BRITISH STANDARD

BS EN 61643-321:2002

Components for low-voltage surge protective devices —

Part 321: Specifications for avalanche breakdown diode (ABD)

The European Standard EN 61643-321:2002 has the status of a British Standard

ICS 29.120.50; 31.080.10

National foreword

This British Standard is the official English language version of EN 61643-321:2002. It is identical with IEC 61643-321:2001.

The UK participation in its preparation was entrusted by Technical Committee PEL/37, Surge arresters, to Subcommittee PEL/37/2, Surge arresters - Low voltage, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

From 1 January 1997, all IEC publications have the number 60000 added to the old number. For instance, IEC 27-1 has been renumbered as IEC 60027-1. For a period of time during the change over from one numbering system to the other, publications may contain identifiers from both systems.

Cross-references

Attention is drawn to the fact that CEN and CENELEC Standards normally include an annex which lists normative references to international publications with their corresponding European publications. The British Standards which implement international or European publications may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

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This British Standard, having been prepared under the direction of the Electrotechnical Sector Policy and Strategy Committee, was published under the authority of the Standards Policy and Strategy Committee on 21 March 2002

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EUROPEAN STANDARD **EN 61643-321**

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ICS 31.080.10

English version

Components for low-voltage surge protective devices Part 321: Specifications for avalanche breakdown diode (ABD)

(IEC 61643-321:2001)

Composants pour parafoudres basse tension
Partie 321: Spécifications pour les diodes à avalanche (ABD)
(CEI 61643-321:2001)

Bauelemente für Überspannungs-schutzgeräte für Niederspannung
Teil 321: Festlegungen für Avalanche-Dioden (ABD)
(IEC 61643-321:2001)

This European Standard was approved by CENELEC on 2002-02-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

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Foreword

The text of document 37B/59/FDIS, future edition 1 of IEC 61643-321, prepared by SC 37B, Specific components for surge arresters and surge protective devices, of IEC TC 37, Surge arresters, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61643-321 on 2002-02-01.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2002-11-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2005-02-01

Annexes designated "normative" are part of the body of the standard.
In this standard, annex ZA is normative.
Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61643-321:2001 was approved by CENELEC as a European Standard without any modification.

CONTENTS

COMPONENTS FOR LOW-VOLTAGE SURGE PROTECTIVE DEVICES –

Part 321: Specifications for avalanche breakdown diode (ABD)

1 Scope

This part of IEC 61643 is applicable to avalanche breakdown diodes (ABDs) which represent one type of surge protective device component (hereinafter referred to as SPDC) used in the design and construction of surge protective devices connected to low-voltage power distribution systems, transmission, and signalling networks. Test specifications in this standard are for single ABDs consisting of two terminals. However, multiple ABDs may be assembled within a single package defined as a diode array. Each diode within the array can be tested to this specification.

This standard contains a series of test criteria for determining the electrical characteristics of the ABD. From the standard test methods described herein, the performance characteristics and ratings of the ABD can be verified or established for specific packaged designs.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 61643. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 61643 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 60068 (all parts), *Environmental testing*

IEC 60364 (all parts), *Electrical installations of buildings*

IEC 60364-3:1993, *Electrical installations of buildings – Part 3: Assessment of general characteristics*

IEC 60721 (all parts), *Classification of environmental conditions*

IEC 60747-2:2000, *Semiconductor devices – Discrete devices and integrated circuits – Part 2: Rectifier diodes*

IEC 60749:1996, *Semiconductor devices – Mechanical and climatic test methods*

3 Definitions and symbols

For the purpose of this part of IEC 61643, the following definitions and symbols apply.

NOTE These definitions apply to one type of SPDC known as an ABD, having both symmetrical and asymmetrical voltage-current (*V-I*) characteristics. Such definitions are for a unidirectional element (see figure 1). If the ABD is considered bidirectional, definitions in the third quadrant will apply in both directions of the *V-I* characteristic curve.

3.1
avalanche breakdown diode ABD
component intended to limit transient voltages and divert surge currents. This is a two-terminal diode that may be packaged with multiple elements having a common terminal

3.2
clamping voltage V_C
peak voltage measured across the ABD during the application of a peak impulse current I_{PP} for a specified waveform

NOTE Due to the thermal, reactive, or other effects, peak voltage and peak pulse current are not necessarily coincident in time. Also shown as V_{CL}.

3.3
rated peak impulse current I_{PPM}
rated maximum value of peak impulse current I_{PP} that may be applied without causing diode failure

NOTE The impulse waveshape used for diode characterization is 10/1 000 µs unless otherwise specified.

3.4
maximum working voltage (maximum d.c. voltage) V_{WM}
maximum peak working or d.c. voltage which may be continuously applied to the ABD without degradation or damaging effects. For a.c. applied voltages, the maximum working r.m.s. voltage is V_{WMrms}

NOTE It is also shown as V_{RM} (rated maximum) and known as rated stand-off voltage.

3.5
stand-by current I_D
maximum current that flows through the ABD at maximum working voltage for a specified temperature

NOTE Also shown as I_R for reverse leakage current.

3.6
breakdown (avalanche) voltage V_{BR}
voltage measured across the ABD at a specified pulsed d.c. current I_T (or I_{BR}) on the *V-I* characteristics curve at, or near, the place where the avalanche occurs

3.7
capacitance C_j
capacitance between two terminals of the ABD measured at a specific frequency and bias

NOTE Also shown as *C*.

3.8
rated peak impulse power dissipation P_{PPM}
peak pulse power dissipation resulting from the product of rated peak impulse current I_{PPM} and clamping voltage V_C

$$P_{PPM} = I_{PPM} \times V_C$$

NOTE Also shown as P_P.

3.9
rated forward surge current I_{FSM}
maximum peak current for an 8,3 ms or 10 ms half-sine wave without causing device failure. (This definition applies to unidirectional ABDs only.)

3.10
forward voltage V_{FS}
peak voltage measured across the ABD for a specified forward surge current I_{FS}. (This definition applies to unidirectional ABDs only.)

NOTE Also shown as V_F.

3.11
temperature coefficient of breakdown voltage αV_{BR}
ratio of the change in breakdown voltage V_{BR} to changes in temperature

NOTE Expressed as either millivolts per degree Kelvin or per cent per degree Kelvin (mV/K or %/K).

3.12
temperature derating
derating above a specified base temperature for either peak impulse current or peak impulse power

NOTE Expressed in percentage of the current or power.

3.13
thermal resistance R_{thJA}, R_{thJC}, R_{thJL}
junction to ambient, case or lead terminal temperature rise per unit input of applied power expressed as degrees Kelvin per watt (K/W)

3.14
transient thermal impedance Z_{thJA}, Z_{thJC}, Z_{thJL}
change in the difference between the virtual junction temperature and the temperature of a specific reference point or region (ambient, case or lead) at the end of a time interval. This change is divided by the step function change in power dissipation at the beginning of the same time interval which causes the change of temperature difference.

NOTE Thermal resistance is expressed as degrees Kelvin per watt (K/W).

3.15
rated average power dissipation $P_{M(AV)}$
rated average power dissipation in the device due to repetitive pulses at a specified current and temperature without causing device failure

3.16
peak overshoot voltage V_{OS}
excess voltage above the clamping voltage V_C of the device for a given current that occurs when current waves of less than, or equal to, 10 μs virtual front duration are applied

NOTE This value may be expressed as a percentage of the clamping voltage V_C for a 10/1 000 μs current wave.

3.17
pulsed d.c. test current I_T
test current for measurement of the breakdown voltage V_{BR}. This is defined by the manufacturer and usually given in milliamperes with a pulse duration of less than 40 ms

NOTE Also shown as I_{BR}.

3.18
peak impulse current I_{PP}
peak impulse current value applied across the ABD to determine the clamping voltage V_C for a specified waveshape

4 Basic function and description for ABDs

The avalanche breakdown diode (ABD), in its basic form, is a single semiconductor P/N junction consisting of an anode (P) and a cathode (N) (see figure 1a). In d.c. applications, this ABD is reverse biased in such a way that a positive potential is applied to the cathode (N) side of the element (see figure 1b).

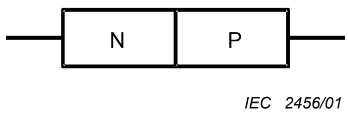


Figure 1a – Structure

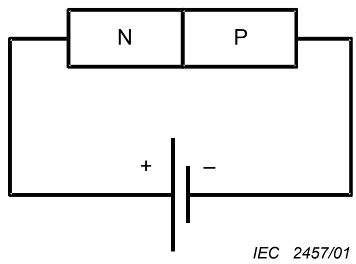


Figure 1b – Bias condition

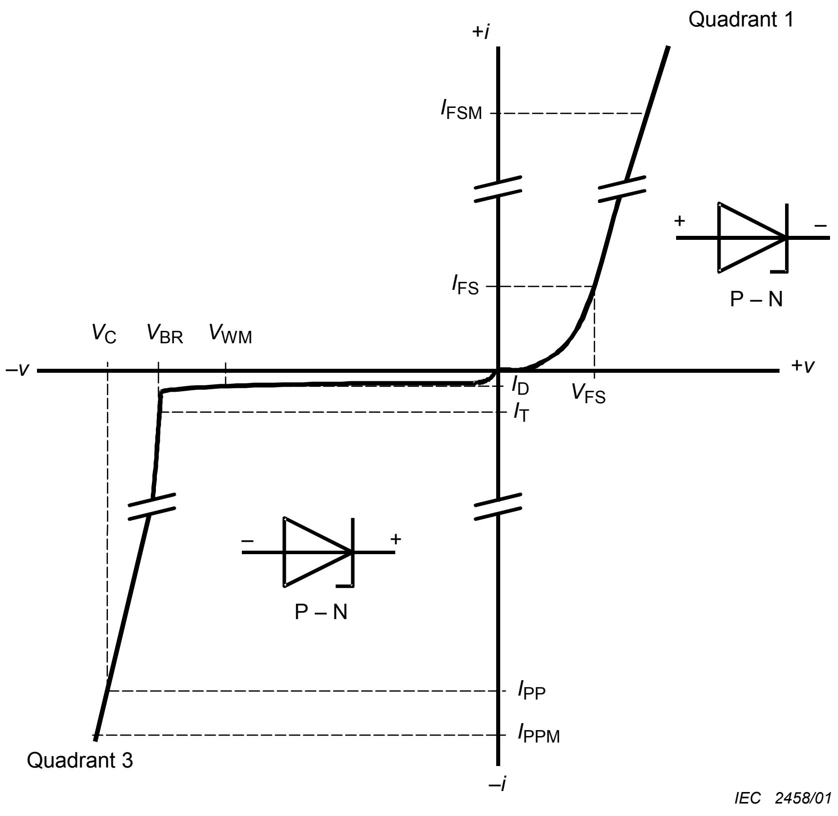


Figure 1c – *V-I* characteristics

Connections and supplies

Avalanche parameters

- V_{WM} Maximum working voltage
- I_D Stand-by current
- V_C Clamping voltage
- V_{BR} Breakdown voltage
- I_{PP} Peak impulse current
- I_{PPM} Rated peak impulse current
- I_T Pulsed d.c. test current

Forward parameters

- V_{FS} Forward voltage
- I_{FS} Forward surge current
- I_{FSM} Rated forward surge current

NOTE For bidirectional ABDs, the *V-I* characteristics of Quadrant 3 are shown in Quadrant 1.

Figure 1 – Structure, bias condition and *V-I* characteristics for a unidirectional ABD

When the applied voltage V_o is greater than the breakdown (avalanche) voltage V_{BR} of the P/N junction, the ABD starts to conduct a current greater than the stand-by current I_D. During a transient voltage impulse, the ABD will limit the voltage to some finite value.

The primary intent of the ABD is to limit transient voltages and divert surge currents. Because ABD's may differ in their characteristics due to packaging, only those diode parameters that are necessary for selection when used in the surge protective device design are listed here. Other parameters may be important for specific applications and selection but are not identified here.

The ABDs may be configured in such a way that there are multiple diodes within a single package. Multiple diode packages may contain individual ABD chips assembled either in series or parallel to achieve a desired SPDC characteristic or rating. ABDs of this configuration are considered as a single SPDC. Multiple junctions within a single package can also be used as independent ABDs for multiple line protection. Each diode within the array of diodes shall be tested individually according to this standard.

When reversed biased, the ABD has two operating modes: stand-by (high impedance) or clamping (relative low impedance) (see figure 1c, third quadrant). The current through the ABD in the stand-by condition is called the stand-by current. This current varies with junction (or ambient) temperature. The initiation of avalanche breakdown is marked by a transition from a high impedance (stand-by) to low impedance (clamping) in the ABD voltage-current characteristics. In this 'on' condition, the diode conducts high transient currents and maintains a relatively low clamping voltage above the breakdown voltage of the semiconductor junction. Figure 1 is a unidirectional ABD. ABDs can be unidirectional or bidirectional. Bidirectional ABDs will show a similar characteristic, with opposite polarity, in the first quadrant and the third quadrant.

In figure 1c, the *V-I* curve of the first quadrant shows the forward biased condition (positive potential applied to the P side of the semiconductor junction) representing a unidirectional avalanche diode. In this condition, the unidirectional ABD shows similar characteristics to a forward biased P/N junction diode. Due to the lower clamping voltage in the forward direction, the transient current can be much higher. However, the forward voltage will exhibit a high voltage under a high transient current of specified waveshape. This voltage is dependent upon the junction area and base resistance of the semiconductor material.

The breakdown voltage exhibits linear shifts with changes in junction or ambient temperature as described by the temperature coefficient of the breakdown voltage. Knowledge of the clamping voltage measurement at 25 °C and of the semiconductor's breakdown voltage temperature coefficient can be used to determine the effective voltage for other ambient temperatures

5 Service conditions

The normal service conditions are the following:

- air pressure 86 kPa to 106 kPa (IEC 60749 and IEC 60721);
- ambient air temperature within the range of –40 °C to +85 °C for outdoor elements and within the range of –20 °C to +70 °C for indoor elements (see IEC 60364);
- solar or other radiation (see IEC 60364-3);
- relative humidity under normal temperature conditions (see IEC 60068);
- indoor relative humidity can be up to 90 % or as directed;
- exposure of the SPDC to abnormal service conditions may require special considerations in the design and application of the ABD, and should be called to the attention of the manufacturer;
- other considerations to be specified by the diode manufacturer: maximum continuous diode voltage, peak impulse power or current temperature derating, peak impulse current rating, transient repetition rating, solvent resistance, solderability and flammability.

6 Standard test methods and procedures

6.1 Standard design test criteria

Characteristic parameter tests are described in 6.3 through 6.8. Rating parameter tests are described in 6.9 through 6.19. Characteristic parameters are inherent and measurable property of the ABD. Rating parameters are values to establish either a limiting capability or limiting condition of the ABD. Tests in 6.3 through 6.8 provide standardized methods for measuring specified parameters of an ABD for the purpose of component selection for a surge protective device (SPD). These parameters may vary from device to device, making it necessary to measure all components to be selected for a SPD. Bidirectional ABDs shall be tested with both positive and negative voltages.

6.2 Test conditions

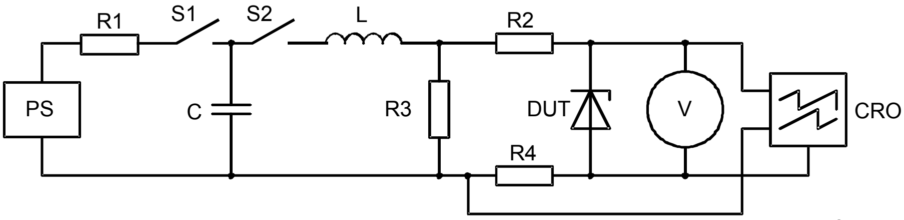
The tests of 6.3 through 6.8, performed on the device, are required for its application. Unless otherwise specified, ambient test conditions shall be as follows:

- temperature: 25 °C ± 5 °C;
- relative humidity: less than 85 %;
- air pressure: 86 kPa to 106 kPa (IEC 60749).

NOTE Due to the voltage and energy levels employed in these tests, all tests should be considered hazardous, and appropriate caution should be taken when performing them.

6.3 Clamping voltage – V_C (see figure 2)

6.3.1 The purpose of this test is to determine the voltage protection level provided by the ABD when conducting a current impulse I_{PP} of specified waveform and peak amplitude. The device shall be tested in both voltage polarities unless otherwise specified.



Components

PS	Charging supply	R2	Impulse shaping and current limiting resistor
R1	Charging resistor	R3	Impulse shaping resistor
S1	Charging switch	R4	Current sensing resistor (coaxial). Alternatively a current transformer or probe of adequate rating may be used
C	Impulse shaping capacitor		
S2	Impulse discharge switch	DUT	Device under test (ABD)
L	Impulse shaping inductor	V	Peak reading voltmeter
CRO	Oscilloscope for observing current and voltage		

CAUTION The circuit shown is for description only. Measurement techniques for high-current, high-frequency testing shall be observed, such as four-point Kelvin contact, differential oscilloscope, short leads, etc.

Figure 2 – Test circuit for clamping voltage V_C, peak impulse current I_{PP}, and rated forward surge current I_{FSM}

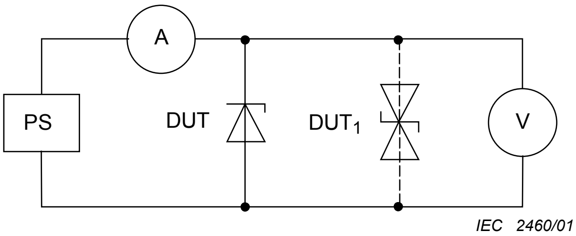
6.3.2 To verify the volt-ampere characteristics curve, the clamping voltage shall be measured at two current levels. The peak clamping voltage and peak test current are not necessarily coincident in time. In the absence of specified requirements, test currents shall be 0,2 I_{PP} and I_{PP} using a 10/1 000 (or 8/20) waveshape.

6.4 Rated peak impulse current I_{PPM} (see figure 2)

The purpose of this test is to verify that an ABD design meets a specific number of current impulses without causing device failure. The multiple peak impulse current rating shall be verified by subjecting the device to a 10/1 000 (or 8/20) current waveform. The impulse currents shall be applied once every 45 s. For symmetrical devices, a single polarity shall be tested for the 10 consecutive pulses. The failure criteria of clause 7 shall apply.

6.5 Maximum working voltage V_{WM} and maximum working r.m.s. voltage V_{WMrms} (see figure 3)

The purpose of this test is to verify the maximum voltage that may be applied across an ABD over a specified temperature range without causing device failure. The manufacturer specifies the maximum stand-by current that is applied to the ABD. The rated working r.m.s. voltage applies only to symmetrical, bidirectional ABD components.



Components

PS	Adjustable d.c. voltage power supply (a.c. supply if an a.c. test)
A	Microammeter d.c. (a.c. ammeter if an a.c. test)
DUT	Unidirectional device under test
DUT_1	Bidirectional device under test
V	Digital voltmeter (substitute an oscilloscope if an a.c. test)

Figure 3 – Test circuit for verifying maximum working voltage V_{WM} stand-by current I_D and maximum working r.m.s. voltage V_{WMrms}

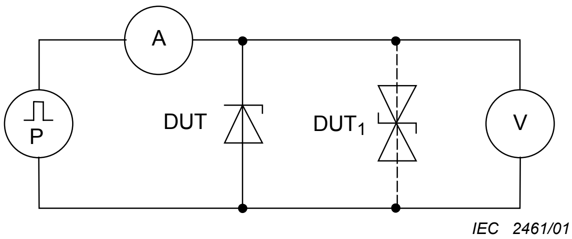
6.6 Stand-by current I_D (see figure 3)

The purpose of this test is to verify the stand-by current level of an ABD at temperatures specified by the manufacturer. The maximum working voltage V_{WM} shall be generated by a well-regulated d.c. power supply and shall be impressed across the device. The stand-by current shall be measured after the voltage has been applied for at least 10 ms to allow stabilization of the conduction.

6.7 Breakdown (avalanche) voltage V_{BR} (see figure 4)

6.7.1 The ABD shall be tested at a specified pulse d.c. current and at a specified temperature. The time of applied test current I_{BR} or I_T shall be less than 400 ms.

6.7.2 This electrical characteristic is indicated as a minimum voltage range for the specified test current. In the absence of a specified requirement, it is recommended that the test current I_{BR} or I_T be at 1 mA. Low voltage or higher power devices may be specified at higher test currents.



Components

P	Pulsed constant current supply
DUT	Unidirectional device under test
DUT_1	Bidirectional device under test
V	Digital voltmeter

Figure 4 – Test circuit for verifying breakdown (avalanche) voltage V_{BR}

6.8 Capacitance C_j

The purpose of this test is to determine the ABD capacitance between two of the terminals. The capacitance between specified terminals shall be measured at a specified sinusoidal frequency and bias voltage. For multiple terminals, one pair of terminals shall be measured at a time; all terminals not involved in the test shall be guarded to remove their capacitance from the measurement. In the absence of specified requirements, a signal of 0,1 V r.m.s. or less at a frequency of 1 MHz and a bias of 0 V d.c. are suggested.

6.9 Rated peak impulse power dissipation P_{PPM}

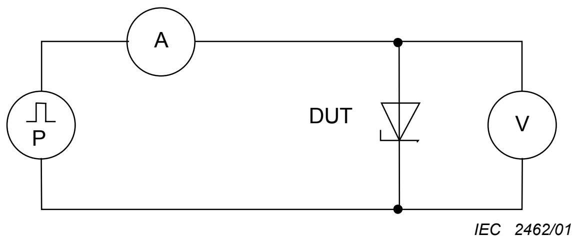
The purpose of this test is to verify the manufacturer's power rating under specific test conditions. This rating is specified by the manufacturer for each product. Verification of the parameter requires the application of the rated peak impulse current I_{PPM} and measuring the clamping voltage V_C. Multiplication of the peak impulse current by the clamping voltage is defined as the peak pulse power dissipation. A sufficient number of devices shall be tested and the voltage-current characteristics shall be measured as described in 6.3 and 6.4 to obtain a statistical distribution within the desired confidence limits.

6.10 Rated forward surge current I_{FSM} (see figure 1c)

The purpose of this test is to verify that an ABD, when subjected to a 10 ms (or 8,3 ms), single half-sine wave maximum peak current, meets a statistically expressed level of reliability. The device shall be tested in accordance with figure 2 except that the unidirectional device is reversed. The surge is applied in the forward direction of the ABD (quadrant 1 of the *V-I* characteristic curve, figure 1c).

6.11 Forward voltage V_{FS}

Peak value of the forward voltage is measured by applying a 10 ms (or 8,3 ms) single half-sine wave maximum peak current in the forward direction of the ABD. Forward surge current I_{FS} is a value of current that flows through the diode in the forward direction for a unidirectional ABD.



Components

P Pulsed constant current supply

DUT Device under test

V Digital voltmeter

A Ammeter

Figure 5 – Test circuit for verifying forward voltage V_{FS}

6.12 Temperature coefficient of breakdown voltage αV_{BR}

The voltage temperature coefficient is the ratio of the change in breakdown voltage to the change in temperature. It may vary from device to device, but it is characteristic of a specific ABD independent of power ratings. This parameter shall be considered when operating over a temperature range. The breakdown voltage and maximum clamping voltage will vary over the temperature range and this variation can be expressed as a voltage temperature coefficient. For breakdown voltages above 5 V, this parameter will always be positive.

$$\alpha V_{BR} = \frac{V_{BR(\text{test temperature})} - V_{BR(\text{reference temperature})}}{V_{BR(\text{reference temperature})}} \times \frac{100}{T_{test} - T_{ref}} \quad \%/\text{K}$$

where

reference temperature = actual ambient (25 °C ± 3 °C) temperature

test temperature = extreme temperature employed in the measurement.

6.13 Temperature derating (see figure 5)

Temperature derating describes the variations in either peak pulse power or peak impulse current with increasing temperatures above a specified temperature level. Power derating applies to both peak pulse and steady-state (average) power conditions. See IEC 60747-2 for this test method.

6.14 Thermal resistance R_{thJA} or R_{thJC} or R_{thJL}

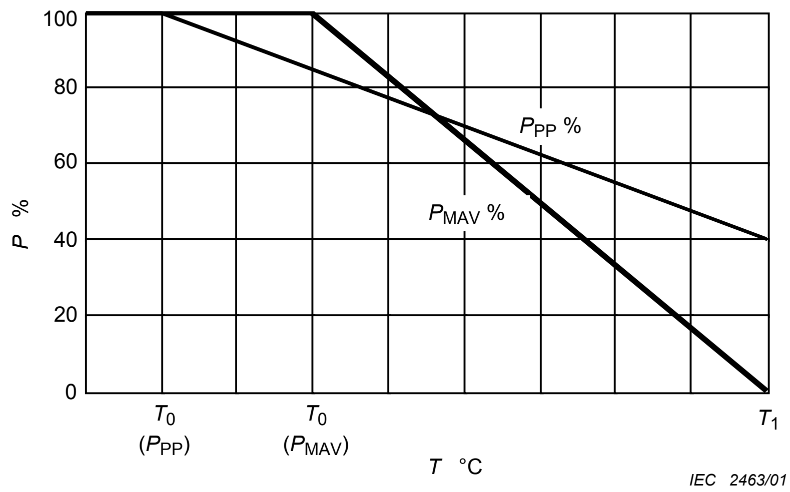
Thermal resistance is a measure of the resistance to heat flow present from the semi-conductor junction to the case, lead or ambient air. Heat transfer occurs by means of radiation, natural or forced convection, or conduction through materials. The thermal characteristics of each device (family) shall be specified (and defined) by the manufacturer. The purpose of this test is to measure the temperature rise per unit power dissipation of the device junction above the case of the device or ambient temperature, under conditions of constant voltage and current (see 6.11).

a) Measure the junction power required to maintain the junction temperature constant (as indicated by a precalibrated temperature sensitive electrical parameter, such as the forward voltage at a defined forward current (see 6.11) when the case of the device or ambient temperature, as specified, is changed by a known amount.

b) Measure the junction temperature (as indicated by a precalibrated temperature sensitive electrical parameter, forward voltage) when the junction power is changed by a known amount while the case of the device or ambient temperature, as specified, is held constant.

6.15 Transient thermal impedance Z_{thJA} or Z_{thJC} or Z_{thJL}

Thermal impedance is a test to determine the pulse power capability of the ABD for a specified power pulse duration. The purpose is to measure the transient thermal impedance between the device junction and a reference point such as the device case or the ambient temperature of the ABD. See 2.2.3 of IEC 60747-2 for this test method.



Key

T_0 Temperature at which derating begins

T_1 Temperature at which there is no power or current or minimum derated value for the specified temperature

NOTE Rated peak pulse power P_{PPM} or rated peak impulse current I_{PPM} in per cent (%) of T_0 rating.

Figure 6 – Derating curve for ABD components

6.16 Rated average power dissipation P_{MAV}

The rated average power dissipation of an ABD is specified by the manufacturer in order to limit device temperatures for reliable long life, taking into consideration two conditions:

a) input average current through the material (junction) by repetitive transients, usually indicated by a duty cycle;

b) the thermal resistance of the device to the environment by leads and/or heatsink mounting as recommended by the manufacturer.

6.17 Peak overshoot voltage V_{OS} (see figure 7)

Peak overshoot voltage V_{OS} is the peak voltage V_1 minus the clamping voltage V_C of the ABD, figure 7. Test conditions and circuit are the same as for the clamping voltage test (see 6.3 and figure 2).

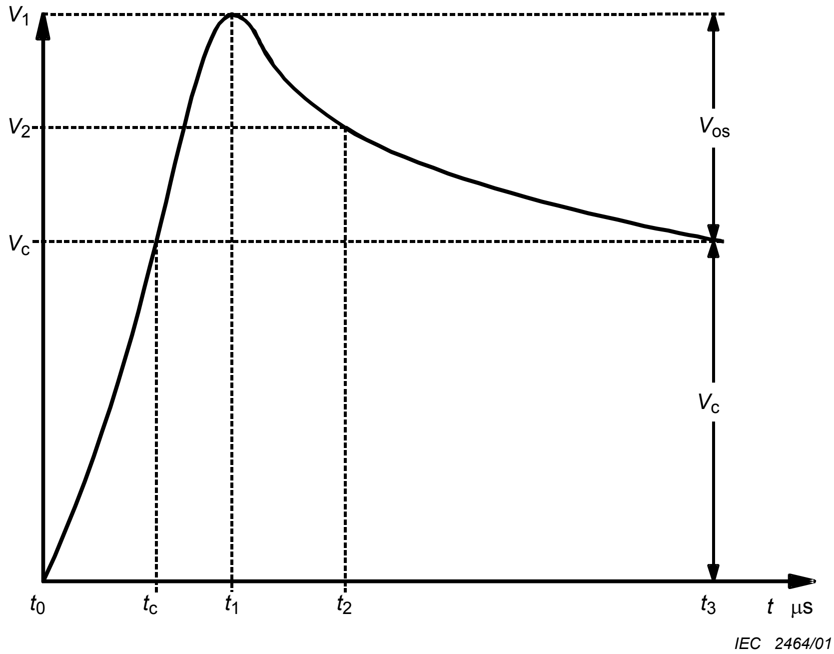
NOTE To assure that the peak overshoot voltage represents the device under test, all wires (connections) to the equipment and the leads of the DUT are to be kept at a minimum length. The peak overshoot voltage is dependent upon the front duration of the pulse and the lead length and of the ABD. There may also be some ringing following the overshoot voltage which is a result of mismatching of circuit impedance.

6.18 Overshoot duration (see figure 7)

Overshoot duration is the time ($t_3 - t_1$) for the overshoot voltage to become asymptotic to the clamping voltage V_C. Test condition and circuit are the same as for the clamping voltage test (see 6.3 and figure 2).

6.19 Response time (see figure 7)

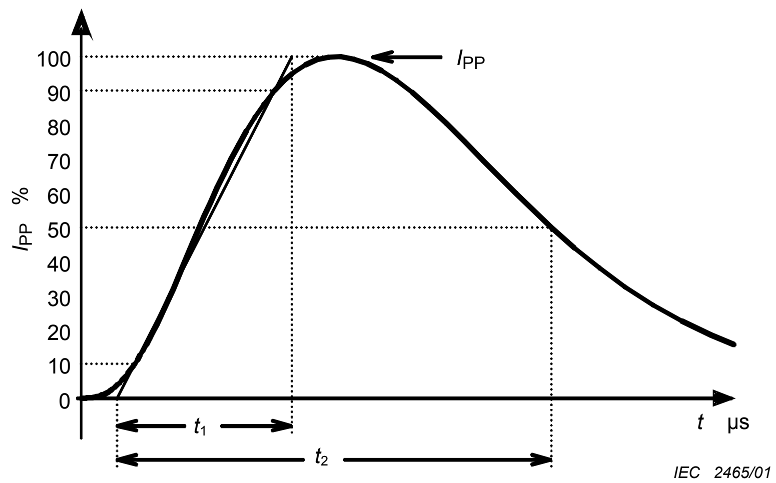
Response time is the ability of an ABD to respond to the front time of the peak impulse current I_{PP}. It is the time from zero t_0 to the time of the peak voltage t_1, figure 7. Test conditions and circuit are the same as for the clamping voltage test (see 6.3 and figure 2).



Key

V_C	Device clamping voltage for specified current and waveform
V_{OS}	Peak overshoot voltage (V_1 – V_C)
t_C	Time for device voltage to reach its clamping level V_C
t_1	Time for device voltage to reach its peak value V_1
t_2	Time for device voltage to decay to 50 % of its peak overshoot value
$t_1 – t_0$	Response time
$t_3 – t_1$	Overshoot duration
V_2	$(V_1 – V_C)/2$

Figure 7 – Graph illustrating voltage overshoot, response time and overshoot duration



Key

t_1 Virtual front duration. Zero cross to peak
t_2 Virtual time to half value of the impulse

EXAMPLE: For 10/1 000 µs current waveform:
10 µs = t_1 (virtual front duration)
1 000 µs = t_2 (impulse duration to 50 % I_{PP})

Figure 8 – Impulse current waveform

7 Fault and failure modes

In the absence of special requirements, the following criteria are suggested. Tests for determining failure shall be performed after the device temperature has returned to 25 °C ± 5 °C.

7.1 Degradation fault mode

In this mode, the ABD has a stand-by current greater than the maximum specified.

7.2 Short-circuit failure mode

In this mode, the ABD is permanently shorted with a resistance of less than 1 Ω at 0,1 V d.c. (This condition may occur when the maximum clamping voltage is exceeded after being subjected to a peak impulse current above the device rating, or when a device is powered beyond its average or multiple peak pulse power dissipation.)

7.3 Open-circuit failure mode

In this mode, the ABD appears as an open circuit that has a breakdown voltage V_{BR} greater than 150 % of the pre-test value at an applied test current I_{BR} or I_T, as discussed in 6.7.2. (This condition may occur if current is sustained in the device while in the shorted condition, or by an abnormally high or short-duration current pulse beyond the device capability.)

7.4 "Fail-safe" operation

The use of "fail-safe" to describe a failure mode of a device can occur in any of the modes described above. Some users may consider that the most desirable failure mode for the device is to maintain the protective function; for example, "fail-safe" in the short-circuit failure mode. However, system objectives of other users can require that a particular device should fail in a high clamping failure mode in order to achieve the desired performance of the system. Thus, failure in the short mode, while considered "fail-safe" by many users, may in fact be opposite to the desired ("safe") mode of other users. Therefore, the recommended practice is to describe the failure by one of the failure modes defined in 7.2 and 7.3.

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Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60068	Series	Environmental testing	EN 60068	Series
IEC 60364 (mod)	Series	Electrical installations of buildings	HD 384 S2	Series
IEC 60364-3 (mod)	1993	Electrical installations of buildings Part 3: Assessment of general characteristics	HD 384.3 S2	1995
IEC 60721	Series	Classification of environmental conditions	EN 60721	Series
IEC 60747-2	2000	Semiconductor devices - Discrete devices and integrated circuits Part 2: Rectifier diodes	-	-
IEC 60749	1996	Semiconductor devices - Mechanical and climatic test methods	EN 60749	1999

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