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Simple Battery Charger ICs for Any Chemistry

By **Steve Knoth**

Background

It is common for many battery-powered devices to require a wide variety of charging sources, battery chemistries, voltages, and currents. For example, industrial, high end, feature-rich consumer, medical, and automotive battery charger circuits demand higher voltages and currents as newer large-battery packs are emerging for all types of battery chemistries. Furthermore, solar panels with wide-ranging power levels are being used to power a variety of innovative systems containing rechargeable sealed lead acid (SLA) and lithium-based batteries. Examples include crosswalk marker lights, portable speaker systems, trash compactors, and even marine buoy lights. Moreover, some lead acid (LA) batteries found in solar applications are deep cycle batteries capable of surviving prolonged, repeated charge cycles, in addition to deep discharges. A good example of this is in deep sea marine buoys, where a 10-year deployment life is a prerequisite. Another example is off-grid (that is, disconnected from the electric utility company) renewable energy systems such as solar or wind power generation, where system up-time is paramount due to proximity access difficulties.

Even in nonsolar applications, recent market trends imply a renewed interest in high capacity SLA battery cells. Automotive, or starting, SLA cells are inexpensive from a cost/power output perspective and can deliver high pulse currents for short durations, making them an excellent choice for automotive and other vehicle starter applications. Embedded automotive applications have input voltages >30 V, with some even higher. Consider a GPS location system used as an antitheft deterrent; a linear charger with the typical 12 V input stepping down to 2-in-series Li-Ion battery (7.4 V typical) and needing protection to much higher voltages, could be valuable for this application. Deep cycle LA batteries are another technology popular in industrial applications. They have thicker plates than automotive batteries and are designed to be discharged to as low as 20% of their total capacity. They are normally used where power is required over a longer time constant such as fork lifts and golf carts. Nevertheless, like their Li-Ion counterpart, LA batteries are sensitive to overcharging, so careful treatment during the charging cycle is very important.

Current integrated circuit (IC)-based solutions cover just a fraction of the many possible combinations of input voltage, charge voltage, and charge current. A cumbersome combination of ICs and discrete components has routinely been used to cover most of the remaining, more difficult combinations and topologies. That wasn't until, in 2011, when Analog Devices addressed and simplified this market application space with its popular 2-chip charging solution consisting of the LTC4000 battery charging controller IC mated with a compatible, externally compensated dc-to-dc converter.

Switching vs. Linear Chargers

Traditional linear topology battery charger ICs were often valued for their compact footprints, simplicity, and low cost. However, drawbacks of these linear chargers include a limited input and battery voltage range, higher relative current consumption, excessive power dissipation, limited charge termination algorithms, and lower relative efficiency (efficiency ~ [VOUT/VIN] × 100%). On the other hand, switch-mode battery chargers are also popular choices due to their flexible topology, multichemistry charging, high charging efficiencies (which minimize heat to enable fast charge times), and wide operating voltage ranges. Nevertheless, some of the drawbacks of switching chargers include relatively high cost, more complicated inductor-based designs, potential noise generation, and larger footprint solutions. Modern LA, wireless power, energy harvesting, solar charging, remote sensor, and embedded automotive applications have been routinely powered by high voltage linear battery chargers for the reasons stated above. However, an opportunity exists for a more modern switch-mode charger that negates the associated drawbacks.

An Uncomplicated Buck Battery Charger

Some of the tougher challenges a designer faces at the outset of a charging solution are the wide range of input sources combined with a wide range of possible batteries, the high capacity of the batteries needing to be charged, and a high input voltage.

Input sources are as wide as they are variable, but some of the more complicated ones that deal with battery charging systems are: high powered wall adapters with voltages spanning from 5 V to 19 V and beyond, rectified 24 V ac systems, high impedance solar panels, car, and heavy truck/Humvee batteries. Therefore, it follows that the combination of battery chemistries possible in these systems—lithium-based (Li-Ion, Li-Polymer, lithium-iron phosphate (LiFePO4)) and LA-based—increases the permutations even more, thus making the design even more daunting.

Due to IC design complexity, existing battery charging ICs are primarily limited to step-down (or buck) or the more complex SEPIC topologies. Add solar charging capability to this mix and you open a variety of other complexities. Finally, some existing solutions charge multiple battery chemistries, some with onboard termination. However, up until now, no single IC charger has provided all of the necessary performance features to solve these issues.

New, Feature-Rich Compact Chargers

A buck IC charging solution that solves the problems discussed above would need to possess most of the following attributes:

- Wide input voltage range
- Wide output voltage range to address multiple battery stacks
- Flexibility—ability to charge multiple battery chemistries
- Simple and autonomous operation with onboard charge termination algorithms (no microprocessor needed)
- High charge current for fast charging, large, high capacity cells
- Solar charging capability
- Advanced packaging for improved thermal performance and space efficiency

When ADI developed the popular LTC4000 battery charging controller IC (which works in conjunction with an externally compensated dc-to-dc converter to form a powerful and flexible 2-chip battery charging solution) a few years ago, it greatly simplified the existing solution, which was quite convoluted and cumbersome. To enable PowerPath™ control, step-up/down functionality, and input current limiting, solutions consisted of a buck-boost dc-to-dc switching regulator or a buck-switching regulator charger controller paired with a front-end boost controller, and a microprocessor, plus several ICs and discrete components. Key drawbacks included limited operating voltage range, no solar panel input capability, inability to charge all battery chemistries, and no onboard charge termination. Fast forward to the present and now some simpler, and much more compact, monolithic solutions are available to solve these problems. The LTC4162 and LTC4015 buck battery chargers from Analog Devices both provide single-chip step-down charging solutions, with varying charge current levels and a full feature set.

The LTC4162 Battery Charger

The LTC4162 is a highly integrated, high voltage multichemistry synchronous monolithic step-down battery charger and PowerPath manager with onboard telemetry functions and optional maximum power point tracking (MPPT). It efficiently transfers power from a variety of input sources, such as wall adapters, backplanes, and solar panels, to charge a Li-Ion/polymer, LiFePO4, or LA battery stack while still providing power to the system load up to 35 V. The device provides advanced system monitoring and PowerPath management, plus battery health monitoring. While a host microcontroller is required to access the most advanced features of the LTC4162, the use of the I²C port is optional. The main charging features of the product can be adjusted using pin-strap configurations and programming resistors. The device offers precision ±5% charge current regulation up to 3.2 A, ±0.75% charge voltage regulation, and operates over a 4.5 V to 35 V input voltage range. Applications include portable medical instruments, USB power delivery (USB-C) devices, military equipment, industrial handhelds, and ruggedized notebooks/tablet computers.

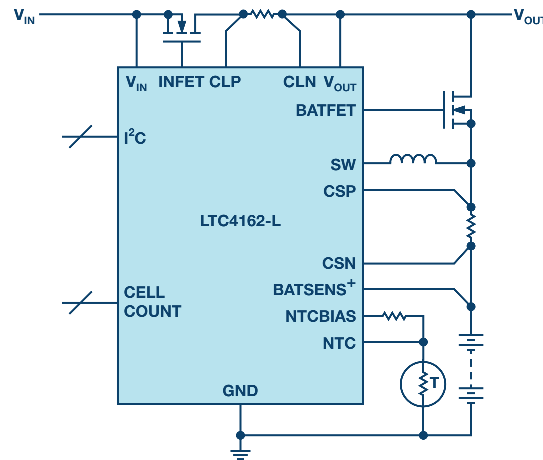


Figure 1. Typical application circuit for the LTC4162-L.

The LTC4162 (see Figure 1) contains an accurate 16-bit analog-to-digital converter (ADC) that continuously monitors numerous system parameters on command, including input voltage, input current, battery voltage, battery current, output voltage, battery temperature, die temperature, and battery series resistance (BSR). All system parameters can be monitored via a two-wire I²C interface, while programmable and maskable alerts ensure that only the information of interest causes an interrupt. The device's active maximum power point tracking algorithm globally sweeps an input undervoltage control loop and selects an operating point to maximize power extraction from solar panels and other resistive sources. Further, its built-in PowerPath topology decouples the output voltage from the battery, thereby allowing a portable product to start up instantly when a charging source is applied under very low battery voltage conditions. The LTC4162's onboard charging profiles are optimized for a variety of battery chemistries including Li-Ion/polymer, LiFePO4, and LA. Both charge voltage and charge current can be automatically adjusted based on battery temperature to comply with JEITA guidelines or be customized. For LA batteries, a continuous temperature curve automatically adjusts the battery voltage based on the ambient temperature. For all chemistries, an optional die junction temperature regulation system can be engaged, preventing excess heating in space constrained or thermally challenged applications. See Figure 2 for Li-Ion charging efficiency performance.

Finally, the LTC4162 is housed in a 28-lead, 4 mm × 5 mm QFN package with an exposed metal pad for excellent thermal performance. E- and I-grade devices are guaranteed for operation from –40°C to +125°C.

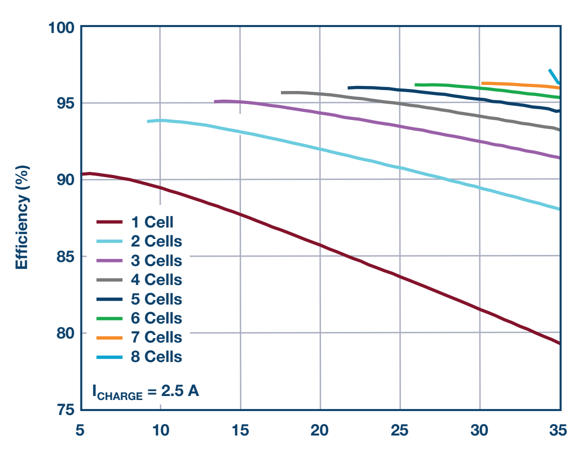


Figure 2. Li-Ion charging efficiency vs. input voltage by cell count.

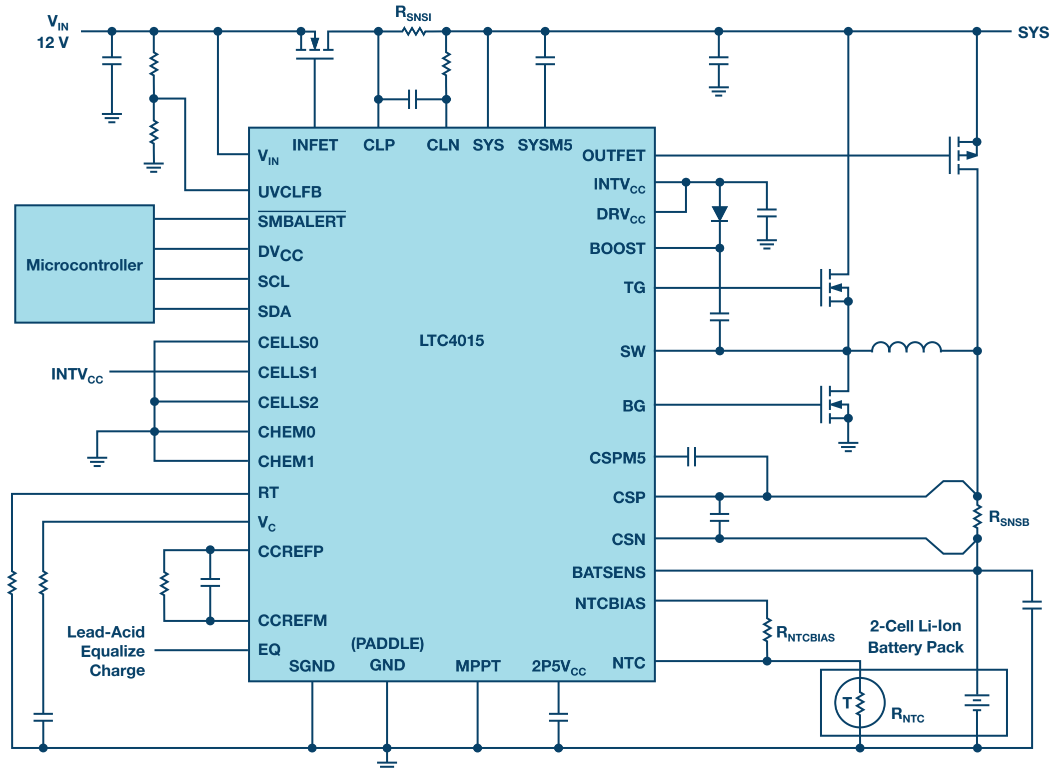


Figure 3. 12 V_{IN} to 2-cell Li-Ion 8 A buck battery charger circuit.

What if Higher Current Is Needed?

The LTC4015 is also a highly integrated, high voltage, multichemistry, synchronous step-down battery charger with onboard telemetry functions. However, it features a controller architecture with offboard power FETs for higher charge current capability (up to 20 A or more depending on external components chosen). The device efficiently supplies power from an input source (wall adapter, solar panel, etc.), to a Li-Ion/polymer, LiFePO4, or LA battery. It provides advanced system monitoring and management functionality, including battery coulomb counting and health monitoring. While a host microcontroller is required to access the most advanced features of the LTC4015, the use of its I²C port is optional. The main charging features of the product can be adjusted using pin-strap configurations and programming resistors.

The LTC4015 offers precision ±2% charge current regulation up to 20 A, ±1.25% charge voltage regulation and operation over a 4.5 V to 35 V input voltage range. Applications include portable medical instruments, military equipment, battery backup applications, industrial handhelds, industrial lighting, ruggedized notebooks/tablet computers, and remote powered communication and telemetry systems.

The LTC4015 also contains an accurate 14-bit analog-to-digital converter (ADC), as well as a high precision coulomb counter. The ADC continuously monitors numerous system parameters, including input voltage, input current, battery voltage, battery current, and reports battery temperature and battery series resistance (BSR) on command. By monitoring these parameters, the LTC4015 can report on the state of health of the battery, as well as its state of charge. All system parameters can be monitored via a two-wire I²C interface, while programmable and maskable alerts ensure that only the information of interest causes an interruption. The LTC4015's onboard charging profiles are optimized for each of a variety of battery chemistries including Li-Ion/polymer, LiFePO4, and LA. Configuration pins allow the user to select between several predefined charge algorithms for each battery chemistry, as well as several algorithms whose parameters can be adjusted via I²C. Both charge voltage and charge current can be automatically adjusted based on battery temperature to comply with JEITA guidelines, or even custom settings. See Figure 4 for LA charging efficiency performance. The LTC4015 is housed in a 5 mm × 7 mm QFN package with an exposed metal pad for excellent thermal performance.

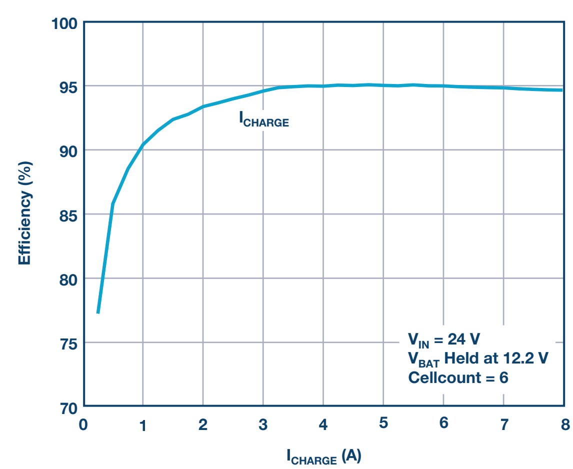


Figure 4. Lead acid charging efficiency with the LTC4015.

Space Savings, Flexibility, and Higher Power Levels

At equal power levels (for example, 3 A), because it is a monolithic device with integrated power MOSFETs, the LTC4162 can save up to 50% of the PCB area compared to the LTC4015. Since their feature sets are similar, the LTC4015 should be used when output currents are >3.2 A up to 20 A or more. None of the industry competing IC battery charger solutions offer the same high level of integration, nor can they generate the same power levels. Those that approach the charge current (2 A to 3 A) are limited to only a single battery chemistry (Li-Ion) or are limited in battery charge voltage (13 V maximum), and therefore do not offer the power levels nor the flexibility of the LTC4162 or LTC4015. Furthermore, when you consider the number of external components required for the nearest competing monolithic battery charger solution, the LTC4162 offers up to 40% savings in PCB area footprint, making it an even more enticing choice for designs.

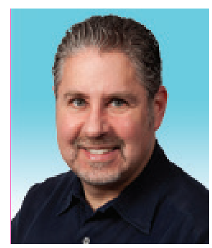
Solar Charging

There are many ways to operate a solar panel at its maximum power point (MPP). One of the simplest methods is to connect a battery to the solar panel through a diode. This technique relies on matching the maximum output voltage of the panel to the relatively narrow voltage range of the battery. When available power levels are very low (approximately less than a few tens of milliwatts), this may be the best approach. However, power levels are not always low. Therefore, the LTC4162 and LTC4015 utilize MPPT, a technique that finds the maximum power voltage (MPV) of a solar panel as the amount of incident light changes. This voltage can change drastically from 12 V to 18 V as the panel current changes over 2 or more decades of dynamic range. The MPPT circuit algorithm finds and tracks the panel voltage value that delivers the maximum charge current to the battery. The MPPT function not only continuously tracks the maximum power point, but it is also able to select the correct maximum on the power curve to increase power harvested from the panel during partial shade conditions when multiple peaks occur on the power curve. During periods of low light, a low power mode allows the charger to deliver a small charge current even if there is not enough light for the MPPT function to operate.

Conclusion

Analog Devices' newest powerful and full-featured battery charging and PowerPath manager ICs, the LTC4162 and LTC4015, simplify a very difficult high voltage and high current charging system. These devices efficiently manage power distribution between input sources, such as wall adapters, backplanes, solar panels, etc., and the charging of various battery chemistries, including Li-Ion/polymer, LiFePO4, and SLA. Their simple solution and compact footprints enable them to achieve high performance in leading-edge applications where only more complicated, older technology switching regulator-based topologies such as SEPIC were once the only option. This greatly simplifies the designer's task when it comes to medium-to-high power battery charger circuits.

Steve Knoth [steve.knoth@analog.com] is a senior product marketing engineer in Analog Devices' Power by Linear™ Group. He is responsible for all power management integrated circuit (PMIC) products, low dropout (LDO) regulators, battery chargers, charge pumps, charge pump-based LED drivers, supercapacitor chargers, low voltage monolithic switching regulators, and ideal diode devices. Prior to joining Analog Devices (formerly Linear Technology) in 2004, Steve held various marketing and product engineering positions since 1990 at Micro Power Systems, Analog Devices, and Micrel Semiconductor. He earned his bachelor's degree in electrical engineering in 1988 and a master's degree in physics in 1995, both from San Jose State University. Steve also received an M.B.A. in technology management from the University of Phoenix in 2000. In addition to enjoying time with his kids, Steve can be found tinkering with pinball and arcade games or muscle cars, and buying, selling, and collecting vintage toys, movie, sports, and automotive memorabilia.



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