

**IEEE Std 181™-2003**

(Revision of  
IEEE Std 181-1977 and  
IEEE Std 194™-1977)

# IEEE Standard on Transitions, Pulses, and Related Waveforms

Sponsor

**Subcommittee on Pulse Techniques**  
of the  
**IEEE Instrumentation and Measurement (I&M) Society**

Approved 20 March 2003

**IEEE-SA Standards Board**

**Abstract:** This standard presents approximately 100 terms, and their definitions, for accurately and precisely describing the waveforms of pulse signals and the process of measuring pulse signals. Algorithms are provided for computing the values of defined terms that describe measurable parameters of the waveform, such as transition duration, state level, pulse amplitude, and waveform aberrations. These analysis algorithms are applicable to two-state waveforms having one or two transitions connecting these states. Compound waveform analysis is accomplished by decomposing the compound waveform into its constituent two-state single-transition waveforms.

**Keywords:** aberration, algorithms, compound waveform, histogram, levels, pulse, pulse amplitude, pulse definitions, pulse measurement, states, state boundaries, state levels, transients, transitions, transition duration, waveforms, waveform analysis, waveform definitions, waveform parameters, waveform terms

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# Introduction

(This introduction is not part of IEEE Std 181-2003, IEEE Standard on Transitions, Pulses, and Related Waveforms.)

## History

The Subcommittee on Pulse Techniques (SCOPT) is a subcommittee of the Waveform Generation, Measurement, and Analysis Committee (TC-10) of the IEEE Instrumentation and Measurement (I&M) Society. Since 1996, the SCOPT has been writing a revision to the now withdrawn IEEE Std 181-1977, IEEE Standard on Pulse Measurement and Analysis by Objective Techniques, and withdrawn IEEE Std 194-1977, IEEE Standard Pulse Terms and Definitions. These standards dealt with terms and definitions for describing and computing waveform parameters and for describing the waveform measurement process. The revised standard combines information from both of these withdrawn IEEE standards.

The SCOPT is comprised of an international group of electronics engineers, mathematicians, and physicists with representatives from national metrology laboratories, national science laboratories, the test instrumentation industry, and academia.

This standard combines the information of and supersedes IEEE Std 181-1977 and IEEE Std 194-1977. IEEE Std 181-1977 superseded IEEE Std 181-1955, Methods of Measurement of Pulse Quantities. Information on IEEE Std 181-1955 and the history of the development of IEEE Std 181-1977 can be found in the Foreword to IEEE Std 181-1977, which is found following this introduction. IEEE Std 194-1977 superseded IEEE Std 194-1951, Standards on Pulses: Definition of Terms—Part 1, 1951. Information on IEEE Std 194-1951 and the history of development of IEEE Std 194-1977 can be found in the Foreword to IEEE Std 194-1977, which is found following this introduction.

The SCOPT submitted a Project Authorization Request (PAR) to the IEEE Standards Board in September 1996 for combining IEEE Std 181-1977 and IEEE Std 194-1977 into a single document and revising the subsequently merged document. The PAR was approved on 11 December 1996, and work on the revised and combined draft started in February 1997. The PAR expiration date was December 2002. SCOPT and TC-10 have applied for a one-year extension to enable balloting and revision as required. The draft went through several major revisions that resulted in the changes to the standard, relative to the withdrawn standards, that will be discussed later. The SCOPT revised the draft several times. These revisions resulted in eliminating previously-proposed suggestions to add frequency-domain terms, which is consistent with the original intent of the SCOPT not to introduce these terms (see forewords to the withdrawn standards), and eliminating the discussion of and terms for pulse modulated radio frequency signals. These revisions also resulted in the development of algorithms for computing the values of certain waveform parameters for which a value is appropriate. The intent of the SCOPT to add these algorithms, which are recommended for use, was to provide industry with a common and communicable reference for these parameters and their computation. Heretofore, this was not available, and there existed much debate and misunderstanding between various groups measuring the same parameters. Similarly, this is the reason the SCOPT decided to add several examples of basic waveforms, with formulae. The draft revisions developed by the SCOPT also resulted in significant changes to terms and their definitions. Development of a set of agreed-upon terms and definitions presented the greatest difficulty because of the pervasive misuse, misrepresentation, and misunderstanding of terms. Legacy issues for instrumentation manufacturers and terms of common use also had to be addressed. In the end, however, the importance of unambiguously and accurately defined terms prevailed. Consequently, many terms were deleted and many others added. Most definitions were modified. This work finally ended in September 2002 with a draft agreed upon by the SCOPT.

## Purpose

The purpose of the standard is to facilitate accurate and precise communication concerning parameters of transition, pulse, and related waveforms and the techniques and procedures for measuring them. Because of the broad applicability of electrical pulse technology in the electronics industries (such as computer, telecommunication, and test instrumentation industries), the development of unambiguous definitions for pulse terms and the presentation of methods and/or algorithms for their calculation is important for communication between manufacturers and consumers within the electronics industry. The availability of standard terms, definitions, and methods for their computation helps improve the quality of products and helps the consumer better compare the performance of different products. Improvements to digital waveform recorders have facilitated the capture, sharing, and processing of waveforms. Frequently, these waveform recorders have the ability to process the waveform internally and provide pulse parameters. This process is done automatically and without operator intervention. Consequently, a standard is needed to ensure that the definitions and methods of computation for pulse parameters are consistent.

## Changes

The most significant change to the IEEE Std 181-1977 and IEEE Std 194-1977 was to merge these two documents. The next major changes were in three areas of information content: definitions, algorithms, and waveform examples. Changes to the definitions included adding new terms and definitions, deleting unused terms and definitions, expanding the list of deprecated terms, and updating and modifying existing definitions. This standard contains definitions for approximately 100 terms commonly used to describe the waveform measurement and analysis process and waveform parameters. Many of the terms in the 1977 IEEE standards have been deleted entirely or deprecated. Deprecated terms were kept in the standard to provide continuity between this and the withdrawn standards. Terms are deprecated whenever they cannot be defined unambiguously or precisely. Terms that were deleted had to do with signal shaping terminology and pulsed radio frequency signals, which is not within the scope of the standard as determined by SCOPT.

The withdrawn standards did not contain algorithms for calculating the value (number plus unit of measure) of a waveform parameter. The SCOPT introduced into this standard algorithms for calculating the values for all defined terms that describe a measurable parameter. Examples of defined terms that describe a measurable parameter are *pulse amplitude*, *transition duration*, and *state level*. Not all defined terms have an associated algorithm because these terms do not describe a measurable parameter. Examples of defined terms that do not describe a measurable waveform parameter are *spike*, *sampling*, and *sampled waveform representation*. The algorithms are provided as a reference, and the user is advised to specify any departures from the algorithm procedures. Furthermore, the algorithms provide default values for variables used in the computation of certain parameters, such as the transition duration of a waveform where the default values for the variables may be the 10% and 90% reference levels. The user is instructed to specify the values for these variables if other than the default values are used.

The SCOPT focused these algorithms on the analysis of two-state, single-transition waveforms. The analysis of compound waveforms (waveforms with two or more states and/or two or more transitions) is accomplished by first decomposing the compound waveform into its constituent two-state single-transition waveforms. A method for performing this decomposition is provided.

Algorithms for the analysis of fluctuation and jitter of waveforms were also introduced into the standard. These algorithms describe the computation of the mean and standard deviation of jitter and fluctuation. Methods to estimate the accuracy of and correcting the value of the standard deviation are also given.

The SCOPT has added a section, Annex A, in this standard that contains numerous figures depicting different types of waveforms. These waveform examples, with the associated expressions used to generate them, help the reader understand use of certain defined terms and provide a common ground of communicating waveform types and how they can be computed.

## Foreword to IEEE Std 194-1977

This standard supersedes IEEE Std 194-1951, Standards on Pulses: Definition of Terms—Part 1, 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 Figure 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, feature, and quadrant.

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 from terms that are nouns 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.

## **Foreword to IEEE Std 181-1977**

This standard supersedes IEEE Std 181-1955, Methods of Measurement of Pulse Quantities. It should be used in conjunction with IEEE Std 194-1977, Pulse Terms and Definitions.

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, or where more exact results were desired, on planimeters techniques. 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 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. In doing this the Subcommittee found it necessary to define or describe in a rigorous manner a number of well-established terms and techniques. Nonetheless, careful study of this standard will show that the techniques and practices of the more casual user have been preserved.

The Subcommittee also made the following decisions relative to the content of this standard: (1) No frequency domain terms (e.g., bandwidth) would be used or defined. (2) No terms which link the time and frequency domains (e.g., pulse bandwidth) would be used or defined. (3) No acronyms or coined words would be used or defined.

The Subcommittee minimized the introduction of new concepts. At the first reading it may appear that there is a significant amount of new material; this is not the case. Section 2, Definitions, merely defines terms and techniques, some, perhaps, for the first time, more completely, or to a finer level of distinction. Section 3 [of Std 181-1977], Measurement of Pulse Characteristics, presents a model of the pulse measurement process. Sections 5 through 9 [of Std 181-1977] merely extend analysis of the single pulse waveform to encompass both simpler and more complex waveforms. Only in Section 4 [of Std 181-1977] is new material found as follows:

- 1) Section 4.2, Waveform Epoch Determination. This material is not really new, but a new emphasis is put on the choice of data. Sections 4.3.1, and 4.3.2 do present new techniques for the determination of base magnitude, top magnitude, and pulse amplitude.
- 2) The presentation of material in this standard, and within its sections, starts with the most general concepts and proceeds to the presentation of concepts which are more specific in terms of concepts which have been presented previously. This arrangement, while sacrificing alphabetical listing, yields a logical presentation of significant tutorial value.

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 mem-

bers of the Subcommittee were from six countries other than the U.S. (France, Germany, Hungary, Japan, the Netherlands and the United Kingdom).

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 469-2, 1974, Pulse Techniques and Apparatus, Part 2: Pulse Measurement and Analysis, General Considerations, is technically (and, otherwise, substantially) identical to this standard.

## Participants

At the time this standard was completed, the Subcommittee on Pulse Techniques had the following membership:

**Nicholas G. Paulter, Jr.,** *Chair*  
**Otis M. Solomon,** *Previous Chair*

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Jerome J. Blair  
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The following members of the balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

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Jerome J. Blair  
Keith Chow  
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Joseph Schachner  
Steven J. Tilden

When the IEEE-SA Standards Board approved this standard on 20 March 2003, it had the following membership:

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**Howard M. Frazier,** *Vice Chair*  
**Judith Gorman,** *Secretary*

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\*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Alan Cookson, *NIST Representative*  
Satish K. Aggarwal, *NRC Representative*

Catherine Berger  
*IEEE Standards Project Editor*

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