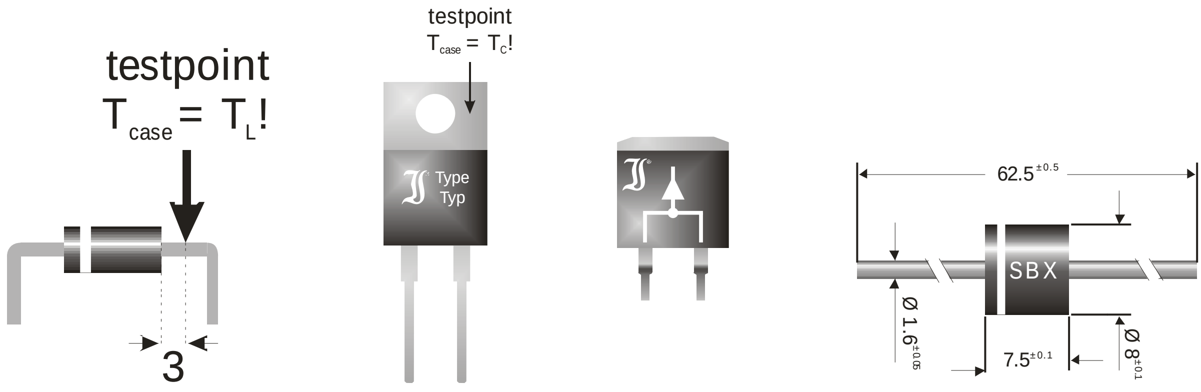
Solar Bypass Diodes



„Low Vf“ Bipolar Diodes *for Standard Modules*

F1200D, FX2000D, FT2000AD/KD

Reverse Voltage up to 200 V
= more rugged against voltage spikes

Lower leakage current than Schottky diodes
= reduced losses in normal mode of operation

Forward losses smaller than for standard rectifiers
= acceptable losses in bypass mode

Schottky Diodes *for High Current Modules*

SB1240, 15SQ045, SB1540, 20SQ045
SBX2040, SBX2540, SBX3040
SK2045YD2, SK3040CD2

Low Forward Voltage Drop
= reduced losses in bypass mode

Lower Leakage current than “ultra low Vf“ Schottky’s
= acceptable losses in normal mode of operation

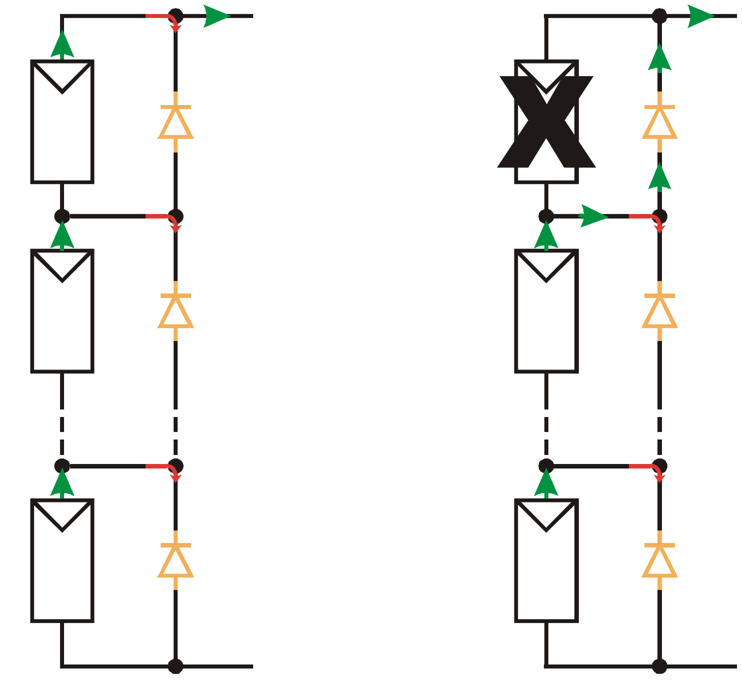
High Voltage Diodes *for Thin Film Modules*

BY880-1000, P2000M, P2000MTL, P2500Y

Reverse Voltage up to 2000 V
= for thin film modules and for blocking operation

Forward current up to 25 Amp
= acceptable losses in normal mode of operation

Function of Bypass Diodes



Normal Mode

Bypass Mode
(module partly shaded)

During construction of solar modules, single cells are switched in series to so called “strings” to achieve higher system voltages, see left picture above.

If one or more cells are shaded (e. g. by branches of trees, antennas, etc), the affected solar cells are no more acting like a current source, but as power consumers. Non-shaded cells are delivering further current through them, generating high power losses. “Hot spots” may occur and even cell breakdowns.

To overcome this problem, bypass diodes are switched parallel to every single or some combined cells, bypassing current flow across the darkened strings, right picture above.

Like every semiconductor device, also bypass diodes have got a certain leakage current, which in normal mode of operation reduces the current supplied by the cells and therefore decreases efficiency of the solar module (see red turn-down arrows in the picture above). Therefore leakage current especially at higher temperatures (full sun irradiation!) should be as low as possible. Compared to that, partly shading of modules is only an extreme operation mode which should be completely avoided or at least occurs only during short time periods. For this mode of operation,l low forward losses are desirable. Finally, the bypass diode has to be rugged against overvoltage spikes. Such spikes may occur during assembly of the system, if e. g. current conducting cables are interrupted, or during operation, caused by lightning etc.

Bypass Diode Tests

Existing standards (e. g. IEC 61730-2, IEC 61215) describe a bypass diode test, applying the module short circuit current for one hour, at an ambient temperature of 75°C. At this test, the junction temperature of the diode has to stay below the maximum admissible value. From 2014, IEC 61215-2 describes two procedures to estimate this junction temperature.

IEC 61215-2, Procedure 1

Uses this formula:

$$T_j = T_{L/C} + R_{thL/C} * V_f * I_{SC}$$

Where:

T_j = junction temperature of the diode, maximum admissible value see datasheet
$T_{L/C}$ = temperature of contact leads (L) resp. cooling fin of case (C) [1]
$R_{thL/C}$ = thermal resistance junction – contact lead (L) resp. cooling fin of case (C)
V_f = forward voltage drop across diode
I_{SC} = module short circuit current

This procedure requires the correct measurment of temperature and correct usage of thermal resistance values given in the data sheet[1].

IEC 61215-2, Procedure 2

At this procedure, the junction box equipped with diodes has to be placed in a thermal chamber and V_f to be tested at I_{SC} and several ambient temperatures (30°C, 50°C, 70°C, 90°C). Care has to be taken that V_f is tested at very short pulses (about 1ms), to avoid self-heating and thus misreading. Furthermore, four-wire-sensing (also called Kelvin contacting) has to be used. The resulting function

$$T_j = f(V_f)$$

can be extrapolated linearly towards higher temperatures. In a second step, the junction box is kept at 75°C, and I_{SC} applied for one hour. By measuring the forward voltage drop V_f (Kelvin contacting!), from above function the according T_j can be derived. This procedure does not require thermal measuring nor thermal resistance calculations, so avoids a lot of misunderstandings and wrong results. It requires however dedicated semiconductor test equipment, providing short pulses and Kelvin contacting. <u>We recommend using this procedure.</u>

To comply with the bypass diode test, products by Diotec are offering several advantages:

V_f

Reduced power losses inside the diode by reduced forward voltage drop V_f. Possible with „**Low Vf**"-bipolar diodes as well as **Schottky** diodes.

T_j

The maximum admissible junction temperature is normally based on a DC load of 80% of the maximum reverse repetitive voltage V_{RRM}. If the actual occuring reverse voltage is much below this value, as typical for solar modules (e. g < 30% V_{RRM}), a higher T_j can be specified. See parameters in the Diotec datasheets.

$R_{thL/C}$

At higher currents, the junction temperature can be reduced by suitable cooling measures. Ideally suited in this case are package outlines like TO-220 und D^2PAK, having low thermal resistance junction to case.

[1] Refer to http://diotec.com/tl_files/diotec/files/pdf/service/applications/thermal-measurements-on-bypass-diodes.pdf

Standard / High Voltage Rectifier

+ Reverse voltage up to **2000 V**
+ Rugged against over voltage
+ Nominal current up to **25 Amp**
+ Low leakage current, therefore reduced losses in normal mode of operation
- Higher forward voltage drop (typ. 1.0 Volt), therefore higher losses in bypass operation

Types e. g.
BY255/BY2000 – 3A, BY550 – 5A, BY880 – 8A, P600 – 6A, P1000 – 10A, P2000 – 20A, P2500 – 25A

„Low Vf“ Rectifier

“Low Vf” rectifier by Diotec are bipolar diodes, having also at higher temperatures a low leakage current. By optimizing the Si-chip it was possible to reduce forward losses compared to standard rectifiers by more than 10%, having positive impact on forward losses.

+ Reverse voltage up to **400 V**
+ Rugged against over voltage
+ Nominal current up to **20 Amp**
+ Reduced forward voltage drop (typ. 0.8 to 0.9 V), therefore lower losses/lower temperature in bypass operation
+ Low leakage current, therefore reduced losses in normal mode of operation

Types e. g.
F1200 – 12A, FX2000 – 20A, FT2000 – 20A (heatsink assembly!)

Schottky Rectifier

+ Reverse voltage up to **100 V**
+ Nominal current up to **30 Amp**
+ Low forward voltage drop (typ. 0.5 to 0.7 Volt), therefore low losses/low temperature in bypass operation
- High leakage current, therefore higher losses in normal mode of operation;
  it is recommended not to load the diodes with DC voltage higher than 30% V_{RRM} [2]

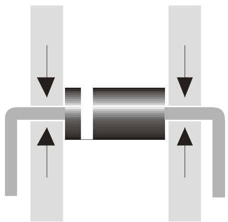
Types e. g.
80SQ05 – 8A, SB12.. – 12A, 15SQ – 15A, SB15.. – 15A, 20SQ – 20A (Axial lead)
SBX20 – 20A, SBX25 – 25A, SBX30 – 30A (Low R_{th} Axial lead)
SBT10.. – 10A, SBT18.. – 18A, SBCT20.. – 20A (TO-220)
PPS1045 – 10A, PPS1545 – 15A (Power-SMD)
SK18...D2 – 18A, SK20...CD2 – 20A, SK30...CD2 – 30A (D^2PAK)
SK1545YD2 – 15A, SK2045YD2 – 20A, SK2545YD2 – 25A (D^2PAK in “Y” configuration)

Datasheets of all mentioned products can be found at www.diotec.com – “Search”

[2] From some manufacturers offered “ultra low Vf” Schottky diodes have got beside a very high *hot leakage current* also a *lower maximum admissible junction temperature*, and are therefore less suited for bypass operations.

Customized solutions

Axial bypass diodes are inserted into the junction box with leads bent. Care has to be taken to do this bending properly, i. e. with strain relief of lead wires during bending[3]. As a special service, Diotec offers to supply the leads already bent for direct insertion into the connectors, saving time and effort during assembly, at only low additional costs. Also possible is the welding of the leads towards metal leadframes; please inform Diotec if you want to do so, in order that we can offer to you devices having weldable contacts.



Don't hesitate to contact us for further questions:
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[3] Refer to http://diotec.com/tl_files/diotec/files/pdf/service/applications/correct-bending.pdf