

Semiconductor devices — Discrete devices —

Part 9: Insulated-gate bipolar transistors (IGBTs)

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National foreword

This British Standard is the UK implementation of IEC 60747-9:2007. It supersedes BS IEC 60747-9:1998 which is withdrawn.

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

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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, verification of ratings and methods of measurement for insulated-gate bipolar transistors (IGBTs).

2 Normative references

The following referenced documents are indispensable for the application 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 60747-2, *Semiconductor devices – Discrete devices and integrated circuits – Part 2: Rectifier diodes*

IEC 60747-6, *Semiconductor devices – Part 6: Thyristors*

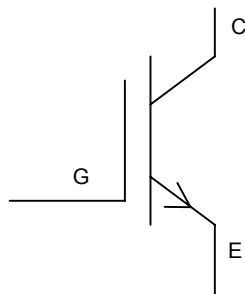
IEC 61340 (all parts), *Electrostatics*

3 Terms and definitions

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

3.1 Graphical symbol of IGBT

The graphical symbol as shown below is used in this edition of IEC 60747-9.



Graphical symbol

NOTE Only the graphical symbol for N-channel IGBT is used in this standard. It equally applies for the measurement of P-channel devices. In the case of P-channel devices polarity must be adapted.

3.2 General terms

3.2.1

insulated-gate bipolar transistor

IGBT

transistor having a conduction channel and a PN junction. 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

See IEC 521-04-05.

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

3.2.2

N-channel IGBT

IGBT that has one or more N-type conduction channels

See IEC 521-05-06.

3.2.3

P-channel IGBT

IGBT that has one or more P-type conduction channels

See IEC 521-04-05.

3.2.4

collector current (of an IGBT)

I_c

direct current that is switched (controlled) by the IGBT

3.2.5

collector terminal, collector (of an IGBT)

C

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

See IEC 521-07-05 and IEC 521-05-02.

3.2.6

emitter terminal, emitter (of an IGBT)

E

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

See IEC 521-07-04.

3.2.7

gate terminal, gate (of an IGBT)

G

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

See IEC 521-07-09.

3.3 Terms related to ratings and characteristics; voltages and currents

3.3.1

collector-emitter (d.c.) voltage

voltage between collector and emitter

3.3.2

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

3.3.3

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.

3.3.4

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

See IEC 521-05-06.

3.3.5

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

3.3.6

gate-emitter (d.c.) voltage

voltage between gate and emitter

3.3.7

gate-collector (d.c.) voltage

voltage between gate and collector

3.3.8

gate-emitter threshold voltage

$V_{GE(th)}$

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

3.3.9

electrostatic discharge voltage

voltage that can be applied to the gate terminal without destruction of the isolation layer
See IEC 521-05-27

3.3.10

collector cut-off current

collector current at a specific collector-emitter voltage below the breakdown region and gate off-state

3.3.11

collector current

current through collector

3.3.12**tail current** I_{CZ}

collector current during the tail time

3.3.13**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

3.3.14**safe operating area****SOA**

collector current versus collector emitter voltage where the IGBT is able to turn-on and turn-off without failure

3.3.14.1**forward bias safe operating area****FBSOA**

collector current versus collector emitter voltage where the IGBT is able to turn-on and is able to be on-state without failure

3.3.14.2**reverse bias safe operating area****RBSOA**

collector current versus collector emitter voltage where the IGBT is able to turn-off without failure

3.3.14.3**short circuit safe operating area****SCSOA**

short circuit duration and collector emitter voltage where the IGBT is able to turn-on and turn-off without failure

3.4 Terms related to ratings and characteristics; other characteristics**3.4.1****input capacitance** C_{ies}

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

3.4.2**output capacitance** C_{oes}

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

3.4.3**reverse transfer capacitance** C_{res}

capacitance between the collector and gate terminals

3.4.4**gate charge** Q_G

charge required to raise the gate-emitter voltage from a specified low to a specified high level

3.4.5

internal gate resistance

r_g

internal series resistance

3.4.6

turn-on energy (per pulse)

E_{on}

energy dissipated inside the IGBT during the turn-on 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.

3.4.7

turn-off energy (per pulse)

E_{off}

energy dissipated 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.

3.4.8

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.

3.4.9

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.

3.4.10

turn-on time

t_{on}

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

3.4.11

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.

3.4.12

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.

3.4.13**turn-off time** **t_{off}**

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

3.4.14**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 2 % or lower specified value

4 Letter symbols**4.1 General**

General letter symbols for IGBTs are defined in Clause 4 of IEC 60747-1.

4.2 Additional general subscripts

C,c	collector
E,e	emitter
G,g	gate
sat	saturation
th	threshold
Z,z	tail
S	termination with a short circuit
R	termination with a resistor
X	termination with specified gate emitter voltage
sus	sustaining

4.3 List of letter symbols

Name and designation	Letter symbol
4.3.1 Voltages	
Collector-emitter voltage	V_{CE}
Collector-emitter voltage, gate-emitter short-circuited	V_{CES}
Collector-emitter sustaining voltage	$V_{CE^{*}sus}$
Collector-emitter breakdown voltage, gate-emitter short-circuited	$V_{(BR)CES}$
Collector-emitter saturation voltage	V_{CEsat}
Gate-emitter voltage	V_{GE}
Gate-emitter voltage, collector-emitter short-circuited	V_{GES}
Gate-emitter threshold voltage	$V_{GE(th)}$
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-emitter cut-off current, gate-emitter short-circuited	I_{CES}
Tail current	I_{CZ}
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_G
Internal gate resistance	r_g
Turn-on power dissipation	P_{on}
Turn-on energy	E_{on}
Turn-off power dissipation	P_{off}
Turn-off energy	E_{off}
Conducting state power dissipation	P_{cond}
Conducting state energy	E_{cond}
Total power dissipation	P_{tot}
4.3.4 Time	
Tail time	t_z
4.3.5 Thermal magnitudes	
Thermal resistance junction to heatsink	$R_{th(j-c)}$
Transient thermal impedance junction to heatsink	$Z_{th(j-c)}$

5 Essential ratings and characteristics

5.1 Ratings (limiting values)

Ratings shall be valid for the whole range of operating conditions as stated for the particular device, with reference to a curve where appropriate.

5.1.1 Ambient or case or virtual junction operating temperature (T_a or T_c or T_{vj})

Maximum and minimum values.

5.1.2 Storage temperature (T_{stg})

Maximum and minimum values.

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

Maximum value.

NOTE This rating should not be less than $V_{(BR)CES}$. (See 5.2.1.)

5.1.4 Gate-emitter voltages with collector emitter short circuit (V_{GES})

Maximum positive and negative values.

5.1.5 Continuous collector current (I_C)

Maximum value.

5.1.6 Repetitive peak collector current (I_{CRM})

Maximum value for rectangular pulses with specified pulse duration and duty cycle.

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

Maximum value for a rectangular pulse with specified pulse duration.

5.1.8 Total power dissipation (P_{tot})

Maximum value with a derating curve where appropriate.

5.1.9 Maximum 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.

5.1.10 Maximum 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 failure under the specified conditions.

5.1.11 Maximum 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 failure.

5.1.12 Maximum terminal current (I_{tRMS}) (where appropriate)

Maximum r.m.s. value of the current through the main terminal.

5.1.13 Mounting force (F)

Maximum and minimum values, where appropriate.

5.1.14 Mounting torque (M)

Maximum and minimum values, where appropriate.

5.2 Characteristics

Characteristics shall be given at $T_{vj} = 25\text{ °C}$ except where otherwise stated; and at one other specified temperature.

5.2.1 Collector-emitter breakdown voltage ($V_{(BR)CES}$)

Minimum value with gate-emitter short-circuited and at specified collector current.

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

Where appropriate, minimum value at specified collector current and gate conditions.

5.2.3 Collector-emitter saturation voltage (V_{CEsat})

Maximum value at specified gate voltage and collector current.

5.2.4 Gate-emitter threshold voltage ($V_{GE(th)}$)

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

5.2.5 Collector-emitter cut-off current (I_{CE*})

Maximum value at specified high collector-emitter voltage and for a specified termination between gate and emitter terminals.

5.2.6 Gate leakage current (I_{GES})

Maximum value at the maximum rated gate-emitter voltage.

5.2.7 Capacitances

Typical values of the following, at specified collector-emitter voltage and test frequency.

5.2.7.1 Input capacitance (C_{ies})

Typical input capacitance as small-signal value, in common-emitter configuration, under specified bias conditions and at a specified frequency, with the output short-circuited to a.c.

5.2.7.2 Output capacitance (C_{oes})

Typical output capacitance as small-signal value, in common-emitter configuration, under specified bias conditions and at a specified frequency, with the input short-circuited to a.c.

5.2.7.3 Reverse transfer capacitance (C_{res})

Typical reverse transfer capacitance as small-signal value, in common-emitter configuration, under specified bias conditions and at a specified frequency.

5.2.8 Gate charge (Q_G)

Typical value at specified values of gate-emitter voltage, collector-emitter voltage before turn-on and collector current after turn-on.

5.2.9 Internal gate resistance (r_g)

Maximum and/or typical value with collector short circuited to emitter in a.c. at the specified values of gate -emitter voltage, collector -emitter voltage and frequency

5.2.10 Turn-on energy (E_{on})

Maximum value per pulse under the following specified conditions:

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

5.2.11 Turn-off energy (E_{off})

Maximum value per pulse under the following specified conditions:

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

5.2.12 Switching times

5.2.12.1 Turn-on delay time ($t_{d(on)}$) and rise time (t_r)

Maximum values under the following specified conditions:

- collector-emitter voltage before turn-on;
- collector current after turn-on,
- load conditions;
- gate-emitter voltage;
- resistance in the gate-emitter circuit.

5.2.12.2 Turn-off delay time ($t_{d(off)}$), fall time (t_f) and tail time (t_z)

Maximum values with a free-wheeling diode connected under the following specified conditions:

- collector-emitter voltage after turn-off;
- collector current before turn-off;
- load conditions;
- gate-emitter voltage;
- resistance in the gate-emitter circuit.

5.2.13 Thermal resistance junction to case ($R_{th(j-c)}$)

Maximum value for case-rated IGBTs.

5.2.14 Thermal resistance junction to ambient ($R_{th(j-a)}$)

Maximum value for ambient-rated IGBTs.

5.2.15 Transient thermal impedance junction to case ($Z_{th(j-c)}$)

For case-rated IGBTs, diagram showing the maximum values against the time elapsed after a step change in power dissipation, or analytical elements.

5.2.16 Transient thermal impedance junction to ambient ($Z_{th(j-a)}$)

For ambient-rated IGBTs, diagram showing the maximum values against the time elapsed after a step change in power dissipation.

6 Measuring methods

6.1 General

The polarities shown in these circuits are applicable to N channel devices. The circuits can be adapted for P channel devices by inverting the polarities of the meters, generators and power supplies. The handling precautions given in IEC 61340 and the measuring method procedures given in 60747-1 apply.

6.2 Verification of ratings (limiting values)

After the following test, confirm the IGBT characteristics specified in Table 1.

Table 1 – Acceptance-defining characteristics

Characteristics	Acceptance criteria
I_{CES}	$I_{CES} < USL$
I_{GES}	$I_{GES} < USL$
$V_{CE(sat)}$	$V_{CE(sat)} < USL$
$V_{GE(th)}$	$V_{GE(th)} < USL$ or $> LSL$
NOTE USL: upper specification limit LSL: lower specification limit	

6.2.1 Collector-emitter voltages (V_{CES} , V_{CER} , V_{CEX})

6.2.1.1 Purpose

To verify that an IGBT withstands the rated collector-emitter voltages V_{CES} , V_{CER} or V_{CEX} under specified conditions.

6.2.1.2 Circuit diagram (see Figure 1)

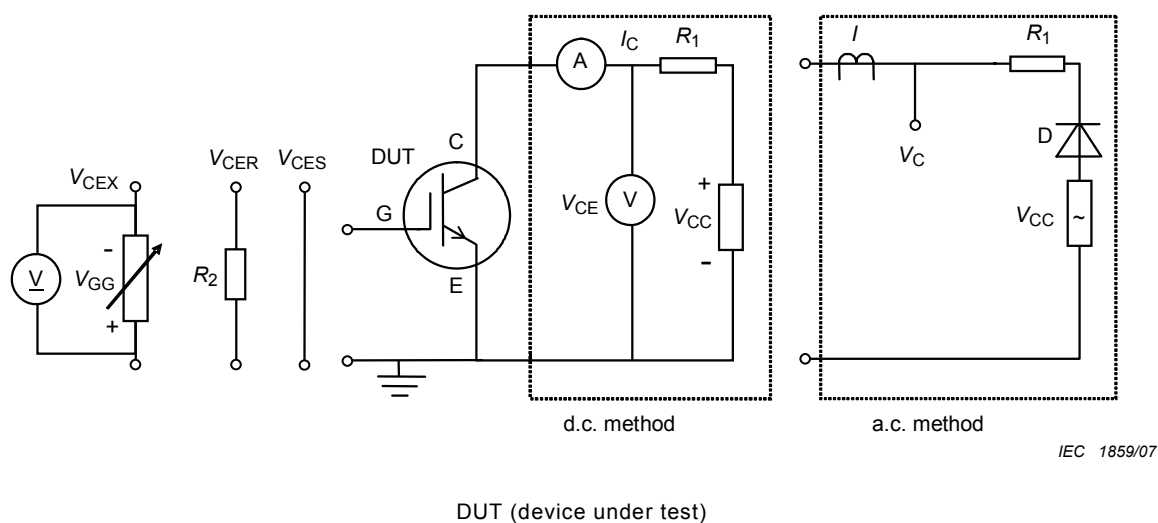


Figure 1 – Circuit for measuring the collector-emitter voltages V_{CES} , V_{CER} , V_{CEX}

6.2.1.3 Circuit description

V_{CC} and V_{GG} are the voltage supply. R_1 is a circuit protection resistor.

6.2.1.4 Test procedure

There are two methods, i.e. the d.c. method and the a.c. method, with circuits according to Figure 1.

The specified conditions between gate and emitter shall be applied. The collector-emitter voltage is set to the specified value.

6.2.1.5 Specified conditions

- Collector-emitter voltage V_{CE}
- Ambient or case or virtual junction temperature T_a or T_c or T_{vj}
- V_{CEX} : gate-emitter voltage $-V_{GG}$
- V_{CER} : resistor connected between gate and emitter
- V_{CES} : short circuit between gate and emitter

6.2.2 Gate-emitter voltage with collector emitter short circuit ($\pm V_{GES}$)

6.2.2.1 Purpose

To verify that an IGBT withstands the rated gate emitter voltage $\pm V_{GE}$ under specified conditions.