Isaac Benatar
Hewlett-Packard, Rockaway, NJ

When testing power systems and electronic assemblies on earth, satellite manufacturers must simulate the operating conditions of space to produce valid test results. You could put a satellite power system into a combination temperature-and-vacuum chamber to simulate environmental conditions, but until recently you couldn't easily simulate the input power conditions that satellite power systems experience in space.

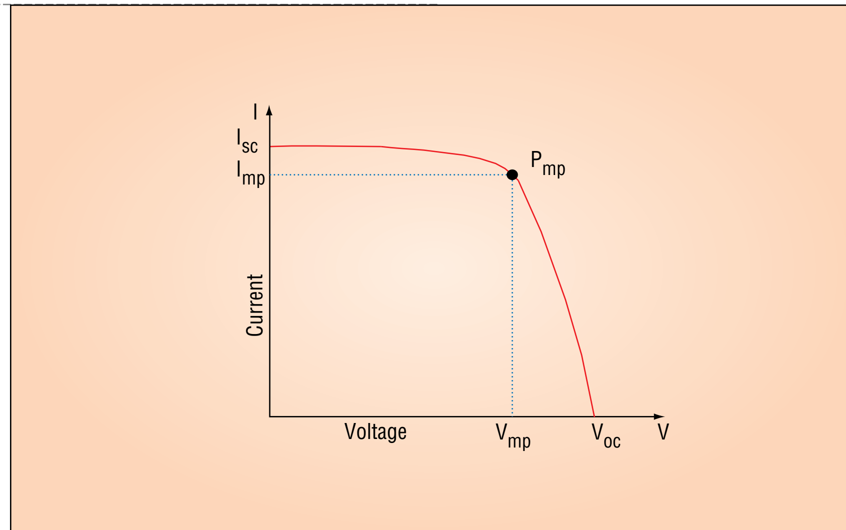

FIGURE 2. All photocell output curves have the same general shape, but the actual voltage and current values depend on operating conditions. Maximum output voltage occurs under open-circuit conditions (V_{oc}), and maximum current occurs under short-circuit conditions (I_{sc}). Attempting to maintain operation at the maximum power point (P_{mp}) on the curve—despite continuously varying operating conditions—presents a great challenge to a solar array simulator.

Solar Panels Power Space Electronics

Batteries store power on a spacecraft, but it is solar panels that generate the power. Solar panels contain arrays of photodiodes. Commonly called photocells, photodiodes are p-n junction devices with a large surface area; they convert solar radiation directly into electrical energy. **Figure 1** represents the equivalent circuit of a typical photodiode, and **Figure 2** shows a typical I-V characteristic.

Photodiodes are the main components in solar arrays. A solar array consists of a series-parallel matrix of photodiodes, and a satellite manufacturer will assemble solar arrays into solar panels that provide the desired I-V characteristics for powering a particular satellite. A solar panel provides the power required to charge the satellite batteries and operate the onboard electronics under proper solar illumination conditions.

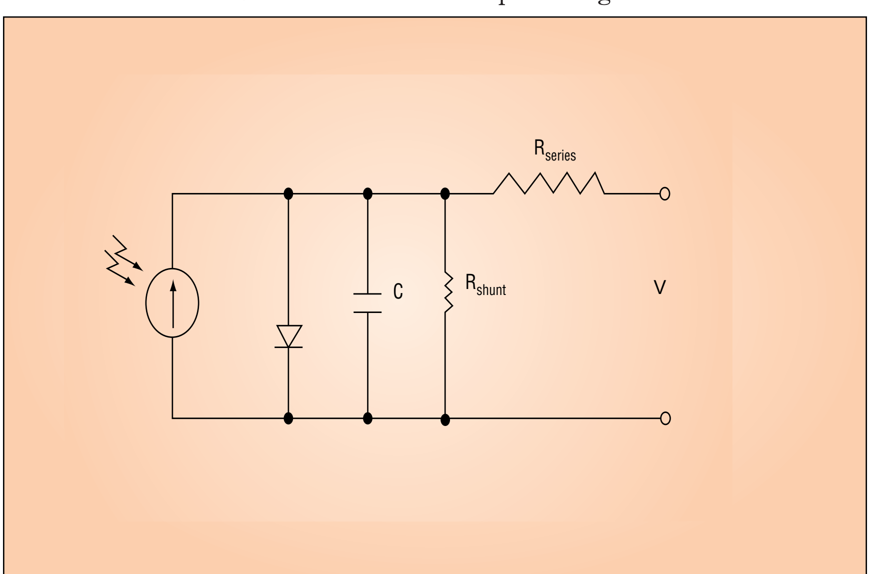

FIGURE 1. This equivalent circuit of a solar cell includes a representation of light sensitivity (the current source), the cell's p-n junction (the diode) and the internal resistances and capacitance typical of electronic components. The user need only supply a light source–such as the sun–to make use of the cell's output (V).

Solar arrays typically exhibit very low output capacitance (≤ 0.5 μF) and very fast transient-recovery times (< 10 μs). Their I-V output curves vary with illumination and temperature (**Fig. 3**), age, and the material of the individual cells. An increase in illumination intensity produces both higher current and higher voltage outputs; an increase in array temperature causes a slight increase in the short-circuit current and a significant decrease in voltage.

Testers Must Simulate Solar Panels

Huge, delicate solar panels for satellites normally function without an atmosphere that attenuates solar radiation, so they don't make practical power sources for earth-bound testing. Because solar array simulation is essential for testing a satellite's power bus and electronics, satellite manufacturers and test equipment manufacturers have developed special power supplies known as solar array simulators (SASs) that accurately simulate the output of solar panels under varying operating conditions.

Solar array simulators can reproduce the output power characteristics of any solar panel. Their designs range from basic to sophisticated, but all SASs must have very low output capacitance and high output impedance, equal to or better than a typical solar array.

Some simulators can reproduce specific I-V characteristics by using an internal DSP and an algorithm; in others, you can set up a table of I-V values to control the simulator. The I-V curves or points simulate different conditions: eclipse, partial eclipse, full illumination, and beginning and end of a panel's operating life. When the satellite power system uses shunt regulation, the SAS must tolerate a direct short across its output—just like a solar array in space whose output exceeds a desired limit (Fig. 3).

If you use a table to control a simulator, you define specific I-V curves by downloading predefined I-V points. This data produces an accurate representation of the output power curve of a solar array. Usually, you can get this data on disk from the solar panel manufacturer. You can buy or build an SAS that uses this operating mode, or you can use a PC and a programmable power supply, provided both can respond to commands quickly enough to satisfy your test requirements. You can apply current and voltage offset values to table data to simulate a change in the operating conditions of the solar array.

You can also use a "bare bones" method—as some satellite manufacturers do—to simulate solar arrays. You can use any power supply that has low output capacitance and high output impedance, operating in constant current mode, if you don't need the type of I-V curve shown in Figure 2. In fact, the operating "curve" of such a power supply would look like the straight lines connecting to the maximum power point of the figure.

You'll have to choose the simulation method that's best for you in order to satisfy the future higher-power testing demands of solar arrays. Upcoming generations of satellite power systems will operate at voltages of 60–150 VDC rather than the present 30–120 VDC range; they will also consume more power. Higher voltage output from the solar panels will reduce wire size and weight as well as power dissipation—a significant accomplishment when every gram saved means a more useful payload. ✳

Isaac Benatar *is an application engineer at Hewlett-Packard's power products division. He has a B.S.E.E. from California State Polytechnic University (Pomona, CA).*

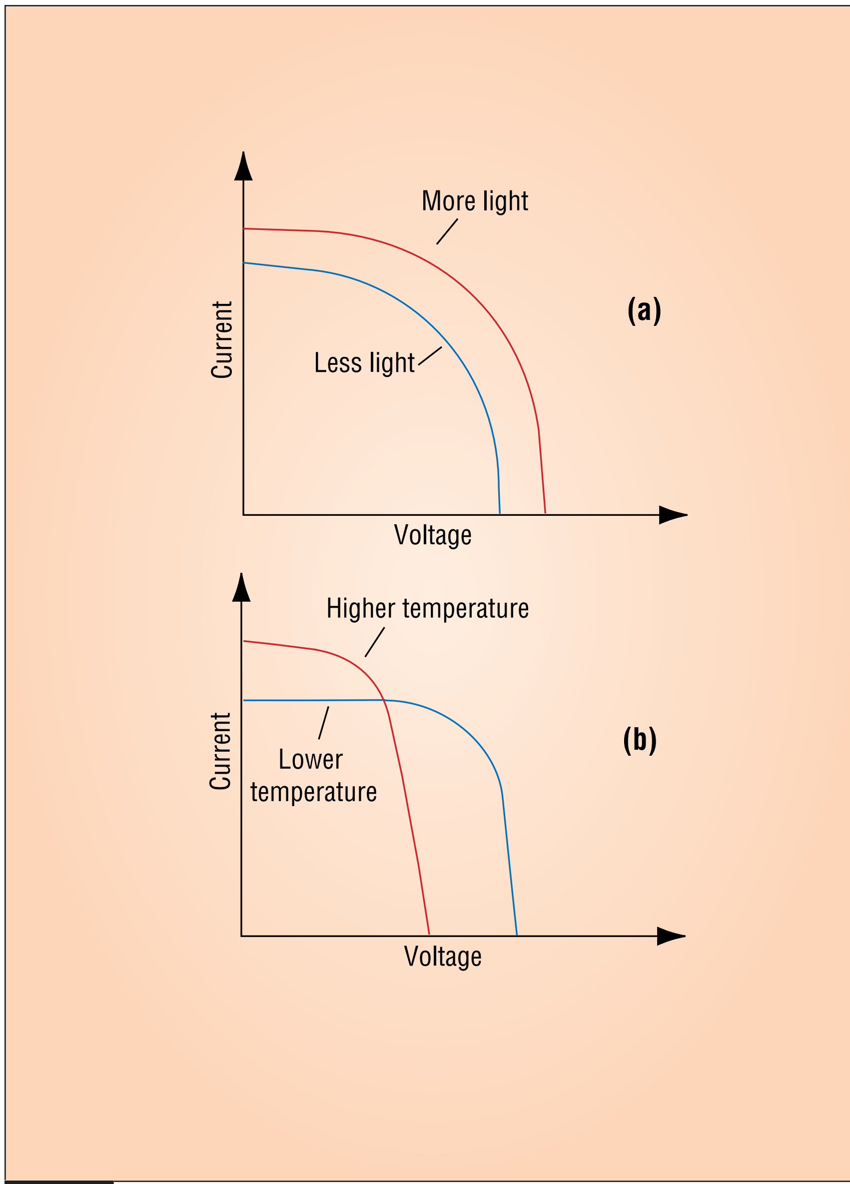

FIGURE 3. Many environmental conditions affect solar cell output. (a) As light intensity increases, both current and voltage outputs rise. (b) As temperature increases, however, current output rises while voltage output falls. Solar cells also become less efficient as they age.