

# 6mm × 6mm DC/DC Controller for High Current DCR Sensing Applications

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The LTC3855 is a versatile 2-phase synchronous buck controller IC with on-chip drivers, remote output voltage sensing and inductor temperature sensing. These features are ideal for high current applications where cycle-by-cycle current is measured across the inductor (DCR sensing). Either channel is suitable for inputs up to 38V and outputs up to 12.5V, further increasing the controller's versatility. The LTC3855 is based on the popular LTC3850, described in the October 2007 issue of *Linear Technology*.

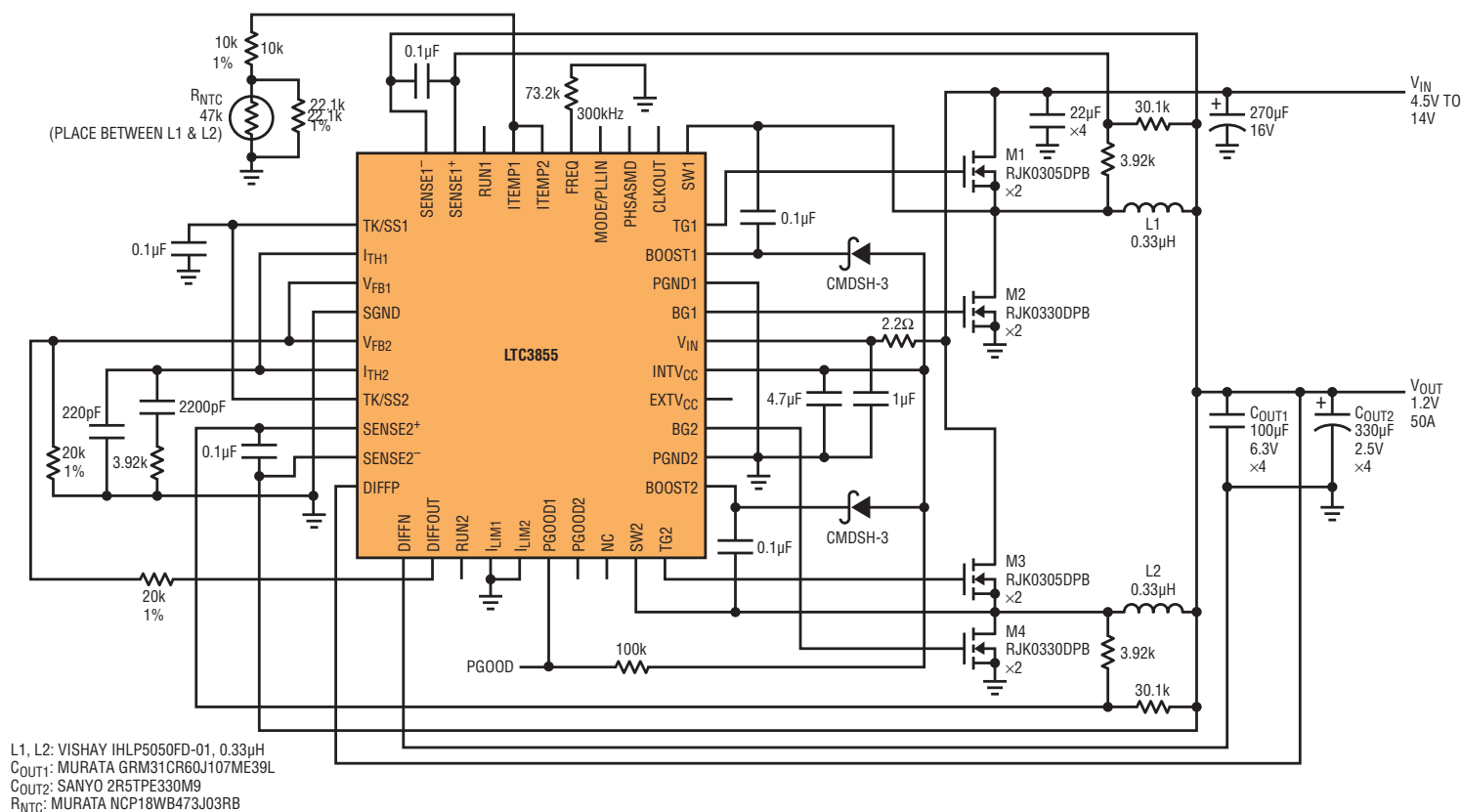
## MONITORING THE TEMPERATURE

When current is sensed at the inductor, either a sense resistor is placed in series with the inductor, or an R-C network across the inductor is used to infer the current information across the inductor's DC resistance (DCR sensing). This

“lossless” method is less accurate than using a sense resistor, in large part because as the inductor heats up, its resistance increases with a temperature coefficient of resistivity (TCR) of 3930ppm/°C. Therefore as the temperature rises, the current limit decreases. When DCR sensing

is used, the current limit for the LTC3855 is determined by the peak sense voltage as measured across the inductor's DCR. The LTC3855 includes a temperature sensing scheme designed to compensate for the TCR of copper by effectively raising the peak sense voltage at high temperature.

Figure 1. A 1.2V, 50A, 2-phase converter. The two channels operate 180° out-of-phase to minimize output ripple and component sizes.



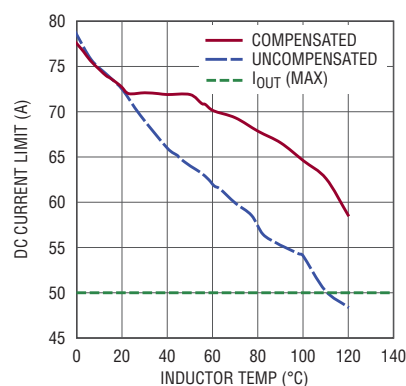


Figure 2. The converter of Figure 1 can deliver the current whether hot or cold, with its calculated worst-case current limit remaining above the target 50A, even well above room temperature.

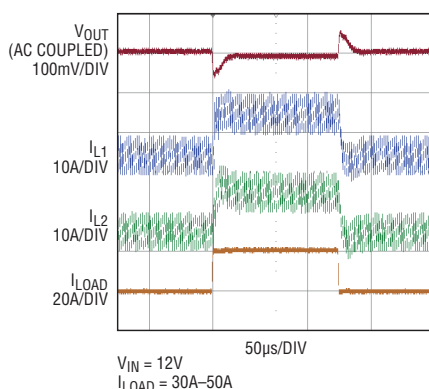


Figure 3.  $V_{OUT}$  is stable in the face of a 30A to 50A load step for the converter of Figure 1, and the inductor current sharing is fast and precise.

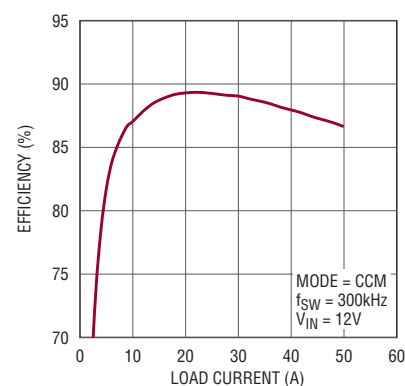


Figure 4. Efficiency for the converter of Figure 1.

## DIFFERENTIAL SENSING

At high load current, an offset can develop between the power ground, where  $V_{OUT}$  is sensed, and the IC's local ground. To overcome this load regulation error, the LTC3855 includes a unity gain differential amplifier for remote output voltage sensing. Inputs DIFFP and DIFFN are tied to the point of load, and the difference between them is expressed with respect to local ground from the DIFFOUT pin. Measurement error is limited to the input offset voltage of the differential amplifier, which is no more than 2mV.

## SINGLE OUTPUT CONVERTER WITH REMOTE OUTPUT VOLTAGE SENSING AND INDUCTOR DCR COMPENSATION

Figure 1 shows a high current DCR application with temperature sensing. The nominal peak current limit is determined by the sense voltage (30mV, set by grounding the ILIM pins) across the DC resistance of the inductor (typically 0.83mΩ), or 36A per phase. This sense voltage can be raised by biasing the ITEMP pins below 500mV. Since each ITEMP pin sources 10μA, peak sense voltage can be increased by inserting a resistance of less than 25k from ITEMP to ground. By using an inexpensive NTC thermistor placed near the inductors (with series and parallel

resistance for linearization), the current limit can be maintained above the nominal operating current, even at elevated temperatures (Figure 2).

The circuit also maintains precise regulation by differentially sensing the output voltage. The measurement is not contaminated by the difference between power ground and local ground. As a result, output voltage typically changes less than 0.2% from no load to full load.

## MULTIPHASE OPERATION

The LTC3855 can be configured for dual outputs, or for one output with both power stages tied together, as shown in Figure 1. In the single output configuration, both channels' compensation (ITH), feedback ( $V_{FB}$ ), enable (RUN) and track/soft-start (TRK/SS) pins are tied together, and both PGOOD1 and PGOOD2 will indicate the power good status of the output voltage. By doubling the effective switching frequency, the single output configuration minimizes the required input and output capacitance and voltage ripple, and allows for fast transient response (Figure 3). The LTC3855 provides inherently fast cycle-by-cycle current sharing due to its peak current mode architecture plus tight DC current sharing.

## OTHER IMPORTANT FEATURES

A precise 10μA flows out of the FREQ pin, allowing the user to set the switching frequency with a single resistor to ground. The frequency can be set anywhere from 250kHz to 770kHz. If an external frequency source is available, a phase-locked loop enables the LTC3855 to sync with frequencies in the same range. A minimum on-time of 100ns allows low duty cycle operation even at high frequencies.

If the external sync signal is momentarily interrupted, the LTC3855 reverts to the frequency set by the external resistor. Its internal phase-locked loop filter is prebiased to this frequency. An internal switch automatically changes over to the sync signal when a clock train is detected. Since the PLL filter barely has to charge or discharge during this transition, synchronization is achieved in a minimum number of cycles, without large swings in switching frequency or output voltage.

The LTC3855 is also useful for designs using three or more phases. Its CLKOUT pin can drive the MODE/PLLIN pins of additional regulators. The PHASMD pin tailors the phase delays to interleave all the switch waveforms.

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### ULTRALOW VOLTAGE STEP-UP CONVERTER AND POWER MANAGER FOR ENERGY HARVESTING

The LTC3108 is a highly integrated DC/DC converter ideal for harvesting and managing surplus energy from extremely low input voltage sources such as TEG (thermoelectric generators), thermopiles and small solar cells. The step-up topology operates from input voltages as low as 20mV. Using a small step-up transformer, the LTC3108 provides a complete power management solution for wireless sensing and data acquisition.

The 2.2V LDO powers an external micro-processor, while the main output is programmed to one of four fixed voltages to power a wireless transmitter or sensors. The power good indicator signals that the main output voltage is within regulation. A second output can be

enabled by the host. A storage capacitor provides power when the input voltage source is unavailable. Extremely low quiescent current and high efficiency design ensure the fastest possible charge times of the output reservoir capacitor.

### POWERFUL SYNCHRONOUS N-CHANNEL MOSFET DRIVER IN A 2MM × 3MM DFN

The LTC4449 is high speed synchronous MOSFET driver designed to maximize efficiency and extend the operating voltage range in a wide variety of DC/DC converter topologies, from buck to boost to buck-boost.

The LTC4449's rail-to-rail driver outputs operate over a range of 4V to 6.5V and can sink up to 4.5A and source up to 3.2A of current, allowing it to easily drive high gate capacitance and/or multiple MOSFETs in parallel for high

current applications. The high side driver can withstand voltages up to 38V.

Adaptive shoot-through protection circuitry is integrated to prevent MOSFET cross-conduction current. With 14ns propagation delays and 4ns to 8ns transition times driving 3nF loads, the LTC4449 minimizes power loss due to switching losses and dead time body diode conduction.

The LTC4449 features a three-state PWM input for power stage control and shutdown that is compatible with all controllers that employ a three-state output feature. The LTC4449 also has a separate supply input for the input logic to match the signal swing of the controller IC. Undervoltage lockout detectors monitor both the driver and logic supplies and disable operation if the voltage is too low. ■

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The MOSFET drivers and control circuits are powered by INTV<sub>CC</sub>, which by default is powered through an internal low dropout regulator from the main input supply, V<sub>IN</sub>. If lower power dissipation in the IC is desired, a 5V supply can be connected to EXTV<sub>CC</sub>. When a supply is detected on EXTV<sub>CC</sub>, the LTC3855 switches INTV<sub>CC</sub> over to EXTV<sub>CC</sub>, with a drop of just 50mV. The strong gate drivers with optimized dead time provide high efficiency. The full load efficiency is 86.7% and the peak efficiency is 89.4% (Figure 4).

The LTC3855 features a RUN and TRACK/SS pin for each channel. RUN enables the output and INTV<sub>CC</sub>, while TRACK/SS acts as a soft-start or allows the outputs to track an external reference. If a multiphase output is desired, all RUN and TRACK/SS pins are typically tied to one another.

Peak current limiting is used in this application, with the peak sense voltage set by the three-state ILIM pin. A high speed rail-to-rail differential current

sense comparator looks across the current sense element (here the inductor's DC resistance, implied from the associated R-C network). If a short circuit occurs, current limit foldback reduces the peak current to protect the power components. Foldback is disabled during start-up, for predictable tracking.

### CONCLUSION

The LTC3855 is ideal for converters using inductor DCR sensing to provide high current outputs. Its temperature compensation and remote output voltage sensing ensure predictable behavior from light load to high current. From inputs up to 38V it can regulate two separate outputs from 0.6V to 12.5V, and can be configured for higher currents by tying its channels together, or by paralleling additional LTC3855 power stages. At low duty cycles, the short minimum on-time ensures constant frequency operation, and peak current limit remains constant even as duty cycle changes. The LTC3855 incorporates these features and more into 6mm × 6mm QFN or 38-lead TSSOP packages. ■

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### CONCLUSION

The LT3029 is a dual 500mA/500mA monolithic LDO with a wide input voltage range and low noise. The two channels are fully independent, allowing for flexible power management. It is ideal for battery-powered systems because of its low quiescent current, small package and integration of battery protection features. ■

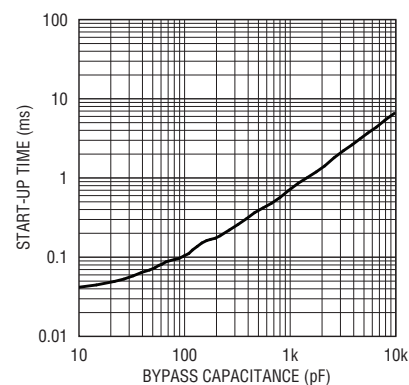


Figure 2. Start-up time vs bypass capacitor value