

# INTERNATIONAL STANDARD

## NORME INTERNATIONALE



**Connectors for electrical and electronic equipment –  
Tests and measurements –  
Part 28-100: Signal integrity tests up to 2 000 MHz – Tests 28a to 28g**

**Connecteurs pour équipements électriques et électroniques –  
Essais et mesures –  
Partie 28-100: Essais d'intégrité des signaux jusqu'à 2 000 MHz – Essais  
28a à 28g**



## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2019 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Central Office  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland

Tel.: +41 22 919 02 11  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)

### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

#### IEC publications search - [webstore.iec.ch/advsearchform](http://webstore.iec.ch/advsearchform)

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

#### IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

#### IEC Customer Service Centre - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: [sales@iec.ch](mailto:sales@iec.ch).

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

#### IEC Glossary - [std.iec.ch/glossary](http://std.iec.ch/glossary)

67 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

### A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

### A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

#### Recherche de publications IEC - [webstore.iec.ch/advsearchform](http://webstore.iec.ch/advsearchform)

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

#### IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

#### Service Clients - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: [sales@iec.ch](mailto:sales@iec.ch).

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 000 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 16 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

#### Glossaire IEC - [std.iec.ch/glossary](http://std.iec.ch/glossary)

67 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

# INTERNATIONAL STANDARD

## NORME INTERNATIONALE



**Connectors for electrical and electronic equipment –  
Tests and measurements –  
Part 28-100: Signal integrity tests up to 2 000 MHz – Tests 28a to 28g**

**Connecteurs pour équipements électriques et électroniques –  
Essais et mesures –  
Partie 28-100: Essais d'intégrité des signaux jusqu'à 2 000 MHz – Essais  
28a à 28g**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

ICS 31.220.10

ISBN 978-2-8322-7590-0

**Warning! Make sure that you obtained this publication from an authorized distributor.  
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

## CONTENTS

FOREWORD .....	6
1 Scope .....	8
2 Normative references .....	8
3 Terms, definitions and abbreviated terms .....	10
3.1 Terms and definitions .....	10
3.2 Abbreviated terms .....	11
4 Overall test arrangement .....	11
4.1 General .....	11
4.2 Test instrumentation .....	11
4.2.1 General .....	11
4.2.2 Vector network analyser .....	11
4.2.3 RF switching unit .....	12
4.2.4 Reference loads and termination loads .....	12
4.3 Measurement precautions .....	12
4.4 Mixed mode S-parameter nomenclature .....	13
4.5 Coaxial cables and interconnect for network analyzers .....	14
4.6 Characteristic for switching matrices .....	14
4.7 Test fixture requirements .....	15
4.7.1 Test fixture types .....	15
4.8 Requirements for termination performance at calibration plane .....	15
4.9 Reference loads for calibration .....	15
4.10 Calibration .....	16
4.10.1 General .....	16
4.10.2 Calibration test interface .....	16
4.10.3 Calibration at end of coaxial test cables .....	16
4.11 Termination loads for termination of conductor pairs .....	17
4.11.1 General .....	17
4.11.2 Impedance matching resistor termination networks .....	17
4.12 Termination of sources .....	17
4.13 Test specimen and reference planes .....	18
4.13.1 General .....	18
4.13.2 Interconnections between device under test (DUT) and the calibration plane .....	18
4.14 Overall test setup requirements .....	20
5 Connector measurements up to 2 000 MHz .....	21
5.1 General .....	21
5.2 Insertion loss, test 28a .....	21
5.2.1 Object .....	21
5.2.2 Connecting hardware insertion loss .....	21
5.2.3 Test method .....	21
5.2.4 Test set-up .....	21
5.2.5 Procedure .....	21
5.2.6 Test report .....	22
5.2.7 Accuracy .....	22
5.3 Return loss, test 28b .....	22
5.3.1 Object .....	22

5.3.2	Connecting hardware return loss .....	22
5.3.3	Test method .....	22
5.3.4	Test set-up .....	23
5.3.5	Procedure.....	23
5.3.6	Test report.....	23
5.3.7	Accuracy .....	23
5.4	Near-end crosstalk (NEXT), test 28c .....	23
5.4.1	Object.....	23
5.4.2	Connecting hardware NEXT .....	23
5.4.3	Test method .....	24
5.4.4	Test set-up .....	24
5.4.5	Procedure.....	24
5.4.6	Test report.....	25
5.4.7	Accuracy .....	25
5.5	Far-end crosstalk (FEXT), test 28d .....	25
5.5.1	Object.....	25
5.5.2	Connecting hardware FEXT .....	25
5.5.3	Test method .....	25
5.5.4	Test set-up .....	25
5.5.5	Procedure.....	26
5.5.6	Test report.....	26
5.5.7	Accuracy .....	26
5.6	Transverse conversion loss (TCL), test 28f .....	27
5.6.1	Object.....	27
5.6.2	Connecting hardware TCL .....	27
5.6.3	Test method .....	27
5.6.4	Test set-up .....	27
5.6.5	Procedure.....	28
5.6.6	Test report.....	28
5.6.7	Accuracy .....	28
5.7	Transverse conversion transfer loss (TCTL), test 28g .....	28
5.7.1	Object.....	28
5.7.2	Connecting hardware TCTL .....	29
5.7.3	Test method .....	29
5.7.4	Test set-up .....	29
5.7.5	Procedure.....	29
5.7.6	Test report.....	29
5.7.7	Accuracy .....	30
5.8	Shield transfer impedance ( $Z_T$ ), test 26e .....	30
5.8.1	Object.....	30
5.8.2	Connecting hardware Transfer impedance ( $Z_T$ ).....	30
5.8.3	Test method .....	30
5.8.4	Test set-up .....	30
5.8.5	Procedure.....	30
5.8.6	Test report.....	31
5.8.7	Accuracy .....	31
5.9	Coupling attenuation ( $a_C$ ) .....	31
5.9.1	Object.....	31
5.9.2	Connecting hardware coupling attenuation ( $a_C$ ).....	31

5.9.3	Test method .....	31
5.9.4	Test set-up .....	31
5.9.5	Procedure.....	31
5.9.6	Test report.....	32
5.9.7	Accuracy .....	32
Annex A (informative) Derivation of mixed mode parameters using the modal decomposition technique .....		33
A.1	General.....	33
A.2	Example of a calculation .....	33
Annex B (normative) Indirect-reference test fixtures.....		36
B.1	General.....	36
B.2	Requirements .....	36
B.2.1	General requirements .....	36
B.2.2	Specific requirements .....	36
Annex C (normative) Direct-probe test fixtures.....		38
C.1	General.....	38
C.2	Requirements .....	38
C.2.1	General requirements .....	38
C.2.2	Specific requirements .....	38
Annex D (normative) Specialized test fixtures .....		40
D.1	General.....	40
D.2	Requirements .....	40
D.2.1	General requirements .....	40
D.2.2	Specific requirements .....	40
Annex E (informative) Symmetry verification of resistors used for calibration .....		41
Bibliography.....		44
Figure 1 – Diagram of a single ended 4-port device .....		13
Figure 2 – Diagram of a balanced 2-port device .....		13
Figure 3 – Calibration of reference loads .....		16
Figure 4 – Resistor termination networks .....		17
Figure 5 – Definition of reference planes.....		18
Figure 6 – Insertion loss and TCTL measurement .....		22
Figure 7 – NEXT measurement .....		24
Figure 8 – FEXT measurement .....		26
Figure 9 – Return loss and TCL measurement .....		27
Figure A.1 – Voltage and current on balanced DUT.....		33
Figure A.2 – Voltage and current on unbalanced DUT.....		34
Figure E.1 – Example of 50 Ω SMA termination comparison (1 MHz – 100 MHz).....		42
Figure E.2 – Comparison of phase selected and only magnitude selected terminations.....		42
Table 1 – Mixed mode S-parameter nomenclature .....		14
Table 2 – Switch performance requirements .....		14
Table 3 – Requirements for terminations at calibration plane .....		15
Table 4 – Interconnection DM return loss requirements.....		20
Table 5 – Overall test setup requirements .....		20

Table B.1 – IEC 60603-7 series, 8-pole connector types detail specifications and respective detail connector test procedures standards ..... 36

Table B.2 – Reference connector crosstalk (NEXT) vector ..... 37

Table C.1 – Direct-probe test fixture requirements ..... 38

Currently in preview, click buy full version

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**CONNECTORS FOR ELECTRICAL AND ELECTRONIC EQUIPMENT –  
TESTS AND MEASUREMENTS –****Part 28-100: Signal integrity tests up to 2 000 MHz –  
Tests 28a to 28g**

## FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization, comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, issue to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60512-28-100 has been prepared by subcommittee 48B: Electrical connectors, of IEC technical committee 48: Electrical connectors and mechanical structures for electrical and electronic equipment.

This second edition cancels and replaces the first edition, issued in 2013, and constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- The title is revised from 1 000 MHz to 2 000 MHz to reflect the range of frequencies which may be tested.
- All tables and requirements have been revised up to 2 000 MHz.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
48B/2756/FDIS	48B/2766/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

A list of all parts of IEC 60512 series, under the general title *Connectors for electrical and electronic equipment – Tests and measurements* can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

**IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.**

# CONNECTORS FOR ELECTRICAL AND ELECTRONIC EQUIPMENT – TESTS AND MEASUREMENTS –

## Part 28-100: Signal integrity tests up to 2 000 MHz – Tests 28a to 28g

### 1 Scope

This part of IEC 60512 specifies the test methods for signal integrity and transmission performance for connectors specified in respective parts of IEC 60603-7, IEC 61076-1, IEC 61076-2, and IEC 61076-3 standards for connecting hardware applications up to 2 000 MHz. It is also suitable for testing lower frequency connectors, however, the test methodology specified in the detail specification for any given connector remains the reference conformance test for that connector. The above list of connector series of standards does not preclude referencing this document in other connector manufacturer specifications or published standards.

Test procedures provided herein are:

- insertion loss, test 28a;
- return loss, test 28b;
- near-end crosstalk (NEXT) test 28c;
- far-end crosstalk (FEXT), test 28d;
- transverse conversion loss (TCL), test 28f;
- transverse conversion transfer loss (TCTL), test 28g.

Other test procedures referenced herein are:

- transfer impedance ( $Z_T$ ), see IEC 60512-26-100, test 26e.
- for coupling attenuation ( $a_C$ ), see IEC 62153-4-12.

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments), applies.

IEC 60050-581, *International Electrotechnical Vocabulary (IEV) – Part 581: Electromechanical components for electronic equipment*

IEC 60169-15, *Radio-frequency connectors – Part 15: R.F. coaxial connectors with inner diameter of outer conductor 4,13 mm (0.163 in) with screw coupling – Characteristic impedance 50 ohms (Type SMA)*

IEC 60512-1, *Connectors for electronic equipment – Tests and measurements – Part 1: Generic specification*

IEC 60512-26-100, *Connectors for electronic equipment – Tests and measurements – Part 26-100: Measurement setup, test and reference arrangement and measurements for connectors according to IEC 60603-7 – Tests 26a to 26g*