Single-IC Converter Operates Buck and Boost to Provide an Output that is Within the Input Voltage Range

by David Burgoon

Introduction

Generating an output voltage that is always above or below the input voltage range can easily be handled by conventional boost or buck regulators, respectively. However, when the output voltage is *within* the input voltage range, as in many Li-Ion battery powered applications requiring a 3V or 3.3V output, conventional designs fall short, suffering variously from low efficiency, complex magnetics, polarity inversion and circuit complexity. The LTC3785 buck-boost controller facilitates a simple, efficient, low parts-count, single-converter solution that is easy to implement and does not have any of the drawbacks associated with conventional circuits.

3.3V, 3A Converter Operates from 2.7V–10V Source

Figure 1 shows a synchronous, 4-switch, buck-boost design that provides a 3.3V, 3A output from a 2.7V–10V input—perfect for a Li-Ion and/or loosely regulated wall adapter input. The controller provides short-circuit protection, offering a choice of burp-mode or latch-off operation for severe overload faults. Other features include soft-start, overvoltage protection (OVP) and a 2.7V–10V output range.

The circuit produces seamless operation throughout the input voltage range, operating as a synchronous buck converter, synchronous boost converter, or a combination of the two through the transition region. At input voltages well above the output, the converter operates in buck mode. Switches Q1A and Q1B commutate the input voltage, and Q2A stays

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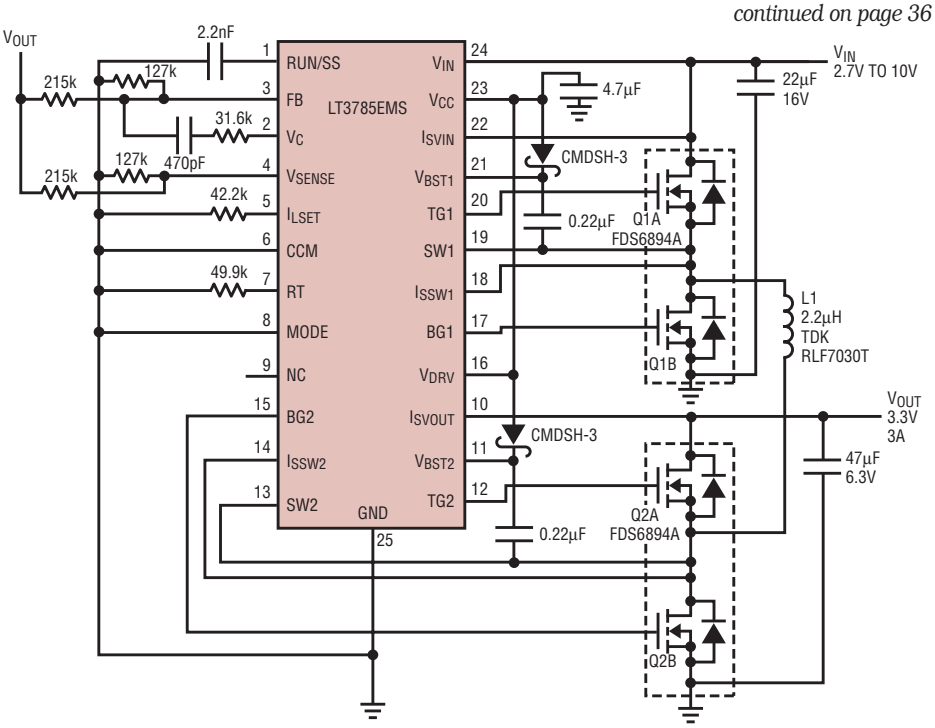

Figure 1. Schematic of buck-boost converter using LTC3785 to provide 3.3V at 3A out from a 2.7V–10V source

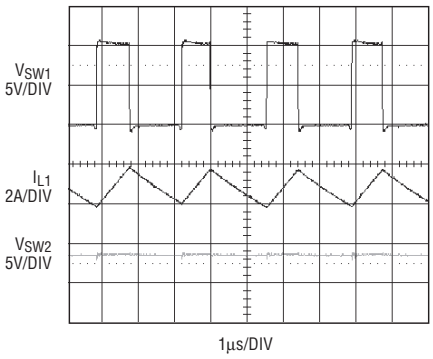

Figure 2. Input-side and output-side switch waveforms along with inductor current for buck mode ($10V_{IN}$)

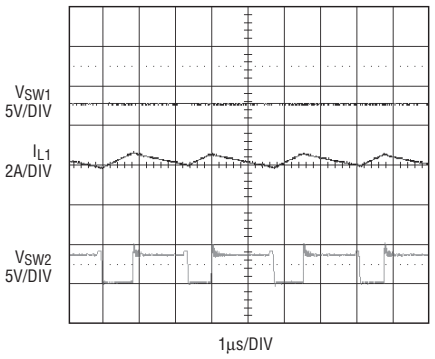

Figure 3. Input-side and output-side switch waveforms along with inductor current for boost mode ($2.7V_{IN}$)

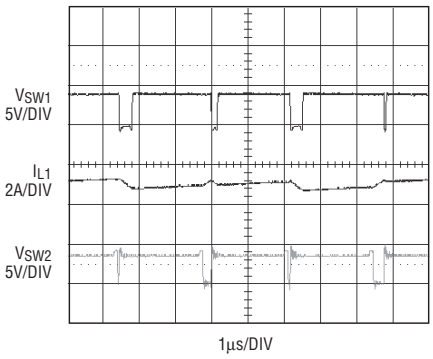

Figure 4. Input-side and output-side switch waveforms along with inductor current for buck-boost mode ($3.8V_{IN}$)

inrush currents while charging the output caps during startup, as well as minimizing voltage overshoot when starting into light loads.

For those applications requiring a power good output on the third channel, the LTC3545-1 version of the part substitutes a PGOOD3 output in place of the MODE/SYNC pin. The option of an external clock is not available on this version, and the part enters Burst Mode operation at light load currents.

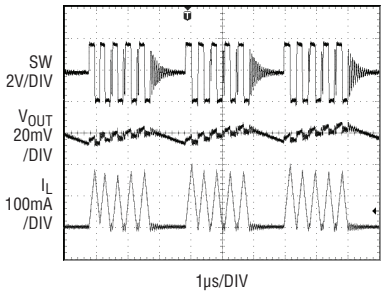

Figure 5. At low load currents, Burst Mode operation improves efficiency without degrading output voltage ripple.

Minimal Channel Crosstalk

A potential problem with multiple output regulators is the interaction between channels when one of the channels undergoes a load transient. Figure 4 shows the response on channels 2 and 3 to a 0mA to 500mA load step on channel 1. Channels 2 and 3 are each loaded at 400mA. In each case, the crosstalk is on the order of 1mV to 2mV.

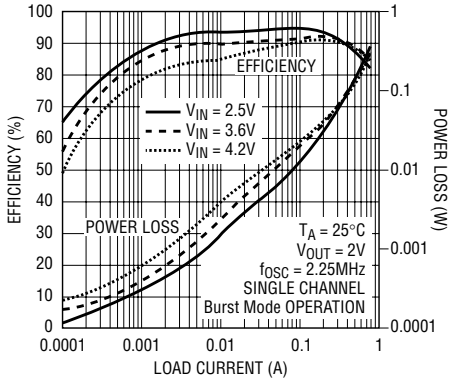

Figure 6. Burst Mode operation maintains high efficiency at low load currents.

High Efficiency with Low Ripple

At low load currents, the LTC3545 operates in either pulse-skipping mode or Burst Mode operation depending on the state of the MODE/SYNC pin. Though pulse-skipping mode exhibits lower output ripple, the ripple in Burst Mode operation is still quite low while maintaining the added advantage of better efficiency at the lightest loads. The Burst Mode operation and Burst Mode efficiency are shown in Figures 5 and 6.

Conclusion

The LTC3545 is a unique part with tremendous flexibility. It greatly simplifies system and board design where multiple voltage supply rails are needed without sacrificing the features and performance found in individual regulators. The LTC3545 is ideally suited for battery powered applications where multiple or isolated voltage rails are required and board space is at a premium.

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on, connecting L1 to the output. As the input voltage is reduced and approaches the output, the converter approaches maximum duty cycle on the input (buck) side of the bridge, and the output (boost) side of the bridge starts to switch, thus entering the buck-boost or 4-switch region of operation. As the input is reduced further, the converter enters the boost region at the minimum boost duty cycle. Switch Q1A stays on, connecting the inductor to the input, while switches Q2A and Q2B commutate the output side of the inductor between the output capacitor and ground.

In boost mode, this converter has the ability to limit input current and to shut down and disconnect the source from the output—two very desirable features that a conventional boost converter cannot provide. Figures 2, 3, and 4 show input-side and output-side switch waveforms along with inductor current for buck ($10V_{IN}$), boost ($2.7V_{IN}$), and buck-boost ($3.8V_{IN}$) modes of operation.

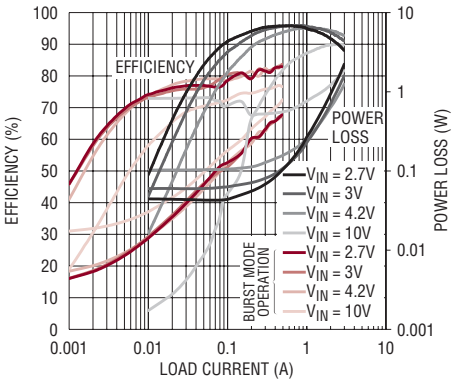

Figure 5. Efficiency in normal mode and Burst Mode operation

95% Efficiency

Figure 5 shows efficiency in both normal (not forced continuous conduction) and Burst Mode operation. Very high efficiency of 95% is achieved at typical loads. This level of performance results in part from sophisticated controller features including high side drivers for N-channel MOSFETs and $R_{DS(ON)}$ current sensing for current limit. Even higher efficiencies are possible by using a larger inductor and better MOSFETs as they become available. Efficiency at 10V in would benefit from an inductor with a low-loss ferrite core, especially at light loads. This circuit easily fits in $0.6in^2$ with components on both sides of the board. The curves show how Burst Mode operation improves efficiency at extremely light loads, dramatically enhancing battery life in applications such as memory that must maintain housekeeping functions even when the system is turned off.

Conclusion

The LTC3785 buck-boost controller overcomes the deficiencies of traditional designs with a smooth-transition, 4-switch, single-IC solution. It is elegant in its simplicity, high in efficiency and requires only a small number of inexpensive external components. The LTC3785 is available in a small 4mm × 4mm QFN package as well as a 28-lead SSOP.