LINEAR TECHNOLOGY

DESIGN NOTES

Li-Ion Linear Charger Allows Fast, Full Current Charging While Limiting PC Board Temperature to 85°C – Design Note 283

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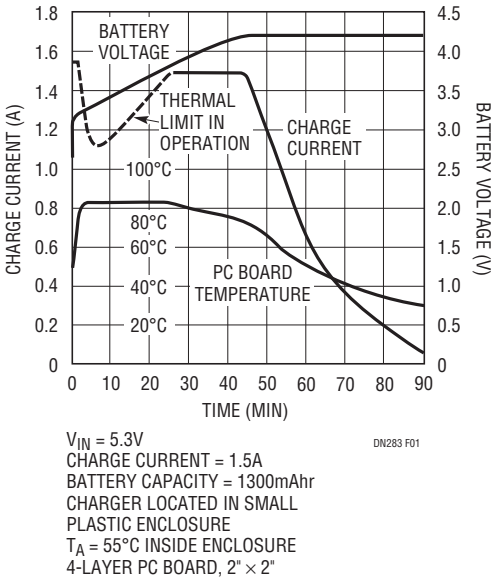
Introduction

Linear battery chargers are typically smaller, simpler and less expensive than their switcher-based counter parts, but they have one major disadvantage: excessive power dissipation when the input voltage is high and the battery voltage is low (discharged battery). Typically, such conditions are temporary—as the battery's voltage rises with its charge—but one must consider this worst-case situation when determining the maximum allowable values for charge current and IC temperature. One simple solution to this overheating problem is to decrease the charge current for the entire constant current part of the charging process. The problem with this method is a corresponding increase in charge time. A better option is to use the LTC®1733 Li-Ion single cell linear charger which overcomes any overheating problem while maintaining fast charge times. A unique thermal feedback loop within the IC allows full current, fast charging under nominal conditions without overheating under worst-case conditions (including high ambient temperature, high input voltage or low battery voltage situations).

Thermal Feedback Loop Limits IC Temperature

A thermal feedback loop limits the maximum junction temperature of the LTC1733 to approximately 105°C, well below the maximum allowable junction temperature of 125°C. As the junction temperature approaches 105°C, the on-chip temperature sensor begins to smoothly decrease the charge current to a level that will limit the maximum junction temperature to 105°C (see Figure 1). Unlike ICs that simply shut down at 160°C to protect themselves, the LTC1733 can operate in this temperature control mode indefinitely. Devices with a 160°C thermal shutdown temperature could begin switching on and off at the thermal limit or might not operate correctly as a charger. Thermal shutdown is not a healthy mode of operation, it is rather intended to protect the IC from failure when overstressed.



V_{IN} = 5.3V
CHARGE CURRENT = 1.5A
BATTERY CAPACITY = 1300mAhr
CHARGER LOCATED IN SMALL PLASTIC ENCLOSURE
T_A = 55°C INSIDE ENCLOSURE
4-LAYER PC BOARD, 2" × 2"

Figure 1. LTC1733 Li-Ion Battery Charge Cycle For High Ambient Temperature Conditions

Charge Cycle with Thermal Limit in Operation

Figure 1 shows a typical single cell Li-Ion charge cycle for a worst-case temperature condition. The curves show battery voltage, charge current and PC board temperature vs time.

A charge cycle begins when the input power is applied with the battery connected and the program resistor connected to ground. Deeply discharged batteries are trickle charged at 10% of full current until the battery voltage reaches 2.48V at which point the charger switches to full current.

At the start of the charge cycle, the charge current quickly rises to the programmed value of 1.5A, resulting in the battery voltage rising to 3.2V. With an input voltage of 5.3V, the 3.2W of power dissipated by the LTC1733 raises the junction temperature to approximately 105°C with the 2" × 2" PC board temperature (heat sink) reaching approximately 85°C in approximately 1.5 minutes. The thermal feedback loop limits any additional temperature rise by reducing the charge current. As the battery voltage rises, the LTC1733 temperature begins to drop allowing the charge current to rise back up to the programmed current level of 1.5A. The charging continues at the 1.5A constant current level until the battery voltage reaches 4.2V, at which time the constant voltage portion of the charge cycle begins. This continues with the charge current continually dropping until the 3-hour timer ends the charge cycle (Figure 1 shows the first 90 minutes).

Thermally Enhanced Package Dramatically Improves Power Dissipation

A special low profile (1.1mm) 10-pin MSOP package with an exposed bottom side metal pad allows the IC to be soldered directly to the PC board copper to greatly reduce the junction-to-case thermal resistance. A good thermal layout allows the LTC1733 to dissipate up to 2.5W continuously using a 2" × 2" 4-layer PC board at a 25°C ambient temperature.

A good thermal layout consists of PC board copper directly below the package spreading out to copper areas and feed-through thermal vias to internal and backside copper layers. For surface mount devices, the PC board copper can become an effective heat sink. It is also important to solder the entire area of the IC's metal pad to the board to assure good heat conduction. Tests have shown that with a large initial power of 4.5W applied to a package, an improperly soldered package will reach the thermal feedback temperature in just seconds, while a good solder attachment will take over a minute.

Complete Standalone Charger

The LTC1733 is a complete constant current, constant voltage, power limiting linear charger for a single cell Li-Ion battery as illustrated in Figure 2. The IC includes a 1.5A power MOSFET, current sense resistor, programmable charge current, programmable timer, selectable charge voltage and thermistor input to monitor battery temperature for charge qualification. There are three status outputs capable of driving LEDs to indicate "AC power good," "charge" and "fault." There is also an output to monitor charge current. Input voltage requirements are 4.5V to 6.5V with manual shutdown and a micropower sleep mode when the input voltage is removed. No input blocking diode is required because of the internal MOSFET construction.

Conclusion

The LTC1733 is a standalone Li-Ion battery linear charger IC that allows the charge current to be programmed for nominal conditions of V_{IN}, $V_{BATTERY}$ and ambient temperature without the excessive temperatures associated with certain temporary charge conditions. This allows for higher charge currents (resulting in a faster charge) with the assurance that an occasional worst-case scenario will not overheat the system.

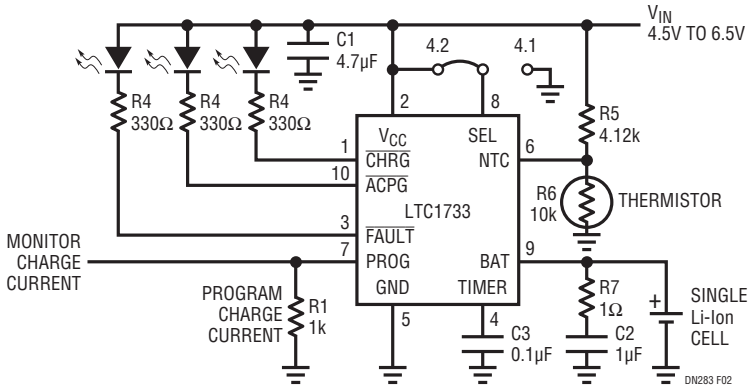


Figure 2. Complete 1.5A Single Cell Li-Ion Charger For 4.1V or 4.2V Cells (No External MOSFET, Blocking Diode or Sense Resistor Required)

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