SLOVENSKI STANDARD
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Laboratorijski upori - 2. del: Laboratorijski upori za izmenični tok

Laboratory resistors. Part 2: Laboratory AC resistors

Résistances de laboratoire - Partie 2: Résistances de laboratoire à courant alternatif

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IEC TC 85 : MEASURING EQUIPMENT FOR ELECTRICAL AND ELECTROMAGNETIC QUANTITIES	
SECRETARIAT: China	SECRETARY: Ms Guiju HAN
OF INTEREST TO THE FOLLOWING COMMITTEES:	PROPOSED HORIZONTAL STANDARD: ☒ Other TC/SCs are requested to indicate their interest, if any, in this CDV to the secretary.
FUNCTIONS CONCERNED: ☐ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☐ SAFETY	
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Laboratory resistors. Part 2: Laboratory AC resistors

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NOTE FROM TC/SC OFFICERS:

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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LABORATORY RESISTORS –

Part 2: Laboratory AC resistors

FOREWORD

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International Standard IEC 60477-2 has been prepared by IEC technical committee 85: Measuring equipment for electromagnetic quantities.

This second edition cancels and replaces the first edition published in 1979, Amendment 1:1997. This edition constitutes a technical revision.

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

– replaced a.c. with AC according IEC 60050-151:2001, 151-15-01;
– extended the resistor frequency scope to 1 MHz of this document;
– updated the classification according the AC resistor construction;
– updated the terms and definition according to IEC 60050 series;
– added the definition of AC/DC difference of an AC resistor;
– added the resistor classification according the AC resistance or AC/DC difference index;
– updated the safety symbols and requirements according to IEC 60047;
– added the three-element equivalent circuit of an AC resistor in Annex C;
– added the annex on constructions of AC resistors.

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

110

FDIS	Report on voting
XX/XX/FDIS	XX/XX/RVD

111

112 Full information on the voting for the approval of this International Standard can be found in
113 the report on voting indicated in the above table.

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

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

118 • reconfirmed,
119 • withdrawn,
120 • replaced by a revised edition, or
121 • amended.

122

123 The National Committees are requested to note that for this document the stability date
124 is 2025.

125 THIS TEXT IS INCLUDED FOR THE INFORMATION OF THE NATIONAL COMMITTEES AND WILL BE
126 DELETED AT THE PUBLICATION STAGE.

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LABORATORY RESISTORS –

Part 2: Laboratory AC resistors

1 Scope

This part of IEC 60477 applies to resistors intended as laboratory AC resistors for use over a range of frequencies from DC up to a stated frequency which is not in excess of 1 MHz. Such resistors are hereinafter referred to as “AC resistors”.

In addition to satisfying the requirements of IEC 60477, resistors satisfying the requirements of this standard are designed to have a small variation of resistance and a small phase displacement over the stated frequency range.

Because of the uncertainties in AC properties which can result from stray inductances, stray capacitances, eddy currents, dielectric absorption effects and skin effect, the AC resistors to which this standard applies are classified according to their construction (see Annex D), as follows:

a) Two-terminal resistor which each of one terminal both for current and potential;

b) Three-terminal resistor which has one more shield terminal (also could be called as guard terminal) connected to the electric screen than the two-terminal resistor to reduce the stray capacitances effect;

c) Four-terminal resistor which has independent current terminals and potential terminals to reduce the stray inductances and contact resistances;

d) Five-terminal resistor which has one more shield terminal than the four-terminal resistor;

e) Four-terminal coaxial resistor which has two terminal-pairs with the outer shield conductors working as the low terminal of current or potential;

f) Two-terminal-pair resistor which has two terminal-pairs with the outer shield conductors working as the return path for the signal current (not grounded);

g) Four-terminal-pair resistor which has four terminal-pairs with the outer shield conductors working as the return path for the signal current (not grounded) to eliminate the effect of mutual coupling between the current and potential leads.

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 60477, *Laboratory DC resistors*

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:

ISO Online browsing platform: available at http://www.iso.org/obp

IEC Electropedia: available at http://www.electropedia.org/

3.1

equivalent electric circuit
circuit composed of ideal circuit elements which has, at the terminals or ports, a behaviour equivalent to that of a given electric or magnetic circuit or device

Note 1 to entry: Equivalent electric circuits can also be used to represent other kinds of devices or phenomena.

[SOURCE: IEC 60050-131:2002,131-15-07]

3.2

circuit element
in electromagnetism, mathematical model of a device characterized by one or more relations between integral quantities

[SOURCE: IEC 60050-131:2002,131-11-03]

3.3

equivalent <electric> circuit of an AC resistor
electrical electric circuit which has the same AC characteristics as a resistor, would have an impedance equal to the resistor under specified operating conditions

Note 1 to entry: Specified operating conditions should include working frequency and voltage.

3.4

two-element equivalent circuit of an AC resistor
an equivalent circuit of an AC resistor with two elements under specified operating conditions

Note 1 to entry: two-element equivalent circuit of an AC resistor is given by either an equivalent AC resistance, R_s in series with an equivalent inductance, L_s or an equivalent AC resistance, R_p in parallel with an equivalent capacitance, C_p (see Annexes C).

3.5

three-element equivalent circuit of an AC resistor
an equivalent electric circuit of an AC resistor with three elements under specified operating conditions

3.6

equivalent AC resistance of an AC resistor
AC resistance

value of resistance (R_s or R_p) which is the AC resistive component of the resistor

Note 1 to entry: The AC resistance is usually taken as the equivalent series resistance R_s, for resistors Category A, and as the equivalent parallel resistance R_p, for resistors Category C (see Annexes B).

3.7

terminal pair
port consisting of two terminals such that the electric current directed from an external circuit or device to one terminal is identical with the current directed from the other terminal to the external circuit or device

[SOURCE: IEC 60050-131:2002,131-12-63]

3.8

time constant
τ

time τ in the expression $F(t) = A + B\mathrm{e}^{-t/\tau}$ of a quantity F growing or decaying exponentially towards a constant value A with increasing time t, or in the expression $F(t) = A + f(t)\mathrm{e}^{-t/\tau}$ of an exponentially damped oscillation, where f is a periodic function of time

Note 1 to entry: for a quantity growing or decaying exponentially towards a constant value the duration of a time interval, at the end of which the absolute value of the difference between that constant value and the value of the variable quantity has decreased to e^{-1} times of the absolute value of the difference at the beginning of the interval, where e is the base of natural logarithms.

Note 2 to entry: For resistor, at any particular frequency, it is defined as either: L_s/R_s, or R_pC_p whichever yields a positive value (see Appendix C). For determining the time constant, the DC resistance may be used instead of the equivalent AC resistance.

Note 3 to entry: For resistor used three-element equivalent circuit expressed, it is approximately equal to: $\frac{L}{R} - CR$, or $CR - \frac{L}{R}$ (see Appendix C) .

Note 4 to entry: The phase displacement of the current flowing through the resistor from the voltage appearing across it with a time constant L_s/R_s or $\frac{L}{R} - CR$ is such that the current is lagging, and that with a time constant

R_pC_p or $CR - \frac{L}{R}$ is leading when L_s and C_p, have positive value, L_s and L being expressed in henrys, R_s, R_p and R in ohms and C_p and C in farads.

[SOURCE: IEC 60050-103:2009, 103-05-26, modified – Note 2, Note 3 and Note 4 to entry has been added to adapt to usage in AC resistor technology]

3.9

time constant index
conventional designation of a time constant by a number or symbol

Note 1 to entry: In this standard, it is expressed in seconds using the appropriate SI prefix.

3.10

AC/DC difference <of an AC resistor>
difference between the equivalent AC resistance at a stated frequency and the DC resistance, expressed in percentage (%) of the DC resistance

3.11

AC/DC difference index
number which designates the limit of the AC/DC difference with in nominal range of use for frequency, expressed in %

3.12

frequency index
number which designates the upper limit of the nominal range of use for frequency, expressed in hertz (see Table 3) using the appropriate SI prefix

3.13

skin effect
for an alternating electric current in a conductor, phenomenon in which the current density is greater near the surface than in the interior of the conductor

Note 1 to entry: The skin effect increases the resistance and decreases the inductance of a conductor with the frequency of the electric current.

Note 2 to entry: The skin effect occurs also in the more general case of any time-varying current.

[SOURCE: IEC 60050-121:1998, 121-13-18]

3.14

residual inductance
inductance value between the points of connection of a multiple or multi-dial AC resistor having switching devices with a zero position, when all switching elements are set to the zero position

4 Resistor characterization

AC resistors satisfying this standard are characterized:

h) by classes related to their DC accuracy as specified in IEC 60477,

i) by classes related to their equivalent AC resistance as specified in Sub clause 5.1.2 or AC/DC difference indices as specified in Sub-clause 5.1.3 and,

j) by time constant indices as specified in Sub-clause 5.1.4 and,

k) by frequency indices as specified in Sub-clause 6.2.

5 General requirements

5.1 DC resistance, AC resistance and time constant

The DC characteristics of an AC resistor shall be as specified in IEC 60477.

The equivalent AC resistance of an AC resistor characterized by class related to the AC resistance shall comply with the limits of relative uncertainty for specified for their AC resistance class index in Table 1 at initial calibration.

Table 1 –limits of the AC resistance relative uncertainty

AC resistance class index	0.00001	0.00002	0.00005	…	2	5	10
limits of relative uncertainty for AC resistance	0.00001%	0.00002%	0.00005%	…	2%	5%	10%

Note 1 The value of the AC resistance of a given resistor is somewhat dependent on the frequency at which it is measured. However, as the purpose here is to affect a classification of resistors, measurements at 1 kHz (or lower) are here generally adequate.

The AC/DC difference of an AC resistor characterized by AC/DC difference index shall comply with the limits of AC/DC difference specified for their AC/DC difference index in Table 2 at initial calibration.

Table 2 –limits of the AC/DC difference

AC/DC difference index	0.000001	0.000002	0.000005	…	0.2	0.5	1
limits of the AC/DC difference	±0.000001%	±0.000002%	±0.000005%	…	±0. 2%	±0. 5%	±1%

Note 2 Measurements at 1 kHz (or lower) are here generally adequate.

Note 3 An AC resistor shall choose either AC resistance class index or AC/DC difference index to show the equivalent AC resistance character.

The time constant of an AC resistor shall not exceed the appropriate value of the time constant index selected from the sequence:

- 1 ns, 2 ns, 5 ns, 10 ns, …100 µs.

Note 4 The value of the time constant of a given resistor is also somewhat dependent on the frequency at which it is measured. Measurements at 1 kHz (or lower) are here generally adequate as same as the measurements of AC resistance.

5.2 Multiple resistors

Multiple resistors, excluding multi-dial resistors, may have different AC resistance class or AC/DC difference and time constant index for each selectable value.

For a multiple resistor in which the lowest selectable resistance value is nominally zero, the manufacturer shall state the value of the residual inductance under this condition.

5.3 Multi-dial resistors

Multi-dial resistors shall have a single AC resistance class index or AC/DC difference index and a single time constant index for all selectable values on any dial used alone. The several dials may each have a different AC resistance class index or AC/DC difference index and a different time constant index.

The AC resistance class index or AC/DC difference index of a given dial shall also apply at any setting of the dial when that dial is used in conjunction with any setting of any dial(s) inferior to it in value.

The time constant index of a given dial shall also apply at any setting of the dial when that dial is used in conjunction with any setting of any dial(s) inferior to it in value.

5.4 Connecting leads

Separate current and potential connections shall be made to a resistor having a pair of terminals for each port of connection, unless other conditions are stated by the manufacturer. The mutual inductances between the current and potential leads and between each of these leads and the resistor shall be minimized.

The leads making connection to a resistor having a single terminal for each port of connection shall be arranged so as to minimize their inductance.

Note 1 This is particularly important for resistors of values of 10Ω and lower.

The leads making connection to a resistor shall not alter significantly the equivalent parallel capacitance, if necessary, by the provision of screen for each lead and by the use of an appropriate measuring circuit.

Note 2 The magnitude of capacitance that will cause a significant alteration will depend upon the value of the resistance and the time constant.

5.5 Conditions for the determination of DC and AC characteristics

All tests of DC characteristics shall be carried out as specified in IEC 60477

Note 1 At low frequencies, the uncertainty of an AC resistor is essentially the same as its uncertainty at DC

Note 2 At higher frequencies, an additional variation as specified by Sub-clause 6.1 is permitted.

All tests of AC characteristics shall be carried out under the reference conditions specified in IEC 60477.

The AC resistance of an AC resistor shall be measured at a frequency of 1 kHz or at the frequency corresponding to its frequency index if the latter is lower (see Clause 6).

The time constant of an AC resistor shall be measured at a frequency of 1 kHz or at the frequency corresponding to its frequency index if the latter is lower (see Clause 6).

The residual inductance of an AC resistor (see Sub-clause 5.2.2) shall be measured with the resistor connected as in normal use and at a frequency of 1 kHz or at the frequency corresponding to its frequency index if the latter is lower (see Clause 6).

A resistor having a shield terminal (see Items b) and d) of Sub-clause 1.3) shall be tested with the screen connected as specified by the manufacturer.

A resistor not having a shield terminal (see Item a) and c) of Sub-clause 1.3) shall be tested within an earthed conductive enclosure as specified by the manufacturer. If this enclosure is not specified, the resistor shall be tested within an earthed conductive enclosure separated from the surface of the resistor by between 10 mm and 20 mm at all places.

A resistor having terminal-pairs (see Items e), f) and g) of Sub-clause 1.3) shall be tested with the terminal-pair connected as specified by the manufacturer.

Any other necessary conditions shall be stated by the manufacturer.

When necessary, details of the testing method shall be agreed between the manufacturer and the user.

6 Permissible variations

Changes in influence quantities over the nominal ranges of use specified in IEC 60477 will cause no significant effect on the AC characteristics of the resistor. Requirements relating to variations of AC characteristics other than those due to frequency are therefore not included in this standard.

The upper limit of the nominal range of use for frequency shall be designated using the appropriate frequency index selected from Table 3.

Table 3 –Upper limit of the nominal range of use for frequency

Frequency index	1M	500k	200k	…	500	200	100	50
Upper limit of the nominal range of use for frequency	1 MHz	500 kHz	200 kHz	…	500 Hz	200 Hz	100 Hz	50 Hz

When the AC resistor is under reference conditions as specified in IEC 60477, the AC resistance relative uncertainty for any frequency within its nominal range of use shall not exceed the permissible AC resistance relative uncertainty (see Sub-clause 5.1.2), or the AC/DC difference for any frequency within its nominal range of use shall not exceed the permissible AC/DC difference (see Sub-clause 5.1.3).

Multiple resistors, excluding multi-dial resistors, may have a different frequency index for each selectable value.

Multi-dial resistors shall have a single frequency index for all selectable values on any dial used alone. The several dials may each have a different frequency index. The frequency index of a given dial shall also apply when that dial is used in conjunction with any dial(s) inferior to it in value.