Application Report

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Using the bq24650 to Charge $LiFePO_4$ Battery

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ABSTRACT

This application report gives an example of using the bq24650 charge management device to provide a high-efficiency, switching-mode charging solution for the $LiFePO_4$ battery.

The bq24650 integrated circuit was designed to charge single-, two- or three-cell Li-ion and Li-polymer battery packs. Its regulation voltage set point can be easily adjusted by two resistors, which allows the bq24650 to support the newly developed lithium iron phosphate ($LiFePO_4$) battery. This application report gives an example of using the bq24650 to provide a high-efficiency, switching-mode charging solution for $LiFePO_4$ batteries.

The $LiFePO_4$ battery has many unique features such as very high thermal runaway temperatures, very high discharge current capability, and high charge current. These special features make it more and more attractive in many applications, such as power tools. Figure 1 shows a typical open-circuit voltage (OCV) curve versus depth of discharge (DOD) of an ANR26650M1 $LiFePO_4$ battery from A123Systems.

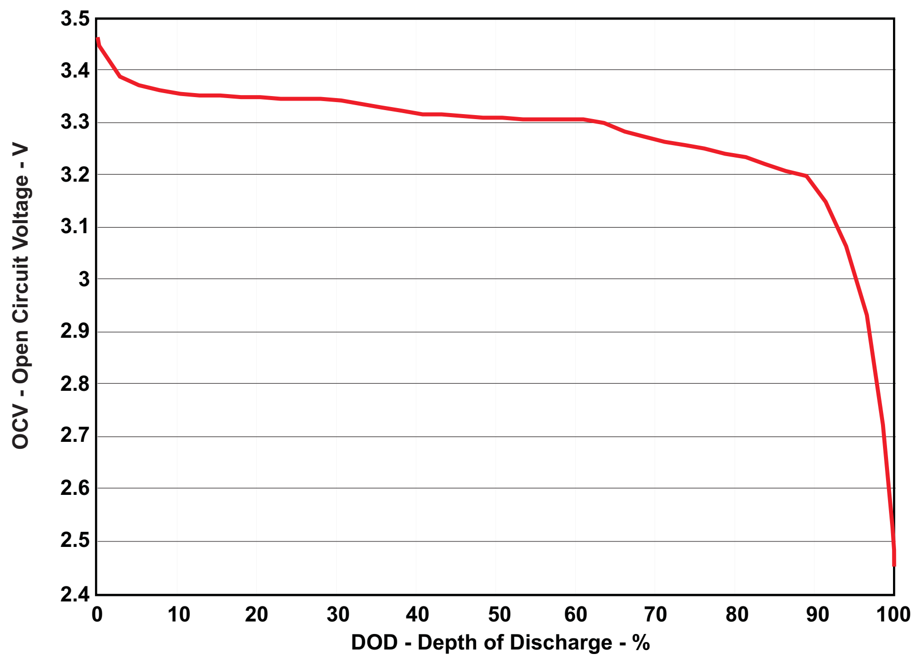

Figure 1. $LiFePO_4$ Battery OCV Curve

Figure 2 shows the typical discharge characteristics at 25°C. It is able to support a very high discharge rate. The recommended charge voltage is 3.6 V, the charge current is 2 A and the termination current is 200mA.

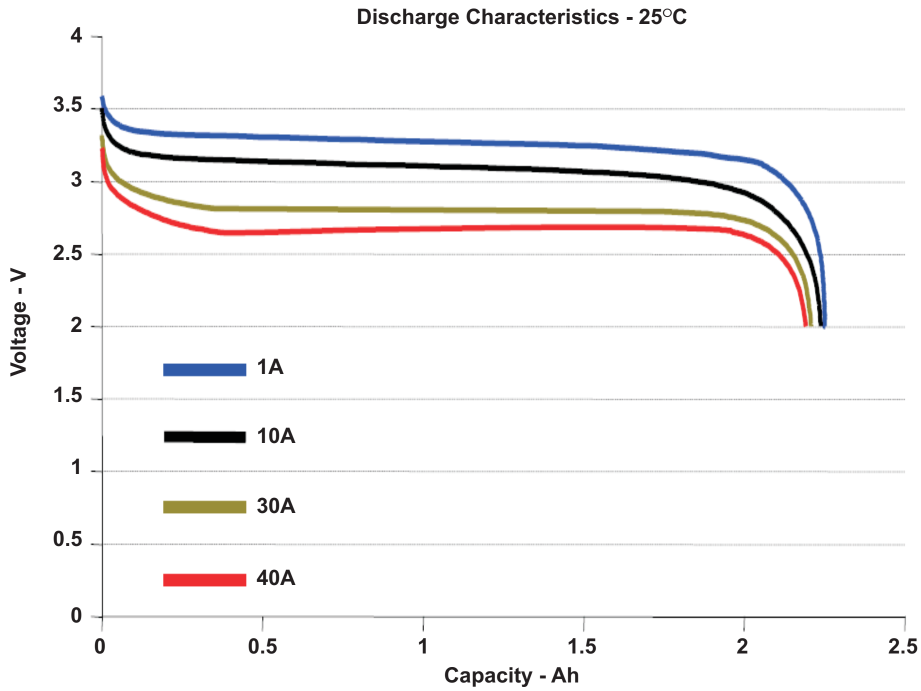

Figure 2. 2 $LiFePO_4$ Battery Discharge Characteristic at 25°C

One bq24650EVM evaluation module was modified to evaluate the performance for charging $LiFePO_4$ battery. The design changes are straightforward. The schematic is shown in Figure 3.

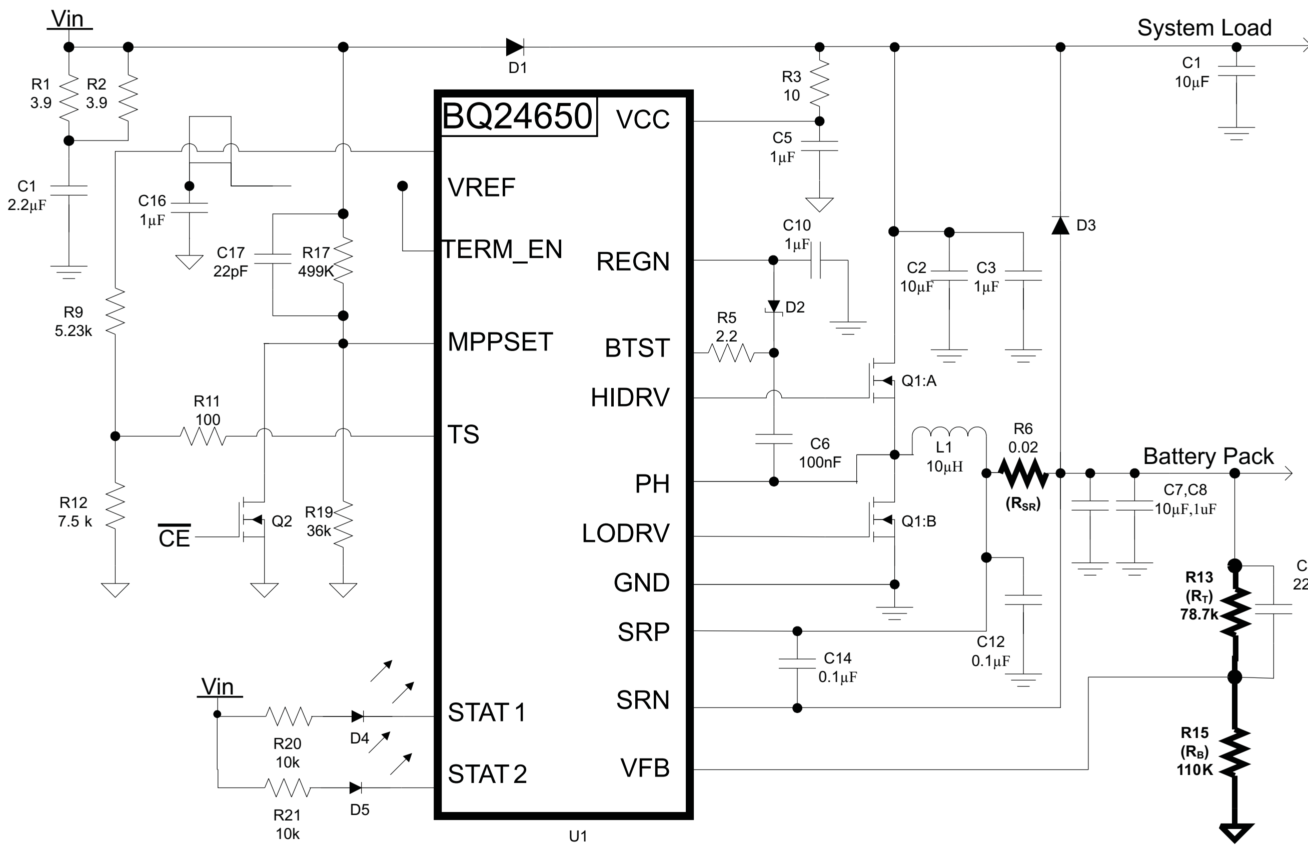

Figure 3. Modified EVM Schematic for $LiFePO_4$ Battery

The internal reference voltage of the bq24650 is set to 2.1 V for voltage regulation. The resistor value for R13 and R15 can be easily calculated by the following equations:

$$R_{13} = \frac{(V_{CHARGE} - V_{REFCHARGE})}{V_{REFCHARGE}} \times R_{15} = \frac{(3.6 - 2.1) \times R_{15}}{2.1} = 0.714R_{15}$$

Set R15 = 110k then R1 3= 78.6k, so select R13 = 78.7k standard value.

All the other components on the EVM are not changed. The recharge threshold is 50mV below the charger's 2.1-V feedback voltage reference, 2.05V. After the 4.2-V regulation voltage set point is changed to 3.6 V, the recharge voltage threshold changes from 4.1 V to the level that can be calculated by the following equation:

$$V_{RECHARGE} = \frac{V_{REFRECHARGE} \times (R_{13} + R_{15})}{V_{15}} = \frac{2.05 \times (78.7k + 110k)}{110k} = 3.515V$$

This leaves only a 85-mV difference between the regulation set point and the rechargeable threshold, making the IC frequently enter into recharge mode when a small load current is applied. This frequent recharging can be prevented by lowering the recharge voltage threshold by 200 mV, for example, to discharge more energy from the battery before it enters the recharge mode again. The modified schematic is shown in Figure 4.

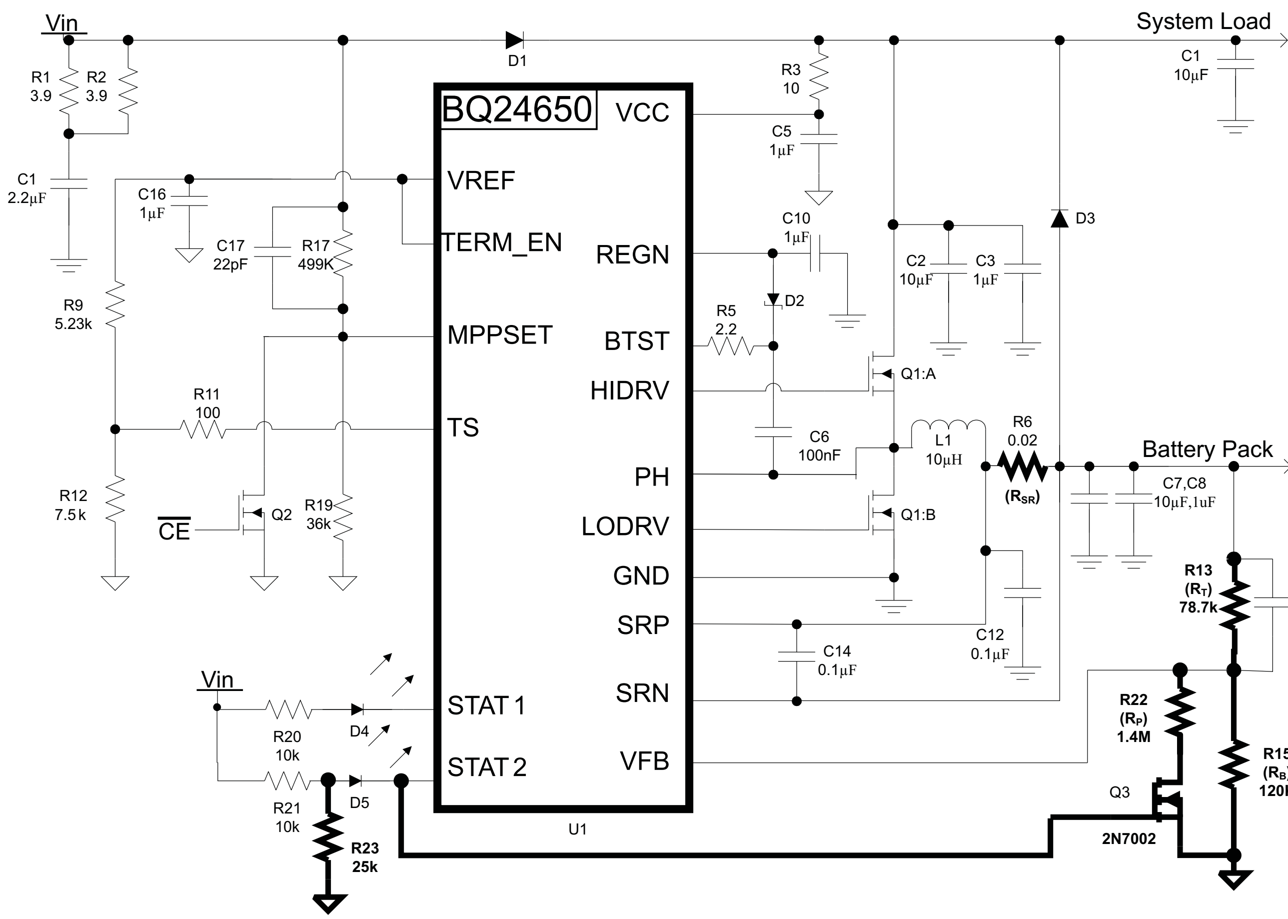

Figure 4. Modified EVM Schematic to Lower Recharge Voltage Threshold for $LiFePO_4$

In constant current phase, the STAT2 pin is turned off with a high-impedance output. As a result, V_{IN} turns on Q3 through R21 and D5. So, R22 is parallel with R15 to set the voltage regulation to 3.6 V. When the termination current is detected, the STAT2 pin goes low and pulls down the Q3 gate to ground to turn off Q3, R15, and R13 to set the recharge voltage threshold to 3.4 V.

$$R_{15} = \frac{V_{REFRECHARGE} \times R_{13}}{V_{REFCHARGE} - V_{REFRECHARGE}} = \frac{2.05 \times R_{13}}{3.4 - 2.05} = 1.519R_{13}$$

Keep R13 = 78.7k, R15 = 119.5k, so select R15 = 120k standard value.

As a check,

$$R_{15equ} = \frac{V_{REFCHARGE} \times R_{13}}{V_{CHARGE} - V_{REFCHARGE}} = \frac{2.1 \times R_{13}}{3.6 - 2.1} = 1.4R_{13},\ R15equ = 110.2k$$

where R15equ is the equivalent resistance of R15 parallel with R22.

$$R_{22} = \frac{R_{15} \times R_{15equ}}{R_{15} - R_{15equ}} = \frac{120k \times 110.2k}{120k - 110.2k} = 1.35M,\ \text{select R22 = 1.4M standard value.}$$

Figure 5 shows a ANR26650M1 $LiFePO_4$ battery being charged by the circuit in Figure 4.

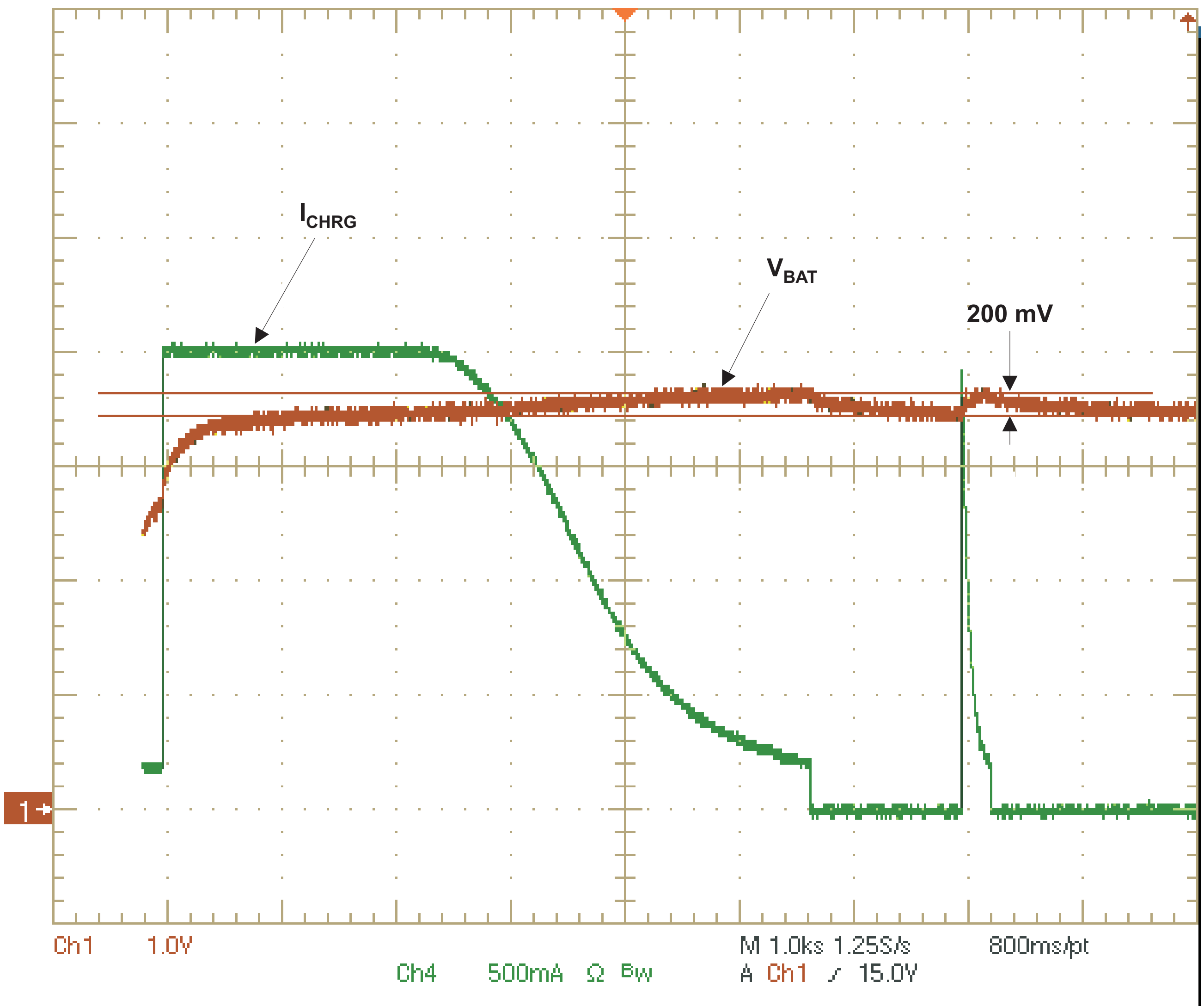

Figure 5. Charging ANR26650M1 $LiFePO_4$ Battery

The measured regulation voltage and recharge voltage thresholds are 3.63 V and 3.42 V, respectively. A small load was applied to the battery after the inital charging in order to quickly discharge the battery and initiate a recharge. The voltage difference is increased from 85 mV to 200 mV.

This application report shows how to modify the bq24650EVM LiIon battery charger to be a $LiFePO_4$ battery charger. The only required changed is to the feedback resistors that set the battery charger regulation voltage. However, only changing the regulation voltage results in the charger beginning to recharge the battery when the battery voltage is only 85mV below the regulation voltage. If the battery is seeing a 1-A discharge rate, the charger begins recharging after only a few seconds. In order to lower the battery recharge threshold, one resistor and one small MOSFET are added, with the MOSFET being controlled by the status output. In this example, a 3.4-V recharge threshold was selected, increasing the difference between the battery regulation and recharge thresholds from 85 mV to 200 mV. In this example, the charger began recharging the battery after a 1 minute and 6 seconds discharge time by 1-A discharge current. The recharge threshold must be selected based on real application conditions, such as system load and battery impedance.

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