LM3525,LM3622

A USB-Powered Lithium-Ion Battery Charger

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Application Brief

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Application Brief 101

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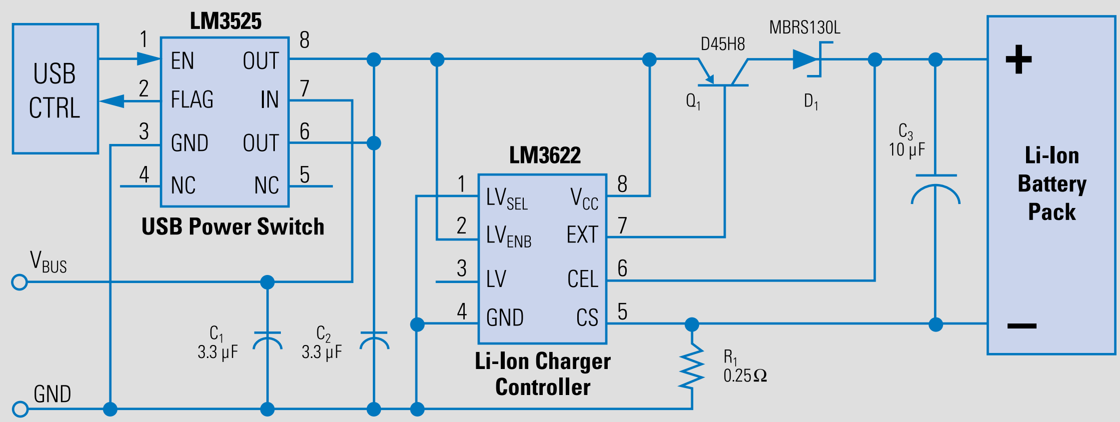
The Universal Serial Bus has become one of the most widespread and convenient ways to connect electronic devices to the PC. Countless modern portable products with built-in USB connectors readily use the USB data bus to transmit and receive data to and from PCs, but many of these battery-powered units still use a separate power supply for battery charging (often a charging cradle or a simple AC/DC converter). Sometimes overshadowed by its data bus partner, each USB connection also contains a power bus. With a maximum power rating 5.25V/500 mA, the USB power bus is a great source for charging a single-cell Lithium-Ion battery. The circuit in Figure 1 shows how to build a USB-powered single-cell Li-Ion battery charger using National Semiconductor's LM3622 Li-Ion Battery Charger Controller.

Circuit uses existing USB power-bus to charge a single-cell Li-Ion battery.

The battery-charger circuit is designed to operate as a high power USB function. To be compliant with USB Specifications (Rev. 1.1), a high-power function must not draw more than 500 mA from the bus during normal operation. The LM3622 uses the 0.25Ω current-limit resistor R_1 to set a 400 mA maximum charging current. This leaves a 100 mA surplus that can be used to supply USB control circuitry and other functions in the device.

There are additional current restraints on a high-power USB function that apply during system start-up or when a device is initially connected to an active bus. Until a device is properly configured by the USB system, the device may not draw more than 100 mA

Figure 1: A USB-powered Lithium-Ion Battery Charger.



from the bus. In the above design, National Semiconductor's LM3525 USB power switch keeps the battery charger circuit isolated from the bus during start-up so that the charge current does not overload the bus. When the port is properly enumerated, a USB control signal enables the LM3525 switch, connecting USB power (V_{BUS}) to the charger circuit. In addition to on-and-off switching, the LM3525 provides over-current and under-voltage protection to the design.

A circuit designed with minimum voltage drop will allow the charger to function at the low USB power-bus voltage.

The voltage drop between the bus supply, V_{BUS}, and the charger circuit should be carefully considered in designing a USB battery charger. The circuit's transistor, Q_1 (D45H8), and diode, D_1 (MBRS130L), were chosen for their low-dropout properties so that the circuit could charge the battery even under low input voltage conditions. With these preferred components, the voltage drop between the LM3525 input and the battery cathode must be 530 mV (typ.) or greater for the circuit to deliver the full 400 mA charge current to the battery. For an optimal charge time, the maximum charge current should be delivered to the battery until the battery reaches its full-charge voltage. With a 4.2V Li-Ion battery, this would require the voltage at the input to this charging circuit to be above 4.7V (typ.). The USB specification sets the minimum output supply voltage at 4.75V, but then provides for resistive drops in the USB cable and connectors up to 350 mV. Thus, in the absolute worst case, the voltage at the input to the charge circuit could be as low as 4.4V and still be within USB specifications, limiting the effectiveness of the charging circuit.

Put clearly, a system with a USB supply voltage on the low end of the specification can slow a battery charge, or even prevent a full battery charge altogether. Optimal charge times of a 4.2V battery will occur when the input voltage of the charge circuit is at or above 4.7V (typ.).

When the input voltage of the circuit falls to 4.6V and the battery nears its fully charged voltage of 4.2V, there is not sufficient voltage across Q1 and D1 to deliver the full charge current. With only 400 mV across Q1 and D1, these components are squeezed so they cannot pass more than 200 mA to the battery. The available charge current has been reduced by 50% as a result of the low input voltage, extending the time it takes to "top off" the battery with constant-voltage charging.

The battery will not even reach the full 4.2V charge when the input voltage falls below 4.5V. With a well designed USB supply using low-impedance connections and cables, however, the voltage at the input to the charging circuit should be high enough that the slow or incomplete charges mentioned here will not occur.

Thus, the circuit presented is able, under most conditions, to utilize the power-supplying capabilities of the USB bus to provide easy and convenient Lithium-Ion battery charging.

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