A Complete 500mA Linear Charger and 300mA Synchronous Buck Converter in a Tiny 3mm × 3mm DFN Package

by Ashish Kirtania

Introduction

The LTC4080 is a full-featured, single-cell 4.2V Li-Ion battery charger with an integrated synchronous buck DC/DC converter designed primarily for handheld applications. Its tiny 3mm × 3mm DFN package and low external component count provide space-savings in today's crowded circuit boards. The high operating frequency (2.25MHz) of the switching regulator minimizes overall solution footprint further by allowing the use of tiny, low profile inductors and ceramic capacitors. To extend battery life, the buck regulator offers high efficiency burst mode operation in which the regulator typically consumes only 20µA at no load.

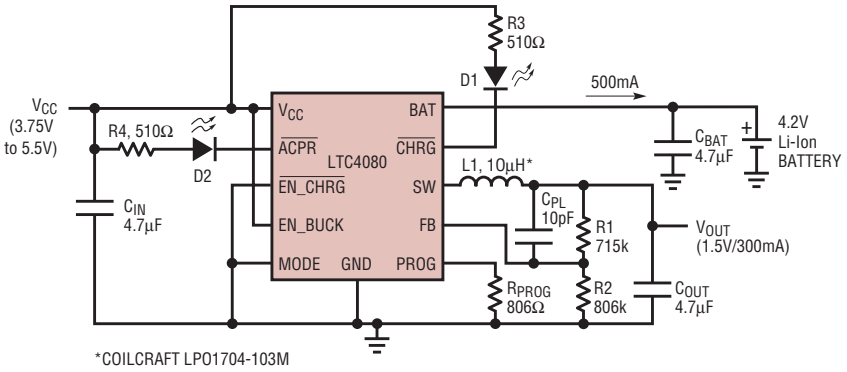

Figure 1. Full featured Li-Ion charger with thermal management and efficient buck regulator in a compact, single IC solution

Battery Charger Features

The LTC4080 battery charger uses a unique constant-current, constant-voltage, constant-temperature algorithm with programmable charge current up to 500mA and a final float voltage of 4.2V±0.5%. The maximum charge current is programmed using a single external resistor (R_{PROG}) from the PROG pin to ground. The charge current (I_{CHRG}) out of the BAT pin can be determined at any time by monitoring the PROG pin voltage (V_{PROG})and applying the following equation:

$$I_{CHRG} = \frac{V_{PROG}}{R_{PROG}} \bullet 400$$

In typical operation, the charge cycle begins in constant current mode. When the battery approaches the final float voltage of 4.2V, the charge current starts to decrease as the battery charger switches to constant-voltage mode. When the charge current drops to 10% of the full-scale charge current, commonly referred to as the C/10 point, the open-drain charge status pin, $\overline{CHRG}$, assumes a high impedance state.

An internal thermal regulator reduces the programmed charge current

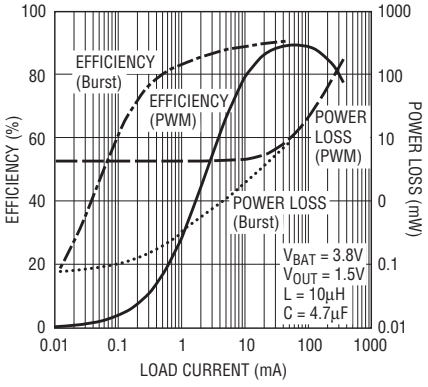

Figure 2. Efficiency of the buck regulator in Figure 1

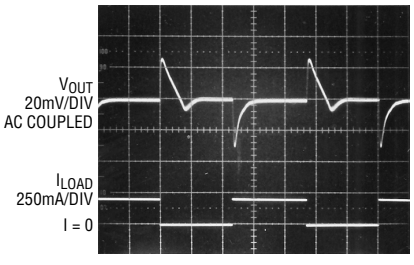

Figure 3. Transient response of the buck regulator to a 0.5mA–200mA load step

if the die temperature attempts to rise above a preset value of approximately 115°C. This feature not only protects the LTC4080 and external components from excessive temperature, it can also reduce the charge time by allowing the user to set a higher maximum charge current—essentially taking into account typical, instead of worst case, ambient temperatures for a given application.

An internal safety timer sets the maximum time for a charge cycle, typically 4.5 hours. When this time elapses, the charge cycle terminates and the $\overline{\text{CHRG}}$ pin assumes a high impedance state even if C/10 has not been reached yet. A new charge cycle of 2.25hr automatically starts if the battery voltage falls below the recharge threshold (typically 4.1V).

Trickle Charge and Defective Battery Detection

At the beginning of a charge cycle, if the battery voltage is below 2.9V, the charger goes into trickle charge mode, reducing the charge current to 10% of the programmed value. If the low voltage condition persists for one quarter of the charge cycle (1.125hr), the battery is assumed to be defective, the charge cycle terminates and the $\overline{\text{CHRG}}$ output blinks at a frequency of 2Hz with a 75% duty cycle. If, for any reason, the battery voltage rises above 2.9V, the charge cycle restarts.

Undervoltage Lockout

An internal undervoltage lockout circuit monitors the input voltage and keeps the battery charger in shutdown until the input rises above 3.6V and approximately 80mV above the battery voltage. The undervoltage condition is indicated by a high-impedance state of the open-drain status output pin $\overline{\text{ACPR}}$.

Undervoltage Charge Current Limiting

The battery charger in the LTC4080 includes undervoltage charge current limiting that prevents full charge current until the input supply voltage reaches approximately 300mV above the battery voltage. This feature is particularly useful if the LTC4080 is powered from a supply with long leads or any relatively high output impedance.

Buck Converter Features

The buck converter in LTC4080 is powered from the BAT pin and has a programmable output voltage (0.8V to V_{BAT}) providing a maximum load current of 300mA. It has two modes of operation, constant frequency mode and Burst Mode operation, selectable via the MODE pin. In constant frequency mode, also referred to as PWM mode, the switching regulator uses current mode control scheme with internal compensation and provides efficiencies up to 91% with very low ripple. The operating frequency of the switching regulator is set at 2.25MHz to minimize possible interference with the AM band. The switching regulator and the battery charger can run simultaneously or independently of each other.

Burst Mode Operation

Burst Mode operation offers higher efficiency at light loads at the cost of higher ripple at the output voltage. In this mode, the inductor current swings between a maximum value (I_{PEAK}) and a minimum value (I_{ZERO}) irrespective of the load as long as the FB pin voltage (V_{FB}) is less than the reference voltage of 0.8V. Once V_{FB} exceeds 0.8V, the control logic turns off both switches along with most of the circuitry and the regulator draws only about 20µA from the battery. When the output voltage drops about 2% from its nominal value, the switching regulator wakes up and the inductor current starts ramping again. To minimize the output voltage ripple, the regulator is limited to a maximum load current of 55mA in Burst Mode operation.

Short-Circuit Protection

In the event of a short circuit at the output or during start-up, the shallow negative slope (~V_{OUT}/L) of the inductor current may prevent the inductor from discharging enough to avoid a cumulative runaway situation over a number of switching cycles. Even the hard current limit on the main PMOS switch is no guarantee against inductor current runaway because of current sense blanking. The switching regulator in the LTC4080 prevents inductor current runaway by imposing a current limit on the synchronous NMOS switch. If the inductor current through the NMOS switch at the end of a discharge cycle is not below this limit, the regulator skips the next inductor charging cycle.

Buck Undervoltage Lockout

To prevent unreliable operation, when V_{BAT} is less than 2.7V, an undervoltage lockout circuit prevents the switching regulator from turning on. However, if the regulator is already running and the battery voltage is dropping, the undervoltage comparator does not turn it off until V_{BAT} becomes less than 2.5V.

Global Thermal Shutdown

The LTC4080 includes a global thermal shutdown which turns off the entire part (both battery charger and switching regulator) if the die temperature exceeds 160°C. The part resumes normal operation once the temperature drops approximately 14°C.

Conclusion

The LTC4080, with its complete Li-Ion battery charger and a moderately high current buck converter in a small 3mm × 3mm package, offers a very compact solution with minimum number of external components. Thermal regulation of the battery charger and the high efficiency of the converter reduce charge times and simplify thermal management.