

ANSI/IEEE Std 390™-1987 (R2007)
(Revision of ANSI/IEEE Std 390-1975 and IEEE Std 391-1976)

An American National Standard

IEEE Standard for Pulse Transformers

Sponsor
**Electronics Transformer Technical Committee
of the
IEEE Magnetics Society**

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Foreword

(This Foreword is not a part of ANSI/IEEE Std 390-1987, IEEE Standard for Pulse Transformers.)

The purpose of this standard is to provide a common ground between electronic system engineers and pulse transformer design engineers.

This standard does not apply to transformers when used in a wire entrance facility to an electric power station. Neither is it intended to include low-power *switching-type* pulse transformers. These are covered in IEEE Std 272 1970, IEEE Standard for Computer-Type (Square-Loop) Pulse Transformers.

This standard pertains to pulse transformers that transmit peak power that averages from a few milliwatts to those that transmit peak power that averages in the kilowatts. Also, the voltage range is from a few peak volts to many peak kilovolts.

Initially, the impetus for developing pulse transformers of all types, came from the need for these devices in the radar used in World War II. The range of voltage and power of these types of transformers is still being increased as magnetrons, klystrons, and traveling wave and cross-field amplifier loads are developed for higher voltage and power. It is hoped that this standard will benefit the manufacturer and the user of these transformers.

This standard is a combination of two original standards: ANSI/IEEE Std 390-1975 and IEEE Std 391-1976. IEEE Std 391-1976 has been simultaneously withdrawn with the publication of this revision of ANSI/IEEE Std 390-1987. This standard was prepared under the Subcommittee Chairmanships of J. D. Schwartz and A. A. Toppeto, respectively, and the Working Group Chairmanships of W. J. Field and A. D. Hasley, respectively.

At the time this standard was approved the membership of the Working Group of the Pulse Transformer Subcommittee was as follows:

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An American National Standard

IEEE Standard for Pulse Transformers

1. Scope and References

1.1 Scope

This standard pertains to pulse transformers for use in electronic equipment. For the various types of these transformers, the peak power transmitted ranges from a few milliwatts to kilowatts; and the peak voltage transmitted ranges from a few volts to many kilovolts.

These transformers are required to transmit unipolar or bipolar pulses of voltage or current within specified tolerances of amplitude and time when operated between specified impedances. They are typically used as coupling devices in electronic circuits. In blocking oscillators, they are connected to provide positive feedback in the circuit. In radar or similar use, they are used to couple the modulator to a magnetron, a klystron, a traveling-wave tube or a cross-field amplifier load.

Whenever numerical values are indicated in this standard, they may be considered as recommended values. Section 6. describes the preferred transformer test methods and Appendix A contains alternate test methods.

1.2 References

This standard shall be used in conjunction with the following publications:

[1] ANSI/IEEE Std 100-1984, IEEE Standard Dictionary of Electrical and Electronics Terms.¹

[2] ANSI/IEEE Std 111-1984, IEEE Standard for Wide-Band Transformers.

[3] ANSI/IEEE Std 260-1978 (R 1985), IEEE Standard Letter Symbols for Units of Measurement (SI Units, Customary Inch-Pound Units and Certain Other Units).

[4] ANSI/IEEE Std 268-1982, American National Standard for Metric Practice.

[5] ANSI/IEEE Std 280-1985, IEEE Standard Letter Symbols for Quantities Used in Electrical Science and Electrical Engineering.

[6] ANSI/IEEE Std 315-1975 (CSA Z99-1975), IEEE Graphic Symbols for Electrical and Electronics Diagrams.

[7] ANSI/IEEE Std 315A-1986, IEEE Standard—Supplement to Graphic Symbols for Electrical and Electronics Diagrams.

¹ANSI/IEEE publications can be obtained from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, or from the Service Center, The Institute of Electrical and Electronics Engineers, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331.

- [8] ANSI/IEEE Std 455-1985, IEEE Standard Test Procedure for Measuring Longitudinal Balance of Telephone Equipment Operating in the Voice Band.
- [9] IEEE Std 119-1974, IEEE Recommended Practice for General Principles of Temperature Measurement as Applied to Electrical Apparatus.
- [10] IEEE Std 194-1977, IEEE Standard Pulse Terms and Definitions.
- [11] IEEE Std 272-1970 (R 1976), IEEE Standard for Computer-Type (Square-Loop) Pulse Transformers.
- [12] IEEE Std 389-1979, IEEE Recommended Practice for Testing Electronics Transformers and Inductors.
- [13] HENRY, D. A. and TOPPETO, A. A. Pulse Inductance — Problems and Peculiarities. *Electronic Components Conference*, 1972.
- [14] MUNK, P. R. and SARTORI, E. F. A Theoretical and Experimental Study of Transformer Balance. *IEEE Transactions on Parts, Materials, and Packaging*, vol PMP-4, no 1, March 1968, pp 12–21.

1.3 Typical Transformer Types to which this Standard Applies

This standard applies to the following transformer types:

- 1) Power output (drivers)
- 2) Impedance matching
- 3) Interstage coupling
- 4) Current sensing
- 5) Blocking-oscillator transformers

1.4 Related Transformer Standards

ANSI/IEEE Std 111-1984, IEEE Standard for Wide-Band Transformers.

IEEE Std 266-1969 (R 1981), IEEE Test Procedure for Evaluation of Insulation Systems for Electronics Power Transformers.

IEEE Std 272-1970 (R 1976), IEEE Standard for Computer-Type (Square-Loop) Pulse Transformers.

IEEE Std 306-1969 (R 1981), IEEE Test Procedure for Charging Inductors.

RS 176-1956, Pulse Transformers for Radar Equipment.²

RS 181-1957, Iron Core Charging Inductors.

2. Definitions

Electrical terms used in this standard shall be in accordance with those given in IEEE Std 194-1977 [10]³ and ANSI/IEEE Std 100-1984 [1]. In addition, a number of terms are defined in this section; however, ANSI/IEEE Std 100-1984 [1] shall take precedence in the case of any conflict.

²These publications can be obtained from the Sales Department, Electronic Industries Association, 2001 Eye St NW, Washington, DC 20006.

³The numbers in brackets correspond to those of the references in 1.2.

2.1 peak working voltage: The maximum instantaneous voltage stress that may appear under operation across the insulation being considered, including abnormal and transient conditions.

2.2 input pulse shape: Current pulse or source voltage pulse applied through associated impedance. The shape of the input pulse is described by a current- or voltage-time relationship and is defined with the aid of Fig 1 in accordance with the following definitions.

NOTE — A general amplitude quantity is designated by A , which may be current I or voltage V

2.2.1 pulse amplitude, A_M : That quantity determined by the intersection of a line passing through the points on the leading edge where the instantaneous value reaches 10% and 90% of A_M and a straight line that is the best least-squares fit to the pulse in the pulse-top region (usually this is fitted visually rather than numerically). For pulses deviating greatly from the ideal trapezoidal pulse shape, a number of successive approximations may be necessary to determine A_M .

NOTE — The pulse amplitude A_M may be arrived at by applying the following procedure.

Step 1: Visually or numerically determine the best straight line fit to the pulse in the pulse-top region and extend this straight line into the leading-edge region.

Step 2: An initial estimate of A_M is the first intersection of the pulse (in the late leading-edge or early pulse-top regions) with the straight line fitted to the pulse top.

Step 3: Using the estimated of A_M calculate $0.1 A_M$ and $0.9 A_M$ and draw a straight line through these two points of the pulse-leading edge.

Step 4: The intersection of the leading-edge straight line and the pulse top straight line gives an improved estimate of A_M

Step 5: Repeat Steps 3 and 4 until the estimate of A_m does not change. The converged estimate is the pulse amplitude A_M

2.2.2 rise time (first transition duration), t_r : The time interval of the leading edge between the instants at which the instantaneous value first reaches the specified lower and upper limits of 10% and 90% of A_M Limits. Other than 10% and 90% may be specified in special cases.

2.2.3 pulse duration (90%), t_p : The time interval between the instants at which the instantaneous value reaches 90% of A_M on the leading edge and 90% of A_T on the trailing edge.

NOTES:

1 — Often the input pulse tilt (droop) is only a few percentages, and in those cases pulse duration may be considered as the time interval between the first and last instants at which the instantaneous value reaches 90% of A_M

2 — Pulse duration may be specified at a value other than 90% A_M and A_T in special cases.

2.2.4 fall time (last transition duration), t_f : The time interval of the pulse trailing edge between the instants at which the instantaneous value first reaches specified upper and lower limits of 90% and 10% of A_T .

2.2.5 trailing edge (last transition) amplitude, A_T : That quantity determined by the intersection of a line passing through the points on the trailing edge where the instantaneous value reaches 90% and 10% of A_T , and the straight-line segment fitted to the top of the pulse in determining A_M .

2.2.6 tilt (droop), A_D : The difference between A_M and A_T . It is expressed in amplitude units or in percentage of A_M .

2.2.7 overshoot (first transition overshoot), A_{os} : The amount by which the first maximum occurring in the pulse-top region exceeds the straight-line segment fitted to the top of the pulse in determining A_M . It is expressed in amplitude units or as a percentage of A_M .

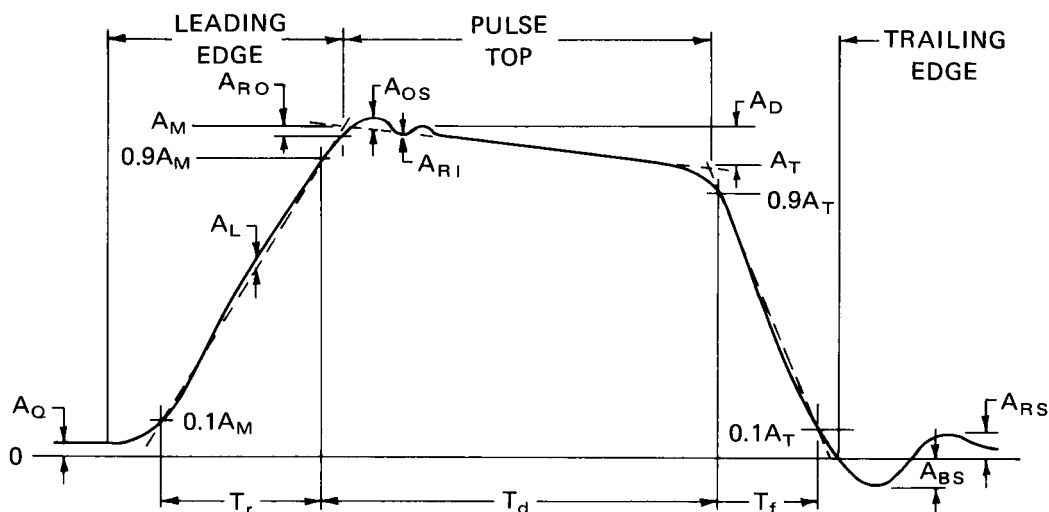


Figure 1—Input Pulse Shape

2.2.8 backswing (last transition overshoot), A_{BS} : The maximum amount by which the instantaneous pulse value is below the zero axis in the region following the fall time. It is expressed in amplitude units or as a percentage of A_M .

2.2.9 return swing (last transition ringing), A_{RS} : The maximum amount by which the instantaneous pulse value is below the zero axis in the region following the backswing. It is expressed in amplitude units or as a percentage of A_M .

2.2.10 rolloff (rounding after first transition), A_{RO} : The amount by which the instantaneous pulse value is less than A_M at the point in time of the intersection of straight-line segments used to determine A_M . It is expressed in amplitude units or as a percentage of A_M .

2.2.11 ringing (first transition ringing), A_{RI} : The maximum amount by which the instantaneous pulse value deviates from the straight-line segment fitted to the top of the pulse in determining A_M in the pulse top region following rolloff, or overshoot, or both. It is expressed in amplitude units or as a percentage of A_M .

2.2.12 leading edge (first transition) linearity, A_L : The maximum amount by which the instantaneous pulse value deviates during the rise time interval from a straight line intersecting the 10% and 90% A_M amplitude points used in determining rise time. It is expressed in amplitude units or as a percentage of 0.8 A_M .

2.2.13 quiescent value (base magnitude), A_Q : The maximum value existing between pulses.

2.2.14 leading edge (first transition): That portion of the pulse occurring between the time the instantaneous value first becomes greater than A_Q to the time of the intersection of straight-line segments used to determine A_M .

2.2.15 pulse top: That portion of the pulse occurring between the time of intersection of straight-line segments used to determine A_M and A_T .

2.2.16 trailing edge (last transition): That portion of the pulse occurring between the time of intersection of straight-line segments used to determine A_T and the time at which the instantaneous value reduces to zero.

2.3 output pulse shape: Load current pulse flowing in a winding or voltage pulse developed across a winding in response to application of an input pulse. The shape of the output pulse is described by a current- or voltage-time relationship. All of the preceding definitions of 2.2 for the **input pulse shape** apply to the **output pulse shape**. Typically, a prominent feature of the output pulse is an accentuated backswing (last transition overshoot), A_{BS} .

2.4 voltage-time product: The time integral of a voltage pulse applied to a transformer winding.

2.5 voltage-time product rating (of a transformer winding): Considered as being a constant and is the maximum voltage-time product of a voltage pulse that can be applied to the winding before a specified level of core saturation-region effects is reached. The level of core saturation-region effects is determined by observing either the shape of the output voltage pulse for a specified degradation (for example, a maximum tilt [droop]), or the shape of the exciting current pulse for a specified departure from linearity (for example, deviation from a linear ramp by a given percentage).

3. Symbols

Except where otherwise stated, the International System of Units (Système International d’Unites) will be used.

3.1 Pulse Transformer Schematics

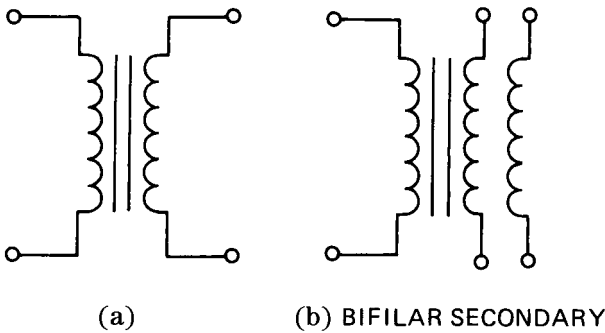


Figure 2—Pulse-Transformer Schematics

3.2 Input Pulse—Source Voltage Pulse Applied Through Associated Impedance or Source Current Pulse

The following terms are defined in Section 2.

Symbol	Term Denoted
I_M, V_M	pulse amplitude (A general amplitude quantity is designated by A, which may be current <i>I</i> or voltage <i>V</i>)
t_r	rise time (first transition duration) (10%–90% I_M or V_M unless otherwise specified)
t_f	fall time (last transition duration) (90%–10% I_T or V_T)
I_T, V_T	trailing edge (last transition) amplitude
t_p	pulse duration (90%–90% I_M or V_M)
I_Q, V_Q	quiescent value (interpulse) (base magnitude)
I_D, V_D	tilt (droop)
I_{os}, V_{os}	overshoot (first transition overshoot)
I_{RO}, V_{RO}	rolloff (rounding after first transition)
I_{RI}, V_{RI}	ringing (first transition ringing)
I_L, V_L	leading edge (first transition) linearity (10%–90% I_M or V_M)
I_{RS}, V_{RS}	return swing (last transition ringing)
I_{BS}, V_{BS}	backswing (last transition overshoot)

3.3 Output Pulse—Transformed Voltage Pulse or Load Current Pulse

The symbols of 3.2 are also used to describe the output pulse.

3.4 Source and Load Impedance

Symbol	Term Denoted
R_G	input pulse source resistance, series
L_G	input pulse source inductance, series
C_G	input pulse source capacitance, parallel
R_L	load resistance, series
L_L	load inductance, series
C_L	load capacitance, parallel

3.5 Transformer Parameters

These terms are described in Section 5.

Symbol	Term Denoted
a	transformer ratio. Where the coefficient of coupling is high, $a \approx N_2/N_1$
A_c	core cross-sectional area
B	magnetic flux density
C_{oc}	capacitive component of open-circuit admittance, shunt representation
C_{11}, C_{22}	equivalent self capacitance, winding indicated by subscripts
C_{12}	equivalent mutual capacitance between windings 1 and 2
C_D	distributed capacitance
G_{oc}	conductance component of open-circuit admittance, shunt representation
I_c	core-loss current
I_e	exciting current
I_L	load current
I_m	magnetizing current
k_f	fall time damping constant
k_r	rise time damping constant

Symbol	Term Denoted
L_{11}, L_{22}	self inductance of winding indicated by subscript
L_{11}, L_{21}	leakage inductance of winding designated by first subscript
L_m	magnetizing inductance
L_{oc}	inductive component of open-circuit impedance, shunt representation
L_{sc}	inductive component of short-circuit impedance, series representation
N_1	primary turns
N_2	secondary turns
R_{11}, R_{21}	resistance associated with leakage inductance, referred to winding indicated by first subscript
R_c	equivalent core-loss resistance, under pulse conditions shunt representation
R_{dc}	direct-current resistance of winding
R_{oc}	resistive component of open-circuit impedance, shunt representation
R_{sc}	resistive component of short-circuit impedance, series representation

4. Performance Tests

NOTE — In 4.1 through 4.3 the tests described are to determine the integrity of the transformer insulation. In 4.4 through 4.10 the tests are to control the pulse response. The tests in 4.11 and 4.12 are for additional control of pulse response in special cases. The test of 4.13 is to obtain design information for applications involving nonlinear core operation, or as an alternate or supplement to the pulse-response control tests when more direct control of pulse response is desired.

4.1 Electric Strength

This test applies to insulation between windings, between windings and core, and between windings and case.

NOTE — Transformer windings with graded insulation or windings internally or externally grounded or operated at direct voltages to ground with one terminal effectively at ground shall be tested by the induced voltage method (see 4.2).

The transformer shall withstand a sinusoidal test voltage applied for a period of one minute between each winding and all other windings and (when applicable) the core or case. The test frequency shall be 60 Hz or an alternative frequency agreed upon between the manufacturer and user (see 4.1.5).

The terminals of the winding under test shall be strapped together, and the terminals of all other windings shall be grounded and (when applicable) connected to the core or case.

4.1.1

Transformer windings operating at a peak working voltage below 25 V shall have a root-mean-square test voltage applied equal to twice the peak working voltage plus 15 V.