Multi-Topology Battery Charging from Milliwatts to Kilowatts

The practice of battery charging spans a wide variety of battery chemistries, voltages and current levels in many market segments. For example, industrial, medical and automotive battery chargers continue to demand higher voltages and currents as new applications are emerging for both existing and new battery chemistries, such as the proliferation of sealed lead acid (SLA) batteries in solar applications. Existing single integrated circuit (IC) based solutions cover just a fraction of the many combinations of input voltage, charge voltage and charge current. A cumbersome combination of ICs and discrete components was routinely used to cover most of these combinations and topologies. A new charger IC overcomes this problem. **Steve Knoth, Senior Product Marketing Engineer Power Products, Linear Technology Corp., USA**

Current market trends would indicate that there is renewed interest in high capacity SLA battery cells - a revival of sorts - they are not just for cars anymore. Automotive or "starting" SLA cells are inexpensive from a cost/power output standpoint and can deliver high pulse currents for short durations, making them excellent for automotive and other vehicle starter applications. Deep cycle lead-acid 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 full charge. They are normally used where power is required over a longer period of time in such applications as fork lifts and golf carts. Nevertheless, lead-acid batteries are very sensitive to overcharging, so careful charging is very important.

Obviously, solar-powered applications are on the rise. Solar panels of various sizes now power a variety of innovative applications from crosswalk marker lights to trash compactors to marine buoy lights. Batteries used in solar powered applications are a type of deep cycle battery capable of surviving prolonged, repeated charge cycles, in addition to deep discharges. This type of battery is commonly found in "off grid" (i.e. disconnected from the electric utility company) renewable energy systems such as solar- or wind-power generation.

All-in-one charger?

Some of the tougher issues a designer must encounter are the high input voltage requirements, the high capacity batteries needing to be charged, or an input voltage range that spans above and below the battery voltage range. Furthermore, to make matters worse, there are many applications without dedicated, simple battery charging solutions. Examples include:

- High series cell count battery stacks - there are no existing IC solutions for >4 Lithium cells,
- high input voltage applications - there are no existing IC solutions above 30V to 40V,
- buck-boost applications and isolated topologies, e.g. a flyback configuration.

Due to IC design complexity, existing battery charging controllers are primarily limited to step-down or buck architectures. Finally, some existing solutions charge multiple battery chemistries - some with on-board termination; however, up until now no chargers have provided the necessary performance features to solve all of these issues. Popular applications for a device such as this would be high power battery charger systems, portable instruments, industrial battery equipped devices, and general purpose charging.

A new IC solution

An IC charging solution that solves the problems outlined needs to possess many, if not all, of the following attributes:

- Flexibility - it must operate in tandem with various switcher topologies
- Wide input voltage range,
- wide output voltage range to address multiple battery stacks,
- ability to charge multiple battery chemistries,
- autonomous operation (no µP needed),
- high output current,
- low profile solution footprints,
- advanced packaging for improved thermal performance and space efficiency.

A typical convoluted competing solution with PowerPath™ control and input current limiting would consist of a DC/DC switching regulator, a microprocessor plus several ICs and discrete components. However, a simpler solution is with the new LTC4000 battery charging controller at hand.

The LTC4000 is a high voltage controller and power manager that converts virtually any externally compensated DC/DC power supply into a full-featured battery charger (Figure 1). The IC is capable of driving typical DC/DC converter topologies, including buck, boost, buck-boost, SEPIC and flyback. The device offers precision input and charge current regulation and operates across a wide 3 V to 60 V input and output voltage range, making it compatible with a variety of different input voltage sources, battery stacks and chemistries. Typical applications include high power battery charger systems, high performance portable instruments, battery back-up systems, industrial battery-equipped devices and notebook computers.

The LTC4000 features an intelligent PowerPath topology that preferentially provides power to the system load when input power is limited. The IC controls two external PFETs to provide low loss reverse current protection, efficient charging and discharging of the battery, and instant-on operation to ensure that system power is available at plug-in even with a dead or deeply discharged battery. External sense resistors and precision sensing enable

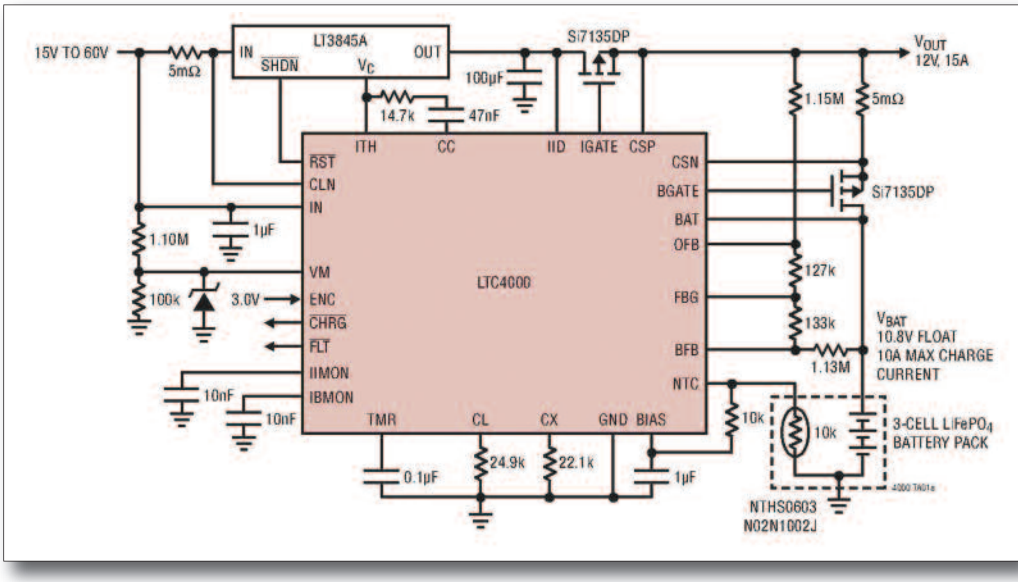

Figure 1: **LTC4000 typical application circuit**

accurate currents at high efficiency, to work with converters that span the power range from milliwatts to kilowatts.

A variety of battery chemistries including Lithium-ion/polymer/phosphate, sealed lead acid and nickel-based can be charged. The device also provides charge status indicators through its FLT and CHRG pins. Other features of the battery charger include: ±0.25% programmable float voltage, selectable timer or C/X current termination, temperature-qualified charging using an NTC thermistor, automatic recharge, C/10 trickle charge for deeply discharged cells and bad battery detection. The LTC4000 is housed in a low profile (0.75mm) 28-pin 4mm x 5mm QFN package and a 28-lead SSOP package. The device is guaranteed for operation from -40°C to 125°C.

Full control of external DC/DC converter

The LTC4000 requires an externally compensated switching regulator to form a complete battery management solution. System performance will vary based on the type of switching regulator that the LTC4000 is paired with.

The charger IC includes four different regulation loops: input current, charge current, battery float voltage and output voltage (A4-A7), please refer to the block diagram in Figure 2. Whichever loop requires the lowest voltage on the ITH pin for its regulation controls the external DC/DC converter. The input current regulation loop ensures that the

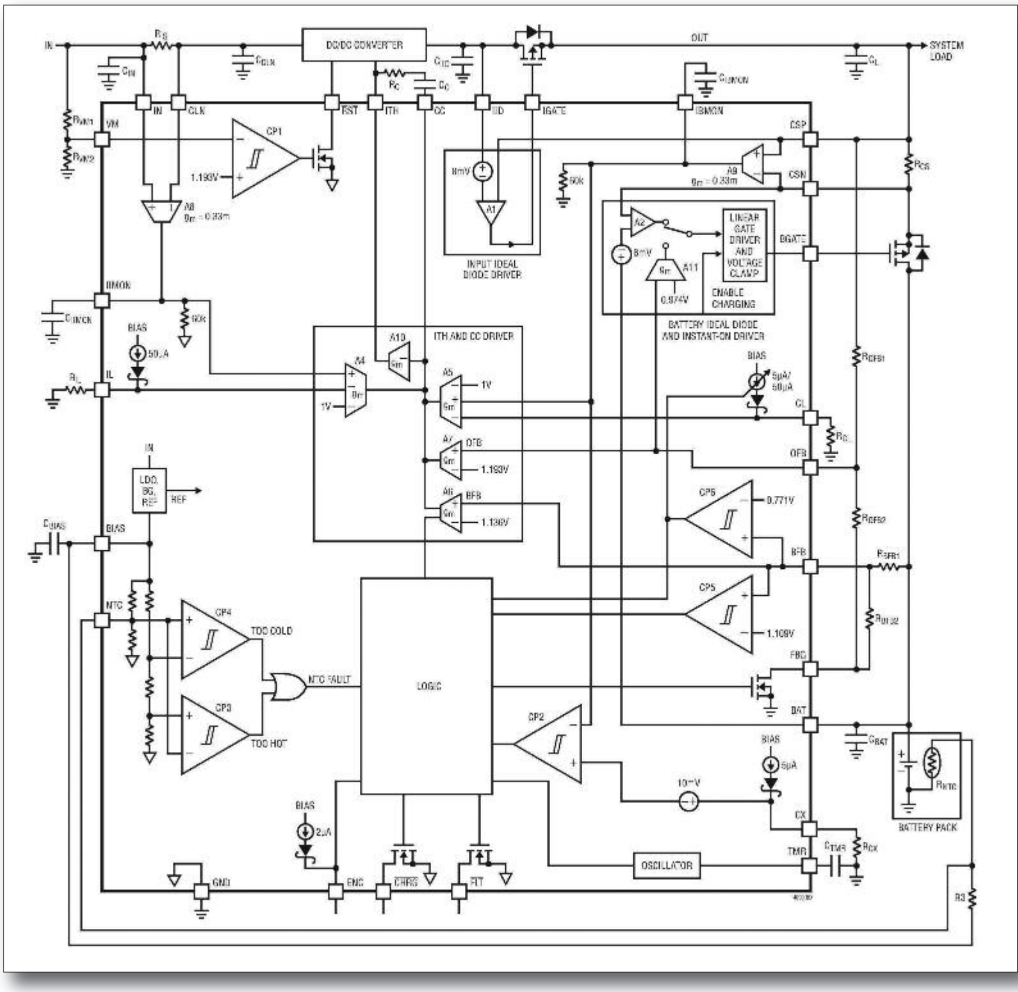

Figure 2: **LTC4000 block diagram**

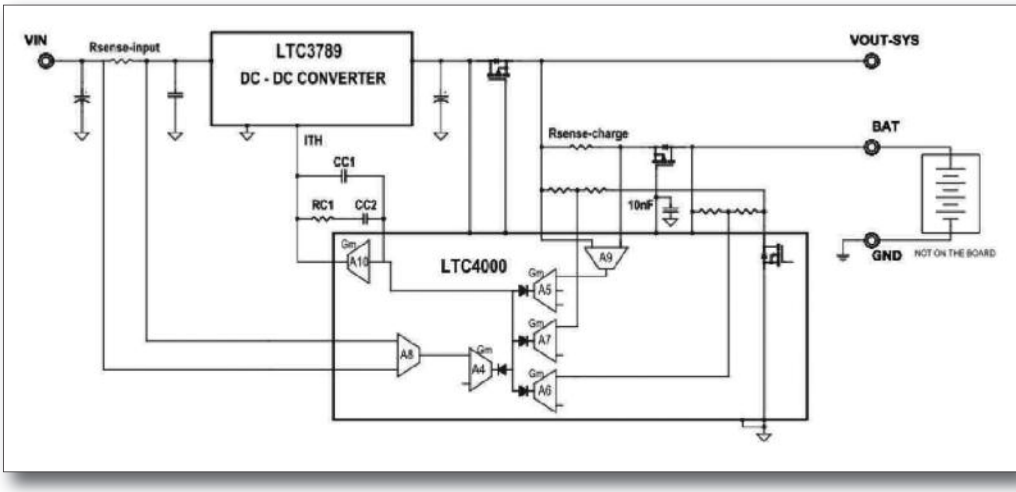

Figure 3: Demo board system block diagram using LTC4000 / LTC3789

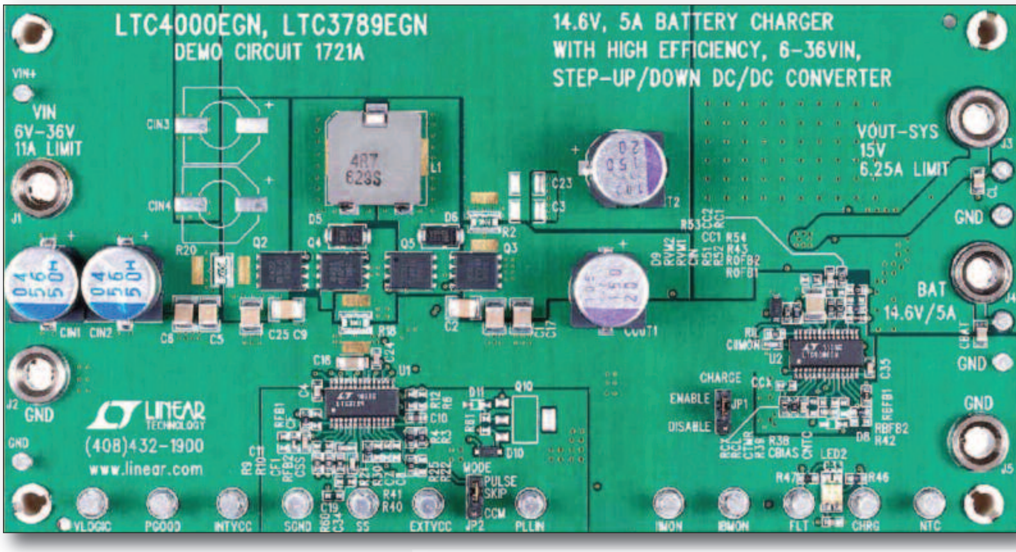

Figure 4: DC1721A demo board

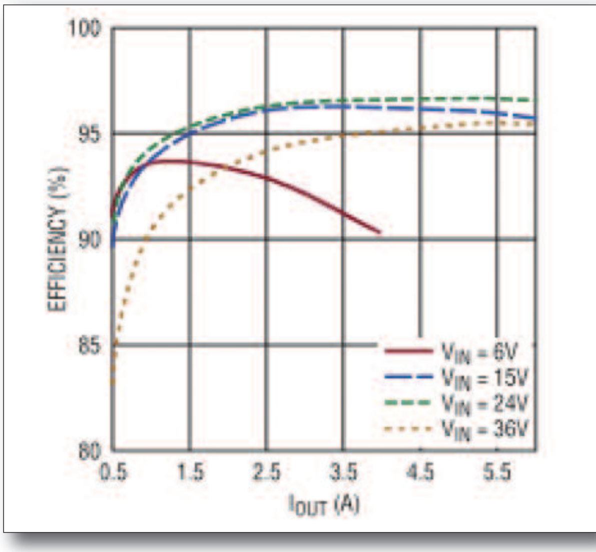

Figure 5: DC1721A efficiency from V_{IN} to V_{OUT_SYS}

programmed input current limit (using a resistor at IL) is not exceeded at steady state. The charge current regulation loop ensures that the programmed battery charge current limit (using a resistor at CL) is not exceeded.

The float voltage regulation loop ensures that the programmed battery stack voltage (using a resistor divider from BAT to FBG via BFB) is not exceeded. The output voltage regulation loop ensures that the programmed system output voltage (using a resistor divider from CSP to FBG via OFB) is not exceeded. The LTC4000 also provides monitoring pins for the input current and charge current at the IIMON and IBMON pins respectively.

Flexible demonstration circuits

The DC1721A-A is a 14.6 V, 5 A battery charger and PowerPath manager with 6 V to 36 V input buck-boost converter featuring the LTC4000/LTC3789, targeted at 4-cell LiFePO4 applications (see Figure 3).

The output of this demo board is specifically tailored for a Tenergy 10 Ah battery. Other voltages can be set by changing external resistors. The desired nominal voltage can be accurately trimmed by using trim resistors. This circuit was designed to demonstrate the high levels of performance, efficiency, and small solution size attainable using these parts in a buck-boost converter battery charger with Intelligent PowerPath manager. It operates at 400 kHz and produces a regulated 5 A/14.6 V battery charger output as well as a system output of up to 6.25 A from an input voltage range of 6 V to 36 V: suitable for a wide variety of portable applications including instruments, industrial equipment, power tools, and computers. It has a total footprint area of 12.4 cm² (3.6 cm2 for the LTC4000 circuit only) enabling a very compact solution (see Figure 4). Synchronous rectification helps to attain efficiency exceeding 96% at full load and nominal input (see Figure 5).

For added circuit evaluation and simulation, demonstration circuit DC1830 will soon be released, allowing the LTC4000 board to be interfaced with other compatible DC/DC converter standalone evaluation boards.