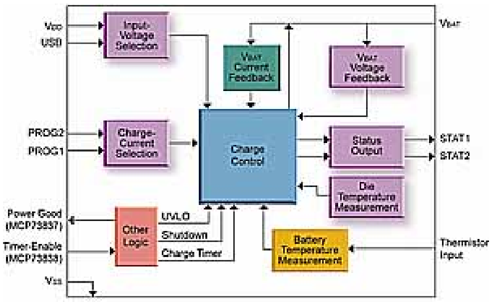
Charger-Circuit Designs Fulfill Consumer Needs

Jon Titus, Senior Technical Editor

Lithium-ion batteries have taken the portable-electronics world by storm. Tony Armstrong, the power-products marketing manager at Linear Technology Corp. recently told me he bought his son a radio-controlled all-terrain vehicle. About half of the RC models and transmitters he examined came with lithium-ion or lithium-polymer batteries. Just two years ago, Armstrong found almost all models relied on nickel-cadmium or nickel-metal-hydride batteries.



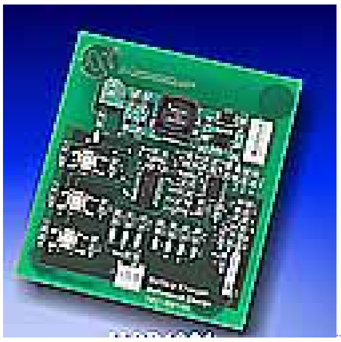
The single-cell, dual-input MCP73837/8 chargers from Microchip Technology can automatically charge from a USB port power source when equipment disconnects from an external DC supply. These ICs include safety features, such as thermal regulation, cell-temperature monitoring and charge-timers.

Now that designers can take advantage of the high energy density of lithium-ion (Li-ion) batteries, they also must figure out how to change them. Fortunately, a number of semiconductor suppliers provide charger ICs and complete reference designs. In some cases, designers can choose a reference design, test it, make minor changes, and go into production.

At times, though, charging circuits for Li-ion batteries require more work. "Designers must know what voltages and currents they have to run a charger," said Trevor Barcelo, a battery-charger design guru at Linear Technology. "Will they connect to a 5-volt adapter, a 12-volt vehicle battery, a USB port, or a 24-volt fork-lift supply?"

"Then, designers must ask how many of those supplies are available simultaneously, do they come into the product on one or several connectors, and how many voltages must the charger deal with?" said Barcelo. "If power comes in on two or more connectors, a product needs a multiple-input charger or a multiplexer."

Designers also should understand when to use a linear or a switch-mode charger circuit. To make that decision, they must know the charge rate their battery requires. "If you charge a Bluetooth headset at, say, a couple of hundred milliamps, then a linear charger will work well," said Masoud Beheshti, product manager for battery-charger ICs at Texas Instruments. "But if you plan to charge at high current--six to seven amps--then a switch-mode charger becomes the only option. A linear charger would waste too much energy." Keep in mind the number of cells you must charge, added Beheshti. "The more cells, the higher the voltage and current, so you need the efficiency of a switch-mode charger."

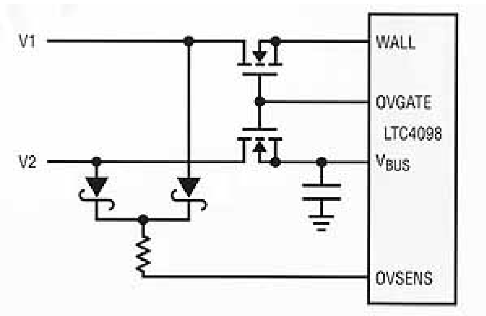


Typically, power comes into a portable product in two ways; from the battery itself and from at least one external power supply or AC adapter. How the power-control circuits handle this "power path" can greatly affect how well a product operates. You can have two general types of power paths. First, power from an external adapter goes through the charger into the battery and then the battery powers your product. Second, you could have separate input-power paths for the product and the battery. Thus the external adapter powers your product and charges the battery independently. This latter method lets you charge the battery quickly because the product does not draw any power from the battery. "And this method removes some of the startup issues you face in a dead battery condition," added TI's Beheshti.

Although the adapter-charger-battery path can simplify a charger circuit, it can lead to customer dissatisfaction with a portable product. "Say you want to listen to music on an MP3 player, but you have a 'dead' Li-ion battery," said Barcelo at Linear Technology. "If you must charge the battery before you can listen to music, you get annoyed. So, why not design a circuit to charge the battery and power the MP3 player?"

In addition, the adapter-charger-battery power path always puts a load on the battery, noted Terry Cleveland a technical staff engineer at Microchip Technology. "So, the battery may never get charged to its maximum capacity. Even if you plan to charge the battery independently, designers and users must understand lithium-ion batteries do not provide the fast-charge capability of NiCd or NiMH batteries."

External power adapters present their own challenge. Consumers can accidentally connect the wrong power adapter to a device, so how does a charger circuit tell one from another? Bob Lyle, staff applications engineer at Intersil said, "Techniques range from simple protection circuits to more complex methods. In any case, engineers must think about many charging situations and then design and test for them. This type of system integration problem proves difficult to predict." Even if a proprietary connector ensures charging only with a specific adapter, that adapter could fail and damage the charging circuits. The Intersil ISL6256 and ISL6256A charger IC for laptop batteries will automatically switch to an AC adapter when one is available and then switch to the battery when a user removes the AC adapter. Many charger circuits work this way.



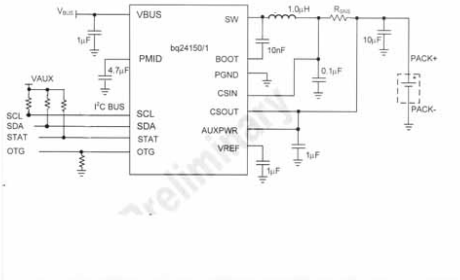
To prevent damage, the Linear Technology LTC4098 switching power manager and Li-ion battery charger can detect an overvoltage and turn off the supply-side FETs. The IC can use two external FETs to protect against a reverse-polarity connection from the supply.

To protect against overvoltages, the Linear Technology LTC4098 power manager/charger IC lets designers put an N-FET in series with the external power input to protect the charger from damage. Users can select an N-FET appropriate for the maximum overvoltage they need to protect against. Of course, as the protection voltage increases, so does the cost of the N-FET.
"To improve efficiency, the LTC4098 can control the output of one of our high-voltage buck regulators so it 'servos' 300 mV above the battery voltage," said LTC's Barcelo. "That small voltage difference lets us power the system from the buck regulator and simultaneously charge the battery through a linear battery charger." So, if you charge a battery at 3.5 volts and one amp through a linear circuit from a 3.8-volt supply--a difference of 300 millivolts--the linear charger dissipates only 300 milliwatts. But if you had to use a standard five-volt supply, the linear charger would dissipate 1.5 watts, a five-fold increase in power loss and heat.

"Ordinarily, linear chargers are fairly inefficient, but the capability to place the buck regulator's output slightly above the battery voltage lets designers create a more efficient system," explained Barcelo.

Is an MCU for You?

Some charging circuits can benefit from the use of a microcontroller (MCU) to set charge parameters. Microchip Technology, for example, provides MCUs and battery-charge algorithms that engineers can modify or use as-is. When combined with a PIC MCU, Microchip's MCP1631 pulse-width modulator controls a power system's duty cycle and regulates output voltage or current. The MCU can adjust output voltage or current, switching frequency, and duty cycle and still have enough processing capability to control other parts of the charger or power circuits. In this type of circuit, the MCU may operate independent of, or together with, a product's "larger" MCU or microprocessor.



This circuit diagram shows the Texas Instruments bq24150/1 IC used to charge a single Li-ion cell under control of an external MCU that communicated with the charger on an I2C bus. This circuit requires only a few common passive components.

Masoud Beheshti of TI explained that by pairing an MCU and charger IC designers can use a simpler charger IC and let the MCU run the control algorithms. "TI offers devices such as the bq24100 for one-, two-, three-, and four-cell battery packs optimized for control from an MCU."

Developers also may need some intelligence in circuits that balance the charge current across two or more cells. Slight electrical differences between cells cause them to charge at different rates. Thus, during charging, a basic circuit might simply measure the voltage across all cells and

The evaluation board for Intersil's ISL6256 IC offers developers easy access to many test points and connectors. This IC uses a synchronous-buck technology and it will charge Li-ion or Li-polymer batteries.

decide to end the charge cycle prematurely, which results in partially charged cells in the pack. The charge-balancing technique bypasses cells at or near full capacity and distributes the current to cells that need it. (See "For further reading.")

Several engineers explained the tradeoff between battery energy and life; another aspect designers should keep in mind. Charging a Li-ion cell to a specified 4.2 volts maximizes the "play time" for portable devices such as MP3 players and games, but over time, the cell will degrade. In expensive consumer products such as PDAs and digital cameras, buyers may choose to trade a slightly shorter play time for the longer battery life that comes from charging a Li-ion cell to only 4.1 volts. Several companies now manufacture ICs specifically for 4.1-volt charger circuits.
Changes in battery chemistries will increase the need for intelligent battery chargers. According to Scott Dearborn, a technical staff engineer at Microchip Technology, lithium-ion battery researchers have started to replace lithium cobalt dioxide with equivalent nickel-, manganese- and aluminum-based compounds. Future consumer products will need the capability to determine the type of lithium-ion battery in use and adjust charging parameters accordingly. The new chemistries will deliver about 4.35 volts.

Sidebar - A PCB Layout Tip [1]

Sidebar - How Does Li-ion Cell Balancing Work? [2]

For Further Reading

Wen, Simon, "Fast Cell Balancing Using External MOSFET," Application Report SLUA420. Texas Instruments, May 2007.
http://focus.ti.com/lit/an/slua420/slua420.pdf [3]

Chu, Brian, "Design A Load Sharing System Power Path Management with Microchip's Stand-Alone Li-Ion Battery Charger," AN1149. Microchip Technology. http://www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=1824&appnote=en533380 [4]

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