

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Semiconductor devices –

Part 9: Discrete devices – Insulated-gate bipolar transistors (IGBTs)

Dispositifs à semiconducteurs –

Partie 9: Dispositifs discrets – Transistors bipolaires à grille isolée (IGBT)



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
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

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 It also gives information on projects, replaced and withdrawn publications.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

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

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

Electropedia - 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

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

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

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

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

Electropedia - 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

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

Semiconductor devices –

Part 9: Discrete devices – Insulated-gate bipolar transistors (IGBTs)

Dispositifs à semiconducteurs –

Partie 9: Dispositifs discrets – Transistors bipolaires à grille isolée (IGBT)

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 31.080.01; 31.080.30

ISBN 978-2-8322-7530-6

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	7
1 Scope	9
2 Normative references	9
3 Terms and definitions	9
3.1 General terms	9
3.2 Terms related to ratings and characteristics, voltages and currents	10
3.3 Terms related to ratings and characteristics	13
4 Letter symbols	15
4.1 General	15
4.2 Graphical symbols	16
4.3 Additional general subscripts	16
4.4 List of letter symbols	16
4.4.1 Voltages	16
4.4.2 Currents	17
4.4.3 Other electrical magnitudes	17
4.4.4 Time	18
4.4.5 Thermal magnitudes	18
5 Essential ratings and characteristics	18
5.1 General	18
5.2 Ratings (limiting values)	18
5.2.1 General	18
5.2.2 Ambient or case or virtual junction operating temperature (T_a or T_c or T_{vj})	18
5.2.3 Storage temperature (T_{stg})	18
5.2.4 Collector-emitter voltage with gate-emitter short-circuited (V_{CES})	18
5.2.5 Gate-emitter voltage with collector-emitter short-circuit (V_{GES})	19
5.2.6 Continuous (direct) reverse voltage of a reverse-blocking IGBT (V_{R*})	19
5.2.7 Continuous (direct) collector current (I_C)	19
5.2.8 Repetitive peak collector current (I_{CRM})	19
5.2.9 Non-repetitive peak collector current (I_{CSM})	19
5.2.10 Continuous (direct) reverse-conducting current of a reverse-conducting IGBT (I_{RC})	19
5.2.11 Repetitive peak reverse-conducting current of a reverse-conducting IGBT (I_{RCRM})	19
5.2.12 Non-repetitive peak reverse-conducting current of a reverse-conducting IGBT (I_{RCSM})	19
5.2.13 Total power dissipation (P_{tot})	19
5.2.14 Maximum forward biased safe operating area (FBSOA) (where appropriate)	19
5.2.15 Maximum reverse biased safe operating area (RBSOA)	19
5.2.16 Maximum short-circuit safe operating area (SCSOA)	20
5.2.17 Maximum terminal current (I_{tRMS}) (where appropriate)	20
5.2.18 Mounting force (F)	20
5.2.19 Mounting torque (M)	20
5.3 Characteristics	20
5.3.1 General	20
5.3.2 Collector-emitter breakdown voltage ($V_{(BR)CES}$) (where appropriate)	20

5.3.3	Collector-emitter sustaining voltage ($V_{CE^{*}sus}$) (where appropriate).....	20
5.3.4	Collector-emitter saturation voltage (V_{CEsat})	20
5.3.5	Gate-emitter threshold voltage ($V_{GE(th)}$).....	20
5.3.6	Reverse-conducting voltage of a reverse-conducting IGBT (V_{RC}).....	20
5.3.7	Collector-emitter cut-off current ($I_{CE^{*}}$)	20
5.3.8	Gate leakage current (I_{GES})	20
5.3.9	Reverse current of a reverse-blocking IGBT ($I_{R^{*}}$)	21
5.3.10	Capacitances.....	21
5.3.11	Gate charge (Q_G)	21
5.3.12	Internal gate resistance (r_g)	21
5.3.13	Switching characteristics	21
5.3.14	Thermal resistance junction to case ($R_{th(j-c)}$)	22
5.3.15	Thermal resistance junction to ambient ($R_{th(j-a)}$).....	22
5.3.16	Transient thermal impedance junction to case ($Z_{th(j-c)}$).....	22
5.3.17	Transient thermal impedance junction to ambient ($Z_{th(j-a)}$).....	23
6	Measuring methods	23
6.1	General.....	23
6.2	Verification of ratings (limiting values).....	23
6.2.1	General	23
6.2.2	Collector-emitter voltages (V_{CES} , V_{CER} , V_{CEX})	23
6.2.3	Reverse voltage of a reverse-blocking IGBT (V_{RS} , V_{RX}).....	24
6.2.4	Gate-emitter voltage with collector-emitter short-circuit ($\pm V_{GES}$)	25
6.2.5	Continuous (direct) collector current (I_C)	26
6.2.6	Maximum peak collector current (I_{CRM} and I_{CSM}).....	27
6.2.7	Continuous (direct) reverse-conducting current of a reverse-conducting IGBT (I_{RC})	28
6.2.8	Maximum peak reverse-conducting current of a reverse-conducting IGBT (I_{RCRM} and I_{RCSM})	29
6.2.9	Maximum reverse biased safe operating area (RBSOA).....	30
6.2.10	Maximum short-circuit safe operating area (SCSOA)	32
6.3	Methods of measurement.....	35
6.3.1	Collector-emitter saturation voltage (V_{CEsat})	35
6.3.2	Gate-emitter threshold voltage ($V_{GE(th)}$).....	36
6.3.3	Reverse-conducting voltage of a reverse-conducting IGBT (V_{RC}).....	36
6.3.4	Collector cut-off current (I_{CES} , I_{CER} , I_{CEX})	37
6.3.5	Gate leakage current (I_{GES})	38
6.3.6	Reverse current of a reverse-blocking IGBT (I_{RS} , I_{RX})	39
6.3.7	Input capacitance (C_{ies})	40
6.3.8	Output capacitance (C_{oes})	41
6.3.9	Reverse transfer capacitance (C_{res}).....	43
6.3.10	Gate charge (Q_G)	43
6.3.11	Internal gate resistance (r_g)	45
6.3.12	Turn-on times ($t_{d(on)}$, t_r , t_{on}) and turn-on energy (E_{on}).....	46
6.3.13	Turn-off times ($t_{d(off)}$, t_f , t_{off} , t_z) and turn-off energy (E_{off}).....	48
6.3.14	Peak reverse recovery current (I_{rrm}), reverse recovery time (t_{rr}), reverse recovery energy (E_{rr}) and reverse recovered charge (Q_{rr}) of a reverse-blocking IGBT	49
6.3.15	Peak forward recovery current (I_{frm}), forward recovery time (t_{fr}), forward recovery energy (E_{fr}) and forward recovered charge (Q_{fr}) of a reverse-conducting IGBT	52

6.3.16	Thermal resistance junction to case ($R_{th(j-c)}$) and transient thermal impedance junction to case ($Z_{th(j-c)}$)	54
7	Acceptance and reliability	60
7.1	General requirements	60
7.2	Specific requirements	60
7.2.1	List of endurance and reliability tests	60
7.2.2	Conditions for endurance and reliability tests	60
7.2.3	Acceptance-defining characteristics and criteria for endurance and reliability tests	60
7.2.4	Procedure in case of a testing error	61
7.2.5	Endurance and reliability tests and test methods	61
7.3	Type tests and routine tests	64
7.3.1	Type tests	64
7.3.2	Routine tests	65
Annex A	(normative) Measuring method for collector-emitter breakdown voltage	66
A.1	General	66
A.2	Purpose	66
A.3	Circuit diagram	66
A.4	Measurement procedure	66
A.5	Specified conditions	67
Annex B	(normative) Measuring method for collector-emitter sustaining voltage	68
B.1	General	68
B.2	Purpose	68
B.3	Circuit diagram	68
B.4	Circuit description and requirements	68
B.5	Measurement procedure	69
B.6	Precautions to be observed	69
B.7	Requirements	69
B.8	Specified conditions	70
Annex C	(normative) Measuring method for inductive load turn-off current under specified conditions	71
C.1	General	71
C.2	Purpose	71
C.3	Circuit diagram and waveforms	71
C.4	Circuit description and requirements	72
C.5	Measurement procedure	72
C.6	Specified conditions	72
Annex D	(normative) Forward biased safe operating area (FBSOA)	73
D.1	General	73
D.2	Purpose	73
D.3	Method 1	73
D.3.1	General	73
D.3.2	Circuit diagram	73
D.3.3	Test procedure	74
D.3.4	Specified conditions	75
D.4	Method 2	75
D.4.1	General	75
D.4.2	Circuit diagram	75
D.4.3	Test procedure and precautions to be taken	76

D.4.4 Specified conditions.....	77
Bibliography.....	78
Figure 1 – Graphical symbols.....	16
Figure 2 – Circuit for testing the collector-emitter voltages V_{CES} , V_{CER} , V_{CEX}	24
Figure 3 – Circuit for testing the reverse voltages V_{RS} , V_{RX}	25
Figure 4 – Circuit for testing the gate-emitter voltage $\pm V_{GES}$	26
Figure 5 – Circuit for testing collector current.....	27
Figure 6 – Circuit for testing peak collector current	28
Figure 7 – Circuit for testing reverse-conducting current	28
Figure 8 – Circuit for testing peak reverse-conducting current.....	29
Figure 9 – Circuit for testing reverse biased safe operating area (RBSOA)	30
Figure 10 – Waveforms of gate-emitter voltage V_{GE} and collector current I_C during turn-off.....	31
Figure 11 – Circuit for testing safe operating pulse width at load short-circuit (SCSOA1)	32
Figure 12 – Waveforms of gate-emitter voltage V_{GE} , collector current I_C and collector-emitter voltage V_{CE} during load short-circuit condition SCSOA1.....	32
Figure 13 – Circuit for testing short-circuit safe operating area 2 (SCSOA2)	33
Figure 14 – Waveforms during SCSOA2	34
Figure 15 – Circuit for measuring the collector-emitter saturation voltage V_{CEsat}	35
Figure 16 – Circuit for measuring the gate-emitter threshold voltage.....	36
Figure 17 – Circuit for measuring the reverse-conducting voltage V_{RC}	37
Figure 18 – Circuit for measuring the collector cut-off current	38
Figure 19 – Circuit for measuring the gate leakage current	39
Figure 20 – Circuit for measuring the reverse current.....	40
Figure 21 – Circuit for measuring the input capacitance.....	41
Figure 22 – Circuit for measuring the output capacitance.....	42
Figure 23 – Circuit for measuring the reverse transfer capacitance	43
Figure 24 – Circuit for measuring the gate charge.....	44
Figure 25 – Basic gate charge waveform	44
Figure 26 – Circuit for measuring the internal gate resistance.....	45
Figure 27 – Circuit for measuring turn-on times and energy	46
Figure 28 – Waveforms during turn-on times.....	47
Figure 29 – Circuit for measuring turn-off times and energy	48
Figure 30 – Waveforms during turn-off times.....	48
Figure 31 – Circuit for measuring reverse recovery characteristics.....	50
Figure 32 – Waveforms during reverse recovery	50
Figure 33 – Circuit for measuring forward recovery characteristics.....	52
Figure 34 – Waveforms during forward recovery	53
Figure 35 – Circuit for measuring the variation with temperature of the collector-emitter voltage V_{CE} at a low measuring current I_{C1} and for heating up the IGBT by a high current I_{C2}	55
Figure 36 – Typical variation of the collector-emitter voltage V_{CE} at a low measuring current I_{C1} with the case temperature T_C (when heated from outside, i.e. $T_C = T_{vj}$)	56
Figure 37 – I_C , V_{CE} and T_C with time.....	57

Figure 38 – Circuit for measuring thermal resistance and transient thermal impedance: Method 2	58
Figure 39 – Typical variation of the gate-emitter threshold voltage $V_{GE(th)}$ at a low measuring current I_{C1} with the case temperature T_C (when heated from the outside, i.e. $T_C = T_{vj}$)	59
Figure 40 – I_C , V_{GE} and T_C with time	60
Figure 41 – Circuit for high-temperature blockings	62
Figure 42 – Circuit for high-temperature gate bias	63
Figure 43 – Circuit for intermittent operating life	64
Figure 44 – Expected number of cycles versus temperature rise ΔT_{vj}	64
Figure A.1 – Circuit for measuring the collector-emitter breakdown voltage.....	66
Figure B.1 – Circuit for measuring the collector-emitter sustaining voltage V_{CE*sus}	68
Figure B.2 – Operating locus of the collector current.....	69
Figure C.1 – Circuit for measuring inductive load turn-off current.....	71
Figure C.2 – Waveforms of collector current I_C and collector voltage V_{CE} during turn-off	72
Figure D.1 – Circuit for testing forward biased safe operating area (method 1)	73
Figure D.2 – Typical ΔV_{CE} versus collector-emitter voltage V_{CE} characteristics	74
Figure D.3 – Typical forward biased safe operating area.....	75
Figure D.4 – Circuit for testing forward biased safe operating area (method 2)	76
Figure D.5 – Latching mode operation waveforms.....	76
Figure D.6 – Latching mode I-V characteristics	76
Table 1 – Acceptance defining characteristics.....	23
Table 2 – Acceptance-defining characteristics for endurance and reliability tests.....	61
Table 3 – Minimum type and routine tests for IGBTs when applicable	65

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR DEVICES –

Part 9: Discrete devices – Insulated-gate bipolar transistors (IGBTs)

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, access 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 60747-9 has been prepared by subcommittee 47E: Discrete semiconductor devices, of IEC technical committee 47: Semiconductor devices.

This third edition cancels and replaces the second edition published in 2007. This edition constitutes a technical revision.

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

- a) reverse-blocking IGBT and its related technical contents have been added;
- b) reverse-conducting IGBT and its related technical contents have been added;
- c) some parts of the previous edition have been amended, combined or deleted.

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

FDIS	Report on voting
47E/675/FDIS	47E/684/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.

A list of all parts in the IEC 60747 series, published under the general title: *Semiconductor devices*, 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.

SEMICONDUCTOR DEVICES –

Part 9: Discrete devices – Insulated-gate bipolar transistors (IGBTs)

1 Scope

This part of IEC 60747 specifies product specific standards for terminology, letter symbols, essential ratings and characteristics, verification of ratings and methods of measurement for insulated-gate bipolar transistors (IGBTs).

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 60747-1:2006, *Semiconductor devices – Part 1: General*
IEC 60747-1:2006/AMD1:2010

IEC 61340 (all parts), *Electrostatics*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 General terms

3.1.1

insulated-gate bipolar transistor IGBT

transistor having a conductive channel and one PN junction in the forward direction and another PN junction in the reverse direction, the current flowing through the channel and the junction being controlled by an electric field resulting from a voltage applied between the gate and emitter terminals

Note 1 to entry: With collector-emitter voltage applied, the collector side PN junction is forward biased.

Note 2 to entry: This note applies to the French language only.

3.1.2

N-channel IGBT

IGBT that has one or more N-type conduction channels

[SOURCE: IEC 60050-521:2002, 521-04-56, modified – reworded for IGBT.]