INTERNATIONAL STANDARD

IEC 60115-1

QC 400000

Third edition
1999-05

Fixed resistors for use in electronic equipment –

Part 1:
Generic specification

Résistances fixes utilisées dans les équipements électroniques –

Partie 1:
Spécification générique

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- **IEC web site***
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Terminology, graphical and letter symbols

For general terminology, readers are referred to IEC 60050: *International Electrotechnical Vocabulary* (IEV).

For graphical symbols, and letter symbols and signs approved by the IEC for general use, readers are referred to publications IEC 60027: *Letter symbols to be used in electrical technology*, IEC 60417: *Graphical symbols for use on equipment. Index, survey and compilation of the single sheets* and IEC 60617: *Graphical symbols for diagrams*.

* See web site address on title page.

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International Electrotechnical Commission
Международная Электротехническая Комиссия

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FIXED RESISTORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 1: Generic specification

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.
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6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60115-1 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment.

This third edition cancels and replaces the second edition published in 1982, amendment 2 (1987), amendment 3 (1989) and amendment 4 (1993).

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

FDIS	Report on voting
40/1087/FDIS	40/1109/RVD

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

The QC number that appears on the front cover of this publication is the specification number in the IEC Quality Assessment System for Electronic Components (IECQ).

Annexes A, B and D form an integral part of this standard.

Annex C is for information only.

A bilingual version of this standard may be issued at a later date.

FIXED RESISTORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 1: Generic specification

1 General

1.1 Scope

This part of IEC 60115 is applicable to fixed resistors for use in electronic equipment.

It establishes standard terms, inspection procedures and methods of test for use in sectional and detail specifications of electronic components for quality assessment or any other purpose.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 60115. For dated references, subsequent amendments to, or revisions of any of these publications do not apply. However, parties to agreements based on this part of IEC 60115 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

NOTE – In the case of IEC 60068 standards, use the referenced edition.

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

IEC 60050 (all parts), *International Electrotechnical Vocabulary (IEV)*

IEC 60060-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60060-2:1994, *High-voltage test techniques – Part 2: Measuring systems*

IEC 60062:1992, *Marking codes for resistors and capacitors*
Amendment 1 (1995)

IEC 60063:1963, *Preferred number series for resistors and capacitors*
Amendment 1 (1967)
Amendment 2 (1977)

IEC 60068-1:1988, *Environmental testing – Part 1: General and guidance*
Amendment 1 (1992)

IEC 60068-2-1:1990: *Environmental testing – Part 2: Tests – Tests A: Cold*
Amendment 1 (1993)
Amendment 2 (1994)

IEC 60068-2-2:1974, *Environmental testing – Part 2: Tests – Tests B: Dry heat*
Amendment 1 (1993)
Amendment 2 (1994)

IEC 60068-2-3:1969, *Environmental testing – Part 2: Tests – Test Ca: Damp heat, steady state*
Amendment 1 (1984)

.IEC 60068-2-6:1995, *Environmental testing – Part 2: Tests – Test Fc: Vibration (sinusoidal*)

IEC 60068-2-13:1983, *Environmental testing – Part 2: Tests – Test M: Low air pressure*

IEC 60068-2-14:1984, *Environmental testing – Part 2: Tests – Test N: Change of temperature*
Amendment 1 (1986)

IEC 60068-2-20:1979, *Environmental testing – Part 2: Tests – Test T: Soldering*
Amendment 2 (1987)

IEC 60068-2-21:1983, *Environmental testing –– Part 2: Tests – Test U: Robustness of terminations and integral mounting devices*
Amendment 2 (1991)
Amendment 3 (1992)

IEC 60068-2-27:1987, *Environmental testing –– Part 2: Tests – Test Ea and guidance: Shock*

IEC 60068-2-29:1987, *Environmental testing –– Part 2: Tests – Test Eb and guidance: Bump*

IEC 60068-2-30:1980, *Environmental testing – Part 2: Tests – Test Db and guidance: Damp heat, cyclic (12 + 12 hour cycle)*
Amendment 1 (1985)

IEC 60068-2-45:1980, *Environmental testing – Part 2: Tests – Test XA and guidance: Immersion in cleaning solvents*
Amendment 1 (1993)

IEC 60068-2-58:1989, *Environmental testing – Part 2: Tests – Test Td: Solderability, resistance to dissolution of metallization and to soldering heat of Surface Mounting Devices (SMD)*

IEC 60195:1965, *Method of measurement of current noise generated in fixed resistors*

IEC 60249-2-4:1987, *Base materials for printed circuits – Part 2: Specifications – Specification No. 4: Epoxide woven glass fabric copper-clad laminated sheet, general purpose grade*

IEC 60294:1969, *Measurement of the dimensions of a cylindrical component having two axial terminations*

IEC 60410:1973, *Sampling plans and procedures for inspection by attributes*

IEC 60440:1973, *Method of measurement of non-linearity in resistors*

IEC QC 001002-3: 1998, *IEC Quality Assessment System for Electronic Components (IECQ) – Rules of procedure – Part 3: Approval procedures*

IEC QC 001003:1998, *IEC Quality Assessment System for Electronic Components (IECQ) – Guidance documents*

IEC QC 001005:1998, *Register of firms, products and services approved under the IECQ system, including ISO 9000*

ISO 1000:1992, *SI units and recommendations for the use of their multiples and of certain other units*

2 Technical data

2.1 Units and symbols

For the purposes of this part of IEC 60115, the following definitions apply. In addition, units, graphical symbols, letter symbols and terminology shall, whenever possible, be taken from the following publications:

– IEC 60027;

– IEC 60050;

– ISO 1000.

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

2.2 Definitions

For the purposes of this part of IEC 60115, the following definitions apply.

2.2.1
type
group of components having similar design features, the similarity of whose manufacturing techniques enables them to be grouped together either for qualification approval or for quality conformance inspection; they are generally covered by a single detail specification

NOTE 1 – Components described in several detail specifications may, in some cases, be considered as belonging to the same type and may therefore be grouped for quality assessment purposes.

NOTE 2 – Mounting accessories are ignored, provided they have no significant effect on the test results.

NOTE 3 – Ratings cover the combination of

– electrical ratings,

– sizes,

– environmental category.

The limits of the range of ratings are to be given in the detail specification.

2.2.2
style
subdivision of a type, generally based on dimensional factors; a style may include several variants, generally of a mechanical order

2.2.3
grade
term indicating additional general characteristics concerning the intended application, for example long-life applications.

The term "grade" may be used only in combination with one or more words (for example, long-life grade) and not with a single letter or number.

The figures to be added after the term "grade" should be arabic numerals

2.2.4
family (of electronic components)
group of electronic components which predominantly displays a particular physical attribute and/or fulfils a defined function

2.2.5
subfamily (of electronic components)
group of components within a family manufactured by similar technological methods

2.2.6
rated resistance
resistance value for which the resistor has been designed, and which is generally indicated on the resistor

2.2.7
critical resistance
resistance value at which the rated voltage is equal to the limiting element voltage (see 2.2.15 and 2.2.16)

NOTE – At an ambient temperature of 70 °C, the maximum voltage which may be applied across the terminations of a resistor is either the calculated rated voltage, if the resistance is less than the critical resistance, or the limiting element voltage, if the resistance is equal to or greater than the critical resistance. At temperatures other than 70 °C, it is important that account be taken of the derating curve and of the limiting element voltage in the calculation of any voltage to be applied.

2.2.8
category temperature range
range of ambient temperatures for which the resistor has been designed to operate continuously, defined by the temperature limits of its appropriate category

2.2.9
upper category temperature
the maximum ambient temperature for which a resistor has been designed to operate continuously at that portion of the rated dissipation which is indicated in the category dissipation

2.2.10
lower category temperature
minimum ambient temperature at which a resistor has been designed to operate continuously

2.2.11
maximum surface temperature
maximum temperature permitted on the surface for any resistor of that type when operated continuously at rated dissipation at an ambient temperature of 70 °C

2.2.12
rated temperature
maximum ambient temperature at which the rated dissipation may be applied continuously under the conditions of the endurance test prescribed for this temperature. It has a value of 70 °C, unless otherwise prescribed in the relevant sectional specification

2.2.13
rated dissipation
maximum allowable dissipation at an ambient temperature of 70 °C under the conditions of the endurance test at 70 °C and for which the permitted change in resistance for this endurance test is not exceeded

2.2.14
category dissipation
fraction of the rated dissipation exactly defined in the detail specification, applicable at the upper category temperature, taking account of the derating curve prescribed in the detail specification

NOTE – The category dissipation may be zero.

2.2.15
rated voltage (U_N or U_R)
d.c. or a.c. r.m.s. voltage calculated from the square root of the product of the rated resistance and the rated dissipation

NOTE – At high values of resistance, the rated voltage may not be applicable because of the size and the construction of the resistor (see 2.2.16).

2.2.16
limiting element voltage
maximum d.c. or a.c. r.m.s. voltage that may be continuously applied to the terminations of a resistor (generally dependent upon size and manufacturing technology of the resistor).

Where the term "a.c. r.m.s. voltage" is used in this standard, the peak voltage shall not exceed 1,42 times the r.m.s. value

NOTE – This voltage can only be applied to resistors when the resistance value is equal to or higher than the critical resistance value.

2.2.17
insulation voltage (applicable only to insulated resistors)
the maximum peak voltage which may be applied under continuous operating conditions between the resistor terminations and any conducting mounting surface

2.2.18
insulated resistor
resistor which fulfils the voltage proof and insulation resistance test requirements and the damp-heat, steady-state test with a polarizing voltage applied when mounted on a metal plate

2.2.19
insulation resistance
Under consideration

2.2.20
variation of resistance with temperature
variation of resistance with temperature which can be expressed either as a temperature characteristic or as a temperature coefficient as defined below

2.2.20.1
temperature characteristic of resistance
maximum reversible variation of resistance produced over a given temperature range within the category temperatures related to a reference temperature of 20 °C

2.2.20.2
temperature coefficient of resistance (α)
relative variation of resistance between two given temperatures divided by the difference in the temperature producing it

NOTE – It should be noted that the use of the term does not imply any degree of linearity for this function, nor should any be assumed.

2.2.21
voltage coefficient of resistance
reversible change in resistance caused by the applied voltage and expressed as a percentage change in resistance per applied volt

2.2.22
visible damage
visible damage which reduces the usability of the resistor for its intended purpose

2.2.23
surface mount resistor
fixed resistor whose small dimensions and nature or shape of terminations make it suitable for use in hybrid circuits and on printed boards

2.2.24
heat-sink resistor
resistor type designed for mounting on a separate heat-sink

2.2.25
rated dissipation (heat-sink resistors only)
maximum allowable dissipation of a heat-sink resistor at an ambient temperature of 25 °C, when mounted on the reference heat-sink, under the conditions of the endurance test at room temperature for heat-sink resistors, and which will result in a change in resistance not greater than that specified for this endurance test

2.2.26
maximum element temperature
maximum stated temperature at any point on or within the resistor, under any permissible operating condition

2.3 Preferred values

2.3.1 General

Each sectional specification shall prescribe the preferred values appropriate to the subfamily; for rated resistance, see also 2.3.2.

2.3.2 Preferred values of rated resistance

The preferred values of rated resistance shall be taken from the series specified in IEC 60063.

2.4 Marking

2.4.1 General

2.4.1.1 The information given in the marking is normally selected from the following list; the relative importance of each item is indicated by its position in the list:

a) rated resistance;

b) tolerance on rated resistance;

c) temperature coefficient (if applicable);

d) year and month (or week) of manufacture;

e) number of the detail specification and style reference;

f) manufacturer's name or trade mark.

2.4.1.2 The resistor shall be clearly marked with a) and b) above, and with as many of the remaining items as is practicable. Any duplication of information in the marking on the resistor should be avoided.

2.4.1.3 The package containing the resistor(s) shall be clearly marked with all the information listed above.

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

2.5 Coding

When coding is used for resistance value, tolerance or date of manufacture, the method shall be selected from those given in IEC 60062.

3 Quality assessment procedures

3.1 General

When this standard and any related standards are used for the purpose of a full quality assessment system such as the IEC quality assessment system for electronic components (IECQ), compliance to 3.5 or 3.6 is required.

When these standards are used outside such quality assessment systems for purposes such as design proving or type testing, the procedures and requirements of 3.5.1 and 3.5.3 b) may be used, but the tests and parts of tests shall be applied in the order given in the test schedules.

Before resistors can be qualified according to the procedures of this clause, the manufacturer shall obtain the approval of his organization, in accordance with the provisions of IEC QC 001002-3.

Two of the methods that are available for the approval of resistors of assessed quality, and which are covered by the following subclause, are qualification approval according to the provisions of clause 3 of IEC QC 001002-3, and capability approval according to the provisions of clause 4 of IEC QC 001002-3. For a given subfamily of resistors, separate sectional specifications for qualification approval and capability approval are necessary, and capability approval is therefore available only when a relevant sectional specification has been published.

3.1.1 Applicability of qualification approval

Qualification approval is appropriate for a standard range of resistors manufactured to similar design and production processes, and conforming to a published detail specification.

The programme of tests defined in the detail specification for the appropriate assessment and performance levels applies directly to the resistor range to be qualified, as prescribed in 3.5 and the relevant sectional specification.

3.1.2 Applicability of capability approval

Capability approval is appropriate when resistors based on common design rules are fabricated by a group of common processes. It is particularly appropriate when resistors are manufactured to a user's specific requirements.

Under capability approval, detail specifications fall into the following three categories.

3.1.2.1 Capability qualifying components (CQCs), including process validation test vehicles

A detail specification shall be prepared for each CQC as agreed with the national supervising inspectorate (NSI). It shall identify the purpose of the CQC and include all relevant test severities and limits.

3.1.2.2 Standard catalogue components

When the manufacturer requires that a resistor approved under the capability approval procedure be listed in the IECQ register of approvals, a capability approval detail specification complying with the blank detail specification shall be written. Such specifications shall be registered by the IECQ and the component shall be listed in IEC QC 001005.

3.1.2.3 Customer specific components

The content of the detail specification (often known as a CDS (customer detail specification)) shall be by agreement between the manufacturer and the customer, in accordance with 4.4.3 of IEC QC 001002-3.

Further information on these detail specifications is given in the relevant sectional specification.

Approval is given to a manufacturing facility on the basis of validated design rules, processes and quality control procedures and the results of tests on capability qualifying components, including any process validation test vehicles. See 3.6 and the relevant sectional specification for further information.

3.2 Primary stage of manufacture

For fixed resistor specifications, the primary stage of manufacture is as follows:

– for film types:
  deposition of the resistive film on the substrate;
– for carbon composition types:
  process which produces the greatest change in polymerization of the binder;
– for wire-wound types:
  winding of the resistance wire (or ribbon) on the former;
– for metal foil resistors:
  fixing of the resistive foil on the substrate.

3.3 Subcontracting

If subcontracting of the primary stage of manufacture and/or subsequent stages is employed, it shall be in accordance with 4.2.2 of IEC QC 001002-3.

The sectional specification may restrict subcontracting, in accordance with 4.2.2.2 of IEC QC 001002-3.

3.4 Structurally similar components

The grouping of structurally similar components for qualification approval testing or for quality conformance testing under qualification approval or capability approval shall be prescribed in the relevant sectional specification.

3.5 Qualification approval procedures

3.5.1 Eligibility for qualification approval

The manufacturer shall comply with 3.1.1 of IEC QC 001002-3.

3.5.2 Application for qualification approval

The manufacturer shall comply with 3.1.3 of IEC QC 001002-3.

3.5.3 Test procedure for qualification approval

One of the following two procedures shall be used.

a) The manufacturer shall produce test evidence of conformance to the specification requirements on three inspection lots for lot-by-lot inspection, taken in as short a time as possible, and on one lot for periodic inspection. No major changes in the manufacturing process shall be made in the period during which the inspection lots are taken.

   Samples shall be taken from the lots in accordance with IEC 60410 (see annex A). The sample shall contain the highest and lowest resistance values represented in the lot and a critical value when this falls between such high and low values. The highest and lowest resistance values so selected shall define the resistance range for which qualification approval is granted.

   Normal inspection shall be used but, when the sample size gives acceptance on zero nonconformances, additional specimens shall be taken in order to meet the sample size requirements to give acceptance on one nonconforming item.

b) The manufacturer shall produce test evidence to show conformance to the specification requirements on the fixed sample size test schedule given in the sectional specification.

   The specimens taken to form the sample shall be selected at random from current production or as agreed with the NSI.

   For the two procedures, the sample sizes and the number of permissible nonconformances shall be of comparable order. The test conditions and requirements shall be the same.

3.5.4 Granting of qualification approval

Qualification approval shall be granted when the procedures in accordance with 3.1.4 of IEC QC 001002-3 have been completed satisfactorily.

3.5.5 Maintenance of qualification approval

Qualification approval shall be maintained by regular demonstration of compliance with the requirements for quality conformance (see 3.5.6).

3.5.6 Quality conformance inspection

The blank detail specification(s) associated with the sectional specification shall prescribe the test schedule for quality conformance inspection. This schedule shall also specify the grouping, sampling and periodicity for the lot-by-lot and periodic inspection.

Operation of the switching rule for reduced inspection in Group C is permitted in all subgroups except endurance. The sampling plans and inspection levels shall be selected from those given in IEC 60410.

If required, more than one schedule may be specified.

3.6 Capability approval procedures

3.6.1 General

Capability approval in fixed resistor technology covers the following:

– the complete design, material preparation and manufacturing techniques, including control procedures and tests;

– the performance limits claimed for the processes and products, that is, those specified for the capability qualifying components (CQCs) and process control parameters (PCPs);

– the range of mechanical structures for which approval is granted.

3.6.2 Eligibility for capability approval

The manufacturer shall comply with the requirements of 4.2.1 of IEC QC 001002-3.

3.6.3 Application for capability approval

The manufacturer shall comply with the requirements of 4.2.4 of IEC QC 001002-3 and with the requirements of the relevant sectional specification.

3.6.4 Description of capability

The capability shall be described in a capability manual in accordance with 4.2.5 of IEC QC 001002-3 and with the requirements of the relevant sectional specification.

The NSI shall treat the capability manual as a confidential document. The manufacturer may, if he so wishes, disclose part or all of it to a third party.

3.6.5 Demonstration and verification of capability

The manufacturer shall demonstrate and verify the capability in accordance with 4.2.6 of IEC QC 001002-3 and with the requirements of the relevant sectional specification, with the following details.

3.6.5.1 CQCs for demonstrating capability

The manufacturer shall agree with the NSI the process qualifying parameters and the range of capability qualifying components which are necessary to demonstrate the capability range specified in the capability manual.

The demonstration shall be made by testing the agreed range of CQCs which shall be designed, manufactured and process-parameter-controlled in accordance with the capability manual. The CQCs shall comply with the following requirements:

a) the range of CQCs used shall represent all the limits of the declared capability. The CQCs shall be chosen to demonstrate mutually attainable combinations of limits.

b) the CQCs shall be
   - either resistors specially designed to demonstrate a combination of limits of capability,
   - or resistors of designs used in general production,
   - or a combination of both of these, provided the requirements of a) are met.

When CQCs are designed and produced solely for capability approval, the manufacturer shall use the same design rules, materials and manufacturing processes as those applied to released products.

A detail specification shall be prepared for each CQC and shall have a front-page format in accordance with annex D. The detail specification shall identify the purpose of the CQC and shall include all relevant stress levels and test limits. It may refer to internal control documentation which specifies production testing and recording in order to demonstrate control and maintenance of processes, and limits of capability.

3.6.5.2 Limits of capability

The limits of capability shall be described in the relevant sectional specification.

3.6.6 Programme for capability approval

In accordance with 4.2.6 of IEC QC 001002-3, the manufacturer shall prepare a programme for the assessment of the declared capability. This programme shall be so designed that each declared limit of capability is verified by an appropriate CQC.

The programme shall include the following:

– a bar chart or other means of showing the proposed timetable for the approval exercise;
– details of all the CQCs to be used, with references to their detail specifications;
– a chart showing the features to be demonstrated by each CQC;
– reference to the control plans to be used for process control.

3.6.7 Capability approval test report

In accordance with 4.2.6.3 of IEC QC 001002-3, a capability report shall be issued. The report shall meet the specific requirements of this specification and shall contain the following information:

– issue number and date of the capability manual;
– programme for capability approval in accordance with 3.6.6;
– all test results obtained during the performance of the programme;
– test methods used;
– reports on actions taken in the event of failure (see 3.6.10.1).

The report shall be signed by the designated management representative (DMR) as a true statement of the results obtained and submitted to the body designated in the national rules which is responsible for the granting of capability approval.

3.6.8 Abstract of description of capability

The abstract is intended for formal publication in IEC QC 001005 after capability approval has been granted.

The abstract shall include a concise description of the manufacturer's capability and give sufficient information on the technology, methods of construction and range of products for which the manufacturer has been approved.

3.6.9 Modifications likely to affect the capability approval

Any modifications likely to affect the capability approval shall satisfy the requirements of 4.2.1.1 of IEC QC 001002-3.

3.6.10 Initial capability approval

The approval is granted when

– the selected range of CQCs has collectively satisfied the assessment requirements of the CQC detail specifications, with no nonconforming item allowed,
– the control plan has been fully implemented in the process control system.

For a general overview of capability approval, see figure 1.

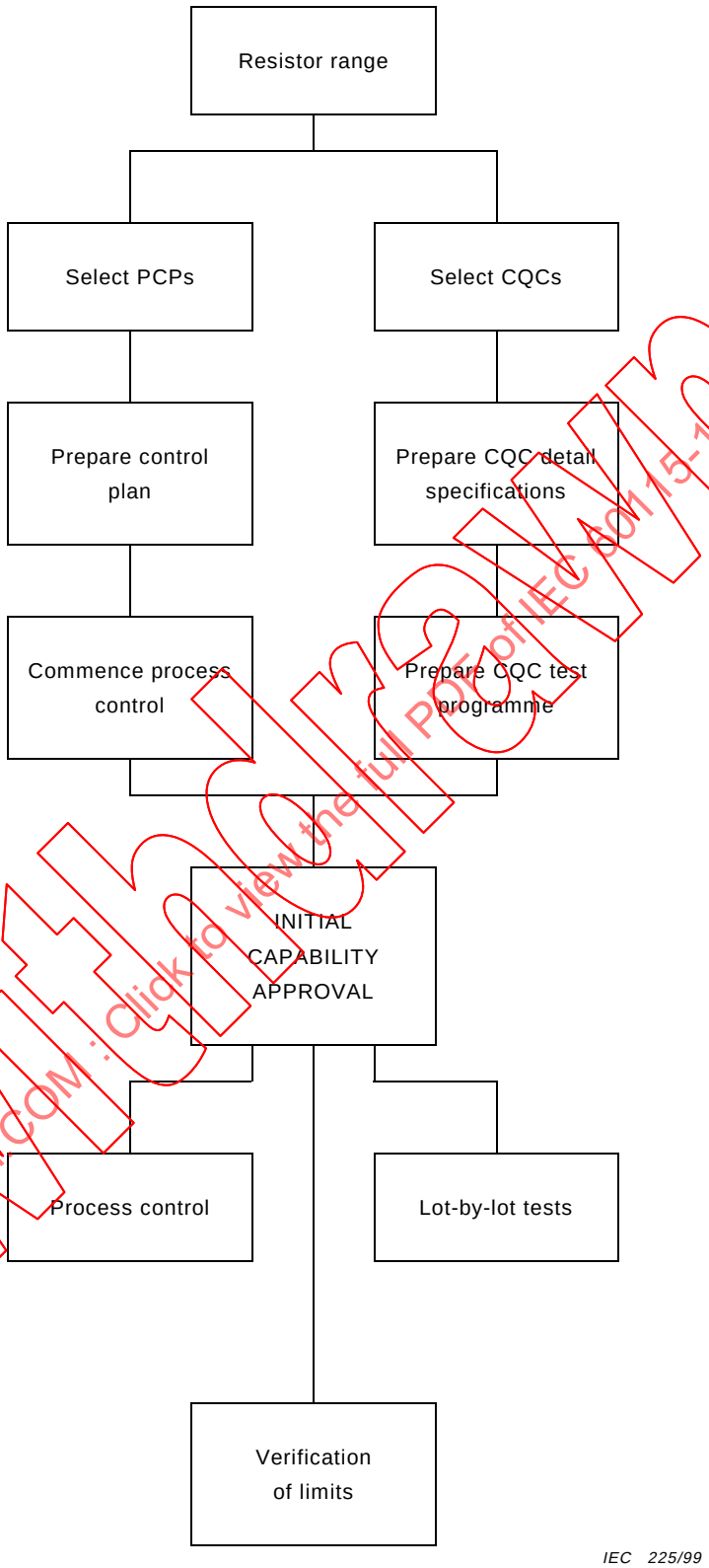


Figure 1 – General scheme for capability approval

3.6.10.1 Procedure in the event of failure

See 4.2.10 of IEC QC 001002-3, with the following details.

In the event of the failure of the specimens to meet the test requirements, the manufacturer shall notify the NSI and shall state his intention to follow one of the actions described in a) and b) below:

a) to modify the proposed scope of his capability;

b) to conduct an investigation to establish the cause of the failure as being

   – either a failure of the test itself, for example test equipment failure or operator error,

   – or a design or process failure.

If the cause of the failure is established as a failure of the test itself, then either the specimen which apparently failed or a new one, if appropriate, shall be returned to the test schedule after the necessary corrective action has been taken. If a new specimen is to be used, it shall be subjected to all of the tests in the given sequence of the test schedule(s) appropriate to the apparently failed specimen.

If the cause of the failure is established as a design or process failure, a test programme shall be carried out to demonstrate that the cause of the failure has been eradicated and that all corrective measures, including documentation, have been carried out. When this has been accomplished, the test sequences in which the failure occurred shall be repeated in full, using new CQCs.

After the action is complete, the manufacturer shall send a report to the NSI, and shall include a copy in the capability approval test report (see 3.6.7).

3.6.10.2 General plan for the selection of PCPs and CQCs

Each manufacturer shall prepare a process flow chart, based on the example given in the relevant sectional specification. For all the process steps included in his flow chart, the manufacturer shall include the corresponding process controls.

Controls shall be denoted by the manufacturer as shown in the example in the relevant sectional specification.

3.6.10.3 Process control test plans

Test plans shall form part of the process control system used by the manufacturer. When statistical process control (SPC) is used, implementation shall be in accordance with SPC basic requirements. SPC plans represent mandatory controls at process nodes.

For each process step where production equipment is used, the manufacturer shall monitor the process parameters at regular intervals, and compare the readings to the control and action limits which he will establish.

3.6.10.4 Test plans for CQCs demonstrating limits of capability

Test plans for CQCs for the demonstration of limits of capability shall be prescribed in the relevant sectional specification.

3.6.11 Granting of capability approval

Capability approval shall be granted when the procedures in accordance with 4.2.6 of IEC QC 001002-3 have been completed satisfactorily and the requirements of the relevant sectional specification have been met.

3.6.12 Maintenance of capability approval

Capability approval shall be maintained by complying with the requirements of 4.2.9 of IEC QC 001002-3 and with the requirements declared in the capability manual following the schedule of maintenance given in the relevant sectional specification.

Additionally, the following details apply.

Capability approval remains valid without retesting for two years.

The programme for the retesting of CQCs shall be defined by the manufacturer. For process control, the manufacturer shall establish a control system. An example of a control programme chart may be given in the sectional specification. For verifying limits of capability, the manufacturer shall ensure that all the test plans of 3.6.10.4 which are relevant to his capability approval are repeated at least every two years.

Quality conformance inspection of resistors for delivery may be used to support the maintenance of capability approval where relevant. In particular, where the manufacturer holds qualification approval for a range of resistors which are manufactured by the same processes and which also fall within the limits of capability for which he holds capability approval, process control test results and periodic quality conformance test results arising from the qualification approval may be used to support the maintenance of capability approval.

The manufacturer shall ensure that the range of CQCs remains representative of the products released and in accordance with the requirements of the relevant sectional specification.

The manufacturer shall maintain production, so that

– the processes specified in the capability manual, with the exception of any additions or deletions agreed with the NSI following the procedure of 3.6.9, remain unchanged,
– there is no change in the place of manufacture and final test,
– there is no break exceeding six months in the manufacturer's production under capability approval.

The manufacturer shall maintain a record of the progress of the maintenance of the capability programme so that at any time, the limits of capability which have been verified and those which are awaiting verification in the specified period can be established.

3.6.13 Extension of capability approval

The manufacturer may extend the limits of his capability approval by carrying out that test plan from those described in 3.6.10.4 which relates to the type of limit to be extended. If the proposed extension refers to a different type of limit from those described in 3.6.10.4, the manufacturer shall propose the sampling and tests to be used, and these shall be approved by the NSI. The manufacturer shall also establish process control over any new processes needed for manufacture to the new limits.

An application for an extension of capability shall be made in the same way as for the original approval.

3.6.14 Quality conformance inspection

The quality conformance test requirements are given in the detail specification and shall be carried out in accordance with 4.3.1 of IEC QC 001002-3.

3.7 Rework and repair

3.7.1 Rework

Rework as defined in 4.1.4 of IEC QC 001002-3 shall not be carried out if prohibited by the relevant sectional specification. The relevant sectional specification shall state if there is a restriction on the number of occasions that rework may take place on a specific component.

Rework shall not be subcontracted.

3.7.2 Repair

Resistors which have been repaired as defined in 4.1.5 of IEC QC 001002-3 shall not be released under the IECQ system.

3.8 Release for delivery

3.8.1 General

Resistors shall be released for delivery according to 3.2.6 and 4.3.2 of IEC QC 001002-3, after the quality conformance inspection prescribed in the detail specification has been carried out.

3.8.2 Release for delivery under qualification approval before completion of Group B tests

When the conditions of IEC 60410 for changing to reduced inspection have been satisfied for all Group B tests, the manufacturer is permitted to release components before the completion of such tests.

3.9 Certified test records of released lots

When certified test records are requested by a purchaser, they shall be specified in the detail specification.

NOTE – For capability approval, the certified test records refer only to tests carried out on capability qualifying components.

3.10 Delayed delivery

Resistors held for a period exceeding two years (unless otherwise specified in the sectional specification) following the release of the lot shall, before delivery, be re-examined for solderability and resistance, as specified in Group A or Group B of the detail specification.

The re-examination procedure adopted by the manufacturer's DMR shall be approved by the NSI.

Once a lot has been satisfactorily re-inspected, its quality is re-assured for the specified period.

3.11 Alternative test methods

See 3.2.3.7 of IEC QC 001002-3 with the following details.

In case of dispute, for referee and reference purposes, only the specified methods shall be used.

3.12 Manufacture outside the geographical limits of IECQ NSIs

A manufacturer may have his approval extended to cover part or all of the manufacture of resistors in a factory of his company located in a country which does not have an NSI for the technical area concerned, whether this country is an IECQ member country or not, provided that the requirements of 2.5.1.3 of IEC QC 001002-3 are met.

3.13 Unchecked parameters

Only those parameters of a component which have been specified in a detail specification and which were subject to testing shall be assumed to be within the specified limits.

It cannot be assumed that any unspecified parameter will remain unchanged from one component to another. If, for any reason, it is necessary for one or more additional parameters to be controlled, then a new, more extensive specification shall be used.

The additional test method(s) shall be fully described, and appropriate limits, sampling plans and inspection levels specified.

4 Test and measurement procedures

4.1 General

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

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

The limits given in all specifications are absolute limits. The principle to take measurement uncertainty into account applies, see IEC QC 001002-3, annex C to clause 2.

4.2 Standard atmospheric conditions

4.2.1 Standard atmospheric conditions for testing

Unless otherwise specified, all tests and measurements shall be made under standard atmospheric conditions for testing, as given in 5.3 of IEC 60068-1:

– temperature: 15 °C to 35 °C;

– relative humidity: 25 % to 75 %;

– air pressure: 86 kPa to 106 kPa.

Before measurements are made, the resistor shall be stored at the measuring temperature for a time sufficient to allow the entire resistor to reach this temperature. The period as prescribed for recovery at the end of a test is normally sufficient for this purpose.

When measurements are made at a temperature other than the specified temperature, the results shall, where necessary, be corrected to the specified temperature. The ambient temperature during the measurements shall be stated in the test report. In the event of a dispute, the measurements shall be repeated using one of the referee temperatures (as given in 4.2.3) and such other conditions as are prescribed in this specification.

When tests are conducted in a sequence, the final measurements of one test may be taken as the initial measurements for the succeeding test.

During the measurements, the resistor shall not be exposed to draughts, direct sunlight or other influences likely to cause error.

4.2.2 Recovery conditions

Unless otherwise specified, recovery shall take place under the standard atmospheric conditions for testing (see 4.2.1).

If recovery has to be made under closely controlled conditions, the controlled recovery conditions of 5.4.1 of IEC 60068-1 shall apply.

4.2.3 Referee conditions

For referee purposes, one of the standard atmospheric conditions for referee tests taken from 5.2 of IEC 60068-1, as given below, shall be chosen.

Table 1 – Referee conditions

Temperature °C	Relative humidity %	Air pressure kPa
20 ± 1	63 to 67	86 to 106
23 ± 1	48 to 52	86 to 106
25 ± 1	48 to 52	86 to 106
27 ± 1	63 to 67	86 to 106

4.2.4 Reference conditions

For reference purposes, the standard atmospheric conditions for reference given in 5.1 of IEC 60068-1 apply:

– temperature: 20 °C;

– air pressure: 101,3 kPa.

4.3 Drying

When drying is prescribed, the resistor shall be conditioned before measurement is made using procedure I or procedure II as prescribed in the detail specification.

Procedure I: for 24 h ± 4 h in an oven at a temperature of 55 °C ± 2 °C and at a relative humidity not exceeding 20 %

Procedure II: for 96 h ± 4 h in an oven at 100 °C ± 5 °C

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

4.4 Visual examination and checking of dimensions

4.4.1 Visual examination

The condition, workmanship and finish shall be satisfactory, as checked by visual examination (see 2.2.22).

The marking shall be legible, as checked by visual examination. It shall be in accordance with the requirements of the detail specification.

4.4.2 Dimensions (gauging)

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

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

4.4.3 Dimensions (detail)

All the dimensions prescribed in the detail specification shall be checked and shall conform to the values prescribed.

4.5 Resistance

4.5.1 Measurements of resistance shall be made by using a direct voltage of small magnitude for as short a time as is practicable, in order that the temperature of the resistance element does not rise appreciably during measurement. In the event of conflicting results attributable to such test voltages, the voltage specified in table 2 shall be used for referee purposes.

Table 2 – Measuring voltages

Rated resistance R	Measuring voltage U^{0}_{-10} % V
$R < 10\ \Omega$	0,1 (see note)
$10\ \Omega \leq R < 100\ \Omega$	0,3
$100\ \Omega \leq R < 1\ k\Omega$	1
$1\ k\Omega \leq R < 10\ k\Omega$	3
$10\ k\Omega \leq R < 100\ k\Omega$	10
$100\ k\Omega \leq R < 1\ M\Omega$	25
$1\ M\Omega \leq R$	50
NOTE – When the rated resistance is less than 10 Ω, the measuring voltage shall be so chosen that the resistor dissipates less than 10 % of its rated dissipation, but does not exceed 0,1 V.	

The accuracy of the measuring method shall be such that the total error does not exceed 10 % of the tolerance. When the measurement forms part of a test sequence, it shall be possible to measure a change of resistance with an error not exceeding 10 % of the maximum change permitted for that test sequence.

4.5.2 The resistance value at 20 °C shall correspond with the rated resistance taking into account the specified tolerance.

4.6 Insulation resistance (insulated styles only)

4.6.1 The test shall be performed using one of the following four methods, as prescribed in the relevant detail specification. The V-block method is the preferred method for resistors without mounting devices.

4.6.1.1 V-block method

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

The clamping force shall be such as to guarantee adequate contact between the resistor and the block. The clamping force shall be chosen in such a way that no destruction or damage to the resistor occurs.

The resistor shall be positioned in accordance with the following:

a) for cylindrical resistors: the resistor shall be positioned in the block so that the termination farthest from the axis of the resistor is nearest to one of the faces of the block;

b) for rectangular resistors: the resistor shall be positioned in the block so that the termination nearest to the edge of the resistor is nearest to one of the faces of the block.

For cylindrical and rectangular resistors with axial leads, any out-of-centre positioning of the point of emergence of the terminations from the body shall be ignored.

4.6.1.2 **Foil method** (alternative method for resistors without mounting devices)

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

For resistors not having axial terminations, a space of 1 mm to 1,5 mm shall be left between the edge of the foil and each termination.

For resistors having axial terminations, the foil shall be wrapped around the whole body of the resistor protruding by at least 5 mm from each end, provided that a minimum space of 1 mm between the foil and the termination can be maintained. The ends of the foil shall not be folded over the ends of the resistor.

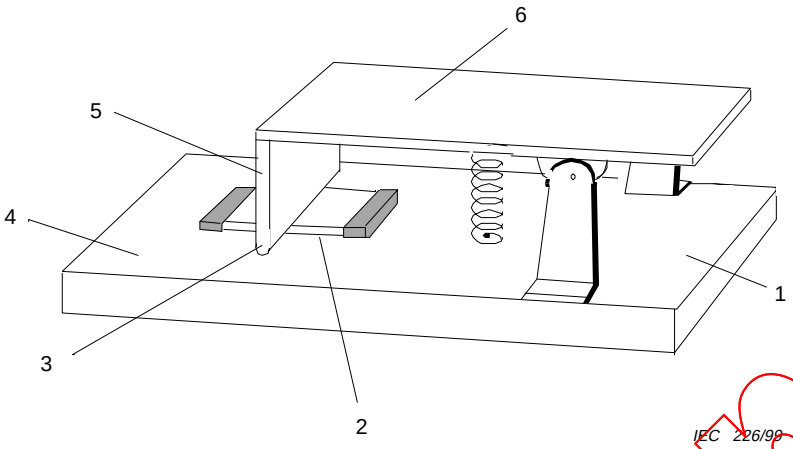
4.6.1.3 Method for resistors with mounting devices

The resistor shall be mounted in its normal manner on a metal plate (or between two metal plates) extending at least 12,7 mm in all directions beyond the mounting face of the resistor.

4.6.1.4 Method for rectangular surface mount resistors

The test shall be performed with the resistor mounted as shown in figure 2.

The clamping force of the spring shall be 1,0 N ± 0,2 N, unless otherwise specified in the detail specification. The point of contact of the metal block shall be centrally located to ensure good repeatability of the results.



1 Metal plate
2 Active side
3 Radius 0,5 mm
4 Test point B
5 Metal block, test point A
6 Insulation material

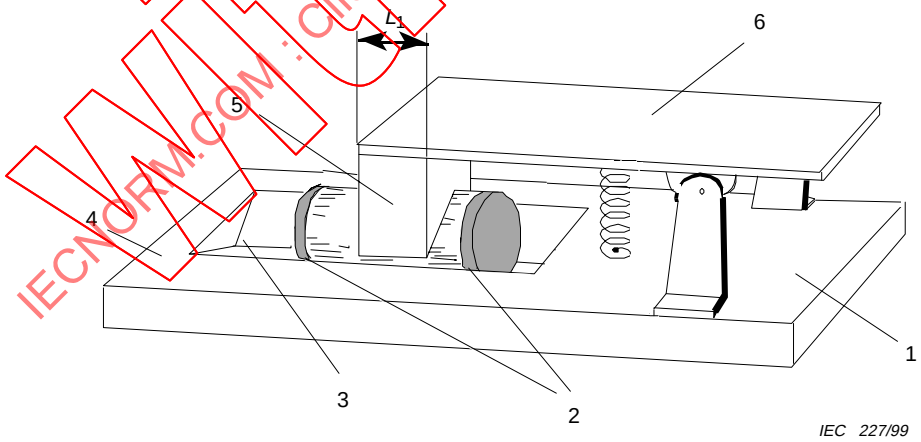
Figure 2 – Insulation resistance and voltage proof test jig for rectangular surface mount resistors

4.6.1.5 Method for cylindrical types

The test shall be performed with the resistor mounted as shown in figure 3.

The clamping force of the spring shall be 1,0 N ± 0,2 N, unless otherwise specified in the detail specification.

Dimension L_1 of the test block shall be chosen so that a minimum distance of 0,5 mm to the contact areas is maintained.



1 Metal plate
2 Terminations shall be in contact with the walls of the groove in the metal plate
3 V-shaped groove
4 Test point B
5 V-shaped metal block, test point A
6 Insulation material

Figure 3 – Insulation resistance and voltage proof test jig for cylindrical surface mount resistors

4.6.2 For all resistors except surface mount resistors, the insulation resistance shall be measured between both terminations of the resistor connected together as one pole and the V-block or the metal foil or the mounting device as the other pole. The measuring voltage shall be either 100 V ± 15 V d.c. for resistors with an insulation voltage lower than 500 V or 500 V ± 50 V d.c. for resistors with an insulation voltage equal or greater than 500 V.

For surface mount resistors, the insulation resistance shall be measured with a direct voltage of 100 V ± 15 V or a voltage equal to the insulation voltage between test points A and B, as shown in figure 2 and figure 3 (test point A shall be positive).

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

4.6.3 The insulation resistance shall be not less than the value prescribed in the relevant specification.

4.7 Voltage proof

4.7.1 The test shall be performed using one of the methods specified in 4.6.1, as prescribed in the relevant specification.

The V-block method is the preferred method for resistors without mounting devices.

4.7.2 For all resistors except surface mount resistors, the test voltage shall be applied between the terminations of the resistor connected together as one pole, and the V-block or metal foil or mounting plate(s) as the other pole. The test voltage shall be alternating (40 Hz to 60 Hz) and shall be increased, at a rate of about 100 V/s, from zero to a peak value of 1,42 times the value of the insulation voltage specified in the detail specification.

After the specified voltage has been reached, the voltage shall continue to be applied for 60 s ± 5 s.

For surface mount resistors, an alternating voltage of 40 Hz to 60 Hz, with a peak value of 1,42 times the insulation voltage, shall be applied for a period of 60 s ± 5 s between test points A and B as shown in figures 2 and 3. The voltage shall be applied gradually at a rate of approximately 100 V/s.

4.7.3 There shall be no breakdown (i.e. a leakage current equal to or greater than 10 μA) or flashover.

4.8 Variation of resistance with temperature

4.8.1 The resistor shall be dried using either procedure I or procedure II of 4.3, as prescribed in the relevant specification.

4.8.2 The resistor shall be maintained at each of the following temperatures in turn or at other temperatures specified in the relevant specification:

a) 20^{+5}_{-1} °C;

b) lower category temperature ± 3°C;

c) 20^{+5}_{-1} °C;

d) upper category temperature ± 2°C;

e) 20^{+5}_{-1} °C.

4.8.3 Resistance measurements shall be made at each of the temperatures specified in 4.8.2, after the resistor has reached thermal stability.

The condition of thermal stability is deemed to be reached when two readings of resistance taken at an interval of not less than 5 min do not differ by an amount greater than that which can be attributed to the measuring apparatus.

The temperature of the resistor at the time of measurement shall be recorded. The error of measurement of temperature shall not exceed 1 °C.

4.8.4 Methods of calculation

NOTE – The results of one measurement may be used for the calculation of the temperature coefficient and for the calculation of the temperature characteristic.

4.8.4.1 Temperature characteristic of resistance

The temperature characteristic of resistance between 20 °C and each of the other temperatures specified in 4.8.2 shall be calculated from the following formula:

$$\text{Temperature characteristic of resistance} = A \times \frac{\Delta R}{R} \times 100\,[\%]$$

where

A is the difference between the nominal specified temperatures divided by the difference between the recorded temperatures;

ΔR is the change in resistance between the two specified ambient temperatures;

R is the resistance value at the reference temperature.

If the resistances recorded in 4.8.3 are designated R_a, R_b, R_c, R_d and R_e, R and ΔR shall be calculated as shown in table 3.

Table 3 – Calculation of resistance value (R) and change in resistance (ΔR)

	Lower category temperature	Upper category temperature
R	$\frac{R_a + R_c}{2}$	$\frac{R_c + R_e}{2}$
ΔR	$R_b - R$	$R_d - R$

If the temperatures recorded in 4.8.3 are designated Θ_a, Θ_b, Θ_c, Θ_d and Θ_e, the temperature differences ($\Delta\Theta$) between the recorded temperatures shall be calculated as shown in table 4.

Table 4 – Calculation of temperature differences ($\Delta\Theta$)

Θ	Lower category temperature	Upper category temperature
$\Delta\Theta$	$\Theta_b - \frac{\Theta_a + \Theta_c}{2}$	$\Theta_d - \frac{\Theta_c + \Theta_e}{2}$

4.8.4.2 Temperature coefficient of resistance α

The temperature coefficient of resistance α between 20 °C and each of the other temperatures specified in 4.8.2 shall be calculated from the following formula:

$$\alpha = \frac{\Delta R}{R \times \Delta\Theta} \times 10^6$$

where $\Delta\Theta$ is the algebraic difference, in kelvins, between the specified ambient temperature and the reference temperature (for calculation, see 4.8.4.1).

For R, ΔR and $\Delta\Theta$, see 4.8.4.1.

The temperature coefficient of resistance α is expressed in parts million per kelvin.

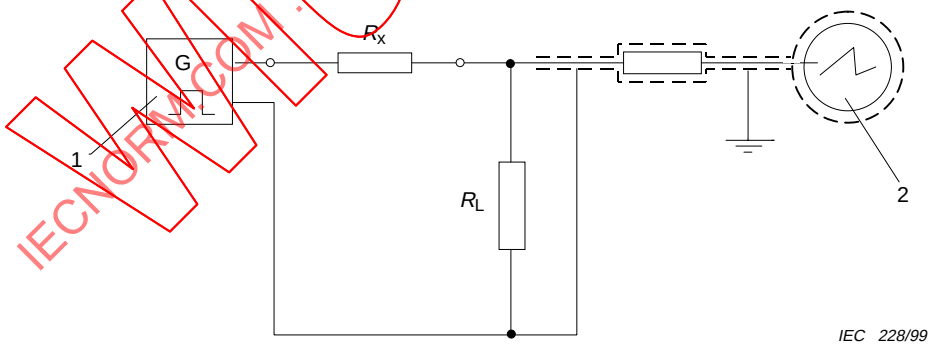
4.8.5 The temperature characteristic of resistance or the temperature coefficient of resistance α, ascertained as described above, shall be within the limits prescribed in the detail specification for the appropriate category temperature.

When the resistance value is greater than 5 Ω but less than 10 Ω, the temperature characteristic or temperature coefficient shall not exceed the limits prescribed in the detail specification for values equal to or above 10 Ω by more than a factor of 2.

NOTE – The temperature characteristic or temperature coefficient of resistance is not specified for resistance values of less than 5 Ω owing to difficulty of accurate measurement.

4.9 Reactance

4.9.1 The reactance test is applicable only to resistors for which a low reactance is required and is specified in the detail specification. It is a suitable test for inductance in the range exhibited by wire-wound resistors. The instrumentation shown in figure 4 can be used for resistors with a L/R time greater than 20 ns. The resistance range which can be tested is from 100 Ω to 1 MΩ.



1 Pulse generator

2 Oscilloscope

R_x Resistor under test

R_L Non-inductive resistor with resistance approximately equal to 0,1 times the resistance of R_x

NOTE – The length of the connecting leads between the generator and resistor R_x shall not exceed 50 mm.

Figure 4 – Test circuit

4.9.2 Pulse generator specification

The pulse generator shall have the following characteristics.

a) Pulse width: sufficient to cover three times L/R period

b) Rise time on load (10 % to 90 %): less than 3 ns

c) Repetition rate: greater than 10 kHz, or that required to obtain good oscilloscope readability

4.9.3 Oscilloscope specification

The oscilloscope shall have the following characteristics.

a) Rise time (10 % to 90 %): less than 12 ns (frequency response: 30 MHz or better)

b) Time base: 2 ns per mm or faster

c) Input capacitance at R_L should be 25 pF or less

d) Amplification shall be sufficient to obtain good readability with the pulse voltage used

4.9.4 The L/R time constant is determined by measuring the time between the start of the pulse and the time when the voltage attains 63,2 % of the maximum (see figure 5). If there is noise or distortion at the start of the rise, the zero voltage point can be determined by extension of the curve. If there is no overshoot or oscillation and the L/R time is greater than 20 ns, then the formula below can be used with sufficient accuracy:

$$\text{effective inductance (H)} = L/R \text{ (s)} \times R\ (\Omega)$$

NOTE – A specification limit could be set either as a maximum L/R time or, resulting from use of the calculation, as a maximum inductance.

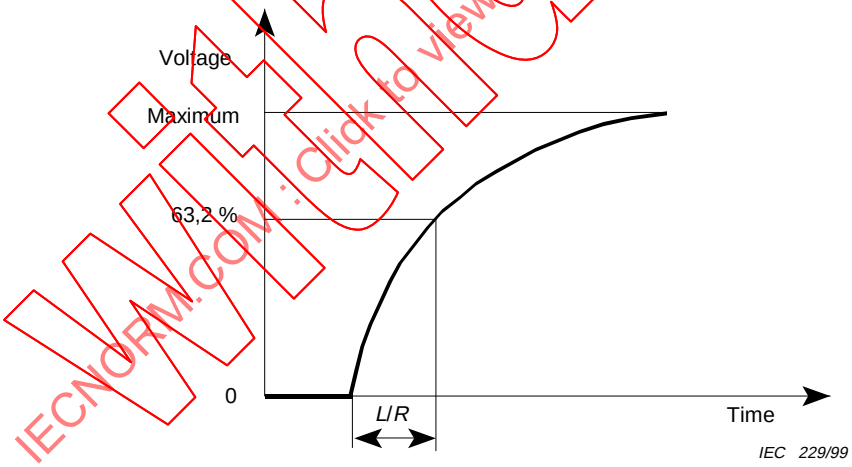


Figure 5 – Oscilloscope trace

4.10 Non-linear properties

The resistors shall be measured for non-linearity in accordance with IEC 60440. When there are specific requirements for non-linearity, such requirements shall be specified in the detail specification.

4.11 Voltage coefficient

(Applicable only when prescribed in the detail specification or when agreed upon between manufacturer and customer.)

4.11.1 The resistor shall be dried using either procedure I or procedure II of 4.3, as prescribed in the relevant specification.

4.11.2 The resistance shall then be measured at 10 % and at 100 % of either the rated voltage or the limiting element voltage, whichever is the smaller. The 100 % voltage shall be applied for not more than 0,5 s in every 5 s; the 10 % voltage shall be applied for 4,5 s. Care shall be taken that there is no appreciable temperature rise of the resistor.

4.11.3 The voltage coefficient is normally expressed in per cent per volt and shall be calculated from the following formula:

$$\text{voltage coefficient} = \frac{(R_2 - R_1)}{0{,}9 \times (U \times R_1)} \times 100\,[\%]$$

where

U is the higher applied voltage;

R_1 is the resistance measured at $0{,}1 \times U$;

R_2 is the resistance measured at U.

4.11.4 The value of the voltage coefficient shall not exceed that prescribed in the relevant specification.

4.12 Noise

(Applicable only when prescribed in the detail specification or when agreed upon between manufacturer and customer.)

The resistors shall be subjected to the procedure given in IEC 60195.

4.13 Overload

4.13.1 The resistance shall be measured as specified in 4.5.

4.13.2 The resistor shall be mounted horizontally. For wire-wound resistors, the axis of the winding shall be horizontal. The resistor shall be in free air at an ambient temperature between 15 °C and 35 °C. A voltage shall then be applied to the terminations of the resistor. The value of the voltage and the duration of its application shall be as prescribed in the relevant specification. Connections shall be made in the usual manner. For resistors with soldering tags, copper wire of approximately 1,0 mm diameter shall be used for connecting the resistors. The relevant specification shall prescribe any special mounting arrangements.

4.13.3 After a recovery of not less than 1 h and not more than 2 h, the resistors shall be visually examined. There shall be no visible damage and the marking shall be legible.

4.13.4 The resistance shall then be measured as specified in 4.5. The change of resistance, with respect to the value measured in 4.13.1, shall not exceed the value prescribed in the relevant specification.

4.14 Temperature rise

4.14.1 Resistors having a rated resistance less than the critical resistance value shall be subjected to the following test.

4.14.2 The resistor shall be mounted horizontally. For wire-wound resistors, the axis of the winding shall be horizontal. Connections shall be made in the usual manner. For resistors with soldering tags, copper wire of approximately 1,0 mm diameter shall be used for connecting the resistors. The relevant specification shall prescribe any special mounting arrangements.

4.14.3 The ambient temperature for the test shall be 15 °C to 35 °C. There shall be no air circulation other than that produced by natural convection caused by the heated resistor.

4.14.4 The rated voltage shall be applied.

4.14.5 The temperature at the hottest point on the surface of the resistor shall be measured after temperature equilibrium has been attained. The temperature measuring device shall be of such dimensions as not to affect the result of the measurement.

4.14.6 The temperature rise shall not exceed the value prescribed in the detail specification.

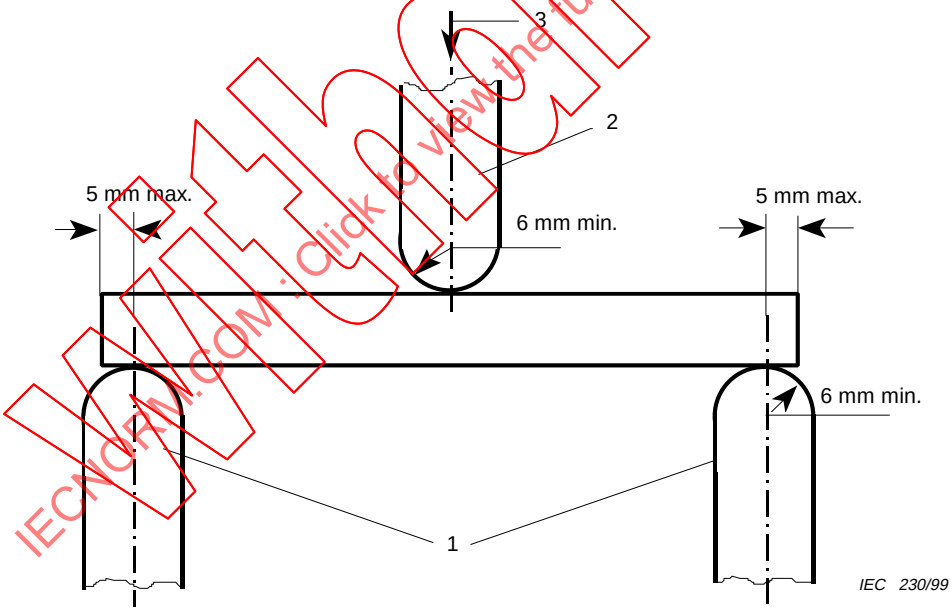
NOTE – A more precise procedure for surface temperature measurement is under consideration.

4.15 Robustness of the resistor body

4.15.1 Resistors having a body length not less than 25 mm shall be subjected to the following test.

4.15.2 The body of the resistor is supported at both ends, the distance of the supports from the end faces being not more than 5 mm. The support shall have a radius of not less than 6 mm. A thrust as prescribed in the detail specification is applied gradually to the centre of the body in a direction perpendicular to the axis, for a period of 10 s. The load shall be applied through a device having a radius of not less than 6 mm (see figure 6).

4.15.3 At the conclusion of the test, the body of the resistor shall not be cracked or broken.



1 Support

2 Device through which the load is applied

3 Load

Figure 6 – Testing of resistor body robustness

4.16 Robustness of terminations

The resistors shall be subjected to tests Ua_1, Ub, Uc and Ud of IEC 60068-2-21, as applicable.

4.16.1 The resistors shall be measured as specified in the detail specification.

4.16.2 Test Ua_1 – Tensile

The force applied shall be as follows:

– for terminations other than wire terminations: 20 N;

– for wire terminations: see table 5.

Table 5 – Tensile force for wire terminations

Nominal cross-sectional area mm^2	Corresponding diameter for circular-section wires mm	Force N
$S \leq 0{,}05$	$d \leq 0{,}25$	1
$0{,}05 < S \leq 0{,}1$	$0{,}25 < d \leq 0{,}35$	2,5
$0{,}1 < S \leq 0{,}2$	$0{,}35 < d \leq 0{,}5$	5
$0{,}2 < S \leq 0{,}5$	$0{,}5 < d \leq 0{,}8$	10
$0{,}5 < S \leq 1{,}2$	$0{,}8 < d \leq 1{,}25$	20
$1{,}2 < S$	$1{,}25 < d$	40
NOTE – For circular-section wires, strips or pins: the nominal cross-sectional area is equal to the value calculated from the nominal dimension(s) given in the relevant specification. For stranded wires, the nominal cross-sectional area is obtained by taking the sum of the cross-sectional areas of the individual strands of the conductor specified in the relevant specification.		

4.16.3 Test Ub – Bending (half of the terminations)

Method 1: two consecutive bends shall be applied in each direction. This test shall not apply if, in the detail specification, the terminations are described as rigid.

4.16.4 Test Uc – Torsion (other half of the terminations)

Method A, severity 2 (two successive rotations of 180°) shall be used.

This test shall not apply if, in the detail specification, the terminations are described as rigid, and it shall not apply to components with unidirectional terminations designed for printed wiring applications.

4.16.5 Test Ud – Torque (for terminations with threaded studs or screws and for integral mounting devices)

Table 6 – Torque

Nominal thread diameter mm		2,6	3	3,5	4	5	6
Torque Nm	Severity 1	0,4	0,5	0,8	1,2	2,0	2,5
	Severity 2	0,2	0,25	0,4	0,6	1,0	1,25

4.16.6 Final measurements

The following procedure shall be applied.

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

b) At the conclusion of the last of these tests the resistance shall be measured as specified in 4.5. The change of resistance with respect to the value measured in 4.16.1 shall not exceed the value prescribed in the relevant specification.

4.17 Solderability

4.17.1 When the solderability test is followed immediately by the resistance to soldering heat test, a drying procedure as prescribed in 4.3 shall be applied. The detail specification shall prescribe whether procedure I or procedure II shall be used.

4.17.2 All resistors except surface mount resistors shall be subject to test T of IEC 60068-2-20 using either the solder bath method (method 1) or the soldering iron method (method 2), or the solder globule method (method 3), as prescribed by the relevant specification.

4.17.3 When the solder bath method (method 1) is specified, the following requirements apply.

4.17.3.1 Test conditions

The test shall be carried out under the following conditions.

a) All resistors, except those of b) below:
   - bath temperature: 235 °C ± 5 °C;
   - immersion time: 2 s ± 0,5 s;
   - depth of immersion (from the seating plane or component body): $2^{+0}_{-0,5}$ mm.

b) Resistors indicated by the detail specification as not being designed for use on printed boards
   - bath temperature: 270 °C ± 10 °C;
   - immersion time: 2 s ± 0,5 s;
   - depth of immersion (from the component body): 6^{+1}_{-0} mm.

4.17.3.2 The terminations shall be examined for good tinning as evidenced by free flowing of the solder with wetting of the terminations.

4.17.4 When the solder bath method is not applicable, the detail specification shall define the test method, test conditions and the requirements.

NOTE – When the solder globule method is used, the soldering time is to be included in the requirements.

4.17.5 Surface mount resistors shall be tested in accordance with test Td of IEC 60068-2-58. The relevant specification shall prescribe the severity and method to be used so that wetting, dewetting or resistance to dissolution or metallization is consistent with the surface mounting classification[1)].

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1) Under consideration.

The detail specification shall also indicate the specific areas of the specimen to be examined after dewetting.

The surface mount resistors shall meet the requirements as prescribed in the relevant specification.

4.18 Resistance to soldering heat

4.18.1 If drying is called for in the detail specification, it shall be stated whether procedure I or procedure II of 4.3 shall be used.

When the resistance to soldering heat test is to be applied immediately after the solderability test, the drying procedure may be performed prior to the solderability test. The resistance shall then be measured as specified in 4.5.

4.18.2 Unless otherwise stated in the relevant specification, one of the following tests shall be applied, as prescribed by the relevant specification:

a) for all resistors except those of items b) and c) below, apply method 1A of test Tb of IEC 60068-2-20, with the following conditions:
   - temperature of the solder bath: 260 °C ± 5 °C;
   - depth of immersion from the seating plane: $2^{+0}_{-0,5}$ mm, using a thermal insulating screen of 1,5 mm ± 0,5 mm thickness;
   - immersion time: 5 s or 10 s, as specified in the detail specification.

b) for resistors not designed for use in printed boards, as indicated by the detail specification, apply method 1B of test Tb of IEC 60068-2-20, with the following conditions:
   - temperature of the solder bath: 350 °C ± 10 °C;
   - depth of immersion from the component body: $3,5^{+0}_{-0,5}$ mm,

or
   - method 2: soldering iron of test Tb of IEC 60068-2-20, with the following conditions:
   - temperature of the soldering iron: 350 °C;
   - soldering time: 10 s ± 1 s.

   The size of the soldering iron and the point of application shall be specified in the detail specification.

c) for surface mount resistors, apply test Td of IEC 60068-2-58. The relevant specification shall prescribe the severity and method to be used for the resistance to soldering heat to be consistent with the surface mounting classification[2)] .

4.18.3 After recovery, the resistors shall be visually examined. There shall be no visible damage and the marking shall be legible.

The resistance shall be measured, as specified in 4.5, 24 h ± 4 h (for surface mount resistors 1 h to 2 h) after the test, unless it can be demonstrated that stability is reached earlier.

The change of resistance with respect to the value measured in 4.18.1 shall not exceed the limit prescribed in the relevant specification.

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2) Under consideration.

4.19 Rapid change of temperature

4.19.1 The resistance shall be measured as specified in 4.5.

4.19.2 The resistors shall be subjected to test Na of IEC 60068-2-14 for five cycles. Unless otherwise specified in the relevant specification, the duration of the exposure at each of the extremes of temperature shall be 30 min.

The resistors shall then remain under standard atmospheric conditions for recovery for not less than 1 h and not more than 2 h.

4.19.3 After recovery, the resistors shall be visually examined. There shall be no visible damage.

The resistance shall be measured as specified in 4.5. The change of resistance with respect to the value measured in 4.19.1 shall not exceed the limit prescribed in the relevant specification.

4.20 Bump

4.20.1 The resistor shall be mounted as indicated in the relevant specification.

4.20.2 The resistance shall be measured as specified in 4.5.

4.20.3 The resistors shall be subjected to test Eb of IEC 60068-2-29, using the degree of severity prescribed in the relevant specification.

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

The resistance shall be measured as specified in 4.5. The change of resistance with respect to the value measured in 4.20.2 shall not exceed the limit prescribed in the relevant specification.

4.21 Shock

4.21.1 The resistor shall be mounted as indicated in the relevant specification.

4.21.2 The resistance shall be measured as specified in 4.5.

4.21.3 The resistors shall be subjected to test Ea of IEC 60068-2-27, using the degree of severity prescribed in the relevant specification.

4.21.4 When prescribed in the detail specification, measurements of resistance shall be made at intervals during the test, as prescribed in the relevant specification.

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

The resistance shall be measured as specified in 4.5. The change of resistance with respect to the value measured in 4.21.2 shall not exceed the limit prescribed in the relevant specification.

4.22 Vibration

4.22.1 The resistor shall be mounted as indicated in the relevant specification.

4.22.2 The resistance shall be measured as specified in 4.5.

4.22.3 Unless otherwise prescribed by the relevant specification, the resistors shall be subjected to test Fc of IEC 60068-2-6, using the degree of severity prescribed in the relevant specification.

When specified in the detail specification, during the last half-hour of the vibration test, in each direction of movement, an electrical measurement shall be made to check intermittent contacts, or open or short circuit. The duration of the measurement shall be the time needed for one sweep of the frequency range from one frequency extreme to the other.

4.22.4 After the test, the resistor shall be visually examined. There shall be no visible damage. When the resistors are tested as specified in 4.22.3, there shall be no intermittent contact greater than or equal to 0,5 ms, nor open or short circuit.

The resistance shall be measured as specified in 4.5. The change of resistance with respect to the value measured in 4.22.2 shall not exceed the limit prescribed in the relevant specification.

4.23 Climatic sequence

In the climatic sequence, an interval of three days maximum is permitted between any of the tests, except that the cold test shall be applied immediately after the recovery period specified for the first cycle of the damp heat, cyclic, test Db.

4.23.1 Initial measurements

The following procedure shall apply.

a) The resistors shall be dried using either procedure I or procedure II of 4.3 as prescribed in the relevant specification.

b) The resistance shall be measured as specified in 4.5.

4.23.2 Dry heat

The resistors shall be subjected to test Ba of IEC 60068-2-2, at the upper category temperature, for a duration of 16 h.

4.23.3 Damp heat, cyclic, test Db, first cycle

The resistors shall be subjected to test Db of IEC 60068-2-30 for one cycle of 24 h, using a temperature of 55 °C (severity b).

4.23.4 Cold

The resistors shall be subjected to test Aa of IEC 60068-2-1, at the lower category temperature, for a duration of 2 h.

4.23.5 Low air pressure

The following procedure shall apply.

a) The resistors shall be subjected to test M of IEC 60068-2-13, using the degree of severity prescribed in the relevant specification.

b) The test shall be carried out at a temperature between 15 °C and 35 °C. The duration of the test shall be 1 h.

4.23.6 Damp heat, cyclic, test Db, remaining cycles

The resistors shall be subjected to test Db of IEC 60068-2-30 for the following cycles of 24 h, as indicated in table 7, under the same conditions as used for the first cycle.

Table 7 – Number of cycles

Categories	Number of cycles
–/–/56	5
–/–/21	1
–/–/10	1
–/–/04	None

4.23.7 DC load (applicable only to non-wire-wound resistors)

At the end of the test, the resistors shall be subjected to the standard atmospheric conditions for testing. The time of transfer shall be as short as possible and shall not exceed 5 min. At 30 min ± 5 min after removal from the chamber, the resistors shall be subjected to a d.c. voltage for 1 min. The voltage shall be the rated voltage, or the limiting element voltage, whichever is the smaller. The resistors shall then remain in the standard atmospheric conditions for testing for not less than 1 h and not more than 2 h.

4.23.8 The resistor shall then be visually examined. There shall be no visible damage and the marking shall be legible.

The resistance and, for insulated resistors only, the insulation resistance shall then be measured as specified. The change of resistance with respect to the value measured in 4.23.1 b) shall not exceed the value prescribed in the relevant specification.

The insulation resistance shall be not less than the value prescribed in the relevant specification.

4.24 Damp heat, steady state

4.24.1 The resistance shall be measured as specified in 4.5.

4.24.2 The resistors shall be subjected to test Ca of IEC 60068-2-3 using the degree of severity corresponding to the climatic category of the resistor as indicated in the relevant specification.

4.24.2.1 For insulated resistors or for resistors which are normally mounted on or between metal plates with or without additional insulation, a division into three groups shall be effected as follows.

a) The first group shall be subjected to the test without any voltage applied.

b) The second group shall be subjected to the test with a direct voltage between the terminations. The voltage to be applied shall be selected from the following series:

0 V, 4 V, 6,3 V, 10 V, 16 V, 25 V, 40 V, 63 V and 100 V.

The voltage selected shall be the next lower value to the value derived from a calculation of the voltage required, so that the resistor is dissipating 0,01 times the rated dissipation, or shall be 0,1 times the limiting element voltage, whichever is the smaller. Throughout the test period the voltage shall be kept as close as possible to the specified voltage, a tolerance of ±5 % being allowed for mains voltage fluctuations and similar factors.

c) The third group shall be subjected to the test with a direct voltage of 20 V ± 2 V applied between the mounting plates and one of the terminations. The mounting plates are connected to the negative pole and the termination to the positive pole of the voltage source. The voltage shall be applied continuously throughout the test.

4.24.2.2 For all other resistors, the lot shall be divided into two groups and only the tests of items a) and b) of 4.24.2.1 shall be carried out.

4.24.3 DC load (applicable only to non-wire-wound resistors)

At the end of the test, the resistors shall be subjected to the standard atmospheric conditions for testing. The time of transfer shall be as short as possible and shall not exceed 5 min. At 30 min ± 5 min after removal from the chamber, the resistors shall be subjected to a d.c. voltage for 1 min. The voltage shall be the rated voltage or the limiting element voltage, whichever is the smaller. The resistors shall then remain in the standard atmospheric conditions for testing for not less than 1 h and not more than 2 h.

4.24.4 The resistors shall then be visually examined. There shall be no visible damage and the marking shall be legible.

The resistance and, for insulated resistors only, the insulation resistance shall then be measured as specified. The change of resistance with respect to the value measured in 4.24.1 shall not exceed the value prescribed in the relevant specification.

The insulation resistance shall be not less than that prescribed in the relevant specification.

4.25 Endurance

The rated dissipation shall always be given with reference to an ambient temperature of 70 °C and shall be verified by means of the endurance test at 70 °C or, in the case of certain high-power resistors, the endurance test at room temperature using the correction factor given in 4.25.2.3.

When changes in the slope of the derating curve occur at temperatures other than 70 °C, one of the following additional procedures shall apply.

a) At temperatures lower than 70 °C (for example, when a resistor is derated linearly from 20 °C, through 70 °C, to zero dissipation at the upper category temperature, or where a resistor has constant dissipation from 20 °C to 40 °C and is then derated linearly from 40 °C, through 70 °C, to zero dissipation at the upper category temperature), the resistors shall be subjected to the conditions specified in 4.25.1 (endurance at 70 °C), except that

   1) the test temperature shall be the temperature at which the change of the slope of the derating curve occurs,

   2) the voltage to be applied shall be the voltage calculated from the square root of the product of the rated resistance and the dissipation at test temperature, or it shall be the limiting element voltage, whichever is the smaller. The test dissipation shall be calculated using the following formula:

$$P_t = P_R + (P_R - P_C)\frac{70 - \Theta_t}{\Theta_{UC} - 70}$$

where

P_t is the dissipation at test temperature, in watts;

P_R is the rated dissipation, in watts;

P_C is the category dissipation, in watts;

Θ_t is the test temperature, in degrees Celsius;

Θ_{UC} is the upper category temperature, in degrees Celsius.

b) At temperatures higher than 70 °C (for example, when a resistor maintains its rated dissipation constant from 20 °C, through 70 °C, to (say) 125 °C and then is derated linearly to either zero dissipation or the category dissipation at the upper category temperature) the resistors shall be subjected to the conditions specified in 4.25.1 (endurance at 70 °C), except that the test temperature shall be the temperature at which the change in the slope of the derating curve occurs.

The requirements for intermediate and final measurements in a) and b) above shall be the same as those specified in the relevant specification for the endurance test used to verify the rated dissipation.

4.25.1 Endurance at 70 °C

4.25.1.1 The resistance shall be measured as specified in 4.5.

4.25.1.2 The resistors shall be subjected to an endurance test of 42 days (1 000 h) at an ambient temperature of 70 °C ± 2 °C. The relevant specification may specify an extended duration of the test (see 4.25.1.8).

4.25.1.3 Resistors with a rated dissipation equal to or less than 15 W shall be tested with a direct voltage. Any ripple voltage shall not exceed 5 % (peak-to-peak).

Resistors with a rated dissipation greater than 15 W shall be tested with an alternating voltage.

The voltage shall be applied in cycles of 1,5 h on and 0,5 h off throughout the test. This voltage shall be the rated voltage or the limiting element voltage, whichever is the smaller.

The applied voltage shall be within ±5 % of this voltage.

NOTE – The half-hour off-periods are included in the total test duration specified in 4.25.1.2.

4.25.1.4 The resistors shall be connected by their terminations to suitable clips on a rack of insulating material. All resistors shall be mounted in a horizontal position, in one layer only, unless otherwise specified in the sectional specification. The distance between the axes of the resistor shall be not less than seven times the diameter of the resistors. There shall be no undue draught over the resistors. If forced air circulation is used in the test chamber, the resistors shall be protected so that there is no draught, other than by natural convection, over the resistors.

4.25.1.5 The size of the testing chamber and the number of resistors under test shall be such that, when all resistors are fully loaded, the heat produced by them shall be less than that required to maintain the atmosphere in the chamber at 70 °C so that the temperature can still be controlled by the heating element. The temperature-controlling elements shall be suitably spaced from the resistors and shall be shielded so as not to be directly influenced by the radiation of the resistors. It is assumed, in this test, that the ambient temperature of the resistors is 70 °C.

4.25.1.6 After approximately 48 h, 500 h and 1 000 h, the resistors shall be removed from the chamber and allowed to recover, under standard atmospheric conditions for testing, for not less than 1 h and not more than 4 h. The removal from the chamber shall take place at the end of the half-hour off-period.

Alternatively, resistance change measurements may be made at test temperature and the marking shall be legible. In that case, at the beginning of the test, an additional resistance measurement at test temperature, for reference purposes, has to be made. However, initial and final measurements shall always be made under standard atmospheric conditions for testing.

For a particular specimen, the same procedure shall always apply.

4.25.1.7 The resistors shall be visually examined. There shall be no visible damage and the marking shall be legible. The resistance shall be measured as specified in 4.5 and the change in resistance with respect to the value measured in 4.25.1.1, in each of the succeeding measurements, shall not exceed the value prescribed in the relevant specification.

After intermediate measurements, the resistors shall be returned to the test chamber. The interval between the removal of any resistor from the chamber and its return to the chamber shall not exceed 12 h.

After 1 000 h, the insulation resistance shall be measured (insulated resistors only) and the value shall be not less than that prescribed in the relevant specification.

4.25.1.8 When prescribed by the relevant specification, the duration of the test shall be extended by a specified period. For this period, the relevant specification shall specify the time at which any measurements shall be made and the requirements.

4.25.2 Endurance at room temperature

4.25.2.1 The resistance shall be measured as specified in 4.5.

4.25.2.2 The resistors shall be subjected to an endurance test of 42 days (1 000 h) at an ambient temperature between 15 °C and 35 °C. When required by the detail specification, the duration of the test may be extended (see 4.25.2.7).

4.25.2.3 Resistors with a rated dissipation equal to or less than 15 W shall be tested with a direct voltage.

Resistors with a rated dissipation greater than 15 W shall be tested with an alternating voltage. However, resistors specifically designed for d.c. application (and described as such in their detail specification) shall be tested with a direct voltage.

When resistors are tested with direct voltage, any ripple voltage shall not exceed 5 %.

All heat-sink resistors shall be tested with an alternating voltage, unless otherwise specified in the detail specification.

When resistors specifically designed for d.c. application are allowed to have a surface temperature that exceeds the ambient temperature by more than 200 °C, the test duration shall be extended to 3 000 h or 5 000 h, as prescribed by the detail specification. In this case, the voltage shall be applied with the same polarity during the total test duration.

The voltage shall be applied in cycles of 1,5 h on and 0,5 h off throughout the test.

For all resistors except heat-sink resistors, the voltage shall be the rated voltage multiplied by the square root of the correction factor, or it shall be the limiting element voltage, whichever is the smaller. For heat-sink resistors, the voltage shall be the rated voltage or it shall be the limiting element voltage, whichever is the smaller.

The correction factor is given in the following formula:

$$\frac{\text{maximum surface temperature} - \text{test temperature (ambient)}}{\text{maximum surface temperature} - 70\ ^\circ\text{C}}$$

The voltage applied to the resistors shall be within ± 5 % of the calculated voltage.

NOTE – The half-hour off-periods are included in the total test duration specified in 4.25.2.2.

4.25.2.4 The resistors, except heat-sink resistors, shall be connected by their terminations to suitable clips, on a rack of insulating material. Half the number of the resistors shall be mounted in a horizontal position and the other half in a vertical position. The resistors shall be mounted in one layer only. The distance between the axes of the resistors shall be not less than seven times the diameter of the resistors. There shall be no undue draught over the resistors. If forced air circulation is used in the test chamber, the resistors shall be protected so that there is no draught, other than by natural convection, over the resistors.

Heat-sink resistors shall be centrally mounted by their normal means on an aluminium reference heat-sink of the dimensions specified (see table 8), with the major axis of the resistor parallel to the major axis of the heat-sink.

The heat-sinks shall be arranged in a horizontal manner on a material having a low thermal conductivity.

Table 8 – Heat sink dimensions

Reference heat-sink (see figure 7)				
Length ***l*** mm	**Width** ***w*** mm	**Height** ***h*** mm	**Thickness** ***t*** mm	**Reference area (see note)** cm^2
155	100	50	1,0	410
180	130	50	1,0	544
230	180	50	1,5	824
NOTE – The area specified is that of the outer surface of the reference heat-sink.				

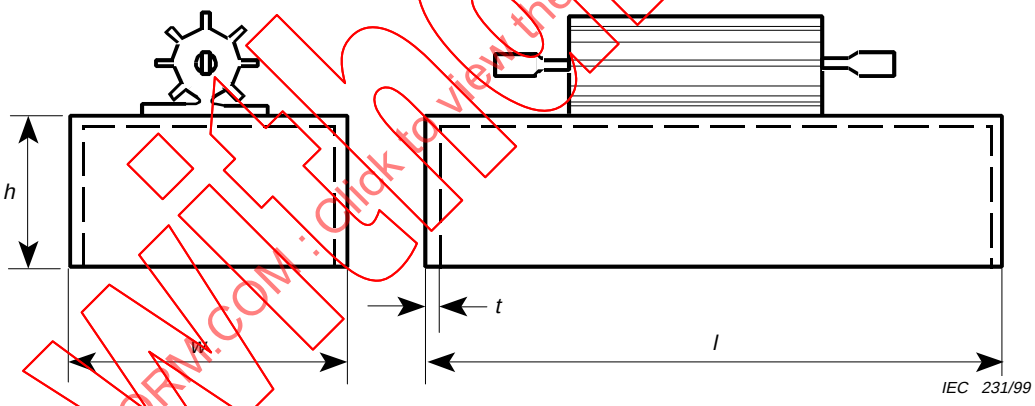


Figure 7 – Reference heat sink

The heat-sink resistors shall be so arranged that the temperature of any one resistor will not appreciably influence the temperature of any other resistor, and in such a manner that natural convection is not hindered. There shall be no undue draught over the resistors.

4.25.2.5 After approximately 48 h, 168 h, 500 h and 1 000 h, the resistors shall be removed from the chamber and allowed to recover, under standard atmospheric conditions, for testing for not less than 1 h and not more than 4 h.

4.25.2.6 The resistors shall be visually examined. There shall be no visible damage and the marking shall be legible. The resistance shall be measured as specified in 4.5 and the change of resistance with respect to the value measured in 4.25.2.1 shall not exceed the value prescribed in the relevant specification.

After intermediate measurements, the resistors shall be returned to the test chamber. The interval between the removal of any resistor from the chamber and its return to the chamber shall not exceed 12 h.

After 1 000 h, the insulation resistance shall be measured (insulated resistors only), as specified in 4.6, and the value shall be not less than that prescribed in the relevant specification.

4.25.2.7 When prescribed by the relevant specification, the duration of the test shall be extended by a specified period. For this period, the relevant specification shall specify the time at which any measurement shall be made and the requirements.

4.25.3 Endurance at the upper category temperature

4.25.3.1 The resistance shall be measured as specified in 4.5.

4.25.3.2 The resistors shall be subjected to an endurance test of 42 days (1 000 h), at an ambient temperature equal to the upper category temperature prescribed in the relevant specification. When required by the detail specification, the duration of the test may be extended (see 4.25.3.8).

For those resistors which are derated to zero at temperatures of 200 °C and below, the test shall be performed at zero dissipation. For those resistors which are derated to zero above 200 °C, the test shall be performed at 200 °C with that portion of their rated dissipation applicable at 200 °C (category dissipation).

4.25.3.3 Resistors with a rated dissipation equal to or less than 15 W shall be tested with a direct voltage. Any ripple voltage shall not exceed 5 %. Resistors with a rated dissipation greater than 15 W shall be tested with an alternating voltage.

The voltage shall be applied in cycles of 1,5 h on and 0,5 h off throughout the test.

The voltage shall be the limiting element voltage, or the voltage calculated from the category dissipation and the rated resistance, whichever is the smaller.

The applied voltage shall be within ±5 % of this voltage.

NOTE – The half-hour off-periods are included in the total test duration specified in 4.25.3.2.

4.25.3.4 When the resistors are dissipating power, they shall be mounted in the same manner as specified in 4.25.1.4 or 4.25.2.4, as appropriate.

There shall be no undue draught over the resistors. If forced air circulation is used in the test chamber, the resistors shall be protected so that there is no draught, other than by natural convection, over the resistors.

4.25.3.5 The size of the testing chamber and the number of resistors under test shall be such that, when all resistors are fully loaded, the heat produced by them shall be less than that required to maintain the atmosphere in the chamber at the upper category temperature so that the temperature can still be controlled by the heating elements. The temperature-controlling elements shall be suitably spaced from the resistors and shall be shielded so as not to be directly influenced by the radiation of the resistors. It is assumed, in this test, that the ambient temperature of the resistors is the same as the upper category temperature.

4.25.3.6 After approximately 48 h, 500 h and 1 000 h, the resistors shall be removed from the chamber and allowed to recover, under standard atmospheric conditions for testing, for not less than 1 h and not more than 4 h. The removal from the chamber shall take place at the end of the half-hour off-period for those resistors which are dissipating power.

4.25.3.7 The resistors shall be visually examined. There shall be no visible damage and the marking shall be legible. The resistance shall be measured as specified in 4.5. The change of resistance with respect to the value measured in 4.25.3.1, in each of the succeeding measurements, shall not exceed the value prescribed in the relevant specification for the corresponding endurance test at 70 °C (4.25.1) or at room temperature (4.25.2).

After intermediate measurements, the resistors shall be returned to the test chamber. The interval between the removal of any resistor from the chamber and its return to the chamber shall not exceed 12 h.

After 1 000 h, the insulation resistance shall be measured (insulated resistors only) and the value shall be not less than that prescribed in the relevant specification.

4.25.3.8 When prescribed by the relevant specification, the duration of the test shall be extended by a specified period. For this period, the relevant specification shall specify the time at which any measurements shall be made and the requirements.

4.25.4 Endurance at maximum element temperature (heat-sink resistors only)

4.25.4.1 The resistance shall be measured as specified in 4.5.

4.25.4.2 The resistors shall be subjected to an endurance test of 42 days (1 000 h), at an ambient temperature equal to the maximum element temperature prescribed in the detail specification.

The test shall be performed at zero dissipation.

4.25.4.3 After approximately 48 h, 500 h and 1 000 h, the resistors shall be removed from the chamber and allowed to recover, under standard atmospheric conditions for testing, for not less than 1 h and not more than 4 h.

4.25.4.4 The resistors shall be visually examined. There shall be no visible damage and the marking shall be legible. The resistance shall be measured as specified in 4.5. The change of resistance with respect to the value measured in 4.25.4.1, in each of the succeeding measurements, shall not exceed the value prescribed in the relevant specification.

After intermediate measurements, the resistors shall be returned to the test chamber. The interval between the removal of any resistor from the chamber and its return to the chamber shall not exceed 12 h.

After 1 000 h, the insulation resistance shall be measured, as specified in 4.6, and the value shall be not less than that prescribed in the relevant specification.

4.25.4.5 When prescribed by the relevant specification, the duration of the test shall be extended by a specified period. For this period, the relevant specification shall specify the time at which any measurements shall be made and the requirements.

4.26 Accidental overload test (for low-power non-wire-wound resistors only)

4.26.1 Object

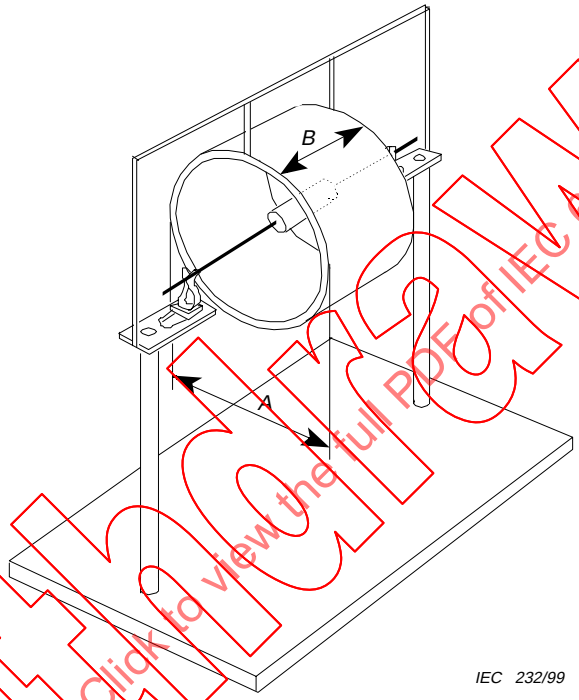
The object of the accidental overload test is to assess the fire hazard, resulting from the application of overload to a resistor.

4.26.2 Test method (gauze cylinder method)

The test fixture shall consist of a single layer gauze cylinder around the specimen under test, at a distance of 25 mm ± 3 mm from the body.

A single layer of cheese-cloth shall be placed around an internal framework to form a cylinder (see figure 8) with open ends.

The internal framework shall be constructed from cylindrical wire with a diameter smaller than or equal to 0,6 mm (22 AWG); copper wire shall not be used. The framework wires shall be equally spaced throughout the cylinder and shall not cover more than 10 % of the gauze cylinder.



A is 50 mm ± 1,5 mm larger than the component diameter.

B is not less than two times the length of the component under test.

Figure 8 – Gauze cylinder fixture

The length of the cylinder shall be not less than two times the length of the body of the specimen under test.

The cheese-cloth used in the forming of the cylinder shall be untreated cotton cloth, the type described as 36 inches wide, running 14 yards to 15 yards per pound (36,3 g/m^2 to 38,8 g/m^2) and having what is known as a count of 32" by 28".

The cheese-cloth shall be pre-conditioned under standard atmospheric conditions for testing for 24 h.

The test specimen shall be placed in the fixture so that the gauze cylinder is centred around the unit under test in both the axial and longitudinal direction.

4.26.3 Conditions of test

4.26.3.1 Ventilation

The test shall be made in an area which is suitably vented for elimination of smoke and fumes.

The air velocity over the test specimen shall not exceed 30 m per minute.

4.26.3.2 Mounting clips

The mounting clips shall be of a lightweight terminal design, and shall contact the leads of the component in such a manner that no excessive heat dissipation resulting from the mounting method affects the test results.

4.26.4 Test procedure

When this test is prescribed by a detail specification, the detail specification shall also specify the resistance range for which the test applies and the resistance range from which the test sample shall be taken.

The resistors shall be connected to a constant a.c. voltage supply at standard atmospheric conditions for testing, unless otherwise specified in the detail specification.

Overloads of 5, 10, 16, 25, 40, 63 and 100 times the rated dissipation shall be applied to the resistors under test, but the applied voltage shall not exceed four times the limiting element voltage, unless otherwise specified in the detail specification.

Each overload shall be applied to a fresh specimen for a duration of 5 min ± 0,5 min, or until the resistor becomes open-circuit or the gauze cylinder ignites, whichever is the shorter.

During the test, the current through each resistor shall be monitored by the measurement of the voltage across a low value resistor in series with the resistor under test. The value of this series resistor shall be equal to or less than 1 % R_{test}.

The voltage across the series resistor is then a measure for the current through R_{test} and shall be observed.

During each overload, the times of occurrence of the following phenomena shall be recorded:

a) flaming of the gauze cylinder;

b) low impedance or open circuit (for information only).

4.26.5 Requirement

There shall be no flaming of the gauze cylinder.

4.27 Single-pulse high-voltage overload test

4.27.1 Object

The object of this test is to determine the ability of a resistor to withstand single-pulse conditions of high-voltage overloads occurring occasionally.

This test shows the effect of high-voltage overload on resistor electrical parameters and characteristics.

NOTE – The repetitive voltage is usually a function of the circuit and increases the power dissipation of the device. A non-repetitive transient voltage is usually due to an external cause and it is assumed that its effect has completely disappeared before the next transient arrives.

4.27.2 Terminology

To define the pulse load, the terms and definitions given in IEC 60060-1 shall apply.

4.27.3 Test procedure

4.27.3.1 Description of test equipment

The test equipment shall be able to deliver at least six pulses per minute of the required pulse shape into the resistor under test.

The circuit diagrams to achieve the two preferred pulse shapes are shown in figures 9 and 10.

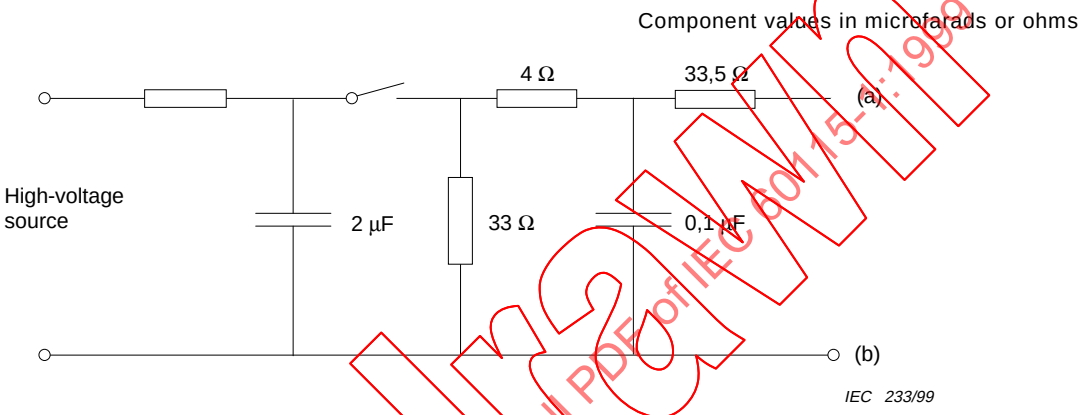


Figure 9 – Pulse generator 1,2/50

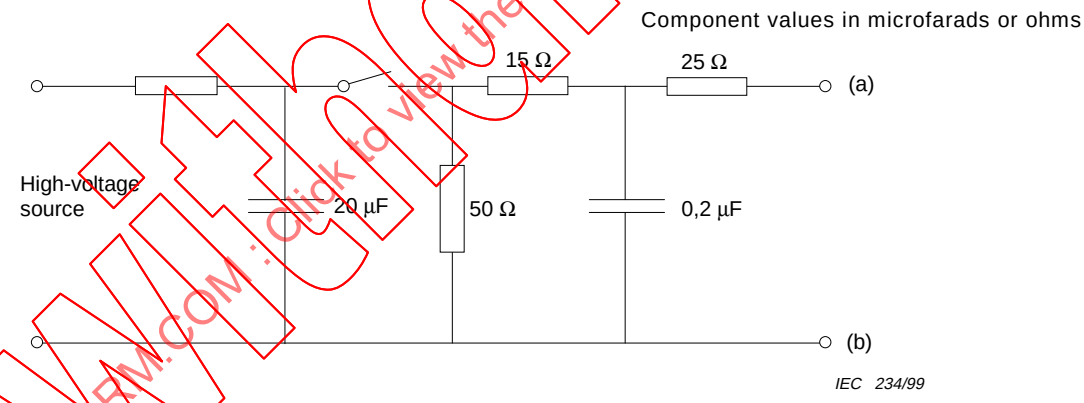


Figure 10 – Pulse generator 10/700

NOTE – The switch indicated in figures 9 and 10 may be a spark gap or a mechanical switch or a thyristor switch, as appropriate with respect to voltage and current.

4.27.3.2 Preconditioning

Before the test begins, the resistor shall have attained thermal and humidity equilibrium under standard atmospheric conditions for testing. If required by the detail specification, the resistors shall be dried by using procedure I of 4.3.

4.27.3.3 Initial measurements

Unless otherwise specified, the resistors shall be visually examined and the resistance shall be measured.

4.27.3.4 Conditioning

4.27.3.4.1 The method of mounting of the resistor shall be specified in the relevant specification.

4.27.3.4.2 The resistor shall be tested under standard atmospheric conditions for testing.

The test is performed with the test specimens dry and clean at ambient laboratory temperature. The voltage pulse applied shall be based upon the application and shall be selected from table 9.

The pulse test voltage shall be applied to the resistor according to 4.27.3.4.3 with the appropriate severity as specified in the relevant specification.

4.27.3.4.3 The resistor under test is connected across (a) and (b) in figure 9 or figure 10. The voltage shall appear across the terminals of the resistor under test. The relevant specification shall give the details.

4.27.3.5 Severities

The test shall be performed with a severity chosen from table 9.

Table 9 – Severities (see note 2)

Severity No.	Pulse shape according to 10.1 or 12 of IEC 60060-2 T_1/T_2 µs	Pulse voltage U		Number of pulses per minute	Total number of pulses
		Multiples of U_R (* and note 1)	Multiples of U_{max} (* and note 1)		
1	1,2/50		10	≤ 6	5
2			15		
3			20		
4	10/1 000 or 10/700	10	2	≤ 1	10
5		20	3		
6		30	4		
7		40	5		
8		50	6		

NOTE 1 – U_R is the rated voltage; U_{max} is the limiting element voltage.

NOTE 2 – The given values of pulse voltage are prospective peak voltages as defined in IEC 60060-1.

* Whichever is the lower.

4.27.3.6 Recovery

Recovery shall take place under standard atmospheric conditions for testing, until thermal equilibrium has been reached, with a maximum of 24 h.

4.27.3.7 Final inspection, measurements and requirements

4.27.3.7.1 The resistors shall be visually examined. There shall be no visible damage. The marking shall be legible.

4.27.3.7.2 The resistance shall be measured. The change of resistance with respect to the value measured initially (see 4.27.3.3) shall not exceed the limit for the endurance test, unless otherwise specified in the detail specification.

4.27.3.8 Information to be given in the detail specification

The detail specification shall include the following.

a) Method of mounting of the resistor for the test.
b) Test severity, to be selected from table 9.
c) Ambient temperature, if other than 15 °C to 35 °C.
d) Failure criteria, for example,
   – permissible resistance change, if different from that specified for the endurance test;
   – insulation breakdown;
   – short circuit;
   – open circuit;
   – other criteria.

4.28 Periodic-pulse high-voltage overload test

4.28.1 Object

The object of this test is to determine the ability of a resistor to withstand conditions of short high overloads occurring periodically (pulse conditions).

Changes in the resistor parameters after the test are basically due to

– internal voltage effects;
– current effects, including local thermal stresses and mechanical forces.

4.28.2 Terminology

The following terms and definitions apply.

4.28.2.1 Pulse duration (t_p)

The duration between pulse start time and pulse stop time.

4.28.2.2 Pulse repetition period (t_r)

The interval between the pulse start time of a first pulse waveform and the pulse start time of the pulse waveform immediately following in a periodic pulse train.

4.28.2.3 Nominal pulse voltage

The steady-state value of the voltage shown in annex C and designated there by $\hat{U}$.

NOTE – $\hat{U}$ may be expressed in multiples of U_R, which is the rated voltage on the resistor as defined in 2.2.16.