

JEDEC STANDARD

Terms, Definitions, and Letter Symbols for Discrete Semiconductor and Optoelectronic Devices

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JEDEC SOLID STATE TECHNOLOGY ASSOCIATION



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TERMS, DEFINITIONS, AND LETTER SYMBOLS FOR DISCRETE SEMICONDUCTOR AND OPTOELECTRONIC DEVICES

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Foreword

The purpose of this standard is to promote the uniform use of symbols, abbreviations, terms, and definitions throughout the semiconductor industry.

Originally developed to assist the writers and users of specifications and to facilitate the use of JEDEC registration formats, the material has received widespread industry acceptance.

Where applicable, reference is made to standardization documents of the following organizations:

American National Standards Institute, Inc. (ANSI)
Electronic Industries Association (EIA)
Institute of Electrical and Electronics Engineers (IEEE)
International Electrotechnical Commission (IEC)
National Institute of Standards and Technology (NIST)

and to Military Specification MIL-S-19500.

The material contained in this standard was formulated under the cognizance of JEDEC Committee JC-10 on Terms and Definitions and approved by the JEDEC Board of Directors.

JEDEC Standard No. 77D incorporates all previously issued supplements and new material. In order that a correct and up-to-date document be maintained, it is the responsibility of the user to collate subsequent supplements. To assist the user, the table of contents of each succeeding supplement will cover all sections. It should be used as the basic reference when looking up each term, definition, or symbol.

The text of this standard is based on JESD77C, which it replaces, and JEDEC Board of Directors ballot JCB-11-56.

SECTION 1 LETTER SYMBOLS AND ABBREVIATIONS

1.1 Definitions of letter symbols and abbreviations

abbreviation: A shortened form of a word or expression.

letter symbol (for a quantity or a unit): One or more letters written successively and without spacing, in a specified style and often provided with additional marks, by convention representing a quantity or a unit. (Ref. ANSI Y10.1 and IEC 27-1.)

NOTE In a few special cases, nonalphanumeric signs are considered as letters in this connection, e.g., the sign ° (degree), which is used as a letter symbol for a unit of angle and in the letter symbol °C for a unit of temperature.

quantity symbol: A letter symbol that is used to represent a physical quantity or a relationship between quantities.

unit symbol: A letter symbol that is used in place of the name of a unit.

1.2 Criteria and conventions for letter symbols and abbreviations

1.2.1 Primary (quantity) symbols

The letter symbol used to designate a quantity or parameter shall be a single letter. This single letter, referred to as the primary symbol, may be modified by subscripts or superscripts. See “secondary (quantity) symbols”.

Table 1-1 illustrates primary symbols and unit symbols. Tables 1-3 and 1-4 illustrate principles of application when combined with secondary symbols.

NOTE The terms “primary” and “secondary” are used as synonyms for “kernel” and “additional marks”, respectively, as defined in ANSI Y10.1 and IEC 21-1 and used in the definition of “letter symbol” in 1.1; they are not to be confused with the terms “chief” and “reserve”.

1.1 Definitions of letter symbols and abbreviations (cont'd)**1.2.1 Primary (quantity) symbols (cont'd)****Table 1-1 — Primary symbols**

Primary symbol	Term	Unit of measurement	Unit symbol¹⁾
<i>b</i>	susceptance	siemens† or mho	S or mho
<i>C</i>	capacitance	farad†	F
<i>E</i>	energy	joule†	J
<i>f</i>	frequency	hertz†	Hz
<i>G</i>	gain (power)	decibel† ²⁾	dB ²⁾
<i>g</i>	conductance	siemens† or mho	S or mho
<i>h</i>	maxtrix parameter	—	—
<i>I, i</i>	current	ampere†	A
<i>L</i>	inductance	henry†	H
<i>P, p</i>	power	watt†	W
<i>Q, q</i>	electric charge	coulomb†	C
<i>R, r</i>	resistance	ohm†	Ω
<i>T</i>	temperature	kelvin† or degree Celsius†	K or °C
<i>t</i>	time	second†	s
<i>V, v</i>	voltage	volt†	V
<i>Y, y</i>	admittance	siemens† or mho	S or mho
<i>Z, z</i>	impedance	ohm†	Ω

† International System (SI) unit

1) The unit symbols are often used with the SI (metric) system multiplier prefixes, for example, μA for microampere.

2) Alternatively, power gain may be expressed as a dimensionless ratio.

1.2 Criteria and conventions for letter symbols and abbreviations (cont'd)

1.2.2 Secondary (quantity) symbols

A subscript or superscript, referred to as a secondary symbol, may be used to modify the primary symbol. The secondary symbol is used to designate special values of state, points, parts, times, etc. An abbreviation may be used as a subscript (secondary symbol).

Symbol subscripts shall be written on one line only. If there is more than one secondary symbol modifying the primary symbol, all such symbols shall be placed on the same (subscripted) line.

Terminal and value abbreviations shall be as shown in table 1-2.

For currents and voltages, the first subscript designates the terminal at which the current is measured, or the terminal where the potential is measured with respect to the reference terminal, which is sometimes designated by the second subscript. Conventional current into the terminal is positive.

NOTE — The term “primary” and “secondary” are used as synonyms for “kernel” and “additional marks”, respectively, as defined in ANSI Y10.1 and IEC 21-1 and used in the definition of “letter symbol” in 1.1; they are not to be confused with the terms “chief” and “reserve”.

1.2.3 Primary and secondary symbols combined

A letter symbol containing both primary and secondary letters has a unique meaning. This meaning cannot necessarily be inferred from the meanings of the individual primary and secondary symbols forming the combination.

Tables 1-3 and 1-4 show the significance of uppercase and lowercase letters. Figure 1-1 illustrates the meaning of the various combinations using, as an example, output voltage with a dc and an ac component.

1.2.4 Descriptive information

Descriptive information concerning a letter symbol may be added in parentheses after the secondary symbol. It is recommended that subscripts attached to subscripts and all secondary symbols with parenthetical expressions be in line. The abbreviations “max” and “min” are excluded from this rule. When these designate limit values, they are not considered to be part of the symbol itself.

EXAMPLES — $I_{F(AV)}$, $h_{ie(imag)}$, $I_{EC(ofs)}$, I_{CBO} max

Refer to 1.2.12.(4) for uppercase or lowercase letters.

1.2 Criteria and conventions for letter symbols and abbreviations (cont'd)

1.2.4 Descriptive information (cont'd)

Table 1-2 — Secondary symbols

Secondary symbol	Description
A, a	anode terminal
A	ambient (temperature), free-air temperature
(AV)	average
B, b	base terminal
(BO)	breakover
(BR)	breakdown
C, c	collector terminal
C	case
D, d	drain terminal, off-state (nontrigger)
d	delay (time)
E, e	emitter terminal
F, f	forward direction, forward transfer
f	fall (time)
fr	forward recovery (time)
G, g	gate terminal
H, h	holding
I, i	input
J, j	general terminal
J	junction (temperature)
K, k	cathode terminal
M, m	maximum value (waveform peak)
(ofs)	offset
O, o	output, open circuit
(OV)	overload
P	peak point
p	pulse (time)
(PP)	peak-to-peak
Q, q	turn-off, recovery (time)
R, r	reverse direction, reverse transfer, repetitive (as 2nd or 3rd subscript), resistive termination
r	rise (time)
(REC)	recovery
(RMS)	root-mean-square
rr	reverse recovery (time)
S, s	source terminal, stored (charge), short circuit, nonrepetitive (as 2nd or 3rd subscript)
T, t	on-state, trigger
U, u	bulk (substrate)
V	voltage termination, valley point
W	working
w	duration (width) of pulse
X	specified circuit termination

1.2 Criteria and conventions for letter symbols and abbreviations (cont'd)

1.2.4 Descriptive information (cont'd)

Table 1-3 — Symbol capitalization for current, voltage, and power

		Primary symbol	
		Lowercase (<i>i</i> , <i>v</i> , <i>p</i>)	Uppercase (<i>I</i> , <i>V</i> , <i>P</i>)
Secondary symbols (terminal subscripts)	Lowercase	Instantaneous value of alternating component	With no additional subscript: root-mean-square value of alternating component
			With additional subscript <i>m</i> : peak value of alternating component
	Uppercase	Instantaneous total value	With no additional subscript: direct current value
			With additional subscript <i>M</i> : peak total value
			With additional subscript (AV): average value
			With additional subscript (RMS): total value
			With additional subscript (PP): peak-to-peak value

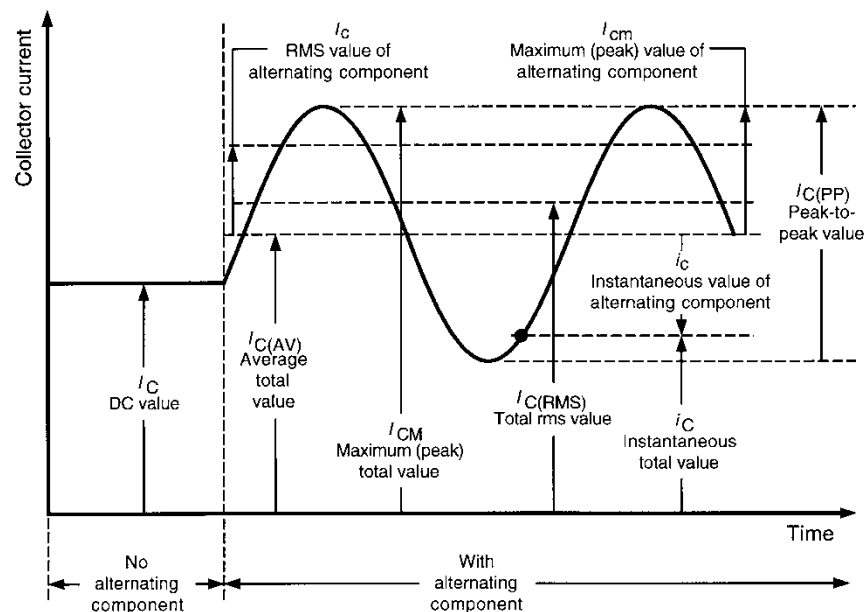


Figure 1-1 — Proper use of symbols

1.2 Criteria and conventions for letter symbols and abbreviations (cont'd)

1.2.4 Descriptive information (cont'd)

Table 1-4 — Symbol capitalization for capacitance and four-pole matrix parameters

		Primary symbol	
		Lowercase (<i>g, h, r, s, z, etc.</i>)	Uppercase (<i>A, C, G, R, Z, etc.</i>)
Secondary symbols (subscripts)	Lowercase	Small-signal values of resistance and impedance inherent within the device (e.g., r_i , z_o), and <i>s</i> parameters (e.g., s_i , s_o)	Small-signal values of amplification, capacitance, and gain (e.g., A_{vd} , C_o , G_{pe})
	Uppercase	Large-signal and static values of conductance, resistance, and impedance inherent within the device (e.g., g_{fs} , r_i , z_o), and <i>s</i> parameters (e.g., s_i , s_o)	Large-signal and static values of amplification, capacitance, and gain (e.g., A_{VD} , C_O , G_{PE}), and resistance and impedance in external circuits (e.g., R_i , Z_O)
NOTE The first subscript, or subscript pair in matrix notation, identifies the element of the four-pole matrix: — <i>i</i> or 11 = input, — <i>o</i> or 22 = output, — <i>f</i> or 21 = forward transfer, and — <i>r</i> or 12 = reverse transfer. The second subscript, or the subscript following the numeric pair, identifies the circuit configuration. For example, — <i>e</i> = common emitter, — <i>b</i> = common base, — <i>c</i> = common collector, and — <i>j</i> = common terminal, general.			

1.2 Criteria and conventions for letter symbols and abbreviations (cont'd)

1.2.5 Subscript sequence

The first subscript designates the terminal at which the current is measured, or the terminal where the potential is measured with respect to the reference terminal designated by the second subscript. (Conventional current flow into the terminal from the external circuit is positive.)

1.2.6 Supply voltage

The supply voltage to a terminal shall be indicated by repeating the terminal subscript, such as V_{BB} , V_{CC} , V_{EE} .

1.2.7 Multiple-unit devices

In multiple-unit devices, terminals that are not common to all the units shall be identified by adding the unit number preceding and in line with each terminal letter designation in accordance with terminal numbering in EIA-321. Example of use in a quantity letter symbol: V_{1B2B} .

1.2.8 Multiple electrodes of the same type

Multiple terminals connected to electrodes of the same type shall be identified by adding a number following and in line with each terminal designation in accordance with terminal numbering in EIA-321. Example of use in a quantity letter symbol: V_{B1B2} .

1.2.9 Multiple-unit devices with multiple electrodes of the same type

Combinations of 1.2.7 and 1.2.8 may be applied. Example of use in a quantity letter symbol: $V_{1G2, 2G2}$.

1.2.10 Multiple subscripts

For the sake of clarity, the different parts of a multiple subscript may be separated by small spaces. Hyphens and commas should be avoided between parts of a subscript unless necessary to avoid ambiguity. For the same purpose, part of a subscript may be put within parentheses. No general rule for the order between parts of a subscript can be given, but for guidance, a part indicating the kind of quantity should be placed first and a part indicating special circumstances last. Examples of use in quantity letter symbols: $R_{\theta JC}$, $V_{CE(sat)}$, $V_{1E1, 1E2}$, α_{vs} .

1.2 Criteria and conventions for letter symbols and abbreviations (cont'd)

1.2.11 Unit symbols

The letter symbol used in place of a unit name shall be taken from a recognized standard such as ANSI/IEEE Std 260.1, ANSI/IEEE Std 268, NIST Special Publication 330, or IEC 27 and shall be used in accordance with the rules given therein. Some of the most important rules are:

- 1) Do not use an attachment to a unit symbol (e.g., a subscript or postscript) as a means of giving information about the special nature of the quantity under consideration. Such information should be conveyed instead by the quantity symbol.
- 2) Unit symbols are to be in lowercase letters (e.g., cd) unless the unit name has been derived from a proper name, in which case the first letter of the symbol is capitalized (e.g., W, Hz). International (SI) prefix symbols representing multipliers of 10^6 or greater are uppercase, those representing 1000 or less are lowercase. Symbols retain their prescribed case regardless of surrounding typography.
- 3) Always leave a space between numerical values and unit symbols (e.g., 10 V, 5 mA, 50 k Ω , 25 °C) except when used as an adjective modifier to a noun, in which case a hyphen should be inserted between the number and the symbol (e.g., a 12-V battery). However, no space is used between a number and the symbols for degree, minute, and second of plane angle (e.g., 12°45'10").
- 4) Do not use compound prefixes formed by juxtaposition of two or more SI prefixes. For example, use 1 pF, not 1 $\mu\mu$ F. If outside the range covered by SI prefixes, which extend from yocto (10^{-24}) to yotta (10^{24}), use powers of ten applied to the base unit.
- 5) Division may be indicated using a slash (e.g., V/ Ω), and this procedure may be extended to cases where the numerator and/or denominator are themselves products or quotients; but in such a combination, a slash should not be followed by a multiplication sign or a division sign on the same line unless parentheses are inserted to avoid ambiguity. For example, write W/(sr·m²) or W·sr⁻¹·m⁻² or (W/sr)/m², but not W/sr/m² or W/sr·m².
- 6) Multiplication may be indicated using either a raised dot or a space between pairs of symbols (e.g., N·m, N m). In systems with limited character sets, a period may be used in place of the raised dot. The space may be omitted provided that special care is taken when the symbol for one of the units is the same as the symbol for a prefix; e.g., mN means millinewton and therefore must not be used for meter newton.

1.2 Criteria and conventions for letter symbols and abbreviations (cont'd)

1.2.12 Abbreviations

- 1) Short words are not usually abbreviated unless their abbreviation has been established by long practice.
- 2) An abbreviation is usually written with no spaces between the letters of the abbreviation. The use of hyphens and slashes is avoided where practicable.
- 3) Periods are used after technical abbreviations only when necessary to avoid misinterpretation of the abbreviation or at the end of a sentence.
- 4) Uppercase or lowercase letters may be used as appropriate except where the use of a particular case has been established by long practice. When used as secondary symbols, the parts of a multiletter abbreviation shall not be a mixture of uppercase and lowercase letters.
- 5) Subscripts and superscripts are not used in abbreviations.
- 6) Abbreviations shall be used only when their meanings are unquestionably clear. When in doubt, spell it out.
- 7) Abbreviations for word combinations shall be used as such and shall not be separated for use singly.
- 8) The same abbreviation shall be used for all tenses and the singular and plural forms of a given word.

1.2.13 Typefaces

In textbooks and technical publications, in both text and equations, the use of italic type is recommended for quantity symbols, whether uppercase or lowercase, Greek or Latin. Numerals, abbreviations, operators (e.g., +, −, /, exp, (), Δ), and unit symbols shall be in roman (upright) type. Characters used as subscripts should be in the same type style as they would be if they were not subscripts; i.e., use roman type unless the subscript represents a quantity symbol. In subscripts, quantity symbols often refer not to a specific quantity but to the concept in the abstract. Examples include G_{PE} , α_C , $\alpha_{V(BR)}$.

For data sheets, specifications, and technical reports prepared on a typewriter, the use of conventional typewriter typefaces is acceptable for symbols that are ordinarily italicized.

SECTION 2 GENERAL

2.1 General terms and definitions

absolute maximum rating: Synonym for “maximum rating”.

anode: The p-type region from which the forward current flows within a semiconductor diode.

NOTE In Schottky diodes, usually the barrier metal replaces the p-type semiconductor region and the remaining semiconductor region is n-type; however, some Schottky diodes have been made with the barrier metal replacing the n-type semiconductor region, in which case the remaining semiconductor region is p-type.

anode current: Synonym for “forward current”.

anode terminal (A, a): The terminal connected to the p-type region of the p-n junction or, when two or more p-n junctions are connected in series and have the same polarity, to the extreme p-type region.

NOTE 1 See note to "anode".

NOTE 2 This definition does not apply to current-regulator diodes.

NOTE 3 For voltage-reference diodes, any temperature-compensating diodes that may be included shall be ignored in the determination of the anode terminal.

NOTE 4 For unidirectional blocking or low-capacitance ABDs, any rectifier diode(s) that may be included shall be ignored in the determination of the anode terminal.



average current: The value of a periodic current averaged over a full cycle unless otherwise specified.

average voltage: The value of a periodic voltage averaged over a full cycle unless otherwise specified.

bipolar technology: A technology for producing devices in which electrical conduction depends on the flow of both majority and minority carriers.

blocking: A term describing the state of a semiconductor device or junction that imposes high resistance to the passage of current. (Ref. JESD282B.)

body (of a semiconductor device): The semiconductor portion of a device limited by the physical extent of the semiconductor material and including any associated oxide layers and metallization.

breakdown: The phenomenon, occurring in a reverse-biased semiconductor junction, whose initiation is observed as a transition from a region of high small-signal resistance to a region of substantially lower small-signal resistance for an increasing magnitude of reverse current. (Ref. JESD282B.)

breakdown current: A current in the breakdown region.

2.1 General terms and definitions (cont'd)

breakdown region: The portion of the voltage-current characteristic beyond the initiation of breakdown for an increasing magnitude of reverse current. (Ref. JESD282B.)

breakdown voltage: A voltage in a breakdown region.

built-in electric field (in a transition region): The internal electric field in the absence of bias.

bulk characteristics (of a semiconductor material): The characteristics of a piece of semiconductor material that has uniform properties throughout the whole piece, as measured in those parts of the piece in which the measured value of a characteristic is not modified by the proximity of the boundaries of the piece.

NOTE Bulk characteristics for pieces smaller than required by the definition are those that would be measured for a sufficiently large piece having the same technological properties.

carrier, (charge) (in a semiconductor): A mobile (i.e., free) conduction electron or mobile hole. (Ref. IEC 747-1.)

cathode: The n-type region to which the forward current flows within a semiconductor diode.

NOTE See note to "anode".

cathode current: Synonym for "reverse current".

cathode terminal (K, k): The terminal connected to the n-type region of the p-n junction or, when two or more p-n junctions are connected in series and have the same polarity, to the extreme n-type region.

NOTE 1 See note to "anode".

NOTE 2 This definition does not apply to current-regulator diodes.

NOTE 3 For voltage-reference diodes, any temperature-compensating diodes that may be included shall be ignored in the determination of the cathode terminal.

NOTE 4 For unidirectional blocking or low-capacitance ABDs, any rectifier diode(s) that may be included shall be ignored in the determination of the cathode terminal.

characteristic: An inherent and measurable property of a device.

NOTE Such a property may be electrical, mechanical, thermal, hydraulic, electromagnetic, or nuclear and can be expressed as a value for stated or recognized conditions. A characteristic may also be a set of related values, usually shown in graphical form. (Ref. IEC 134.)

chip: A separated part of a wafer (or, in some cases, a whole wafer) intended to perform a function or functions in a device.

2.1 General terms and definitions (cont'd)

component (general): A constituent part.

NOTE 1 Examples include source and drain regions as components of transistors, lead frames and dice/dies as components of packaged integrated circuits, resistors and integrated circuits as components of printed circuit boards, motherboards as components of computers, LCD screens as components of monitors, ac and dc components of complex waveforms, and loops and algorithms as components of software programs.

NOTE 2 Unless the context identifies the thing of which a component is a part, a descriptive prepositional phrase identifying the thing should follow the word “component”.

collecting junction: A semiconductor junction in an operating condition in which the net flow of charge carriers of each type across the junction is in the direction from the region where they are minority carriers to the region where they are majority carriers, i.e., in the direction of the force resulting from the internal electric field.

collection region (within a semiconductor device): A functional region that receives the principal current leaving the control region.

control-charge region (within a semiconductor device): A functional region that contains the controlling charge and that may or may not be the path for the principal current.

control region (within a semiconductor device): A functional region through which the principal-current charge carriers flow and are controlled in the manner for which the device is intended.

device: A piece of equipment, a mechanism, or another entity designed to serve a special purpose or perform a special function.

NOTE 1 In JEDEC documents, the word “device” is often used as an abbreviated reference to the type or types of solid-state devices that are within the scope of those documents. Context could indicate otherwise; e.g., in the phrase “the device used to hold the device under test”, the first usage of the word “device” refers to a mechanism; the second to a solid-state device.

NOTE 2 Contrast with “component (general)”.

dice; dies: Plural of “die”.

die: Synonym for “chip”.

diffusion (of charge carriers): The movement of charge carriers caused only by a charge carrier concentration gradient.

NOTE In the case of transfer across a p-n junction, the amount of transfer depends on the internal electric field resulting from the built-in electric field and applied bias.

2.1 General terms and definitions (cont'd)

discrete semiconductor device: A semiconductor device that is specified to perform an elementary electronic function and is not divisible into separate components functional in themselves.

NOTE 1 Diodes, transistors, rectifiers, thyristors, and multiple versions of these devices are examples. Other semiconductor structures having the physical complexity of integrated circuits but performing elementary electronic functions (e.g., complex Darlington transistors) are usually considered to be discrete semiconductor devices.

NOTE 2 If a semiconductor device is not considered to be an integrated circuit in both complexity and functionality, it is considered to be a discrete device.

electrical connection (within a semiconductor device): An electrically conducting element that is intended to function as a pathway between other elements, including terminals, and whose primary purpose is to conduct electric current in a confined manner.

NOTE The connection may consist of a separate conductive entity such as a wire or metallic film or be an integral part of the body.

electrode (of a semiconductor device): An element that performs one or more functions of emitting or collecting electrons or holes, or of controlling their movements by an electric field.

electrostatic-discharge-sensitive device: A discrete device or integrated circuit that may be permanently damaged by electrostatic potentials encountered in routine handling, testing, and shipping.

NOTE In documents of the IEC and CENELEC, the abbreviation ESDS stands for “electrostatic-discharge-sensitive device”; in the USA, ESDS stands merely for “electrostatic discharge sensitive” or “electrostatic discharge sensitivity”, and “ESDS device” is not further abbreviated. The abbreviation ESD stands for “electrostatic discharge”.

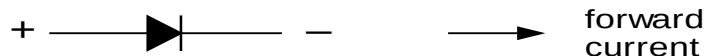
element (of a discrete device): Any constituent part of the discrete device that contributes directly to its operation and performs a definable function.

NOTE The definition includes electrical interconnections between elements or between elements and terminals.

emitting junction: A semiconductor junction in an operating condition in which the net flow of charge carriers of each type across the junction is in the direction from the region where they are majority carriers to the region where they are minority carriers, i.e., in the direction opposite to the force resulting from the internal electric field.

extrinsic semiconductor: A semiconductor with charge-carrier concentration dependent upon impurities or other imperfections. (Ref. IEC 747-1.)

forward bias: The bias that tends to produce forward current.



2.1 General terms and definitions (cont'd)

forward current (in a p-n junction): The current flowing from the p-type region to the n-type region.

forward current (in a semiconductor diode): The current flowing from the external circuit into the anode terminal.

forward direction: The direction of a (positive) forward current.

forward voltage (across a p-n junction): The voltage between the p-type region and the n-type region when the p-type region is at a positive voltage relative to the n-type region.

forward voltage (across a semiconductor diode): A positive anode-cathode voltage.

functional region (within a semiconductor material): An identifiable volume whose boundaries depend on operating conditions.

EXAMPLES space-charge region, channel region.

heterojunction: A region of transition between two different semiconductor materials, usually with a negligible discontinuity in the crystalline structure.

NOTE A heterojunction can be between materials of the same conductivity type (isotype heterojunction) or of the opposite conductivity type (anisotype heterojunction).

inherent electric field (in a transition region): Synonym for “built-in electric field”.

internal electric field (in a transition region): The electric field due to the presence of space charges in the transition region.

NOTE This field is dependent on the impurity profile of the transition region and on the bias applied between the two adjacent neutral regions.

i-type (intrinsic) semiconductor: A nearly pure and ideal semiconductor in which the electron and hole densities are nearly equal under conditions of thermal equilibrium. (Ref. IEC 747-1.)

junction diode: A semiconductor diode consisting of two physical regions of opposite conductivity type separated by a p-n transition region.

junction (in a semiconductor device) (general term): A transition region between semiconductor regions of different electrical properties, or a physical region between a semiconductor region and a region of a different type; it is characterized by a potential barrier that impedes the movement of charge carriers from the region of higher concentration to the region with lower concentration.

majority carrier: The type of carrier constituting more than half of the total charge-carrier concentration.

2.1 General terms and definitions (cont'd)

maximum rating: A rating that establishes either a limiting capability or a limiting condition beyond which damage to the device may occur. (Ref. IEC 747-1.)

NOTE 1 A limiting condition may be either a maximum or a minimum.

NOTE 2 IEC 747-1 refers to such a limiting condition as a “rating (limiting value)”.

minority carrier: The type of carrier constituting less than half of the total charge-carrier concentration.

no (internal) connection (NC): A terminal that has no internal connection and that can be used as a support for external wiring without disturbing the function of the device if the voltage applied to this terminal (by means of the wiring) does not exceed the highest supply voltage rating of the circuit.

NOTE 1 If higher voltages are acceptable, this should be stated.

NOTE 2 The IEC equivalent term is “blank terminal”; nevertheless, the IEC abbreviation is “NC”.

nonusable terminal (NU): A terminal that shall not be used in normal applications and that may or may not have an internal connection.

n-type semiconductor: An extrinsic semiconductor in which the conduction-electron density exceeds the mobile-hole density. (Ref. IEC 747-1.)

open circuit: A circuit having a terminating impedance sufficiently high that halving its magnitude does not produce a change in the parameter being measured that is greater than the required accuracy of the measurement.

physical region (within a semiconductor material): An identifiable volume material whose technological boundaries are fixed by the manufacturing process and independent of operating conditions.

EXAMPLES Transition region, buried layer, substrate.

p-n boundary: An interface in the transition region between p-type and n-type materials at which the donor and acceptor concentrations are equal.

p-n junction; p-n transition region: A junction between p-type and n-type semiconductor regions.

principal-current charge carriers (within the body of a device): The charge carriers that compose the principal current.

NOTE The definition excludes charge carriers that are present for control purpose only.

principal current (in a semiconductor device): The current that is controlled by the semiconductor device.

2.1 General terms and definitions (cont'd)

p-type semiconductor: An extrinsic semiconductor in which the mobile-hole density exceeds the conduction-electron density. (Ref. IEC 747-1.)

rating: The nominal value of any electrical, thermal, mechanical, or environmental quantity assigned to define the operating conditions under which a component, machine, apparatus, electronic device, etc., is expected to give satisfactory service. (Ref. IEC 747-1.)

NOTE “Rating” is a generic term, but also see “maximum rating”.

rectifying junction: A junction in a semiconductor device that exhibits asymmetrical conductance.

reverse bias: The bias that tends to produce reverse current.



reverse current (in a p-n junction): The current flowing from the n-type region to the p-type region.

reverse current (in a semiconductor diode): The current flowing from the external circuit into the cathode terminal.

reverse direction: The direction of a (positive) reverse current.

reverse voltage (across a p-n junction): The voltage between the n-type region and the p-type region when the n-type region is at a positive voltage relative to the p-type region.

reverse voltage (across a semiconductor diode): A positive cathode-anode voltage.

semiconductor (nonspecific): A substance whose conductivity due to the charge carriers of both signs is normally in the range between that of metals and that of insulators and in which the charge carrier density can be changed by external means.

semiconductor device (general term): A device whose essential characteristics are due, in whole or in part, to the flow of charge carriers within a semiconductor material.

NOTE For specification purposes, a semiconductor device must be considered to be either a discrete semiconductor device or an integrated circuit.

semiconductor diode: A semiconductor device having two electrodes and exhibiting a nonlinear voltage-current characteristic; in more restricted usage, a semiconductor device that has the asymmetrical voltage-current characteristic exemplified by a single p-n junction. (Ref. IEEE Std 100.)

semiconductor (material) (within a semiconductor device): A material in which the electric current is made up of both negative and positive mobile charge carriers (i.e., conduction electrons and holes, respectively).

2.1 General terms and definitions (cont'd)

short circuit: A circuit having a terminating impedance sufficiently low that doubling its magnitude does not produce a change in the parameter being measured that is greater than the required accuracy of the measurement.

small signal: A signal that when doubled in magnitude does not produce a change in the parameter being measured that is greater than the required accuracy of the measurement.

solid-state (within the scope of JEDEC): Relating to, or utilizing, those electrical, magnetic, optical, thermal, and/or chemical properties of semiconductors that are based on the arrangement or behavior of atoms, ions, molecules, nucleons, electrons, holes, and/or imperfections.

solid-state component: A solid-state device that is, or is intended to be, a constituent part of a higher order assembly.

solid-state device: An electronic device whose operation depends on the properties of the integral solid semiconductor materials.

solid-state industry: Those companies and organizations whose primary function is associated with design, fabrication, assembly, test, inspection, and/or distribution of solid-state devices.

solid-state physics: The study of the physical properties of solids, with special emphasis on the electrical, magnetic, optical, thermal, and chemical properties of semiconducting materials in relation to their electronic structure.

solid-state technology: The applied sciences and skills of developing and manufacturing solid-state devices.

space-charge region (of a semiconductor device): A functional region in which the net charge density is significantly different from zero.

NOTE 1 The net charge is caused by electrons, holes, and ionized acceptors and donors.

NOTE 2 The space-charge regions of a semiconductor device include accumulation (enhancement), depletion, and inversion layers.

space-charge region (of a p-n junction): A space-charge region contained between two neutral regions of types p and n.

static value: (1) A nonvarying value or quantity of measurement at a specified fixed point.

(2) The slope of the line from the origin to the operating point on the appropriate characteristic curve.

2.1 General terms and definitions (cont'd)

substrate (of a semiconductor device): (1) The part of the original material that remains essentially unchanged when the device elements are formed upon or within the original material.

NOTE The original material may be a layer of semiconductor material cut from a single crystal, a layer of semiconductor material deposited on a supporting base, or the supporting base itself.

(2) The original semiconductor material being processed.

NOTE The intended meaning will usually be clear from the context in which the term is used. If necessary, distinction can be made between the “original substrate” and the “remaining substrate”.

supply region (within a semiconductor device): A functional region that delivers principal-current charge carriers to the control region of the device.

surge protective device (SPD): Synonym for “transient voltage suppressor”.

temperature coefficient: The change in a parameter divided by the change in temperature that caused it.

NOTE This quotient is the average value over the total temperature change. The specific term should be “temperature coefficient of (parameter)”. The change in the parameter may or may not be normalized to the initial value of the parameter.

temperature derating: A specification showing how a rating stated at a particular temperature is reduced at higher temperatures.

NOTE 1 Derating is usually expressed graphically or in terms of derating factors (e.g., mA/°C or mW/°C).

NOTE 2 Average power ratings are derated to zero at the maximum-rated junction temperature. Peak pulse power ratings may exceed zero at the maximum-rated junction temperature.

terminal (of a semiconductor device): An externally available point of connection.

NOTE The use of the term “termination” as a synonym is deprecated because that term denotes the external elements connected to the terminal.

thermal impedance, (transient): The change in temperature difference between two specified points or regions that occurs during a time interval divided by the step-function change in power dissipation that occurred at the beginning of the interval and caused the change in temperature difference. (Ref. JESD282B.)

thermal resistance, (steady-state): The temperature difference between two specified points or regions divided by the power dissipation under conditions of thermal equilibrium.

transient voltage suppressor (TVS): A semiconductor device that is intended to limit voltage transients by conducting surge currents.

2.1 General terms and definitions (cont'd)

transistor (general): A semiconductor device, capable of providing power amplification, whose basic functional structure includes the series connection of a supply region, a control region, and a collection region, and whose output is a simple, continuous function of the input.

transition region, (physical) (within a semiconductor material): The physical region between two homogeneous semiconductor regions that have different electrical properties.

unipolar technology: A technology for producing devices in which electrical conduction is due entirely to the flow of majority carriers.

2.2 General letter symbols, terms, and definitions

F or NF^* **spot noise figure† ; spot noise factor†:** The ratio of (1) the total output noise power per unit bandwidth (spectral density) at a single output frequency when the noise temperature of all input terminations is at the reference noise temperature, T_0 , at all frequencies that contribute to the output noise to (2) that part of (1) caused by the noise of the signal-input termination at the signal-input frequency.

$\overline{F}$ or $\overline{NF}^*$ **average noise figure†; average noise factor†:** The ratio of (1) the total output noise power within an output frequency band when the noise temperature of all input terminations is at the reference noise temperature, T_0 , at all frequencies that contribute to the output noise to (2) that part of (1) caused by the noise of the signal-input termination within the signal-input frequency band.

I_F **forward current, dc:** The dc current flowing from the external circuit into the anode terminal.

I_n **noise current, equivalent input (of a two-port device):** The current of an ideal current source (having an internal impedance equal to infinity) in parallel with the input terminals of the device that represents the part of the internally generated noise that can properly be represented by a current source.

NOTE In the definition, the equivalent input noise voltage, which would be needed for a complete and precise description of the device noise, is neglected. If the external source impedance is infinite, the noise current represents the total noise.

I_R **reverse current, dc:** The dc current flowing from the external circuit into the cathode terminal.

R_θ or R_{th}
(formerly θ) **thermal resistance:** Synonym for “thermal resistance, (steady-state)” in 2.1.

* NF and $\overline{NF}$ abbreviations are often used for symbols F and $\overline{F}$; however, symbols F and $\overline{F}$ are preferred.

† These quantities may be expressed logarithmically in decibels (dB).

2.2 General letter symbols, terms, and definitions (cont'd)

$R_{\theta CA}$ or R_{thCA}	case-to-ambient thermal resistance: The thermal resistance from the device case to the ambient.
$R_{\theta JA}$ or R_{thJA} (formerly θ_{JA})	junction-to-ambient thermal resistance: The thermal resistance from the semiconductor junction(s) to the ambient.
$R_{\theta JC}$ or R_{thJC} (formerly θ_{JC})	junction-to-case thermal resistance: The thermal resistance from the semiconductor junction(s) to a stated location on the case.
$R_{\theta JL}$ or R_{thJL}	junction-to-lead thermal resistance: The thermal resistance from the semiconductor junction(s) to a stated location on a lead.
$R_{\theta JM}$ or R_{thJM}	junction-to-mounting-surface thermal resistance: The thermal resistance from the semiconductor junction(s) to a stated location on the mounting surface.

All temperature symbols are shown together, followed by all time symbols.

T_A	ambient temperature; free-air temperature: The air temperature measured below a device, in an environment of substantially uniform temperature, cooled only by natural air convection and not materially affected by reflective and radiant surfaces.
T_C	case temperature: The temperature measured at a specified location on the case of a device.
T_J	junction temperature: The temperature of a semiconductor junction.

NOTE In data sheets it is common practice to use this term to mean virtual-junction temperature.

T_J or T_{VJ}	virtual-junction temperature: A temperature representing the temperature of the junction(s) calculated on the basis of a simplified model of the thermal and electrical behavior of the semiconductor device.
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NOTE The term “virtual-junction temperature” is taken from IEC standards. It is particularly applicable to multijunction semiconductors and is used in this standard to denote the temperature of the active semiconductor element when required in specifications and test methods. The term “virtual-junction temperature” is used interchangeably with the term “junction temperature” in this standard.

T_n	noise temperature: The uniform physical absolute temperature at which a network (and all its sources, if it is a multiport network) would have to be maintained, if it (and its sources) were passive, in order to make available (or deliver) the same random noise power per unit bandwidth (spectral density) at a given frequency as is actually available (or delivered) from the network.
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2.2 General letter symbols, terms, and definitions (cont'd)

T_{stg} **storage temperature:** The temperature at which the device, without any power applied, is stored.

T_0 **reference noise temperature:** A specified absolute temperature to be assumed as a noise temperature at the input ports of a network when calculating certain noise parameters and for normalizing purposes.

NOTE When the reference noise temperature is 290 K, it is considered to be the standard reference noise temperature.

**All time symbols are shown together; preceding lines and pages show temperature symbols.
For illustration of pulse times, see figure 2-1.**

t_d **delay time (general):** The time interval between a reference point on one waveform and a reference point on another waveform.

delay time (between input and output): The time interval between a transition at an input and a resultant change at an output. (See also t_d , t_{di} , and t_{dv} in 4.1.2.)

t_f **fall time (general):** The time interval between one reference point on a waveform and a second reference point of smaller magnitude on the same waveform. (See also t_f , t_{fi} , and t_{fv} in 4.1.2 and 4.3.2.)

NOTE The first and second reference points are usually 90% and 10%, respectively, of the steady-state amplitude of the waveform existing before the transition, measured with respect to the steady-state amplitude existing after the transition.

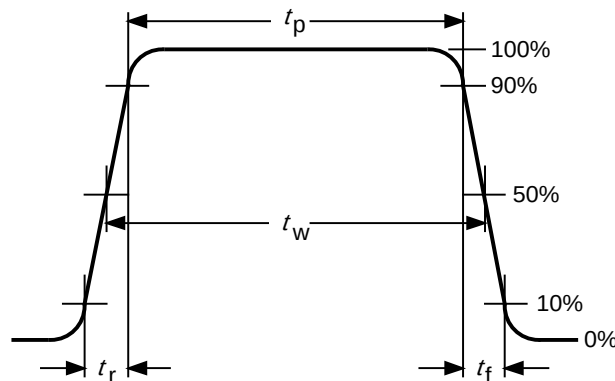


Figure 2-1 — Pulse time symbology

2.2 General letter symbols, terms, and definitions (cont'd)

t_p **pulse duration (formerly pulse time):** The time interval between a reference point on the leading edge of a pulse waveform and a reference point on the trailing edge of the same waveform.

NOTE The two reference points are usually 90% of the steady-state amplitude of the waveform existing after the leading edge, measured with respect to the steady-state amplitude existing before the leading edge. If the reference points are 50% points, the symbol t_w and the term “average pulse duration” should be used.

t_r **rise time (general):** The time interval between one reference point on a waveform and a second reference point of greater magnitude on the same waveform. (See also t_r , t_{ri} , and t_{rv} in 4.1.2 and 4.3.2.)

NOTE The first and second reference points are usually 10% and 90%, respectively, of the steady-state amplitude of the waveform existing after the transition, measured with respect to the steady-state amplitude existing before the transition.

t_w **average pulse duration (formerly pulse average time):** The time interval between a reference point on the leading edge of a pulse waveform and a reference point on the trailing edge of the same waveform, with both reference points being 50% of the steady-state amplitude of the waveform existing after the leading edge, measured with respect to the steady-state amplitude existing before the leading edge.

NOTE If the reference points are not 50% points, the symbol t_p and the term “pulse duration” should be used.

V_F **forward voltage, dc:** A positive dc anode-cathode voltage.

V_n **noise voltage, equivalent input (of a two-port device):** The voltage of an ideal voltage source (having an internal impedance equal to zero) in series with the input terminals of the device that represents the part of the internally generated noise that can properly be represented by a voltage source.

NOTE In the definition, the equivalent input noise current, which would be needed for a complete and precise description of the device noise, is neglected. If the external source impedance is zero, the noise voltage represents the total noise.

V_R **reverse voltage, dc:** A positive dc cathode-anode voltage.

Z_θ or Z_{th}
(formerly $\theta_{(t)}$) **(transient) thermal impedance:** See “thermal impedance, (transient)” in 2.1.

$Z_{\theta JA}$ or $Z_{th JA}$
(formerly $\theta_{J-A(t)}$) **junction-to-ambient (transient) thermal impedance:** The transient thermal impedance from the semiconductor junction(s) to the ambient.

2.2 General letter symbols, terms, and definitions (cont'd)

$Z_{\theta JC}$ or Z_{thJC}
(formerly
 $\theta_{J-C(t)}$) **junction-to-case (transient) thermal impedance:** The transient thermal impedance from semiconductor junction(s) to a stated location on the case.

$Z_{\theta JL}$ or Z_{thJL} **junction-to-lead (transient) thermal impedance:** The transient thermal impedance from the semiconductor junction(s) to a stated location on a lead.

$Z_{\theta JM}$ or Z_{thJM} **junction-to-mounting-surface (transient) thermal impedance** The transient thermal impedance from the semiconductor junction(s) to a stated location on the mounting surface.

SECTION 3 DIODES AND RECTIFIERS

For the definition of “semiconductor diode”, see 2.1.

3.1 Signal diodes and rectifier diodes

3.1.1 General terms and definitions

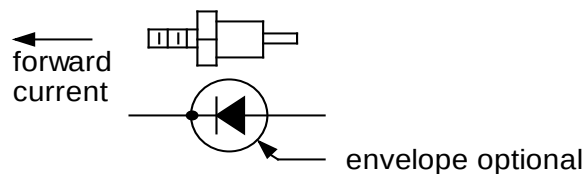
bridge rectifier circuit: A double-way rectifier circuit in which (1) each terminal of the alternating-voltage circuit is connected to the anode of one rectifier element in a set of elements whose cathodes are all connected to the positive output of the circuit, (2) each terminal of the alternating-voltage circuit is also connected to the cathode of one rectifier element in another set of elements whose anodes are all connected to the negative output, and (3) the load is connected between the positive and negative outputs.

NOTE The term is derived from the similarity in layout of a single-phase four-element bridge rectifier to that of a Wheatstone bridge.

double-way rectifier circuit: A circuit in which the current flows in both directions from each terminal of the alternating-voltage circuit to the rectifier circuit elements connected to each terminal.

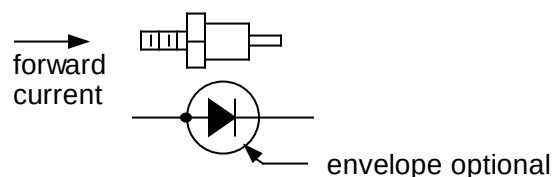
NOTE The terms “single-way” and “double-way” provide a means for describing the effect of the rectifier circuit on current in the transformer windings connected to the rectifier circuits. Most rectifier circuits may be classified into these two general types. Many double-way circuits are also referred to as bridge circuits.

forward-polarity rectifier diode with heat sink: A rectifier diode whose cathode is connected to the mounting stud or heat sink.



rectifier stack: An integral assembly of two or more rectifier diodes, including its associated housing, and any integral mounting and cooling attachments.

reverse-polarity rectifier diode with heat sink: A rectifier diode whose anode is connected to the mounting stud or heat sink.



3.1 Signal diodes and rectifier diodes (cont'd)

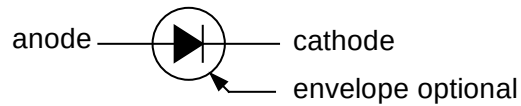
3.1.1 General terms and definitions (cont'd)

semiconductor rectifier diode: A semiconductor diode intended to be used for current and voltage rectification.

NOTE 1 The term “semiconductor rectifier diode” includes the associated housing and any integral mounting and cooling attachments.

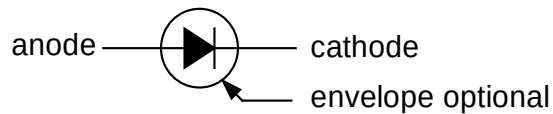
NOTE 2 The term “rectifier cell” is sometimes used as a synonym for “rectifier diode” when the diode is an element of a rectifier stack.

Graphic symbol (ref. IEEE Std 315):



semiconductor signal diode: A semiconductor diode intended to be used for signal processing.

Graphic symbol (ref. IEEE Std 315):



3.1.2 Letter symbols, terms, and definitions

For illustration of currents, see Figure 3-1.

$I_{F(RMS)}$, I_F , $I_{F(AV)}$, i_F , I_{FM}	forward current*: The current flowing from the external circuit into the anode terminal.
$I_{FM(OV)}$	overload forward current: A current whose continuous application would cause the maximum-rated virtual junction temperature to be exceeded, but that is limited in duration such that this temperature is not exceeded. NOTE Devices may be subjected to overload currents as frequently as called for by the application while being subjected to normal operating voltages. (Ref. IEC 747-2.)
I_{FRM}	repetitive peak forward current: The peak forward current including all repetitive transient currents but excluding all nonrepetitive transient currents. (Ref. JESD282B.)
I_{FSM}	surge peak forward current: The peak forward current including all nonrepetitive transient currents but excluding all repetitive transient currents. (Ref. JESD282B.)
I_O	average rectified output current, 50-Hz or 60-Hz sine-wave input, 180° conduction angle: The output current averaged over a full cycle from a rectifier with a 50-Hz or 60-Hz sine-wave input and a 180° conduction angle. (Ref. JESD282B.)
$I_{(OV)}$	Alternative symbol for $I_{FM(OV)}$.
$I_{R(RMS)}$, I_R , $I_{R(AV)}$, i_R , I_{RM}	reverse current*: The current flowing from the external circuit into the cathode terminal.
$i_{R(REC)}$, $I_{RM(REC)}$	reverse recovery current*: The transient reverse current associated with a change from forward current to a reverse condition. (Ref. JESD282B.)

* See Table 3-1 for detailed meaning of symbols.

3.1 Signal diodes and rectifier diodes (cont'd)

3.1.2 Letter symbols, terms, and definitions (cont'd)

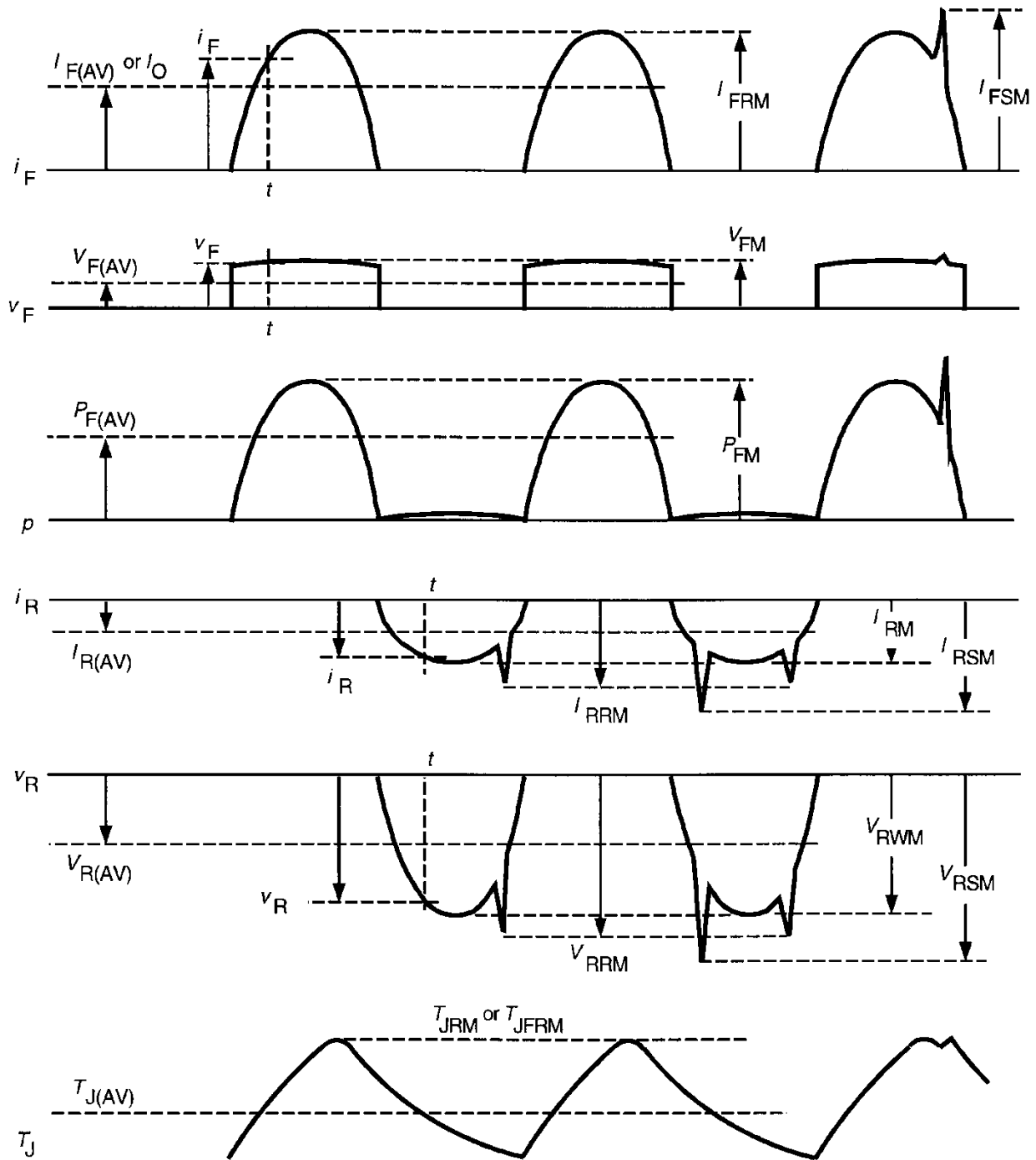


Figure 3-1 — Symbols for rectifier diode current, voltage, power dissipation, and the resulting junction temperature

3.1 Signal diodes and rectifier diodes (cont'd)

3.1.2 Letter symbols, terms, and definitions (cont'd)

Table 3-1 — Current

Quantity	Total rms value	RMS value of alternating component	DC value with no alternating component	Mean value averaged over full cycle	Instantaneous total value	Maximum (peak) total value
Forward current	$I_{F(RMS)}$	I_f	I_F	$I_{F(AV)}$	i_F	I_{FM}
Forward current, overload	—	—	—	—	—	$I_{FM(OV)}$, $I_{(OV)}$
Forward current, repetitive peak	—	—	—	—	—	I_{FRM}
Forward current, surge peak	—	—	—	—	—	I_{FSM}
Average rectified current, 50-Hz or 60-Hz sine-wave input, 180° conduction angle	—	—	—	I_O	—	—
Reverse current	$I_{R(RMS)}$	I_r	I_R	$I_{R(AV)}$	i_R	I_{RM}
Reverse recovery current	—	—	—	—	$i_{R(REC)}$	$I_{RM(REC)}$
Reverse current, repetitive peak	—	—	—	—	—	I_{RRM}
Reverse current surge peak	—	—	—	—	—	I_{RSM}

I_{RRM} **repetitive peak reverse current:** The peak reverse current including all repetitive transient currents but excluding all nonrepetitive transient currents. (Ref. JESD282B.)

I_{RSM} **surge peak reverse current:** The peak reverse current including all nonrepetitive transient currents but excluding all repetitive transient currents.

3.1 Signal diodes and rectifier diodes (cont'd)

3.1.2 Letter symbols, terms, and definitions (cont'd)

P_F , $P_{F(AV)}$,
 p_F , P_{FM} **forward power dissipation***: The power dissipation resulting from the respective forward current. (Ref. JESD282B.)

P_R , $P_{R(AV)}$,
 p_R , P_{RM} **reverse power dissipation***: The power dissipation resulting from the respective reverse current. (Ref. JESD282B.)

P_T , $P_{T(AV)}$,
 P_{TM} **total power dissipation***: The sum of the respective forward and reverse power dissipations. (Ref. JESD282B.)

Q_{rr} **recovered charge**: The total amount of charge recovered from a diode, including the capacitive component of charge, when the diode is switched from a specified conductive condition to 1) a specified nonconductive condition, or 2) an unspecified nonconductive condition with the measurement ending after a specified integration time, t_i , with other circuit conditions as specified. (Ref. JESD282B.)

Q_{rrf} **fall time charge**: That part of the recovered charge that is recovered from the diode during the reverse recovery fall time. (Ref. JESD282B.)

NOTE The time intervals t_{rrf} and t_{rr} are defined so that their sum is equal to the reverse recovery time t_{rr} , whereas the recovered charge Q_{rr} is defined for an integration time t_i . As a consequence, the sum of the partial charges Q_{rrf} and Q_{rr} will differ from Q_{rr} unless t_{rr} equals t_i .

Q_{rrr} **rise time charge**: That part of the recovered charge that is recovered from the diode during the reverse recovery rise time. (Ref. JESD282B.)

NOTE See note to Q_{rrf} .

Q_s **stored charge**: The total amount of charge recovered from a diode minus the capacitive component of charge when the diode is switched from a specified conductive condition to a specified nonconductive condition with other circuit conditions specified. (Ref. JESD282B.)

RRSF **reverse recovery softness factor**: The absolute value of the ratio of (1) di_{RR}/dt (the rate of rise of the reverse recovery current) when the current is passing through zero at the beginning of the reverse recovery time, to (2) di_{RF}/dt (the maximum value of the rate of fall of the reverse recovery current) after the current has passed through its peak value, I_{RM} . (Ref. JESD282B.)

NOTE The ratio of reverse recovery current fall time (t_b) to the reverse recovery current rise time (t_a) has been called "recovery softness factor" (RSF); however, RRSF is a more useful measure of the diode softness characteristic.

RSF **recovery softness factor**: See "RRSF" (reverse recovery softness factor).

* See Table 3-2 for detailed meaning of symbols.

3.1 Signal diodes and rectifier diodes (cont'd)

3.1.2 Letter symbols, terms, and definitions (cont'd)

Table 3-2 — Power and temperature

Quantity	Total rms value	RMS value of alternating component	DC value with no alternating component	Mean value averaged over full cycle	Instantaneous total value	Maximum (peak) total value
Forward power dissipation	—	—	P_F	$P_{F(AV)}$	P_F	P_{FM}
Reverse power dissipation	—	—	P_R	$P_{R(AV)}$	P_R	P_{RM}
Total power dissipation	—	—	P_T	$P_{T(AV)}$	—	P_{TM}
(Virtual) junction temperature	—	—	T_J	$T_{J(AV)}$	T_J	T_{JM}
(Virtual) junction temperature, repetitive peak ¹⁾	—	—	—	—	—	T_{JFRM}
(Virtual) junction temperature, surge peak ¹⁾	—	—	—	—	—	T_{JFSM}
(Virtual) junction temperature, repetitive peak	—	—	—	—	—	T_{JRM}
(Virtual) junction temperature, repetitive peak ²⁾	—	—	—	—	—	T_{JRRM} , T_{JRWMM}
1) With forward current flowing						
2) With reverse voltage applied						

All temperature symbols are shown together, followed by time symbols.

For illustration of temperatures, see Figure 3-1.

T_J , $T_{J(AV)}$,
 T_{JM} **(virtual) junction temperature*:** See “ T_J , junction temperature” and “ T_J , T_{VJ} , virtual junction temperature” in 2.2.

T_{JFRM} **repetitive peak (virtual) junction temperature (with forward current flowing):** The peak (virtual) junction temperature resulting from repetitive peak forward current.

T_{JFSM} **surge peak (virtual) junction temperature (with forward current flowing):** The peak (virtual) junction temperature resulting from surge peak forward current.

* See Table 3-2 for detailed meaning of symbols.

3.1 Signal diodes and rectifier diodes (cont'd)

3.1.2 Letter symbols, terms, and definitions (cont'd)

T_{JRM}	repetitive peak (virtual) junction temperature: The peak (virtual) junction temperature resulting from repetitive peak forward current alternating with repetitive peak reverse voltage.
T_{JRMM}	repetitive peak (virtual) junction temperature (with reverse voltage applied): The peak (virtual) junction temperature resulting from repetitive peak reverse voltage.
T_{JRWMM}	working peak (virtual) junction temperature (with reverse voltage applied): The peak (virtual) junction temperature resulting from working peak reverse voltage.

All time symbols are shown together; preceding pages show temperature symbols.

t_a	reverse recovery current rise time: The portion of the reverse recovery time interval prior to the instant when the reverse recovery current reaches its maximum (peak) value. (See Figure 3-2.) (Ref. JESD282B.)
t_b	reverse recovery current fall time: The portion of the reverse recovery time interval after the reverse recovery current has reached its maximum (peak) value. (See Figure 3-2.) (Ref. JESD282B.)
t_{fr}	forward recovery time: The time interval between the instant when the forward voltage rises through a specified first value, usually 10% of its final value, and the instant when it falls from its peak value, V_{FRM} , to a specified low second value, V_{FR} , upon the application of a step current following a zero-voltage or specified reverse-voltage condition.
t_{rr}	reverse recovery time: The time interval between the instant when the current passes through zero when changing from the forward direction to the reverse direction and, after reverse current reaches its peak value $I_{RM(REC)}$, the instant when

- 1) the reverse current first intersects the zero-current axis as shown in Figure 3-2a, or
- 2) the extrapolated reverse current reaches zero, as shown in Figure 3-2b, or
- 3) the reverse current reaches a specified low value $i_{R(REC)}$, as shown in Figure 3-2c.

NOTE 1 In 2), the extrapolation is carried out with respect to specified points "A" and "B", as shown in generalized form in Figure 3-2b. Point "A" may be specified at other than $I_{RM(REC)}$.

NOTE 2 JESD282B includes definitions 1), 2), and 3).

NOTE 3 IEC 747-2 includes definitions 2) and 3) only.

3.1 Signal diodes and rectifier diodes (cont'd)

3.1.2 Letter symbols, terms, and definitions (cont'd)

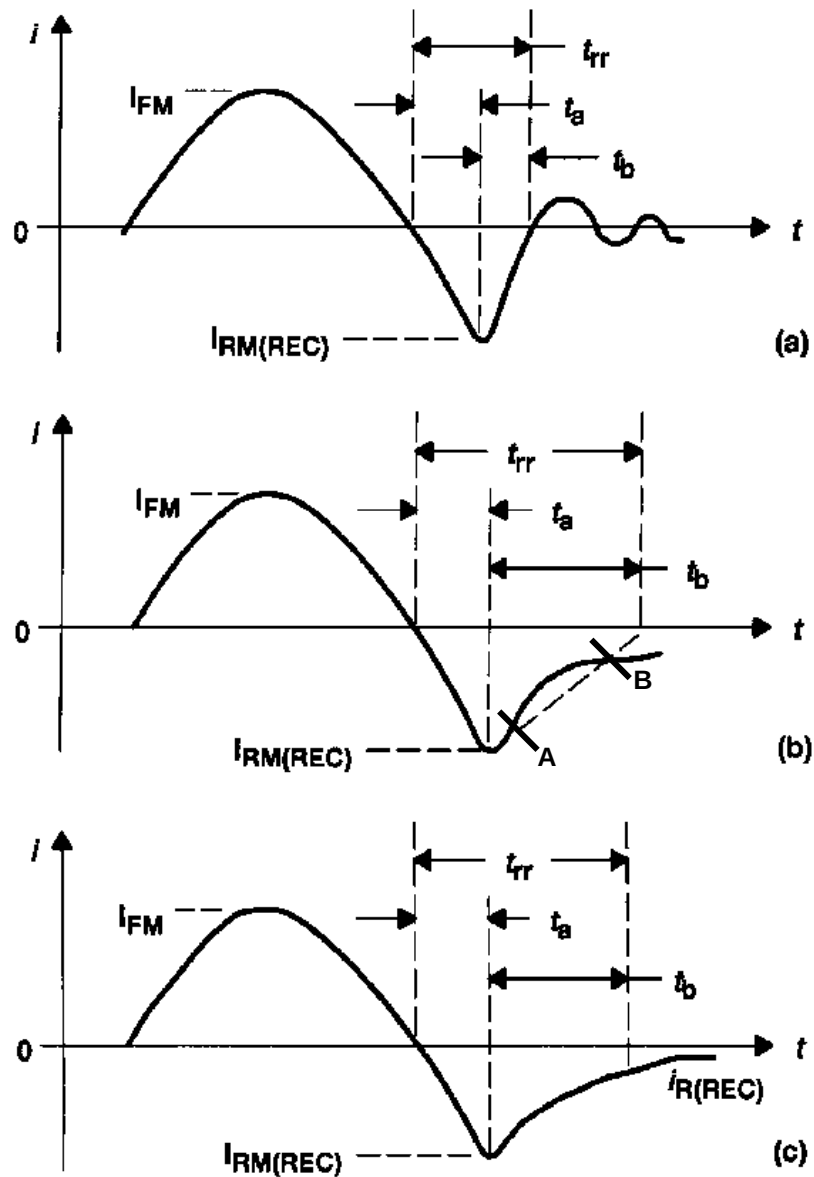


Figure 3-2 — Current waveforms during rectifier diode reverse recovery

3.1 Signal diodes and rectifier diodes (cont'd)

3.1.2 Letter symbols, terms, and definitions (cont'd)

For illustration of voltages, see Figure 3-1.

$V_{(BR)}$, $v_{(BR)}$	breakdown voltage* : A voltage in a breakdown region.
$V_{F(RMS)}$, V_F , V_F , $V_{F(AV)}$, v_F , v_{FM}	forward voltage* : A positive anode-cathode voltage.
$V_{R(RMS)}$, V_R , V_R , $V_{R(AV)}$, v_R , v_{RM}	reverse voltage* : A positive cathode-anode voltage.
V_{RRM}	repetitive peak reverse voltage : The peak reverse voltage including all repetitive transient voltages but excluding all nonrepetitive transient voltages. (Ref. JESD282B.)
V_{RSM}	nonrepetitive peak reverse voltage : The peak reverse voltage including all nonrepetitive transient voltages but excluding all repetitive transient voltages. (Ref. JESD282B.)
V_{RWM}	working peak reverse voltage : The peak reverse voltage excluding all transient voltages. (Ref. JESD282B.)
$V_{(TO)}$, $v_{(TO)}$	threshold voltage* : The forward voltage at which the device conducts forward current of a specified low value.

* See Table 3-3 for detailed meaning of symbols.

3.1 Signal diodes and rectifier diodes (cont'd)

3.1.2 Letter symbols, terms, and definitions (cont'd)

Table 3-3 — Voltage

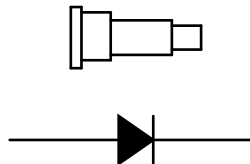
Quantity	Total rms value	RMS value of alternating component	DC value with no alternating component	Mean value averaged over full cycle	Instantaneous total value	Maximum (peak) total value
Breakdown voltage	—	—	$V_{(BR)}$	—	$v_{(BR)}$	—
Forward voltage	$V_{F(RMS)}$	V_f	V_F	$V_{F(AV)}$	v_F	V_{FM}
Reverse voltage	$V_{R(RMS)}$	V_r	V_R	$V_{R(AV)}$	v_R	V_{RM}
Reverse voltage, working peak	—	—	—	—	—	V_{RWM}
Reverse voltage, repetitive peak	—	—	—	—	—	V_{RRM}
Reverse voltage, nonrepetitive peak	—	—	—	—	—	V_{RSM}
Threshold voltage	—	—	$V_{(TO)}$	—	$v_{(TO)}$	—

3.2 Microwave diodes

3.2.1 General terms and definitions

detector diode: A diode, often associated with microwave circuits, that converts rf energy into dc or video output.

forward-polarity (microwave) diode: A microwave diode in which the anode is connected to the base (i.e., the larger-diameter terminal) of the package.



Gunn diode: A transferred-electron diode intended to operate at a frequency determined by the transit time of charge packets or “domains” that are formed due to the transferred-electron effect.

3.2 Microwave diodes (cont'd)

3.2.1 General terms and definitions (cont'd)

IMPATT [impact avalanche and transit-time] diode; avalanche diode operating in the IMPATT mode: A semiconductor microwave diode that, when its junction is biased into avalanche, exhibits a negative resistance over a frequency range determined by the transit time of charge carriers through the depletion region.

LSA [limited space-charge accumulation] diode: A transferred-electron diode similar to the Gunn diode except that it is intended to operate at frequencies that are determined by the microwave cavity in which the diode is mounted and that are several times higher than the transit-time frequency so that the formation of charge packets (or domains) is limited.

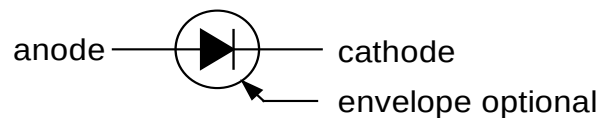
NOTE Compared to the Gunn diode, higher output power at higher frequency is achievable.

matched pair (of microwave diodes): A pair of microwave diodes identical in outline dimensions and with matched electrical characteristics as described in EIA-370.

NOTE The two diodes may both be forward polarity, or one forward and one reverse polarity, or both reverse polarity.

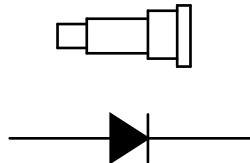
microwave diode: A two-terminal device that is responsive in the microwave region of the electromagnetic spectrum, commonly regarded as extending from 1 GHz to 300 GHz.

Graphic symbol (ref. IEEE Std 315):



mixer diode: A diode, often associated with microwave circuits, that combines rf signals at two frequencies to generate an rf signal at a third frequency.

reverse-polarity (microwave) diode: A microwave diode in which the cathode is connected to the base (i.e., the larger-diameter terminal) of the package.



3.2 Microwave diodes (cont'd)

3.2.1 General terms and definitions (cont'd)

transferred-electron diode: A semiconductor microwave diode that exhibits negative resistance arising from the transferred-electron effect.

NOTE 1 The transferred-electron effect is the generation of bulk negative differential conductivity in compound semiconductor devices that have multiple energy valleys when the applied electrical field is greater than the critical value at which electrons transfer from (1) a lower energy valley in which they have greater mobility and smaller effective mass to (2) a higher energy valley in which they have smaller mobility and greater effective mass.

NOTE 2 The term “energy valley” refers to a valley in an energy-versus-momentum profile.

TRAPATT [trapped plasma avalanche transit-time] diode; avalanche diode operating in TRAPATT mode: A semiconductor microwave diode that, when its junction is biased into avalanche, exhibits a negative resistance at frequencies below the transit-time frequency range of the diode due to generation and dissipation of trapped electron-hole plasma resulting from the intimate interaction between the diode and a multiresonant microwave cavity.

3.2.2 Letter symbols, terms, and definitions

$\overline{F}_o$ **overall average noise figure (of a mixer diode):** The average noise figure of the cascaded combination of a mixer and IF amplifier.

$\overline{F}_{os}$ **standard overall average noise figure (of a mixer diode):** The overall average noise figure when the average noise figure of the IF amplifier is a specified standard value (usually 1.5 dB) and the passband of the IF amplifier is sufficiently narrower than that of the mixer so that the mixer conversion loss and output noise temperature are essentially constant over the IF passband.

L_c **conversion loss:** The ratio of available input power at a single signal frequency to the available single signal frequency output power, not including intrinsic mixer noise or power converted from other than the single-input frequency.

NOTE Delivered signal output power may be used, in which case the loss is referred to as “conversion insertion loss”.

M **figure of merit (of a detector diode):** The quantitative excellence of the detector in terms of current sensitivity and video impedance; i.e., that part of the signal-to-noise ratio equation that pertains to the crystal parameters and the equivalent noise resistance of the video amplifier.

N_r **output noise ratio:** The ratio of the noise temperature of an output port to the reference noise temperature, T_0 , when the noise temperature of all input terminations is at T_0 at all frequencies that contribute to the output noise.

TSS **tangential signal sensitivity:** The signal power below a 1-milliwatt reference level required to produce an output pulse whose amplitude is sufficient to raise the noise fluctuation by an amount equal to the average noise level.

3.2 Microwave diodes (cont'd)

3.2.2 Letter symbols, terms, and definitions (cont'd)

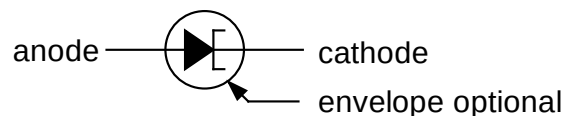
VSWR	voltage-standing-wave ratio: The ratio of the sum of the amplitudes of the incident and reflected voltages to their difference.
Z_{if}	intermediate-frequency impedance: The impedance at the intermediate frequency of a mixer semiconductor diode as presented at the output terminals of the mixer when the device is driven by the local oscillator under the specified conditions.
Z_m	modulator-frequency load impedance: The ac load impedance presented to the diode at the output terminals.
Z_{rf}	radio-frequency impedance: The radio-frequency impedance of a mixer as measured at the local-oscillator terminals of the mixer.
Z_v	video impedance: The impedance at the specified frequency presented at the output terminals of the diode.

3.3 Tunnel diodes and backward diodes

3.3.1 General terms and definitions

backward diode: A semiconductor diode in which quantum-mechanical tunneling leads to a current-voltage characteristic with a reverse current greater than the forward current, for equal and opposite applied voltages, in some voltage range centered about the origin.

Graphic symbol (ref. IEEE Std 315):

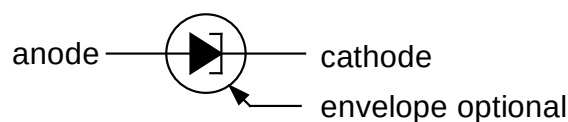


tunnel diode: A semiconductor diode in which quantum-mechanical tunneling leads to a region of negative slope in the forward direction of the current-voltage characteristic.

NOTE 1 The current is typically a single-valued function of voltage.

NOTE 2 In practice, the distinction between tunnel diodes and backward diodes is based on circuit application emphasis of the negative-resistance property (tunnel diode) or the low-level rectification property (backward diode).

Graphic symbol (ref. IEEE Std 315):



3.3 Tunnel diodes and backward diodes (cont'd)

3.3.2 Letter symbols, terms, and definitions

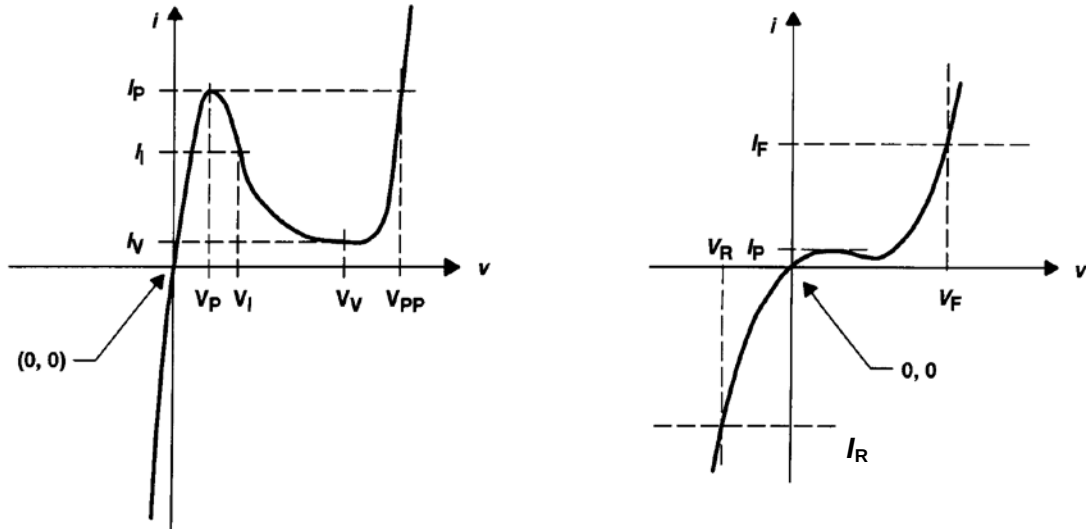
For illustration of these parameters, see Figure 3-3.

I_I	inflection-point current: The current at that point on the forward current-voltage characteristic at which the slope of the characteristic reaches its most negative value.
I_P	peak-point current: The current at that point on the forward current-voltage characteristic corresponding to the lowest positive (forward) voltage at which $di/dv = 0$.
I_V	valley-point current: The current at that point on the forward current-voltage characteristic corresponding to the second-lowest positive (forward) voltage at which $di/dv = 0$.
r_i	dynamic resistance at inflection point: The small-signal incremental terminal resistance at that point on the forward current-voltage characteristic at which the slope of the characteristic reaches its most negative value.
V_I	inflection-point voltage: The voltage at that point on the forward current-voltage characteristic at which the slope of the characteristic reaches its most negative value.
V_P	peak-point voltage: The voltage at that point on the forward current-voltage characteristic corresponding to the lowest positive (forward) voltage at which $di/dv = 0$.
V_{PP}	projected peak-point voltage: The voltage at that point on the forward current-voltage characteristic where the current is equal to the peak-point current and where the voltage is greater than the valley-point voltage.

3.3 Tunnel diodes and backward diodes (cont'd)

3.3.2 Letter symbols, terms, and definitions (cont'd)

V_V **valley-point voltage:** The voltage at that point on the forward current-voltage characteristic corresponding to the second lowest positive (forward) voltage at which $di/dv = 0$.



(a) — Typical tunnel-diode characteristic

(b) — Typical backward-diode characteristic

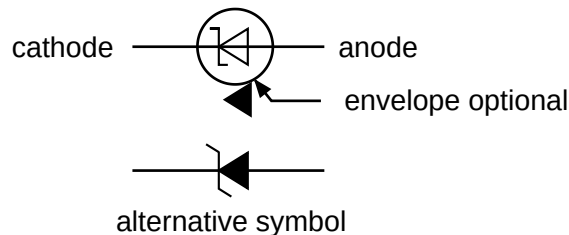
Figure 3-3 — Current-voltage characteristics

3.4 Voltage-regulator and voltage-reference diodes

3.4.1 General terms and definitions

voltage-reference diode: A diode that is normally biased to operate in the breakdown region of its voltage-current characteristic and that develops across its terminals a reference voltage of specified accuracy when biased to operate throughout a specified current and temperature range. (Ref. IEC 747-1.)

Graphic symbol (ref. IEEE Std 315):



3.4 Voltage-regulator and voltage-reference diodes (cont'd)

3.4.1 General terms and definitions (cont'd)

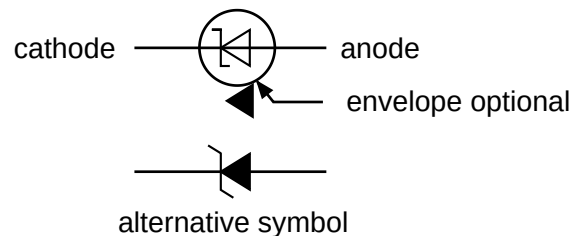
voltage-regulator diode: A semiconductor diode with a single p-n junction (or with multiple p-n junctions, none of which interact) that is normally biased in the breakdown region of its voltage-current characteristic and limits variation in voltage across its terminals over a specified current range. (Ref. JESD211.)

NOTE 1 The breakdown region may be due to either avalanche breakdown or Zener breakdown phenomenon (also often known as tunneling or field-emission breakdown).

NOTE 2 When forward-biased, a voltage-regulator diode has a voltage-current characteristic similar to that of a rectifier diode.

NOTE 3 In general usage, voltage-regulator diodes are often referred to as **Zener diodes**, even if their breakdown characteristics are due to avalanche breakdown. A voltage-regulator diode may also be referred to as a **voltage-reference diode** when its application is to maintain a reference voltage within a specified accuracy over a specified current and temperature range in the breakdown region of the diode's voltage-current characteristic.

Graphic symbol (ref. IEEE Std 315):



Zener diode: A semiconductor diode with a single p-n junction whose breakdown characteristics are due to the Zener effect. (Ref. JESD211.)

NOTE Although true Zener breakdown occurs below approximately 6 volts, the term “Zener diode” is often used interchangeably with “voltage-regulator diode” and “voltage-reference diode” even for voltages over 6 volts, where the breakdown characteristic is due to avalanche breakdown.

temperature-compensated voltage-reference diode: A voltage-regulator diode that is designed to have minimal changes in the regulated voltage over a broad temperature range. (Ref. JESD211.)

NOTE A temperature-compensated voltage-reference diode is often provided with one or more forward-biased p-n junctions placed in series with a Zener p-n junction to offset or compensate the positive temperature coefficient of the Zener. This series combination may also involve more than one Zener p-n junction within the temperature-compensated voltage-reference diode, particularly for higher voltages.

3.4 Voltage-regulator and voltage-reference diodes (cont'd)

3.4.2 Letter symbols, terms, and definitions

I_Z	regulator [reference] current, dc:
I_{ZK}	regulator [reference] current, dc near breakdown knee:
I_{ZM}	regulator [reference] current, dc maximum-rated:
I_{ZT}	regulator [reference] current, dc at specified test point: The dc reverse current through the diode when it is biased to operate in its breakdown region at, respectively, — an operating point between I_{ZK} and I_{ZM}, — a specified current near the breakdown knee, — a specified current based on the maximum-rated power, or — a specified current between I_{ZK} and I_{ZM} for the purpose of specifying V_Z.
I_{Zk}, I_{Zt}	regulator [reference] current, rms components: A specified rms current for measuring regulator impedance. NOTE According to JEDEC registration formats, this current should not exceed 10% of the simultaneously applied dc current I_{ZK} or I_{ZT} .
I_{ZRM}	reverse surge current, repetitive peak: The peak reverse current in the breakdown region including all repetitive transient currents but excluding all nonrepetitive transient currents.
I_{ZSM}	reverse surge current, nonrepetitive peak: The peak reverse current in the breakdown region including all nonrepetitive transient currents but excluding all repetitive transient currents.
V_Z	regulator [reference] voltage, dc:
V_{ZM}	regulator [reference] voltage, dc at maximum-rated current: The dc voltage across the diode when it is biased to operate in its breakdown region at I_{ZT} or I_{ZM} , respectively.
z_z	regulator [reference] impedance, small-signal at I_{ZT}:
z_{zk}	regulator [reference] impedance, small-signal at I_{ZK}: The small-signal impedance of the diode when it is biased to operate in its breakdown region with I_{Zt} applied at I_Z or I_{ZK} , respectively.
α_{VZ}	temperature coefficient of regulator voltage: The change in regulator voltage, divided by the change in temperature that caused it. NOTE This quotient may be expressed as mV/°C, mV/K, %/°C, or %/K and is the average value for the total temperature change.