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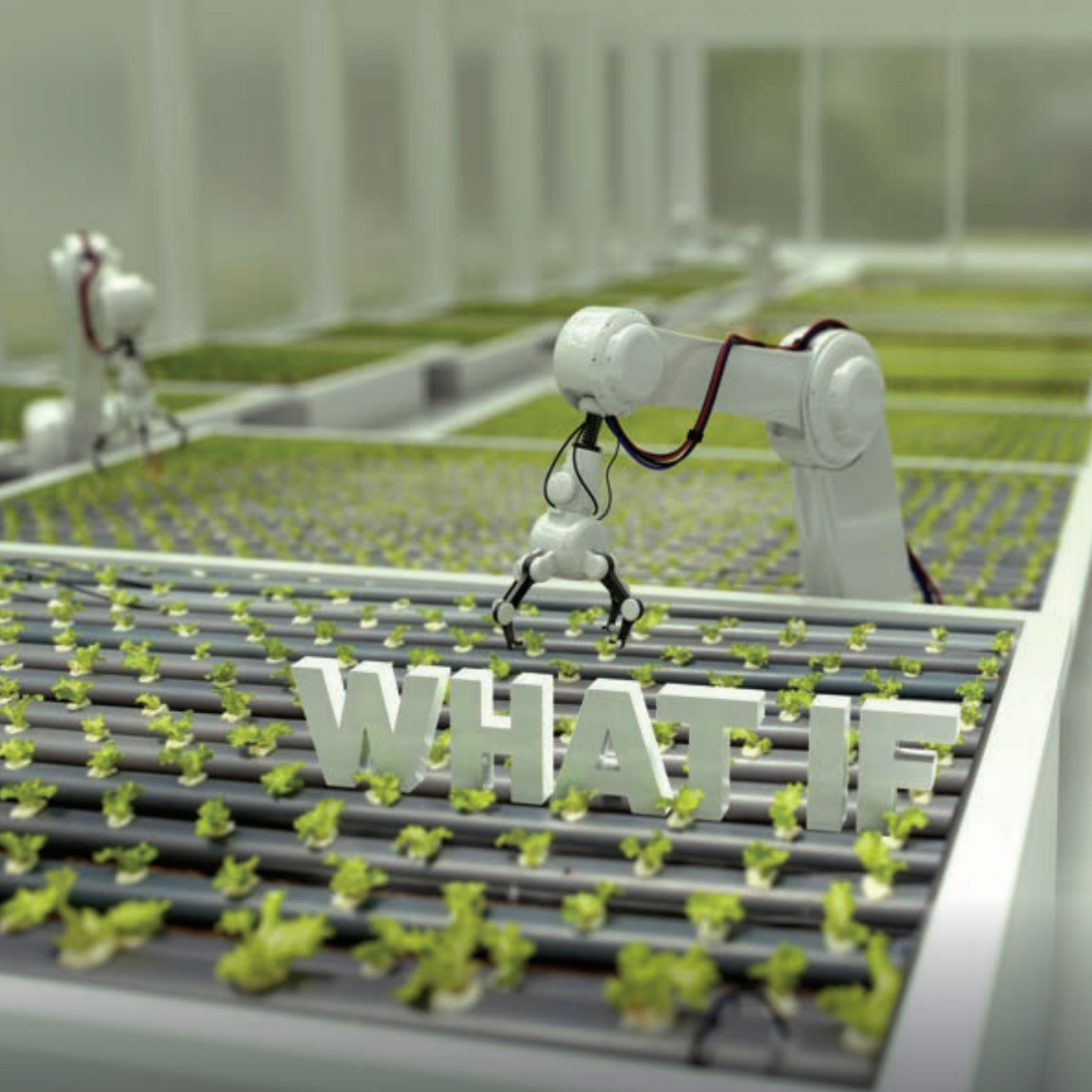
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Seven Ways to Make Your Battery-Powered Design a Success

Battery-powered solutions include a vast array of applications such as collaborative robots, condition-based monitors, field instruments, industrial sensors, backup power supplies, healthcare devices, and more. Designing for different battery chemistry, lifetime, and size constraints requires a system-level strategy to achieve the best power management solution. Start your battery power management solution with Analog Devices' comprehensive portfolio:

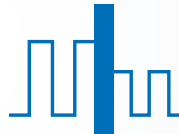
- 1 Input Protection (Ideal Diode Controller)
- 2 Charging (Buck-Boost Charger, Linear/Switching/Supercap Charger)
- 3 Single-Cell Battery (Boost and Buck Controller/DC-to-DC/ μ Module Device)
- 4 Multicell Battery (Boost and Buck Controller/DC-to-DC/ μ Module Device)
- 5 System Input 24 V Battery ($48 V_{IN}$ to $24 V_{IN}$ Controller/DC-to-DC/ μ Module Device, Buck and Boost Controller/DC-to-DC/ μ Module Device)
- 6 Intermediate Voltage ($48 V_{IN}$ to $24 V_{IN}$ Controller/DC-to-DC/ μ Module Device, Multi-Output Buck Regulators, Sequencers and Supervisors)
- 7 Low Noise and Control (Low Voltage DC-to-DC/LDO, Low Noise DC-to-DC, Supervisor)



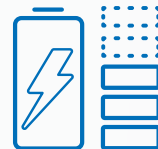
System-Level Power Strategy



Efficient Battery Usage



Optimized Power Regulation



Superior Battery-Powered Solution

Simple Battery Charger ICs for Any Chemistry

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 $\sim [V_{OUT}/V_{IN}] \times 100\%$). 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.

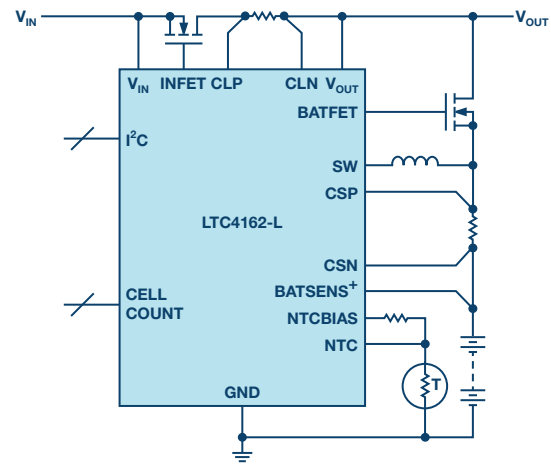


Figure 1. Typical application circuit for the LTC4162-L.

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.

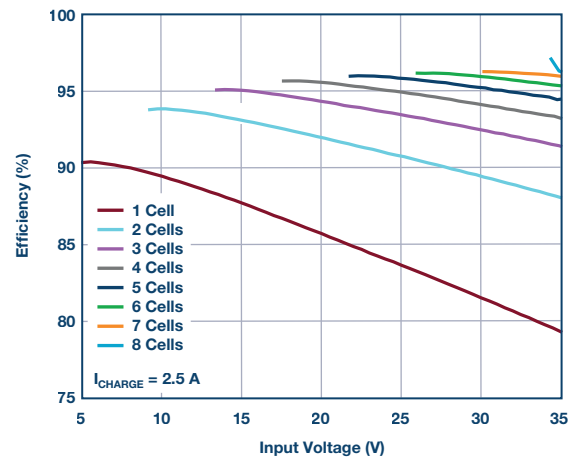


Figure 2. Li-Ion charging efficiency vs. input voltage by cell count.

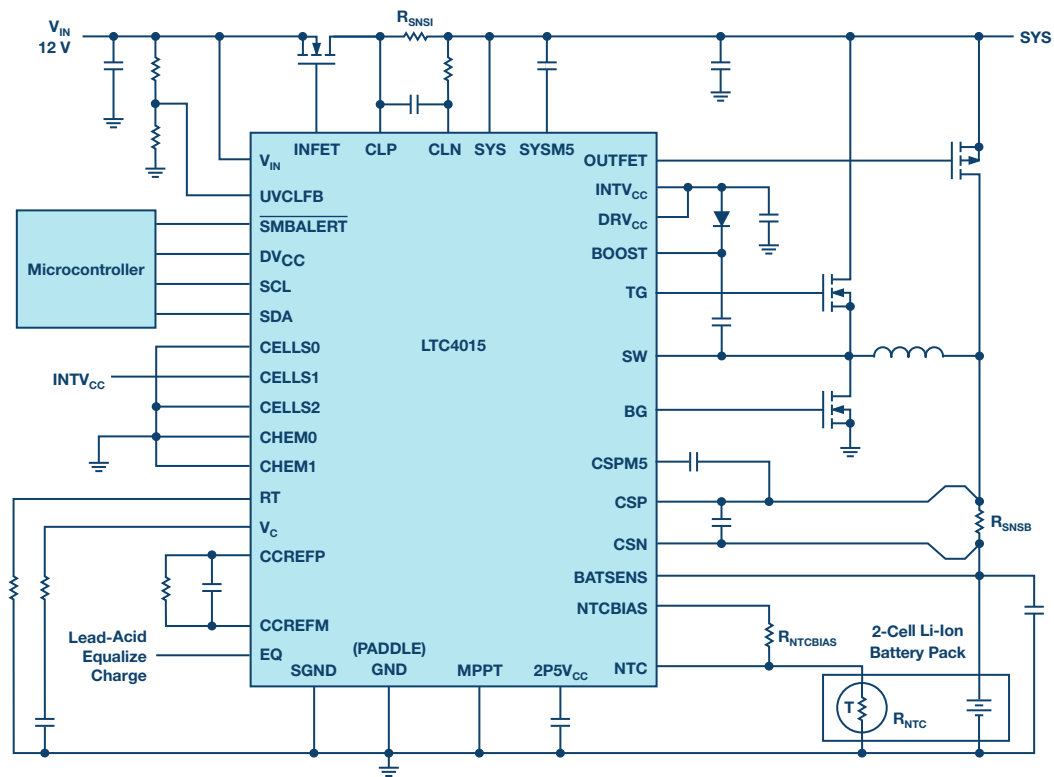


Figure 3. 12 VIN to 2-cell Li-Ion 8 A buck battery charger circuit.

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.

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.

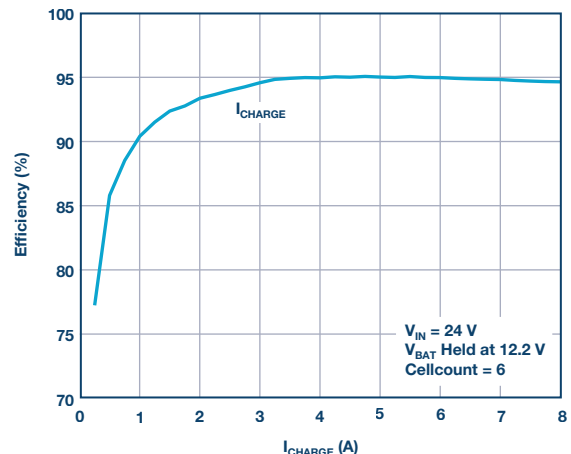


Figure 4. Lead acid charging efficiency with the LTC4015.

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.

About the Author

Steve Knoth 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.

RELATED CONTENT

PRODUCTS

LTC4015

Multichemistry Buck Battery Charger Controller with Digital Telemetry System

LTC4162-F

35 V/3.2 A Multicell LiFePO₄ Step-Down Battery Charger with PowerPath and I²C Telemetry

LTC4162-L

35 V/3.2 A Multicell Lithium-Ion Step-Down Battery Charger with PowerPath™ and I²C Telemetry

LTC4162-S

35 V/3.2 A Lead-Acid Step-Down Battery Charger with PowerPath and I²C Telemetry

PRODUCT CATEGORY

[Power Management
Battery Charger IC](#)

What Are the Best Applications for IoT in the New World of IC Power Management?

With the growing use of IoT (Internet of Things) devices in industrial equipment, home automation, and medical applications, there is increasing pressure to optimize the power management portion of these devices—either through smaller form factor, better efficiency, improved current consumption, or faster charging times. This article explores IoT battery technology, describes some of the problems that designers face with power sourcing, and provides solutions from Analog Devices.

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Honey, Where Is My Power Cord?

Thong Huynh, Application Engineering Director

Introduction

A more common modern-day question would probably be “Honey, where is my battery charger?” The reduction in cost and improvement in battery performance, especially Li-Ion based, at the turn of the century has fueled a steady growth of battery-powered energy storage and portable equipment. Also, supercapacitors (aka ultracapacitors) are increasingly finding usage in a variety of applications due to their unique characteristics. The lead-acid battery, a 150-year-old technology, is still popularly used in cars, wheelchairs, scooters, golf carts, and uninterruptible power supply (UPS) systems. These energy storage devices must be recharged once their energy has been depleted. The worldwide charging IC shipment was 1.16 billion units in 2019 and is expected to grow to 1.72 billion units in 2024 with a healthy 8.6% annual growth rate. The respective revenue was \$518.1 billion and \$735.4 billion with a 7.3% CAGR. Figure 1 shows this trend, according to OMDIA’s “Power IC Market Tracker - 2019.”

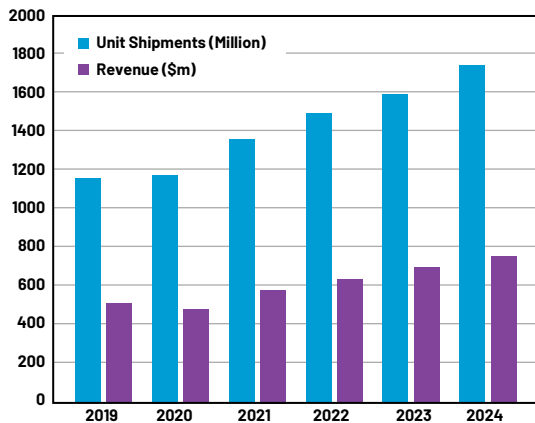


Figure 1. The world market for charging ICs.

The demand for more power, along with longer range or run time, dictates an increase in the voltages used in energy storage devices. For example, Li-Ion battery stacks have gone from one or two cells to multiple (up to 12) cells used in robots, drones, power tools, and a host of other things. A 12-cell Li-Ion battery stack provides 50.4 V maximum voltage. A 12-cell battery would last 12 times longer than a 1-cell battery at the same current rating. Alternatively, 12 batteries can be connected in parallel for higher power, but this method would increase the current 12x. Higher current causes more conduction losses, so paralleling batteries is not preferred.

Industrial systems such as emergency lighting with battery backup, UPS backup power, and HVAC use a 24 VDC power source—that is, a 24 V battery is used to back up these systems. The 24 VDC power source, however, can rise to 60 V peak voltage during transient conditions, according to IEC 61131-2 and IEC 60664-1 standards.

In either situation, the equipment requires charger solutions that can accommodate higher battery voltage and withstand higher input voltage during transient events.

Charger Basics

There are many charger topologies. The linear charger drops the voltage difference between the power source and the battery through a power switch. This type of charger is the least efficient, since it dissipates a lot of power across the power switch when the voltage difference between the power source and the battery is large. The boost charger boosts the voltage from the power source to the battery voltage. This topology requires the power source voltage to be lower than the battery voltage. The buck charger steps down the voltage from the power source and requires the power source voltage to be higher than the battery voltage. The buck-boost charger can charge the battery with a power source voltage that is either higher or lower voltage than the battery voltage. This topology requires four power switches (compared to two for the buck) and generally is not as efficient.

The synchronous rectification buck charger is the most efficient and is the focus of this article. Figure 2 shows a generic synchronous rectification buck charger circuit. Most buck chargers today operate at a relatively low voltage. Many are rated at only 28 V input with some at 40 V. Allowing ±10% input voltage regulation and a 2 V drop across the buck charger, a 28 V-rated charger can only practically charge a 5S Li-Ion battery stack (maximum). We will examine a new family of 60 V input charger ICs that allow higher voltage charging—up to 52 V battery voltage (or a 12-cell Li-Ion stack)—and that can withstand a 65 V input voltage transient.

The standby current on a charger should be low to save energy. Energy Star® assigns five stars to mobile phone chargers and other small chargers that draw 30 mW or less on standby. One star goes to chargers with 300 mW or more, and there are other ratings for everything else in between. Energy Star aims to reduce current consumption of personal chargers that are mostly left plugged in when not in use. There are over 1 billion such chargers connected to the grid globally at any given time.

Even though the lead-acid battery, Li-Ion-based battery, and supercapacitor are all energy storage devices, they have very distinct charging/discharging characteristics. We will examine these characteristics and discuss a charging solution for each of them. A good battery charger provides battery performance and durability, especially when charging under adverse conditions.

Lead-Acid Battery Charger

Lead-acid is the oldest rechargeable battery in existence and was invented by the French physician Gaston Planté in 1859.2 One hundred and fifty years later, it is still popularly used in cars, wheelchairs, scooters, electric bikes, golf carts, and UPS systems.

The lead-acid battery must be charged slowly. Typical charge time is 8 to 16 hours. The battery must always be stored in a charged state, and a periodic fully saturated charge is essential to prevent sulfation. It is common practice to charge lead-acid batteries to 70% in about 8 hours, and another 8 hours to do the all-important absorption charge. A partial charge is fine provided the lead-acid occasionally receives a fully saturated charge to prevent sulfation. Leaving the battery on float charge for a prolonged time does not cause damage.

Finding the ideal charge voltage limit is critical. A high voltage (above 2.45 V/cell) produces good battery performance but shortens service life due to grid corrosion on the positive plate. A low voltage limit is subject to sulfation on the negative plate. Temperature also affects the cell voltage with a typical $-5 \text{ mV}/^\circ\text{C}$ (0.028 V per cell for every 10°F). A good charger must compensate for this temperature coefficient to avoid overcharge of the battery when hot or undercharge when cold.

As an example, the **MAX17702** (see Figure 3) is a complete lead-acid battery charger controller designed to operate over an input voltage range of 4.5 V to 60 V. The device offers a high efficiency (over 97%), high voltage, synchronous buck solution to charge 12 V/24 V/48 V lead-acid battery stacks. Figures 4a and 4b show its charging cycle and charging efficiency.

Li-Ion Battery Charger

Li-Ion is the universally accepted battery for portable applications, heavy industries, electric powertrains, and satellites due to its light weight and high energy density.

Li-Ion is a low maintenance battery. The battery has no memory and does not need exercising (deliberate full discharge) to keep it in good shape. But it needs protection circuits, both built-in inside the battery pack as well as in the charger to prevent short circuit, overcharge, thermal runaway, and overdischarge. If a Li-Ion battery has dwelled below 1.5 V/cell for a week or longer, dendrites may have developed that could compromise safety.

To prevent overdischarge, the built-in battery protection circuit puts the battery into a sleep condition. This happens when storing the battery in a discharged state in which self-discharge brings the voltage to the cutoff point. A regular charger treats such a battery as unserviceable, and the pack is often discarded. An advanced Li-Ion charger includes a wake-up feature, or "precharge," to allow recharging if a Li-Ion battery has fallen asleep due to overdischarge. In precharge mode, the charger applies a small charge current to safely raise the voltage to between 2.2 V/cell and 2.9 V/cell to activate the protection circuit, at which point a normal charge commences.

The lead-acid battery has low energy densities, making it unsuitable for portable devices. This is where a lithium-based battery comes into play.

During normal charge, the Li-Ion charger operates on constant current constant voltage (CCCV). The charge current is constant, and the voltage is capped when it reaches a set limit. Reaching the voltage limit, the battery saturates; the current drops until the battery can no longer accept further charge and charging terminates. Each battery has its own low current threshold.

Li-Ion batteries should always stay cool on charge. Li-Ion cannot absorb overcharge. Thus, it is very important to monitor the battery temperature and its charging voltage to assure battery health and safety. A good charger must include these features.

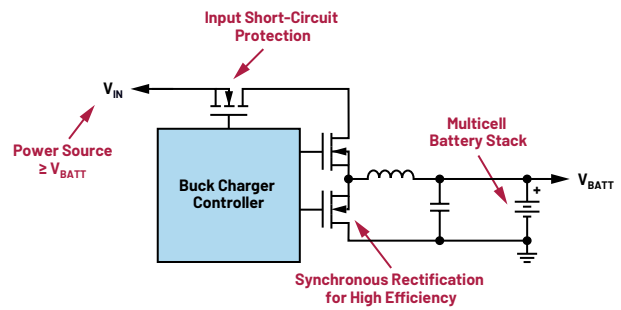


Figure 2. Generic synchronous rectification buck charger.

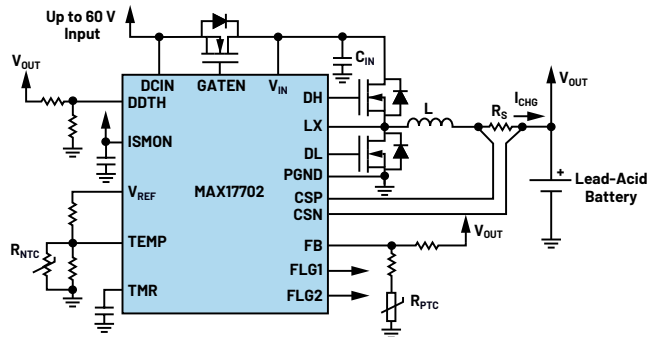


Figure 3. High voltage lead-acid battery charger controller.

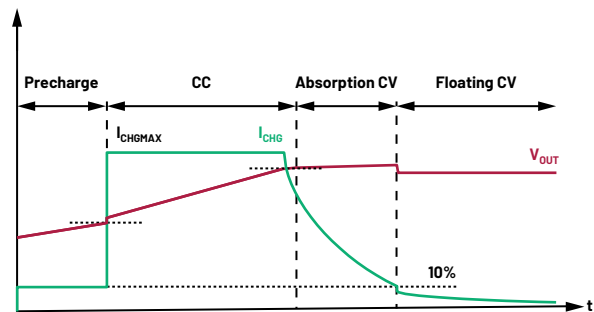


Figure 4a. MAX17702 lead-acid charging cycle.

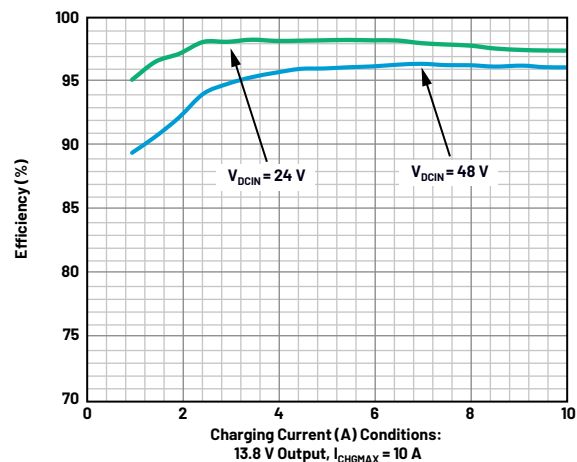


Figure 4b. MAX17702 charging efficiency.

Figure 5 shows an example of an advanced Li-Ion battery charger. The [MAX17703](#) is a high efficiency, high voltage, synchronous, step-down charger controller designed to operate over a wide input voltage range of 4.5 V to 60 V. The device offers a complete charging solution for up to 12 Li-Ion cell stacks.

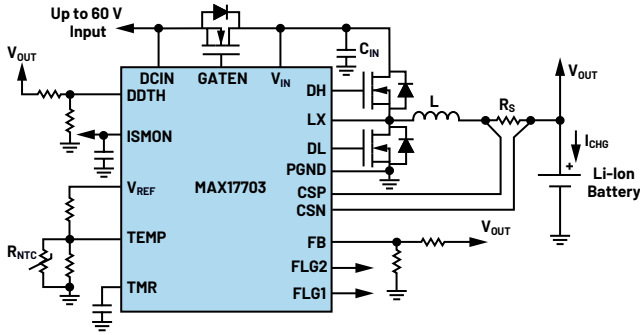


Figure 5. Advanced, high voltage Li-Ion battery charger circuit.

The device offers accurate CCCV charging current/voltage at $\pm 4\%$ and $\pm 1\%$, respectively. The charger enters a top-up-charge state when the charging current reduces to the taper-current threshold and then exits charging after a taper-timer period elapse. The charger initiates a recharge cycle when the output voltage falls below the recharge threshold voltage. This is a nice feature to keep the battery fully charged, if left in the charging cradle for a long period, without using too much power and to comply with Energy Star requirements. The device can detect and precondition deeply discharged batteries, waking them up with the precharge feature. For added protection, the device senses the battery temperature and allows charging only when within the temperature range. There is also an input short-circuit protection feature, which prevents discharging of the battery when the input is accidentally short circuited. Figure 6 illustrates the MAX17703's charging cycle.

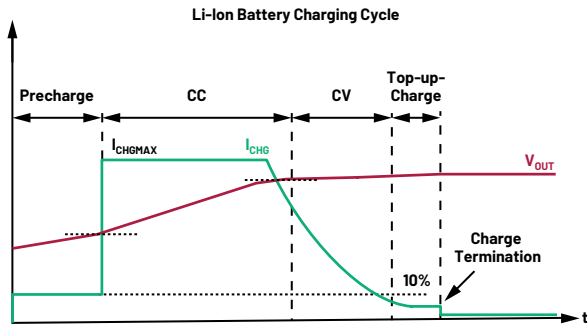


Figure 6. MAX17703 Li-Ion battery charging cycle.

Supercapacitor Charger

Supercapacitors are increasingly finding usage in a variety of applications, thanks to their unique advantages over batteries. Supercapacitors function on electrostatic principles with no chemical reactions, avoiding the lifetime issues associated with chemical storage of batteries. Their high durability allows for

millions of charge/discharge cycles with lifetimes up to 20 years, one order of magnitude above batteries. Their low impedance enables fast charge and discharge in a matter of seconds. This, in conjunction with their moderate ability to hold charge over long periods of time, makes supercapacitors ideal for applications requiring short charge and discharge cycles. They are also used in parallel with batteries, in applications where instantaneous peaks of power delivery are necessary during load transitions.

Supercapacitor short-charge and discharge cycles require chargers to handle high currents and work smoothly in constant current (CC) mode during a charge, which may start at 0 V, and in constant voltage (CV) mode once the final output value is achieved. In high voltage applications, many supercapacitors are connected in series, requiring chargers to manage high input and output voltage.

The [MAX17701](#) (see Figure 7) is a high efficiency, high voltage, synchronous, step-down supercapacitor charger controller designed for high current charging and operates over an input voltage range (VDCIN) of 4.5 V to 60 V. The output voltage is programmable from 1.25 V up to (VDCIN - 4 V). The device uses an external N-MOSFET to provide an input supply-side OR'ing function, preventing supercapacitor discharge back to the input. Figure 8 illustrates the simplistic, but high current charging profile.

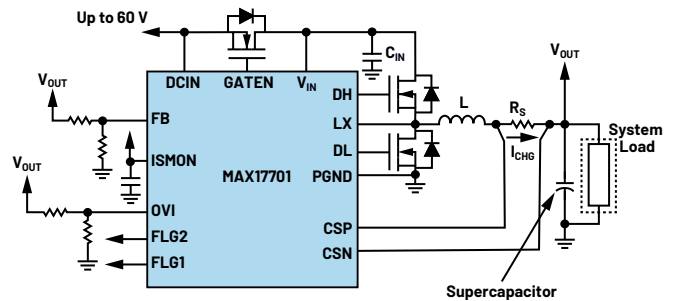


Figure 7. Supercapacitor high voltage, high current charger.

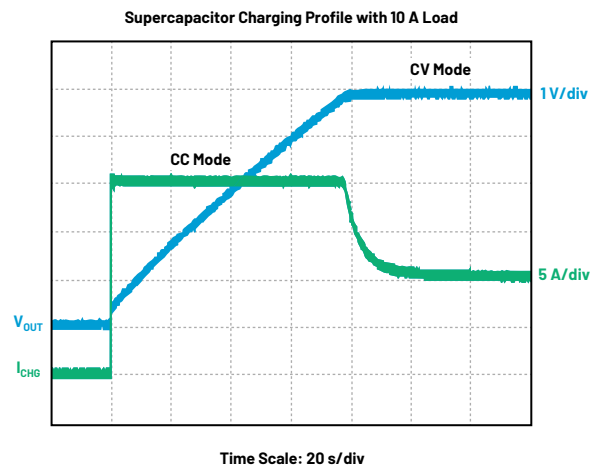


Figure 8. MAX17701 supercapacitor charging profile.

Conclusion

The use of battery-powered energy storage and portable equipment has grown steadily. The demand for more power, along with longer range or run time, dictates an increase in the voltages used in their battery stacks. Applications in industrial systems using a 24 VDC power supply can see 60 V peak voltage during transient conditions. Legacy charger solutions are mostly limited to 28 V input. Newer charger solutions from Analog Devices enable higher battery stack voltage and higher charging efficiency, thanks to the high voltage, synchronous buck charging topology.

Lead-acid batteries, lithium-based batteries, and supercapacitors are all energy storage devices that have very distinct charging/discharging characteristics and require a dedicated charger for an optimum charging solution. An advanced battery charger also provides adequate protection to give battery performance and durability, especially when charging under adverse conditions. These are also addressed in newer charger solutions.

References

¹Kevin Anderson. "Power IC Market Tracker - 2019." OMDIA, September 2020.

²"Advancements in Lead Acid." Battery University, July 2016.

³US 31DC XC2 - Data Sheet. U.S. Battery, 2019.

About the Author

Anthony T. Huynh (aka Thong Anthony Huynh) was a principal member of technical staff (MTS), applications engineering, at Maxim Integrated (now part of Analog Devices). He has more than 20 years of experience designing and defining isolated and nonisolated switching power supplies and power management products. At ADI, he has defined more than 100 power management products including DC-to-DC converters, hot swap controllers, Power over Ethernet, and various system-protection ICs adopted by the world's leading manufacturers.

Anthony holds four U.S. patents in power electronics and has written several public articles and application notes in this area. He has a B.S. in electrical engineering from Oregon State University and has completed all coursework for an M.S. in electrical engineering at Portland State University, where he also taught a power electronics class as an adjunct instructor.

RELATED CONTENT

PRODUCTS

MAX17701

4.5 V to 60 V, Synchronous Step-Down Supercapacitor Charger Controller

MAX17702

4.5 V to 60 V, Synchronous Step-Down Lead-Acid Battery Charger Controller

MAX17703

4.5 V to 60 V, Synchronous Step-Down Li-Ion Battery Charger Controller

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Make Your Small Asset Tracker Last Longer

Anil Telikepalli, Managing Director
 Nazzareno Rossetti, Analog and Power Management Expert
 Simo Radovic, Applications Director

Abstract

This design solution reviews a typical asset tracking solution and shows how the MAX3864x nanopower buck converter family, with its high efficiency and small size, enables longer battery life in small portables. New, low power data connections are sparking a proliferation of asset tracking solutions thanks to their low cost of deployment. The effects can be seen in multiple applications, particularly transportation and supply chain management.

In a typical application, a sensor provides updates from a given location, transmitting data about temperature, humidity, pressure, and motion. The sensor only needs to transmit small amounts of data, which results in higher coverage and ultra low power consumption, enabling far greater device longevity. The sensor's battery must last from several weeks to a few years. Asset tracking, depending on the application, may require the deployment of several tracker devices. Accordingly, these asset tracker devices must also be small, portable, and cost-effective.

In this design solution, we discuss the power management challenges encountered by a typical battery-operated asset tracker device and show an example using a small, high efficiency buck converter.

Edge-to-Enterprise Communication

Figure 1 illustrates a typical tracking communication chain. The asset being tracked transmits the data via a beacon, which reaches a server through a dedicated cellular network. From here, the data reach the enterprise portal for asset management and analytics.

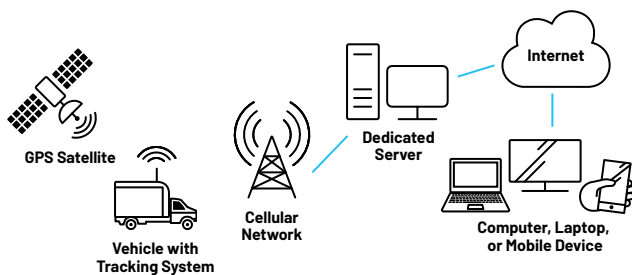


Figure 1. Real-time GPS tracking.

In the factory environment, asset tracking brings the management of facilities, vehicle fleet equipment, and maintenance into a single platform, resulting in improved safety, productivity, and extended asset life.

Asset Tracking Networks

A new generation of beacons connects directly to dedicated cellular networks (LTE-M, NB-IoT), eliminating the use of Bluetooth® to communicate with a gateway. These technologies can be very different but are all characterized by low power consumption, enabling several years of battery life (Table 1).

Table 1. Networks Characteristics

| | NB-IoT | LTE-M | Units |
|----------------|--------|-------|-------|
| Bandwidth | 180 | 1400 | kHz |
| Peak Data Rate | 100 | 384 | kbps |
| U/D Link Speed | 62.5 | 1000 | Mbps |
| Latency | 10 | 100 | ms |
| Battery Life | >10 | 10 | Years |
| Voice | No | Yes | |

Typical Asset Tracker System

Figure 2 shows a typical asset tracker block diagram. The three-series alkaline battery supplies a charge of 2000 mAh. A step-down regulator powers the on-board controller, sensors, and radio.

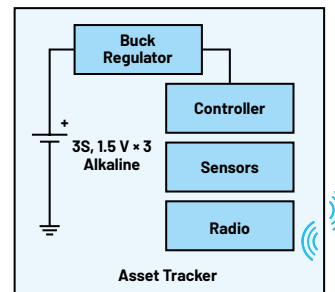


Figure 2. An asset tracker block diagram.

For demanding asset tracking applications, the system must last for a year on three alkaline batteries, drawing only 100 µA in deep sleep, and transmitting 100 mA once per day for about 2 minutes (Figure 3). While it is true that, depending on power

level and other options supported in the LTE-M or NB-IoT asset trackers, currents can be higher, for our discussion, we will stick to the 100 μ A to 100 mA range.

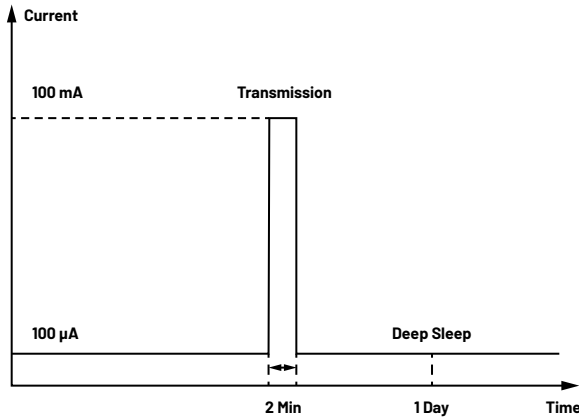


Figure 3. Asset tracker current profile.

High use performance requires careful selection of each block for minimum power consumption. The buck regulator must be efficient over a wide range from 100 μ A to 100 mA. For instance, a 4% average loss of efficiency by the buck converter translates into a field deployment reduction of about two weeks.

Ultralow Quiescent Current

The buck converter's quiescent current is especially important since the device is in deep sleep or quiet mode most of the time, consuming only 100 μ A or less. With $V_{OUT} = 1.8$ V, the output power during deep sleep is $P_{OUT} = 1.8$ V \times 100 μ A = 180 μ W. With $\eta = 90\%$, the input power is:

$$P_{IN} = 180 \mu\text{W} / 0.9 = 200 \mu\text{W} \quad (1)$$

If the buck converter is not carefully chosen and has a typical quiescent current of 3 μ A and a 3.6 V input voltage, there is an additional power dissipation of:

$$P'_{IN} = 3 \mu\text{A} \times 3.6 \text{V} = 10.8 \mu\text{W} \quad (2)$$

The final buck converter efficiency is:

$$\eta = P_{OUT} / (P_{IN} + P'_{IN}) = 180 / (200 + 10.8) = 86\% \quad (3)$$

A quiescent current of 3 μ A robs the buck converter of 4 efficiency points, draining the battery significantly faster!

On the other hand, a buck converter with 300 nA quiescent current will barely reduce the efficiency, lowering it by only half a percentage point. For asset tracking applications, it is critical to select a buck converter with ultralow quiescent current as the system spends the majority of the time in quiet mode and relies on a battery.

Nanopower Buck Converter

As an example of high efficiency, the nanopower ultralow 330 nA quiescent current buck (step-down) DC-to-DC converter shown in Figure 4 operates from a 1.8 V to 5.5 V input voltage and supports load currents of up to 175 mA with peak efficiencies of 96%. While in sleep mode, it consumes only 5 nA of shutdown current. The device is housed in a space-saving 1.42 mm \times 0.89 mm, 6-ball wafer-level package

(2 \times 3 ball WLP, 0.4 mm pitch). If higher currents are desired based on the power level in the NB-IoT or LTE-M networks, sister parts can deliver higher currents.

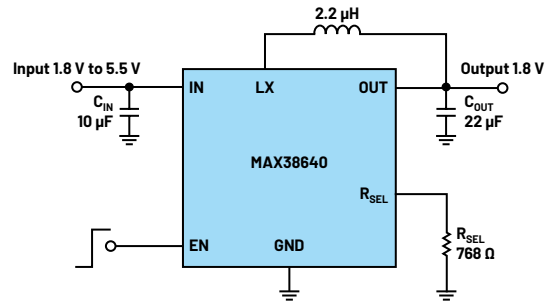


Figure 4. An integrated buck converter.

Small Size

The nanopower buck converter's application footprint is shown in Figure 5. Thanks to its WLP package, high switching frequency operation, and small external passives, the net PCB area of the buck converter is a meager 7.1 mm².

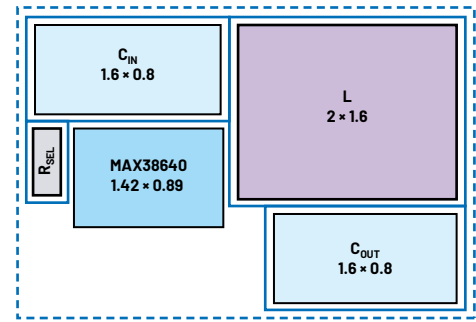


Figure 5. Asset tracker buck converter application (7.1 mm² net area).

Efficiency Advantage

Figure 6 shows the efficiency curve of the buck converter with a 3.6 V input and a 1.8 V output. Synchronous rectification at high load and pulsed operation at light load and ultralight load assure high efficiency across a wide operating range.

An 87.5% high efficiency operation at 100 μ A and 92% efficiency at 100 mA make the IC ideal for asset tracking applications. This buck converter has the advantage of several efficiency points compared to alternative solutions.

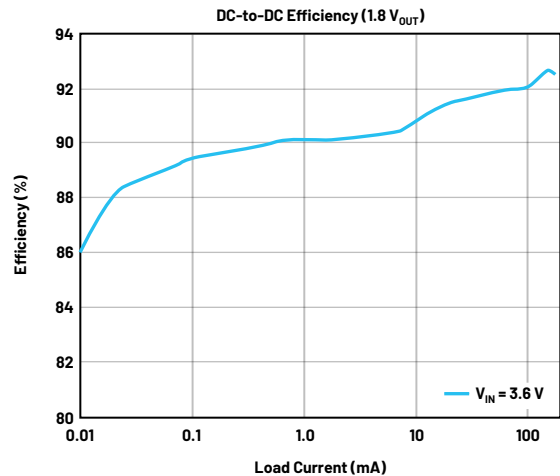


Figure 6. MAX38640 efficiency curve.

The benefits of high efficiency and smaller footprint go hand in hand, resulting in less heat generation. This helps in designing a smaller, cooler asset tracker, easing concerns of device overheating.

Conclusion

Asset trackers, depending on their specific application, must operate in the field for several weeks to a few years powered only by small batteries. This type of operation requires careful selection of each block for minimum power consumption. The buck regulator must operate efficiently over a wide input current range, from tens of microamps to hundreds of milliamps. The [MAX3864x](#) nanopower buck converter family, with its high efficiency and small size, provides an ideal power solution for asset tracking applications.

References

[MAX38640](#). Analog Devices, Inc.

[MAX38641](#). Analog Devices, Inc.

[MAX38642](#). Analog Devices, Inc.

[MAX38643](#). Analog Devices, Inc.

About the Authors

Anil Telikepalli was the managing director of the Core Products Business Unit at Analog Devices with responsibility for power and data converter products. Anil joined Analog Devices in 2010 and managed definition, product development, marketing, and business development with a global team across North America, Europe, and Asia. Prior to ADI, Anil held multiple roles at Xilinx and MIPS Technologies in engineering applications, marketing, and business operations, enabling growth in communications, computing, consumer, automotive, and industrial markets. Anil holds master's and bachelor's degrees in electrical engineering from the University of Kentucky and Osmania University, respectively. He holds several patents in the field and has advised multiple hardware and internet software startups.

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MAX38642

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Got Backup? Maintain Power Continuity

Tony Armstrong and Steve Knoth

In today's world of constant connectivity, it is commonplace for many electronic systems to be always operational—regardless of their external environment or operating conditions. Said another way, any glitch in a system's power supply, whether momentary, seconds, or even minutes, must be taken into account during its design process. The most common way of dealing with such circumstances is to use uninterruptible power supplies (UPSs) to cover these brief downtimes, thus ensuring high reliability, continuous operation of the system. Similarly, many of today's emergency and standby systems are used to provide backup power for building systems to provide assurance that safety systems and critical equipment can maintain their operation during a power outage—whatever the root cause.

Obvious examples can be readily found in the ubiquitous handheld electronic devices used in our everyday lives. Because dependability is paramount, handhelds are carefully engineered with lightweight power sources for reliable use under normal conditions. But no amount of careful engineering can prevent the mistreatment they will undergo at the hands of people. For example, what happens when a factory worker drops a handheld portable scanning device, causing its battery to detach? Such events are electronically unpredictable and important data stored in volatile memory would be lost without some form of safety net—namely some sort of short-term power holdup system that stores sufficient energy to supply standby power until the battery can be replaced or the data can be stored in permanent memory.

This example clearly demonstrates the need for an alternative form of power source to be available in electronic systems, just in case there is an interruption in their primary power source.

In automotive electronic systems there are many applications that require continuous power even when a car is parked (engine not running), such as remote keyless entry, security, and even personal infotainment systems. These systems usually incorporate navigation, GPS location, and eCall functionality. It is easy to understand why these systems have to remain on even when the car is not moving, since the GPS aspect of these systems must be always-on for emergency and security purposes. This is a necessary requirement so that rudimentary control can be activated by an external operator when necessitated.

Consider an eCall system (take General Motor's OnStar® system in the USA as a prime example), which is becoming more pervasive in newer automobiles across the globe, with many manufacturers having already rolled them out across their ranges. In fact, these systems became mandatory in Europe in all new cars and light trucks sold after March 31st, 2018. It's a pretty simple bit of technology: in the event of a collision in which a car's airbags are deployed, the eCall system automatically contacts emergency services. It uses GPS to relay the time, your location, what type of car you're in, and what kind of fuel it uses to the authorities, while a microphone in the car allows you to speak directly to call handlers when the system is activated. These eCall system can share what direction you were travelling in when the incident occurred, allowing authorities to know which side of the freeway they need to head to in the event of a collision. All this allows ambulance, police, and fire crews to reach you as quickly as they can following

an accident, armed with as much information as possible. An individual can also activate eCall by pressing a button, so if someone becomes ill (or has been injured in a collision in which the airbags haven't deployed), help can still be easily summoned.

Storage Mediums

Having acknowledged the need for backup power in a wide array of systems, the question then arises: what are the options for storage mediums for this type of backup power? Traditionally, the choices have been capacitors and batteries.

It is fair to say that capacitor technology has played a major role in power transmission and delivery applications for multiple decades. For example, traditional thin film and oil-based capacitor designs performed a variety of functions, such as power factor correction and voltage balancing. However, in the past decade there was substantial research and development that has led to significant advances in capacitor design and capabilities. These advanced capacitors have been called supercapacitors (also known as ultracapacitors) and they are ideal for use in battery energy storage and backup power systems. Supercapacitors may be limited in terms of their total energy storage; nevertheless, they are energy dense. Furthermore, they possess the ability to discharge high levels of energy quickly and recharge rapidly.

Supercapacitors are not only compact, but they are robust and reliable, and they can support the requirements of a backup system for short-term power-loss events such as the ones already outlined herein. Furthermore, they can easily be paralleled or stacked in series or even a combination of both to deliver the necessary voltage and current demand by the end application. Nevertheless, a supercapacitor is more than just a capacitor with a very high level of capacitance. Compared to standard ceramic, tantalum, or electrolytic capacitors, supercapacitors offer higher energy density and higher capacitance in a similar form factor and weight. And, although supercapacitors require some special care, they are augmenting or even replacing batteries in data storage applications requiring high current/short duration backup power.

Moreover, they are also finding use in a variety of high peak power and portable applications in need of high current bursts or momentary battery backup, such as UPS systems. Compared to batteries, supercapacitors provide higher peak power bursts in smaller form factors and feature a longer charge cycle life over a wider operating temperature range. Supercapacitor lifetime can be maximized by reducing the capacitor's top-off voltage and avoiding high temperatures (>50°C).

Batteries, on the other hand, can store a lot of energy, but are limited in terms of power density and delivery. Due to the chemical reactions that occur within a battery, they have limited life with regard to cycling. As a result, they are most effective when delivering modest amounts of power over a long period of time, since pulling many amps out of them very quickly severely limits their useful operating life. Table 1 shows a summary of the pros and cons among supercapacitors, capacitors, and batteries.

Table 1. Supercapacitor Characteristics Comparison vs. Capacitors and Batteries

| Parameter | Supercapacitors | Capacitors | Batteries |
|----------------------------|--|--|--|
| Energy Storage | Wsec of energy | Wsec of energy | Wh of energy |
| Charge Method | Voltage across terminals (for example, from a battery) | Voltage across terminals (for example, from a battery) | Current and voltage |
| Power Delivered | Rapid discharge, linear or exponential voltage decay | Rapid discharge, linear or exponential voltage decay | Constant voltage over long time period |
| Charge/Discharge Time | msec to sec | psec to msec | 1 hour to 10 hours |
| Form Factor | Small | Small to large | Large |
| Weight | 1 g to 2 g | 1 g to 10 kg | 1g to >10 kg |
| Energy Density (Wh/kg) | 1 to 5 | 0.01 to 0.05 | 8 to 600 |
| Power Density (W/kg) | High, >4000 | High, >5000 | Low, 100 to 3000 |
| Operating Voltage | 2.3 V to 2.75 V/cell | 6 V to 800 V | 1.2 V to 4.2 V/cell |
| Lifetime | >100k cycles | >100k cycles | 150 to 1500 cycles |
| Operating Temperature (°C) | -40 to +85 | -20 to +100 | -20 to +65 |

New Backup Manager Power Solutions

Now that we have established that either supercapacitors, batteries, and/or a combination of both are candidates for use as a backup power sources in almost any electronic system, what are some of the solutions available?

First of all, any IC solution would need to be a complete lithium ion battery backup power management system with the capability to keep 3.5 V to 5 V supply rails active during a main power failure event. Since batteries provide considerably more energy than supercapacitors, they are superior for applications that require backup for extended periods of time. Accordingly, any IC solution would need to have an on-chip bidirectional synchronous converter to provide high efficiency charging of the backup battery, as well as be able to deliver high current backup power to the downstream load should an interruption on the main power rail occur. Thus, when external power is available, the device would operate as a step-down battery charger for single-cell Li-ion or LiFePO₄ batteries while giving preference to the system load. However, if the input supply was to suddenly drop below the adjustable power-fail input (PFI) threshold the IC would need to operate as a step-up regulator, capable of delivering multiple amps to the system output from the backup battery. Accordingly, if a power failure were to occur, then the IC would need power path control to provide reverse blocking and a seamless switchover between input power and the backup power source. Typical applications for such an IC would include fleet and asset tracking, automotive GPS data loggers, automotive telematics systems, toll collection systems, security systems, communications systems, industrial backup, and USB-powered devices. Figure 1 shows a typical application schematic for this purpose using Analog Devices' Power by Linear™ LTC4040 lithium ion battery backup manager.

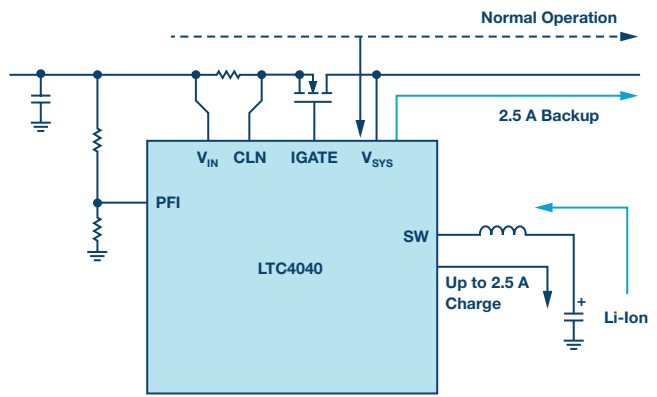


Figure 1. A backup supply using the LTC4040 with a user set PFI threshold.

The LTC4040 also includes optional overvoltage protection (OVP) that protects the IC from input voltages greater than 60 V with an external FET. Its adjustable input current limit function enables operation from a current limited source while prioritizing system load current over battery charge current. An external disconnect switch isolates the primary input supply from the system during backup. The LTC4040's 2.5 A battery charger provides eight selectable charge voltages optimized for Li-ion and LiFePO₄ batteries. The device also includes input current monitoring, an input power loss indicator, and a system power loss indicator.

Analogous to batteries are supercapacitors. However, instead of supporting long time intervals of power loss, they are an excellent choice for systems that need high power, short duration backup power. Accordingly, any IC that supports this type of application would typically require the capability to support 2.9 V to 5.5 V supply rails during a main power interruption. It is well known that supercapacitors have higher power density than batteries, making them an ideal choice for systems whose applications require high peak power backup for brief time intervals. By way of example, the LTC4041 from Analog Devices' Power by Linear product line uses an on-chip bidirectional synchronous converter to provide high efficiency step-down supercapacitor charging, as well as high current, high efficiency boost backup power. When external power is available, the device operates as a step-down battery charger for one or two supercapacitor cells while giving preference to the system load. When the input supply drops below the adjustable PFI threshold, the LTC4041 switches to step-up mode operation and can deliver up to 2.5 A to the system load from the supercapacitor(s). During a power fail event, the device's PowerPath™ control provides reverse blocking and a seamless switchover from input power to backup power. Typical applications for the LTC4041 include ride-through "dying gasp" supplies, high current ride-through 3 V to 5 V UPSs, power meters, industrial alarms, servers, and solid-state drives. Figure 2 shows a typical LTC4041 application schematic.

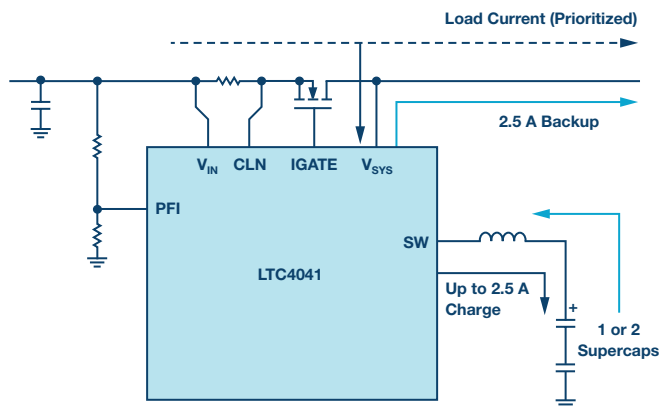


Figure 2. LTC4041 supercapacitor backup application schematic.

The LTC4041 includes an optional OVP function using an external FET that can protect the IC from input voltages greater than 60 V. An internal supercapacitor balancing circuit maintains equal voltages across each supercapacitor and limits the maximum voltage of each supercapacitor to a predetermined value. Its adjustable input current limit function enables operation from a current limited source while prioritizing system load current over battery charge current. An external disconnect switch isolates the primary input supply from the system during backup. The device also includes input current monitoring, an input power fail indicator, and a system power fail indicator.

Conclusion

Whenever a system must have constant availability, even if the primary power source should fail or is briefly interrupted, it is always a wise choice to have a backup power source available. Fortunately, there are many IC options for designers to consider for their specific needs, including the LTC4040/LTC4041 backup managers. These types of ICs allow an easy method to have backup power available if the main power is interrupted or lost, regardless of whether their storage medium is a supercapacitor, an electrolytic capacitor, or even a battery. The LTC4040 and/or LTC4041 have the functionality to provide an end system with backup power, whether it be a momentary burst or for extended periods of time. So, make sure that your system has the right backup when it is needed. Got it?

About the Authors

Tony Armstrong is the product marketing director for Analog Devices' Power by Linear product group. He is responsible for all aspects of power conversion and management products, from their introduction through obsolescence. Prior to joining ADI, Tony held various positions in marketing, sales, and operations at Linear Technology (now part of ADI), Siliconix Inc., Semtech Corp., Fairchild Semiconductors, and Intel. He attained a B.S. (honors) in applied mathematics from the University of Manchester, England.

Steve Knoth 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 regulators (LDOs), battery chargers, charge pumps, charge pump-based LED drivers, supercapacitor chargers, low voltage monolithic switching regulators, and ideal diode devices. Prior to joining Linear Technology (now ADI) 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/arcade games or muscle cars, and buying, selling, and collecting vintage toys and movie/sports/automotive memorabilia.

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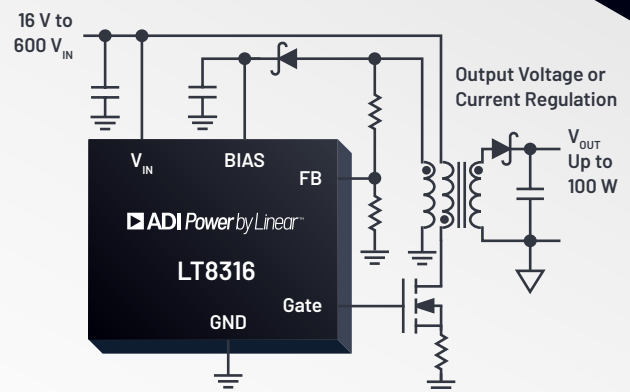
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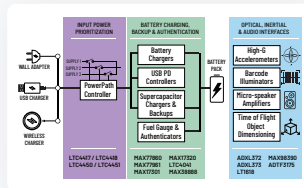
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