Application Report
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bq2000 in Constant Voltage Phase for Li-Ion Battery

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ABSTRACT

The bq2000 charger can be used to charge Li-Ion, NiCd, or NiMH batteries. It uses three charging modes, the pre-charge, fast charge, and termination mode. It detects the battery chemistry type during the fast charge mode by monitoring the battery voltage profile. Once the chemistry is determined, the part completes the fast charge algorithm for the appropriate chemistry type. For Li-Ion batteries, after the constant current phase, the IC moves into a constant voltage phase. In this phase, the voltage is kept constant and the current switches ON and OFF until termination. This application report explores the charging algorithm for Li-Ion batteries.

Theory

The bq2000 is a multi-chemistry battery charger. It uses the pre-charge mode to revive deeply discharged cells by applying a small amount of current as shown in Figure 1. It inhibits the fast charge mode until the battery voltage and the temperature are within desired levels. As soon as the BAT pin voltage crosses above the minimum pre-charge qualification voltage (V_{LBAT}) threshold, the IC enters a fast charge mode.

During the fast charge mode, a programmed maximum charging current is applied to the battery terminals allowing the battery to charge faster. If the BAT pin voltage rises to V_{MCV} before fast-charge MTO (Maximum Time Out) is over, the device identifies the cell as Li-Ion and changes the termination criterion from PVD (Peak Voltage Detection) to minimum current detection.

Once the battery is identified as a Li-Ion battery chemistry type, the bq2000 moves into a constant voltage phase. In this phase, it regulates the battery with a constant voltage of V_{MCV} (Maximum Cell Voltage) at the BAT pin, and terminates when the average charging current falls below the I_{MIN} threshold or the timer expires, whichever happens first. The entire charging cycle for Li-Ion batteries can be seen in Figure 1.

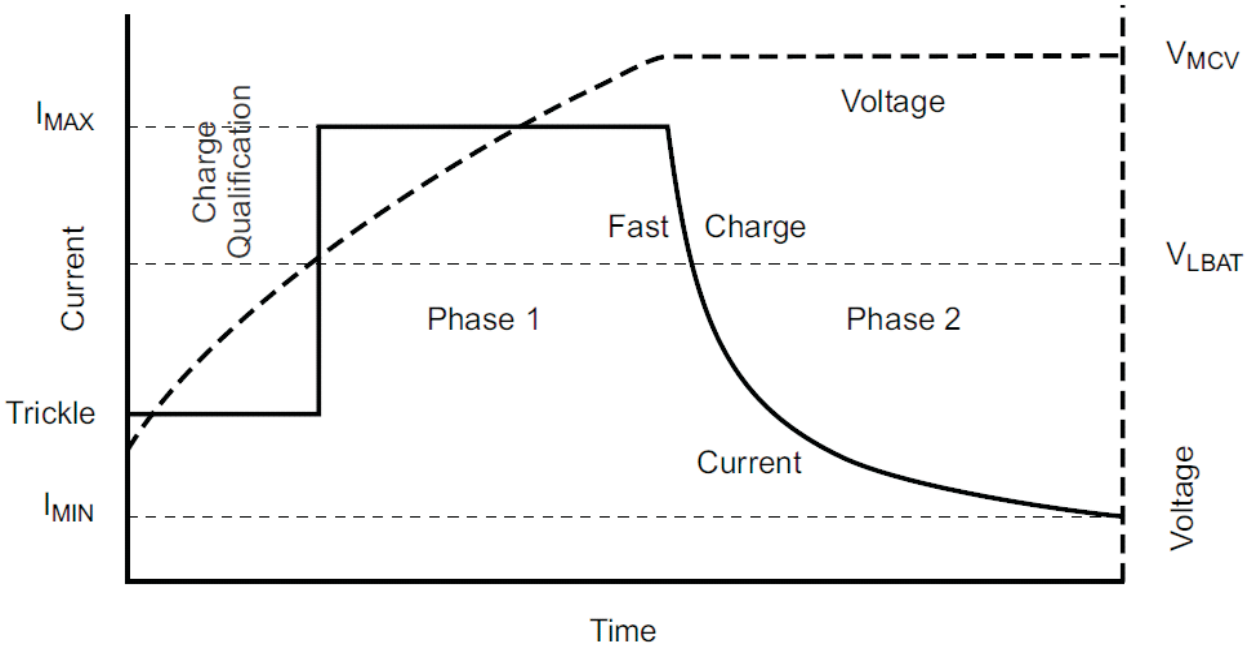

Figure 1. Lithium-Ion Battery Charging Algorithm

The pre-charge mode and the constant current phase are captured in Figure 1. However, the constant voltage phase needs more explanation. According to Figure 1, the bq2000 appears to implement the constant voltage phase by gradually tapering down the output current. In actuality, the output current is turned ON and OFF rapidly, between 0 Amps and I_{MAX}. The duty cycle is adjusted so that the average current gradually tapers off as shown in Phase 2 in Figure 1.

Test Results

Figure 2 shows the actual battery voltage, charging current, and BAT pin voltage of an emulated battery when charged with the bq2000. In this figure, the voltage of the emulated battery gradually increases until it reaches the V_{MCV} threshold. Notice that once the V_{MCV} voltage is reached at the BAT pin, the charging current starts turning ON and OFF with varying duty cycles.

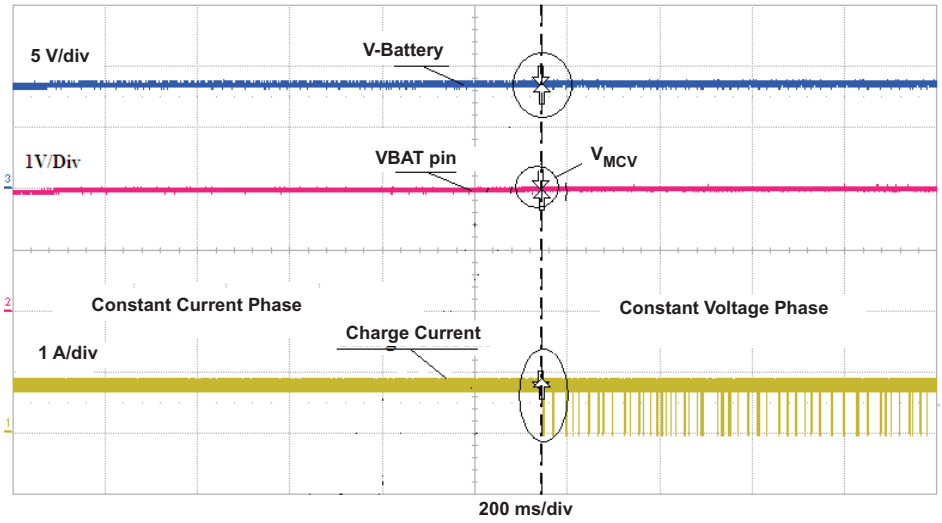

Figure 2. 2-Cell Li-Ion battery Charging Cycle

In Figure 3 , the battery charging current is shown in the fast charge and termination modes. During the fast charge mode, the battery charges with a constant current of about 1A during the constant current phase. Then in the constant voltage phase, the current switches ON and OFF as expected and the duty cycle decreases as the battery charges. When the average charging current decreases to about 14% of I_{MAX}, the IC terminates the charging.

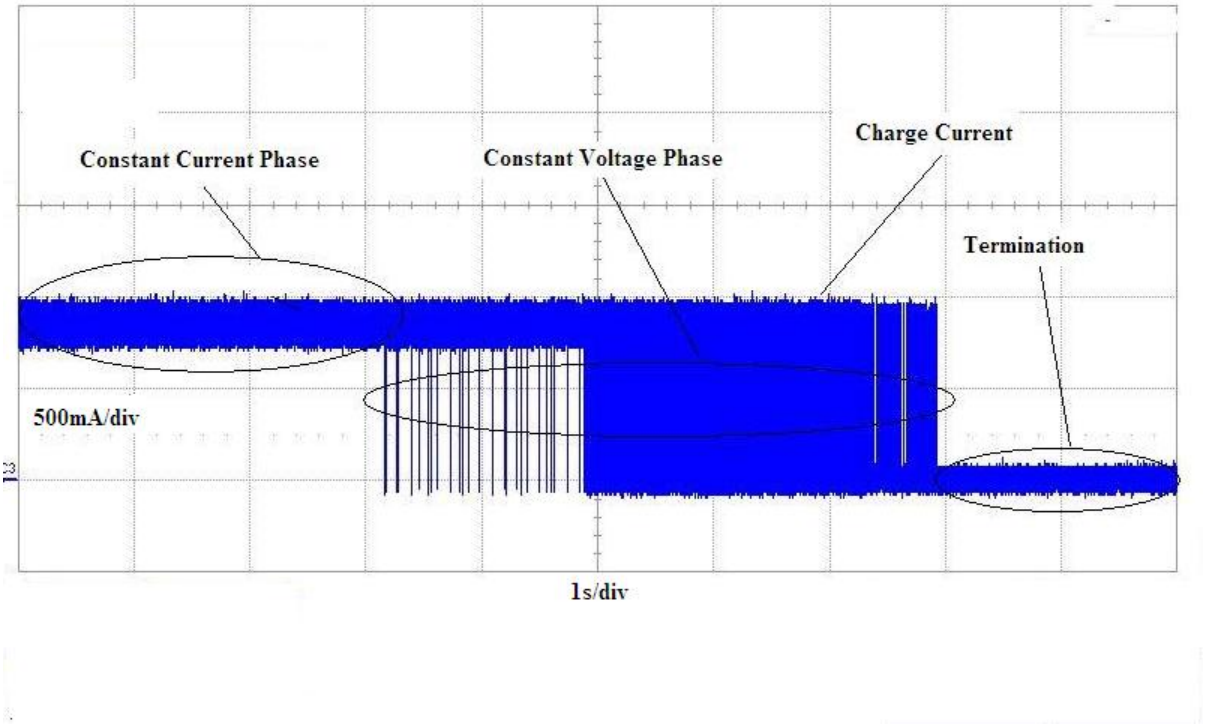

Figure 3. Emulated Li-Ion Battery Charging Cycle

Figure 4 shows a zoomed in view of the constant voltage phase. Notice that the duty cycle of the output current is changing. As the duty cycle decreases, the average current decreases.

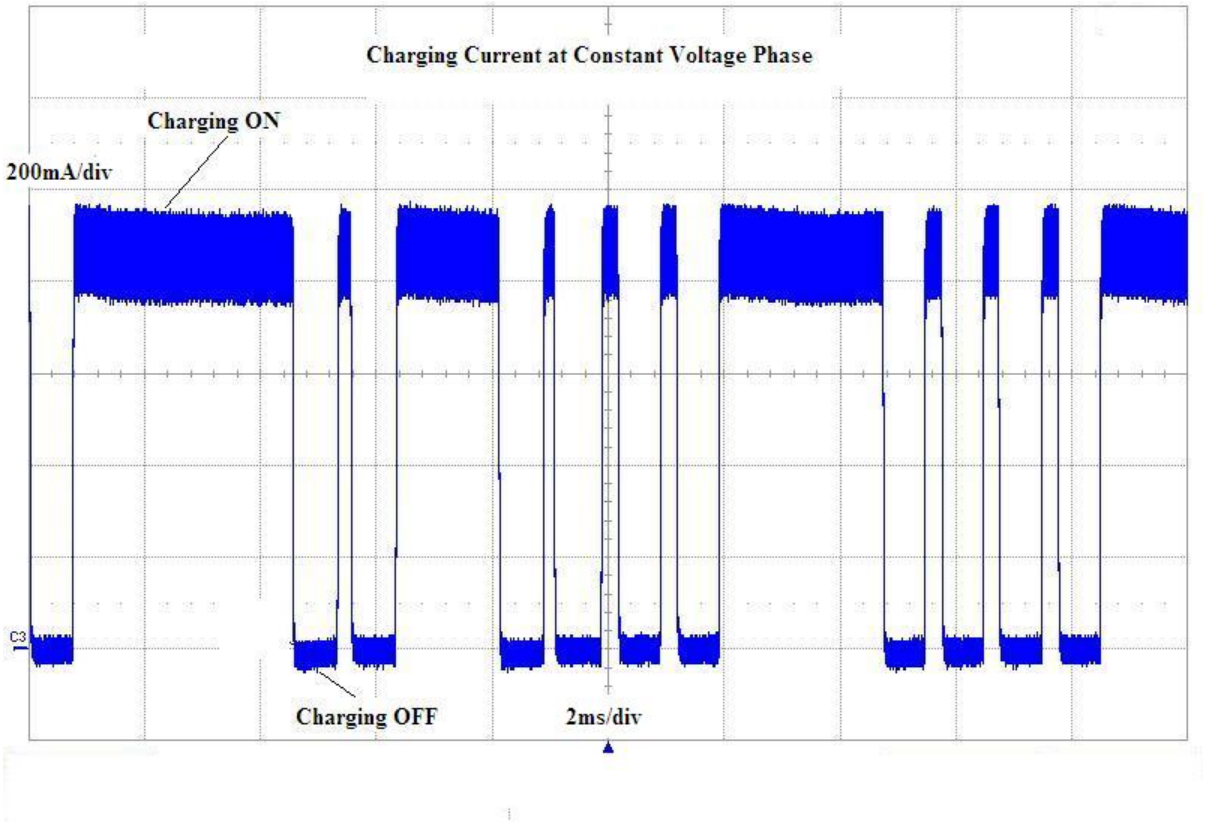

Figure 4. Zoomed In of Charging Current at CV Phase

Conclusion

In addition to the constant current phase, the bq2000 uses the constant voltage phase during the fast charge mode for the Li-Ion chemistry battery type. During the constant voltage phase, the voltage is regulated to V_{MCV} at the BAT pin and the average current decays as the battery charges up with time. The current turns ON and OFF with decreasing duty cycles until the average current reaches the minimum current level, which is where the IC terminates the charging.

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