

# Dual Output Step-Down Regulator Features Pin Selectable Outputs, DCR Sensing, Reverse Current Protection and a 5mm × 5mm QFN

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The LTC3865 is a high performance step-down controller with two constant frequency, current mode, synchronous buck controllers and on-chip drivers. It offers high output current capability over a wide input range. An important feature offered by the LTC3865 is its highly accurate programmable output voltage. Internal precision feedback resistors make it possible to select from nine different output voltages via two VID pins. The internal resistors reduce the number of external components and assure 1% accuracy for low voltage rails.

The LTC3865 is suitable for applications with input voltages up to 38V and output voltages up to 5V. It can be synchronized to a frequency of up to 750kHz and comes in a compact 5mm × 5mm QFN package. The part is also capable of inductor DCR sensing, allowing for increased efficiencies at higher load currents. These features are ideal for wide input voltage range, high current applications where design solution footprint size is restricted.

## PIN SELECTABLE OUTPUTS

The LTC3865 features pin programmable output voltages. Tying each channel's two VID pins to INTV<sub>CC</sub>, GND or leaving

them floating can result in nine different output voltages from 0.6V to 5V (see Table 1). Pin programming eliminates at least four external feedback resistors, making the overall design solution space conservative and cost effective. If an application requires an output voltage not supported by pin programming, one still has the option to use external resistors to set the output voltage. Since the LTC3865 integrates precision feedback resistors, it can achieve 1% output accuracy for outputs from 0.6V to 1.8V and 1.5% percent output accuracy for 2.5V to 5V, with this accuracy maintained over the temperature range of -40°C to 85°C.

## R<sub>SENSE</sub> AND DCR SENSING

For applications requiring the highest possible efficiency at high load currents, a sense resistor would sacrifice several percentage points of efficiency compared to DCR sensing. Inductor DCR is a manifestation of the inductor's copper winding resistance. In high current applications, typical inductance values are low, allowing for a high saturation current inductor with sub 1mΩ DCR values. DCR current sensing takes advantage of this by sensing the voltage drop across the low copper DCR to monitor the inductor current. This eliminates the sense resistor and its additional power loss, thus increasing efficiency as well as lowering solution size and cost. An example of a DCR sensing application is shown in Figure 1. Figure 2 shows an efficiency comparison.

## MULTIPHASE OPERATION

The LTC3865 operates both of channels 180° out-of-phase. This reduces the required input capacitance and power supply induced noise. With its current mode architecture, it can be configured for dual outputs, or for one output with both power stages tied together.

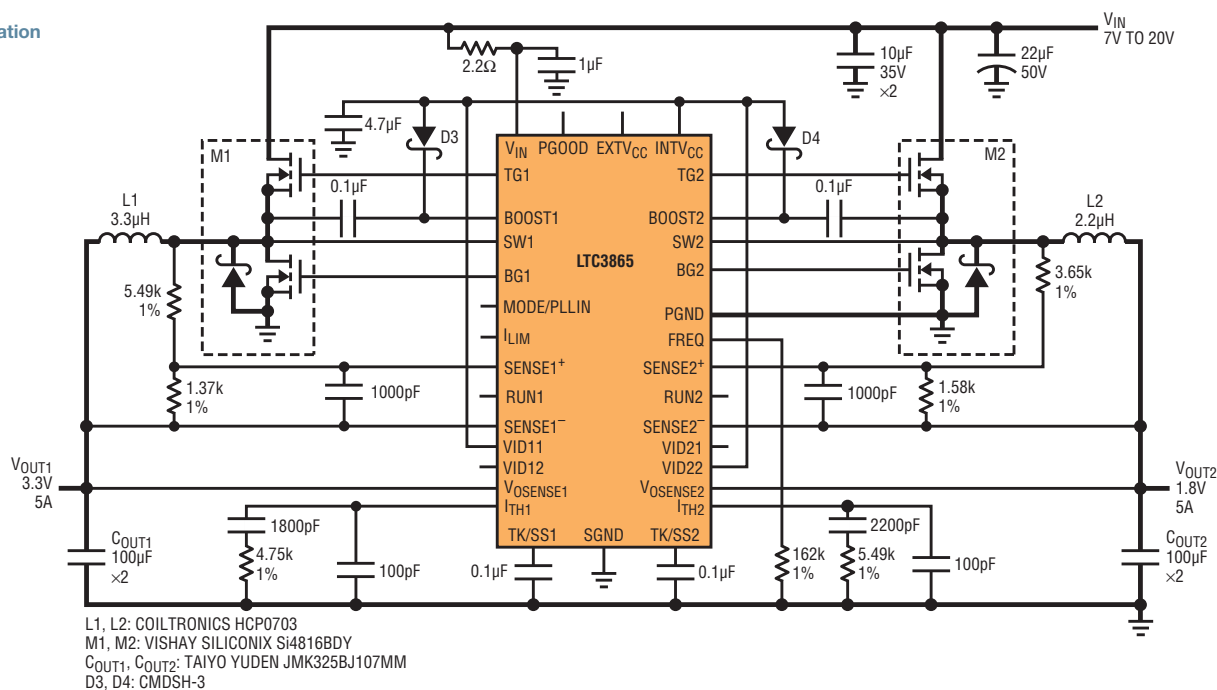
A dual-phase single output application is easy to configure; just tie the channels' compensation (ITH), feedback (V<sub>FB</sub>),

Table 1. Programming the Output Voltages

VID11/VID21	VID21/VID22	V <sub>OUT1</sub> /V <sub>OUT2</sub> (V)
INTV <sub>CC</sub>	INTV <sub>CC</sub>	5.0
INTV <sub>CC</sub>	Float	3.3
INTV <sub>CC</sub>	GND	2.5
Float	INTV <sub>CC</sub>	1.8
Float	Float	0.6 or External Divider
Float	GND	1.5
GND	INTV <sub>CC</sub>	1.2
GND	Float	1.0
GND	GND	1.1

The LTC3865 step-down regulator is ideal for applications requiring inductor DCR sensing for maximum efficiency under heavy load.

Figure 1. DCR sensing application



enable (RUN), power good (PGOOD) and track/soft-start (TRK/SS) pins together. By doubling the effective switching frequency and interleaving phases, the single output configuration minimizes the required input and output capacitance and voltage ripple, and allows for a fast transient response and increased current capability. An example for a dual-phase single output application is shown in Figure 3.

#### OUTPUT OVERVOLTAGE PROTECTION WITH A NEGATIVE REVERSE CURRENT LIMIT

The traditional way of protecting an IC against overvoltage conditions is to use an overvoltage comparator, which guards against transient overshoots (>10%) as well as other more serious conditions that

may cause the output voltage to overshoot. In such cases, the top MOSFET is turned off and the bottom MOSFET is turned on and kept on until excessive energy has been

discharged from the output capacitor, bringing the output back to regulation.

One problem with turning on the bottom MOSFET indefinitely to clear an overvoltage condition is that sometimes excessive reverse current is required to discharge the output capacitor. In these cases the bottom FET experiences extreme current stress. To avoid this scenario, the LTC3865 adds a -53mV of reverse current limit. By setting a floor on how much reverse current is allowed, the LTC3865 limits how long the bottom FET can be turned on. This feature is important in applications that reprogram output voltages on the fly. For example, if the output voltage is changed from 1.8V to 1.5V, the reverse current limit is activated as shown in the Figure 4.

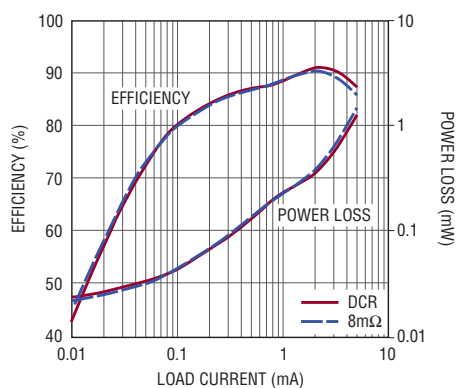


Figure 2. Efficiency for the circuit in Figure 1

The LTC3865's VID programmable output voltage decreases parts count while increasing design flexibility.

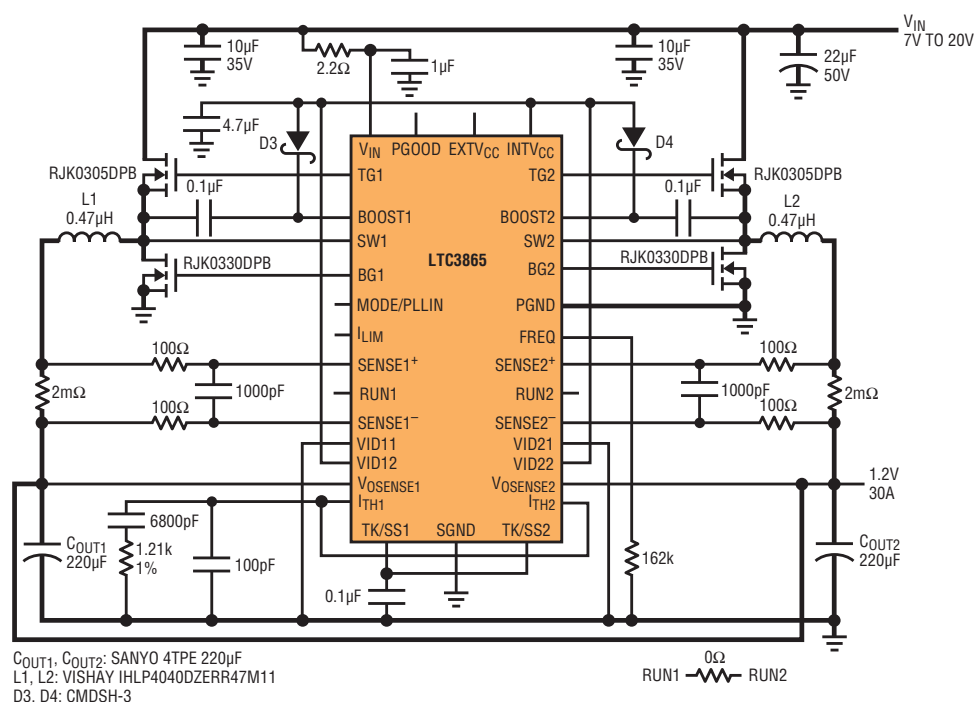


Figure 3. Single output application

## FREQUENCY SELECTION AND MODE/PLLIN

To maximize efficiency at light loads, the LTC3865 can be set for automatic Burst Mode® operation. Alternately, to minimize noise at the expense of light load efficiency, it can be set to operate in forced continuous conduction mode. For both relatively high efficiency and low noise operation, it can be set to operate with a hybrid of the two, namely pulse-skipping mode. Pulse-skipping mode, like forced continuous mode, exhibits lower output ripple as well as low audio noise and reduced RF interference as compared to Burst Mode operation. It also improves light load efficiency, but not as much as Burst Mode operation.

A clock on the  $MODE/PLLIN$  pin forces the controller into forced continuous mode and synchronizes the internal oscillator with the clock on this pin. The phase-locked loop integrated at this pin is composed of an internal voltage-controlled oscillator and a phase detector. This allows the turn-on of the top MOSFET of controller 1 to be locked to the rising edge of an external clock signal applied to the  $MODE/PLLIN$  pin. The frequency range for the LTC3865 is from 250kHz to 750kHz. If no external synchronization signal is applied, there is a precision 7.5µA current flow out of the  $FREQ$  pin that can be used to program the operating frequency of the LTC3865 from 250kHz to 750kHz through a single resistor from the pin to  $SGND$ .

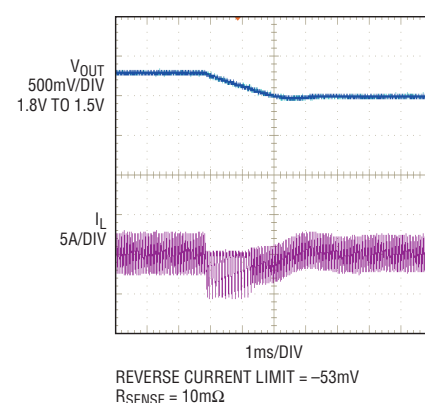


Figure 4. As  $V_{OUT}$  transitions from 1.8V to 1.5V, with -53mV reverse current limit and 10mΩ sense resistor, the reverse inductor current is limited at around 5.3A.

## CONCLUSION

The LTC3865 step-down regulator is ideal for applications requiring inductor DCR sensing for maximum efficiency under heavy load. It can regulate two separate outputs and can be configured for higher load current capability by tying its channels together, and/or by paralleling additional LTC3865 power stages. The LTC3865's VID programmable output voltage decreases parts count while increasing design flexibility. These features, along with its additional negative reverse current limit and integrated PLL features, make the LTC3865 an easy fit in a wide variety of applications. ■