

IEEE Guide for the Application of Surge-Protective Components in Surge Protective Devices and Equipment Ports—Part 6 High Frequency Signal Isolation Transformers

IEEE Power and Energy Society

Sponsored by the
Surge Protective Devices Committee

IEEE Guide for the Application of Surge-Protective Components in Surge Protective Devices and Equipment Ports—Part 6 High Frequency Signal Isolation Transformers

Sponsor

**Surge Protective Devices Committee
of the
IEEE Power and Energy Society**

Approved 5 December 2018

IEEE-SA Standards Board

Abstract: Surge protective components (SPCs) used in power and telecom surge protective devices (SPDs) and equipment ports are covered in the IEEE C62.42 guide series. The following are covered in this part of the series on high-frequency signal isolation-transformer technology SPCs: component construction, characteristics, and ratings.

Keywords: characteristics, common-mode surge, differential-mode surge, Ethernet, high frequency, IEEE C62.42.6™, isolation transformer, PoE, ratings

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2019 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 12 April 2019. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent and Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

PDF: ISBN 978-1-5044-5345-5 STDPD23435
Print: ISBN 978-1-5044-5346-2 STDPD23435

IEEE prohibits discrimination, harassment, and bullying.

For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html>.

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading “Important Notices and Disclaimers Concerning IEEE Standards Documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/ipr/disclaimers.html>.

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (“IEEE-SA”) Standards Board. IEEE (“the Institute”) develops its standards through a consensus development process, approved by the American National Standards Institute (“ANSI”), which brings together volunteers representing varied viewpoints and interests to achieve the final product. IEEE Standards are documents developed through scientific, academic, and industry-based technical working groups. Volunteers in IEEE working groups are not necessarily members of the Institute and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

IEEE Standards do not guarantee or ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers and users of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. IEEE standards documents are supplied “AS IS” and “WITH ALL FAULTS.”

Use of an IEEE standard is wholly voluntary. The existence of an IEEE standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, or be relied upon as, a formal position of IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to comments or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854 USA

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

IEEE draft and approved standards are copyrighted by IEEE under US and international copyright laws. They are made available by IEEE and are adopted for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making these documents available for use and adoption by public authorities and private users, IEEE does not waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate fee, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. A current IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every 10 years. When a document is more than 10 years old and has not undergone a revision process, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE standard.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE Xplore at <http://ieeexplore.ieee.org/> or contact IEEE at the address listed previously. For more information about the IEEE-SA or IEEE's standards development process, visit the IEEE-SA Website at <http://standards.ieee.org>.

Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE-SA Website at the following URL: <http://standards.ieee.org/findstds/errata/index.html>. Users are encouraged to check this URL for errata periodically.

Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA Website at <http://standards.ieee.org/about/sasb/patcom/patents.html>. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Participants

At the time this IEEE guide was completed, the 3.6.3 Low Voltage Surge Protective Components Application Guide Working Group had the following membership:

Michael J. Maytum, *Chair*

Albert Martin, *Vice Chair*

Tim Ardley
Robert Ashton
Frank Basciano
Leonard Drewes

Ernest Gallo
Phillip Havens
Bogdan Klobassa

Peter Kobsa
Wolfgang Oertel
Thomas Tran
Bill Travis

The following members of the individual balloting committee voted on this guide. Balloters may have voted for approval, disapproval, or abstention.

Saleman Alibhay
Frank Basciano
William Bloethe
Kenneth Bow
Demetrio Bucaneg Jr.
William Bush
Paul Cardinal
Glenn Davis
Douglas Dorr
Jalal Gohari
Randall Groves
Raymond Hill

Werner Hoelzl
Philip Hopkinson
Richard Jackson
John John
Sheldon Kennedy
Doug Kramer
Wei-Jen Lee
Lawrenc Long
Albert Martin
Michael J. Maytum
R. Murphy

Arthur Neubauer
Wolfgang Oertel
Bansi Patel
Jim Phillips
Iulian Profir
Bartien Sayogo
Gary Smullin
David Tepen
James Timperley
Roger Verdolin
John Vergis
Matthew Wakeham

When the IEEE-SA Standards Board approved this guide on 5 December 2018, it had the following membership:

Jean-Phillipe Faure, *Chair*

Gary Hoffman, *Vice Chair*

John D. Kulick, *Past Chair*

Konstantinos Karachalios, *Secretary*

Ted Burse
Guido Hiertz
Christel Hunter
Joseph Koepfinger*
Thomas Koshy
Hung Ling
Dong Liu

Xiaohui Liu
Kevin Lu
Daleep Mohla
Andrew Myles
Paul Nikolich
Ron Petersen
Annette Reilly

Robby Robson
Dorothy Stanley
Mehmet Ulema
Phil Wennblom
Philip Winston
Howard Wolfman
Jingyi Zhou

*Member Emeritus

Introduction

This introduction is not part of IEEE Std C62.42.6-2018, IEEE Guide for the Application of Surge-Protective Components in Surge Protective Devices and Equipment Ports—Part 6 High Frequency Signal Isolation Transformers.

Failures of the Ethernet Local Area Network (LAN) ports have been attributed to use of inappropriate Surge Protective Devices (SPDs) and lack of insulation coordination, which caused the breakdown of transformers, associated wiring, and connectors. This guide discusses isolation-transformer parameters and how they influence the equipment common-mode and differential-mode surge performance. A copy of IEEE C62.69™, IEEE Standard for the Surge Parameters of Isolating Transformers Used in Networking Devices and Equipment is necessary to fully understand this document.¹

Dedication

This standard is dedicated to the memory of Phillip Havens, a great friend and contributor.

¹Information on references can be found in [Clause 2](#).

Contents

1. Overview	12
1.1 Scope	12
2. Normative references	12
3. Terms, definitions, acronyms, and abbreviations	13
3.1 Terms and definitions	13
3.2 Acronyms and abbreviations	14
4. Component construction	14
4.1 Transformer basics	14
4.2 Transformer parasitics	14
4.3 Transformer core saturation	15
4.4 High-frequency signal transformers	16
5. Characteristics	18
5.1 Measurement	18
5.2 Insulation resistance	19
5.3 Core saturation V-s value	20
5.4 Winding resistance	21
5.5 Saturated core secondary winding inductance	22
6. Ratings	23
6.1 Verification	23
6.2 Rated impulse voltage	23
6.3 Rated winding dc	24
7. Application examples	25
7.1 Transformer example	25
7.2 Common-mode surge	26
7.3 DC insulation resistance	29
7.4 Differential-mode primary winding surge	29
7.5 Rated impulse voltage	35
7.6 Rated winding dc	36
Annex A (informative) Bibliography	37
Annex B (informative) Secondary circuit parameter influence on secondary circuit current	39

List of Figures

Figure 1—Ideal transformer	14
Figure 2—Ideal transformer with winding leakage inductance, winding resistance and the actual primary self-inductance added	15
Figure 3—Transformer winding flux without a core in place	15
Figure 4—Transformer winding flux with a core in place	15
Figure 5—Winding inductance, L , versus winding magnetizing current I_{MAG}	16
Figure 6—Quadfililar wound center-tapped primary and secondary windings	17
Figure 7—Magnetic assembly circuits	17
Figure 8—Unpotted and potted magnetic assembly for one Ethernet port	18
Figure 9—Test circuit to measure the transformer inter-winding capacitance.....	18
Figure 10—Test circuit to measure the inter-winding capacitance of a transformer with an electric screen...	19
Figure 11—Test circuit to measure the insulation resistance of a transformer	19
Figure 12—Test circuit to measure the insulation resistance of a transformer with an electric screen.....	20
Figure 13—Test circuit to measure the transformer voltage-time product	20
Figure 14—Generator and transformer secondary voltage waveforms	21
Figure 15—Resistance measurement of a) secondary winding and b) primary winding	22
Figure 16—Test circuit for measuring secondary short-circuit current under surge conditions	22
Figure 17—Transformer rated impulse voltage test circuit	23
Figure 18—Rated impulse voltage test circuit for a transformer with an electric screen	24
Figure 19—Winding conductor temperature rise test circuit.....	25
Figure 20—Transformer circuit model.....	25
Figure 21—Capacitive currents.....	26
Figure 22—Smith termination voltages and current with two pairs connected	27
Figure 23—Smith termination voltages and current with four pairs connected.....	27
Figure 24—Secondary capacitive current for a 10 pF inter-winding capacitance	28
Figure 25—“Smith” termination discharge current caused by an 800 V switching voltage limiter	28
Figure 26—Inter-winding capacitance discharge current caused by an 800 V switching voltage limiter.....	29
Figure 27—Common-mode and differential-mode impulse generator configurations.....	30
Figure 28—Example waveform of transformer secondary winding differential surge let-through current	30
Figure 29—Effective secondary circuit for differential surge	31

Figure 30—Transformer primary magnetizing inductance voltage and current	31
Figure 31—Secondary current decay circuit after core saturation.....	32
Figure 32—Basic and enhanced secondary current levels.....	32
Figure 33—Generator and secondary currents for 1.2/50-8/20 and < 2/>10 generators	34
Figure 34—Comparison of secondary currents from three different configurations	35
Figure B.1—Equivalent secondary circuit during I_s current decay time	39
Figure B.2—Magnetizing inductance voltage and secondary current for 2.5 kV generator voltage, 10 ΩR_{LIM} and clamping voltage limiter.....	39
Figure B.3—Magnetizing inductance voltage and secondary current for 6 kV generator voltage, 10 ΩR_{LIM} and clamping voltage limiter.....	40
Figure B.4—Magnetizing inductance voltage and secondary current for 2.5 kV generator voltage, 0 ΩR_{LIM} and clamping voltage limiter.....	40
Figure B.5—Magnetizing inductance voltage and secondary current for 6 kV generator voltage, 0 ΩR_{LIM} and clamping voltage limiter.....	40
Figure B.6—Magnetizing inductance voltage and secondary current for 2.5 kV generator voltage, 10 ΩR_{LIM} and switching voltage limiter	40
Figure B.7—Magnetizing inductance voltage and secondary current for 6 kV generator voltage, 10 ΩR_{LIM} and switching voltage limiter	41
Figure B.8—Magnetizing inductance voltage and secondary current for 2.5 kV generator voltage, 0 ΩR_{LIM} and switching voltage limiter	41
Figure B.9—Magnetizing inductance voltage and secondary current for 6 kV generator voltage, 0 ΩR_{LIM} and switching voltage limiter	41

List of Tables

Table 1—Typical Figure 20 PoE transformer parameter values	26
Table 2—Impulse withstand test voltage for rated impulse voltage	35
Table B.1—Circuit parameters and waveform values	42

IEEE Guide for the Application of Surge-Protective Components in Surge Protective Devices and Equipment Ports—Part 6 High Frequency Signal Isolation Transformers

1. Overview

1.1 Scope

The IEEE C62.42™ guide series covers surge protective components (SPCs) used in power and telecom surge protective devices (SPDs) and equipment ports. This part on high-frequency signal isolation-transformer technology SPCs covers:

- Component construction
- Characteristics
- Ratings
- Application examples

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std C62.69™, IEEE Standard for the Surge Parameters of Isolating Transformers Used in Networking Devices and Equipment.^{2,3}

²The IEEE standards or products referred to in [Clause 2](#) are trademarks owned by The Institute of Electrical and Electronics Engineers, Incorporated.

³IEEE publications are available from The Institute of Electrical and Electronics Engineers (<http://standards.ieee.org/>).