

Semiconductor devices — Discrete devices and integrated circuits —

Part 2: Rectifier diodes

ICS 31.080.10

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Summary of pages

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**Part 2:
Rectifier diodes**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR DEVICES – DISCRETE DEVICES AND INTEGRATED CIRCUITS –

Part 2: Rectifier diodes

FOREWORD

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International standard IEC 60747-2 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, its amendments 1 (1992) and 2 (1993). This second edition constitutes a technical revision.

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

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

FDIS	Report on voting
47E/136/FDIS	47E/143/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 2005. At this date, the publication will be

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- withdrawn;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

SEMICONDUCTOR DEVICES – DISCRETE DEVICES AND INTEGRATED CIRCUITS –

Part 2: Rectifier diodes

Introductory note

As a rule, it will be necessary to use IEC 60747-1 together with the present publication. In IEC 60747-1, the user will find all basic information on:

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

1 Scope

The present publication gives standards for the following categories or sub-categories of devices.

Rectifier diodes, including:

- avalanche rectifier diodes;
- controlled-avalanche rectifier diodes;
- fast-switching rectifier diodes.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard 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*
Amendment 3 (1996).

3 Terms and definitions

According to the ISO/IEC Directives for the drafting and presentation of International Standards this part of IEC 60747 contains only those definitions which are necessary for the understanding of the terms used and of their exact meaning. Further definitions may be found in IEC 60747-1 and in Chapter 521 of the International Electrotechnical Vocabulary (IEC 60050(521)).

3.1 General terms

3.1.1

forward direction

direction of the flow of continuous (direct) current in which a semiconductor diode has the lower resistance

3.1.2

reverse direction

direction of the flow of continuous (direct) current in which a semiconductor diode has the higher resistance

3.1.3

anode terminal (of a semiconductor rectifier diode or rectifier stack)

terminal to which forward current flows from the external circuit

3.1.4

cathode terminal (of a semiconductor rectifier diode or rectifier stack)

terminal from which forward current flows to the external circuit

3.1.5

rectifier stack arm

that portion of a rectifier stack bounded by two circuit terminals which has the characteristic of conducting current substantially in one direction only

NOTE A rectifier stack arm may consist of one rectifier diode or of a number of rectifier diodes connected in either a series, a parallel or a series-parallel arrangement, to operate as a unit. This means that a rectifier stack arm may be the part or the whole of a rectifier stack.

3.2 Terms related to ratings and characteristics: voltages

NOTE When several distinctive forms of a letter symbol exist, the most commonly used form is given (see clause 4).

3.2.1

forward voltage (V_F)

voltage across the terminals which results from the flow of current in the forward direction

3.2.2

threshold voltage (V_{TO})

value of the forward voltage obtained at the intersection of the straight line approximation of the forward characteristic with the voltage axis

3.2.3

forward recovery voltage (V_{FR})

varying voltage occurring during the forward recovery time after instantaneous switching from zero or a specified reverse voltage to a specified forward current

3.2.4

continuous (direct) reverse voltage (V_R)

value of the constant voltage applied to a diode in the reverse direction

3.2.5

crest (peak) working reverse voltage (V_{RWM})

highest instantaneous value of the reverse voltage, excluding all repetitive and non-repetitive transient voltages

3.2.6

repetitive peak reverse voltage (V_{RRM})

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

3.2.7

non-repetitive peak reverse voltage; peak transient reverse voltage (V_{RSM})

highest instantaneous value of any non-repetitive transient reverse voltage

NOTE 1 Preference should be given to the term "non-repetitive peak reverse voltage".

NOTE 2 The repetitive voltage is usually a function of the circuit and increases the power dissipation 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.

3.2.8

breakdown voltage (V_{BR})

voltage in the region where breakdown occurs.

3.3 Terms related to ratings and characteristics: currents

3.3.1

forward current (I_F)

current flowing through the diode in the direction of lower resistance

3.3.2

mean forward current (I_{FAV})

value of the forward current averaged over the full cycle

3.3.3

r.m.s. forward current (I_{FRMS})

r.m.s value of the forward current over one complete cycle of the operating frequency

3.3.4

repetitive peak forward current (I_{FRM})

peak value of the forward current including all repetitive transient currents

3.3.5

overload forward current (I_{FOV})

forward current of substantially the same waveshape as the specified normal forward current, but having a greater value, such that its continuous application would cause the rated maximum virtual junction temperature to be exceeded, but that is limited in duration to such an extent that this temperature is not exceeded

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

3.3.6

surge forward current (I_{FSM})

forward current pulse of short time duration and specified waveshape, whose application causes or would cause the maximum rated 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)

3.3.7

reverse current (I_R)

total conductive current flowing through the diode when specified reverse voltage is applied

3.3.8

resistive reverse current (i_{rr})

that part of the steady-state reverse current exclusive of the recovery current, if any

3.3.9

reverse recovery current (i_{RR})

that part of the reverse current which occurs during the reverse recovery time

3.3.10

I^2t value

integral of the square of a surge forward current over the duration of the current surge

3.3.11

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 current, waveshape and time

NOTE 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.

3.3.12

case non-rupture $I^2_{RC}t$

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

$$I^2_{RC}t = \int_0^{t_w} i^2 dt$$

where

t_w is the reverse current pulse duration

NOTE This definition implies that a fine crack in the case might be found in a device subjected to the case non-rupture $I^2_{RC}t$ provided that no plasma was emitted. Parts of the case shall not break away, nor shall the device melt externally or burst into flames.

3.4 Terms related to ratings and characteristics: power dissipations

3.4.1

total power dissipation (P_{tot})

sum of the dissipations due to currents in the forward and reverse directions

3.4.2

forward power dissipation (P_F)

power dissipation due to the flow of forward current

3.4.3

mean forward power dissipation (P_{FAV})

mean value of the product of the instantaneous forward voltage and the instantaneous forward current averaged over a full cycle

3.4.4

reverse power dissipation (P_R)

power dissipation resulting from the flow of reverse current

3.4.5

surge reverse power dissipation (of avalanche and controlled-avalanche rectifier diodes) (P_{RSM})

power which is dissipated within the diode resulting from surges occurring when it is operating in the reverse direction

3.4.6

turn-on dissipation (P_{Fon})

power dissipated within the diode during the change between reverse voltage and forward current when the diode is switched from a reverse voltage to a forward current

3.4.7

turn-off dissipation (P_{RR})

power dissipated within the diode during the change between forward current and reverse voltage when the diode is switched from a forward current to a reverse voltage

3.5 Terms related to ratings and characteristics: other characteristics

3.5.1

straight line approximation of the forward characteristic

approximation of the voltage versus current forward characteristic by means of a straight line which crosses this characteristic at two specified points (see figure 5)

3.5.2

forward slope resistance (r_T)

value of the resistance calculated from the slope of the straight line approximation of the forward characteristic (see figure 5)

3.5.3

forward recovery time (t_{fr})

time interval between the instant when the forward voltage rises through a specified first value and the instant when it falls from its peak value V_{FRM} to a specified second value close to the final stable value of forward voltage (as shown in figure 1a), or when the extrapolated forward voltage reaches zero (as shown in figure 1b), upon the application of a specified step of forward current following a zero-voltage or other specified reverse-voltage condition

NOTE 1 Specification method I: The specified first and second values referred to in the definition are usually 10 % and 110 %, respectively, of the final stable value (V_F^* in figures 1a and b).

NOTE 2 Specification method II: The extrapolation is carried out with respect to specified points A and B where A and B are usually 90 % and 50 % of V_{FRM} as shown in generalized form in figure 1b.

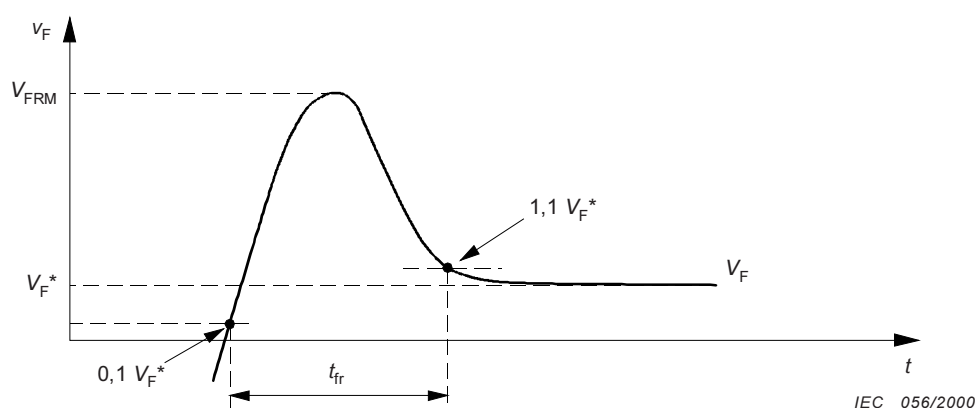


Figure 1a – Specification method I

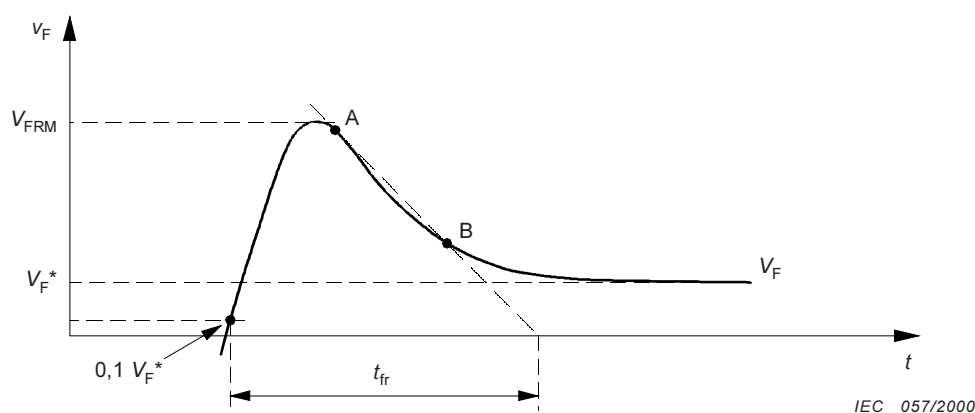


Figure 1b – Specification method II

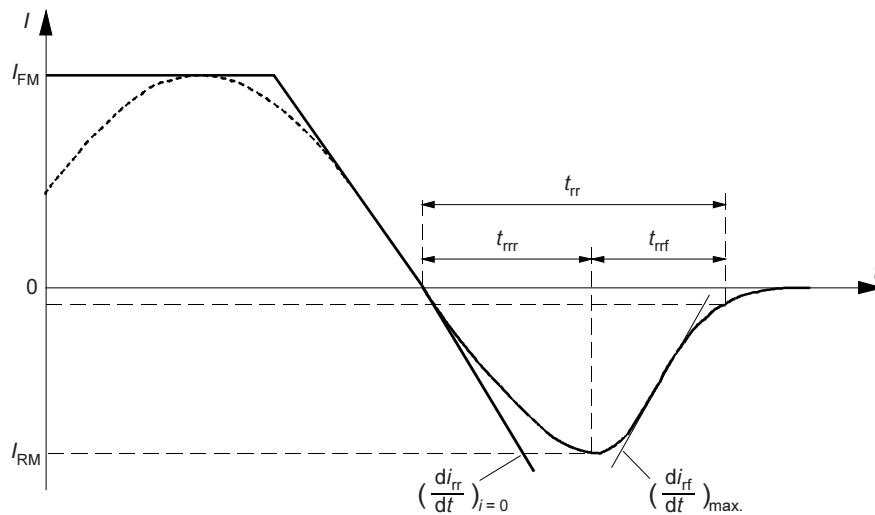
Figure 1 – Voltage waveform during forward recovery

3.5.4

reverse recovery time (t_{rr})

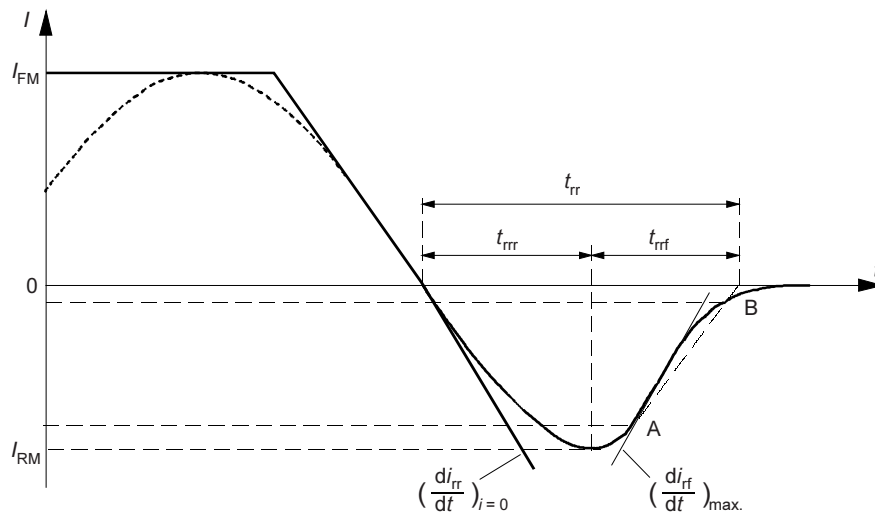
time interval between the instant when the current passes through zero, when changing from the forward direction to the reverse direction, and the instant when the reverse current is reduced from its peak value I_{RM} to a specified low value (as shown in figure 2a) or when the extrapolated reverse current reaches zero (as shown in figure 2b)

NOTE The extrapolation is carried out with respect to specified points A and B, as shown in generalised form in figure 2b. Although point A is often specified at 90 % of I_{RM} , it may be specified at I_{RM} .



IEC 058/2000

Figure 2a – Specification using low value of I_{rr}



IEC 059/2000

Figure 2b – Specifications using points "A" and "B"

Figure 2 – Current waveform during reverse recovery

3.5.5

recovered charge (Q_r)

total charge recovered from the diode during a specified integration time after switching from a specified forward current condition to a specified reverse condition:

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

where

t_0 is the instant when the current passes through zero;

t_i is the specified integration time (see figure 3).

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

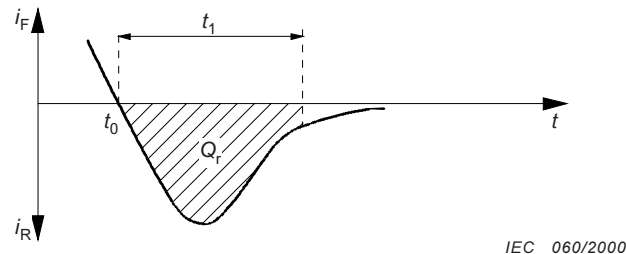


Figure 3 – Recovered charge

3.5.6

reverse recovery current rise time (t_{rrr} , t_a)

time interval between the beginning of the reverse recovery time and the instant when the reverse recovery current reaches its peak value after instantaneous switching from a specified forward current to a specified reverse voltage

NOTE The letter symbol t_a is sometimes used.

3.5.7

reverse recovery current fall time (t_{rrf} , t_b)

time interval between the instant when the reverse recovery current reaches its peak value and the end of reverse recovery time after instantaneous switching from a specified forward current to a specified reverse voltage

NOTE The letter symbol t_b is sometimes used.

3.5.8

rise time charge (Q_{RRR})

part of the recovered charge that is recovered from the diode during the reverse recovery current rise time

3.5.9

fall time charge (Q_{RRF})

that part of the recovered charge that is recovered from the diode during the reverse recovery current fall time

NOTE The time intervals t_{rrr} (3.5.6) and t_{rrf} (3.5.7) are defined so that their sum equals the reverse recovery time t_{rr} , whereas the recovered charge Q_r (3.5.5) is defined for an integration time t_i . As a consequence, the sum of the partial charges Q_{RRR} (3.5.8) and Q_{RRF} (3.5.9) will differ from Q_r unless t_{rr} equals t_i .

3.5.10

(reverse recovery) softness factor (F_{RRS})

absolute value of the ratio of the rate of rise of the reverse recovery current when passing through zero to the maximum rate of fall of the recovery current. See figures 2a and 2b.

$$F_{RRS} = \frac{(di_{rr} / dt)_{i=0}}{(di_{rf} / dt)_{\max}}$$

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 rectifier diodes:

4.2.1 For currents, voltages and powers

(See also 2.2.1 of IEC 60747-1, Chapter V):

A, a = anode

K, k = cathode

(TO) = threshold

4.2.2 For electrical parameters

(See also 2.2.2 of IEC 60747-1, Chapter V):

T = slope

4.3 List of letter symbols

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

4.3.1 Voltages

Name and designation	Letter symbol	Remarks
Continuous (direct) forward voltage	V_F	
Crest (peak) forward voltage	V_{FM}	
Average forward voltage (with I_O specified)	$V_{F(AV)}$	
Continuous (direct) reverse voltage	V_R	
Crest (peak) working reverse voltage	V_{RWM}	
Repetitive peak reverse voltage (maximum recurrent reverse voltage)	V_{RRM}	
Non-repetitive peak reverse voltage (peak transient reverse voltage)	V_{RSM}	
Breakdown voltage	$V_{(BR)}$	
Forward recovery voltage	V_{FR}	
Peak value of forward recovery voltage	V_{FRM}	

IEC 061/2000

Figure 4 – Reverse voltage ratings

Name and designation	Letter symbol	Remarks
Forward slope resistance	r_T	IEC 062/2000 Figure 5 – Forward characteristic
Threshold voltage	$V_{(TO)}$	

4.3.2 Currents

Name and designation	Letter symbol	Remarks
Continuous (direct) forward current	I_F	
Mean forward current	I_{FAV}	
Repetitive peak forward current	I_{FRM}	
r.m.s forward current	I_{FRMS}	
Overload forward current	$I_{(OV)}$	
Surge (non-repetitive) forward current	I_{FSM}	
Continuous (direct) reverse current	I_R	
Peak reverse recovery current	I_{RM}	
Reverse recovery current	i_{RR}	
Peak case non-rupture current	I_{RSMC}	

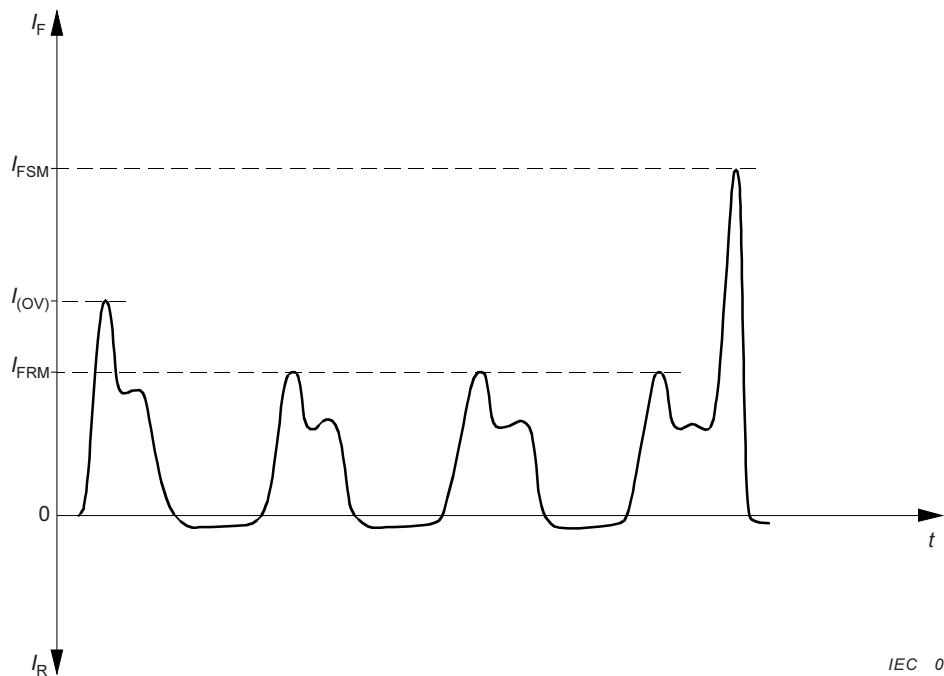


Figure 6 – Forward current ratings

4.3.3 Powers

Name and designation	Letter symbol	Remarks
Forward power dissipation	P_F	
Reverse power dissipation	P_R	
Turn-on dissipation: – average turn-on dissipation – total instantaneous turn-on dissipation – peak turn-on dissipation	$P_{FT(AV)}$ P_{FT} P_{FTM}	
Turn-off dissipation: – average turn-off dissipation – total instantaneous turn-off dissipation – peak turn-off dissipation	$P_{RQ(AV)}$ P_{RQ} P_{RQM}	

4.3.4 Switching

Name and designation	Letter symbol	Remarks
Forward recovery time	t_{fr}	
Reverse recovery time	t_{rr}	
Reverse recovery current rise time	t_{rrr}, t_a	
Reverse recovery current fall time	t_{rrf}, t_b	
Recovered charge	Q_r, Q_{RR}	
Rise time charge	Q_{RRR}	
Fall time charge	Q_{RRF}	
(Reverse recovery) softness factor	F_{RRS}	

5 Essential ratings and characteristics

5.1 General

5.1.1 Range of application

This clause gives standards for rectifier diodes including:

- avalanche rectifier diodes;
- controlled-avalanche rectifier diodes;
- fast-switching rectifier diodes.

5.1.2 Rating methods

Rectifier diodes should be specified as ambient-rated or as case-rated devices.

5.1.3 Recommended temperatures

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

Unless otherwise stated, the one other specified temperature should be chosen by the manufacturer from the list in IEC 60747-1; in addition, temperatures of $-40\text{ }^{\circ}\text{C}$ and $+35\text{ }^{\circ}\text{C}$ may be used.

5.2 Rating conditions

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

5.2.1 Ambient-rated rectifier diodes

5.2.1.1 Natural convection

At $25\text{ }^{\circ}\text{C}$ and at one higher temperature (see 5.1.3). The cooling fluid and pressure (in the case of a gas) should be specified.

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

5.2.1.2 Forced circulation

At a temperature taken from the list of recommended temperatures (see 5.1.3). The type, pressure and flow of the cooling fluid should be specified.

5.2.2 Case-rated rectifier diodes

At a reference-point temperature taken from the list of recommended temperatures (see 5.1.3).

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

5.3 Voltage and current ratings (limiting values)

The following ratings must be valid for the whole range of operating conditions as stated for the particular device.

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

Maximum value of a pulse of reverse voltage with a half-wave sinusoidal waveform, the duration of which has to be specified.

This duration should be chosen from the following values: 10 ms; 8,3 ms; 1 ms and 0,1 ms.

5.3.2 Repetitive peak reverse voltage (V_{RRM})

Maximum value of repetitive reverse voltage pulses, with half-wave sinusoidal waveform, whose duration and repetition rate have to be specified.

This duration should be chosen from the following values: 10 ms; 8,3 ms; 1 ms and 0,1 ms.

5.3.3 Crest (peak) working reverse voltage (V_{RWM})

Maximum value of a repetitive reverse voltage having a half-wave sinusoidal waveform at mains frequency, usually 50 Hz or 60 Hz (duration: 10 ms or 8,3 ms).