MicroNOTE #304

by:

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Introduction To Photovoltaic By-Pass Diodes

To produce a reasonably high output voltage, photovoltaic cells are often connected in a series configuration. If a portion of the series becomes shaded, then the output of the remaining active cells is applied to the inactive cells, as shown in *figure 1*. Note that the normal current flow in a photovoltaic cell is from cathode to anode.

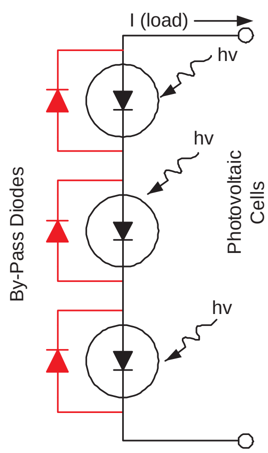

Figure 1

The inactive cells will become reverse-biased and block current flow. Because photovoltaic cells are not designed to support a reverse voltage, they may be degraded, depending on the applied voltage. The addition of by-pass diodes to the circuit, as shown in *figure 1*, provides two advantages. The output of the active cells can flow past an inactive cell, losing only a voltage equal to the forward voltage of the by-pass diode. Second, the inactive cell is protected from a reverse voltage bias greater than the forward voltage of the by-pass diode. When the cell is active, the only current through the by-pass diode is the reverse leakage current, which is typically low. *Figure 1* shows one by-pass diode per photocell, a common configuration, but many other configurations are used. Depending on the output voltage and the tolerance to reverse voltage of the photocells, and cost targets, a by-pass diode may be used every few cells, or even across an entire array. The by-pass diodes described here are primarily targeted for inclusion on the photocell array. Diodes to by-pass an entire array can be externally mounted, and can be selected from Microsemi's standard rectifiers, based on current and voltage requirements.

In selecting an on-board by-pass diode for a particular application, the primary considerations are size (shape), whether leads are attached as delivered, forward voltage drop at the intended current level, and reverse leakage current throughout the planned operational temperature range.

The by-pass diode products shown at this site are some standard types which have been delivered to various customers. Most are about 5 mils (127 micrometers) thick, to match typical photocell thickness. The thickness can be tailored for specific applications, with a minimum about 2 mils (51 micrometers). There is a cost increase for very thin products to offset the increase in wafer breakage associated with handling very thin silicon wafers. For volume orders, shapes other than those shown may be designed. Most types have the anode and cathode on the opposite sides of the silicon die, but the MXP1125 is an example where an additional cathode contact is available on the topside. There is an area penalty for the additional contact, but mounting may be easier.

All the displayed devices may be ordered with leads attached using high temperature gold-tin solder. This solder is space qualified, and the leads may be welded or brazed provided that reasonable times and temperatures are used. There is a significant cost increase for devices ordered with leads, and so some customers prefer to attach their own leads or use other mounting techniques. The metallization on all of the devices shown is space qualified Ti/Pd/Ag, which is suitable for welding, brazing, or soldering.

The forward voltage drop through the device is dependent upon the device area. A larger area device will have a lower forward voltage (not simply proportional to area), but will of course cost more, and will take up more space. The forward voltage can be significantly reduced by diffusing gold into the silicon, but there is a resultant increase in reverse leakage current. The particular application will determine whether the decrease in power loss through the diode during forward bias is worth the increase in reverse leakage current. The MXP1005 is an example of a gold-diffused device, but gold diffusion may be used in conjunction with any of the other types. Comparing the MXP1005 with devices of similar area without gold diffusion, it is apparent that the forward voltage is lower, and that the reverse leakage current is higher, especially at high temperature. It should be noted that in addition to increasing with gold diffusion, reverse leakage current also increases with light exposure. Optimal designs locate the by-pass diode in the dark, or at least “upside-down”, so that the back metal blocks light penetration.

All of the devices shown are designed to be operated at relatively low current densities. At low current densities, most of the forward voltage drop in the device is across the P-N junction, versus at higher current densities the series resistance through the lightly doped region becomes significant. Upon exposure to a space radiation environment, the junction voltage drop decreases, and the series resistance increases. By designing for operation at low current density, the forward voltage will decrease upon exposure to radiation. An example of this is shown in *figure 2*, for an extremely high radiation dose. Gold diffused devices do not exhibit as much of a change in forward voltage after radiation exposure, since the forward voltage has already been reduced by the introduction of the gold.

At voltages below about 0.9V, the intended operating range, the curve to the left shows the decrease in forward voltage at a given current level.

In summary, the efficiency and reliability of space and terrestrial photovoltaic arrays can be improved with the addition of by-pass diodes. Several standard types for inclusion on arrays are available, and custom types are available for volume orders. To view the data sheets for the types that have been posted, go to:

http://www.microsemi.com and type in the part number on the top right left side of the website.

For further information, you may send your inquiries via e-mail to Eric Karlsson at ekarlsson@microsemi.com.

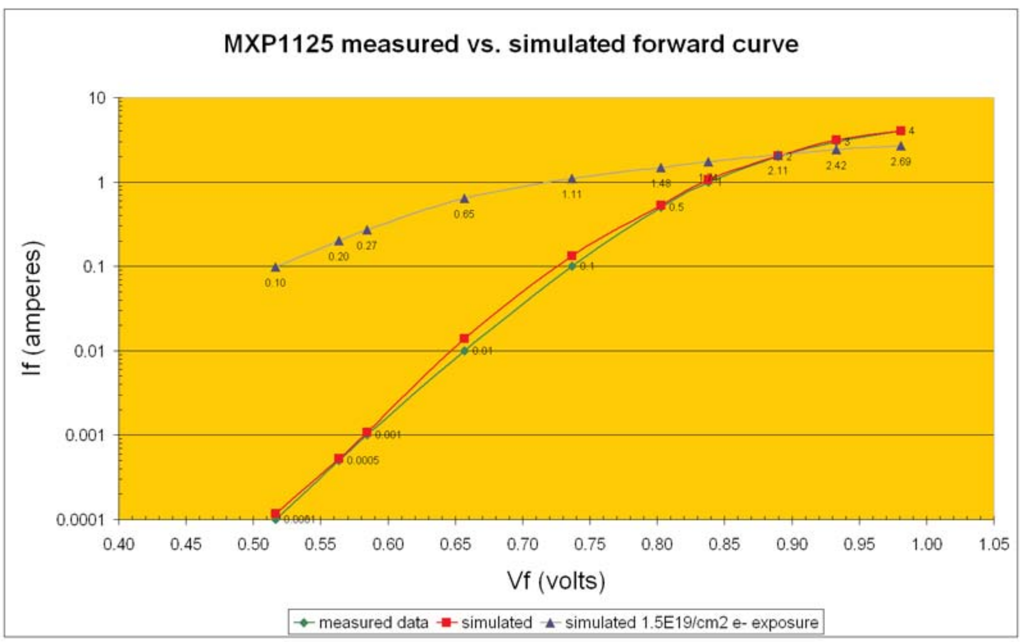

Figure 2