MPPT IC Li-Ion Battery Charger System

In an era characterized by the internet of things (IoT), more connectivity means more outdoor devices are now battery-powered and constantly communicating. In particular, an increasing number of outdoor devices are being powered through solar panels. The charger should be suitable for maximum power point tracking (MPPT) in outdoor designs with a solar panel. This article illustrates design tips for a solar panel charger with a Lithium-ion battery, suitable for applications such as outdoor solar surveillance cameras or outdoor lighting. **Alex Jiang, Senior Technical Marketing Engineer, Monolithic Power Systems, San José, USA**

This reference design is developed based on the MP2731 IC from MPS with an MC96F1206 controller (a low-cost 8051 MCU). It is suitable for small and medium solar-powered charging solutions. Compared to a conventional MPPT system, the MP2731-based system integrates a VIN connection switch, ADC, and voltage/current-sensing circuitry, which significantly reduces the system cost. The system design uses the perturb-and-observe (P&O) algorithm for MPPT to achieve 98 % or greater tracking accuracy.

Features of the MP2731 include up to 93 % efficiency in a 9 V input 5 W system, 98 % MPPT accuracy, a small 25 mm x 25 mm core circuit area, fully integrated power switches with built-in robust charging protection including JEITA and programmable safety timer, and an I?C interface for flexible system parameter setting and status reporting (see Figure 1).

MPPT theory and implementation

The output power from a solar panel is determined by several factors: the irradiance level, the operating voltage and current of the panel, and the load. There exists a maximum power point where solar panel is outputting optimal power to the system (see Figure 2). Maximum power point tracking techniques like P&O or incremental conductance methods are used to actively keep the solar panels operating at MPPT during changing irradiance conditions.

In the power-based P&O MPPT algorithm, the derivative of power to voltage dP/dV of a PV panel is used as a tracking parameter. Calculate when MPP is reached using Equation (1):

$$\frac{dP_{\text{in}}}{dV_{\text{in}}} = 0 \qquad (1)$$

A DC/DC converter is generally used to ensure MPP optimization inside the system. A highly integrated switching charger - the MP2731 from MPS in this reference design (Figure 3) - is connected between the PV panel and battery load.

A reverse-blocking FET Q1 is used to block the path from the battery load to the PV panel when the panel is under low irradiance. The input voltage/current and output voltage/current of the IC are sampled through an 8-bit ADC. The IC

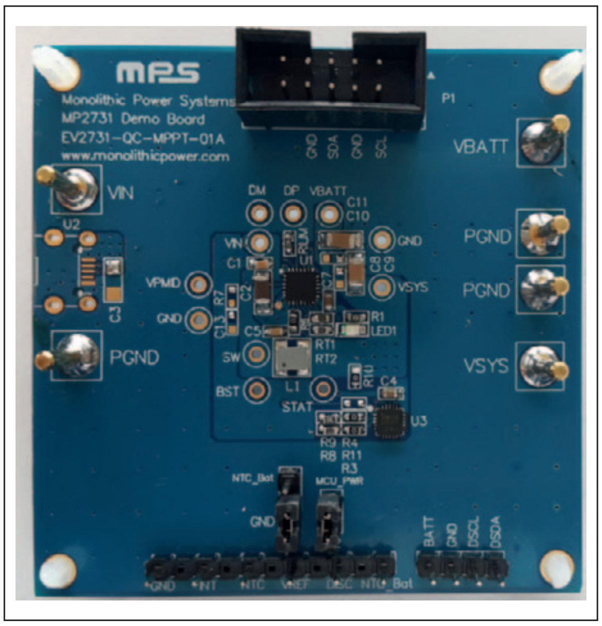

Figure 1: PCB of the MPPT control system

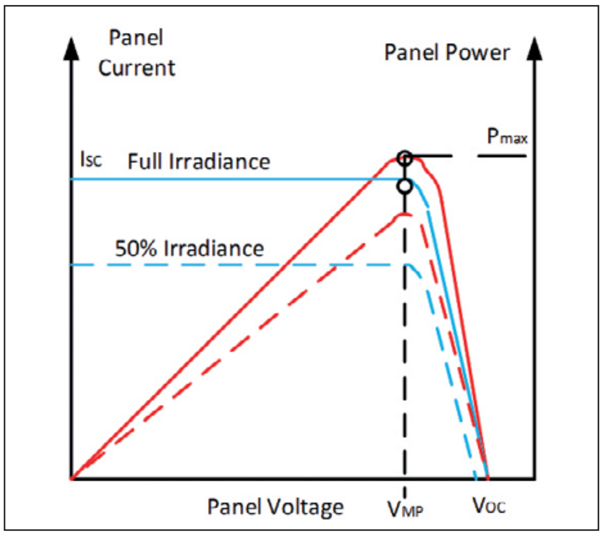

Figure 2: Solar panel P-V and I-V curve

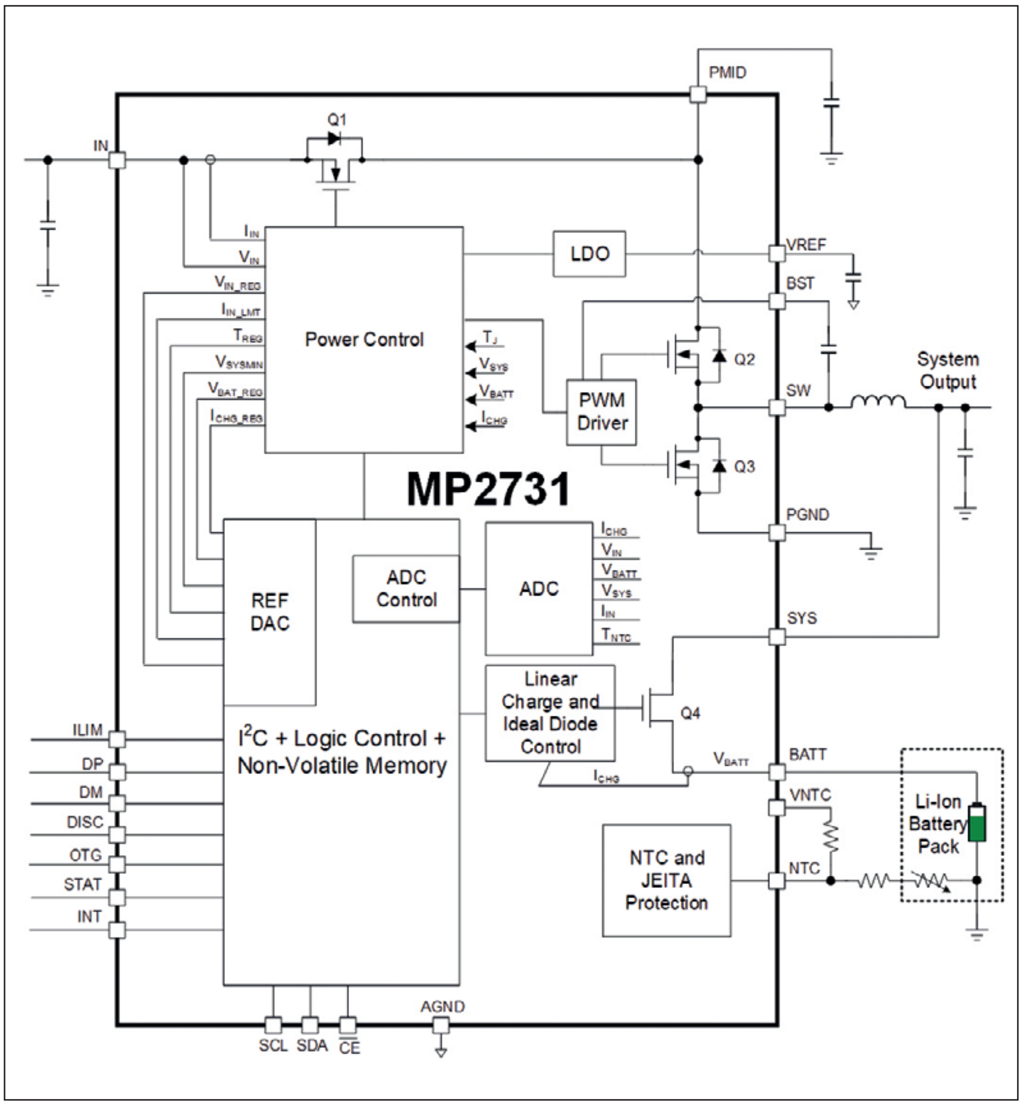

Figure 3: Functional block diagram for the MP2731

supports I?C communication, so the digitized current and voltage information can be easily communicated to the external MCU.

The P&O MPPT algorithm is implemented in a 20-pin, 8-bit MC96F1206 MCU from ABOV Semiconductor. To communicate with the MP2731, the I?C peripherals in the MCU are activated.

Figure 4 shows the system-level software flow. The MCU is in sleep mode when VIN drops below the under-voltage threshold. When VIN recovers, it sends an interrupt (INT) to wake the MCU. Then the MCU reads the MP2731 registers and initiates those registers.

By setting the input current limit to its maximum value, the panel voltage is controlled only by the input voltage limit loop. By adjusting the input voltage limit loop reference, the PV panel's voltage can be adjusted. After initializing the MP2731, read the ADC initial value, then enable charging.

Check if VIN_STAT is equal to 1. If it is not equal to 1, increase VIN_REG by one unit, and then go back to the previous value for VIN_STAT. When VIN_REG reaches its maximum limit, VIN_STAT is still not equal to 1. The charging current gradually decreases, and returns to the previous value set by VIN_STAT. When VIN_REG set has reached its limit, the ICC is set to a minimum. If VIN_STAT is still not equal to 1, the MCU enters sleep mode, and the MP2731's charging functionality is disabled until the INT interrupt function wakes the MCU.

In case the PV panel is partially covered and a local MPP can be tracked using a conventional P&O MPPT algorithm, the MCU initiates an scan every time the input voltage flag changes. The MCU adjusts the input regulation voltage reference of the MP2731 with a 100 mV step from 50 % of the panel open-circuit voltage (VOC) to 80 % VOC to scan the optimum power point. After the initial scan, the PV panel is set to operate at the maximum power point. To continue tracking the optimum point under varying load and irradiance conditions, the P&O algorithm runs in every 256 ms on the MCU (see Figure 5).

Experiment results

Figure 6 shows the MPPT process for a PV panel with (8 V, 500 mA) MPP. Before t0, with no load, the PV panel outputs 12V at open-circuit voltage. After the MP2731 IC and MCU power up, the PV panel runs at the preset 6 V input voltage, configured by the MCU. From t0 to t2, the MCU scans for MPP.

At t1, the MPP is located but the scan algorithm keeps sweeping the input voltage until the power falls to 85 % of the recorded peak power at t2. After t2, the MCU sets the panel voltage to the scanned peak power voltage, then activates the real-time P&O algorithm.

Figure 7 shows the complete charging behavior for a Lithium-ion battery. From t0

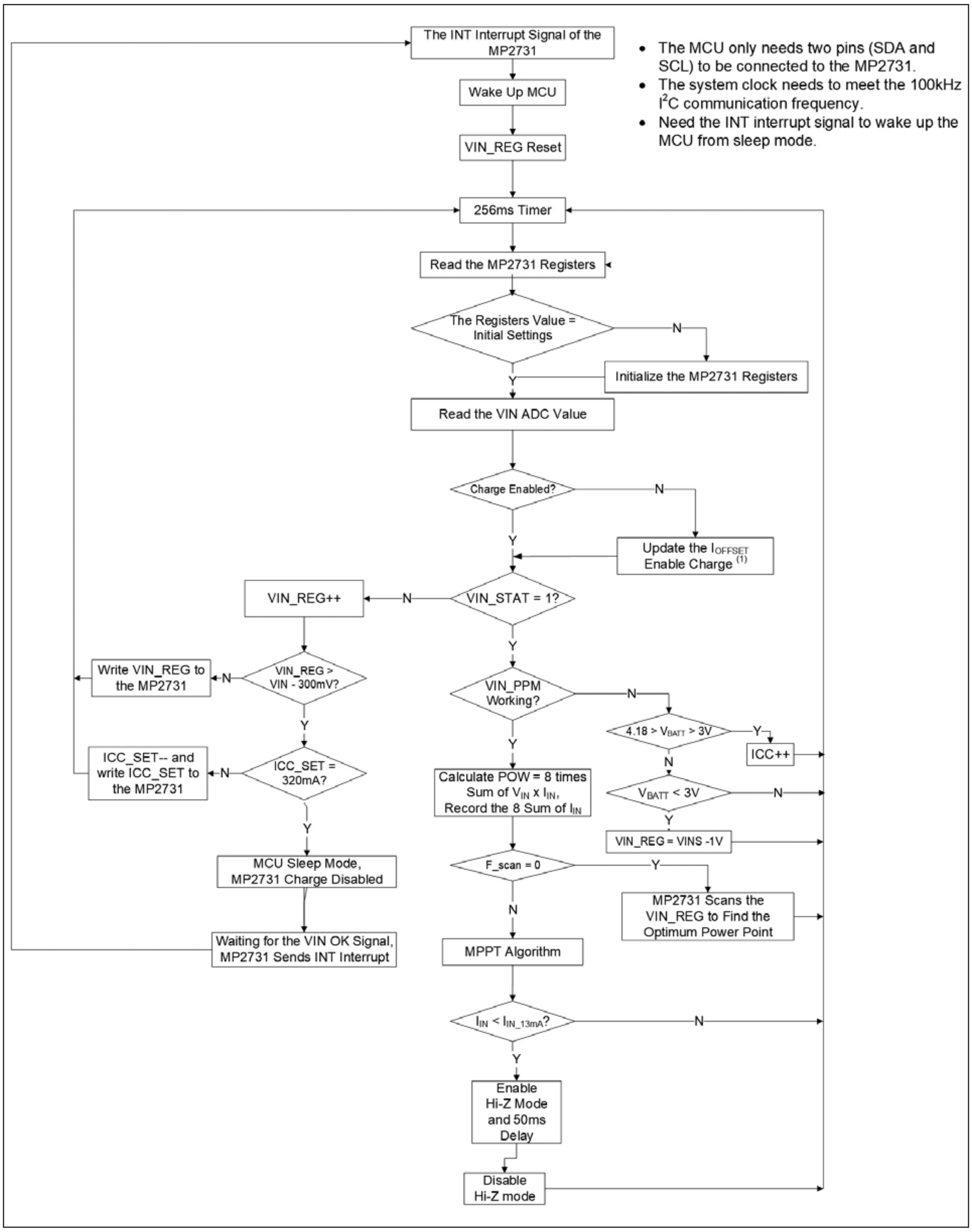

Figure 4: System-level software flowchart

to t1, the system powers up and scans MPP. From t1 to t2, the battery goes through the CC and CV stages as the battery charge current changes from constant current to lower values. When the battery is close to fully charged, the PV panel voltage starts ramping up to the open-panel voltage again. There is a light-load condition because the battery consumes a lower load current when fully charged.

With low-resistance, integrated MOSFETs, the MP2731-based MPPT system also achieves high efficiency above 95 % under various conditions.

Conclusion

The MP2731 lithium-ion battery charger IC effectively reduces the cost for outdoor IoT systems by eliminating discrete voltage and current-sensing circuitry from the BOM. Highly integrated low RDS(ON) allows for a high-efficiency system with a compact PCB area. Future product development projections include accommodating design in higher power, higher voltage applications, further reduction in system quiescent power consumption, and developing solutions for multi-panel systems.

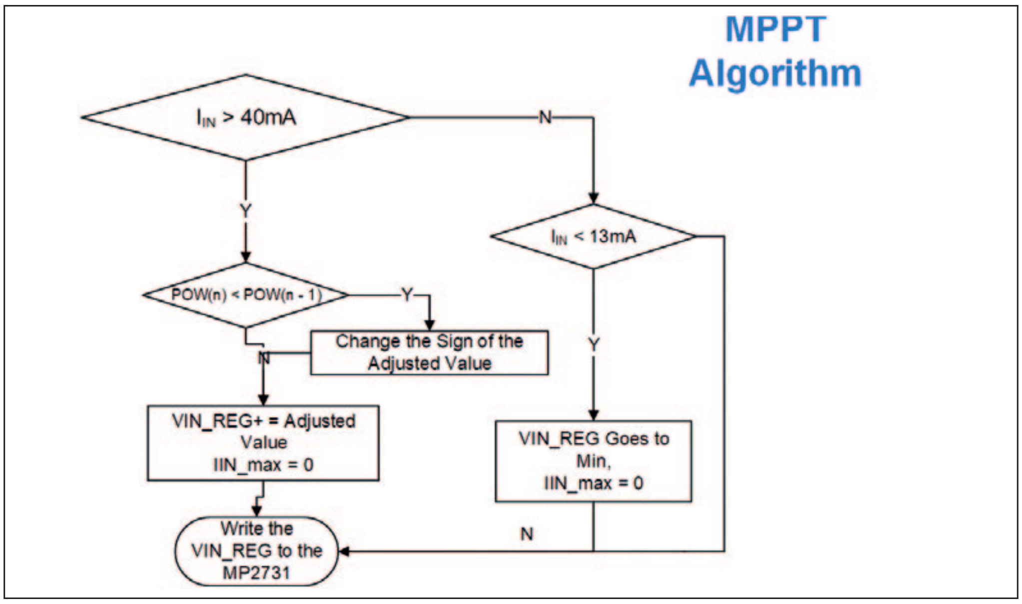

Figure 5: P&O MPPT algorithm

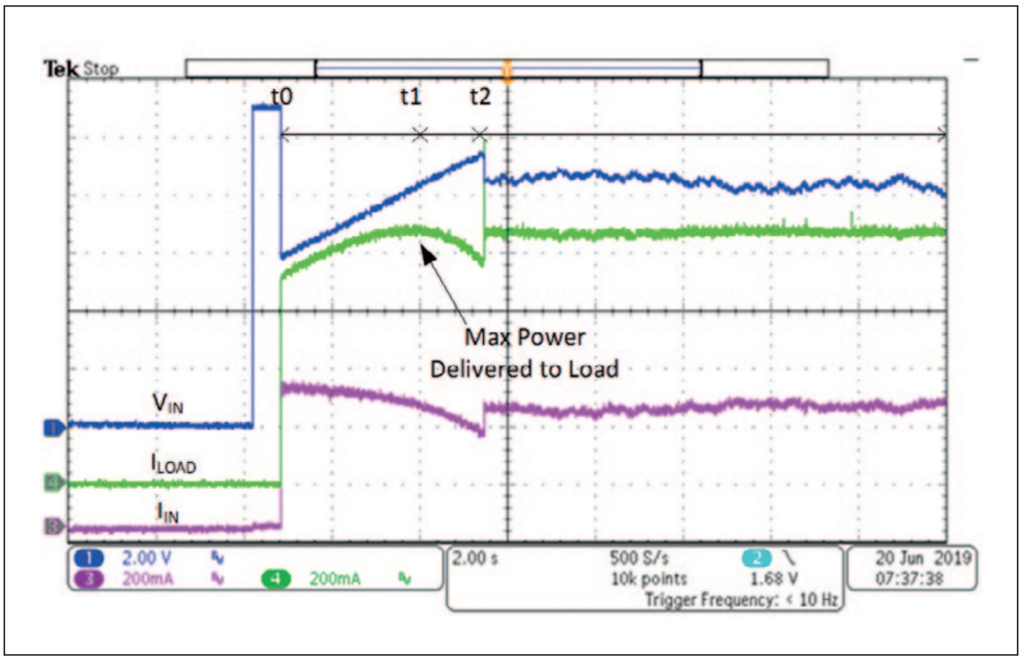

Figure 6: MPPT process for PV panel from power-up to steady state

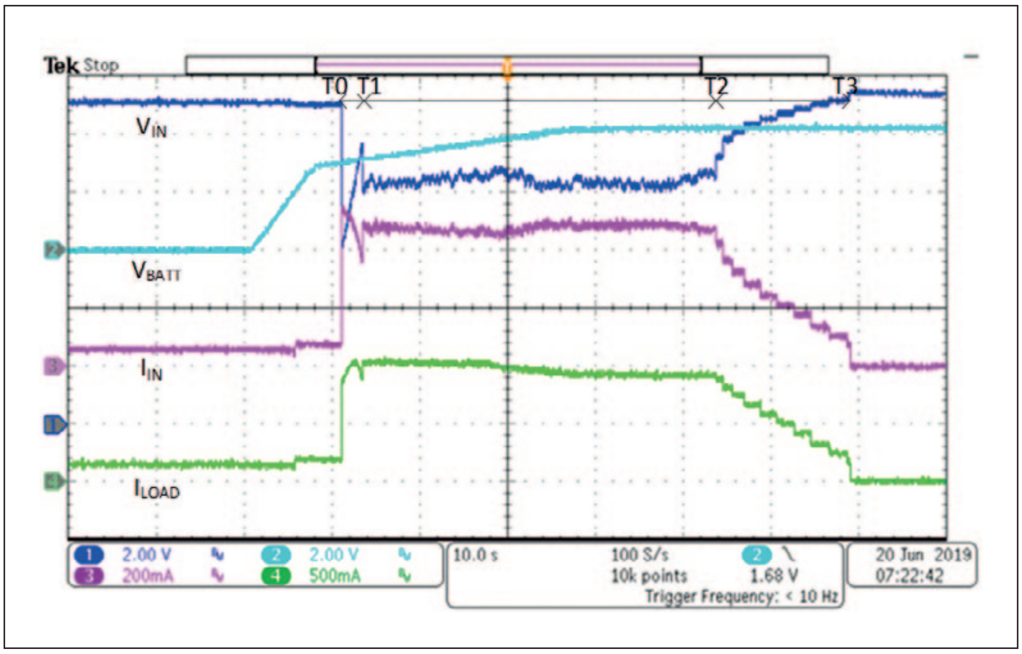

Figure 7: MPPT behavior during charging cycle