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Interested committees:

Title: BS EN 60747-6 Semiconductor devices

Part 6: Discrete devices - Thyristors

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This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

Submission of Comments

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
------------------	------------------------

1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



47E/811/CD

COMMITTEE DRAFT (CD)

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IEC 60747-6 ED4

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2023-06-16

CLOSING DATE FOR COMMENTS:

2023-09-08

SUPERSEDES DOCUMENTS:

47E/776A/RR

IEC SC 47E : DISCRETE SEMICONDUCTOR DEVICES

SECRETARIAT:

Korea, Republic of

SECRETARY:

Mr Hojun Ryu

OF INTEREST TO THE FOLLOWING COMMITTEES:

PROPOSED HORIZONTAL STANDARD:



Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.

FUNCTIONS CONCERNED:

☐ EMC

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TITLE:

Semiconductor devices - Part 6: Discrete devices - Thyristors

NOTE FROM TC/SC OFFICERS:

This new edition work was decided at SC47E/WG3 ON-line meeting, and reported at SC47E plenary meeting 2021.

The voting result of this document will be discussed at the Frankfurt meeting 2023.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR DEVICES –

Part 6: Discrete devices – Thyristors

FOREWORD

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- IEC 60747-6 has been prepared by subcommittee 47E: Discrete semiconductor devices, of IEC technical committee 47: Semiconductor devices. It is an International Standard.
- This fourth edition cancels and replaces the third edition published in 2016. This edition constitutes a technical revision.
- This edition includes the following significant technical changes with respect to the previous edition:
- a) Some mistakes and confusing wording were amended;
 - b) The terms and definitions for partial thermal resistance junction-to-case and voltages related to ratings and characteristics (properties) are added;
 - c) Clauses 3, 4, 5, 6, and 7 were amended with some deletions of information no longer in use and

with some necessary additions.

This International Standard is to be used in conjunction with IEC 60747-1:2006 and Amendment 1:2010.

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

Draft	Report on voting
47E/XX/FDIS	47E/XX/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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

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

SEMICONDUCTOR DEVICES –

Part 6: Discrete devices – Thyristors

1 Scope

This part of IEC 60747 specifies product specific standards for terminology, letter symbols, essential ratings and characteristics (properties), measuring and test methods, requirements for type tests, routine tests, endurance tests and marking for the following discrete semiconductor devices:

- reverse blocking triode thyristors;
- reverse conducting (triode) thyristors;
- bidirectional triode thyristors (triacs);
- turn-off thyristors.

If no ambiguity is likely to occur, any of the above will be referred to as thyristors.

2 Normative references

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

IEC 60050-521, *International Electrotechnical Vocabulary – Part 521: Semiconductor devices and integrated circuits* (available at <http://www.electropedia.org>)

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

IEC 60747-2, *Semiconductor devices – Part 2: Discrete devices – Rectifier diodes*

IEC 60749-23, *Semiconductor devices – Mechanical and climatic test methods – Part 23: High temperature operating life*

IEC 60749-25, *Semiconductor devices – Mechanical and climatic test methods – Part 25: Temperature cycling*

IEC 60749-34:2010, *Semiconductor devices – Mechanical and climatic test methods – Part 34: Power cycling*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60747-1, IEC 60050-521 and the following apply.

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

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

3.1 General

3.1.1

bidirectional triode thyristor

triac

three-terminal thyristor having substantially the same switching behaviour in the first and third quadrants

of the current-voltage characteristic

[SOURCE: IEC 60050-521:2002, 521-04-67]

3.1.2

turn-off thyristor

thyristor which can be switched from the on state to the off state and vice versa by applying control signals of appropriate polarity to the gate terminal

[SOURCE: IEC 60050-521:2002, 521-04-68]

3.1.3

reverse conducting triode thyristor

three-terminal thyristor which for negative anode voltage does not switch and conducts large currents at voltages comparable in magnitude to the forward on-state voltage

[SOURCE: IEC 60050-521:2002, 521-04-65]

3.2 Voltages

3.2.1

repetitive peak reverse voltage

V_{RRM}

maximum instantaneous value of the reverse voltage, including all repetitive transient voltages, but excluding all non-repetitive transient voltages

Note 1 to entry: 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.

3.2.2

non-repetitive peak reverse voltage

peak transient reverse voltage

V_{RSM}

maximum instantaneous value of any non-repetitive transient reverse voltage

Note 1 to entry: 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.

3.2.3

off-state voltage

V_D

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

3.2.4

repetitive peak off-state voltage

V_{DRM}

maximum instantaneous value of the off-state voltage, including all repetitive transient voltages, but excluding all non-repetitive transient voltages

Note 1 to entry: 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.

3.2.5

non-repetitive peak off-state voltage

peak transient off-state voltage

V_{DSM}

maximum instantaneous value of any non-repetitive transient off-state voltage

Note 1 to entry: 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.

3.2.6

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

3.2.7

on-state voltage

V_T

anode, principal or thyristor voltage which results from the flow of current while the thyristor is in the on state

3.2.8

peak on-state voltage

V_{TM}

anode, principal or thyristor voltage which results from the specified peak on-state current

3.2.9

critical rate of rise of commutating voltage

$(dv_{D(com)}/dt)_{cr}$

<reverse conducting triode thyristor> maximum 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 to entry: The measuring method for the rate of rise of commutating voltage is to be specified.

Note 2 to entry: If no ambiguity is likely to result, the shorter expression of the letter symbol " $dv_{(com)}/dt$ " may be used.

3.2.10

critical rate of rise of commutating voltage

critical rate of rise of re-applied off-state voltage

$(dv_{D(com)}/dt)_{cr}$

<bidirectional triode thyristor> maximum 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 to entry: The measuring method for the rate of rise of commutating voltage is to be specified.

Note 2 to entry: If *no ambiguity* is likely to result, the shorter expression of the letter symbol " $dv_{(com)}/dt$ " may be used.

3.3 Currents

3.3.1

non-repetitive surge on-state current

I_{TSM}

on-state current pulse with short duration and specified waveform

Note 1 to entry: Occurrence of the non-repetitive surge on-state current 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 (e.g., a fault) (see Figure 1).

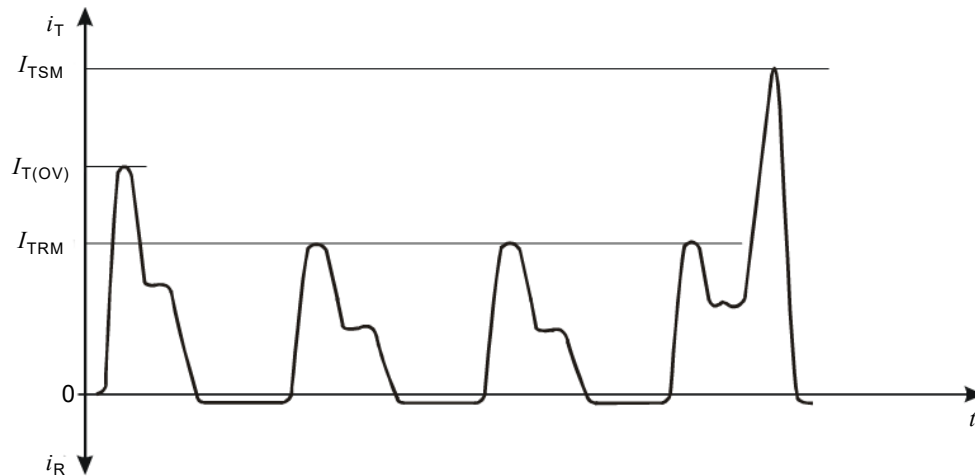


Figure 1 – Peak values of on-state currents

3.3.2 repetitive peak on-state current

I_{TRM}

peak value of the on-state current, including all repetitive transient currents

Note 1 to entry: See Figure 1.

3.3.3 overload on-state current

$I_{T(OV)}$

on-state current whose continuous application would cause the maximum rated virtual junction temperature to be exceeded

Note 1 to entry: See Figure 1.

3.3.4 overload reverse conducting current

$I_{RC(OV)}$

<reverse conducting triode *thyristor*> reverse conducting current whose continuous application would cause the maximum rated virtual junction temperature to be exceeded

3.3.5 non-repetitive surge reverse current

I_{RCSM}

<reverse conducting triode *thyristor*> non-repetitive peak reverse current pulse with short duration and specified waveform

3.3.6 tail current

<turn-off thyristor> anode current flowing during the tail time

Note 1 to entry: Refer to 3.6.4.1.

3.3.7 peak tail current

I_{ZM}

<turn-off thyristor> peak value of the tail current that occurs shortly after the beginning of the tail time

Note 1 to entry: Refer to 3.6.4.1.

3.3.8**peak case non-rupture current** I_{RSMC}

peak value of reverse current that will not cause bursting of the case or the emission of a plasma beam under specified conditions, waveform and *duration of the current* as well as *temperature*

Note 1 to entry: This definition implies that a fine crack in the case might be found in a device subjected to the peak case non-rupture current, provided that no plasma beam was emitted. Parts of the case shall not break away, nor shall the device melt externally or burst into flames.

3.4 Gate voltages and currents**3.4.1****on-state gate bias current** I_{FGB}

forward gate current flowing after the thyristor has been turned on

3.4.2**sustaining gate current** I_{FGsus}

<turn-off thyristor> minimum forward gate current required ensuring that, if the anode current drops below the value required to maintain all the subdivided cathode areas in conduction, they will all return to conduction when the anode current is increased again

3.4.3**off-state gate bias voltage** V_{RGB}

<turn-off thyristor> reverse gate voltage applied after the thyristor has been turned off

3.4.4**turn-off gate voltage** V_{RGQ}

<turn-off thyristor> reverse gate voltage during the time interval within which the thyristor is turning off

3.4.5**turn-off gate current** I_{RGQ}

<turn-off thyristor> reverse gate current during the time interval within which thyristor is turning off

3.4.6**peak turn-off gate voltage** V_{RGQM}

<turn-off thyristor> peak value of the turn-off gate voltage at the end of its rapid rise after the peak turn-off gate current has been reached

3.4.7**peak turn-off gate current** I_{RGQM}

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

Note 1 to entry: Specifications refer to the minimum value of the peak turn-off gate current 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.

3.4.8**turn-off gate bias voltage** V_{RGQB}

<turn-off thyristor> 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

3.4.9**turn-off gate bias current** I_{RGQB}

<turn-off thyristor> reverse gate current associated with the turn-off gate bias voltage

3.5 Power and energy dissipation**3.5.1 General**

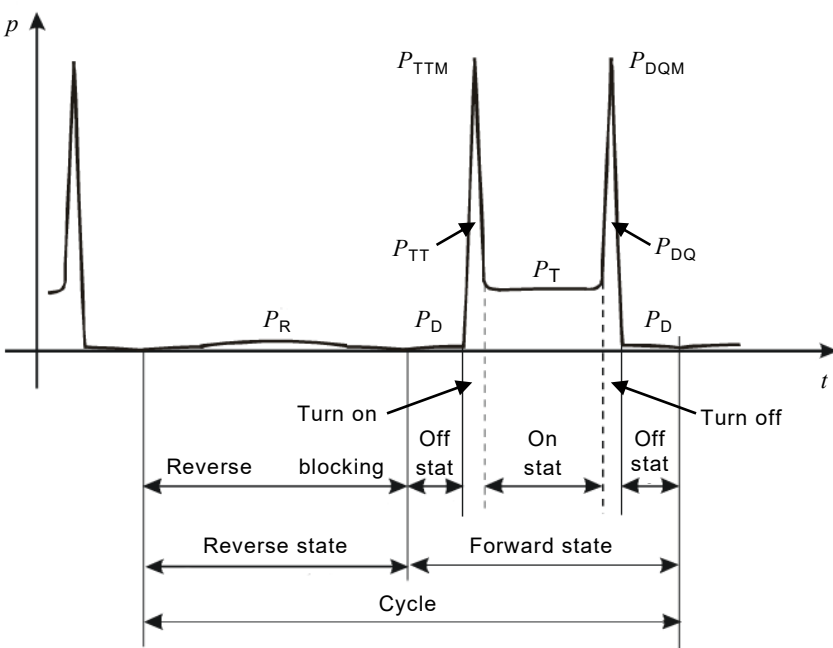
All definitions are written in terms of triode thyristors. Where appropriate, they apply also to diode thyristors.

All definitions for power and power dissipation refer, if not otherwise specified, to the product of anode or principal current and anode or principal voltage. The definitions are general. They are not considered 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 dissipation” and “partial energy dissipation” meaningful. However, guidance for the specification of these time intervals is given in the relevant notes.

3.5.2 Instantaneous power in a whole period of cycle**3.5.2.1****reverse power** P_{R}

power while the thyristor is in the reverse blocking state

Note 1 to entry: 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 $V = 0$) (see Figure 2).



Key

P_D	off-state power	P_T	on-state power
P_{DQ}	turn-off power	P_{TT}	turn-on power
P_R	reverse power		

Figure 2 – Partial power (dissipation) of reverse blocking triode thyristor in a whole period of cycle

3.5.2.2
off-state power
 P_D

power while the thyristor is in the off state

Note 1 to entry: 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 (either $I = 0$ or $V = 0$) and the beginning of the turn-on time and, 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.

3.5.2.3
on-state power
 P_T

power while the thyristor is in the on state

Note 1 to entry: If not otherwise specified, the term refers to the power in the time intervals between the ending of the turn-on time and the beginning of the turn-off time.

3.5.2.4
turn-on power
 P_{TT}

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

Note 1 to entry: If not otherwise specified, the corresponding time interval is the turn-on time.

3.5.2.5**turn-off power** P_{RQ}

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

Note 1 to entry: If not otherwise specified, the corresponding time interval is the turn-off time.

Note 2 to entry: For turn-off thyristors, the letter symbol P_{RQ} is replaced with P_{DQ} .**3.5.2.6****reverse conducting power** P_{RC}

<reverse conducting triode thyristor> power while the thyristor is in the reverse conducting state

Note 1 to entry: 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 $V = 0$).**3.5.3 Mean power dissipation****3.5.3.1****mean partial power dissipation**

mean value of the instantaneous power dissipation in a particular time interval of the cycle, averaged over a whole period of cycle

3.5.3.2**mean total power dissipation** $P_{\text{tot(AV)}}$

sum of all mean partial power dissipation and the mean gate power dissipation, in a whole period of cycle

Note 1 to entry: It means that there is an expression as follows:

$$P_{\text{tot(AV)}} = P_{T(AV)} + P_{\text{add(AV)}} + P_{G(AV)} \quad (1)$$

3.5.3.3**mean on-state power dissipation** $P_{T(AV)}$

mean partial power dissipation resulting from the on-state power

3.5.3.4**mean additional power dissipation** $P_{\text{add(AV)}}$

sum of all power dissipation except on-state power dissipation and gate power dissipation

Note 1 to entry: It means that there is an expression as follows:

$$P_{\text{add(AV)}} = P_{TT(AV)} + P_{RQ(AV)} + P_{D(AV)} + P_{R(AV)} \quad (2)$$

Note 2 to entry: For turn-off thyristors, the letter symbol $P_{RQ(AV)}$ is replaced with $P_{DQ(AV)}$.**3.5.3.5****mean turn-on power dissipation** $P_{TT(AV)}$

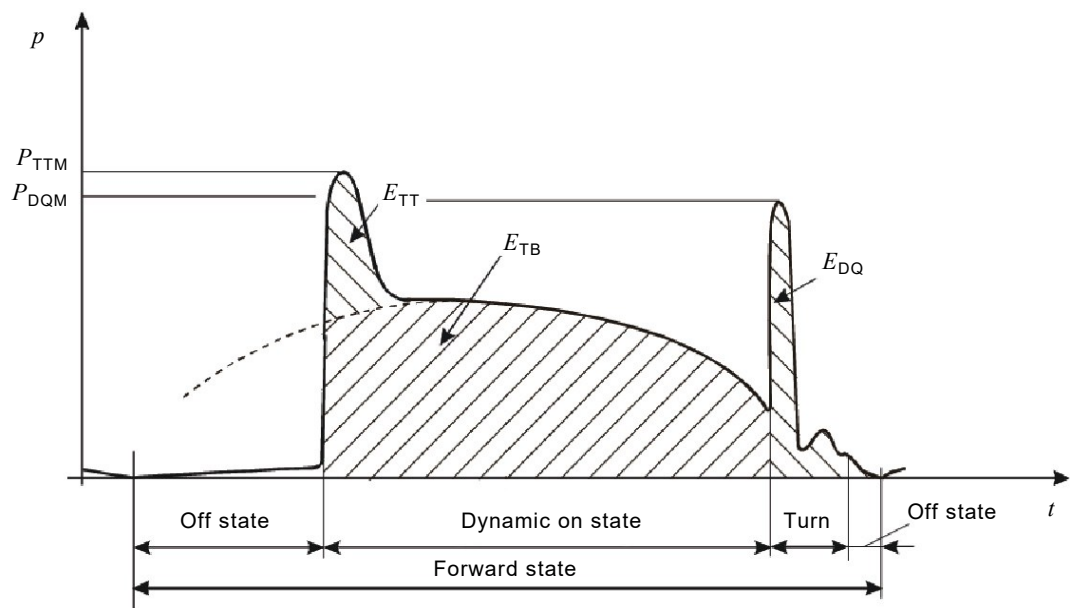
mean partial power dissipation resulting from the turn-on power

3.5.3.6**mean turn-off power dissipation** $P_{RQ(AV)}$

mean partial power dissipation resulting from the turn-off power

Note 1 to entry: For turn-off thyristors, the letter symbol $P_{RQ(AV)}$ is replaced with $P_{DQ(AV)}$.

- 577 **3.5.3.7**
578 **mean off-state power dissipation**
579 $P_{D(AV)}$
580 mean partial power dissipation resulting from the off-state power
- 581 **3.5.3.8**
582 **mean reverse power dissipation**
583 $P_{R(AV)}$
584 mean partial power dissipation resulting from the reverse power
- 585 **3.5.3.9**
586 **mean gate power dissipation**
587 $P_{G(AV)}$
588 gate power dissipation averaged over a whole period of cycle
- 589 **3.5.3.10**
590 **partial thermal resistance junction to case, anode side**
591 $R_{th(j-c)A}$
592 thermal resistance between the junction and the anode side of the case
- 593 **3.5.3.11**
594 **partial thermal resistance junction to case, cathode side**
595 $R_{th(j-c)K}$
596 thermal resistance between the junction and the cathode side of the case
- 597 **3.5.4 Energy dissipation**
- 598 **3.5.4.1**
599 **dynamic on-state energy dissipation**
600 E_T
601 total energy dissipation from the instant when the rising on-state current reaches a specified low value
602 to the instant that defines the beginning of the turn-off time
- 603 **3.5.4.2**
604 **basic on-state energy dissipation**
605 E_{TB}
606 energy dissipation resulting from the flow of on-state current when the thyristor is fully turned on during
607 the entire on state period
- 608 Note 1 to entry: This energy dissipation can only be determined by calculations based on the observed waveform of the
609 current. The calculation method is to be specified (see Figure 3).



Key

E_{DQ}	turn-off energy dissipation	E_{TB}	basic on-state energy dissipation
$E_T = E_{TB} + E_{TT}$	dynamic (total) on-state energy dissipation	E_{TT}	additional turn-on energy dissipation

Figure 3 – Components of dynamic on-state energy dissipation of reverse blocking triode thyristor in forward state

3.5.4.3
additional turn-on energy dissipation

E_{TT}
calculated difference between the dynamic on-state energy dissipation and the basic on-state energy dissipation

Note 1 to entry: It means that there is an expression as follows:

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

(3)

3.5.4.4
turn-off energy dissipation

E_{RQ}
energy dissipation during the turn-off time

Note 1 to entry: For turn-off thyristors, the letter symbol E_{RQ} is replaced with E_{DQ} .

3.6 On-state, recovery and other characteristics

3.6.1 On-state characteristics

3.6.1.1
on-state slope resistance

r_T
value of the resistance calculated from the slope of the straight-line approximation of the on-state characteristic that crosses this characteristic at two specified points

3.6.1.2**on-state threshold voltage** $V_{T(TO)}$ $V_{(TO)}$

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

3.6.2 Recovery times**3.6.2.1****reverse recovery time** t_{rr}

<reverse blocking triode thyristor> 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 reaches a specified low value and which may be zero) during reducing from its peak value I_{rrm} , or the extrapolated reverse current reaches zero

Note 1 to entry: The specified values of reverse recovery time refer to a specified waveform of the preceding on-state current pulse, which may be either a half sinusoidal waveform (solid line) or a trapezoidal waveform (dashed line) in Figure 4.

Note 2 to entry: The specified low value of the reverse current is as I_b given in Figure 4a). The extrapolation is carried out with respect to specified points A and B, as shown in generalized form in Figure 4b). The point A may be specified at the peak value of the reverse current.

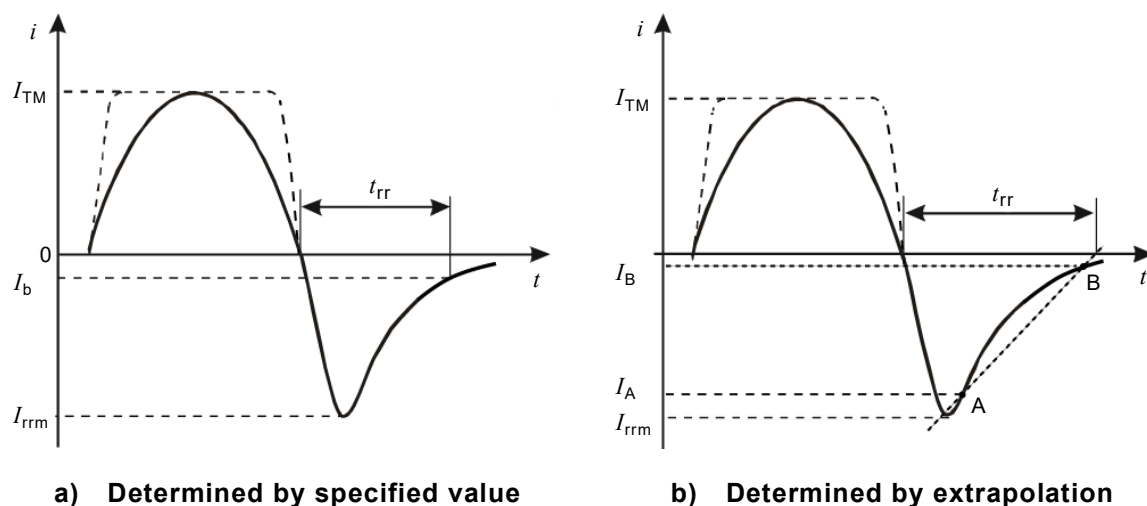


Figure 4 – Reverse recovery time of reverse blocking triode thyristor

3.6.2.2**off-state recovery time** t_{dr}

<reverse conducting triode thyristor> 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 reaches a specified low value during reducing from its peak value I_{DM} , or the extrapolated off-state current reaches zero

Note 1 to entry: The specified values of off-state recovery time refer to a specified waveform of the preceding reverse current pulse, which may be either a half sinusoidal waveform (solid line) or a trapezoidal waveform (dashed line) in Figure 5.

Note 2 to entry: The specified low value of the reverse current is as I_b given in Figure 5a). The extrapolation is carried out

with respect to specified points A and B, as shown in generalized form in Figure 5b). The point A may be specified at the peak value of the off-state current.

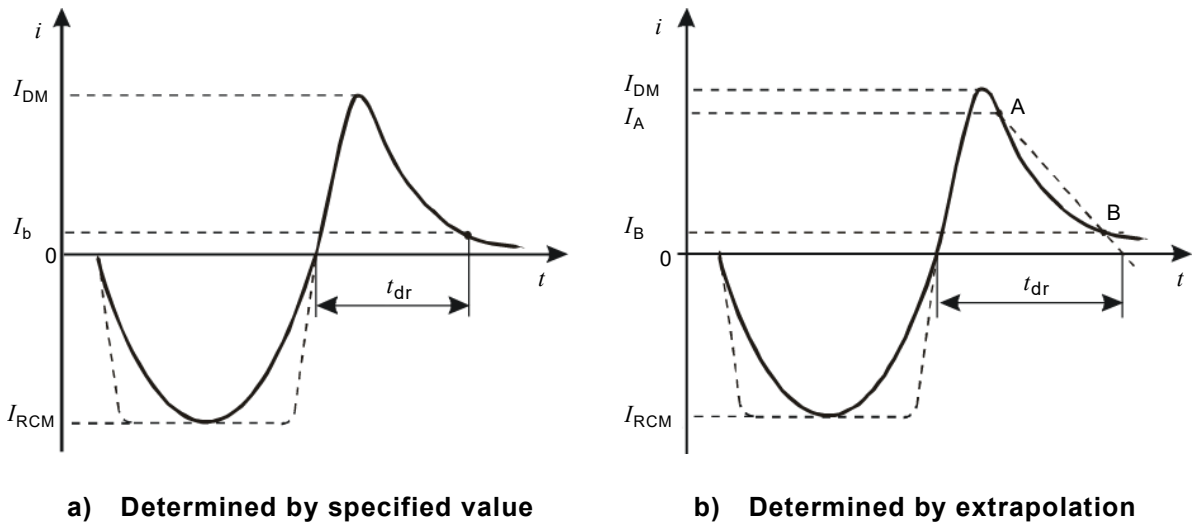


Figure 5 – Off-state recovery time of reverse conducting triode thyristor

3.6.2.3
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 or begins from a low positive value

Note 1 to entry: The curve a) in Figure 6 shows that the steeply rising off-state voltage of a reverse blocking triode thyristor passes through zero without breakover. The curve b) in Figure 6 shows that the steeply rising off-state voltage of the thyristor begins from a low positive value, which can appear, if the thyristor is bypassed by an external or internal inverse diode (for reverse conducting triode thyristor), due to the lead inductance of the diode.

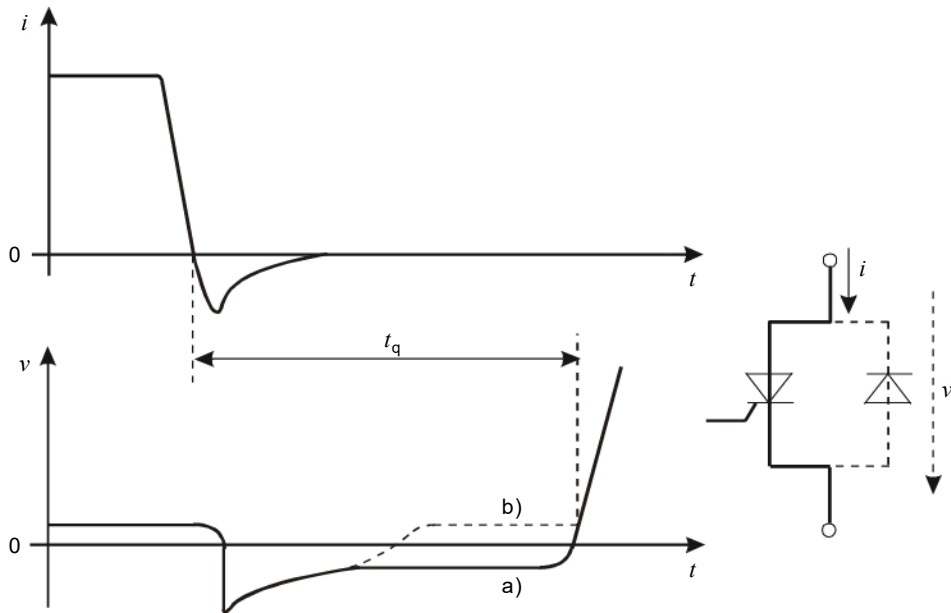


Figure 6 – Circuit commutated turn-off time

3.6.2.4**hold-off interval** t_H

<in a converter> time interval between

– the instant when the anode current of the thyristor in a converter has decreased to zero, and

– the instant when the same thyristor is subjected to the off-state voltage

Note 1 to entry: 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 commutated turn-off time, which also depends on the service conditions of the converter.

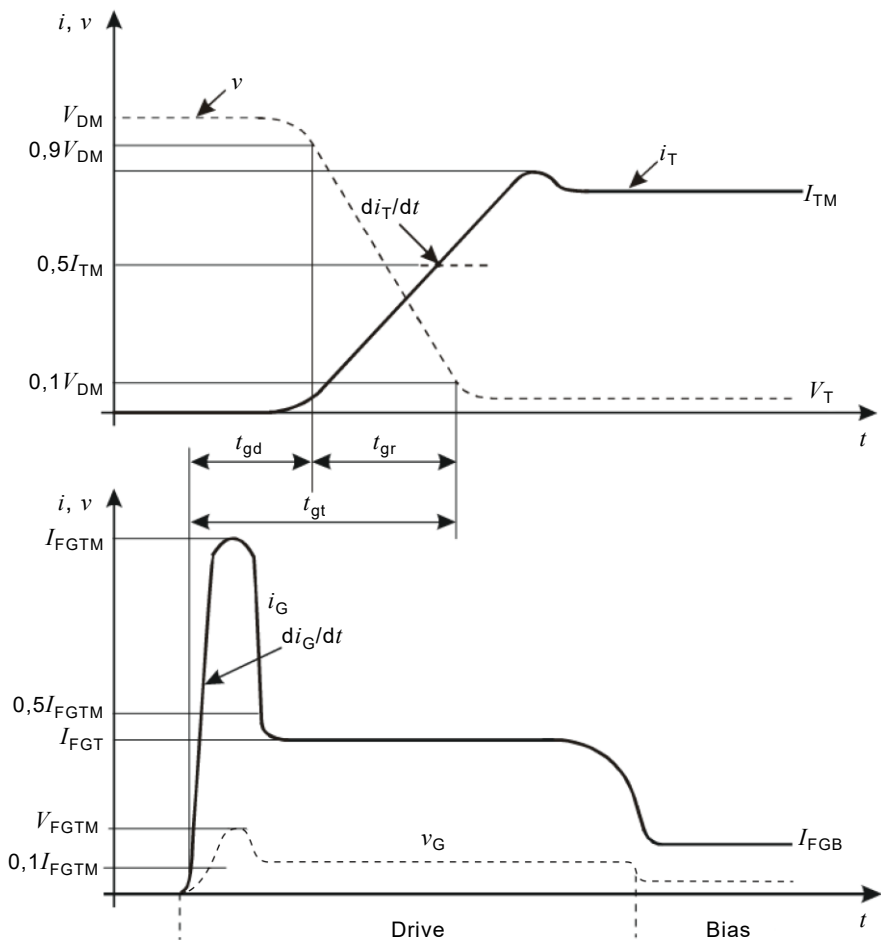
3.6.3 Times and rates of rise characterizing gate controlled turn on**3.6.3.1 General**

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 (see Figure 7).

3.6.3.2**gate controlled turn-on delay time** t_{gd}

time interval between the instant when the rising gate current reaches 10% of the peak forward gate current and the instant when the decreasing off-state voltage reaches 90% of its peak value before the turn on

Note 1 to entry: If no ambiguity is likely to occur, the term may be abbreviated to “turn-on delay time”.



NOTE The reference values of current and voltage are usually specified as follows:

Peak forward gate current I_{FGTM} :

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

Peak anode voltage V_{DM} , which is the peak off-state voltage before the turn on:

- upper specified value: 90% of V_{DM} ,
- lower specified value: 10% of V_{DM} .

Peak anode current I_{TM} :

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

Figure 7 – Gate controlled turn-on time

3.6.3.3 gate controlled turn-on rise time

t_{gr}

time interval between the instants when the decreasing off-state voltage reaches 90% and 10% of its peak value before the turn on

Note 1 to entry: If no ambiguity is likely to occur, the term may be abbreviated to “turn-on rise time”.

3.6.3.4**gate controlled turn-on time** t_{gt}

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

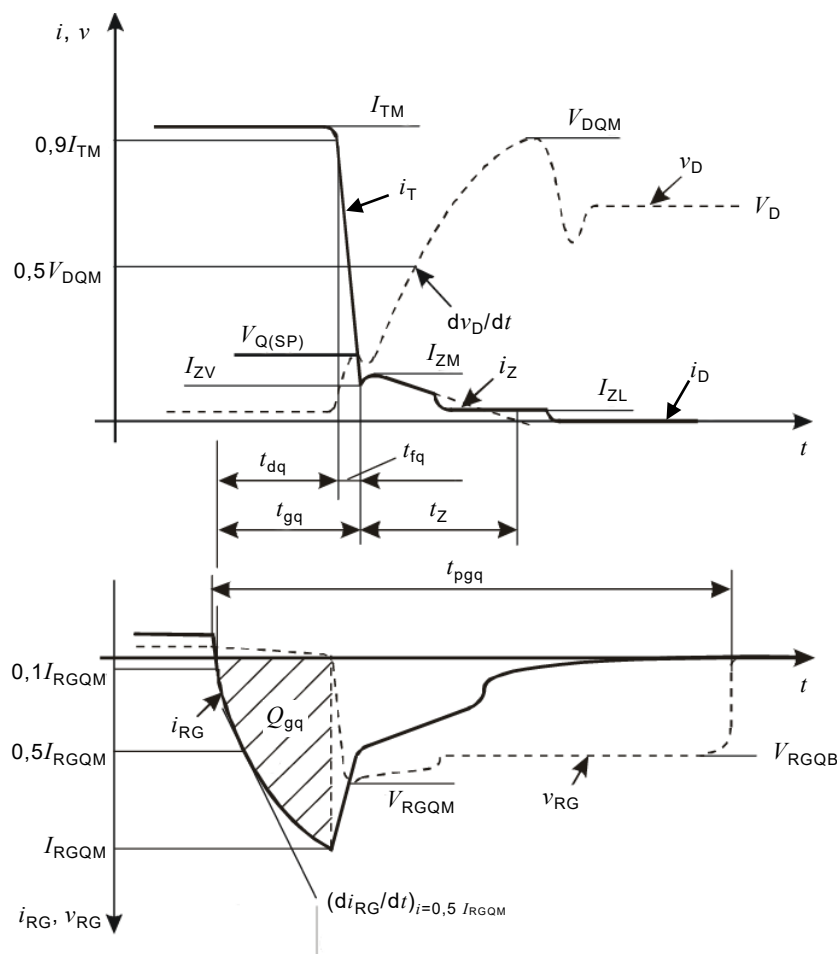
Note 1 to entry: It means that there is an expression as follows:

$$t_{gt} = t_{gd} + t_{gr} \quad (4)$$

Note 2 to entry: If no ambiguity is likely to occur, the term may be abbreviated to "turn-on time".

3.6.4 Times and rates of rise characterizing gate controlled turn off**3.6.4.1 General**

The defined terms refer to the switching of a turn-off 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 (see Figure 8).



NOTE The reference values of current and voltage referred to in 3.6.4.1 to 3.6.4.4 are usually specified as follows:

Peak turn-off gate current I_{RGQM} :

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

Peak anode current I_{TM} :

- upper reference value: 90% of I_{TM} .

- 738 Peak anode voltage V_{DQM} :
 739 – specified level for the measurement of dv_{D}/dt : 50% of V_{DQM} .

Figure 8 – Gate controlled turn-off time of turn-off thyristor

741 3.6.4.2 742 gate controlled turn-off delay time

743 t_{dq}

744 time interval between the instant when the rising reverse gate current reaches 10% of peak turn-off gate
 745 current and the instant when the decreasing anode current reaches 90% of its peak value before the
 746 turn off

747 Note 1 to entry: If no ambiguity is likely to occur, the term may be abbreviated to “turn-off delay time”.

748 3.6.4.3 749 gate controlled turn-off fall time

750 t_{fq}

751 time interval between the instant when the decreasing anode current reaches 90% of its peak value
 752 before the turn off and the instant at the end of its steep decrease, the valley point current I_{ZV}

753 Note 1 to entry: If no ambiguity is likely to occur, the term may be abbreviated to “turn-off fall time”.

754 3.6.4.4 755 gate controlled turn-off time

756 t_{gq}

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

758 Note 1 to entry: It means that there is an expression as follows:

$$759 \quad t_{\text{gq}} = t_{\text{dq}} + t_{\text{fq}} \quad (5)$$

760 Note 2 to entry: If no ambiguity is likely to occur, the term may be abbreviated to “turn-off time”.

761 3.6.4.5 762 tail time

763 t_{Z}

764 time interval between the instant when the anode current has decreased to the end of its steep decrease,
 765 the valley point current I_{ZV} , and the instant when the extrapolated tail current reaches zero

766 Note 1 to entry: Unless otherwise specified, the extrapolation is carried out between the peak value of the tail current I_{ZM} and
 767 its specified low value $I_{\text{ZL}} = 0,25I_{\text{ZM}}$ (see Figure 8).

768 3.6.5 Recovered charges

769 3.6.5.1 770 recovered charge

771 Q_{r}

772 <reverse blocking triode thyristor> total charge recovered from the thyristor during a specified
 773 integration time after switching from a specified on-state current condition to a specified reverse
 774 condition as:

$$775 \quad Q_{\text{r}} = \int_{t_0}^{t_0+t_i} i_{\text{r}} \cdot dt \quad (6)$$

776 where

777 t_0 is the instant when the current passes through zero;

778 t_i is the specified integration interval.

779 Note 1 to entry: This recovered charge includes components due to both carrier storage and depletion layer capacitance.

Note 2 to entry: The specified integration interval refers Figure 9.

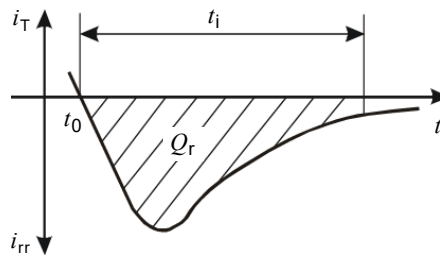


Figure 9 – Recovered charge

3.6.5.2

off-state recovered charge

Q_{dr}

<reverse conducting triode thyristor> 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 1 to entry: The formula (6) and Figure 9 in 3.6.5.1 apply analogously.

3.6.5.3

gate turn-off charge

Q_{gq}

<turn-off thyristor> 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 at which the reverse gate current reaches the peak turn-off gate current

Note 1 to entry: see Figure 8.

3.7 Mechanical ratings

3.7.1

mounting torque

M

torque needed to rotate a screw or stud to mount a thyristor

Note 1 to entry: For thyristors having screw connections, the minimum and maximum values of the rated mounting torque shall be specified.

3.7.2

clamping force

F

additive vector quantity characterizing external interactions on a particle or body

Note 1 to entry: For thyristors mounted by means of clamps, the minimum and maximum values of the rated clamping force as well as the planarity of mounting surfaces shall be specified.

[SOURCE: IEC 60050-113:2011, 113-03-14, modified — The word “clamping” has been added to the term, the notes have been deleted and Note 1 to entry has been added.]

4 Letter symbols

4.1 General

The general rules given in IEC 60747-1:2006, Clause 4, are applicable in part.

4.2 Additional general subscripts

In addition to the lists of recommended general subscripts given in IEC 60747-1:2006, Clause 4, the special subscripts given in Table 1 are recommended for the thyristors.

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Table 1 – Additional general subscripts

Subscripts	Significance	Remarks
A, a	Anode	
(com)	Commutating	
G, g	Gate	
G	Gate controlled	
H	Holding	
L	Latching	
Q, q	Turn off	
RC	Reverse conducting	
(SP)	Spike	
sus	Sustaining	
T	On state	
T, t	Turn on, trigger	
V (in uppercase letter)	Valley	<i>For the letter symbol I_{zV} only</i>
W (in uppercase letter)	Working	
Z, z	Tail	

820

821 **4.3 List of letter symbols**

822 The letter symbols contained in Table 2 to Table 7 are recommended for use in the thyristors.

823

Table 2 – Principal voltages and anode-cathode voltages

Letter symbol	Name and designation	Remarks
V_D	Off-state voltage	
V_{DM}	Peak off-state voltage	
V_{DRM}	Repetitive peak off-state voltage	
V_{DSM}	Non-repetitive peak off-state voltage	
V_{DWM}	Peak working off-state voltage	See 5.2.3.3
V_R	Reverse voltage	
V_{RRM}	Repetitive peak reverse voltage	
V_{RSM}	Non-repetitive peak reverse voltage	
V_{RWM}	Peak working reverse voltage	See 5.2.3.4
V_T	On-state voltage	
V_{TM}	Peak on-state voltage	See 5.3.2.2
$V_{T(TO)}$	On-state threshold voltage	

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Table 3 – Principal currents, anode currents and cathode currents

Letter symbol	Name and designation	Remarks
I_D	Off-state current	See 5.3.8
I_H	Holding current	
I_L	Latching current	
I_R	Reverse current	
I_{RC}	Reverse conducting current	For reverse conducting triode thyristor
$I_{RC(OV)}$	Overload reverse conducting current	For reverse conducting triode thyristor
I_{RRM}	Repetitive peak reverse current	
I_{rrm}	Peak reverse recovery current	
I_T	On-state current	
$I_{T(AV)}$	Mean on-state current	
I_{TM}	Peak on-state current	
$I_{T(OV)}$	Overload on-state current	
$I_{T(RMS)}$	RMS on-state current	
I_{TRM}	Repetitive peak on-state current	See 5.2.4.6
I_{TSM}	Non-repetitive surge on-state current	

Table 4 – Gate voltages and currents

Letter symbol	Name and designation	Remarks
I_{FG}	Forward gate continuous (direct) current	
I_{GD}	Gate non-trigger continuous (direct) current	
I_{GT}	Gate trigger continuous (direct) current	
V_{GD}	Gate non-trigger continuous (direct) voltage	
V_{GT}	Gate trigger continuous (direct) voltage	

Table 5 – Time quantities

Letter symbol	Name and designation	Remarks
t_{dr}	Off-state recovery time	For reverse conducting triode thyristor
t_{gd} or t_d	Turn-on delay time	t_d used only when misinterpretation will not result
t_{gq}	Turn-off time	
t_{gr} or t_r	Turn-on rise time	t_r used only when misinterpretation will not result
t_{gt}	Turn-on time	
t_H	Hold-off interval	See 3.6.2.4 and 5.2.4.6
t_q	Circuit commutated turn-off time	

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Table 6 – Power and energy dissipation

Letter symbol	Name and designation	Remarks
E_{TB}	Basic on-state energy dissipation	See 3.5.4.2
E_{RQ} or E_{DQ}	Turn-off energy dissipation	See 3.5.4.4, E_{DQ} for turn-off thyristor
P_D	Off-state power dissipation	
P_{FGM}	Peak forward gate power	See 5.2.5.3.4
P_R	Reverse power dissipation	For reverse blocking and reverse conducting triode thyristor
P_{RC}	Reverse conducting power dissipation	See 3.5.2.2
$P_{RQ(AV)}$ or $P_{DQ(AV)}$ P_{RQ} or P_{DQ} P_{DQM}	Turn-off power dissipation – average turn-off power dissipation – total instantaneous turn-off power dissipation – peak turn-off power dissipation	
P_T	On-state power dissipation	
$P_{TT(AV)}$ P_{TT}	Turn-on power dissipation – average turn-on power dissipation – total instantaneous turn-on power dissipation	

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833

Table 7 – Other quantities

Letter symbol	Name and designation	Remarks
$di_T/dt_{(cr)}$	Critical rate of rise of on-state current	See 5.2.4.8
$dv_{(c)}/dt$ or $dv_{(com)}/dt$	Critical rate of rise of commutating voltage	See 3.2.9 and 3.2.10, $dv_{(c)}/dt$ is preferred for triac
$dv/dt_{(cr)}$	Critical rate of rise of off-state voltage	See 5.3.15.3
Q_{dr}	Off-state recovered charge	For reverse conducting triode thyristor
Q_r	Recovered charge	
r_T	On-state slope resistance	

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5 Essential ratings and characteristics (properties)**5.1 General**

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

5.2 Ratings (limiting values)**5.2.1 Storage temperature (T_{stg})**

Minimum and maximum values.

5.2.2 Operating ambient, case, heatsink or junction temperature (T_a , T_c , T_s or T_{vj})

Minimum and maximum values.

NOTE The case temperature is normally measured on the body of the device. For some thyristors, the case temperature is

specified on one of the terminals.

5.2.3 Principle anode-cathode voltages

5.2.3.1 Non-repetitive peak off-state voltage (V_{DSM})

Maximum value of an off-state voltage pulse with half sinusoidal waveform, the pulse duration of which has to be specified. If this value has to be derated at higher operating frequencies, the derating factor or curve shall be given.

5.2.3.2 Repetitive peak off-state voltage (V_{DRM})

Maximum value of off-state voltage pulses with half sinusoidal waveform, the pulse duration and repetition rate of which has to be specified. If this value has to be derated at higher operating frequencies, the derating factor or curve shall be given.

5.2.3.3 Peak working off-state voltage (V_{DWM})

Maximum value of off-state voltage pulses with half sinusoidal waveform at mains frequency, usually 50 Hz or 60 Hz.

5.2.3.4 Peak working reverse voltage (V_{RWM})

Maximum value of reverse voltage pulses with half sinusoidal waveform at mains frequency, usually 50 Hz or 60 Hz.

5.2.3.5 Non-repetitive peak reverse voltage (V_{RSM})

Maximum value of a reverse voltage pulse with half sinusoidal waveform, the pulse duration of which has to be specified. If this value has to be derated at higher operating frequencies, the derating factor or curve shall be given.

5.2.3.6 Repetitive peak reverse voltage (V_{RRM})

Maximum value of reverse voltage pulses with half sinusoidal waveform, the pulse duration and repetition rate of which has to be specified. If this value has to be derated at higher operating frequencies, the derating factor or curve shall be given.

5.2.3.7 Continuous (direct) reverse voltage (V_R) (where appropriate)

Maximum value.

NOTE For gate turn-off thyristor (GTO) the letter symbol $V_{R(D)}$ can be used.

5.2.3.8 Continuous (direct) off-state voltage (V_D) (where appropriate)

Maximum value under specified conditions of control signal and gate.

NOTE For GTO the letter symbol $V_{D(D)}$ can be used.

5.2.4 Principal anode-cathode currents

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

Maximum value for continuous operation with half *sinusoidal waveform* of 180° conduction angle and with rectangular pulses of various conduction angles, at least 180° and 120°, at 50 Hz or 60 Hz, versus ambient or case temperature.

5.2.4.2 RMS on-state current ($I_{T(RMS)}$)

Maximum value for continuous operation with half sinusoidal waveform of 180° conduction angle and with rectangular pulses of various conduction angles, at least 180° and 120°, at 50 Hz or 60 Hz, versus ambient or case temperature.

NOTE The *RMS* on-state current is given on the assumption that no overload occurs.

5.2.4.3 Continuous (direct) on-state current

Maximum value at a specified ambient, case, heatsink or junction temperature.

5.2.4.4 Non-repetitive surge on-state current (I_{TSM})

Maximum value with initial conditions corresponding to maximum rated virtual junction temperature.

These ratings shall be given for the following time periods:

- a) For times smaller than one half cycle (at 50 Hz or 60 Hz), but greater than approximately 1 ms, in terms of maximum value of

$$\int i^2 \cdot dt$$

These ratings may be given by means of a curve or by specified values. No immediate subsequent application of reverse voltage or off-state voltage is assumed.

For fast turn-on thyristors or fast plasma-spreading thyristors such as those with distributed gate or inter-digitated gate structures (e.g., in GTO), values for times below 1 ms may be needed.

- b) For times equal to, or greater than, one half cycle and smaller than 15 cycles (at 50 Hz or 60 Hz), in the form of a curve showing the rated surge on-state current versus time. Temporary loss of gate control shall be assumed to occur.

These ratings should preferably be given for a reverse voltage of 80% of the rated repetitive peak reverse voltage. Additional ratings may be given for reverse voltages of 50% or 100% of the rated repetitive peak reverse voltage.

- c) For a time equal to one cycle, with no reverse voltage applied.

NOTE Although surge on-state current ratings are given for half sinusoidal waveform, they are, according to experience, also applicable to approximately triangular current waveform, which occur when a sinusoidally rising fault current is interrupted by a current-limiting fuse.

5.2.4.5 I^2t value (of surge on-state current) (I^2t)

Maximum value used for the specification of surge on-state current, given in terms of

$$I^2t = \int_0^t i^2 \cdot dt \quad (7)$$

for a specified short integration time t_i .

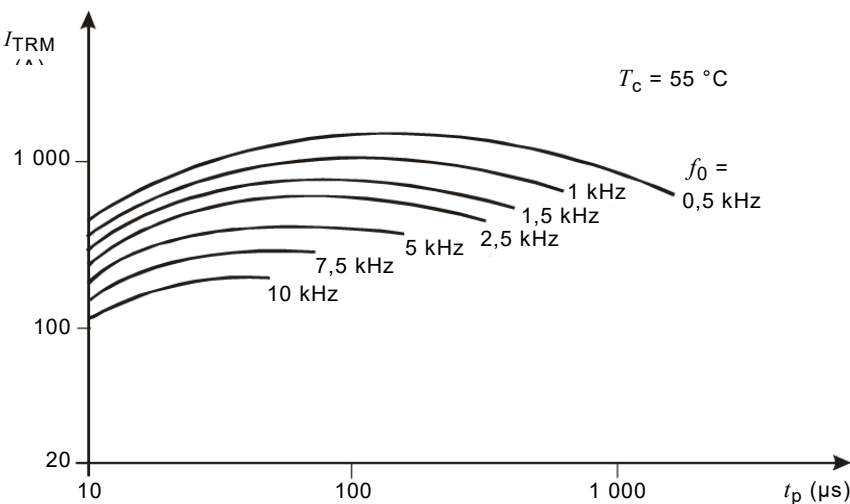
5.2.4.6 Repetitive peak on-state current (I_{TRM}) (where appropriate)

5.2.4.6.1 Repetitive peak sinusoidal on-state current (where appropriate)

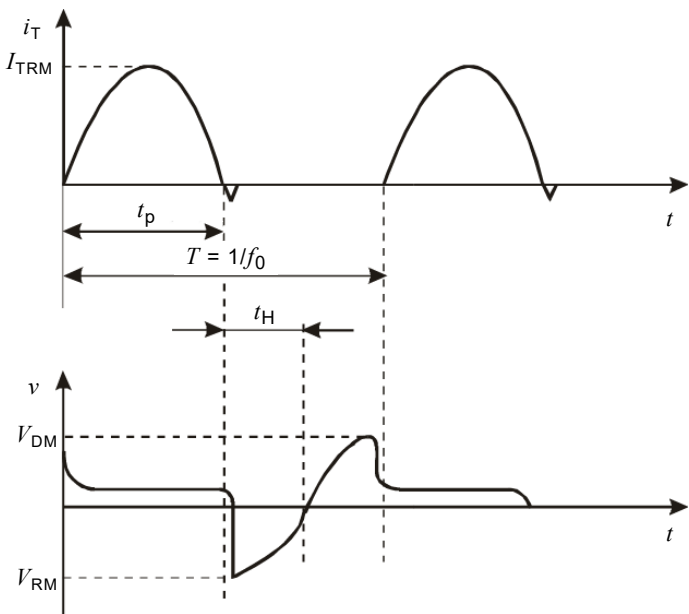
Maximum values given in form of curves, as functions of the *pulse duration of half sinusoidal current*, with the repetition frequency f_0 as a parameter, under the following specified conditions:

- case temperature T_c ;
- off-state voltage V_{DM} before the turn on;
- reverse voltage V_{RM} ;
- gate conditions during the turn on and turn off;
- RC damping network (snubber).

Figure 10a) is given as an example. Figure 10b) is given for explanatory purposes only.



a) Repetitive peak sinusoidal on-state current I_{TRM} as a function of pulse duration t_p with repetition frequency f_0



b) Typical current and voltage waveform for repetitive peak sinusoidal on-state current pulses

NOTE 1 t_H is the hold-off interval (see 3.6.2.4).

NOTE 2 The pulse waveform includes the current pulse due to the RC damping network.

Figure 10 – Peak sinusoidal currents and typical waveform at higher frequencies

5.2.4.6.2 Repetitive peak trapezoidal on-state current (where appropriate)

Maximum values given in form of curves, related to the rate of rise of on-state current, the repetition frequency and either the duty cycle or *average pulse duration*, under the following specified conditions:

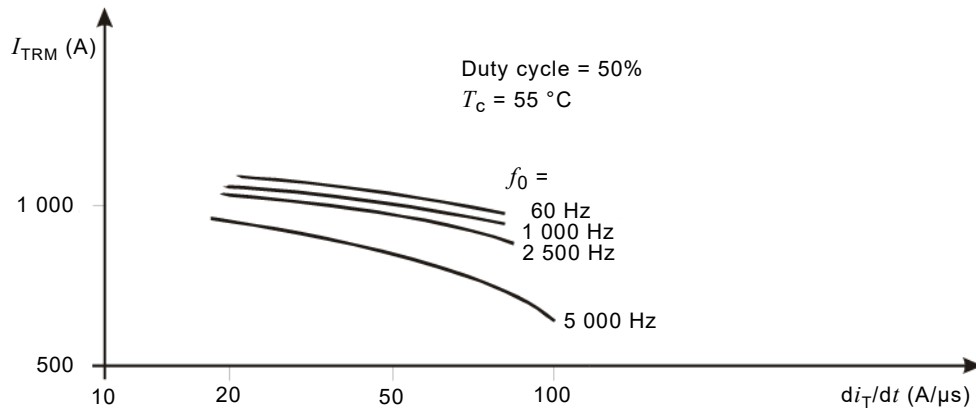
- a) case temperature T_c ;
- b) off-state voltage V_{DM} before the turn on;
- c) reverse voltage V_{RM} (two or more families of curves should be given as there is a significant dependence on the applied reverse voltage);

d) gate conditions during the turn on and turn off;

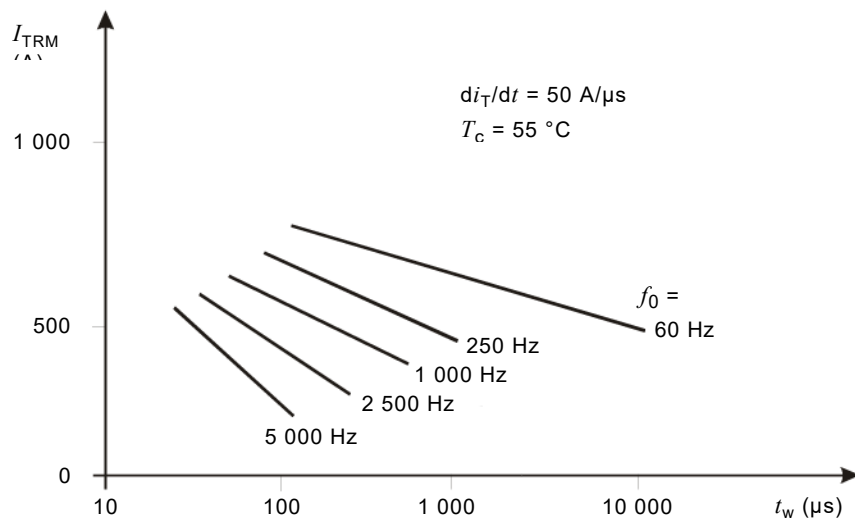
e) RC damping network (snubber);

f) duty cycle or *average pulse duration*.

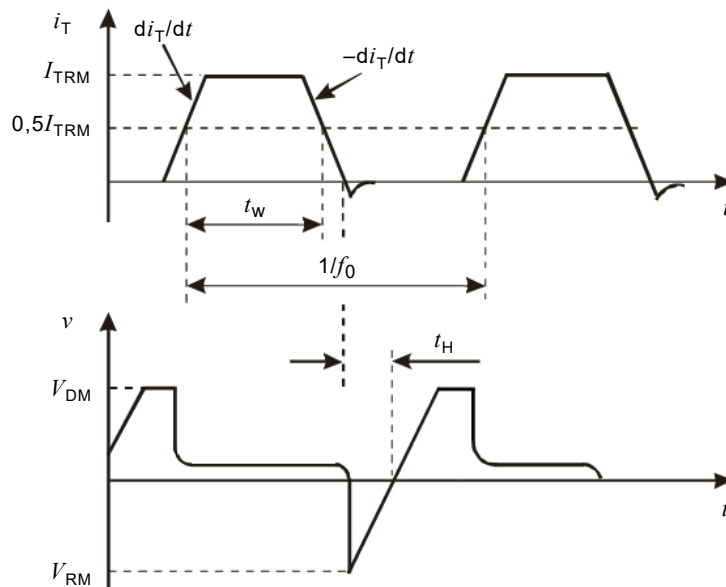
Figure 11a) and Figure 11b) are given as an example. Figure 11c) is given for explanatory purposes only.



a) Repetitive peak trapezoidal on-state current I_{TRM} for a specified t_w as a function of the rate of rise of on-state current with repetition frequency f_0



b) Repetitive peak trapezoidal on-state current I_{TRM} having a specified di_T/dt as a function of t_w with repetition frequency f_0



c) Typical current and voltage waveform for repetitive peak trapezoidal on-state current pulses

NOTE 1 t_H is the hold-off interval (see 3.6.2.4).

NOTE 2 Different sets of curves are required for different values of di_T/dt .

Figure 11 – Peak trapezoidal currents and typical waveform at higher frequencies

5.2.4.7 Overload on-state current ($I_{T(OV)}$)

Where this rating is appropriate, it shall be given by stating the initial maximum rated virtual junction temperature and the maximum transient thermal impedance. In addition, overload current ratings can be given by means of graphs. Sometimes, figures corresponding to lower initial junction temperatures may be given.

5.2.4.8 Critical rate of rise of on-state current ($di_T/dt_{(cr)}$)

Maximum value under the following specified conditions:

- off-state voltage before the turn on, preferably equal to a half or two-thirds the maximum rated repetitive peak off-state voltage in 5.2.3.2;
- peak value of on-state current,
 - preferably equal to specified on-state current in 5.2.4.1 specified at 45 °C ambient or 85 °C case temperature;
 - in case of triacs: preferably equal to $\sqrt{2}$ times the rated RMS on-state current in 5.2.4.2 specified at 45 °C ambient or 85 °C case temperature;
 - in case of GTO: preferably equal to the rated repetitive peak controllable on-state current, with current waveform and average pulse duration specified.
- repetition rate, preferably 50 Hz or 60 Hz;
- ambient, case or junction temperature equal to the maximum value at which the peak value of on-state current is permitted;
- gate trigger conditions;
- test duration (should be longer than the thermal time constant of the thyristor under test, e.g., 30 s).

The rated value of di/dt should be given where there is no RC network connected in parallel with the

thyristor. If an additional di/dt rating is given where an RC network is present, the permissible amplitude and duration of the surge from this network or the parameters of this network shall be stated.

NOTE The di/dt ratings are not applicable to low current thyristors.

5.2.4.9 Peak reverse current (I_{RCM}) (for reverse conducting thyristor)

Maximum value for continuous operation with half sinusoidal waveforms of 180° conduction angle and with rectangular pulses of various conduction angles, at least 180° and 120° , at 50 Hz or 60 Hz, versus ambient or case temperature.

5.2.4.10 Mean reverse current ($I_{RC(AV)}$) (for reverse conducting thyristor)

Maximum value for continuous operation with half sinusoidal waveforms of 180° conduction angle and with rectangular pulses of various conduction angles, at least 180° and 120° , at 50 Hz or 60 Hz, versus ambient or case temperature.

5.2.4.11 Continuous (direct) reverse current (I_{RC}) (for reverse conducting thyristor)

Maximum value at a specified ambient, case, heatsink or junction temperature. See IEC 60747-2.

NOTE The letter symbol $I_{RC(D)}$ can be used.

5.2.4.12 Non-repetitive surge reverse current (I_{RCSM}) (for reverse conducting thyristor)

Maximum value under specified pulse conditions. See IEC 60747-2.

5.2.4.13 Non-repetitive peak controllable on-state current (I_{TQSM}) for GTO

Maximum value under the following specified conditions:

- a) maximum rated virtual junction temperature;
- b) re-applied off-state voltage, preferably a half or two-thirds of the rated repetitive peak off-state voltage;
- c) rate of rise of the re-applied off-state voltage;
- d) turn-off spike voltage;
- e) turn-off gate voltage, preferably equal to the rated turn-off gate voltage;
- f) rate of rise of the turn-off gate current.

5.2.4.14 Repetitive peak controllable on-state current (I_{TQRM}) for GTO

Maximum value under the following specified conditions:

- a) maximum rated virtual junction temperature reached at the end of the turn off procedure;
- b) re-applied off-state voltage, preferably a half or two-thirds of the rated repetitive peak off-state voltage;
- c) rate of rise of the re-applied off-state voltage;
- d) turn-off spike voltage
- e) turn-off gate voltage, preferably equal to the rated turn-off gate voltage;
- f) rate of rise of the turn-off gate current.

5.2.4.15 Short-time and intermittent duty current (for GTO)

Maximum on-state current under short-time or intermittent duty. This rating can be calculated from the resulting total power loss, the transient thermal impedance and the maximum rated virtual junction temperature.

5.2.4.16 Peak case non-rupture current (I_{RSMC}) (where appropriate)

Maximum value for the reverse current, at specified waveform, average pulse duration and rate of rise

of the current, as well as specified initial case or junction temperature.

NOTE The value of the peak case non-rupture current depends considerably on the location of the initial breakdown, on the silicon chip and is usually lowest if the breakdown occurs near the edge.

5.2.5 Gate voltages, current and power dissipation

5.2.5.1 Gate voltages

5.2.5.1.1 General

Gate voltages are applied between gate and cathode terminals of a P-gate thyristor (gate positive for a forward gate voltage), and between anode and gate terminals of an N-gate thyristor (anode positive for a forward gate voltage). See Figure 12.

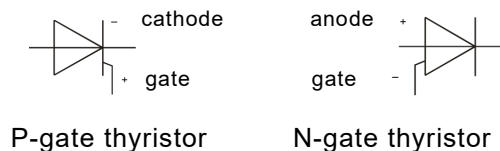


Figure 12 – Application of gate voltages for thyristors

5.2.5.1.2 Peak forward gate voltage (V_{FGM})

Maximum value.

5.2.5.1.3 Peak reverse gate voltage (V_{RGM})

Maximum value.

5.2.5.2 Peak forward gate current (I_{FGM})

Maximum value with anode-cathode voltage polarity specified and any qualifications (e.g., of time, energy, etc.) applicable to this rating.

5.2.5.3 Gate power dissipation

5.2.5.3.1 General

If these ratings are dependent on temperature or pulse repetition rate, derating information shall be given.

5.2.5.3.2 Mean gate power

Maximum value.

5.2.5.3.3 Peak gate power dissipation (P_{GM})

Maximum value for specified average pulse duration.

5.2.5.3.4 Peak forward gate power (P_{FGM}) for GTO

Maximum value for specified average pulse duration and repetition rate.

5.2.6 Total power dissipation (P_{tot})

Where thermal resistance is not given in the characteristics (properties), maximum total power dissipation as a function of temperature over the range of operating temperatures shall also be given.

5.2.7 Frequency ratings

Where applicable, maximum and/or minimum frequencies for which the voltage and current ratings apply.