High Voltage Step-Down Controller Delivers High Power with Minimum Number of Components

by Stephanie Dai and Theo Phillips

Introduction

The LTC3824 is a non-synchronous buck controller that accepts inputs from 4V to 60V and is robust in the presence of large input transient voltages (Figure 1). It draws just 40µA of quiescent current in Burst Mode operation, prolonging run time in battery-powered applications. To handle the wide range of temperatures found in automotive and industrial applications, the LTC3824 comes in a thermally enhanced 10-pin MSE package.

12V/2A from a Wide Input Voltage Range

A typical LTC3824 application (Figure 2) can deliver up to 2A of continuous load current, and provides up to 90% efficiency at 1A (Figure 3). Sturdy 2A, 8V gate drivers accommodate industrial high voltage P-channel MOSFETs. By using a P-FET as a main switch, the controller is able to operate up to 100% duty cycle, and does not require the boost capacitor and diode

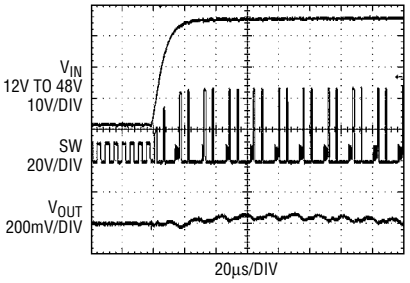

Figure 1. The output voltage remains steady regardless of wide swings in the input voltage.

found in N-channel buck regulators. This means that whenever the input voltage dips below the programmed output voltage, the output voltage gracefully follows the input voltage (reduced by I^2R losses through the sense resistor, P-FET and the inductor) (Figure 4). LTC3824's current mode architecture provides excellent line and load transient response with few compensation components. Input current is continuously sensed through a resistor in series with the P-FET, providing accurate current limiting and rapid overvoltage and short circuit protection.

Two Modes of Operation

The LTC3824's SYNC/MODE pin allows the user to select between operating modes that improve efficiency at light loads. If the pin is left open or held above 2V, the part commences Burst Mode operation at about 1/3 of the programmed current limit. During Burst Mode operation, switching cycles are skipped to reduce switching losses, especially important to extend battery life in mobile applications. Grounding or applying an external clock to the SYNC/MODE pin forces the controller into pulse skip mode at light load. In pulse skip mode, the burst clamp is set to zero current, which limits the minimum peak inductor current to a level set by the minimum on-time of the control loop. Although pulse skip mode is not quite as efficient as Burst Mode operation at very light loads, it reduces V_{OUT} ripple while operating at a constant frequency, thus reducing possible noise in the radio and audio ranges and simplifying noise filtering. The operating frequency can be programmed with a single resistor R_{SET}, or it can synchronize to an ex-

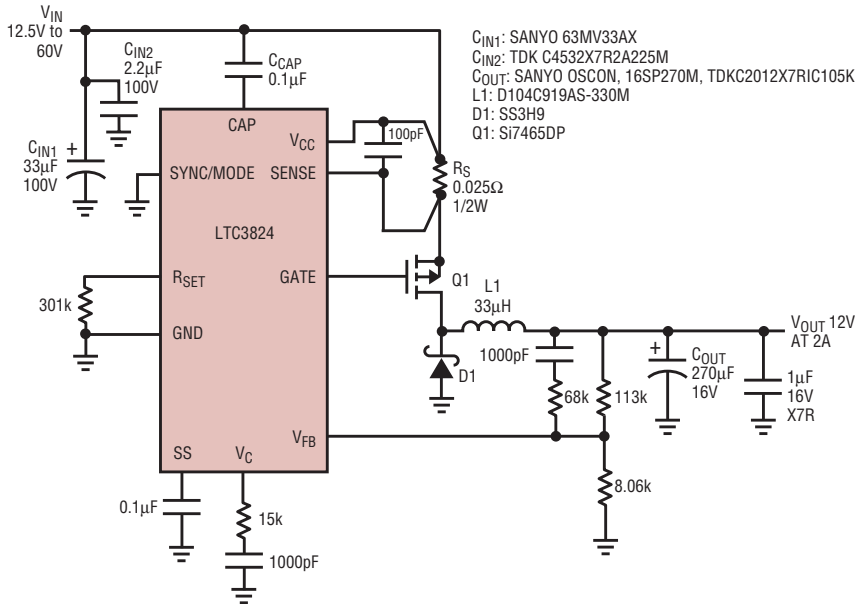

Figure 2. A typical LTC3824 application

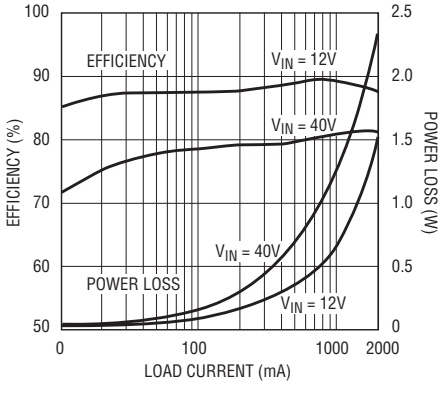

Figure 3. Efficiency for the circuit of Figure 2 is as high as 90% at moderate loads.

ternal clock from 200kHz to 600kHz. Synchronization facilitates integration into applications using other switching regulators.

Essential Soft-Start, Short Circuit and Overvoltage Protection

The LTC3827 includes a programmable soft-start time, which requires only a single external capacitor between the SS pin and ground. At high input voltages, a relatively large capacitor prevents inrush currents during start-up. This in turn prevents output overvoltage and sudden drops in V_{IN}, which in the extreme case could force the LTC3824 below its 4V undervoltage lockout. During soft-start, the voltage on the SS pin, V_{SS}, acts as the reference voltage that controls the output voltage ramp-up. The effective range of V_{SS} during ramp-up is 0V to 0.8V. The typical time for the output to reach the programmed level is determined by the selected soft-start capacitor and the SS pin's 7µA pull-up current: $T_{SS} = (C \bullet 0.8V)/7\mu A$.

Short circuit and overvoltage protection are designed to keep the LTC3824 operating normally even under extreme conditions. In normal operation, the feedback voltage V_{FB} is regulated to 0.8V. If V_{FB} drops below 0.5V, the LTC3824's switching frequency folds back to 50kHz on the assumption that inductor current is ramping up too quickly during the MOSFET's on-time. Runaway is avoided by providing extra time for the inductor current to discharge. An overvoltage comparator monitors the voltage at V_{FB}, and in the event of an overshoot adjusts the V_C voltage downward, keeping the MOSFET off. The overvoltage protection (OVP) threshold is lowered during light load Burst Mode operation, which causes cycles to be skipped. The OVP threshold goes up when load current increases. This scheme maintains protection yet ensures the tightest possible output voltage regulation.

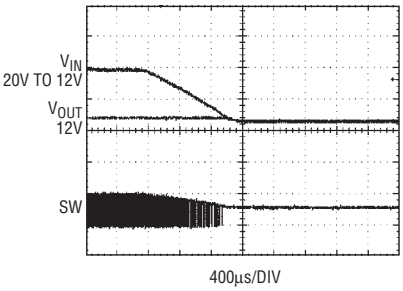

Figure 4. When the input voltage drops to below the programmed output voltage, the output voltage gracefully tracks the input voltage.

Figure 5. The LTC3824 comes in a small, thermally enhanced MSE package.

Conclusion

LTC 3824 is a high voltage step-down controller with essential features for many sophisticated industrial and automotive systems. It comes in a tiny thermally enhanced 10-pin MSE package (Figure 5) to save space, and is highly configurable, including the ability to synchronize with external frequency sources, two modes of light load operation, and programmable soft-start and current limit.

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when the channel 2 feedback voltage is within ±7.5% window.

The LTC3828 incorporates protection features such as current limit, short circuit current foldback limit, input undervoltage lockout and output overvoltage protection. The current comparators have a maximum sense voltage of 75mV resulting in a maximum MOSFET current of $75mV/R_{SENSE}$. If the output falls below 70% of its nominal output level, then the maximum sense voltage is progressively lowered from 75mV to 25mV. A comparator monitors the output for overvoltage condition. When the comparator detects the feedback voltage higher than 7.5% of reference voltage, the top MOSFET is turned off and the bottom MOSFET is turned on.

Table 1. The phase relationships of the two output channels and the clock out (CLKOUT) pin depend on the voltage at the PHSMD pin.

V_{PHSMD}	GND	OPEN	$INTV_{CC}$
Controller 1	0°	0°	0°
Controller 2	180°	180°	240°
CLKOUT	60°	90°	120°

Phase-Locked Loop and Phase Mode Selection

The LTC3828 includes a phase-locked loop comprising an internal voltage controlled oscillator and phase detector. This allows the top MOSFET turn-on to be locked to the rising edge of an external source, where the frequency range of the voltage controlled oscillator is ±50% around the center frequency. A voltage applied to the PLLFLTR pin of 1.2V corresponds to a frequency of approximately 400kHz. The nominal operating frequency range is 260kHz to 550kHz.

In the LTC3828, there is an internal master oscillator running at a frequency twelve times that of each controller's frequency. The PHSMD pin (UH package only) determines the relative phases between the internal controllers as well as the CLKOUT signal as shown in Table 1. The phases tabulated are relative to zero phase being defined as the rising edge of the top gate (TG1) driver output of controller 1. The CLKOUT signal can be used to synchronize additional power stages in a multiphase (3-, 4-, or 6-phase) power supply solution feeding a single, high current output or separate outputs. In the G28 package, CLKOUT is 90° out of phase with channel 1 and channel 2.

Conclusion

The LTC3828 is a constant-frequency dual high performance step-down switching regulator controller. Its high efficiency, high power density, current mode architecture make this product ideal for automotive, telecom and battery systems.