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Method for

Expression of the properties of sampling oscilloscopes

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- British Industrial Measuring and Control Apparatus Manufacturers' Association
- Department of Industry (British Calibration Service)
- Department of Industry (National Physical Laboratory)
- Technical Expert

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National foreword

This British Standard, published under the direction of the Electronic Equipment Standards Committee, is identical with IEC Publication 548 “*Expression of the properties of sampling oscilloscopes*” published in 1976 by the International Electrotechnical Commission (IEC).

Terminology and conventions. The text of the International Standard has been approved as suitable for publication, without deviation, as a British Standard. Some terminology and certain conventions are not identical with those used in British Standards; attention is especially drawn to the following.

In some places unit symbols and numerical values are printed in italic type instead of roman (upright) type as required by convention.

Scope. The scope (clause 1) and object (clause 2) of the International Standard are not presented in the way which is customary for the scope of a British Standard. Clauses 1 and 2 should be read as the following, which makes no change in the technical meaning and is essentially a re-arrangement of the existing text.

This standard specifies the standardization of methods of expression of the properties of sampling oscilloscopes and defines special terminology and catalogue data related to such apparatus. The conditions and methods for testing sampling oscilloscopes are specified so that compliance with properties claimed or specified by the manufacturer of the apparatus may be verified.

Safety requirements are specified in IEC Publication 348 “*Safety requirements for electronic measuring apparatus*”.

This standard is applicable to the following devices.

- a) Equivalent-time sampling oscilloscopes for measuring electrical qualities.
NOTE At lower sweep rates some equivalent-time sampling oscilloscopes may operate in a real-time sampling mode.
- b) Multi-trace sampling oscilloscopes complying with a).
- c) Complete assemblies comprising sampling oscilloscopes with detachable or incorporated parts, e.g. probes or interchangeable plug-in units.
- d) Oscilloscopes for measuring non-electrical quantities when it is possible to express their performance in terms of an electrical quantity which represents the non-electrical quantity.

This standard is concerned with the qualities of cathode-ray tubes only when these are necessary for the evaluation of oscilloscopes. The intrinsic qualities of cathode-ray tubes are not the subject of this standard.

By special agreement between the manufacturer and the user some portions of this standard may be regarded as applicable to the other types of sampling oscilloscopes, for instance, real-time sampling oscilloscopes or oscilloscopes with digital displays or programmable units; this standard is not directly applicable to such units.

Cross-references

International Standard ^a	Corresponding British Standard
IEC 348:1978	BS 4743:1979 <i>Safety requirements for electronic measuring apparatus</i> (Identical)
IEC 351-1:1976	BS 4739 <i>Method for expression of the properties of cathode-ray oscilloscopes</i> Part 1:1979 <i>General</i> (Identical)

^a Undated in the text

International Standard	Corresponding British Standard
IEC 359:1971	BS 4889:1973 <i>Method for specifying the performance of electronic measuring equipment</i> (Technically equivalent)

At present there is no corresponding British Standard for IEC 106:1974. The technical committee has reviewed the provisions of IEC 106:1974 and has decided that they are acceptable for use in conjunction with this standard.

NOTE *Textual error.* In 51.4, section 8, “kPA” should be read as “kPa”.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 42, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

1.1 This standard applies to equivalent-time sampling oscilloscopes for measuring electrical quantities.

NOTE At lower sweep rates some equivalent-time sampling oscilloscopes may operate in a real-time sampling mode.

1.2 This standard is also applicable to:

- multi-trace sampling oscilloscopes when they comply with Sub-clause 1.1;
- complete assemblies comprising sampling oscilloscopes with detachable or incorporated parts, e.g. probes or interchangeable plug-in units.

1.3 This standard applies also to oscilloscopes for measuring non-electrical quantities when it is possible to express their performance in terms of an electrical quantity which represents the non-electrical quantity.

1.4 This standard is concerned with the qualities of the cathode-ray tubes only when these are necessary for the evaluation of oscilloscopes. The intrinsic qualities of cathode-ray tubes will be dealt with in another standard.

1.5 Some portions of this standard may be applicable, by special agreement between manufacturer and user, to the other types of sampling oscilloscopes; for instance, real-time sampling oscilloscopes or those using digital displays or programmable units.

2 Object

The object of this standard is the standardization of methods of expression of the properties of sampling oscilloscopes and more particularly:

- the definition of special terminology and catalogue data related to these types of apparatus;
- the specification of conditions and methods for testing these types of apparatus in order to verify their compliance with properties claimed or specified by the manufacturer.

2.1 Safety requirements are not dealt with in this standard. Unless otherwise agreed upon, devices such as those in Clause 1 shall comply with IEC Publication 348, Safety Requirements for Electronic Measuring Apparatus.

Section 1. Definitions

For the purpose of this standard, it has been agreed that the special meanings contained in the following clauses shall apply. Definitions taken from the International Electrotechnical Vocabulary are shown by the reference I.E.V.

3 Types of oscilloscopes

3.1

cathode-ray oscilloscope

an apparatus for measurement or observation purposes which uses the deflection of one or more electron beams to produce a display which represents the instantaneous value of functions of varying quantities, one of them in general being time

3.2

sampling oscilloscope

an oscilloscope which employs signal sampling together with means for constructing a coherent display from the samples taken

NOTE Sampling oscilloscopes may use sequential sampling or random sampling (see Sub-clauses 4.2 and 4.3) and the display may be represented in equivalent time or in real time (see Sub-clauses 4.4 and 4.5).

3.3

X-Y sampling oscilloscope

a sampling oscilloscope in which two components of a phenomenon are sampled by two channels; the first determines the vertical deflection of the dots, the other the horizontal deflection

4 Terms fundamental to the sampling process

4.1 sampling

a process of sensing and storing one or more instantaneous values of a signal for further processing or display

4.2 sequential sampling

a sampling process in which samples are taken at successively later (or earlier, according to the process involved) times relative to the trigger recognition point (see Sub-clause 7.6)

4.3 random sampling

a sampling process allowing a significant time-interval uncertainty between the signal and sample-taking operation. Also the process of coherent display construction from such randomly taken samples

4.4 equivalent-time sampling

a sampling process in which no more than one sample is taken during one occurrence of that portion of the input signal which is to be displayed. The real duration of the sweep is equal to the time required for several repetitions of the input signal

4.5 equivalent-time sampling display

a display constructed by means of equivalent-time sampling

4.6 equivalent-time

the time scale associated with a display constructed by an equivalent-time sampling process

4.7 real-time sampling

a sampling process in which more than one sample is taken during each occurrence of that portion of the input signal which is to be displayed. The real duration of the sweep is equal to the real duration of that portion of the input signal

4.8 real time

the time scale associated with a display constructed by a real-time sampling process

4.9 sample

that part of the input signal which is taken during the operation of the sampling gate (see Sub-clause 6.3)

4.10 feed-through sampler

a signal-path configuration in which the input signal is conducted past the sampling gate to be made available for further use or external termination

4.11 sample distribution

in a random sampling oscilloscope, a mathematical function of equivalent time which describes how the density of randomly placed samples varies along the trace

4.12 probability distribution of samples

the average number of samples that fall left of a chosen point on the equivalent time axis, divided by the total average number of samples, both being averaged for the same length of real time

NOTE The probability distribution of samples is a function of the equivalent time; it starts from zero, ends at unity and has only positive or zero slopes.

4.13**probability density of samples**

the average number of samples falling within a relatively narrow (in comparison with the length of equivalent time for which it is averaged) equivalent-time interval, divided by the total average number of samples, both being averaged for the same length of real time

NOTE The probability density of samples generally depends on where the chosen narrow interval lies on the equivalent-time axis and is, therefore, a function of the equivalent time. Mathematically, it is the derivative of the probability distribution function, and the area under the curve is equal to unity.

4.14**dot transient response**

the ability of a sampling oscilloscope to display a change in two successively sampled values of the input signal

NOTE Dot transient response depends on smoothing (see Sub-clause 6.13).

5 Cathode-ray tube**5.1****cathode-ray tube**

an electron-beam tube in which the beam can be focused to a small cross-section on a surface and varied in position and intensity to produce a pattern either visible or otherwise detectable (I.E.V. 07-30-090)

5.2**cathode-ray tube size**

the overall dimension of the face of the cathode-ray tube (external diameter of tubes with a circular face, the height and width of tubes having a rectangular face)

5.3**screen**

the surface of the tube upon which the visible pattern is produced (I.E.V. 07-30-145)

5.4**spot**

the small area of the screen surface instantaneously affected by the impact of the electron beam (I.E.V. 07-30-160)

5.5**spot size and focus**

under consideration

5.6**measuring area**

that part of the screen within which measurements can be made with defined accuracy

NOTE This is not necessarily the whole screen area within which a display can be obtained.

6 Terms related to the sampling loop

a) *Terms related to sampling loop techniques*

6.1**feedback sampler**

a sampling system employing a feedback sampling loop

6.2**sampling loop**

the feedback system which is established to improve linearity and accuracy by operating the sampling gate as a null detector

NOTE The sampling loop, in general, will consist of those items defined in Sub-clauses 6.3, 6.4, 6.5, 6.6, 6.7 and 6.8.

6.3**sampling gate**

a switch, usually electronic, which operates briefly upon command for the purpose of sampling the input signal

6.4**balanced sampling gate**

a type of sampling gate arranged symmetrically so that the strobe signals are balanced

6.5**forward attenuator**

a circuit which determines forward gain and is normally ganged with the feedback attenuator

6.6**sample-and-hold gate**

a switch, usually electronic, between a sample-and-hold circuit and its driving amplifier

6.7**sample-and-hold circuit**

a circuit which stores the vertical (or horizontal) co-ordinate value of a sample

6.8**feedback attenuator**

a circuit which determines attenuation of the feedback signal in the sampling loop

b) *Terms relating to sampling loop performance*

6.9**loop gain**

the product of sampling gate efficiency, forward gain and feedback attenuation

6.10**forward gain**

the effective gain between the sampling gate output and the sample-and-hold output

6.11**feedback attenuation**

in a sampling loop, the effective attenuation in the signal path between sample-and-hold output and sampling gate

6.12**sampling gate efficiency**

the ratio of the gate output voltage change between the instant before sampling (t^-) and the instant after sampling (t^+) to the difference between the gate input voltage (E_i) and gate output voltage (E_o) at the instant before sampling (t^-) expressed as a percentage

$$\text{Sampling gate efficiency} = \frac{E_o(t^+) - E_o(t^-)}{E_i(t^-) - E_o(t^-)} \times 100\%$$

6.13**smoothing**

a process affecting dot transient response wherein sampling loop gain is purposely made to be less than unity in order to reduce the effects of random noise and horizontal jitter

7 Terms related to the slewing process (see Figure 1, page 37)**7.1****slewing**

the process of causing successive samples to be taken at different instants relative to the trigger recognition point. This term also applies to sequential sampling and to random sampling

7.2**scanning**

the process by which slewing is controlled

NOTE The function performed is the association of the time function of the input signal with the horizontal position function of the spot. In an equivalent-time sampling oscilloscope, it is governed by the scanning signal.

7.3**scanning signal (scanning ramp, slow ramp)**

a staircase, ramp or other changing voltage which governs the horizontal deflection of the spot and directly or proportionately interacts with the slewing ramp

7.4**slewing ramp (fast ramp)**

a linear ramp which interacts with the scanning signal to cause slewing

7.5**trigger recognition**

the process of responding to a suitable triggering signal (see Sub-clause 14.6 and Figure 1, page 37)

7.6**trigger recognition point**

the point in time at which trigger recognition occurs, also that point on a display waveform representing the instant of trigger recognition (see Sub-clause 14.6)

7.7**sampling command**

a general term relating to a trigger or other electrical signal intended to cause sampling

7.8**strobe**

a pulse of short duration which directly operates the sampling gate

7.9**slewing interval**

the particular equivalent-time interval over which the scanning signal allows sampling to occur

8 Terms related to the presentation of the display**8.1****dot**

a spot, the position of which indicates the horizontal and vertical co-ordinates of a particular sample

8.2**dot density**

the number of dots per centimetre without input signal

8.3**coherent display**

a display in which the time function of the input signal is preserved. A coherent display may be produced by either random or sequential sampling

8.4**false display**

a sampling display allowing faulty or ambiguous interpretation, usually caused by insufficient dot density, improper triggering, or improper setting of the controls

8.5**magnified display (expanded display)**

when associated with sweep timing or horizontal deflection, a display whose time per division has been decreased. Usually produced either by attenuation of the scanning signal or by amplification of the horizontal deflection signal

8.6**display window**

the equivalent-time interval represented within the limits of the rated horizontal deflection

8.7**time positioning**

the process of moving the display window by, for example, offsetting the d.c. level of the scanning signal or of the slewing ramp

8.8**time position range**

the equivalent-time interval over which the display window can be moved by time positioning

9 General terms concerning waveform**9.1****departures from a sinewave**

the distortion of a sinewave is defined by its crest factor and/or by limits β defined by the formula:

$$y = a(1 - \beta) \sin \omega t < y < a(1 + \beta) \sin \omega t$$

NOTE When the value assigned to the quantity β is especially significant, it is necessary, in addition, to establish a limit for the difference between the peak value and $\sqrt{2}$ times the r.m.s. value.

9.2**square wave**

a periodic wave that alternately assumes two fixed values for equal lengths of time, the time of transition being negligible in comparison with the half-length (I.E.V. 55-35-090)

9.3**rectangular pulse**

a waveform having a profile approximately rectangular, the rise and fall times being sufficiently short in comparison with the pulse duration (from I.E.V. 55-35-085)

10 Terms concerning preparation of tests**10.1****warm-up time**

the time interval after switching on the oscilloscope under reference conditions necessary for it to comply with all accuracy requirements

10.2**adjustment**

the operation by means of which certain adjusting parts are set according to the manufacturer's directions, so as to cause the oscilloscope to conform with the specified accuracy

NOTE This process is termed *preliminary adjustment* when it is carried out before tests, and *readjustment* during tests. With oscilloscopes having built-in calibrating devices, calibration may form a part of preliminary adjustments.

10.3**centring**

the process by which the spot (or the base line drawn by the spot) is adjusted to a definite place on the screen

11 Terms related to accuracy

a) *Quantities related to the function of the oscilloscope and terms related to conditions of operation, transport and storage*

11.1

performance characteristic

one of the quantities assigned to an oscilloscope in order to define by values, tolerances, ranges, etc., the performance of the oscilloscope

NOTE The term “performance characteristic” does not include influence quantities (see Note to Sub-clause 11.2).

11.2

influence quantity

any quantity, generally external to an oscilloscope, which may affect the performance of the oscilloscope

NOTE Where a change in a performance characteristic affects another performance characteristic, it is referred to as an *influencing characteristic* (see Sub-clause 11.23).

11.3

reference value

a single value of an influence quantity at which the oscilloscope (or accessory) complies with the requirements concerning intrinsic errors

11.4

reference range

a range of values of an influence quantity within which the oscilloscope (or accessory) complies with the requirements concerning intrinsic errors

11.5

reference conditions

a set of values with tolerances (reference values), or of restricted ranges (reference ranges) of influence quantities and, if necessary, of influencing characteristics, specified for making comparison and calibration tests

11.6

rated range of use

the range of values for an influence quantity within which the requirements concerning operating error are satisfied

11.7

rated operating conditions

the whole of the effective ranges for performance characteristics and rated ranges of use for influence quantities within which the performance of the apparatus is specified

11.8

limit conditions of operation

the whole of the ranges of values for influence quantities and performance characteristics (beyond the rated ranges of use and effective ranges respectively) within which an apparatus can function without resulting damage or degradation of performance when it is afterwards operated under rated operating conditions

NOTE These limit conditions will, in general, include overload.

11.9

conditions of storage and transport

the whole of the conditions of temperature, humidity, air pressure, vibration, shock, etc., within which the apparatus may be stored or transported in an inoperative condition, without resulting damage or degradation of performance when it is afterwards operated under rated operating conditions

b) *Values related to quantities*

11.10

rated value

the value (or one of the values) of a quantity to be measured, observed, supplied or set, which the manufacturer has assigned to the oscilloscope

11.11

rated vertical (horizontal) deflection

distance measured in the vertical (horizontal) direction between the limits of the measuring area

11.12

rated range

the range of a quantity to be measured, observed, supplied or set, which the manufacturer has assigned to the oscilloscope

11.13

effective range

that part of the rated range where measurements can be made or quantities be supplied within the stated limits of error (I.E.V. 20-40-035, modified)

c) Terms related to the specification of performance

11.14

performance

the degree to which the intended functions of an oscilloscope are accomplished

Errors

11.15

absolute error

the error expressed algebraically, in the unit of the measured quantity

- a) For a measuring apparatus, the error is the indicated value of the measured quantity minus its true value.
- b) For a supply apparatus, the error is the true value of the quantity supplied minus its rated, indicated or preset value.

NOTE 1 The *true value* of a quantity is the ideal value that would be measured by a measuring process having no error.

In practice, since this true value cannot be determined by measurement, a *conventionally true* value, approaching the true value as closely as necessary (having regard to the error to be determined), is used in place of the true value. This value may be traced to standards agreed upon by the manufacturer and the user, or to national standards. In both cases, the uncertainty of the conventionally true value shall be stated.

NOTE 2 The above definitions do not apply to deflection coefficients or time coefficients of an oscilloscope as these coefficients are neither measured nor supplied quantities.

11.16

relative error

the ratio of the absolute error to a stated value

11.17

absolute error of a deflection (time) coefficient

the difference between the measured value and the rated value of a deflection (time) coefficient

NOTE The measured value of a coefficient is the value that is calculated from the deflection measured on the screen when a known signal is applied to input terminals.

11.18

relative error of a deflection (time) coefficient

the ratio of the absolute error of a deflection (time) coefficient to the rated value

11.19

percentage error

the relative error expressed as a percentage

11.20**relative linearity error of a coefficient**

relative linearity error of a coefficient is given by whichever of the following two expressions has the greater value without regard to sign:

$$\frac{K_a - K_b}{K_a} \quad \text{or} \quad \frac{K_a - K_c}{K_a}$$

where:

K_a = average deflection coefficient measured over the central 80 % region of the rated deflection

K_b and K_c = average deflection coefficient for each of the two extreme 10 % regions of the rated deflection

NOTE This definition of linearity is intended solely for oscilloscopes and takes account of the fact that departures from linearity are generally negligible in the central 80 % of the rated deflection but become significant in the extreme 10 % regions.

11.21**intrinsic error**

the error determined under reference conditions

11.22**operating error**

the error determined under rated operating conditions (see Sub-clause 11.7)

11.23**influence error**

the error determined when one influence quantity assumes any value within its rated range of use (or an influencing performance characteristic assumes any value within its effective range), all others being at reference conditions

NOTE When over the whole rated range of use a substantially linear relationship exists between the influence error and the effect causing it, the relationship may be conveniently expressed in coefficient form.

11.24**limits of error**

the maximum values of error assigned by the manufacturer to a measured quantity of an oscilloscope operating under specified conditions

11.25**limits of error of a deflection (time) coefficient**

the maximum values of error assigned by the manufacturer to a deflection (time) coefficient of an oscilloscope operating under specified conditions

d) *Variation*

11.26**variation**

the difference between the values of a measured or supplied quantity when one influence quantity assumes successively two specified values within its rated range of use, the others being at reference conditions

NOTE A variation may be considered as absolute or relative in the same way as an error.

12 Terms related to vertical (horizontal) deflection

a) General

12.1**vertical (horizontal) deflection**

the deflection of the spot when a signal is applied to the vertical (horizontal) input, the horizontal (vertical) system being non-operative

12.2**vertical (horizontal) deflection coefficient**

the ratio between the voltage (current) and the length of vertical (horizontal) deflection produced by this voltage (current) (from I.E.V. 531-14-16)