Application Note

Hysteresis Control MPPT Method with Generic DC/DC Converter

Nathan Ding, Severi Zhou

ABSTRACT

For battery powered outdoor equipment, such as video doorbell, to increase the battery working time and easy to install anywhere, sometimes the photovoltaic (PV) panel is used as an auxiliary power supply to charge the battery. Photovoltaic cells are one of the most important parts in PV panel, the output power and output voltage of PV cells varies with sunlight intensity, so a MPPT (maximum power point tracking) method is used to maximize the output energy of PV cells.

To achieve MPPT, it means that the power converter needs to automatically operate within a specific supply voltage range, which is often different from converter default startup and shutdown voltage, so it is hard to find an usual power converter that can be used to different types of PV panel.

This application note introduces a simple hysteresis control method which can provide a flexible design to achieve MPPT with generic DC/DC converter, regardless of the different maximum power point. Take TI's Boost converter TPS61023 as an example, the detailed operation scheme and test results are also given in this documentation.

Table of Contents

Trademarks

All trademarks are the property of their respective owners.

1 Introduction of Photovoltaic Cell and MPPT Requirement

As an important component of PV system, photovoltaic cells have a complex relationship about operating voltage and the power produced. The equivalent circuit of the solar cell is shown as Figure 1-1, R_S is the series resistance of a single cell connected to others, R_P is parallel leakage resistance and large, typically > 100kΩ.

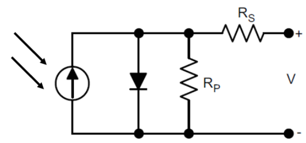

Figure 1-1. Solar Cell Equivalent Circuit

For any given set of conditions, cells have a single operating point where the values of the current (I) and voltage (V) of the cell allow maximum power output. Figure 1-2 shows the typical I-V curve and P-V curve of a general PV panels at different times in a day, where the light is strongest at noon, moderate in the morning and poor in the evening.

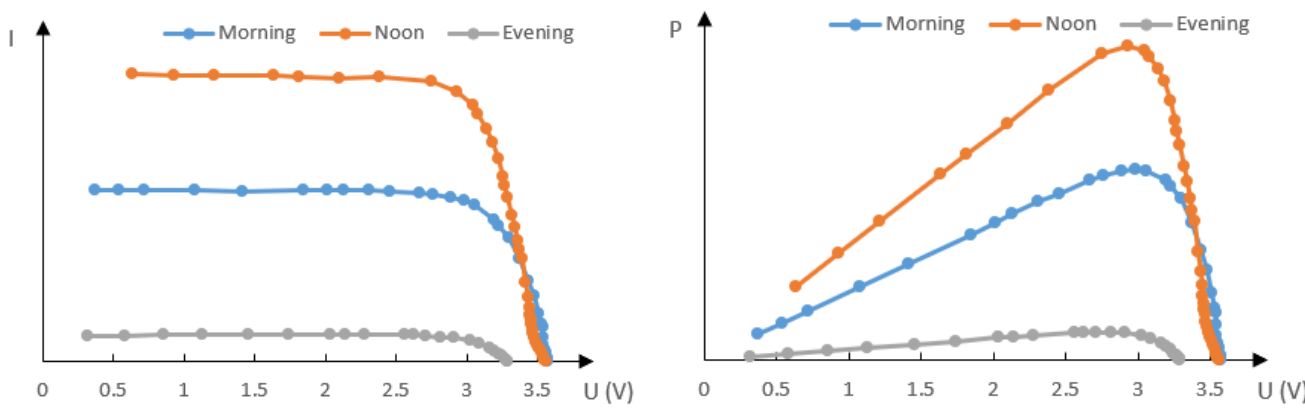

Figure 1-2. Solar Panel I-V and P-V Curve

The no-load output voltage V_{OC} is 3.3V approximately 3.5V under different light conditions. The output voltage of the solar cells decreases at first as the load current increases. When the output voltage is less than 2.9V, the output current almost unchanged, so 2.9V here is the so called maximum power point (MPP) of this PV panel, and generally engineer needs to make sure that the PV panel operates at this MPP so that the PV panel can always output maximum power.

Therefore, a MPPT (maximum power point tracking) method is used to maximize energy extraction as conditions vary, make sure that the PV system always operate at the maximum output power point.

2 Typical Battery Powered Outdoor System with PV Panel

PV system is used to convert the light into electricity by using semiconducting materials that exhibit the photovoltaic effect. A PV system is composed of one or more solar panels combined with an electrical and mechanical hardware that use energy from the Sun to generate electricity. In some battery powered outdoor equipments, sometimes there are PV panels which is used to charge the battery and increase the usage time of battery, such as video doorbell, wireless camera, and so on.

Figure 2-1 is the function block diagram of a battery powered outdoor equipment with PV panel.

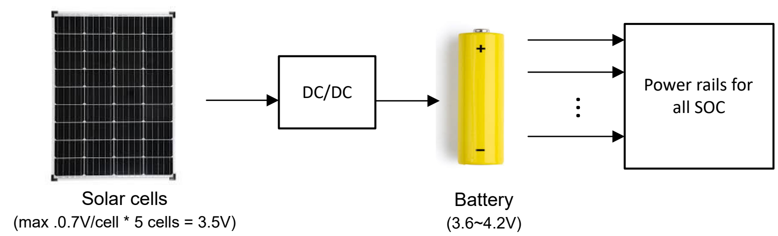

Figure 2-1. Block Diagram of Battery Powered Outdoor Equipment with PV Panel

The system requirements are listed in Table 2-1.

Table 2-1. System Requirements of Battery Powered Outdoor Equipment with PV Panel

Parameters	Values
Solar Panel MPP voltage	approximately 2.9V
Charge Current	1A
Charge Voltage	4.2V

The MPP voltage is important and decides the output power of the PV panel and if the PV panel can operate with the highest efficiency.

3 MPPT Method with Generic DC/DC Converter

Some MPPT method regulates the operation voltage of PV panel at MPP accurately, but usual needs a very complex control circuit or algorithm. Considering sometimes the output power of PV panel around MPP is not much worse than the power at MPP, so it is not necessary to take much effort to regulated at MPP accurately. There is a rough but very simple MPPT method called hysteresis control, it means to startup and shutdown the PV system to make sure that the PV panel operates around MPP.

Define $V_{PV\_UVLO\_rise}$ and $V_{PV\_UVLO\_fall}$ separately as the startup voltage and shutdown voltage. And the PV system is turned on when the voltage of PV panel is rising to $V_{PV\_UVLO\_rise}$ (the sunlight becomes stronger), and turned off when the voltage is falling below $V_{PV\_UVLO\_fall}$ (the sunlight becomes weaker).

Based on this, the engineer needs to program the startup and shutdown voltage of the DC/DC power converter for different types of PV panels.

Figure 3-1 shows a diagram of hysteresis control MPPT method.

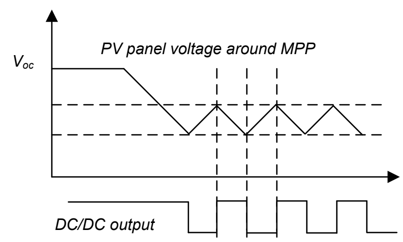

Figure 3-1. Hysteresis Control MPPT Method

3.1 TPS61023 Introduction

TPS61023 is a synchronous boost converter with 3.7A valley switching current limit. In outdoor PV panel equipment, TPS61023 is used to boosts the PV panel voltage to a stable 4.2V. If the battery voltage is lower than 4.2V, boost starts to charge the battery. This process makes the system be able to continuously charge the battery when PV panel voltage changes.

However, as shown in TPS61023 data sheet, under-voltage lockout (UVLO) threshold of V_{IN} is typically 1.7V rising and 0.4V falling. This means the converter startup when V_{IN} rises above 1.7V and shutdown when V_{IN} falls below 0.4V, it is different from the maximum power point of PV panel, so the engineer needs to use another way to control the DC/DC converter.

3.2 Hysteresis Control MPPT Method with TPS61023

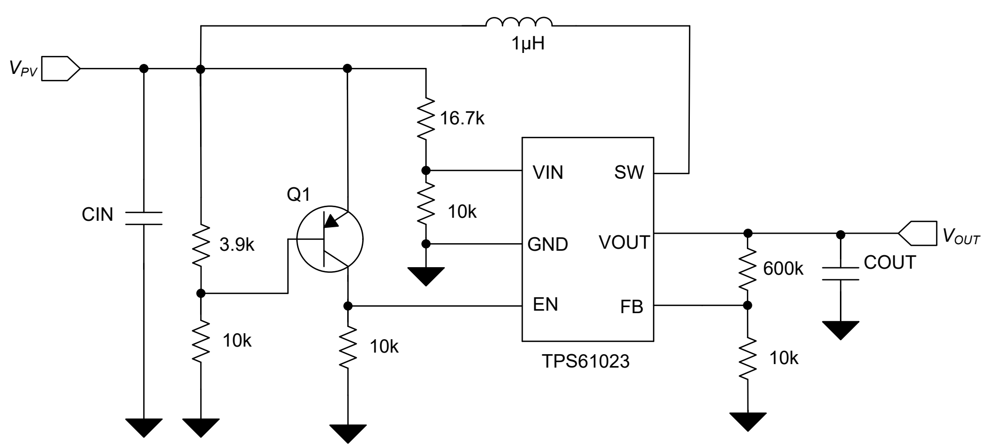

Figure 3-2. Generic Hysteresis Control with TPS61023

When using 6 solar cells, the MPP of the PV panle is about approximately 2.9V, so we define the $V_{PV\_UVLO\_rise}$=2.9V and $V_{PV\_UVLO\_fall}$=2.2V.

As shown in Figure 3-2, the generic hysteresis control can be realized by building the external circuit consisting of several resistors and PNP transistor Q_1. V_{PV} is the supply voltage of PV panel, and V_{OUT} is the output voltage of DC/DC converter, which is regulated to about 4.2V by divider resistors on FB pin.

The operation scheme of the circuit works as follow:

At first, when sunlight is weak, the output voltage of PV panel is much lower than the maximum output power point operation voltage, the collector-base voltage is decided by R3 and R4, defined by Equation 1. If V_{cb} at this time is lower than the threshold voltage ($V_{BE(ON)}$) of the PNP transistor Q1, Q1 is turned off then the EN pin is connected to ground by R_{EN}, TPS61023 is disabled.

When sunlight becomes stronger, the output voltage of PV panel is rising, and the V_{cb} is higher than the threshold voltage ($V_{BE(ON)}$) of the PNP transistor Q_1, Q_1 is turned on and then the EN pin is pull up to V_{PV}. The voltage of VIN pin is decided by R1 and R2, and defined by Equation 2. When VIN voltage is higher than the UVLO rising threshold voltage, the TPS61023 is enabled to charge the battery.

Then when the sunlight becomes weak again, Q1 is turned off again and the EN pin is pulled down to GND by R_{EN}. TPS61023 is disabled, and the charge phase stops.

$$V_{PV\_UVLO\_rise} \times \frac{R_2}{R_1 + R_2} > V_{DCDC\_UVLO\_rise} \tag{1}$$

$$V_{PV\_UVLO\_fall} \times \frac{R_3}{R_3 + R_4} < \left|V_{BE(ON)}\right| \tag{2}$$

Where

- $V_{DCDC\_UVLO\_rise}$ is the UVLO rising threshold voltage of DC/DC converter, that is 1.7V here.
- $V_{BE(ON)}$ is the collector-base threshold voltage of PNP transistor.

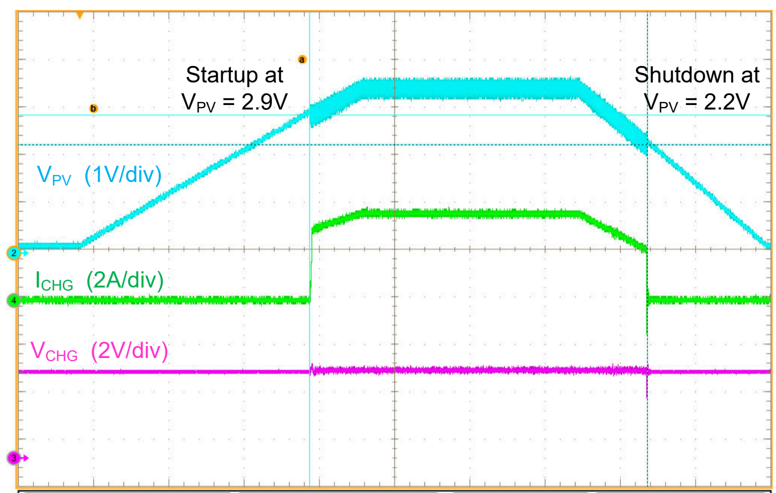

Figure 3-3. Generic Hysteresis Control MPPT Method Test

The circuit is verified in Figure 3-3, the V_{PV} is supplied with an adjustable power supply, V_{OUT} is connected to a Li-ion with 3.6V remaining voltage. When V_{PV} is rising and higher than 2.9V, TPS61023 is turned on and outputs current to charge the battery. When V_{PV} is falling and lower than 2.2V, TPS61023 is turned off and stops output current.

3.3 Experiment Results

Test result with a real PV panel in different sunlight, with a test setup is listed in Table 3-1.

Table 3-1. Test Setup

Parameters	Values
Solar Panel	0.6V, 200mA solar cells × 6
Charge Current	1A
Charge Voltage	4.2V

As shown in Figure 3-4, when the PV panel voltage is up to 2.9V, the DC/DC converter starts to work and charge the battery with 1A charging current, and when PV panel voltage is lower than 2.2V, the DC/DC converter stops working and the charging current is 0A. By this way, the voltage of PV panel is approximately triangular wave during operation, the PV panel voltage is always around MPP, and so the PV panel operates with the highest efficiency. The MPPT is realized by this circuit.

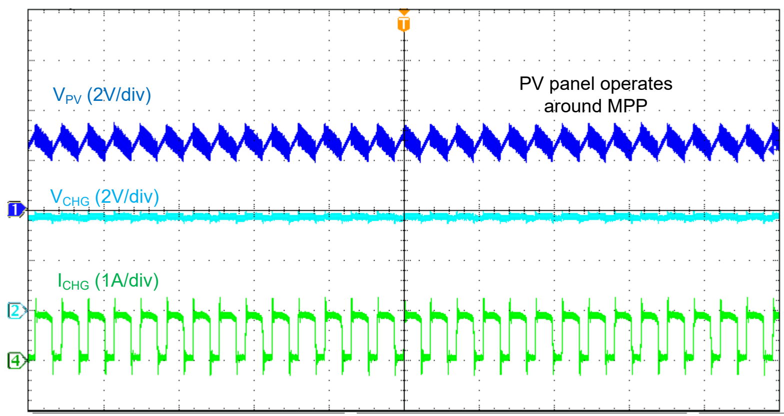

Figure 3-4. Generic Hysteresis Control MPPT Method Test

Note that, TPS61023 loses true disconnection feature when disabled with this hysteresis control circuit. When the Boost converter is turned off, V_{PV} is connected to V_{OUT} via the body diode of internal high side FET, therefore at this time V_{OUT} isn't 0V. If the true disconnection when disabled is needed, additional circuit as shown in Figure 3-5 can be used.

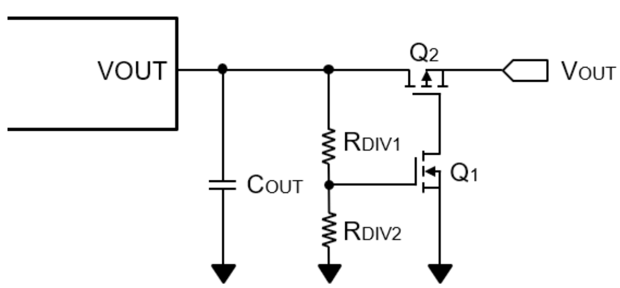

Figure 3-5. True Load Disconnection Circuit

4 Summary

This application note introduces a simple and flexible MPPT method with all generic DC/DC converter in battery powered PV system. With the proposed circuit, the battery powered PV system can operate around the maximum output power point, so that the PV panel can work around the max power point and charge the battery efficiently, extending the working time of battery powered equipment and improving the lifetime of the system.

5 References

- Texas Instruments, *Power Rails Design for Battery Powered Camera and Video Doorbell*, application note.
- Texas Instruments, *Texas Instruments, Buck Charger with MPPT and Boost Converter for Solar Powered Application Based on TPS61094*, application note.
- Texas Instruments, *Texas Instruments, Introduction to Photovoltaic Systems Maximum Power Point Tracking*, application note.
- Texas Instruments, *Texas Instruments, Implementing a Simple Maximum Power Point Tracking MPPT Algorithm*, application note.
- Texas Instruments, *Texas Instruments, TPS61023 3.7-A Boost Converter with 0.5-V Ultra-low Input Voltage*, data sheet.