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Edition 1.0 2022-03

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Laboratory resistors – Part 1: Laboratory DC resistors

Résistances de laboratoire – Partie 1: Résistances de laboratoire à courant continu

IEC 60477-1:2022-03(en-fr)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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Laboratory resistors – Part 1: Laboratory DC resistors

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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LABORATORY RESISTORS –

Part 1: Laboratory DC resistors

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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IEC 60477-1 has been prepared by IEC technical committee 85: Measuring equipment for electrical and electromagnetic quantities. It is an International Standard.

This first edition cancels and replaces the first edition of IEC 60477 published in 1974, and its Amendment 1:1997. This edition constitutes a technical revision.

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

a) extended the resistor accuracy classes;
b) deleted the resistor accuracy class expression in parts per million (ppm);
c) excluded the active resistor from the scope of this document;
d) updated the terms and definitions according to new IEC 60050 series;
e) changed the term "resistance decade" to "resistance dial" to cover the multi-dial resistors with other resistance step values;
f) updated the intrinsic error to intrinsic uncertainty according to IEC 60359;

g) added the limits of relative stability for resistors of classes 0,000 05 to 0,01;

h) added the requirements of high voltage resistors;

i) updated the safety symbols and requirements according to the new IEC 61010 series;

j) updated the insulation resistance requirements of resistors;

k) added the requirements of temperature coefficient;

l) updated the temperature requirements for transport and storage of resistors.

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

Draft	Report on voting
85/821/FDIS	85/824/RVD

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

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

A list of all parts in the IEC 60477 series, published under the general title *Laboratory resistors*, can be found on the IEC website.

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

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

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

LABORATORY RESISTORS –

Part 1: Laboratory DC resistors

1 Scope

This document applies to resistors intended for use as laboratory DC resistors (hereinafter referred to as "resistors") comprising standard resistors, single or multiple resistors of accuracy Classes 0,000 05 to 10 and single or multi-dial resistors of accuracy Classes 0,000 5 to 10.

This document does not apply to:

1) resistors which are intended for use solely as permanently mounted circuit components,
2) resistors used on alternating current or on pulsed current,
3) active resistors,
4) series resistors and shunts which are considered as accessories of electrical measuring instruments in the relevant IEC document (examples of these are as follows).

EXAMPLE 1 IEC 60051 series: Recommendations for direct acting indicating analogue electrical measuring instruments and their accessories.

EXAMPLE 2 IEC 60258: Direct acting recording electrical measuring instruments and their accessories.

2 Normative references

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

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

IEC 60417 (all parts), *Graphical symbols for use on equipment* (available at http://www.graphical-symbols.info/equipment)

IEC 61010-1:2010, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*
IEC 61010-1:2010/AMD1:2016

IEC 61010-2-030, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 2-030: Particular requirements for equipment having testing or measuring circuits*

3 Terms and definitions

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

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

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

3.1 General terms

3.1.1
terminal
point of interconnection of an electric circuit element, an electric circuit or a network with other electric circuit elements, electric circuits or networks

Note 1 to entry: For an electric circuit element the terminals are the points at which or between which the related integral quantities are defined. At each terminal, there is only one electric current from outside into the element.

[SOURCE: IEC 60050-131:2002, 131-11-11, modified – Note 2 to entry omitted.]

3.1.2
two-terminal device
device having two terminals, or device having more than two terminals where only the performance at two terminals forming a pair is of interest

[SOURCE: IEC 60050-151:2001, 151-12-13, modified – Note 1 to entry omitted.]

3.1.3
resistor
two-terminal device characterized essentially by its resistance

[SOURCE: IEC 60050-151:2001, 151-13-19, modified – Note 1 to entry omitted.]

3.1.4
four-terminal resistor
resistor fitted with two current terminals and two voltage terminals

[SOURCE: IEC 60050-313:2001, 313-09-06, modified – deletion of the words "injection" and "measuring".]

3.1.5
single value resistor
device which provides a single definite resistance value between certain terminals

3.1.6
multiple value resistor
assembly comprising a number of resistors which are accessible either singly or in combination and which provides definite resistance values between certain terminals

3.1.7
resistance dial
multiple resistor which, by means of a switching device, generally allows the selection of a combination of resistance values rising in equal steps, each step corresponding to an increment of an n-ary resistance value

Note 1 to entry: Resistance decade with each step corresponding to an increment of a decadic resistance value is common (e.g. 0,1 Ω or 1 Ω or 10 Ω, etc.).

Note 2 to entry: A resistance decade generally allows a selection of 10, 11 or 12 resistance values (including zero).

3.1.8
multi-dial resistor
multiple resistor comprising a number of resistance dials which are generally connected in series

Note 1 to entry: A resistor comprising a number of resistance decades is usually called a multi-decade resistor.

3.1.9
material measure
device intended to reproduce or supply, in a permanent manner during its use, one or more known values of a given quantity

EXAMPLE: Standard electric resistor.

Note 1 to entry: The quantity concerned may be called the supplied quantity.

Note 2 to entry: The definition covers also those devices, such as signal generators and standard voltage or current generators, often referred to as supply instruments.

Note 3 to entry: The identification of the value and uncertainty of the supplied quantity is given by a number tied to a unit of measurement or a code term, called the nominal value or marked value of the material measure.

[SOURCE: IEC 60359:2001, 3.2.3, modified – The example has been added, as given in IEC 60050-311:2001, 311-03-03.]

3.1.10
(measurement) standard
material measure, measuring instrument, reference material or measuring system intended to define, represent physically, conserve or reproduce a unit of a quantity, or a multiple or sub-multiple thereof (for example, standard resistance), or a known value of a quantity (for example, standard cell), with a given uncertainty

[SOURCE: IEC 60050-311:2001, 311-04-01]

3.1.11
residual resistance
resistance value between the terminals of a multiple resistor having switching devices with a zero position, when all switching elements are set to the zero position

3.1.12
screen
shield (US)
device intended to reduce the penetration of an electric, magnetic or electromagnetic field into a given region

[SOURCE: IEC 60050-151:2001, 151-13-09]

3.1.13
local earth
local ground, US
part of the Earth that is in electric contact with an earth electrode and that has an electric potential not necessarily equal to zero

[SOURCE: IEC 60050-195:2021, 195-01-03]

3.1.14
earth, verb
ground, verb US
to make an electric connection between a conductive part and a local earth

Note 1 to entry: The connection to local earth can be

– intentional, or

– unintentional or accidental

and can be permanent or temporary.

[SOURCE: IEC 60050-195:2021, 195-01-08]

3.1.15
earthing terminal
grounding terminal, US
terminal provided on equipment and intended for the electric connection with the earthing arrangement

[SOURCE: IEC 60050-195:2021, 195-02-31]

3.1.16
working voltage
highest RMS value of the AC or DC voltage across any particular insulation which can occur when the equipment is supplied at rated voltage

Note 1 to entry: Transients and voltage fluctuations are not considered to be part of the working voltage.

Note 2 to entry: Both open-circuit conditions and normal operating conditions are taken into account.

[SOURCE: IEC 60050-581:2008, 581-21-19, modified – Note 1 and Note 2 to entry have been added according to IEC 61010-1:2010, 3.3.3.]

3.1.17
measurement category
classification of testing and measuring circuits according to the type of mains to which they are intended to be connected

Note 1 to entry: Measurement categories take into account overvoltage categories, short-circuit current levels, the location in the building installation where the test or measurement is to be made, and some forms of energy limitation or transient protection included in the building installation. See IEC 61010-2-30:2017, Annex AA for more information.

[SOURCE: IEC 61010-2-30:2017, 3.5.101]

3.1.18
insulation resistance
resistance under specified conditions between two conductive elements separated by the insulating materials

[SOURCE: IEC 60050-151:2001, 151-15-43]

3.2 Characteristic values

3.2.1
nominal value
value of a quantity used to designate and identify a component, device, equipment, or system

Note 1 to entry: The nominal value is generally a rounded value.

[SOURCE: IEC 60050-151:2001, 151-16-09]

3.2.2
(measure-) value
mid element of the set assigned to represent the measurand

Note 1 to entry: The measure-value is no more representative of the measurand than any other element of the set. It is singled out merely for the convenience of expressing the set in the format $V \pm U$, where V is the mid element and U the half-width of the set, rather than by its extremes. The qualifier "measure-" is used when deemed necessary to avoid confusion with the reading-value or the indicated value.

Note 2 to entry: For a multiple resistor with switching devices having a zero position, the measure-value for a given setting is the value obtained for that setting minus the residual resistance (see 3.1.11).

[SOURCE: IEC 60359:2001, 3.1.3, modified – Note 2 to entry has been added.]

3.2.3
indication
reading-value
output signal of the instrument

Note 1 to entry: The indicated value can be derived from the indication by means of the calibration curve.

Note 2 to entry: For a material measure, the indication is its nominal or stated value.

Note 3 to entry: The indication depends on the output format of the instrument:

– for analogue outputs it is a number tied to the appropriate unit of the display;

– for digital outputs it is the displayed digitized number;

– for code outputs it is the identification of the code pattern.

Note 4 to entry: For analogue outputs meant to be read by a human observer (as in the index-on-scale instruments) the unit of output is the unit of scale numbering; for analogue outputs meant to be read by another instrument (as in calibrated transducers) the unit of output is the unit of measurement of the quantity supporting the output signal.

Note 5 to entry: The indication is the assigned value for a resistor, the measure-value stated in this document (see 9.1 p)) for a single or a multiple resistor of classes 0,00005 to 0,01, or the nominal value for a single or a multiple resistor of classes 0,01 to 10.

[SOURCE: IEC 60359:2001, 3.1.5, modified – Note 5 to entry has been added.]

3.2.4
indicated value
value given by an indicating instrument on the basis of its calibration curve

Note 1 to entry: The indicated value is the measure-value of the measurand when the instrument is used in a direct measurement under all the operating conditions for which the calibration diagram is valid.

[SOURCE: IEC 60359:2001, 3.1.9]

3.2.5
stability of a measuring instrument
stability
property of a measuring instrument, whereby its metrological properties remain constant in time

Note 1 to entry: Stability may be quantified in several ways.

EXAMPLE 1 In terms of the duration of a time interval over which a metrological property changes by a stated amount.

EXAMPLE 2 In terms of the change of a property over a stated time interval.

Note 2 to entry: For a resistor, stability is quantified in the change of resistance measure-value over a year. In this document, it is expressed in relative form divided by the resistance measure-value.

[SOURCE: ISO/IEC GUIDE 99:2007, 4.19, modified – Note 2 to entry has been added.]

3.3 Accuracy class, class index

3.3.1
accuracy class
class of measuring instruments, all of which are intended to comply with a set of specifications regarding uncertainty

Note 1 to entry: An accuracy class always specifies a limit of uncertainty (for a given range of influence quantities), whatever other metrological characteristics it specifies.

Note 2 to entry: An instrument may be assigned to different accuracy classes for different rated operating conditions.

Note 3 to entry: Unless otherwise specified, the limit of uncertainty defining an accuracy class is meant as an interval with coverage factor 2.

Note 4 to entry: Accuracy class of a resistor is defined by the limits of intrinsic relative uncertainty, the limits of relative stability and the limits of variations due to influence quantities.

[SOURCE: IEC 60359:2001, 3.3.7, modified – Note 4 to entry has been added.]

3.3.2
class index
conventional designation of an accuracy class by a number or symbol

[SOURCE: IEC 60050-311:2001, 311-06-10]

3.4 Influence quantities, reference conditions, nominal range of use

3.4.1
influence quantity
quantity which is not the subject of the measurement and whose change affects the relationship between the indication and the result of the measurement

Note 1 to entry: Influence quantities can originate from the measured system, the measuring equipment or the environment.

Note 2 to entry: As the calibration diagram depends on the influence quantities, in order to assign the result of a measurement it is necessary to know whether the relevant influence quantities lie within the specified range.

Note 3 to entry: An influence quantity is said to lie within a range C' to C'' when the results of its measurement satisfy the relationship: $C' \leq V - U < V + U \leq C''$.

[SOURCE: IEC 60359:2001, 3.1.14]

3.4.2
reference conditions
appropriate set of specified values and/or ranges of values of influence quantities under which the smallest permissible uncertainties of a measuring instrument are specified

Note 1 to entry: The ranges specified for the reference conditions, called reference ranges, are not wider, and are usually narrower, than the ranges specified for the rated operating conditions.

[SOURCE: IEC 60359:2001, 3.3.10]

3.4.3
reference value
specified value of one of a set of reference conditions

[SOURCE: IEC 60359:2001, 3.3.11]

3.4.4
reference range
specified range of values of one of a set of reference conditions

[SOURCE: IEC 60359:2001, 3.3.12]

3.4.5
rated operating conditions
set of conditions that must be fulfilled during the measurement in order that a calibration diagram may be valid

Note 1 to entry: Beside the specified measuring range and rated operating ranges for the influence quantities, the conditions may include specified ranges for other performance characteristics and other indications that cannot be expressed as ranges of quantities.

[SOURCE: IEC 60359:2001, 3.3.13]

3.4.6
nominal range of use (for influence quantities)
rated operating range (for influence quantities)
specified range of values which an influence quantity can assume without causing a variation exceeding specified limits

Note 1 to entry: The rated operating range of each influence quantity is a part of the rated operating conditions.

[SOURCE: IEC 60359:2001, 3.3.14]

3.4.7
limiting values for operation
extreme values which an influence quantity can assume during operation without damaging the measuring instrument so that it no longer meets its performance requirements when it is subsequently operated under reference conditions

Note 1 to entry: The limiting values can depend on the duration of their application.

[SOURCE: IEC 60050-311:2001, 311-07-06]

3.4.8
storage and transport conditions
extreme conditions which a non-operating measuring instrument can withstand without damage and without degradation of its metrological characteristics when it is subsequently operated under its rated operating conditions

[SOURCE: IEC 60359:2001, 3.3.17]

3.4.9
temperature coefficient
<of a resistor> coefficient of the formula which defines the measure-value of resistance as a function of temperature

Note 1 to entry: In general, the value of resistance at any temperature can be calculated according to the following temperature formula:

$$R_t = R_{t_0}\left[1+\alpha\left(t-t_0\right)+\beta\left(t-t_0\right)^2\right] \quad (1)$$

where:

R_t value of resistance at t °C (Ω)

R_{t_0} measure-value of resistance at t_0 °C (Ω)

α primary temperature coefficient of resistance (1/°C)

β secondary temperature coefficient of resistance (1/°C^2)

t temperature of resistance

t_0 reference temperature value.

3.4.10
temperature coefficient of resistance
TCR
α
reversible relative variation of resistance between two given temperatures divided by the difference in the temperature producing it

Note 1 to entry: It should be noted that the term expresses a maximum relative resistance variation within a given temperature range, hence the use of the term does not imply any degree of linearity for this function, nor should any be assumed.

Note 2 to entry: The temperature coefficient of resistance is usually determined between the reference temperature and the category temperatures, LCT and UCT, respectively, for which the larger of the two determined coefficients is expressed as the result.

Note 3 to entry: Related terminology: variation of resistance with temperature

[SOURCE: IEC 60115-1:2021, 3.1.34]

3.4.11
steady-state conditions
operating conditions of a measuring device in which the variation of the measurand with the time is such that the relation between the input and output signals of the instruments does not suffer a significant change with respect to the relation obtaining when the measurand is constant in time

[SOURCE: IEC 60359:2001, 3.1.15]

3.5 Uncertainty and variations

3.5.1
uncertainty (of measurement)
parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

Note 1 to entry: The parameter can be, for example, a standard deviation (or a given multiple of it), or a half-width of an interval having a stated level of confidence.

Note 2 to entry: Uncertainty of measurement comprises, in general, many components. Some of these components can be evaluated from the statistical distribution of the results of a series of measurements and can be characterized by experimental standard deviations. The other components, which can also be characterized by standard deviations, are evaluated from the assumed probability distributions based on experience or other information.

Note 3 to entry: It is understood that the result of the measurement is the best estimate of the value of the measurand, and that all components of uncertainty, including those arising from systematic effects, such as components associated with corrections and reference standards, contribute to the dispersion.

Note 4 to entry: The definition and notes 1 and 2 are from GUM, clause B.2.18. The option used in this standard is to express the uncertainty as the half-width of an interval with the GUM procedures with a coverage factor of 2. This choice corresponds to the practice now adopted by many national standards laboratories. With the normal distribution a coverage factor of 2 corresponds to a level of confidence of 95 %. Otherwise statistical elaborations are necessary to establish the correspondence between the coverage factor and the level of confidence. As the data for such elaborations are not always available, it is deemed preferable to state the coverage factor. This interval can be "reasonably" assigned to describe the measurand, in the sense of the GUM definition, as in most usual cases it ensures compatibility with all other results of measurements of the same measurand assigned in the same way at a sufficiently high confidence level.

Note 5 to entry: Following CIPM document INC-1 and GUM, the components of uncertainty that are evaluated by statistical methods are referred to as components of category A, and those evaluated with the help of other methods as components of category B.

[SOURCE: IEC 60359:2001, 3.1.4]

3.5.2
variation (due to an influence quantity)
difference between the indicated values for the same value of the measurand of an indicating instrument, or the values of a material measure, when an influence quantity assumes, successively, two different values

Note 1 to entry: The uncertainty associated with the different measure values of the influence quantity for which the variation is evaluated should not be wider than the width of the reference range for the same influence quantity. The other performance characteristics and the other influence quantities should stay within the ranges specified for the reference conditions.

Note 2 to entry: The variation is a meaningful parameter when it is greater than the intrinsic instrumental uncertainty.

[SOURCE: IEC 60359:2001, 3.3.5]