

Direct Battery Connection Benefits Portable Designs

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Directly connecting the battery and load in a portable device improves reliability and reduces cost with only a minor increase in charging time.

In any in-circuit rechargeable battery application, such as a mobile phone, Bluetooth headset or GPS receiver, power-management circuit designers have two options. They can either isolate the battery from the load while charging the battery, powering the load directly from the adapter (Figure 1).

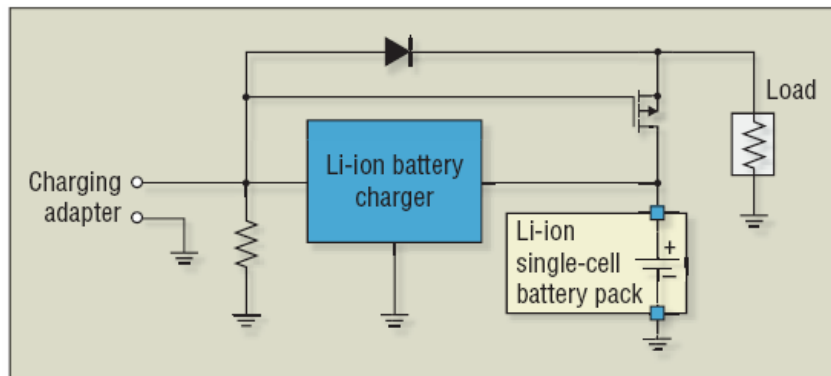


Figure 1. In this circuit, a MOSFET and bypass diode isolate the load from the battery during charging.

Alternatively, they can keep the battery connected to the load, powering the load with the battery while charging the battery from the adapter (Figure 2).

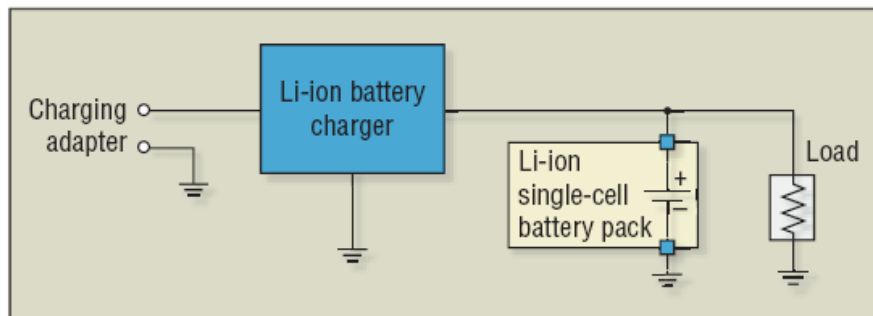


Figure 2. Direct connection of the battery to the load while charging allows the regulator stages of the load to benefit from the protective features of the charger, as well as simplifying the overall power design.

There are many commercial battery charger ICs that implement either option. While both connection topologies have their own sets of tradeoffs, the advantages in cost and performance of the direct permanent connection of the load to the battery is the better choice in many applications.

There are cases in which the battery must be isolated from the load while charging. For example, consider the case in which the system can operate at voltages below the pre-charge threshold voltage of the charger IC. Charger ICs typically supply a small trickle-charge current until the cell voltage exceeds a fast-charge threshold. Once the voltage reaches this threshold, it is considered safe to fast-charge the battery.

If the system requires normal operation at voltages below this threshold, the charger IC may not be capable of supplying adequate current to charge the battery and supply the load. By separating the battery charging system from the load supply, as shown in Fig. 1, the designer can supply necessary currents to the load regardless of the battery-cell voltage with no degradation in performance or reduction in battery-charging time. However, if it is possible to operate all components of the load from a low-battery voltage, there are many advantages to charging a battery and supplying the load from the same output (Fig. 2).

Non-Isolated Charging Benefits

One advantage of the non-isolated or direct battery charging configuration is that it enables simple, compact and low-cost designs. The linear and switching regulators, and other load elements that are powered from the battery, can operate even while the battery is charging. Connecting the load directly to the battery also eliminates the need for low-resistance isolation switches. These switches consume large areas of silicon, increasing the cost of a charger IC or requiring the use of discrete components, such as the MOSFET shown in Fig. 1.

Another benefit of this configuration is that continuity of load power is ensured while connecting or disconnecting the charging adapter, or at the beginning or end of a battery charge cycle. This is because no switching devices are used that could potentially disrupt current flow to the load.

Also, load devices do not need to be tolerant of input transients and overshoots caused by ESD, adapter hot-plug overshoots, adapter noise and charging adapters with incorrect output voltages. The charger isolates the charging adapter from the regulator stages of the load circuitry powered by the battery, providing overvoltage protection and power supply regulation for the latter. Furthermore, the battery acts as a large capacitive source for load transients, such as inrush currents through the input capacitor of regulator, without reliance on the transient response of the adapter to power the load.

Because the voltage drop associated with a battery-isolation switch is eliminated, the effective discharge operating voltage range of the battery is extended. This increases the effective battery life by allowing the system to operate at a lower battery-cell voltage.

One additional benefit of charging the battery and supplying the load from a single output is that charging adapters with lower current limits can be used. If the load is powered directly from the adapter while isolated from the battery, then the adapter must provide both the charging current and the load current. If the adapter current capacity is less than the sum of the charging current and the peak load current, the adapter voltage (and load voltage) will be pulled down to a voltage equal to the sum of the battery voltage and the switch dropout. The load may experience large supply-voltage transients.

If the charger does not have an undervoltage lockout feature with a low-threshold voltage, then the charger will reset. If the battery remains connected directly to the load while charging, the adapter does not need to supply a large current to drive the peak load plus the charging current. Instead, the battery can supply any large peak load current, while the charger continues to supply the average load current and the average charging current. If the average load current is less

than both the charger current limit and adapter current limit, the load will be powered without supply-voltage transients, and the battery will be charged without interruption.

Charge Time Mitigation

Load current will be drawn from the charger output while charging, so the actual battery-charge current during the constant-current portion of the charging process will be the difference of the programmed current limit and the load current. While the impact on charge time is not zero, steps can be taken to minimize the increase in charge time.

Any known static loads can be added to the charge-current limit, and thus will have no impact on actual charging currents. For example, some products will power certain subsystems whenever the adapter power is present, such as a display backlight or a phone receiver in idle mode. These loads are known and relatively constant, so their effects can be eliminated simply by increasing the current limit accordingly. It is quite simple and inexpensive to dynamically adjust the current limit. If a charger's current limit is inversely proportional to a programming resistor (a common programming method), simply switch in a parallel-current programming resistor to ground to dynamically increase the fast charge current.

For example, Bluetooth transmitters and receivers are switched on and off, and the range of load due to the transmitter is easily characterized. The programmed charging current can be boosted with a small signal switch operated by the transmit enable signal. Dynamically adjusting the fast-charge current to compensate for load changes will preserve the benefits of the battery-to-load connection. Small signal switches are less expensive than additional discrete-power devices to isolate the battery from the load and to bypass the charger to power the load.

The dynamic adjustment of charge current can be as complex or simple as you like, but added complexity provides a diminishing return. One or two levels of current switching will be more than sufficient despite the resulting small fluctuations in charge current with load. This is especially true for Li-ion charging, for which increasing fast-charge current (in the constant current [CC] stage of charging) provides a diminishing reduction of total charge time. Therefore, modest reductions in average fast-charge current will have little impact on total charge time.

A higher current in the CC mode may charge the battery to constant voltage (CV) regulation at 4.2 V (the end-of-charge voltage for Li-ion battery) sooner, but then the CV portion of charging will take longer to complete. Considering that the CV phase of charging is typically twice as long as the CC phase, even if the battery is initially deeply discharged, maintaining maximum CC current seems even less important. The impact of all this is that total charge time will not vary with varying fast charge current nearly as much as a simple integration of charge current would suggest. The dynamic adjustment of charger-current limit may preserve the minimum charge-time performance of charging an isolated battery, but the modest benefit of doing so may not be worth the additional cost.

For battery chargers with independent programming of termination current, this setting also can be adjusted according to the known load. However, this is usually not necessary. Most digital handheld device loads are highly variable. During CV charging (at a 4.2-V regulated output), the output current is the sum of the battery charge current and the load current. As the load current varies from a few milliamps to tens or hundreds of milliamps, such as with a wireless device in its idle state, the current that the battery will accept (which varies with its particular state of charge) summed with the minimum instantaneous load current becomes the floor of the output-current waveform.

The total output current must typically be below the termination-current threshold continuously for only a few milliseconds for termination current to be detected. Thus, charge-termination current into the battery can be detected during the idle state of most digital-phone or headset radios in standby mode. The termination current could be programmed to the desired termination charge current plus the known minimum load. But since the minimum load is typically small compared to the termination current, the effect of the minimum load can often be neglected.

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