

Semiconductor devices —

Part 6: Thyristors

ICS 31.080.01

National foreword

This British Standard reproduces verbatim IEC 60747-6:2000 and implements it as the UK national standard. It supersedes BS 6493-1.6:1984 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EPL/47, Semiconductors, which has the responsibility to:

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**Partie 6:
Thyristors**

Semiconductor devices –

**Part 6:
Thyristors**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR DEVICES –

Part 6: Thyristors

FOREWORD

- 1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the 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, the IEC publishes International Standards. 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. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60747-6 has been prepared by subcommittee 47E: Discrete semiconductor devices, of IEC technical committee 47: Semiconductor devices.

This second edition cancels and replaces the first edition, published in 1983, and its amendments 1 and 2 and constitutes a technical revision.

The text of this standard is based on the following documents:

FDIS	Report on voting
47E/155/FDIS	47E/168/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

Annex A is for information only.

The committee has decided that the contents of this publication will remain unchanged until 2006. At this date, the publication will be

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- withdrawn;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

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INTRODUCTION

This part of IEC 60747 should be read in conjunction with IEC 60747-1. It provides basic information on semiconductor

- terminology,
- letter symbols,
- essential ratings and characteristics,
- measuring methods,
- acceptance and reliability.

SEMICONDUCTOR DEVICES –

Part 6: Thyristors

1 Scope

This part of IEC 60747 provides standards for the following categories of discrete semiconductor devices:

- (reverse-blocking) (triode) thyristors,
- asymmetrical (reverse-blocking) (triode) thyristors,
- reverse-conducting (triode) thyristors,
- bidirectional triode thyristors (triacs),
- gate turn-off thyristors (GTO thyristors).

It does not apply to thyristor surge suppressors nor to diacs.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 60747. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, 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. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

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

3 Terms and definitions

For the purpose of this part of IEC 60747, the following definitions, together with definitions from IEC 60747-1 and IEC 60050(521), apply.

NOTE 1 For unidirectional thyristors terms and definitions can be written in terms of either “node” and “cathode” or “principal” and “main”. In this standard, the first alternative has been chosen because the second is less suitable for GTO thyristors. In contrast, the second alternative had to be chosen for bidirectional triode thyristors as the first does not apply to them.

NOTE 2 Current and voltage terms and definitions for bidirectional diode thyristors use the adjective “thyristor” because reference to principal current or voltage would imply there is other current or voltage. For the same reason, the adjective “main” is not used with the terminal designations for these devices.

Table 1 summarizes the qualifiers that could be chosen for voltages/currents and terminals.

Table 1 – Qualifiers used for the different kinds of thyristors

Type of thyristor	Triode thyristors	Diode thyristors
Unidirectional thyristors	Anode/cathode voltage/current or principal voltage/current	Anode/cathode voltage/current or thyristor voltage/current
	Anode/cathode terminal or main terminal 1/2	Anode/cathode terminal or terminal 1/2
Bidirectional thyristors	Principal voltage/current	Thyristor voltage/current
	Main terminal 1/2	Terminal 1/2

3.1 Types of thyristors

3.1.1

Classification criteria

Thyristors are classified into subcategories using one or more of the following criteria

- a) number of terminals:
 - triode thyristor,
 - diode thyristor;
- b) way of acting in the third quadrant of the voltage-current characteristic:
 - unidirectional,
 - bidirectional;
- c) physical kind of control:
 - electrically controlled (this usual way of control is not indicated in the term),
 - light-controlled;
- d) control capabilities at the gate:
 - only turn on (this restriction is usually not indicated in the term),
 - gate turn-off capability (GTO thyristor);
- e) controlled layer:
 - P-gate thyristor (usual technology, not indicated in the term),
 - N-gate thyristor.

3.1.2

thyristor (general)

semiconductor device that is capable, due to internal feedback, of assuming either of two stable states and maintaining the assumed state either with no sustained control current or voltage or at least with considerably less than that necessary to initially establish that state, and that is designed to operate as a switch for the principal or on-state current

NOTE 1 A thyristor is a switch that can be switched on either for only one direction of the principal current (a unidirectional thyristor), or for both directions (a bidirectional thyristor).

NOTE 2 The usual configuration is a PNP configuration to which can be added other elements needed for additional functions.

NOTE 3 The term “thyristor” may be used for any member of the PNP family when such use does not result in ambiguity or misunderstanding. In particular, the abbreviated term “thyristor” is widely used for the reverse-blocking triode thyristor, formerly called “semiconductor controlled rectifier”.

3.1.3

unidirectional thyristor

see figure 1

3.1.4

unidirectional triode thyristor

three-terminal thyristor that can switch only when the anode voltage is positive

NOTE In this definition, a second cathode or anode terminal for connecting to the control circuit is not counted.

3.1.5

unidirectional diode thyristor

two-terminal thyristor that can switch only when the anode voltage is positive

3.1.6

bidirectional thyristor

see figure 2

3.1.7

bidirectional triode thyristor (triac)

three-terminal thyristor having substantially the same switching behaviour in the first and third quadrants of the principal characteristic (see curve B of figure 2)

3.1.8

bidirectional diode thyristor

two-terminal thyristor having substantially the same switching behaviour in the first and third quadrants of the thyristor voltage-current characteristic (see curve A of figure 2)

3.1.9

reverse-blocking triode thyristor

unidirectional triode thyristor that exhibits a blocking state in the reverse direction (see curves a) and b) of figure 1)

NOTE If no ambiguity is likely to occur, the term may be abbreviated to "thyristor".

3.1.10

(symmetrical) reverse-blocking triode thyristor

reverse-blocking triode thyristor whose rated reverse voltage and rated off-state voltage are equal or insignificantly different

3.1.11

asymmetrical reverse-blocking triode thyristor

reverse-blocking triode thyristor whose rated reverse voltage is significantly lower than its rated off-state voltage (see curve b) of figure 1)

3.1.12

reverse-conducting triode thyristor

unidirectional triode thyristor that conducts large currents in the reverse direction at reverse voltages comparable in magnitude to the forward on-state voltage (see curve c) of figure 1)

3.1.13

reverse-blocking diode thyristor

unidirectional diode thyristor that exhibits a blocking state in the reverse direction (see curves a) and b) of figure 1)

3.1.14

(reverse-blocking) gate-turn-off thyristor GTO thyristor

reverse-blocking triode thyristor that can be switched from the on state to the off state as well as from the off state to the on state by applying control signals of appropriate polarity to the gate terminal

3.1.15

reverse-conducting gate-turn-off thyristor

reverse-conducting triode thyristor that can be switched from the on state to the off state as well as from the off state to the on state by applying control signals of appropriate polarity to the gate terminal

3.1.16

symmetrical gate-turn-off thyristor

gate-turn-off thyristor whose rated reverse voltage and rated off-state voltage are equal or insignificantly different

3.1.17

asymmetrical gate-turn-off thyristor

gate-turn-off thyristor whose rated reverse voltage is significantly lower than its rated off-state voltage

3.1.18

P-gate thyristor

unidirectional triode thyristor whose gate terminal is connected to the P region nearest the cathode and that is normally switched to the on state by applying a positive signal to the gate terminal with respect to the cathode terminal

3.1.19

N-gate thyristor

unidirectional triode thyristor whose gate terminal is connected to the N region nearest the anode and that is normally switched to the on state by applying a negative signal to the gate terminal with respect to the anode terminal

NOTE Any practical realization of an N-gate thyristor was not known when this publication was issued.

3.2 Basic terms defining the static voltage-current characteristics of triode thyristors

3.2.1

gate terminal

terminal unique to the control circuit

3.2.2

gate current

(control) current into the gate terminal

3.2.3

principal current

current that is switched (controlled) by the thyristor

3.2.4

main terminals

two terminals through which the principal current flows

3.2.5

anode terminal (of a unidirectional triode thyristor)

main terminal to which the principal current flows from the circuit being controlled when the thyristor is in the on state

NOTE A second anode terminal may be provided for connecting to the control circuit of an N-gate thyristor.

3.2.6

cathode terminal (of a unidirectional triode thyristor)

main terminal from which the principal current flows to the circuit being controlled when the thyristor is in the on state

NOTE A second cathode terminal may be provided for connecting to the control circuit of a P-gate thyristor.

3.2.7

main terminal 1 (of a bidirectional triode thyristor (triac)) (MT1)

main terminal intended by the triac manufacturer to conduct the control current in addition to the principal current

NOTE Some bidirectional triode thyristors are completely symmetrical, e.g. Silicon Bilateral Switch (SBS) thyristors. For these, the choice for the manufacturer is arbitrary, and the user can return the control circuit to whichever main terminal will provide the required polarity of gate current.

3.2.8

main terminal 2 (of a bidirectional triode thyristor (triac)) (MT2)

other main terminal after main terminal 1 has been designated by the triac manufacturer

3.2.9

anode-cathode voltage

anode voltage (of an unidirectional triode thyristor)

voltage (potential difference) between anode and cathode terminals

3.2.10

principal voltage

voltage (potential difference) between the main terminals

NOTE 1 In the case of unidirectional triode thyristors, the principal voltage is called positive when the anode potential is more positive than the cathode potential and called negative when the anode potential is less positive than the cathode potential. Thus, for these thyristors, "principal voltage" and "anode-cathode voltage" are synonymous.

NOTE 2 In the case of bidirectional triode thyristors, the polarity of the principal voltage (with regard to main terminals 1 and 2) is to be specified.

3.2.11

(static) voltage-current characteristic

(static) principal characteristic (of a unidirectional triode thyristor (see figure 1))

function, usually represented graphically, relating the anode voltage to the anode current for a specified virtual junction temperature, under conditions of internal electrical and thermal equilibrium

NOTE 1 Where applicable, the characteristic may be given with the gate current as a parameter.

NOTE 2 The word "static" is usually omitted except when a distinction between static and dynamic characteristics is necessary.

3.2.12

(static) principal characteristic (of a bidirectional triode thyristor (see figure 2))

function, usually represented graphically, relating the principal voltage to the principal current for a specified virtual junction temperature, under conditions of internal electrical and thermal equilibrium

NOTE 1 Where applicable, the characteristic may be given with the gate current as a parameter.

NOTE 2 The word “static” is usually omitted except when a distinction between static and dynamic characteristics is necessary.

3.3 Basic terms defining the static voltage-current characteristics of diode thyristors

3.3.1

anode terminal (of a unidirectional diode thyristor)

terminal to which the current flows from the external circuit when the thyristor is in the on state

3.3.2

cathode terminal (of a unidirectional diode thyristor)

terminal from which the current flows to the external circuit when the thyristor is in the on state

3.3.3

terminal 1 (of a bidirectional diode thyristor)

terminal that is designated “1” by the manufacturer

3.3.4

terminal 2 (of a bidirectional diode thyristor)

terminal that is designated “2” by the manufacturer

3.3.5

anode-cathode voltage

anode voltage (of a unidirectional diode thyristor)

voltage between the anode and cathode terminals

NOTE The anode-cathode voltage is called positive when the anode potential is higher than the cathode potential, and called negative when the anode potential is lower than the cathode potential.

3.3.6

thyristor voltage (of a bidirectional diode thyristor)

voltage between the two terminals

NOTE The polarity of the thyristor voltage (with regard to terminals 1 and 2) is to be specified.

3.3.7

(static) characteristic (of a unidirectional diode thyristor)

function, usually represented graphically, relating the anode voltage to the anode current for a specified virtual junction temperature, under conditions of internal electrical and thermal equilibrium

NOTE The word “static” is usually omitted, except when a distinction between static and dynamic characteristics is necessary.

3.3.8

(static) characteristic (of a bidirectional diode thyristor)

function, usually represented graphically, relating the thyristor voltage to the thyristor current for a specified virtual junction temperature, under conditions of internal electrical and thermal equilibrium

NOTE The word “static” is usually omitted, except when a distinction between static and dynamic characteristics is necessary.

Particulars of the static voltage-current characteristics of triode and diode thyristors (see figures 1 and 2)

NOTE The states referred to in 3.4.2 through 3.4.7 concern portions of the static characteristic, i.e. static states, although in the more general terms, this restriction is not indicated. If necessary, distinction will be made between static and dynamic states.

3.4.1
on state

state of a thyristor, in a quadrant in which switching may occur, that corresponds to the low-resistance portion of the characteristic

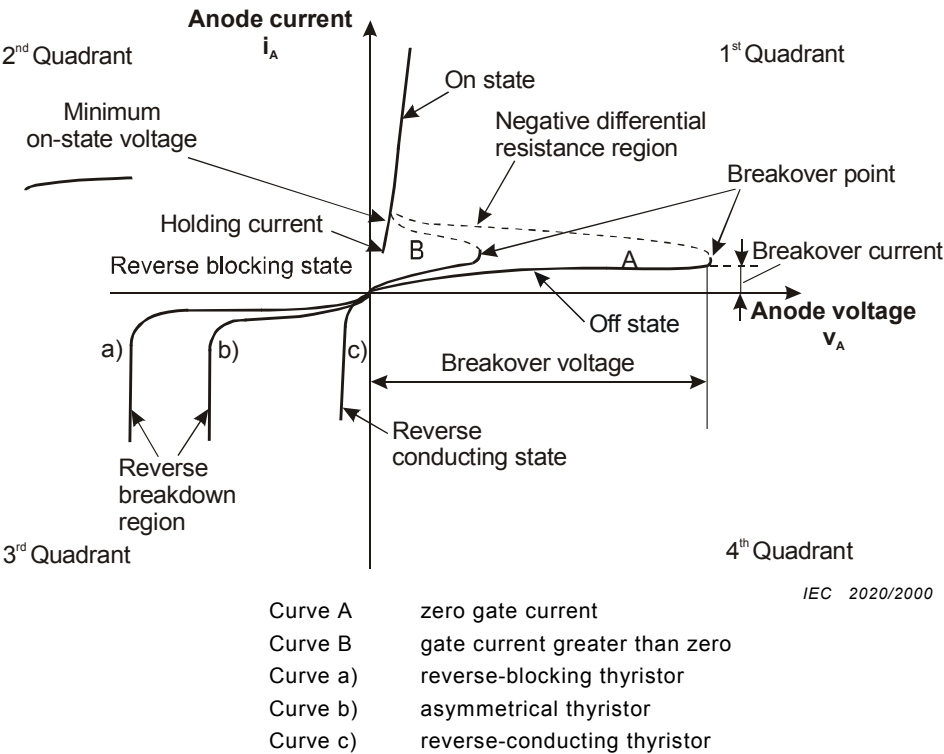
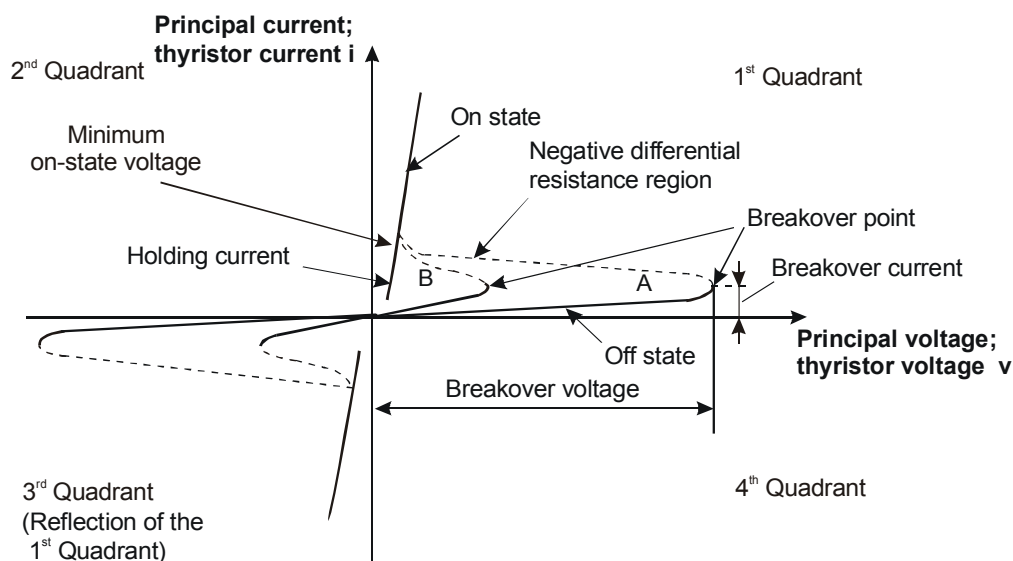


Figure 1 – Particulars of the static characteristic of unidirectional thyristors



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Curve A bidirectional diode thyristors or bidirectional triode thyristors with zero gate current
Curve B bidirectional triode thyristors with gate current greater than zero

Figure 2 – Particulars of the static characteristic of bidirectional thyristors

3.4.2

off state

state of a thyristor, in a quadrant in which switching may occur, that corresponds to the portion of the characteristic between the origin and the breakover point

3.4.3

reverse-blocking state

state of a reverse-blocking or asymmetrical thyristor that corresponds to a reverse voltage between the origin and the beginning of the reverse breakdown region

3.4.4

reverse breakdown region

portion of the characteristic in which reverse breakdown occurs (the term “reverse breakdown” is defined in IEC 60747-1)

3.4.5

reverse-conducting state

state of a reverse-conducting triode thyristor that corresponds to the third quadrant of the characteristic

3.4.6

negative differential resistance region

any portion of the characteristic within which the differential resistance is negative

3.4.7

breakover point

in a quadrant in which switching may occur, the point for which the differential resistance is zero and the off-state voltage reaches a maximum value

3.4 Terms related to ratings and characteristics; principal voltages

NOTE 1 In this subclause, similar definitions for more than one kind of thyristor are combined in a single wording in which reference is made to all relevant qualifiers. For example, in 3.5.8, the wording “anode, principal, or thyristor voltage” indicates that the term “on-state voltage” applies to unidirectional thyristors, bidirectional triode thyristors and bidirectional diode thyristors (see table 1).

NOTE 2 When several distinctive forms of letter symbols exist, the most commonly used form(s) is (are) given.

3.5.1

breakover voltage ($V_{(BO)}$)

voltage at the breakover point

3.5.2

reverse voltage (of a unidirectional thyristor) (V_R)

negative anode voltage

3.5.3

direct reverse voltage (of a unidirectional thyristor) ($V_{(D)}$)

reverse voltage that is independent of time or in which the changes are so small that they can be neglected

3.5.4

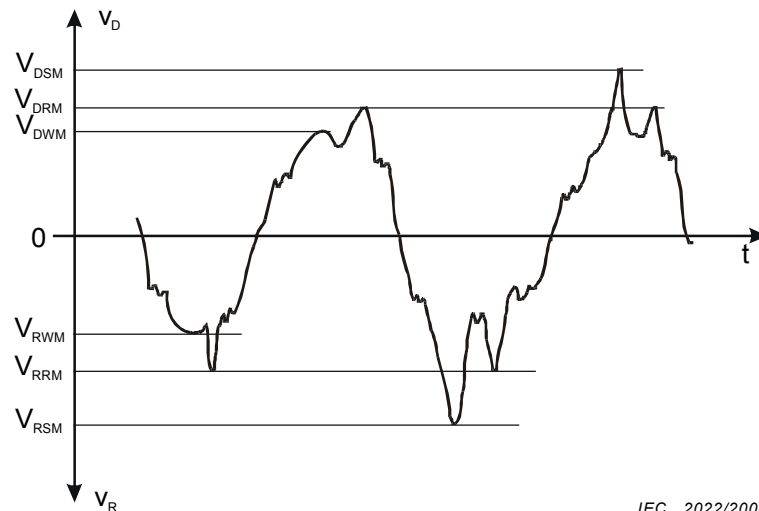
reverse breakdown voltage (of a unidirectional thyristor) ($V_{(BR)}$)

voltage in the reverse breakdown region

3.5.5**crest working reverse voltage****peak working reverse voltage (of a unidirectional thyristor) (V_{RWM})**

highest instantaneous value of the reverse voltage, excluding all repetitive and non-repetitive transient voltages (see figure 3)

NOTE The repetitive voltage is usually a function of the circuit and increases the power loss of the device. A non-repetitive transient voltage is usually due to an external cause, and it is assumed that its effect has completely disappeared before the next transient arrives.



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Figure 3 – Peak reverse and peak off-state voltages of a thyristor

3.5.6**repetitive peak reverse voltage (of a unidirectional thyristor) (V_{RRM})**

highest instantaneous value of the reverse voltage, including all repetitive transient voltages, but excluding all non-repetitive transient voltages (see figure 3)

NOTE The repetitive voltage is usually a function of the circuit and increases the power loss of the device. A non-repetitive transient voltage is usually due to an external cause, and it is assumed that its effect has completely disappeared before the next transient arrives.

3.5.7**non-repetitive peak reverse voltage;****peak transient reverse voltage (of a unidirectional thyristor) (V_{RSM})**

highest instantaneous value of any non-repetitive transient reverse voltage (see figure 3)

NOTE See note to 3.5.5. (The repetitive voltage is usually a function of the circuit and increases the power loss of the device. A non-repetitive transient voltage is usually due to an external cause, and it is assumed that its effect has completely disappeared before the next transient arrives.)

NOTE 2 Preference should be given to the term “non-repetitive peak reverse voltage”.

3.5.8**on-state voltage (V_T)**

anode, principal, or thyristor voltage when the thyristor is in the on state

3.5.9**off-state voltage (V_D)**

anode, principal, or thyristor voltage when the thyristor is in the off state

3.5.10**direct off-state voltage ($V_{D(D)}$)**

off-state voltage that is independent of time or in which the changes are so small that they can be neglected

3.5.11

crest working off-state voltage

peak working off-state voltage (V_{DWM})

highest instantaneous value of the off-state voltage, excluding all repetitive and non-repetitive transient voltages (see figure 3)

NOTE The repetitive voltage is usually a function of the circuit and increases the power loss of the device. A non-repetitive transient voltage is usually due to an external cause, and it is assumed that its effect has completely disappeared before the next transient arrives.

3.5.12

repetitive peak off-state voltage (V_{DRM})

highest instantaneous value of the off-state voltage, including all repetitive transient voltages, but excluding all non-repetitive transient voltages (see figure 3)

NOTE The repetitive voltage is usually a function of the circuit and increases the power loss of the device. A non-repetitive transient voltage is usually due to an external cause, and it is assumed that its effect has completely disappeared before the next transient arrives.

3.5.13

non-repetitive peak off-state voltage

peak transient off-state voltage (V_{DSM})

highest instantaneous value of any non-repetitive transient off-state voltage (see figure 3)

NOTE 1 The repetitive voltage is usually a function of the circuit and increases the power loss of the device. A non-repetitive transient voltage is usually due to an external cause, and it is assumed that its effect has completely disappeared before the next transient arrives

NOTE 2 Preference should be given to the term “non-repetitive peak off-state voltage”

3.5.14

critical rate of rise of off-state voltage ($(dv_D/dt)_{cr}$)

highest value of the rate of rise of off-state voltage that will not cause switching from the off state to the on state.

NOTE 1 The measuring method for the rate of rise is to be specified.

NOTE 2 If no ambiguity is likely to result, the shorter expression “dv/dt” may be used.

3.5.15

critical rate of rise of commutating voltage (of a reverse-conducting triode thyristor) ($(dv_{D(com)}/dt)_{cr}$)

highest value of the rate of rise of off-state voltage, immediately following reverse current conduction, that will not cause switching from the off state to the on state

NOTE 1 The measuring method for the rate of rise is to be specified.

NOTE 2 If no ambiguity is likely to result, the shorter expression “ $dv_{(com)}/dt$ ” may be used.

3.5.16

critical rate of rise of commutating voltage

critical rate of rise of the reapplied off-state voltage (of a triac) ($(dv_{D(com)}/dt)_{cr}$)

highest value of the rate of rise of off-state voltage, immediately following on-state current conduction in the opposite direction, that will not cause switching from the off state to the on state

NOTE 1 The measuring method for the rate of rise is to be specified.

NOTE 2 If ambiguity is likely to result, the shorter expression “ $dv_{(com)}/dt$ ” may be used.

3.5.17

turn-off (off-state) spike voltage (of a GTO thyristor) ($V_{Q(SP)}$)

peak value of a spike on the reapplied off-state voltage that occurs shortly after the off-state voltage begins to rise (see figure 13)

NOTE The turn-off spike voltage is not an inherent characteristic of the thyristor as its value depends on the parasitic inductance in the snubber network connected in parallel to the GTO thyristor. Its value has an influence on the turn-off energy loss.

3.5.18

turn-off peak off-state voltage (of a GTO thyristor) (V_{DQM})

peak value, higher than the final steady-state value, to which the re-applied off-state voltage rises towards the end of the turn-off process (see figure 13)

NOTE The turn-off peak off-state voltage is not an inherent characteristic of the GTO thyristor as its value depends on the design of the external circuits. Its value has an influence on the turn-off energy loss.

3.5 Terms related to ratings and characteristics; principal currents

3.6.1

breakover current (I_{BO})

anode, principal, or thyristor current at the breakover point

3.6.2

reverse current (of a unidirectional thyristor) (I_R)

anode current for a negative anode voltage

3.6.3

reverse-conducting current (of a reverse-conducting thyristor) (I_{RC})

reverse current of a reverse-conducting thyristor

3.6.4

mean reverse-conducting current ($I_{RC(AV)}$)

value of the reverse-conducting current averaged over a full cycle

3.6.5

overload reverse-conducting current ($I_{RC(OV)}$)

reverse-conducting current whose continuous application would cause the maximum rated virtual junction temperature to be exceeded, but that is limited in duration such that this temperature is not exceeded

NOTE 1 Devices may be subjected to overload currents as frequently as called for by the application, while being subjected to normal operating voltages.

NOTE 2 If not otherwise stated, specifications for the rated (limiting) value of an overload reverse-conducting current refer to a waveshape that is substantially the same as for the rated value of the reverse-conducting current.

3.6.6

surge reverse-conducting current ($I_{RC(SM)}$)

reverse-conducting current pulse of short duration and specified waveshape, whose application causes or would cause the maximum rated virtual junction temperature to be exceeded, but which is assumed to occur rarely and with a limited number of such occurrences during the service life of the device and to be a consequence of unusual circuit conditions (for example, a fault)

3.6.7

reverse blocking current (of a unidirectional thyristor) (I_R)

reverse current when a thyristor is in the reverse-blocking state

3.6.8

reverse recovery current (of a unidirectional thyristor) (I_{RR} , $I_{R(REC)}$)

reverse current that occurs during the reverse recovery time

NOTE For the peak value of the reverse recovery current during the reverse recovery time, only the letter symbol I_{RM} or $I_{RM(REC)}$ may be used (see figure 9) because the letter symbol I_{RRM} is already attributed to the repetitive peak reverse current.

3.6.9

on-state current (I_T)

anode, principal, or thyristor current when the thyristor is in the on state

3.6.10

direct on-state current ($I_{T(D)}$)

on-state current that is independent of time or in which the changes are so small that they can be neglected

3.6.11

mean on-state current ($I_{T(AV)}$)

value of the on-state current averaged over a full cycle

3.6.12

r.m.s. on-state current ($I_{T(RMS)}$)

r.m.s. value of the on-state current averaged over a full cycle

3.6.13

peak sinusoidal on-state current (I_{TM})

peak value of a sinusoidal on-state current, excluding any transient currents

3.6.14

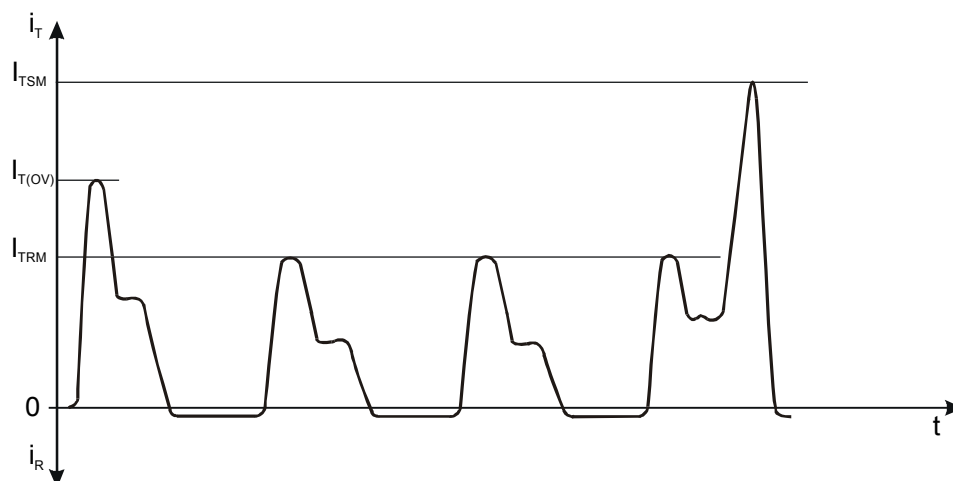
peak trapezoidal on-state current (I_{TM})

peak value of a trapezoidal on-state current, excluding any transient currents

3.6.15

repetitive peak on-state current (I_{TRM})

peak value of the on-state current, including all repetitive transient currents (see figure 4)



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Figure 4 – Peak values of on-state currents

3.6.16**overload on-state current ($I_{T(OV)}$)**

on-state current whose continuous application would cause the maximum-rated virtual junction temperature to be exceeded, but that is limited in duration such that this temperature is not exceeded (see figure 4)

NOTE 1 Devices may be subjected to overload currents as frequently as called for by the application while being subjected to normal operating voltages.

NOTE 2 If not otherwise stated, specifications for the rated (limiting) value of an overload on-state current refer to a waveshape that is substantially the same as for the rated value of the on-state current.

3.6.17**surge on-state current (I_{TSM})**

on-state current pulse of short duration and specified waveshape, whose application causes or would cause the maximum rated virtual junction temperature to be exceeded, but which is assumed to occur rarely and with a limited number of such occurrences during the service life of the device and to be a consequence of unusual circuit conditions (for example, a fault) (see figure 4)

3.6.18 **I^2t value (of a surge on-state current) (I^2t)**

value used for the specification of a maximum rated value of surge on-state current, given in terms of the maximum rated value of

$$I^2t = \int_0^{t_i} i^2 dt$$

for a specified short integration time t_i

3.6.19**repetitive peak controllable on-state current (of a GTO thyristor) (I_{TORM})**

highest peak value of the on-state current that can be turned off periodically by means of gate control

NOTE A repetitive current is usually a function of the circuit and increases the power loss within the device. A non-repetitive transient current is usually due to an external cause and it is assumed that its effect has completely disappeared before the next transient arrives.

3.6.20**non-repetitive peak controllable on-state current (of a GTO thyristor) (I_{TQSM})**

highest non-repetitive peak value of the on-state current that can be turned off by means of gate control

NOTE A repetitive current is usually a function of the circuit and increases the power loss within the device. A non-repetitive transient current is usually due to an external cause and it is assumed that its effect has completely disappeared before the next transient arrives.

3.6.21**peak case non-rupture current (I_{RSMC})**

peak value of reverse current that should not be exceeded in order to avoid bursting of the case or the emission of a plasma beam, under specified conditions of the waveshape and duration of the reverse current pulse

NOTE 1 This definition implies that a fine crack in the case is tolerated, if found in a device subjected to the peak case non-rupture current, provided that no plasma beam was emitted, parts of the case did not break away, and the device did not melt externally or burst into flames.

NOTE 2 Such very high reverse currents may occur in large thyristor assemblies if one of the thyristors has a reverse breakdown. Very large thyristors may have a peak surge on-state current that is higher than the peak case non-rupture current so that a fuse selected for the peak surge on-state current cannot provide protection against rupture of the case.

3.6.22

case non-rupture $I^2 t$ value ($I_{RSC}^2 t$)

value of $I_{RSC}^2 t$ that should not be exceeded in order to avoid bursting of the case or the emission of a plasma beam, under specified conditions of the waveshape and duration of the reverse current pulse and given as follows:

$$I_{RSC}^2 t = \int_0^{t_p} i_R^2 dt$$

where t_p is the reverse current pulse duration

NOTE 1 This definition implies that a fine crack in the case is tolerated if found in a device subjected to the case non-rupture $I^2 t$ value, provided that no plasma beam was emitted, parts of the case did not break away, and the device did not melt externally or burst into flames.

NOTE 2 Such very high reverse currents may occur in large thyristor assemblies if one of the thyristors has a reverse breakdown. Very large thyristors may have an (on-state) $I^2 t$ value that is higher than the case non-rupture $I_{RSC}^2 t$ value so that a fuse selected for the $I^2 t$ value cannot provide protection against rupture of the case.

3.6.23

critical rate of rise of on-state current ($(di_T/dt)_{cr}$)

highest value of the rate of rise of on-state current that a thyristor can withstand without deleterious effect

3.6.24

latching current (I_L)

minimum anode or principal current required to maintain the thyristor in the on-state immediately after the triggering condition has been removed following switching from the off state to the on state

3.6.25

holding current (I_H)

minimum anode, principal, or thyristor current that will maintain the thyristor in the on state

3.6.26

off-state current (I_D)

anode, principal, or thyristor current when the thyristor is in the off state

3.6.27

direct off-state current ($I_{D(D)}$)

off-state current that is independent of time or in which the changes are so small that they can be neglected

3.6.28

tail current (of a GTO thyristor) (I_Z)

anode current that flows during the tail time (see figure 13)

3.6.29

peak tail current (of a GTO thyristor) (I_{ZM})

peak value of tail current that occurs shortly after the beginning of the tail time (see figure 13)

3.6 Terms related to ratings and characteristics; gate voltages and currents

3.7

3.7.1

gate voltage (V_G)

voltage between the gate terminal and

- for unidirectional triode thyristors, the cathode in the case of a P-gate thyristor and the anode in the case of an N-gate thyristor,
- for bidirectional triode thyristors, the specified main terminal

3.7.2

gate current (I_G)

(control) current into the gate terminal

3.7.3

forward gate voltage (V_{FG})

- for P-gate thyristors, the positive gate-cathode voltage
- for N-gate thyristors, the negative gate-anode voltage

3.7.4

peak forward gate voltage (V_{FGM})

highest instantaneous value of the forward gate voltage including all transient voltages

3.7.5

reverse gate voltage (V_{RG})

- for P-gate thyristors, the negative gate-cathode voltage
- for N-gate thyristors, the positive gate-anode voltage

3.7.6

peak reverse gate voltage (V_{RGM})

highest instantaneous value of the reverse gate voltage including all transient voltages

3.7.7

forward gate current (I_{FG})

- for P-gate thyristors, the positive gate current
- for N-gate thyristors, the negative gate current

3.7.8

peak forward gate current (I_{FGM})

highest instantaneous value of the forward gate current including all transient currents

3.7.9

reverse gate current (I_{RG})

- for P-gate thyristors, the negative gate current
- for N-gate thyristors, the positive gate current

3.7.10

peak reverse gate current (I_{RGM})

highest instantaneous value of the reverse gate current including all transient currents

3.7.11

sustaining gate current (of a GTO thyristor) (I_{FGsus})

minimum forward gate current required to ensure that, if the anode current drops below the value required to keep all the subdivided cathode areas in conduction, they will all return to conduction when the anode current is increased again

3.7.12

turn-on gate voltage (V_{FGT})

forward gate voltage during the time interval within which the thyristor is turning on

3.7.13

turn-on gate drive voltage (V_{FGT})

gate voltage required to produce the turn-on gate drive current

3.7.14

on-state gate bias voltage (V_{FGB})

forward gate voltage during the time interval following the time within which the thyristor was turning on

3.7.15

turn-off gate voltage (of a GTO thyristor) (V_{RGQ})

reverse gate voltage during the time interval within which the thyristor is turning off

3.7.16

peak turn-off gate voltage (of a GTO thyristor) (V_{RGQM})

peak value of the turn-off gate voltage at the end of its rapid rise after the peak value of turn-off gate current (I_{RGQM}) has been reached

3.7.17

turn-off gate bias voltage (of a GTO thyristor) (V_{RGQB})

essentially constant value of the turn-off gate voltage that occurs towards the end of the turn-off process, in the case where the gate-control circuit supports this process by maintaining the turn-off gate voltage at a value that is higher than the off-state gate bias voltage

3.7.18

off-state gate bias voltage (of a GTO thyristor) (V_{RGB})

reverse gate voltage during the time interval following the time within which the thyristor was turning off

3.7.19

turn-on gate current (i_{FGT})

forward gate current during the time interval within which the thyristor is turning on

3.7.20

turn-on gate drive current (I_{FGT})

turn-on gate current supplied by the trigger circuit

NOTE Often the turn-on process is accelerated by an extra high peak current at the beginning of the trigger pulse (see figure 12).

3.7.21

peak turn-on gate drive current (I_{FGTM})

peak value of the turn-on gate drive current pulse

3.7.22

on-state gate bias current (I_{FGB})

forward gate current during the time interval following the time within which thyristor was turning on

3.7.23

turn-off gate current (of a GTO thyristor) (I_{RGQ})

reverse gate current during the time interval within which thyristor is turning off

3.7.24

turn-off gate bias current (of a GTO thyristor) (I_{RGQB})

gate current associated with the turn-off gate bias voltage V_{RGQB}

3.7.25

peak turn-off gate current (of a GTO thyristor) (I_{RGQM})

peak value of the reverse gate current reached at the end of its rapid rise in the beginning of the turn-off process

NOTE Specifications refer to the minimum value of I_{RGQM} that the gate turn-off pulse generator is capable of supplying as a function of the peak on-state current to be switched off under specified conditions.

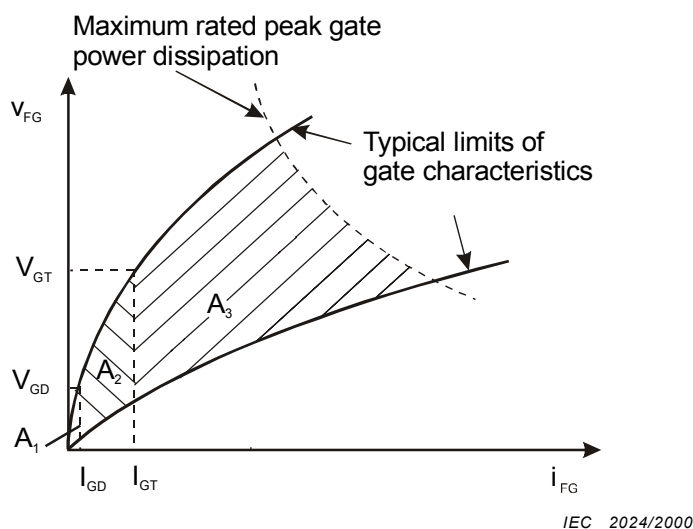


Figure 5 – Forward gate voltage versus forward gate current

3.7.26

off-state gate bias current (I_{RGB})

reverse gate current during the time interval following the time within which the thyristor was turned off

3.7.27

gate trigger current (I_{GT})

lowest gate current required to safely trigger any thyristor of a type under specified conditions

3.7.28

gate trigger voltage (V_{GT})

gate voltage required to produce the gate trigger current

3.7.29

gate non-trigger current (I_{GD})

highest value of an undesired current in the gate circuit which will safely not trigger any thyristor which is under specified conditions

3.7.30

gate non-trigger voltage (V_{GD})

gate voltage associated with the gate non-trigger current

3.8 Terms related to ratings and characteristics; powers, energies and losses

NOTE 1 All definitions are written in terms of triode thyristors. Where appropriate, they apply also to diode thyristors.

NOTE 2 All definitions for power, energy and losses refer, if not otherwise specified, to the product of anode or principal current and anode or principal voltage.

A Instantaneous power during a cycle

NOTE 1 The following definitions refer to a chronological subdivision of the cycle time into particular intervals during which the thyristor is either in a particular state or during which it changes state.

NOTE 2 The definitions are general. They do not consider that the beginning and ending of the particular time interval should be identified in order to make specifications for the derived characteristics "mean partial power loss" and "partial energy loss" meaningful. However, guidance for the specification of these times is given in the relevant notes.

3.8.1

reverse power (P_R)

power when the thyristor is in the reverse-blocking state

NOTE If not otherwise specified, the term refers to the power in the time interval between the ending of the turn-off time and the change from the reverse blocking state to the off state (either $I = 0$ or $V = 0$).

3.8.2

reverse-conducting power (of a reverse-conducting thyristor) (P_{RC})

power while the thyristor is in the reverse-conducting state

NOTE If not otherwise specified, the term refers to the power in the time interval between the ending of the turn-off time and the change from the reverse conducting state to the off state (either $I = 0$ or $V = 0$).

3.8.3

off-state power (P_D)

power while the thyristor is in the off state

NOTE If not otherwise specified, the term refers to the power generated during the time interval between the crossing of the origin from the reverse blocking (or conducting) state to the off state ($I = 0$ or $V = 0$) and the beginning of the turn-on time, with GTO thyristors; in addition during the time interval between the ending of the turn-off time and the crossing of the origin from the off state to the reverse-blocking (or conducting) state.

3.8.4

turn-on power (P_{TT})

power in the time interval during which the thyristor is turning on

NOTE If not otherwise specified, this time interval corresponds with the turn-on time.

3.8.5

on-state power (P_T)

power while the thyristor is in the on state

NOTE If not otherwise specified, the term refers to the power during the period between the ending of the turn-on time and the beginning of the turn-off time.

3.8.6

turn-off power (P_{RO}); for GTO thyristors: (P_{DQ})

power in the time interval during which the thyristor is turning off

NOTE If not otherwise specified, this time interval corresponds with the turn-off time.

3.8.7**gate power (P_G)**

product of the instantaneous values of gate current and voltage

B Mean power losses

NOTE 1 The term “power dissipation” has been used in the past as a true synonym for “power loss”. This is no longer recommended. The term “loss” should refer to the loss at the place of its origin and the term “dissipation” should refer to the heat that is dissipated from the surface of the device into the environment. Different terms are provided for the two quantities because, due to internal storage of heat, the two differ with time.

NOTE 2 As an exception, “mean power dissipation” may still be used as a synonym for “mean power loss”, but only where appropriate, i.e. when the different course with time has no influence on the mean values of the two. This is the case when the mean values are averaged over a full cycle.

3.8.8**mean partial power loss**

mean value of the instantaneous power loss in a particular time interval of the cycle, averaged over the full cycle

3.8.9**mean total power loss ($P_{\text{tot(AV)}}$)**

sum of all mean partial power losses and the mean gate power loss, during a full cycle

$$P_{\text{tot(AV)}} = P_{\text{T(AV)}} + P_{\text{add(AV)}} + P_{\text{G(AV)}}$$

3.8.10**mean on-state power loss ($P_{\text{T(AV)}}$)**

mean partial power loss resulting from on-state power

3.8.11**mean additional power loss ($P_{\text{add(AV)}}$)**

Sum of $P_{\text{add(AV)}} = P_{\text{TT(AV)}} + P_{\text{RQ(AV)}} + P_{\text{D(AV)}} + P_{\text{R(AV)}}$

With GTO thyristors, $P_{\text{RQ(AV)}}$ is replaced by $P_{\text{DQ(AV)}}$.

3.8.12**mean turn-on power loss ($P_{\text{TT(AV)}}$)**

mean partial power loss resulting from the turn-on power

3.8.13**mean turn-off power loss ($P_{\text{RQ(AV)}}$); for GTO thyristors: ($P_{\text{DQ(AV)}}$)**

mean partial power loss resulting from turn-off power

3.8.14**mean off-state power loss ($P_{\text{D(AV)}}$)**

mean partial power loss resulting from off-state power

3.8.15**mean reverse power loss ($P_{\text{R(AV)}}$)**

mean partial power loss resulting from reverse power

3.8.16**mean gate power loss ($P_{\text{G(AV)}}$)**

gate power loss averaged over a full cycle

C Energy losses (for GTO thyristors: see figure 7)

3.8.17

dynamic on-state energy loss (E_T)

total energy loss from the instant when the rising on-state current reaches a specified low value to the instant that defines the beginning of the turn-off time

3.8.18

basic on-state energy loss (E_{TB})

energy loss that would result from the flow of on-state current if the thyristor were fully turned on during the entire on-state period

NOTE This energy loss can only be determined by calculations based on the observed waveform of the current. The calculation method is to be specified.

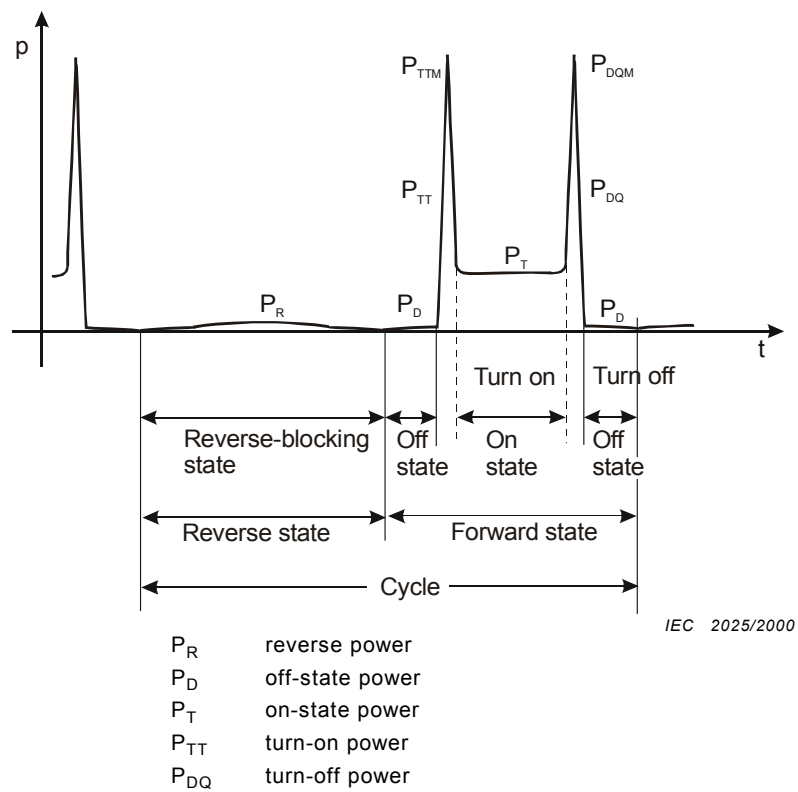


Figure 6 – Partial power (losses) of GTO thyristors at relatively low frequencies

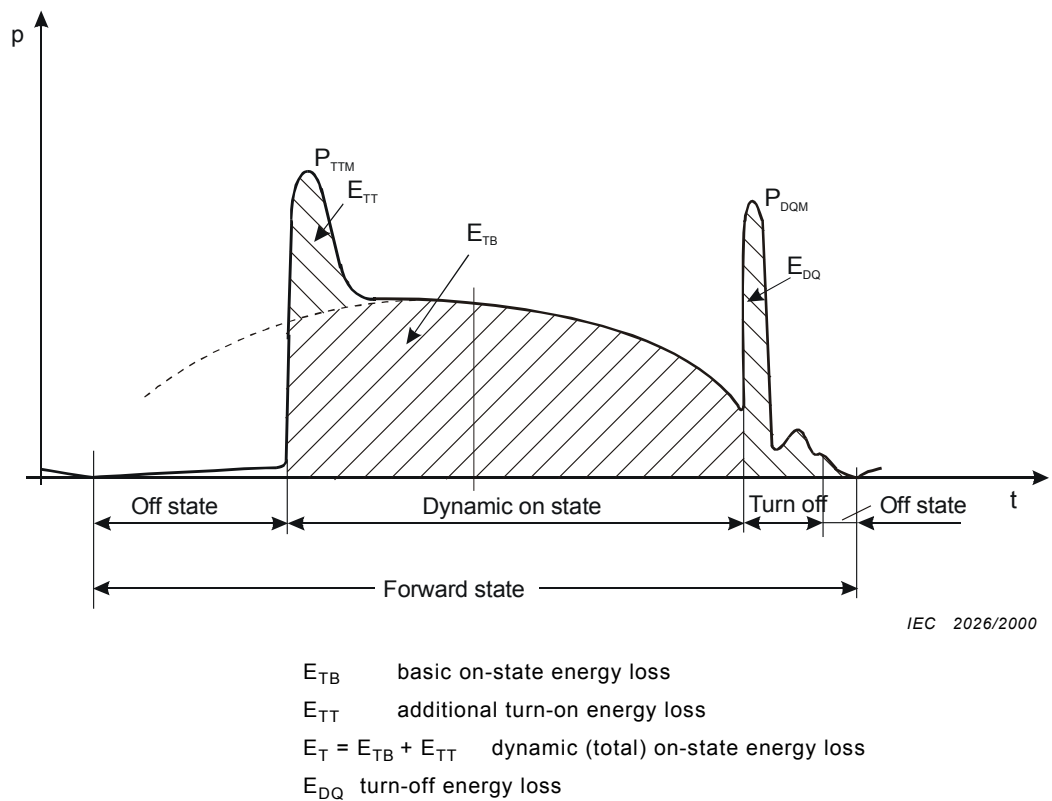


Figure 7 – Components of dynamic on-state energy loss of GTO thyristors at relatively high frequencies

3.8.19

additional turn-on energy loss (E_{TT})

calculated difference between the dynamic on-state energy loss and the basic on-state energy loss:

$$E_{TT} = E_T - E_{TB}$$

3.8.20

turn-off energy loss (E_{RQ}); for GTO thyristors: (E_{DQ})

energy loss during the turn-off time

3.9 Terms related to ratings and characteristics; recovery times and other characteristics

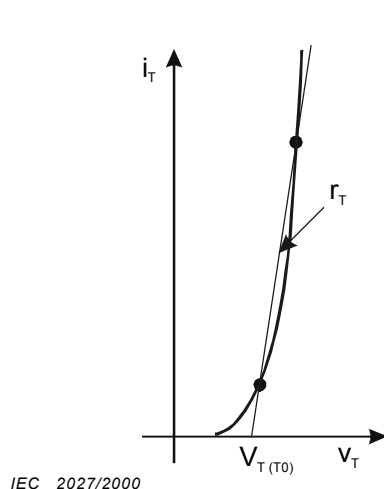


Figure 8a – On-state characteristic

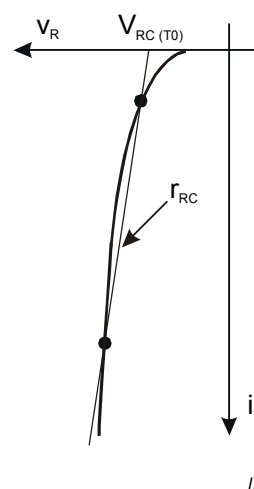


Figure 8b – Reverse-conducting characteristic

Figure 8 – Approximation of characteristics

A Approximation of the on-state characteristic (see figure 8a)

3.9.1

straight-line approximation of the on-state characteristic

approximation of the current versus voltage on-state characteristic by means of a straight line that crosses this characteristic at two specified points

3.9.2

on-state slope resistance (r_T)

value of the resistance calculated from the slope of the straight-line approximation of the on-state characteristic

3.9.3

on-state threshold voltage ($V_{T(T0)}$, $V_{(T0)}$)

value of the on-state voltage obtained at the intersection of its straight-line approximation with the voltage axis

B Approximation of the reverse-conducting characteristic (see figure 8b)**3.9.4****straight-line approximation of the reverse-conducting characteristic**

approximation of the current versus voltage reverse-conducting characteristic by means of a straight line that crosses this characteristic at two specified points

3.9.5**reverse-conducting slope resistance (r_{RC})**

value of the resistance calculated from the slope of the straight-line approximation of the reverse-conducting characteristic

3.9.6**reverse-conducting threshold voltage ($V_{RC(TO)}$)**

value of the reverse voltage obtained at the intersection of its straight-line approximation with the voltage axis

C Thermal characteristics, basic definitions

The definitions given in IEC 60747-1, chapter IV, apply. The following additional definitions may be useful.

D Partial thermal resistances (of thyristors in disc-type housings)**3.9.7****partial thermal resistance junction-to-case, anode side ($R_{th(j-c)A}$)**

thermal resistance between the virtual junction and the anode side of the case

3.9.8**partial thermal resistance junction-to-case, cathode side ($R_{th(j-c)K}$)**

thermal resistance between the virtual junction and the cathode side of the case

E Partial thermal resistances (of reverse-conducting thyristors with integrated inverse diodes)

NOTE 1 As on-state power loss and reverse-conducting power loss occur in different places, a distinction between the thyristor junction-to-case thermal resistance and the diode junction-to-case thermal resistance may be necessary.

NOTE 2 The application of specifications for these partial thermal resistance's in the case of concurrent power losses in the thyristor and in the reverse diode is under consideration.

3.9.9**thyristor junction-to-case thermal resistance ($R_{th(j-c)T}$)**

quotient of

- the temperature difference between the thyristor junction and the reference point, by
- the steady-state on-state power loss in the thyristor, under the condition that the whole power loss in the device is due to on-state current.

3.9.10

diode junction-to-case thermal resistance ($R_{th(j-c)D}$)

quotient of

- the temperature difference between the diode junction and the reference point, by
- the steady-state reverse conducting power loss in the diode, under the condition that the whole power loss in the device is due to reverse-conducting current

F Recovery times

3.9.11

reverse recovery time (of a reverse-blocking thyristor) (t_{rr})

time interval between

- the instant when the current passes through zero while changing from the on state to the reverse-blocking state, and
- the instant when either the reverse current is reduced from its peak value I_{RM} to a specified low value (as shown in figure 9a and which may be zero), or the extrapolated reverse current reaches zero (as shown in figure 9b).

NOTE 1 The extrapolation is carried out with respect to specified points A and B, as shown in generalized form in figure 9b. Point A may be specified at I_{RM} .

NOTE 2 Specified values of t_{rr} refer to a specified waveform of the preceding on-state current pulse, which may be either a half sine wave (solid line) or a trapezoidal wave (dashed line).

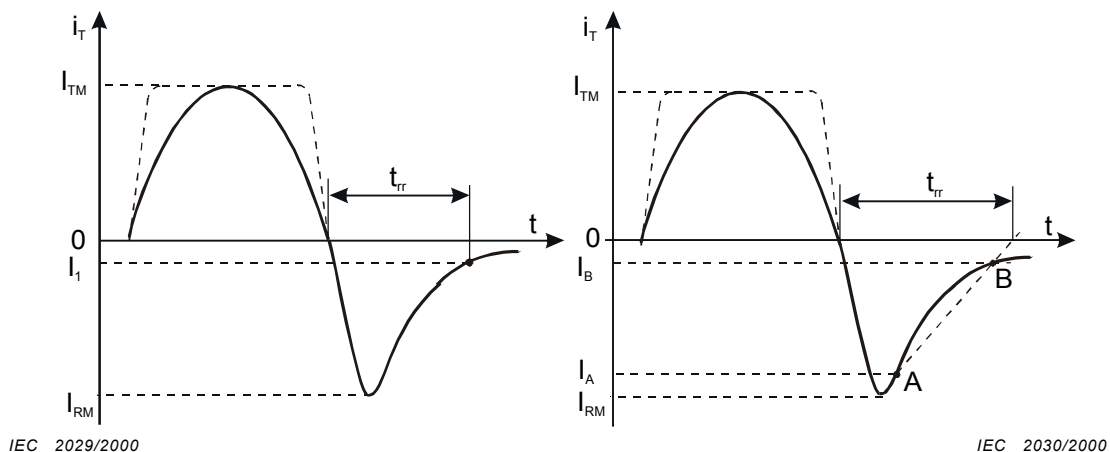


Figure 9a – Determined by specified value

Figure 9b – Determined by extrapolation

Figure 9 – Reverse recovery time

3.9.12

off-state recovery time (of a reverse-conducting thyristor) (t_{dr})

The time interval between

- the instant when the current passes through zero while changing from the reverse-conducting state to the off state,
- and
- the instant when either the off-state current is reduced from its peak value I_{DM} to a specified low value I_1 (as shown in figure 10a and which may be zero), or the extrapolated reverse current reaches zero (as shown in figure 10b).

NOTE 1 The extrapolation is carried out with respect to specified points A and B, as shown in generalized form in figure 10b. Point A may be specified at I_{DM} .

NOTE 2 Specified values of t_{dr} refer to a specified waveform of the preceding reverse-current pulse, which may be either a half sine wave (solid line) or a trapezoidal wave (dashed line).

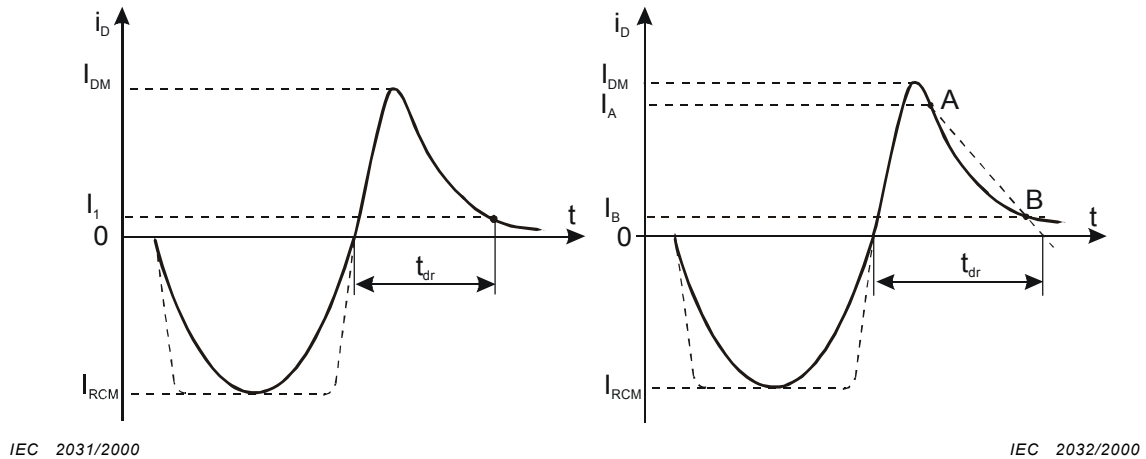


Figure 10a – Determined by specified value

Figure 10b – Determined by extrapolation

Figure 10 – Off-state recovery time

3.9.13 circuit-commutated turn-off time (t_q)

time interval between

- the instant when the on-state current has decreased to zero after external switching of the main circuit, and
- the earliest instant when a steeply rising off-state voltage that the thyristor is capable of supporting without breaking over either passes through zero (curve a) in figure 11, or begins from a low positive value (curve b) in figure 11.

NOTE Curve a) refers to a simple reverse-blocking triode thyristor. Curve b) may appear, if the thyristor is bypassed by an external or internal inverse diode (reverse-conducting thyristor), due to the lead inductance of the diode.

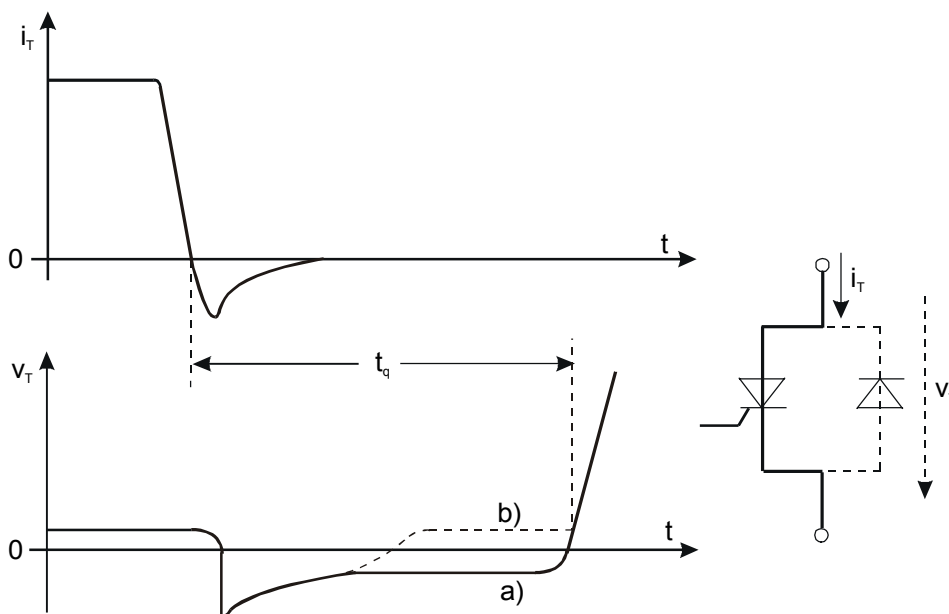


Figure 11 – Circuit-commutated turn-off time

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3.9.14

hold-off interval (in a converter) (t_H)

time interval between

- the instant when the anode current of the thyristor of a converter has decreased to zero, and
- the instant when the same thyristor is subjected to off-state voltage.

NOTE The hold-off interval is not a characteristic of the thyristor but a service condition of the converter. It will exceed the longest expected individual circuit-commuted turn-off time, which also depends on the service conditions of the converter.

G Times and rates of rise characterizing gate-controlled turn-on (see figure 12)

NOTE 1 The defined terms refer to the switching of a thyristor from the off state to the on state by means of a forward gate drive current pulse.

NOTE 2 The reference values of current and voltage referred to in the following subclauses are usually specified as follows:

gate current:

- specified low value: 10 % of I_{FGTM} ,
- specified level for the measurement of t_{gtw} and di_G/dt : 50 % of I_{FGTM} ,

anode voltage:

- upper specified value: 90 % of V_D ,
- lower specified value: 10 % of V_D , (where V_D is the off-state voltage prior to turn on),

anode current:

- specified level for the measurement of di_G/dt : 50 % of I_{TM} .

3.9.15

gate-controlled turn-on delay time (t_{gd})

time interval between

- the instant when the rising gate drive current pulse reaches a specified low value, and
- the instant when the decreasing off-state voltage reaches an upper specified value near its initial value V_D .

NOTE If no ambiguity is likely to occur, the term may be abbreviated to "turn-on delay time".

3.9.16

gate-controlled turn-on rise time (t_{gr})

time interval between

- the instant when the off-state voltage reaches the upper specified value referred to in 3.9.15, and
- the instant when the decreasing off-state voltage reaches a lower specified value near its final steady-state value

NOTE If no ambiguity is likely to occur, the term may be abbreviated to "turn-on rise time".

3.9.17

gate-controlled turn-on time (t_{gt})

sum of gate-controlled turn-on delay time and rise time:

$$t_{gt} = t_{gd} + t_{gr}$$

NOTE If no ambiguity is likely to occur, the term may be abbreviated to "turn-on time".

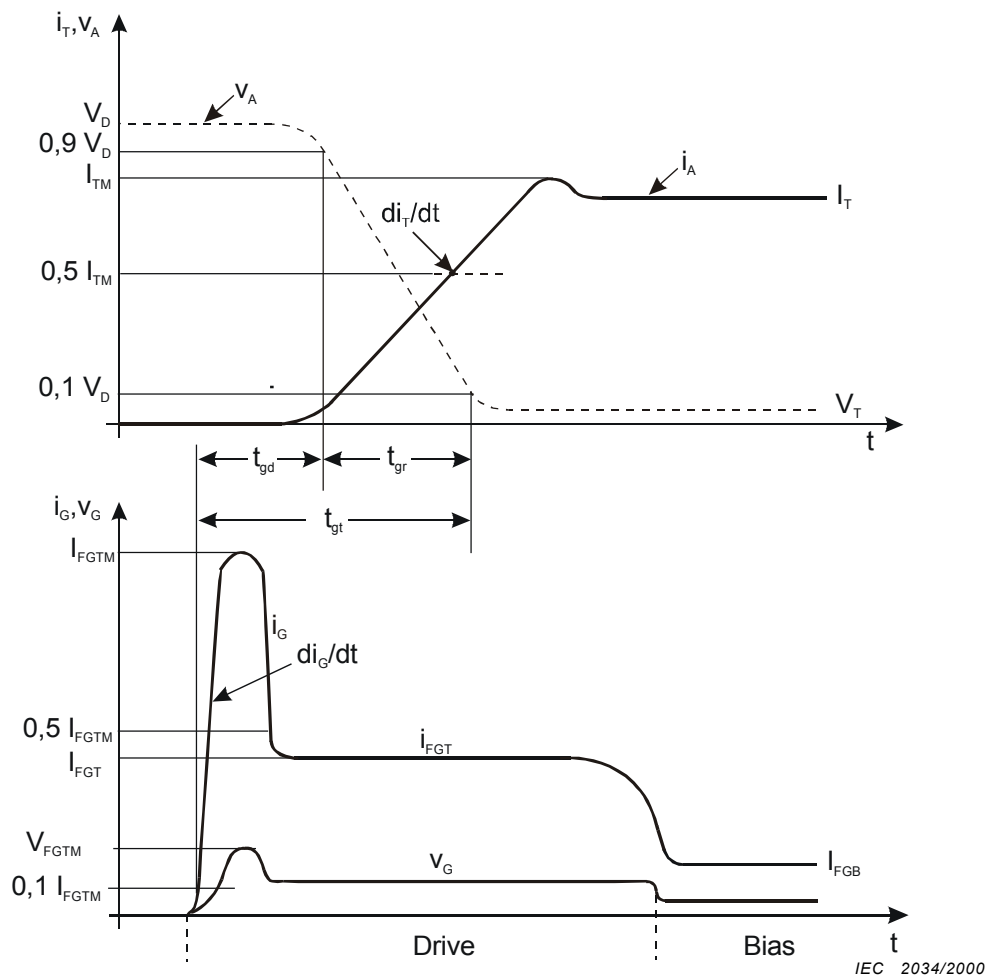


Figure 12 – Gate-controlled turn-on times

3.9.18

gate turn-on drive-pulse duration (t_{gtw})

duration of the forward gate drive current pulse measured between two specified levels of the forward gate current

3.9.19

critical gate turn-on drive-pulse duration ($t_{gtw(cr)}$)

lowest value to which the gate turn-on drive pulse duration can be reduced without the thyristor failing to turn on

H Times and rates of rise characterizing, gate-controlled turn-off (see figure 13)

NOTE 1 The defined terms refer to the switching of a GTO thyristor from the on state to the off state by means of a reverse gate drive current pulse that is supported by an additional reverse gate drive voltage pulse and that is followed by a smaller reverse gate bias current.

NOTE 2 The reference values of current and voltage referred to in 3.9.20 through 3.9.25 are usually specified as follows:

gate current:

- specified low value near zero: 10 % of I_{RGQM} ,
- specified level for the measurement of di_{RG}/dt : 50 % of I_{RGQM} ,

anode current:

- upper reference value: 90 % of I_T ,

anode voltage:

- specified level for the measurement of dv_D/dt : 50 % of V_{DQM} .

3.9.20

gate-controlled turn-off delay time (t_{dq})

time interval between

- the instant when the rising reverse gate current reaches a low reference value near zero, and
- the instant when the anode current has decreased to an upper reference value near its initial value I_T .

NOTE If no ambiguity is likely to occur, the term may be abbreviated to “turn-off delay time”.

3.9.21

gate-controlled fall time (t_{fq})

time interval between

- the instant when the anode current has decreased to the upper reference value referred to in 3.9.20, and
- the instant when the anode current reaches, at the end of its steep decrease, the valley point current I_{ZV}

NOTE If no ambiguity is likely to occur, the term may be abbreviated to “turn-off fall time”.

3.9.22

gate-controlled turn-off time (t_{gq})

sum of gate-controlled turn-off delay time and fall time:

$$t_{gq} = t_{dq} + t_{fq}$$

NOTE If no ambiguity is likely to occur, the term may be abbreviated to “turn-off time”.

3.9.23

tail time (t_z)

time interval between

- the instant when the anode current has decreased to the valley point I_{ZV} , referred to in 3.9.21, and
- the instant when the extrapolated tail current reaches zero.

NOTE Unless otherwise specified, the extrapolation is carried out between the peak point of the tail current I_{ZM} and $I_{ZL} = 25\% I_{ZM}$ (see figure 13).

3.9.24

gate turn-off drive-pulse duration (t_{pgq})

duration of the reverse gate-drive voltage pulse measured between two specified levels of reverse gate-drive voltage

3.9.25

critical gate turn-off drive-pulse duration ($t_{pgq(cr)}$)

lowest value to which the gate turn-off drive-pulse duration can be reduced without the thyristor failing to turn off

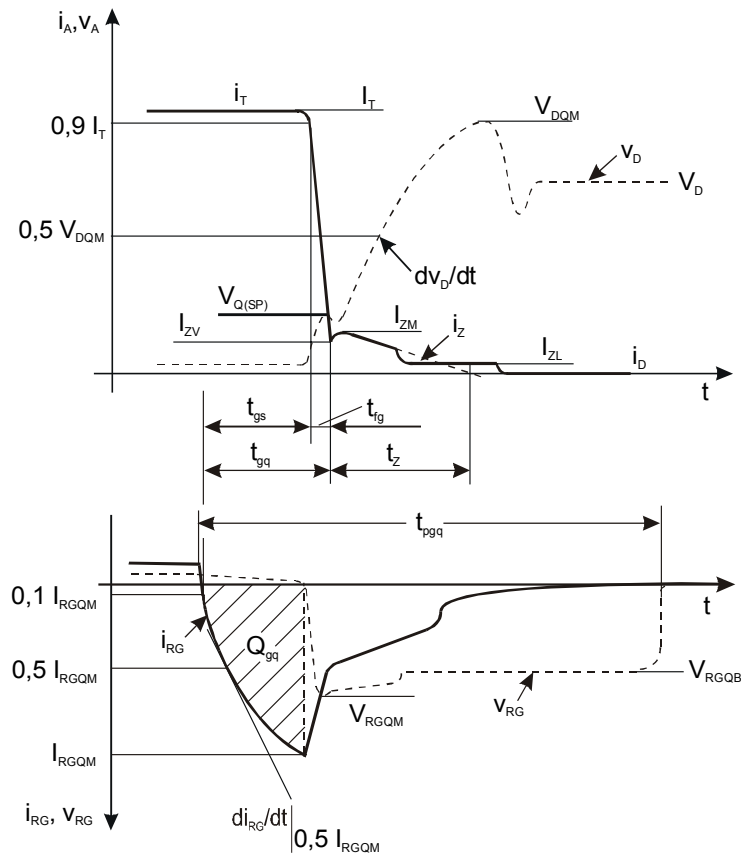


Figure 13 – Gate-controlled turn-off times

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I Recovered charges

3.9.26

recovered charge(of a reverse-blocking triode thyristor) (Q_r)

total charge recovered from the thyristor during a specified integration time after switching from a specified on-state current condition to a specified reverse condition:

$$Q_r = \int_{t_0}^{t_0 + t_i} i_R \, dt$$

where

t_0 is the instant when the current passes through zero;

t_i is the specified integration interval (see figure 14).

NOTE This charge includes components due to both carrier storage and depletion layer capacitance.

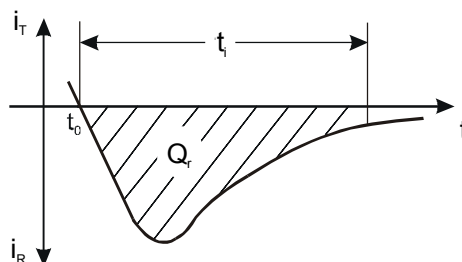


Figure 14 – Recovered charge Q_r

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3.9.27

off-state recovered charge (of a reverse-conducting triode thyristor) (Q_{dr})

total charge recovered from the thyristor during a specified integration time after switching from a specified reverse current condition to a specified off-state condition

NOTE The formula given in 3.9.26 and figure 14 apply analogously.

3.9.28

gate turn-off charge (of a GTO thyristor) (Q_{gq})

total charge derived from the integration of the reverse gate current between the instant when the falling forward gate current crosses zero and the instant in which the reverse gate current reaches its peak value I_{RGQM} (see figure 13)

4 Letter symbols

4.1 General

The general rules of IEC 60747-1, chapter V, are applicable in part.

4.2 Additional general subscripts

In addition to the lists of recommended general subscripts given in IEC 60747-1, chapter V, the following special subscripts are recommended for the field of thyristors.

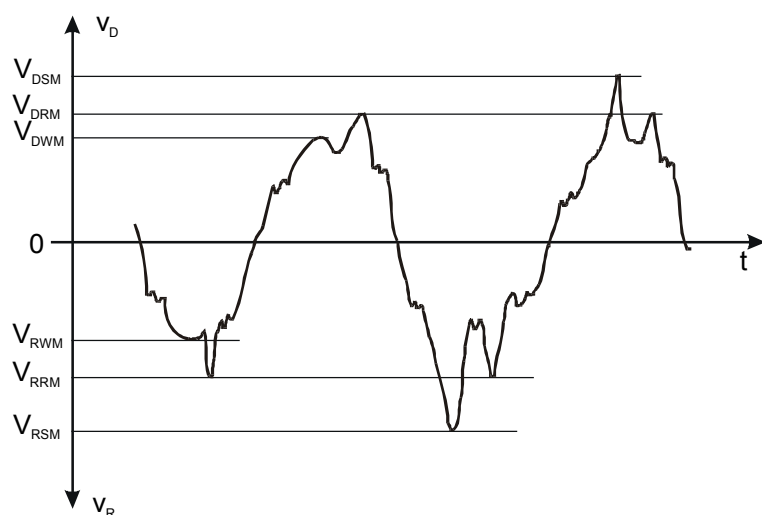
Subscript	Significance	Remarks
A, a	Anode	
B	Bias	As last subscript only
B	Basic	As last subscript only
(BO)	Breakover	
(com)	Commutating	As for fourth subscript only
D, d	Off-state	In $R_{th(j-c)D}$ only
D	Drive	
D	Diode	
G, g	Gate	
G	Gate-controlled	
H	Holding	
h	Hold-off	
K, k	Cathode	
L	Latching	
Q, q	Turn-off	
R, (REC)	Reverse recovery	In I_{RM} or $I_{R(REC)}$ and $I_{RM(REC)}$ only
RC	Reverse-conducting	
(SP)	Spike	
Sus	Sustaining	
T	On state	
T, t	Turn-on, trigger	
T	Thyristor	
V	Valley	
W	Working	
Z, z	Tail	

4.3 List of letter symbols

The symbols contained in the following lists are recommended for use in the field of thyristors; they have been compiled in accordance with the general rules.

4.3.1 Principal voltages, anode-cathode voltages

Name and designation	Letter symbol	Remarks
Off-state voltage	V_D	
Direct off-state voltage	$V_{D(D)}$	
Peak off-state voltage	V_{DM}	
Crest (peak) working off-state voltage	V_{DWM}	
Repetitive peak off-state voltage	V_{DRM}	
Non-repetitive peak off-state voltage	V_{DSM}	
Breakover voltage	$V_{(BO)}$	
On-state voltage	V_T	
Minimum on-state voltage	V_{TMIN}	
On-state threshold voltage	$V_{T(TO)}$	
Reverse voltage	V_R	
Direct reverse voltage	$V_{R(D)}$	
Crest (peak) working reverse voltage	V_{RWM}	
Repetitive peak reverse voltage	V_{RRM}	
Non-repetitive peak reverse voltage	V_{RSM}	
Reverse breakdown voltage	$V_{(BR)}$	
Reverse-conducting threshold voltage	$V_{RC(TO)}$	



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Figure 15 – Letter symbols for rated off-state reverse voltages

4.3.2
Principal currents, anode currents, cathode currents

Name and designation	Letter symbol	Remarks
Off-state current	I_D	
Breakover current	$I_{(BO)}$	
Holding current	I_H	
On-state current	I_T	
Overload on-state current	$I_{(OV)}$	
Repetitive peak on-state current	I_{TRM}	
Surge (non-repetitive) on-state current	I_{TSM}	
Reverse blocking current	I_R	
Repetitive peak reverse current	I_{RRM}	
Reverse recovery current	I_{RR}	
Peak reverse recovery current	I_{RM}	
Latching current	I_L	
Reverse-conducting current	I_{RC}	
Mean reverse-conducting current	$I_{RC(AV)}$	
Peak reverse-conducting current	I_{RCM}	
Overload reverse-conducting current	$I_{RC(OV)}$	
Surge reverse-conducting current	I_{RCSM}	
Direct on-state current	$I_{T(D)}$	
Direct off-state current	$I_{D(D)}$	

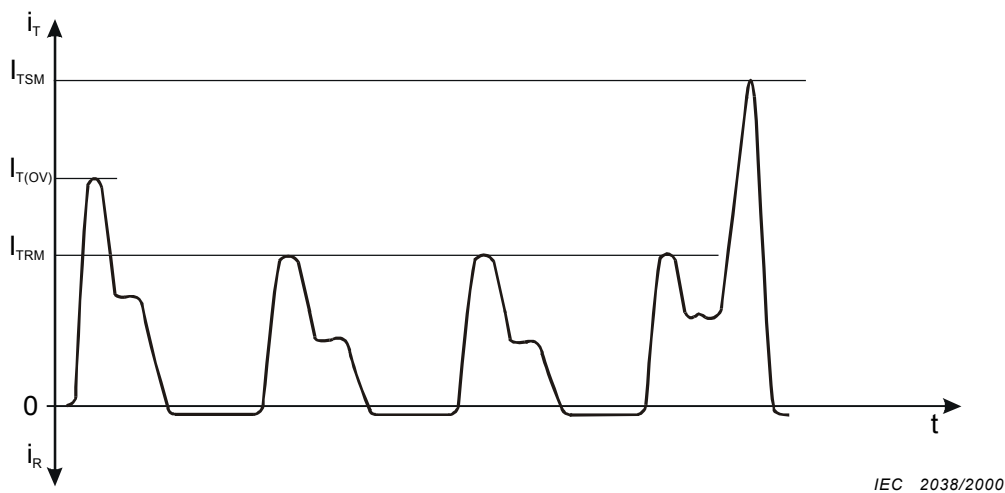


Figure 16 – Letter symbols for on-state current ratings

4.3.3 Gate voltages

Name and designation	Letter symbol	Remarks
Forward gate continuous (direct) voltage	V_{FG}	
Peak forward gate voltage	V_{FGM}	
Reverse gate continuous (direct) voltage	V_{RG}	
Peak reverse gate voltage	V_{RGM}	
Gate trigger continuous (direct) voltage	V_{GT}	
Minimum gate trigger voltage	V_{GTMIN}	
Gate non-trigger continuous (direct) voltage	V_{GD}	
Gate turn-off continuous (direct) voltage	V_{GQ}	

4.3.4 Gate currents

Name and designation	Letter symbol	Remarks
Forward gate continuous (direct) current	I_{FG}	
Peak forward gate current	I_{FGM}	
Reverse gate continuous (direct) current	I_{RG}	
Gate trigger continuous (direct) current	I_{GT}	
Gate non-trigger continuous (direct) current	I_{GD}	
Gate turn-off continuous (direct) current	I_{GQ}	

4.3.5 Time quantities

Name and designation	Letter symbol	Remarks
Gate controlled turn-on time	t_{gt}	
Gate controlled turn-off time	t_{gq}	
Circuit commutated recovery time (circuit commutated turn-off time)	t_q	
Gate-controlled delay time	$t_{gd}, (t_d)$	t_d and t_r shall be used only when misinterpretation will not result
Gate-controlled rise time	$t_{gr}, (t_r)$	t_d and t_r shall be used only when misinterpretation will not result
Off-state recovery time	t_{dr}	For reverse conducting triode thyristors
Hold-off interval	t_H	

4.3.6 Sundry quantities

Name and designation	Letter symbol	Remarks
On-state slope resistance	r_T	
Critical rate of rise of commutating voltage	$dv/dt(c)$, ($dv/dt(com)$)	For reverse conducting triode thyristors, $dv/dt(c)$ is the preferred symbol
Off-state recovered charge	Q_{dr}	For reverse conducting triode thyristors
Total energy of on-state current pulse	E_p W_p	
Reverse-conducting slope resistance	r_{RC}	

4.3.7 Power loss

Name and designation	Letter symbol	Remarks
On-state power loss	P_T	
Reverse power loss	P_R	For reverse blocking and conducting triode thyristors
Off-state power loss	P_D	
Turn-on loss – average turn-on loss – total instantaneous turn-on loss – peak turn-on loss	$P_{TT(AV)}$ P_{TT} P_{TTM}	
Turn-off loss – average turn-off loss – total instantaneous turn-off loss – peak turn-off loss	$P_{RQ(AV)}$ or $P_{DQ(AV)}$ P_{RQ} or P_{DQ} P_{RQM} or P_{DQM}	
Reverse-conducting power loss	P_{RC}	

5 Essential ratings and characteristics for reverse-blocking and reverse-conducting triode thyristors

This clause gives standards for (symmetrical and asymmetrical) reverse-blocking triode thyristors and for reverse-conducting triode thyristors. The ratings and characteristics are specified for reverse-blocking thyristors but most of them may be applied also to reverse-conducting thyristors.

The term “reverse-blocking triode thyristor” has been abbreviated in the text to “thyristor”.

5.1 Thermal conditions

Thyristors shall be specified as ambient-rated devices or as case-rated devices.