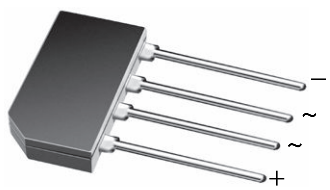
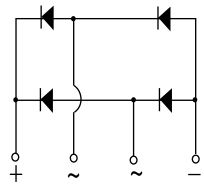
Glass Passivated Single-Phase Bridge Rectifier





Case Type GBL

PRIMARY CHARACTERISTICS	
Package	GBL
$I_{F(AV)}$	4 A
V_{RRM}	50 V, 100 V, 200 V, 400 V, 600 V, 800 V, 1000 V
I_{FSM}	150 A
I_R	5 µA
V_F at I_F = 4.0 A	1.0 V
T_J max.	150 °C
Diode variations	In-Line

FEATURES

- UL recognition file number E54214
- Ideal for printed circuit boards
- High surge current capability
- Typical I_R less than 0.1 µA
- High case dielectric strength
- Solder dip 275 °C max. 10 s, per JESD 22-B106
- Material categorization: For definitions of compliance please see www.vishay.com/doc?99912

TYPICAL APPLICATIONS

General purpose use in AC/DC bridge full wave rectification for monitor, TV, printer, SMPS, adapter, audio equipment, and home appliances application.

MECHANICAL DATA

Case: GBL

Molding compound meets UL 94 V-0 flammability rating
Base P/N-E3 - RoHS-compliant, commercial grade

Terminals: Matte tin plated leads, solderable per J-STD-002 and JESD 22-B102
E3 suffix meets JESD 201 class 1A whisker test

Polarity: As marked on body

MAXIMUM RATINGS (T_A = 25 °C unless otherwise noted)

PARAMETER		SYMBOL	GBL005	GBL01	GBL02	GBL04	GBL06	GBL08	GBL10	UNIT
Maximum repetitive peak reverse voltage		V_{RRM}	50	100	200	400	600	800	1000	V
Maximum RMS voltage		V_{RMS}	35	70	140	280	420	560	700	V
Maximum DC blocking voltage		V_{DC}	50	100	200	400	600	800	1000	V
Maximum average forward rectified output current at	T_C = 50 °C (1)	$I_{F(AV)}$	4.0							A
	T_A = 40 °C (2)		3.0							
Peak forward surge current single sine-wave superimposed on rated load		I_{FSM}	150							A
Rating for fusing (t < 8.3 ms)		I^2t	93							A^2s
Operating junction and storage temperature range		T_J, T_{STG}	- 55 to + 150							°C

Notes
(1) Unit mounted on 3.0" x 3.0" x 0.11" thick (7.5 cm x 7.5 cm x 0.3 cm) aluminum plate
(2) Unit mounted on PCB at 0.375" (9.5 mm) lead length and 0.5" x 0.5" (12 mm x 12 mm) copper pads

ELECTRICAL CHARACTERISTICS (T_A = 25 °C unless otherwise noted)

PARAMETER	TEST CONDITIONS	SYMBOL	GBL005	GBL01	GBL02	GBL04	GBL06	GBL08	GBL10	UNIT
Maximum instantaneous forward voltage drop per diode	4.0 A	V_F	1.0							V
Maximum DC reverse current at rated DC blocking voltage per diode	T_A = 25 °C	I_R	5.0							µA
	T_A = 125 °C		500							
Typical junction capacitance per diode	4.0 V, 1 MHz	C_J	95				40			pF

THERMAL CHARACTERISTICS (T_A = 25 °C unless otherwise noted)										
PARAMETER	**SYMBOL**	**GBL005**	**GBL01**	**GBL02**	**GBL04**	**GBL06**	**GBL08**	**GBL10**	**UNIT**
Typical thermal resistance	$R_{\theta JA}$ [(2)]	22							°C/W
	$R_{\theta JC}$ [(1)]	3.5							

Notes
(1) Unit mounted on 3.0" x 3.0" x 0.11" thick (7.5 cm x 7.5 cm x 0.3 cm) aluminum plate
(2) Unit mounted on PCB at 0.375" (9.5 mm) lead length and 0.5" x 0.5" (12 mm x 12 mm) copper pads

ORDERING INFORMATION (Example)				
PREFERRED P/N	**UNIT WEIGHT (g)**	**PREFERRED PACKAGE CODE**	**BASE QUANTITY**	**DELIVERY MODE**
GBL06-E3/45	2.18	45	20	Tube
GBL06-E3/51	2.18	51	400	Anti-static PVC tray

RATINGS AND CHARACTERISTICS CURVES (T_A = 25 °C unless otherwise noted)

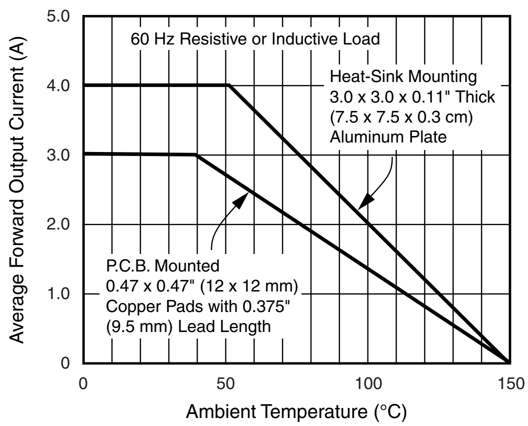


Fig. 1 - Derating Curves Outzput Rectified Current

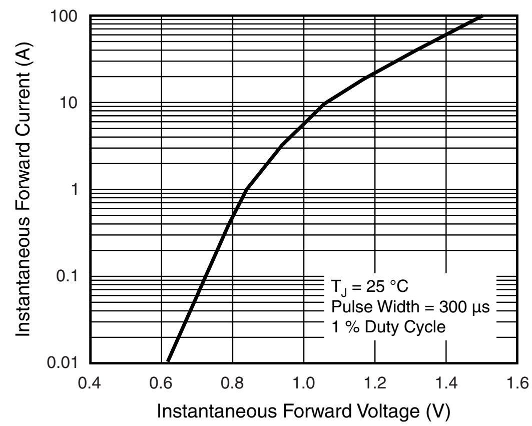


Fig. 3 - Typical Forward Voltage Characteristics Per Diode

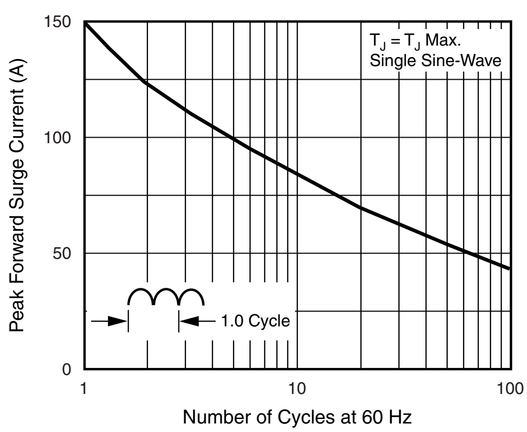


Fig. 2 - Maximum Non-Repetitive Peak Forward Surge Current Per Diode

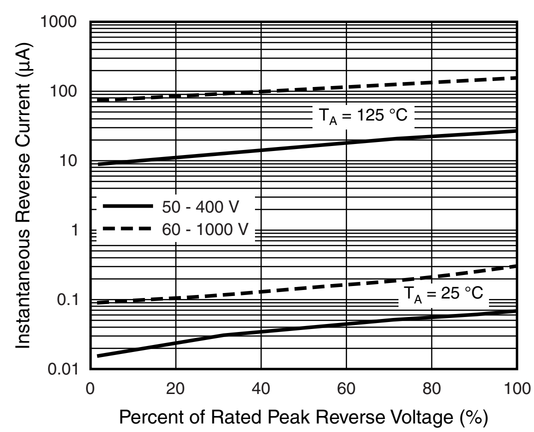


Fig. 4 - Typical Reverse Characteristics Per Diode

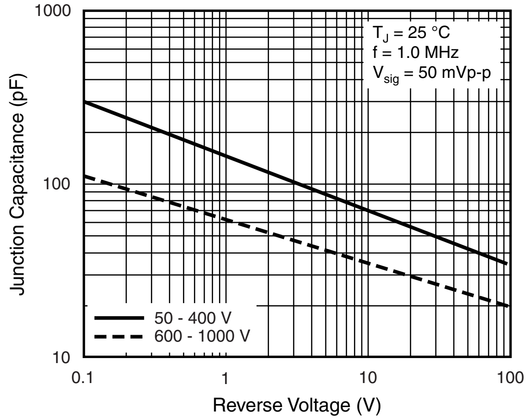


Fig. 5 - Typical Junction Capacitance Per Diode

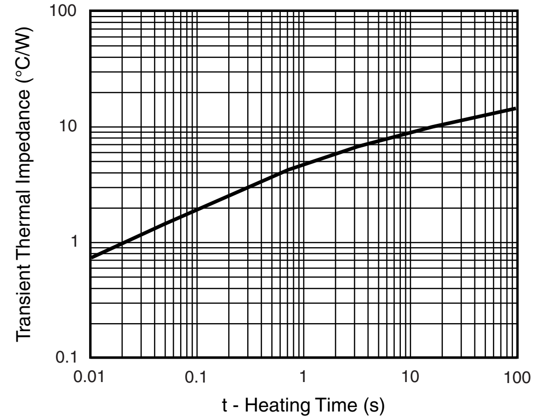
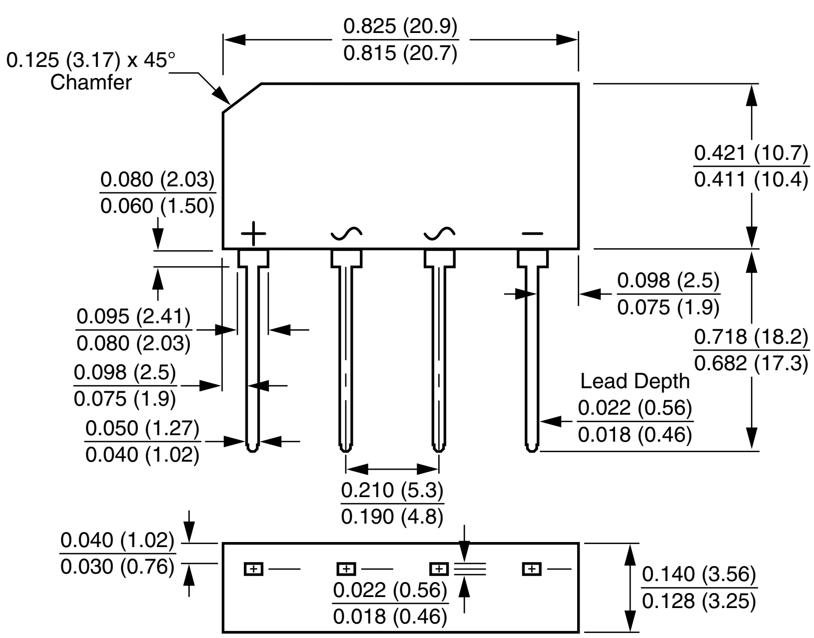


Fig. 6 - Typical Transient Thermal Impedance Per Diode

PACKAGE OUTLINE DIMENSIONS in inches (millimeters)

Case Type GBL



Polarity shown on front side of case, positive lead beveled corner

SUPERECTIFIER® Design Brings New Level of Reliability to Surface Mount Components

By Joseph M. Beck

Surface Mount technology is here to stay. After years of plodding through cautious experimentation, many manufacturers now have fully automated production lines in place. These production lines place circuit components at speeds that until recently would have been unthinkable. Finally being realized are the benefits of what was once considered a “Voo Doo” manufacturing technology. Component manufacturers have learned a great deal over the past several years as well. Initially most surface mount components were nothing more than retrofit, lead formed versions of their conventional leaded, through-hole counterparts. For most manufacturers this was the quickest and least costly method of “developing” a line of surface mountable components.

It was soon discovered, however, that this approach to component assembly would be unacceptable. Surface mount technology placed new demands upon circuit components. Electrically, the same power was being required from smaller and smaller packages. Package geometries and dimensions became critical in relation to pick and place equipment and circuit board mounting. In addition, the construction of these devices needed to be such that they would suffer no ill effects when subjected to the rigors of the new assembly environment that surface mount technology presented. Encountered in this environment was extremely high-speed pick and place equipment, component adhesive attachment, immersion in molten solder and rapid temperature changes associated with reflow soldering processes. All this meant that component manufacturers would have to re-think their approach to device fabrication. Yes, components needed to be smaller; but they also needed to be more reliable.

At Vishay General Semiconductor, the development of new surface mount components is not something that is taken lightly. It is realized that in order to produce a truly reliable surface mount product one must first consider all relevant aspects of the technology. Only when this process has been completed can a product be developed which is surface mountable, and inherently reliable.

SURFACE MOUNT SUPERECTIFIER®

Vishay General Semiconductor manufactures surface mount rectifiers in the popular MELF (metalized electro-face) package style. These devices, denoted as SUPERECTIFIERS, are available with a wide variety of electrical characteristics. The main difference, however, between these rectifiers and other MELF style devices lies in the area of device construction. Fig. 1. shows the unique construction employed in the manufacture of the Superectifier.

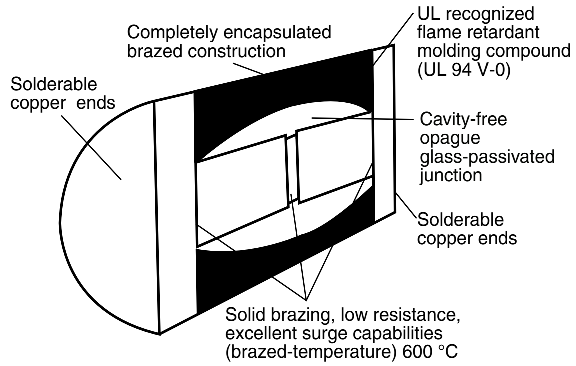


Fig. 1 - SUPERECTIFIER Construction

The construction of the Superectifier does not internally utilize any soft solders. All interconnects are accomplished by the use of a high temperature brazing process (600 °C). Hence, any chances of solder void occurrence or internal solder reflow during circuit board processing are eliminated. In addition, the silicon rectifier junction is completely encapsulated by a cavity-free glass. This glass encapsulation ensures that the rectifier junction is hermetically isolated from humidity and other harmful environmental intrusions.

The resultant sub-assembly could be considered to be a fully functional surface mount rectifier. In fact, many component manufacturers offer MELF devices which have this appearance; namely, an oblong glass bead with two protruding metal end terminations. However, in order that the device have a uniform shape, the General Semiconductor sub-assembly is over molded with epoxy. The result is a smooth, perfectly cylindrical package.

TWO SIZES

Two different size Superectifier MELF packages are available. Vishay General Semiconductor designation GL34 and GL41 are for 0.5 A and 1.0 A rectifier types, respectively. JEDEC® mechanical specifications DO-213AA and DO-213AB detail the dimensions of the GL34 and GL41, respectively. Fig. 2 gives these package dimensions.

SUPERECTIFIER® Design Brings New Level of Reliability to Surface Mount Components

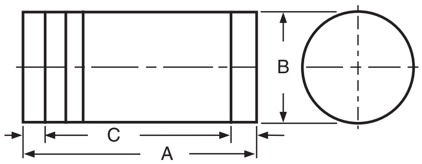


Fig. 2 - Dimensional Outline

DIMENSIONAL OUTLINE in inches				
DIMENSION	**GL34 DO-213AA**		**GL41 DO-213AB**	
	MIN.	**MAX.**	**MIN.**	**MAX.**
A	0.130	0.146	0.189	0.205
B	0.063	0.067	0.094	0.105
C	0.016	0.022	0.016	0.022

MANUFACTURING CONSIDERATIONS

Pick and Place-Surface mount SUPERECTIFIERS are supplied on tape and reel in accordance with JEDEC standard RS-481A. Removal of the devices from the embossed carrier tape is easily accomplished by all vacuum pick-up mechanisms which utilize a compliant tip. The compliant tip will form a tight seal around the cylindrical MELF design once contact with the device has been made. This is not always the case, however, when MELF devices with a non-uniform package outline are used. Fig. 3. shows two such MELF outlines. Fig. 3. A is a device with a concave package outline. This type of package is difficult to consistently remove from the carrier tape as the exact position of pick-up on the component body is critical. Fig. 3. B is that of the most common form of MELF packaging. This type of construction utilizes a nontransparent glass body which is often characterized by pitting and surface irregularities. The irregularities make it difficult for a vacuum pick-up to form a tight seal around the device body. The result is that components are often dropped onto the production room floor instead of being placed on the targeted circuit board.Vishay General Semiconductor solves these problems with a smooth surface and perfectly cylindrical package outline.

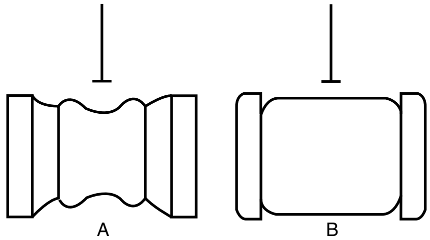


Fig. 3 - Non-Uniform Melf Outlines

Bonding Pads - The geometries and dimensions of bonding pads are critical to the proper mounting, soldering and overall performance of all surface mount components. Fig. 4. gives the recommended pad layouts for GL34 and GL41 MELF outlines. Use of these pad layouts will be primary assistance in the following three areas:

- Surface mount technology by nature dictates that smaller component packages dissipate the same power as their larger through-hole counterparts. Hence, adequate bonding pad land area is required in order to aid the component package in the dissipation of this power.The recommended pad layouts provide the needed land area for GL34 and GL41 devices to operate safely at their maximum ratings.
- Component adhesive attachment allows the package to shift slightly from its original placement position prior to adhesive curing. In addition, most adhesives tend to spread during the curing process which also may allow package misalignment. The geometry of the recommended pad layouts will tend to minimize such movements.This assumes, of course, that the package was originally positioned correctly.
- During reflow soldering, solder surface tension can have a significant effect on the movement and final position of components in relations to their bonding pads. The recommended pad layouts will actually make use of the solder surface tensions to bring MELF devices into alignment with the two bonding pad land areas.

This means that MELF devices which are initially placed in slight misalignment on their bonding pads will reposition themselves during solder reflow until a position of alignment is reached.

Soldering - Surface mount SUPERECTIFIERS are capable of withstanding all present forms of wave and reflow soldering. The following guidelines should be followed, however, in order to ensure overall package integrity:

- GL34-Maximum temperature at device and terminations not to exceed 400 °C for 5 s. Complete device submersible temperature not to exceed 260 °C for 10 s in solder bath.
- GL41-Maximum temperature at device end terminations not to exceed 450 °C for 5 s. Complete device submersible temperature not to exceed 265 °C for 10 s in solder bath.

Vishay General Semiconductor's surface mount SUPERECTIFIERS combine superb electrical performance with unmatched levels of reliability. The construction of the SUPERECTIFIER virtually eliminates all problems associated with high-speed pick and place of MELF components. In addition, SUPERECTIFIER construction ensures that performance and reliability are never compromised when the device is subjected to the demands of surface mount assembly techniques or when other seemingly harmful environments are encountered. Quite simply, no other surface mount rectifier comes close to offering all the advantages of the SUPERECTIFIER MELF.

SUPERECTIFIER® Design Brings New Level of Reliability to Surface Mount Components

All surface mount components are small and save space. However, performance and reliability should never be considered necessary trade-offs in order to utilize surface mount technology. Use of Vishay General Semiconductor surface mount SUPERECTIFIERS requires no such sacrifices; no trade-offs.

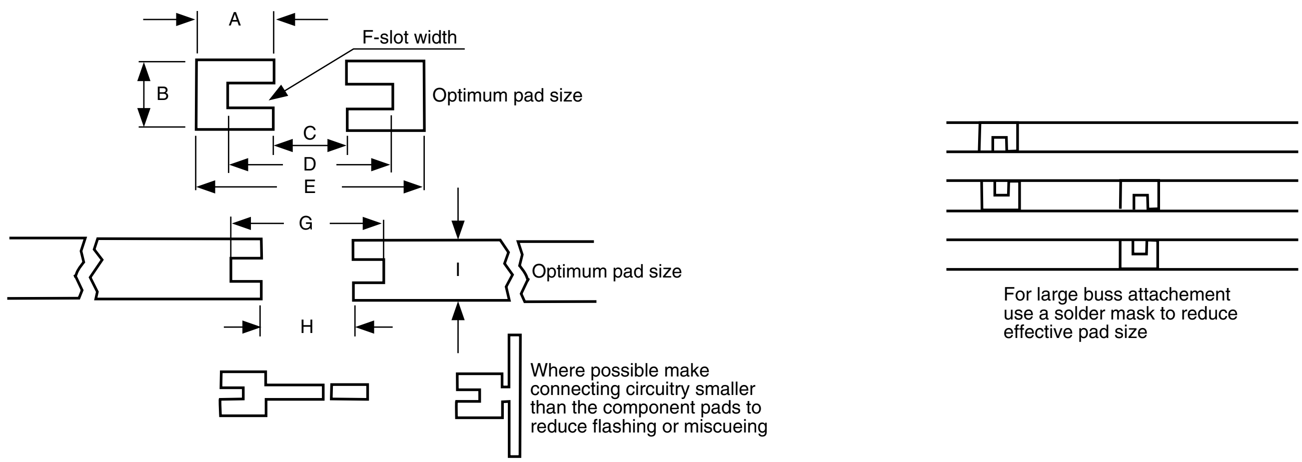


Fig. 4 - Recommended Pad Layout

RECOMMENDED PAD LAYOUT in inches		
DIMENSION	**GL34**	**GL41**
A	0.069	0.100
B	0.63	0.100
C	0.69	0.100
D	0.138	0.200
E	0.207	0.300
F	0.016	0.025
G	0.138	0.200
H	0.035 to 0.80	0.050 to 0.125
I	0.048 min.	0.075 min.

PART NUMBER	**CURRENT (A)**	**VOLTAGE (V)**	**t_{rr} (ns)**	**PACKAGING**
GENERAL PURPOSE				
GL34-J	0.5	50 to 600	-	GL34
1N6478-84	1.0	50 to 1000	-	GL41
GL41A-Y	1.0	50 to 1600	-	GL41
FAST RECOVERY				
RGL34A-J	0.5	50 to 600	150 to 250	GL34
RGL41A-M	1.0	50 to 1000	150 to 500	GL41
ULTRA FAST RECOVERY				
EGL34A-G	0.5	50 to 400	50.0	GL34
EGL41A-G	1.0	50 to 400	50.0	GL41

High Speed Data Line Protection

Low Current Bridges Rectifiers Lend Themselves to Data Line Protection

By Jon Schleisner

Local area network (LAN) data lines require protection against direct and induced transient over voltages on the lines. Protecting these lines and the associated network is not a trivial task. The power range is somewhere between static discharge (very low power) and lightening protection which is at the other end of the spectrum (high power).

Power handling capability is only one aspect of the design. The designer must take care not to “load down” the line with a highly capacitive TVS or R/C network. As data rates go beyond 50 mb. It is not possible to use a TVS unit with capacitance above 100 pF to 200 pF. Most standard TVS devices have zero volt capacitance values greater that 500 pF. To make matters worse, the lower voltage TVS units have higher capacitance values than their higher voltage counterparts. Enter the steering diode bridge.

Vishay offers two surface mount bridge rectifiers. These components are ideal for use in protection circuits where power handling, capacitive loading and cost are all design considerations. These are the 1 A bridge (DF01S) the smaller 1/2 A (MB1S) SMD bridge rectifiers. Each diode within the 1 A part has a 0 V capacitance of 70 pF. The 1/2 bridge has a junction capacitance of about 25 pF. These components can be configured with TVS components (such as an SMBJ12) to form a high performance, low capacitance network capable of outstanding data line protection in LAN and other similar applications where data lines are exposed to transient surges beyond the scope of static discharge. Since each bridge contains four diodes each component can protect 2 independent lines.

Fig. 1. shows the forward voltage drop of the 1 A and 1/2 A bridge when configured as shown in figure 1. The surge can be applied in either polarity and to either input individually or simultaneously.

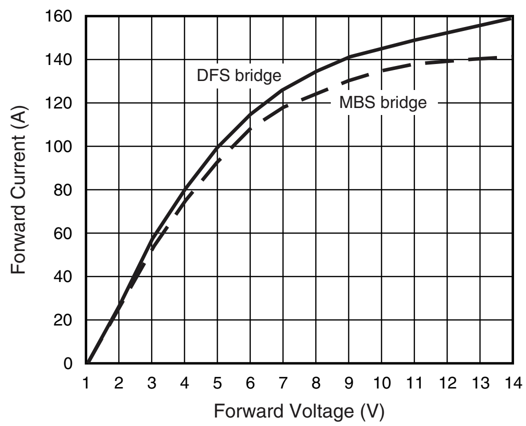


Fig. 1 - Forward Current vs. Forward Voltage

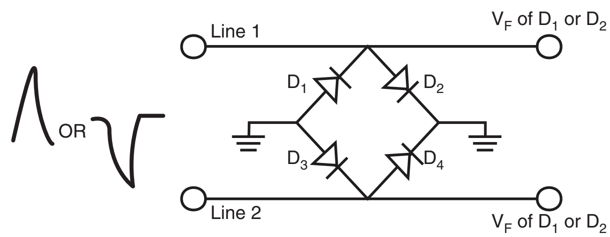


Fig. 2

These small components are capable of handling 120 (MBS) and 160 (DFS) A on the industry standard 10 μs/1000 μs current waveform. This is the same waveform that is used to test the axial and surface mount TVS components. For the MB1S the maximum V_F encountered at 120 A is 7 V hence, it is possible to use the 100 V version of either bridge in this application without fear of reliability issues caused by reverse breakdown of the diodes within the bridge during surge events.

The different steering diode / TVS configurations are illustrated in Fig. 3. through Fig. 7.

High Speed Data Line Protection

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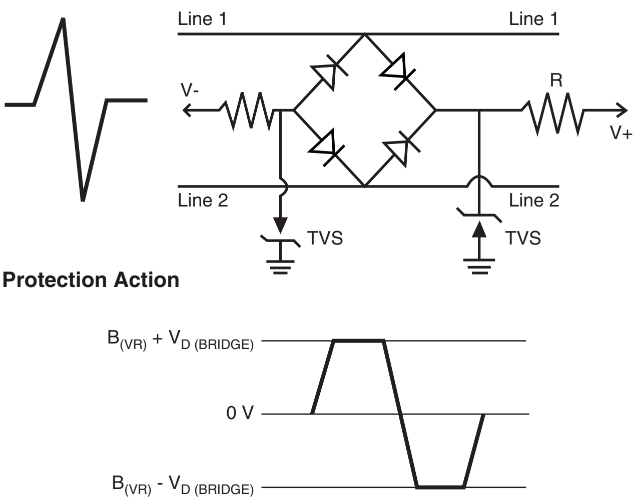
Fig. 3. shows the classic symmetrical bidirectional protector. TVS units are utilized to provide clamping protection for both positive and negative going transients. The “turn on threshold” of the network is specified by the B_{VR} of the TVS unit selected plus the forward voltage drop of the rectifier diode junction within the bridge being utilized. Because the currents encountered can vary between below 1 A and higher than 100 A. The forward voltage drop of the bridge may vary between 0.6 V and 7 V.

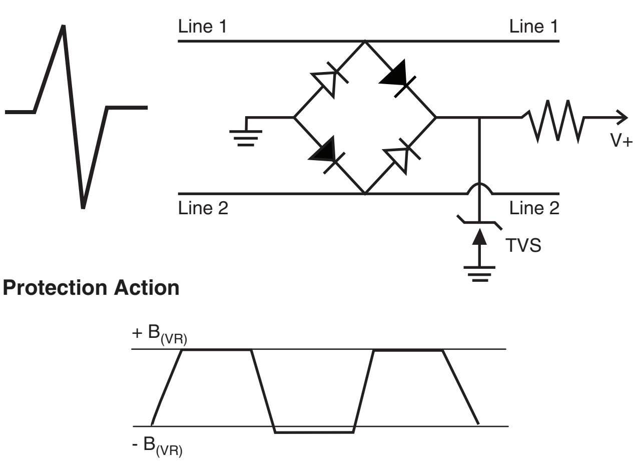
Incoming Transient



The Surge can be Applied to Either Line or Both
+ $B_{(VR)}$ and - $B_{(VR)}$ are Adjusted via TVS Parts Selection.

Fig. 3

Incoming Transient



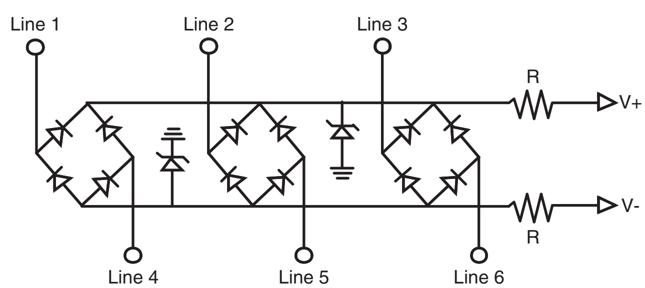
The Clamping Voltage Becomes:
$B_{(VR)\,(TVS)} + 2\,V_{F\,(BRIDGE)} = V_C$

Fig. 4

Fig. 4. is a configuration designed to provide a-symmetrical bi-polar protection, that is, the diode drop of 1 V is observed for negative going transients and the B_{VR} of the selected TVS provides the turn on characteristic for a positive going surge. This is a common configuration when protecting the input stages of transceiver ICs that are powered by ground and B+ and no negative power rail is utilized. The configuration can be reversed to provide the same style of surge suppression with a negative power source.

Both Fig. 3. and Fig. 4. have a resistor designated “R” going to either V+ or V-. These resistors can be any low power chip resistor in the 50K or above range. They are optional. The purpose of these resistors is to provide a low current forcing the TVS into the avalanche mode causing the impedance at this node to be low. This reduces crosstalk and maintains a reasonable voltage across the steering diodes minimizing the diode junction capacitance and assuring minimum circuit loading.

Fig. 5. graphically shows how multiple SMD bridge rectifiers can be used in conjunction with one or two TVS units in order to protect multiple line applications. Note that the cost of the TVS units then becomes amortized over the number of lines tied into it. In significant volumes it is possible to protect multiple data lines to a legitimate 600 W (on the 10 μs/1000 μs waveform) level at a cost far less than an individual TVS per line. And all the while the data lines are being loaded with less than 50 pF capacitance.



Multiple line protection can be implemented by tying several bridges into one set of TVS’s. For single supply systems, one TVS can be eliminated and that node connected to ground.

Fig. 5

High Speed Data Line Protection

Low Current Bridges Rectifiers Lend Themselves to Data Line Protection

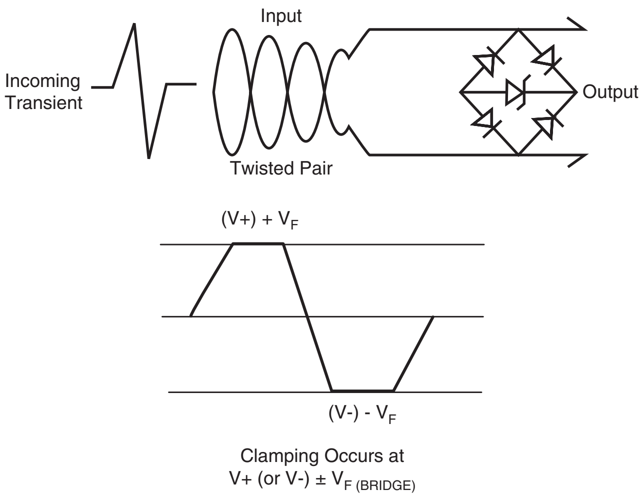
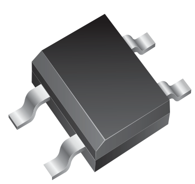


Fig. 6

Fig. 6. shows an alternate method of using a SMD bridge to provide effective low loss protection for “twisted pair” arrangements.

DFS



MBS

Fig. 7. demonstrates a method of using the bridge rectifier arrangement to protect transceiver I/O ports by “steering” the transient overvoltages to either power supply rail or a single rail and ground. It is important to remember good “house keeping” when employing this topology ie; low inductance capacitors should bypass the power supply rails close to the circuitry being protected. If these rules are not followed the leading edge of any steep rise time transient will not be absorbed by the power supply. This will result in higher “let through” voltages and less effective protection.

The resultant performance of any of these circuits is severely influenced by parasitic elements in the circuit. Robust low impedance ground planes and simple PCB traces are essential. Series inductance in the PCB traces or grounding scheme will cause higher than expected let though voltage on fast rising transients. How fast is fast? and how much let through voltage is excessive? That will depend on the components you are protecting.

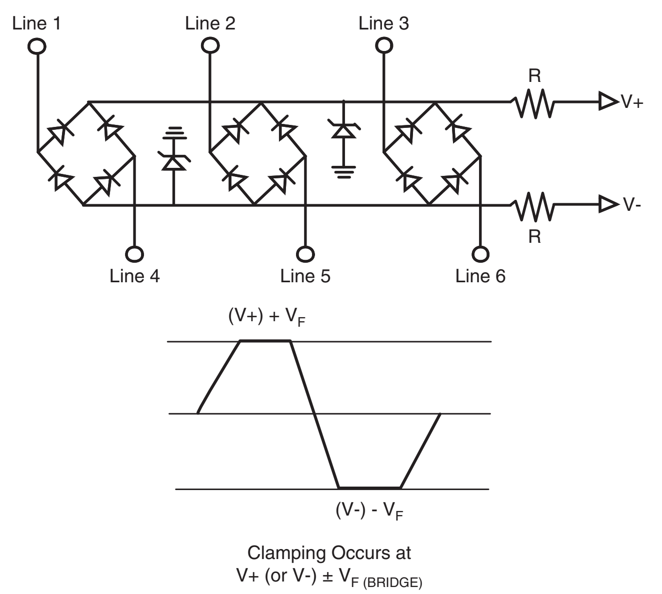


Fig. 7

Design Guidelines for Schottky Rectifiers

By Jon Schleisner, Senior Technical Marketing Manager

INTRODUCTION

Known limitations of Schottky rectifiers - including limited high temperature operation, high leakage and limited voltage range - can be measured and controlled, allowing wide application on switch mode power supplies.

Schottky rectifiers have been used in the power supply industry for approximately 15 years. During this time, significant fiction as well as fact has been associated with this type of rectifier. The primary assets of Schottky devices are switching speeds approaching zero-time and very low forward voltage drop (V_F). This combination makes Schottky barrier rectifiers ideal for the output stages of switching power supplies. On the negative side, Schottky devices are also known for limited high-temperature operation, high leakage and limited voltage range B_{VR}. Though these limitations exist, they are quantifiable and controllable, allowing wide application of these devices in switch mode power supplies.

High leakage, when associated with standard P-N junction rectifiers, usually indicates “badness,” implying poor reliability. In a Schottky device, leakage at high temperature (75 °C and greater) is often on the order to several mA, depending on chip size. In the case of Schottky barrier rectifiers, high-temperature leakage and forward voltage drop are controlled by two primary factors: the size of the chip’s active area and the barrier height (ϕB).

Design of a Schottky rectifier can be viewed as a trade off. A high barrier height device exhibits low leakage at high temperature, however, the forward voltage drop increases. These parameters are also controlled by the die size and resistivity of the starting material. A larger die will lower the V_F but raise the leakage if all other parameters are held constant. The resistivity of the starting material must be chosen in a range where the breakdown voltage (B_{VR}) is not degraded at the low end and the forward end of the resistivity range. Since a larger chip size is obviously more expensive, this is not the primary method for controlling these parameters. Chip size is usually set to a dimension where the current density through the die is kept at a safe level.

BARRIER HEIGHT (ϕB), A FACTOR

Vishay General Semiconductor produces two product lines of Schottky barrier rectifiers. One line is referred to as the “MBR” series, a high-temperature, low-leakage, relatively high V_F type of Schottky device with a high barrier height (ϕB). The second line is the “SBL” series, designed to operate at lower temperature (125 °C or less); however, while leakage current is higher, forward voltage drop (V_F) is significantly lower and they are designed with a low-ϕB barrier height. The low- ϕB-line SBL series uses a nichrome barrier metal with a barrier height of ϕB = 0.64 eV. The high-ϕB MBR series uses a nichrome-platinum barrier metal to achieve barrier height (ϕB = 0.71 eV). Both series are guard-ring protected against excessive transient voltages.

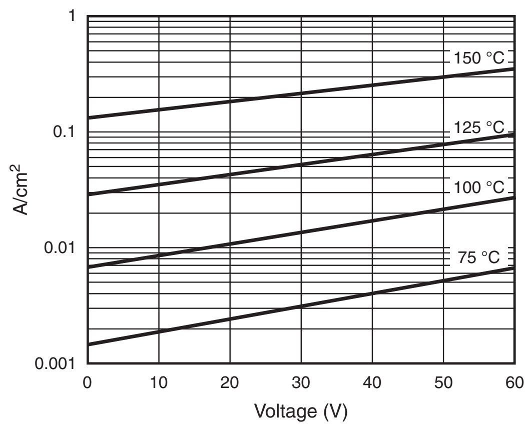


Figure 1.

Both the low and high-barrier-height Schottky devices are valuable in a variety of applications. When the true operating temperature of the Schottky rectifier exceeds 125 °C, the high-barrier-height series must be used to avoid thermal runaway.

This occurs when excessive self-heating of the rectifier causes large leakage currents, resulting in additional selfheating. The process becomes a form of positive thermal feedback and may lead to damage in the rectifier or inappropriate functioning of the circuit utilizing the device.

Design Guidelines for Schottky Rectifiers

Using a high-barrier-height (MBR) component prevents this anomaly, but sacrifices higher forward voltage. Operating the low barrier height (SBL) series at a junction temperature of 125 °C, a decision on the use of a low- or high-barrier-height Schottky device must be made.

The following procedure has been developed to provide an analytical method of selecting the most efficient Schottky barrier device for a given application.

CALCULATING THE BARRIER HEIGHT (ϕB) OF SCHOTTKY RECTIFIERS

Calculating the barrier height of a Schottky rectifier where ϕB is not given is a straightforward process. The following two equations will yield an excellent engineering approximation of the barrier height, ϕB:

ϕB = (- KT/q) LN (J/R x T) *(1)*

$J_0 = I_0$ / active area (cm^2)
ϕB = barrier height (eV)
K = Boltzmann's constant = 8.62 x 105 eV/°K
T = ambient temperature in degrees Kelvin
J_0 = current density at zero volts
R^* = Richardson's constant = $112/cm^2k^2$
I_0 = forward current at zero volts

To solve equation (1), the current density J_0 (equation (2)) must be found first:

$J = I_0$ / active area ($cm^{2)}$) *(2)*

Vishay General Semiconductor provides the active area of its Schottky die in its product literature. If a manufacturer does not supply this information, decapsulating the device under question and measuring it with a precision caliper can provide an approximation of the active Schottky area, assuming 90 % of the total chip area is active.

Total die area x 0.9 = active area *(3)*

The calculation of I_0 is done graphically (figure 2.). A minimum of three low-current room-temperature forward voltage drop V_F measurements are needed. This data is graphed on semi-log paper (figure 2.) where the vertical axis (log scales) is the current and the horizontal axis (linear scale) is the measured V_F When these points are graphed, the result should be a true straight line. If the graph curves downward (see the dotted line on the left side of figure 2.), it indicates that the lowest measurement current is being affected by the rectifier's room temperature leakage. In this case, the current level at which the V_F measurements are taken should be increased to "swamp" out the contribution of low level leakage on the measurement. If the current levels are raised excessively, the series resistance of the device in question will influence the measurements. This causes a downward curve as represented by the dotted line on the right side of figure 2. Again, the results should yield a true straight line.

The point where the line intercepts the vertical axis is the current at zero Volts (I_0). J_0 is then calculated:

$J_0 = I_0$ / active area (cm^2) *(2)*

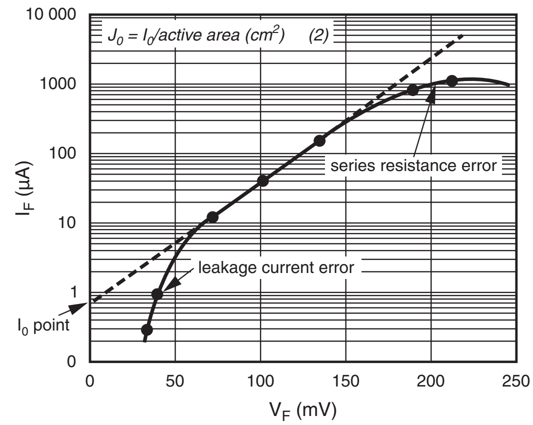


Figure 2. Calculation of J_0 (current density at zero Volts)

This result is then placed into the first equation:

ϕB = (- KT/q) LN ($J_0/R \times T^2$) *(4)*

The results of the calculation are usually in the range of 0.6 eV to 0.8 eV. Results well outside this range indicated either a defective rectifier, measurement, or calculation error.

SELECTING EFFICIENT SCHOTTKY DEVICES

Normalized graphs of the low (SBL) and high (MBR) barrier height processes are provided. The vertical axis on all graphs is in Amperes per square centimeter (A/cm^2). The horizontal axis provides forward voltage drop for the low and high barrier parts. Two additional graphs have the horizontal axis labeled for reverse voltage (V_R) for both the low and high barrier series. The graphs for the low barrier (SBL) series parts have curves for operation at 75 °C, 100 °C, and 125 °C.

Design Guidelines for Schottky Rectifiers

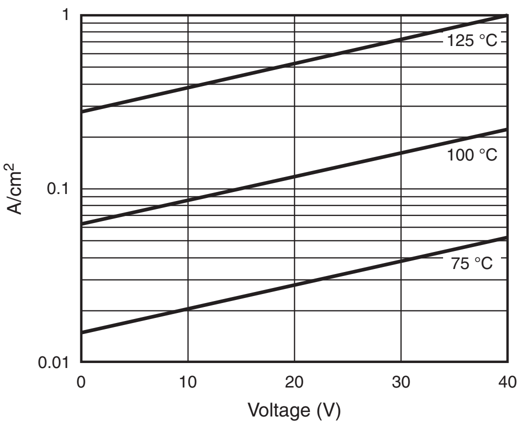


Figure 3. Voltage vs. Die Area Leakage Barrier Height = 0.64 V

These curves may be used in two ways. If the die size, barrier height, temperature and forward current (I_F) are known, V_F can be graphically calculated. Using the leakage curves, and knowing the reverse voltage (V_R) to which the device will be subjected, it is possible to find the leakage current. Conversely, if the circuit parameters are set, the curves will provide the die size in A/cm² equations, making it possible to analytically select either a low or high-barrier-height rectifier for maximum circuit efficiency. Most Schottky rectifiers are used in switch mode power supplies.

To select a Schottky rectifier that yields maximum efficiency, it is necessary to determine the "duty cycle equilibrium point", or the duty cycle point at which both a low- and high-barrier-height part will dissipate precisely the same amount of power:

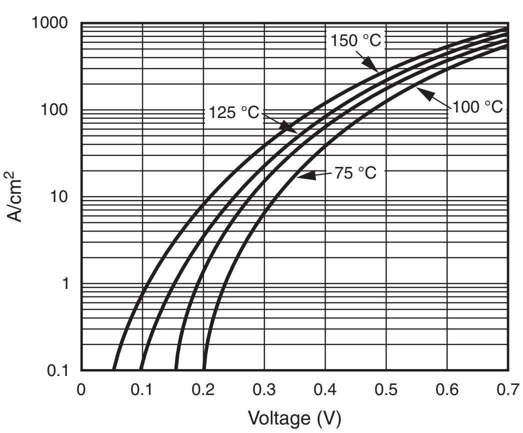


Figure 4. Die Area Current vs. Forward Voltage Drop Barrier Height = 0.71

$$D\,(P_{df}\phi BL) + (1 - D)(P_{dr}\phi BL) + = D(P_{dr}\phi BH) + (1 - D)(D_{dr}\phi BH) \tag{1}$$

$$P_{dt} = P_{df} + P_{dr} \tag{2}$$

$$P_{df} = I_F \times V_F \tag{3}$$

$$P_{dr} = I_R \times V_R \tag{4}$$

D = duty cycle forward conduction
$1 - D$ = duty cycle reverse blocking
I_F = forward current
I_R = reverse current
P_{df} = power dissipation in forward
P_{dt} = power dissipation in reverse
P_{dt} = total power dissipation
V_F = forward voltage drop
V_R = reverse voltage
ϕBL = low barrier height
ϕBBH = high barrier height

The following is an example of the use of this equation:

Given the need for a 30 V Schottky capable of operating at 10 A, the choice is between a SBL1040 (ϕB = 0.64) or a MBR1045 (ϕBH = 0.71). These two devices were chosen for convenience in this example because of their equal die size (0.0477 cm² active area).

The equilibrium point must be calculated for 75 °C, 100 °C, and 125 °C. For demonstration purposes, only the 75 °C equilibrium point will be calculated in the same manner. The reverse leakage (I_R) and forward voltage drop (V_F) are derived from graphs 1 through 4 using the temperature, die size and ϕB given above.

For the low-barrier-height SBL1040:

$$P_{dr} = V_R \times I_R = Watts \tag{4}$$

$$30\ V \times (1.9 \times 10^{-3}\ A) = 0.057\ W$$

$$P_{dr} = I_F \times V_F = Watts \tag{3}$$

$$10\ A \times 0.46\ V = 4.6\ W$$

For the high-barrier-height MBR1045:

$$P_{dr} = V_R \times I_R = Watts \tag{4}$$

$$-\ 30\ V \times (1.43 \times 10^{-4}\ A) = 4.29 \times 10^{-3}\ W$$

$$P_{df} = I_F \times V_F = Watts$$

$$10\ A \times 0.565\ V = 5.65\ W$$

Solving for the equilibrium point at 75 °C:

LOW BARRIER **HIGH BARRIER**

$$(D \times P_{df}\phi BL) + [(1 - D) \times P_{dr}\phi BL] = (D \times P_{df}\phi BH) + [(1 - D) \times P_{dr}\phi BH]$$

$$(D \times 4.6\ W) + [(1 - D)\ 0.057\ W] = (D \times 5.65\ W) + [(1 - D)\ 0.00429\ W]$$

$$0.05271 = 1.1027 \times D$$

$$D = 0.0478$$

$$D\ \% = 0.0478 \times 100$$

Duty cycle equilibrium point, D - 4.78 %

Design Guidelines for Schottky Rectifiers

Switching loss is assumed to be equal on both sides of the equation and thus ignored. This procedure is then repeated for 100 °C and 125 °C. After calculating the equilibrium point for 100 °C and 125 °C, the results are:

DUTY CYCLE EQUILIBRIUM	
TEMPERATURE	**POINT %**
75 °C	4.78 %
100 °C	15.93 %
125 °C	52.42 %

The results of these calculations are graphed in figure 6. To the left of the equilibrium curve, the high-barrier-height MBR1045 is most efficient; to the right of the equilibrium curve, the low barrier-height SBL1040 is more efficient. This is easy to understand because the high-barrier-height part exhibits lower reverse power loss and at a low duty cycle more time is spent in the reverse mode.

With the duty cycle higher than the equilibrium point, the part spends a larger percentage of time in the forward mode, and the low-barrier-height type part has a lower V_F and the forward power losses are reduced.

With knowledge of the application, including expected duty cycle and temperature, it is possible to choose the most efficient Schottky barrier rectifier, constructing a graph similar to figure 5.

It is thus easy to graph the duty cycle versus temperature, as in figure 6., and by knowing the application (expected duty cycle and temperature), make the intelligent choice of the most efficient Schottky rectifier for the application in question.

This analysis technique enables the design engineer to make an efficient and cost-effective choice of Schottky rectifier in duty-cycle-based systems. In addition, light has hopefully been shed on the difference in design philosophies between the low- and high-ϕB style of Schottky rectifiers.

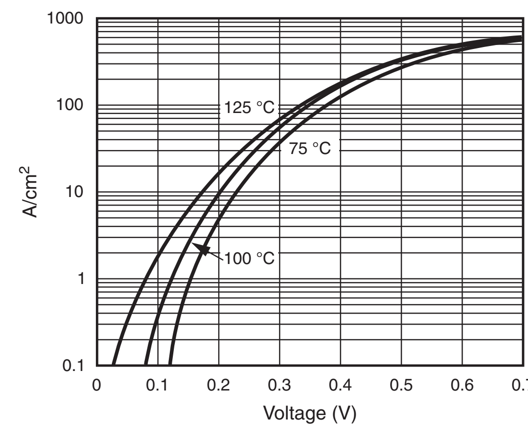


Figure 5. Die Area Current vs. Forward Voltage Drop
Barrier Height = 0.64

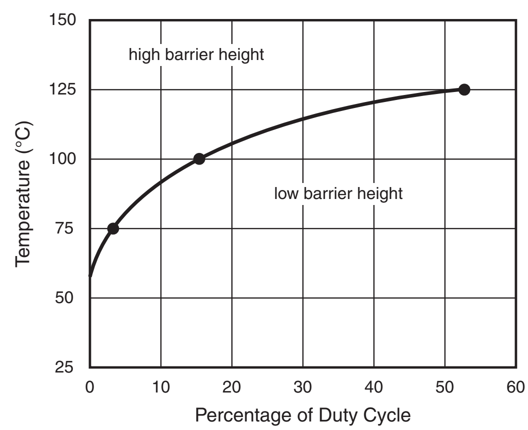


Figure 6. Duty Cycle Equilibrium MBR1045 vs. SBL1040

APPLICATION NOTE

Physical Explanation

GENERAL TERMINOLOGY

Semiconductor diodes are used as rectifiers, switches, varactors and voltage stabilizers (see Zener data book).

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 1.

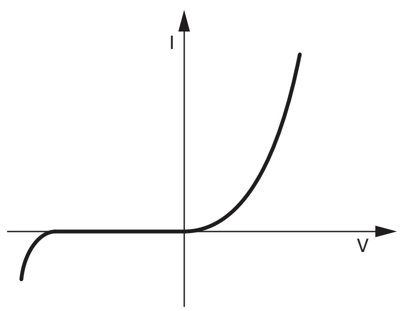


Fig. 1

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

$V_T = \frac{k \times T}{q}$ = 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 valid 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 V_{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.

Physical Explanation

Rectification efficiency, η_r

The ratio of the DC load voltage to the peak input voltage of an RF rectifier.

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, $f \geq 25$ Hz, or pulse operation, $f \geq 25$ Hz, having a duty cycle $t_p/T \leq 0.5$.

Peak reverse voltage, V_{RRM}

The maximum reverse voltage having an operating frequency $f \geq 25$ 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_A = 25 °C at a specified distance from the case (both ends).

Switching on Characteristic

Forward recovery time, t_{fr}

The time required for the voltage to reach a specified value (normally 110 % of the steady state forward voltage drop), after instantaneous switching from zero or a specified reverse voltage to a specified forward biased condition (forward current).

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.

Turn on transient peak voltage, V_{fp}

The voltage peak (overshoot) after instantaneous switching from zero or a specified reverse voltage to a specified forward biased condition (forward current). The forward recovery is very important especially when higher forward currents must be switched on within a very short time (switching on losses).

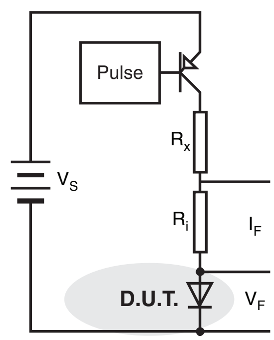


Fig. 2

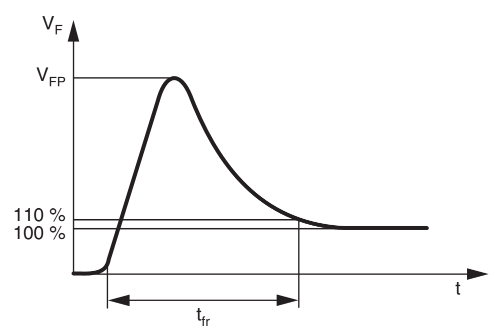


Fig. 3

Switching off Characteristic, Inductive Load

Reverse recovery time, t_{rr}

The time required for the current to reach a specified reverse current, i_R (normally 0.25 % of I_{RM}), after switching from a specified forward current I_F to a specified reverse biased condition (reverse voltage V_{Batt}) with a specified slope dI_F/dt.

Physical Explanation

Peak reverse recovery current, I_{RM}

The peak reverse current after switching from a specified forward current I_F to a specified reverse biased condition (reverse voltage V_R) with a specified switching slope dI_F/dt.

The reverse recovery is very important especially when switching from higher currents to high reverse voltage within a very short time (switching off losses).

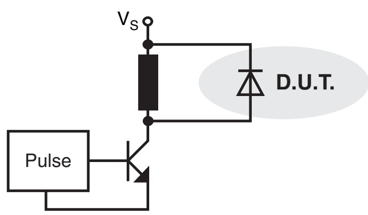


Fig. 4

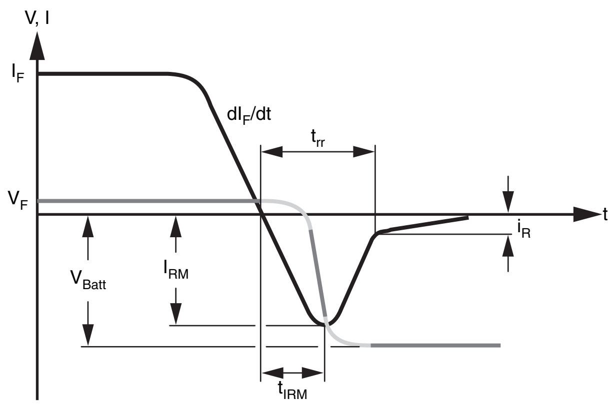


Fig. 5

Reverse avalanche energy, E_R

The reverse avalanche energy when using the rectifier as a freewheeling diode with an indicutive load. When the inductance is switched off, the current through the inductance will keep on flowing through the D.U.T. until the stored energy,

$$E_R = \frac{1}{2} \times L \times I^2$$

is dissipated within the rectifier. Under this condition the diode is in a reverse avalanche mode with a reverse current at the beginning which is equal to the current that was flowing through the inductance just before it was switched off.

The reverse energy capability depends on the reverse current and the junction temperature prior to the avalanche mode.

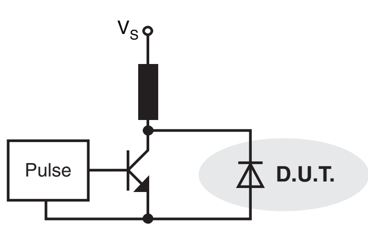


Fig. 6

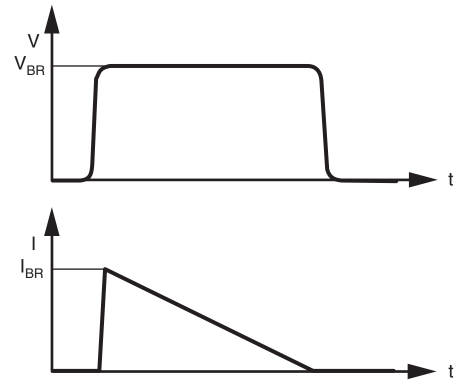


Fig. 7

Switching off Characteristic, Instantaneous Switching

Reverse recovery time, t_{rr}

The time required for the current to reach a specified reverse current, i_R (normally 0.25 A), after instantaneous switching from a specified forward current I_F (normally 0.5 A) to a specified reverse current I_R (normally 1.0 A).

Reverse recovery charge, Q_{rr}

The charged stored within the diode when instantaneous switched from a specified forward current I_F (normally 0.5 A) to a specified reverse current I_R (normally 1.0 A).

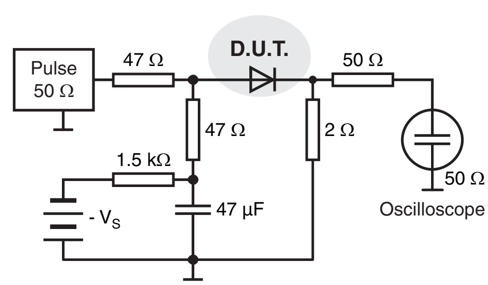


Fig. 8

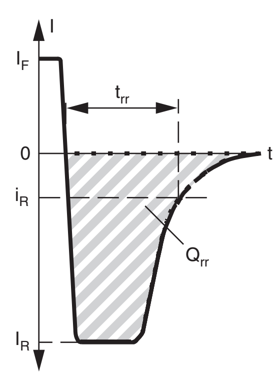
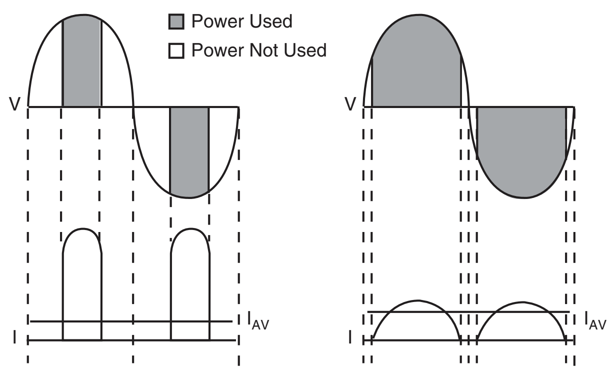


Fig. 9

Power Factor Correction with Ultrafast Diodes

More and more switched mode power supplies (SMPS) are being designed with an active power factor correction (PFC) input stage. This is mainly due to the introduction of regulations aimed at restricting the harmonic content of the load current drawn from power lines. However, both the user and the power company benefit from PFC, so it just makes good sense.

Non-PFC power supplies use a capacitive input filter, when powered from the AC power line. This results in rectification of the AC line, which in turn causes high peak currents at the crests of the AC voltage, as in Fig. 1a. These peak currents lead to excessive voltage drops in the wiring and imbalance problems in the three-phase power delivery system. This means that the full energy potential of the AC line is not utilized.



a. No Power Factor Correction
b. Power Factor Corrected Input

Fig. 1 - Non-PFC vs. PFC Waveforms (Current, Voltage)

Power Factor Correction (PFC) can be defined as the reduction of the harmonic content, and / or the aligning of the phase angle of incoming current so that it is in phase with the line voltage. By making the current waveform look as sinusoidal and in phase with the voltage waveform as possible, as in Fig. 1b, the power drawn by the power supply from the line is maximized for real power.

Real power is equal to $V_{RMS} \times I_{RMS} \times \cos \varphi$, where φ is the phase difference between the voltage and current waveforms. Therefore, as φ approaches zero, $\cos \varphi$ approaches unity, which maximizes the real power (now just $V_{RMS} \times I_{RMS}$).

Mathematically, Power Factor (PF) is equal to Real Power / Apparent Power.

The basic concept behind PFC is to make the input look as much like a resistor as possible. Resistors have a power factor of 1 (unity). This is ideal, because it allows the power distribution system to operate at its maximum efficiency.

Lets consider a continuous conduction mode (CCM) boost converter being used for active PFC. The boost topology was chosen because it is the least expensive (cheapest) solution, and cost is always a major consideration. Please refer to Fig. 2.

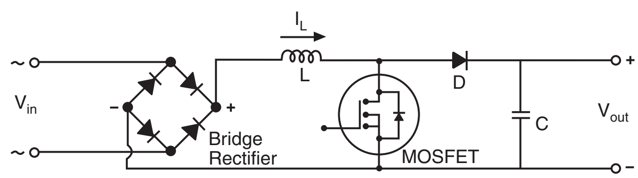


Fig. 2 - Continuous Mode Boost Converter Circuit

The input full-wave bridge rectifier converts the alternating current (AC) to direct current (DC). The MOSFET is used as an electronic switch, and is cycled "on" and "off" by an external source. While the MOSFET is "on", the inductor (L) current increases. While the MOSFET is "off", the inductor delivers current to the capacitor (C) through the forward biased output diode (D). The inductor current does not fall to zero during each switching cycle, which is why this is known as a "continuous conduction mode." The MOSFET is pulse-width-modulated so that the input impedance of the circuit appears purely resistive, and the ratio of peak to average current is kept low.

The most cost-effective way of reducing losses in the circuit is by choosing a suitable diode for the application. Diodes for use in PFC circuits typically have higher forward voltages than conventional ultrafast epitaxial diodes, but much shorter (faster) reverse recovery times.

Vishay recommends the use of the UH-series for PFC applications.

Power Factor Correction with Ultrafast Diodes

TABLE 1 - PFC ULTRAFAST RECTIFIERS - MINI SELECTOR GUIDE					
VISHAY PART NUMBERS	**CASE OUTLINE**	**DESCRIPTION**	**I_{AV} (A)**	**V_{RRM} (V)**	**t_{rr} (ns)**
USB260	DO-214AA (SMB)	Plastic SMD	2	600	30
MURS260	DO-214AA (SMB)	Plastic SMD	2	600	50
31GF6	DO-201AD	Plastic Axial	3	600	30
SUF30J	P600	Plastic Axial	3	600	35
MURS360	DO-214AB (SMC)	Plastic SMD	3	600	50
MUR460	DO-201AD	Plastic Axial	4	600	50
UHF5JT	ITO-220AC	Isolated Power Pack	5	600	25
UH5JT	TO-220AC	Plastic Power Pack	5	600	25
UG5JT	TO-220AC	Plastic Power Pack	5	600	25
UGB5JT	TO-263AB	Power Pack SMD	5	600	25
UGF5JT	ITO-220AC	Isolated Power Pack	5	600	25
UH8JT	TO-220AC	Plastic Power Pack	8	600	25
UHF8JT	ITO-220AC	Isolated Power Pack	8	600	25
UG8JT	TO-220AC	Plastic Power Pack	8	600	25
UGB8JT	TO-263AB	Power Pack SMD	8	600	25
UGF8JT	ITO-220AC	Isolated Power Pack	8	600	25
UG12JT	TO-220AC	Plastic Power Pack	12	600	30
UGB12JT	TO-263AB	Power Pack SMD	12	600	30
UGF12JT	ITO-220AC	Isolated Power Pack	12	600	30
UG15JT	TO-220AC	Plastic Power Pack	15	600	35
UGB15JT	TO-263AB	Power Pack SMD	15	600	35
UGF15JT	ITO-220AC	Isolated Power Pack	15	600	35

Rectifiers for Power Factor Correction (PFC)

CCM (continuous-conduction-mode) and CRM (critical-conduction-mode) devices are most widely adapted in commercial applications for power factor correction. CCM devices are often used in SMPS with output power ratings greater than 300 W; while CRM devices are often used in SMPS with output power ratings less than 300 W. CRM PFC devices operate in the boundary mode between CCM PFC and DCM (discontinuous-conduction-mode) PFC devices.

PFC devices are generally selected base on the speed of their reverse recovery time (t_{rr}). Currently for CCM and CRM PFC devices in market, rectifiers up to 600 V with t_{rr} smaller or equal to 35 ns are generally used as CCM PFC; rectifiers up to 600 V with reverse recovery time between 35 ns to 60 ns, are used as CRM PFC.

It should be noted there is a trade-off between forward voltage drops and switching speed; when the reverse recovery time of ultrafast rectifiers are less than 35 ns, their forward voltage drops would increase significantly, in turn the devices' forward surge current abilities would be diminished, therefore cautious attention should be taken when selecting the appropriate CCM or CRM PFC devices for various switch mode power supply applications, such that expected performance could be achieved and better reliability would still be ensured.

WHAT ARE THE EFFECTS OF NON-PFC-EQUIPPED CIRCUITS

Non-PFC power supplies use a capacitive input filter, as shown in Fig. 1, when powered from AC power line. This results in rectification of the AC line, which in turn causes peak currents at the crest of the AC voltage, as shown in Fig. 2. These peak currents lead to excessive voltage drops in the wiring and imbalance problems in the three-phase power delivery system. This means that the full energy potential of the AC line is not utilized.

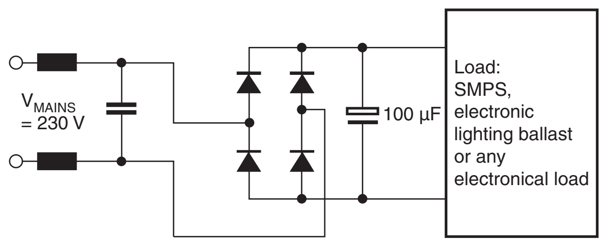


Fig. 1 - Standard Bridge Rectification of Line Voltage

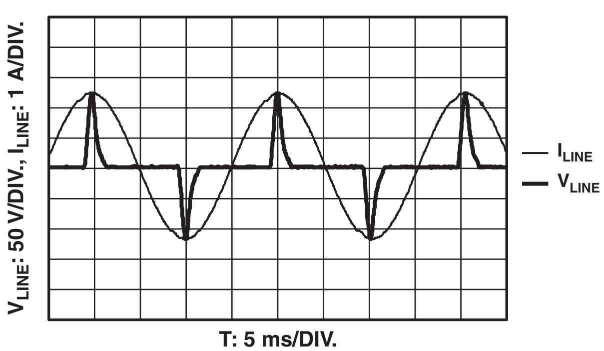


Fig. 2 - 20 W Resistive Load Powered by a Circuit like Fig. 1

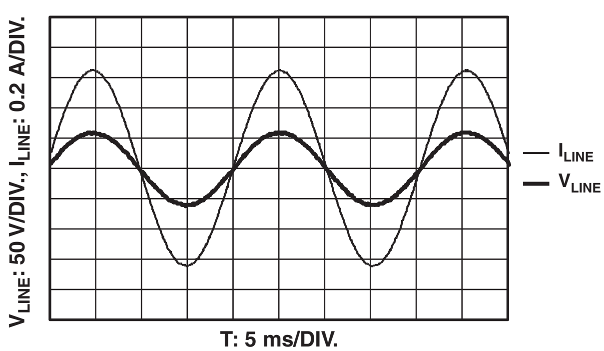


Fig. 3 - Same Load like Fig. 2, but Unity Power Factor

Rectifiers for Power Factor Correction (PFC)

Power factor correction (PFC) can be defined as the reduction of the harmonic content. By making the current waveform look as sinusoidal as possible, as shown in Fig. 3, the power drawn by the power supply from the line is then maximized to real power. Assuming that the voltage is almost sinusoidal, power factor depends first of all on the current waveform.

Thus real power can be defined as:

$$P = V_{RMS} \times I_1 \times \sin(\omega_1 t)$$

$$S = \sqrt{P^2 + Q^2}$$

$$V_{RMS} \times \sqrt{I_1^{\ 2} \times \sin(\omega_1 t)^2 + I_2^{\ 2} \times \sin(\omega_2 t)^2 + \ldots + I_n^{\ 2} \times \sin(\omega_n t)^2}$$

That means that real power only is carried by the fundamental harmonic, all the higher harmonics are carrying only reactive power. Eliminating the higher harmonics means increasing power factor to unity.

The definition of power factor is:

$$\text{Power factor} = \frac{\text{Real power}}{\text{Apparent power}}$$

For the circuit in Fig. 1. the power factor is typically about 40 % to 50 %.

For example (related to Fig. 1. and Fig. 2.):

The following measurements can be done with the circuit in Fig. 1.:

C =	100 µF	R =	680 Ω
I_{TRMS} =	495 mA	P =	20 W
S =	43 VA	Q =	38 var

Power factor = 0.464

With the same resistor directly connected to the line terminals or using power factor correction the following results can be achieved:

I_{TRMS} =	172 mA	P =	20 W
S =	20 W	Q =	0

Power factor = 1

This simple example gives a good impression what happens if all electronic equipment is powered without PFC. Obviously we see in this example the same real power, but big differences in RMS current.

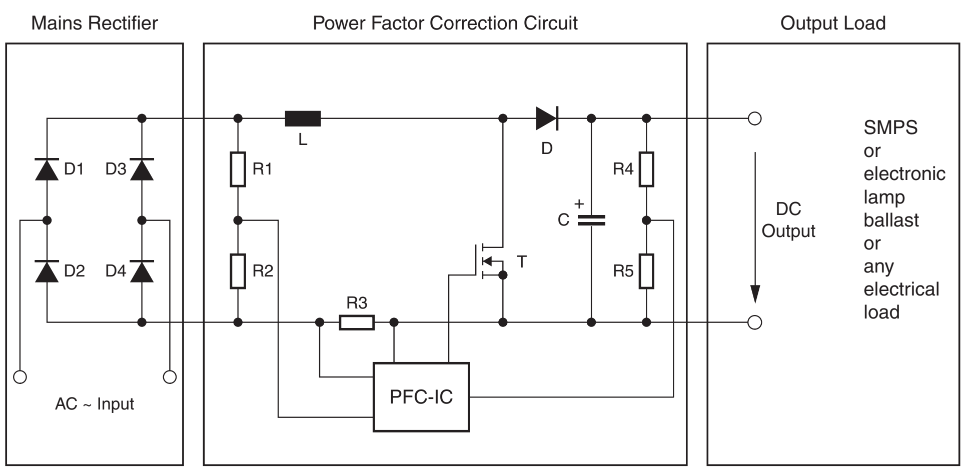


Fig. 4 - Typical Boost Converter Topology for Active PFC

Because it is the most cost saving solution the continuous conduction mode (CCM) boost converter as shown in Fig. 4, is today the most used topology for active power factor correction.

The bridge rectifier BR1 converts the AC input current into DC current. The MOSFET T is used as an electronic switch, and is cycled "on" and "off" driven by the PFC-IC. While the MOSFET is "on" the inductor current through L increases. While the MOSFET is "off", the inductor delivers current to the capacitor C through the forward biased output rectifier diode D. The inductor current does not fall to zero during the entire switching cycle, because this operation is called "continuous conduction mode (CCM)". This mode is suitable for almost all load current variations. If a constant load current is expected the so-called "discontinuous conduction mode (DCM)", where currents falls at the end of each cycle to zero, should be preferred. The MOSFET anyway is pulse-width-modulated so that the input impedance of the circuit appears purely resistive, and the ratio of peak to average current is kept low.

The most cost-effective way of reducing losses in the circuit is by choosing a suitable diode D for the application. Diodes for use in PFC circuits typically have higher forward voltages than conventional fast epitaxial diodes, but much shorter (faster) reverse recovery times.

Rectifiers for Power Factor Correction (PFC)

HOW A STANDARD PFC CIRCUIT WORKS

Fig. 4. shows the typical topology of a PFC pre-stage that is built of a standard boost converter driven by a control IC. It is important that at the output of the Rectifier BR1 there will be no ”large” smoothing capacitor with several μF connected, because that would eliminate all efforts of the PFC circuit, although it would operate sufficiently. The input voltage of the PFC is a rectified DC voltage pulsed with double line frequency. The shown switch is usually implemented by an IGBT or Power-MOS transistor.

Operation principle:

The instantaneous value of the current through the boost inductor has to be adapted as well as possible to the instantaneous value of the line voltage through suitable pulse-width modulation of the transistor switch T. The actual inductor current can be won by the voltage drop at R3. The input voltage can be found at the voltage divider R1, R2. The current amplitude will be regulated on the value of the output voltage, R4, R5.

To be able to control the current through the boost inductor, the output voltage of the PFC has to be higher at every moment of operation than the crest of the line input voltage. For 230 V mains the DC output should be about 400 V. A large capacitor at the output does not affect the power factor, but is good for smoothing the DC voltage.

An additional advantage of PFC circuit is the regulated DC voltage that gives the opportunity of having a following SMPS to be wide range operated (e.g. 110 V to 230 V input voltage).

ADVANTAGES OF CIRCUITS WITH PFC

- The use of PFC allows the manufacturer of electrical load to use smaller, more cost-effective mains rectifiers because of smaller RMS current with PFC.
- Offers a stable regulated output voltage which is the input voltage for the following electrical load. Indeed the PFC makes it a system based wide-range power supply itself.
- The following electrical load (SMPS, electronic ballast unit or other electrical load) can be much simpler, which is also a cost saving factor.

Vishay General Semiconductor recommends the use of their ultrafast rectifier series of PFC rectifier.

RECOMMENDED REVERSE VOLTAGES FOR MOST USED LINE VOLTAGE LEVELS	
V_{LINE} RMS (V)	V_{RRM} (V)
110	400
120	400
230	600
277	600

Fundamentals of Rectifiers

Within the diode family rectifiers are the largest class. One talks about rectifiers, if the specified current is above 0.5 A. Below 0.5 A one normally talks about diodes.

Rectifiers are primarily used, as their name already indicates, for conducting in one direction and blocking in the other.

Within rectifiers there are several groups depending on the reverse recovery characteristic (reverse recovery time t_{rr}):

- Standard rectifiers with a $t_{rr} > 500$ ns
- Fast rectifiers with a 100 ns $< t_{rr} <$ 500 ns
- Ultrafast rectifiers with a $t_{rr} < 100$ ns
- Schottky rectifiers with majority carrier effect

Except Schottky rectifiers all these are of p-n junction technology with different processes to optimize the characteristics for different applications. They are placed in different packages, leaded like the Sinterglass, SMD like DO214AC (SMA) or TO-220 to fullfill different mounting and power requirements.

Because of their predominant rectifying qualities, rectifiers are primarily used for power or signal conditioning in a variety of applications. This can range from high power output rectifier applications (e.g. power plants, railways,...) to low power switching rectifier requirements (e.g. mobile phone chargers, energy saving lamps,...). They are also used in several other specialized ways like clamping networks for SMPS (e.g. BYT42), damper and modulator diodes for the deflection circuits in CRTs (e.g. BY228), freewheeling diodes for inductive loads etc.

For specialized rectifying applications, silicon controlled rectifiers (SCRs) are used. But these are not simply diodes they have a third terminal, the gate.

The other special group of rectifiers, the Schottky rectifiers, are not use the conventional p-n junction, they have a barrier metal design. These are also non controlled rectifiers with two terminals only. Their big advantage is the excellent switching characteristic compared to even the fastest p-n junction diode. For more details about Schottky rectifiers, please refere to Application Note “Fundamentals of Schottky Rectifiers”

Figure 1. below shows the basic rectifier characteristics with the two regions, the forward conducting region, in which the forward current I_F flows and the reverse blocking region, in which the reverse leakage current I_R flows.

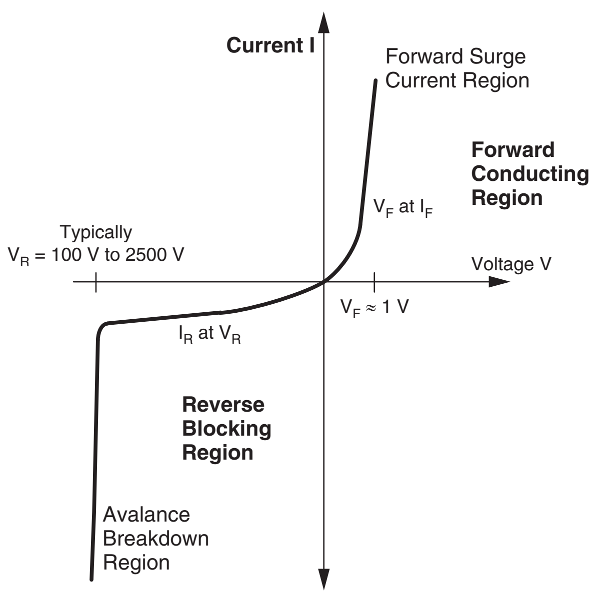


Fig. 1 - Basic Rectifier Characteristics

Fundamentals of Rectifiers

The major parameters for the selection of the appropriate rectifier are the maximum reverse voltage (V_{RRM}), the average forward current ($I_{F(AV)}$) and for switching application the reverse recovery characteristic (t_{rr}) too. Additional parameters may be, for example forward, surge capability (I_{FSM}) etc.

BASIC RECTIFIER PARAMETERS

V_R Reverse voltage

V_{RRM} Repetitive peak reverse voltage, including all repeated reverse transient voltages

V_{BR} Reverse breakdown voltage

I_R Reverse (leakage) current, at a specified reverse voltage V_R and temperature T_J

I_F Forward current

V_F Forward voltage drop, at a specified forward current I_F and temperature T_J

$I_{F(AV)}$ Average forward output current, at a specified current waveform (normally 10 ms/50 Hz half sine wave, sometimes 8.3 ms/60 Hz half sine wave), a specified reverse voltage and a specified mounting condition (e.g. lead-length = 10 mm or PCB mounted with certain pads and distance)

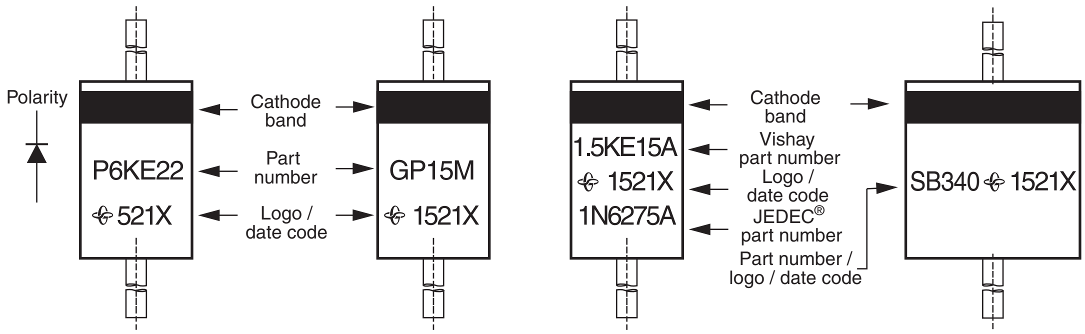
I_{FSM} Peak forward surge current, with a specified current waveform (normally 10 ms/50 Hz half sine wave, sometimes 8.3 ms/60 Hz half sine wave)

t_{rr} Reverse recovery time, at a specified forward current (normally 0.5 A), a specified reverse current (normally 1.0 A) and specified measurement conditions (normally from 0 to 0.25 A)

Vishay General Semiconductor

AXIAL MARKING

Package: DO-41 (DO-204AL), DO-15 (DO-204AC), DO-201AD, GP20, 1.5KE, P600
Examples:



DATE CODE (for RoHS-compliant products)

5 21 X   15 21 X

Factory designator
Week by calendar year (21st)
Last two digits of year (2015)

Factory designator
Week by calendar year (21st)
Last digit of year (2015)

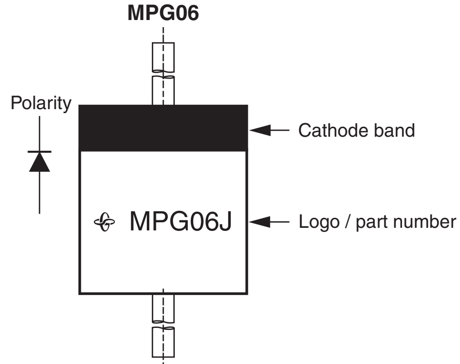
DATE CODE (for halogen-free products)

M 5 21 X

Factory designator
Week by calendar year (21st)
Last digit of year (2015)
"M" prefix denotes halogen-free compound

Notes
(1) No cathode band marking for TVS bi-directional type
(2) Date code per individual part number specification

MPG06

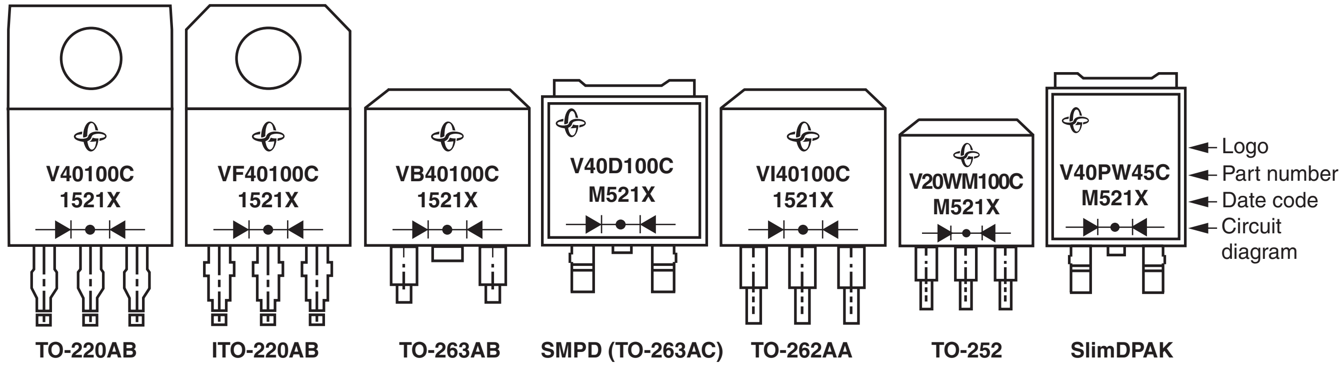


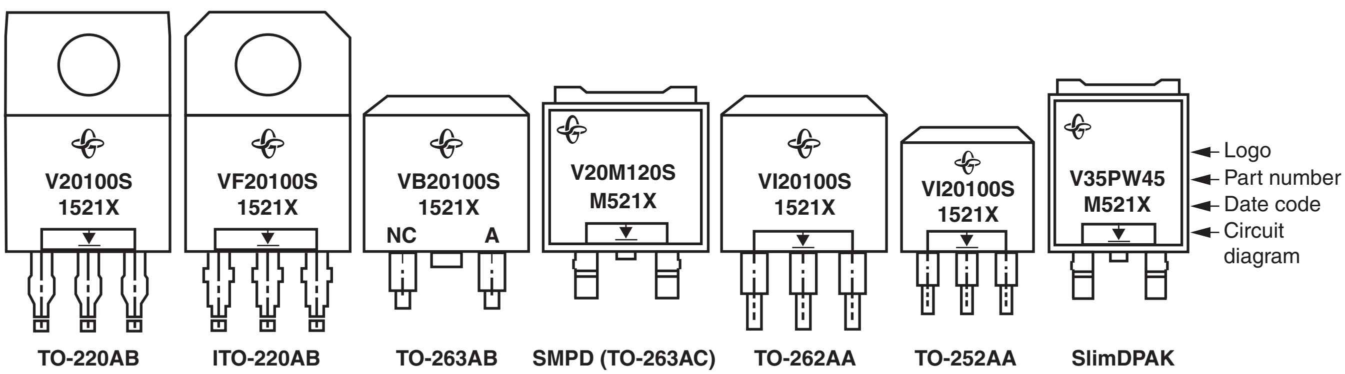
PART NUMBER MARKING CODE		
TYPE	**RoHS-COMPLIANT**	**HALOGEN-FREE**
MPG06 series	MPG06x	M06x
RMPG06 series	RMPG06x	MR06x
UG06 series	UG06x	MUG06x
SB0x series	SB0x0	MSB0x0
TPMP06 series	T-x	MT-x

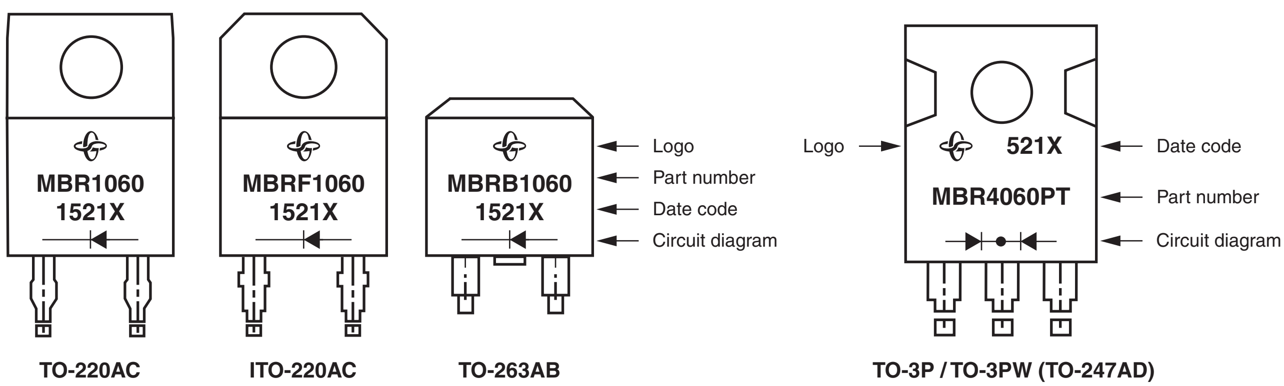
Note
- x - type code

POWER PACK MARKING

Examples:







DATE CODE (for RoHS-compliant products)

5 21 X — 15 21 X

- X: Factory designator
- 21: Week by calendar year (21st)
- 15: Last two digits of year (2015)

- X: Factory designator
- 21: Week by calendar year (21st)
- 5: Last digit of year (2015)

DATE CODE (for halogen-free products)

M 5 21 X

- X: Factory designator
- 21: Week by calendar year (21st)
- 5: Last digit of year (2015)
- M: "M" prefix denotes halogen-free compound

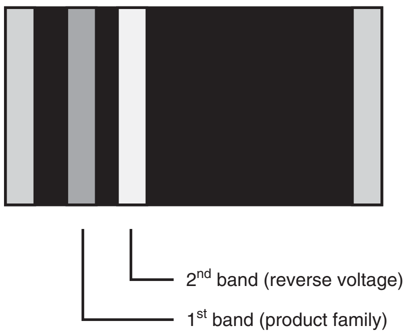
Notes

(1) Date code per individual part number specification

PLASTIC MELF AND MiniMELF MARKING

1. Package: GL41 (DO-213AB)

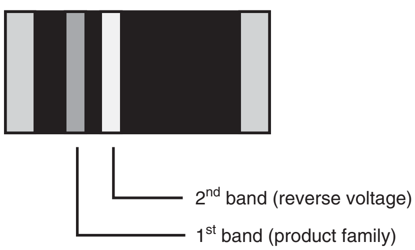
MELF
2.5 mm x 4.9 mm



TYPE	1st BAND	2nd BAND	
BYM10 series	white	gray: 50 V	violet: 1000 V
GL41 series	white	red: 100 V	white: 1300 V
BYM11 series	red	orange: 200 V	brown: 1600 V
RGL41 series	red	yellow: 400 V	
BYM12 series	green	green: 600 V	
EGL41 series	green	blue: 800 V	
BYM13 series	orange	gray: 20 V orange: 40 V green: 60 V	
SGL41 series	orange	red: 30 V yellow: 50 V	
TGL41-xx	blue		
ZGL41-xx	red		

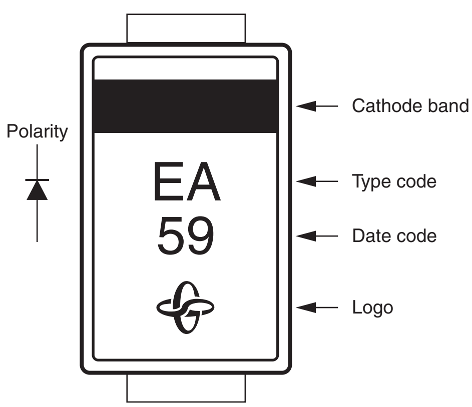
2. Package: GL34 (DO-213AA)

MiniMELF
1.6 mm x 3.5 mm

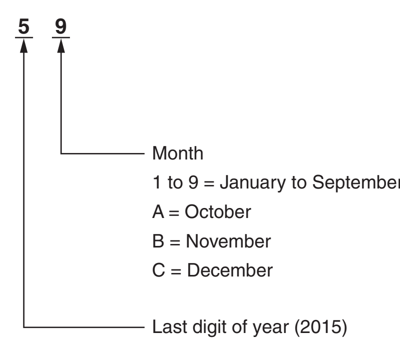


TYPE	1st BAND	2nd BAND	
BYM07 series	white	gray: 50 V	brown: 300 V
GL34 series	white	red: 100 V	yellow: 400 V
EGL34 series	green	pink: 150 V	green: 600 V
RGL34 series	red	orange: 200 V	blue: 800 V

GF1 (DO-214BA) MARKING



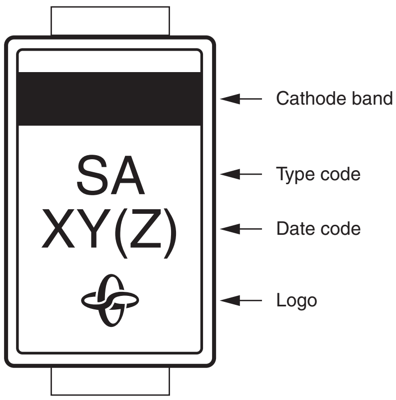
DATE CODE



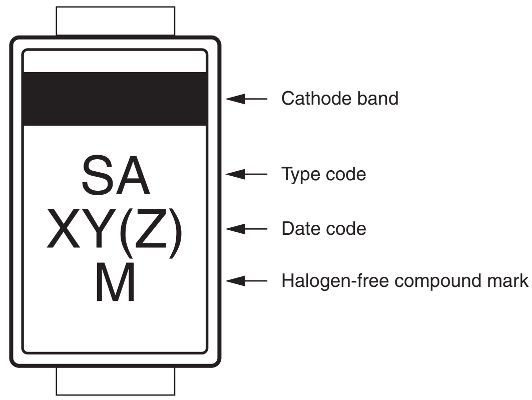
Note
- Type code refers to individual datasheet

SMA (DO-214AC), SMB (DO-214AA), SMC (DO-214AB), SlimSMA (DO-221AC), AND SMPA (DO-221BC) MARKING

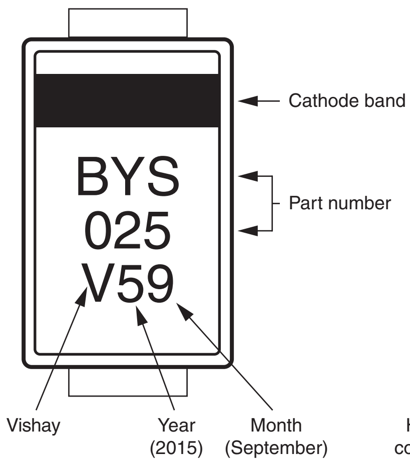
SMA, SMB, SMC



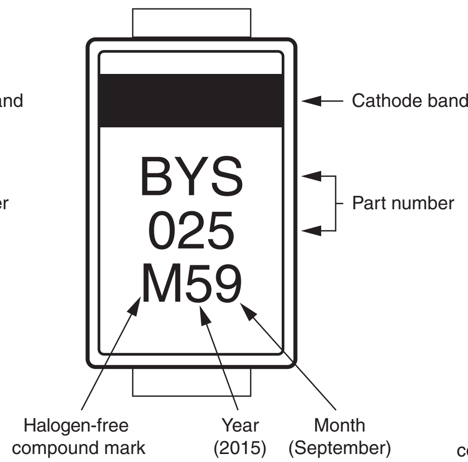
SMA, SMB, SMC, SlimSMA, SMPA



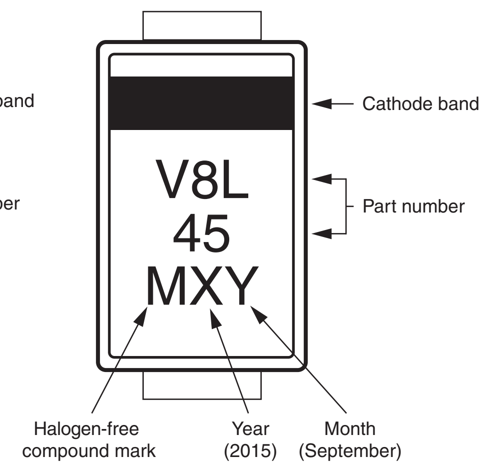
SMA
with "BYS", "BYG" Prefix



SMA
with "BYS", "BYG" Prefix



SMA, SMB, SMC
(for TMBS products with long core part number)



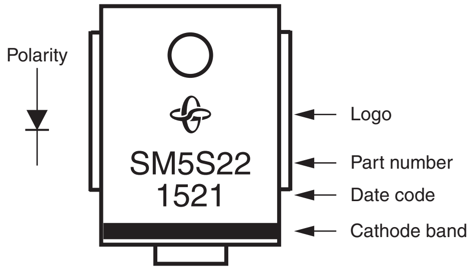
DATE CODE

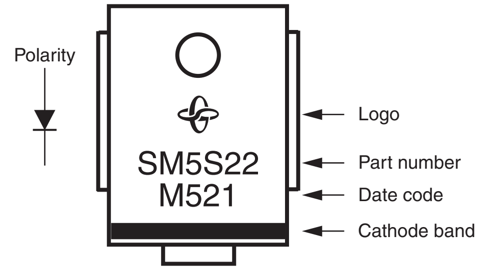
X Y Z

- Z: Factory designator
- Y: Month
  - 1 to 9 = January to September
  - A = October
  - B = November
  - C = December
- X: Year (e.g., 5 = 2015
  6 = 2016)

Notes
- Type code refers to individual datasheet
- No cathode band marking for TVS bi-directional type
- "XY" 2 digits: For rectifiers and PAR TVS (TPSMA, TPSMB, TPSMB, TPSMC, and TA6F)
- "XYZ" 3 digits: For TransZorb® TVS and Power Voltage-Regulating Diodes
- Non "M" mark belongs to RoHS-compliant product

DO-218AB MARKING





DATE CODE (for RoHS-compliant products)

15 21

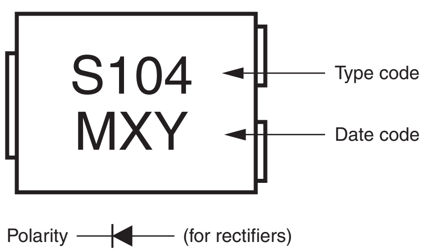
- 21: Week by calendar year (21st)
- 15: Last two digits of year (2015)

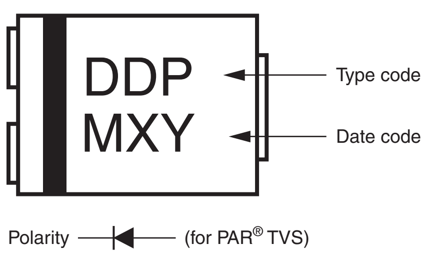
DATE CODE (for halogen-free products)

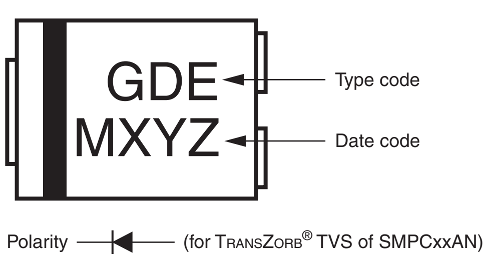
M 5 21

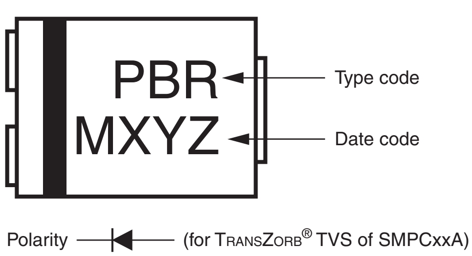
- 21: Week by calendar year (21st)
- 5: Last digit of year (2015)
- M: "M" prefix denotes halogen-free compound

SMPC (TO-277A) MARKING









DATE CODE

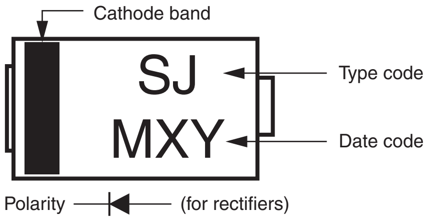
M X Y Z

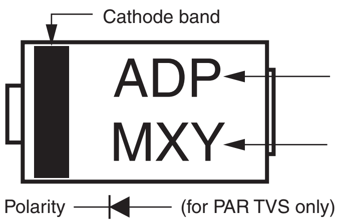
- Z: Factory designator
- Y: Month
  - 1 to 9 = January to September
  - A = October
  - B = November
  - C = December
- X: Year (e.g., 5 = 2015, 6 = 2016)
- M: "M" prefix denotes halogen-free compound

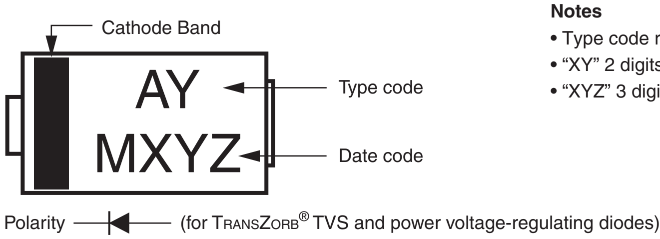
Notes

- Type code refers to individual datasheet
- "XY" 2 digits: for rectifiers and PAR® TVS
- "XYZ" 3 digits: for TransZorb® TVS
- TransZorb® TVS: cathod band depends on actual polarity
- No cathode band marking for bi-directional PAR TVS type

SMP (DO-220AA) MARKING







DATE CODE

M X Y Z

- Z: Factory designator
- Y: Month
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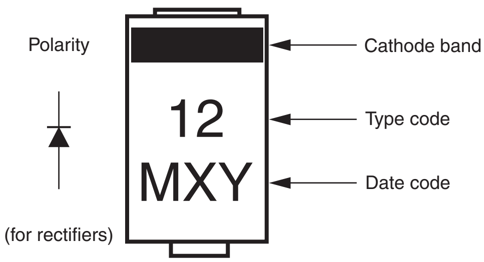
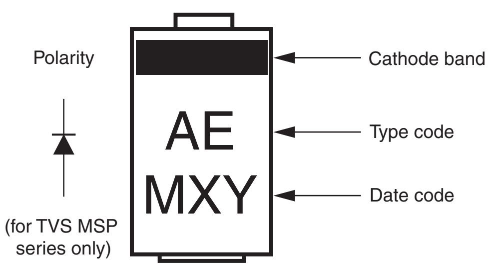
  - A = October
  - B = November
  - C = December
- X: Year (e.g., 5 = 2015
  6 = 2016)
- M: "M" prefix denotes halogen-free compound

Notes

- Type code refers to individual datasheet
- "XY" 2 digits: for rectifiers and PAR TVS
- "XYZ" 3 digits: for TransZorb® TVS and power voltage-regulating diodes

MicroSMP (DO-219AD) MARKING





DATE CODE

M X Y Z

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  - B = November
  - C = December
- X: Year (e.g., 5 = 2015
  6 = 2016)
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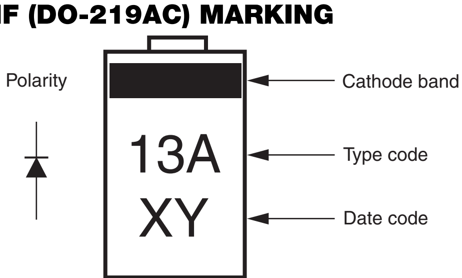
Note

- Type code refers to individual datasheet

MicroSMF (DO-219AC) MARKING



Note

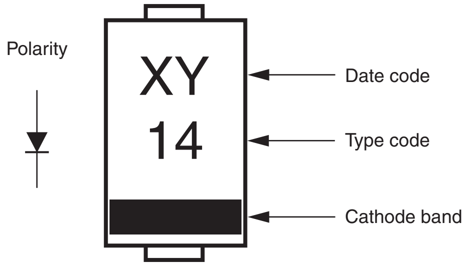
- Type code refers to individual datasheet

DATE CODE

X Y

- Y: Month
  - 1 to 9 = January to September
  - A = October
  - B = November
  - C = December
- X: Year (e.g., 5 = 2015
  6 = 2016)

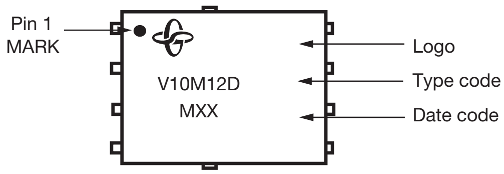
SMF (DO-219AB) MARKING



DATE CODE
X Y

- Y: Month
  - 1 to 9 = January to September
  - O = October
  - N = November
  - D = December
- X: Year (e.g., G = 2015; H = 2016; I = 2017; K = 2018; L = 2019) According EN 600626

FlatPAK 5 X 6 MARKING



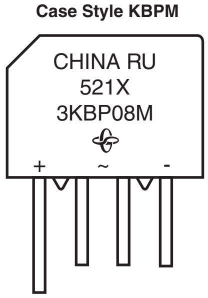
DATE CODE
M X Y

- Y: Month
  - 1 to 9 = January to September
  - A = October
  - B = November
  - C = December
- X: Year (e.g. 6 = 2016
  7 = 2017)
- M: "M" prefix denotes halogen-free compound

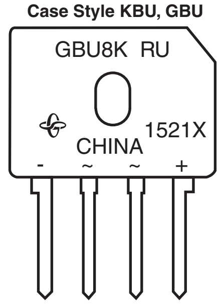
BRIDGE MARKING

Single in-line bridge marking

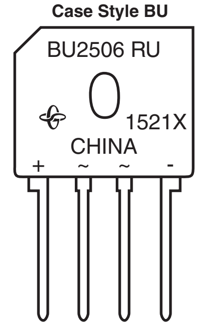
Case Style KBPM



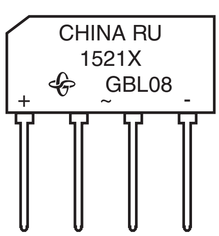
Case Style KBU, GBU



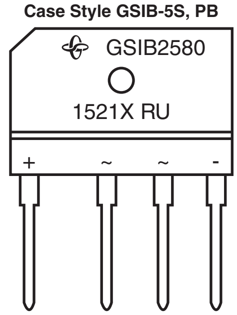
Case Style BU



Case Type KBL, GBL



Case Style GSIB-5S, PB



Logo :

Part number: 3KBP08M, BU2506 (example)
UL approved: RU
Location: China
Date code (e.g.,521X, 1521X or M521X)
Polarity: + Positive output terminal
- Negative output terminal
~ Alternate

DATE CODE (for RoHS-compliant products)

5 21 X

- X: Factory designator
- 21: Week by calendar year (21st)
- 5: Last digit of year (2015)

DATE CODE (for RoHS-compliant products)

15 21 X

- X: Factory designator
- 21: Week by calendar year (21st)
- 15: Last two digits of year (2015)

DATE CODE (for halogen-free products)

M 5 21 X

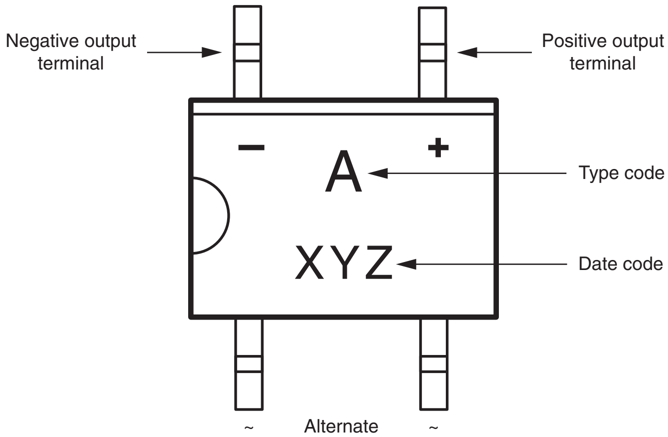
- X: Factory designator
- 21: Week by calendar year (21st)
- 5: Last digit of year (2015)
- M: "M" prefix denotes halogen-free compound

Note

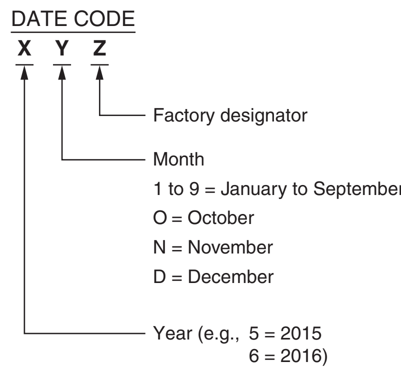
(1) Date code per individual part number specification

DUAL IN-LINE BRIDGE MARKING

MBS (TO-269AA) and MBM Mini-Bridge



Polarity: + Positive output terminal
- Negative output terminal

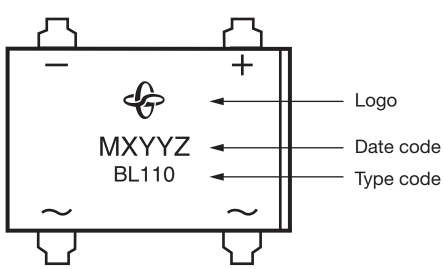


TYPE	TYPE CODE	TYPE	TYPE CODE
B2S, B2M	B2	MB4S, MB4M	4
B4S, B4M	B4	MB6S, MB6M	6
B6S, B6M	B6	RMB2S	2R
MB2S, MB2M	2	RMB4S	4R

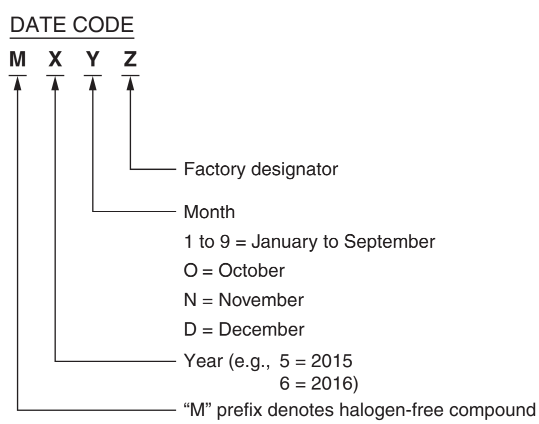
Note

- For halogen-free: add "Underline" below type code (e.g., 6)
- RMB2S and RMB4S only has type code without date code

MBLS



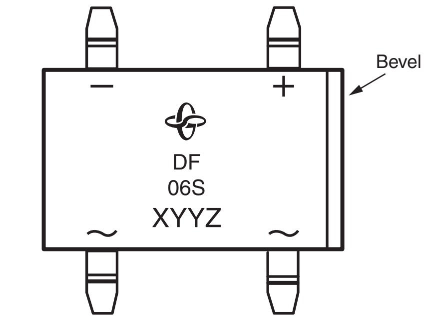
(top view)



TYPE	TYPE CODE
MBL104S	BL104
MBL106S	BL106
MBL108S	BL108
MBL110S	BL110

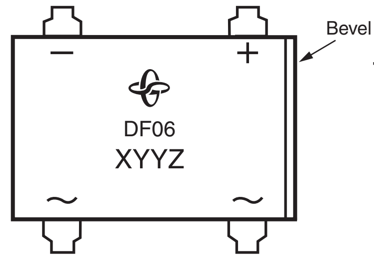
DFS, DFM, and WOG

DFS



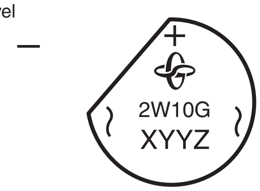
(top view)

DFM



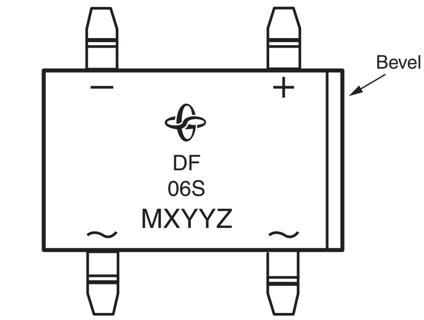
(top view)

WOG



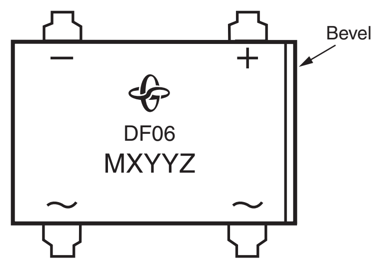
(top view)

DFS



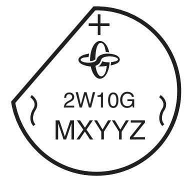
(top view)

DFM



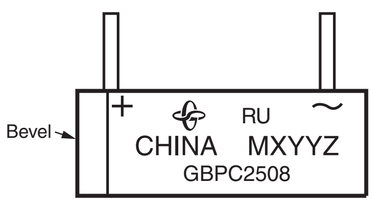
(top view)

WOG



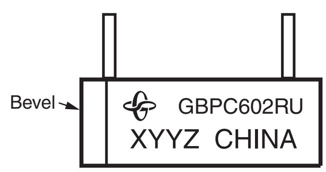
(top view)

Case Style GBPC/GBPC-W



(side view)

Case Style GBPC1/GBPC6



(side view)

Logo:
Part number: GBPC2508 (example)
UL approved: RU
Location: China
Date code: (M)XYYZ
Polarity: + Positive output terminal
- Negative output terminal
~ Alternate

DATE CODE

M X YY Z
- Z: Factory designator
- YY: Week by calendar year (21st)
- X: Last digit of year (2015)
- M: "M" prefix denotes halogen-free compound

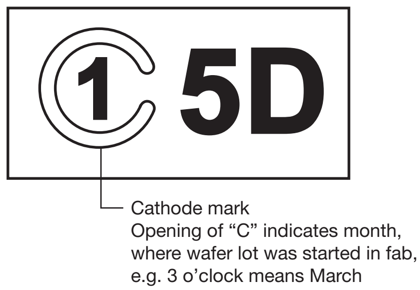
Notes

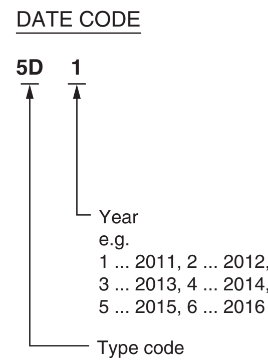
(1) Date code per individual part number specification
(2) Non "M" mark belongs to RoHS-compliant product
(3) "M" prefix denotes halogen-free compound

Vishay Semiconductors (Small Signal Products)

SMD MARKING

CLP0603 MARKING

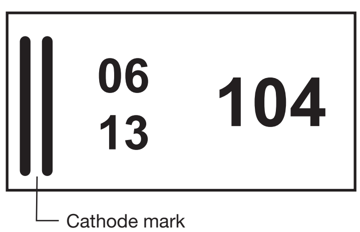


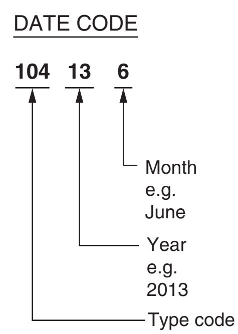


Note

• Type code refers to individual datasheet

CLP1608 MARKING



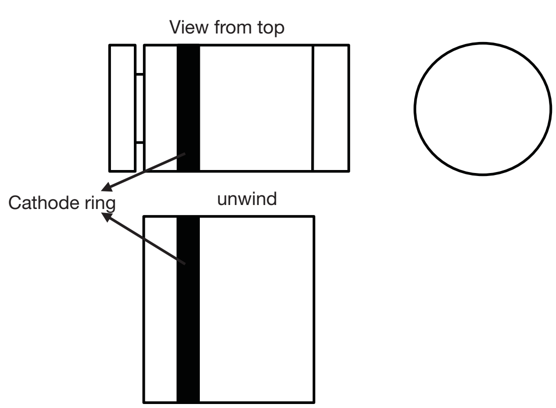


Note

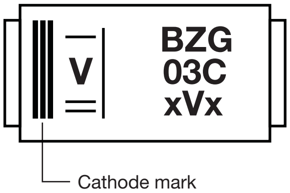
• Type code refers to individual datasheet

DO-213 MARKING

Marking: cathode



SMA (DO-214AC) MARKING



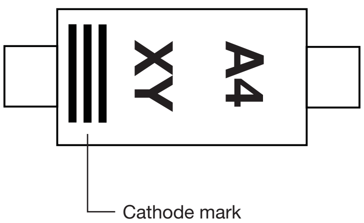
Note
• Type code refers to individual datasheet

DATE CODE

xVx 03C BZG V

- V — Factory designation
- BZG — Type code
- 03C — Family identifier
- xVx — Zener voltage

SMF (DO-219AB) MARKING



Note
• Type code refers to individual datasheet

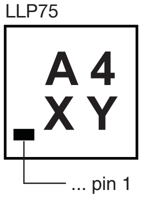
DATE CODE

XY 4 A

- A — Year
  e.g.
  W... 2008, X... 2009, A...2010,
  B... 2011, C... 2012, E...2013,
  F... 2014, G... 2015, H...2016,
  I... 2017, K... 2018, L... 2019 According EN 600626
- 4 — Month
  e.g.
  1... Jan, 2... Feb,
  9... Sep, O...Oct,
  N... Nov, D... Dec
- XY — Type code

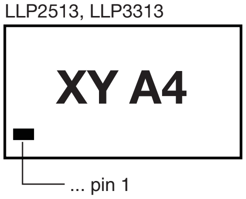
LLP75, LLP1713, LLP2510, LLP2513, LLP3313 MARKING

LLP75



LLP1713, LLP2510

LLP2513, LLP3313



DATE CODE

X... 4 A...

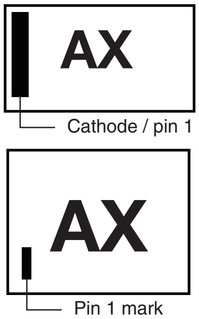
- A... — Year
  e.g.

A ... 2010	K ... 2018	U ... 2026
B ... 2011	L ... 2019	V ... 2027
C ... 2012	M ... 2020	W ... 2028
D ... 2013	N ... 2021	X ... 2029
E ... 2014	P ... 2022	A ... 2030
F ... 2015	R ... 2023	....
G ... 2016	S ... 2024	
J ... 2017	T ... 2025	According EN 600626

- 4 — Month
  e.g.
  1 ... Jan, 2 ... Feb, 3... Mar, 4 ... Apr, 5 ... May, 6 ... Jun,
  7 ... Jul, 8 ... Aug, 9 ... Sep, O ... Oct, N ... Nov, D ... Dec
- X... — Type code

Note
• Type code refers to individual datasheet

LLP1006, LLP1010 MARKING



DATE CODE

X... A...

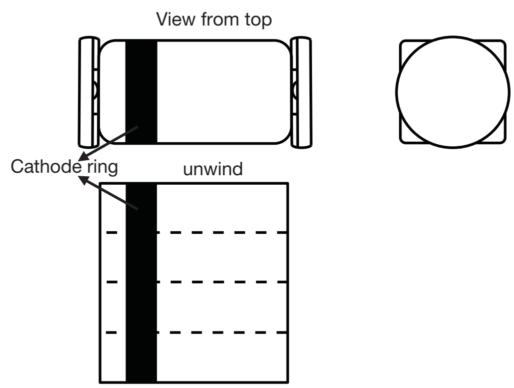
Jan14-A, Feb14-B, Mar14-C, Apr14-D, May14-E, Jun14-F,
Jul14-G, Aug14-H, Sep14-J, Oct14-K, Nov14-M, Dec14-N,
Jan15-P, Feb15-Q, Mar15-R, Apr15-S, May15-T, Jun15-U,
Jul15-V, Aug15-W, Sep15-X, Oct15-Y, Nov15-Z, Dec15-∀,
Jan16-ꓭ, Feb16-Ɔ, Mar16-ᗡ, Apr16-Ǝ, May16-Ⅎ, Jun16-⅁,
Jul16-ſ, Aug16-ꓘ, Sep16-W, Oct16-⅃, Nov16-O, Dec16-Ԁ,
Jan17-⊥, Feb17-∩, Mar17-Λ, Apr17-M, May17-⅄, Jun17-1,
Jul17-2, Aug17-3, Sep17-4, Oct17-5, Nov17-6, Dec17-7,
Jan18 = Jan14,....

Type code

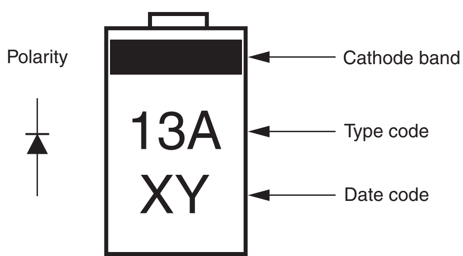
Note
- Type code refers to individual datasheet

MicroMELF MARKING

Marking: cathode



MicroSMF (DO-219AC) MARKING



DATE CODE

X Y

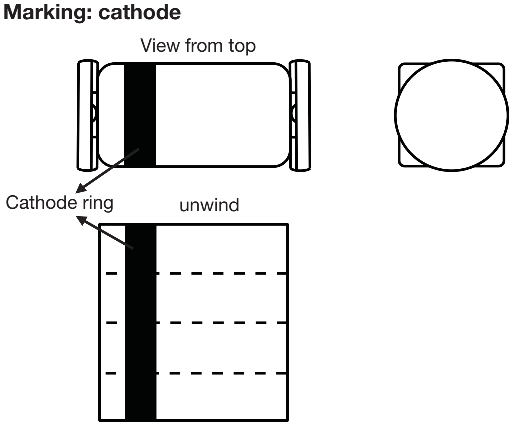
Month
1 to 9 = January to September
A = October
B = November
C = December

Year (e.g., 5 = 2015
6 = 2016)

Note
- Type code refers to individual datasheet

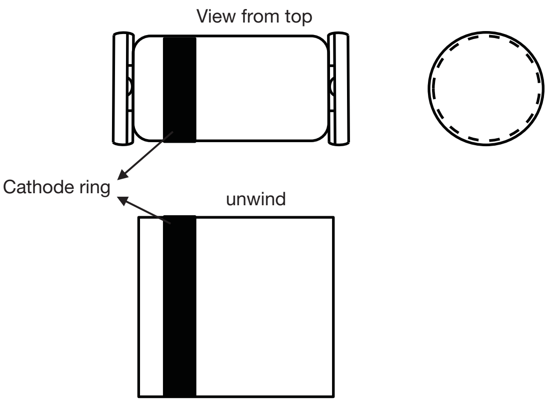
QuadroMELF (SOD-80) MARKING

Marking: cathode



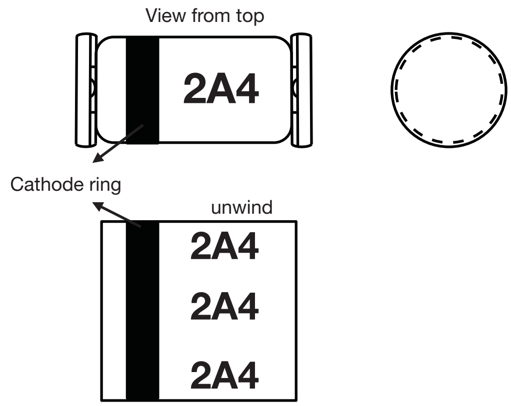
MiniMELF (SOD-80) MARKING

Marking: cathode

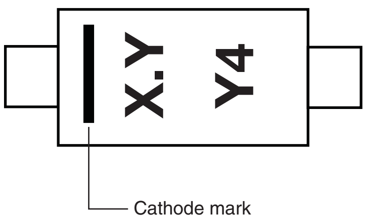


MiniMELF (SOD-80) TLZ MARKING

Marking: type and cathode



SOD-123 MARKING



Note

- Type code refers to individual datasheet

DATE CODE

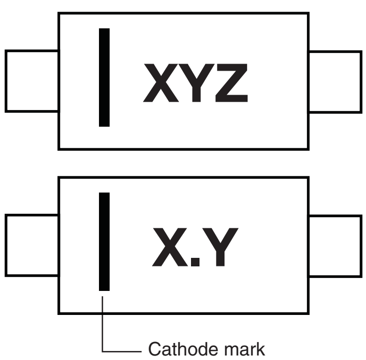
X.Y 4 Y

Year
e.g.
Y... 2010, B... 2011, C...2012,
E... 2013, F... 2014, G...2015,
H... 2016, J... 2017, K...2018 According EN 600626

Month

Type code (.) for more codes

SOD-323 MARKING



XYZ or X.Y

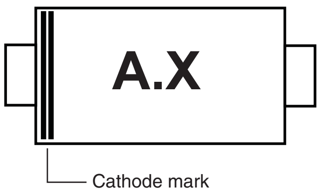
Type code

No date code

Note

- Type code refers to individual datasheet

SOD-523 MARKING



DATE CODE

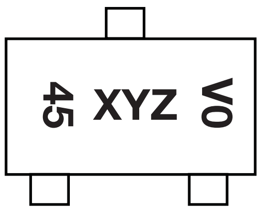
X A.

Jan14-A, Feb14-B, Mar14-C, Apr14-D, May14-E, Jun14-F, Jul14-G, Aug14-H, Sep14-J, Oct14-K, Nov14-M, Dec14-N, Jan15-P, Feb15-Q, Mar15-R, Apr15-S, May15-T, Jun15-U, Jul15-V, Aug15-W, Sep15-X, Oct15-Y, Nov15-Z, Dec15-∀, Jan16-ᗺ, Feb16-Ɔ, Mar16-ᗡ, Apr16-Ǝ, May16-Ⅎ, Jun16-⅁, Jul16-ſ, Aug16-ꓘ, Sep16-Ɯ, Oct16-ꓷ, Nov16-Ꝺ, Dec16-ꓤ, Jan17-⊥, Feb17-∩, Mar17-Λ, Apr17-ʍ, May17-⅄, Jun17-1, Jul17-2, Aug17-3, Sep17-4, Oct17-5, Nov17-6, Dec17-7, Jan18 = Jan14,….

Type code

Note
- Type code refers to individual datasheet

SOT-23 MARKING



DATE CODE

XYZ 45 0 V

Vishay

Year
e.g.

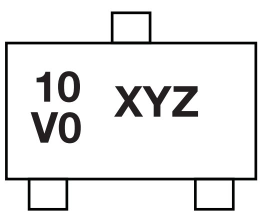
H ... 2016	M ... 2020
J ... 2017	N ... 2021
K ... 2018	
L ... 2019	According EN 600626

Work week 45

Type code

Note
- Type code refers to individual datasheet

SOT-3xx MARKING



DATE CODE

XYZ 10 0 V

Vishay

Year
e.g.

H ... 2016	M ... 2020
J ... 2017	N ... 2021
K ... 2018	
L ... 2019	According EN 600626

Work week 10

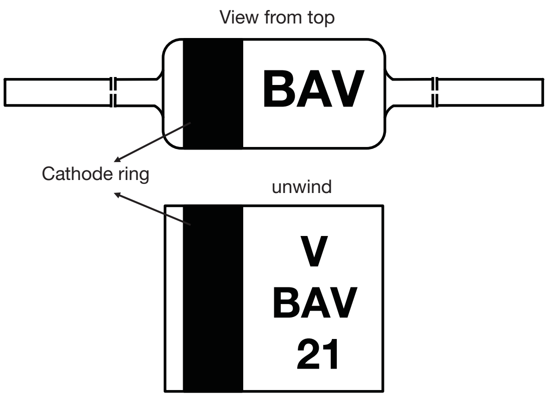
Type code

Note
- Type code refers to individual datasheet

AXIAL MARKING

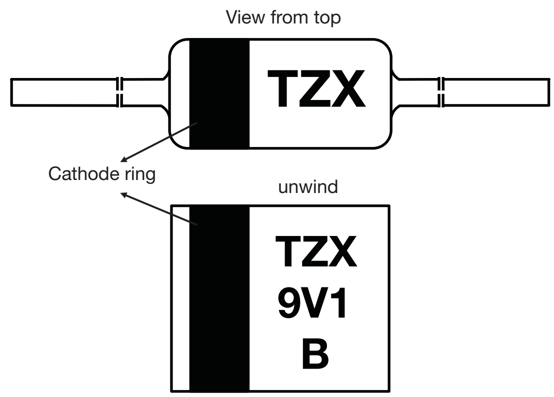
DO-35 (DO-204AH) BAV, BAW, BAS MARKING

Marking: type and cathode



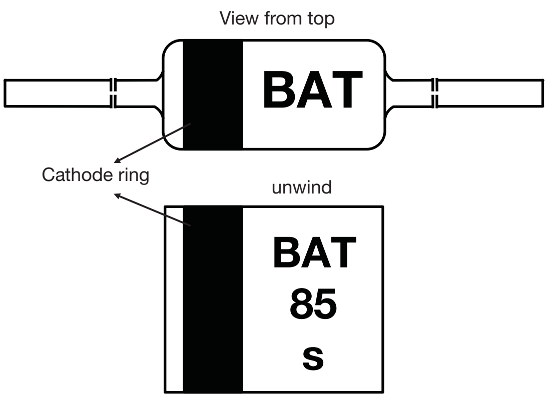
DO-35 (DO-204AH) ZENER TZX MARKING

Marking: type and cathode



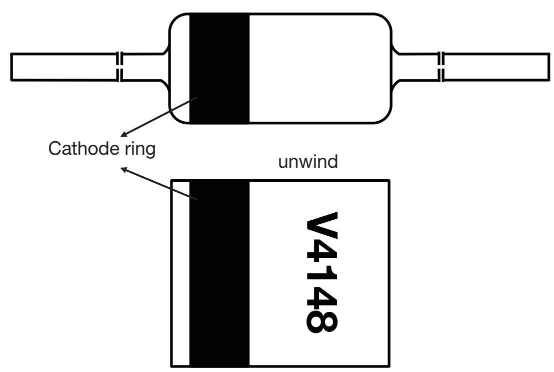
DO-35 (DO-204AH) SCHOTTKY BAT, SD MARKING

Marking: type and cathode



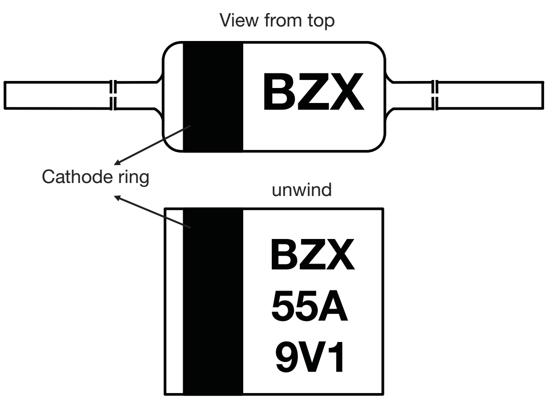
DO-35 (DO-204AH) 1N4148 MARKING

Marking: type and cathode



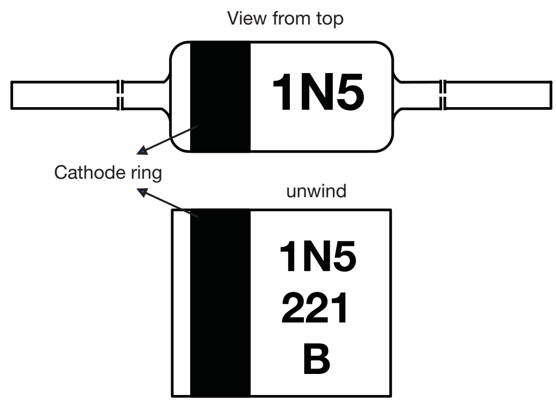
DO-35 (DO-204AH) ZENER BZX55 MARKING

Marking: type and cathode



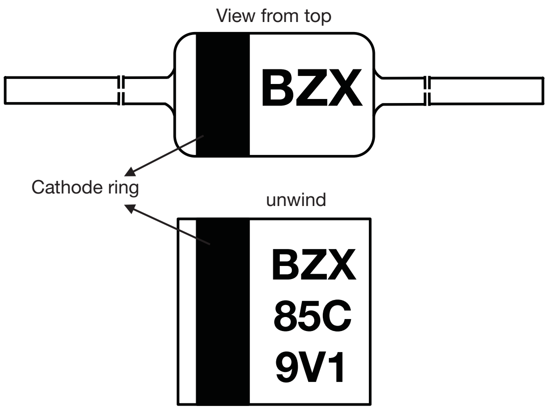
DO-35 (DO-204AH) ZENER 1N52 MARKING

Marking: type and cathode



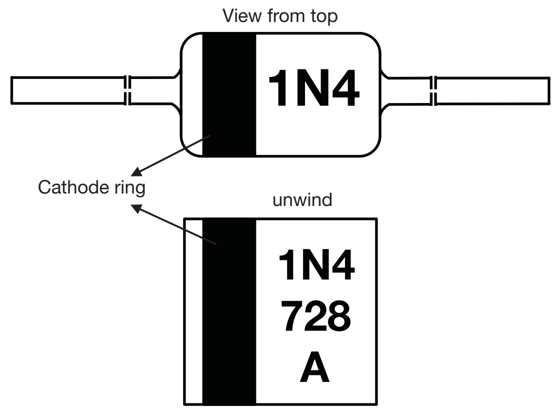
DO-41 (DO-204AL) BZX85 MARKING

Marking: type and cathode



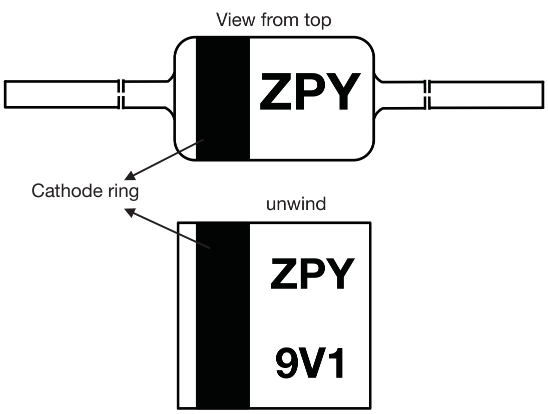
DO-41 (DO-204AL) 1N47xx MARKING

Marking: type and cathode

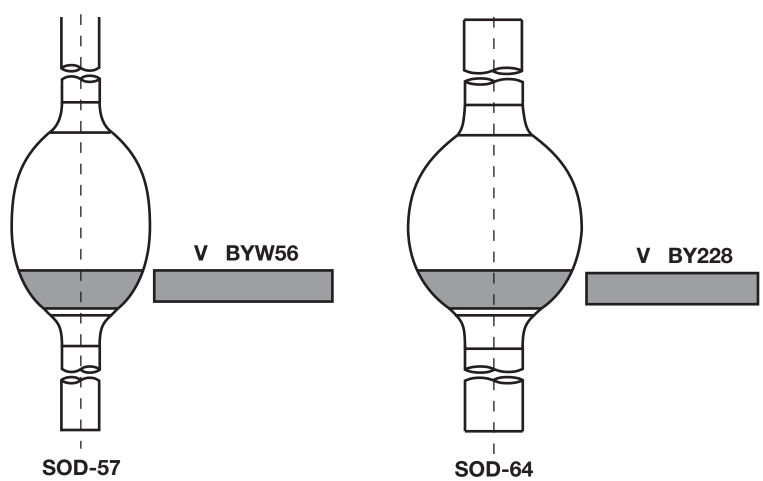


DO-41 (DO-204AL) ZPY MARKING

Marking: type and cathode



SOD-57, SOD-64 MARKING CODE



SOD-57 and SOD-64 Avalanche diodes
The unique part number is followed by letter “V”, means Vishay
e.g. BYT62 V; SF1600 V or BYW83 V

SOD-57 Zener diodes
BZT03Cxx - where “xx” means the Zener voltage (no “V” after the part number)

SOD-64 Zener diodes
BZW03Cxx - where “xx” means the Zener voltage (no “V” after the part number)

Vishay Semiconductors (High Power Products)

SMF (DO-219AB) MARKING

1st row

First digit: year (E = 2013; F = 2014; G = 2015; H = 2016; I = 2017; K = 2018; L = 2019.....) According EN 600626

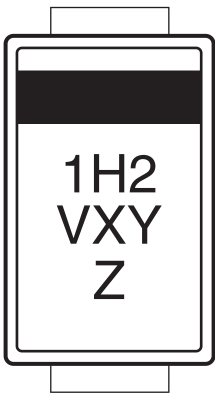
Second digit: month (1 = Jan; 2 = Feb; ... O = Oct; N = Nov; D = Dec)

2nd row

First digit: environmental digit

Second digit: current / voltage rating

SMA (DO-214AC), SMB (DO-214AA), SMC (DO-214AB) (FRED Pt®) MARKING



Cathode band

Type code

Date code

Environmental digit code

Type Code

1 H 2

Voltage
FRED Pt®
2 = 200 V
..
..
6 = 600 V

Process type:
X = hyperfast recovery time
H = hyperfast recovery time
U = ultrafast recovery time
L = low V_F ultrafast recovery time

Current
1 = 1 A
..
..
5 = 5 A

Date Code

X Y

Month:
1 to 9 = January to September
A = October
B = November
C = December

Year
(e.g. 1 = 2011, 2 = 2012)

SMA (DO-214AC), SMB (DO-214AA), SMC (DO-214AB) (Schottky) MARKING

Cathode band

Type code

Date code

Halogen-free compound mark

Type Code

S A

Voltage

Schottky standard:	Schottky MBR series:
C = 15 V	2 = 20 V
E = 30 V	3 = 30 V
F = 40 V	4 = 40 V
H = 60 V	6 = 60 V
J = 100 V	9 = 90 V
	0 = 100 V

Current
1 = 1 A
X = 1.5 A
2 = 2 A
3 = 3 A
4 = 4 A
..
..

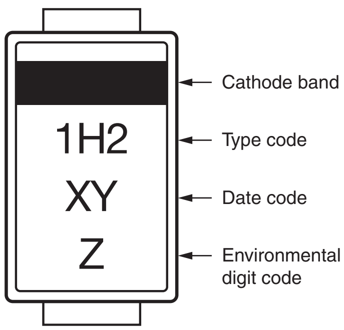
Date Code

X Y

Month:
1 to 9 = January to September
A = October
B = November
C = December

Year
(e.g. 1 = 2011, 2 = 2012)

SlimSMA (DO-221AC) MARKING



Type Code

1 H 2

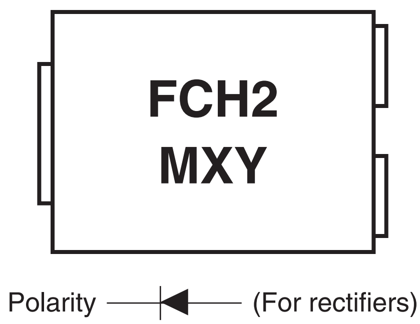
- 1 – Current: 1 = 1 A, .., .., 5 = 5 A
- H – Process type:
  - X = hyperfast recovery time
  - H = hyperfast recovery time
  - U = ultrafast recovery time
  - L = low V_F ultrafast recovery time
- 2 – Voltage: 2 = 200 V, 3 = 300 V, .., ..

Date Code

X Y

- X – Year (e.g. 1 = 2011, 2 = 2012)
- Y – Month:
  - 1 to 9 = January to September
  - A = October
  - B = November
  - C = December

SMPC MARKING



1st row

F C H 2

- F – Current
- C – C = common cathode, E = single die
- H – Family: H, U, X, L
- 2 – Volt class: 1 = 100 V, 2 = 200 V, 3 = 300 V, ..

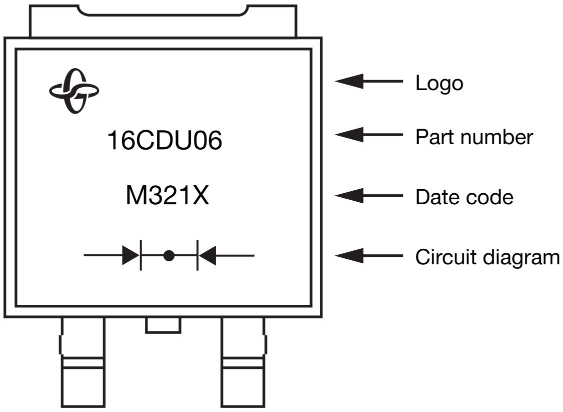
CURRENT	DIGIT	CURRENT	DIGIT
1	D	8	Q
2	F	7	R
3	G	10	S
4	J	11	T
5	K	12	V
6	N	13	Y
7	P	14	Z

2nd row

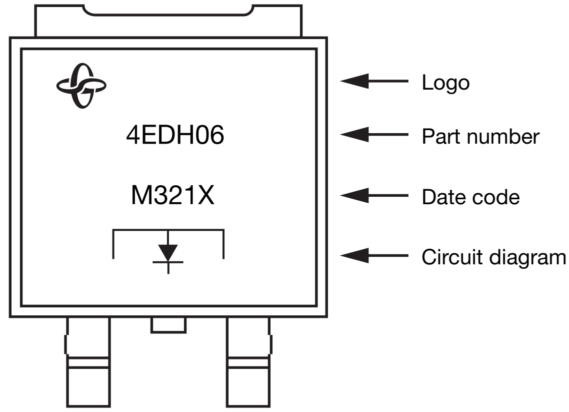
M X Y

- M – Environmental digit
- X – Year: 1 = 2011, 2 = 2012, ..
- Y – Month:
  - 1 to 9 = January to September
  - A = October
  - B = November
  - C = December

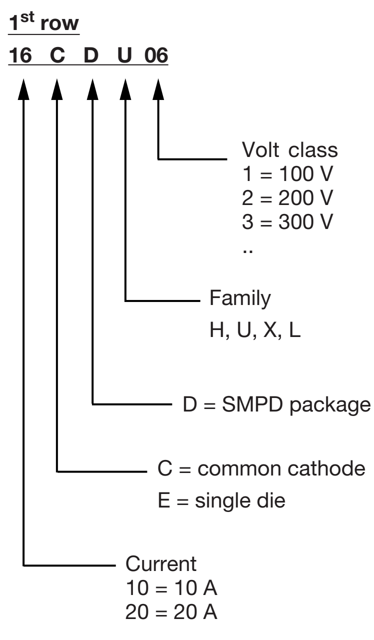
SMPD MARKING

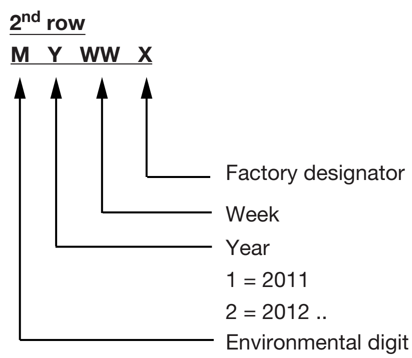


(For Dual Die Parts)



(For Single Die Parts)

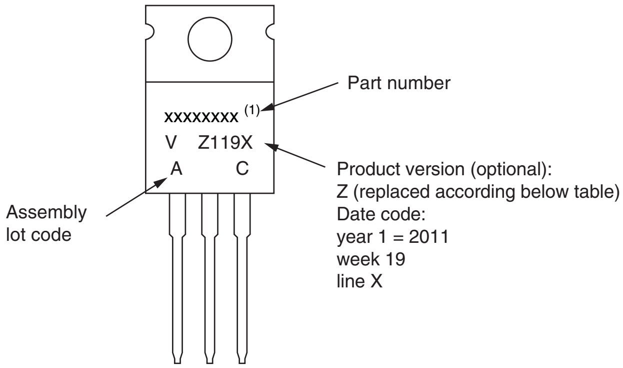




TO-220 MARKING

Examples: TO-220AB, TO-220FP, TO-220AC E, TO-220AC-N3

TO-220AB E

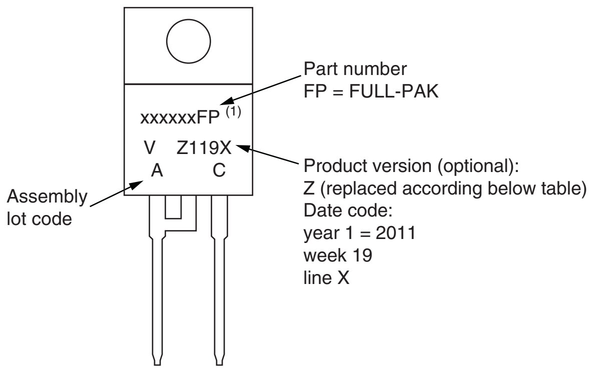


Example: This is a xxxxxxxx [1] with assembly lot code AC, assembled on WW 19, 2011 in the assembly line "X"

Note

[1] If part number contains "H" as last digit, product is AEC-Q101 qualified

TO-220FP-N3

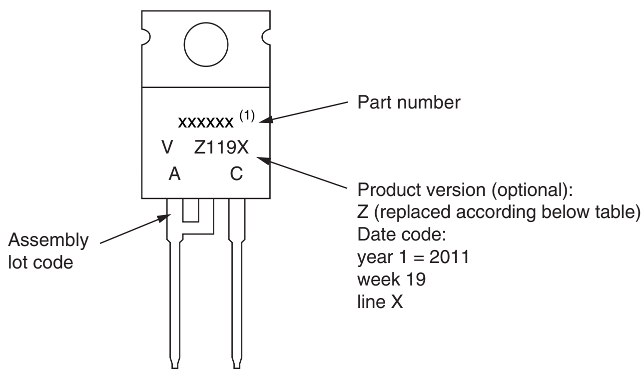


Example: This is a xxxxxxFP [1] with assembly lot code AC, assembled on WW 19, 2011 in the assembly line "X"

Note

[1] If part number contains "H" as last digit, product is AEC-Q101 qualified

TO-220AC E, TO-220AC-N3

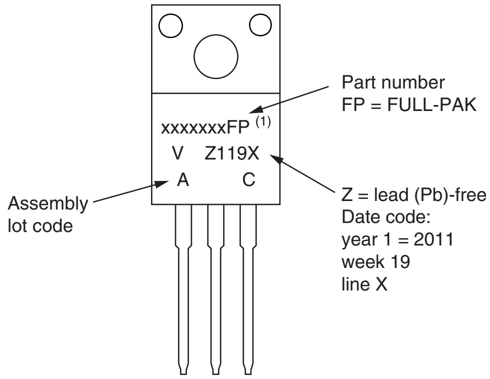


Example: This is a xxxxxx [1] with assembly lot code AC, assembled on WW 19, 2011 in the assembly line "X"

Note

[1] If part number contains "H" as last digit, product is AEC-Q101 qualified

TO-220FP 2L

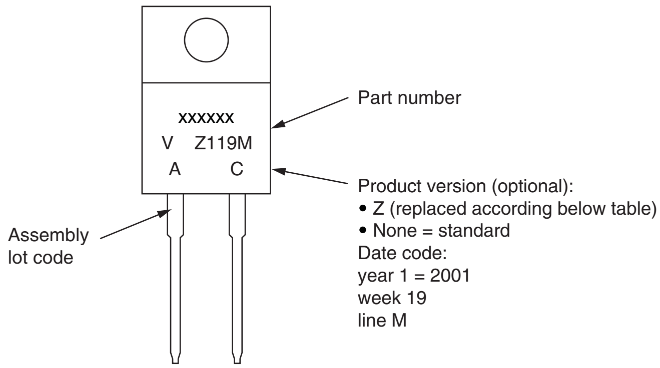


Example: This is a xxxxxxxFP [1] with assembly lot code AC, assembled on WW 19, 2011 in the assembly line "X"

Note

[1] If part number contains "H" as last digit, product is AEC-Q101 qualified

TO-220AC 2L



Example: This is a xxxxxx with assembly lot code AC, assembled on WW 19, 2001 in the assembly line "M"

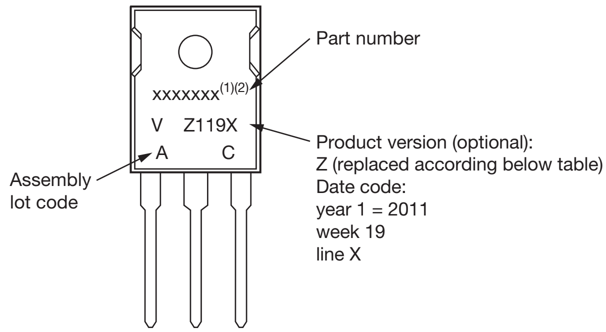
Note

[1] If part number contains "H" as last digit, product is AEC-Q101 qualified

TO-247 MARKING

Examples:

TO-247, 3 pins long-lead



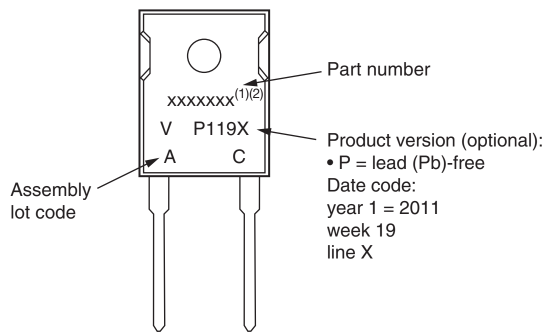
Example: This is a xxxxxxx [1] with assembly lot code AC, assembled on WW 19, 2011 in the assembly line "X"

Notes

[1] If part number contains "H" as last digit, product is AEC-Q101 qualified

[2] If part number contains "L", product is long-lead

TO-247, 2 pins long-lead



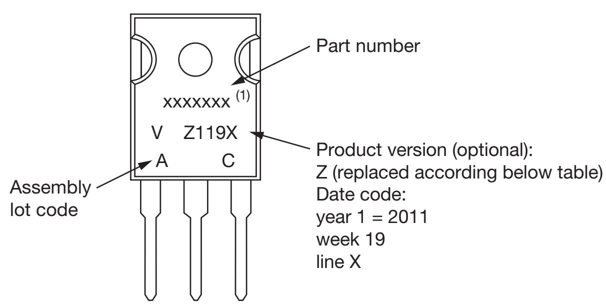
Example: This is a xxxxxxx with assembly lot code AC, assembled on WW 19, 2011 in the assembly line "X"

Notes

[1] If part number contains "H" as last digit, product is AEC-Q101 qualified

[2] If part number contains "L", product is long-lead

TO-247AC-N3

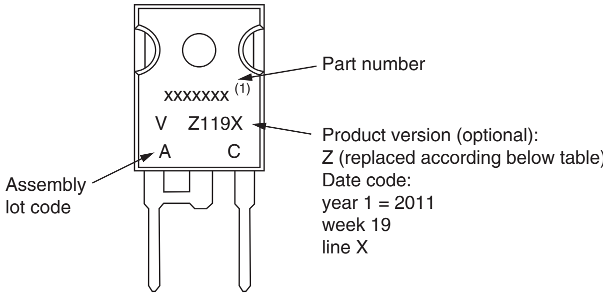


Example: This is a xxxxxxx [1] with assembly lot code AC, assembled on WW 19, 2011 in the assembly line "X"

Note

[1] If part number contains "H" as last digit, product is AEC-Q101 qualified

TO-247AC-N3 modified

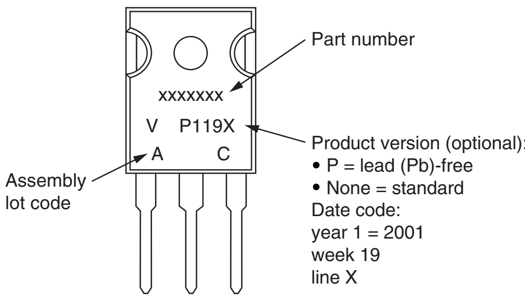


Example: This is a xxxxxxx [1] with assembly lot code AC, assembled on WW 19, 2011 in the assembly line "X"

Note

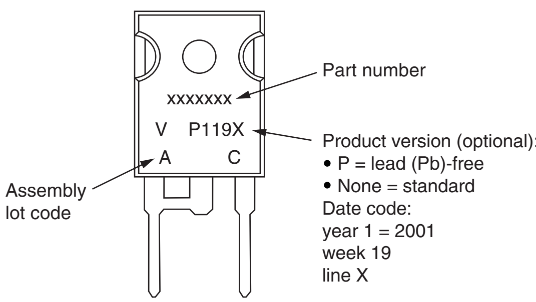
[1] If part number contains "H" as last digit, product is AEC-Q101 qualified

TO-247 PbF



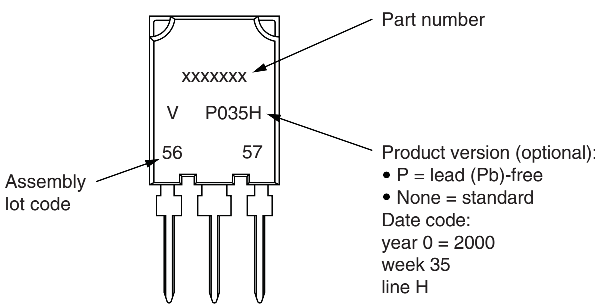
Example: This is a xxxxxxx with assembly lot code AC, assembled on WW 19, 2001 in the assembly line "X"

TO-247 PbF modified



Example: This is a xxxxxxx with assembly lot code AC, assembled on WW 19, 2001 in the assembly line "X"

Super TO-247

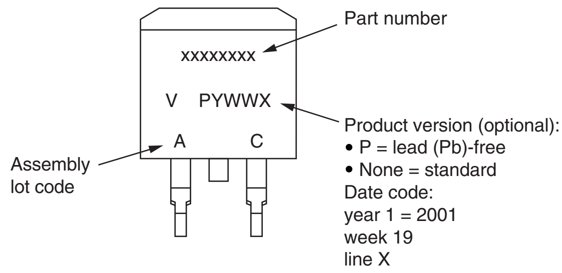


Example: This is a xxxxxxx with assembly lot code 5657, assembled on WW 35, 2000 in assembly line "H"

D²PAK (TO-263AA), TO-262 MARKING

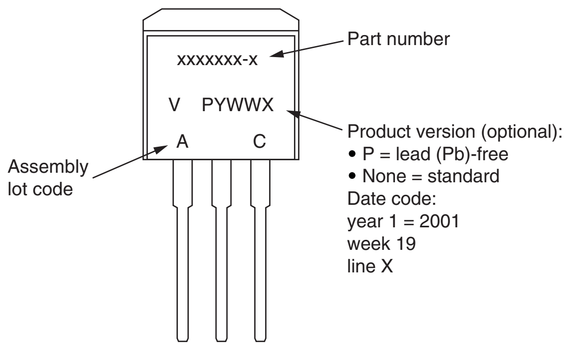
Examples:

D²PAK E (TO-263AA)



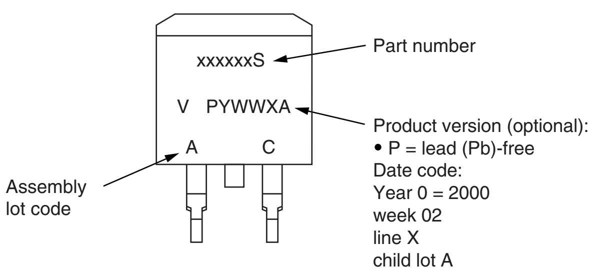
Example: This is a xxxxxxxx with assembly lot code AC, assembled on WW 19, 2001 in the assembly line "X"

TO-262AA



Example: This is a xxxxxxx-x with assembly lot code AC, assembled on WW 19, 2001 in the assembly line "X"

D²PAK (TO-263AA)

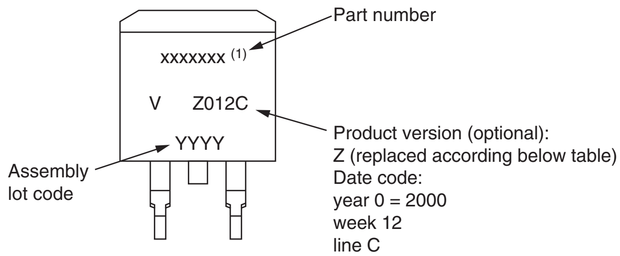


Example: This is a xxxxxxS with assembly lot code AC, assembled on WW 02, 2000

DPAK (TO-252AA) MARKING

Examples:

DPAK E

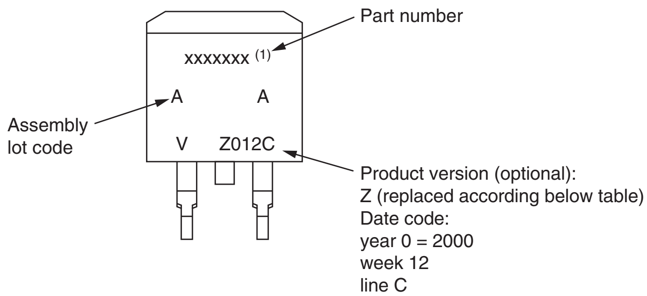


Example: This is a xxxxxxx with assembly lot code YYYY, assembled on WW 12, 2000 in the assembly line “C”

Note

(1) If part number contains “H” as last digit, product is AEC-Q101 qualified

DPAK



Example: This is a xxxxxxx with assembly lot code YYYY, assembled on WW 12, 2000 in the assembly line “C”

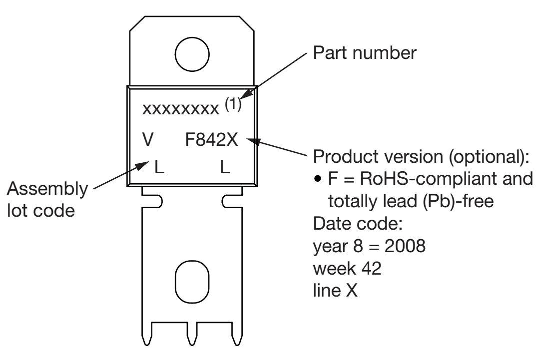
Note

(1) If part number contains “H” as last digit, product is AEC-Q101 qualified

PowerTab® MARKING

Examples:

PowerTab®



Example: This is a xxxxxxxx (1) with assembly lot code LL, assembled on WW 42, 2008 in the assembly line ”X”

Note

(1) If part number contains “H” as last digit, product is AEC-Q101 qualified

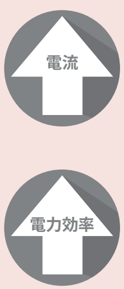
eSMP® シリーズ

パワーダイオード製品の小型・薄型パッケージソリューション

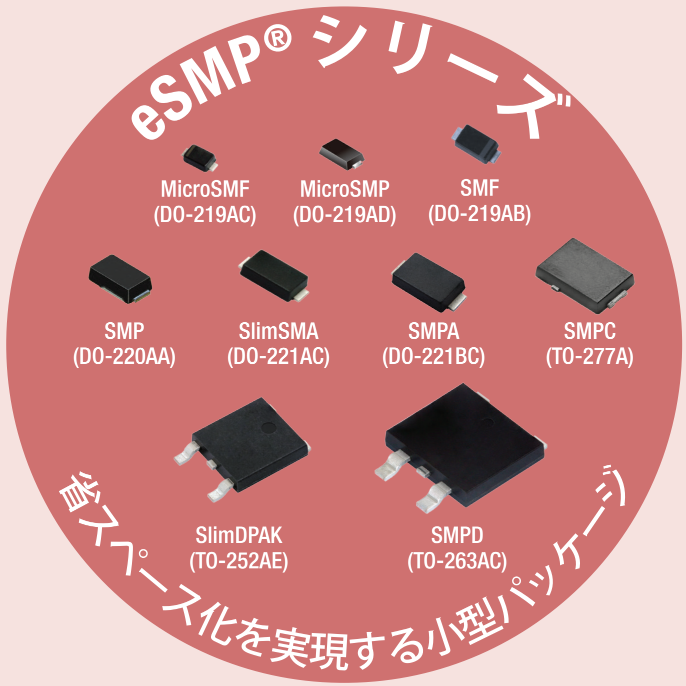
IN A NUTSHELL

eSMP® パッケージ

パワーデバイス向けに最適化した表面実装型パッケージ



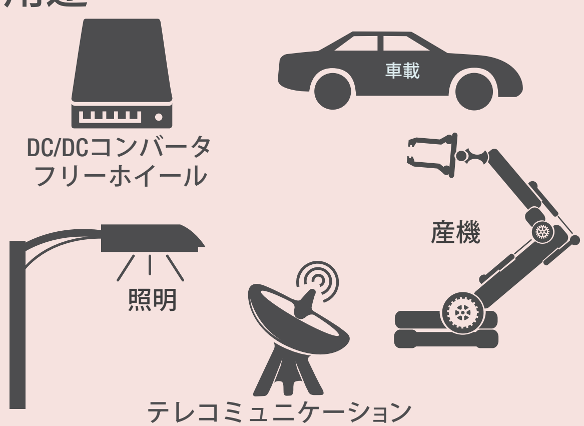
- 独自開発パッケージ
- 電力効率の向上
- 高い電流駆動能力
- 熱性能と信頼性の向上に貢献



各種eSMP®パッケージで提供される製品シリーズ

- ESD保護ダイオード
- PAR® TVSダイオード
- TRANSZORB® TVS ダイオード
- ツェナーダイオード
- アバランシェダイオード
- FRED Pt®ダイオード
- ショットキーダイオード
- 標準・高速リカバリーダイオード
- TMBS® ダイオード
- 超高速リカバリーダイオード

用途



端子形状が**非対称・対称**なフラットリードタイプパッケージで**提供**

参照リンク：

eSMP® シリーズ製品概要
www.vishay.com/doc?49383

ダイオード（eSMP®シリーズパッケージ）
www.vishay.com/landingpage/tradeshows/diodes/

技術に関するお問い合わせ先： DiodesAmericas@vishay.com、DiodesEurope@vishay.com、DiodesAsia@vishay.com

VISHAY 威世

eSMP® 系列

用于选定二极管和整流器的小尺寸和低型面高度封装解决方案

快速了解

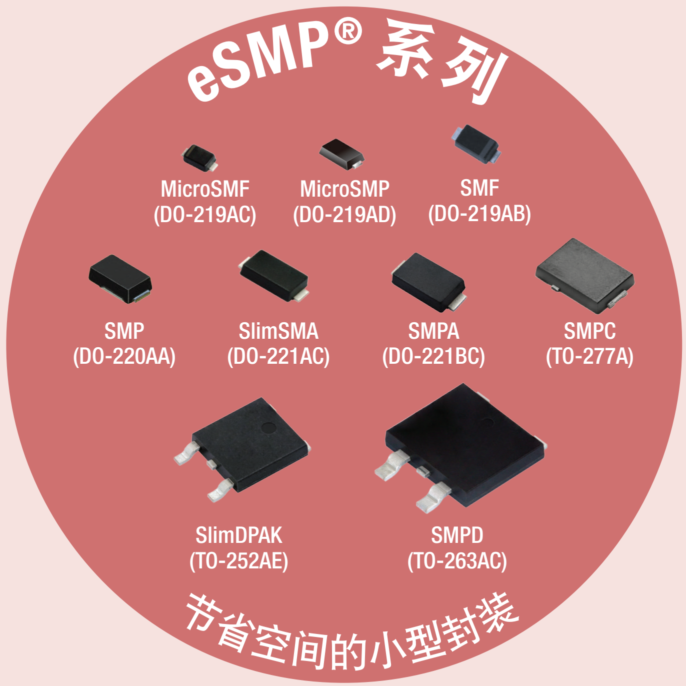
eSMP® 封装

增强型表面贴装功率封装

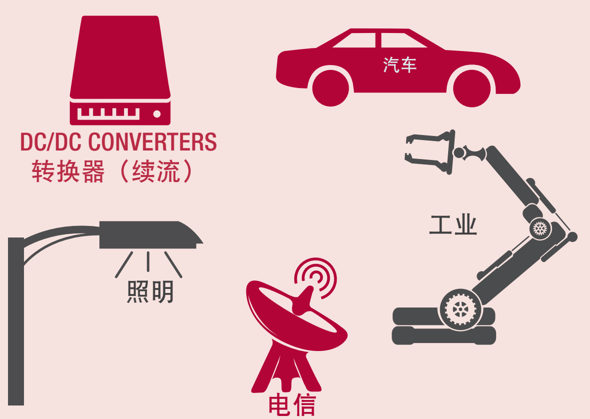
电流

功率效率

利用可提供更出色热性能和可靠性的独特设计支持更高的电流和功率效率



应用



eSMP®系列封装提供的产品技术：

- ESD 保护二极管
- PAR® TVS 二极管
- TransZorb® TVS 二极管
- 齐纳二极管
- 雪崩整流器
- FRED Pt® 整流器
- 肖特基整流器
- 标准和快速恢复整流器
- TMBS® 整流器
- 超快恢复整流器

提供不对称和对称扁平式封装

有用链接

eSMP® 系列产品概述：
www.vishay.com/doc?49383

采用 eSMP® 系列封装的二极管/整流器：
www.vishay.com/landingpage/tradeshows/diodes/

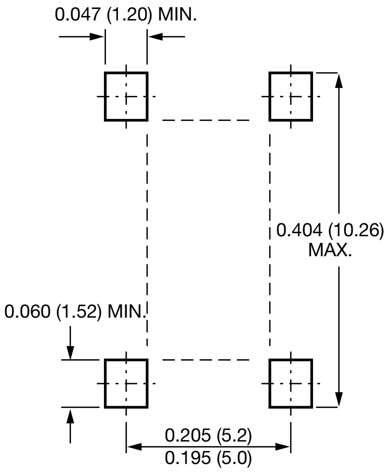
技术问题垂询：DiodesAmericas@vishay.com、DiodesEurope@vishay.com 或 DiodesAsia@vishay.com

VMN-MS7319-1703

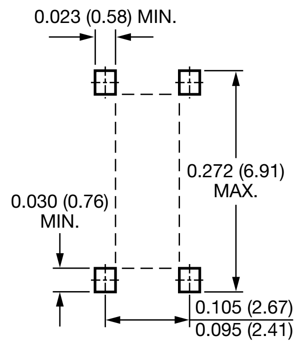
Pad Layouts/Soldering Process

VISHAY GENERAL SEMICONDUCTOR RECOMMENDED MINIMUM MOUNTING PAD LAYOUT SIZES FOR THE SURFACE MOUNT RECTIFIER

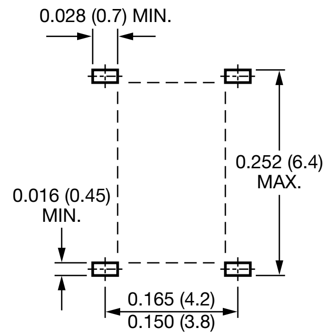
DFS BRIDGE



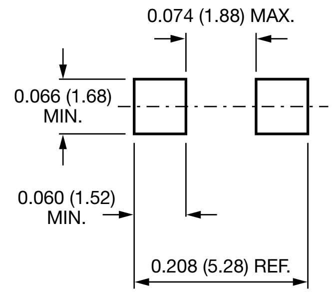
MBS BRIDGE



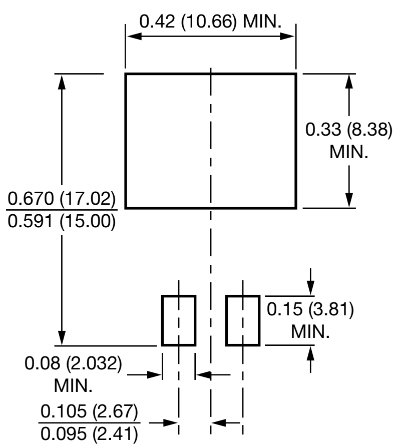
MBLS BRIDGE



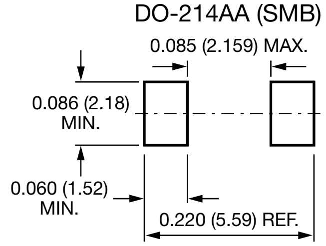
DO-214AC (SMA)/
DO-214BA (GF1)



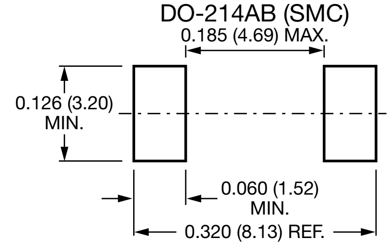
TO-263



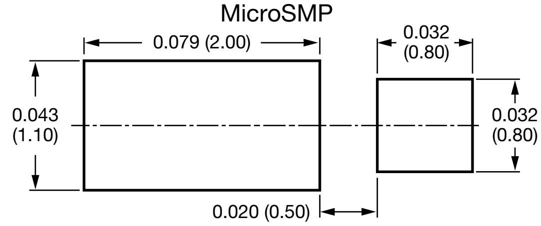
DO-214AA (SMB)



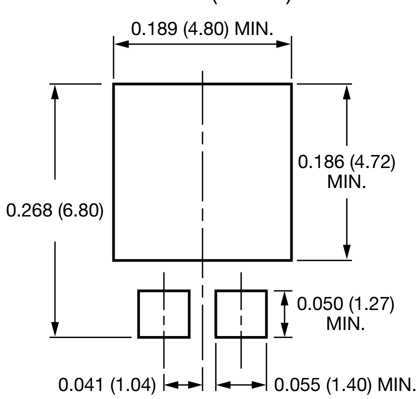
DO-214AB (SMC)



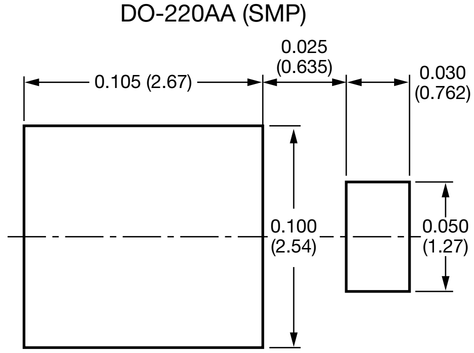
MicroSMP



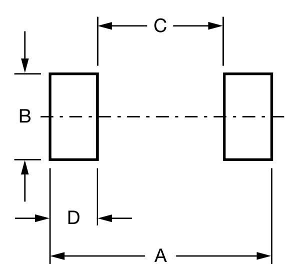
TO-277A (SMPC)



DO-220AA (SMP)

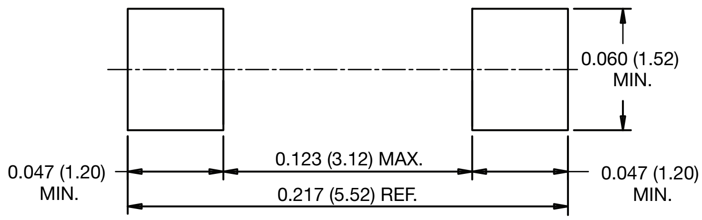


DO-213AA (GL34)/
DO-213AB (GL-41)

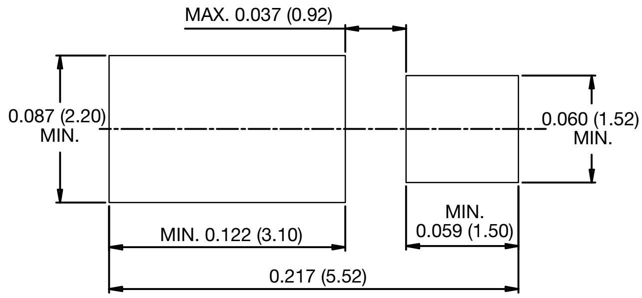


All dimensions in inches (millimeters)

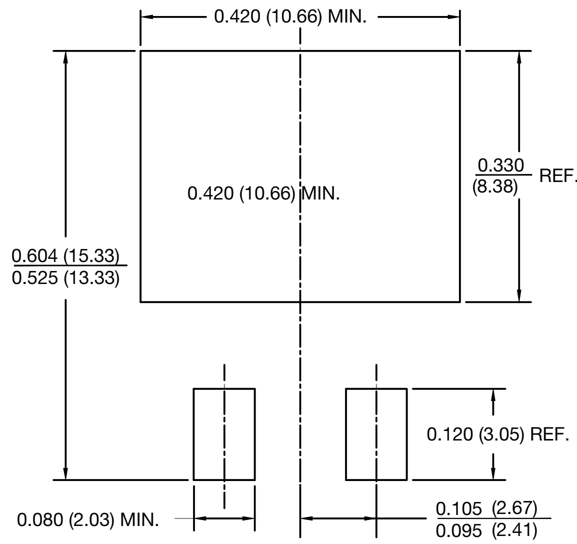
DO-221AC (SlimSMA)



DO-221BC (SMPA)



TO-263AC (SMPD)



DIMENSIONS in inches (millimeters)		
	DO-213AA (GL34)	**DO-213AB (GL41)**
A	0.177 (4.5) ref.	0.236 (6.0) ref.
B	0.079 (2.0) min.	0.118 (3.0) min.
C	0.079 (2.0) max.	0.138 (3.5) max.
D	0.050 (1.25) min.	0.050 (1.25) min.

VISHAY GENERAL SEMICONDUCTOR RECOMMENDED SOLDERING PROCESS

Through hole device (THD) and surface mount device (SMD) imply different soldering technologies leading to different constraints.

In THD, the package body is exposed to relatively low temperatures (< 150 °C) because the lead extremeties are only dipped in the soldering alloy, whereas in SMD the whole package body is exposed to a very high temperature (> 240 °C) during reflow soldering process.

In addition, molding compounds used for encapsulation absorb moisture from the ambient medium. During rapid heating in solder reflow process; this absorded moisture can vaporize, generating pressure at lead frame pad/silicon to plastic interfaces in the package, with a risk of package cracking and potential degradation of device reliability.

Wave soldering with SMD packages is not recommended because the thermal shock associated with package body solder dipping may induce internal structural damage to the package (interface delamination) that may affect long term reliability.

SMD package characterizations performed as a standard by Vishay only induce Solder Reflow Resistance assessment.

JEDEC JESD A111 recommends that wave soldering of SMD packages should be evaluated by the USER, because the stress induced inside the package is very dependant of solder process parameters.

Due to the higher melting point of lead (Pb)-free alloys, the temperature of the solder pot will also increase to improve solderability and shorten contact times. For AgSnCu with melting point of 217 °C, the solder pot temperature will be between 250 °C to 270 °C or as high as 260 °C to 280 °C for SnCu.

RECOMMENDED WAVE SOLDERING PROFILE FOR THROUGH HOLE COMPONENTS

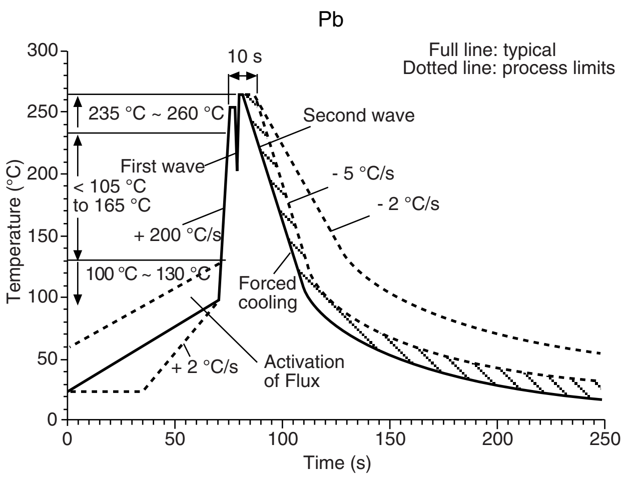
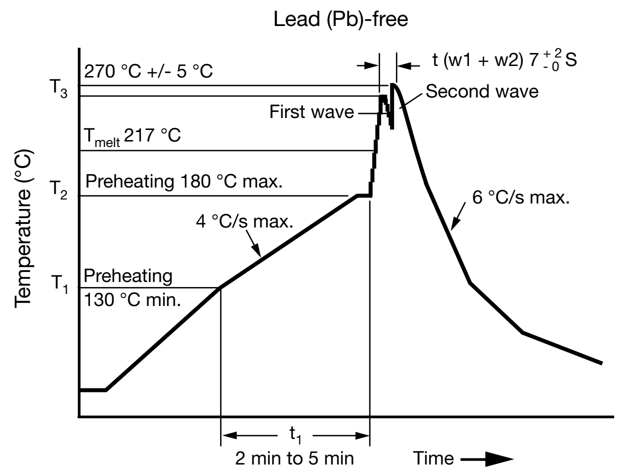


Fig. 1



Notes

- Temperature jump from T_2 to T_3 (w1): 150 °C max.
- Time from 25 °C to T_3 (wave temp.): 8 min max.

Fig. 2

REFLOW FOR SURFACE MOUNTED COMPONENTS

TABLE 1 - CLASSIFICATION REFLOW PROFILE		
PROFILE FEATURE	**Sn-Pb EUTECTIC ASSEMBLY**	**LEAD (Pb)-FREE ASSEMBLY**
Preheat and soak		
Temperature min. ($T_{Smin.}$)	100 °C	150 °C
Temperature max. ($T_{Smax.}$)	150 °C	200 °C
Time ($T_{Smin.}$ to $T_{Smax.}$) (t_S)	60 s to 120 s	60 s to 120 s
Average ramp-up rate ($T_{Smax.}$ to T_p)	3 °C/s maximum	
Liquidous temperature (T_L)	183 °C	217 °C
Time to liquidous (t_L)	60 s to 150 s	60 s to 150 s
Peak package temperature (T_p) (1)	See classification temperature in table 2	See classification temperature in table 3
Time (t_p) (2) with 5 °C of the specified classification temperature (T_C)	20 s (2)	30 s (2)
Average ramp-down rate (T_p to $T_{Smax.}$)	6 °C/s maximum	
Time 25 °C to peak temperature	6 min maximum	8 min maximum

Notes

(1) Tolerance for peak profile temperature (T_p) is defined as a supplier minimum and user maximum

(2) Tolerance for time at peak profile temperature (T_p) is defined as a supplier minimum and user maximum

REFLOW PROFILE

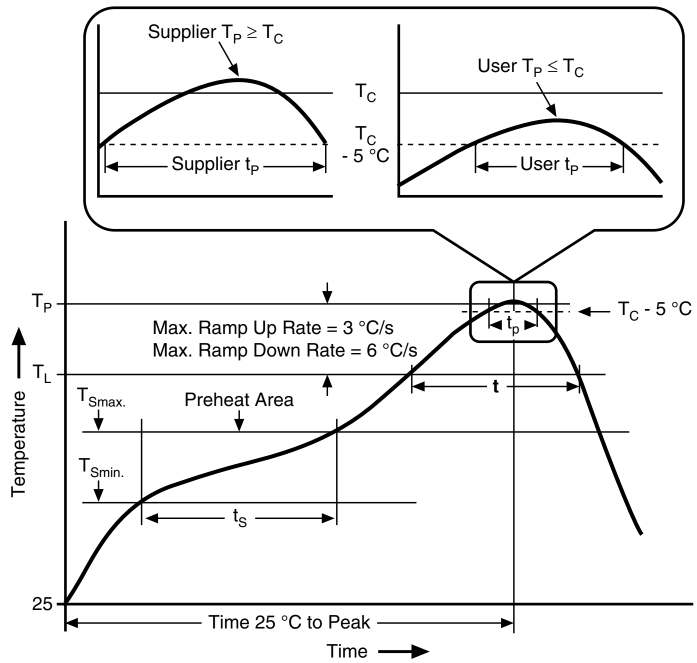


Fig. 3

TABLE 2 - Sn-Pb EUTECTIC PROCESS PACKAGE PEAK REFLOW TEMPERATURES		
PACKAGE THICKNESS	VOLUME mm³ < 350	VOLUME mm³ ≥ 350
< 2.5 mm	235 °C	220 °C
≥ 2.5 mm	220 °C	220 °C

TABLE 3 - LEAD (Pb) - FREE PROCESS PACKAGE CLASSIFICATION REFLOW TEMPERATURES			
PACKAGE THICKNESS	VOLUME mm³ < 350	VOLUME mm³ 350 TO 2000	VOLUME mm³ > 2000
< 1.6 mm	260 °C	260 °C	260 °C
1.6 mm to 2.5 mm	260 °C	250 °C	245 °C
≥ 2.5 mm	250 °C	245 °C	245 °C

Tolerance: The device manufacturer/supplier shall assure process compatibility up to and including the stated classification temperature at the rated MSL level.

Notes

- Package volume excludes external terminals (balls, bumps, lands, leads) and/or non-integral heatsinks.
- The maximum component temperature reached during reflow depends on package thickness and volume. The use of convection reflow processes reduces the thermal gradients between packages. However, thermal gradients due to differences in thermal mass of SMD packages may still exist.
- Recommended soldering process is accordance with J-STD-020D.

Packaging Information

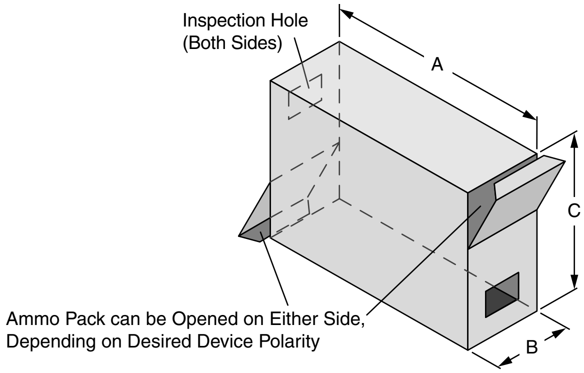
PACKAGING ORDERING CODE		
ANTI-STATIC PACKAGE CODE	**PREFERRED PACKAGE CODE**	**PACKAGING DESCRIPTION**
51, A		Bulk
52, 52T	**P**	**SMB (DO-214AA) /SMBG (DO-215AA), 12 mm tape, 7" diameter plastic reel**
2D	**P**	**SM5-8A (DO-218AB), 24 mm tape, 13" diameter plastic reel, anode towards sprocket hole**
2E, K		SM5-8A (DO-218AB), 24 mm tape, 13" diameter plastic reel, cathode towards sprocket hole
2M, P		Tube packaging for 5KP/6KA type lead formed components
53, B		26 mm horizontal taping and ammo box packaging
54, C	**P**	**52.4 mm horizontal tape, 13" diameter paper reel**
5A, 5AT	**P**	**SMA (DO-214AC), 12 mm tape, 13" diameter plastic reel**
5B, 5BT	**P**	**SMB (DO-214AA) / SMBG (DO-215AA), 12 mm tape, 13" diameter plastic reel**
5CA	**P**	**GF1 (DO-214BA), 12 mm tape, 13" diameter plastic reel**
57, 57T	**P**	**SMC (DO-214AB) / SMCG (DO-215AB), 16 mm tape, 7" diameter plastic reel**
6A	**P**	**SlimSMA (DO-221AC), 12 mm tape, 7" diameter plastic reel**
6B	**P**	**SlimSMA (DO-221AC), 12 mm tape, 13" diameter plastic reel**
9A, 9AT	**P**	**SMC (DO-214AB) / SMCG (DO-215AB), 16 mm tape, 13" diameter plastic reel**
61, 61T	**P**	**SMA (DO-214AC), 12 mm tape, 7" diameter plastic reel**
67A	**P**	**GF1 (DO-214BA), 12 mm tape, 7" diameter plastic reel**
72, E	**P**	**Bulk pack for bridge and special axial-leaded formed devices**
73, D		52.4 mm horizontal tape and ammo box packaging
77	**P**	**DFS bridge, 16 mm tape, 13" diameter paper reel**
80	**P**	**MB-S (TO-269AA) bridge, 12 mm tape, 13" diameter paper reel**
81	**P**	**D^2PAK (TO-263AB) 24 mm tape, 13" diameter reinforced hub plastic reel**
8W	**P**	**D^2PAK (TO-263AB) (wire bond) 24 mm tape, 13" diameter reinforced hub plastic reel**
83	**P**	**GL34 (DO-213AA) 8 mm tape, 13" diameter plastic reel**
84A	**P**	**SMP (DO-220AA) 12 mm tape, 7" diameter plastic reel**
85A	**P**	**SMP (DO-220AA) 12 mm tape, 13" diameter plastic reel**
86A	**P**	**SMPC (TO-277A), 12 mm tape, 7" diameter plastic reel**
87A	**P**	**SMPC (TO-277A), 12 mm tape, 13" diameter plastic reel**
89A	**P**	**MicroSMP (DO-219AD), 8 mm tape, 7" diameter plastic reel**
45, P	**P**	**Anti-static tube packaging for Bridge and Power Pack**
4W, P	**P**	**Anti-static tube packaging for wire bond TO-220, ITO-220, TO-262 and TO-263**
96	**P**	**GL41 (DO-213AB), 12 mm tape, 7" diameter plastic reel**
97	**P**	**GL41 (DO-213AB), 12 mm tape, 13" diameter plastic reel**
98	**P**	**GL34 (DO-213AA), 8 mm tape, 7" diameter plastic reel**
100, V		MPG06 pseudo radial tape, cathode first out of ammo pack
H	**P**	Tape in 7" diameter plastic reel
I	**P**	Tape in 13" diameter plastic reel
TR	**P**	**SMA (DO-214AC), 12 mm tape, 7" diameter plastic reel** (1)
TR3	**P**	**SMA (DO-214AC), 12 mm tape, 13" diameter plastic reel** (1)

Notes
- "P" and bold letter denotes preferred package code
- A "T" suffix added to the packaging codes for SMA, SMB and SMC products indicates that the patented folded-frame construction is used. This does not apply to TR and TR3 codes or TransZorb® TVS in SMA and SMB

(1) Formerly sold by Vishay Telefunken® (Telefunken® is a registered trademark of Electro Holding GmbH)

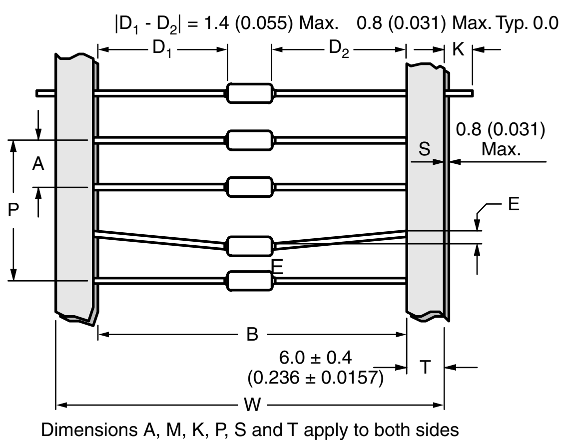
BULK PACKAGING					
CASE TYPES	PREFERRED PACKAGE CODE	PACKAGING	BOX SIZE		QUANTITY
			INCHES	cm	EA.
DF-M, DF-S, DFL-S	45	Anti-static plastic tubes	17.4 length	44.1 length	50
GSIB-3S	45	Anti-static plastic tubes	25.1 length	63.9 length	20
GSIB-5S, PB	45	Anti-static plastic tubes	24.2 length	61.5 length	20
GBU, BU	45	Anti-static plastic tubes	18.5 length	47 length	20
GBL	45	Anti-static plastic tubes	17.5 length	44.5 length	20
TO-220AB / AC, ITO-220AC / AB, TO-262AA	45, 4W	Anti-static plastic tubes	21.0 length	53.7 length	50
TO-247AD	45	Anti-static plastic tubes	20.0 length	50.8 length	30
MBS (TO-269AA)	45	Anti-static plastic tubes	20.3 x 0.41	51.5 x 1.04	100
GBL	51	Anti-static PVC tray	12.5 x 6.1 x 1.0	31.7 x 15.5 x 2.5	400
GBPC12-35W	51	Paper box	12.5 x 12.5 x 1.7	31.7 x 31.7 x 4.3	100
GBPC1, GBPC6	51	Paper box	7.5 x 7.5 x 1.43	19.0 x 19.0 x 3.6	100
KBL	51	Anti-static PVC tray	12.2 x 6.1 x 1.5	30.9 x 15.5 x 3.8	300
GBPC12-35	51	Paper box	12.5 x 12.5 x 1.7	31.7 x 31.7 x 4.3	100
KBU4, 6, 8	51	Anti-static PVC tray	12.2 x 6.1 x 1.5	30.9 x 15.5 x 3.8	250
WOG, 2WOG	51	Plastic bags	-	-	100
GBU / BU	51	Paper tray	13.1 x 6.6 x 1.2	33.2 x 16.8 x 3.0	250

AXIAL-LEADED TAPE AND REEL PACKAGING



All axial-leaded devices are packed in accordance with EIA standard RS-296-E. The diagrams given below refer to these specifications.

TABLE 1 - AMMO PACK PACKAGING						
PACKAGING	**AVAILABLE PRODUCT OUTLINES**	**PREFERRED PACKAGE CODE**	**DIMENSION A**	**DIMENSION B**	**DIMENSION C**	**QUANTITY BOX**
26 mm horizontal tape, ammo pack	DO-41(DO-204AL), MPG06 DO-15 (DO-204AC) P300	53, B 53, B 53, B	9.7" (247 mm)	1.7" (44 mm)	3.7" (95 mm)	3.0K 1.5K 0.75K
52 mm horizontal tape, ammo pack	DO-41(DO-204AL), MPG06 DO-15 (DO-204AC) DO-201AD, GP20 P600	73, D 73, D 73, D 73, D	10.0" (255 mm)	3.15" (80 mm)	4.53" (115 mm)	3.0K 2.0K 1.0K 0.3K
Pseudo / radial tape, ammo pack	MPG06	100, V	13.4" (340 mm)	1.8" (47 mm)	7.9" (200 mm)	2.0K

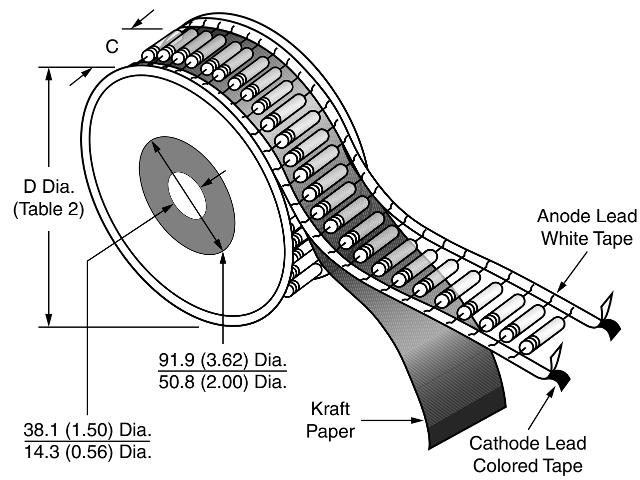


Dimensions in millimeters (inches)

Description	Symbol	
Component Pitch	A	2, 3
Inside Tape Spacing	B	2, 3
Lead to Lead Eccentricity	|D1 - D2|	-
Lead Extension	K	-
Lead Bending	E	2
Cumulative Pitch	P	3
Exposed Adhesive	S	-
Tape Width	T	-

All polarized components shall be oriented in the same direction

Fig. 1



The “C” dimension of Fig. 2 is between flanges of the component reel and shall be 1.5 mm (0.059") to 8.00 mm (0.315") greater than the overall taped component width “W” (Fig. 1). Where “W” dimension is 68.2 mm (2.68") max.

Fig. 2

AXIAL-LEADED TAPE AND REEL PACKAGING

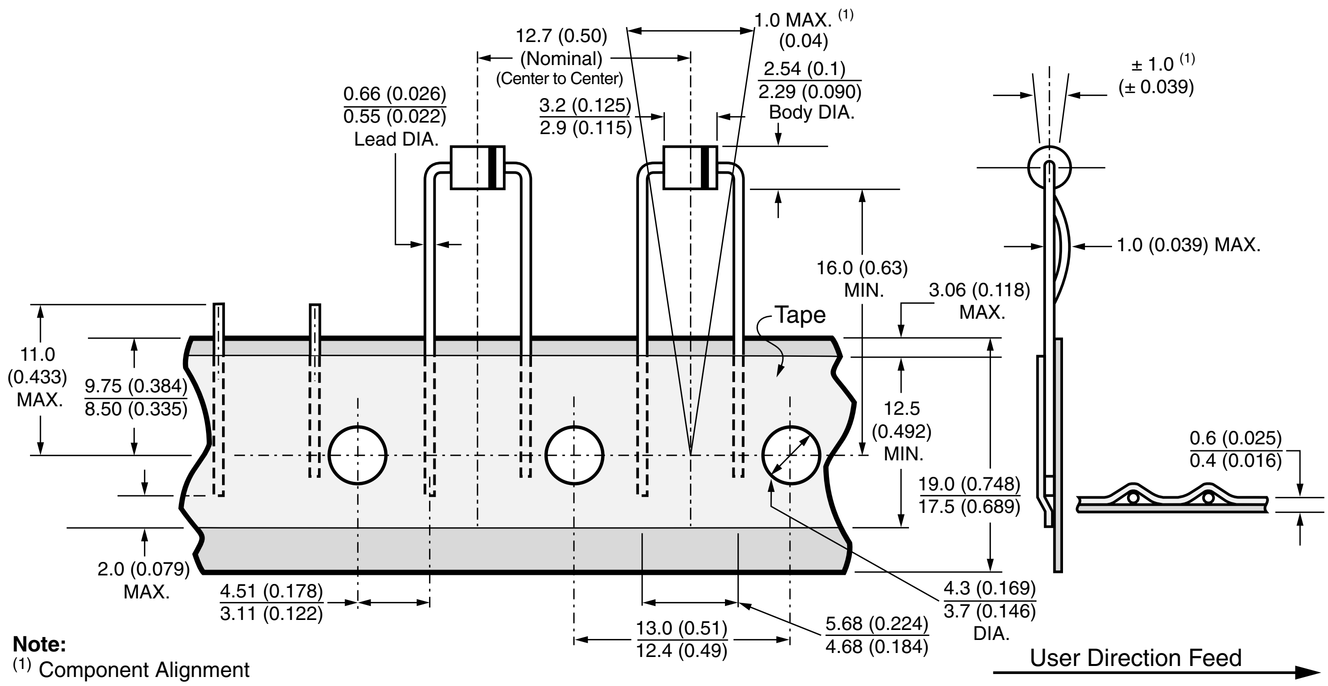
TABLE 2 - REEL AND AMMO PACK TAPING SPECIFICATIONS										
COMPONENT CASE TYPE	PREFERRED PACKAGE CODE	UNITS PER REEL	COMPONENT PITCH "A" Fig. 1		INSIDE TAPE SPACING "B" Fig. 1		REEL DIMENSION "D" Fig. 2		LEAD BENDING "E" Fig. 1	
		EA.	INCHES	mm	INCHES	mm	INCHES	mm	INCHES	mm
DO-15 (DO-204AC)	54, C	4000	0.200	5.0	2.06	52.4	13.0	330	0.047	1.2
DO-201AD	54, C	1400	0.395	10.0	2.06	52.4	13.0	330	0.047	1.2
DO-41 (DO-204AL)	54, C	5500	0.200	5.0	2.06	52.4	13.0	330	0.047	1.2
DFS Surface-Mount	77	1500	Fig. 8		-	-	13.0	330	Fig. 8	-
GF1 (DO-214BA)	67A, H / 5CA, I	1500 / 6500			-	-	7.0 / 13.0	178 / 330	Fig. 8	-
GL34 (DO-213AA)	98, H / 83, I	2500 / 9000			-	-	7.0 / 13.0	178 / 330	Fig. 8	-
GL41 (DO-213AB)	96, H / 97, I	1500 / 5000			-	-	7.0 / 13.0	178 / 330	Fig. 8	-
GP10E Radial	Fig. 5 and Fig. 6	2500	0.500	12.7	-	-	13.0	330	0.079	2.0
GP10E	54, C	5500	0.200	5.0	2.06	52.4	13.0	330	0.047	1.2
GP20/1.5KE	54, C	1400	0.395	10.0	2.06	52.4	13.0	330	0.047	1.2
MPG06	54, C	5500	0.200	5.0	2.06	52.4	13.0	330	0.047	1.2
P600	54, C	800	0.395	10.0	2.06	52.4	13.0	330	0.047	1.2
SMP (DO-220AA)	84A, H / 85A, I	3000 / 10 000	Fig. 8		-	-	7.0 / 13.0	178 / 330	Fig. 8	-
SMF (DO-219AB)	H / I	3000 / 10 000			-	-	7.0 / 13.0	178 / 300	Fig. 8	-
SMPD (TO-263AC) / SMPA (DO-221BC)	I	2000 / 14 000			-	-	13.0	330	Fig. 8	-
MicroSMP (DO-219AD) / MicroSMF (DO-219AC)	89A / H	4500			-	-	7.0	178	Fig. 8	-
SMPC (TO-277A)	86A, H / 87A, I	1500 / 6500			-	-	7.0 / 13.0	178 / 330	Fig. 8	-
SMA (DO-214AC)	61, 61T, TR, H / 5A, 5AT, TR3, I	1800 / 7500			-	-	7.0 / 13.0	178 / 330	Fig. 8	-
SMB (DO-214AA) / SMBG (DO-215AA)	52, 52T, H / 5B, 5BT, I	750 / 3200			-	-	7.0 / 13.0	178 / 330	Fig. 8	-
SMC (DO-214AB) / SMCG (DO-215AB)	57, 57T, H / 9A, 9AT, I	850 / 3500			-	-	7.0 / 13.0	178 / 330	Fig. 8	-
DO-218AB / AC	2D / I	750			-	-	13.0	330	Fig. 8	-
D^{2}PAK (TO-263AB)	81, 8W, I	800			-	-	13.0	330	Fig. 8	-
MBS (TO-269AA)	80, I	3000			-	-	13.0	330	Fig. 8	-
SlimSMA (DO-221AC)	6A, H / 6B, I	3500 / 14 000			-	-	7.0 / 13.0	178 / 330	Fig. 8	-
SlimSMAW	H, I	3500 / 14 000			-	-	7.0 / 13.0	178 / 330	Fig. 8	-
SlimDPAK (TO-252AE)	I	4500			-	-	13.0	330	Fig. 8	-
FlatPAK 5 x 6	H / I	1500 / 6000			-	-	7.0 / 13.0	178 / 330	Fig. 8	-

Note

- Package codes, 61/5A, 52/5B are matrix-frame constructions for TRANSZORB® TVS in SMA and SMB only

TABLE 3 - COMPONENT AND INSIDE HORIZONTAL TAPE SPACING			
COMPONENT BODY DIAMETER	COMPONENTS SPACING A (LEAD TO LEAD)	INSIDE TAPE SPACING "B"	CUMULATIVE PITCH TOLERANCE
0 mm to 5 mm (0.0" to 0.197")	5.0 mm ± 0.5 mm (0.197" ± 0.020")	26 mm + 1.5 mm / - 0.0 mm (1.024" + 0.059" / - 0.0")	Not to exceed 1.5 mm (0.059") over 6 consecutive components
0 mm to 5 mm (0.0" to 0.197")	5.0 mm ± 0.5 mm (0.197" ± 0.020")	52.4 mm + 1.5 mm / - 0.4 mm (2.062" + 0.059" / - 0.016")	
5.01 mm to 10 mm (0.197" to 0.394")	10 mm ± 0.5 mm (0.394" ± 0.020")	52.4 mm + 1.5 mm / - 0.4 mm (2.062" + 0.059" / - 0.016")	

DIMENSIONS in millimeters (inches)



Note:
(1) Component Alignment

Available only for MPG06 Product in Ammo Pack in Accordance with EIA Standard RS-468-A Utilizing 0.61 mm (0.024") Diameter Leads. Maximum Cumulative Pitch Tolerance: 1.0 mm (0.039")/20 Pitch.

Fig. 3 - Pseudo Radial

RADIAL TAPE PACKAGING

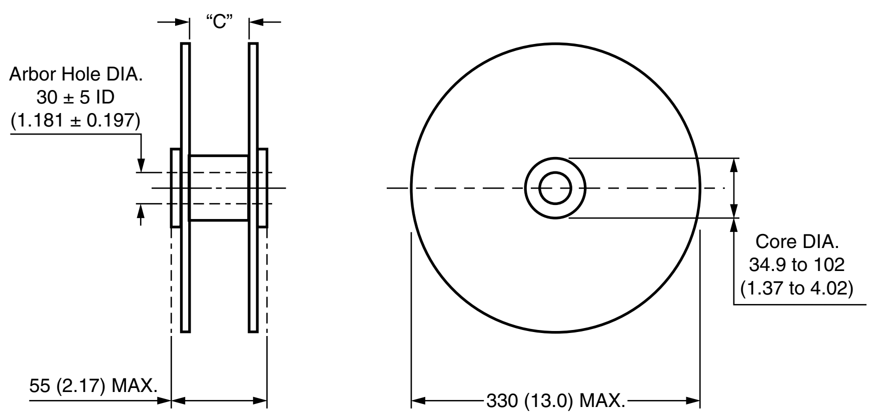


Fig. 4 - Reel Dimensions

Notes
- "C" dimension between the reel flanges shall be governed by the overall width of the taped components and shall be 1.5 mm (0.057") to 8.0 mm (0.315") greater than the overall width
- All leaded devices are packaged in accordance with EIA standard RS-468-A specification and are available on reel or in fan fold box (ammo pack)
- All dimensions are in millimeters and (inches)

SURFACE MOUNT TAPE AND REEL PACKAGING

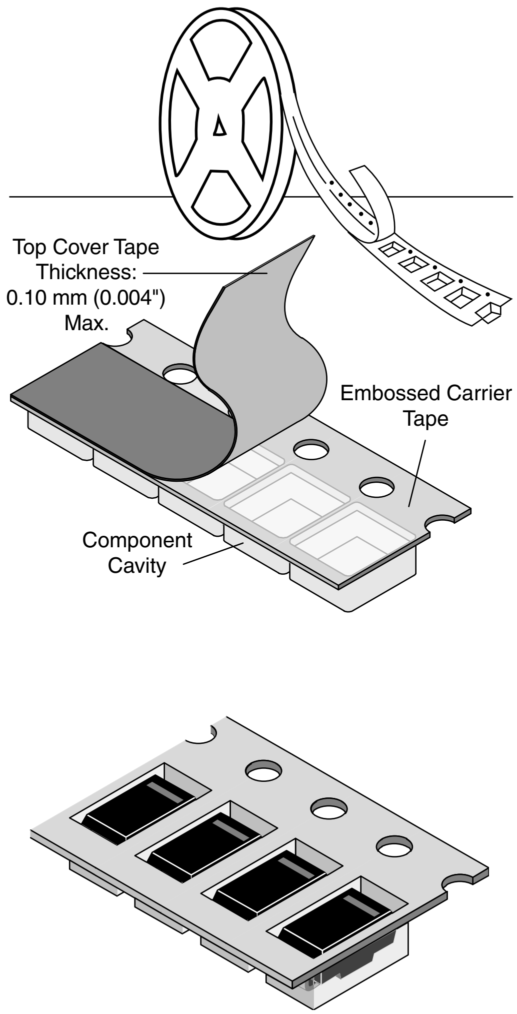


Fig. 5

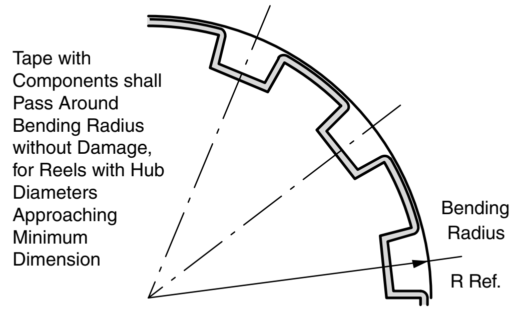


Fig. 6

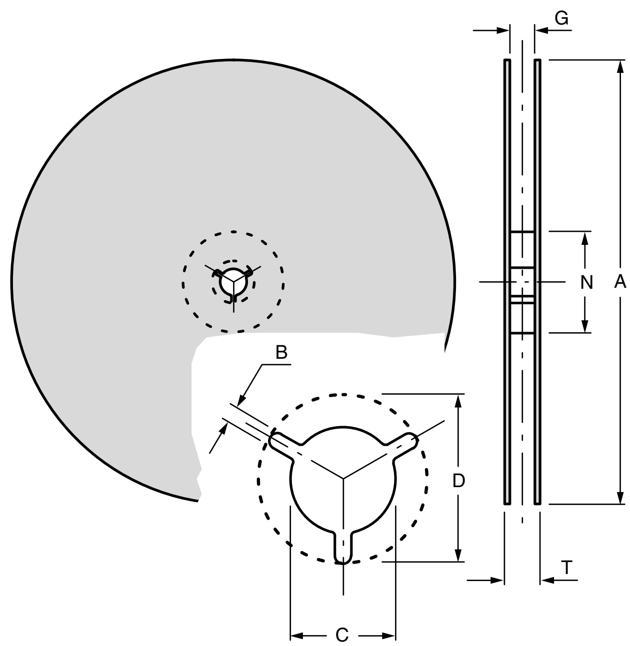


Fig. 7

DIMENSIONS in millimeters (inches)

TAPE SIZE	A MAX.	B MIN.	C	D MIN.	N MIN.	G MAX.	T MAX.
8 mm (0.315)	330 ± 2.0 (13.0 ± 0.079) 178 ± 2.0 (7.0 ± 0.079)	1.5 (0.059)	13.0 ± 0.20 (0.51 ± 0.008)	20.2 (0.795)	50 (1.97)	9.9 (0.389)	14.4 (0.567)
12 mm (0.472)	330 ± 2.0 (13.0 ± 0.079) 178 ± 2.0 (7.0 ± 0.079)	1.5 (0.059)	13.0 ± 0.20 (0.51 ± 0.008)	20.2 (0.795)	50 (1.97)	14.4 (0.567)	18.4 (0.724)
16 mm (0.630)	330 ± 2.0 (13.0 ± 0.079) 178 ± 2.0 (7.0 ± 0.079)	1.5 (0.059)	13.0 ± 0.20 (0.51 ± 0.008)	20.2 (0.795)	50 (1.97)	18.4 (0.724)	22.4 (0.802)
24 mm (0.945)	330 ± 2.0 (13.0 ± 0.079) 178 ± 2.0 (7.0 ± 0.079)	1.5 (0.059)	13.0 ± 0.20 (0.51 ± 0.008)	20.2 (0.795)	50 (1.97)	26.4 (1.039)	30.4 (1.197)

SURFACE MOUNT TAPE AND REEL PACKAGING

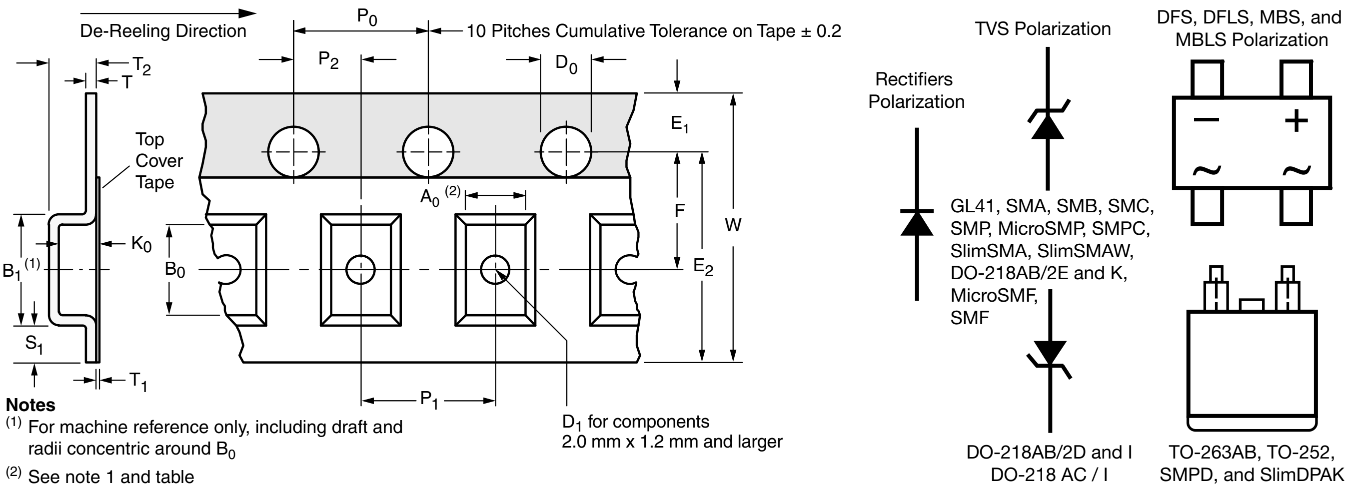


Fig. 8

8 mm, 12 mm, 16 mm, AND 24 mm EMBOSSED TAPE in millimeters (inches)								
TAPE SIZE	**D_0**	**E_1**	**P_0**	**P_2**	**A_0, B_0, K_0**	**S_1 MIN.**	**T MAX.**	**T_1 MAX.**
8 mm, 12 mm	1.5 ± 0.1 (0.059 ± 0.004)	1.75 ± 0.1 (0.069 ± 0.004)	4.0 ± 0.1 (0.157 ± 0.004)	2.0 ± 0.05 (0.079 ± 0.002)	(1)	0.6 (0.024)	0.600 (0.024)	0.1 (0.004)
16 mm, 24 mm				2.0 ± 0.1 (0.079 ± 0.004)				

DIMENSIONS in millimeters (inches)									
CASE TYPE	**TAPE SIZE**	**B_1 MAX.**	**D_1 MIN.**	**E_2 MIN.**	**F**	**P_1**	**R REF.**	**T_2 MAX.**	**W MAX.**
GL34 (DO-213AA)	8 (0.315)	4.2 (0.165)	1.0 (0.039)	6.25 (0.246)	3.5 ± 0.05 (0.138 ± 0.002)	4.0 ± 0.10 (0.157 ± 0.004)	20 (0.787)	2.4 (0.094)	8.3 (0.327)
MicroSMP (DO-219AB) / MicroSMF (DO-219AD)		3.28 (0.129)		6.05 (0.238)				1.919 (0.076)	
SMF (DO-219AB)		-						1.8 (0.07)	8.2 (0.322)
GL34 (DO-213AA)	12 (0.472)	8.2 (0.323)	1.5 (0.059)	10.25 (0.404)	5.5 ± 0.05 (0.217 ± 0.002)		25 (0.984)	4.5 (0.177)	12.3 (0.484)
GF1 (DO-214BA)								3.25 (0.128)	
SMA (DO-214AC)								2.64 (0.104)	
SMP (DO-220AA)								1.84 (0.072)	
SMPC (TO-277A)		7.0 (0.276)				8.0 ± 0.10 (0.315 ± 0.004)		1.43 (0.056)	
SMB (DO-214AA) / SMBG (DO-215AA)		8.2 (0.323)						2.77 (0.109)	
SMC (DO-214AB) / SMCG (DO-215AB)	16 (0.630)	12.1 (0.476)		14.25 (0.561)	7.5 ± 0.1 (0.295 ± 0.004)			2.64 (0.104)	16.3 (0.642)
SlimDPAK (TO-252AE)								2.0 (0.079)	
DFS						12.0 ± 0.10 (0.472 ± 0.004)		3.91 (0.154)	
D^2PAK (TO-263AB) DO-218AB / AC	24 (0.945)	20.1 (0.791)		22.25 (0.876)	11.5 ± 0.1 (0.453 ± 0.004)	16.0 ± 0.10 (0.630 ± 0.004)		5.31 (0.209)	24.3 (0.957)
SMPD (TO-263AC)						12.0 ± 0.10 (0.472 ± 0.004)		2.35 (0.093)	
SlimSMA (DO-221AC) / SMPA (DO-221BC)	12 (0.472)	6.2 (0.244)		10.25 (0.404)	5.5 ± 0.05 (0.217 ± 0.002)	4.0 ± 0.10 (0.157 ± 0.004)		1.53 (0.060)	12.3 (0.484)
SlimSMAW								1.61 (0.063)	
FlatPAK 5 x 6		6.4 (0.252)				8.0 ± 0.10 (0.315 ± 0.004)		1.20 ± 0.10 (0.047 ± 0.004)	

Notes

(1) A_0, B_0, and K_0 are determined by the maximum dimensions of the component size. The clearance between the component and the cavity must be within 0.05 mm (0.002") min. to 0.5 mm (0.02") max. for 8 mm tape and 12 mm tape, 0.15 mm (0.066") min. to 0.90 mm (0.035") max. for 16 mm tape and 0.15 mm (0.006") min. to 1.0 mm (0.59") max. for 24 mm tape

(2) All surface mount components are packed in accordance with EIA standard 481-E

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