

# Feature-Packed Charger Handles All Battery Chemistries and Produces 3A/50W for Fast Charging from a 4mm × 4mm QFN

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## Introduction

The LTC4009, LTC4009-1 and LTC4009-2 are a family of high power battery charger ICs that achieve a small circuit size and high performance without compromising functionality. The family operates with high efficiency while packing the most desirable charging and protection features into a space-efficient 20-lead 4mm × 4mm QFN package. When combined with just a few external components and termination control, the LTC4009 family facilitates construction of chargers capable of delivering up to 3A to batteries with output power levels approaching 50W. These ICs are

especially well-suited to implementing microprocessor-controlled chargers for all chemistry types, including smart batteries.

## High Performance

The LTC4009 family builds upon the proven quasi-constant frequency, constant off-time PWM control architecture found in other Linear Technology battery chargers such as the LTC4006, LTC4007, LTC4008, and LTC4011. This buck topology provides continuous switching with synchronous rectification, even with no load current.

Normally the charger operates over a wide duty cycle range in a manner similar to a fixed-frequency PWM controller running at 550kHz. However, if the input or output voltage drives the duty cycle to extremes, below 20% or above 80%, the LTC4009 smoothly adjusts the operating frequency downward to avoid pulse-skipping that might otherwise begin to occur at 550kHz. Under very low dropout conditions requiring high duty cycle operation, the internal watchdog timer on the LTC4009 prevents the charger from switching below 25kHz. This allows the charger to achieve a

Table 1. LTC4009 family features

Feature	LTC4009	LTC4009-1	LTC4009-2	LTC4008
Output Voltage Selection	External Resistor Divider	Pin Programmable at 4.1V/cell	Pin Programmable at 4.2V/cell	External Resistor Divider
Output Voltage Accuracy (Room Temperature)	±0.5% + Divider Error	±0.6%	±0.6%	±0.8% + Divider Error
Maximum Charge Current	3A	3A	3A	4A
Charge Current Accuracy	±5%	±5%	±5%	±5%
Input Current Limit Accuracy	±4%	±4%	±4%	±7%
Input Current Limit/Indicator				
External PWM Switching MOSFETs	All NFET	All NFET	All NFET	PFET/NFET
Nominal PWM Frequency	550kHz	550kHz	550kHz	300kHz
Shutdown Pin				Merged with ACP
C/10 Indicator				
Charge Current Monitor				
Termination Method	External	External	External	External
Fault Indicator				
Thermistor Interface				
INFET Control				

maximum duty cycle of 98% or higher without producing frequencies that could extend down into the audible range.

With a synchronous rectifier, not only are high current applications supported at efficiency levels greater than 90%, but switching activity is continuous and independent of the load current. Maintaining full continuous conduction mode in the inductor at final output voltage, under no-load conditions, avoids pulse-skipping which can generate audible noise and provide poor load regulation.

The input current limit accuracy is typically  $\pm 3\%$  and a maximum of  $\pm 4\%$  over the full operating temperature range. Output voltage accuracy is typically  $\pm 0.5\%$  and a maximum of  $\pm 0.8\%$  over temperature.

### Small PCB Footprint

Besides its small surface mount package size, the LTC4009 family offers other features that drive down the total solution size.

For instance, as shown in Figure 1, the family supports direct drive of both an N-channel MOSFET power switch and N-channel MOSFET synchronous

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rectifier. N-channel MOSFETs are desirable in high current applications because of their lower  $R_{DS(ON)}$ , and the LTC4009 family uses a novel adaptive gate drive that is insensitive to MOSFET inertial delays to avoid overlap conduction losses. Many suppliers now source dual N-channel MOSFETs in a single space-efficient package, often with individual drive

capabilities tailored to synchronous buck PWM switching topologies.

Increasing the switching frequency to 550kHz and adjusting internal bias circuits to allow higher charge current ripple minimize both the inductor size and output capacitance requirements. This is particularly important because these components tend to dominate the overall solution size due to continual improvements in IC and passive SMD packaging technology.

The physical layout of a typical 3A application is shown in Figure 3, requiring only 240mm<sup>2</sup> of board space.

### A Rich Tradition

The LTC4009 family builds upon the general purpose features offered by the LTC4008 and the output voltage programming convenience afforded by the LTC4006. Each member of the LTC4009 family contains the same charge current and input current limit programming features, along with a full complement of charge monitoring, safety and fault management functions. The LTC4009 has a fully adjustable output voltage, which is set with a simple resistor divider. Charge

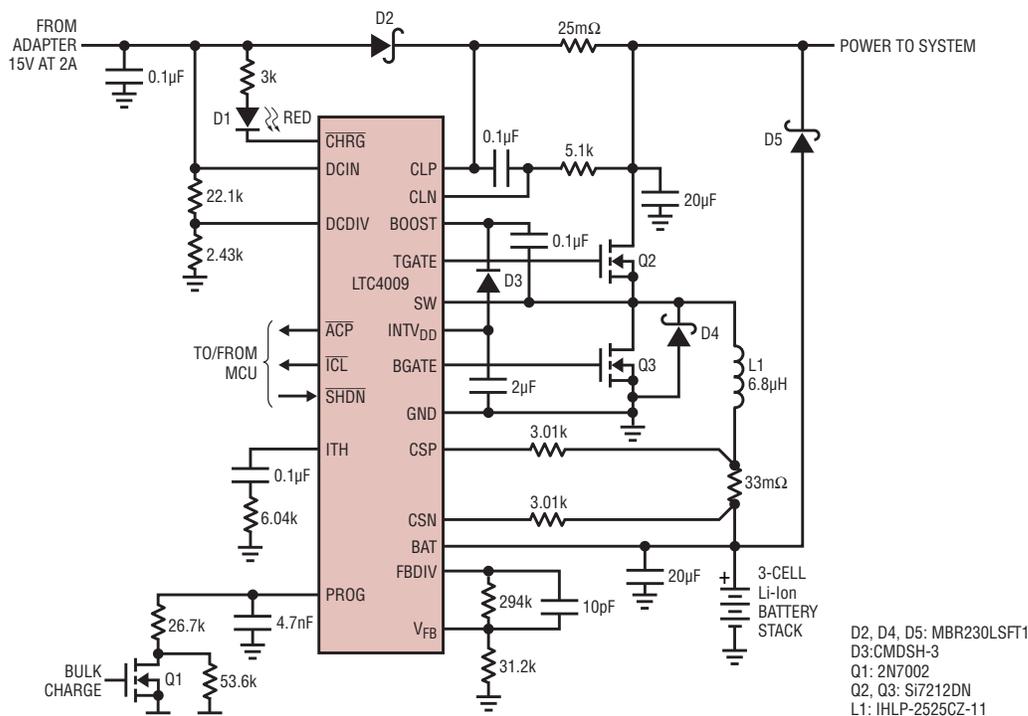


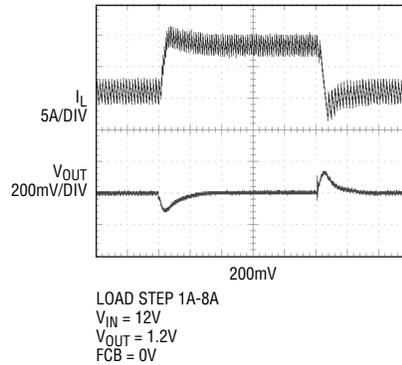
Figure 1. A 12.6V, 3A lithium-ion charger



part are shown in Table 1. Soft-start and latch off functions are controlled by the RUN/SS pin, preventing inrush current and current overshoot during startup, and providing the option of latch-off if an under voltage or short circuit is presented. An open drain power-good pin monitors the output and pulls low if the output voltage is  $\pm 10\%$  from the regulation point.

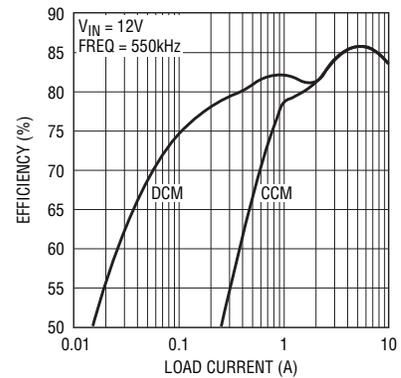
### Conclusion

The LTC3608, LTC3609, LTC3610 and LTC3611 buck regulators offer the efficiency and power output capability of separate (controller + discrete) MOSFET solutions with the ease-of-use and space-saving advantages of traditional MOSFET-on-the-die monolithics. These parts also yield higher efficiencies than



**Figure 3. Transient response for the typical LTC3608 application represented in Figure 1 with a load step of 1A to 8A**

traditional monolithic solutions. They conserve power, save space, and simplify power designs. They reduce discrete components over controller-based solutions, making them a



**Figure 2. Efficiencies for a typical LTC3608 application in discontinuous conduction mode (DCM) and continuous conduction mode (CCM)**

good fit in everything from low power portable device applications such as notebook and palmtop computers to high-power industrial distributed power systems. 

**Table 1. Integrated MOSFET buck regulators**

	LTC3610	LTC3611	LTC3608	LTC3609
$PV_{IN}$ Max	24V	32V	18V	32V
$I_{LOAD}$ Max	12A	10A	8A	6A
Package	9mm × 9mm × 0.9mm 64-pin	9mm × 9mm × 0.9mm 64-pin	7mm × 8mm × 0.9mm 52-pin	7mm × 8mm × 0.9mm 52-pin
$R_{DS(ON)}$ Top FET	12m $\Omega$	15m $\Omega$	14m $\Omega$	19m $\Omega$
$R_{DS(ON)}$ Bottom FET	6.5m $\Omega$	9m $\Omega$	8m $\Omega$	12m $\Omega$

LTC4009, continued from page 20

LTC4009 family monitors the voltage across the input blocking diode for unexpected voltage reversal. Initial startup, restarts from fault conditions, and charge current reduction during input current limit are also carefully controlled to avoid producing reverse current.

All members of the family provide an input current limit flag to tell the system when the adapter is running at over 95% of its current capacity. Finally, each IC features internal over-temperature protection to prevent silicon damage during elevated thermal operation.

Recovery from all fault conditions is under full control of the analog feed-

back loops, which guarantees charging remains suspended until the internal feedback loops respond coherently and report the need to supply current to the load to maintain proper voltage or current regulation.

### Conclusion

The LTC4009 family integrates a full set of charger building blocks in a small PCB footprint. The result is a high power battery charger IC with high precision and a full set of monitoring and fault handling features.

The LTC4009 provides adjustable output voltage control with a simple, external, user-programmed resistive voltage divider. As such, it is suitable as a general purpose charger that works

with multiple battery chemistries and supercaps. It offers direct control over the entire charge process, facilitating implementation of a wide range of charge termination algorithms with an external microprocessor.

The LTC4009-1 and LTC4009-2 feature pin-programmable output voltage for common lithium-ion or lithium-polymer battery pack configurations with one to four series cells. For these chemistries, the number of precision external application components is reduced without sacrificing accuracy. Both 4.1V/cell (LTC4009-1) and 4.2V/cell (LTC4009-2) options are available, allowing the user to balance capacity and safety per the demands of the application. 