

IEEE Standard for Transformers and Inductors in Electronic Power Conversion Equipment

Sponsor
**Electronics Transformers Technical Committee
of the
IEEE Power Electronics Society**

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Abstract: Transformers of both the saturating and non saturating type are covered. The power transfer capability of the transformers and inductors covered range from the minimal (less than 1 W) to the multikilowatt level. The purpose is to provide a common basis for the engineers designing the transformers and inductors used in those activities. This standard does not cover apparatus used in equipment for high-voltage power conversion for distribution by electric utilities.

Keywords: Converter, inductor, transformer.

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Foreword

(This foreword is not a part of IEEE Std 388-1992, IEEE Standard for Transformers and Inductors in Electronic Power Conversion Equipment.)

The purpose of this standard is to provide a common understanding between the engineers designing electronic power conversion circuits and the engineers designing the transformers and inductors used in those circuits.

This standard pertains to magnetic apparatus that transform, store, and/or control electrical energy in the process of converting that energy from what is available from the power source to the voltage and current levels required by the load.

The power transfer capability of transformers and inductors covered by this standard ranges from the minimal (less than 1 W) to the multikilowatt level. This standard does not cover apparatus used in equipment for high-voltage power conversion for distribution by electric utilities.

It should be noted that the electronic power conversion field is evolving rapidly and that this standard may not include some configurations and nomenclature.

This publication was prepared by the Converter Transformers Working Group of the Power Transformer Subcommittee of the Electronics Transformers Technical Committee of the IEEE Power Electronics Society.

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IEEE Standard for Transformers and Inductors in Electronic Power Conversion Equipment

1. Scope

This standard pertains to transformers and inductors of both the saturating and nonsaturating type that are used in electronic power conversion equipment.

Power conversion equipment includes items known as inverters, converters, power conditioners, switching power supplies, switched mode power supplies, and the like. These items are mostly devices used to change dc power from one voltage to another, to change dc power to ac, and to change ac power of one frequency to another frequency. This equipment is best described as utilizing transistors, silicon controlled rectifiers (SCRs), or other similar devices that switch power on and off at a high rate in order to achieve the power conversion or regulation desired. Therefore, this standard covers the various transformers and inductors that are used in any of the above mentioned equipment or devices, except for transformers operated directly from the mains.

2. References

- [1] ANSI S1.4-1983, American National Standard Specification for Sound Level Meters.¹
- [2] IEEE C57.12.90-1987, IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers; and Guide for Short-Circuit Testing of Distribution and Power Transformers (ANSI).²
- [3] IEEE Std 4-1978, IEEE Standard Techniques for High Voltage Testing (ANSI).
- [4] IEEE Std 100-1988, IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).
- [5] IEEE Std 119-1974, IEEE Recommended Practice for General Principles of Temperature Measurement as Applied to Electrical Apparatus.³
- [6] IEEE Std 389-1990, IEEE Recommended Practice for Testing Electronic Transformers and Inductors (ANSI).
- [7] Chambers, D. "Designing High Power SCR Resonant Converters for Very High Frequency Operation," *Proceedings of Powercon 9*, Section F-2, pp. 1–12, July 1982.
- [8] Bloom, G. and Severns, R. "The Generalized Use of Integrated Magnetics in Switchmode Power Converters," Paper no. 84CH 2000-8, IEEE Power Electronics Conference, pp. 15–33, June 1984.

¹ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

²IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

³This standard has been withdrawn. A photocopy is available from the IEEE Service Center.

3. Definitions

All definitions, except as specifically covered in this section, are defined in IEEE Std 100-1988 [4]⁴.

converter. A machine or device for changing dc power to ac power, for changing ac power to dc power, or for changing from one frequency to another. This definition covers several different power conversion functions, each of which is known by a separate term, see *dc-dc converter*, *frequency converter*, *inverter*, and *rectifier*.

dc-dc converter. A machine, device, or system, typically combining the functions of inversion and rectification, for changing dc at one voltage to dc at a different voltage.

duty cycle. The ratio of the sum of all pulse durations to the total period during a specified period of continuous operation.

frequency converter. A machine, device, or system for changing ac at one frequency to ac at a different frequency.

inverter. A machine or device that changes dc power to ac power.

percent ripple. The ratio of the value of the ripple voltage to the value of the total voltage multiplied by 100.

rectifier. A machine or device that changes ac power to dc power.

ripple amplitude. The maximum value of the instantaneous difference between the average and instantaneous value of a pulsating unidirectional wave.

4. Circuits

4.1 Voltampere Ratings. The size and voltampere rating of a converter transformer is directly related to the type of circuit in which the transformer is used. It is desirable, therefore, that a specification clearly indicate the circuit connections as well as the duty cycle and ripple amplitude. The circuit topology will, therefore, facilitate calculation of the rms values of current and voltage in each winding of the transformer. The VA (voltampere) rating of the transformer can then be calculated as the average of the primary voltamperes and the secondary voltamperes.

4.1.1 Calculation of VA Rating. *Example:* Consider the converter circuit shown in Fig 3(b) (half bridge input, full wave center-tap output). Assume an ideal transformer (negligible losses), ideal diodes (zero volts forward drop), and an ideal inductor (negligible resistance). Also, assume that all windings will be designed for uniform current density.

Let output $V_{\text{out}} = 100$ V dc, load current (I_{load}) = 1 A, and output power = 100 W. Calculate transformer VA rating (defined as the equivalent power rating in a unity power factor circuit) as follows:

$$\text{VA of each half-secondary} = 100 \text{ V} \cdot .707 \text{ A rms} = 70.7 \text{ VA}$$

$$\text{VA of secondary} = 2 \cdot 70.7 = 141.4 \text{ VA}$$

⁴The numbers in brackets correspond to those of the references in Section 2.

VA of primary (neglecting losses) = 100 VA

$$\text{Rating of transformer} = \frac{141.4 + 100}{2} = 120.7 \text{ VA average}$$

Note that the use of this FWCT circuit, which furnishes 100 W of dc power, will require a core that is rated 121 VA. The size of the core can therefore be significantly larger than the core used in a unity power-factor circuit.

4.2 Circuit Topology. Circuits can be classified as either nonisolated converters (see Fig 1) or isolated converters (see Figs 2 and 3).

4.2.1 Nonisolated Converters. Nonisolated converters are characterized by the following terminology:

- (1) Buck, step-down [see Fig 1(a)]
- (2) Boost, step-up [see Fig 1(b)]
- (3) Flyback, either step-up or step-down [see Fig 1(c)]

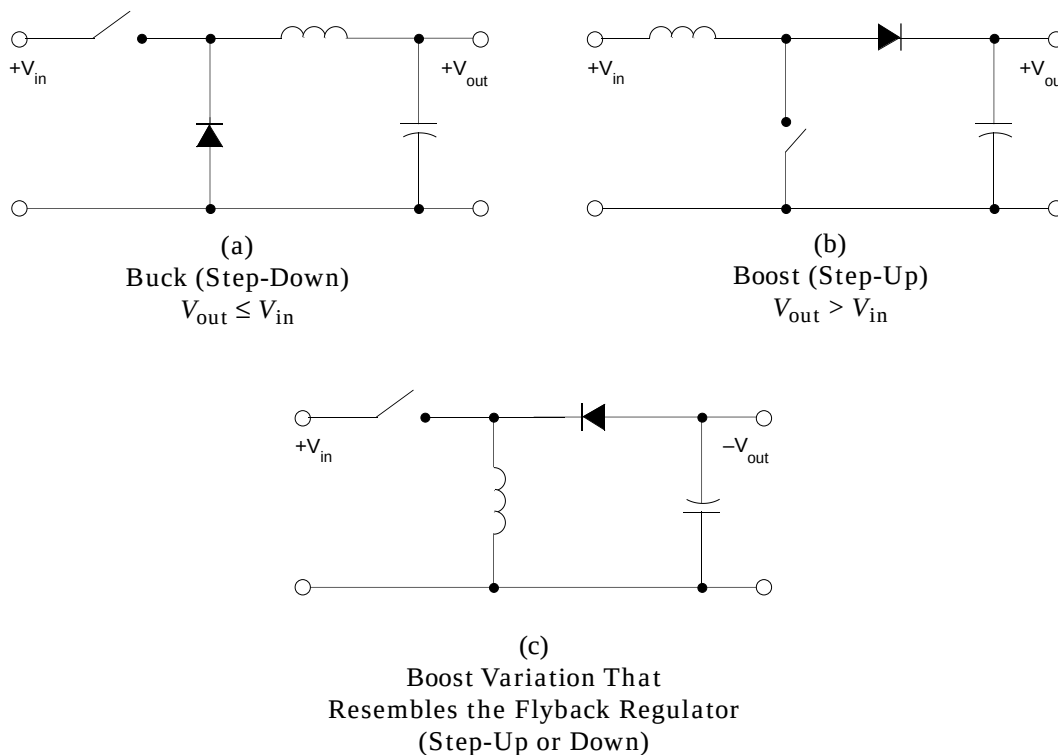


Fig 1
Nonisolated DC-DC Converters

4.2.2 Isolated Converters. Isolated converters can be characterized as either low-power or high-power circuits.