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 conver-

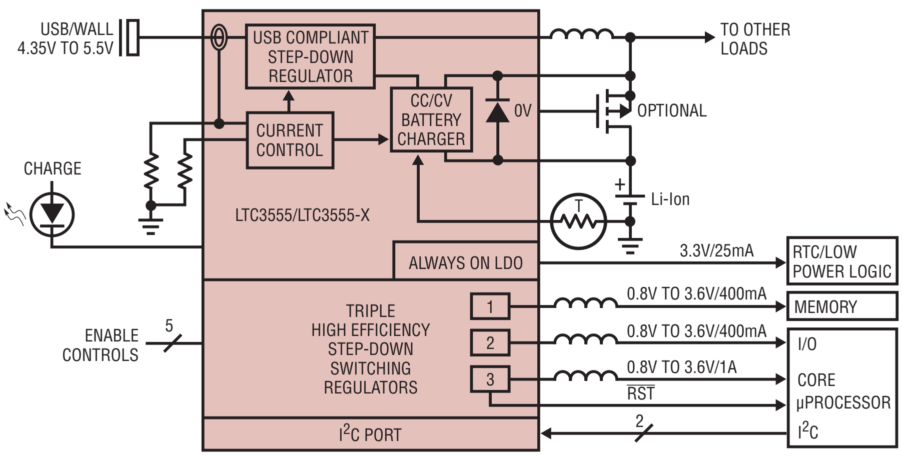


Figure 1. High efficiency PowerPath manager and triple step-down regulator

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

Part Number	PowerPath Topology	Interface	Integrated Converters and Load Current Capabilities				Package
			Buck	Buck-Boost	Boost	LDO	
LTC3555/-1/-3	Switching	I²C	1A, 400mA × 2			25mA	4mm × 5mm QFN-28
LTC3556	Switching	I²C	400mA × 2	1A		25mA	4mm × 5mm QFN-28
LTC3566	Switching			1A		25mA	4mm × 4mm QFN-24
LTC3567	Switching	I²C		1A		25mA	4mm × 4mm QFN-24
LTC3586*	Switching		400mA × 2	1A	0.8A	20mA	4mm × 6mm QFN-38
LTC3557/-1	Linear		600mA, 400mA × 2			25mA	4mm × 4mm QFN-28
LTC3455	Linear		600mA, 400mA			Controller	4mm × 4mm QFN-24
LTC3558			400mA	400mA			3mm × 3mm QFN-20
LTC3559/-1			400mA × 2				3mm × 3mm QFN-16

*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 LTC3555, 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.")

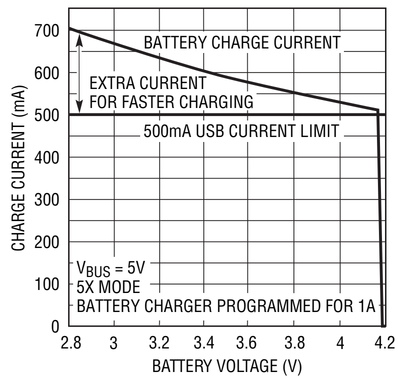


Figure 2. Switching power manager charge current vs battery voltage with a 500mA input current limit. Peak charge current = 700mA.

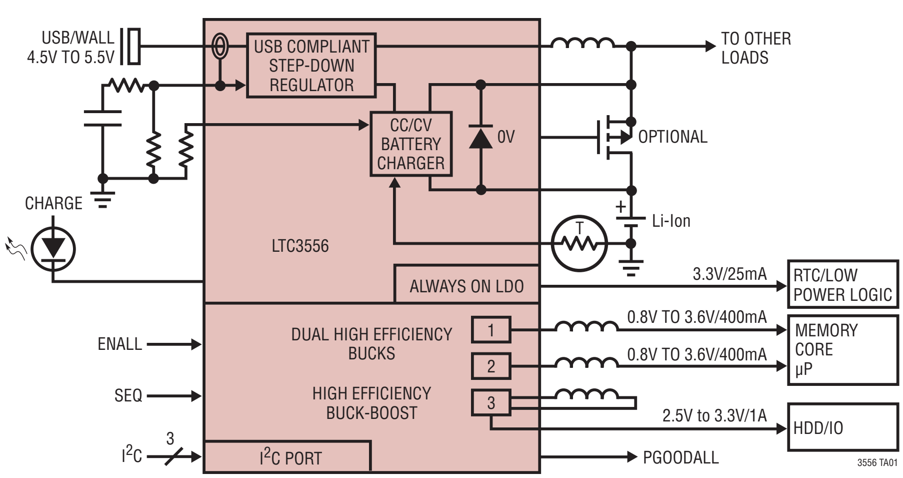
For instance, portable products with large capacity batteries (1Ahr plus) face a direct tradeoff between charge time and charger power dissipation—especially when a linear charging method is used. At relatively low charge currents, a linear charger dissipates a modest amount of power, but at currents 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 an external source rather than 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_{OUT} supply equal to V_{BAT} + 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



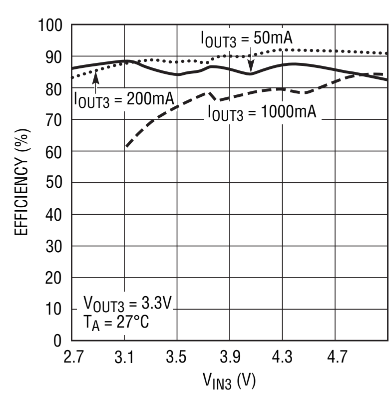


Figure 3. 1A buck-boost efficiency vs V_{IN} (LTC3556, LTC3566/7, LTC3586)

charger under worst case conditions. The LTC35xx switching power managers can charge at up to 1.2A max and provide seamless switchover to battery power when the external power is removed. In USB applications, the constant power (vs constant current) nature of the switching PowerPath controller makes it possible to charge with *more than* 500mA from a fixed 500mA USB input source, as shown in Figure 2.

Higher Current Chargers Go Hand-In-Hand with Higher Current Regulators

An obvious companion to a high performance battery charger is a corresponding set of DC/DC regulators with similar peak current handling and high efficiency. As shown in Table 1, the latest PMICs offer between one and four DC/DCs of varied topologies with peak currents reaching 1A. The new parts provide a variety of specific options to meet the high performance needs of specific applications.

Need a Buck-Boost? Not a Problem…

Most high end portable products need a minimum of three key power supplies: one for the µP core (~1.0V–1.5V), one for memory (~1.8V), and one for the I/O and main system supply (~3.3V). The LTC3555 covers all three with its built-in three synchronous bucks. However, some applications, particularly the more feature-rich variety, face occasional high peak power transients during wireless transmissions or when a hard drive spins up. The effective voltage of the battery drops during these transient currents due to the battery series resistance (BSR), trace impedance or power path losses. This poses a problem for the 3.3V supply, which can drop out of regulation even if the battery is still significantly charged. In such cases, a buck-boost regulator can save the day by riding through such battery transients—maintaining regulation as if nothing happened. Several new PMICs contain buck-boost DC/DCs specifically for this purpose. As shown in Figure 3, the PMIC buck-boosts can provide a high efficiency 3.3V output with an input that ranges from 2.7V to 5.5V.

The LTC3566 and LTC3567 products include a 1A buck-boost supply in addition to a high performance switching PowerPath controller as cornerstone high performance building blocks. The LTC3556 ups the integration further by including two 400mA buck regulators to accompany the charger and buck-boost supply. The LTC3586 contains all of the blocks of the LTC3556, but ups the integration one step further…

Need an Additional 5V Boost? The LTC3586 Has It Covered

While the buck-boost regulators are capable of regulating a 5V supply, some applications require both. To meet this need, the LTC3586 includes not only a full complement of low voltage regulators, it also includes a high

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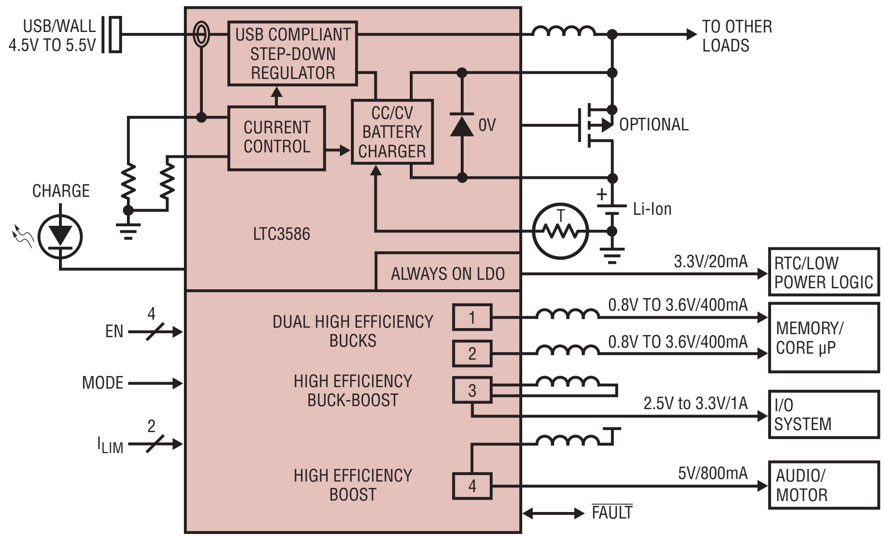

Figure 4. The LTC3586 is a high efficiency PowerPath controller, always-on LDO, dual buck, buck-boost, plus boost—all in a 4mm × 6mm package

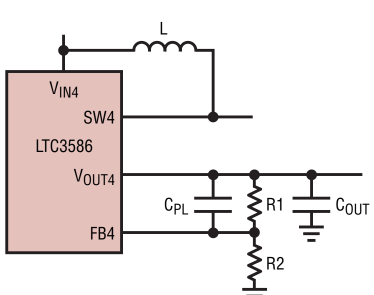

Figure 5. Boost converter application circuit

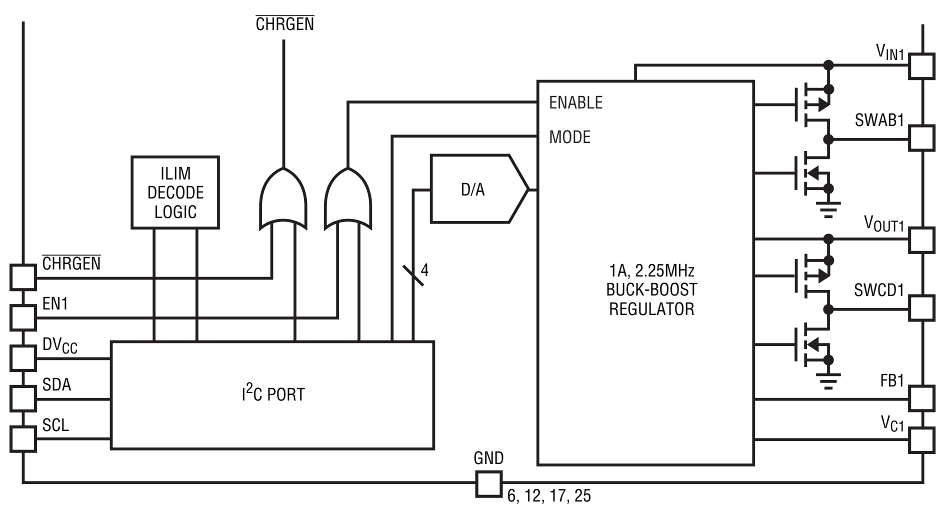

Figure 6. The LTC3567 I/O and DC/DC output voltage control interface

the range of 1.4V to 3.3V. If possible, using a lower OV_{DD} can reduce power consumption. The termination scheme is largely based on the receiver. When choosing the OV_{DD} 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.

LTC35xx, continued from page 6

power synchronous boost converter (Figure 5).

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.

I^2C, 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 I^2C 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 I^2C V_{OUT} control power-up at their maximum V_{OUT} (as determined by the FB servo point and external dividers) when enabled via simple I/O, and can independently reduce V_{OUT} by as much as 50% in equal 16-step increments via I^2C.

All DC/DC converters in all the PMICs discussed here can survive an indefinite output fault. The parts all provide a $\overline{RST}$ 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.