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Edition 4.0 2023-02

INTERNATIONAL STANDARD

Fixed resistors for use in electronic equipment –
Part 2: Sectional specification: Low-power film resistors with leads for through-hole assembly on circuit boards (THT)

IEC 60115-2:2023-02(en)

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INTERNATIONAL
ELECTROTECHNICAL
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FIXED RESISTORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 2: Sectional specification: Low-power film resistors with leads for through-hole assembly on circuit boards (THT)

FOREWORD

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IEC 60115-2 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 2014. This edition constitutes a technical revision.

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

a) the definitions of product technologies and product classification levels of the generic specification, IEC 60115-1:2020, have been adopted;
b) the preferred dimensions given in Table 1 have been reviewed, and the legacy style RA_0922 has been removed;
c) a basis for the optional specification of the lead eccentricity of axial leaded resistors has been amended in 4.2;

d) the 'period-pulse high-voltage overload test' of IEC 60115-1:2020, 8.3 has been adopted as default test method in 5.3.8, thereby replacing the legacy test 'periodic-pulse overload test' of IEC 60115-1:2020, 8.4;

e) the revised solderability test of IEC 60115-1:2020, 11.1 has been adopted in 5.3.19 and 5.3.20;

f) the combined solvent resistance test of IEC 60115-1:2020, 11.3 has been adopted in 5.3.22;

g) the 'endurance at room temperature test' of IEC 60115-1:2020, 7.2 (prior IEC 60115 2:2014, Annex C) has been adopted as an optional test in 5.4.1;

h) the 'single-pulse high-voltage overload test' of IEC 60115 1:2020, 8.2, applied with the pulse shape 10/700 in 5.3.7, is complemented with the optional alternative provided by the pulse shape 1,2/50 in 5.4.2;

i) climatic tests for 'operation at low temperature' of IEC 60115-1:2020, 10.2, and for 'damp heat, steady state, accelerated' of IEC 60115-1:2020, 10.5, have been adopted as optional tests in 5.4.4 and 5.4.5, respectively;

j) new guidance is provided in 6.2 on the presentation of stability requirements with their permissible absolute and relative deviations;

k) acceptance criteria for the visual examination have been added in 6.5 and in Annex B;

l) visual examination for the primary and proximity packaging has been added in 6.5.2 and in 7.2;

m) the periodical evaluation of termination platings has been added as a new topic of quality assessment in 9.8;

n) the revised test clause numbering of IEC 60115-1:2020 has been applied;

o) a new Annex C has been added to summarize workmanship requirements for the assembly of leaded film resistors, e.g. as given in the prior IEC 61192 series of standards;

p) the informative Annex F (prior Annex B) on radial formed styles has been amended with details on a formed Z-bend style for surface-mount assembly.

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

Draft	Report on voting
40/2943/CDV	40/3001/RVC

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 60115 series, published under the general title *Fixed resistors for use in electronic equipment*, 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.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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

FIXED RESISTORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 2: Sectional specification: Low-power film resistors with leads for through-hole assembly on circuit boards (THT)

1 Scope

This part of IEC 60115 is applicable to fixed low-power film resistors with termination leads for use in electronic equipment, which are typically assembled in through-hole technology (THT) on circuit boards.

These resistors are typically described according to types (different geometric shapes) and styles (different dimensions) and product technology. The resistive element of these resistors is typically protected by a conformal lacquer coating. These resistors have wire terminations and are primarily intended to be mounted on a circuit board in through-hole technique.

The object of this document is to state preferred ratings and characteristics and to select from IEC 60115-1 the appropriate quality assessment procedures, tests and measuring methods and to give general performance requirements for this type of resistor.

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 60062:2016, *Marking codes for resistors and capacitors*

IEC 60063:2015, *Preferred number series for resistors and capacitors*

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

IEC 60068-2-6:2007, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-20:2021, *Environmental testing – Part 2-20: Tests – Test Ta and Tb – Test methods for solderability and resistance to soldering heat of devices with leads*

IEC 60115-1:2020, *Fixed resistors for use in electronic equipment – Part 1: Generic specification*

IEC 60286-1, *Packaging of components for automatic handling – Part 1: Tape packaging of components with axial leads on continuous tapes*

IEC 60294:2012, *Measurement of the dimensions of a cylindrical component with axial terminations*

IEC 60301, *Preferred diameters of wire terminations of capacitors and resistors*

IEC 61193-2:2007, *Quality assessment systems – Part 2: Selection and use of sampling plans for inspection of electronic components and packages*

3 Terms and definitions

3.1 Terms

For the purposes of this document, the terms and definitions given in IEC 60115-1:2020, 3.1, as well as the following, 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

3.1.1

axial type

physical design of a component with leads extending to both sides along the longitudinal axis of the components body

Note 1 to entry: Figure 1 shows an illustration of a typical axial leaded resistor.

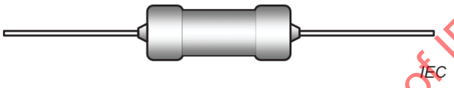


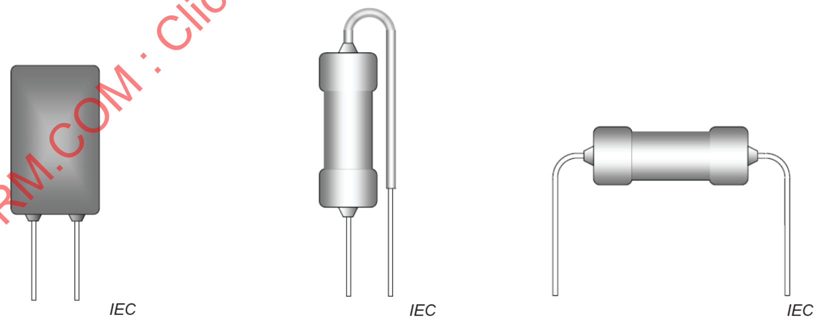
Figure 1 – Illustration of a typical axial leaded resistor

3.1.2

radial type

physical design of a component with leads extending to one side along the longitudinal or along the diagonal axis of the component body

Note 1 to entry: The single direction of the leads may originate from inside the component body or by forming one or both leads outside of the component body, see Figure 2.



a) Radial leaded resistor

b) Radial formed type, upright body position

c) Radial formed type, lateral body position

Figure 2 – Illustrations of typical radial leaded resistors

Note 2 to entry: See Annex F for information on radial formed types.

3.1.3
insulated resistor

resistor that is declared as being insulated by the relevant specification, which in order to support this has a specified insulating voltage and insulation resistance, and which is assessed for these properties with the suitable tests of this specification

Note 1 to entry: The mere existence of a protection of the resistive element, e.g. by means of a lacquer coating, does not constitute an insulation unless the insulating properties have been assessed properly.

Note 2 to entry: Typical tests for the assessment of insulating properties are endurance, climatic sequence and damp heat steady state tests.

[SOURCE: IEC 60115-1:2020, 3.1.7, modified – Note 3 to entry omitted.]

3.2 Product technologies

The definitions of product technologies intend to provide the reader with a guidance on the variety of technologies used for the making of resistors, and to aid their identification.

For the purposes of this document, the following product technologies as described in IEC 60115-1:2020, 3.2 apply:

- metal film technology,
- metal glaze technology,
- metal oxide technology,
- carbon film technology.

3.3 Product classification

The introduction of a product classification permits the user to select performance requirements according to the conditions of the intended end-use application.

For the purposes of this document, the following product classification levels as defined in IEC 60115-1:2020, 3.4 apply:

- Level G – general electronic equipment
- Level P – high-performance electronic equipment
- Level R – high-performance and high-reliable electronic equipment

4 Preferred characteristics

4.1 General

The values given in detail specifications shall be selected from the values given in 4.2 to 4.9.

4.2 Style and dimensions

4.2.1 Preferred styles and outline dimensions

The shape and dimensions of axial leaded resistors are shown in Figure 3, with preferred styles and their respective dimensions given in Table 1. Style designators of axial leaded film resistors begin with RA.

Table 1 – Preferred styles of axial leaded resistors

Style[a]	Dimensions			
	Body diameter D[c] mm	**Body length L[b]** mm	**Lead diameter d[d]** mm	**Lead length $l_{\min}$[e]** mm
RA_0204	$2^{0}_{-0,7}$	$4^{+1,0}_{-1,0}$	0,5	21
RA_0207	$2^{+0,5}_{0}$	$7^{+0,5}_{-2,0}$	0,6	21
RA_0309	$3^{+0,5}_{-0,5}$	$9^{+0,5}_{-2,5}$	0,7	21
RA_0411	$4^{+0,5}_{-1,0}$	$11^{+0,5}_{-3,5}$	0,7	21
RA_0414	$4^{+0,5}_{-1,0}$	$14^{+0,5}_{-4,0}$	0,8	21
RA_0617	$6^{+0,5}_{-1,0}$	$17^{+0,5}_{-4,0}$	0,8	21

[a] The style reference starts with the characters RA, representing Resistor, Axial.
The style reference is completed by a third character for the product technology, as given in 3.2:
M = metal film; G = metal glaze; C = carbon film; X = metal oxide.
The numerals indicate the dimensions of the resistor body, using 2 digits for the diameter D, followed by 2 digits for the length L, both given in tenths of millimetres.
Examples for complete style references are RAM0204, RAX0414.

[b] The body length of the resistor L shall be gauged as described in 5.3.11.

[c] The body diameter of the resistor D shall be gauged as described in 5.3.11.

[d] Nominal diameter of the lead wires d, with permissible tolerances in accordance with IEC 60301.

[e] The minimum lead length $l_{\min}$ applies only to the free lead length in tape packaging in accordance with IEC 60286-1.

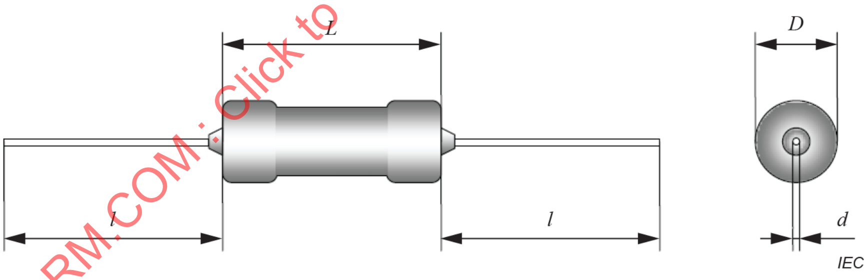


Figure 3 – Shape and dimension of axial leaded resistors

The detail specification shall present a realistic outline illustration of the resistors covered therein, which shall contain all relevant dimensions. The detail specification may deviate from the preferred styles or their recommended dimensions given in Table 1, e.g. due to specific technical requirements or due to deviating styles existing for legacy products.

The recommendation for lead wire diameters in Table 1 applies to standard copper wires with a tin plating. The detail specification may specify other wire materials and other wire diameters where this is justified by specific technical requirements or by a prior specification of a legacy product. Special attention is drawn to the impact of different wire materials or diameters on the thermal conductivity of the lead wires, which affects the thermal management of the products in their application situation. Therefore, a change of wire is likely to require an adaptation of the dissipation rating or of the limiting temperatures and the depending stability data of the affected product.

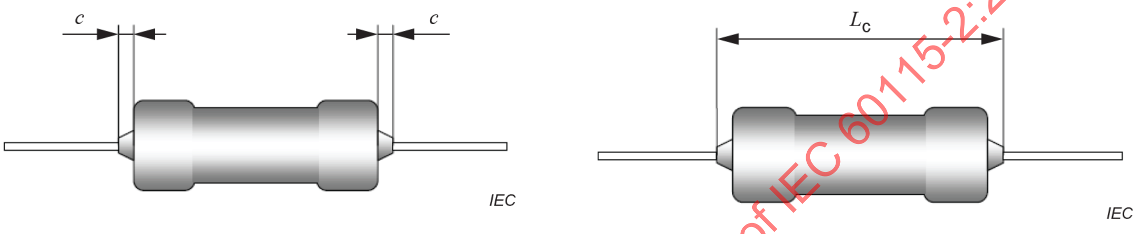
For the specification of any unsolderable area on the lead wires, e.g. due to excessive coating or due to extended welding beads, if required, the provisions of 4.2.2 shall be applied.

For the specification of any eccentricity of the lead wires, if required, the provisions of 4.2.4 shall be applied.

4.2.2 Length of excessive coating or welding bead

As an optional element, the detail specification may specify the permissible length of excessive protective coating extending onto the leads of the resistor, using one of the alternative methods given in Figure 4.

The length of excessive protective coating, dimension c as shown in Figure 4a, shall be gauged as specified in IEC 60294:2012, Clause 4, using a gauge plate of a thickness corresponding to the maximum permissible length of excessive protective coating. A method for measuring or gauging the length between clean leads, dimension L_c, as shown in Figure 4b, shall be stated in the detail specification, if required.



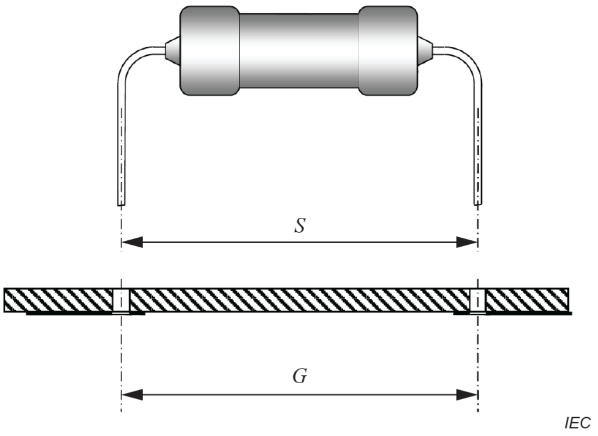
a) Length of excessive coating, c

b) Length between clean leads, L_c

Figure 4 – Alternative methods for specification of the length of excessive protective coating on axial leaded resistors

4.2.3 Lead wire spacing

Associated with a style and the actual dimensions of the respective products is the shortest possible standard distance of the centre line of the lead wires bent to 90° from the direct axis of the resistor body, which sets the lead-wire spacing S, as shown in Figure 5. The spacing S also defines the minimum grid dimension G of PCB bores into which the resistor can be assembled with its body located lateral on the PCB surface, when the required forming is done in the assembly process.



Key:

S Resistor lead-wire spacing, distance of the centre lines of the bent leads.

G Grid of the bores in the circuit board intended for assembly of the resistor

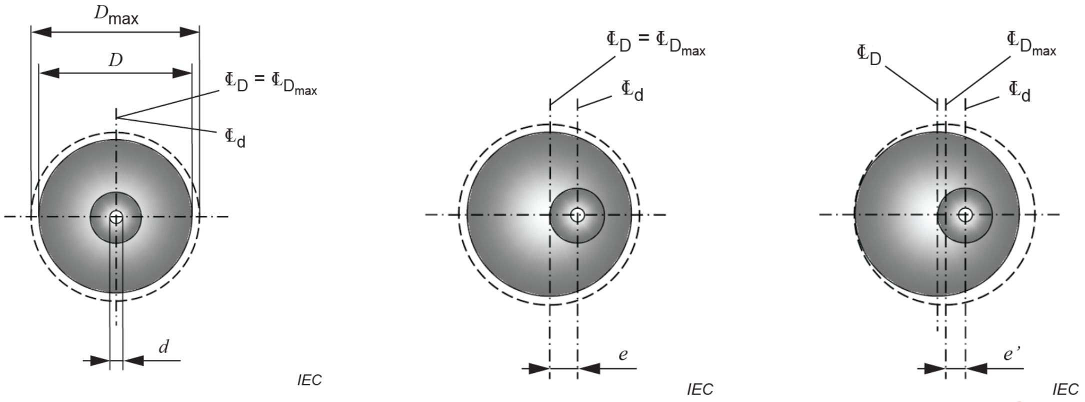
NOTE The drawing of the resistor with formed leads is not intended to suggest the availability of ready formed resistors under this specification.

Figure 5 – Lead-wire spacing of axial leaded resistors with bent leads

If the component type is other than described above, for example for radial leaded resistors, the detail specification shall state such dimensional information as will adequately describe the resistor. See the provisions on radial formed types of resistors in Annex F.

4.2.4 Lead eccentricity

Axial leaded resistors are typically designed with centric leads emerging from both faces of the resistor body, unless specifically declared and specified otherwise. A significant offset lead position can jeopardize an automated assembly process and is likely to infringe upon designed distances within the assembled circuit and thereby adversely affect safety requirements.



a) Designed lead position

b) Real offset lead position

c) Effective offset lead position

Key

d, D	nominal diameters, see Table 1
D_{max}	maximum permissible diameter D, including the permissible tolerance given in Table 1
℄	centre line
e	real eccentricity, distance between centre lines of D and d
e'	effective eccentricity, distance between centre lines of D_{max} and d

Figure 6 – Specification of the lead eccentricity of axial leaded resistors

As an optional element, the detail specification may specify the permissible eccentricity of the leads of a resistor, by means of the real eccentricity e, or of the effective eccentricity e' as shown in Figure 6. The eccentricity shall be assessed on the straight part of each lead nearest to the resistor body.

The detail specification shall state a suitable method for measuring or gauging the lead eccentricity, if required.

4.3 Preferred climatic categories

The leaded film resistors covered by this specification are classified into climatic categories according to the general rules given in IEC 60068-1:2013, Annex A.

The lower and upper category temperature and the duration of the damp heat, steady state test shall be chosen from the following:

Lower category temperature (LCT)	−65 °C; −55 °C; −40 °C; −25 °C and −10 °C.
Upper category temperature (UCT)	85 °C; 100 °C; 125 °C; 155 °C; 175 °C and 200 °C.
Duration of damp heat, steady-state test:	21 days and 56 days.

The severities for the cold and dry heat tests are the lower and upper category temperatures, respectively.

4.4 Resistance

See IEC 60115-1:2020, 4.2.2.

The series of resistance values should be selected according to the tolerance on resistance as recommended by IEC 60063:2015, Table 3.

4.5 Tolerances on resistance

The preferred tolerances on resistance are:
±10 %; ±5 %; ±2 %; ±1 %; ±0,5 %; ±0,25 %; ±0,1 %; ±0,05 %; ±0,02 % and ±0,01 %.

4.6 Rated dissipation P_{70}

The preferred values of rated dissipation P_{70} for mounted resistors at 70 °C ambient temperature are taken from every third value of the R10 series of preferred numbers of ISO 3: 0,063 W; 0,125 W; 0,25 W; 0,5 W; 1 W and 2 W.

The detail specification shall specify the conditions under which the rated dissipation applies.

Figure 7 shows the format of a typical derating curve, suitable for providing information on the required derating of the permissible dissipation for any ambient temperature above the rated temperature.

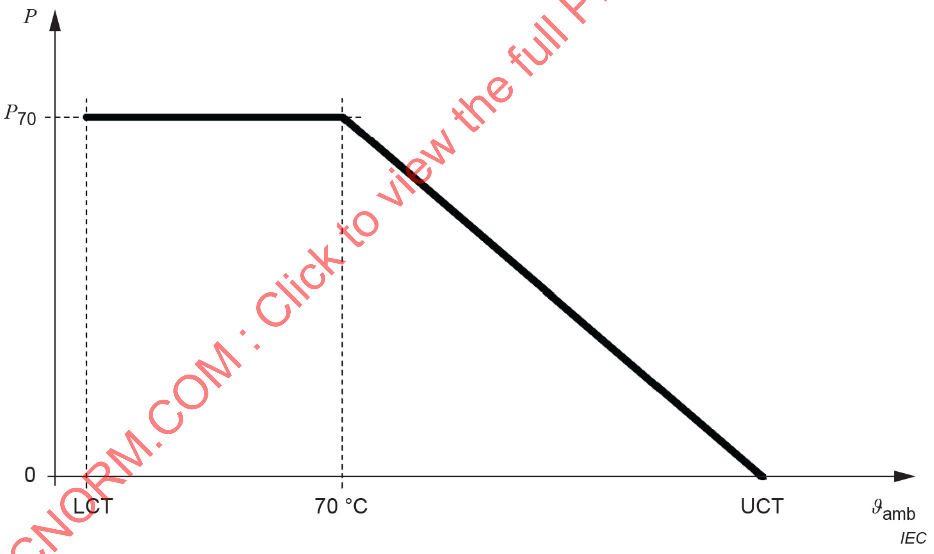


Figure 7 – Derating curve

The upper category temperature (UCT), which is used for test procedures, should be based on the maximum element temperature (MET).

All end points and break points on the derating curve shall be verified by test.

4.7 Limiting element voltage U_{max}

The preferred values of DC or AC RMS limiting element voltage U_{max} are taken from the R10 series of preferred numbers of ISO 3: 50 V; 63 V; 80 V; 100 V; 125 V; 160 V; 200 V; 250 V; 315 V; 400 V; 500 V; 630 V; 800 V and 1 000 V.

In addition, the following customary values are still in use:

- 300 V (2^{nd} more rounded R"10 value from ISO 497);
- 750 V (R40 value from ISO 3).

4.8 Insulation voltage U_{ins}

For insulated resistors, the preferred values of DC or AC peak insulation voltage U_{ins} are taken from the R10 series of preferred numbers of ISO 3: 80 V; 100 V; 125 V; 160 V; 200 V; 250 V; 315 V; 400 V; 500 V; 630 V; 800 V; 1 000 V; 1 250 V and 1 600 V.

In addition, the following customary values are still in use:

- 150 V; 300 V and 1 500 V (2^{nd} more rounded R″10 values from ISO 497);
- 1 100 V (1^{st} more rounded R'20 value from ISO 497);
- 75 V and 750 V (R40 values from ISO 3).

The insulation voltage U_{ins} shall not be specified lower than the AC voltage peak value that can be applied continuously and therefore shall not be rated less than $U_{ins} = 1,42 \cdot U_{max}$.

4.9 Insulation resistance R_{ins}

For insulated resistors, the insulation resistance R_{ins} shall be not less than 1 GΩ.

NOTE See 6.7 for requirements to the insulation resistance R_{ins} after tests.

5 Tests and test severities

5.1 General provisions for tests applied by this specification

Subclause 5.2 provides detailed prescriptions related to the preparation of specimens for tests, particularly on a preferred variety of mounting methods. Any deviation from these prescriptions required by the type of resistors covered by a particular detail specification under this sectional specification shall be clearly stated in that particular detail specification.

Subclause 5.3 provides detailed prescriptions of all the tests applied by the test schedules for qualification approval and for quality conformance inspection. The amount of information given here clearly exceeds any short overview information fitted into the conditions of test column of the respective test schedule and therefore shall take precedence over the overview information.

Subclause 5.4 provides detailed prescriptions of additional tests which are not contained in the test schedules for qualification approval and for quality conformance inspection. These tests are intended to be used as an alternative to tests contained in the test schedules, or as additions to the specified number of tests, in the drafting of a detail specification aiming to cover special requirements. Any prescription of such additional tests shall be accompanied by the prescription of suitable inspections, e.g. visual examination or assessment of the change of resistance. Furthermore, the respective detail specification shall present suitable performance requirements for any applied additional test. See Annex E for recommendations on the suitable implementation of these optional and/or additional tests into the test schedules.

The specified tests shall be conducted under standard atmospheric conditions for testing as outlined in IEC 60115-1:2020, 5.2.3, unless stated otherwise.

Tolerances on specified test parameters shall be applied in accordance with IEC 60115-1:2020, 5.3, unless stated otherwise.

5.2 Preparation of specimens

5.2.1 Drying

Procedure 1 of IEC 60115-1:2020, 5.4 shall be used.

5.2.2 Mounting of components on test boards

5.2.2.1 General

If the relevant specification calls for mounting of the specimens on a test board, the axial leaded resistors, regardless of their product technology, shall be mounted on a board as specified in 5.2.2.2, applying the assembly provisions of 5.2.2.3.

The provisions of IEC 60115-1:2020, 5.5.2 shall be applied.

In order to minimize the effect of heat emitted from any specimen to any other specimen, the test boards shall be positioned vertically, with the specimens aligned in a vertical orientation in a horizontal row.

5.2.2.2 Specification of test boards

Unless specified otherwise, the test boards shall be an epoxide woven glass type with a thickness of (1,6 ± 0,1) mm, with conductors made of un-tinned copper with a nominal thickness of 35 µm.

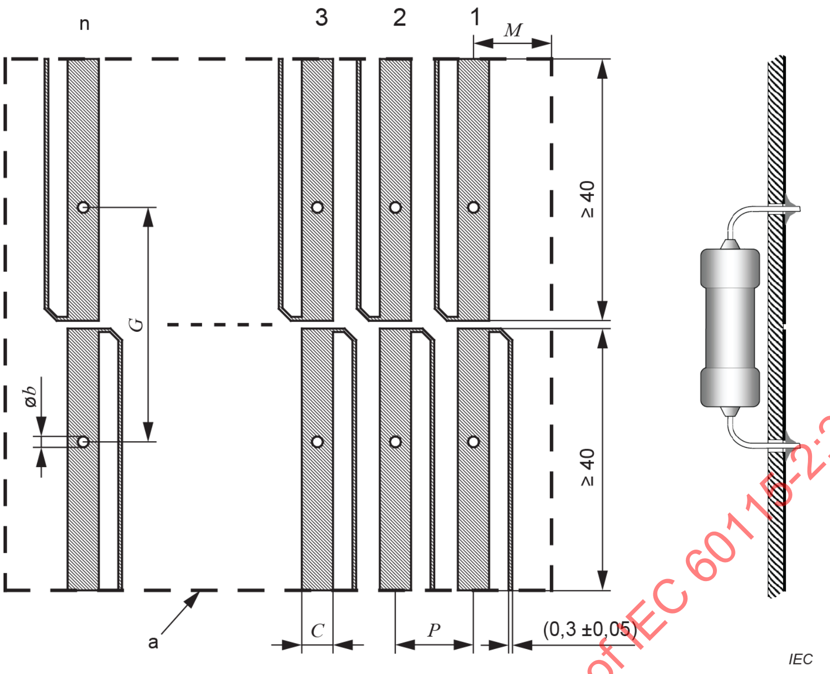
Unless specified otherwise, the central area of tests boards shall comply with the basic layout as shown in Figure 8. Outside of the defined area, the conductor tracks should not be wider than specified inside the defined area. The total board size, connector style, use of solder mask, and number of specimens on each board are at the discretion of the executor of tests, and subject to the approval of the responsible certification body.

The detail specification may provide a different material specification and basic layout, as technically required for the scope of components covered therein.

Test boards with Kelvin (4 point) connections in accordance with Figure 8a, with the dimensions given in Table 2, shall be used for tests for a stability class 0,1 or below and if the resistance of the specimens is below 100 Ω. As a variation of the layout shown in Figure 8a, the test board may also run both sense conductors to the same edge of the defined area.

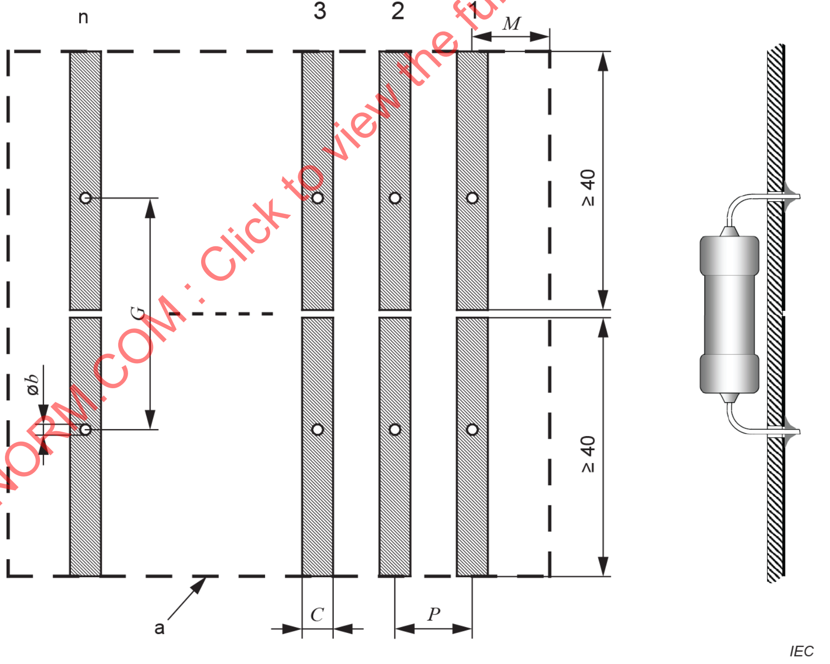
Test boards in accordance with Figure 8b, with the dimensions given in Table 2, may be used for tests for any stability class above 0,1, when the resistance of the specimens is 100 Ω or higher, or for tests not requiring a measurement of the resistance value.

Dimensions in millimetres



a) Basic layout with Kelvin (4 point) connections

Dimensions in millimetres



b) Basic layout with standard connections

Key

a	limit of the defined area, where dimensions apply as given in Table 2
C	width of the force copper conductor
P	centre line pitch of any two adjacent force conductors
M	distance from any first or last force conductor's centre line of to the defined area's edge
G	centre distance of the holes for specimen assembly
b	bore diameter of the holes for specimen assembly
■	copper layer

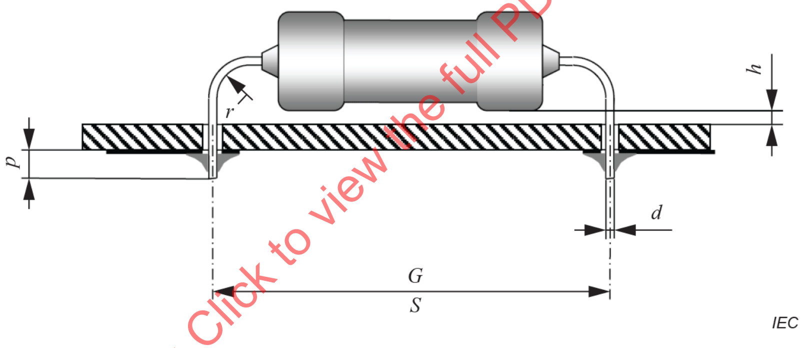
Figure 8 – Basic layout for mechanical, environmental and electrical tests

Table 2 – Test board dimensions

Style	*b* mm	*G* mm	*C* mm	*P* mm	*M* mm
RA_0204	0,8 ± 0,1	7,5 ± 0,1	2,0 ± 0,1	15,0 ± 0,1	7,5 ± 0,1
RA_0207	1,0 ± 0,1	10,0 ± 0,1	5,0 ± 0,1	20,0 ± 0,1	10,0 ± 0,1
RA_0309	1,3 ± 0,1	12,5 ± 0,1	7,5 ± 0,1	25,0 ± 0,1	12,5 ± 0,1
RA_0411	1,3 ± 0,1	15,0 ± 0,1	10,0 ± 0,1	30,0 ± 0,1	15,0 ± 0,1
RA_0414	1,3 ± 0,1	17,5 ± 0,1	10,0 ± 0,1	30,0 ± 0,1	15,0 ± 0,1
RA_0617	1,3 ± 0,1	22,5 ± 0,1	10,0 ± 0,1	45,0 ± 0,1	22,5 ± 0,1
No metal area is permitted on the bottom side or on any inner layer under the defined area, except a single straight sense conductor with a maximum width of 0,3 mm for every Kelvin connection. If applicable, the test board layout may also run both sense conductors to the same edge of the defined area.					

5.2.2.3 Assembly on test boards

The resistor specimens shall be mounted laterally to the component side (primary side) of the test board, with the axial leads bent each to 90° in order to fit into the appropriate bores, as shown in Figure 9.



Key:

S resistors lead-wire spacing

d nominal diameter of the lead-wire

r lead-wire bending radius, measured on the inside of the wire

h clearance of the resistor body above the circuit board

p protrusion length of the cropped lead-wire below the circuit board

G Grid of bores in the circuit board intended for assembly of the resistor

NOTE Plated via holes can be required for the vibration test, the bump test or the shock test in order to build a stronger solder joint.

Figure 9 – Assembly of specimens to the test board

The workmanship requirements of Annex C shall be observed, particularly

- C.2.1 for details concerning the straight length and the radius of the lead forming;
- C.3.2 for details concerning the lateral mounting position of the resistor;
- Clause C.4 for details concerning the cropping of the protruding lead ends.

Special provisions can be required on a minimum clearance of resistors specified for a high limiting element voltage. Such provisions and constraints are subject to the relevant detail specification.

5.2.3 Mounting of components on a test rack

As the default mounting method, or if the relevant specification calls for mounting of the specimens on a test rack, the resistors shall be connected by their terminations (e.g. lead wires) to suitable fixation devices on the rack. The relevant provisions of IEC 60115-1:2020, 5.5 shall be applied.

In order to minimize the effect of heat emitted from any specimen to any other specimen, the test rack shall be positioned horizontally, with the specimens aligned horizontally within the rack, and racks shall not be stacked.

See Figure 10 for the dimensions within a rack. Unless specified otherwise, the following constraints shall apply:

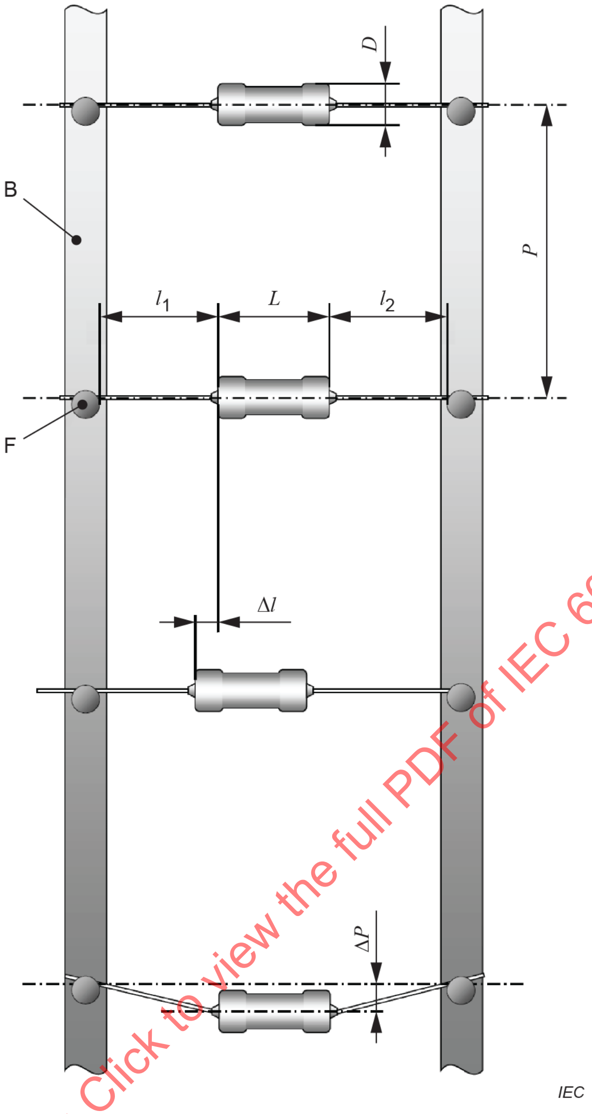
a) the specimens' mounting pitch shall at least be 7 times the body diameter, $P \geq 7 \times D$;

b) the specimens shall be approximately centred between the fixations on each bar, $l_1 \approx l_2$;

c) the length of lead wires shall not be shorter than 20 mm, $l_1 \geq 20$ mm, $l_2 \geq 20$ mm;

d) the axial displacement shall not exceed 50 % of the specimens' body length, $\Delta l \leq 0,5 \times L$;

e) the radial displacement shall not exceed the specimens' body diameter, $\Delta P \leq D$.

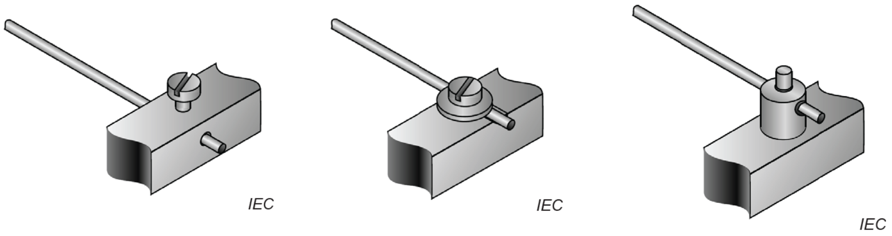


Key

B	conductive bar
F	specimen fixation device
D	specimen body diameter
L	specimen body length
l_1, l_2	specimen lead length
Δl	axial specimen displacement
P	centre line pitch of any two adjacent specimens
ΔP	radial specimen displacement

Figure 10 – Mounting of axial leaded specimens on a rack, top view

A rack normally consists of two parallel conductive strips or bars, which either are sufficiently rigid to support the specimens' mass themselves or are supported by a suitable insulating substrate or construction. The strips or bars may carry fixation devices (e.g. clips, clamps, screw terminals) at the appropriate places for the connection of the specimens' lead wires. See Figure 11 for examples of specimen lead fixation devices.



a) Through holes with screw clamp **b) V groove with press clamp** **c) Spring loaded wire clamp**

Figure 11 – Examples of specimen lead fixation devices

5.3 Details of applied tests

5.3.1 Resistance

See IEC 60115-1:2020, 6.1 and IEC 60115-1:2020, 5.6.

Unless otherwise specified, the points of measurement on unmounted specimens shall be on the leads at a distance of l_{meas} = (6 ± 1) mm from the resistor body. For specimens mounted on a test board in accordance with 5.2.2, the points of measurement are determined by the solder joints.

5.3.2 Temperature coefficient of resistance

See IEC 60115-1:2020, 6.2 and IEC 60115-1:2020, 5.6.

Unless otherwise specified, the points of measurement on unmounted specimens shall be on the leads at a distance of l_{meas} = (6 ± 1) mm from the resistor body. For specimens mounted on a test board in accordance with 5.2.2, the points of measurement are determined by the solder joints.

The sequence of temperatures, 20 °C / LCT / 20 °C / UCT / 20 °C, shall be applied consecutively.

5.3.3 Temperature rise

See IEC 60115-1:2020, 6.7, with the following details:

As stated in the detail specification, for execution of this test, the specimens shall be mounted on a test board in accordance with 5.2.2, or mounted on a test rack in accordance with 5.2.3.

The specimens shall be positioned in such a way that heat from any one specimen affects the adjacent specimens to the least possible extent. The specimens shall be in free air at the standard atmospheric conditions for testing as given in IEC 60115-1:2020, 5.2.3 (e.g. ambient temperature 15 °C to 35 °C).

NOTE For specimens mounted on a test rack, this will normally be achieved by positioning the rack horizontally, with the specimens aligned horizontally within the rack. For specimens mounted on a test board, this will normally be achieved by positioning the test boards vertically, with the specimens aligned in vertical orientation in a horizontal row.

5.3.4 Endurance at the rated temperature 70 °C

See IEC 60115-1:2020, 7.1, with the following details:

As stated in the detail specification, for execution of this test, the specimens shall be mounted on a test board in accordance with 5.2.2, or mounted on a test rack in accordance with 5.2.3.

The specimens shall be positioned in such a way that heat from any one specimen affects the adjacent specimens to the least possible extent.

NOTE For specimens mounted on a test rack, this will normally be achieved by positioning the rack horizontally, with the specimens aligned horizontally within the rack. For specimens mounted on a test board, this will normally be achieved by positioning the test boards vertically, with the specimens aligned in vertical orientation in a horizontal row.

The test shall be performed with the rated voltage:

$$U_{\text{test}} = U_{\text{r}} = \sqrt{P_{70} \times R_{\text{n}}} \text{ ,}$$

which shall be limited by

$$U_{\text{test}} \leq U_{\text{max}} \text{ ,}$$

where

U_{r} is the rated voltage;

P_{70} is the rated dissipation;

R_{n} is the nominal resistance;

U_{max} is the limiting element voltage.

The duration of the endurance test shall be $t_{\text{test}} = 1\,000\ {}^{+24}_{\ 0}\ \text{h}$.

The extension of the endurance test to a total duration of $t_{\text{test}} = 8\,000\ {}^{+48}_{\ 0}\ \text{h}$, is mandatory only for resistors categorized as level P or R.

See 5.3.23 for the measurement of the insulation resistance of insulated resistors.

5.3.5 Endurance at a maximum temperature: UCT

See IEC 60115-1:2020, 7.3, with the following details:

As stated in the detail specification, for execution of this test, the specimens shall be mounted on a test board in accordance with 5.2.2, or mounted on a test rack in accordance with 5.2.3, or shall be tested unmounted.

The duration of the endurance test shall be $t_{\text{test}} = 1\,000\ {}^{+24}_{\ 0}\ \text{h}$.

See 5.3.23 for the measurement of the insulation resistance of insulated resistors.

5.3.6 Short-term overload

See IEC 60115-1:2020, 8.1, with the following details:

As stated in the detail specification, for execution of this test, the specimens shall be mounted on a test board in accordance with 5.2.2, or mounted on a test rack in accordance with 5.2.3.

The specimens shall be positioned in such a way that heat from any one specimen affects the adjacent specimens to the least possible extent. The specimens shall be in free air at the standard atmospheric conditions for testing as given in IEC 60115-1:2020, 5.2.3 (e.g. ambient temperature 15 °C to 35 °C).

NOTE For specimens mounted on a test rack, this is normally achieved by positioning the rack horizontally, with the specimens aligned horizontally within the rack. For specimens mounted on a test board, this will normally be achieved by positioning the test boards vertically, with the specimens aligned in a vertical orientation in a horizontal row.

The preferred overload test voltage is

$$U_{\text{test}} = 2{,}5 \times U_{\text{r}} = \sqrt{6{,}25 \times P_{70} \times R_{\text{n}}}\ ,$$

which shall be limited by

$$U_{\text{test}} \leq 2 \times U_{\text{max}}\ ,$$

where

U_{r} is the rated voltage;

P_{70} is the rated dissipation;

R_{n} is the nominal resistance;

U_{max} is the limiting element voltage.

The overload duration is a function of the resistor style.

The detail specification shall state the values for the overload duration t_{load}, preferably from the following preferred values: 0,5 s; 1 s; 2 s; 5 s and 10 s. A relative tolerance of 0 %/+5 % shall apply to the overload duration.

5.3.7 Single-pulse high-voltage overload test

See IEC 60115-1:2020, 8.2.

As stated in the detail specification, for execution of this test, the specimens shall be mounted on a test board in accordance with 5.2.2, or mounted on a test rack in accordance with 5.2.3, or shall be tested unmounted. If the specimens are to be tested unmounted, they shall be placed in a suitable fixture for the execution of the test.

The test shall be performed with pulses defined by:

Pulse shape:	10/700
Pulse peak voltage:	$\hat{U}_{\text{test}} = x \times \sqrt{P_{70} \times R_{\text{n}}}$, with $x \geq 10$,
which shall be limited by	$\hat{U}_{\text{test}} \leq y \times U_{\text{max}}$, with $y \geq 2$.

The detail specification shall specify the values for x and y.

NOTE The given minimum values for multipliers, $x = 10$ and $y = 2$, establish the lowest severity No.4 as defined for pulses of shape 10/700 in IEC 60115-1:2020, 8.2.

This test is mandatory only for resistors categorized as level P or R.

5.3.8 Periodic-pulse high-voltage overload test

See IEC 60115-1:2020, 8.3, with the following details:

As stated in the detail specification, for execution of this test, the specimens shall be mounted on a test board in accordance with 5.2.2, or mounted on a test rack in accordance with 5.2.3.

The specimens shall be positioned in such a way that heat from any one specimen affects the adjacent specimens to the least possible extent. The specimens shall be in free air at the standard atmospheric conditions for testing as given in IEC 60115-1:2020, 5.2.3 (e.g. ambient temperature 15 °C to 35 °C).

NOTE For specimens mounted on a test rack, this will normally be achieved by positioning the rack horizontally, with the specimens aligned horizontally within the rack. For specimens mounted on a test board, this will normally be achieved by positioning the test boards vertically, with the specimens aligned in a vertical orientation in a horizontal row.

The preferred square pulse overload test voltage is, specified as severity 3:

$$\hat{U}_{\mathrm{test}} = \sqrt{25 \times P_{70} \times R_{\mathrm{n}}} \quad ,$$

which shall be limited by

$$\hat{U}_{\mathrm{test}} \leq 3 \times U_{\mathrm{max}}$$

where

P_{70} is the rated dissipation;

R_{n} is the nominal resistance;

U_{max} is the limiting element voltage.

Duration of the test: $t_{\mathrm{test}} = 100\,^{+5}_{0}\ \mathrm{h}$;

Pulse duration: t_{pulse} = 100 µs;

Pulse frequency: f_{pulse} = 400 Hz.

The detail specification may specify a higher overload factor than the 25 given in severity 3. In such a case, the test duration of 100 h and the pulse duration of 100 µs shall be maintained and the pulse frequency be adjusted in order to establish a mean dissipation of the pulse sequence of 100 % of the rated dissipation P_{70}. See the preferred alternative overload conditions given in Table 3.

Table 3 – Preferred aggravated overload conditions

Severity	Peak load $\hat{P}$ W	Pulse voltage $\hat{U}_{\text{test}}$ V	Pulse duration t_{pulse} µs	Pulse frequency f_{pulse} Hz
3a	$40 \times P_r$	$\sqrt{40 \times P_r \times R_n}$	100	250
3b	$63 \times P_r$	$\sqrt{63 \times P_r \times R_n}$	100	160
3c	$100 \times P_r$	$\sqrt{100 \times P_r \times R_n}$	100	100
3d	$160 \times P_r$	$\sqrt{160 \times P_r \times R_n}$	100	63
3e	$250 \times P_r$	$\sqrt{250 \times P_r \times R_n}$	100	40
3f	$400 \times P_r$	$\sqrt{400 \times P_r \times R_n}$	100	25
3g	$630 \times P_r$	$\sqrt{630 \times P_r \times R_n}$	100	16
3h	$1\,000 \times P_r$	$\sqrt{1\,000 \times P_r \times R_n}$	100	10

This test is mandatory only for resistors categorized as level P or R.

5.3.9 Electrostatic discharge (ESD) test

See IEC 60115-1:2020, 8.5, with the following details:

As stated in the detail specification, for execution of this test, the specimens shall be mounted on a test board in accordance with 5.2.2, or mounted on a test rack in accordance with 5.2.3, or shall be tested unmounted. If the specimens are to be tested unmounted, they shall be placed in a suitable fixture for the execution of the test.

The ESD test voltage is a function of the resistor style. The detail specification shall state the values for the test voltage U_{HBM}, preferably from the preferred values given in IEC 60115-1:2020, 8.5.4. A relative tolerance of ±2 % shall apply to the test voltage.

An equal number of discharges with positive polarity, n_{pos} , and with negative polarity, n_{neg}, shall be applied to the specimens, where

$n_{\text{pos}} = n_{\text{neg}} = 1$ for resistors categorized as level G; or

$n_{\text{pos}} = n_{\text{neg}} = 3$ for resistors categorized as level P or R.

The minimum time between any two discharges shall be 1 s.

5.3.10 Visual examination

See IEC 60115-1:2020, 9.1

The visual examination shall be applied to the resistor body and to its terminations.

The visual examination of the marking of marked resistors shall be applied to the required marking items, in accordance with 7.1.

5.3.11 Gauging of dimensions

See IEC 60115-1:2020, 9.2, with the following details:

The length and diameter (or height and width) of the resistor body and of the leads shall be gauged.

The length of the resistor body shall be assessed as stated in IEC 60294:2012, 3.1.

The diameter of the resistor body shall be gauged in accordance with IEC 60294:2012, Clause 5. A similar approach shall be used for a non-cylindrical resistor body.

If stated in the detail specification, the effective eccentricity e' as shown in Figure 6c shall be gauged as stated therein.

If stated in the detail specification, either the length of excessive protective coating, dimension c as shown in Figure 5a, shall be gauged as specified in IEC 60294:2012, Clause 4, or the length between clean leads, dimension L_c, as shown in Figure 5b shall be measured or gauged as stated in the detail specification.

5.3.12 Detail dimensions

See IEC 60115-1:2020, 9.3, with the following details:

All dimensions specified by the detail specification shall be measured.

For measurement of the length of the resistor body, a gauge plate in accordance with IEC 60294:2012, 3.1 shall be used.

If stated in the detail specification, the real eccentricity e as shown in Figure 6b shall be gauged as specified therein.

If stated in the detail specification, either the length of excessive protective coating, dimension c as shown in Figure 4a, or the length between clean leads, dimension L_c, as shown in Figure 4b shall be measured as stated in the detail specification.

5.3.13 Robustness of terminations

See IEC 60115-1:2020, 9.5, with the following details:

The tests shall be carried out at the standard atmospheric conditions for testing as given in IEC 60115-1:2020, 5.2.3 (e.g. ambient temperature 15 °C to 35 °C). The specimen shall be kept in standard atmospheric conditions for at least 1 h prior to the tests.

The following tests shall be applied to the group of specimens subjected to this test:

- The whole group of specimens shall be subjected to test Ua_1 – Tensile, as described in IEC 60115-1:2020, 9.5.4.2.
- Then half of the group of specimens shall be subjected to test Ub – Bending, as described in IEC 60115-1:2020, 9.5.4.3, where each two successive bends shall be applied in alternate directions.
- The other half of the group of specimens shall be subjected to test Uc – Torsion, as described in IEC 60115-1:2020, 9.5.4.4, where method 1, severity 2 shall be applied.

5.3.14 Vibration

See IEC 60115-1:2020, 9.11, with the following details:

The method to be employed is endurance by sweeping in accordance with IEC 60068-2-6:2007, 8.3.1, with the specimens mounted in such a way that they are not exposed to resonances, and with the following details:

Frequency range:	f_1 = 10 Hz to f_2 = 2 000 Hz;
Amplitude:	$\hat{a}$ = 200 m/s^2, limited by d = 1,5 mm;
Duration:	n = 10 sweep cycles in each axis (x, y, z), resulting in a test duration t_{load} = 2,5 h per axis.

5.3.15 Rapid change of temperature

See IEC 60115-1:2020, 10.1, with the following details:

Lower temperature:	ϑ_{inf} = LCT;
Upper temperature:	ϑ_{sup} = UCT;
Number of cycles:	n = 5.

5.3.16 Rapid change of temperature, ≥ 100 cycles

See IEC 60115-1:2020, 10.1, with the following details:

Lower temperature:	ϑ_{inf} = LCT;
Upper temperature:	ϑ_{sup} = UCT;
Number of cycles:	preferred values for n are 100; 200; 500 and 1 000.

The detail specification may state different values for n depending on the properties and capabilities of the individual style.

This test is mandatory only for resistors categorized as level P or R.

5.3.17 Climatic sequence

5.3.17.1 General

See IEC 60115-1:2020, 10.3.

As stated in the detail specification, for execution of this test, the specimens shall be mounted on a test board in accordance with 5.2.2, or mounted on a test rack in accordance with 5.2.3.

5.3.17.2 Dry heat

IEC 60115-1:2020, 10.3.4.2.

The test specimens may be introduced directly into the heated chamber at any temperature from laboratory temperature to the upper category temperature, and withdrawn directly from it, since the effects of the sudden change of temperature are not known to be detrimental to the test specimens.

5.3.17.3 Damp heat, cyclic, first cycle

See IEC 60115-1:2020, 10.3.4.3.

5.3.17.4 Cold

IEC 60115-1:2020, 10.3.4.4.

The test specimens may be introduced directly into the cooled chamber at any temperature from the lower category temperature to laboratory temperature, and withdrawn directly from it, since the effects of the sudden change of temperature are not known to be detrimental to the test specimens.

Precaution against condensation of moisture on the test specimen is required if the specimens are inserted into the test chamber at a temperature below laboratory temperature.

5.3.17.5 Low air pressure

See IEC 60115-1:2020, 10.3.4.5, with the following details:

Air pressure: p_{amb} = 8 kPa, for resistors categorized as level G, or
p_{amb} = 1 kPa, for resistors categorized as level P or R.

NOTE According to ISO 2533, the air pressure of 1 kPa represents an approximate altitude of 31 200 m above sea level, and the air pressure of 8 kPa represents an approximate altitude of 17 600 m above sea level.

5.3.17.6 Damp heat, cyclic, additional cycles

See IEC 60115-1:2020, 10.3.4.6.

The number of additional cycles is ruled by the climatic category and given in IEC 60115-1:2020, Table 20.

5.3.17.7 DC load

See IEC 60115-1:2020, 10.3.4.7.

5.3.17.8 Final measurements

See IEC 60115-1:2020, 10.3.5.

See 5.3.23 for the measurement of the insulation resistance of insulated resistors.

5.3.18 Damp heat, steady state

NOTE This test is also known as "load humidity test" with no obvious discrimination from the "85/85 test" covered in 5.4.5, or "40/93 test".

See IEC 60115-1:2020, 10.4, with the following details:

As stated in the detail specification, for execution of this test, the specimens shall be mounted on a test board in accordance with 5.2.2, or mounted on a test rack in accordance with 5.2.3.

The duration t_{exp} of this test is determined by the climatic category, see IEC 60115-1:2020, Table 21.

See 5.3.23 for the measurement of the insulation resistance of insulated resistors.

5.3.19 Solderability, with lead-free solder

See IEC 60115-1:2020, 11.1, with the following details:

The solderability test shall be preceded by an accelerated ageing. Unless specified different by the detail specification, Ageing 3a (i.e. 4 h at 155 °C dry heat, see IEC 60115-1:2020, Table 27) shall be employed. After the accelerated ageing, the specimens shall be subjected to the standard atmospheric conditions for testing for a duration in the range of 2 h to 24 h.

A variety of lead-free solder alloys is applicable for the assembly of leaded low-power film resistors, with their own process temperature requirements and their typical soldering method, see IEC 60115-1:2020, 11.1.4.1.

- Components to be assembled in through-hole technique are typically soldered by a wave soldering or selective soldering process, with the typical solder alloys listed in the solder process temperature group 4: high.
- Components to be assembled in surface-mount technique are typically soldered by a reflow soldering process, with the typical solder alloys listed in the solder process temperature group 3: medium-high.

The detail specification shall specify one of the following solderability test conditions selected from IEC 60115-1:2020, 11.1.4.4, based on the predominant assembly technique used for the resistors covered by it.

Solderability testing for group 4 shall employ the solder bath method, see IEC 60115-1:2020, Table 30, Method 1, with the following details:

Solder alloy:	Sn99,3Cu0,7;
Bath temperature:	ϑ_{bath} = (250 ± 3) °C;
Immersion time:	t_{imm} = (3 ± 0,3) s.

Solderability testing for group 3 shall employ the solder bath method, see IEC 60115-1:2020, Table 30, Method 1, with the following details:

Solder alloy:	Sn96,5Ag3,0Cu0,5;
Bath temperature:	ϑ_{bath} = (245 ± 3) °C;
Immersion time:	t_{imm} = (3 ± 0,3) s.

A thermal insulating screen may be used only if stated in the detail specification.

Execution of this test is not required if the relevant detail specification explicitly excludes compatibility of the components covered therein with any lead-free soldering process.

5.3.20 Solderability, with SnPb solder

See IEC 60115-1:2020, 11.1, with the following details:

The solderability test shall be preceded by an accelerated ageing. Unless specified different by the detail specification, Ageing 3a (i.e. 4 h at 155 °C dry heat, see IEC 60115-1:2020, Table 27) shall be employed. After the accelerated ageing, the specimens shall be subjected to the standard atmospheric conditions for testing for a duration in the range of 2 h to 24 h.

The variety of lead-bearing solder alloys applicable for the assembly of leaded low-power film resistors, are listed in the solder process temperature group 2: medium, see IEC 60115-1:2020, 11.1.4.1. These solders are likewise used for wave soldering and for reflow soldering.

Solderability testing for group 2 shall employ the solder bath method, see IEC 60115-1:2020, Table 30, Method 1, with the following details:

Solder alloy:	Sn60Pb40 or Sn63Pb37
Bath temperature:	ϑ_{bath} = (235 ± 3) °C

Immersion time: t_{imm} = (2 ± 0,2) s

A thermal insulating screen may be used only if stated in the detail specification.

This test is normally also applicable to components with lead-free termination plating, since most of these platings are compatible with a lead-bearing solder process, too. Execution of this test is not required if the relevant detail specification explicitly excludes compatibility of the components covered therein with a traditional soldering process using lead-bearing solder (SnPb).

5.3.21 Resistance to soldering heat

See IEC 60115-1:2020, 11.2, with the following details:

Resistance to soldering heat shall be tested according to IEC 60068-2-20, Test Tb, solder bath method, with the following severity:

Solder alloy: any alloy, SnPb or SnCu or SnAgCu or SnAg

Bath temperature: ϑ_{bath} = (260 ± 3) °C

Immersion time: t_{imm} = (10 ± 1) s

A thermal insulating screen shall be used only if stated in the detail specification.

5.3.22 Solvent resistance

See IEC 60115-1:2020, 11.3, with the following details:

Method: Method 1: with rubbing

Solvent: Isopropyl Alcohol (IPA)

Solvent temperature: ϑ_{bath} = (23 ± 5) °C or $(50^{\ 0}_{-5})$ °C.

Soak time: t_{imm} = (5 ± 0,5) min

Rubbing device: Wad of cotton wool, or toothbrush,
as stated in the detail specification.

Number of strokes: n = 10.

NOTE The bath temperature of 23 °C is preferred in some regions due to safety concerns about the bath at 50 °C.

5.3.23 Insulation resistance

This test shall be applied only to insulated resistors.

See IEC 60115-1:2020, 12.1.

A suitable method given in IEC 60115-1:2020, 12.1 shall be applied for measurement of the insulation resistance, preferably the V-block method of IEC 60115-1:2020, 12.1.3.2.

For a specimen mounted on a test board, such a board placed in a suitable fixture may be used as the lower support, with its connections to the specimen's lead wires tied together and connected to the negative terminal of the test instrumentation. A V-shaped metal block, or a conformal clamp shall be applied from above with a suitable clamping force and connected to the positive terminal.

5.3.24 Voltage proof

This test shall be applied only to insulated resistors.

See IEC 60115-1:2020, 12.2.

A suitable method given in IEC 60115-1:2020, 12.2 shall be applied for the voltage proof test, preferably the V-block method of IEC 60115-1:2020, 12.1.3.2.

For a specimen mounted on a test board, such a board placed in a suitable fixture may be used as the lower support, with its connections to the specimen's lead wires tied together and connected to the negative terminal of the test instrumentation. A V-shaped metal block, or a conformal clamp shall be applied from above with a suitable clamping force and connected to the positive terminal.

5.3.25 Flammability

The needle-flame test in accordance with IEC 60115-1:2020, 12.4 shall be applied with the following detail:

Duration of flame application: $t_{\mathrm{a}} = 10_{-1}^{\ 0}\ \mathrm{s}$.

5.4 Optional and/or additional tests

5.4.1 Endurance at room temperature

For resistors categorized as level G, the testing for endurance at the rated temperature 70 °C may be replaced by testing for endurance at room temperature.

See IEC 60115-1:2020, 7.2, with the following details:

As stated in the detail specification, for execution of this test, the specimens shall be mounted on a test board in accordance with 5.2.2, or mounted on a test rack on accordance with 5.2.3.

The specimens shall be positioned in such a way that heat from any one specimen affects the adjacent specimens to the least possible extent. The specimens shall be in free air at the standard atmospheric conditions for testing as given in IEC 60115-1:2020, 5.2.3 (i.e. ambient temperature 15 °C to 35 °C).

NOTE For specimens mounted on a test rack, this will normally be achieved by positioning the rack horizontally, with the specimens aligned horizontally within the rack. For specimens mounted on a test board, this will normally be achieved by positioning the test boards vertically, with the specimens aligned vertically in a horizontal row.

The test shall be performed with a test dissipation P_{test} determined by:

$$P_{\mathrm{test}} = P_{70} \times \frac{(UCT - 25\ ^{\circ}\mathrm{C})}{(UCT - 70\ ^{\circ}\mathrm{C})}$$

where

P_{70} is the rated dissipation for $\vartheta_{\mathrm{rated}}$ = 70 °C

Hence the test shall be performed with the voltage:

$$U_{\mathrm{test}} = \sqrt{P_{\mathrm{test}} \times R_{\mathrm{n}}}\ ,$$

which shall be limited by

$$U_{\mathrm{test}} \leq U_{\mathrm{max}}$$

where

P_{70} is the rated dissipation;

R_{n} is the nominal resistance;

U_{max} is the limiting element voltage.

The duration of the endurance test shall be $t_{\text{test}} = 1\,000\ {}^{+24}_{\ 0}$ h.

See 5.3.23 for the measurement of the insulation resistance of insulated resistors.

If this test is applied in an advanced test schedule, the specimens shall be examined for visual defects and for the occurred change of resistance. The requirement for the permissible resistance change is stated in Table 4.

5.4.2 Single-pulse high-voltage overload test

This test presents as an alternative set of severities for the single-pulse high-voltage overload test of 5.3.7, using the pulse shape 1,2/50.

See IEC 60115-1:2020, 8.2.

As stated in the detail specification, for execution of this test, the specimens shall be mounted on a test board in accordance with 5.2.2, or mounted on a test rack in accordance with 5.2.3, or shall be tested unmounted. If the specimens are to be tested unmounted, they shall be placed in a suitable fixture for the execution of the test.

The test shall be performed with pulses defined by:

Pulse shape:	1,2/50	
Pulse peak voltage:	$\hat{U}_{\text{test}} = x \times \sqrt{P_{70} \times R_{\text{n}}}$,	with $x \geq 20$,
which shall be limited by	$\hat{U}_{\text{test}} \leq y \times U_{\text{max}}$,	with $y \geq 5$.

The detail specification shall state the values for x and y.

The single-pulse high-voltage overload test of 5.4.2 is recommended only for resistors categorized as level P or R.

If this test is applied in an advanced test schedule, the specimens shall be examined for visual defects and for the occurred change of resistance. The requirement for the permissible resistance change shall be stated in the clause on performance requirements of the detail specification, preferably added to the table on limits for the change of resistance at tests.

5.4.3 Periodic-pulse overload test

This test is a legacy test method which has been employed by traditional specifications of leaded fixed low-power non-wirewound (i.e. film) resistors. This test should only be used in specifications that require a strict continuance of historical test requirements. Then it should replace the periodic-pulse high-voltage overload test of 5.3.8.

The overall severity of this test is regarded as being inadequate in light of actual product's capabilities and of typical application requirements. The deficiency is recognized in the low peak load, the mean dissipation being lower than the specimens rated dissipation, and the limited number of applied pulses.

See IEC 60115-1:2020, 8.4, with the following details:

As stated in the detail specification, for execution of this test, the specimens shall be mounted on a test board in accordance with 5.2.2, or mounted on a test rack in accordance with 5.2.3.

The specimens shall be positioned in such a way that heat from any one specimen affects the adjacent specimens to the least possible extent. The specimens shall be in free air at the standard atmospheric conditions for testing as given in IEC 60115-1:2020, 5.2.3 (i.e. ambient temperature 15 °C to 35 °C).

NOTE For specimens mounted on a test rack, this will normally be achieved by positioning the rack horizontally, with the specimens aligned horizontally within the rack. For specimens mounted on a test board, this will normally be achieved by positioning the test boards vertically, with the specimens aligned vertically in a horizontal row.

The preferred pulse overload test voltage is

$$\hat{U}_{\text{test}} = \sqrt{15 \times P_{70} \times R_{\text{n}}}\ ,$$

which shall be limited by

$$\hat{U}_{\text{test}} \leq 2 \times U_{\text{max}}$$

where

P_{70} is the rated dissipation,

R_{n} is the nominal resistance,

U_{max} is the limiting element voltage.

The duration of the test is determined by the following details:

Number of pulse cycles: n = 1 000,

On state duration: t_{on} = 0,1 s, and

Off state duration: t_{off} = 2,5 s within each pulse cycle.

If this test is applied in an advanced test schedule, the specimens shall be examined for visual defects and for the occurred change of resistance. The requirement for the permissible resistance change is stated in Table 4.

5.4.4 Operation at low temperature

This test is presented as a supplement to the passive cold test of the climatic sequence of 5.3.18 and IEC 60115-1:2020, 10.3, which remains a mandatory part of all test schedules under the scope of this specification.

See IEC 60115-1:2020, 10.2, for the details of this test.

If this test is applied in an advanced test schedule, the specimens shall be examined for visual defects and for the occurred change of resistance. The requirement for the permissible resistance change shall be stated in the clause on performance requirements of the detail specification, preferably added to the table on limits for the change of resistance at tests.

5.4.5 Damp heat, steady state, accelerated

NOTE This test is also known as the "load humidity test" with no obvious discrimination from the "40/93 test" covered in 5.3.18, or as the "85/85 test".

This test is presented as a supplement to the damp heat, steady-state test of 5.3.19 and IEC 60115-1:2020, 10.5, which remains a mandatory part of all test schedules under the scope of this specification.

See IEC 60115-1:2020, 10.5, with the following details:

In order to follow the recommendation for this test of IEC 60068-2-67:1995, B.2 a) about limiting the temperature increase to below 2 K, the test shall be performed with a bias of 10% of the rated voltage U_r, see DC bias voltage option a) of IEC 60115-1:2020, Table 23.

For practical simplification, the test may be performed with the grouped DC bias voltages as given in IEC 60115-1:2020, 10.5.4.2.

See 5.3.23 for the measurement of the insulation resistance of insulated resistors.

If this test is applied in an advanced test schedule, the specimens shall be examined for visual defects, and for the occurred change of resistance. Insulated resistors shall also be inspected for the insulation resistance. The requirement for the permissible resistance change shall be stated in the clause on performance requirements of the detail specification, preferably added to the table on limits for the change of resistance at tests.

6 Performance requirements

6.1 General

Test severities and requirements stated in detail specifications referring to this sectional specification shall be of equal or superior performance level. Inferior performance levels are not permitted.

The severities for the tests shall be stated in the detail specifications, following the prescriptions of the generic specification IEC 60115-1 and Clause 5 of this sectional specification.

6.2 Limits for change of resistance at tests

Table 4 lists preferred limits for resistance change for all tests listed in the column headings. To classify the performance of resistors, the resistance change limits are assigned to stability classes. The performance requirements stated in the detail specification shall be based on a suitable selection of these stability classes and the assigned preferred limits.

Limits for resistance change are generally expressed as the sum of an absolute deviation, a, and a relative deviation, $p \times R$:

$$\Delta R = p \times R + a$$

where the dimensionless real number p typically is expressed as a percentage.

EXAMPLE 1 For a resistor of $R = 100\ \Omega$, the factor for the permissible relative deviation is given as $p = 0{,}005 = 0{,}5\ \%$, and the permissible absolute deviation is given as $a = 0{,}01\ \Omega = 10\ \mathrm{m}\Omega$. This results in a total permissible deviation of $\Delta R = (0{,}5\ \% \times 100\ \Omega + 10\ \mathrm{m}\Omega) = (0{,}005 \times 100\ \Omega + 0{,}01\ \Omega) = 0{,}51\ \Omega$.

NOTE The sum of an absolute and a relative share reflects the nature of some resistance change mechanisms being linked with the actual resistance value, and some others being independent of it.

Another historic background of an absolute deviation is related to the uncertainty of low-resistance measurements, for whatever low resistance was available then. The improvement of measurement capabilities over time can suggest the absolute deviation having become redundant. These improvements, however, do not waive the whole absolute share of resistance change mechanisms.

An equal share of absolute and relative deviations applies for

$$R' = \frac{a}{p}$$

For low-ohmic resistors with $R < R'$ the relative share loses significance versus the absolute share. For $R \ll R'$ the dominant absolute deviation reaches the same order of magnitude as the tested resistance R, or can even exceed R, which can render such stability requirement to appear mismatched with the general qualities of the resistor. Hence the writers of detail specifications are advised to specify a reasonable absolute deviation for the range of low resistance to be covered, which may be less than any proposal presented in Table 4.

EXAMPLE 2 Applying a permitted resistance change of $\Delta R = \pm(0{,}5\ \% \times R + 50\ \mathrm{m\Omega})$ to a resistance range extending down to 100 mΩ renders the permissible change to be ±50,5 % at the lower range limit. Component users will probably expect a much better stability, hence the specification writers are advised to use a lower permitted absolute deviation for such a case.

For high-ohmic resistors with $R > R'$ the absolute share loses significance versus the relative share, e.g. at $R = 100 \times R'$ the absolute share amounts to only 1 % of the relative share. For clarity of presentation, such insignificant absolute share should no longer be presented nor applied.

EXAMPLE 3 Applying a permitted resistance change of $\Delta R = \pm(0{,}5\ \%\ R + 50\ \mathrm{m\Omega})$ results in an equal share of deviation for $R' = 10\ \Omega$. At 1 kΩ the absolute share is only a mere 0,005 % R, which is 1 % of the relative share, and which can hardly be essential for the quality assessment of the resistors. Therefore, it will only confuse the readers of specifications or related test reports if the absolute share is still presented and applied for any $R \geq 1$ kΩ.

Table 4 – Limits for the change of resistance at tests

Stability class	Limit of resistance change, DR Ω						
	Long-term tests			Short-term tests	Advanced stress tests		
	IEC 60115-1:2020, 7.3 Endurance at a maximum temperature: UCT 10.3 Climatic sequence 10.4 Damp heat, steady state	IEC 60115-1:2020, 7.1 Endurance at the rated temperature 70 °C, 1 000 h 7.2 Endurance at room temperature, 1 000 h[b,d]	Extended, 8 000 h[a]	IEC 60115-1:2020, 8.1 Short-term Overload 9.5 Robustness of terminations 9.11 Vibration 10.1 Rapid change of temperature, 5 cycles 11.2 Resistance to soldering heat	IEC 60115-1:2020, 10.1 Rapid change of temperature, ≥ 100 cycles[a]	IEC 60115-1:2020, 8.2 Single-pulse high-voltage overload test[a] 8.5 Electrostatic discharge[c]	IEC 60115-1:2020, 8.3 Periodic-pulse high-voltage overload test[a] 8.4 Periodic-pulse overload test[d]
10	±(10 % R + 0,5 Ω)	±(10 % R + 0,5 Ω)	±(20 % R + 0,5 Ω)	±(2 % R + 0,1 Ω)	±(1 % R + 0,05 Ω)	±(1% R + 0,05 Ω)	±(2 % R + 0,05 Ω)
5	±(5 % R + 0,1 Ω)	±(5 % R + 0,1 Ω)	±(10 % R + 0,1 Ω)	±(1 % R + 0,05 Ω)			
2	±(2 % R + 0,1 Ω)	±(2 % R + 0,1 Ω)	±(5 % R + 0,1 Ω)	±(0,5 % R + 0,05 Ω)			
1	±(1 % R + 0,05 Ω)	±(1 % R + 0,05 Ω)	±(2 % R + 0,05 Ω)	±(0,25 % R + 0,05 Ω)	±(0,5 % R + 0,05 Ω)	±(0,5 % R + 0,05 Ω)	±(1 % R + 0,05 Ω)
0,5	±(0,5 % R + 0,05 Ω)	±(0,5 % R + 0,05 Ω)	±(1 % R + 0,05 Ω)	±(0,1 % R + 0,01 Ω)			
0,25	±(0,25 % R + 0,05 Ω)	±(0,25 % R + 0,05 Ω)	±(0,5 % R + 0,05 Ω)	±(0,05 % R + 0,01 Ω)	±(0,25 % R + 0,05 Ω)		
0,1	±(0,1 % R + 0,02 Ω)	±(0,1 % R + 0,02 Ω)	±(0,25 % R + 0,02 Ω)	±(0,05 % R + 0,01 Ω)			
0,05	±(0,05 % R + 0,01 Ω)	±(0,05 % R + 0,01 Ω)	±(0,1 % R + 0,01 Ω)	±(0,025 % R + 0,01 Ω)			
0,025	±(0,025 % R + 0,01 Ω)	±(0,025 % R + 0,01 Ω)	±(0,05 % R + 0,01 Ω)	±(0,01 % R + 0,01 Ω)			

[a] This test is mandatory only for resistors categorized as level P or as level R.

[b] This test is applicable only for resistors categorized as level G.

[c] See 5.3.10 for the applicability of this test.

[d] This test is optional, see the respective subclause of 5.4.

6.3 Temperature coefficient of resistance

Table 5 lists preferred limits for the reversible resistance change at the temperature coefficient of resistance test according to IEC 60115-1:2020, 6.2 and 5.3.2 of this specification. The performance requirements stated in the detail specification shall be based on a suitable selection of these preferred limits.

Each row of Table 5 presents a preferred temperature coefficient of resistance (TCR) with the limits for the change of resistance at the various category temperatures used within this specification.

Table 5 – Permitted change of resistance due to the variation of temperature

Temperature coefficient[a]		**Limit of resistance change $\Delta R/R$** %								
		Cold TCR				**Hot TCR**				
		Lower category temperature / Reference temperature				**Reference temperature / Upper category temperature**				
10^{-6}/K	**Code**[b]	**−55 °C / 20 °C**	**−40 °C / 20 °C**	**−25 °C / 20 °C**	**−10 °C / 20 °C**	**20 °C / 85 °C**	**20 °C / 125 °C**	**20 °C / 155 °C**	**20 °C / 175 °C**	**20 °C / 200 °C**
±1 000	W	±7,50	±6,00	±4,50	±3,00	±6,50	±10,50	±13,50	±15,50	±18,00
±500	V	±3,75	±3,00	±2,25	±1,50	±3,25	±5,25	±6,75	±7,75	±9,00
±250	U	±1,875	±1,500	±1,125	±0,750	±1,625	±2,625	±3,375	±3,875	±4,500
±100	S	±0,750	±0,600	±0,450	±0,300	±0,650	±1,050	±1,350	±1,550	±1,800
±50	R	±0,375	±0,300	±0,225	±0,150	±0,325	±0,525	±0,675	±0,775	±0,900
±25	Q	±0,188	±0,150	±0,113	±0,075	±0,163	±0,263	±0,338	±0,388	±0,450
±15	P	±0,113	±0,090	±0,068	±0,045	±0,098	±0,158	±0,203	±0,233	±0,270
±10	N	±0,075	±0,060	±0,045	±0,030	±0,065	±0,105	±0,135	±0,155	±0,180
±5	M	±0,038	±0,030	±0,023	±0,015	±0,033	±0,053	±0,068	±0,078	±0,090
±2	L	±0,015	±0,012	±0,009	±0,006	±0,013	±0,021	±0,027	±0,031	±0,036
±1	K	±0,008	±0,006	±0,005	±0,003	±0,007	±0,011	±0,014	±0,016	±0,018

[a] If additional temperature coefficients are required, these shall be specified by the detail specification, where the applicable coding according to IEC 60062 for the next larger TCR shall be applied.

[b] Code letters according to IEC 60062:2016, 7.2.

6.4 Temperature rise

The permissible temperature rise $\Delta\vartheta_{\max}$ for the temperature rise test according to IEC 60115-1:2020, 6.7 and 5.3.3 of this specification is determined by

$$\Delta\vartheta_{\max} = \text{UCT} - 70\ °\text{C}$$

where

UCT is the upper category temperature, which is based on the maximum element temperature (MET).

6.5 Visual examination

6.5.1 General visual criteria

The detail specification shall specify acceptance criteria for the visual examination of the resistor body and its terminations. These acceptance criteria shall be based on the following information:

- the general criteria given in IEC 60115-1:2020, 9.1.3, list items a) through d); and
- the illustrated examples for specific criteria, applicable to resistors from the scope of this sectional specification, given in Annex B (under consideration).

The detail specification shall specify acceptance criteria for the visual examination of the marking of the items specified in 7.1. These acceptance criteria shall be based on the following information:

- the general criteria given in IEC 60115-1:2020, 9.1.3, list item e); and
- the illustrated examples for specific criteria, applicable to resistors from the scope of this sectional specification, given in Annex B (under consideration).

6.5.2 Visual criteria after tests

Unless more specific requirements are given in the relevant specification for the visual examination after tests, the following criteria shall apply:

- there shall not be any visible damage to the resistor body and to its terminations after the test, except for an acceptable discoloration after endurance tests; and
- the required marking of marked resistors shall be legible after the test, except after extended duration endurance tests.

6.5.3 Visual criteria for the packaging

Unless more specific requirements are given in the relevant specification for the visual examination of the packaging, the following criteria shall apply:

- for the primary packaging,
  - the adhesive tapes shall be properly aligned in order to not expose adhesive;
  - the ends of the leads shall not protrude beyond the tapes;
  - the resistors shall be centred at the specified pitch, within the given tolerances;
  - the tapes shall not be spliced;
- for the proximity packaging,
  - the inner width of the box or reel shall fit snugly around the outer tape width, however without jamming the tape at its extraction;
  - the marking applied to the box or reel shall present all details as required by 7.3 and shall not be blurred or crumpled.

6.6 Solderability

See IEC 60115-1:2020, 11.1.5 and 11.1.6.

The requirement for the visual examination for the assessment of good solderability shall be:

≥ 95 % of the surface shall be covered with new solder. The new solder shall show no more than small amounts of scattered imperfections, such as pinholes or non-wetted or dewetted areas. These imperfections shall not be concentrated in one area.

6.7 Insulation resistance

The requirements of this clause only apply to insulated resistors.

The insulation resistance R_{ins} shall be not less than 1 GΩ in the test IEC 60115-1:2020, 12.1 in group 3 of the test schedule for the qualification approval.

The insulation resistance R_{ins} shall be not less than 1 GΩ after any of the tests

- Endurance at the rated temperature 70 °C test in accordance with IEC 60115-1:2020, 7.1; and
- Endurance at room temperature test in accordance with IEC 60115-1:2020, 7.2; and
- Endurance at a maximum temperature: UCT test in accordance with IEC 60115-1:2020, 7.3;

and not less than 100 MΩ after any of the tests

- Climatic sequence test in accordance with IEC 60115-1:2020, 10.3; and
- Damp heat, steady state test in accordance with IEC 60115-1:2020, 10.4; and
- Damp heat, steady state, accelerated test in accordance with IEC 60115-1:2020, 10.5.

6.8 Flammability

IEC 60115-1:2020, 12.4.5 and 12.4.6.

The duration of burning, t_{b} shall not exceed 30 s.

7 Marking, packaging and ordering information

7.1 Marking of the component

See IEC 60115-1:2020, 4.4, with the following details:

Resistance, tolerance on resistance, and, if applicable and feasible, the temperature coefficient of resistance shall be marked according to IEC 60062, preferably by means of a colour code according to IEC 60062:2016, Clause 3.

If the marking is done by means of a letter and digit code, this shall use one of the methods given in IEC 60062:2016, Clause 4, the code letter for the tolerance given in IEC 60062:2016, 5.2, and the code letter for the temperature coefficient given in IEC 60062:2016, 7.2.

7.2 Packaging

Wherever applicable, the axial leaded resistors shall be taped for automatic handling according to the provisions of IEC 60286-1. For that matter, the pair of adhesive tapes constitutes the primary packaging, and the box or reel holding the taped resistors constitutes the proximity packaging.

The primary and proximity packaging shall be subjected to a visual examination.

Information and recommendations on the packaging of radial formed types of resistors is given in Annex F.

7.3 Marking of the packaging

The complete required information as listed in IEC 60115-1:2020, 4.5 shall be marked on the proximity packaging.

7.4 Ordering information

The detail specification should specify the following minimum information as required for the ordering of resistors:

– The number of the detail specification and style reference.

– Resistance, the tolerance on resistance and, if applicable, the temperature coefficient of resistance. Wherever applicable, an alphanumeric coding given in IEC 60062 shall be used.

The detail specification should specify the special ordering information for 0 Ω resistors, if these parts are a supplementary part of the product family covered by it.

Special variants of the products covered by a detail specification may be identified by means of an optional suffix to the standard ordering information.

EXAMPLE A detail specification covers a range of axial leaded film resistors where the lead wires feature a lead-free plating. The same detail specification offers the option of the axial leaded film resistors being supplied with a lead-bearing plating (SnPb), which in the ordering information are identified with the suffix letter B.

The packaging and form of delivery of the resistors are usually not an integral part of the ordering information, hence the packaging needs to be specified separately in an ordering process. This permits focusing the entries of the bills of material to the technically relevant prescriptions, separated from the mere logistical information.

The recommendations of this clause shall be applied as mandatory provisions for detail specifications covering products classified to level P or level R.

The ordering information used for electronic order processing shall not contain any spaces.

8 Detail specifications

8.1 General

Detail specifications shall be derived from the relevant blank detail specification.

Detail specifications shall not specify requirements inferior to those of the generic specification, sectional specification or blank detail specification. When more severe requirements are included, they shall be listed in the respective clause on performance requirements of the detail specification and indicated in the test schedules, for example by a note.

The following information shall be given in each detail specification and the stated values shall be selected from those given in the appropriate clause of this sectional specification.

8.2 Information to be specified in a detail specification

8.2.1 Outline drawing or illustration

There shall be an outline drawing or illustration of the resistor as an aid to easy recognition and for comparison of the resistor with others.

8.2.2 Style and dimensions

See 4.2.

All dimensions and their associated tolerances, which affect interchangeability and mounting, shall be given in the detail specification, using a dedicated outline and dimensions drawing.

The free termination length should be given for appropriate tape packaging.

Where applicable, a method for the specification of the lead eccentricity should be applied, selected from those given in Figure 6. Then a suitable measurement method shall be specified, and the relevant maximum permissible dimension shall be specified in the table of dimensions.

Where applicable, a method for the specification of the length of excessive protective coating on the leads should be applied, selected from those given in Figure 4. Then a suitable measurement method shall be specified, and the relevant maximum permissible dimension shall be specified in the table of dimensions.

The mass of the products may be given for information.

8.2.3 Climatic category

See 4.3.

8.2.4 Resistance range

See 4.4.

If products approved to the detail specification have different ranges, the following statement should be added: "The range of values available in each style, together with the associated tolerance and temperature coefficient, is given in the register of approvals, available e.g. on the website www.iecq.org.".

8.2.5 Tolerances on resistance

See 4.5.

If products approved to the detail specification have different ranges, the following statement should be added: "The range of values available in each style, together with the associated tolerance and temperature coefficient, is given in the register of approvals, available e.g. on the website www.iecq.org".

8.2.6 Rated dissipation P_{70}

See 4.6.

The detail specification shall state the maximum allowable dissipation P_{70} at an ambient temperature of 70 °C (i.e. the rated temperature).

The detail specification shall state the maximum dissipation at temperatures other than 70 °C, i.e. the derating, either in a diagram or in the form of a statement.

8.2.7 Limiting element voltage U_{max}

See 4.7 and the definition given in IEC 60115-1:2020, 3.1.11.

8.2.8 Insulation voltage U_{ins}

This information is required for insulated resistors only.

See 4.8 and the definition given in IEC 60115-1:2020, 3.1.9.

8.2.9 Insulation resistance R_{ins}

This information is required for insulated resistors only.

See 4.9 and 6.7.

8.2.10 Test severities

See 5.3 and, where applicable, 5.4.

8.2.11 Limits of resistance change after testing

See 6.2.

8.2.12 Temperature coefficient of resistance

See 6.3.

8.2.13 Marking

See 7.1 for the marking of the resistors.

See 7.3 for the marking of the packaging.

8.2.14 Ordering information

See 7.4.

8.2.15 Mounting

The detail specification shall give guidance on methods of mounting for normal use. Such guidance may be based on the applicable specifications of process conditions for the assembly of component with leads, e.g. through-hole technology (THT), given in IEC 61760-1.

Mounting required for test and measurement purposes shall be in accordance with the provisions of 5.2.

8.2.16 Storage

See IEC 60115-1:2020, 4.9.

The detail specification shall specify the permissible duration of storage and, if required, periodicity, method and requirements of a re-examination to be applied.

8.2.17 Transportation

See IEC 60115-1:2020, 4.10

8.2.18 Additional information

The detail specification may include additional information (which is not normally required to be verified by the inspection procedure), such as circuit diagrams, curves, drawings and notes needed for the clarification of the detail specification.

8.2.19 Quality assessment procedures

The detail specification shall provide complete test schedules for the qualification approval and for the quality conformance inspection of the resistors covered therein.

8.2.20 0 Ω resistors

The detail specification may provide all information required for the specification and for the quality assessment of 0 Ω resistors, see Annex D.

9 Quality assessment procedures

9.1 General

See IEC 60115-1:2020, Annex Q.

9.2 Definitions

9.2.1 Primary stage of manufacture

See IEC 60115-1:2020, Q.1.3.1

For fixed low-power film resistors, the primary stage of manufacture is the deposition of the resistive film on the substrate.

9.2.2 Structurally similar components

See IEC 60115-1:2020, Q.1.3.2

Fixed low-power film resistors are accepted as being structurally similar

a) if they are manufactured at one or several manufacturing sites
   - within the same product technology; and
   - using the same specified raw-materials, manufacturing and quality inspection procedures; and
   - under the same leading manufacturing site's responsibility for product and quality.

   If there are several manufacturing sites, the manufacturer shall nominate the leading manufacturing site and the associated Designated Management Representative (DMR).
b) if all manufacturing sites are supervised by the same IECQ Certification Body (IECQ CB). Preferably it should be an IECQ CB of that country in which the leading manufacturing site is located;
c) if they have the same stability class and climatic category;
d) if they are different in dimensions only; and
e) if they have similar terminal types.

Resistors which differ only in c) may be accepted as structural similar if the different requirements of the stability class and/or the climatic category are judged separately in the final measurements.

The concept of structural similarity may only be employed for resistors categorized as level R, and for the purpose of the evaluation and determination of a failure rate, see IEC 60115-1:2020, Annex R.

9.2.3 Assessment level EZ

See IEC 60115-1:2020, Q.1.3.3

Assessment level EZ shall be applied for the quality assessment of leaded fixed film resistors in a detail specification referring to this sectional specification.

9.3 Formation of inspection lots

An inspection lot shall consist of resistors of the same product technology, type and style.

Where a range of resistors is to be qualified, the distribution of resistance values within the sample shall be as follows:

- 1/3 with the lowest resistance within that range, R_{min},
  to be collected from the range of R_{min} to 2 × R_{min},
  or the lowest resistance produced within the approval range;
- 1/3 with the critical resistance, R_{crit},
  to be collected from the range of 0,8 × R_{crit} to R_{crit};
- 1/3 with the highest resistance within that range, R_{max},
  to be collected from the range of 0,7 × R_{max} to R_{max},
  or the highest resistance produced within the approval range.

The range to be qualified may be a subset of the range covered by the detail specification. If the critical resistance is outside of the range to be qualified, resistors from the middle of the range (near the geometric mean between lowest and highest resistance, e.g. 1 kΩ for a range of 1 Ω to 1 MΩ) shall be used for substitution.

If approval is being sought for more than one temperature coefficient of resistance (TCR), the sample shall contain specimens representative of the different TCRs. In general, a superior TCR is accepted as being representative of any inferior TCR. In a similar manner, the sample shall contain a proportion of specimens of different resistances having the closest tolerance for which approval is being sought. The proportion of specimens having different characteristics is subject to the approval of the IECQ Certification Body (CB).

If required for a periodic inspection, an inspection lot should be representative of those extremes of the resistance range produced during the period. Styles of the same nominal dimensions but of different TCR produced during the period may be aggregated, except for the purposes of subgroups which contain a test for the TCR.

The low and high extreme resistances, or any critical resistance of the ranges of resistance and temperature characteristics of resistance for which qualification approval has been granted shall be inspected during a period which is approved by the IECQ CB.

The specimens shall be collected over the last 13 weeks of the inspection period.

9.4 Approved component (IECQ AC) procedures

The provisions of IEC 60115-1:2020, Clause Q.2 shall apply.

9.5 Qualification approval (QA) procedures

9.5.1 General

The procedures for qualification approval testing are given and referenced in IEC 60115-1:2020, Clause Q.3.

The sample shall be established in accordance with 9.3.

One spare specimen per resistance and one spare specimen per each temperature coefficient may be used to replace specimens that are defective because of incidents not attributable to the manufacturer.

For mounted specimens, any specimen found defective after mounting shall not be taken into account when calculating the permissible nonconforming items for the succeeding test. They shall be replaced by spare specimens.

9.5.2 Qualification approval

The required total sample size is the sum of all sample sizes in the qualification approval test schedule of Table 6 identified as destructive. If additional groups with destructive tests are introduced into the qualification approval test schedule, the total sample size shall be increased by the number of specimens required for the additional groups.

The test schedule for the qualification approval of resistors is given in Table 6. The schedule offers advice on the applicability of individual tests, which shall be applied in the normative detailed test schedule given by the detail specification. The tests of each group shall be carried out in the given order.

The whole sample except the specimens required for group 4 shall be subjected to the tests of group 1 and group 2 and then be allocated to the other test groups. Specimens found nonconforming during the tests of group 1 or group 2 shall not be used for any other test group.

Special rulings apply to the quality assessment of 0 Ω resistors; see Annex D.

The qualification approval shall be granted after successful completion of 1 000 h of the endurance test at 70 °C and all other tests of Table 6.

9.5.3 Quality conformance inspection

The schedule for the lot-by-lot and periodic tests for quality conformance inspection of resistors is given in Table 7.

The schedule offers advice on the applicability of individual tests, which shall be applied in the normative detailed test schedule given by the detail specification. The conditions of tests and the performance requirements shall be the same as specified for the respective tests in the schedule for qualification approval. The tests of each group shall be carried out in the given order.

Special rulings apply to the quality assessment of 0 Ω resistors; see Annex D.

9.6 Capability certification (IECQ AC-C) procedures

This sectional specification does not support the capability approval as described in IEC 60115-1:2020, Clause Q.4.

9.7 Technology certification (IECQ-AC-TC) procedures

The provisions of IEC 60115-1:2020, Clause Q.5 shall apply, and the test schedules of Table 6 and Table 7 shall be used.

9.8 Periodical evaluation of termination plating

The resistor manufacturer should establish a system for the periodical evaluation of the properties of their component's termination plating. A key aspect of these evaluations is the propensity of the solderable surface finishes to grow whiskers.

Such an evaluation system should employ suitable test methods for the assessment of the whisker propensity, preferably those of IEC 60068-2-82, as proposed by IEC 60115-1:2020, 10.7.

9.9 Delayed delivery

The provisions of IEC 60115-1:2020, Q.1.8 shall apply, except that the inspection level shall be reduced to S-2.

9.10 Certified test records

Certified test records according to IEC 60115-1:2020, Q.1.6 can be supplied, if agreed between the manufacturer and the customer.

9.11 Certificate of conformity (CoC)

The conformity is declared by marking the packing in accordance to the relevant system rules if components are qualified to this specification by a certification body of a quality assessment system (e.g. IECQ, successor of CECC).

An additional certificate of conformity (CoC) is not required for qualified components.

Table 6 – Test schedule for the qualification approval

Test[a]	Conditions of test[b]	D[c] or ND	n[c]	c[c]	Performance requirements
			Group 1		
6.1 [prior test 4.5] Resistance	See 5.3.1	ND	…	0	As in IEC 60115-1:2020, 6.1.4.
			Group 2		
9.1 [prior test 4.4.1] Visual examination	See 5.3.10	ND	…	0	As specified in 6.5.1 and by the detail specification
9.2 [prior test 4.4.2] Gauging of dimensions	See 5.3.11		(… of the sample)		As specified by the detail specification.
			Group 3		
12.1 [prior test 4.6] Insulation resistance (for insulated resistors only)	See 5.3.23	ND	…	0	As in 6.7.
12.2 [prior test 4.7] Voltage proof (for insulated resistors only)	See 5.3.24 $U_{\text{test}} = \ldots \cdot U_{\text{ins}}$; $t_{\text{load}} = \ldots$ s.				As in IEC 60115-1:2020, 12.2.5.
8.1 [prior test 4.13] Short-term overload	See 5.3.6 $U_{\text{test}} = \ldots$; **Style** | t_{load} … | … … | … … | … Visual examination. Resistance.	D	(… of the sample)		As in 6.5.2 As specified in 6.2 and by the detail specification.

Test[a]	**Conditions of test**[b]	**D**[c] **or ND**	n[c]	c[c]	**Performance requirements**
			Group 4[d]		
		D	…	0	
11.1 [prior test 4.17] Solderability, with lead-free solder[e]	See 5.3.19 Ageing: … . Solder bath method; Solder …; ϑ_{bath} = (… ± …) °C; t_{imm} = (… ± …) s. Visual examination.		(half of the sample)		As in 6.6.
11.1 [prior test 4.17] Solderability, with SnPb solder[e]	See 5.3.20 Ageing: … . Solder bath method; Solder …; ϑ_{bath} = (… ± …) °C; t_{imm} = (… ± …) s. Visual examination.		(the other half of the sample)		As in 6.6.
			Group 5		
6.2 [prior test 4.8] Temperature coefficient of resistance	See 5.3.2 ϑ = {20 °C, LCT, 20 °C}; α_{LCT}; ϑ = {20 °C, UCT, 20 °C}; α_{UCT}.	D	…	0	As specified in 6.3 and by the detail specification. As specified in 6.3 and by the detail specification.
			Group 6		
		D	…	0	
9.5 [prior test 4.16] Robustness of terminations	See 5.3.13 Visual examination. Resistance.		(half of the sample)		As in 6.5.2. As specified in 6.2 and by the detail specification.
10.1 [prior test 4.19] Rapid change of temperature	See 5.3.15 ϑ_{inf} = LCT, ϑ_{sup} = UCT; n = 5. Visual examination. Resistance.		(the other half of the sample)		As in 6.5.2 As specified in 6.2 and by the detail specification.
9.11 [prior test 4.22] Vibration	See 5.3.14 Endurance by sweeping; f_1 = … Hz; f_2 = … Hz; n = … for each axis; $\hat{a}$ = … m/s^2 , limited by d = … mm. Electrical continuity. Visual examination. Resistance.				As in IEC 60115-1:2020, 9.11.7.1. As in 6.5.2. As specified in 6.2 and by the detail specification.

Test[a]	Conditions of test[b]	D[c] or ND	n[c]	c[c]	Performance requirements
10.3 [prior test 4.23] Climatic sequence	See 5.3.17		(all of the sample)		
– Dry heat	ϑ = UCT; t_{exp} = 16 h.				
– Damp heat, cyclic, first cycle	1 cycle; ϑ_{sup} = 55 °C.				
– Cold	ϑ = LCT; t_{exp} = 2 h.				
– Low air pressure	p_{amb} = … kPa; t_{exp} = 1 h.				
– Damp heat, cyclic, additional n cycle(s)	n cycle(s); ϑ_{sup} = 55 °C.				
– DC load	$U_{\mathrm{test}} = \sqrt{P_{70} \cdot R_{\mathrm{n}}}$, limited by $U_{\mathrm{test\,max}} = U_{\mathrm{max}}$; 1 min.				
– Final measurements	Visual examination.				As in 6.5.2.
	Resistance.				As specified in 6.2 and by the detail specification.
	Insulation resistance[f].				As in 6.7.
			Group 7		
7.1 [prior test 4.25.1] Endurance at the rated temperature 70 °C	See 5.3.4 $U_{\mathrm{test}} = \sqrt{P_{70} \cdot R_{\mathrm{n}}}$, limited by $U_{\mathrm{test}} \le U_{\mathrm{max}}$; t_{on} = 1,5 h; t_{off} =0,5 h; t_{load} = 1 000 h.	D	…	0	
	Visual examination.				As in 6.5.2.
	Resistance.				As specified in 6.2 and by the detail specification.
	Insulation resistance[f].				As in 6.7.
7.1.9 [prior test 4.25.1.8] Extended endurance at the rated temperature 70 °C (for resistors categorized as level P or R only)	Duration extended to t_{load} = 8 000 h. Resistance.				As specified in 6.2 and by the detail specification.
			Group 8		
10.4 [prior test 4.24] Damp heat, steady state	See 5.3.18 ϑ = 40 °C; RH = 93 %; t_{exp} = … .	D	…	0	
	Visual examination.				As in 6.5.2.
	Resistance.				As specified in 6.2 and by the detail specification.
	Insulation resistance[f].				As in 6.7.

<table>
<tr><th>Test[a]</th><th>Conditions of test[b]</th><th>D[c] or ND</th><th>n[c]</th><th>c[c]</th><th>Performance requirements</th></tr>
<tr><td></td><td></td><td></td><td colspan="2">Group 9</td><td></td></tr>
<tr><td>11.2 [prior test 4.18]
Resistance to soldering heat</td><td>See 5.3.21
Solder bath method;
ϑ_{bath} = (… ±…) °C;
t_{imm} = (… ±…) s.
Visual examination.
Resistance.</td><td>D</td><td>…</td><td>0</td><td>As in 6.5.2.
As specified in 6.2 and by the detail specification.</td></tr>
<tr><td>12.4 [prior test 4.35]
Flammability</td><td>See 5.3.25
t_{a} = … s.
Duration of burning.</td><td></td><td>(… of the sample)</td><td></td><td>As in 6.8.</td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Group 10</td><td></td></tr>
<tr><td>9.3 [prior test 4.4.3]
Detail dimensions</td><td>See 5.3.12</td><td>D</td><td>…</td><td>0</td><td>As specified by the detail specification</td></tr>
<tr><td>7.3 [prior test 4.25.3]
Endurance at a maximum temperature: UCT</td><td>See 5.3.5
ϑ = UCT; t_{exp} = 1 000 h.
Visual examination.
Resistance.
Insulation resistance[f].</td><td></td><td></td><td></td><td>As in 6.5.2.
As specified in 6.2 and by the detail specification.
As in 6.7.</td></tr>
<tr><td>6.7 [prior test 4.14]
Temperature rise
(only for resistors with $R_{\text{n}} < R_{\text{crit}}$)</td><td>See 5.3.3
$U_{\text{test}} = \sqrt{P_{70} \cdot R_{\text{n}}}$
Temperature rise</td><td></td><td>(… of the sample)</td><td></td><td>As in 6.4</td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Group 11</td><td></td></tr>
<tr><td>8.5 [prior test 4.38]
Electrostatic discharge</td><td>See 5.3.9<table><tr><th>Style</th><th>U_{HBM}</th></tr><tr><td>…</td><td>…</td></tr><tr><td>…</td><td>…</td></tr><tr><td>…</td><td>…</td></tr></table>n_{pos} = …; n_{neg} = … .
Visual examination.
Resistance.</td><td>D</td><td>…</td><td>0</td><td>As in 6.5.2.
As specified in 6.2 and by the detail specification</td></tr>
<tr><td>11.3 [prior tests 4.29, 4.30]
Solvent resistance</td><td>See 5.3.22
Solvent: …;
ϑ_{bath} = … °C;
t_{imm} = … s;
Rubbing device: … .
Number of strokes n = …
Visual examination.</td><td></td><td></td><td></td><td>As in 6.5.2.</td></tr>
</table>

Test[a]	**Conditions of test**[b]	**D**[c] **or ND**	n[c]	c[c]	**Performance requirements**
			Group 12		
8.3 [prior test 4.39] Periodic-pulse high-voltage overload test (for resistors categorized as level P or R only)	See 5.3.8 $\hat{U}_{\text{test}}$ = …; t_{pulse} = … µs; f_{pulse} = … Hz; t_{test} = … h Visual examination. Resistance.	D	…	0	As in 6.5.2. As specified in 6.2 and by the detail specification
			Group 13		
10.1 [prior test 4.19] Rapid change of temperature, ≥ 100 cycles (for resistors categorized as level P or R only)	See 5.3.16 ϑ_{inf} = LCT; ϑ_{sup} = UCT; **Style** – n … – … … – … … – … Visual examination. Resistance.	D	…	0	As in 6.5.2. As specified in 6.2 and by the detail specification.
			Group 14		
8.2 [prior test 4.27] Single-pulse high-voltage overload test (for resistors categorized as level P or R only)	See 5.3.7 Pulse shape: …; $\hat{U}_{\text{test}}$ = …; n = … , $f \le$ … . Visual examination. Resistance.	D	…	0	As in 6.5.2. As specified in 6.2 and by the detail specification.

[a] Test clause numbers refer to IEC 60115-1:2020, with indication of the prior used test clause number referring to IEC 60115-1:2008 in square brackets.

[b] The information given here shall provide a suitable overview of the most relevant parameters of each test, however shall not take precedence over any more detailed prescription given in a respective clause of this specification or in a cited normative reference.

[c] Refer to Annex A for lists of symbols and of abbreviated terms.

[d] Resistors submitted to this test shall not be measured in Group 1, 2 and 3, they are not included in the number of specimens for Group 1 or 2.

[e] This test is not applicable if the relevant detail specification explicitly excludes compatibility of the components covered therein with the soldering processes represented by this test. See 5.3.19 or 5.3.20, respectively.

[f] This measurement is applicable only to insulated resistors.

Table 7 – Test schedule for the quality conformance inspections

Lot-by-lot tests					
Test[a]	**Conditions of test[b]**	**D[c] or ND**	**IL[c]**	c[c]	**Performance requirements**
			Group A1		
6.1 [prior test 4.5] Resistance[d]	See 5.3.1	ND	100 %		As in IEC 60115-1:2020, 6.1.4.
			Group A2		
9.1 [prior test 4.4.1] Visual examination[e]	See 5.3.10	ND	S-4	0	As in 6.5.1 and by the detail specification.
9.2 [prior test 4.4.2] Gauging of dimensions[e]	See 5.3.11				As specified by the detail specification.
			Group B1		
12.2 [prior test 4.7] Voltage proof (for insulated resistors only)	See 5.3.24 $U_{\text{test}} = \ldots \cdot U_{\text{ins}}$; $t_{\text{load}} = \ldots$ s.	ND	S-3	0	As in IEC 60115-1:2020, 12.2.5.
8.1 [prior test 4.13] Short-term overload	See 5.3.6 $U_{\text{test}} = \ldots$; **Style** **t_{load}** … … … … … … Visual examination. Resistance.	D			As in 6.5.2. As specified in 6.2 and by the detail specification.
			Group B2[f]		
		D		0	
11.1 [prior test 4.17] Solderability with lead-free solder[g]	See 5.3.19 Ageing: … . Solder bath method; Solder …; $\vartheta_{\text{bath}} = (\ldots \pm \ldots)$ °C; $t_{\text{imm}} = (\ldots \pm \ldots)$ s. Visual examination.		S-3		As in 6.6.
11.1 [prior test 4.17] Solderability with SnPb solder[g]	See 5.3.20 Ageing: … . Solder bath method; Solder …; $\vartheta_{\text{bath}} = (\ldots \pm \ldots)$ °C; $t_{\text{imm}} = (\ldots \pm \ldots)$ s. Visual examination.		S-3		As in 6.6.
			Group B3		
6.2 [prior test 4.8] Temperature coefficient of resistance (only for resistors with a TCR $\lvert\alpha\rvert < 50 \times 10^{-6}$/K)	See 5.3.2 ϑ = {20 °C, LCT, 20 °C}; α_{LCT}; ϑ = {20 °C, UCT, 20 °C}; α_{UCT}.	D	S-3	0	As specified in 6.3 and by the detail specification. As specified in 6.3 and by the detail specification.

Periodic tests

Test[a]	**Conditions of test**[b]	**D**[c] **or ND**	p[c]	n[c]	c[c]	**Performance requirements**
				Group C1[i]		
		D	3	20	0	
9.5 [prior test 4.16] Robustness of terminations	See 5.3.13 Visual examination. Resistance.			(half of the sample)		 As in 6.5.2. As specified in 6.2 and by the detail specification.
10.1 [prior test 4.19] Rapid change of temperature	See 5.3.15 ϑ_{inf} = LCT; ϑ_{sup} = UCT; n = 5. Visual examination. Resistance.			(the other half of the sample)		 As in 6.5.2. As specified in 6.2 and by the detail specification.
9.11 [prior test 4.22] Vibration	See 5.3.14 Endurance by sweeping; f_1 = … Hz; f_2 = … Hz; $\hat{a}$ = … m/s^2, limited by d = … mm; n = … for each axis Electrical continuity. Visual examination. Resistance.					 As in IEC 60115-1:2020, 9.11.7.1 As in 6.5.2. As specified in 6.2 and by the detail specification.
10.3 [prior test 4.23] Climatic sequence	See 5.3.17			(all of the sample)		
– Dry heat	ϑ = UCT; t_{exp} = 16 h.					
– Damp heat, cyclic, first cycle	1 cycle; ϑ_{sup} = 55 °C.					
– Cold	ϑ = LCT; t_{exp} = 2 h.					
– Low air pressure	p_{amb} = … kPa; t_{exp} = 1 h.					
– Damp heat, cyclic, additional n cycle(s)	n cycle(s); ϑ_{sup} = 55 °C.					
– DC load	$U_{\text{test}} = \sqrt{P_{70} \cdot R_{\text{n}}}$, limited by $U_{\text{test max}} = U_{\text{max}}$; 1 min.					
– Final measurements	Visual examination.					As in 6.5.2.
	Resistance.					As specified in 6.2 and by the detail specification.
	Insulation resistance[h].					As in 6.7.

			Group C2[i]			
7.1 [prior test 4.25.1] Endurance at the rated temperature 70 °C	See 5.3.4 $U_{\text{test}} = \sqrt{P_{70} \cdot R_{\text{n}}}$, limited by $U_{\text{test max}} = U_{\text{max}}$; t_{on} = 1,5 h; t_{off} = 0,5 h; t_{load} = 1 000 h. Visual examination. Resistance. Insulation resistance[h].	D	3	20	0	As in 6.5.2. As specified in 6.2 and by the detail specification. As in 6.7.
7.1.9 [prior test 4.25.1.8] Extended endurance at the rated temperature 70 °C (for resistors categorized as level P or R only)	Duration extended to t_{load} = 8 000 h. Resistance.		12			As specified in 6.2 and by the detail specification.
			Group C3[i]			
11.2 [prior test 4.18] Resistance to soldering heat	See 5.3.21 Solder bath method; ϑ_{bath} = (… ±…) °C; t_{imm} = (… ±…) s. Visual examination. Resistance.	D	3	20	0	As in 6.5.2. As specified in 6.2 and by the detail specification
12.4 [prior test 4.35] Flammability	See 5.3.25 t_{a} = … s. Duration of burning.		36	(5 of the sample)		As in 6.8.
			Group D1[i]			
6.2 [prior test 4.8] Temperature coefficient of resistance (only for resistors with a TCR $\lvert\alpha\rvert \geq 50 \times 10^{-6}$/K)	See 5.3.2 ϑ = {20 °C, LCT, 20 °C}; α_{LCT}; ϑ = {20 °C, UCT, 20 °C}; α_{UCT}.	D	12	20	0	As specified in 6.3 and by the detail specification. As specified in 6.3 and by the detail specification.
			Group D2[i]			
10.4 [prior test 4.24] Damp heat, steady state	See 5.3.18 ϑ = 40 °C; RH = 93 % t_{exp} = … . Visual examination. Resistance. Insulation resistance[h].	D	12	20	0	As in 6.5.2. As specified in 6.2 and by the detail specification. As in 6.7

			Group D3[i]			
9.3 [prior test 4.4.3] Detail dimensions	See 5.3.12	D	36	20	0	As specified by the detail specification
7.3 [prior test 4.25.3] Endurance at a maximum temperature: UCT	See 5.3.5 ϑ = UCT; t_{exp} = 1 000 h. Visual examination. Resistance. Insulation resistance[h].					As in 6.5.2. As specified in 6.2 and by the detail specification. As in 6.7
6.7 [prior test 4.14] Temperature rise (only for resistors with $R_{\text{n}} < R_{\text{crit}}$)	See 5.3.3 $U_{\text{test}} = \sqrt{P_{70} \cdot R_{\text{n}}}$ Temperature rise.			(6 of the sample)		As in 6.4.
			Group E[i]			
8.5 [prior test 4.38] Electrostatic discharge	See 5.3.9 **Style** | U_{HBM} … | … … | … … | … n_{pos} = …; n_{neg} = … . Visual examination. Resistance.	D	12	20	0	As in 6.5.2. As specified in 6.2 and by the detail specification
11.3 [prior tests 4.29, 4.30] Solvent resistance	See 5.3.22 Solvent: …; ϑ_{bath} = … °C; t_{imm} = … s; Rubbing device: … . Number of strokes n = … Visual examination.					As in 6.5.2.
			Group F[i]			
10.1 [prior test 4.19] Rapid change of temperature, ≥ 100 cycles (for resistors categorized as level P or R only)	See 5.3.16 ϑ_{inf} = LCT; ϑ_{sup} = UCT; **Style** | n … | … … | … … | … Visual examination. Resistance.	D	36	20	0	As in 6.5.2. As specified in 6.2 and by the detail specification.

			Group G[i]			
8.2 [prior test 4.27] Single-pulse high-voltage overload test (for resistors categorized as level P or R only)	See 5.3.7 Pulse shape: …; $\hat{U}_{\text{test}}$ = …; n = … , $f \leq$ … . Visual examination. Resistance.	D	12	20	0	As in 6.5.2. As specified in 6.2 and by the detail specification.

[a] Test clause numbers refer to IEC 60115-1:2020, with indication of the prior used test clause number referring to IEC 60115-1:2008 in square brackets.

[b] The information given here shall provide a suitable overview of the most relevant parameters of each test, however shall not take precedence over any more detailed prescription given in a respective clause of this specification or in a cited normative reference.

[c] Refer to Annex A for lists of symbols and of abbreviated terms.

[d] This inspection shall be performed after removal of nonconforming items by 100 % testing during the manufacturing process. Whether the lot was accepted or not, all samples used for sampling inspection shall be inspected in order to monitor the outgoing quality level. The sampling level shall be established by the manufacturer, preferably according to IEC 61193-2:2007, Annex A.

In case one or more nonconforming items occur in a sample, this lot shall be rejected but all nonconforming items shall be counted for the assessment of a quality level. The statistically verified quality limit (SVQL) shall be calculated by accumulating inspection data according to the method given in IEC 61193-2:2007, 6.2.

[e] This test may be replaced by in-production testing if the manufacturer installs SPC on dimensional measurements or other mechanisms to avoid parts exceeding the dimensional limits.

[f] Resistors submitted to this test shall not be measured in Group A2 or B1.

[g] This test is not applicable if the relevant detail specification explicitly excludes compatibility of the components covered therein with the soldering processes represented by this test. See 5.3.19 or 5.3.20, respectively.

[h] This measurement is applicable only to insulated resistors.

[i] All tests of the sub-group shall be repeated if one or more nonconforming item is obtained. No nonconforming items are permitted in the repeat testing. Release of products may continue during repeat testing.

Annex A
(normative)

Symbols and abbreviated terms

A.1 Symbols

α	Angle of a lead wire bend	°
α_{LCT}	TCR between the reference temperature and LCT, cold TCR	10^{-6}/K
α_{UCT}	TCR between the reference temperature and UCT, hot TCR	10^{-6}/K
ϑ	Temperature (Celsius temperature)	°C
	NOTE 1 The vast majority of temperatures applied in the scope of this specification is established according to IEC 60027-1 and ISO 80000-5 as Celsius temperatures and thus expressed in °C, e.g. ambient temperature, rated temperature, category temperatures, thermal test conditions, process conditions, thermal criteria. Most of these temperatures do not have a particular thermodynamic relevance.	
ϑ_{inf}	Lower temperature, e.g. in a respective temperature sequence	°C
ϑ_{sup}	Upper temperature, e.g. in a respective temperature sequence	°C
ϑ_{amb}	Ambient temperature	°C
$\vartheta_{\mathrm{bath}}$	Bath temperature, e.g. in solvent resistance or solder bath tests	°C
ϑ_{max}	Maximum temperature, maximum element temperature	°C
ϑ_{r}	Rated temperature	°C
$\Delta\vartheta$	Temperature rise	K
$\Delta\vartheta_{\mathrm{max}}$	Maximum permissible temperature rise	K
a	Acceleration, e.g. in a vibration test	m/s^2
a	Absolute portion of a permitted deviation	Ω
a	Length of a solder land in an SMD land pattern, along the direct axis	mm
b	Diameter of bores in a test board or PCB	mm
b	Width of a solder land in an SMD land pattern, transversal	mm
B_{max}	Maximum height of a lead wire bow	mm
c	Acceptance number (permitted number of nonconforming items)	1
c	Length of excessive protective coating extending on a lead-wire	mm
C	Width of a conductor on a test board or PCB	mm
d	Diameter of the wire terminations	mm
d	Displacement, e.g. in a vibration test	mm
D	Diameter of the resistor body	mm
D_{max}	Maximum diameter of the resistor body, using the permitted tolerance	mm
e	Real lead eccentricity, offset of lead versus resistor body	mm
e'	Effective lead eccentricity, offset of lead versus permissible resistors body diameter	mm
f	Frequency or repetition rate of test loads	Hz; min^{-1}
f_{pulse}	Repetition rate of a pulse load	Hz
f_1	Lower frequency of a sweep cycle, e.g. in a vibration test	Hz

f_2	Upper frequency of a sweep cycle, e.g. in a vibration test	Hz
F	Transversal length of a base limb of a Z-bent lead wire	mm
g	Distance between the solder lands of an SMD land pattern, along the direct axis	mm
G	Grid dimension on a test board or PCB, along the direct axis of a resistor	mm
G	Total length of a resistor with Z-bend lead wires	mm
h	Mounting height of a component above a PCB surface, clearance	mm
H	Total height of a component above the mounting plane	mm
H_0	Distance of the formed resistor's seating plane to the sprocket holes centre line of a carrier tape	mm
H_1	Distance of the top of the formed resistor, including a bent lead wire, to the sprocket holes centre line of a carrier tape	mm
I	Current, for example a test current,	A
I_{max}	Maximum permissible current	A
I_{r}	Rated current, $I_{\mathrm{r}} = \sqrt{P_{70} / R_{\mathrm{n}}}$	A
I_{test}	Current to be applied in a respective test	A
$\hat{I}_{\mathrm{test}}$	Peak current to be applied in a respective pulse load test	A
l	Length of wire terminations	mm
Δl	Longitudinal displacement	mm
l_{min}	Minimum length of wire terminations	mm
$l_{\mathrm{f\ min}}$	Minimum free length of formed wire terminations not covered by tape packaging	mm
l_{meas}	Distance of the point of measurement from the resistor body	mm
L	Length of the resistor body	mm
L_{c}	Length between clean lead-wires, outside of any excessive protective coating extending on a lead-wire	mm
m	Mass	mg
M	Margin on a test board between an outer grid position and the limit of the defined area	mm
n	Sample size	1
n	Number of test cycles	1
n	Arbitrary number, position	1
n_{pos}	Number of discharges with positive polarity in a HBM ESD test	1
n_{neg}	Number of discharges with negative polarity in a HBM ESD test	1
p	Repetition period of a test	month
p	Lead-wire protrusions below a test board or PCB	mm
p	Relative portion of a permitted deviation (percentage)	1
p_{amb}	Air pressure, e.g. as an atmospheric condition for testing	kPa
P	Pitch, grid dimension on a test board or test rack, perpendicular to the direct axis of a resistor	mm
ΔP	Transversal displacement, pitch error	mm
P	Pitch of components in a carrier tape	mm
P	Dissipation	W

P_0	Pitch of sprocket holes in a carrier tape	mm
P_1	Pitch of component pockets in a carrier tape	mm
P_{70}	Rated dissipation at 70 °C ambient temperature	W
P_r	Rated dissipation	W
P_test	Dissipation to be applied in a respective test	W
r	Inner bending radius of a lead-wire	mm
R	Actual resistance	Ω
R_crit	Critical resistance, $R_\text{crit} = U_\text{max}{}^2 / P_{70}$	Ω
R_ins	Insulation resistance	Ω
R_min	Lowest resistance in a given range	Ω
R_max	Highest resistance in a given range	Ω
R_n	Nominal resistance	Ω
R_rsd	Residual resistance, actual resistance of a 0 Ω resistor	Ω
$R_\text{rsd max}$	Maximum permissible residual resistance	Ω
RH	Relative humidity, e.g. as an atmospheric condition for testing	1; %
ΔR	Change of resistance	Ω
$\Delta R/R$	Change of resistance related to the prior measurement	1; %
S	Spacing of the lead-wires of a resistor with radial formed leads	mm
Δs_max	Maximum spread of formed lead wires	mm
t_a	Duration of application of a test flame	s
t_b	Duration of burning after removal of the test flame	s
t_exp	Duration of exposure to respective climatic test conditions	h; d
t_imm	Duration of immersion, e.g. in solvent resistance or solder bath tests	s; min
t_load	Duration of load applied in respective electrical or mechanical tests	s
t_on	Duration of the on state in a periodic load cycle	s; h
t_off	Duration of the off state in a periodic load cycle	s; h
t_pulse	Duration of a square wave pulse	s
t_test	Duration of a test procedure or test sequence	s; h
T	Thermodynamic temperature	K
	NOTE 2 In the scope of this specification, a thermodynamic temperature is employed only in a few special cases: – Calculation of thermal noise, see IEC 60195; – Calculation of the heat radiation according to Planck's law of thermal radiation; – Estimation of ageing effects according to Arrhenius' equation on the temperature dependence of reaction rates.	
u	Clearance of unprotected lead wire, relative to the lower body end	mm
U	Voltage	V
U_HBM	Human body model discharge voltage in an ESD test	V
U_ins	Insulation voltage	V
U_max	Limiting element voltage, maximum permissible voltage	V

U_r	Rated voltage, $U_\mathrm{r}=\sqrt{P_{70}\cdot R_\mathrm{n}}$	V
U_test	Voltage to be applied in a respective test	V
$U_\mathrm{test\ max}$	Limitation to the voltage applied in a respective test	V
$\hat{U}_\mathrm{test}$	Peak voltage to be applied in a respective pulse load test	V
$\hat{U}_\mathrm{test\ max}$	Limitation to the peak voltage applied in a respective pulse load test	V
W	Width of a carrier tape	mm
x	Load factor	1
y	Load factor	1

A.2 Abbreviated terms

AC	Alternating current, voltage or current of approximate sinusoidal waveform
C	Carbon film technology (character for style designations)
CA	Capability approval
CAS	Chemical Abstracts Service of the American Chemical Society
CB	Certification body
CoC	Certificate of conformity
D	Destructive
DC	Direct current, non-alternating voltage or current
DMR	Designated management representative (quality system manager)
ESD	Electrostatic discharge
G	Metal glaze technology (character for style designations)
HBM	Human body model, representation of the capacitance and resistance of a human body for ESD testing
IECQ	IEC quality assessment system for electronic components
IECQ AC	IECQ approved components scheme, a component qualification scheme
IECQ CB	IECQ Certification body
IL	Inspection level
IPA	Isopropyl alcohol (CAS Registry Number: 67-63-0), also known as Isopropanol, 2-Propanol, or Popan-2-ol
IUPAC	International Union of Pure and Applied Chemistry
L	Suffix to style designations for axial leaded film resistors, if formed subsequently to a radial version with lateral body position
LCT	Lower category temperature
M	Metal film technology (character for style designations)
MET	Maximum temperature of the resistive element
ND	Non destructive
NSI	National supervising inspectorate

NOTE 1 IECQ 01, IEC Quality Assessment System for Electronic Components (IECQ Scheme) – Basic Rules, has implemented in its 2007-12 revision a change of the term Supervising Inspectorate to IECQ Certification Body (IECQ CB).

ONS	Organisme National de Surveillance (National supervising inspectorate)

NOTE 2 This term has been used in specifications prior to using the term National Supervising Inspectorate (NSI)

PCB	Printed circuit board
QA	Qualification approval
RA	Style designation prefix for axial leaded film resistors
RC	Style designation for "Resistor, Cylindrical", typically used for SMD film resistors
RL	Style designation prefix for radial leaded film resistors with lateral body position
RMS	Root mean square, designating an effective alternating voltage or current
RR	Style designation for "Resistor, Rectangular", typically used for SMD film resistors
RU	Style designation prefix for radial leaded film resistors with upright body position
SMD	Surface-mounted device
SMT	Surface-mount technology
SPC	Statistical process control
TA	Technology approval
TADD	Technology approval declaration document
TAS	Technology approval schedule
TC	Temperature coefficient (not specific to resistance)
TCR	Temperature coefficient of resistance
TIM	Thermal interface material
U	Suffix to style designations for axial leaded film resistors, if formed subsequently to a radial version with upright body position
UCT	Upper category temperature
VCR	Voltage coefficient of resistance
X	Metal oxide technology (character for style designations)

Annex B
(normative)

Visual examination acceptance criteria

B.1 General

The pictures presented in this annex (under consideration) shall be applied as representative examples of typical product appearance and of feasible imperfections.

The photographed specimens have been selected particularly for the demonstration of the potential effects and imperfections, specimens can even have been specifically manufactured or altered to meet this objective.

The photographed specimens shall not be assumed to represent any particular manufacturer's standard deliverables or general quality level of its products.

B.2 Criteria for general visual inspection of specimens

Under consideration.

B.3 Criteria for visual inspection of specimens after tests

Under consideration.

Annex C
(normative)

Workmanship requirements for the assembly of leaded film resistors

C.1 General

These workmanship requirements apply to the forming of leads and to the mounting of resistors on a circuit board. They however do not address issues like design and manufacture of the circuit board, or choice of solder alloy and execution of a soldering process.

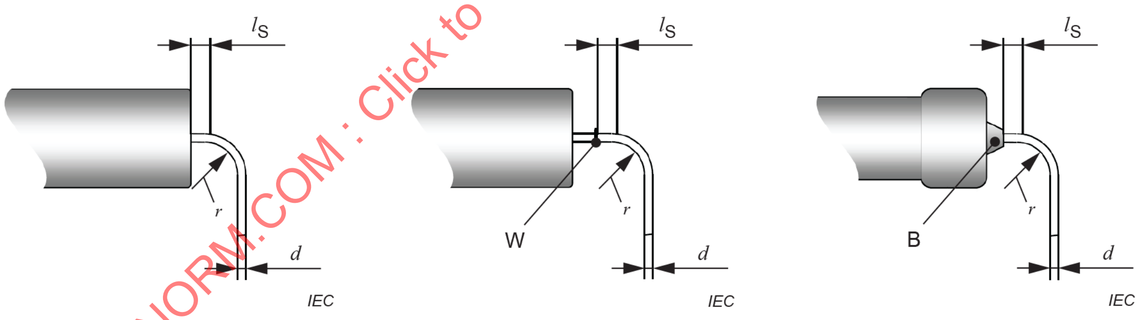
NOTE These workmanship requirements are based on the applicable requirements for soldered assemblies as given by IEC 61191-1 and by IEC 61191-3, on the workmanship recommendations of the prior IEC 61192-1:2003 and IEC 61192-3:2002 and of IPC A-610.

C.2 Lead forming

C.2.1 General

Resistor leads shall be pre-formed to the final configuration, excluding the final clinch or retention bend, before assembly or installation.

Leads shall be formed in such a manner that the lead-to-body seal is not damaged or degraded. To prevent damage to the resistor body, the internal connections and outgoing lead seals when preparing resistor leads, all bending and forming tools shall clamp the portion of the lead adjacent to the body (lead seal) prior to exerting bending, pull, shear or torsion forces on the lead(s). On leads with designed or unintended protruding coating material 'trouser legs' (see 4.2.2) or flash from the moulding process the clamping part of the tool shall be clear of all protruding plastic material. See the illustrations in Figure C.1.



a) **Lead emerging from the flat face of a body**

b) **Lead welded outside of the body**

c) **Lead emerging from a protrusion of the body**

Key

l_S	straight length of the lead
d	nominal diameter of the lead-wire
r	lead bending radius, measured on the inside of the bend
W	weld
B	solder or welding bead, and/or protruding coating

Figure C.1 – Lead forming dimensions

The straight portion of the lead l_S shall extend from the body face, its protrusion or solder or weld to the start of the bend radius by:

$$l_S \geq (1 \times d)$$

which shall be limited by

$$l_S \geq 0{,}8 \text{ mm}$$

The clamp of the bending tool can require a longer straight portion of the lead in order to achieve the required fixation.

The minimum lead bending radius r depends on the lead diameter as given in Table C.1.

Table C.1 – Lead bend radius

Lead diameter d	Inner lead bend radius r
$d < 0{,}8$ mm	$r \geq (1{,}0 \times d)$
0,8 mm $\leq d \leq$ 1,2 mm	$r \geq (1{,}5 \times d)$
1,2 mm $< d$	$r \geq (2{,}0 \times d)$

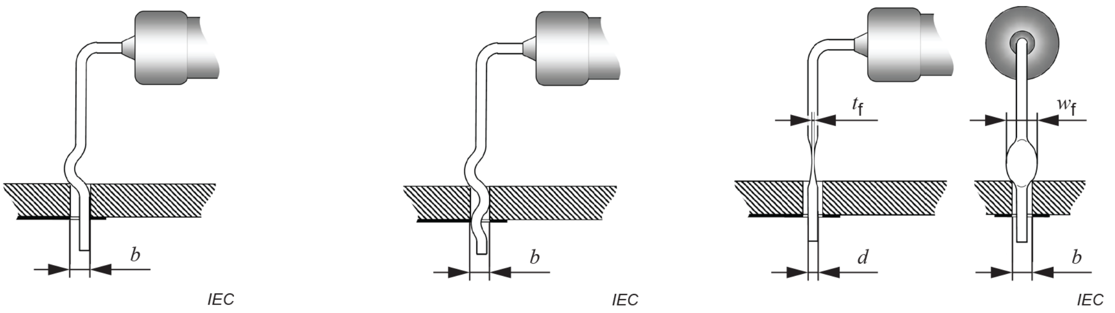
For resistors with rectangular leads, the lead thickness t, measured parallel to the bending radius r, shall be applied in lieu of the diameter d.

The clamping and bending of the lead shall not produce any nick or deformation exceeding 10 % of the lead diameter d. The lead shall not be deformed from repeated bendings. The exposure of lead basis material is acceptable, if it does not exceed 5 % of the solderable surface.

C.2.2 Means for support of mounting height

The leads of resistors may be fitted with means to establish a desired clearance between the resistor body and the component side (primary side) surface of the circuit board. Typical examples for such means, kinked or forged leads, are shown in Figure C.2.

Such supporting means can additionally serve as a means for retaining the inserted resistors in their position above the circuit board until being fixed by the solder connection. Examples for such means include double kinked leads, or leads forged to an arrowhead shape.



a) Single kinked lead **b) Double kinked lead** **c) Forged lead**

Key

b	circuit board bore diameter
d	nominal lead diameter
t_f	thickness of forged lead
w_f	width of forged lead

Figure C.2 – Examples of mounting height support

The performance of such kinked or forged leads depends on the bore diameter b, for which a suitable prescription shall be provided for each kink or forge design.

For forged leads, a minimum thickness $t_{f\,min}$ shall be specified and observed in order to maintain the required mechanical robustness of the resistor in its mounting position.

C.3 Mounting

C.3.1 General

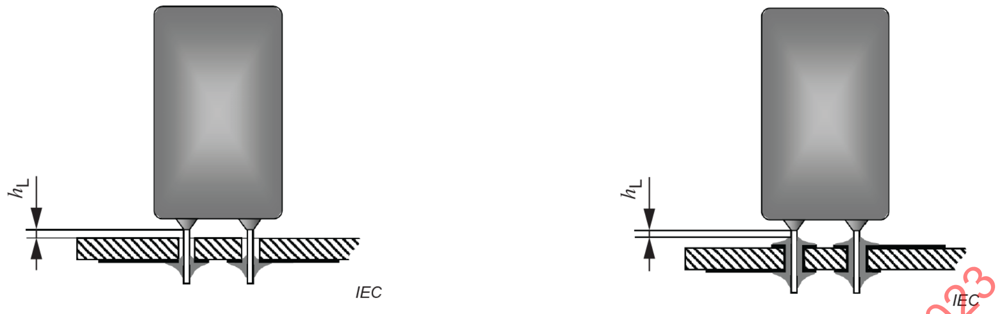
If resistors are to be mounted to a circuit board, the board shall provide bores with a suitable diameter to support the insertion of the lead ends and the building of a solder fillet around the full perimeter of the lead. The bores may be without metallization on the inner wall (unsupported holes), so that the solder connection will only build up between the lead and the annular ring on the soldering side (secondary side) of the circuit board. Plated through-holes (via holes, supported holes) have a metallized inner wall, which enables the solder to rise from the soldering side in the gap between lead and wall.

Unless specified otherwise, the bore diameters given in Table C.2 shall be applied.

Table C.2 – Recommended circuit board bore diameters

Nominal lead diameter d	Nominal bore diameter b
≤ 0,5 mm	0,8 mm
0,6 mm	1,0 mm
0,7 mm; 0,8 mm	1,3 mm
1,0 mm	1,6 mm
1,2 mm	1,8 mm
NOTE The bore diameters conform with the values stated in IEC 60717.	

Resistors shall be mounted to provide a visible clearance h_L between the end face or the meniscus of its coating on each lead and the solder connection, or the top surface of the circuit board. Trimming of the resistor coating meniscus is prohibited.



a) Mounting on a single layer board

b) Mounting on a multi-layer board with plated via holes

Key

h_L visible clearance on the lead between the resistor coating and the solder connection or the circuit board

Figure C.3 – Clearance between coating and solder

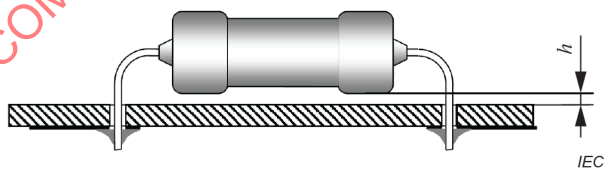
For the clearance h_L shall apply

$$h_L \geq 0,3 \text{ mm}.$$

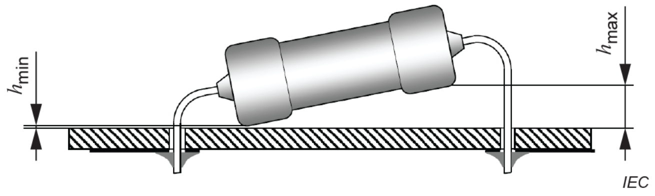
C.3.2 Lateral mounting

NOTE The lateral mounting is also referred to as "horizontal mounting", regardless of the actual orientation of the circuit board.

Resistors shall be mounted parallel to the component side (primary side) surface of the circuit board; see Figure C.4. They should be mounted at an even clearance h, as given in Table C.3.



a) Parallel mounting



b) Tilted mounting

Key

h	clearance between the resistor body and the circuit board
h_{min}	smallest distance between the resistor body and the circuit board
h_{max}	largest distance between the resistor body and the circuit board

Figure C.4 – Lateral mounting

Table C.3 – Clearance of lateral mounted resistors

Rated dissipation P_{70}	**Height h**
$P_{70} < 1$ W	0 mm $\leq h \leq$ 0,25 mm
$P_{70} \geq 1$ W	1,5 mm $\leq h \leq$ 2,0 mm

Where an even clearance is not achievable (See Figure C.3b), the limitations given in Table C.2 apply to both the smallest clearance h_{min} and to the largest clearance h_{max}.

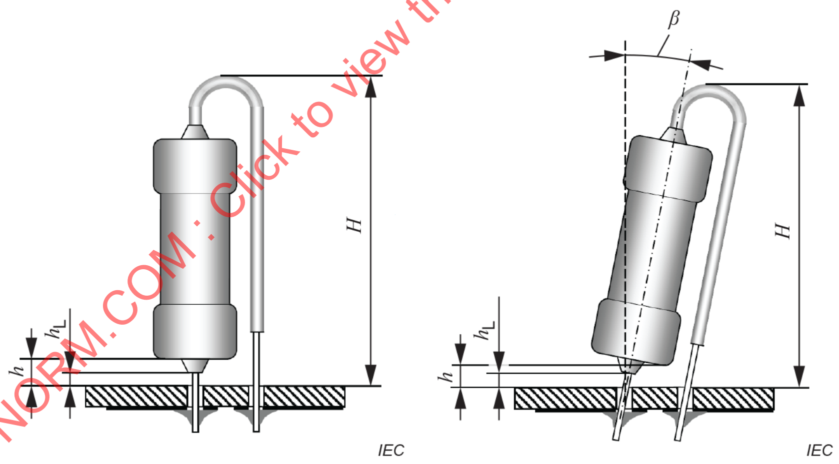
These requirements do not apply if the mounting height and attitude is determined by lead bends of a radial formed resistor, as described in C.2.2 and in Annex F.

Special provisions apply for circuits handling a higher voltage level, for example increased minimum distances between adjacent conductors. An increased minimum clearance between the resistor body and the surface of the circuit board can be required. In particular, the routing of a connector component side surface under the resistor body should be avoided if the electric tension between that connector and the resistor exceeds 50 V.

C.3.3 Upright mounting

NOTE The upright mounting is also referred to as "vertical mounting", regardless of the actual orientation of the circuit board.

Wherever possible, resistors shall be mounted perpendicular to the component side (primary side) surface of the circuit board; see Figure C.5.



a) **Perpendicular mounting**

b) **Tilted mounting**

Key

H	total height of the resistor above the circuit board
h	clearance between the component body and the circuit board
h_{L}	visible clearance on the lead between the resistor coating and the solder connection or the circuit board
β	tilt angle, deviation from rectangularity above the circuit board

Figure C.5 – Upright mounting

The visible clearance h_{L} shall meet the requirement given in C.3.1.

For resistors with a rated dissipation $P_{70} \geq 1$ W, the clearance h shall meet the respective requirement given in Table C.2.

For the tilt angle β shall apply

$$|\beta| \leq 15°$$

These requirements do not apply if the mounting height and attitude is determined by lead bends of a radial formed resistor, as described in C.2.2 and in Annex F.

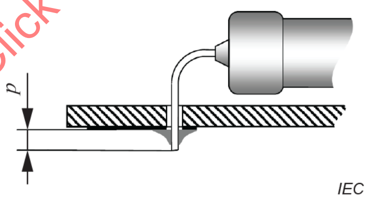
The leads can remain unformed if the required stand-off height beneath the body is achieved by other means (for example, a spacer) and the receiving holes in the printed board are suitably located.

The design of the assembled equipment can result in a limitation of the permissible total height H. The resistor and its bent long lead shall not violate clearance requirements to conductive parts across from the circuit board.

C.4 Lead trimming

To prevent damage to the resistor body, its internal connections and outgoing lead seals when cropping resistor leads, all cropping tools shall either clamp the portion of the lead adjacent to the body (lead seal) prior to exerting bending or shear or torsion forces on the lead(s), or allow free movement of the resistor body at 90° to the direction of cutting.

Leads may be trimmed after soldering, provided the cutters do not damage the resistor or the solder connection due to physical shock. When lead cutting is performed after soldering, appropriate means shall be employed to ensure that the original solder connection has not been damaged.



Key

p lead protrusion

Figure C.6 – Lead protrusion

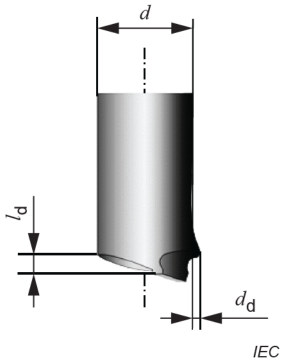
The protruding lead shall be visible in the solder, see Figure C.6. For single-sided boards the minimum straight-through lead protrusion shall be

$$p \geq 0{,}5 \text{ mm}$$

The maximum lead protrusion shall be

$$p \leq 2{,}5 \text{ mm}$$

NOTE Assemblies of high-performance and high-reliable electronic equipment usually set a tighter requirement to the lead protrusion: $p \leq 1{,}5$ mm.



Key

d lead diameter

d_d radial lead distortion

l_d axial lead distortion

Figure C.7 – Lead end distortion

Any distortion of the lead ends resulting from the cropping process (see Figure C.7) shall not exceed the following limits:

$$d_d \leq (0,5 \times d)$$

$$l_d \leq (0,25 \times d)$$

If the lead is clinched, for example in order to secure the inserted resistor in position prior to soldering, the permissible protruding lead is longer than the length for straight-through leads, since protrusion p is measured perpendicular to the board surface. The clinched lead should be directed along the connecting conductor.

Any lead protrusion shall not violate clearance requirements to an adjacent unconnected conductor on the circuit board or to conductive parts across from the circuit board.

Annex D
(normative)

Zero-ohm resistors (jumpers)

D.1 General

This annex permits coverage of 0 Ω resistors within the same specification and within the same quality assessment scheme, if they are assessed as supplementary parts to a family of resistors with $R_n > 0\ \Omega$.

All the rulings of this sectional specification are applicable to 0 Ω resistors, except where specific deviations are given below.

D.2 Preferred characteristics

For 0 Ω resistors, the preferred characteristics given in Clause 4 of this sectional specification apply with the following modifications:

- Subclause 4.3, preferred climatic categories: the climatic category specified within the same specification for resistors with $R_n > 0\ \Omega$ shall apply to the testing of 0 Ω resistors. In case of more than a single climatic category being specified, the most severe shall apply to the testing of 0 Ω resistors.
- Subclause 4.4, resistance: the resistance value of 0 Ω resistors (jumpers) is 0 Ω.
- Subclause 4.5, tolerance on resistance: this characteristic is not applicable to 0 Ω resistors as it applies a symmetric relative tolerance; instead, a maximum permissible residual resistance $R_{\text{rsd max}}$ shall be applied as an asymmetric absolute tolerance, to be selected from the preferred values: 10 mΩ; 20 mΩ and 50 mΩ.
- Subclause 4.7, limiting element voltage: the limiting element voltage U_{max} is not applicable to 0 Ω resistors; instead, a DC or AC RMS maximum permissible current I_{max} shall be applied.

D.3 Tests and test severities

For 0 Ω resistors, the prescriptions for tests given in Clause 5 of this sectional specification apply with the following modifications:

- Neither a test voltage U_{test} nor a limitation of the test voltage by $U_{\text{test max}}$ is applicable to 0 Ω resistors; instead, a respective prescription for I_{test} shall be applied, which may be based on the rated current $I_r = \sqrt{P_{70} / R_{\text{rsd max}}}$, or on the maximum permissible current I_{max}.
- The rated voltage $U_r = \sqrt{P_{70} \cdot R_n}$ is not applicable to 0 Ω resistors; instead, the maximum permissible current I_{max} shall be applied.
- Subclause 5.3.7, short-time overload test: the specified test voltage is not applicable to 0 Ω resistors; instead, the following shall be applied:

  The preferred overload test current is

$$I_{\text{test}} = 2{,}5 \cdot I_{\text{max}}.$$

where

I_{max} is the maximum permissible current.

The overload duration t_{load} shall be the same as used for resistors with R_{n} > 0 Ω.

- Subclause 5.3.7, single-pulse high voltage overload test: this test is not applicable to 0 Ω resistors.
- Subclause 5.3.8, periodic-pulse high-voltage overload test: the specified test voltage is not applicable to 0 Ω resistors; instead, the following shall be applied:

  The preferred pulse overload test current is

  $$\hat{I}_{\text{test}} = \sqrt{25} \cdot I_{\text{max}}$$

  where

  I_{max} is the maximum permissible current.

  For any advanced overload condition, the respective test current shall be applied as correspondingly established via the overload factor.
- Subclause 5.3.9, electrostatic discharge (ESD) test: this test is not applicable to 0 Ω resistors.
- Subclause 5.4.3, periodic-pulse overload test: the specified test voltage is not applicable to 0 Ω resistors; instead, the following shall be applied:

  The preferred pulse overload test current is

  $$\hat{I}_{\text{test}} = \sqrt{15} \cdot I_{\text{max}}$$

  where

  I_{max} is the maximum permissible current.

D.4 Performance requirements

For 0 Ω resistors, the performance requirements given in Clause 6 of this sectional specification apply with the following modifications:

- Subclause 6.2, limits for change of resistance at tests: the specified stability classes and the specified limits for change of resistance are not applicable to 0 Ω resistors; instead, compliance of the residual resistance R_{rsd} with the maximum permissible residual resistance $R_{\text{rsd max}}$ shall be applied as a limit to each test:

  $$R_{\text{rsd}} \leq R_{\text{rsd max}}$$

- Subclause 6.3, temperature coefficient of resistance: the specified limits for change of resistance are not applicable to 0 Ω resistors.

D.5 Marking, packaging and ordering information

For 0 Ω resistors, the provisions given in Clause 7 of this sectional specification apply with the following modifications:

- Subclause 7.1, marking of the component:

  If 0 Ω resistors are regarded as being part of a family of resistors which are marked with colour code in accordance with IEC 60062:2016, Clause 3, then the 0 Ω resistors shall be marked with a single black colour band.

  If 0 Ω resistors are regarded as being part of a family of resistors which are marked with letter and digit codes in accordance with IEC 60062:2016, Clause 4, then the 0 Ω resistors shall be marked with a single digit zero.

- Subclause 7.4, ordering information: the specification of the tolerance on resistance and of the temperature coefficient of resistance is not required for the ordering of 0 Ω resistors.

  The detail specification may specify the use of fill characters instead of the tolerance and TCR in order to maintain a consistent length of the ordering information.

D.6 Detail specification

For 0 Ω resistors, the information given in Clause 8 of this sectional specification applies with the modifications as given in this annex.

D.7 Quality assessment procedures

For 0 Ω resistors, the quality assessment procedures given in Clause 9 of this sectional specification apply with the following modifications:

- Neither a test voltage U_{test} nor a limitation of the test voltage by $U_{\text{test max}}$ is applicable to 0 Ω resistors; instead, a respective prescription for I_{test} shall be applied.
- The maximum permissible current I_{max} shall be used where the rated voltage $U_{\text{r}} = \sqrt{P_{70} \cdot R_{\text{n}}}$ is required.
- For the formation of inspection lots, 0 Ω resistors are not regarded as part of any range of resistors, and therefore shall not be applied as the lowest resistance within such ranges.

The temperature rise test of IEC 60115-1:2020, 6.7 is applicable to 0 Ω resistors.

For the qualification approval and for the quality conformance inspection of 0 Ω resistors, the following tests applied in the respective test schedule of Table 6 or Table 7 are not applicable to 0 Ω resistors:

- The temperature coefficient of resistance test of IEC 60115-1:2020, 6.2.
- The single-pulse high-voltage overload test of IEC 60115-1:2020, 8.2.
- The electrostatic discharge test, human body model, of IEC 60115-1:2020, 8.5.

Annex E
(informative)

Guidance on the application of optional and additional tests

E.1 General

The optional and additional tests offered in 5.4 of this specification are not included in any of the presented test schedules. This annex provides a recommendation for the suitable implementation of each test into the test schedules.

E.2 Endurance at room temperature

For resistors categorized as level G, the test endurance at the rated temperature 70 °C may be replaced by the test endurance at room temperature of IEC 60115-1:2020, 7.2 presented as the default endurance test. In this case, the extended endurance testing is not required

Table E.1 – Implementation of the test endurance at room temperature

Entry for the test schedule for the qualification approval					
Test[a]	**Conditions of test**[b]	**D**[c] **or ND**	n[c]	c[c]	**Performance requirements**
			Group 7		
7.2 Endurance at room temperature (prior test acc. Annex C)	See 5.4.1 $U_{\text{test}} = \sqrt{P_{\text{test}} \cdot R_{\text{n}}}$, imited by $U_{\text{test}} \le U_{\text{max}}$; t_{on} = 1,5 h; t_{off} = 0,5 h; t_{load} = 1 000 h. Visual examination. Resistance. Insulation resistance[f].	D	…	0	As in 6.5.2. As specified in 6.2 and by the detail specification. As in 6.7.

Entry for the test schedule for quality conformance inspections						
Periodic tests						
Test[a]	**Conditions of test**[b]	**D**[c] **or ND**	p[c]	n[c]	c[c]	**Performance requirements**
			Group C2[i]			
7.2 Endurance at room temperature (prior test acc. Annex C)	See 5.4.1 $U_{\text{test}} = \sqrt{P_{\text{test}} \cdot R_{\text{n}}}$, limited by $U_{\text{test}} \le U_{\text{max}}$; t_{on} = 1,5 h; t_{off} = 0,5 h; t_{load} = 1 000 h. Visual examination. Resistance. Insulation resistance[h].	D	3	20	0	As in 6.5.2. As specified in 6.2 and by the detail specification. As in 6.7.

This affects Group 7 of Table 6 and Group C2 of Table 7 as shown in Table E.1. The presented table fragments should be used as a direct replacement in the respective table, hence the footnote references in Table E.1 point to the table footnotes of the original tables.

The test for endurance at room temperature is not a suitable basis for the assessment of a failure rate level according to IEC 60115-1:2020, Annex R.

E.3 Single-pulse high-voltage overload test

For resistors categorized as level P or level R, the single-pulse high-voltage overload test is employed with a severity based on the pulse shape 10/700. The 10/700 based severity of this test may be replaced by a severity based on the pulse shape 1,2/50, where suitable higher overload factors x and y should be established to maintain the discriminative relevance of this test.

This affects Group 14 of Table 6 and Group G of Table 7 as shown in Table E.2. The presented table fragments should be used as a direct replacement in the respective table, hence the footnote references in Table E.2 point to the table footnotes of the original tables.

Table E.2 – Implementation of the single-pulse high-voltage overload test

Entry for the test schedule for the qualification approval					
Test[a]	**Conditions of test**[b]	**D**[c] **or ND**	n[c]	c[c]	**Performance requirements**
			Group 14		
8.2 Single-pulse high-voltage overload test (Variation of prior test 4.27) (for resistors categorized as level P or R only)	See 5.4.2 Pulse shape: 1,2/50; $\hat{U}_{\text{test}} = x \times \sqrt{P_{70} \times R_{\text{n}}}$; limited by $\hat{U}_{\text{test}} \le y \times U_{\text{max}}$ n = … , $f \le$ … . Visual examination. Resistance.	D	…	0	As in 6.5.2. As specified in 6.2 and by the detail specification.

Entry for the test schedule for quality conformance inspections						
Periodic tests						
Test[a]	**Conditions of test**[b]	**D**[c] **or ND**	p[c]	n[c]	c[c]	**Performance requirements**
			Group G[i]			
8.2 Single-pulse high-voltage overload test (Variation of prior test 4.27) (for resistors categorized as level P or R only)	See 5.4.2 Pulse shape: 1,2/50; $\hat{U}_{\text{test}} = x \times \sqrt{P_{70} \times R_{\text{n}}}$; limited by $\hat{U}_{\text{test}} \le y \times U_{\text{max}}$ n = … , $f \le$ … . Visual examination. Resistance.	D	12	20	0	As in 6.5.2. As specified in 6.2 and by the detail specification.

E.4 Periodic- pulse overload test

For resistors categorized as level P or level R, a periodic-pulse overload test is employed in the test schedule for the qualification approval. While the periodic-pulse overload test of IEC 60115-1:2020, 8.4 has been employed in a variety of historical detail specifications on leaded low-power film resistors, this test is regarded as being inadequate in light of modern application requirements and therefore has been replaced by the more severe periodic-pulse high-voltage overload test of IEC 60115-1:2020, 8.3.

There can however be specifications requiring a strict continuance of the historical test requirements. In such cases, the periodic-pulse high-voltage overload test may be replaced by the traditional periodic-pulse overload test.

This only affects Group 12 of Table 6 as shown in Table E.3. The presented table fragment should be used as a direct replacement in the respective table, hence the footnote references in Table E.3 point to the table footnotes of the original tables.

Table E.3 – Implementation of the periodic-pulse overload test

Entry for the test schedule for the qualification approval					
Test[a]	**Conditions of test**[b]	**D**[c] **or ND**	n[c]	c[c]	**Performance requirements**
			Group 12		
8.2 [prior test 4.39] Periodic-pulse overload test (for resistors categorized as level P or R only)	See 5.4.3 $\hat{U}_{\text{test}} = \sqrt{15 \times P_{70} \times R_{\text{n}}}$, limited by $\hat{U}_{\text{test}} \le 2 \times U_{\text{max}}$; t_{on} = 0,1 s; t_{off} = 2,5 s n = 1 000.	D	…	0	
	Visual examination.				As in 6.5.2.
	Resistance.				As specified in 6.2 and by the detail specification.

E.5 Operation at low temperature

For resistors categorized as level P or level R, modern application requirements can call for a test for operation at low temperature, which would be regarded as being more severe than the plain cold test of the climatic sequence. It is however not recommended to replace this test in the climatic sequence, in order to maintain the integrity of test results collected over time.

This test is recognised as being destructive to the subjected specimens, hence it is not suitable for sequential combination with another test in an existing test group. It should therefore be established as a new, independent test group in each schedule, probably amended at their ends.

The details of the proposed implementation are shown in Table E.4. The presented table fragments should be used as a direct amendment of the respective table, hence the footnote references in Table E.4 point to the table footnotes of the original tables.

Table E.4 – Implementation of the operation at low temperature test

<table>
<tr><th colspan="7">Entry for the test schedule for the qualification approval</th></tr>
<tr><th>Test[a]</th><th>Conditions of test[b]</th><th>D[c] or ND</th><th colspan="2">n[c]</th><th>c[c]</th><th>Performance requirements</th></tr>
<tr><td>10.2 [prior test 4.36]
Operation at low temperature
(for resistors categorized as level P or R only)</td><td>See 5.4.4
ϑ_{inf} = LCT;
$U_{\text{test}} = \sqrt{P_{70} \cdot R_{\text{n}}}$,
limited by $U_{\text{test}} \le U_{\text{max}}$
Visual examination.
Resistance.</td><td>D</td><td colspan="2">…</td><td>0</td><td>As in 6.5.2.
As specified in 6.2 and by the detail specification.</td></tr>
<tr><th colspan="7">Entry for the test schedule for quality conformance inspections</th></tr>
<tr><th colspan="7">Periodic tests</th></tr>
<tr><th>Test[a]</th><th>Conditions of test[b]</th><th>D[c] or ND</th><th>p[c]</th><th>n[c]</th><th>c[c]</th><th>Performance requirements</th></tr>
<tr><td>10.2 [prior test 4.36]
Operation at low temperature
(for resistors categorized as level P or R only)</td><td>See 5.4.4
ϑ_{inf} = LCT;
$U_{\text{test}} = \sqrt{P_{70} \cdot R_{\text{n}}}$,
limited by $U_{\text{test}} \le U_{\text{max}}$
Visual examination.
Resistance.</td><td>D</td><td>12</td><td>20</td><td>0</td><td>As in 6.5.2.
As specified in 6.2 and by the detail specification.</td></tr>
</table>

The evaluation of results of this test would require suitable acceptance criteria, which should be stated in Table 4. The nature of this test permits it to be allocated to the group of short-term tests.

E.6 Damp heat, steady state, accelerated

For resistors categorized as level P or level R, modern application requirements can call for an accelerated damp heat, steady-state test, which would be regarded as being more severe than the standard damp heat, steady-state test. It is however not recommended to replace this test in the test schedule, in order to maintain the comparability of damp heat test results collected over time.

This test is regarded as being destructive to the subjected specimens, hence it is not suitable for sequential combination with another test in an existing test group. It should therefore be established as a new, independent test group in each schedule, probably amended at their ends.

The details of the proposed implementation are shown in Table E.5. The presented table fragments should be used as a direct amendment of the respective table, hence the footnote references in Table E.5 point to the table footnotes of the original tables.

Table E.5 – Implementation of the test damp heat, steady state, accelerated

Entry for the test schedule for the qualification approval					
Test[a]	**Conditions of test**[b]	**D**[c] **or ND**	n[c]	c[c]	**Performance requirements**
			Group ##		
10.5 [prior test 4.37] Damp heat, steady state, accelerated (for resistors categorized as level P or R only)	See 5.4.5 ϑ_{test} = 85 °C; RH_{test} = 85 % $U_{\text{bias}} = 0{,}1 \times \sqrt{P_{70} \times R_{\text{n}}}$, limited by $U_{\text{bias}} \leq 100\ \text{V}$; t_{test} = 1 000 h. Visual examination. Resistance.	D	…	0	As in 6.5.2. As specified in 6.2 and by the detail specification.

Entry for the test schedule for quality conformance inspections						
Periodic tests						
Test[a]	**Conditions of test**[b]	**D**[c] **or ND**	p[c]	n[c]	c[c]	**Performance requirements**
				Group ##		
10.5 [prior test 4.37] Damp heat, steady state, accelerated (for resistors categorized as level P or R only)	See 5.4.5 ϑ_{test} = 85 °C; RH_{test} = 85 % $U_{\text{bias}} = 0{,}1 \times \sqrt{P_{70} \times R_{\text{n}}}$, limited by $U_{\text{bias}} \leq 100\ \text{V}$; t_{test} = 1 000 h. Visual examination. Resistance.	D	12	20	0	As in 6.5.2. As specified in 6.2 and by the detail specification.

The evaluation of results of this test would require suitable acceptance criteria, which should be stated in Table 4. The nature of this test permits it to be allocated to the group of climatic long-term tests.