Dual DC/DC Controller Brings 2-Phase Benefits to Low Input Voltage Applications

by Jason Leonard

Introduction

The LTC3701 is an efficient, low input voltage, dual DC/DC controller that fits into the tight spaces required by the latest portable electronics. It uses 2-phase switching techniques to reduce required input capacitance (saving space and cost) and increase efficiency. The versatile LTC3701 accepts a wide range of input voltages, from 2.5V to 9.8V, making it useful for single lithium-ion cell and many multicell systems. It can provide output voltages as low as 0.8V and output currents as high as 5A. The 100% duty cycle allows low dropout for maximum energy extraction from a battery, and the optional Burst Mode operation enhances efficiency at low load currents. It also includes other popular features, such as a Power Good voltage monitor, a phase-locked loop, and an internal soft start. Its small 16-lead narrow SSOP package and relatively high operating frequency (300kHz–750kHz) allow the use of small, surface mount components, making for a compact overall power supply solution.

Operation

Figure 1 shows the LTC3701 used in a step-down converter with an input of from 2.5V to 9.8V and two outputs of 2.5V at 2A and 1.8V at 2A. Figure 2 shows its efficiency versus load current. The LTC3701 uses a constant frequency, current mode architecture with the two controllers operating 180 degrees out of phase.

The LTC3701 offers the benefits of 2-phase operation, which include lower input filtering requirements, reduced electromagnetic interference (EMI) and increased efficiency.

During normal operation, each external P-channel power MOSFET is turned on every cycle when the oscillator for that controller sets a latch and turned off when the current comparator resets the latch. The peak inductor current at which the current comparator resets the latch is controlled by the voltage on the ITH/RUN pin, which is the output of the error amplifier. The VFB pin receives the output voltage feedback signal, which is compared to the internal 0.8V reference by the error amplifier. When the load current increases, it causes a slight decrease in VFB relative to the reference, which, in turn, causes the ITH/RUN voltage to increase until the average inductor current matches the load current.

2-Phase Operation

The LTC3701 offers the benefits of 2-phase operation, which include lower input filtering requirements, reduced electromagnetic interference (EMI) and increased efficiency.

In a single phase dual switching regulator, both top-side P-channel MOSFETS are turned on at the same time, causing current pulses of up to twice the amplitude of those from a single regulator to be drawn from the input capacitor. These large amplitude pulses increase the total RMS current flowing into the input capacitor, requiring the use of more expensive input capacitors, and increasing both EMI and losses in the input capacitor and input power supply.

With 2-phase operation, the two channels of the LTC3701 are operated 180 degrees out of phase. This effectively interleaves the current

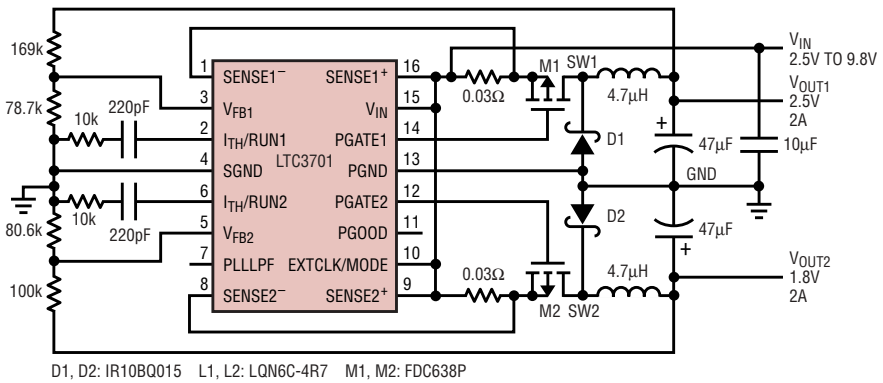


Figure 1. 2-phase step-down converter with an input of 2.5V to 9.8V and two outputs: 2.5V at 2A and 1.8V at 2A

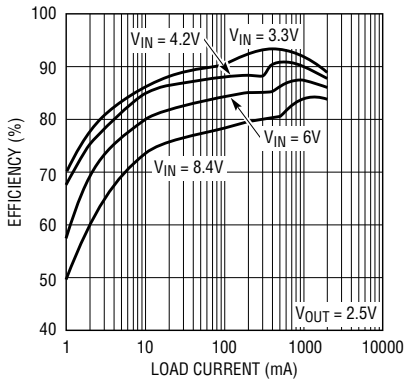


Figure 2. Efficiency vs load current

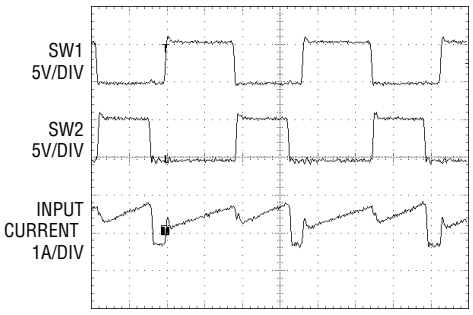


Figure 3. These input waveforms for the circuit in Figure 1 show how 2-phase operation reduces ripple. Reduced ripple translates directly to less expensive input capacitors, reduced shielding requirements for EMI, and improved efficiency.

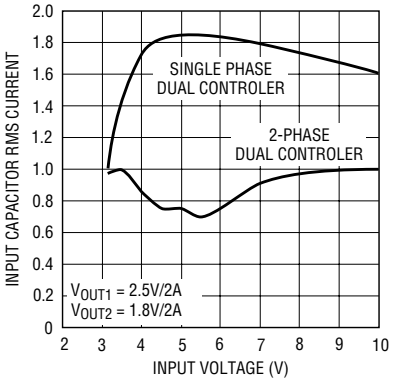


Figure 4. RMS input current comparison

pulses coming from the switches, greatly reducing the amount of time where they overlap and add together. The dead bands in the input current waveform are "filled up," so to speak. The result is a significant reduction in the total RMS input current, which in turn allows for the use of less expensive input capacitors, reduces shielding requirements for EMI, and improves efficiency. Figure 3 shows the input waveforms for the circuit in Figure 1. The RMS input current is significantly reduced by the interleaving current pulses. Of course, the improvement afforded by 2-phase operation is a function of the dual switching regulator's relative duty cycles, which are dependent on the input voltage V_{IN}. Figure 4 shows how the RMS input current varies for single-phase and 2-phase operation for 2.5V and 1.8V regulators over a wide input voltage range.

Burst Mode Operation

The LTC3701 can be enabled to enter Burst Mode operation at low load currents by connecting the EXTCLK/MODE pin to VIN. In this mode, the minimum peak current is set as if VITH/RUN = 1V, even though the voltage at the ITH/RUN pin is at a lower value. If the inductor's average current is greater than the load requirement, the voltage at the ITH/RUN pin will drop as VOUT rises slightly. When the ITH/RUN voltage goes below 0.85V, a sleep signal is generated, turning off the external MOSFET and much of the LTC3701's internal circuitry. The load current is then supported by the output capacitor. When the ITH/RUN voltage goes above 0.925V, the sleep signal goes low and normal operation resumes. For frequency sensitive applications, Burst Mode operation can be inhibited by connecting the EXTCLK/MODE pin to ground. In this case, constant frequency operation is maintained at a lower load current with a lower output voltage ripple. If the load current is low enough, cycle skipping occurs to maintain regulation.

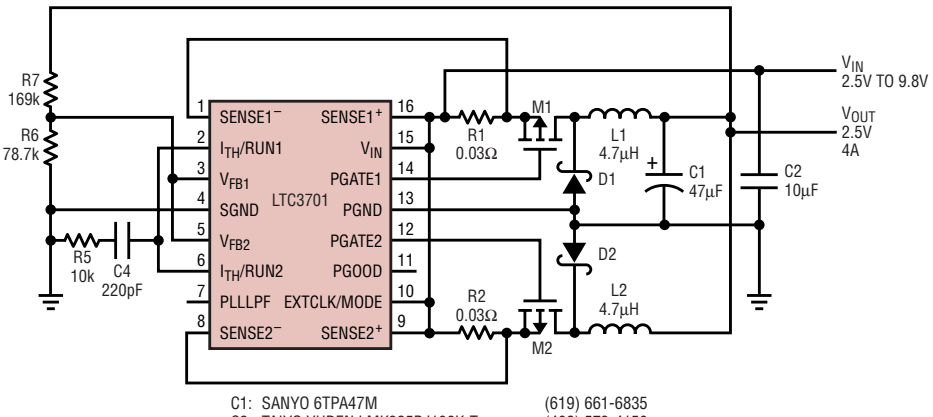
Frequency Selection/Synchronization (Phase-Locked Loop)

The LTC3701 operates at a constant frequency between 300kHz and 750kHz. The frequency can be selected by forcing a voltage at the PLLLPF pin. Grounding the PLLLPF pin selects 300kHz, while tying it to VIN or a voltage greater than 2V selects 750kHz. Floating the PLLLPF pin selects 550kHz operation.

The LTC3701 can also be synchronized to an external clock source (300kHz to 750kHz) using the LTC3701's true phase-locked loop. The clock signal is applied to the EXTCLK/MODE pin and an RC filter is connected between the PLLLPF pin and ground. Burst Mode operation is disabled when synchronized to an external clock.

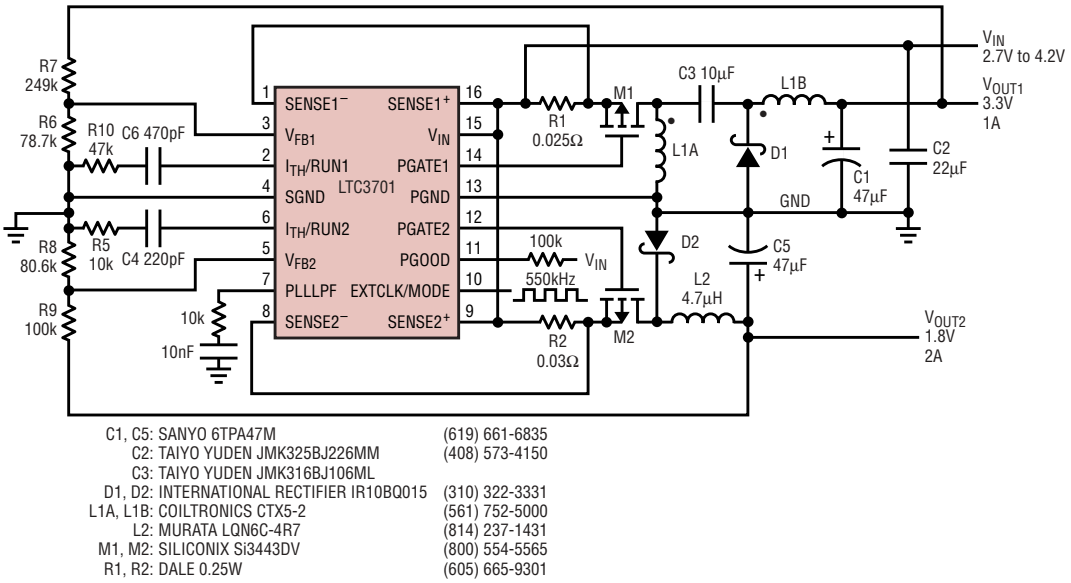
Run/Soft Start

Either controller can be shutdown by pulling its respective ITH/RUN pin below 0.35V, which turns off most circuits associated with that control-



C1: SANYO 6TPA47M (619) 661-6835
C2: TAIYO YUDEN LMK325BJ106K-T (408) 573-4150
D1, D2: INTERNATIONAL RECTIFIER IR10BQ015 (310) 322-3331
L1, L2: MURATA LQN6C-4R7 (814) 237-1431
M1, M2: SILICONIX Si3443DV (800) 554-5565
R1, R2: DALE 0.25W (605) 665-9301

Figure 5. 2.5V–9.8V to 2.5V/4A 2-phase step-down converter operating at 550kHz



C1, C5: SANYO 6TPA47M	(619) 661-6835
C2: TAIYO YUDEN JMK325BJ226MM	(408) 573-4150
C3: TAIYO YUDEN JMK316BJ106ML	
D1, D2: INTERNATIONAL RECTIFIER IR10BQ015	(310) 322-3331
L1A, L1B: COILTRONICS CTX5-2	(561) 752-5000
L2: MURATA LQN6C-4R7	(814) 237-1431
M1, M2: SILICONIX Si3443DV	(800) 554-5565
R1, R2: DALE 0.25W	(605) 665-9301

Figure 6. Single cell Li-Ion to 3.3V/1A and 1.8V/2A DC/DC converter

ler and holds its external MOSFET off. If both ITH/RUN pins are pulled low, the LTC3701 is shutdown and draws only 9µA.

The LTC3701 has separate internal soft start functions that allow each output to power up gently. The maximum allowed inductor current is stepped up from 0 to 120mV/R_{SENSE} in four equal steps of 30mV/ R_{SENSE}, with each step lasting 512 clock cycles (just under 1ms per step at 550kHz).

Power Good Output Voltage Monitor

A window comparator monitors both output voltages and the open-drain PGOOD output is pulled low when the divided down output voltages are not within ±8% of the reference voltage of 0.8V.

2-Phase 2.5V/2A and 1.8V/2A Step-Down Regulator

Figure 1 shows a typical application of the LTC3701. This circuit supplies a 2A load at 2.5V and a 2A load at 1.8V with an input supply from 2.5V to 9.8V. Due to the reduced input current ripple associated with 2-phase operation, only a single 10µF ceramic input capacitor is required. The 0.03Ω sense resistors ensure that both outputs are capable of supplying 2A with a low input voltage. The circuit operates at the internally set frequency of 550KHz. 4.7µH inductors are chosen so that the inductor currents remain continuous during burst periods at low load current.

2-Phase Single Output 2.5V/4A Step-Down Regulator

In addition to dual output applications, the LTC3701 can also be used in a single output configuration to take advantage of the benefits of 2-phase operation, as shown in Figure 5. This circuit provides a 2.5V output with up to 4A of load current. In this case, 2-phase operation reduces both the input and output current ripple, in turn reducing the required input and output capacitances.

Single Cell Li-Ion to 3.3V/1A (Zeta Converter) and 1.8V/2A

In addition to step-down applications, the LTC3701 can also be used in a zeta converter configuration that will do both step-down and step-up conversions, as shown in Figure 6. This circuit delivers 1A at 3.3V (zeta converter) and 2A at 1.8V (step-down converter) from an input of 2.7V to 4.2V (Li-Ion voltage range). The circuit takes advantage of the LTC3701's true phase-locked loop by synchronizing to an external clock source.

Conclusion

The LTC3701 brings the benefits of 2-phase operation to low-voltage dual power supply systems. It offers flexibility, high efficiency, and many other popular features in a small 16-pin narrow SSOP package.