

Semiconductor devices — Discrete devices —

Part 9: Insulated-gate bipolar transistors (IGBTs)

ICS 31.080.30

National foreword

This British Standard reproduces verbatim IEC 60747-9:1998 Edition 1.1, which comprises the first edition consolidated by amendment 1:2001 published by the International Electrotechnical Commission (IEC), and implements it as the UK national standard.

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**Part 9:
Insulated-gate bipolar transistors (IGBTs)**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR DEVICES – DISCRETE DEVICES –**Part 9: Insulated-gate bipolar transistors (IGBTs)**

FOREWORD

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

This consolidated version of IEC 60747-9 is based on the first edition (1998) [documents 47E/109/FDIS and 47E/115/RVD] and its amendment 1 (2001) [documents 47E/194/FDIS and 47E/198/RVD].

It bears the edition number 1.1.

A vertical line in the margin shows where the base publication has been modified by amendment 1.

This standard is to be read in conjunction with IEC 60747-1.

Annexes A, B and C form an integral part of this standard.

Annex D is for information only.

The committee has decided that the contents of this publication will remain unchanged until 2002. At this date, the publication will be

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- withdrawn;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

INTRODUCTION

IGBTs are in use exclusively in power switching applications. Their use for proportional amplification is not provided because the collector current rises with temperature at constant gate voltage which would cause thermal runaway in this application. In switching applications the collector current during the on-state intervals is given by the supply voltage and the load characteristic, and the stress on the IGBT is controlled by the pulse duration and repetition frequency.

In IEC 60747-1 the user will find all basic information on:

- terminology;
- letter symbols;
- essential ratings and characteristics;
- measuring methods;
- acceptance and reliability;
- electrostatic-sensitive devices.

SEMICONDUCTOR DEVICES – DISCRETE DEVICES –

Part 9: Insulated-gate bipolar transistors (IGBTs)

1 Scope

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

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 60747. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 60747 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60617-5:1996, *Graphical symbols for diagrams – Part 5: Semiconductors and electron tubes*

IEC 60747-1:1983, *Semiconductor devices – Discrete devices and integrated circuits – Part 1: General*

IEC 60747-2:1983, *Semiconductor devices – Discrete devices and integrated circuits – Part 2: Rectifier diodes*

IEC 60747-7:2000, *Semiconductor discrete devices and integrated circuits – Part 7: Bipolar transistors*

3 Definitions

For the purpose of this standard, the following definitions apply.

3.1 General terms

3.1.1

insulated-gate bipolar transistor (IGBT)

transistor provided for power switching having a conduction channel and a PN junction and in which the current flowing through the channel and the junction is controlled by an electric field resulting from a voltage applied between the gate and emitter terminals

NOTE With collector-emitter voltage applied the PN junction is forward biased.

3.1.2

N-channel IGBT

IGBT that has one or more N-type conduction channels

3.1.3**P-channel IGBT**

IGBT that has one or more P-type conduction channels

3.1.4**collector current (I_C) (of an IGBT)**

direct current that is switched (controlled) by the IGBT

3.1.5**collector terminal, collector (C) (of an IGBT)**

for an N-channel (a P-channel) IGBT the terminal to (from) which the collector current flows from (to) the external circuit

3.1.6**emitter terminal, emitter (E) (of an IGBT)**

for an N-channel (a P-channel) IGBT the terminal from (to) which the collector current flows to (from) the external circuit

3.1.7**gate terminal, gate (G) (of an IGBT)**

terminal to which a voltage is applied against the emitter terminal in order to control the collector current

3.2 Terms related to ratings and characteristics; voltages and currents

3.2.1**collector (-emitter) breakdown voltage ($V_{(BR)CES}$)**

voltage between collector and emitter above which the collector current rises steeply, with gate to emitter short-circuited

3.2.2**collector (-emitter) saturation voltage (V_{CEsat})**

collector-emitter voltage under conditions of gate-emitter voltage at which the collector current is essentially independent of the gate-emitter voltage

3.2.3**(gate-emitter) threshold voltage ($V_{GE(TO)}$)**

gate-emitter voltage at which the collector current has a specified low (absolute) value

3.2.4**collector (-emitter) cut-off current (I_{CES})**

collector current at a specified collector-emitter voltage below the breakdown region and with gate to emitter short-circuited

3.2.5**gate leakage current (I_{GES})**

leakage current into the gate terminal at a specified gate-emitter voltage with the collector terminal short-circuited to the emitter terminal

3.2.6

tail current (I_{CZ})

collector current during the tail time

3.2.7

collector(-emitter) voltage with gate-emitter short-circuited (V_{CES})

collector-emitter voltage at which the collector current has a specified low (absolute) value with gate-emitter short-circuited

3.2.8

collector-emitter sustaining voltage ($V_{CE^{*}sus}$)

collector-emitter breakdown voltage at relatively high values of collector current where the breakdown voltage is relatively insensitive to changes in collector current, for a specified termination between gate and emitter terminals

NOTE 1 The specified termination between gate and emitter terminals is indicated in the letter symbol by the third subscript '**'; see 4.1.2 of IEC 60747-7.

NOTE 2 When necessary, a suitable qualifier is added to the basic term to indicate a specific termination between gate and emitter terminals.

Example: Collector-emitter sustaining voltage with gate and emitter terminals short-circuited V_{CESsus} .

NOTE 3 The basic term may be shortened if the meaning is clear from the letter symbol used.

Example: Collector-emitter sustaining voltage V_{CERsus} .

NOTE 4 This term is important for high-voltage devices, for example more than 4 kV.

3.2.9

electrostatic discharge voltage

Under consideration.

3.3 Terms related to ratings and characteristics; other characteristics

3.3.1

input capacitance (C_{ies})

capacitance between the gate and emitter terminals with the collector terminal short-circuited to the emitter terminal for a.c

3.3.2

output capacitance (C_{oes})

capacitance between the collector and emitter terminals with the gate terminal short-circuited to the emitter terminal for a.c

3.3.3

reverse transfer capacitance (C_{res})

capacitance between the collector and gate terminals with the emitter terminal short-circuited to the gate terminal for a.c

3.3.4

gate charge (Q_{ge})

charge required to raise the gate-emitter voltage from zero to a specified value

3.3.5**turn-on delay time ($t_{d(on)}$, t_d)**

time interval between the beginning of a voltage pulse across the input terminals which switches the IGBT from the off-state to the on-state and the beginning of the rise of the collector current

NOTE Usually the time is measured between points corresponding to 10 % of the input and output pulse amplitudes.

3.3.6**rise time (t_r)**

time interval between the instants at which the rise of the collector current reaches specified lower and upper limits, respectively, when the IGBT is being switched from the off-state to the on-state

NOTE Usually the lower and upper limits are 10 % and 90 % of the pulse amplitude.

3.3.7**turn-on time (t_{on})**

sum of the turn-on delay time and the rise time

3.3.8**turn-off delay time ($t_{d(off)}$, t_s)**

time interval between the end of the voltage pulse across the input terminals which has held the IGBT in its on-state and the beginning of the fall of the collector current when the IGBT is switched from the on-state to the off-state

NOTE Usually the time is measured between points corresponding to 90 % of the input and output pulse amplitudes.

3.3.9**fall time (t_f)**

time interval between the instants at which the fall of the collector current reaches specified upper and lower limits, respectively, when the IGBT is switched from the on-state to the off-state

NOTE Usually the upper and lower limits are 90 % and 10 % of the pulse amplitude.

3.3.10**turn-off time (t_{off})**

sum of the turn-off delay time and the fall time

3.3.11**tail time (t_z)**

time interval from the end of the turn-off time to the instant at which the collector current has fallen to a specified very low value

NOTE Usually the tail time is measured between points corresponding to 10 % and 2 % of the on-state collector current.

3.3.12**turn-on energy (per pulse) (E_{on})**

energy produced inside the IGBT during the turn-on time of a single collector current pulse

NOTE The corresponding turn-on power dissipation under periodic pulse conditions is obtained by multiplying E_{on} by the pulse frequency.

3.3.13**turn-off energy (per pulse) (E_{off})**

energy produced inside the IGBT during the turn-off time plus the tail time of a single collector current pulse

NOTE The corresponding turn-off power dissipation under periodic pulse conditions is obtained by multiplying E_{off} by the pulse frequency.

4 Letter symbols**4.1 General**

Clauses 2, 3 and 4 of IEC 60747-1, chapter V, apply.

4.2 Additional general subscripts

C,c collector

E,e emitter

G,g gate

sat saturation

(TO) threshold

Z,z tail

4.3 List of letter symbols**4.3.1 Voltages**

Collector-emitter voltage	V_{CE}
Collector-emitter voltage, gate-emitter short-circuited	V_{CES}
Collector-emitter saturation voltage	V_{CEsat}
Collector-emitter sustaining voltage	$V_{\text{CE}^*\text{sus}}$
Electrostatic discharge voltage: letter symbols are under consideration	
Collector-emitter breakdown voltage, gate-emitter short-circuited	$V_{(\text{BR})\text{CES}}$
Gate-emitter voltage	V_{GE}
Gate-emitter voltage, collector-emitter short-circuited	V_{GES}
Gate-emitter threshold voltage	$V_{\text{GE}(\text{TO})}$
Collector-gate voltage, gate-emitter resistance specified	V_{CGR}

4.3.2 Currents

Collector current	I_{C}
Peak collector current	I_{CM}
Repetitive peak collector current	I_{CRM}
Collector cut-off current, gate-emitter short-circuited	I_{CES}
Tail current	I_{CZ}
Peak tail current	I_{CZM}
Gate current	I_{G}
Gate leakage current, collector-emitter short-circuited	I_{GES}

4.3.3 Other electrical magnitudes

Input capacitance	C_{ies}
Output capacitance	C_{oes}
Reverse transfer capacitance	C_{res}
Gate charge	Q_{ge}
Turn-on power dissipation*	P_{on}
Turn-on energy*	E_{on}
Turn-off power dissipation*	P_{off}
Turn-off power energy*	E_{off}
Conducting state power dissipation*	P_{cond}
Conducting state energy*	E_{cond}
Total power dissipation	P_{tot}

4.3.4 Thermal magnitudes

Virtual junction temperature	T_{vj}
Case temperature	T_c
Thermal resistance junction to case	$R_{th(j-c)}$
Thermal resistance junction to ambient	$R_{th(j-a)}$
Transient thermal impedance junction to case	$Z_{th(j-c)}$
Transient thermal impedance junction to ambient	$Z_{th(j-a)}$
Thermal impedance junction to case under pulse conditions	$Z_{th(j-c)p}$
Thermal impedance junction to ambient under pulse conditions	$Z_{th(j-a)p}$

4.3.5 Times

Turn-on time	t_{on}
Turn-on delay time	$t_{d(on)}, t_d$
Rise time	t_r
Turn-off time	t_{off}
Turn-off delay time	$t_{d(off)}, t_s$
Fall time	t_f
Tail time	t_z
Pulse duration	t_p

* Energy is always per pulse.

5 Essential ratings and characteristics

5.1 General

5.1.1 Rating methods

IGBTs should be specified as ambient-rated or as case-rated devices.

5.1.2 Recommended temperatures

Many of the ratings and characteristics are required to be quoted at a temperature of 25 °C and at one other specified temperature.

Unless otherwise stated, the other specified temperature should be chosen by the manufacturer from the list in IEC 60747-1, chapter VI, clause 5; in addition, temperatures of -40 °C and +35 °C may be used.

5.2 Rating conditions

The ratings given in 5.3 are stated under one or more of the following thermal conditions:

5.2.1 Ambient-rated IGBTs

At 25 °C and at one higher temperature (see 5.1.2). The cooling fluid and pressure (in the case of a gas) should be specified.

Air pressure should be at least 90 kPa (900 mbar), corresponding to a maximum level of 1 000 m above sea-level.

5.2.2 Case-rated IGBTs

At a reference-point temperature taken from the list of recommended temperatures (see 5.1.2).

NOTE The reference-point temperature is normally the case temperature. For small IGBTs the temperature on one of the terminals may be specified.

5.3 Ratings (limiting values)

5.3.1 Collector-emitter voltage with gate-emitter short-circuited (V_{CES})

Maximum rated value.

5.3.2 Gate-emitter voltages with collector-emitter short-circuited (V_{GES})

Maximum rated values for both polarities.

5.3.3 (Continuous) collector (direct) current (I_C)

Maximum rated value.

5.3.4 Repetitive peak collector current (I_{CRM})

Maximum rated value for rectangular pulses at specified case temperature, pulse duration and duty cycle.

5.3.5 Non-repetitive peak collector current (I_{CSM})

Maximum rated value for a rectangular pulse at specified case temperature and pulse duration.

5.3.6 Safe operating area

Diagram showing the maximum rated collector current I_C after turn-on, which may not be exceeded, even under best cooling conditions, as a function of the collector-emitter voltage V_{CE} before and during turn-on for direct current and various pulse durations at 25 °C case temperature.

NOTE The safe operating area is mainly valid under overload conditions.

5.3.7 Total power dissipation (P_{tot})

Maximum rated value at specified case temperature.

5.3.8 Virtual junction temperature (T_{vj})

Maximum and minimum rated values.

5.3.9 Case temperature (T_C) (for case-rated IGBTs)

Minimum and maximum operating temperatures up to the value where the maximum rated total power dissipation approaches zero ($T_C = T_{vj}$).

5.3.10 Storage temperature (T_{stg})

Minimum and maximum rated value.

5.3.11 Mounting force (F)

Minimum and maximum value.

5.3.12 Collector-emitter sustaining voltage (V_{CE*sus})

Not less than the specified minimum value under specified conditions.

5.3.13 Reverse biased safe operating area (RBSOA)

Diagram showing the area of collector current I_C and collector-emitter voltage V_{CE} which the IGBTs will sustain simultaneously for a short period of time during turn-off without being damaged under the specified conditions.

5.3.14 Short-circuit safe operating area (SCSOA)

SCSOA is given by a pair of values of short-circuit duration t_{psc} and collector-emitter voltage V_{CE} which may not be exceeded under the load short-circuit conditions. The device may be turned on and turned off again for shorting a voltage source without being damaged.

5.3.15 Rated electrostatic discharge voltage

Maximum voltages for discharge without damage between gate and emitter at specified collector-emitter circuit conditions, short-circuit or series resistor circuit or series battery circuit or open circuit.

*= R,S,O or X definitions: (R), (S), (O), (X)

5.4 Characteristics

Characteristics are to be given for 25 °C, except where otherwise stated; other temperatures should be taken from the list in IEC 60747-1, chapter VI, clause 5.

5.4.1 Collector(-emitter) breakdown voltage with gate-emitter short-circuited ($V_{(BR)CES}$)

Minimum value at specified collector current.

5.4.2 Collector-emitter saturation voltage ($V_{CE(sat)}$)

Maximum value at specified gate voltage and collector current.

5.4.3 Gate-emitter threshold voltage ($V_{GE(TO)}$)

Minimum and maximum values at specified collector-emitter voltage and collector current.

5.4.4 Collector cut-off current (I_{CES})

Maximum value at case temperatures of 25 °C and of a higher, specified value.

5.4.5 Gate leakage current (I_{GES})

Maximum value at the maximum rated gate-emitter voltage.

5.4.6 Turn-on energy (per pulse) (E_{on})

Maximum value under specified conditions:

- collector-emitter voltage before turn-on;
- collector current after turn-on;
- gate-emitter voltage;
- resistance in the gate-emitter circuit;
- case or ambient temperature or virtual junction temperature.

5.4.7 Turn-off energy (per pulse) (E_{off})

Maximum value under specified conditions:

- collector current before turn-off;
- collector-emitter voltage after turn-off;
- gate-emitter source voltage;
- resistance in the gate-emitter circuit;
- case or ambient temperature or virtual junction temperature.