New Standalone Linear Li-Ion Battery Chargers

by Alfonso Centuori

Introduction

Rechargeable batteries are commonly used to power portable devices such as digital cameras, PDAs, mobile phones and MP3 players. A wall adapter is the most common source of charging power, but an increasing number of applications are tapping into available USB power. The LTC4061 and LTC4062 are specifically designed to charge single-cell lithium-ion batteries from either of these sources.

Both devices use constant current/constant voltage algorithms to deliver up to 1A of charge current (programmable) with a final float voltage accuracy of ±0.35%. They include an internal P-channel power MOSFET and thermal regulation circuitry with no blocking diode or external sense resistor required—the basic charger circuit requires only two external components.

The LTC4061 and LTC4062 include both programmable time and programmable current based charge termination schemes. The open-drain charge status pin, $\overline{\text{CHRG}}$, can be programmed to indicate the state of the battery charge according to the needs of the application. The LTC4061 provides an AC Power open-drain status pin, $\overline{\text{ACPR}}$, to indicate that enough voltage is present at the input to charge a battery. Additional safety features designed to maximize battery lifetime and reliability include Negative Temperature Coefficient, NTC, battery temperature sensing (LTC4061) and the SmartStart™ charging algorithm, which extends the lifetime of the battery by preventing unnecessary charge cycles.

In the LTC4062, a low I_q precision comparator replaces the NTC and $\overline{\text{ACPR}}$ functions of the LTC4061. Without input power applied, the LTC4062 internal low power comparator can function while drawing just 10µA from the battery. With input power applied, LTC4061 and LTC4062 can be put into shutdown mode to reduce the supply current to a very low value (20µA) and the battery drain current to less than 2µA.

Internal thermal feedback regulates the charge current to maintain a constant die temperature during high power operation or high ambient temperature conditions.

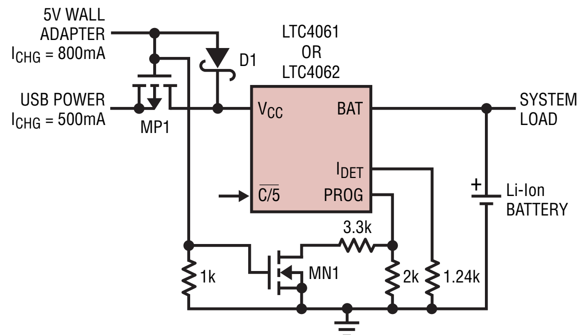

Figure 1. LTC4061 and LTC4062 USB/wall adapter power Li-Ion charger configuration using charge current termination

Programmability

The LTC4061 and LTC4062 provide a great deal of design flexibility including programmable charge current and programmable total time termination or programmable current termination. The maximum charge current is programmed using a single resistor from the PROG pin to ground. The charge current out of the BAT pin can be determined at any time by monitoring the PROG pin voltage and applying the following equation:

$$I_{BAT} = \frac{V_{PROG}}{R_{PROG}} \bullet 1000$$

A current detection threshold, I_{DETECT}, is set by connecting a resistor, R_{DETECT}, from IDET to ground. This threshold is used to change the state of the $\overline{\text{CHRG}}$ pin indicating that a battery is nearly full. Alternatively, this threshold can be used as the termination current threshold completing the charge cycle.

When using total time termination, the charge time is set by connecting a capacitor, C_{TIMER}, from TIMER to ground.

The TIMER pin controls which method of termination the LTC4061 and LTC4062 uses. Connecting an external capacitor to the TIMER pin activates an internal timer that stops the charger after the programmed time period has elapsed. Grounding the TIMER pin and connecting a resistor to the IDET pin causes the charge cycle to terminate once the charge current falls below a programmed threshold (I_{DETECT}). Connecting the TIMER pin to the input supply disables internal termination, allowing the charger to be manually shut down through the enable, $\overline{\text{EN}}$, input.

USB Compatibility

The $\overline{C/5}$ pin on LTC4061 and LTC4062 provides an easy method to choose between the two different power modes: high power and low power. A logic high on the $\overline{C/5}$ pin sets the charge current to 100% of the current programmed by the PROG pin resistor (up to 1A), while a logic low on the $\overline{C/5}$ pin sets the current limit to 20% of the current programmed by the PROG pin resistor. A weak pull down on the $\overline{C/5}$ pin defaults to the low power state.

The $\overline{C/5}$ pin provides great flexibility in applications that can automatically choose between wall adapter or USB power, as shown in Figure 1. If wall adapter is present and its voltage is

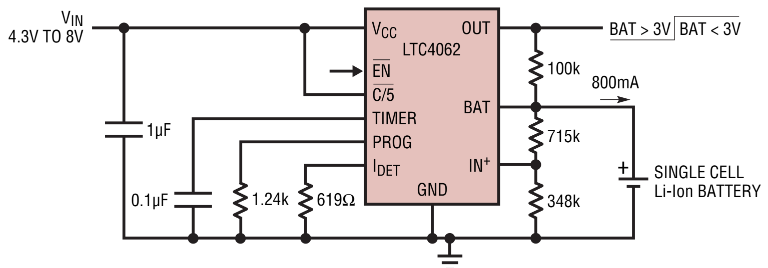

Figure 2. LTC4062 Li-Ion charger configuration using time termination and battery detection

above the V_{TH} of MP1, the power is applied through the diode D1 and the power available through the USB port is not used since MP1 is in open state. MN1 is closed and the 3.3kΩ and 2kΩ resistors are in parallel, setting the total maximum charge current up to 800mA (160mA if $\overline{\text{C/5}}$ is set low). If wall adapter is not present, the USB powers the charger; MN1 is open leaving only the 2kΩ resistor to set the charge current up to maximum 500mA. Through the $\overline{\text{C/5}}$ pin it is possible to set the charge current to 100mA or 500mA as necessary by USB applications.

Avoiding Unnecessary Charge Cycles

LTC4061 and LTC4062 are designed to avoid unnecessary charge cycles to extend the life of Li-Ion batteries. When power is first applied or when exiting shutdown, the LTC4061 and LTC4062 check the voltage on the BAT pin to determine its initial state. If the BAT pin voltage is below the recharge threshold of 4.1V (which corresponds to approximately 80%–90% battery capacity), the LTC4061 and LTC4062 enter charge mode and begin a full charge cycle. If the BAT pin is above 4.1V, the battery is nearly full and the charger does not initiate a charge cycle and enters standby mode. When in standby mode, the chargers continuously monitor the BAT pin voltage. When the BAT pin voltage drops below 4.1V, the charge cycle is automatically restarted and the internal timer is reset to half the programmed charge time (if time termination is being used). These features eliminate the need for periodic charge cycle initiations, ensure that the battery is always fully charged and reduce the number of unnecessary charge cycles, prolonging battery life.

Fault Detection and Reporting

LTC4061 has an NTC (Negative Temperature Coefficient) input to qualify charge based on the temperature of the battery, as shown in Figure 3. When the battery temperature is above or below safe levels, charging is suspended, the internal timer is frozen and the $\overline{\text{CHRG}}$ pin output blinks with a square wave at either the frequency set with C_{TIMER} (if in timer mode) or 1.5Hz if in current or user termination mode (TIMER connected to GND or to the input supply). The frequency of the blinking using C_{TIMER} is set by the following formula:

$$f_{\overline{CHRG}} = \frac{0.1\mu F}{C_{TIMER}} \bullet 1.5Hz$$

This feature can be disabled by grounding the NTC pin.

While only the LTC4061 has the ability to report a temperature fault, both parts have the ability to report a bad battery. When the BAT pin voltage is below the 2.9V trickle charge threshold (V_{TRIKL}), the charge current is reduced to 10% of the programmed value. If the battery remains in trickle charge for more than 25% of the total programmed charge time, the chargers terminate charging and report that the battery is defective. LTC4061 and LTC4062 report this fault by driving the $\overline{\text{CHRG}}$ output with a square wave. The duty cycle of this oscillation is 50% and the frequency is set by C_{TIMER}.

An LED driven by the $\overline{\text{CHRG}}$ output exhibits a blinking pattern, indicating to the user that the battery needs replacing. A bad battery fault can be cleared by toggling the $\overline{\text{EN}}$ input or removing and reapplying power to $V_{CC.}$ The defective battery detection feature is only available when time termination is being used.

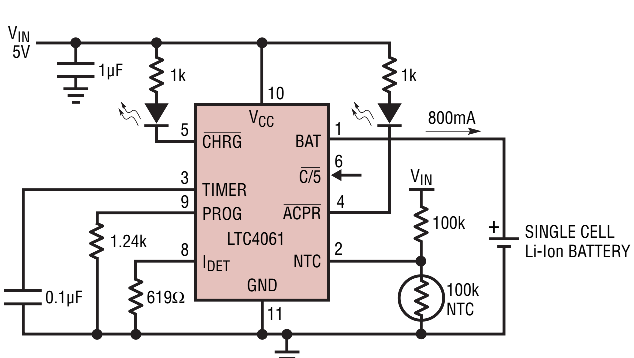

Figure 3. LTC4061 fully featured (using time termination)

Feature Differences between LTC4061 and LTC4062

In addition to the NTC feature, LTC4061 has an $\overline{\text{ACPR}}$ power supply status indicator. When sufficient voltage is present on V_{CC} to charge a battery, this pin is pulled low with an open-drain NMOS device. Otherwise, the pin assumes a high impedance state.

In place of the NTC and $\overline{\text{ACPR}}$ functions, the LTC4062 includes an undedicated, precision, low power comparator. The comparator is powered from the BAT pin and consumes just 10µA. The open drain output, OUT, is capable of driving an LED. Possible uses for this comparator include precision low battery detection as shown in Figure 2 and user programmable input supply monitoring.

Conclusion

LTC4061 and 4062 are complete linear Li-Ion battery chargers for wall adapt-

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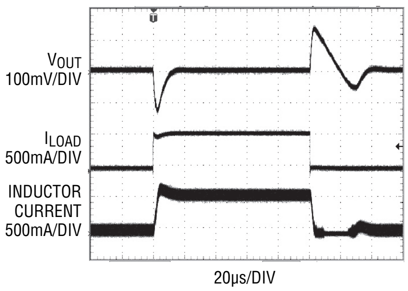

Figure 4. LTC3409 transient response to a 50mA–600mA load step, pulse skip mode

eration at light loads, but comparable when the output load exceeds 50mA (see Figure 1 & 2).

In Burst Mode operation, the internal power MOSFETs operate intermittently based on load demand. Short burst cycles of normal switching are followed by longer idle periods where the load current is supplied by the output capacitor. During the idle period, the power MOSFETs and any unneeded circuitry are turned off, reducing the quiescent current to 65µA. At no load, the output capacitor discharges slowly through the feedback resistors resulting in very low frequency burst cycles that add only a few µA to the supply current. Burst Mode operation offers higher efficiency at low output currents than pulse skip mode, but when activated, Burst Mode operation produces higher output ripple than pulse skip mode.

Output Voltage Programmability

The LTC3409 output voltage is externally programmed with two resistors to any value above the 0.613V internal reference voltage, and is capable of 100% duty cycle. In dropout, the output voltage is determined by the input voltage minus the voltage drop across the internal P-channel MOSFET and the inductor resistance.

Fault Protection

The LTC3409 protects against output over-voltage, output short-circuit and power over-dissipation conditions. When an over-voltage condition at the output (>10% above nominal) is sensed, the top MOSFET is turned off until the fault is removed. If the output is shorted to ground, reverse current in the synchronous switch is monitored to prevent inductor-current runaway. If the synchronous switch current is too high, the top MOSFET remains off until the synchronous switch current falls to a normal level.

When the junction temperature reaches approximately 160°C, the thermal protection circuit turns off the power MOSFETs allowing the part to cool. Normal operation resumes when the die temperature drops to 150°C.

1.5V/600mA Step-Down Regulator Using Ceramic Capacitors

Figure 3 shows an application of the LTC3409 using ceramic capacitors. This particular design supplies up to a 600mA load at 1.5V with an input supply between 1.8V and 3.1V. Ceramic capacitors have the advantages of small size and low equivalent series resistance (ESR), allowing very low ripple voltages at both the input and output. Because the LTC3409's control loop does not depend on the output capacitor's ESR for stable operation, ceramic capacitors can be used to achieve very low output ripple and small circuit size. Figures 4 and 5 show the transient response to a 50mA to 600mA load step for the LTC3409 in pulse skip mode, and burst mode.

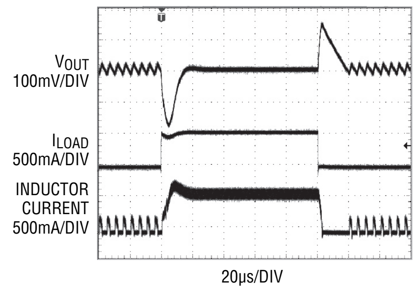

Figure 5. LTC3409 Transient response to a 50mA–600mA load step, Burst Mode operation

Efficiency Considerations

Figure 1 shows the efficiency curves for the LTC3409 (Burst Mode operation enabled) at various supply voltages. Burst Mode operation significantly lowers the quiescent current, resulting in high efficiencies even with extremely light loads. Figure 2 shows the efficiency curves for the LTC3409 (pulse skipping mode enabled) at various supply voltages. Pulse skipping mode maintains constant-frequency operation at lower load currents. This necessarily increases the gate charge losses and switching losses, which impact efficiency at light loads. Efficiency is still comparable to Burst Mode operation at higher loads.

Conclusion

The LTC3409 operates over a wide, 1.6V to 5.5V, input range, which allows it to operate from various power sources, from a 5V AC wall adapter to two series alkaline batteries. This flexible device is available in a 3mm × 3mm DFN package and includes a number of features to improve battery life and save space.

LTC4061/62, continued from page 21

ers and USB sources. They extend lifetime of the batteries by avoiding unnecessary charge cycles. The LTC4061 and LTC4062's versatility of charge terminations, low quiescent current, simplicity, high level of integration and small size makes them an ideal choice for many portable USB applications. LTC4061 and LTC4062 are available in a small 10-lead low profile 3mm x 3mm DFN package.

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