4A Li-Ion Battery Charger Accepts Inputs to 32V

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Advances in Li-ion battery technologies continue to produce batteries with increased capacity and energy density. Charge/discharge rate capabilities are also rising, sometimes to multiple C rates (C is the standard designator for battery capacity stated in amp-hrs). These technologies are making their way into consumer, automotive, medical and industrial markets. In most cases, the charger must be able to recharge multiple sources over a wide range of input voltages.

High capacity/current batteries require chargers that handle the high currents safely, efficiently and cost effectively. Until now, building a safe high current battery charger required the use of multiple ICs and a host of external components resulting in expensive and bulky solutions. The LT3651 integrated battery charger solves this problem by supporting charge currents up to 4A and accepting input voltages to 32V.

BATTERY CHARGER FEATURES

Charger safety is a significant concern as batteries increase in capacity. The LT3651 includes all of the necessary charge termination and protection features. Charge termination methods include C/10 termination or safety timer termination. Additional protection features include battery temperature monitoring, disabling charging of a battery that is too hot or cold, battery preconditioning for deeply discharged batteries and bad battery detection when in timer mode.

The LT3651 provides an additional PowerPath™ feature that regulates battery charge current in response to total input supply current. With this feature, the battery charger current is reduced if other loads on the input supply increase their current such that the total input supply load exceeds a programmed limit. This allows designers to reduce the input supply requirements to more efficiently manage power. This feature can also be used to enforce a thermal budget by limiting a set maximum input power.

The LT3651 can be programmed via an external resistor for switching frequency, average battery charger current and input current limit (reducing battery charge current to try and maintain constant input current). An external capacitor sets timeout period for timer controlled termination.

The LT3651 operates at high frequency, reducing inductor and filter component size. The frequency is user adjustable, offering the advantage of reduction of power dissipation at higher voltages and control of spectral harmonics.

THE CHARGE CYCLE

Li-ion battery charging typically uses a constant-current/constant-voltage (CC/CV) charging algorithm. A Li-ion battery is initially charged with constant current, generally between 0.5C and 1C, though newer batteries can use higher rates. As the battery voltage approaches the full-charge float voltage, the charger reduces charge current and transitions into constant voltage operation. The LT3651 prevents overcharging of the battery, protecting the battery against damage. There are four variants of the LT3651 supporting 4.1V, 4.2V, 8.2V and 8.4V float voltages.

The LT3651 combines a synchronous buck switcher with a battery charger to efficiently produce high charge current. It provides a CC/CV charging characteristic and adjusts charge current

Figure 1. Basic single cell 4A charger

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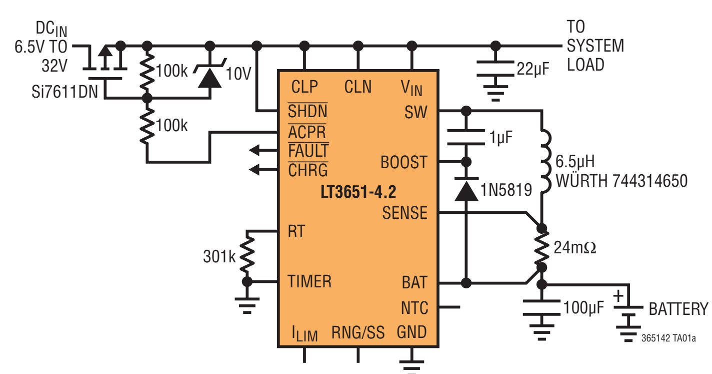

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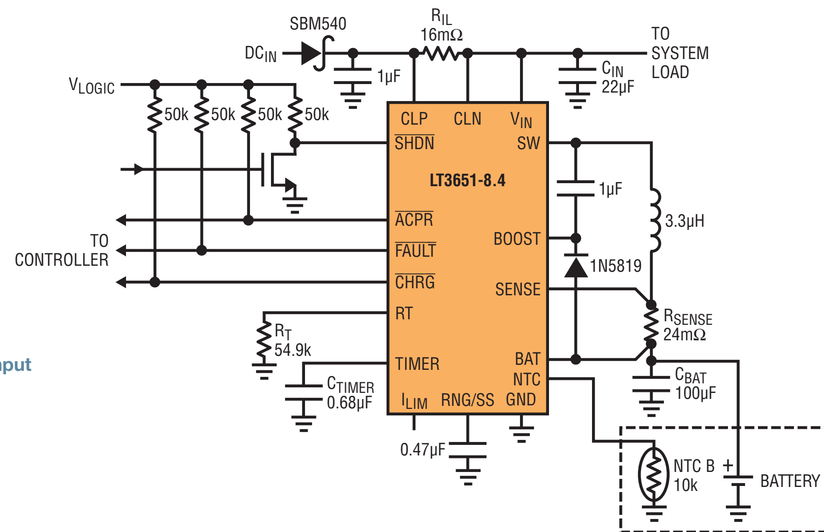

Figure 2. 2-cell Li-ion 9V to 32V charger with input current limit and 3-hour charge timeout

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based on battery voltage. During constant-current operation, the maximum charge current provided to the battery is programmable via a sense resistor, up to a maximum of 4A and adjustable using the RNG/SS pin. Charge current is internally reduced as the battery approaches the full-charge float voltage and the charger transitions to constant voltage charging mode.

A charge cycle terminates by either charge current level or time. Once terminated, the charger is in a low power state, which draws about 85µA from the input supply and less than 1µA from the battery. With both termination modes, charging is restarted when the battery voltage drops to 97.5% of the float voltage (the recharge voltage).

Two pins indicate the charging state. While charging the $\overline{\text{CHRG}}$ pin actively sinks current so an LED from a supply to this pin provides visual indication of charging. The pin transitions to a high impedance upon completion of a charge cycle. A $\overline{\text{FAULT}}$ pin provides additional information about charging disruptions such as a battery out of temperature range fault or a bad battery fault.

A 4A CHARGER WITH INPUT SHORT PROTECTION

Figure 1 shows a basic 4A single-cell Li-ion battery charger that operates from a 6.5V to 32V input. Charging is suspended if the input supply voltage exceeds 32V, but the IC can withstand input voltages as high as 40V without damage. So this application can be used for charging from different inputs inside the 6.5V to 32V range.

The 4A maximum charge current corresponds to 95mV across the 24mΩ external sense resistor. This basic design does not take advantage of the status pins, battery temperature monitoring or safety timer features. The battery charging cycle terminates when the battery voltage approaches 4.2V and the charge current falls to approximately 400mA. A new charge cycle is automatically initiated when the battery voltage falls to 4.1V.

A MOSFET is used as a low loss diode to provide reverse blocking in the event of an input short. This prevents battery discharge through the charger.

WIDE INPUT RANGE, 2-CELL CHARGER

Figure 2 shows a 2-cell 9V to 32V charging application. This could be used in an automotive application where the input needs to tolerate a wide input voltage. This application uses the -8.2 or -8.4 option for charging two Li-ion cells at 4A. This application also uses the input current regulation feature. R_{IL} monitors the current drawn from the supply that supplies both the charge current and system load. It is set such that if the combined input current exceeds 6.3A, charge current is reduced to keep input current from increasing. Often input supply voltages

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are relatively constant. For applications where this is true, then the setup in Figure 2 also limits total input power. For example, with a 12V input supply total input power will be limited to about 75W.

In this application, the safety timer is used for termination, the timer is paused for the duration of a temperature fault, so a battery receives a full-duration charging cycle, even if that cycle is interrupted if the battery is out of the allowed temperature range. The capacitor on the timer pin sets the charge time, in this case it is three hours, so charging continues past the C/10 charge point. At timeout the part goes into standby and reduces battery discharge current to less than 1µA.

The timer also provides for determination of a bad battery. The LT3651 has an automatic precondition mode, which gracefully initiates a charging cycle for deeply discharged batteries. If the battery voltage is below the precondition threshold of 70% of the float voltage (5.8V for the -8.4), the maximum charge current is reduced to 15% of the programmed maximum (0.15C) until the battery voltage rises past the precondition threshold. This current is sufficient to activate any safety circuitry in a battery pack and also provides a small charge current. If the battery does not respond to the precondition current and the battery voltage does not rise past the precondition threshold after 1/8 of the charge cycle (22.5min in this application), full-current charge is not initiated and a battery fault is issued.

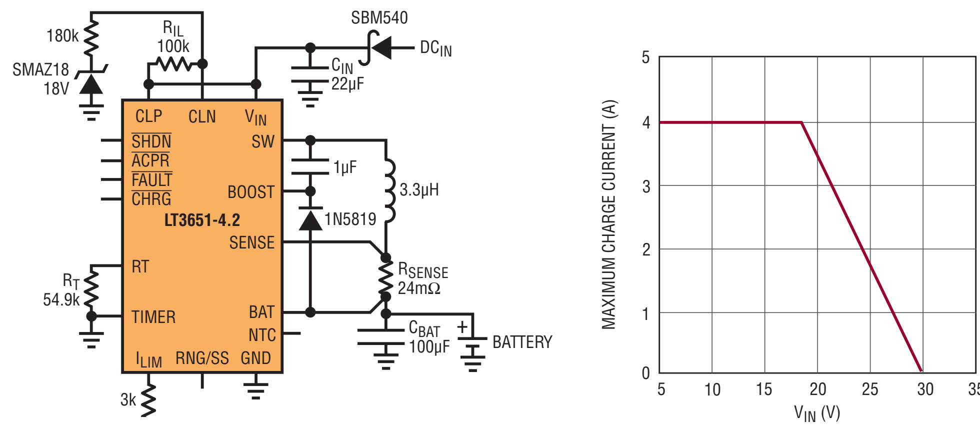

Figure 3. 4A single cell charger with high voltage current foldback

This application also makes use of an external NTC resistor in the battery pack to monitor battery temperature. Under- and overtemperature protection is enabled by connecting a 10k NTC thermistor from the part's NTC pin to ground. This function suspends a charging cycle if the temperature of the thermistor is greater than 40°C or less than 0°C.

The two status pins $\overline{\text{CHRG}}$ and $\overline{\text{FAULT}}$ are used to communicate charger status back to a controller. While the LT3651 does not need a controller to operate, one could be used for additional functionality. The status pins indicate: standby/shutdown; CC/CV charging (>C/10); bad battery detection and temperature fault. Of course in other applications an LED could be placed on these pins for visual indication.

An additional feature of the LT3651 is the ability to withstand input voltages to 40V, which helps in automotive designs.

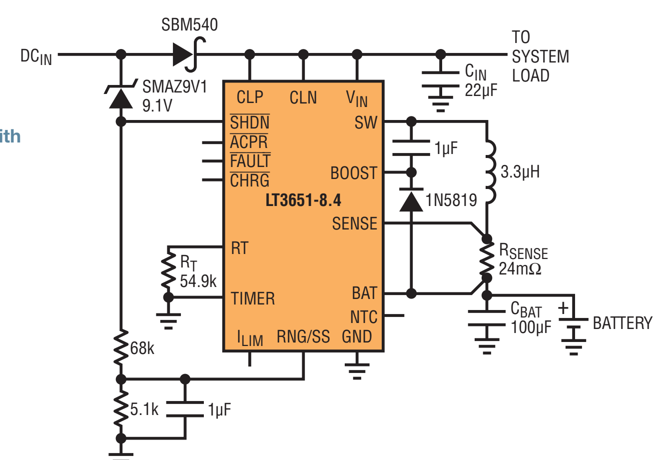

Figure 4. 4A 2-cell charger with low voltage current foldback

The LT3651 is a versatile, compact and easy-to-use solution for charging Li-ion batteries with up to 4A in current and from input supplies up to 32V (40V ride through). High efficiency, built in safety controls and compact size make it an easy fit in a wide variety of applications.

When the input voltage exceeds 32V the output switches are disabled but can ride out the overvoltage condition.

An input diode is used to protect from discharging the Li-ion batteries in the event of an input short. This could be replaced with a MOSFET as in the previous example to improve efficiency.

MORE OPTIONS

The charge current and input current limit control pins can also be used to provide other functionality to a charger application. Figure 3 shows an application where the charge current is diminished with increasing DC_{IN}, a useful feature to control power dissipation of the input source.

Figure 4 shows an application with the inverse feature, where charge current is reduced at lower input voltage, so in the event a supply voltage drops, less load is drawn.

Note in general both the ILIM pin and the RNG/SS pin provide control over charge current and can be changed dynamically to produce additional functionality.

Figure 5 shows an application that offers a maximum power point control (MPPC) feature that regulates input voltage at a constant voltage. This is useful for solar panel applications. It makes use of the input current limit amplifier and reconfigures it for input voltage regulation. The differential CLP-CLN voltage is used to regulate output current. The reference is set with a Zener diode but could be done many ways. The NPNs are used to buffer the CLN input bias current. ILIM is shorted to remove the built-in offset between CLP and CLN. In this case the input regulation is set for 17V, but is adjustable with the 100k/61.9k divider.

SUMMARY

The LT3651 is a versatile, compact and easy-to-use solution for charging Li-ion batteries with up to 4A in current and from input supplies up to 32V (40V ride through). High efficiency, built-in safety controls and compact size make it ideal for a wide variety of applications.

Visit www.linear.com/LT3651 for data sheets, demo boards and other applications information. ■

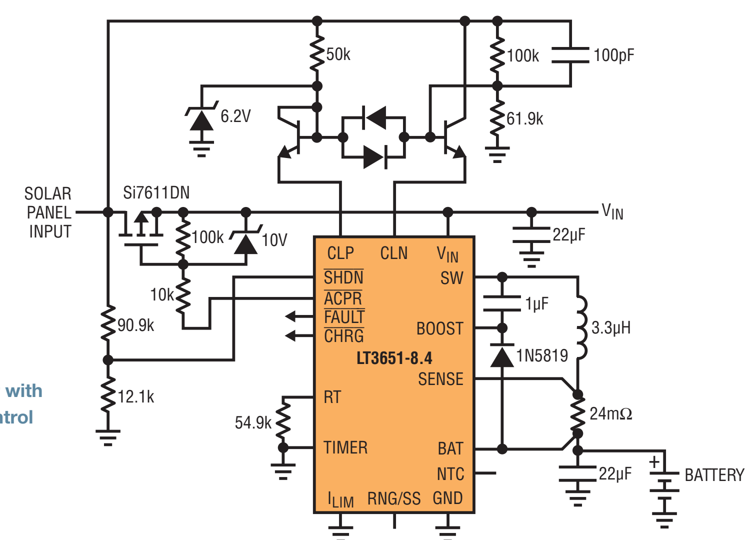

Figure 5. 4A 2-cell charger with maximum power point control

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