Reduce the Size and Cost of High Current, High-Power-Density Systems with Tracking Dual, 2-Phase Constant Frequency Step-Down Regulator

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Introduction

PolyPhase® power converters offer several advantages over single phase converters, including higher efficiency, smaller size and lower capacitor ripple currents. The LTC3828 is a 2-phase, constant frequency, dual synchronous buck controller that minimizes both the size and total cost of the power system.

The LTC3828 offers voltage tracking with flexibility of start-up control, a fixed internal start-up time and an adjustable external soft-start. Multiple LTC3828s can be daisy-chained in applications that require more than two tracked and synchronized voltages.

The LTC3828 is well suited to high current and high density power solutions. Its adjustable operating frequency (260kHz–550kHz) allows the use of small surface mount inductors and capacitors, and powerful gate drivers and short dead time make it possible to achieve high efficiency over a wide range of load currents. Figure 1 shows a typical application and Figure 2 shows its efficiency.

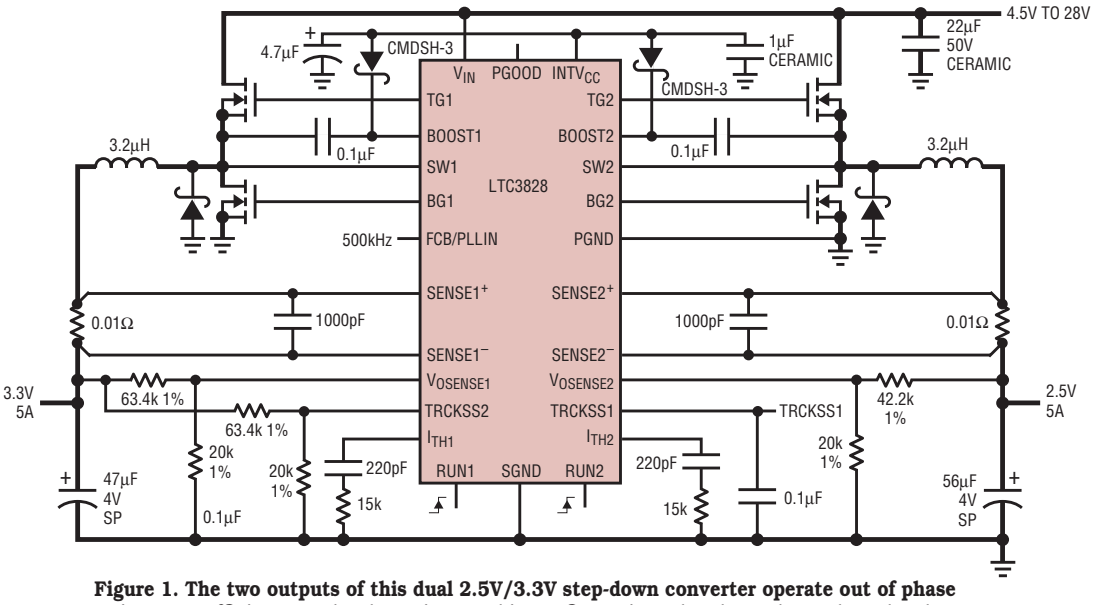

Figure 1. The two outputs of this dual 2.5V/3.3V step-down converter operate out of phase to increase efficiency and reduce size. In this configuration, the channels track each other.

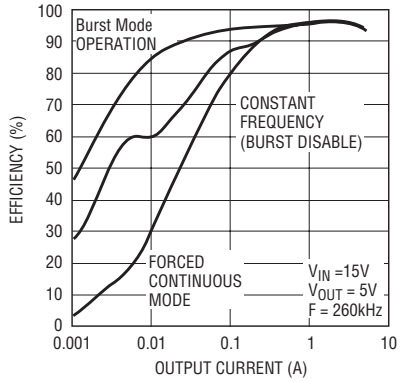

Figure 2. Efficiency of circuit in Figure 1

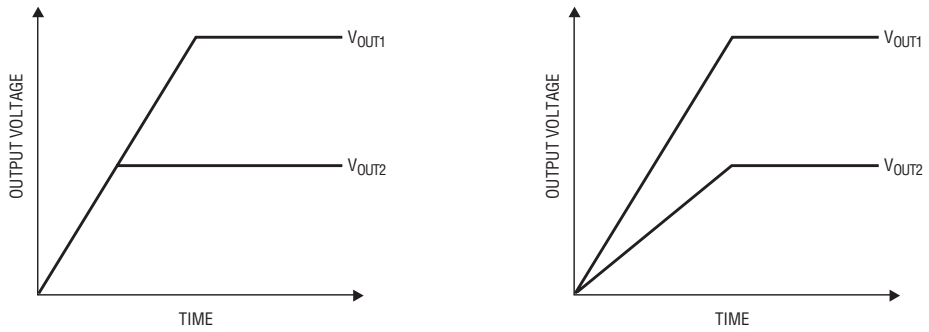

Figure 3. Two different methods of output voltage tracking

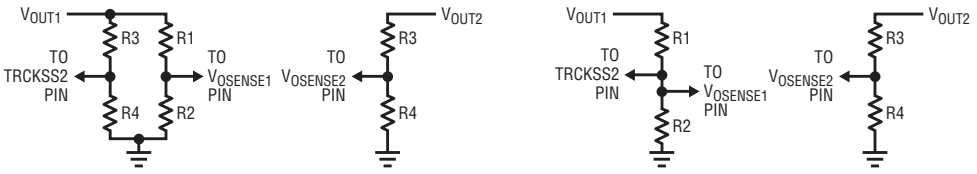

Figure 4. Setups for coincident and ratiometric tracking

Tracking and Soft-Start

The two supply channels are ramped according to the voltages on the TRCKSS pins. The channel outputs track either coincidentally or ratiometrically, as shown in Figure 3.

To implement coincident tracking (Figure 3a), connect a resistive divider to the output of the master channel (for coincident tracking, the master must be the higher output volatge) and connect its midpoint to the slave channel's TRCKSS pin. The ratio of this divider should be the same as the slave channel's feedback divider (Figure 4a). To implement ratiometric tracking (Figure 3b), no extra divider is needed; simply connect one of the TRCKSS pins to the other channel's V_{FB} pin (Figure 4b).

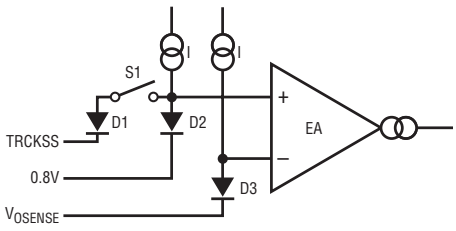

Figure 5. Equivalent input circuit of error amplifier to implement start-up tracking

Figure 5 shows the tracking function. At the input stage of the error amplifier, three diodes are used to clamp the equivalent reference voltage. The top two current sources are of the same value. When TRCKSS voltage is low, switch S1 is on and V_{OSENSE} follows the TRCKSS voltage. When the TRCKSS voltage is close to the reference voltage, 0.8V, switch S1 is off and V_{OSENSE} follows the reference voltage. Regulation of the channels' outputs is not affected by the tracking mode. In the ratiometric tracking mode, the two channels do not exhibit cross talk.

When LTC3828 is configured to soft-start by itself, an external soft-start capacitor should be connected to the TRCKSS pin. A soft-start current of 1.2µA charges the soft-start capacitor. If during start-up, the voltage at TRCKSS pin is already higher than 0.8V, the soft-start for this particular channel is provided by an internal soft-start timer (about 450µs). If the voltage at TRCKSS pin is already high, but lower than 0.8V, this channel's VOSENSE follows the internal soft-start voltage until the internal soft-start voltage higher than the voltage on TRCKSS pin.

During start-up, if the voltage on TRCKSS pin is lower than 60mV, there is no switching action to force the output to follow the tacking pin voltage. This is helpful to prevent the power supply from mis-tracking noise and potentially damaging the system. When the TRCKSS pin voltage ramps up and is lower than 0.6V, no negative inductor current is allowed and the converter stays in pulse skip mode. Figure 6 shows the output voltage and inductor current waveforms during start-up.

Power Good Monitor and Fault Protection

Two window comparators monitor the feedback voltages and the open-drain PGOOD output is pulled low when the feedback is not within the 7.5% of the 0.8V reference voltage. The PGOOD only monitors the channel when the channel is enabled (This channel's RUN pin voltage is high). For example, if channel 1 is shutdown and channel 2 is enabled, PGOOD is high only

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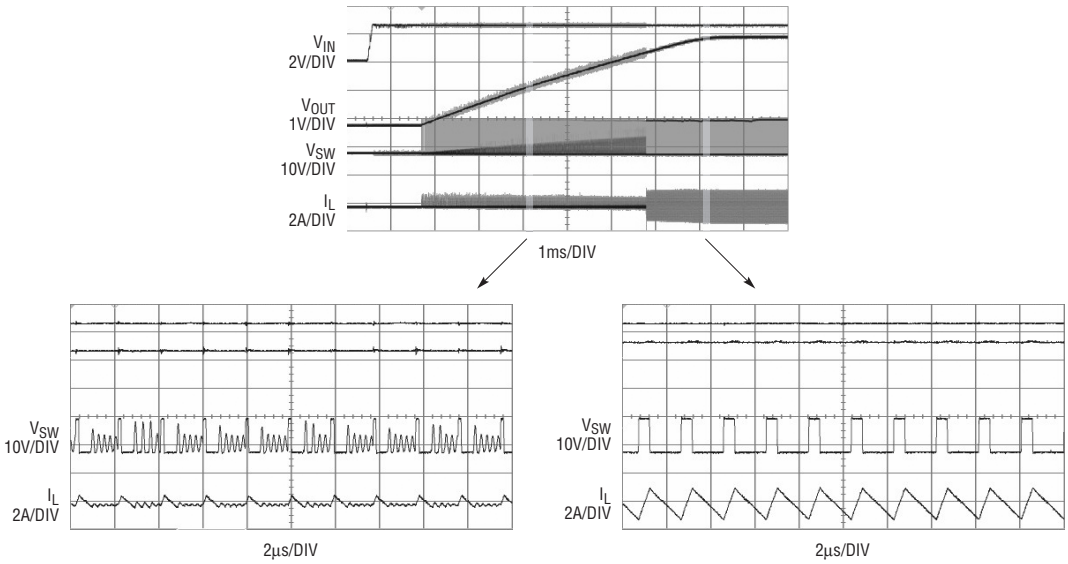

Figure 6. Soft-start waveforms (no negative current)

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

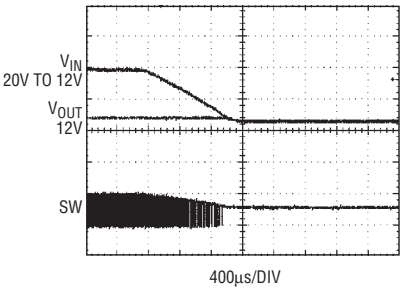

Figure 4. When the input voltage drops to below the programmed output voltage, the output voltage gracefully tracks the input voltage.

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

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

goes up when load current increases. This scheme maintains protection yet ensures the tightest possible output voltage regulation.

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.

LTC3828, continued from page 7

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.

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°

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.

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.