

# Complete USB Solution Provides PowerPath Control and Input Current Limiting while Charging a Li-Ion Battery

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## Introduction

An increasing number of portable handheld devices are using the Universal Serial Bus (USB) to exchange data with a host computer. Now, more portable device designs are taking advantage of the power-supply provisions of the USB specification—hosts can supply up to 500mA at a nominal 5V—to power the portable device and charge its batteries. The most effective use of the USB-limited 500mA requires a USB-compliant battery charger and well-designed PowerPath™ controls.

## USB Power Specifications

USB power specifications require that a Li-Ion battery charger is able to operate at input voltages as low as 4.75V (ignoring resistive drops in the cable and connectors which further reduce this value to 4.4V), has a low current standby mode, and that it limits the total current drawn from the USB power port to 500mA.

The LTC4056 provides a unique feature allowing it to work well with USB power. The undervoltage charge current limiting function automatically reduces charge current if the input supply voltage drops to approxi-

mately 4.575V. This feature prevents resistive drops from lowering the USB voltage below approximately 4.575V. Typically, if a battery charger is connected to a particularly resistive USB cable, the USB voltage drops below the charger's undervoltage lockout threshold as soon as charge current is turned on. This causes the charger to turn off, the USB supply voltage rebounds, and the cycle repeats. If an LTC4056 is connected to a particularly resistive USB cable, the charge current is reduced to ensure that the input voltage does not drop below the undervoltage lockout threshold. In fact, charge current is adjusted to maintain the USB voltage at or above the undervoltage charge current limit voltage of approximately 4.575V.

The TIMER/SHDN pin of the LTC4056 can be used to reduce its supply current to about 40µA allowing it to meet the USB low current standby mode specification.

The final USB requirement is that the device cannot draw more the 500mA from the USB port. Careful PowerPath design is required to efficiently meet this requirement.

## Basic Solution

Figure 1 shows a basic USB solution. This solution draws system power directly from the battery as it is charging. Since the battery charger is the only system on the device that draws current directly from the USB port, the current limit is set simply by programming the battery charge current. For instance, if the battery charger is programmed to charge at 490mA and the system load is 140mA, then 350mA is effectively used to charge the battery.

This design works within the confines of the USB specification, but it does not maximize efficiency. Here's why. Consider an application with a buck switching regulator that needs to provide a 1.8V supply at 300mA. Powering the buck regulator directly from the battery (at a nominal voltage of 3.85V) would require approximately 140mA, leaving 350mA to charge the battery (assuming the same 490mA charge current as above). On the other hand, powering the buck regulator from the USB supply (nominally 5V) would require just 110mA leaving 380mA to charge the battery, 30mA more. This additional 10% charge current can reduce the battery charge time by about 10%.

## PowerPath Solution

Figure 2 shows an application allowing the peripheral to draw current from the USB supply when it is present, and otherwise, draw current from the battery. The LTC4056 actually regulates the current output from the I<sub>SENSE</sub> pin (rather than the BAT pin current). This feature allows the 500mA maximum USB power port consumption to be easily enforced by tying all system loads to the I<sub>SENSE</sub> pin and programming the charger to

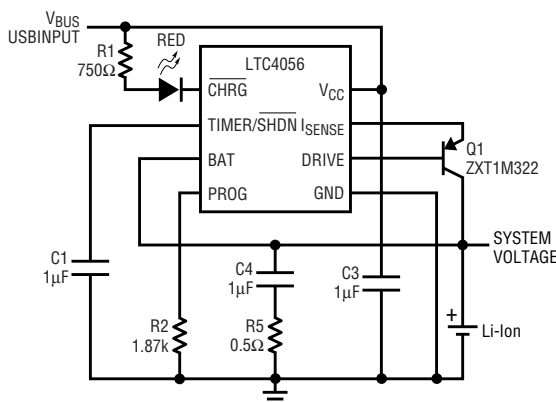
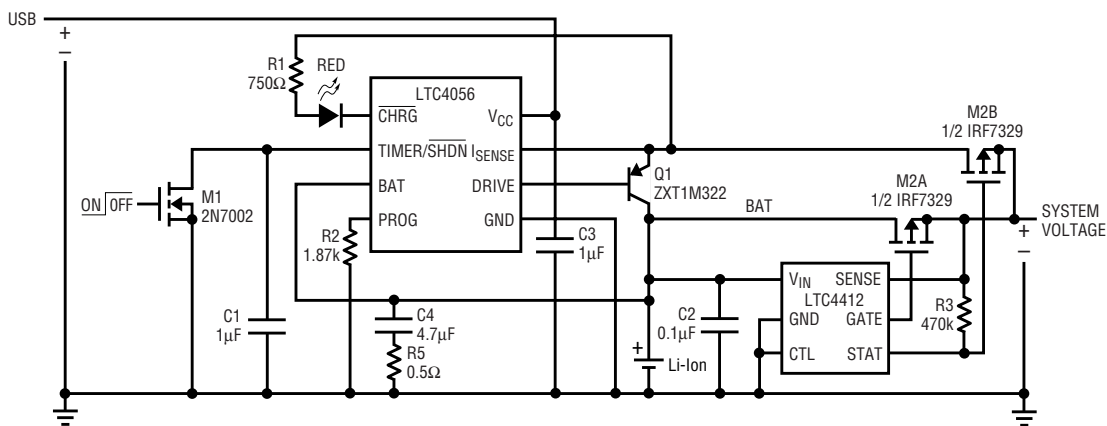


Figure 1. Basic USB charger solution



**Figure 2. Complete USB PowerPath control and battery charger solution**

supply just under 500mA (in Figure 2 the charger is programmed for 490mA). The total impedance between the  $V_{CC}$  pin and  $I_{SENSE}$  pin is typically  $0.2\Omega$ , so the maximum drop is just 100mV (at 500mA) allowing the peripheral device to operate at a voltage significantly higher than a single Li-Ion battery when the USB supply is present.

It is important to keep in mind that the LTC4056 can only control charge current. If the system load is less than 500mA, then the LTC4056 simply reduces the charge current by an amount equal to the system load current. For instance, if the system load is 110mA, then the charge current is reduced from 490mA to 380mA to keep the total USB input current at 490mA, thereby meeting the specification. The 110mA system load, however, is now being provided at approximately 5V rather than the battery voltage. Assuming a nominal battery voltage of 3.85V, the circuit in Figure 2 can provide approximately 23% more power to the system than the circuit in Figure 1 for a given battery charge current.


Of course, if the system load is increased beyond 500mA the LTC4056 will reduce the charge current to zero, and all of the system load will be provided by the USB input. This scenario violates the USB power specification. In order to avoid this situation, it is important to ensure that the system load never exceeds 500mA.

Note that even the  $\overline{\text{CHRG}}$  LED is connected to  $\text{I}_{\text{SENSE}}$ . This is a good example of a peripheral load current. When the LTC4056 is charging a battery, the  $\overline{\text{CHRG}}$  pin is pulled low drawing 4mA to 5mA through R1. This load current reduces the amount of current delivered to the battery by an equal amount.

To ensure that the system voltage is always present (even when USB power is not), the LTC4412 provides automatic switchover of the system load between a battery and the USB input supply. This feature reduces the current drain on the battery to just a few microamps when a USB input is present. Figure 2 shows a dual FET solution to minimize voltage drop between the USB input voltage and

the system voltage (a Schottky diode can also be used in place of M2B). The combination of the LTC4412 and M2A forms an ideal diode from BAT to SYSTEMVOLTAGE. M2B serves as a switch that is ON when the ideal diode is not conducting and OFF otherwise. Therefore, as long as the USB input is present and the voltage on the  $I_{SENSE}$  pin is higher than BAT, M2B is ON and M2A is OFF. As soon as the USB input supply drops below the battery voltage, M2A turns on and acts as an ideal diode.

## Conclusion

The USB specification allows for up to 500mA of current to be delivered from the USB port. Portable devices are increasingly using the USB power provided by a host computer to power the device system bus and to charge batteries. When used in a PowerPath control configuration, the LTC4056 makes the most of this 500mA to efficiently charge the battery, even while the system draws power from the USB. 

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charge transfer reactivates once the junction temperature drops back to approximately 150°C. The LTC3252 can cycle in and out of thermal shutdown, without latch-up or damage, until the fault condition is removed.

The EN1 and EN2 pins are used to individually enable OUT1 and OUT2 respectively. When both EN pins are low the outputs become high impedance and all control circuitry is

disabled leaving only a few nanoamps of supply current. The LTC3252 includes a soft-start feature that limits the inrush currents required to charge the output capacitor when an output is enabled, thereby minimizing input supply transients caused by the power on phase of the IC. The soft-start is implemented whenever an output is brought out of shutdown.

## Conclusion

The LTC3252 is well suited for medium to low power step-down applications requiring multiple low noise outputs in a small footprint. It is an especially good match for single cell Li-Ion and multi-cell NiMH/NiCd battery powered applications and where EMI is a concern. 