2-Phase Synchronous Step-Down DC/DC Controller with Programmable Stage Shedding Mode and Active Voltage Positioning for High Efficiency and Fast Transient Response

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The LTC3856 is a versatile and feature-rich single-output 2-phase synchronous buck controller with on-chip drivers, remote output voltage sensing, inductor DCR temperature compensation, Stage Shedding™ mode and active voltage positioning (AVP). It is suitable for converting inputs of 4.5V–38V to outputs from 0.6V up to 5V. The LTC3856 facilitates the design of high efficiency, high power density solutions for telecom and datacom systems, industrial and medical instruments, DC power distribution systems and computer systems. The controller is available in 32-pin 5mm × 5mm QFN and 38-pin TSSOP packages.

MAJOR FEATURES

The LTC3856's constant-frequency peak current-mode control architecture allows a phase-lockable frequency of up to 770kHz. For high frequency applications, the LTC3856 can operate at low duty cycles due to its small minimum on-time (90ns), making it possible to produce a large step-down ratio applications in very little space.

The LTC3856 includes a high speed differential amplifier for remote output voltage sensing, which can eliminate the regulation error due to PCB voltage drops during heavy load conditions. Figure 1 shows a typical 4.5V~14V input, 1.5V/50A output application schematic.

The LTC3856's two channels operate anti-phase, which reduces the input RMS current ripple and thus the input

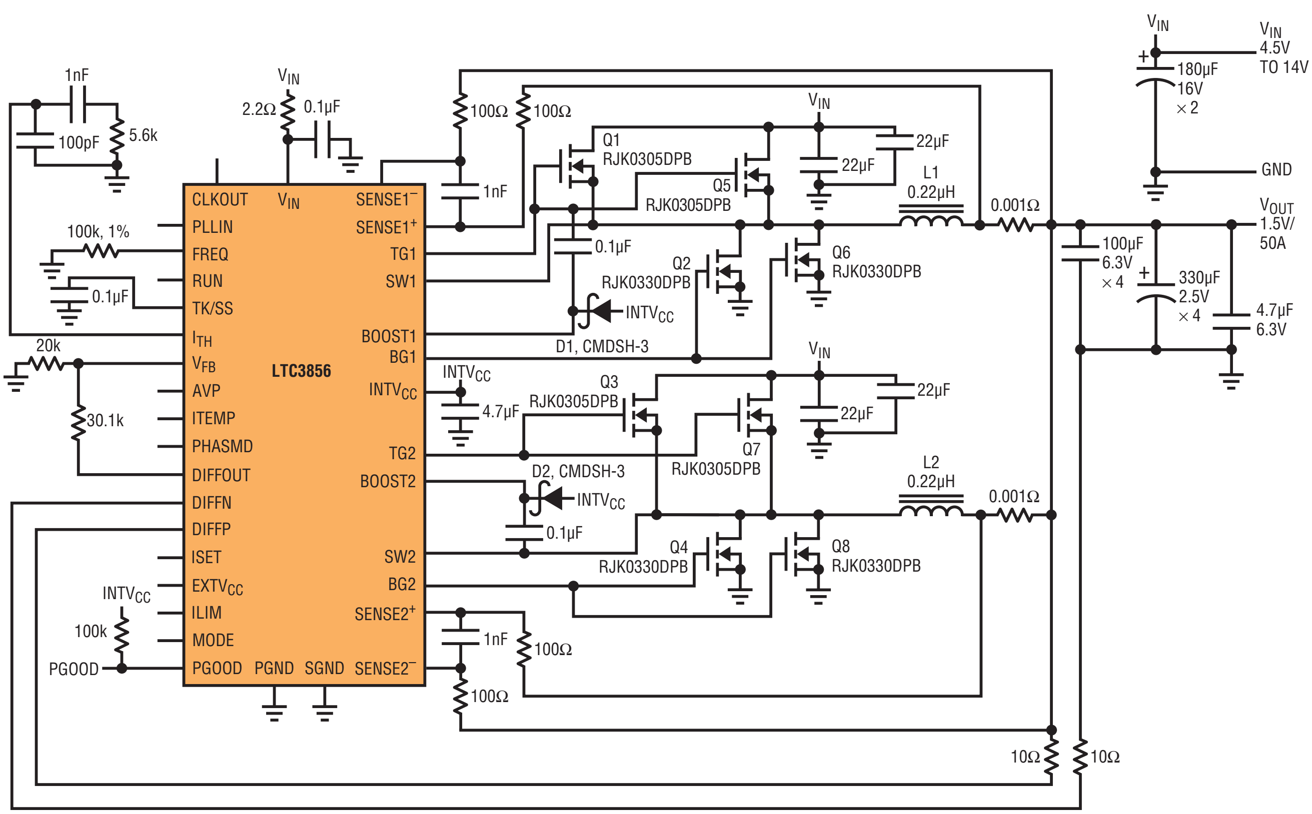

Figure 1. A 1.5V/50A, 2-phase converter featuring the LTC3856

At light load, switching-related power losses dominate the total loss. With Stage Shedding mode, the LTC3856 can shut down one channel at light loads to reduce switching related losses.

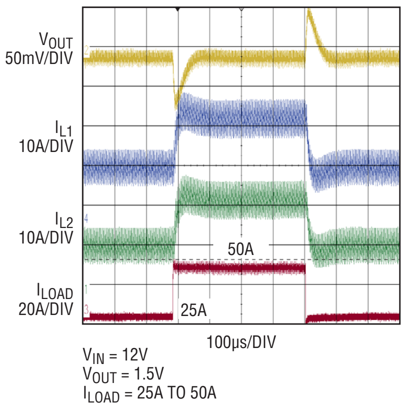

Figure 2. Load transient performance

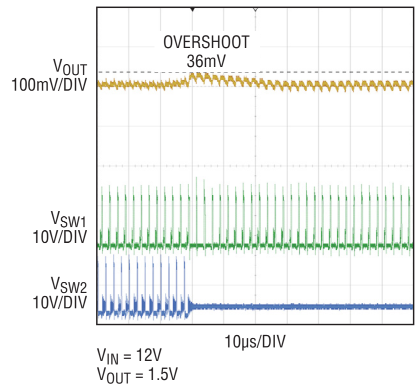

Figure 3. Stage Shedding mode: 2-phase to 1-phase transition

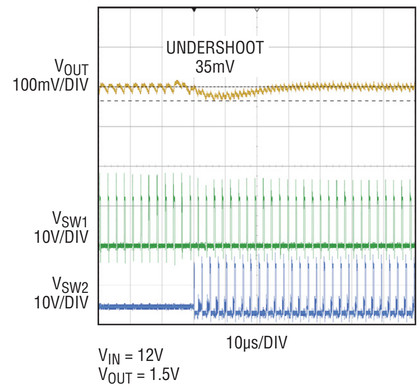

Figure 4. Stage Shedding mode: 1-phase to 2-phase transition

capacitance. Up to six LTC3856s can be combined for 12-phase operation by using the CLKOUT, PLLIN and PHASMD pins. Due to its peak current mode control architecture, the LTC3856 provides fast cycle-by-cycle dynamic current sharing plus tight DC current sharing, as shown in Figure 2.

The LTC3856's maximum current sense voltage is selectable for either 30mV, 50mV or 75mV, allowing the use of either the inductor DCR or a discrete sense resistor as the sensing element. Inductor winding resistance (DCR) changes over temperature, so the LTC3856 senses the inductor temperature via the ITEMP pin and maintains a constant current limit over a broad temperature range. It makes high efficient inductor DCR sensing more reliable for high current applications.

At heavy load, the LTC3856 operates in constant frequency PWM mode. At light loads, it can operate in any of three modes: Burst Mode® operation, forced continuous mode and Stage Shedding™ mode. Burst Mode operation switches in pulse trains of one to several cycles, with the output capacitors supplying energy during internal sleep periods. This provides the highest possible efficiency at very light load. Forced continuous conduction mode (CCM) offers continuous PWM operation from no load to full load, providing the lowest possible output voltage ripple. Programmable Stage Shedding mode is unique to the LTC3856. In Stage Shedding mode, one channel can be shut down at light load to reduce switching related losses, thus improving efficiency in the load range up to 20% of full load.

The programmable active voltage positioning (AVP) is another unique design feature of the LTC3856. AVP modifies the regulated output voltage depending on its current loading. AVP can improve overall transient response and save output capacitors.

STAGE SHEDDING MODE

At light load, switching-related power losses dominate the total loss. With Stage Shedding mode, the LTC3856 can shut down one channel at light loads to reduce switching related losses. When the MODE pin is tied to INTVCC, the

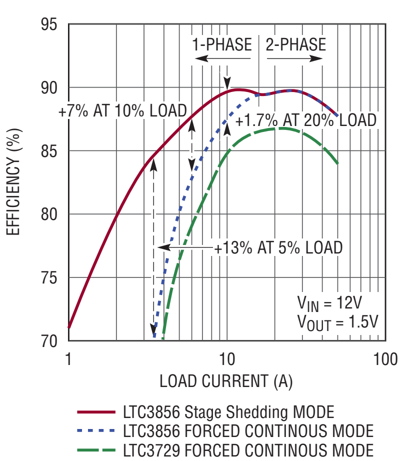

Figure 5. Efficiency comparison

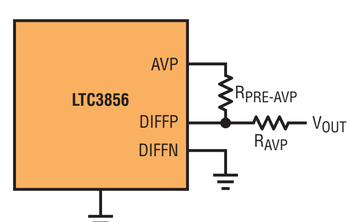

Figure 6. Programmable AVP

The LTC3856's two channels operate anti-phase, which reduces the input RMS current ripple and thus the input capacitance. Up to six LTC3856s can be combined for 12-phase operation. Due to its peak current mode architecture, the LTC3856 provides fast cycle-by-cycle dynamic current sharing, plus tight DC current sharing.

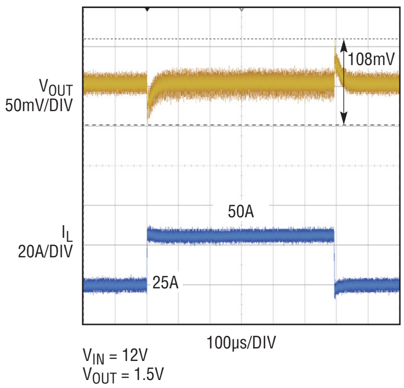

Figure 7. Transient performance without AVP

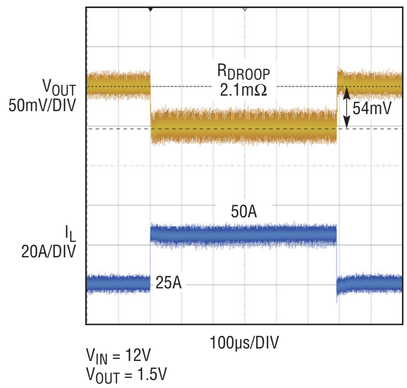

Figure 8. Transient performance with AVP

LTC3856 enters Stage Shedding mode. This means that the second channel stops switching when I_{TH} is below a certain programmed threshold. The threshold voltage V_{SHED} on I_{TH} is programmed according to the following formula:

$$V_{SHED} = 0.5 + \frac{5}{3}(0.5 - V_{ISET})$$

There is a precision 7.5µA flowing out of the ISET pin. Connecting a resistor to SGND sets the V_{ISET} voltage.

Current mode control allows the LTC3856 to transition smoothly from 2-phase to 1-phase operation and vice versa, as shown in Figures 3 and 4. A voltage mode, multiphase supply cannot transition between 1- and 2-phase operation as smoothly.

The efficiency improvements brought on by Stage Shedding mode are shown in Figure 5. Due to stronger gate driver and shorter dead-time, the LTC3856 can achieve around 4%~5% higher efficiency than the LTC3729, a comparable single-output, 2-phase controller, over the whole load range. With Stage Shedding mode, significant efficiency improvement is further achieved at light load. At 5% load, the efficiency is improved by 13%.

ACTIVE VOLTAGE POSITIONING

Transient performance is an important parameter in the requirements for the latest power supplies. To minimize the voltage excursions during a load step, the LTC3856 uses AVP to lower peak-to-peak output voltage deviations caused by load steps without having to increase the output filter capacitance. Likewise, the output filter capacitance can be reduced in applications while maintaining peak-to-peak transient response.

The LTC3856 senses inductor current information by monitoring the voltage across the sense resisters R_{SENSE} or the DCR sensing network of the two channels. The voltage drops are added together and applied as $V_{PRE\text{-}AVP}$ between the AVP and DIFFP pins, which are connected through resistor $R_{PRE\text{-}AVP}$. Then, $V_{PRE\text{-}AVP}$ is scaled through R_{AVP} and added to the output voltage as the compensation for the load voltage drop. As shown in Figure 6, the load slope (R_{DROOP}) is set to:

$$R_{DROOP} = \frac{R_{SENSE} \bullet R_{AVP}}{R_{PRE\text{-}AVP}} \bullet \frac{V}{A}$$

With proper design, AVP can reduce load transient-induced peak-to-peak voltage spikes by 50%, as shown in Figures 7 and 8.

CONCLUSION

The LTC3856 delivers an outsized set of features for its small 5mm × 5mm 32-pin QFN package. It can run at high efficiency using temperature compensated DCR sensing with Stage Shedding mode/Burst Mode operation. AVP can improve the transient response even as output capacitance is reduced. Tracking, strong on-chip drivers, multichip operation and external sync capability fill out its menu of features. The LTC3856 is ideal for high current applications, such as telecom and datacom systems, industrial and computer systems applications. ■