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Pulse techniques and apparatus – Part 2: Pulse measurement and analysis, general considerations

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Part 2:
Pulse measurement and analysis, general considerations

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PULSE TECHNIQUES AND APPARATUS

Part 2: Pulse measurement and analysis, general considerations

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 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 is based upon the following documents:

Six Months' Rule	Report on Voting
66A(CO)37	66A(CO)39

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 publication is quoted in this standard:

Publication No. 469-1 (1987): Pulse Techniques and Apparatus, Part 1: Pulse Terms and Definitions.

Other publication quoted:

ISO Standard 3534 (1977): Statistics – Vocabulary and Symbols.

PULSE TECHNIQUES AND APPARATUS

Part 2: Pulse measurement and analysis, general considerations

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1. General

1.1 *Scope*

This standard provides definitions and descriptions of the techniques and procedures for time domain pulse measurements. The definitions and descriptions provided are independent of specific devices, apparatus, instruments or computing devices which may be used in pulse measurements and are necessary for:

- efficient communication of the results of pulse measurements,
- standards for pulse apparatus, and
- standards for apparatus which employs pulse techniques.

1.2 *Object*

Within its scope, the object of this standard is the definition of terms and the description of techniques and procedures which are applicable:

- to the determination of the characteristics of practical and hypothetical pulses,
- regardless of the applicable limits of error, and
- to a wide range of technologies and disciplines.

2. Definitions

For the definitions of general pulse terms used in this standard reference should be made to IEC Publication 469-1.

When necessary, the references to clauses of IEC Publication 469-1 are given in this standard.

2.1 *Pulse measurement terms*

The pulse measurement terms defined in this sub-clause are applicable to measurement in general and are not defined in order to draw a distinction between pulse measurement and measurement in general.

For the purpose of this standard, the following definitions shall apply:

2.1.1 *Pulse measurement*

The assignment of a number and a unit of measurement to a characteristic, property or attribute of a pulse wherein the number and unit assigned indicate the magnitude of the characteristic which is associated with the pulse. Typically, this assignment is accomplished by comparison of a transform of the pulse (its pulse waveform) with a scale or reference which is calibrated in the unit of measurement.

2.1.2 *Method of pulse measurement*

A method of making a *pulse measurement** comprises:

- the complete specification of the functional characteristics of the devices, apparatus, instruments and auxiliary equipment to be used;

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* Terms in italic type are defined in this standard.

- the essential adjustments required;
- the procedures to be used in making essential adjustments;
- the operations to be performed and their sequence;
- the corrections that will ordinarily need to be made;
- the procedures for making such corrections;
- the conditions under which all operations are to be carried out.

2.1.3 *Pulse measurement process*

A realization of a *method of pulse measurement* in terms of specific devices, apparatus, instruments, auxiliary equipment, conditions, operators and observers.

2.1.4 *State of statistical control*

In a *pulse measurement process,* that state wherein a degree of consistency among repeated measurements of a characteristic, property or attribute is attained.

2.1.5 *Error*

The difference between the result of the application of a *pulse measurement process* and the true value of the characteristic, property or attribute being measured.

2.1.6 *Dispersion*

The degree of mutual disagreement among the results of independent measurements of a pulse characteristic, property or attribute yielded by repeated applications of a *pulse measurement process.*

2.1.7 *Resolution*

The smallest change in the pulse characteristic, property or attribute being measured which can unambiguously be discerned or detected in a *pulse measurement process.*

2.2 *Statistical terms*

Statistical terms are given in ISO Standard 3534.

2.3 *Waveform formats*

Waveforms may exist, be recorded or be stored in a variety of formats. Throughout this standard, it is assumed that:

- waveform formats are in terms of Cartesian co-ordinates or some transform thereof,
- conversion from one waveform format to any other is possible, and
- such waveform format conversions can be made with limits of *error, dispersion* and *resolution* * which are consistent with the limits of error desired in the *pulse measurement process.*

* Throughout the remainder of this standard, the term "limits of error" will be used in place of the phrase "limits of error, dispersion and resolution".

2.3.1 *Pictorial format*

A graph, plot or display in which a waveform is presented for observation and/or analysis. Any of the *waveform formats* defined in the following sub-clauses may be presented in the pictorial format.

2.3.2 *Equational format*

One or more algebraic equations which specify a waveform wherein, typically, a first equation specifies the waveform from t_0 to t_1, a second equation specifies the waveform from t_1 to t_2, etc. The equational format is typically used to specify hypothetical, ideal or reference waveforms.

2.3.3 *Sampled format*

A waveform which is a series of sample magnitudes taken sequentially or non-sequentially as a function of time. It is assumed that non-sequential samples may be rearranged in time sequence to yield the following sampled formats:

2.3.3.1 *Periodically sampled real time format*

A finite sequence of magnitudes $m_0, m_1, m_2, \ldots, m_n$ each of which represents the magnitude of the wave at times $t_0, t_0 + \Delta t, t_0 + 2\Delta t, \ldots, t_0 + n\Delta t$, respectively, wherein the data may exist in a pictorial format or as a list of numbers.

2.3.3.2 *Periodically sampled equivalent time format*

A format which is identical to the *periodically sampled real time format,* except that the time co-ordinate is equivalent to and convertible to real time. Typically, each datum point is derived from a different measurement on a different wave in a sequence of waves.

2.3.3.3 *Aperiodically sampled real time format*

A format which is identical to the *periodically sampled real time format,* except that the sampling in real time is not periodic and wherein the data exist as co-ordinate point pairs, t_1, m_1; t_2, m_2; ...; t_n, m_n.

2.3.3.4 *Aperiodically sampled equivalent time format*

A format which is identical to the *aperiodically sampled real time format,* except that the time co-ordinate is equivalent to and convertible to real time. Typically, each datum point is derived from a different measurement on a different wave in a sequence of waves.

2.4 *Waveform epoch expansion and contraction*

2.4.1 *Waveform epoch expansion*

A technique for the determination of the characteristics of a transition waveform (or pulse waveform) wherein the transition waveform epoch (or pulse waveform epoch) is expanded in time to a pulse waveform epoch (or waveform epoch) for the determination of magnitude and/or time reference lines. The reference lines determined by analysis of the pulse waveform (or waveform) are transferred to the transition waveform (or pulse waveform) for the determination of characteristics (see Figure 1, page 30).

In any waveform epoch expansion procedure, two or more sets of reference lines may exist, and the set of reference lines being used in any *pulse measurement process* shall be specified.

2.4.2 *Waveform epoch contraction*

A technique for the determination of the characteristics of individual pulse waveforms (or pulse waveform features) wherein the waveform epoch (or pulse waveform epoch) is contracted in time to a pulse waveform epoch (or transition waveform epoch) for the determination of time and/or magnitude characteristics (see Figure 1).

In any waveform epoch contraction procedure, two or more sets of time and/or magnitude reference lines may exist and the set of reference lines being used in any *pulse measurement process* shall be specified.

2.5 *Reference pulse waveforms*

A reference pulse waveform (see IEC Publication 469-1, Sub-clauses 2.4.1.3 and 2.8.1) may be specified by any of the *waveform formats* defined in Sub-clause 2.3. The characteristics of the devices, apparatus techniques, or algorithms used in producing or deriving a reference pulse waveform shall be specified.

2.5.1 *Defined reference pulse waveform*

A *reference pulse waveform* which is defined without reference to any practical or derived pulse waveform. Typically, a defined reference pulse waveform is an ideal pulse waveform.

2.5.2 *Derived reference pulse waveform*

A *reference pulse waveform* which is derived by a specified procedure or algorithm from the pulse waveform which is being analysed in a *pulse measurement process* (see Figure 2, page 31 for an example of a derived reference pulse waveform and its algorithm).

2.5.3 *Practical reference pulse waveform*

A *reference pulse waveform* which is derived from a pulse which is produced by a device or apparatus.

3. Measurement of pulse characteristics

3.1 *The distinction between waves and waveforms*

The distinction between waves, pulses and transitions and their respective waveforms is clearly drawn: the former are modifications of the physical state of a medium, or phenomena, while the latter are manifestations, respresentations, or visualizations of these phenomena (see IEC Publication 469-1, Sub-clauses 2.2 and 2.3.1).

Note. – Throughout the remainder of this standard, the terms "pulse" and "pulse waveform" are used in the following inclusive sense:

a) "pulse" and "pulse waveform" include "transition" and "transition waveform", respectively, and

b) in so far as is applicable, "pulse" and "pulse waveform" include "wave" and "waveform", respectively.

3.2 *Description of the pulse measurement process*

The object of any *pulse measurement process* is the determination, within some limits of error, either expressed or implied, of the magnitude of a characteristic, property or attribute of a pulse. Figure 3, page 31, shows the constituent steps of any *pulse measurement process* where, as indicated, the process involves two distinct sequential sub-processes:

a) pulse to pulse waveform conversion, and

b) pulse waveform analysis.

Thus, the *pulse measurement process* involves:

- the conversion of a pulse into its transform, its pulse waveform,
- analysis of the pulse waveform to determine the magnitude of a pulse waveform characteristic,
- the assertion or assumption, that the magnitude of the pulse waveform characteristic thus determined is, within some limits of *error,* identical to the magnitude of the pulse characteristic.

The validity of the final assertion or assumption is dependent on the combined validity of the first two steps.

The vast array of devices, apparatus, instruments and techniques which may be configured in virtually limitless combinations to provide pulse to pulse waveform conversion renders the discussion of specific implementations beyond the scope of this standard. Such discussion is deferred to other standards, recommendations, documents or specifications which describe or define the characteristics or methods concerned with specific devices, apparatus, instruments or techniques.

A state of statistical control shall be achieved before a *pulse measurement process* can be considered to be a realization of a *method of pulse measurement.*

3.3 *Pulse to pulse waveform conversion*

Item *a)* of Figure 3 shows the five basic operations – transduction, transmission, conversion, correction and storage – which, in some sense, are always present in pulse to pulse waveform conversion. The order in which these basic operations occur is not necessarily that shown in the figure and, frequently, an operation occurs more than once.

Three of the basic operations, transduction, transmission and conversion, involve apparatus or devices whose transfer functions must be known to limits of *error* consistent with the overall limits of *error* desired in the *pulse measurement process.* The determination of transfer functions is indicated in item *a)* of Figure 3 by the broken lines leading to auxiliary operations. In these auxiliary operations, which may be other *pulse measurement processes,* the transfer functions of the apparatus are:

a) adjusted to predetermined values, that is, the apparatus is calibrated, or

b) determined and retained for subsequent use in the correction operation.

Item *a)* of figure 3 also shows that the determination or adjustment of transfer functions entails comparison, either directly or indirectly, with basic or derived time and magnitude standards.

The following sub-clauses describe each of the five operations which are present in pulse to pulse waveform conversion.

3.3.1 *Transduction*

Pulses propagate in numerous modes in gases, liquids, solids, in vacuum and in networks made up of such media. In transduction, a device or apparatus abstracts energy from the medium in which the pulse propagates and converts the energy to a form suitable for transmission.

3.3.2 *Transmission*

Transmission may occur over signal paths which utilize radiative, electrical, hydraulic, pneumatic or mechanical phenomena or analogue to digital or digital to analogue conversion techniques.

3.3.3 *Conversion*

Typically, the conversion operation involves an instrument which relates its input signal to real or equivalent time.

Such an instrument may provide a display of the relationship of the input signal to time. Such displays frequently function as the storage operation (see Sub-clause 3.3.5). Display is not necessarily an attribute of the conversion operation.

3.3.4 *Correction*

The correction operation combines the results of the conversion operation with the transfer function information to yield a pulse waveform which is a more accurate transform of the pulse. Correction may be effected by *a)* a mental process by an operator, *b)* a computational process or *c)* a compensating device or apparatus. Correction shall be performed with limits of error which are consistent with the overall limits of error desired in the *pulse measurement process*.

3.3.5 *Storage*

Storage is a transitional operation between pulse to pulse waveform conversion and pulse waveform analysis. Storage may be effected in numerous ways and display is not required, but the stored data must be available or retrievable for pulse waveform analysis. Typically, storage is effected in one of the *waveform formats* defined in Sub-clause 2.3.

4. Pulse waveform analysis

4.1 *Generality of pulse waveform analysis*

Pulse waveform analysis has broad utility since, when it is combined with *waveform epoch expansion* and *contraction* or applied to waveforms which are produced by operations on pulse waveforms (see Publication 469-1, Sub-clause 5.5.1), its principles and techniques apply to:

a) transition waveform analysis,

b) analysis of complex waveforms,

c) analysis of the constituent pulse waveforms of a pulse train or pulse burst, and

d) analysis of the top and base envelopes of a pulse burst,