

Semiconductor devices: discrete devices and integrated circuits —

Part 1: Discrete devices —

Section 1.2 Recommendations for rectifier diodes

UDC 621.382.2

Committees responsible for this British Standard

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- British Telecommunications
- Electronic Components Industry Federation
- Electronic Engineering Association
- Ministry of Defence
- National Supervising Inspectorate
- Telecommunication Engineering and Manufacturing Association (TEMA)

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- Society of British Aerospace Companies Limited

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National foreword

This British Standard has been prepared under the direction of the Electronic Components Standards Committee. It is identical with IEC Publication 747-2 “*Semiconductor devices. Discrete devices and integrated circuits — Part 2: Rectifier diodes*”, as amended by Amendment No. 1 published in February 1992 and Amendment No. 2 published in October 1993, published in 1983 by the International Electrotechnical Commission (IEC).

This British Standard constitutes Section 1.2 of the British Standard for semiconductor devices (BS 6493). (See national foreword of BS 6493-1.1:1984.)

Terminology and conventions. The text of the International Standard has been approved as suitable for publication as a British Standard without deviation. Some terminology and certain conventions are not identical with those used in British Standards.

Cross reference

International Standard	Corresponding British Standard
IEC 747-1:1983	BS 6493 <i>Semiconductor devices: discrete devices and integrated circuits</i> Section 1.1:1984 <i>General</i> (Identical)

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 53 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Chapter I. General

1 Introductory note

As a rule, it will be necessary to use Publication 747-1 together with the present publication. In 747-1, the user will find all basic information on:

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

2 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.

The sequence of the different chapters is in accordance with Publication 747-1, Chapter III, Sub-clause 2.1.

3 Marking of rectifier diodes

Each rectifier diode shall be clearly and indelibly marked with the following information:

- manufacturer's name or identification;
- manufacturer's or supplier's type;
- marking to permit the distinction between anode and cathode terminals.

Chapter II. Terminology and letter symbols

1 General terms

1.1

forward direction

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

1.2

reverse direction

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

1.3

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

the terminal to which forward current flows from the external circuit

1.4

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

the terminal from which forward current flows to the external circuit

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.

2 Terms related to ratings and characteristics

NOTE When several distinctive forms of a letter symbol exist, the most commonly used form is given (see Clause 3).

2.1 Voltages

2.1.1

forward voltage

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

2.1.2

threshold voltage (V_{TO})

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

2.1.3

forward recovery voltage (V_{FR})

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

2.1.4

continuous (direct) reverse voltage (V_R)

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

2.1.5

crest (peak) working reverse voltage

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

2.1.6

repetitive peak reverse voltage

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

2.1.7

non-repetitive peak reverse voltage: (peak transient reverse voltage)

the 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.

2.1.8

breakdown voltage

a voltage in the region where breakdown occurs

2.2 Currents

2.2.1

forward current

the current flowing through the diode in the direction of lower resistance

2.2.2

mean forward current

the value of the forward current averaged over the full cycle

2.2.3

repetitive peak forward current (I_{FRM})

the peak value of the forward current including all repetitive transient currents

2.2.4**overload forward current**

a 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.

2.2.5**surge forward current**

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

2.2.6**reverse current**

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

2.2.7**resistive reverse current**

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

2.2.8**reverse recovery current (i_{RR})**

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

2.2.9**R.M.S. forward current**

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

2.2.10 **I^2t value**

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

2.2.11**peak case non-rupture current**

the peak value of 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.

2.3 Power dissipations**2.3.1****total power dissipation**

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

2.3.2**forward power dissipation**

the power dissipation due to the flow of forward current

2.3.3**mean forward power dissipation**

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

2.3.4**surge reverse power dissipation (of avalanche and controlled-avalanche rectifier diodes)**

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

2.3.5**turn-on dissipation**

the 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

2.3.6**turn-off dissipation**

the 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

2.3.7**reverse power dissipation**

the power dissipation resulting from the flow of reverse current

2.3.8**case non-rupture I^2t**

the value of I^2t 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:

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

where

t_w is the 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^2t , provided no plasma was emitted. Parts of the case shall not break away, nor shall the device melt externally or burst into flames.

2.4 Other characteristics**2.4.1****straight line approximation of the forward characteristics**

an approximation of the voltage versus current forward characteristic by means of a straight line which crosses this characteristic at two specified points (see Figure 4, page 9)

2.4.2**forward slope resistance (r_T)**

the value of the resistance calculated from the slope of the straight line approximation of the forward characteristic (see Figure 4)

2.4.3**reverse recovery time (t_{rr})**

the 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 1) or when the extrapolated reverse current reaches zero (as shown in Figure 2)

NOTE The extrapolation is carried out with respect to specified points A and B, as shown in generalized form in Figure 2.

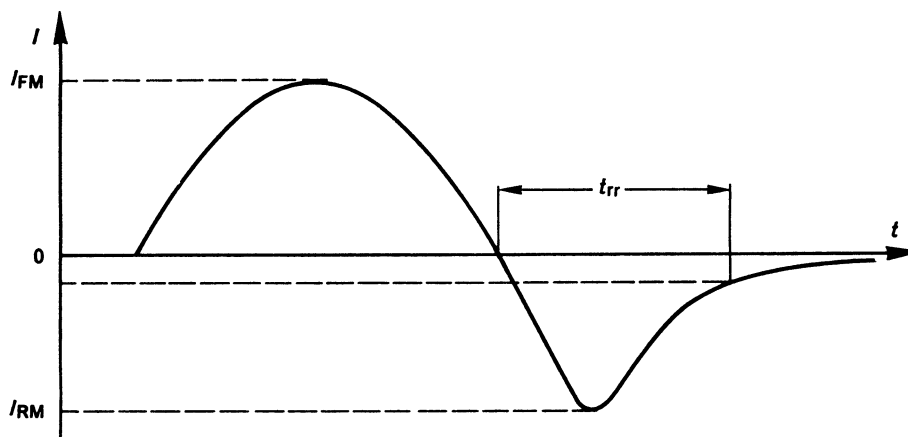


Figure 1

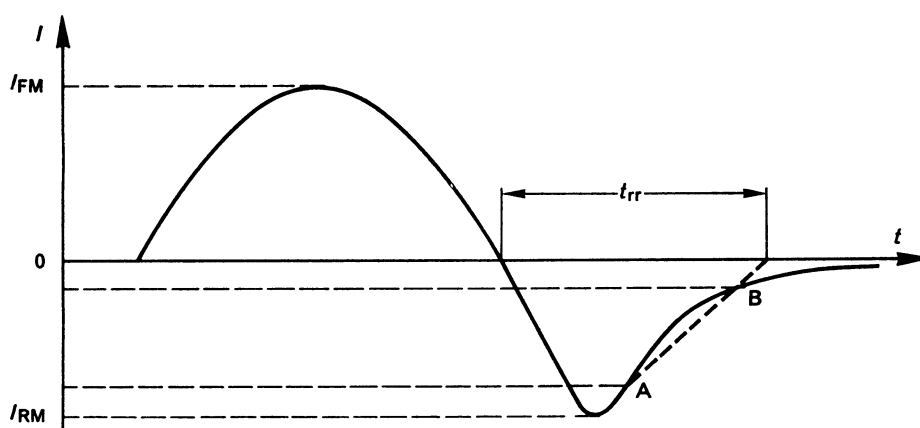


Figure 2

2.4.4

forward recovery time (t_{fr}) (of a rectifier diode)

the 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 35a), or when the extrapolated forward voltage reaches zero (as shown in Figure 35b), upon the application of a specified step of forward current following a zero-voltage or other specified reverse-voltage condition

NOTE 1 Specification method A: The specified first and second values referred to in the definitions are usually 10 % and 110 % respectively, of the final stable value V_F^* in Figure 35a and Figure 35b.

NOTE 2 Specification method B: The extrapolation is carried out with respect to specified points A and B as shown in generalized form in Figure 35b.

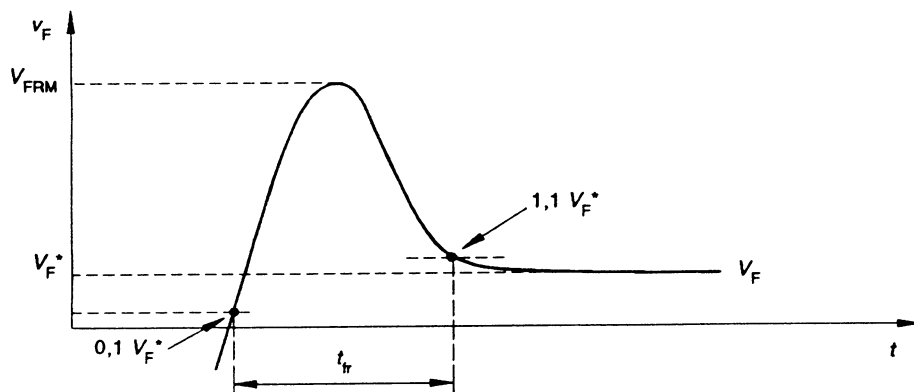


Figure 35a — Specification method A

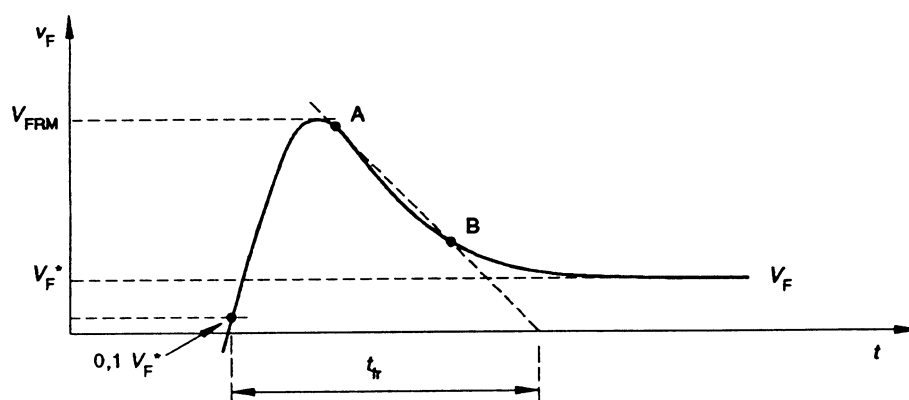


Figure 35b — Specification method B

Figure 35 — Forward recovery time

2.4.5

recovered charge (Q_r)

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

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

where:

t_o is the instant when the current passes through zero

t_i is the specified integration time (see Figure 36).

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

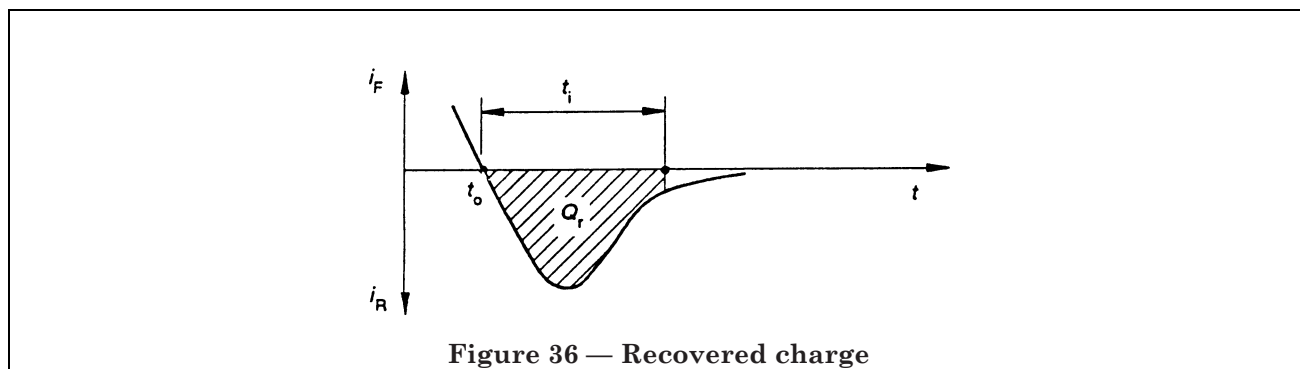


Figure 36 — Recovered charge

2.4.6**reverse recovery current rise time**

the 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

2.4.7**reverse recovery current rise time**

the 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

2.4.8**rise time charge**

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

2.4.9**fall time charge**

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

3 Letter symbols**3.1 General**

The general rules of Publication 747-1, Chapter V, are applicable in part.

3.2 Additional general subscripts

In addition to the lists of recommended general subscripts given in Publication 747-1, Chapter V, the following special subscripts are recommended for the field of rectifier diodes:

3.2.1 For currents, voltages and powers

(See also Sub-clause 2.2.1 of Publication 747-1, Chapter V):

- A, a = anode
- K, k = cathode
- O = average output rectified
- (TO) = threshold

3.2.2 For electrical parameter

(See also Sub-clause 2.2.2 of Publication 747-1, Chapter V):

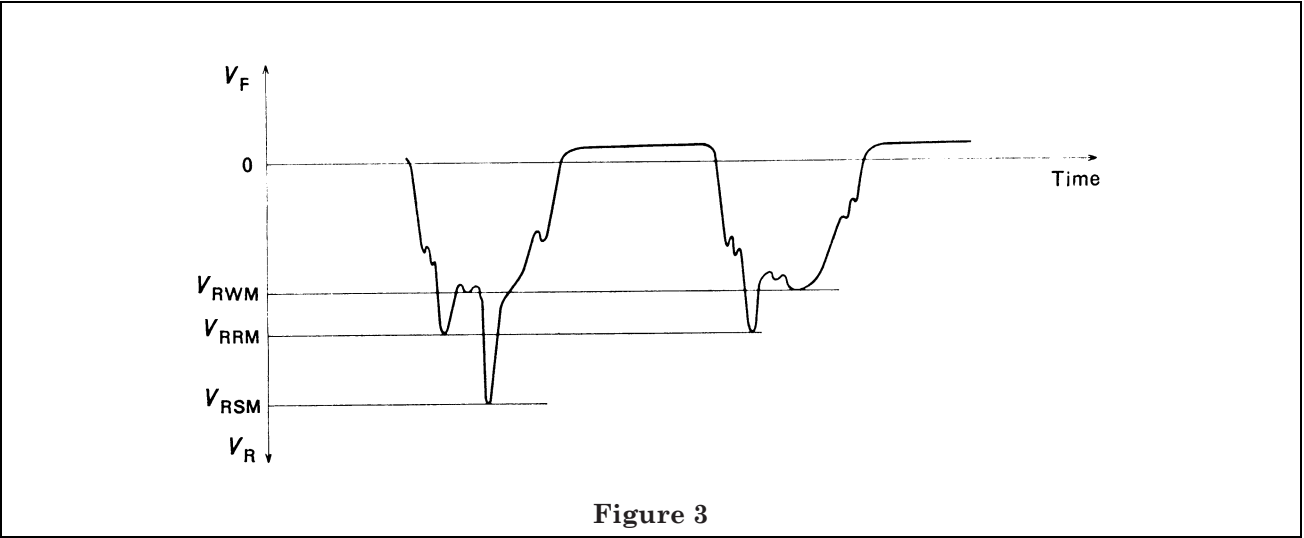
- T = slope

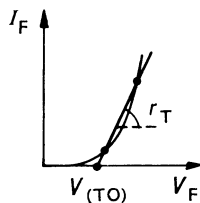
3.3 List of letter symbol

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.

3.3.1 Voltages

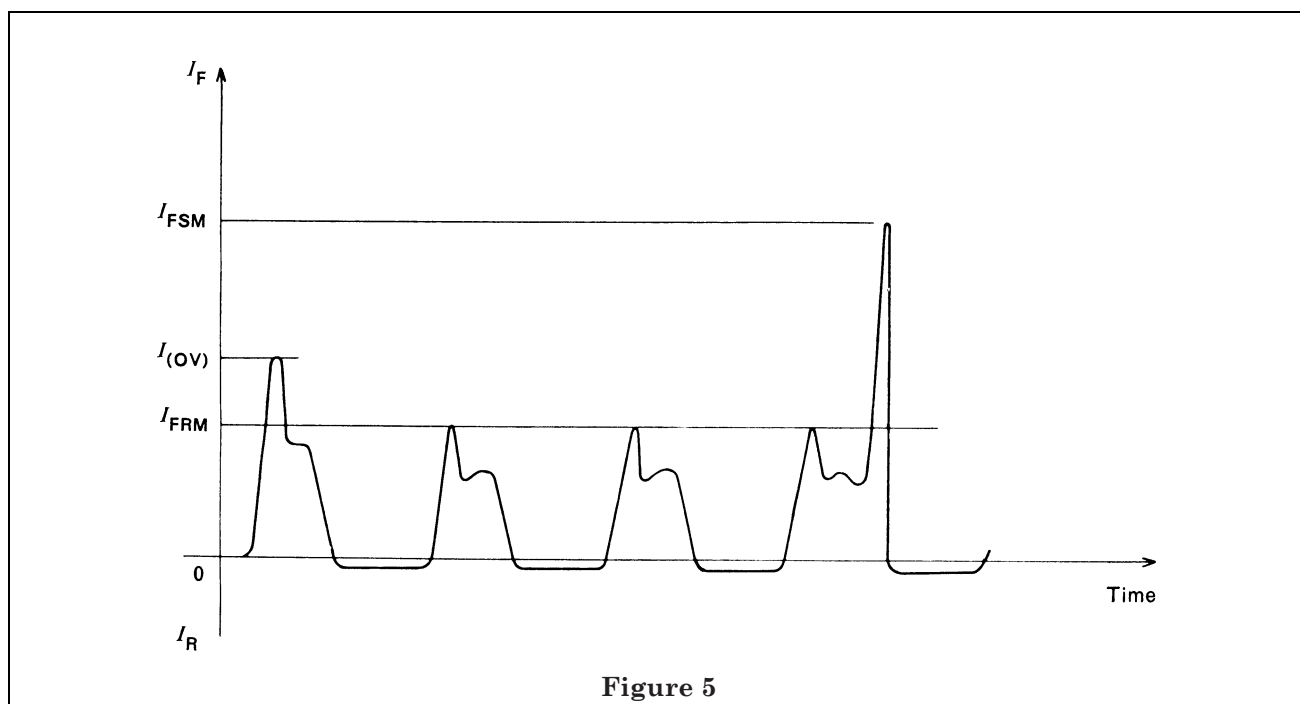
Name and designation	Letter symbol	Remarks
Continuous (direct) forward voltage	V_F	
Crest (peak) forward voltage	V_{FM}	
Average forward voltage (with I_O specified)	$V_{F(AV)}$	
Continuous (direct) reverse voltage	V_R	
Crest (peak) working reverse voltage	V_{RWM}	
Repetitive peak reverse voltage (maximum 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}	



Name and designation	Letter symbol	Remarks
Forward slope resistance	r_T	 Figure 4
Threshold voltage	$V_{(TO)}$	

3.3.2 Currents

Name and designation	Letter symbol	Remarks
Continuous (direct) forward current	I_F	
Repetitive peak forward current	I_{FRM}	
Overload forward current	$I_{(OV)}$	
Surge (non-repetitive) forward current	I_{FSM}	
Average output rectified current	I_O	
Continuous (direct) reverse current	I_R	
Average reverse current (with I_O specified)	$I_{R(AV)}$	
Reverse recovery current	i_{RR}	



3.3.3 Powers

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

Chapter III. Essential ratings and characteristics

1 General

1.1 Range of application

This chapter gives standards for rectifier diodes including:

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

1.2 Rating methods

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

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 Publication 747-1; in addition, temperatures of – 40 °C and ± 35 °C may be used.

2 Rating conditions

The ratings given in Clause 3 should be stated under one or more of the following thermal conditions:

2.1 Ambient-rated rectifier diodes

2.1.1 Natural convection

At 25 °C and at one higher temperature (see Sub-clause 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.

2.1.2 Forced circulation

At a temperature taken from the list of recommended temperatures (see Sub-clause 1.3). The type, pressure and flow of the cooling fluid should be specified.

2.2 Case-rated rectifier diodes

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

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.

3.1 Voltage ratings

3.1.1 *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.

3.1.2 *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.

3.1.3 *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).

3.1.4 *Continuous (direct) reverse voltage* (V_R) (where appropriate)

Maximum value.

3.2 Current ratings

3.2.1 *Mean forward current*

A curve showing maximum values versus ambient or case temperature for single-phase half-wave circuit with resistive load. In addition, curves for other circuits may be given.

NOTE The rated mean forward current is given on the assumption that no overload occurs.

3.2.2 *Repetitive peak forward current* (I_{FRM}) (where appropriate), (especially for fast-switching diodes)

Curves showing the maximum (repetitive peak) forward current values as a function of the half-sine wave current duration, with the repetition frequency as a parameter, under the following specified conditions:

- reference-point temperature;
- reverse voltage;
- RC damping network (snubber), where appropriate.

Figure 6 is given as an example and Figure 6A is given for explanatory purposes.

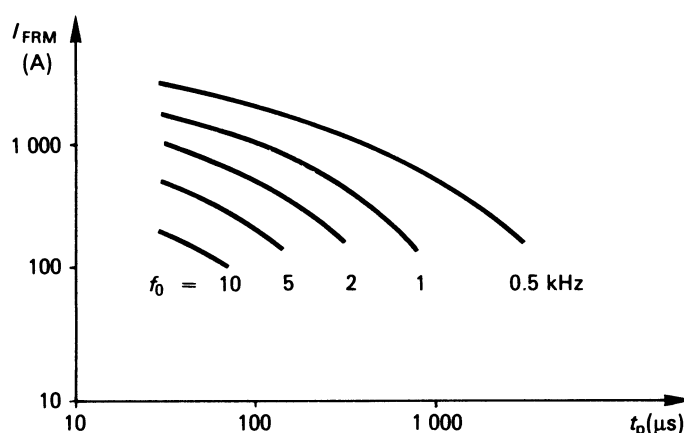


Figure 6 — Maximum peak forward current I_{FRM} as a function of pulse duration t_p .
Parameter: repetition frequency f_0

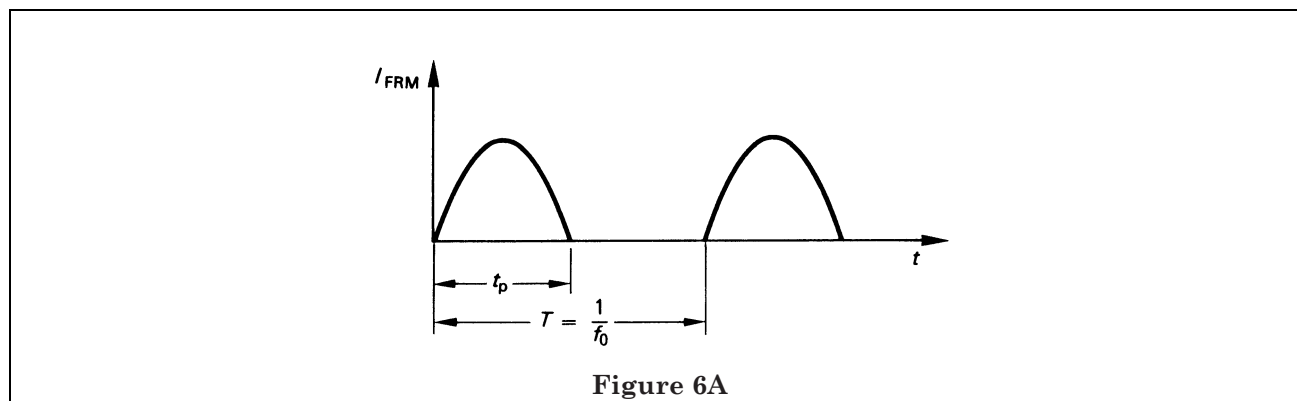


Figure 6A

3.2.3 Overload forward current ($I_{(OV)}$)

Where this rating is appropriate, it should be given by stating the maximum virtual junction temperature and the maximum transient thermal impedance. In addition, overload current ratings may be given by means of diagrams.

3.2.4 Surge (non-repetitive) forward current (I_{FSM})

This rating should be given at initial conditions corresponding to maximum virtual junction temperature. In addition, figures corresponding to lower initial virtual junction temperatures may be given.

Surge current ratings should be given for the following time periods:

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

$$\int i^2 dt$$

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

- For times equal to, or greater than, one half-cycle and smaller than 15 cycles (at 50 or 60 Hz) in the form of a curve showing the maximum rated surge current versus time.

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

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

3.2.5 Continuous (direct) forward current (I_F)

Maximum value.

3.2.6 Peak case non-rupture current

The limiting value “peak case non-rupture current” should be specified, where appropriate, as the maximum value of a triangular current rising at a specified rate, preferably 25 A/μs, and having a specified pulse duration for a starting case temperature to be specified, preferably 25 °C.

NOTE The limiting value “peak case non-rupture current” is needed for high-current rectifier diodes (mean current ratings of about 1 000 A and higher) that are used in large convertor installations (as a rule, several devices are connected in parallel), where a device failing to block reverse voltage causes a high, steeply rising, short-circuit current that can fracture the case and cause damage to the equipment before a fuse operates.

Therefore, the determination or verification of this limiting value of current needs a high-power testing facility, and the costs of the testing itself and of the samples which are destroyed in the test are considerable and are justified only in cases where the above-mentioned danger really exists.

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.

4 Frequency ratings (limiting values)

Where applicable, maximum and/or minimum frequencies for which the voltage and current ratings in Clause 3 apply.