Application Note

EVIX-CX3AA Solar Charging Evaluation Board

By Gilbert Bates and Bob Schmid

List of Figures

1.0 Introduction

The EVIX-CX3AA solar charging evaluation board demonstrates several IXYS technologies in a simple solar charger for a single AA rechargable alkaline battery. The circuit represents an improvement over the the typical solar cell charger that uses a blocking rectifier diode to prevent back discharge from the battery when no sun light is present. Instead, it uses a MOSFET as the blocking mechanism and a small solar cell to power the gate of the MOSFET to turn it on and off. The use of the MOSFET eliminates the need for an additional more costly solar cell to overcome the forward voltage drop of the blocking diode. Charge rate or speed is not the goal for this evaluation board; it is to convey ideas of solar battery charging by way of a low power, low cost, uncomplicated design.

Fig. 1 Evaluation Board Photo

2.0 Background

Some basic information needs to be covered to better understand what to expect in terms of the evaluation board's performance with regards to solar cell type, lighting conditions in terms of power density, and general industry standards as they relate to battery charging.

2.1 Solar Cell Types

Keep in mind these cost and performance tradeoffs when comparing various solar cell materials:

Polycrystalline cells are commonly found in outdoor applications and have a spectral sensitivity range of 500nm to 1100nm. They're in the medium price range and typically offer a 13% power conversion efficiency. They suffer from impurities on the polycrystalline material which degrate cell efficiency over operating time. Many polycrystalline cells degrade by 20% over the first 100 operating hours.

Monocrystalline cells, such as the IXYS Solar Bits used in this circuit, have a spectral sensitivity range from 300 nm (near-ultraviolet) to 1100 nm (near-infrared), which includes visible light (400 to 700 nm). Due to this wide spectral range, they can be used in both indoor and outdoor applications. Monocrystalline or single-crystalline material is the most expensive but it does not contain impurities, and as such the power conversion efficiency does not degrade over operating time. The power conversion efficiency of commercially available monocrystalline cells ranges from 15 to 19%. The surface of these cells is a homogenous dark blue or dark grey.

Finally, amorphous cells, which work in the spectral range of 300nm to 600nm, are used predominantly indoors in products such as solar powered calculators since they are not sensitive to the upper light spectrum and cannot take advantage of natural sunlight. They offer about 5% power conversion efficiency and are mostly used with ultra low power devices like clocks and electronic calculators. Amorphous cells, like polycrystalline cells, suffer from efficiency degradation.

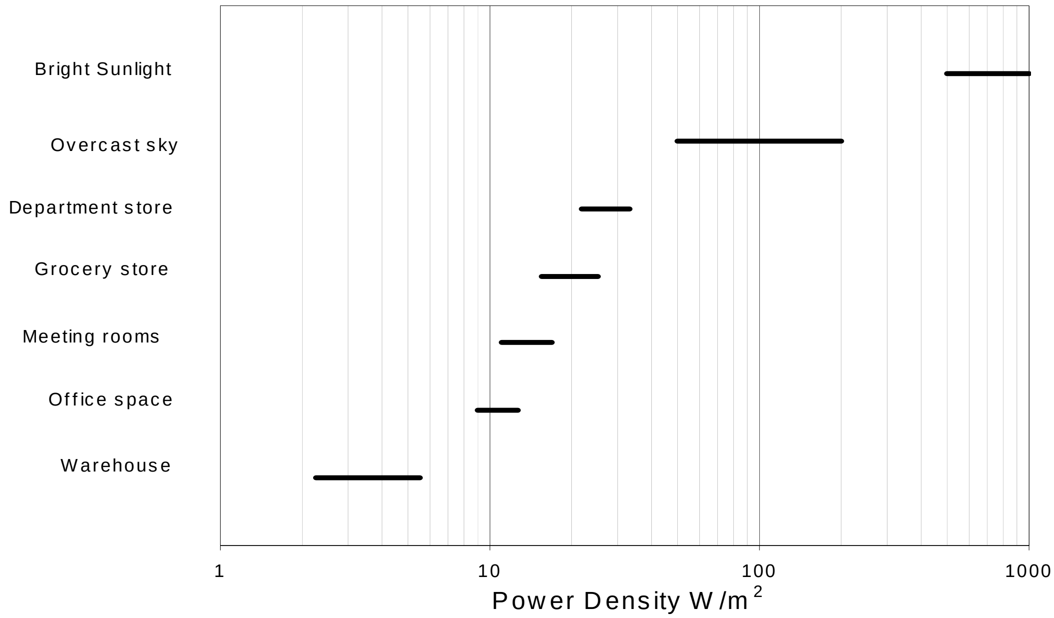

Fig. 2 Relative Light Power Densities

2.2 Relative Lighting Power Density

Figure 2 compares relative power density for various lighting conditions in units of Watts per square meter (W/m^2). The reference standard condition is 1 Sun and is equal to 1000 Watts per square meter of sunlight irradiance at a constant 25°C cell temperature and at 1.5 Air Mass (Air Mass stands for a well defined light spectrum which appears if the sunlight goes through the earth's athmosphere at a defined angle). As the chart clearly shows, the power density of typical indoor lighting is dramatically lower than that of sunlight. Not only is irradiance from indirect and artificial light lower; the spectrum is also narrower. In typical Office Space lighting with a spectrum produced from incandescent or halogen light bulbs, the power output may be roughly 100 times less than bright sunlight. It may be 200 to 500 times less with fluorescent lighting due to the further limited spectrum.

2.3 General Industry Standards for Batteries

The primary rating of a battery is its capacity, symbol C, which refers to its ability to deliver current (power) while discharging over time. Capacity is stated in either milliamp-hours (mAh) or amp-hours (Ah) and increases slightly with lower drain current and higher temperature. Because these conditions affect capacity, additional manufacturer data typically includes a specified discharge time period, temperature, and a voltage cutoff point (such as 0.8 V for alkalines). For example, if an alkaline battery provides 50 mA for 20 hours until it discharges to 0.8 V (95% exhausted), then its capacity is 50 mA x 20 hours = 1000 mAh for that cutoff voltage.

In the opposite sense, the charge rate capacity is the ability to supply current (power) over time to the battery. Trickle charging of alkaline cells is usually done at 0.1C or less. The EVIX-CX3AA evaluation board charges with a maximum current of about 40 mA if exposed to direct bright sunlight (1 Sun), so a 1000 mAh battery will require 1000 mAh/40 mA or 25 hours to charge.

There are a number of battery chemistries available in AA size packages, but we recommend using the rechargeable alkaline cell supplied with the evaluation board for best performance.

3.0 Circuit Operation and Description of Components

3.1 Circuit Operation

Figure 3 is the schematic diagram of the evaluation board. The board contains three solar cells to provide charging power. A power MOSFET prevents the battery from discharging through the solar cell array during low light conditions when the solar array output voltage sinks below the battery voltage. A CPC1832N micro power solar cell turns the MOSFET on when light is present. A resistor in parallel with the CPC1832N prevents the gate from accumulating charge and partially turning on in very low light conditions.

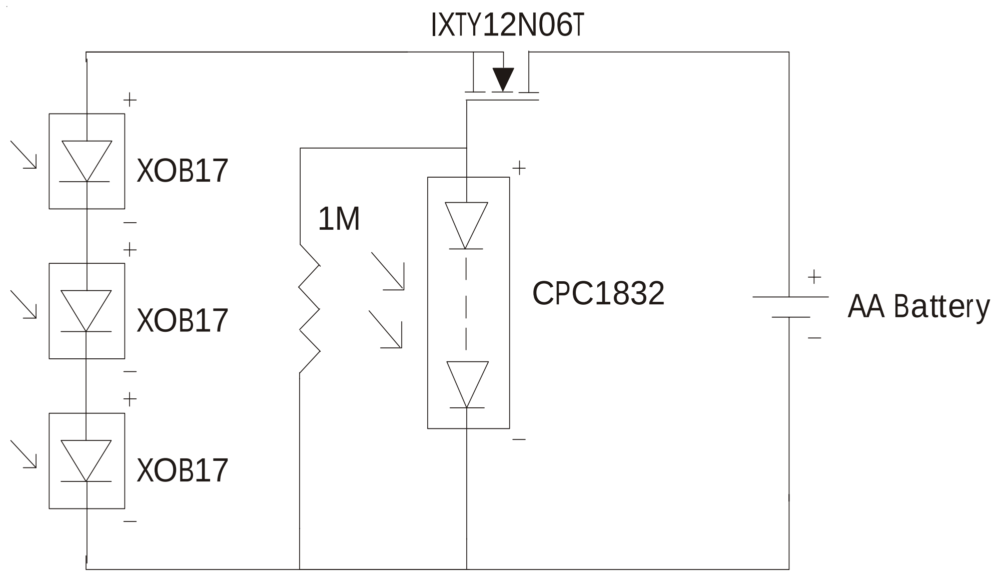

Fig. 3 Schematic Diagram

3.2 Component Description

3.2.1 IXYS XOB17-12x1 Solar Cell

The battery charging current is generated by three series-connected IXYS XOB17-12x1 Solar Bits. Each of these monocrystalline, high-efficiency solar cells generates 0.63 V open circuit voltage and 42 mA short circuit current (0.51 V and 39 mA at the Maximum Power Point at 1 Sun irradiance). Their small size and very high power conversion efficiency makes these cells ideal for portable devices with limited space to accommodate solar cells, such as cell phones, PDAs, MP3 players, GPS systems, and remote low power systems and sensors. These applications are very different from those involving arrays of polycrystalline panels and their associated higher power levels.

3.2.2 IXYS IXTY12N06T Power MOSFET

The purpose of the power MOSFET in circuit is to serve as a blocking mechanism. It prevents the battery from discharging back through the solar cells when the output voltage from the solar cells is lower than the battery, such as during low light conditions and night time hours. While the blocking duty could be performed by a rectifier diode, the MOSFET imposes no diode forward voltage drop penalty and eliminates the need for additional, more costly, solar cells to overcome the voltage drop.

3.2.3 Clare CPC1832N Solar Cell

The Clare CPC1832N solar cell serves to provide gate voltage to the blocking MOSFET, turning the MOSFET on when the cells are exposed to sunlight and off at darkness. The CPC1832N's wavelength sensitivity lies within the upper spectral range (infrared) so the cell needs to be exposed to direct sunlight for charging to occur. It's current output is only in the microampere (uA) range, but its 8V output is sufficient to overcome the gate threshold level of the blocking MOSFET and the additional 1.5V present in the MOSFET source to ground path.

3.2.4 IXYS Solar AA Battery

The 1.5V AA battery provided with the evaluation board is a rechargeable alkaline of Zinc-Manganese Dioxide (Zn/MnO_2) construction. Compared to a carbon zinc battery, it has higher energy density, lower internal resistance, and better low temperature performance. The capacity of the battery for use in general applications is listed in Figure 4.

Application	Condition	Minimum Average
Cassette	10 ohms 1 hr/day to 0.9V	18.0 hrs
Motor/Toy	3.9 ohms 1 hr/day to 0.8V	6.8 hrs
Radio	43 ohms 4 hr/day to 0.9V	85 hrs
Pulse test	1.8 ohms 15 sec/min to 0.9V	600 pulses
Photo flash	1000 mA continuous to 1V	27 mins

Figure 4. Battery Capacity Table

4.0 Test Results

4.1 Battery Discharge Test

To provide an additional set of data for the battery capacity, a 22-ohm resistor was connected across a fresh battery to continuously discharge it down to 0.8V. The voltage across the resistor was measured during the test (Figure 5) and the resultant current was then calculated (Figure 6). The battery was discharged a little more than it should have as the capacity dropped off rather quickly after a certain point was reached. Using the average current over the time it took the battery to reach 0.8V we can calculate the apparent capacity: 55 mA x 34 hrs = 1870 mAh.

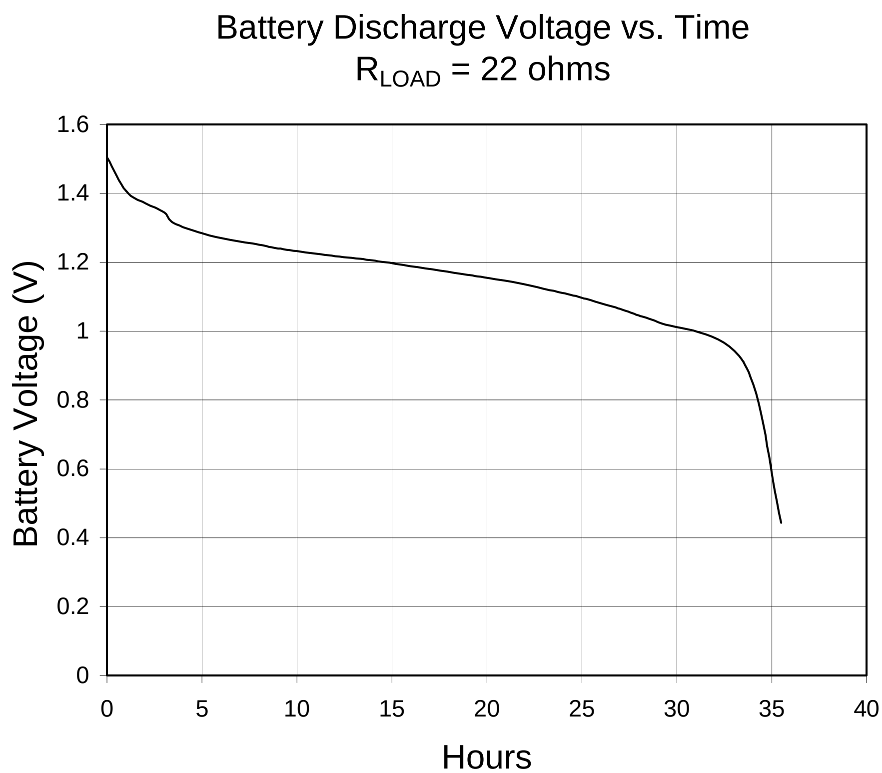

Fig. 5 Battery Discharge Voltage Chart

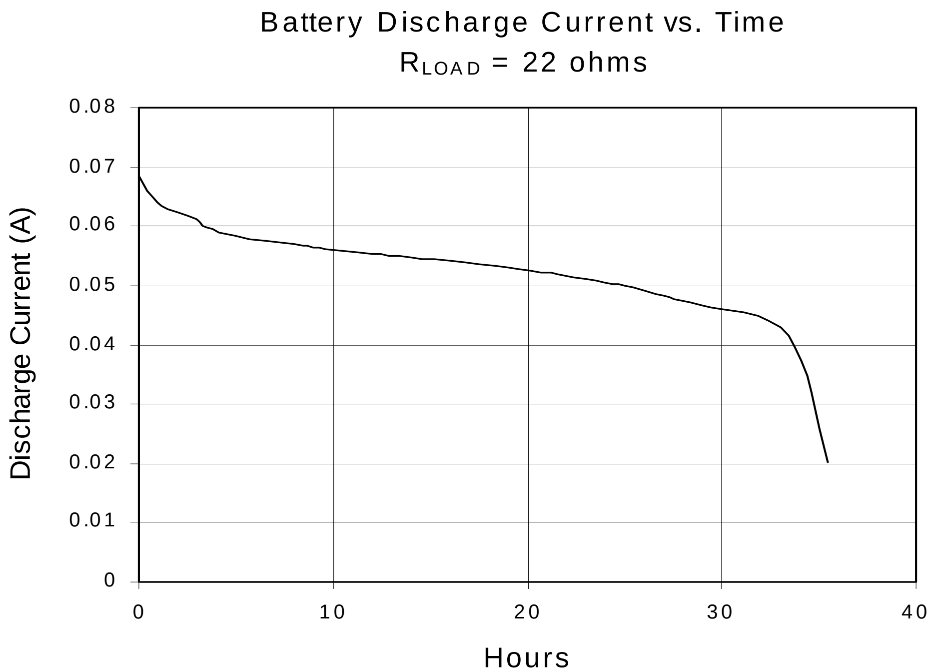

Fig. 6 Battery Discharge Current

4.2 Battery Charge Test

Using the battery that was discharged in the previous section, an experiment was run to see how long it would take to recharge it using solar power. The current from the solar cells was measured to monitor charging progress. No special or fixed conditions were used. The battery and charger were simply placed outside at our facility in Fort Collins, Colorado in August, and sun conditions and charging current measured.

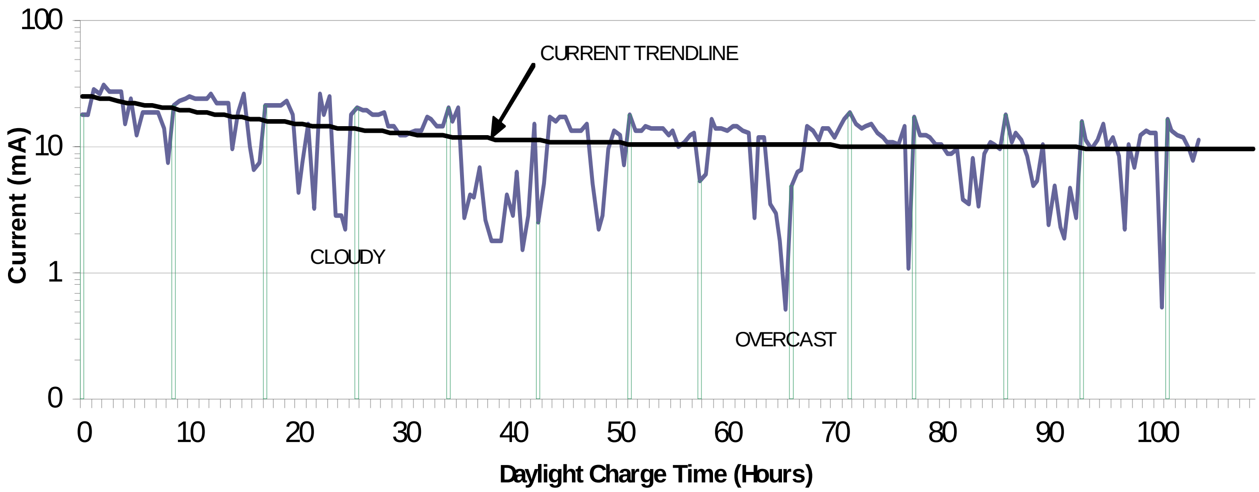

Fig. 7 Battery Charging Profile

5.0 Conclusion

The purpose of this application note is to discuss some general topics as they relate to solar battery charging, including solar cells and basic AA battery charging. This simple eval board cannot replace a sophisticated battery charger with charge control and monitoring, but it does illustrate the movement of charge (“free electricity”) from the solar cells to a storage battery with relatively high efficiency and low loss.

A lot of variables are in play when it comes to solar charging. The jagged line in the solar charging profile of Figure 8 shows common effects of atmospheric conditions, from full sun to slight haze to broken clouds to full overcast. Sunlight early and late in the day travels through more atmosphere and denser air. Charging was halted on a few occasions due to rain. But as the trend line shows, charge is transferred to the battery over time resulting in increased battery voltage and the resulting tapering off of charging current.

Device Datasheet Links

IXYS XOB17 Solar Cell
http://ixdev.ixys.com/DataSheet/XOB17-Solar-Bit-Datasheet_Mar-2008.pdf

IXYS IXTY12N06T Power MOSFET
http://ixdev.ixys.com/DataSheet/99947.pdf

Clare CPC1832N Solar Cell
http://www.clare.com/home/pdfs.nsf/www/CPC1832.pdf/$file/CPC1832.pdf