New Family of Integrated Power Controllers Combine Fast Battery Charging, PowerPath Control and Efficient DC/DC Converters in Less Than 20mm²

by Sam Nork

Introduction
The quickest way to build an efficient power system for a battery-powered portable application is to use an IC that combines all power control functions into a single chip, namely a Power Management Integrated Circuit (PMIC). PMICs seamlessly manage power flow from various power sources (wall adapters, USB and batteries) to power loads (device systems and the charging battery), while maintaining current limits where required (such as that specified for USB). To this end, PMICs typically feature built-in PowerPath™ control, DC/DC converters, and other IC functions.

Table 1. Power management ICs with Li-ion/polymer battery chargers

<table>
<thead>
<tr>
<th>Part Number</th>
<th>PowerPath Topology</th>
<th>Interface</th>
<th>Integrated Converters and Load Current Capabilities</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTC3555/-1/-3</td>
<td>Switching</td>
<td>I²C</td>
<td>1A, 400mA x 2</td>
<td>25mA</td>
</tr>
<tr>
<td>LTC3556</td>
<td>Switching</td>
<td>I²C</td>
<td>400mA x 2</td>
<td>1A</td>
</tr>
<tr>
<td>LTC3566</td>
<td>Switching</td>
<td></td>
<td>1A</td>
<td>25mA</td>
</tr>
<tr>
<td>LTC3567</td>
<td>Switching</td>
<td>I²C</td>
<td>1A</td>
<td>25mA</td>
</tr>
<tr>
<td>LTC3586*</td>
<td>Switching</td>
<td></td>
<td>400mA x 2</td>
<td>1A</td>
</tr>
<tr>
<td>LTC3557/-1</td>
<td>Linear</td>
<td></td>
<td>600mA, 400mA x 2</td>
<td></td>
</tr>
<tr>
<td>LTC3455</td>
<td>Linear</td>
<td></td>
<td>600mA, 400mA</td>
<td></td>
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<tr>
<td>LTC3558</td>
<td></td>
<td></td>
<td>400mA</td>
<td>400mA</td>
</tr>
<tr>
<td>LTC3559/-1</td>
<td></td>
<td></td>
<td>400mA x 2</td>
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*For an application of the LTC3586 see “Complete Power Solution for Digital Cameras and Other Complex Compact Portable Applications” in this issue.
sion and battery charging functions. PMICs can be applied in everything from consumer electronics such as MP3 players and Bluetooth headsets to specialized portable medical and industrial equipment.

Table 1 shows the wide variety of integrated charger and DC/DC combinations now available from Linear Technology. The latest additions to the family, the LTC3556, LTC3566, LTC3567 and LTC3586, are primarily targeted toward relatively high power Li-Ion applications and contain blocks capable of high efficiency at high current levels. (To see an application of the LTC3586, see “Complete Power Solution for Digital Cameras and Other Complex Compact Portable Applications” in the Design Ideas section of this issue.)

The most noteworthy feature of the new parts is the use of a proprietary switching PowerPath design, which improves efficiency over linear power path or battery fed solutions.

**Switching PowerPath Control Efficiently Harnesses Available External Power**

To speed up charging, some of Linear’s new PMICs employ a unique current limited synchronous buck switching charger architecture that uses more power from the USB or adapter than other topologies. This is a big improvement over battery fed and linear PowerPath control schemes. (For a more detailed description of the switching PowerPath architecture, see the cover article in the June 2008 issue of *Linear Technology magazine* titled “Speed Up Li-ion Battery Charging and Reduce Heat with a Switching PowerPath Manager.”)

For instance, portable products with large capacity batteries (1Ahr plus) face a direct tradeoff between charge time and charger power dissipation—especially when a linear charging method is used. At relatively low charge currents, a linear charger dissipates a modest amount of power, but at currents required to quickly charge high capacity batteries, a linear charger can dissipate 2W or more.

A switching PowerPath topology is an improvement over the commonly used linear PowerPath topology, and both are an improvement over battery fed applications. A linear PowerPath powers the application directly from the battery itself and provides “instant on” capability if the battery is dead or missing (as long as the load current is less than the input current limit). However, neither a linear charger nor linear power manager is well-suited for high current charging due to poor efficiency under certain conditions.

USB is now a common source of power, but charging/powering from the USB host is complicated by the host’s 2.5W limit. To take advantage of the limited USB power, all components in the power path must be as efficient as possible.

A key attribute in these new PMICs is a battery-tracking (Bat-Track™) synchronous buck design with logic programmable input current limit to ensure USB compatibility. When USB or adapter power is available, the LTC35xx power manager generates a V<sub>OUT</sub> supply equal to V<sub>BAT</sub> + 300mV. The 300mV difference voltage is sufficient to keep the battery charger just out of dropout and deliver the programmed charge current at high efficiency. As with linear power managers, the load current is provided first, and current that is left over is directed to the battery. Input current limit is controlled via an external resistor to set absolute current and two logic pins to control the ratio (e.g., 100mA, 500mA, 1A and Suspend).

Charging efficiency of over 80% with a completely discharged battery is achievable vs 60% or so for a linear charger. Or said another way, the switching power path dissipates only 50% of the power dissipated by a linear

**Figure 2. Switching power manager charge current vs battery voltage with a 500mA input current limit. Peak charge current = 700mA.**

**Figure 3. 1A buck-boost efficiency vs V<sub>IN</sub> (LTC3556, LTC3566/7, LTC3586)**
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the range of 1.4V to 3.3V. If possible, using a lower OVD can reduce power consumption. The termination scheme is largely based on the receiver. When choosing the OVD voltage, refer to the receiver's data sheet to terminate the CML lines properly.

CML uses true double termination. Generally, LVDS is only terminated at the receiver, which means that any signal reflection back to the source reflects back to the receiver with little attenuation. This limits the data rate and trace length that LVDS can drive. The truly differential nature of CML radiates less energy than LVDS and CMOS signals, allowing devices to be in closer proximity to antennas, mixers or other sensitive analog front end systems. CML also has common mode termination. This gives CML a better common mode behavior than LVDS. LVDS is only terminated differentially, which does not reject any common mode signal that may appear on the transmission line—another limiting factor in LVDS signaling.

**CML Power Consumption**

With a constant 16mA of bias current and a voltage swing of 800mV differential, CML logic consumes a moderate amount of power. For an equal data rate, CML logic consumes less total power than PECL and LVPECL. A single CML driver uses more power than a single LVDS driver, but only marginally more that the three pairs of LVDS drivers required for a typical LVDS serial bus.

**8B/10B Encoding Makes for Simple Connection**

The 8B/10B encoding process results in an average DC offset of zero, allowing the data to be routed through transformers or fiber channel transceivers that can provide isolation between the digital and analog realm. 8B/10B encoding also does not require a framing signal or a data clock, whereas both are required in traditional serial communication. 8B/10B encoding transmits data over a single pair of data lines, whereas a typical serial ADC requires three or more pairs, and a typical parallel ADC can require more than 16 pairs.

The complexity of decoding 8B/10B lies in the receiver. Fortunately Xilinx, Altera and Lattice have solutions to receive data from the LTC2274 and decode the 8B/10B data, simplifying the collection of 8B/10B data. Other 8B/10B decoding solutions may be available. The FPGA required to receive data from the LTC2274 must be able to receive high speed serial transmissions of 2GHz or more.

**Conclusion**

Without sacrificing resolution or sample rate, the LTC2274 delivers full 16-bit performance at 105Msps over a single pair of transmission lines, greatly simplifying layout and saving valuable board space. This mitigates interaction with other circuitry in software defined radio, base station or industrial applications which involve many channels of an ADC routed to one FPGA.

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**DESIGN FEATURES**

The fully integrated boost in the LTC3586 can regulate up to a 5V output with up to 800mA from a battery voltage as low as 3V. The regulator has built in output disconnect making it well-suited for USB OTG supplies or for powering motors in printer and camera applications. The current mode synchronous boost is internally compensated and operates at a fixed 2.25MHz switching frequency. Pulse-skipping at low loads achieves low noise output for driving high power audio circuits.

**I²C, Programmable Sequencing and Easy I/O**

Despite the progress in new cutting edge features and design, one old problem does not go away: power supply control. Power supplies require startup and power down sequencing, fault detection/reporting/handling and voltage and operating mode adjustments. Getting it all right can be a system control nightmare depending on the complexity and limitations of the power supply circuits.

The LTC35xx family provides very simple and flexible control of all essential power supply functions. The LTC3566 and LTC3586 employ dedicated I/O control pins for enabling, disabling and changing DC/DC operating modes. Voltages on these parts are fixed and set with external resistor dividers. The LTC3555, LTC3556 and LTC3567 accommodate either I²C control or simple I/O pins to control the supplies. The LTC3556 provides a three-state SEQ pin to allow the power up sequence of its three DC/DC converters to be programmed via pin-strapping. Those parts with I²C VOUT control power up at their maximum VOUT (as determined by the FB servo point and external dividers) when enabled via simple I/O, and can independently reduce VOUT by as much as 50% in equal 16-step increments via I²C.

All DC/DC converters in all the PMICs discussed here can survive an indefinite output fault. The parts all provide a RST output and all converters are actively pulled down in shutdown to ensure proper power-up sequencing. The LTC3586 contains an additional fault handing feature that automatically powers down all DC/DC converters whenever a valid fault is detected. In short, the entire family is designed for simple, flexible and trouble-free control and operation.

**Conclusion**

Linear Technology's latest PMIC products improve the performance and simplify the design of a wide variety of portable power management applications. Instead of kitchen sink alternatives with large packages, Linear Technology offers a number of devices with various feature mixes in small packages. These new PMICs are simple to use, highly integrated and high performance, allowing for shorter design times, greater PCB flexibility, and better power/thermal management than traditional solutions.