Diodes
Data Book
1996

TEMIC
Semiconductors

Contents

Conventions Used in Presenting Technical Data

Nomenclature for Semiconductor Devices According to Pro Electron

The part number of a semiconductor device consists of two letters followed by a serial number.

For example: B A W 24

- B – Material
- A – Function
- W 24 – Serial number

The **first letter** indicates the material used for the active part of the device.

A	GERMANIUM (Materials with a bandgap 0.6–1.0 eV) [1]
B	SILICON (Materials with a bandgap 1.0–1.3 eV) [1]
C	GALLIUM-ARSENIDE (Materials with a bandgap > 1.3 eV) [1]
R	COMPOUND MATERIALS (For example Cadmium-Sulphide)

The **second letter** indicates the circuit function.

A	DIODE: detection, switching or mixer
B	DIODE: variable capacitance
C	TRANSISTOR: low power, audio frequency
D	TRANSISTOR: power, audio frequency
E	DIODE: tunnel
F	TRANSISTOR: low power, high frequency
G	DIODE: oscillator and miscellaneous
H	DIODE: magnetic sensitive
K	HALL EFFECT DEVICE: in an open magnetic circuit
L	TRANSISTOR: power, high frequency
M	HALL EFFECT DEVICE: in a closed magnetic circuit
N	PHOTO COUPLER
P	DIODE: radiation sensitive
Q	DIODE: radiation generating
R	THYRISTOR: low power
S	TRANSISTOR: low power, switching
T	THYRISTOR: power
U	TRANSISTOR: power, switching
X	DIODE: multiplier, e.g., varactor, step recovery
Y	DIODE: rectifying, booster
Z	DIODE: voltage reference or voltage regulator, transient suppressor diode

The **serial number** consists of:

- A four digit number from 100 to 9999 for devices primarily intended for consumer equipment.
- One letter (Z, Y, X, etc.) and a three-digit number from 10 to 999 for devices primarily intended for professional equipment.

A version letter can be used to indicate a deviation of a single characteristic, either electrical or mechanical. This letter does not have a fixed meaning. The only exception is the use of the letter R, indicating reversed voltage (e.g., collector to case).

[1] The materials mentioned are examples

Polarity Conventions

The voltage direction is given

- by an arrow which points out from the measuring point to the reference point

or

- by a two letter subscript, where the first letter is the measuring point and the second letter is the reference point.

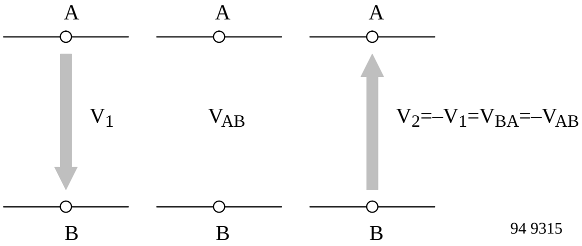


Figure 1.

The numerical value of the voltage is positive if the potential at the arrow tail is higher than at the arrow head; i.e., the potential difference from the measuring point (A) to the reference point (B) is positive.

The numerical value of the voltage is negative if the potential at the arrow head is higher than the tail; i.e., the potential difference from the measuring point to the reference point is negative.

In the case of alternating voltages, once the voltage direction is selected, it is maintained throughout. The alternating character of the quantity is given with the time dependent change in sign of its numerical values.

Figure 2.

The numerical value of the current is positive if the charge of the carriers moving in the direction of the arrow is positive (conventional current direction), or if the charge of the carriers moving against this direction is negative. The numerical value of the current is negative, if the charge of the carriers moving in the direction of the arrow is negative, or if the charge of the carriers moving against this direction is positive.

The general rules stated above are also valid for alternating quantities. Once the direction is selected, it is maintained throughout. The alternating character of the quantity is given with the time-dependent change in sign of its numerical values.

Polarity conventions for diodes

Here, the direction of arrows is selected in such a way that the numerical values of currents and voltages are positive both for forward (F or f) and reverse (R or r) directions.

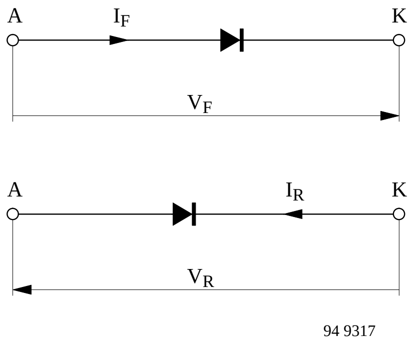


Figure 3.

Arrangement of Symbols

Letter symbols for current, voltage and power (according to DIN 41 785, sheet 1)

To represent current, voltage and power, a system of basic letter symbols are used. Capital letters are used for the representation of peak, mean, dc or root-mean-square values. Lower case letters are used for the representation of instantaneous values which vary with time.

Capital letters are used as subscripts to represent continuous or total values, while lower case letters are used to represent varying values.

The following table summarizes the rules given above.

Basic letter	
Upper-case	Upper-case
Instantaneous values which vary with time	Maximum (peak) average (mean) continuous (dc) or root-mean-square (RMS) values

Subscript(s)	
Upper-case	Upper-case
Varying component alone, i.e., instantaneous, root-mean-square, maximum or average values	Continuous (without signal) or total (instantaneous, average or maximum) values

Letter symbols for impedance, admittances, two-port parameters etc.

For impedance, admittance, two-port parameters, etc., capital letters are used for the representation of external circuits of which the device is only a part. Lower case letters are used for the representation of electrical parameters inherent in the device.

The rules are not valid for inductance and capacitance. Both these quantities are denoted with capital letters.

Capital letters are used as subscripts for the designation of static (dc) values, while lower case letters are used for the designation of small-signal values.

If more than one subscript is used (h_{FE}, h_{fe}), the letter symbols are either all capital or all lower case.

If the subscript has numeric (single, double, etc.) as well as letter symbol(s) (such as h_{21E} or h_{21e}'), the differentiation between static and small-signal value is made only by a subscript letter symbol.

Other quantities (values) which deviate from the above rules are given in the list of letter symbols.

The following table summarizes the rules given above.

Basic letter	
Upper-case	Upper-case
Electrical parameters inherent in the semiconductor devices except inductances and capacitances	Electrical parameters of external circuits and of circuits in which the semiconductor device forms only a part; all inductances and capacitances

Subscript(s)	
Upper-case	Upper-case
Small-signal values	Static (dc) values

Examples:

R_G Generator resistance
G_P Power gain
h_{FE} DC forward current transfer ratio in common emitter configuration
r_P Parallel resistance, damping resistance

Example for the use of symbols

according to 41785 and IEC 148

a) Transistor

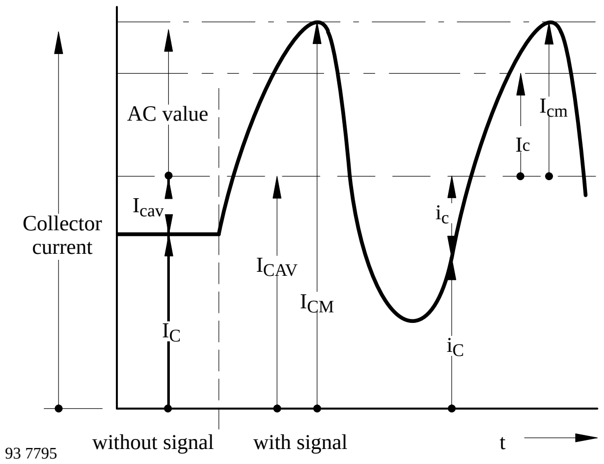


Figure 4.

I_C	dc value, no signal
I_{CAV}	Average total value
$I_{CM};I_C$	Maximum total value
I_{CEFF}	RMS total value
$I_C;I_{CEFF}$	RMS varying component
$I_{CM};I_C$	Maximum varying component value
i_C	Instantaneous total value
i_C	Instantaneous varying component value

The following relationships are valid:

$I_{CM} = I_{CAV} + I_{cm}$

$i_C = I_{CAV} + i_c$

b) Diode

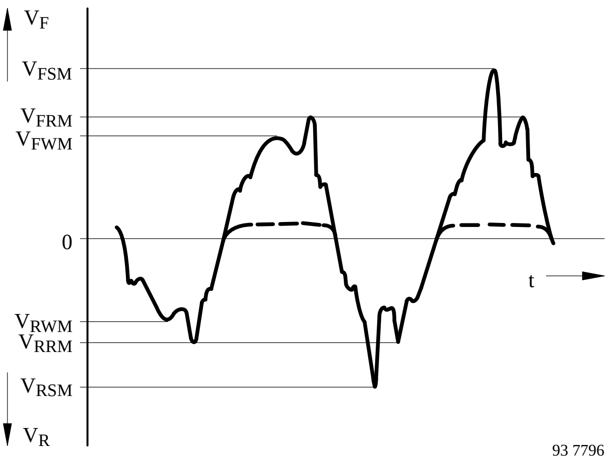


Figure 5.

V_F	Forward voltage
V_R	Reverse voltage
V_{FSM}	Surge forward voltage (non-repetitive)
V_{RSM}	Surge reverse voltage (non-repetitive)
V_{FRM}	Repetitive peak forward voltage
V_{RRM}	Repetitive peak reverse voltage
V_{FWM}	Crest working forward voltage
V_{RWM}	Crest working reverse voltage

List of Symbols

A
Anode

a
Distance (in mm)

b_{pn}
Normalized power factor

C
Capacitance, general

C_{case}
Case capacitance

C_D
Diode capacitance

C_j
Junction capacitance

C_L
Load capacitance

C_P
Parallel capacitance

F
Noise figure

f
Frequency

f_g
Cut-off-frequency

g
Conductance

I_F
Forward current

i_F
Forward current, instantaneous total value

I_{FAV}
Average forward current, rectified current

I_{FRM}
Repetitive peak forward current

I_{FSM}
Surge forward current, non-repetitive

I_{FWM}
Crest working forward current

I_R
Reverse current

i_R
Reverse current, instantaneous total value

I_{RAV}
Average reverse current

I_{RRM}
Repetitive peak reverse current

I_{RSM}
Non-repetitive peak reverse current

I_{RWM}
Crest working reverse current

I_S
Supply current

I_Z
Z-operating current

I_{ZM}
Z-maximum current

l
Length (in mm), (case-holder/soldering point)

LOCEP (local epitaxy)
A registrated trade mark of TEMIC for a process of epitaxial deposition on silicon. Applications occur in planer Z-diodes. It has an advantage compared to the normal process, with improved reverse current.

P
Power

P_{tot}
Total power dissipation

P_V
Power dissipation, general

P_{vp}
Pulse-power dissipation

Q
Quality

Q_{rr}
Reverse recovery charge

R_F
Forward resistance

r_f
Differential forward resistance

R_L
Load resistor

r_P
Parallel resistance, damping resistance

R_R
Reverse resistance

r_r
Differential reverse resistance

r_s
Series resistance

R_{thJA}
Thermal resistance between junction and ambient

R_{thJC}
Thermal reistance between junction and case

r_z
Differential Z-resistance in breakdown region (range)

$$r_z = r_{zj} + r_{zth}$$

r_{zj}
Z-resistance at constant junction temperature, inherent Z-resistance

r_{zth}
Thermal part of the Z-resistance

T
Temperature, measured in centigrade

T
Absolute temperature, Kelvin temperature

T
Period duration

T_{amb}
Ambient temperature (range)

t_{av}
Integration time

T_{case}
Case temperature

t_{fr}
Forward recovery time

T_j
Junction temperature

TK
Temperature coefficient

T_L
Connecting lead temperature in the holder (soldering point) at the distance/(mm) from case

t_P
Pulse duration (time)

$\frac{t_p}{T}$
Duty cycle

t_r
Rise time

t_{rr}
Reverse recovery time

t_s
Storage time

T_{sd}
Soldering temperature

T_{stg}
Storage temperature (range)

$V_{(BR)}$
Breakdown voltage

V_F
Forward voltage

V_F
Forward voltage, instantaneous total value

V_{FAV}
Average forward voltage

V_o
Rectified voltage

V_{FSM}
Surge forward voltage, non-repetitive

V_{FRM}
Repetitive peak forward voltage

V_{FWM}
Crest working forward voltage

V_{HF}
RF voltage, RMS value

V_{HF}
RF voltage, peak value

V_R
Reverse voltage

V_R
Reverse voltage, instantaneous total value

V_{RSM}
Surge reverse voltage, non-repetitive

V_{RRM}
Repetitive peak reverse voltage

V_{RWM}
Crest working reverse voltage

V_S
Supply voltage

V_T
Temperature voltage

V_Z
Z-operating voltage

Z_{thp}
Thermal resistance – pulse operation

φ
Angle of current flow

η_r
Rectification efficiency

T_o
Time constant

ΔC_D
Capacitance deviation

Assembly Instructions

General

Semiconductor devices can be mounted in any position. The terminal length may be bent at a distance greater than 1.5 mm from the case provided no mechanical force has an effect on the case.

If the device is to be mounted near heat generating components, consideration must be given to the resultant increase in ambient temperature.

Soldering Instructions

Leaded Devices

Protection against overheating is essential when a device is being soldered. It is recommended, therefore, that connection terminals are left as long as possible, are soldered at the tip only, and that any heat generated is quickly conducted away. The time during which the specified maximum permissible device junction temperature is exceeded during the soldering operation should be as short as possible, (i.e., for silicon, 260°C for 5 seconds.

Avoid any force on the body or leads during or just after soldering.

Do not correct the position of an already soldered device by pushing, pulling or twisting the body. Prevent fast cooling after soldering.

The maximum soldering temperatures are shown in table 1.

Surface Mounted Devices

Surface mounted devices (SMD) are components which are mounted directly on the surface of a printed circuit board without having to drill holes. In addition, these components can be completely submerged in a solder bath (overhead soldering). The SMD technology offers the following main advantages:

- Higher packing density (miniaturization)
- Reduction of the component mounting costs by fully automatic mounting

a) Gluing

In the case of flow or drag soldering, the components must be glued to the printed circuit board. The adhesive used for this purpose must be electrically neutral and must not react chemically with the materials of the printed circuit board or the components. The adhesive must not negatively affect subsequent soldering. After mounting, the adhesive must be hardened. The ultraviolet and/or thermal radiation commonly used for hardening is uncritical for our components. In the case of other soldering methods, gluing can be omitted if the flux or the solder paste provides sufficient adhesion of the components to the printed circuit board.

b) Soldering

The pins of TEMIC components are already tinned.

Dip soldering, flow soldering, reflow soldering, and vapor phase soldering are permissible.

The maximum temperature of 260°C over a period of 5 s must not be exceeded during soldering. Preheating (e.g., to 80°C) results in a higher chip temperature during soldering and should, therefore, not be done.

No aggressive fluxes may be used.

Table 1. Maximum soldering temperatures

	Iron Soldering			Dip or Flow Soldering			
	Iron Temperature	Soldering Distance from the Case	Maximum Allowable Soldering Time	Soldering Temperature	Soldering Distance from the Case		Maximum Allowable Soldering Time
					Vertical	Horizontal	
Glass case	≦260°C ≦260°C 260 to 400°C	1.5 to 5 mm > 5 mm > 5 mm	5 s 10 s 5 s	≦260°C	> 1.5 mm	> 5 mm	5 s
Plastic case	≦260°C ≦260°C	2 to 5 mm > 5 mm	3 s 5 s	≦260°C	> 1.5 mm	> 5 mm	3 s

A soldering iron should be used only in exceptional cases (repairs, etc.). A temperature regulated miniature soldering iron must be used, and care should be taken to avoid touching the component with the tip of the soldering iron.

For optoelectronic semiconductor components, the maximum soldering temperature is 240°C for 5 s.

c) Cooling

Cooling of the components with a fan after soldering is permissible.

d) Cleaning

If cleaning is necessary after soldering, it is recommended to wash with water which contains a detergent free of deposits.

Important layout notes

If components are to be arranged in rows, then separate soldering surfaces must be provided for each component. If this is not carried out, a block of solder forms between the components during soldering, and a rigid connection result. This can cause breakage or cracks in the component as the result of the slightest bending of the board, and thus lead to failures. If it is necessary to solder a wire (standard conductor, etc.) to the board, a separate soldering surface must be provided in order to avoid excessive heating of the components during soldering with a soldering iron.

Heat Removal

To keep the thermal equilibrium, the heat generated in the semiconductor junction(s) must be removed.

In the case of low-power devices, the natural heat-conductive path between the case and surrounding air is usually adequate for this purpose. However, in the case of medium-power devices, heat radiation may have to be improved by the use of star- or flag-shaped heat dissipators, which increase the heat radiating surface.

Finally, in the case of high-power devices, special heat sinks must be provided, the cooling effect of which can be increased further by the use of special coolants or air blowers.

The heat generated in the junction is conveyed to the case or header by conduction rather than convection. A measure of the effectiveness of heat conduction is the inner thermal resistance or thermal resistance junction case, R_{thJC}, the value of which is governed by the construction of the device.

Any heat transfer from the case to the surrounding air involves radiation convection and conduction. The effectiveness of transfer is expressed in terms of an R_{thCA}-value, i.e., the external or case-ambient thermal resistance. The total thermal resistance between junction and ambient is consequently

$$R_{thJA} = R_{thJC} + R_{thCA}.$$

The total maximum power, $P_{tot\ max}$, of a semiconductor device can be expressed as follows

$$P_{tot\ max} = \frac{T_{jmax} - T_{amb}}{R_{thJA}} = \frac{T_{max} - T_{amb}}{R_{thJC} + R_{thCA}}$$

where

T_{jmax}
is the maximum junction temperature,

T_{amb}
is the highest ambient temperature likely to be reached under the most unfavorable conditions,

R_{thJA}
is the thermal resistance between junction and ambient. For diodes with axial leads, it is measured with a heat sink at a specified distance from the case,

R_{thJC}
is the thermal resistance between junction and case,

R_{thCA}
is the thermal resistance between case and ambient. Its value is cooling dependent. When using heat sink, it can be influenced through thermal contact between the case and heat sink, thermal distribution in the heat sink and heat transfer to the surroundings.

Therefore, the maximum permissible total power dissipation for a given semiconductor device can be influenced only by changing T_{amb} and R_{thCA}. The value of R_{thCA} can be obtained either from the data of heat sink suppliers or through direct measurements.

Heat due to energy losses is mainly conducted with power diodes without cooling pins through the connecting leads and hence the pc board.

Figure 6 shows the thermal resistance plotted as a function of edge length. The values are valid with a heat source in the middle of the plate, resting air and vertical position. With horizontal position, thermal resistance increases approximately by 15 to 20%.

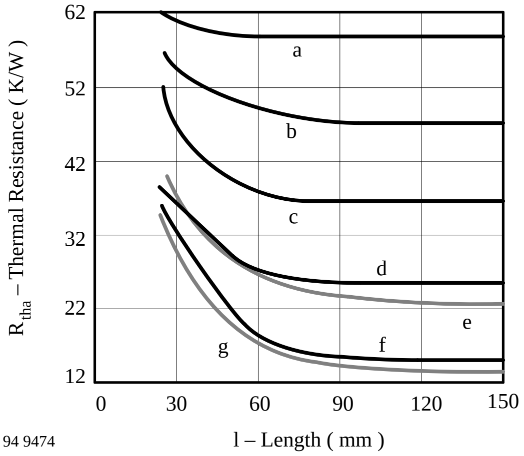


Figure 6.

Pertinax boards 1.5 mm thick

a: Pertinax non-metallized

b: Pertinax with 35 µm cooper metallization on one side; heat source fitted to non-metallized side

c: Pertinax with 70 µm cooper metallization on one side; heat source fitted to non-metallized side

d: Pertinax with 35 µm cooper metallization on one side; heat source fitted to metallized side

e: Pertinax with 35 µm cooper metallization on both sides

f: Pertinax with 70 µm cooper metallization on one side; heat source fitted to metallized side

g: Pertinax with 70 µm cooper metallization on both sides

R_{tha}: Thermal resistance of boards

l: Edge length

Quality Data

With an extensive system consisting of qualification, intermediate and final tests, TEMIC Semiconductors endeavours to supply the customers with components which fulfil the specifications of the OEM-industry.

If you are interested in detailed information regarding “Quality Assurance of Semiconductor Components”, please ask for our booklet “Quality and Reliability”.

Delivery Quality

To secure the delivery quality the following precautions are used:

- 2 × 100% final test
- Process control by SPC and FMEA
- Observation of the ppm level

Manufacturing has ISO 9001 approval

To designate the delivery quality, the following specifications are given:

- Maximum and minimum values of the characteristics
- AQL values (Acceptable Quality Level)

Shipment lots whose defect percentage is equal to or less than the percentage given in AQL value shall be accepted with greater probability ($L \geqq 90\%$) due to sampling tests (see ‘Sampling Inspection Plans’).

Classification of Defects

The possible defects with which a semiconductor device could be subjected are classified according to the probable influence of existing circuits:

- Total (critical) defect
  When this defect occurs the functional use of the device is impossible.
  For example: open contacts, short circuit, non-functioning, unstable characteristics, wrong polarity marking, gross mechanical failure, non-solderability, wrong parts in a belt, mixtures with wrong parts.
- Major defect
  This is a defect which is usually responsible for the failure of a device to function in its intended purpose.
  For example: parameter limits exceeded, incomplete type data, dimensional tolerance exceeded.
- Minor defect
  This is a defect which is responsible for the function of a device with no or only a slight reduction in effectiveness.
  For example: markings difficult to read, uncritical parameters, slightly bent connector pins.

AQL Values

According to the classification of defects mentioned above, the following AQL values, unless otherwise specified, are valid for data sheets of semiconductor devices. Under this classification, the inspection is carried out after the single sampling plan for attribute testing (see section ‘Sampling Inspection Plans’) which corresponds largely to ABC-STD 105 D, inspection level II.

Classification of Defects	AQL	n-c
Total defects	0.065	200-0
Major electrical defects	0.065	200-0
Major mechanical defects	0.25	200-1
Minor defects	0.4	200-2

A cumulative AQL equal to 0.4 is valid for all defects mentioned above.

Sampling Inspection Plans

List of symbols:

AQL Acceptable Quality Level

N Lot size

n Sample size

c Acceptance number

D_{max} Average outgoing quality level

Single sampling plan for attribute testing (according to DIN)

<table>
<tr><th rowspan="2">Normal Inspection</th><th colspan="11">AQL</th><th rowspan="2">Reduced Inspection</th></tr>
<tr><th>0.06</th><th>0.10</th><th>0.15</th><th>0.25</th><th>0.40</th><th>0.65</th><th>1.0</th><th>1.5</th><th>2.5</th><th>4.0</th><th>6.5</th></tr>
<tr><th>N</th><th colspan="11">n–c
(D_{max} in %)</th><th>N</th></tr>
<tr><td>2–15</td><td rowspan="9">200–0
(0.18)</td><td rowspan="8">125–0
(0.29)</td><td rowspan="7">80–0
(0.45)</td><td rowspan="6">50–0
(0.71)</td><td rowspan="5">32–0
(1.1)</td><td rowspan="4">20–0
(1.7)</td><td rowspan="3">13–0
(2.6)</td><td rowspan="2">8–0
(3.9)</td><td rowspan="2">5–0
(6.7)</td><td>3–0
(9.6)</td><td>2–0
(15.6)</td><td>2–15</td></tr>
<tr><td>16–50</td><td>13–1
(4.8)</td><td>8–1
(9.2)</td><td>16–150</td></tr>
<tr><td>51–150</td><td rowspan="2">32–1
(2.3)</td><td>20–1
(3.6)</td><td>20–2
(6.0)</td><td>20–3
(8.4)</td><td>151–280</td></tr>
<tr><td>151–280</td><td rowspan="2">50–1
(1.5)</td><td>32–2
(3.8)</td><td>32–3
(5.4)</td><td>32–5
(8.8)</td><td>281–500</td></tr>
<tr><td>281–500</td><td rowspan="2">80–1
(1.0)</td><td>50–2
(2.4)</td><td>50–3
(3.5)</td><td>50–5
(5.7)</td><td>50–7
(8.1)</td><td>501–1200</td></tr>
<tr><td>501–1200</td><td rowspan="2">125–1
(0.64)</td><td>80–2
(1.6)</td><td>80–3
(2.2)</td><td>80–5
(3.7)</td><td>80–7
(5.2)</td><td>80–10
(7.7)</td><td>1201–3200</td></tr>
<tr><td>1201–3200</td><td rowspan="2">200–1
(0.41)</td><td>125–2
(1.1)</td><td>125–3
(1.5)</td><td>125–5
(2.4)</td><td>125–7
(3.5)</td><td>125–10
(5.0)</td><td>125–14
(7.2)</td><td>3201–10000</td></tr>
<tr><td>2101–10000</td><td rowspan="2">315–1
(0.27)</td><td>200–2
(0.68)</td><td>200–3
(0.68)</td><td>200–5
(1.6)</td><td>200–7
(2.2)</td><td>200–10
(3.2)</td><td>200–14
(4.6)</td><td rowspan="2">200–21
(7.3)</td><td>10001–35000</td></tr>
<tr><td>10001–35000</td><td>500–1
(0.17)</td><td>315–2
(0.44)</td><td>315–3
(0.61)</td><td>315–5
(0.99)</td><td>315–7
(1.4)</td><td>315–10
(2.1)</td><td>315–14
(3.0)</td><td>315–21
(4.7)</td><td></td></tr>
</table>

Single sampling plan for destructive or very costly test procedures (AEG 1416, Z-plans)

<table>
<tr><th rowspan="2">Normal Inspection</th><th colspan="11">AQL</th><th rowspan="2">Reduced Inspection</th></tr>
<tr><th>0.06</th><th>0.10</th><th>0.15</th><th>0.25</th><th>0.40</th><th>0.65</th><th>1.0</th><th>1.5</th><th>2.5</th><th>4.0</th><th>6.5</th></tr>
<tr><th>N</th><th colspan="11">n–c
(D_{max} in %)</th><th>N</th></tr>
<tr><td>2–25</td><td rowspan="7">200–0
(0.18)</td><td rowspan="7">125–0
(0.29)</td><td rowspan="7">80–0
(0.46)</td><td rowspan="7">50–0
(0.74)</td><td rowspan="7">32–0
(1.2)</td><td rowspan="6">20–0
(1.8)</td><td rowspan="5">13–0
(2.8)</td><td rowspan="4">8–0
(4.5)</td><td rowspan="3">5–0
(7.2)</td><td rowspan="2">3–0
(11.6)</td><td>2–0
(16.6)</td><td>2–50</td></tr>
<tr><td>26–90</td><td rowspan="3">8–1
(10.8)</td><td>51–150</td></tr>
<tr><td>91–150</td><td rowspan="2">13–1
(6.3)</td><td>151–500</td></tr>
<tr><td>151–500</td><td rowspan="2">20–1
(4.1)</td><td>501–3200</td></tr>
<tr><td>501–1200</td><td rowspan="2">32–1
(2.6)</td><td>20–2
(6.8)</td><td>20–3
(9.5)</td><td>3201–35000</td></tr>
<tr><td>1201–10000</td><td rowspan="2">50–1
(1.7)</td><td>32–2
(4.3)</td><td>32–3
(6.1)</td><td>32–5
(9.9)</td><td></td></tr>
<tr><td>10001–35000</td><td>80–1
(1.1)</td><td>50–2
(2.7)</td><td>50–3
(3.9)</td><td>50–5
(6.3)</td><td>50–7
(9.0)</td><td></td></tr>
</table>

Physical Explanation

General Terminology

Semiconductor diodes are used as rectifiers, switchers, varactors and voltage stabilizers (see chapter 'Voltage Regulator and Z-diodes').

Semiconductor diodes are two-terminal solid-state devices having asymmetrical voltage-current characteristics. Unless otherwise stated, this means a device has single pn-junction corresponding to the characteristics shown in figure 7.

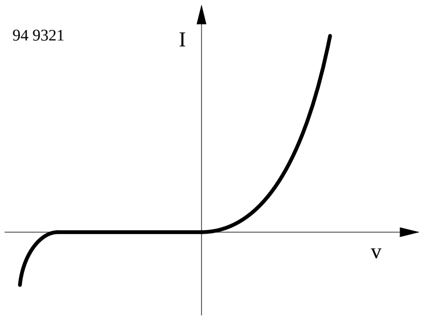


Figure 7.

An application of the voltage current curve is given by

$$I = I_S \left(\exp \frac{V}{V_T} - 1 \right)$$

where

I_S = saturation current

$$V_T = \frac{k \times T}{q} = \text{temperature potential}$$

If the diode is forward-biased (anode positive with respect to cathode), its forward current ($I = I_F$) increases rapidly with increasing voltage. That is, its resistance becomes very low.

If the diode is reverse-biased (anode negative with respect to cathode), its reverse current ($-I = I_R$) is extremely low. This is only ralid until the breakdown voltage $V_{(BR)}$ has been reached. When the reverse voltage is slightly higher than the breakdown voltage, a sharp rise in reverse current results.

Bulk resistance
Resistance of the bulk material between junction and the diode terminals.

Parallel resistance, r_P
Diode resistance resulting from HF rectification which acts as a damping resistance to the pre-tuned demodulation circuit.

Differential resistance
See forward resistance, differential

Diode capacitance, C_D
Total capacitance between the diode terminals due to case, junction and parasitic capacitances.

Breakdown voltage, $V_{(BR)}$
Reverse voltage at which a small increase in voltage results in a sharp rise of reverse current. It is given in the technical data sheet for a specified current.

Forward voltage, V_F
The voltage across the diode terminals which results from the flow of current in the forward direction.

Forward current, I_F
The current flowing through the diode in the direction of lower resistance.

Forward resistance, r_F
The quotient of dc forward voltage across the diode and the corresponding dc forward current.

Forward resistance, differential r_f
The differential resistance measured between the terminals of a diode under specified conditions of measurement, i.e., for small-signal ac voltages or currents at a point of forward direction V-I characteristic.

Case capacitance, C_{case}
Capacitance of a case without a semiconductor crystal.

Integration time, t_{av}
With certain limitations, absolute maximum ratings given in technical data sheets may be exceeded for a short time. The mean value of current or voltage is decisive over a specified time interval termed integration time. These mean values over time interval, t_{av}, should not exceed the absolute maximum ratings.

Average rectified output current, I_{FAV}
The average value of the forward current when using the diode as a rectifier. The maximum allowable average rectified output current depends on the peak value of the applied reverse voltage during the time interval at which no current is flowing. In the absolute maximum ratings, one or both of the following are given:

- The maximum permissible average rectified output current for zero diode voltage (reverse)
- The maximum permissible average rectified output current for the maximum value of U_{RRM} during the time interval at which no current is flowing.

Note: I_{FAV} decreases with an increasing value of the reverse voltage during the interval of no current flow.

Rectification efficiency, η_r
The ratio of the dc load voltage to the peak input voltage of an RF rectifier.

Reverse recovery time, t_{rr}
The time required for the current to reach a specified reverse current, i_R, after instantaneous switching from a specified forward condition (e.g., I_F) to a specified reverse bias condition (e.g., I_R).

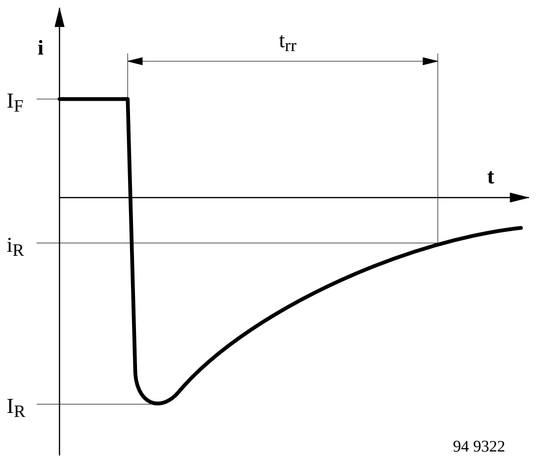


Figure 8.

Series resistance, r_s
The total value of resistance representing the bulk, contact and lead resistance of a diode given in the equivalent circuit diagram of variable capacitance diodes.

Junction capacitance, C_j
Capacitance due to a pn junction of a diode which decreases with increasing reverse voltage.

Reverse voltage, V_R
The voltage drop which results from the flow of reverse current (through the semiconductor diode).

Reverse current, I_R (leakage current)
The current which flows when reverse bias is applied to a semiconductor junction.

Reverse resistance, R_R
The quotient of the dc reverse voltage across a diode and the corresponding dc reverse current.

Reverse resistance, differential, r_r
The differential resistance measured between the terminals of a diode under specified condition of measurement i.e., for small-signal (ac) voltage or currents at a point of reverse-voltage direction V-I characteristic.

Peak forward current, I_{FRM}
The maximum forward current with sine-wave operation, f $\geqq$ 25 Hz, or pulse operation, f $\geqq$ 25 Hz, having a duty cycle $t_p/T \leqq 0.5$.

Peak reverse voltage, V_{RRM}
The maximum reverse voltage having an operating frequency f $\geqq$ 25 Hz for sine-wave as well as pulse operation.

Peak surge forward current, I_{FSM}
The maximum permissible surge current in a forward direction having a specified waveform with a short specified time interval (i.e., 10 ms) unless otherwise specified. It is not an operating value. During frequent repetitions, there is a possibility of change in the device's characteristic.

Peak surge reverse voltage, V_{RSM}
The maximum permissible surge voltage applied in a reverse direction. It is not an operating value. During frequent repetitions, there is a possibility of change in the device's characteristic.

Power dissipation, P_V
An electrical power converted into heat. Unless otherwise specified, this value is given in the data sheets under absolute maximum ratings, with $T_{amb} = 25°C$ at a specified distance from the case (both ends).

Forward recovery time, t_{fr}
The time required for the voltage to reach a specified value after instantaneous switching from zero or a specified reverse voltage to a specified forward-biased condition.

This recovery time is especially noticeable when higher currents are to be switched within a short time. The reason is that the forward resistance during the turn-on time could be higher than the dc current (inductive behavior). This can result in the destruction of a diode because of high instantaneous power loss if constant current control is used.

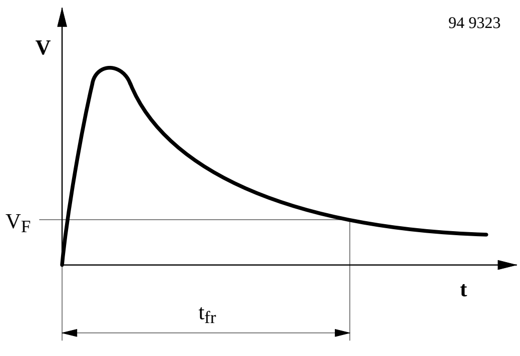


Figure 9.

Voltage Regulator Diodes and Z-diodes

A voltage regulator diode is a diode which develops an essentially constant voltage across its terminals throughout a specified current range.

Special reverse-biased diodes known as Z-diodes and certain forward-biased silicon diodes can be used as voltage regulator diodes.

Z-diodes are silicon diodes which result from a specified applied reverse voltage onward in a rapid increase of reverse current avalanche or Z-breakdown voltage. These diodes are operated permanently in this breakdown region.

Due to the sharp rise of the reverse, current the corresponding breakdown voltage is nearly constant.

Z-diodes are used for voltages above 2.4 V. If lower operating voltages are needed, the above mentioned forward-biased silicon diodes can be used.

Operating or working voltage, in the breakdown region, V_Z
Voltage across the terminals of a Z-diode for a specified value of reverse current in the breakdown region.

Operating or working current in the breakdown region, I_Z
Reverse current flowing in an allowable area of the breakdown region of a Z-diode.

Differential resistance in the breakdown region, r_Z
Differential quotient between operating voltage and operating current for a specified working current.

$$r_Z = \frac{dV_Z}{dI_Z}$$

This value is the sum of inherent (r_Z) and thermal differential (r_{zj}) resistances.

$$r_Z = r_{zj} + r_{zth}$$

Inherent differential resistance, r_{zj}, in the breakdown region
This value is a part of the total differential resistance of a Z-diode in the breakdown region. It is responsible for short-time load change and constant junction temperature.

$$r_{zj} = \left(\frac{\delta V_Z}{\delta I_Z}\right) \quad T_j = \text{constant}$$

It is valid for the case where the frequency of load changes is so high that the junction temperature does not change.

Thermal differential resistance, r_{zth}, in the breakdown region
The thermal differential resistance is a result of the thermal characteristics of the diode. This should be considered together with inherent differential resistance, r_{zj}.

$$r_{zth} = \frac{dT_j}{dI_Z} \times \left(\frac{\delta V_Z}{\delta T_j}\right) \quad I_Z = \text{constant}$$

$$= U_Z^2 \times R_{thJA} \times TK_{VZ}$$

Measuring current, I_Z
The value given in technical data serves as a measuring condition for the operating voltage, V_Z, inherent differential resistance, r_{zj}, and the temperature coefficient of the operating voltage, TK_{VZ}.

Temperature coefficient, TK_{VZ}
This characteristic gives the temperature dependence of the operating voltage for a specified operating current such as

$$TK_{VZ} = \frac{1}{V_Z} \times \frac{dV_Z}{dt}$$

The unit for measure used is either %/°C or 10^{-4}/°C

Z-voltage, V_Z
See operating or working voltage

Z–current, I_Z
See operating or working current

Z-resistance, r_Z
See differential resistance

Varactor Diodes

Varactor diodes are used in different circuits, such as tuning, AFC, frequency multiplier, modulation, couple element in filters with controlled bandwidth, parametric amplification, switching in the VHF- and microwave regions, etc. In all these applications, the basic variation of junction capacitance with reverse voltage has been investigated.

A simplified equivalent circuit of an encapsulated varactor diode is shown in figure 10.

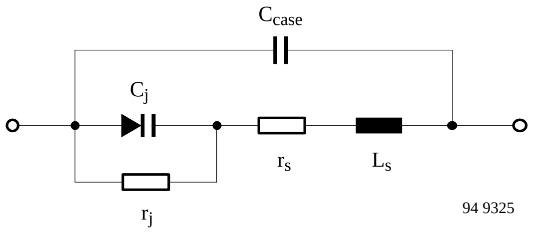


Figure 10.

C_{case} = Case capacitance
C_j = Junction capacitance
r_s = Series resistance
L_s = Series inductance
r_j = Junction resistance

In the case of silicon (varactor) diodes, the junction resistance, r_j, is very high at zero or negative (reverse) bias. At high resonant frequency, C_{case} can be neglected and the equivalent circuit is the one shown in figure 11.

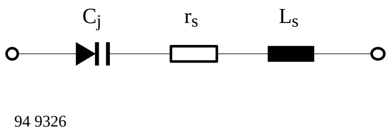


Figure 11.

Junction capacitance C_j can be calculated as follows:

$$C_j = \frac{C_{jo}}{\left(\frac{1+V_R}{V_D}\right)^n}$$

C_{jo} = Junction capacitance at zero bias ($V_R = 0$)
V_D = Diffusion voltage, 0.7 V for silicon
n = The exponent n has different values according to the technology used, such as:
n = 0.33-diffused diode with linear technology
n = 0.5-abrupt pn junction, planar epitaxial technology
n ≧ 0.75-diode with retrograded junction

Retrograded junction diodes (n ≧ 0.75) are capable of very large capacitance deviation and are therefore suitable for tuning with large frequency range (i.e., BB205 for VHF). For these diodes, n is a function of reverse voltage, i.e., n = f(V_R). The quality, Q, of the varactor is an important factor and can be calculated as follows:

$$Q = \frac{1}{2\pi \times f \times C_j \times r_s}$$

The series resistance, r_s, decreases with the increasing applied bias. It is also frequency dependent. The non-linearity of a capacitance characteristic results in a signal distortion or deformation due to the ratio of a signal amplitude to the applied bias.

In push-pull arrangements one can further minimize the distortion even with a larger range of signal. Because the signal modulates the diode in counter phase, the capacitance changes. The diode is now almost compensated.

The temperature coefficient of the junction capacitance is approximately 3×10^{-4}/°C with V_R = 3 V. It is a result of a change of –2 mV/°C in diffusion voltage, V_D. The temperature coefficient of the junction capacitance decreases with increasing reverse voltage.

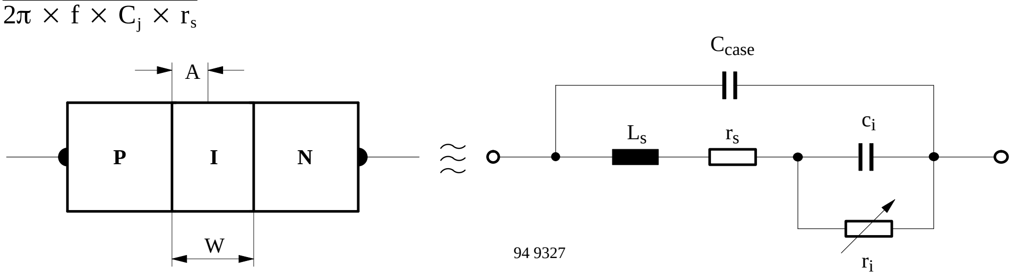
The junction resistance, r_j, decreases 6% and the series resistance, r_s, decreases approximately 1% with an increase in the junction temperature of 1°C.

PIN Diodes

PIN stands for p-intrinsic-n. In this type of diode, a heavily doped p region and a heavily doped n region are separated by a layer of high resistivity material which is nearly intrinsic (I), as shown in figure 12.

Under reverse bias, the PIN diode has a very high impedance (at microwave frequencies), whereas at moderate forward current it has a very low impedance. This permits the use of the PIN diode as a low-loss switch with small self capacitance.

Because the RF resistance of the diode can be varied continuously from large to small values by changing the diode bias. the PIN diode can therefore be used more advantageously as an HF attenuator in a π or T-circuit. Typical examples are: VHF-band switch diode BA282, BA682 and attenuator diode BA479G and BA679.



W = Width of the I-Zone
A = Space charge carrier area
L_s = Total series inductance
r_s = Total resistance of the p and n layers and any resistance associated with the contacts of these layers
r_i and c_i = Represent the resistance and capacitance of the portion of the I-layer exclusive of the swept-out region

Figure 12.

Data Sheet Construction

Data sheet information is generally presented in the following sequence:

- Device description
- Absolute maximum ratings
- Thermal data – thermal resistances
- Characteristics, switching characteristics
- Electrical characteristics
- Dimensions (mechanical data)

Additional information on device performance is provided where necessary.

Device Description

The following information is provided: part number, semiconductor materials used, sequence of zones, technology used, device type and, if necessary construction.

Also, information on the typical **Applications** and special **Features** is given

Absolute Maximum Ratings

The absolute maximum ratings indicate the maximum permissible operational and environmental conditions. Exceeding any one of these conditions could result in the destruction of the device. Unless otherwise specified, an ambient temperature of 25°C ± 3°C is assumed for all absolute maximum ratings. Most absolute ratings are static characteristics; if they are measured by a pulse method, the associated measurement conditions are stated.

Maximum ratings are absolute
(i.e., not interdependent).

Any equipment incorporating semiconductor devices must be designed so that even under the most unfavorable operating conditions the specified maximum ratings of the devices used are never exceeded. These ratings could be exceeded because of changes in:

- Supply voltage
- The properties of other components used in the equipment
- Control settings
- Load conditions
- Drive level
- Environmental conditions
- The properties of the devices themselves (aging)

Thermal Data – Thermal Resistances

Some thermal data (e.g., junction temperature, storage temperature range, total power dissipation), impose a limit on the application range of the device, are given under the heading “Absolute Maximum Ratings”.

A special section is provided for thermal resistances.

Temperature coefficients, on the other hand, are listed together with the associated parameters under “Characteristics, Switching Characteistics”.

Characteristics, Switching Characteristics

Under this heading, the most important operational electrical characteristics (minimum, typical and maximum values) are grouped together with associated test conditions supplemented with curves.

Dimensions (Mechanical Data)

Important dimensions and the sequence of connections supplemented by a circuit diagram are included in the mechanical data. Case outline drawings carry DIN, JEDEC or commercial designations. Information on weight completes is also included.

Note:

If the dimension information does not includes any tolerances, then lead length and mounting hole dimensions are minimum values. All other dimensions are maximum.

Additional Information

Not for new developments: This heading indicates that the device concerned should not be used in equipment under development. It is, however, available for present production.

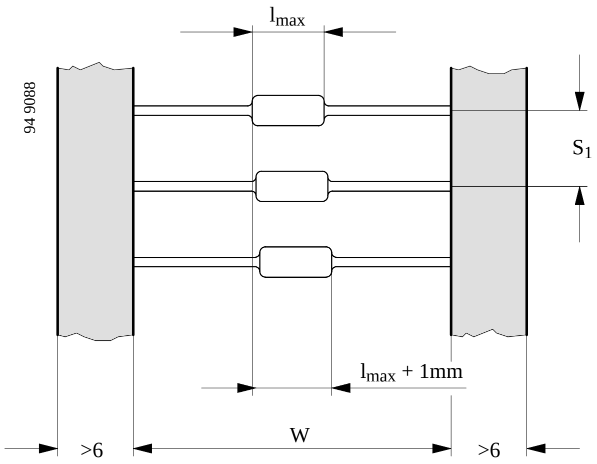
Packing

Packing Specification for Axial Lead Components

Diodes and rectifiers with axial leads are normally delivered in taped form according to IEC 286-1 (see figure 13). The cathode side is designated by a colored tape. Taped devices are normally delivered in ammoboxes (Ammopack). Delivery on reels is available on request. Diodes in DO35 packages are also available with 26 mm tapewidth and radial taped. For details please contact factory.

Quantities per box dimensions 264 (L) x 146(H) x 73(W)

Case Type	Quantity
DO35	10000
DO41	5000
SOD57	5000
SOD64	2500



S_1 = 5 ± 0.5 for devices with diameter d < 4.5 mm
= 10 ± 0.5 mm for devices with diameter d > 4.5 mm

W = 53 ± 2 mm for normal taped form
= 26 + 1.5 for GPS version

Allowable deviation above 10 taped steps ± 2 mm

Figure 13. Standard taped diodes with axial leads

Packing Specification for Surface-Mounted Devices (SMDs)

SMDs are normally delivered taped on blister tape and reeled according to IEC 286–3. The mounting side of the component is oriented to the bottom side of the tape. For components with two terminations, the cathode side, is oriented to the sprocket hole. For components in SOT23 package, the side from which one single termination emerges is oriented to the sprocket hole. Components can be delivered either on 180 mm or on 330 mm reels. For quantities per reel, see below.

Case Type	Suffix	Quantity	Reel Size in mm (Diameter)	Tape Width in mm
SOD80 (MiniMelf)	GS08	2500	180	8
SOD80 (MiniMelf)	GS18	10000	330	8
QuadroMelf	GS08	2500	180	8
QuadroMelf	GS18	10000	330	8
SOT23	GS08	3000	180	8
SOT23	GS18	10000	330	8
DO214AC (SMA)	TR	1500	180	12
DO214AC (SMA)	TR3	6000	330	12
Micro Melf	TR	2500	180	8
Micro Melf	TR3	10000	330	8

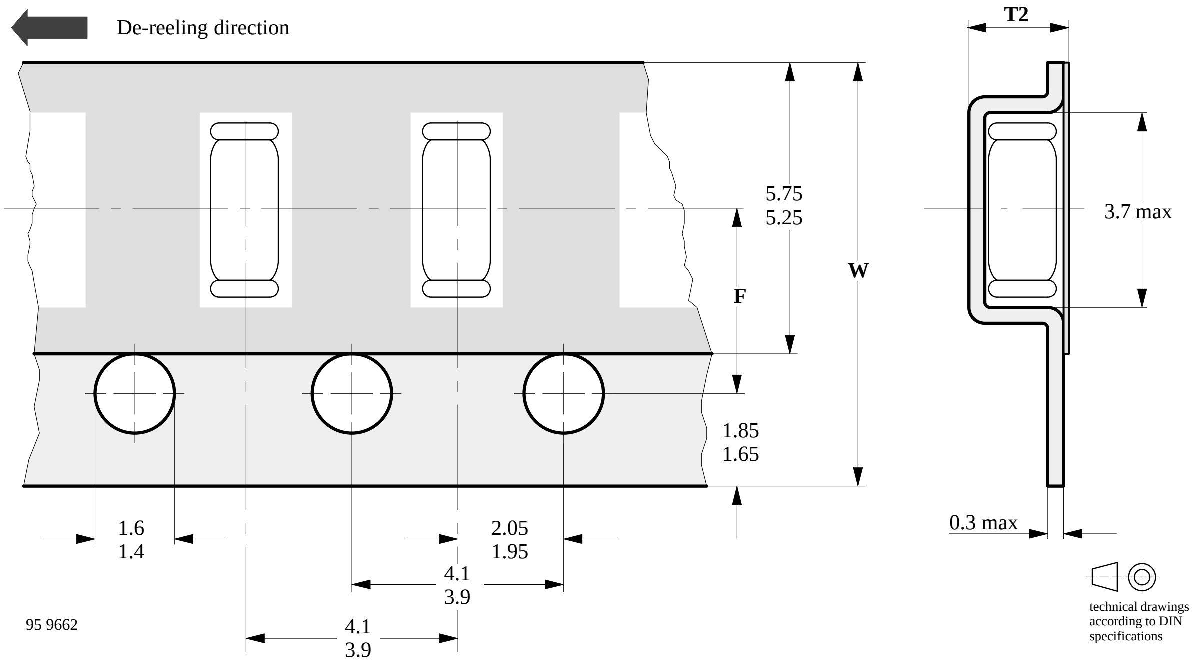


Figure 14.

Dimensions (mm)		
W	F	T2
8 ± 0.3	3.5 ± 0.05	2.5 mm max.
12 ± 0.3	5.5 ± 0.05	4.5 mm max.

Missing devices

A maximum of 0.5% of the total number of components per reel may be missing – exclusively at the beginning and at the end of the reel. A maximum of three consecutive com- ponents may be missing, provided this gap is followed by six consecutive components (see figure 15).

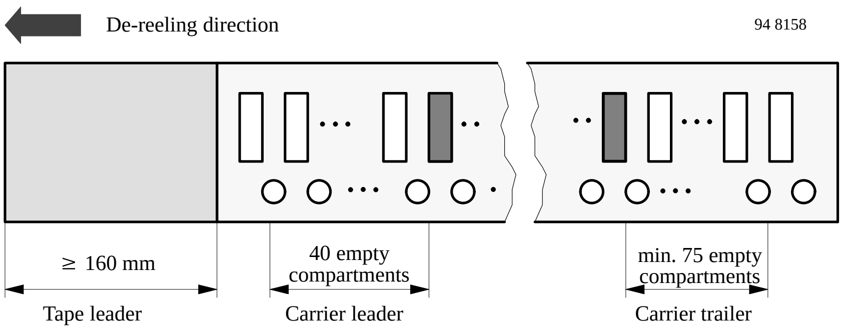
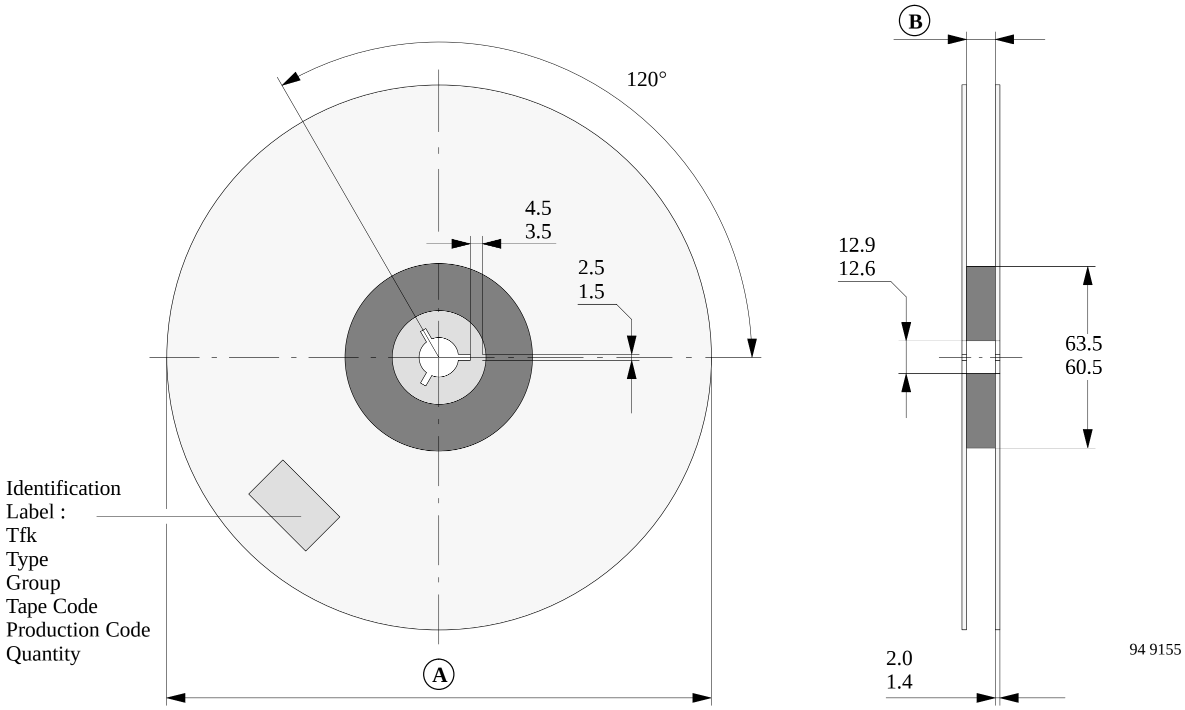


Figure 15.



A: 180 –2 mm or 330 – 2 mm
B: 9 to 10 mm or 12.4 to 14.4 mm

Figure 16.