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IEEE Standard for High-Power Wide-Band Transformers (100 Watts and Above)

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(Revision of
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IEEE Standard for High-Power Wide-Band Transformers (100 Watts and Above)

Sponsor

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of the
IEEE Magnetics Society

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Foreword

[This Foreword is not part of IEEE Std 264-1977, Standard for High-Power Wide-Band Transformers (100 Watts and Above).]

Acknowledgement

The Institute wishes to acknowledge its indebtedness to those who have so freely given of their time and knowledge and have conducted experimental work on which many of the IEEE publications are based.

The major task of preparing this publication was carried on by the Working Group on High-Power Wide-Band Transformers of the Frequency Range Transformer Subcommittee of the Electronics Transformers Technical Committee of the IEEE Magnetics Society.

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IEEE Standard for High-Power Wide-Band Transformers (100 Watts and Above)

1. Scope

This publication pertains to wide-band transformers, transmitting power of equal to or more than 100 W[1]. Guides to application and test procedures are included. Appendices contain certain precautions and recommended practices. Provision is made for including data for use in the design of feedback amplifiers and control networks or other circuits in which knowledge of the transformer amplitude- and phase-frequency response is needed by the system designer. These transformers are required to transform voltage within specified tolerances of amplitude and phase when operating between specified impedances.

1.1 Specific types to which this standard applies.

1.1.1 *Power Audio-Frequency Transformers.* Operated from amplifier tube or transistor sources. The fundamental full power frequency range will normally fall within the band of 20–20 000 Hz. Performance characteristics one or more octaves beyond the specified range may be of interest and specified. Feedback windings or screen-grid windings or taps may be incorporated in the design. The use of Class A, Class AB, or Class B must be recognized and taken into consideration.

The performance of these transformers is generally expected to be uniform over the specified range and not be the cause of undue distortion of the input waveshape.

1.1.2 *Transducer Service Transformers.* Normally require a step-down ratio transformer having one or more secondary windings with or without taps. The load impedance may be permitted to vary with frequency, or with other parameters, but the transformer performance is generally based on a specific load impedance.

1.1.3 *Random-Noise Transformers.* Used in vibration machine applications. They are subject to random signals of varying amplitude and duration. Response may be expressed in terms of frequency spectrum but the amplitude variation allowable over the relevant frequency range is much greater than for audio-frequency transformers because of the Gaussian distribution of random noise. Random noise transformers are often included in feedback loops. When included in such a loop, their amplitude and phase response is of interest and all of the problems listed in 9.3 must be solved in addition to producing a transformer capable of handling the amplitude of random noise.

1.1.4 *Modulation Transformers.* Used in amplitude-modulated transmitters and may employ a modulation inductor to bypass the final amplifier plate current.

The transformer is used in a manner which makes it a part of a capacitance, resistance, and inductance network and it must have characteristics which permit it to match the network for proper overall system performance. Phase angle, frequency response, and impedances are important measurements and are required to be made in the actual or substitute network with major elements in place to establish performance. Modulation transformers are usually designed for specific applications and large units are not considered suitable for general-purpose use.

1.1.5 *Driver Transformers.* Used to supply power to the grids of Class AB_2 and Class B_2 amplifier tubes and to the base (control element) of transistors.

1.1.6 *Line-Matching Transformers.* Used

[1] Except in the cases of modulation transformers and inductors and driver transformers for class AB_2 and class B amplifiers where the power delivered may be less or equal to 100 W as well as above 100 W.

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where power is received at one impedance level and delivered at another.

1.1.7 *Load-Matching Autotransformers.* Used where power is received at one impedance level and provides output taps at various impedances, or vice versa.

1.1.8 *Control-System Transformers.* Used in open- or closed-loop (feedback) control systems. The transformers used in the closed-loop system are subject to signals of a definite carrier frequency, modulated in accordance with error signals imposed by the control system requirements. The response of these transformers to control signals may be expressed either in terms of frequency and phase or in Laplace terms. In this standard, the phase and amplitude frequency response concepts are used.

1.1.9 *Ultrasonic Frequency Transformers.* Used in various communication and industrial applications in which the lowest frequency is higher than 10 kHz.

1.1.10 *Carrier Frequency Transformers.* Transmit signals of specified frequency; which signals are modulated or varied in amplitude, frequency, or phase.

1.1.11 *Video Frequency Transformers.* Characterized by an exceptionally wide-band transmission characteristics over part or all of the range from 10 Hz to 10 MHz.

1.1.12 *Power Transistor Source Audio-Frequency and Driver Transformers.* Operated from solid-state power source devices. The use of Class AB_2 or Class B_2 current operation and their effect in the secondary winding must be recognized.

1.1.13 *Inductors (Reactors).* Used in wide-band circuits. The required degree of linearity and self-resonance must be specified.

1.2 Related Transformer Standards.

1.2.1 IEEE Std 111-1971, Low-Power Wide-Band Transformers.

1.2.2 IEEE Std 295-1969, Electronics Power Transformers.

1.2.3 IEEE Std 436-1977, Guide for Making Corona (Partial Discharge) Measurements on Electronics Transformers.

1.2.4 IEEE Std 266-1969, Test Procedure for Evaluation of Insulation Systems for Electronics Power Transformers.

1.2.5 IEEE Std 93-1968, Guide for Transformer Impulse Tests.

1.2.6 IEEE Transformer and Inductor Bibliography, 21 S 89, 1967.

1.2.7 IEEE Std 390-1975, Standard for Low-Power Pulse Transformers.

1.2.8 IEEE Std 391-1976, Standard for High-Power (>300 Watts Peak) Pulse Transformers.

1.2.9 IEEE Std 393-1977, Test Procedures for Magnetic Cores.

2. Definitions

Electrical terms used in this standard shall be in accordance with those given in IEEE Std 100-1972 (ANSI C42.100-1972), Dictionary of Electrical and Electronics Terms. In addition, other terms are defined below:

2.1 control system. A system in which a desired effect is achieved by operating on the various inputs to the system until the output, which is a measure of the desired effect, falls within an acceptable range of values.

2.2 open-loop control system. A system in which the controlled quantity is permitted to vary in accordance with the inherent characteristics of the control system and the controlled power apparatus for any given adjustment of the controller. See Ref [2].

2.3 closed-loop control system. A system in which the controlled quantity is measured and compared with a standard representing the desired performance. Any deviation from the standard is fed back into the control system in such sense that it will reduce the deviation of the controlled quantity from the standard. See Ref [2].

2.4 transfer function. The complex ratio of the output of the device to its input. It is also the combined phase and frequency responses.

3. References

[1] EIA (formerly RETMA) Std RS-1974, December 1956, Audio Transformers for Electronic Equipment.

[2] IEEE Std 100-1972 (ANSI C42.100-1972), Dictionary of Electrical and Electronics Terms.

[3] IEEE Std 150-1956 (ANSI C16.29-1957, Methods of Measurement of Gain, Amplification, Loss, Attenuation, and Amplitude-Frequency-Response on Audio Systems and Components.

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[16] IEEE Std 280-1968 (ANSI Y10.5-1968), Letter Symbols for Quantities Used in Electrical Science and Electrical Engineering.

[17] IEEE Std 393-1977, IEEE Standard for Test Procedures for Magnetic Cores.

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4. Symbols

Symbol	Term Denoted
a	Transformer ratio.
A, B, C, D	Bridge corner designation.
C_A, C_D	Capacitance connected to bridge corners A and D, respectively.
C_{AB}	Capacitance connected between bridge corners A and B.
C_p	Distributed capacitance of primary winding.
C_S	Distributed capacitance of secondary winding.
C_{sh}	Effective parallel capacitance.
e	Variable ac potential source.
E_O	Output potential.
E_I	Input potential.
f	Frequency.
f_1	Low-frequency 1 dB point.
f_2	High-frequency 1 dB point.
f_0	$=\sqrt{f_1 f_2}$ (mid-band frequency)
G_{AB}	Conductance connected between bridge corners A and B.
G_{sh}	Conductance, $1/R_{sh}$.
k	Coefficient of coupling $=\sqrt{1-\frac{Z_{1s}}{Z_{1o}}}$ $=\sqrt{1-\frac{Y_{1o}}{Y_{1s}}}$.
L_l	Leakage inductance.
L_{11}	Self-inductance; primary.
L_{22}	Self-inductance; secondary.
L_{12}, M	Mutual inductance; inductance common to primary and secondary.
L_{sh}	Shunt or parallel inductance.
L_{ser}	Series inductance.

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N_1, N_p	Primary turns.
N_2, N_s	Secondary turns.
Q	Quality factor, $= 2\pi f L_{ser}/R_{ser}$ or $R_{sh}/2\pi f L_{sh}$.
ρ	Reflection coefficient.
R_c	Core loss resistance.
R_p	Primary winding resistance.
R_S	Secondary winding resistance.
R_1, R_2, R_3, R_4	Terminating resistance.
R_A, R_B	Resistance connected to bridge corners A and B, respectively.
R_{AD}, R_{AB}, R_{BC}	Resistance connected between bridge corners A and D, A and B, B and C, respectively.
R_l	Leakage resistance.
R_L	Load resistance.
R_G	Source resistance.
R_{sh}	Shunt or parallel resistance.
R_{ser}	Series resistance.
t	Temperature of winding (hot).
t_1	Reference temperature.
t_0	Temperature of winding (ambient).
X_{ser}	Series reactance ($= 2\pi f L_{ser}$).
X_{sh}	Shunt or parallel reactance ($= 2\pi f L_{sh}$).
Y_{1O}	Open-circuit admittance; primary side.
Y_{2O}	Open-circuit admittance; secondary side.
Y_{1S}	Short-circuit admittance; primary side.
Y_{2S}	Short-circuit admittance; secondary side.
Z_L	Load impedance.
Z_G	Source impedance.
Z_0	Standard source impedance.
Z_{1O}	Open-circuit impedance; primary side.
Z_{2O}	Open-circuit impedance; secondary side.
Z_{1S}	Short-circuit impedance; primary side.
Z_{2S}	Short-circuit impedance; secondary side.

5. Performance Tests

5.1 Electrical Tests (Not Recorded). The following electrical tests should be made on all transformers, where practicable. The transformer terminals normally grounded in service should be grounded during these tests or connected as otherwise required or noted in following test description. The results of these need not be recorded.

5.1.1 Ratio of transformation (turns ratio).

5.1.2 Polarity.

5.1.3 *Electric Strength Tests.*

(1) Transformer windings operating above 25 PWV should have a 60 Hz rms test voltage equal to 1000 V plus 1.5 times the PWV applied between each winding and each other winding and the core and case (if the case is meant to be isolated from the core).

(2) For the transformer windings with PWV 25 V and below, the test applied should be 500 V rms at 60 Hz or an equivalent test.

(3) Test voltages should be increased gradually (at the rate of 2kV per second maximum) from zero to the specified value, maintained for a period of 1 min, and decreased to zero at the same rate.

(4) The connection for windings not under test should be specified so that unwarranted stresses will not occur during the electrical strength tests. Windings with relatively low working voltages to ground should be grounded during the test of other windings to prevent the lower voltage insulation from being damaged through capacitative coupling. The transformer or inductor windings internally or externally grounded, or operated at direct voltages to ground and having one terminal grounded through a capacitor network, should be tested by induced voltage methods or a combination of the direct-current electric strength test voltage on the terminals to which direct current is directly applied together with the induced voltage, as applicable, in lieu of the standard electric strength test.

5.1.4 *Induced Voltage.* An induced-voltage test is made at twice the maximum rated voltage, using a frequency of twice the minimum rated frequency or higher as agreed. In addition to this test, twice the rated direct voltage should be applied simultaneously for 70 s to the terminals normally connected to the direct voltage. This test should be performed as follows: the direct voltage (twice normal) should be first applied, then by means of exciting a suitable winding, the alternating voltage should be increased from zero to twice normal over a 5 s interval,[2] held for 60 s,

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