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Pulse techniques and apparatus

Part 1:
Pulse terms and definitions

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PULSE TECHNIQUES AND APPARATUS

Part 1: Pulse terms and definitions

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 recommendations and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This standard has been prepared by Sub-Committee 66A: Generators, of IEC Technical Committee No. 66: Measuring Equipment for Electronic Techniques.

The text of this standard which replaces the first edition is based upon the following documents:

Six Months' Rule	Report on Voting
66A(CO)36	66A(CO)38

Full information on the voting for the approval of this standard can be found in the Voting Report indicated in the above table.

The following IEC publications are quoted in this standard:

Publications Nos. 351 (1976): Expression of the Properties of Cathode-ray Oscilloscopes.
469-2 (1987): Pulse Techniques and Apparatus,
Part 2: Pulse Measurement and Analysis, General Considerations.

PULSE TECHNIQUES AND APPARATUS

Part 1: Pulse terms and definitions

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1. General

1.1 *Scope*

This standard provides fundamental definitions for general use in time domain pulse technology. It defines terms for pulse phenomena and pulse characteristics which are prerequisite to:

- efficient communication of technical information;
- standards for methods of pulse characteristic measurement;
- standards for pulse apparatus;
- standards for apparatus which employ pulse techniques.

1.2 *Object*

Within its scope, the object of this standard is the definition of an internally consistent, mathematically rigorous and general set of pulse terms which are applicable:

- to hypothetical and practical pulses;
- regardless of the applicable limits of error;
- to a wide range of technologies and disciplines;
- in a measurement situation, regardless of the means of measurement or the means for waveform evaluation employed.

2. General terms

2.1 *Co-ordinate system*

Throughout the following, a rectangular Cartesian co-ordinate system is assumed in which, unless otherwise specified:

- time (t) is the independent variable taken along the horizontal axis, increasing in the positive sense from left to right;
- magnitude (m) is the dependent variable taken along the vertical axis, increasing in the positive sense or polarity from bottom to top;
- the following additional symbols are used:

e	=	base of natural logarithms;
a, b, c, etc.	=	real parameters which, unless otherwise specified, may have any value and either sign;
n	=	a positive integer.

2.2 *Wave, pulse and transition*

2.2.1 *Wave*

A modification of the physical state of a medium which propagates in that medium as a function of *time** as a result of one or more disturbances.

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* Terms in italic type are defined in this standard.

2.2.2 *Pulse*

A *wave* which departs from a first nominal state, attains a second nominal state and ultimately returns to the first nominal state.

Throughout the remainder of this standard, "pulse" is included in "wave".

2.2.3 *Transition*

A portion of a *wave* or *pulse* between a first nominal state and a second nominal state. Throughout the remainder of this standard, "transition" is included in *"pulse"* and *"wave"*.

2.3 *Waveform, epoch and feature*

2.3.1 *Waveform, pulse waveform, transition waveform*

A manifestation or representation (e.g. graph, plot, oscilloscope presentation, equation(s), table of co-ordinates or statistical data) or a visualization of a *wave*, *pulse* or *transition*. Throughout the remainder of this standard:

— "pulse waveform" is included in "waveform;"

— "transition waveform" is included in "pulse waveform" and "waveform."

2.3.2 *Waveform epoch*

The span of *time* for which *waveform* data are known or knowable. A waveform epoch manifested by equations may extend in *time* from $-\infty$ to $+\infty$ or, like all *waveform* data, may extend from a first datum *time* t_0, to a second datum *time* t_1 (see Figure 1, page 40).

2.3.3 *Waveform feature*

A specified portion or segment of, or a specified event in, a *waveform*.

2.4 *Qualitative adjectives*

The adjectives in this sub-clause may be used individually or in combination, or in combination with adjectives in Sub-clause 2.5, to modify any substantive term in this standard.

2.4.1 *Descriptive adjectives*

2.4.1.1 *Major (minor)*

Having or pertaining to greater (lesser) importance, *magnitude*, *time*, extent, or the like, than another similar *feature(s)*.

2.4.1.2 *Ideal*

Of or pertaining to perfection in, or existing as a perfect exemplar of, a *waveform* or a *feature*.

2.4.1.3 *Reference*

Of or pertaining to a *time*, *magnitude*, *waveform*, *feature* or the like, which is used for comparison with, or evaluation of, other *times*, *magnitudes*, *waveforms*, *features* or the like. A reference entity may, or may not, be an *ideal* entity.

2.4.2 *Time-related adjectives*

2.4.2.1 *Periodic (aperiodic)*

Of or pertaining to a series of specified *waveforms* or *features* which repeat or recur regularly (irregularly) in *time*.

2.4.2.2 *Coherent (incoherent)*

Of or pertaining to two or more repetitive *waveforms* whose constituent *features* have (lack) *time* correlation.

2.4.2.3 *Synchronous (asynchronous)*

Of or pertaining to two or more repetitive *waveforms* whose sequential constituent *features* have (lack) *time* correlation.

2.4.3 *Magnitude-related adjectives*

2.4.3.1 *Proximal (distal)*

Of or pertaining to a region near to (remote from) a first state or region of origin.

2.4.3.2 *Mesial*

Of or pertaining to the region between the *proximal* and *distal* regions.

2.4.4 *Polarity-related adjectives*

2.4.4.1 *Unipolar*

Of, having or pertaining to a single *polarity*.

2.4.4.2 *Bipolar*

Of, having or pertaining to both *polarities*.

2.4.5 *Geometrical adjectives*

2.4.5.1 *Trapezoidal*

Having or approaching the shape of a trapezoid.

2.4.5.2 *Rectangular*

Having or approaching the shape of a rectangle.

2.4.5.3 *Triangular*

Having or approaching the shape of a triangle.

2.4.5.4 *Sawtooth*

Having or approaching the shape of a right-angled triangle (see Figure 2, page 41, waveform D).

2.4.5.5 *Rounded*

Having a curved shape characterized by a relatively gradual change in slope.

2.5 *Quantitative adjectives*

The adjectives in this sub-clause may be used individually or in combination, or in combination with adjectives in Sub-clause 2.4, to modify any substantive term in this standard.

2.5.1 *Integer adjectives*

The ordinal integers (i.e. first, second, ..., *n*th, last) or the cardinal integers (i.e. 1, 2, ..., *n*) may be used as adjectives to identify or distinguish between similar or identical *features*. The assignment of integer modifiers should be sequential as a function of time within a *waveform epoch* and/or within *features* thereof.

2.5.2 *Mathematical adjectives*

All definitions in this sub-clause are stated in terms of *time* (the independent variable) and *magnitude* (the dependent variable). Unless otherwise specified, the following terms apply only to *waveform* data within a *waveform epoch*. These adjectives may also be used to describe the relation(s) between other specified variable pairs (e.g. *time* and power, *time* and voltage).

2.5.2.1 *Instantaneous*

Pertaining to the *magnitude* at a specified *time*.

2.5.2.2 *Positive (negative) peak*

Pertaining to the maximum (minimum) *magnitude*.

2.5.2.3 *Peak-to-peak*

Pertaining to the absolute value of the algebraic difference between the *positive peak magnitude* and the *negative peak magnitude*.

2.5.2.4 *Root-mean-square (r.m.s.)*

Pertaining to the square root of the average of the squares of the values of the *magnitude*. If the *magnitude* takes on n discrete values, m_j, its root-mean-square value is:

$$m_{rms} = \left[\left(\frac{1}{n} \right) \sum_{j=1}^{n} m_j^2 \right]^{\frac{1}{2}}$$

wherein the time intervals between adjacent values of m_j are equal.

If the *magnitude* is a continuous function of *time*, $m(t)$, its r.m.s. value is:

$$m_{rms} = \left[\left(\frac{1}{t_2 - t_1} \right) \int_{t_1}^{t_2} m^2(t)\, dt \right]^{\frac{1}{2}}$$

The summation or the integral extends over the interval of *time* for which the r.m.s. *magnitude* is desired or, if the function is *periodic*, over any integral number of *periodic* repetitions of the function.

2.5.2.5 *Average*

Pertaining to the mean of the values of the *magnitude*. If the *magnitude* takes on n discrete values, m_j, its average value is:

$$\overline{m} = \left(\frac{1}{n} \right) \sum_{j=1}^{n} m_j$$

wherein the time intervals between adjacent values of m_j are equal.

If the *magnitude* is a continuous function of *time*, $m(t)$, its average value is:

$$\overline{m} = \left(\frac{1}{t_2 - t_1} \right) \int_{t_1}^{t_2} m\,(t)\, dt$$

The summation or the integral extends over the interval of *time* for which the average *magnitude* is desired or, if the function is *periodic*, over any integral number of *periodic* repetitions of the function.

2.5.2.6 *Average absolute*

Pertaining to the mean of the absolute values of the *magnitude*. If the *magnitude* takes on n discrete values, m_j, its average absolute value is:

$$|\overline{m}| = \left(\frac{1}{n}\right) \sum_{j=1}^{n} |m_j|$$

wherein the time intervals between adjacent values of m_j are equal.

If the *magnitude* is a continuous function of *time*, $m(t)$, its average absolute value is:

$$|\overline{m}| = \left(\frac{1}{t_2 - t_1}\right) \int_{t_1}^{t_2} |m\ (t)| \mathrm{d}t$$

The summation or the integral extends over the interval of *time* for which the average absolute *magnitude* is desired or, if the function is *periodic*, over any integral number of *periodic* repetitions of the function.

2.5.2.7 *Root sum of squares (r.s.s.)*

Pertaining to the square root of the arithmetic sum of the squares of the values of the *magnitude*. If the *magnitude* takes on n discrete values, m_j, its root sum of squares value is:

$$m_{rss} = \left[\sum_{j=1}^{n} m_j^2\right]^{\frac{1}{2}}$$

wherein the time intervals between adjacent values of m_j are equal.

If the *magnitude* is a continuous function of *time*, $m(t)$, its root sum of squares value is:

$$m_{rss} = \left[\int_{t_1}^{t_2} m^2\ (t)\ \mathrm{d}t\right]^{\frac{1}{2}}$$

The summation or the integral extends over the interval of *time* for which the root sum of squares *magnitude* is desired or, if the function is *periodic*, over any integral number of *periodic* repetitions of the function.

2.5.3 *Functional adjectives*

2.5.3.1 *Linear*

Pertaining to a *feature* whose *magnitude* varies as a function of *time* in accordance with the following relation or its equivalent:

$$m = a + bt$$

2.5.3.2 *Exponential*

Pertaining to a *feature* whose *magnitude* varies as a function of *time* in accordance with either of the following relations or their equivalents:

$$m = a\mathrm{e}^{-bt}$$
$$m = a(1 - \mathrm{e}^{-bt})$$

2.5.3.3 *Gaussian*

Pertaining to a *waveform* or *feature* whose *magnitude* varies as a function of *time* in accordance with the following relation or its equivalent:

$$m = ae^{-b(t-c)^2} \text{ where } b > 0$$

2.5.3.4 *Trigonometric*

Pertaining to a *waveform* or *feature* whose *magnitude* varies as a function of *time* in accordance with a specified trigonometric function or by a specified relationship based on trigonometric functions (e.g. cosine squared).

2.6 *Time-related definitions*

2.6.1 *Instant*

Unless otherwise stated, a *time* specified with respect to the first datum *time*, t_0, of a *waveform epoch*.

2.6.2 *Interval*

The algebraic *time* difference calculated by subtracting the *time* of a first specified *instant* from the *time* of a second specified *instant*.

2.6.3 *Duration*

The absolute value of the *interval* during which a specified *waveform* or *feature* exists or continues.

2.6.4 *Period*

The absolute value of the minimum *interval* after which the same characteristics of a *periodic waveform* or a *periodic feature* recur.

2.6.5 *Frequency*

The reciprocal of *period*.

2.6.6 *Cycle*

The complete range of states or *magnitudes* through which a *periodic waveform* or a *periodic feature* passes before repeating itself identically.

2.7 *Reference lines and points*

The reference lines and points defined in this sub-clause and used throughout the remainder of this standard are constructions which are (either actually or figuratively) superimposed on *waveforms* for descriptive or analytical purposes. Unless otherwise specified, all defined lines and points lie within a *waveform epoch*.

2.7.1 *Time origin line*

A line of constant and specified *time* which, unless otherwise specified, has a *time* equal to zero and passes through the first datum *time*, t_0, of a *waveform epoch* (see Figure 1, page 40).

2.7.2 *Magnitude origin line*

A line of specified *magnitude* which, unless otherwise specified, has a *magnitude* equal to zero and extends through the *waveform epoch* (see Figure 1).

2.7.3 *Time reference line*

A line parallel to the *time origin line* at a specified *instant*.

2.7.4 *Time referenced point*

A point at the intersection of a *time reference line* and a *waveform*.

2.7.5 *Magnitude reference line*

A line parallel to the *magnitude origin line* at a specified *magnitude*.

2.7.6 *Magnitude referenced point*

A point at the intersection of a *magnitude reference line* and a *waveform*.

2.7.7 *Knot*

A point t_k, m_k (where $k = 1, 2, 3, \ldots, n$) in a sequence of points wherein $t_k \leqslant t_{k+1}$ through which a *cubic natural spline* passes (see Figure 3, page 41).

2.7.8 *Cubic natural spline*

A catenated piecewise sequence of cubic polynomial functions $p\,(1,2)$, $p\,(2,3)$, ..., $p\,(n-1, n)$ between *knots* $t_1\ m_1$ and $t_2\ m_2$, $t_2\ m_2$ and $t_3\ m_3$, ..., $t_{(n-1)}\ m_{(n-1)}$ and $t_n\ m_n$, respectively, wherein:

a) at all *knots*, the first and second derivatives of the adjacent polynomial functions are equal, and

b) for all values of t less than t_1 and greater than t_n the function is linear (see Figure 3 and Sub-clause 5.5).

Note. — The cubic natural spline yields a curve which, throughout, is continuous and has continuous first and second derivatives. The resulting curve is the rigorous mathematical embodiment of what is conventionally called a smooth curve drawn through a group of points (i.e. knots) and it consists of a sequence of curvilinear segments which are defined by equations of the third degree.

2.8 *Miscellaneous*

2.8.1 *Pulse shape*

For descriptive purposes, a *pulse waveform* may be imprecisely described by any of the adjectives, or combinations thereof, in Sub-clauses 2.4.1.1, 2.4.4, 2.4.5 and 2.5.3.2 to 2.5.3.4, inclusive. When so used, these adjectives describe general shape only and no precise distinctions are defined.

For tutorial purposes, a hypothetical *pulse waveform* may be precisely defined by the further addition of the adjective "*ideal*" (Sub-clause 2.4.1.2).

For measurement or comparison purposes, a *pulse waveform* may be precisely defined by the further addition of the adjective "*reference*" (Sub-clause 2.4.1.3).

2.8.2 *Transition shape*

For descriptive purposes, a *transition waveform* may be imprecisely described by any of the adjectives, or combinations thereof, in Sub-clauses 2.4.1.1, 2.4.4, 2.4.5.5 and 2.5.3. When so used, these adjectives describe general shape only and no precise distinctions are defined.

For tutorial purposes, a hypothetical *transition waveform* may be precisely defined by the further addition of the adjective "*ideal*" (Sub-clause 2.4.1.2).

For measurement or comparison purposes, a *transition waveform* may be precisely defined by the further addition of the adjective "*reference*" (Sub-clause 2.4.1.3).

2.8.3 *Pulse power*

The power transferred or transformed by a *pulse(s)*. Unless otherwise specified by a *mathematical adjective* (from Sub-clause 2.5.2), *average* power over a specified *interval* is assumed.