Application Note
Solar MPPT with Single Cell Battery Charger

TEXAS INSTRUMENTS

Mike Emanuel

ABSTRACT

For single-cell batteries, there is an increasing application need to charge with a solar panel. To charge the battery from a solar panel with the most charge current, the charger needs to operate at the Maximum Power Point (MPP). If the charger input voltage is not held at the MPP, then the charger attempts to pull as much power as possible from the panel, potentially collapsing the input voltage. A feature of TI Battery Chargers called Input Voltage Dynamic Power Management (VINDPM) can be used to hold the input voltage of the battery charger at the MPP.

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1 Introduction

The current drawn from a solar panel is closely related to the output voltage of the solar panel being used. When no current is drawn, the solar panel relaxes to the open circuit voltage (OCV) condition. The OCV for a fixed solar panel increases as the temperature decreases [1 - 3]. At the opposite end of the operation spectrum, if too much current is drawn, then the output voltage of the solar panel moves to a short condition. At this operating window, the current is called the short circuit current (SCC). The SCC current for a fixed solar panel increases as the irradiance increases. The MPP lies in between these conditions and requires careful selection of the input voltage limit to not only avoid operation at the OCV and SCC conditions, but to meet the MPP [4].

Typically, the MPP voltage lies between 75% to 85% of the OCV in fully irradiated sunlight conditions. This ratio of MPP voltage to the OCV is also known as the k-factor. Having the ability to modulate the input voltage around this ratio can help to achieve the MPP of the solar panel. The sample current vs voltage and power vs voltage curves for a solar panel are shown in Figure 1-1. In the power vs voltage curve, there is a clear MPP of 7W and 13.5V. Moving the voltage up or down beyond this point lowers the output power [5]. Finding a way to keep the solar panel voltage at the best point is critical to help charge the battery faster.
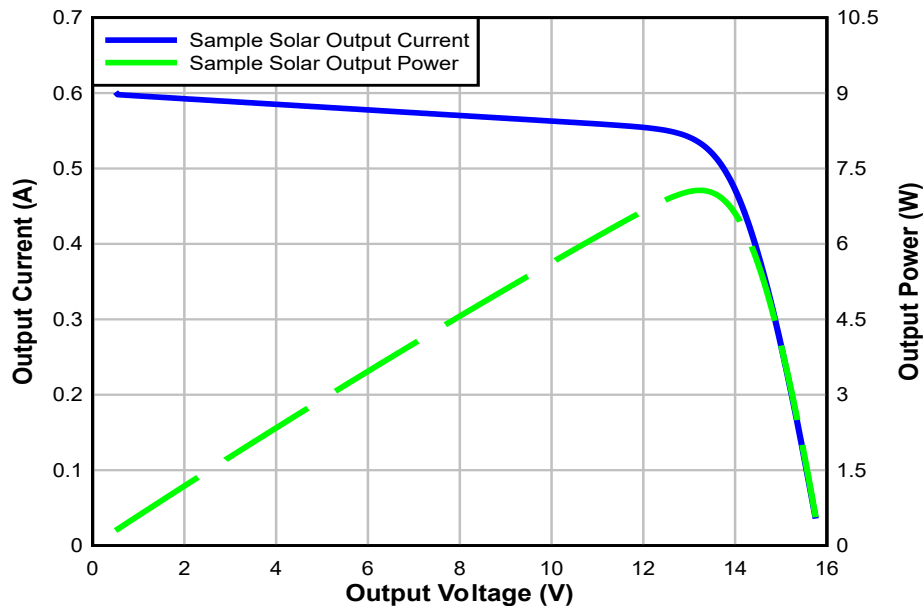

Figure 1-1. Sample I-V and P-V Curve

2 What is Dynamic Power Management?

The key to extracting the most power possible from a solar panel is to stay at the MPP. When charging near the MPP, the battery charger has the potential to crash the panel voltage to the short circuit condition. One way to prevent this crash is to regulate the input voltage of the battery charger. If the MPP is known and the battery charger holds the input voltage at this limit, maximum power transfer can be achieved.

TI makes use of VINDPM and Input Current Dynamic Power Management (IINPDM) to regulate the input of a battery charger. With VINDPM and IINDPM, the battery charger keeps the input voltage and input current at the set point to prevent browning out the adapter. In this mode, the battery charger also prioritizes system current over battery current to continue supporting the load. In cases of extreme load while overloading the adapter, the battery charger can supplement current from the battery to the load. The key here is in all of these cases, the input voltage and/or input current is being regulated to keep the adapter from collapsing.

3 How to Achieve Solar Battery Charging with VINDPM

For the solar use case, VINDPM is more applicable than IINDPM. Set the VINDPM of the battery charger at the MPP to extract maximum power from the solar panel. By the nature of the battery charger, if users try to request maximum current, then this browns out the adapter. However, fixing the VINDPM keeps the input voltage at the correct operation point. To make use of VINDPM, the battery charger needs to have sufficient VINDPM step resolution to be able to zero in on the MPP.

An algorithm is needed to get a good MPP throughout the charge cycle as the environmental conditions change. The best way to do that is to measure the charge current at each VINDPM setting and keep the VINPDM fixed at the setting that gives the most charge current. For a fixed battery voltage in the short term, whatever input voltage gives the most charge current is the MPP.

There are two scenarios (assuming no system load). First, the charger is in VINDPM with the setting that gives the most charge current. This indicates operation at the MPP. Second, the charger is not in VINDPM while the full charge current is realized. This indicates the solar panel has more energy to provide than is requested.

4 Using the BQ25638 and BQ2562x for Solar Battery Charging

As mentioned above, there are two few key things necessary to achieve solar battery charging, which are listed below:

1. Small step size for VINDPM setting
2. Ability to measure the charge current

The BQ25638 and BQ2562x both have a 40mV step size for VINDPM with a range from 3.800V to 16.800V. Since both parts are I2C controlled, the user can easily step the VINDPM setting for each charger while in search of the MPP.

The second requirement is being able to measure the charge current while the VINDPM is changing. Both devices have a charge current ADC that can be used for approximate values of charge current. A demonstration of the buck topology of the BQ25638 in gray with the attached solar application is shown in Figure 4-1.
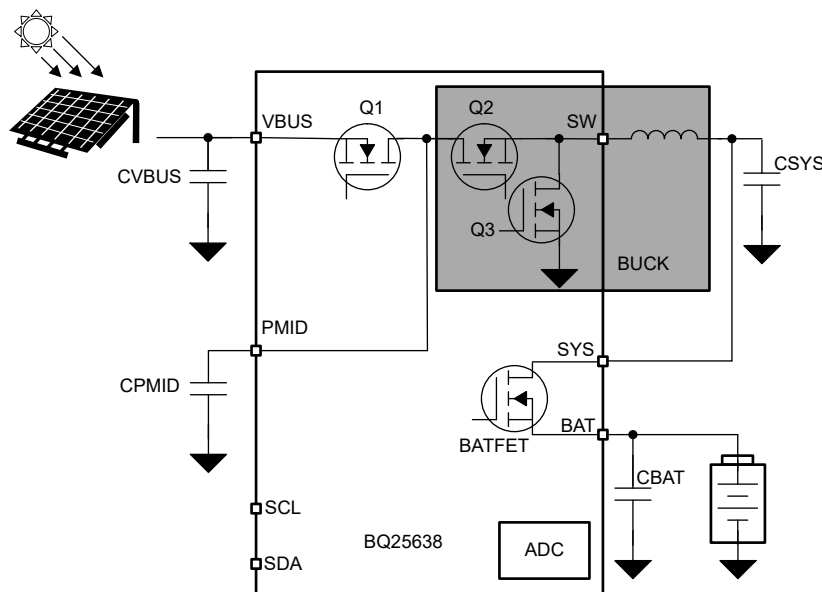

Figure 4-1. Solar Buck Charger

The algorithm is as follows for each device. First, program the desired charge current. Second, sweep the VINDPM setting from the OCV to the lowest available. Record the charge current at each step. Third, return to the step that gave the most charge current. Fourth, periodically iterate this process as the load changes and environmental conditions change. For a simple demonstration of the algorithm using the BQ25638, see Figure 4-2.
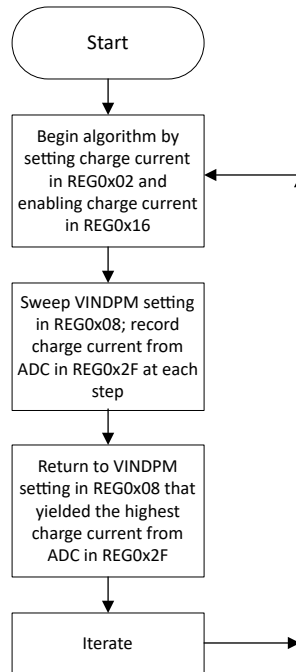
Figure 4-2. Solar Charging Algorithm for BQ25638

5 Other Key Takeaways

There are several key things to remember when using a solar panel with a battery charger. First, the OCV of the panel must be less than the OVP of the charger selected. When the solar panel is connected in low light or nighttime conditions, the solar panel voltage rises to the OCV. Keeping the OCV below the OVP allows for proper operation of the battery charger.

Second, there is a balance needed between sweeping the VINPDM of the battery charger and sticking at the last found MPP. Take the example of Figure 1-1. From a 14V to 16V solar panel output voltage, the solar panel output power is fairly linear from 0W to 6.5W. Assuming equal time at each step and a perpetual sweep to the MPP, the average power is about 3.25W as shown in Equation 1. However, if the sweep is done for only 25% of the time with 75% dedicated to the 14V/6.5W operating point, then the average power goes to about 5.69W as shown in Equation 2. That equates to a best case of 43% reduction in total average power if the sweep is constantly run. Therefore, this is important to evaluate how long the panel is swept versus how long the panel is kept in a steady state.

$$\text{Sweep Average Power} = 0.5 \text{ x } (0W + 6.5W) = 3.25W \tag{1}$$

$$\text{Sweep and Hold Average Power} = 0.25 \text{ x } 3.25W + 0.75*6.5W = 5.69W \tag{2}$$

6 Summary

When trying to pull maximum current with a battery charger from a solar panel, the solar panel tends to brown out the input voltage. To prevent this phenomenon, the battery charger needs to hold the input voltage at a fixed value. Preferably, the user needs to hold the input voltage at the MPP. BQ25638 and BQ2562x present designs with programmable VINDPM in 40mV steps to hone in on the MPP. Furthermore, the devices have an ADC that can be used to monitor the charge current. This can be used to periodically sweep the VINDPM settings looking for the MPP as conditions for the solar panel change.

7 References

1. N. H. Zaini, M. Z. Ab Kadir, M. Izadi, N. I. Ahmad, M. A. M. Radzi and N. Azis, *The effect of temperature on a mono-crystalline solar PV panel, 2015 IEEE Conference on Energy Conversion (CENCON)*, 2015, pp. 249-253.
2. Texas Instruments, Maximum Power Point Tracking With the bq24650 Charger, application note.
3. N. I. Ahmad, M. Z. Ab Kadir, M. Izadi, N. H. Zaini, M. A. M. Radzi and N. Azis, *Effect of temperature on a poly-crystalline solar panel in large scale solar plants in Malaysia, 2015 IEEE Conference on Energy Conversion (CENCON)*, 2015, pp. 244-248.
4. Texas Instruments, Implementing a Simple Maximum Power Point Tracking (MPPT) Algorithm, application note.
5. Texas Instruments, Choosing the Correct Solar Battery Charger for Your Solar Application, application note.

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