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Expression of the properties of cathode-ray oscilloscopes

Part 1: General

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

EXPRESSION OF THE PROPERTIES OF CATHODE-RAY OSCILLOSCOPES

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FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This publication has been prepared by Sub-Committee 66B, Oscilloscopes, of IEC Technical Committee No. 66, Electronic Measuring Equipment.

It forms Part 1 of IEC Publication 351 and replaces Publication 351 (1971).

A first draft was discussed at the meeting held in Baden-Baden in 1972. As a result of this meeting, a draft, Document 66B(Central Office)6, was submitted to the National Committees for approval under the Six Months' Rule in August 1973.

The following countries voted explicitly in favour of publication:

Australia	Japan
Belgium	Netherlands
Egypt	Sweden
France	Turkey
Hungary	Union of Soviet Socialist Republics
Israel	United Kingdom
Italy	United States of America

Other IEC publications quoted in this publication:

Publications Nos. 106: Recommended Methods of Measurement of Radiated and Conducted Interference from Receivers for Amplitude-modulation, Frequency-modulation and Television Broadcast Transmissions.

348: Safety Requirements for Electronic Measuring Apparatus.

359: Expression of the Functional Performance of Electronic Measuring Equipment.

EXPRESSION OF THE PROPERTIES OF CATHODE-RAY OSCILLOSCOPES

Part 1: General

1. General

1.1 *Scope*

1.1.1 This standard applies to general-purpose cathode-ray oscilloscopes (hereinafter called "oscilloscopes") for measuring electrical quantities, containing at least:

— a cathode-ray tube,
— a vertical deflection device,
— a time base and/or a horizontal deflection device.

1.1.2 This standard is also applicable to:

— multitrace oscilloscopes (Sub-clause 2.1.4) when they comply with Sub-clause 1.1.1,

— complete assemblies of oscilloscopes with detachable or incorporated parts, e.g. probes or interchangeable plug-in units.

1.1.3 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.

1.1.4 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.

1.1.5 Some portions of this standard may be applicable, by special agreement between manufacturer and user, to observation or special-purpose oscilloscopes, e.g.:

— sampling oscilloscopes,
— characteristic curve tracers,
— vectorscopes;
— radial deflection oscilloscopes,
— storage oscilloscopes.

1.1.6 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.

1.2 *Object*

The object of this standard is the standardization of methods of expression of the properties of cathode-ray 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 compliance with properties claimed or specified by the manufacturer.

2. Terminology

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 to I.E.V. Group 07 or 20.

2.1 *Types of oscilloscopes*

2.1.1 *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.

2.1.2 *Measuring oscilloscope*

An oscilloscope which, by means of scales or calibrated switch positions associated with the controls of deflection and time coefficients, is suitable for measuring with defined accuracy.

Note. — A measuring oscilloscope may, or may not, have built-in calibrating devices. It is further necessary to distinguish between oscilloscopes in which measurement is made by a calibrated graticule and oscilloscopes in which the graticule is not used directly, except as a means of referring to another calibrated control.

2.1.3 *Observation oscilloscope*

An oscilloscope which is suitable only for the qualitative observations of varying quantities, being without defined accuracy.

Note. — Some observation oscilloscopes have sufficient linearity and stability of performance to permit their use for measuring purposes after calibration by external means.

2.1.4 *Multitrace oscilloscope*

An oscilloscope with which it is possible to measure or observe simultaneously several electrical phenomena, each phenomenon being displayed on a separate trace.

Note — This result may be obtained by:

- a tube with several guns (multi-beam),
- a tube with one divided beam (split-beam),
- one beam and electronic switching (displayed alternately or chopped),
- an oscilloscope with several tubes (multi-tube).

2.2 *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).

2.2.1 *Cathode-ray tube size*

The overall dimensions 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).

2.2.2 *Screen*

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

2.2.3 *Spot*

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

2.2.3.1 *Spot size and focus*

Under consideration.

2.2.4 *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.

2.3 *General terms*

2.3.1 *Amplifiers and attenuators*

2.3.1.1 *Amplifier*

The circuitry which provides amplification of the voltage applied to the input terminals to obtain a deflection or other function.

2.3.1.2 *Attenuator*

A device which provides the attenuation of a voltage according to defined ratios.

2.3.2 *Accessory parts*

2.3.2.1 *Plug-in unit*

A removable part of an oscilloscope, adapted by plug and socket connection to compose a set intended to perform a particular function.

Examples of plug-in units:

— high sensitivity amplifier,
— wide-band amplifier,
— difference amplifier,
— electronic beam switching.

2.3.2.2 *Probe*

An input device of an oscilloscope made as a separate unit and connected by a flexible cable which transmits, in a suitable manner, the measuring quantity to the oscilloscope.

2.3.3 *Terms concerning waveform*

2.3.3.1 *Departures from a sine-wave*

The distortion of a sine-wave is defined by the difference between the peak value and $\sqrt{2}$ times the r.m.s. value and/or by limits as specified by value β of the formula:

$$y = a\,(1 \pm \beta)\sin \omega t$$

2.3.3.2 *Square wave*

A periodic wave that alternately for equal lengths of time assumes two fixed values, the time of transition being negligible in comparison with that length.

2.3.3.3 *Rectangular pulse*

A waveform having a profile approximately rectangular, the rise and fall times being sufficiently short in comparison with the pulse duration.

2.4 *Terms concerning preparation of tests*

2.4.1 *Warm-up time*

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

2.4.2 *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.

2.4.3 *Centring*

The process by which the spot (or the base line drawn by the spot) is positioned to the centre of the screen.

2.5 *Terms related to accuracy*

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

2.5.1.1 *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 2.5.1.2).

2.5.1.2 *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 2.5.3.5).

2.5.1.3 *Reference value*

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

2.5.1.4 *Reference range*

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

2.5.1.5 *Reference conditions*

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

2.5.1.6 *Rated range of use*

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

2.5.1.7 *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.

2.5.1.8 *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. — The limit conditions will, in general, include overload.

2.5.1.9 *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.

2.5.2 *Values related to quantities*

2.5.2.1 *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.

2.5.2.1.1 *Rated vertical (horizontal) deflection*

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

2.5.2.2 *Rated range*

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

2.5.2.3 *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).

2.5.3 *Terms related to the specification of performance*

2.5.3.1 *Performance*

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

2.5.3.2 *Error*

2.5.3.2.1 *Absolute error*

The error expressed algebraically, in the unit of the measured or supplied 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.

Notes 1. — The true value of a quantity is the 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.

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.

2.5.3.2.2 *Relative error*

The ratio of the absolute error to a stated value.

2.5.3.2.3 *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.

2.5.3.2.4 *Relative error of a deflection (time) coefficient*

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

2.5.3.2.5 *Percentage error*

The relative error expressed as a percentage.

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

K_b and K_c = the 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.

2.5.3.3 *Intrinsic error*

The error determined under reference conditions.

2.5.3.4 *Operating error*

The error determined under rated operating conditions (Sub-clause 2.5.1.7).

2.5.3.5 *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 condition.

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.

2.5.3.6 *Limits of error*

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

2.5.3.7 *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.

2.5.4 *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.

2.6 *Terms related to vertical (horizontal) deflection*

2.6.1 *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.

2.6.1.1 *Vertical (horizontal) deflection coefficient*

The ratio between the voltage and the length of vertical (horizontal) deflection produced by this voltage.

Note. — Deflection coefficients are expressed in the dimension voltage (or current) per unit length, and a coefficient of 5 V/cm is larger than 5 mV/cm. This means, accordingly, that the sensitivity with a coefficient of 5 V/cm is smaller than with a coefficient of 5 mV/cm.

2.6.2 *Instability of the spot position*

This term comprises the following three phenomena which occur whether a signal is present or not.

2.6.2.1 *Drift*

The (unwanted) generally slow and continuous deviation of the spot as a function of time.

a) Long-term drift

Maximum deviation of the spot recorded during 1 h.

b) Short-term drift

Maximum deviation of the spot recorded during the most unfavourable minute within 1 h total recording.

Note. — Drift has, in general, vertical and horizontal components which can be measured separately, the values of the influence quantities being held constant in every case.

2.6.2.2 *Periodic and/or random deviations (PARD)*

Unwanted deflections of a periodic (hum, ripple, etc.) and/or random (noise, fluctuation, etc.) nature due to various causes and appearing on the screen in the absence of a signal or added to the display of an input signal.

2.6.2.3 *Zero shift*

The movement of the spot or of the trace without any signal due to the effect of a prescribed change in a specified influence quantity.

Note. — The zero shift is generally not instantaneous. The maximum value of this shift shall be determined during a specified time interval.

2.6.3 *Pulse and frequency responses*

2.6.3.1 *Frequency response: —3 dB bandwidth*

Band of frequencies within which the value of the reciprocal of the deflection coefficient does not differ by more than —3 dB from its value at reference frequency.

Note. — This definition does not take into account any rise or other irregularity in the frequency response between reference frequency and the —3 dB points, as this would cause irregularities concerning pulse response defined in Sub-clauses 2.6.3.2, 2.6.3.3 and 2.6.3.4.

2.6.3.2 *Rise (fall) time*

Time interval within which the current or voltage of the edge of a rectangular pulse passes from 10% to 90% (from 90% to 10%) of its steady-state amplitude (Figure 1, page 74).

Note. — In the case of amplifiers having a proper pulse response, the following relationship between rise time (t_r), expressed in nanoseconds, and the upper limit of the —3 dB bandwidth (B), expressed in megahertz, is approximately true:

$$t_r = \frac{350}{B}$$

2.6.3.3 *Overshoot*

That part of the initial response which exceeds the steady-state value of the response to a rectangular (square) pulse (Figure 1). It is expressed as a percentage of the steady-state value.

2.6.3.4 *Pulse tilt*

The relative difference between the initial and final amplitude of the representation of a rectangular pulse (Figure 2a, page 75) or of a square wave (Figure 2b, page 75) ignoring overshoot and other distortions (see Sub-clause 2.6.3.2). It is expressed as a percentage of the initial amplitude and for a specified time period:

$$\text{pulse tilt} = \frac{\Delta A}{A} 100 \quad \text{(Figure 2a).}$$

Note. — When tests for pulse tilt are performed with a symmetrical square wave, the formula:

$$\text{pulse tilt} = \frac{2\,\Delta A}{A_2} 100 \quad \text{(Figure 2b)}$$

may be used for convenience.

2.6.3.5 *Other pulse distortions*

Distortions other than those defined in Sub-clauses 2.6.3.2, 2.6.3.3 and 2.6.3.4 are identified by the titles to Figures 3a to 3g, pages 76 and 77; verbal descriptions are not given, as the diagrams are sufficient in themselves for the effects to be identified. These distortions may appear on the display either singly, in groups or combined, depending on the selected time coefficient.

When these distortions have durations comparable to the rise time t_r, the diagrams show the rise time as having finite magnitude. Conversely, when the distortions can occupy time durations up to several orders of magnitude greater than the rise time, the diagrams show the rise time as zero. This is particularly so in the case of Figure 3g, Defect of sustained step response, when the effects are thermal in origin.

2.6.4 *Positioning*

The vertical or horizontal movement of the trace obtained by actuating the appropriate control.

2.6.5 *Input impedance*

The impedance measured between the input terminals of the oscilloscope.

Note. — It is represented by the values of a resistor and a capacitor, connected in parallel, which produce an equivalent impedance.

2.6.6 *Interaction between circuits of an oscilloscope*

2.6.6.1 *Interaction between the circuits of a multitrace oscilloscope*

The influence of the voltage at one input on the deflection of a beam which is normally intended to display the voltage of another input.

2.6.6.2 *Interaction between x and y signals*

Under consideration.

2.6.6.3 *Decoupling factor*

Quantity defining the suppression of interaction between any two channels of an oscilloscope. It is the ratio between the unwanted deflection coefficient (i.e. the ratio between the amplitude of the signal of the disturbing channel to the unwanted deflection at the other channel) and the deflection coefficient of the disturbed channel.

Note. — The size of the decoupling factor is, therefore, in inverse ratio to the size of the disturbance. Decoupling factor is a number larger than 1. This means, accordingly, that the interaction corresponding to a factor of 10000 is smaller than that corresponding to a factor of 1000.
To simplify the interpretation of this definition, the following example is given: if the two channels are numbered 1 and 2, and have individual deflection coefficients of x V/cm and y V/cm respectively, then if channel No. 1 is considered as being the disturbing one and the magnitude of the display on trace No. 1 is A cm and if the magnitude of the display on trace No. 2 is B cm, the decoupling factor is given by the expression:

$$\frac{Ax}{By}$$

where normally $x > y$ and $A > B$.

2.6.6.4 *Phase difference between displays of a multitrace oscilloscope*

Phase difference (unwanted) observed between any two displays of a multitrace oscilloscope when the same signal is applied to both inputs.

Notes 1. — This difference may result from:
— different phase angle of the amplifiers,
— different linearity errors of the separate time bases,
— different geometrical structures of deflection plates.

2. — For test purposes, it is convenient to measure the phase difference in terms of time by applying the same pulse signal to both inputs.

2.6.6.5 *Common-mode rejection factor for difference amplifiers*

Relation between the deflection coefficient determined when a voltage is applied between the input terminals of the deflection circuit and the deflection coefficient determined when a voltage is applied between the input terminals, joined together, and the earth terminal of the oscilloscope.

Note. — The common-mode rejection factor is a measure of the ability of a circuit to reject interference and its size is, therefore, in inverse ratio to the size of the disturbance. Common-mode rejection factor is a number larger than 1, and a common-mode rejection factor of 10000 is larger than 1000. This means, accordingly, that the interaction with a common-mode rejection factor of 10000 is smaller than with a common-mode rejection factor of 1000.

2.6.7 *Delay line*

A transmission line having distributed or lumped constants intended to delay the signal.

Note. — The value of the delay is such that its duration is sufficient to allow the sweep to start and the spot to be unblanked before the signal is displayed.

2.6.7.1 *Apparent signal delay*

The time which elapses between the moment of the appearance of the sweep and the moment when the signal trace reaches 10% of the final amplitude.

Note. — The apparent signal delay is not to be mistaken for the actual signal delay which is the time elapsing between the application of a signal voltage at the input of the oscilloscope and the time of the appearance of the signal display on the screen.

2.6.8 *Switching rate (of multitrace oscilloscopes or associated plug-in units)*

The repetition frequency of the switching processes in oscilloscopes or associated plug-in units which employ electronic beam switching to produce multitrace displays. This frequency may have a fixed or adjustable value (chopped display) or may be controlled by the repetition rate of the time base and triggering (alternate display).

2.7 *Terms related to the time base*

2.7.1 *Time base*

The circuitry by which a spot displacement depending upon time is obtained.

Note. — The term "sweep" is reserved for the spot displacement produced by the time base.

2.7.1.1 *Free running time base*

A time base running periodically, even in the absence of a signal.

Note. — A free running time base may be synchronized either externally or internally.

2.7.1.2 *Triggered time base*

A time base which, for each single sweep, is initiated by a trigger pulse. The repetition rate is not necessarily periodic.

Note. — In this mode, any value of time coefficient can be chosen independently of the period of the observed quantity, and without affecting the stability of the display.