a solder bath at 260 °C $\pm$ 5 °C and a soldering time of 5 s $\pm$ 0,5 s.

The soldering operation shall be repeated once more (two cycles in total).

The substrate shall be cleaned for 3 min in propan-2-ol (see IEC 60068-2-45:1980/AMD1:1993, 3.1.2).

5.4.4 Reflow soldering method

When the detail specification specifies reflow soldering, the following mounting procedure applies.

- a) The solder used in preform or paste form shall be silver bearing (2 % minimum) eutectic Sn/Pb solder together with a non-activated flux as stated in IEC 60068-2-20. Alternative solders such as 60/40 or 63/37 may be used on surface mount thermistors whose construction includes solder leach barriers. The Pb-free solder used in preform or paste form shall be Sn96,5-Ag3,0-Cu0,5 or derivative solder together with a flux as stated in IEC 60068-2-58.
- b) The surface mount thermistor shall then be placed across the metallized land areas of the test substrate to make contact between thermistor and substrate land areas.
- c) The substrate shall then be placed in or on a suitable heating system (molten solder, hot plate, tunnel oven, etc.). The temperature of the unit shall be maintained between 215 °C and 260 °C, until the solder melts and reflows forming a homogeneous solder bond, but for not longer than 10 s. The detail specification can require a more restricted temperature range.

Flux should be removed with propan-2-ol (see IEC 60068-2-45:1980/AMD1:1993, 3.1.2). All subsequent handling shall be such as to avoid contamination. Cleanliness shall be maintained in test chambers and during post-test measurements.

If vapour phase soldering is applied, the same method may be used with the temperatures adapted.

6 Electrical tests and measurements

6.1 Zero-power resistance

6.1.1 General

The zero-power resistance shall be measured at the temperature given in the detail specification.

6.1.2 Measurement procedures

The thermistors shall be mounted by their normal means in corrosion-resistant clips on a mounting plate made of polytetrafluoroethylene (PTFE) or equivalent insulating material. An example of a mounting for thermistors is shown in Annex A.

The thermistors shall then be immersed in a non-corrosive and non-reducing medium, the temperature of which shall be controlled in accordance with the relevant test method.

All measurements shall be made without self-heating of the devices (zero-power condition). If the voltage produces self-heating of the device, a pulsating voltage shall be applied. The value and the characteristics of the pulsating voltage shall be specified in the detail specification.

The measuring method shall be such that

- a) for temperatures lower than, or equal to, T_{Rmin}
 - 1) for absolute resistance measurement, the error does not exceed 10 % of the resistance tolerance;
 - 2) for measurements of variation of resistance, the error does not exceed 10 % of the specified maximum change of resistance.
- b) For temperatures higher than T_{Rmin}
 - 1) for absolute resistance measurements,
 - i) when tolerances are specified on the resistance value, the error shall not exceed 10 % of the specified tolerance;
 - ii) when a minimum resistance value is specified, the error shall not exceed $0,5 \alpha_R$ (%) of the specified minimum value;
 - 2) for measurements of variation of resistance,
 - i) when tolerances are specified on the resistance value, the error shall not exceed 10 % of the specified tolerance;
 - ii) when a minimum resistance value is specified, the error shall not exceed $0,5 \alpha_R$ (%) of the value measured.

Where a pulse voltage is used, the characteristics of the pulse shall be given in the detail specification.

NOTE α_R is the average temperature coefficient.

6.1.3 Requirements

The zero-power resistance shall be within the limits given in the detail specification.

6.2 Temperature coefficient of resistance

6.2.1 General

Calculate the temperature coefficient at a specified voltage using resistance values R_p and R_b measured at any pair of temperatures to be specified in the detail specification and using the formula specified in 3.19.

6.2.2 Requirements

The temperature coefficient of resistance shall be within the specified tolerance.

6.3 Insulation resistance (for insulated types only)

6.3.1 General

The insulation resistance of the protective coating shall be measured.

6.3.2 Test methods

According to the instructions given in the detail specification, one of the following test methods is used.

a) Method 1

- 1) The non-insulated parts of the thermistor shall be wrapped in a good insulating material.
The thermistor is placed in a vessel containing metallic balls having a diameter of $(1,6 \pm 0,2)$ mm, so that only the insulated part is immersed (the metal of the balls shall be such that it does not develop a resistive surface.)

An electrode is placed in the metallic balls.

- 2) The thermistor shall be placed in a saline solution, so that only the insulated part is immersed.

The solution shall be of the same concentration as for the salt mist test of IEC 60068-2-11.

An electrode is immersed in the solution.

b) Method 2

A metal foil shall be wrapped closely around the body of the thermistor.

For those types not having axial terminations, a space of 1 mm to 1,5 mm shall be left between the edge of the foil and each termination. For those types having axial terminations, the foil shall be wrapped round the whole body of the thermistor protruding by at least 5 mm from each end, provided that the minimum space of 1 mm between the foil and the termination can be maintained. The ends of the foil shall not be folded over the ends of the thermistor.

c) Method 3

The thermistor shall be clamped in the trough of a 90° metallic V-block of such size that the thermistor body does not extend beyond the extremities of the block.

The clamping force shall be such as to maintain adequate contact between the thermistor and the block.

The thermistor shall be positioned in the V-block in accordance with the following:

- for cylindrical thermistors: the thermistor shall be positioned in the block so that the termination furthest from the axis of the thermistor is nearest to one of the faces of the block;
- for rectangular thermistors: the thermistor shall be positioned in the block so that the termination nearest to the edge of the thermistor is nearest to one of the faces of the block;

for cylindrical and rectangular thermistors with axial leads: any out-of-centre positioning of the point of emergence of the terminations from the body shall be ignored.

6.3.3 Applied voltage

The insulation resistance shall be measured with a direct voltage of $100\text{ V} \pm 15\text{ V}$ between both terminations of the thermistor connected as one pole and the metallic balls, metal foil or V-block as the other pole.

The voltage shall be applied for 1 min, or for such shorter time as is necessary to obtain a stable reading, the insulation resistance being read at the end of that period.

6.3.4 Requirements

When thermistors are measured as specified, the insulation resistance shall not be less than the appropriate figure specified in the detail specification.

6.4 Voltage proof (for insulated types only)

6.4.1 General

The thermistors shall be tested as specified below.

6.4.2 Test methods

As required by the detail specification, one of the test methods given in 6.3.2 shall be used.

6.4.3 Test voltage

The applied voltage shall be that specified in the applicable safety document. In the absence of a safety document, the applied voltage shall be as follows.

An alternating voltage with a frequency of 40 Hz to 60 Hz and with a peak value of 1,4 times the isolation voltage specified in the detail specification, shall be applied for $60\text{ s} \pm 5\text{ s}$ between all terminations of the thermistor connected together as one pole and the metallic balls, the metal foil or the V-block as the other pole.

The voltage shall be applied gradually at a rate of approximately 100 V/s. The test time may be reduced to 1 s provided the test voltage is increased by 10 %.

6.4.4 Requirements

There shall be no breakdown or flashover.

6.5 Resistance/temperature characteristic

6.5.1 Test methods

Resistance measurements shall be made in accordance with the method specified in 7.5, but at the temperatures and voltages indicated in the detail specification.

6.5.2 Requirements

The resistance/temperature characteristic shall be within the limits specified in the detail specification.

6.6 Dissipation factor at $U_{\max}$ (δ)

6.6.1 General

The dissipation factor of the PTC thermistor shall be determined at maximum voltage unless otherwise specified in the detail specification.

6.6.2 Preconditioning

Thermistors with wire terminations shall be gripped and connected by clips at the distance from the body given in the detail specification.

Preferential lengths shall be chosen in the series 1 mm, 2 mm, 5 mm and decimal multiples.

Thermistors with terminations that are not wires shall be mounted and connected as described in the detail specification.

The clips carrying the thermistors shall then be enclosed in a chamber having a volume at least 1 000 times as great as that of the thermistors under test. The wires shall be so positioned that no thermistor is within 75 mm of any other thermistor or the walls of the chamber.

The air in the chamber shall be stationary and shall be at a temperature of $(25 \pm 0,5)$ °C. The thermistors shall be connected in the circuit shown below.

6.6.3 Test circuit

$U_{\max}$ as specified in the detail specification shall be applied gradually ensuring that I_{mo} is not exceeded (see Figure 6).

After stabilization at maximum voltage ($U_{\max}$), the current through the thermistor shall be measured and noted. For AC current, both the peak value and the RMS value of the current shall be noted.

6.6.4 Test methods

The thermistors shall be immersed in the medium as defined in 5.2 and the maximum DC or AC peak voltage shall be applied under zero-power conditions (pulses).

The temperature of the medium shall be increased until the DC current or the AC peak current reaches the same value as registered under the previous conditions.

The temperature (°C) reached shall be noted (T_3).

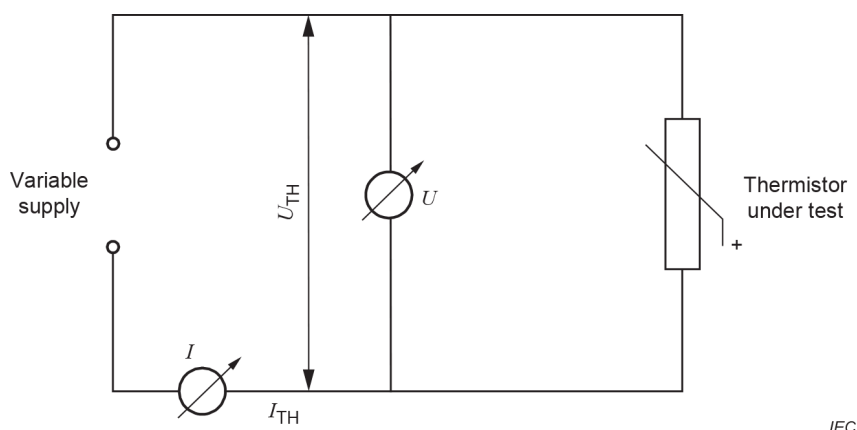


Figure 6 – Dissipation factor test circuit

6.6.5 Requirements

The dissipation factor (δ) shall be calculated using the following formula:

$$\delta = \frac{U_{TH} \times I_{TH}}{T_3 - 25}$$

For DC
$$\delta = \frac{U_{dc} \times I_{dc}}{T_3 - 25}$$

For AC
$$\delta = \frac{U_{rms} \times I_{rms}}{T_3 - 25}$$

6.7 Response time by ambient temperature change (t_a)

6.7.1 General

The resistances R_1 and R_2 of the thermistor at temperatures T_1 and T_2 shall be recorded using the method specified in the detail specification.

6.7.2 Preconditioning

The thermistor shall be immersed in the medium as defined in 5.2 and as specified in the detail specification, with a temperature T_1 , until it has reached thermal equilibrium.

6.7.3 Test procedures

The thermistor shall then be immersed in the medium as defined in 5.2, and as specified in the detail specification, with a temperature T_3 ($T_3 > T_2$, T_3 and T_2 shall be specified in the detail specification). The transfer time from the medium at T_1 to the medium at T_3 shall not exceed 2 s.

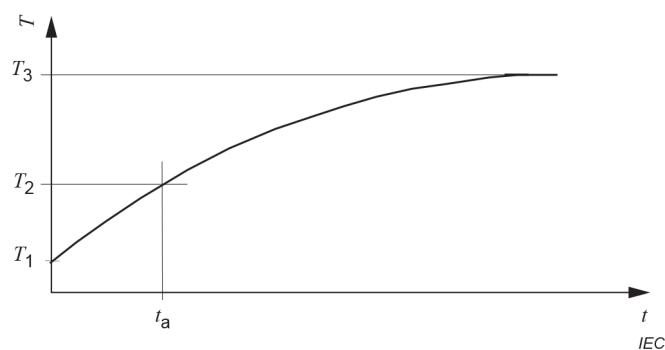


Figure 7 – Temperature gradient

6.7.4 Measurement procedures

The time elapsing between the moment of immersion as described in 6.7.3 and the moment when the resistance value of the thermistor reaches R_2 is the response time t_a (see Figure 7).

6.7.5 Requirements

The response time shall be within the limits given in the detail specification.

6.8 Response time by power change (t_p)

6.8.1 Mounting

Thermistors with wire terminations shall be gripped and connected by clips at the distance from the body given in the detail specification.

Preferential lengths shall be chosen in the series 1 mm, 2 mm, 5 mm and decimal multiples.

Thermistors with terminations that are not wires shall be mounted and connected as described in the detail specification.

When the terminations are insulated, measurements are carried out at their end points, irrespective of their lengths.

6.8.2 Test methods

The thermistors shall be enclosed in a chamber in such a way that the temperature of other thermistors and the proximity of the walls will not materially affect the results of the test.

The temperature of the chamber is adjusted to the value given for this test in the detail specification and the air allowed to become stationary.

The thermistors are each connected to separate constant current supplies pre-set to the value given for this test in the detail specification and with voltage limiting at 50 % of $U_{\max}$.

The response time shall be measured when the current reaches half of its pre-set value or at the moment stated in the detail specification.

The response time shall be within the limits given in the detail specification.

6.9 Thermal time constant by ambient temperature change (τ_a)

The method described in 6.7 shall be applied for which the temperature T_2 shall be determined as $T_2 = T_1 + (T_3 - T_1) \times 0,632$. The thermal time constant by ambient temperature change is by definition equal to the response time covering 63,2 % of the temperature difference by ambient temperature change (t_a) measured in 6.7.

6.10 Thermal time constant by cooling (τ_c)

6.10.1 Mounting

Thermistors with wire terminations shall be gripped and connected by clips at the distance from the body given in the detail specification.

Preferential lengths shall be chosen in the series 1 mm, 2 mm, 5 mm and decimal multiples.

Thermistors with terminations that are not wires shall be mounted and connected as described in the detail specification.

When the terminations are insulated, measurements are carried out at their end points, irrespective of their lengths.

6.10.2 Test methods

The thermistors are introduced in still air at temperature T_0 ($T_0 = 25\text{ °C} \pm 0,5\text{ °C}$) in a test chamber the volume of which is at least 1 000 times that of the thermistors under test, in such a way that no thermistor is less than 75 mm from other thermistors or from the wall of the enclosure.

Before introduction in the test chamber, the thermistors are inserted in the circuit shown in Figure 8.

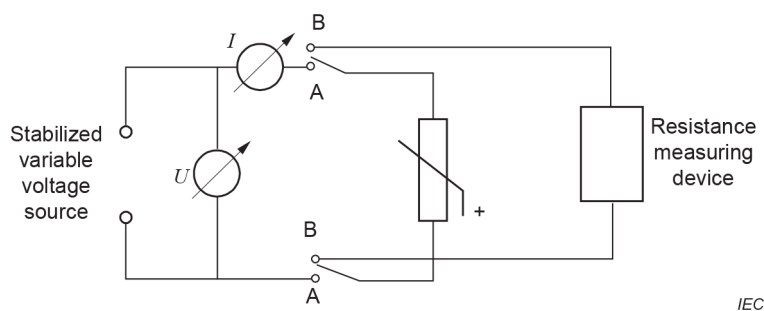


Figure 8 – Circuit for measurement of thermal time constant by cooling

The high-impedance voltmeter and the ammeter shall measure to an accuracy of 1 %. The resistance-measuring equipment shall measure to an accuracy of 0,1 % or less.

Depending on the cases determined below, Method A or Method B shall be used.

a) Method 1

Applicable when $(T_3 - T_b) > 0,632 (T_3 - T_0)$

Initial measurements: $-R_{T_3}$ and R_{T_2} with $T_2 = T_3 - 0,632 (T_3 - T_0)$.

With the contacts AA closed, the voltage is adjusted in such a way that the power dissipated in the thermistor raises its temperature to a value slightly above T_3 (calculated as in 6.6), and the indications of the instruments are stable.

The applied power may then be calculated as follows:

$$P = U \times I = 1,1 (T_3 - T_0) \times \delta$$

where δ is the value calculated in accordance with 6.6.

The thermistor is then switched to contact position BB, and measurement of the time is started as soon as the resistance value has returned to R_{T_3} and the resistance-measuring equipment is in balance.

Time measurement shall be stopped when the resistance-measuring equipment indicates a value of R_{T_2} .

The elapsed time is noted. In this case, it represents the thermal time constant.

b) Method 2

Applicable when $T_3 - T_b \geq 0,632 (T_3 - T_0)$.

Initial measurements: R_{T_3} and R_b .

With the contacts AA made, the voltage is adjusted in such a way that the power dissipated in the thermistor raises its temperature to a value slightly above T_3 and the indications of the instruments are stable.

The applied power may then be calculated as follows:

$$P = U \times I = 1,1 (T_3 - T_0) \times \delta$$

where δ is the value calculated in accordance with 6.6.

The thermistor is then switched to contact position BB, and measurement of the time is started as soon as the resistance value has returned to R_{T_3} and the resistance-measuring equipment is in balance.

Time measurement is stopped when the resistance-measuring equipment indicates a value of R_b . The elapsed time (t) is noted, and the thermal time constant is then calculated as follows:

$$\tau_c = t / \ln [(T_3 - T_0) / (T_b - T_0)]$$

For thermistors with low time constants, automatic switching should be provided between both resistance measurements, as well as for measuring the time interval between both equilibria.

The power applied to the thermistor via the resistance-measuring equipment shall be equal to or less than the power applied when measuring the zero-power resistance of the thermistor.

6.10.3 Requirements

The thermal time constant shall correspond to the value given in the detail specification, taking into consideration the tolerance.

6.11 Tripping current and tripping time

Thermistors with wire terminations shall be gripped and connected by clips at the distance from the body given in the detail specification.

Thermistors with terminations that are not wires shall be mounted and connected as described in the detail specification.

The thermistors shall be enclosed in a chamber such that the temperature of other thermistors and the proximity of the walls will not materially affect the results of the test.

The temperature of the chamber is adjusted to the value given for this test in the detail specification and the air allowed to become stationary.

The thermistors shall each be connected to a constant current supply pre-set to the I_t value specified in the detail specification. The voltage of the current supply shall be lower than 50 % of $U_{\max}$ or the voltage specified in the detail specification.

After applying the current, the thermistors shall trip and reduce the current to a lower level relative to I_t .

When specified in the detail specification, the tripping time shall be measured. It is defined as the time between the start of the test and the moment at which the current is reduced to 50 % of the specified I_t .

6.12 Non-tripping current

The thermistors shall be connected and enclosed in a chamber, as in 8.4.

The temperature of the chamber is adjusted to the value given for this test in the detail specification and the air in the chamber shall be stationary before measurements are taken.

The thermistors are connected to constant current or constant voltage supplies pre-set to the value given for this test in the detail specification and with voltage limiting at 30 % of $U_{\max}$.

The voltage across each thermistor is measured after the time given in the detail specification and the value recorded.

The thermistor shall not pass into the tripped condition.

6.13 Residual current

Thermistors with wire terminations shall be gripped and connected by clips at the distance from the body given in the detail specification.

Thermistors with terminations that are not wires shall be mounted and connected as described in the detail specification.

The thermistors shall be enclosed in a chamber such that the temperature of other thermistors and the proximity of the walls will not materially affect the results of the test.

The temperature of the chamber is adjusted to the value given for this test in the detail specification and the air in the chamber shall be stationary before measurements are taken.

The thermistors are tripped by increasing the voltage to the maximum voltage (AC or DC) unless otherwise specified in the detail specification.

The thermistors are allowed to stabilize for a time given in the detail specification.

The current shall be within the limits given in the detail specification.

6.14 Surface temperature

The surface temperature of the thermistor shall be determined at the maximum voltage unless otherwise specified in the detail specification.

The insulated heating element shall be mounted as specified in the detail specification (see Annex B for an example) and connected to a stabilized voltage source and to a time/temperature recorder via a double-pole switch, as shown in Figure 9.

The accuracy of the recorder shall be better than 1,5 K.

For products such as small PTC devices where the thermocouple changes heat dissipation and affects the measurement of surface temperature, measurements can also be made using IR radiation methods under conditions where the measurement distance and emissivity are well defined.

The test set shall be enclosed in a chamber and positioned so that it is not within 75 mm of any other thermistor or the walls of the chamber.

The air in the chamber shall be still and shall be at a temperature of $(25 \pm 0,5) ^\circ\text{C}$. The thermistor shall be connected to the circuit shown in Figure 9.

By operation of the double-pole switch, the maximum voltage is applied to the thermistor and simultaneously the recorder is set into operation.

At times/temperatures to be specified in the detail specification, the time/temperature shall be noted and shall be within the limits specified in the detail specification.

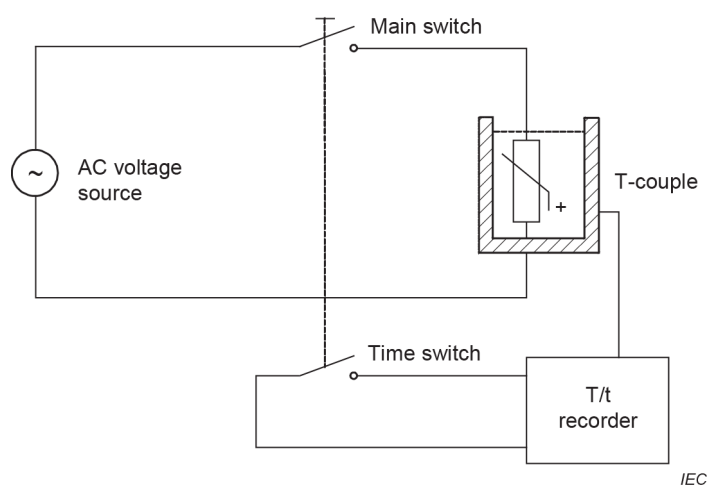
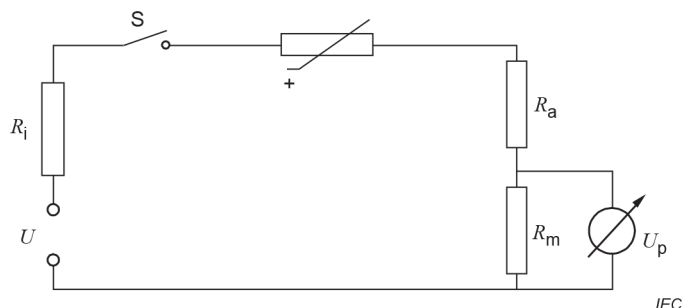


Figure 9 – Circuit for surface temperature measurement

6.15 Inrush current

6.15.1 Measuring circuit

The thermistor shall be connected to the circuit shown in Figure 10.



Key

- U stabilized variable voltage source
- R_i internal resistance
- S high-current switch
- R_a series resistance
- R_m measuring resistance
- U_p peak voltmeter (clamp and hold)

Figure 10 – Measuring circuit

6.15.2 Measuring method

The thermistor shall be mounted by its normal means with a series resistance as described in the detail specification.

The current measuring resistance shall be part of the total series resistance R_s so that $R_s = R_a + R_m + R_i$ is within the limits given in the detail specification.

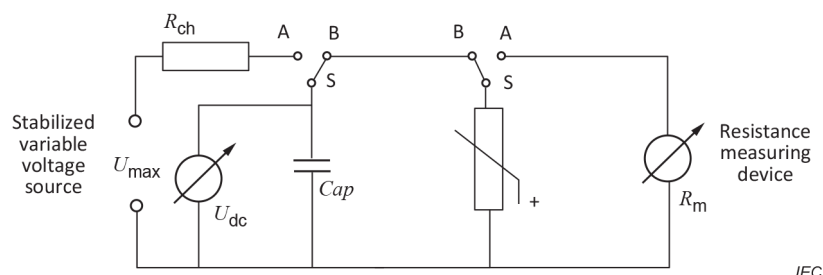
The voltage and the ambient temperature shall be specified in the detail specification.

The stabilized voltage source shall maintain this output voltage with a maximum variation of 1 % during the measurement (the source impedance shall be taken into account).

The inrush current shall be measured to an accuracy better than 3 % with a clamp and peak reading voltmeter or a memory oscilloscope.

6.16 Energy by discharge

6.16.1 Measuring circuit



Key

$U_{\max}$	stabilized variable voltage source (DC)
Cap	capacitor
S	high-current switch
R_m	measuring resistance
R_{ch}	charging resistor
U_{dc}	DC voltmeter

Figure 11 – Measuring circuit

6.16.2 Measuring method

The thermistors are introduced in still air at temperature T_0 ($T_0 = 25\text{ °C} \pm 0,5\text{ °C}$) in a test chamber whose volume is at least 1 000 times that of the thermistors under test, in such a way that no thermistor is less than 75 mm from other thermistors or from the wall of the enclosure. The thermistor shall be mounted by its normal means.

Before introduction in the test chamber, the thermistors are inserted in the circuit shown in Figure 11.

With the switch in position AA, the capacitor is charged through the charging resistor R_{ch} to the max specified DC voltage level of the PTC. The PTC resistance (R_{PTC}) is measured by R_m . The capacitor Cap needs to be chosen so that the charged energy equals the max specified energy of the PTC ($E_{\max} = C \times U_{\max}^2 / 2$).

The max energy, the max DC voltage and the ambient temperature shall be specified in the detail specification.

When the capacitor Cap is charged to $U_{\max}$, the switch S is put in the position BB and the voltage U_{dc} is recorded by means of a memory oscilloscope to an accuracy better than 3 %. The time to reach 13,5% of the applied $U_{\max}$ is measured. The discharge time to 13,5 % of $U_{\max}$ should be less than or equal to $2 \times 2 \times R_{\text{PTC}} \times \text{Cap}$ seconds. 13,5 % of $U_{\max}$ represents 2 RC times in which the maximum R is represented by 2 times the RPTC measured by R_m at start of the test.

7 Mechanical test and measurements

7.1 Visual examination and check of dimensions

7.1.1 Visual examination

The condition, workmanship and finish shall be satisfactory as determined by visual examination.

7.1.2 Marking

Marking shall be legible, as determined by visual examination.

7.1.3 Dimensions (gauging)

The dimensions indicated in the detail specification as being suitable for gauging shall be checked and shall comply with the values prescribed in the detail specification.

When applicable, measurements shall be made in accordance with IEC 60294 and IEC 60717.

7.1.4 Dimensions (detail)

All dimensions prescribed in the detail specification shall be checked and shall comply with the values prescribed.

Also, the spacings in accordance with 4.2.2 shall be checked, except for lot-by-lot inspection and/or periodic testing.

7.2 Robustness of terminations

7.2.1 General

- a) The appropriate parameter(s) given in the detail specification shall be measured and shall be recorded.
- b) The thermistors shall be subjected to the procedure of Tests U_a, U_b and U_c of IEC 60068-2-21 as appropriate.
- c) Tests U_b and U_c shall not be applied if the detail specification describes the terminations as rigid.

7.2.2 Test U_{a1} – Tensile

Unless otherwise stated in the detail specification, the force applied for 10 s shall be:

- for all types of terminations except wire terminations: 20 N;
- for wire terminations: see Table 3.

Table 3 – Tensile force

Nominal cross-sectional area (<i>S</i>) (see note) mm ²	Corresponding diameter (<i>d</i>) for circular-section wires mm	Force with tolerance of ± 10 % N
$S \leq 0,05$	$d \leq 0,25$	1
$0,05 < S \leq 0,1$	$0,25 < d \leq 0,35$	2,5
$0,07 < S \leq 0,2$	$0,35 < d \leq 0,5$	5
$0,2 < S \leq 0,5$	$0,5 < d \leq 0,8$	10
$0,5 < S \leq 1,2$	$0,8 < d \leq 1,25$	20
$1,2 < S$	$1,25 < d$	40

NOTE For circular-section wires, strips or pins: the nominal cross-sectional area is equal to the value calculated from the nominal dimension(s) given in the relevant specification. For stranded wires, the nominal cross-sectional area is obtained by taking the sum of the cross-sectional areas of the individual strands of the conductor specified in the relevant specification.

7.2.3 Test Ub – Bending

Concerns half of the samples. This test is not applicable to thermistors encapsulated in glass or in envelopes.

Two consecutive bends shall be applied (Method 1).

7.2.4 Test Uc – Torsion

Concerns the remaining samples (those not used for the test in 7.2.3).

Two rotations of 180° shall be applied (Severity 2).

7.2.5 Visual examination

After each of these tests, the thermistors shall be visually examined. There shall be no visible damage.

7.2.6 Final measurements and requirements

After the test, the appropriate parameter(s) given in the detail specification shall be measured and shall comply with the requirements stated in the detail specification.

7.3 Vibration

The appropriate parameter(s) given in the detail specification shall be measured using the method specified and shall be recorded.

The thermistors shall be securely mounted by their terminations and/or by their normal mounting means, as defined in the detail specification.

The design of the thermistor can be such that special mounting fixtures are required in its use. In this case, the detail specification shall describe the mounting fixtures and they shall be used for carrying out the vibration, and shock tests.

The thermistors shall be subjected to the procedure of Test Fc of IEC 60068-2-6, using the degree of severity given in the detail specification.

When specified in the detail specification, an electrical measurement shall be made in each direction of movement during the last 30 min of the vibration test to check for intermittent contacts or open or short-circuits.

The method of measurement shall be stated in the detail specification.

The duration of the measurement shall be the time needed for one sweep of the frequency range from one frequency extreme to the other.

After the test, the thermistors shall be visually examined. There shall be no visible damage.

The appropriate parameter(s) given in the detail specification shall be measured using the method specified. The change in value compared with that measured initially shall not exceed the limit specified in the detail specification.

7.4 Shock

The appropriate parameter(s) given in the detail specification shall be measured using the method specified and shall be recorded.

Mounting shall be as specified in 6.8.1.

The thermistors shall be subjected to the procedure of Test Ea of IEC 60068-2-27 using the appropriate degree of severity as specified in the detail specification.

After the test, the thermistors shall be visually examined. There shall be no visible damage.

The appropriate parameter(s) given in the detail specification shall be measured using the method specified. The change in value compared with that measured initially shall not exceed the limit specified in the detail specification.

7.5 Shear (adhesion) test

7.5.1 Test conditions

The surface mount thermistors shall be mounted as described in IEC 60068-2-21, Test U.

7.5.2 Test methods

The thermistors shall be subjected to Test Ue3 of IEC 60068-2-21 using the following conditions.

A force of 5 N shall be applied to the surface mount thermistor body progressively, without shock, and shall be maintained for a period of $10 \text{ s} \pm 1 \text{ s}$.

7.5.3 Requirements

The surface mount thermistors shall be visually examined in the mounted state. There shall be no visible damage.

7.6 Substrate bending test

7.6.1 Mounting

The surface mount thermistor shall be mounted on an epoxide woven glass printed board as described in IEC 60068-2-21.

7.6.2 Initial measurements

The zero-power resistance of the surface mount thermistor shall be measured as specified in 6.1 and in the relevant specification.

7.6.3 Test procedures

The thermistor shall be subjected to Test Ue of IEC 60068-2-21 using the conditions stated in the relevant specification for the deflection D and the number of bends.

7.6.4 Measurements

The zero-power resistance of the surface mount thermistor shall be measured as specified in 7.6.2 with the board in the bent position. The change of resistance shall not exceed the limits stated in the relevant specification.

7.6.5 Requirements

The printed board shall be allowed to recover from the bent position and then removed from the test jig.

7.6.6 Final inspection and requirements

The surface mount thermistor shall be visually examined and there shall be no visible damage.

8 Environmental and climatic tests

8.1 Rapid change of temperature

This test is only applicable to thermistors having a difference between the upper and lower category temperatures exceeding 95 °C.

The appropriate parameter(s) given in the detail specification shall be measured using the method specified and shall be recorded.

The thermistors shall then be subjected to Test Na of IEC 60068-2-14 for five cycles. The time of exposure at each extreme temperature is 30 min.

The thermistors shall be visually examined. There shall be no visible damage.

After recovery in accordance with 5.3.2, the appropriate parameter(s) given in the detail specification shall be measured using the method specified. The change in value compared with that measured initially shall not exceed the limit specified in the detail specification.

8.2 Climatic sequence

8.2.1 General

In the climatic sequence, an interval of not more than three days is permitted between any of these tests, except between damp heat, cyclic, first cycle and dry cold. In this case, the cold test shall follow immediately after the recovery period specified for the damp heat test.

The test and measurements shall be performed in the order of 8.2.2 to 8.2.8.

8.2.2 Initial measurements

The thermistors shall be dried using Procedure I of 5.3.1.