SLOVENSKI STANDARD
SIST IEC 60359:1995

01-avgust-1995

Expression of the performance of electrical and electronic measuring equipment

Electrical and electronic measurement equipment - Expression of performance

Appareils de mesure électriques et électroniques - Expression des performances

Ta slovenski standard je istoveten z: **IEC 60359**

ICS:

17.220.20	Merjenje električnih in magnetnih veličin	Measurement of electrical and magnetic quantities

SIST IEC 60359:1995 **en**

NORME INTERNATIONALE

INTERNATIONAL STANDARD

CEI
IEC
60359

Troisième édition
Third edition
2001-12

Appareils de mesure électriques et électroniques – Expression des performances

Electrical and electronic measurement equipment – Expression of performance

International Electrotechnical Commission 3, rue de Varembé Geneva, Switzerland
Telefax: +41 22 919 0300 e-mail: inmail@iec.ch IEC web site http://www.iec.ch

Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

CODE PRIX
PRICE CODE V

Pour prix, voir catalogue en vigueur
For price, see current catalogue

CONTENTS

FOREWORD 5
INTRODUCTION 9

1 Scope and object 11
2 Normative references 11
3 Definitions 13
4 Specification of values and ranges 31
5 Requirements for IEC standards related to the equipment 33
6 Specification of limits of uncertainty 33
7 Specification of influence quantities 49
8 General rules for compliance testing 53

Annex A (informative) Conceptual and terminological evolution from "error" to "uncertainty" 55
Annex B (informative) Steps in the specification of performance 63

Bibliography 67

Figure 1 – Calibration diagram 35
Figure 2 – Calibration diagram with scale marks in units of measurement 37
Figure 3 – Calibration diagram in different operating conditions 41
Figure 4 – Calibration diagram for extended operating conditions 43
Figure B.1 – Steps in the specification of performance 63

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTRICAL AND ELECTRONIC MEASUREMENT EQUIPMENT – EXPRESSION OF PERFORMANCE

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.
2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.
3) The documents produced have the form of recommendations for international use published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.
4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.
5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.
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 60359 has been prepared by IEC technical committee 85: Measuring equipment for electrical and electromagnetic quantities.

This third edition cancels and replaces the second edition published in 1987 and its amendment 1 (1991), of which it constitutes a technical revision.

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

FDIS	Report on voting
85/219/FDIS	85/220/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.

This International Standard was prepared by IEC TC 85 following its resolution 85/45/AC of 1994-12-16 “to revise the IEC 60359, taking into account the "Guide to the Expression of Uncertainty in Measurement" (GUM) published by ISO in 1993”.

The main technical changes from the previous edition of this International Standard consist in adapting the requirements on the instrument performance to the approach on uncertainty taken by the GUM, adapting the terminology to the new edition of the IEV, and offering a wider and more correct choice of options in specifying the limits of uncertainty.

Annexes A and B are for information only.

The committee has decided that the contents of this publication will remain unchanged until 2005-12. At this date, the publication will be:

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

INTRODUCTION

With the appearance of the interorganizational *Guide to the expression of uncertainty in measurement* (GUM) that embodied the suggestions of CIPM[1] Recommendation CI-1981, it became clear that the classical approach to the precision and accuracy of measurement in terms of true value and error is being superseded by the approach in terms of uncertainty. The intrinsic pitfalls of the concept of true value (hence of error) had indeed led the operative measurement world to rely increasingly on the concept of uncertainty, notwithstanding that the main body of standards concerning the performance of measuring instruments was still written in terms of the traditional approach. The widening gap between the best practice in metrology and the wording of the standards prompted the normative organizations to invite their Technical Committees to update these publications.

This new edition of the International Standard IEC 60359 was prepared in order to bring it into agreement with the GUM. During the procedure for its approval the chapters on measurement of the new edition of the International Electrotechnical Vocabulary (IEV) were published, and the opportunity was taken to bring the standard into agreement with the terms used in the IEV.

The main performance characteristics of an instrument are those related to the uncertainty of the results obtained by using the instrument. The GUM provides a general terminology and a computational framework for combining uncertainties of different origin, but it substantially deals with the issue of evaluating uncertainty in the measurement of a quantity defined as a function of other measured quantities, and does not address the issue of evaluating instrumental uncertainty, i.e. the uncertainty of the results of the single direct measurements carried out by the instruments. The GUM treats it as a component of uncertainty of category B, known from information supplied by the manufacturer or calibrator of the instrument, in the form of an expanded uncertainty with a stated coverage factor. It is therefore up to this standard to provide indications for expressing and evaluating instrumental uncertainty in a way consistent with the philosophy of the GUM. This means stating the requirements on performance of the instruments in terms of limits of uncertainty instead of limits of error, which implies a careful distinction between the indication of the instrument and the set of values assigned to describe the measurand (see Annex A for the conceptual evolution from the notion of error to the notion of uncertainty).

To this purpose, this standard systematically uses (in agreement with the IEV) the notion of calibration diagram, which is also quite helpful in describing the interplay between intrinsic uncertainty, variations, and operating uncertainty. Distinctions of this kind are essential, by the way, for the new measuring systems, based on microprocessors with internal software or using more than one input (multisensorial systems), that need to address the issue in general terms without restrictive hypotheses on the instrumental hardware. They also allow a wider choice of options in specifying performance characteristics.

For many people, of course, the passage from time-honored traditional terms and notions to the ones evolved by modern metrology will require some mental adjustment, which is altogether necessary, as current instrumentation has made giant steps from the times of index-on-scale instruments. However, no particular difficulty is expected in translating into terms consistent with this standard the bulk of existing technical specifications, most of which are written in terms of "limits of error", often with ambiguities about whether or not suggested corrections for influence quantities are included. When such ambiguities are removed, the old specifications are easily harmonized to this standard by substituting the "limits of error" with the "limits of instrumental uncertainty" expounded in clause 5, provided the contextual indications (if any) on the means of evaluating these limits are adjusted to satisfy the definitions given in this standard.

———————

1 Comité International des Poids et Mesures (CIPM)

ELECTRICAL AND ELECTRONIC MEASUREMENT EQUIPMENT — EXPRESSION OF PERFORMANCE

1 Scope and object

This International Standard applies to the specification of performance, with primary reference to industrial applications, of the following kinds of electrical and electronic equipment:

– indicating and recording instruments which measure electrical quantities;

– material measures which supply electrical quantities;

– instruments which measure non-electrical quantities using electrical means, for all parts of the measuring chain which present electrical output signals.

This standard applies to the specification of performance of instruments operating in steady-state conditions (see 3.1.15), usual in industrial applications.

It is based on the methods expounded in GUM for expressing and evaluating the uncertainty of measurement, and refers to GUM for the statistical procedures to be used in determining the intervals assigned to represent uncertainty (including the way to account for non-negligible uncertainties in the traceability chain).

This standard does not address the propagation of uncertainty beyond the instrument (or the measuring equipment) whose performance is considered and which may undergo compliance testing.

The object is to provide methods for ensuring uniformity in the specification and determination of uncertainties of equipment within its scope. All other necessary requirements have been reserved for dependent IEC product standards pertaining to particular types of equipment which fall within the scope of this standard.

For example: the selection of metrological characteristics and their ranges, and of influence quantities and their specified operating ranges, is reserved for IEC product standards.

2 Normative references

The following referenced documents are indispensable for the application 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 60050-300:2001, *International Electrotechnical Vocabulary (IEV) – Electrical and electronic measurements and measuring instruments – Part 311: General terms relating to measurements – Part 312: General terms relating to electrical measurements – Part 313: Types of electrical measuring instrument – Part 314: Specific terms according to the type of instrument*

ISO/IEC GUIDE EXPRES:1995, *Guide to the Expression of Uncertainty in Measurement*

3 Definitions

For the purposes of this International Standard, the following definitions apply.

A word between brackets in the title of a definition is a qualifier that may be skipped if there is no danger of confusion with a similar term. When two terms may be used interchangeably with the same definition, these are separated by "or". Terms in italics in a note are new terms defined by the context.

Most definitions are taken or adapted, together with their notes, from Part 311 of IEC 60050-300 (International Electrotechnical Vocabulary – IEV). As only terms pertaining to the "uncertainty approach" are used, IEV notes stating that the term is used in this approach were omitted. Where such definitions are simultaneously drawn from the International Vocabulary of Basic and General Terms in Metrology (VIM), this has been indicated. In some cases, notes have been added for the purposes of this standard.

3.1 Basic definitions

3.1.1
measurand
quantity subjected to measurement, evaluated in the state assumed by the measured system during the measurement itself

NOTE 1 The value assumed by a quantity subjected to measurement when it is not interacting with the measuring instrument may be called *unperturbed value* of the quantity.

NOTE 2 The unperturbed value and its associated uncertainty can only be computed through a model of the measured system and of the measurement interaction with the knowledge of the appropriate metrological characteristics of the instrument, that may be called *instrumental load*.

3.1.2
(result of a) measurement
set of values attributed to a measurand, including a value, the corresponding uncertainty and the unit of measurement
[IEV 311-01-01, modified]

NOTE 1 The mid-value of the interval is called the value (see 3.1.3) of the measurand and its half-width the uncertainty (see 3.1.4) [IEV modified].

NOTE 2 The measurement is related to the indication (see 3.1.5) given by the instrument and to the values of correction obtained by calibration [IEV modified].

NOTE 3 The interval can be considered as representing the measurand provided that it is compatible with all other measurements of the same measurand [IEV modified].

NOTE 4 The width of the interval, and hence the uncertainty, can only be given with a stated level of confidence (see 3.1.4, NOTE 1) [IEV modified].

3.1.3
(measure-) value
mid element of the set assigned to represent the measurand

NOTE 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.

3.1.4
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
[IEV 311-01-02, VIM 3.9]

NOTE 1 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 [IEV, VIM].

NOTE 2 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 [IEV, VIM].

NOTE 3 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 [IEV, VIM].

NOTE 4 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 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.*

3.1.5
indication or reading-value
output signal of the instrument
[IEV 311-01-07, modified]

NOTE 1 The indicated value can be derived from the indication by means of the calibration curve [IEV].

NOTE 2 For a material measure, the indication is its nominal or stated value [IEV].

NOTE 3 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 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.

3.1.6
calibration
set of operations which establishes the relationship which exists, under specified conditions, between the indication and the result of a measurement by reference to standards
[IEV 311-01-09]

NOTE 1 The relationship between the indications and the results of measurement can be expressed, in principle, by a calibration diagram [IEV].

NOTE 2 The calibration must be performed under well defined operating conditions for the instrument. The calibration diagram representing its result is not valid if the instrument is operated under conditions outside the range used for the calibration.

NOTE 3 Quite often, specially for instruments whose metrological characteristics are sufficiently known from past experience, it is convenient to predefine a simplified calibration diagram and perform only a verification of calibration (see 3.2.12) to check whether the response of the instrument stays within its limits. The simplified diagram is of course wider than the diagram that would be defined by the full calibration of the instrument, and the uncertainty assigned to the results of measurements is consequently larger.

3.1.7
calibration diagram
portion of the co-ordinate plane, defined by the axis of indication and the axis of results of measurement, which represents the response of the instrument to differing values of the measurand
[IEV 311-01-10]

3.1.8
calibration curve
curve which gives the relationship between the indication and the value of the measurand
[IEV 311-01-11]

NOTE 1 The calibration curve is the curve bisecting the width of the calibration diagram parallel to the axis of results of measurement, thus joining the points representing the values of the measurand (see 6.1 and Figure 1).

NOTE 2 When the calibration curve is a straight line passing through zero, it is convenient to refer to the slope which is known as the instrument constant [IEV].

3.1.9
indicated value
value given by an indicating instrument on the basis of its calibration curve
[IEV 311-01-08]

NOTE The indicated value is the measure-value of the measurand when the instrument is used in a direct measurement (see 3.2.7) under all the operating conditions for which the calibration diagram is valid.

3.1.10
(measurement) compatibility

property satisfied by all the results of measurement of the same measurand, characterized by an adequate overlap of their intervals
[IEV 311-01-14]

NOTE 1 The compatibility of any result of a measurement with all the other ones that represent the same measurand can be asserted only at some level of confidence, as it depends on statistical inference, a level that should be indicated, at least by implicit convention or through a coverage factor.

NOTE 2 The compatibility of the results of measurements obtained with different instruments and methods is ensured by the traceability (see 3.1.16) to a common primary standard (see 3.2.6) of the standards used for the calibration of the several instruments (and of course by the correctness of the calibration and operation procedures).

NOTE 3 When two results of a measurement are not compatible one must decide by independent means whether one or both results are wrong (perhaps because the uncertainty is too narrow), or whether the measurand is not the same.

NOTE 4 Measurements carried out with wider uncertainty yield results which are compatible on a wider range, because they discriminate less among different measurands allowing to classify them with simpler models; with narrower uncertainties the compatibility calls for more detailed models of the measured systems.

3.1.11
intrinsic uncertainty of the measurand
minimum uncertainty that can be assigned in the description of a measured quantity

NOTE 1 No quantity can be measured with narrower and narrower uncertainty, inasmuch as any given quantity is defined or identified at a given level of detail. If one tries to measure a given quantity with uncertainty lower than its own intrinsic uncertainty one is compelled to redefine it with higher detail, so that one is actually measuring another quantity. See also GUM D.1.1.

NOTE 2 The result of a measurement carried out with the intrinsic uncertainty of the measurand may be called the *best measurement* of the quantity in question.

3.1.12
(absolute) instrumental uncertainty
uncertainty of the result of a direct measurement of a measurand having negligible intrinsic uncertainty

NOTE 1 Unless explicitly stated otherwise, the instrumental uncertainty is expressed as an interval with coverage factor 2.

NOTE 2 In single-reading direct measurements of measurands having intrinsic uncertainty small with respect to the instrumental uncertainty, the uncertainty of the measurement coincides, by definition, with the instrumental uncertainty. Otherwise the instrumental uncertainty is to be treated as a component of category B in evaluating the uncertainty of the measurement on the basis of the model connecting the several direct measurements involved.

NOTE 3 The instrumental uncertainty automatically includes, by definition, the effects due to the quantization of the reading-values (minimum evaluable fraction of the scale interval in analogic outputs, unit of the last stable digit in digital outputs).

NOTE 4 For material measures the instrumental uncertainty is the uncertainty that should be associated to the value of the quantity reproduced by the material measure in order to ensure the compatibility of the results of its measurements.

NOTE 5 When possible and convenient the uncertainty may be expressed in the relative form (see 3.3.3) or in the fiducial form (see 3.3.4). The *relative uncertainty* is the ratio U/V of the absolute uncertainty U to the measure value V, and the *fiducial uncertainty* the ratio U/V_f of the absolute uncertainty U to a conventionally chosen value V_f.

3.1.13
conventional value
measure-value of a standard used in a calibration operation and known with uncertainty negligible with respect to the uncertainty of the instrument to be calibrated

NOTE This definition is adapted to the object of this standard from the definition of "conventional true value (of a quantity)": value attributed to a particular quantity and accepted, sometimes by convention, as having an uncertainty appropriate for a given purpose [IEV 311-01-06, VIM 1.20]

3.1.14
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
[IEV 311-06-01]

NOTE 1 Influence quantities can originate from the measured system, the measuring equipment or the environment [IEV].

NOTE 2 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 [IEV].

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

3.1.15
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

3.1.16
traceability
property of the result of a measurement or of the value of a standard such that it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties
[IEV 311-01-15, VIM 6.10]

NOTE 1 The concept is often expressed by the adjective traceable [IEV, VIM].

NOTE 2 The unbroken chain of comparisons is called a traceability chain [IEV, VIM].

NOTE 3 The traceability implies that a metrological organization be established with a hierarchy of standards (instruments and material measures) of increasing intrinsic uncertainty. The chain of comparisons from the primary standard to the calibrated device adds indeed new uncertainty at each step.

NOTE 4 Traceability is ensured only within a given uncertainty, that should be specified.

3.2 Definitions of devices and operations

3.2.1
(measuring) instrument
device intended to be used to make measurements, alone or in conjunction with supplementary devices
[IEV 311-03-01, VIM 4.1]

NOTE The term "(measuring) instruments" includes both the indicating instruments and the material measures.