DESIGN NOTES

Inexpensive Circuit Charges Lithium-Ion Cells – Design Note 188

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Introduction

A single Lithium-Ion cell is often the battery of choice for portable equipment because of its high energy density. The 3V to 4.1V provided by a Lithium-Ion cell is also a good match for modern low voltage circuits, often simplifying the power supply. Despite these advantages, designers are often frustrated when attempting to design precision charging circuitry that meets battery manufacturers' specifications. Figure 2 is a simple, cost-effective linear charger that satisfies these precision Lithium-Ion charging requirements.

Lithium-Ion cell manufacturers generally recommend a constant-current/constant-voltage (CC/CV) charging technique. Although conceptually simple, charging a Lithium-Ion cell requires very accurate control of the float voltage to obtain high capacity with long cycle life. If the voltage is too low, the cell will not be fully charged; if the voltage is too high, the cycle life is significantly degraded. Excessive voltage to the cell can also result in venting and other hazardous conditions (specific hazards depend upon the cell's construction and chemistry).

Figure 1 depicts CC/CV charging characteristics for a typical Lithium-Ion cell. A fully discharged cell will initially be charged by a constant current, since the cell's voltage is below the 4.1V constant-voltage limit. (Most Lithium-Ion cells require either a 4.1V or 4.2V float voltage, depending on the cell's chemistry.) Once the cell's voltage rises to the float voltage of 4.1V, the charger limits further rise in terminal voltage and the charging current naturally begins to fall off. Most battery manufacturers recommend that charging be terminated roughly one hour after the current has fallen to 10% of its peak value. Alternatively, a timer can be started when charging begins, with time-out used to suspend charging once sufficient time has elapsed to charge a fully depleted cell.

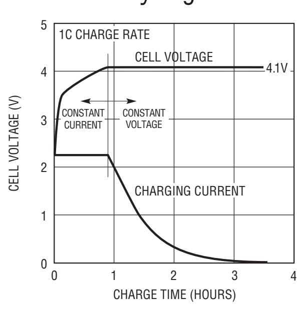

Figure 1. Typical Lithium-Ion Charge Characteristics

Circuit Description

Figure 2 depicts a simple and inexpensive linear charger that can be used to charge a single Lithium-Ion cell. The circuit provides constant-current/constant-voltage (CC/CV) charging from an inexpensive, unregulated 6V wall adapter. The charger is built around a single LTC®1541, which contains a voltage reference, op amp and comparator. The high accuracy voltage reference (±0.4%) regulates the battery float voltage to ±1.2%, as required by most Lithium-Ion battery manufacturers. Even tighter accuracy can be obtained by specifying higher accuracy for feedback divider resistors R6 and R7. The charger may be configured to float at either 4.1V or 4.2V by changing the value of R6. Use 252k for a 4.1V float voltage; use 261k for a 4.2V float voltage.

Transistor Q1 is used to regulate battery charging current. Q1's base current is controlled by the op amp output (Pin 1) and buffered by transistor Q2 for additional current gain. Diode D1 is needed to prevent reverse current flow when the wall adapter is unplugged or unpowered. Because this is a linear regulator, the designer must consider power dissipation in Q1. As shown with a 6V wall adapter, Q1 dissipates a maximum of about 1W and can be heat sinked directly to the printed circuit board. Higher current levels or higher input voltages will increase dissipation and additional heat sinking will be needed.

Battery charging current is sensed by R11 and fed to the op amp's noninverting input via R10. IC1's internal 1.2V reference voltage is divided to 44mV by R4 and R2 and connects to the op amp's inverting input. The op amp compares the current sense voltage against the 44mV

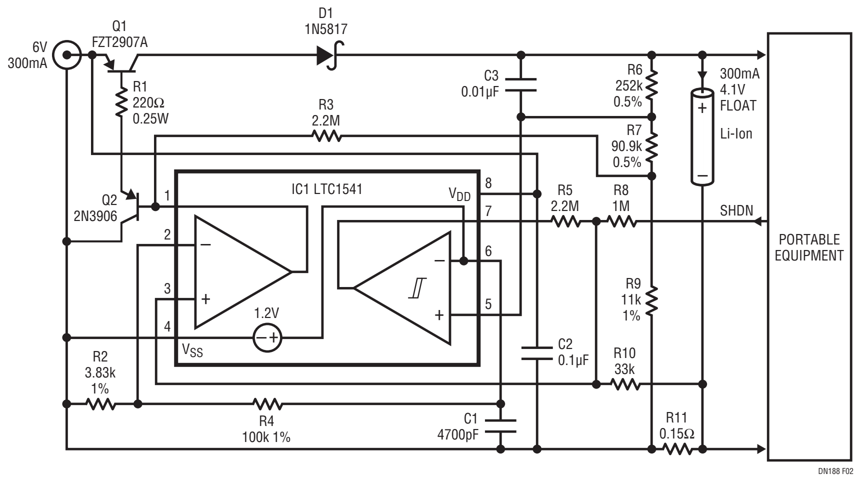

Figure 2. Lithium-Ion Battery Charger

reference and adjusts the base drive to Q1 as needed to regulate current to 300mA. The op amp's ±1.25mV maximum input offset voltage guarantees accurate charge current regulation while dropping only 44mV across the sense resistor.

Once the battery charges to 4.1V, the voltage loop begins to reduce charging current to maintain the desired float voltage. A resistor divider comprising R6, R7 and R9 generates a feedback voltage to IC1's comparator (Pin 5). Once the voltage at this node reaches 1.2V, the comparator output goes high, pulling the current sense signal high via R5. During voltage regulation, the comparator output (Pin 7) is a pulsed waveform; however, the low slew rate of the micropower op amp smoothes this signal to a small amplitude triangle wave at Pin 1. In fact, the voltage at Pin 7 may be monitored by a microprocessor to detect the onset of constant-voltage regulation.

Current sense resistor R11 is in series with the battery charging path and would normally result in voltage regulation beginning at around 4.05V instead of the desired 4.1V (44mV is dropped across the sense resistor). However, the addition of R3 and R9 compensates for this voltage drop, and results in activation of the constant-voltage loop at 4.1V. In essence, R3 and R9 create a negative output impedance from the regulator that cancels the 0.15Ω resistance of R11. By carefully selecting the values of R3, R7 and R9, one can produce an even larger negative output resistance and compensate for the internal resistance of the battery and its internal protection circuitry. The result is faster recharge times without exceeding the 4.1V limit within the cell itself.

Because the current sense loop actually monitors the total current drawn from the wall adapter, the charger will automatically "load share" with the portable equipment. In other words, when the equipment draws no power, all of the 300mA is available to charge the battery. However, any current drawn by the equipment will simply subtract from the battery charging current, keeping the wall adapter load limited to 300mA. The charger may also be shut down by logic control, as shown in Figure 2. Pulling high on the shutdown signal forces the current feedback signal above the 44mV threshold, thereby turning off Q1. The charger operates normally when the shutdown pin is a high impedance state—the default state on most microprocessor port pins. R8 may be eliminated if the shutdown feature is not needed.

Other Charging Options

The simple linear charger described above is suitable for many handheld portable products, where total charging current is modest. For higher current or multicell applications, a high efficiency switching regulator charger, such as the LT®1510 or LT1511, may be appropriate. The LT1510 is a CC/CV charger capable of delivering up to 1.25A of charging current from an SO-8 package. The LT1511 can deliver up to 3A and includes an input current limiting feature.

The CC/CV charging technique is not limited to Lithium-Ion batteries; sealed lead-acid (SLA) batteries may also be charged using similar circuitry. The constant-voltage control loop can easily be converted to a "hysteretic charger" for optimal SLA charging. Contact Linear Technology Applications Engineering for additional details.

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