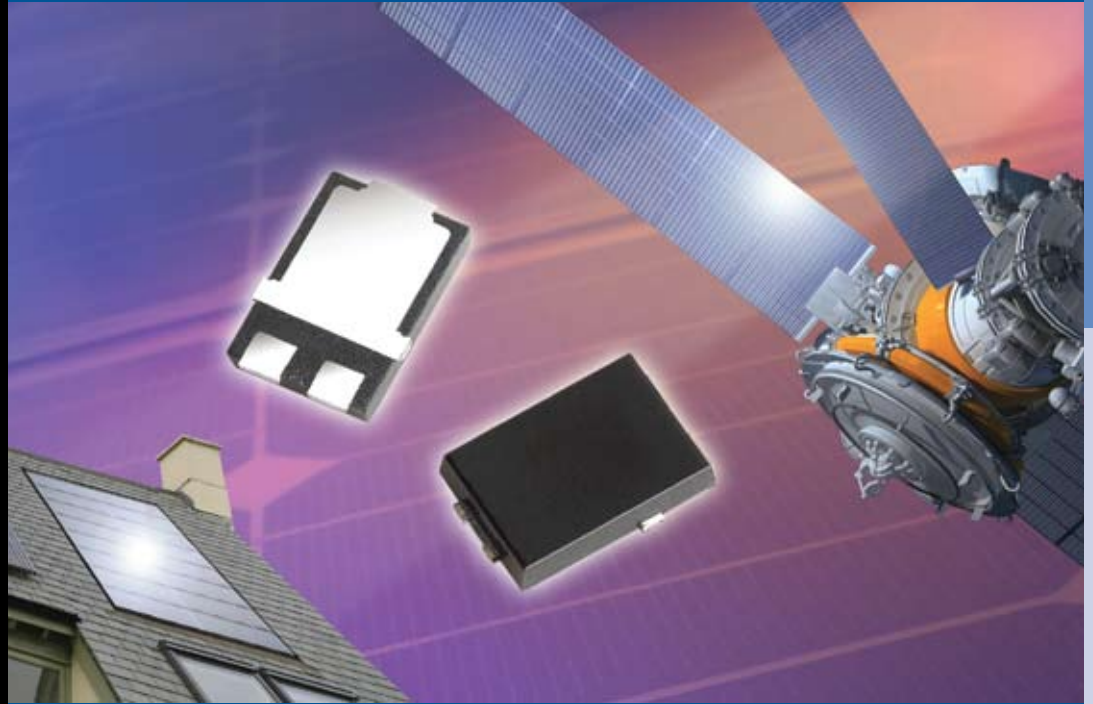




VISHAY INTERTECHNOLOGY, INC.



SOLAR CELLS HOT SPOT DAMAGE PROTECTION

Vishay General Semiconductor
Power Schottky Rectifiers



POWER SCHOTTKY RECTIFIERS PROTECT SOLAR CELLS AGAINST HOT SPOT DAMAGE

By Jon Schleisner, Technical Marketing Manager, Vishay General Semiconductor

Hot spot heating occurs in a solar cell module when the operating current exceeds the reduced short-circuit current (I_{sc}) of a shadowed or damaged cell or group of cells. When such a condition occurs, the affected cell or group of cells is subject to a reverse bias condition. Under reverse bias conditions, the cell starts to dissipate power. If this power dissipation occurs in a localized spot, damage to the cell can result.

Damages can include: reflowing of solder, damage to the cell structure, or damage to the encapsulant and backplane. The typical condition that causes a hot spot is referred to as shadowing. Shadowing occurs when part or all of a particular cell (or group of cells) is placed into a shadowed (reduced light exposure) condition. This can be caused by a bird standing on a solar panel, passing clouds, or snow partially covering a portion of an array of solar cells.

The reverse characteristics of solar cells break down into two general categories: low shunt resistance cells and high shunt resistance cells.

Low Shunt Resistance Cells

The worst case shadowing occurs when all or most of the cell is covered.

Low shunt resistance cells have localized shunts within the cell structure. In this case, hot spot heating occurs because large amounts of current flow through a narrow conduction area.

As the current channel is narrow, localized cell heating is very rapid (damage can occur in seconds).

High Shunt Resistance Cells

The worst case shadowing occurs when a small portion of a cell is shadowed.

Highly resistive cells limit the reverse current flow of the circuit and dissipate the energy as heat. The cell with the highest impedance will dissipate the most power.

The power dissipation occurs over the surface area of the entire cell; as a result, hot spot damage can take minutes, as opposed to seconds, to occur.

The Schottky Rectifier Solution

The most practical solution to the hot spot problem is to bypass each solar cell with a Schottky rectifier, as shown in Figure 1.

Figure 1 depicts a portion of a string of solar cells. Each individual cell is protected by a Schottky rectifier in parallel with the cell. When the string of cells is in good working order and all the cells are exposed to sunlight, the bypass diodes are effectively out of the circuit. Typically, each rectifier dissipates a small amount of power due to reverse current leakage in the rectifiers. At +150 °C (in bright sunlight), the typical power loss would be around 15 mW per protected cell.

When one of the cells is partially covered or damaged, the current flow is as depicted in Figure 2.

Here the top cell (C1) has the light source block off. The result is that the solar voltaic cell becomes a high impedance. Without the bypass diode (D1), the energy contribution of the series string of cells will be severely impaired, rendering the entire string of cells as noncontributors. The worst case scenario is the energy from the light cells will be dissipated in the shaded cell, resulting in hot spot damage.

Figure 3 displays the V/I curve for the typical solar cell with and without the bypass diode.

Here the forward (current generating mode) shows a forward voltage of roughly .6 V; current delivery is typically around 700 mA. In the reverse direction, without the bypass diode, the solar cell appears as high impedance, which at some point exhibits a reverse breakdown, where it dissipates power (like a non-linear resistor). If this power is great enough, or concentrated in one spot, the cell can be damaged at the extreme temperature point where the current crowding occurs. The bypass diode limits the reverse voltage across the solar cell, shunting the current away from the cell and maintaining the integrity (power delivery) to the solar cell string.

Vishay General Semiconductor offers a variety of Schottky rectifier solutions ideally suited for the bypass application. (See table below.)

Part Number	B_{VR} , Volts	I_F (max), Amps	V_f @ I_{fmax} , Volts	Max. Operating Temperature, °C	Package
SS10P4-E3	40	10	0.56	150	TO-277A (SMPC)
SS10PH45-E3	45	10	0.72	175	TO-277A (SMPC)
SB15H45-E3	45	15	0.64	175	P600 (Axial)
SS8PH10-E3	100	8	0.9	175	TO-277A (SMPC)
SS10PH10-E3	100	10	0.74	175	TO-277A (SMPC)

All the Schottky rectifiers in the above table, with the exception of the SB15H45-E3, use the Vishay SMPC (TO-277A) high-density, surface-mount package. With a maximum height of 1.15 mm, the SMPC (shown at right) is thin enough to fit directly into most cell constructions.



The Schottky die is mounted directly on the heat spreader, which is designed to make intimate (solder onto) contact with the PCB/heat-sink. This design results in very low-thermal impedance (3 °C/W). The top clip also pulls heat away from the die and supports a very low inductance connection to the top of the chip. The special wide-bottom plate design also provides great heat dissipation performance.

The importance of using correct, industry-standard soldering techniques to mount the bypass diode within the cell cannot be overemphasized. Vishay provides recommended solder profiles for the SMPC (TO-277A) and other packages, including:

- DO-214AC/DO-214BA
- SMC/DO-214AB
- SMB/DO-214AA
- DO-220AA (SMP)
- TO-277A (SMPC)
- MicroSMP
- DO-215AA (SMBG)
- DO-215AB (SMCG)
- DO-213AA

For solder profile information, please refer to Vishay's website at: <http://www.vishay.com/docs/88854/padlayso.pdf>.

Figure 1.

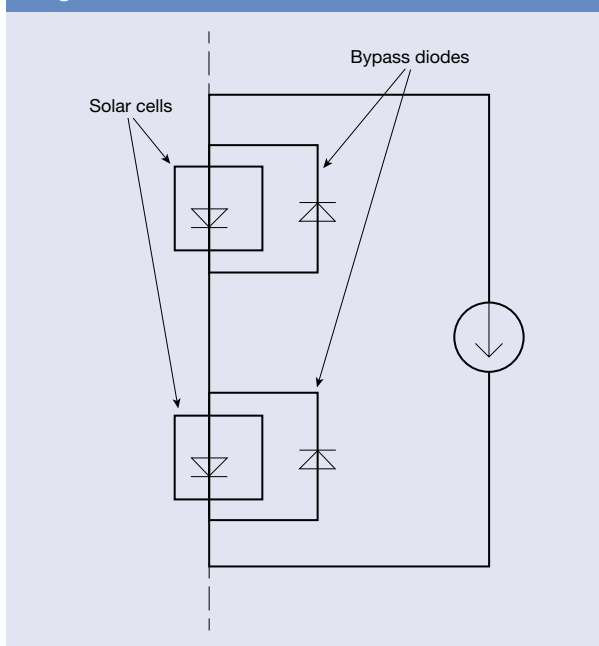


Figure 2.

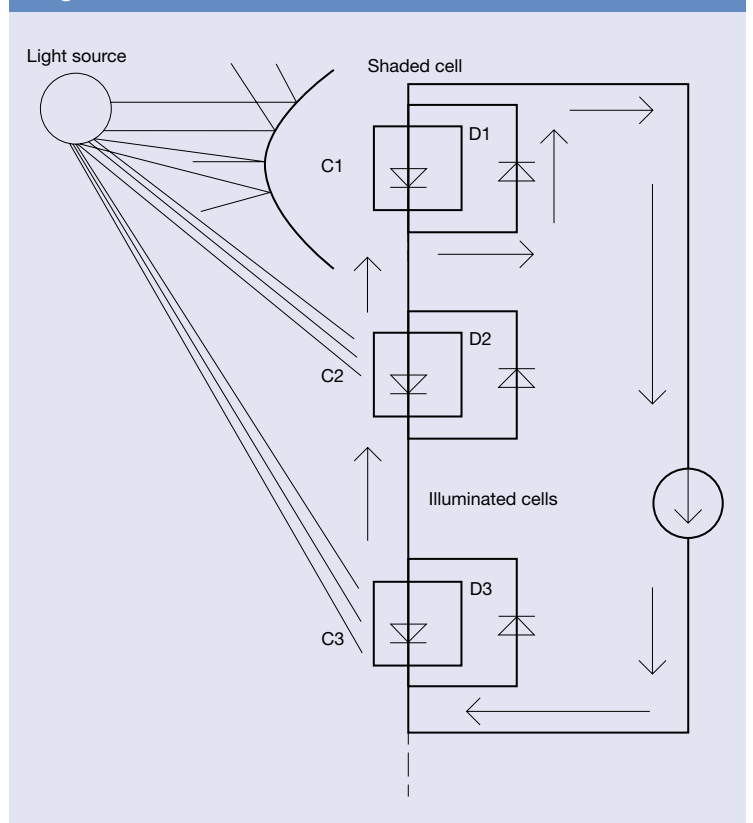
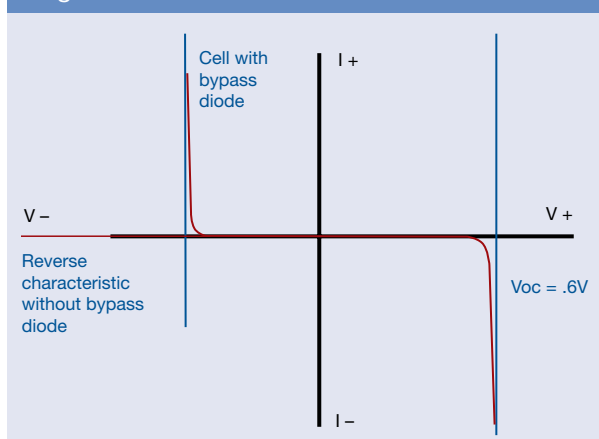


Figure 3.



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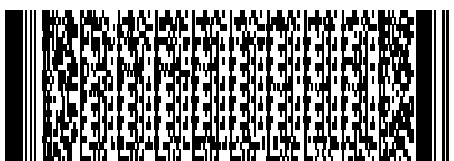
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