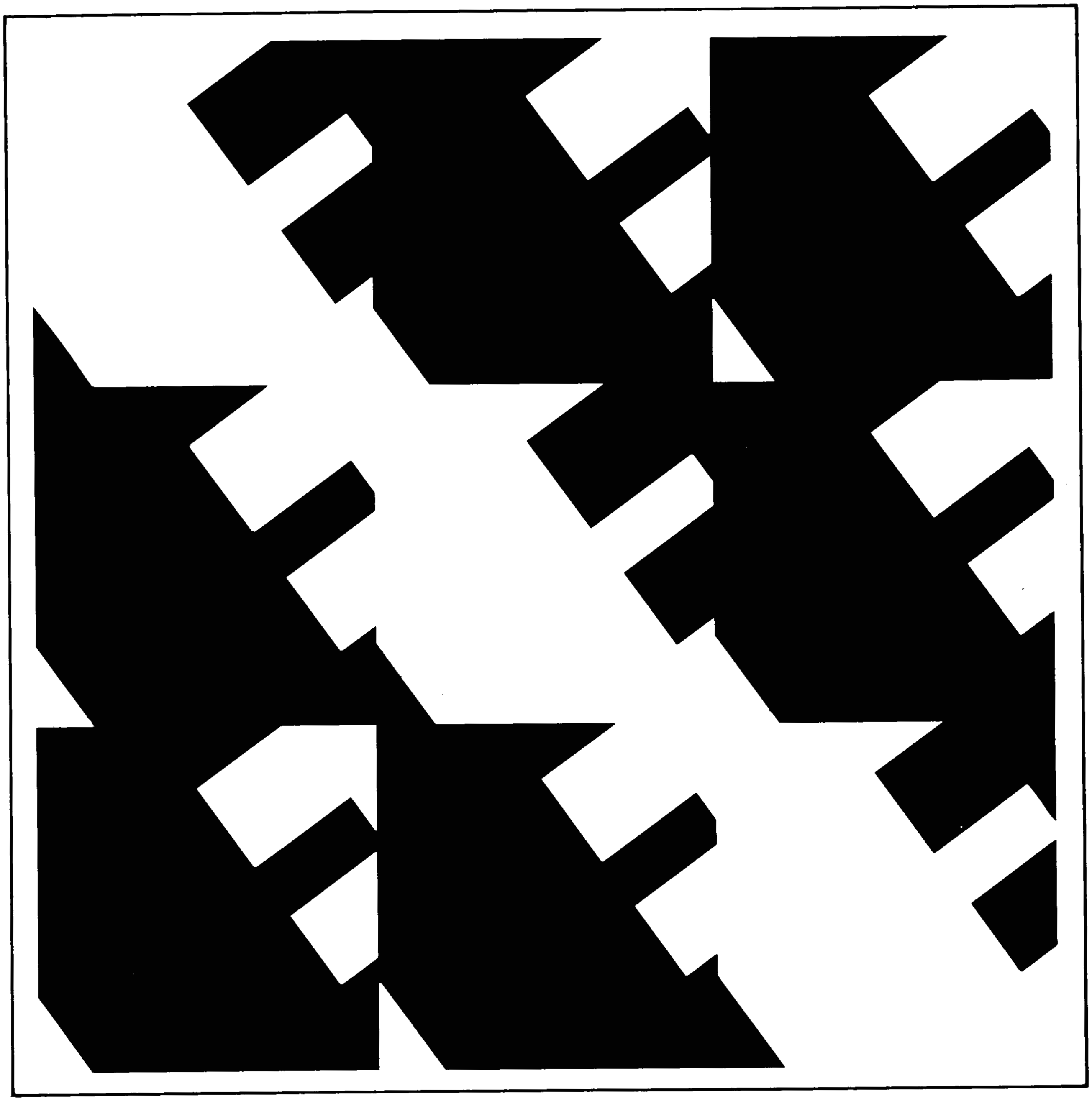
IEEE Standard Pulse Terms and Definitions

IEEE Std 194-1977



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IEEE Standard
Pulse Terms and Definitions

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Foreword

(This foreword is not a part of IEEE Std 194-1977, IEEE Standard Pulse Terms and Definitions.)

This standard supersedes IEEE Std 194-1951, Standards on Pulses: Definition of Terms - Part I, 1951. It should be used in conjunction with IEEE Std 181-1977, IEEE Standard on Pulse Measurement and Analysis by Objective Techniques.

The previous editions of the IEEE standards on pulses were published in 1951-1955, a period when pulse measuring instruments (principally, the cathode ray oscilloscope) were completing their evolution from qualitative indicators to quantitative instruments. These previous standards reflected this evolutionary stage in nomenclature, definitions, and methods of measurement which relied heavily on visual observation and subjective evaluation. No review of the growth of pulse technology in the intervening years is needed here; by 1966, when the IEEE Subcommittee on Pulse Techniques was formed, the previous edition of this standard was obsolete.

The greatest challenge the subcommittee faced was the development of a standard which would satisfy the needs of a wide range of users, users whose measurement practices ranged from the casual and inexact to the most careful and exact. Since a standard which covers exact work can, by degradation or omission, also cover inexact work, the subcommittee developed a standard which satisfies the needs of the user and manufacturer of sophisticated pulse apparatus. Nonetheless, study of Fig 2 will show that, barring changes in nomenclature, nothing has changed and the previous practices of the casual user are preserved.

The subcommittee also made the following decisions relative to the content of this standard:

(1) No frequency domain terms (for example, bandwidth) would be used or defined.

(2) No terms which link the time and frequency domains (for example, pulse bandwidth) would be used or defined.

(3) No acronyms or coined words would be used or defined.

(4) No synonyms would be used or defined. (For example, pulse is defined and impulse is neither used nor defined.)

(5) The introduction of new concepts would be minimized. The only new concepts that are introduced are found in the definitions of epochs (2.3.2 and 5.3.2.8), feature (2.3.3), and quadrant (3.4.2).

The presentation of definitions in this standard, and within its sections, starts with the most general terms and proceeds to the definition of terms which are more specific *in terms of terms that have been defined previously.* This arrangement, while sacrificing alphabetical listing, yields a logical presentation of significant tutorial value. Terms that are adjectives are defined separately (in sections 2.4 and 2.5) from terms that are nouns (all sections except 2.4 and 2.5) with the expectation that, as the need arises, adjective and noun terms will be combined to provide the required term.

Since its formation in 1966, the IEEE Subcommittee on Pulse Techniques has been broadly based. Collectively, its members represented or provided liaison with seven IEEE societies or groups (Circuits and Systems, Computer, Electron Devices, Engineering in Medicine and Biology, Instrumentation and Measurement, Magnetics, and Nuclear and Plasma Sciences), six technical associations (American Society for Testing and Materials, Electronic Industries Association, Instrument Society of America, National Conference of Standards Laboratories, Precision Measurement Association, and Scientific Apparatus Makers Association), and three technical committees of the International Electrotechnical Commission (Electron Tubes and Valves, Electronic Measuring Equipment, and Magnetic Materials and Components). Nine members of the subcommittee were from six countries other than the U.S. (France, Germany, Hungary, Japan, the Netherlands, and the United Kingdom). Subcommittee members who represented users of pulse apparatus outnumbered members who represented manufacturers.

Beginning in 1970 the liaison between the subcommittee and Technical Committee 66, Electronic Measuring Equipment, of the International Electrotechnical Commission (IEC) became progressively closer and culminated in an informal mutual understanding that both groups would attempt to provide their parent organizations with pulse standards which were the same. This goal was achieved; IEC Publication 469-1, 1974, Pulse Techniques and Apparatus, Part 1: Pulse Terms and Definitions, is technically (and, otherwise, substantially) identical to this standard.

The IEEE Subcommittee on Pulse Techniques, which prepared this standard, had the following members:

P. E. Stuckert*, *Chairman* (1971-1977)
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C. E. White
J. Worcester
H. A. Zimmerman

* Members of International Electrotechnical Commission Technical Committee 66: Electronic Measuring Equipment, Subcommittee 66A: Generators, Working Group I: Pulse Techniques and Apparatus.

This standard was approved by the IEEE G-IM Technical Committee on High Frequency Instrumentation and Measurement, which had the following members:

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Contents

FIGURES

IEEE Standard
Pulse Terms and Definitions

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 parameters which are prerequisite to:

(1) Efficient communication of technical information

(2) Standards for methods of pulse parameter measurement

(3) Standards for pulse apparatus

(4) Standards for apparatus which employs 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:

(1) To hypothetical and practical pulses

(2) Regardless of accuracy or precision

(3) To a wide range of technologies and disciplines

(4) In a measurement situation, regardless of the means of measurement or the means for waveform evaluation employed.

2. General Terms

2.1 Coordinate System. Throughout the following, a rectangular Cartesian coordinate system is assumed in which, unless otherwise specified:

(1) Time (t) is the independent variable taken along the horizontal axis, increasing in the positive sense from left to right

(2) Magnitude (m) is the dependent variable taken along the vertical axis, increasing in the positive sense or polarity from bottom to top

(3) The following additional symbols are used:

(a) e—The base of natural logarithms

(b) a, b, c, etc—Real constants which, unless otherwise specified, may have any value and either sign

(c) 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 the medium as a function of *time*[1] as a result of one or more disturbances.

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 document the term pulse is included in the term *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 document the term transition is included in the terms *pulse* and *wave*.

2.3 Waveform, Epoch, and Feature

2.3.1 ***Waveform, Pulse Waveform, Transition Waveform.*** A manifestation or representation (that is, graph, plot, oscilloscope presentation, equation(s), table of coordinate or statistical data, etc) or a visualization of a *wave, pulse,* or *transition*. Throughout the remainder of this document:

(1) The term pulse waveform is included in the term waveform

(2) The term transition waveform is included in the terms 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 − infinity to + infinity or, like all *waveform* data, may extend from a first datum *time* t_0 to a second datum *time* t_1. (See Fig 1.)

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

2.4 Qualitative Adjectives. The adjectives in this section may be used individually or in combination, or in combination with adjectives in Section 2.5, to modify any substantive term in this standard.

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[1]Terms shown in *italic type* are defined previously 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 triangle. (See Fig 2, 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 section may be used individually or in combination, or in combination with adjectives in Section 2.4, to modify any substantive term in this glossary.

2.5.1 ***Integer Adjectives.*** The ordinal integers (that is, first, second, . . ., *n*th, last) or the cardinal integers (that is, 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* or within *features* thereof.

2.5.2 ***Mathematical Adjectives.*** All definitions in this section 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 be used to describe the relation(s) between other specified variable pairs (for example, *time* and power, *time* and voltage, etc).

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 (rms).* Pertaining to the square root of the average of the square of the *magnitude.* If the *magnitude* takes on *n* discrete values m_j, the root-mean-square *magnitude* is

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

If the *magnitude* is a continuous function of *time m(t),*

$$M_{\text{rms}} = \left[\left(\frac{1}{t_2 - t_1}\right)\int_{t_1}^{t_2} m^2\,(t)\,\mathrm{d}t\right]^{\frac{1}{2}}$$

The summation or the integral extends over the interval of *time* for which the rms *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 *magnitude.* If the *magnitude* takes on *n* discrete values m_j, the average *magnitude* is

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

If the *magnitude* is a continuous function of *time m(t)*,

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

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 *magnitude.* If the *magnitude* takes on n discrete values m_j, the average absolute *magnitude* is

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

If the *magnitude* is a continuous function of *time m(t)*,

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

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 (rss).* Pertaining to the square root of the arithmetic sum of the squares of the *magnitude.* If the *magnitude* takes on n discrete values m_j the root sum of squares *magnitude* is

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

If the *magnitude* is a continuous function of *time m(t)*,

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

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:

$$m = ae^{-bt}$$

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

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:

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

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 (for example, cosine squared).

2.6 Time-Related Definitions

2.6.1 ***Instant.*** Unless otherwise specified, 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 section and used throughout the remainder of this document are constructs 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 Fig 1.)

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 Fig 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 $t_k\ m_k$ ($k = 1,2,3,\ldots, n$) in a sequence of points wherein $t_k \leqq t_{k+1}$ through which a spline function passes. (See Fig 3.)

2.7.8 ***Cubic Natural Spline.*** A catenated piecewise sequence of cubic polynomial functions $p(1,\ 2)$, $p(2,\ 3)$,. . ., $p(n\text{-}1,\ n)$ 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:

(1) At all *knots* the first and second derivatives of the adjacent polynomial functions are equal, and

(2) For all values of t less than t_1 and greater than t_n the function is linear. (See Fig 3 and Section 5.5).

2.8 Miscellaneous

2.8.1 ***Pulse Shape***

(1) For descriptive purposes a *pulse waveform* may be imprecisely described by any of the adjectives, or combinations thereof, in Sections 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.

(2) For tutorial purposes a hypothetical *pulse waveform* may be precisely defined by the further addition of the adjective *ideal* (Section 2.4.1.2).

(3) For measurement or comparison purposes a *pulse waveform* may be precisely defined by the further addition of the adjective *reference* (Section 2.4.1.3).

2.8.2 ***Transition Shape***

(1) For descriptive purposes a *transition waveform* may be imprecisely described by any of the adjectives, or combinations thereof, in Sections 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.

(2) For tutorial purposes a hypothetical *transition waveform* may be precisely defined by the further addition of the adjective *ideal* (Section 2.4.1.2).

(3) For measurement or comparison purposes a *transition waveform* may be precisely defined by the further addition of the adjective *reference* (Section 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 Section 2.5.2), *average* power over a specified *interval* is assumed.

2.8.4 ***Pulse Energy.*** The energy transferred or transformed by a *pulse(s).* Unless otherwise specified by a *mathematical adjective* (from Section 2.5.2), the total energy over a specified *interval* is assumed.

3. The Single Pulse

3.1 Major Pulse Waveform Features

3.1.1 ***Base.*** The two portions of a *pulse waveform* which represent the first nominal state from which a *pulse* departs and to which it ultimately returns.

3.1.2 ***Top.*** The portion of a *pulse waveform* which represents the second nominal state of a *pulse.*

3.1.3 ***First Transition.*** The *major transition waveform* of a *pulse waveform* between the *base* and the *top.*

3.1.4 ***Last Transition.*** The *major transition waveform* of a *pulse waveform* between the *top* and the *base.*

3.2 Magnitude Parameters and References. All *magnitude* parameters, unless otherwise

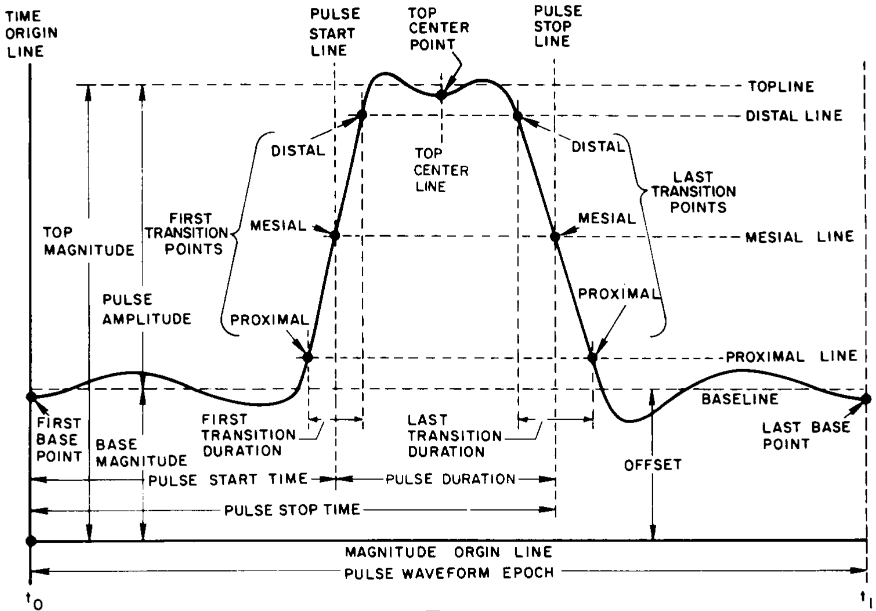


Fig 1
Single Pulse

specified, are derived from data within the *waveform epoch.*

3.2.1 ***Base Magnitude.*** The *magnitude* of the *base* as obtained by a specified procedure or algorithm. Unless otherwise specified, both portions of the *base* are included in the procedure or algorithm. (See Fig 1 and see IEEE Std 181-1977. Pulse Measurement and Analysis by Objective Techniques. Section 4.3, for suitable algorithms.).

3.2.2 ***Top Magnitude.*** The *magnitude* of the *top* as obtained by a specified procedure or algorithm. (See Fig 1 and see IEEE Std 181-1977, Section 4.3, for suitable algorithms.)

3.2.3 ***Pulse Amplitude.*** The algebraic difference between the *top magnitude* and the *base magnitude.* (See Fig 1.)

3.2.4 ***Magnitude Reference Lines***

3.2.4.1 *Baseline (Topline).* The *magnitude reference line* at the *base (top) magnitude.* (See Fig 1.)

3.2.4.2 *Percent Reference Magnitude*
A *reference magnitude* specified by:

$$(x)\%M_r = M_b + \frac{x}{100}(M_t - M_b)$$

where

$0 < x < 100$
$(x)\%M_r$ = percent reference magnitude
M_b = *base magnitude*
M_t = *top magnitude*
M_b, M_t, and $(x)\%M_r$ are all in the same unit of measurement.

3.2.4.3 *Proximal (Distal) Line.* A *magnitude reference line* at a specified *magnitude* in the *proximal (distal)* region of a *pulse waveform.* Unless otherwise specified, the proximal (distal) line is at the 10 (90) *percent reference magnitude.* (See Fig 1.)

3.2.4.4 *Mesial Line.* A *magnitude reference line* at a specified *magnitude* in the *mesial* region of a *pulse waveform.* Unless otherwise specified, the mesial line is at the 50 *percent reference magnitude.* (See Fig 1.)

3.2.5 ***Magnitude Reference Points***

3.2.5.1 *Proximal (Distal) Point.* A *magnitude referenced point* at the intersection of a *waveform* and a *proximal (distal) line.* (See Fig 1.)

3.2.5.2 *Mesial Point.* A *magnitude referenced point* at the intersection of a *waveform* and a *mesial line.* (See Fig 1.)

3.3 Time Parameters and References

3.3.1 ***Pulse Start (Stop) Time.*** The *instant* specified by a *magnitude referenced point* on the *first (last) transition* of a *pulse waveform.* Unless otherwise specified, the pulse start (stop) time is at the *mesial point* on the *first (last) transition.* (See Fig 1.)

3.3.2 ***Pulse Duration.*** The *duration* between *pulse start time* and *pulse stop time.* (See Fig 1.)

3.3.3 ***Time Reference Lines***

3.3.3.1 *Pulse Start (Stop) Line.* The *time reference line* at *pulse start (stop) time.* (See Fig 1.)

3.3.3.2 *Top Center Line.* The *time reference line* at the *average* of *pulse start time* and *pulse stop time.* (See Fig 1.)

3.3.4 ***Pulse Time Reference Points***

3.3.4.1 *Top Center Point.* A specified *time referenced point* or *magnitude referenced point* on a *pulse waveform top.* If no point is specified, the top center point is the *time referenced point* at the intersection of a *pulse waveform* and the *top center line.* (See Fig 1.)

3.3.4.2 *First (Last) Base Point.* Unless otherwise specified, the first (last) datum point in a *pulse epoch.* (Compare with *base center point,* Section 5.3.2.7.) (See Fig 1.)

3.3.5 ***Transition Duration.*** The *duration* between the *proximal point* and the *distal point* on a *transition waveform.*

3.3.6 ***First (Last) Transition Duration.*** The *transition duration* of the *first (last) transition waveform* in a *pulse waveform.* (See Fig 1.)

3.4 Other Pulse Waveform Features

3.4.1 ***Pulse Corner.*** A continuous *pulse waveform feature* of specified extent which includes a region of maximum curvature or a point of discontinuity in the *waveform* slope. Unless otherwise specified, the extent of the corners in a *rectangular* or *trapezoidal pulse waveform* are as specified in the following table:

Corner	First Point	Last Point
First	first base point	first transition proximal point
Second	first transition distal point	top center point
Third	top center point	last transition distal point
Fourth	last transition proximal point	last base point

3.4.2 ***Pulse Quadrant.*** One of the four continuous and contiguous *pulse waveform features* of specified extent which include a region of maximum curvature or a point of discontinuity in the *waveform* slope. Unless otherwise specified, the extent of the quadrants in a *rectangular* or *trapezoidal pulse waveform* are as specified in the following table:

Quadrant	First Point	Last Point
First	first base point	first transition mesial point
Second	first transition mesial point	top center point
Third	top center point	last transition mesial point
Fourth	last transition mesial point	last base point

4.The Single Transition

4.1 Step. A *transition waveform* which has a *transition duration* which is negligible relative to the *duration* of the *waveform epoch* or to the *duration* of its adjacent first and second nominal states.

4.2 Ramp. A *linear feature.*

5. Complex Waveforms

5.1 Combinations of Pulses and Transitions

5.1.1 ***Double Pulse.*** Two *pulse waveforms* of the same *polarity* which are adjacent in *time* and which are considered or treated as a single *feature.*

5.1.2 ***Bipolar Pulse.*** Two *pulse waveforms* of opposite *polarity* which are adjacent in *time* and which are considered or treated as a single *feature.*

5.1.3 ***Staircase.*** Unless otherwise specified, a *periodic* and finite sequence of *steps* of equal *magnitude* and of the same *polarity.*

5.2 Waveforms Produced by Magnitude Superposition

5.2.1 ***Offset.*** The algebraic difference between two specified *magnitude reference lines.* Unless otherwise specified, the two *magnitude reference lines* are the *waveform baseline* and the *magnitude origin line.* (See Fig 1.)

5.2.2 ***Offset Waveform.*** A *waveform* whose *baseline* is *offset* from, unless otherwise specified, the *magnitude origin line.*

5.2.3 ***Composite Waveform.*** A *waveform*

Fig 2
Composite Waveform

which is, or which for analytical or descriptive purposes is treated as, the algebraic summation of two or more *waveforms.* (See Fig 2.)

5.3 Waveforms Produced by Continuous Time Superposition of Simpler Waveforms

5.3.1 *Pulse Train.* A continuous repetitive sequence of *pulse waveforms.*

5.3.2 *Pulse Train Time-Related Definitions*

5.3.2.1 *Pulse Repetition Period.* The *interval* between the *pulse start time* of a first *pulse waveform* and the *pulse start time* of the immediately following *pulse waveform* in a *periodic pulse train.*

5.3.2.2 *Pulse Repetition Frequency.* The reciprocal of *pulse repetition period.*

5.3.2.3 *Pulse Separation.* The *interval* between the *pulse stop time* of a first *pulse waveform* and the *pulse start time* of the immediately following *pulse waveform* in a *pulse train.*

5.3.2.4 *Duty Factor.* Unless otherwise specified, the ratio of the *pulse waveform duration* to the *pulse repetition period* of a *periodic pulse train.*

5.3.2.5 *On – Off Ratio.* Unless otherwise specified, the ratio of the *pulse waveform duration* to the *pulse separation* of a *periodic pulse train.*

5.3.2.6 *Base Center Line.* The *time reference line* at the *average* of the *pulse stop time* of a first *pulse waveform* and the *pulse start time* of the immediately following *pulse waveform* in a *pulse train.*

5.3.2.7 *Base Center Point.* A specified *time referenced point* or *magnitude referenced point* on a *pulse train waveform base.* If no point is specified, the base center point is the *time referenced point* at the intersection of a *pulse train waveform base* and a *base center line.* (Compare with *first (last) base point,* Section 3.3.4.2.)

5.3.2.8 *Pulse Train Epoch.* The span of *time* in a *pulse train* for which *waveform* data are known or knowable and which extends from a first *base center point* to the immediately following *base center point.*

5.3.3 *Square Wave.* A *periodic rectangular pulse train* with a duty factor of 0.5 or an *on – off ratio* of 1.0.

5.4 Waveforms Produced by Noncontinuous Time Superposition of Simpler Waveforms

5.4.1 ***Pulse Burst.*** A finite sequence of *pulse waveforms.*

5.4.2 *Pulse Burst Time-Related Definitions*

5.4.2.1 *Pulse Burst Duration.* The *interval* between the *pulse start time* of the first *pulse waveform* and the *pulse stop time* of the last *pulse waveform* in a *pulse burst.*

5.4.2.2 *Pulse Burst Separation.* The *in-*

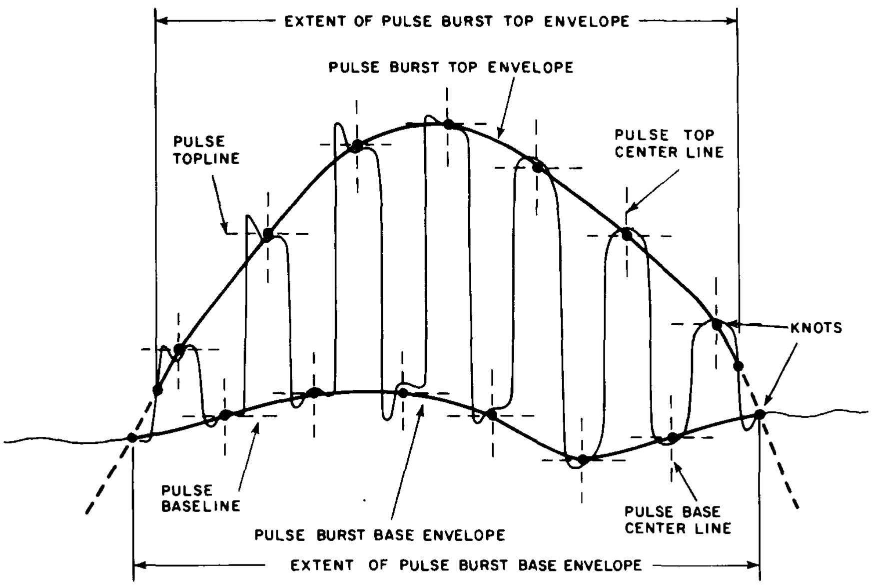


Fig 3
Pulse Burst Envelopes

terval between the *pulse stop time* of the last *pulse waveform* in a *pulse burst* and the *pulse start time* of the first *pulse waveform* in the immediately following *pulse burst*.

5.4.2.3 *Pulse Burst Repetition Period.* The *interval* between the *pulse start time* of the first *pulse waveform* in a *pulse burst* and the *pulse start time* of the first *pulse waveform* in the immediately following *pulse burst* in a sequence of *periodic pulse bursts*.

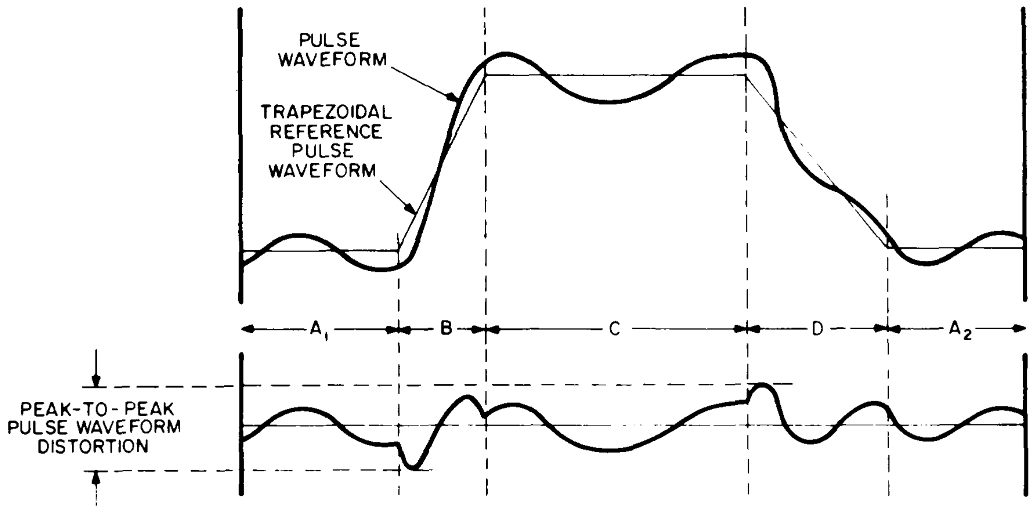
5.4.2.4 *Pulse Burst Repetition Frequency.* The reciprocal of *pulse burst repetition period*.

5.5 Waveforms Produced by Operations on Waveforms. All envelope definitions in this section are based on the *cubic natural spline* (or its related approximation, the draftsman's spline) with *knots* at specified points. All *burst* envelopes extend in *time* from the first to the last *knots* specified, the remainder of the *waveform* being (1) that portion of the waveform which precedes the first *knot* and (2) that portion of the *waveform* which follows the last *knot*. *Burst* envelopes and their adjacent *waveform bases*, taken together, comprise a continuous *waveform* which has a continuous first derivative except at the first and last *knots* of the envelope.

5.5.1 ***Pulse Train Top (Base) Envelope.*** Unless otherwise specified, the *waveform* defined by a *cubic natural spline* with *knots* at each point of intersection of the *top center line* and the *topline* (the *base center line* and the *baseline*) of each (between adjacent) *pulse waveform(s)* in a *pulse train*.

5.5.2 ***Pulse Burst Top Envelope.*** Unless otherwise specified, the *waveform* defined by a *cubic natural spline* with *knots* at (1) the *first transition mesial point* of the first *pulse waveform* in a *pulse burst*, (2) each point of intersection of the *top center line* and the *topline* of each *pulse waveform* in a *pulse burst*, and (3) the *last transition mesial point* of the last *pulse waveform* in a *pulse burst*. (See Fig 3.)

5.5.3 ***Pulse Burst Base Envelope.*** Unless otherwise specified, the *waveform* defined by a *cubic natural spline* with *knots* at (1) that point of intersection of the *pulse burst top envelope* and the *pulse burst waveform* which precedes the first *pulse waveform* in a *pulse burst*, (2) each point of intersection of the *base center line* and the *baseline* between adjacent *pulse waveforms* in a *pulse burst*, and (3) that point of intersection of the *pulse burst top envelope* and the *pulse burst waveform which follows the last pulse waveform* in a *pulse burst*. (See Fig 3.)



Extent of Data Included in Pulse Waveform Feature Distortion

A_1 and A_2 Pulse Base Distortion — *C* Pulse top distortion
B First Transition Distortion — *D* Last transition distortion

Fig 4
Pulse Waveform Distortion and Pulse Waveform Feature Distortion

6. Time Relationships Between Different Waveforms

6.1 Pulse Advance (Delay). The occurrence in *time* of one *pulse waveform* before (after) another *pulse waveform.*

6.2 Pulse Advance (Delay) Interval. The *interval* by which, unless otherwise specified, the *pulse start time* of one *pulse waveform* precedes (follows), unless otherwise specified, the *pulse start time* of another *pulse waveform.*

6.3 Pulse Coincidence (Noncoincidence). The occurrence (lack of occurrence) of two or more *pulse waveforms* in different *waveforms* either essentially simultaneously or for a specified *interval.*

6.4 Pulse Coincidence (Noncoincidence) Duration. The *interval* between specified points on two or more *pulse waveforms* in different *waveforms* during which *pulse coincidence (noncoincidence)* exists.

7. Distortion, Jitter, and Fluctuation

7.1 Distortion

7.1.1 ***Pulse Waveform Distortion.*** The algebraic difference in *magnitude* between all corresponding points in *time* of a *pulse waveform* and a *reference pulse waveform.* Unless otherwise specified by a *mathematical adjective* (from Section 2.5.2), *peak-to-peak* pulse waveform distortion is assumed. (See Fig 4.)

7.1.2 ***Percent Pulse Waveform Distortion.*** *Pulse waveform distortion* expressed as a percentage of, unless otherwise specified, the *pulse amplitude* of the *reference pulse waveform.*

7.1.3 ***Pulse Waveform Feature Distortion.*** The algebraic difference in *magnitude* between all corresponding points in *time* of a *pulse waveform* and a *reference pulse waveform feature.* Unless otherwise specified by a *mathematical adjective* (from Section 2.5.2), *peak-to-peak* pulse waveform feature distortion is assumed. (See Fig 4.)

7.1.4 ***Percent Pulse Waveform Feature Distortion.*** *Pulse waveform feature distortion* expressed as a percentage of, unless otherwise specified, the *pulse amplitude* of the *reference pulse waveform.*

7.2 Qualitative Distortion Terms. The terms defined in this section are colloquial terms which qualitatively describe various types of *distortion*. Quantitative measures of *distortion* are defined in Section 7.1.

7.2.1 ***Preshoot.*** A distortion which precedes a *major transition.*

7.2.2 ***Overshoot.*** A distortion which follows a *major transition.*

7.2.3 ***Rounding.*** A distortion in the form of a *rounded feature* which occurs where a relatively abrupt change in slope is desired or expected.

7.2.4 ***Spike.*** A distortion in the form of a *pulse waveform* of relatively short *duration* superimposed on an otherwise regular or desired *pulse waveform.*

7.2.5 ***Ringing.*** A distortion in the form of a superimposed damped oscillatory *waveform* which, when present, usually follows a *major transition.*

7.2.6 ***Tilt.*** A distortion of a *pulse top* or *pulse base* wherein the overall slope over the extent of the *pulse top* or the *pulse base* is essentially constant and other than zero. Tilt may be of either *polarity.*

7.2.7 ***Valley.*** A portion of a *pulse waveform* between two specified *peak magnitudes* of the same *polarity.*

7.3 Jitter and Fluctuation

7.3.1 ***Jitter.*** Dispersion of a *time* parameter of the *pulse waveforms* in a *pulse train* with respect to a reference *time, interval,* or *duration.* Unless otherwise specified by a *mathematical adjective* (from Section 2.5.2), *peak-to-peak* jitter is assumed.

7.3.2 ***Fluctuation.*** Dispersion of the *pulse amplitude* or other *magnitude* parameter of the *pulse waveforms* in a *pulse train* with respect to a *reference pulse amplitude* or a *reference magnitude.* Unless otherwise specified by a *mathematical adjective* (from Section 2.5.2), *peak-to-peak* fluctuation is assumed.

8. Miscellaneous Pulse Terms

Throughout this section, where applicable, the term *pulse* includes the terms *pulse train* and *pulse burst.*

NOTE: All terms listed in Sections 8.1.1, 8.2.1, 8.3, and 8.4.1 have their conventional technical meanings. All other terms have unique meanings in pulse technology and are individually defined. However, some defined terms also have conventional technical meanings. In any particular use of such terms, the distinction between conventional usage and pulse usage can only be determined from context.

8.1 Operations on a Pulse

8.1.1 ***General.*** Amplification, attenuation, conditioning, conversion, coupling, demodulation, detection, discrimination, filtering, inversion, reception, reflection, and transmission may occur or be performed.

8.1.2 ***Clamping.*** A process in which a specified *instantaneous magnitude* of a *pulse* is fixed at a specified *magnitude.* Typically, after clamping, all *instantaneous magnitudes* of the *pulse* are *offset,* the *pulse shape* remaining unaltered.

8.1.3 ***Delaying.*** A process in which a *pulse* is delayed in *time* by active circuitry or by propagation.

8.1.4 ***Shaping.*** A process in which the shape of a *pulse* is modified to one which is *ideal* or more suitable for the intended application wherein *time* and *magnitude* parameters may be changed. Typically, some property(ies) of the original *pulse* is preserved.

8.1.4.1 *Regeneration.* A *shaping* process in which a *pulse* with desired *reference* characteristics is developed from a *pulse* which lacks certain desired characteristics.

8.1.4.2 *Stretching.* A *shaping* process in which *pulse duration* is increased.

8.1.4.3 *Clipping.* A *shaping* process in which the *magnitude* of a *pulse is* constrained at one or more predetermined *magnitudes.*

8.1.4.4 *Limiting.* A *clipping* process in which the *pulse shape* is preserved for all *magnitudes* between predetermined *clipping magnitudes.*

8.1.4.5 *Slicing.* A *clipping* process in which the *pulse shape* is preserved for all *magnitudes* less (greater) than a predetermined *clipping magnitude.*

8.1.4.6 *Differentiation.* A *shaping* process in which a *pulse* is converted to a *wave* whose shape is or approximates the time dirivative of the *pulse.*

8.1.4.7 *Integration.* A *shaping* process in which a *pulse* is converted to a *wave* whose shape is or approximates the time integral of the *pulse.*

8.2 Operations by a Pulse

8.2.1 *General.* Activation, blanking, clearing, deactivation, deflection, reading, resetting, selection, sequencing, setting, starting, stopping, storing, switching, and writing may occur or be performed.

8.2.2 *Synchronizing.* The process of rendering a first *pulse train* or other sequence of events *synchronous* with a second *pulse train*.

8.2.3 *Strobing.* A process in which a first *pulse* of relatively short *duration* interacts with a second *pulse* or other event of relatively longer *duration* to yield a signal which is indicative (typically, proportional to) the *magnitude* of the second *pulse* during the first *pulse.*

8.2.4 *Sampling.* A process in which *strobing pulses* yield signals which are proportional to the *magnitude* (typically, as a function of *time*) of a second *pulse* or other event.

8.2.5 *Triggering.* A process in which a *pulse* initiates a predetermined event or response.

8.3 Operations Involving the Interaction of Pulses. Addition, chopping, coding, comparison, decoding, encoding, mixing, modulation, subtraction, summation, and superposition (see also Section 5.) may occur or be performed.

8.4 Logical Operations with Pulses. This section considers the *pulse* as a logical operator. Some operations defined in Sections 8.1, 8.2, and 8.3, frequently are logical operations in the sense of this section.

8.4.1 *General.* AND, NAND, OR, NOR, EXCLUSIVE OR, INVERSION, inhibiting, enabling, disabling, counting, or other logical operations may be performed.

8.4.2 *Slivering.* A process in which a (typically, unwanted) *pulse* of relatively short *duration* is produced by a logical operation. Typically, slivering is a result of partial *pulse coincidence.*

8.4.3 *Gating.* A process in which a first *pulse* enables or disables portions of a second *pulse* or other event for the *duration* of the first *pulse.*

8.4.4 *Shifting.* A process in which logical states in a specified sequence are transferred without alteration of the sequence from one storage element to another by the action of a *pulse.*

Index

The following conventions are used throughout this index:
1. A comma (,) separating section numbers indicates a combination or catenation of terms.
2. A semicolon (;) separating section numbers indicates alternate terms.
3. Numerous terms are listed in this index which are neither used nor defined in the standard. In such cases the section number(s) of the preferred synonymous terms(s) is shown.

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