1.5A Monolithic Buck-Boost DC/DC Converter with Up to 95% Efficiency Features 2.5V–15V Input and Output Voltage Ranges

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Multicell high capacity batteries are increasingly becoming commonplace in handheld devices and industrial instruments that receive their power from a variety of sources. To maximize battery run time and support the variety of power sources, voltage regulators in multipower source systems must be able to maintain a constant output voltage even as the input voltage source resides above, below or equal to the output. This can be accomplished using two separate power converters with two controller ICs. A better solution is to use a single buck-boost DC/DC converter, which offers a smaller, simpler and more efficient design, attributes critically important in handheld devices.

The LTC3111 is a monolithic buck-boost converter with input and output voltage ranges of 2.5V to 15V and an output current capability of 1.5A. It allows conversion from a variety of power sources such as single or multi Li-ion cells, lead acid batteries, capacitor banks, USB cables or wall adapters.

In addition to its wide operating range, the LTC3111 features Linear Technology's proprietary low noise buck-boost PWM control architecture, effectively eliminating jitter and EMI that can occur when crossing the boundary between step-up and step-down operation. This reduces or eliminates the need for expensive filtering or shielding for noise sensitive data conversion or RF circuitry in the system. Selectable Burst Mode® operation extends the operating time when battery-powered devices are in idle by substantially reducing the quiescent current of the power converter.

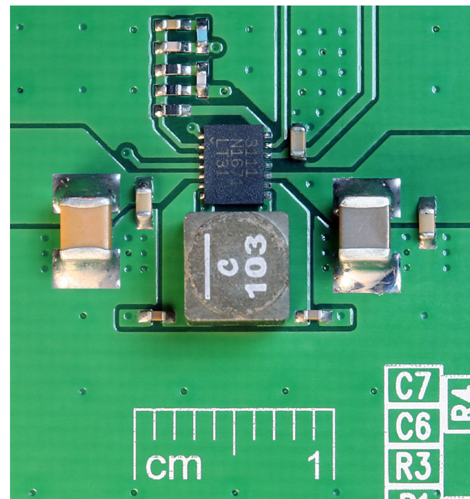
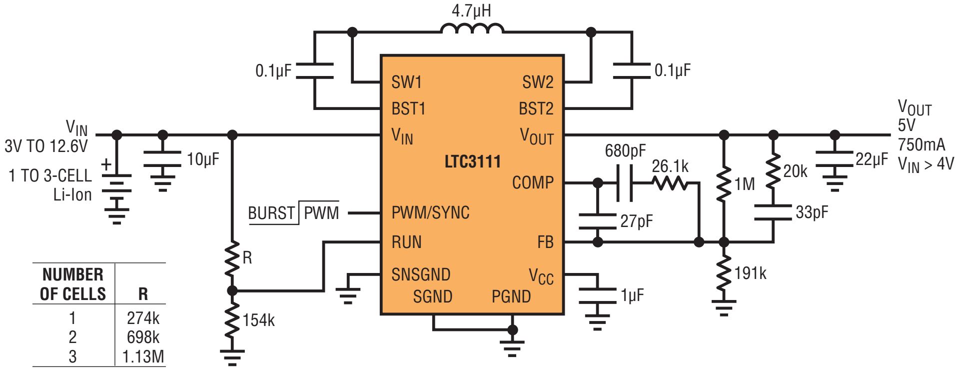


Figure 1. LTC3111-based 18W solution

An accurate run threshold provides the ability to precisely program the turn-on threshold voltage of the converter. The integrated fault protection features include: current limit, thermal shutdown and short-circuit protection, which provides robust operation in harsh environments. For applications where component size is critical, the 800kHz default switching frequency can be synchronized up to 1.5MHz.

Figure 2. One, two and three Li-ion cells can be used in this solution with the LTC3111's accurate RUN threshold feature



NUMBER OF CELLS	R
1	274k
2	698k
3	1.13M

The LTC3111 based converter shown in Figure 1 can generate 18W of power with a 12V output. The solution footprint is less than 180mm², more compact than a controller-based buck-boost and much more efficient than a complex dual-inductor SEPIC converter design at similar power levels. The main external components are limited to the input, output filter capacitors and the power inductor. The LTC3111

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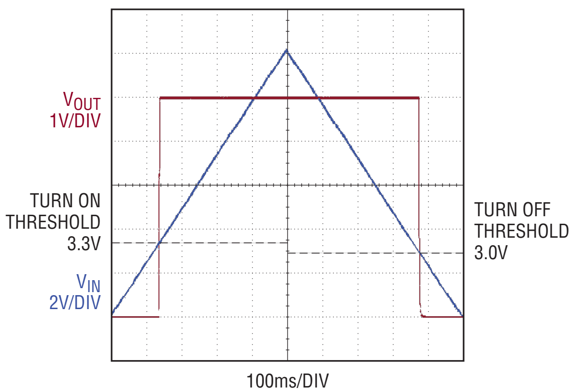


Figure 3. LTC3111 ramped input voltage response using the accurate run for a single Li-ion solution

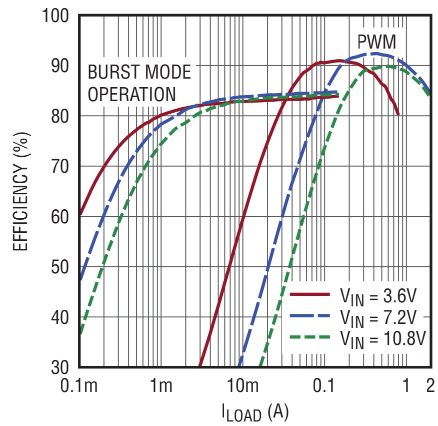


Figure 4. 5V output efficiency from one, two and three Li-ion cells

is offered in a thermally enhanced 16-lead 4mm × 3mm DFN or 16-lead MSOP package.

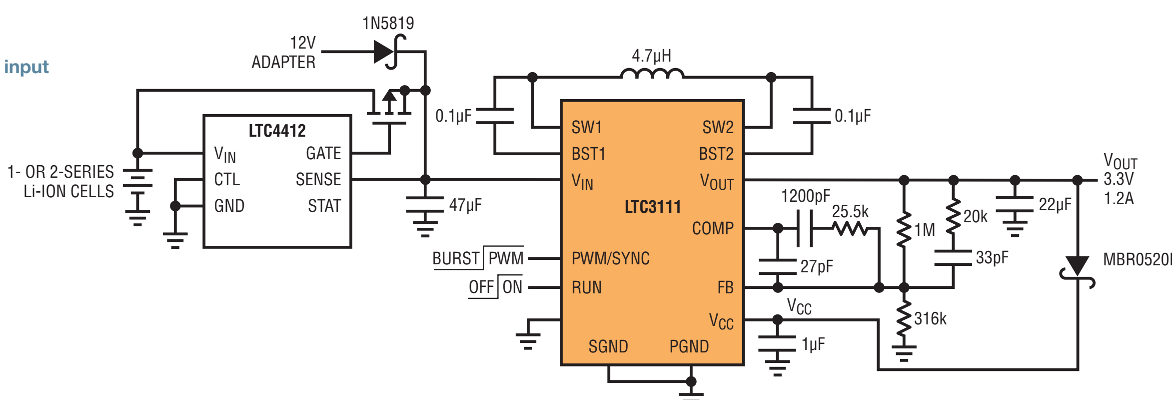
ACCURATE RUN THRESHOLD WITH 1-, 2- AND 3-CELL LI-ION

The LTC3111's RUN pin can either be used to enable/disable the converter via digital select, or to set an accurate user-programmable undervoltage lockout (UVLO) threshold—by a resistive divider from V_{IN} to ground. The LTC3111's RUN threshold of 1.2V (±5% over temperature) allows customization of the turn-on threshold voltage of the converter. Once enabled, 120mV of hysteresis is introduced at the RUN pin, requiring the source input voltage to drop 10% before disabling power conversion.

Figure 2 shows an application circuit where the accurate RUN pin threshold is used to turn the LTC3111 converter on/off when powered from a one, two or three Li-ion cell battery. For the single cell case, R is 267k, configuring the LTC3111 RUN pin to turn on when the input voltage is greater than 3.3V and to turn off when the input voltage drops below 3V.

This technique can be applied to two or three series cell designs by changing the value of R, as shown in the table for Figure 2. The output voltage response to a slowly ramped V_{IN} for the single cell case is shown in Figure 3. V_{OUT} in the single cell configuration turns on when the input voltage reaches 3.3V and turns off at 3V. Similarly, this plot can be scaled for 2- and 3-cell cases, where turn-on/

Figure 5. LTC4412 PowerPath™ controller selects highest voltage input to power the LTC3111 converter



The LTC3111 includes circuitry to minimize loop gain variation, resulting in improved line transient response. Regulation for V_{OUT} = 3.3V remains within 50mV, or 1.5%, during a 20μs, 7.2V-to-12V, V_{IN} rise and fall transition with a 22μF output capacitor and 1A load.

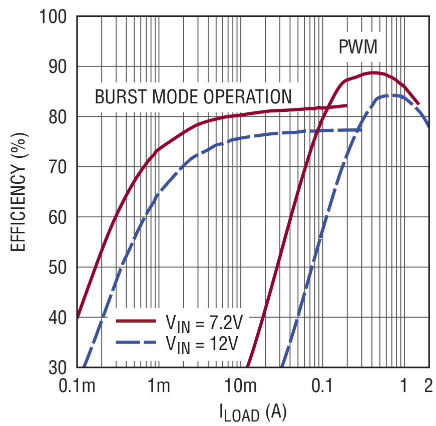


Figure 6. LTC3111 efficiency vs load current V_{OUT} = 3.3V, V_{IN} = 7.2V and 12V

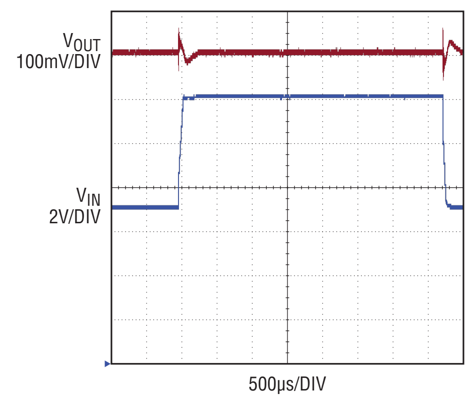


Figure 7. Line response for V_{OUT} = 3.3V, V_{IN} stepped from 7.2V to/from 12V

turn-off thresholds are 6.6V/6V and 9.9V/9V, respectively. The accurate RUN feature can also be applied to sources where operation must be restricted to a minimum input operating voltage such as a bank of capacitors, lead acid or NiCd batteries.

Efficiency curves for the one, two and three Li-ion cell designs operating at their typical voltages are shown in Figure 4. Peak efficiencies of greater than 90% are achieved over all three battery voltages. Note that the maximum load current capability for a 5V output decreases when the input voltage is less than 6V. The LTC3111 data sheet provides performance curves showing maximum output current capability versus input voltage in PWM and Burst Mode operation for various output voltages to aid in determining if the load can be supported over a specific input range.

MULTIPLE INPUT SOURCES

The wide operating range of the LTC3111 makes it easy to power devices from multiple input sources. Figure 5 shows an application where the LTC4412 PowerPath controller (SOT-23 package) selects from the higher of two input sources. The LTC4412 maintains a 20mV forward voltage across the selected P-channel MOSFET, keeping losses to a minimum. In this circuit, the LTC4412 switches the input of the LTC3111 to the greater of a 7.2V lithium ion battery or 12V wall adapter.

Efficiency curves versus load current for the 3.3V output, based on the two input sources, are given in Figure 6. Peak efficiencies of greater than 89% are achieved. Selectable Burst Mode operation with 49μA of typical sleep current extends high efficiency over two decades of load current.

The LTC3111 includes circuitry to minimize loop gain variation, resulting in improved line transient response. As illustrated in Figure 7, V_{OUT} regulation is maintained within 50mV, or 1.5%,

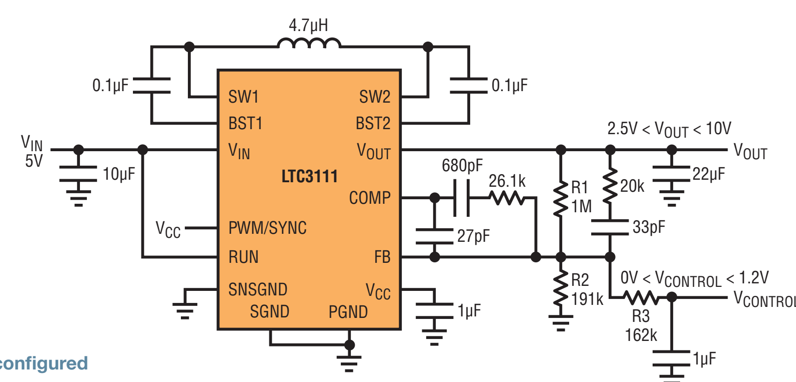


Figure 8. LTC3111 configured as a variable output supply

The LTC3111 provides low noise buck-boost conversion for a variety of applications requiring an extended input or output voltage range. The LTC3111's ability to support heavy loads makes it ideal for power hungry devices. Solution size and conversion efficiency benefit from the 90mΩ internal N-channel MOSFET switches and thermally enhanced packages.

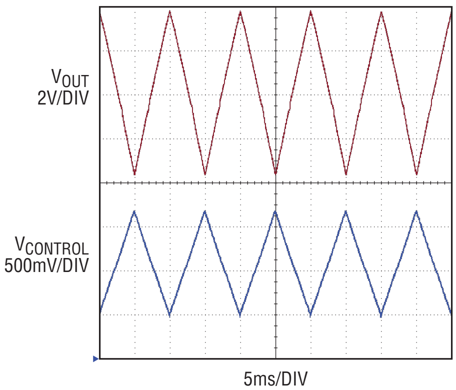


Figure 9. Variable output response using the LTC3111

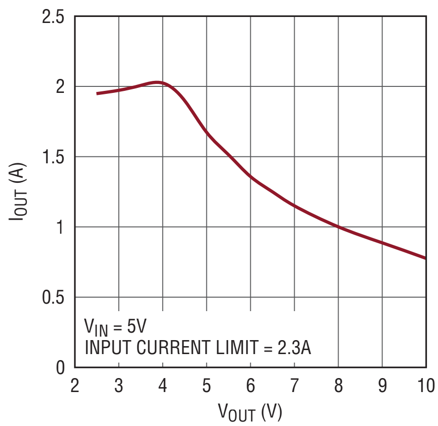


Figure 10. Maximum output current in PWM mode vs output voltage for V_{IN} = 5V

during the 20µs rise and fall transition with a 22µF output capacitor and 1A load in stepdown operation.

VARIABLE OUTPUT VOLTAGE USING THE LTC3111

For applications such as motor control, lighting or power supply margin testing, the LTC3111 can be configured as a variable voltage supply. This can be accomplished in a number of ways. Figure 8 shows one method: adding a summing resistor between the FB pin and a control voltage ($V_{CONTROL}$).

The programmed output voltage can be calculated using the following equation:

$$V_{OUT} = 0.8V\left(1+\frac{R1}{R2}\right)+\frac{R1}{R3}(0.8V - V_{CONTROL})$$

where R1 is the resistor connected between V_{OUT} and FB, R2 is the resistor connected from FB and ground and R3 is the resistor connected from FB and $V_{CONTROL}$.

Figure 9 shows the output voltage response of a 0V to 1.2V ramped control signal operating at 100Hz. The corresponding output voltage swings from 10V to 2.5V, providing an inverting gain of 6.2 from $V_{CONTROL}$ to V_{OUT}. The low noise PWM control provides low distortion and high quality replication of the input signal.

When using the LTC3111 as a variable output voltage regulator, the maximum load current capability of the LTC3111 is reduced when $V_{OUT} > V_{IN}$ (i.e., when the part is in boost or step-up mode). As Figure 10 shows, the maximum output current capability is effectively reduced by the step-up ratio of the converter.

For example, the output current capability when $V_{OUT} = 2V_{IN}$ is roughly one half the capability when $V_{OUT} = V_{IN}$. In the example application above, a fixed 500mA load is applied to the output, which the part is capable of supplying at all output voltages. To ensure converter stability, compensation values for this application are determined at the highest boost ratio of V_{IN} = 5V to V_{OUT} = 10V.

SUMMARY

The LTC3111 provides low noise buck-boost conversion for a variety of applications requiring an extended input or output voltage range. The LTC3111's ability to efficiently support heavy load currents makes it ideal for power hungry devices. Solution size and conversion efficiency benefit from the 90mΩ internal N-channel MOSFET switches and thermally enhanced packages. Low quiescent current Burst Mode operation extends high efficiency over several decades of load current, enabling longer run times in many battery powered applications. ■