

2-Phase DC/DC Controller Reduces Capacitance and Increases Battery Life in Portable Applications

The LTC®1628 dual high efficiency DC/DC controller brings the considerable benefits of 2-phase operation to portable applications for the first time. Notebook computers, PDAs, handheld terminals and automotive electronics will all benefit from the lower input filtering requirement, reduced electromagnetic interference (EMI) and increased efficiency associated with 2-phase operation.

Why the need for 2-phase operation? Before the LTC1628, constant-frequency dual switching regulators operated both channels in phase (i.e., 1-phase operation). This means that both switches turned on at the same time, causing current pulses of up to twice the amplitude of those for one regulator to be drawn from the input capacitor and battery. These large amplitude current pulses increased the total RMS current flowing from the input capacitor, requiring the use of more expensive input capacitors and increasing both EMI and losses in the input capacitor and battery.

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

coming from the switches, greatly reducing the overlap time where they add together (see Figure 1). The result is a significant reduction in total RMS input current, which, in turn, allows less expensive input capacitors to be used, reduces shielding requirements for EMI and improves real world operating efficiency.

Figure 2 compares the input waveforms for a representative 1-phase dual switching regulator to the new LTC1628 2-phase dual switching regulator. An actual measurement of the RMS input current under these conditions shows that 2-phase operation lowers the input current from $2.53A_{RMS}$ to $1.55A_{RMS}$.

Although this is an impressive reduction in itself, remember that the power losses are proportional to I_{RMS}^2 , meaning that the actual power wasted is reduced by a factor of 2.66. The reduced input ripple voltage also means less power lost in the input power path, which could include batteries, switches, trace/connector resistances and protection circuitry (see Figure 4). Improvements in both conducted and radiated EMI also directly accrue as a result of the reduced RMS input current and voltage.

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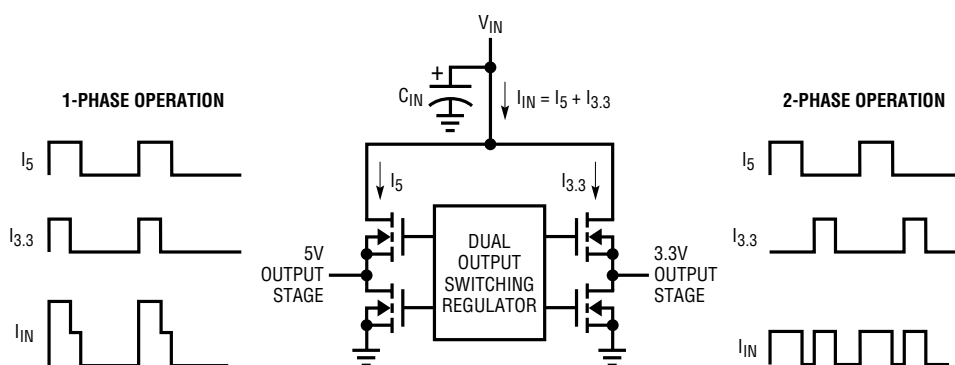
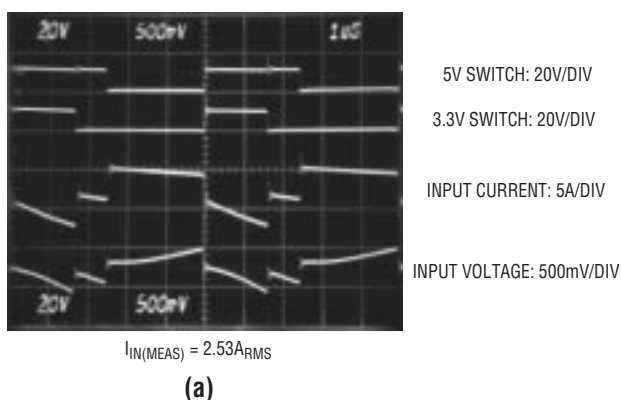


Figure 1. With 2-Phase Operation, the Two Channels of the Dual Switching Regulator are Operated 180 Degrees Out of Phase. This Effectively Interleaves the Current Pulses Coming from the Switches, Greatly Reducing the Overlap Time Where They Add Together

Typical Single-Phase



LTC1628 2-Phase

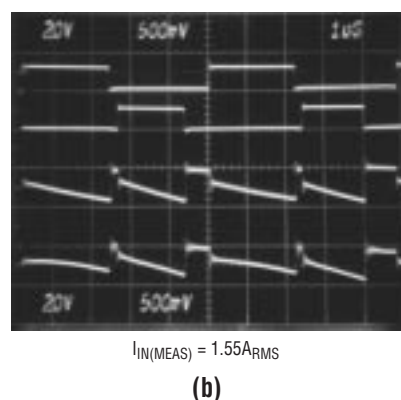


Figure 2. Actual Input Waveforms Comparing Single-Phase and 2-Phase Operation for Dual Switching Regulators Converting 12V to 5V and 3.3V at 3A Each. The Reduced Input Ripple with the LTC1628 2-Phase Regulator Allows Less Expensive Input Capacitors, Reduces Shielding Requirements for EMI and Improves Efficiency

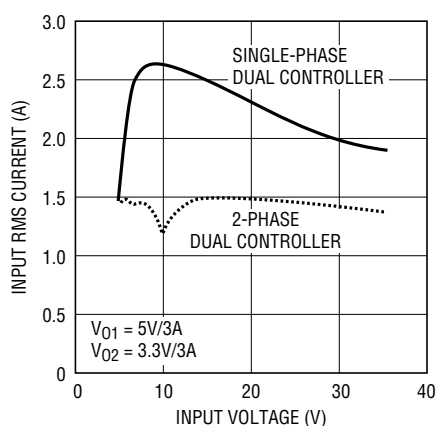


Figure 3. The 2-Phase Solution Results in Significantly Reduced RMS Ripple Current, Which in Turn, Allows Less Expensive Input Capacitors and Increases Real World Operating Efficiency

Of course, the improvement afforded by 2-phase operation is a function of the dual switching regulator's relative duty cycles which, in turn, are dependent upon the input voltage V_{IN} (Duty Cycle = V_{OUT}/V_{IN}). Figure 3 shows how the RMS input current varies for 1-phase and 2-phase operation for 3.3V and 5V regulators over a wide input voltage range.

It can be readily seen that the advantages of 2-phase operation are not limited to a narrow operating range, but in fact extend over a wide region. A good rule of thumb for most applications is that 2-phase operation will reduce the input capacitor requirement to that for just one channel operating at maximum current and 50% duty cycle.

A final question: If 2-phase operation offers such an advantage over 1-phase operation for dual switching regulators, why hasn't it been done before? The answer is that, while simple in concept, it is hard to implement. Constant-frequency, current mode switching regulators require an oscillator-derived "slope compensation" signal to allow stable operation of each regulator at over 50% duty cycle. This signal is relatively easy to derive in 1-phase dual switching regulators, but required the development of a new and proprietary technique to allow 2-phase operation. In addition, isolation between the two channels becomes more critical with 2-phase operation because switch transitions in one channel could potentially disrupt the operation of the other channel.

The LTC1628 is proof that these hurdles have been surmounted. The new device offers unique advantages for the ever expanding number of high efficiency power supplies required in portable electronics.

LTC1628 Operation

The LTC1628 switching regulator performs high efficiency DC/DC voltage conversion while maintaining constant frequency over a wide range of load current, using a 2-phase current mode architecture. The 2-phase approach results in 75% less power loss (and heat generated) in the input source resistance because dissipated power is proportional to the square of the RMS current as illustrated in Figure 4.

What is completely ignored in bench testing of a supply is the power loss internal to the battery due to switcher input ripple current being forced to flow through the battery. By reducing the amplitude of this ripple term, the internal battery power losses are also reduced. Figure 5 shows the measured impedance of a typical Li-Ion battery pack as a function of frequency. Clearly, at the switching frequencies of today's regulators the battery is a lot more lossy than would be expected at DC. This picture starts to look even worse when one considers that a switcher's input current waveform is trapezoidal, and therefore harmonic

rich. Much of the energy contained in this input ripple current is at frequencies above 1MHz even though the fundamental switching frequency is only 200kHz to 300kHz. Because of these additional losses, efficiency measured with a lab supply as the input source will produce results that are somewhat optimistic. The only way to accurately characterize the system efficiency is to measure actual run time with various converter designs.

The input ripple frequency is also double the individual controller's switching frequency, further reducing the

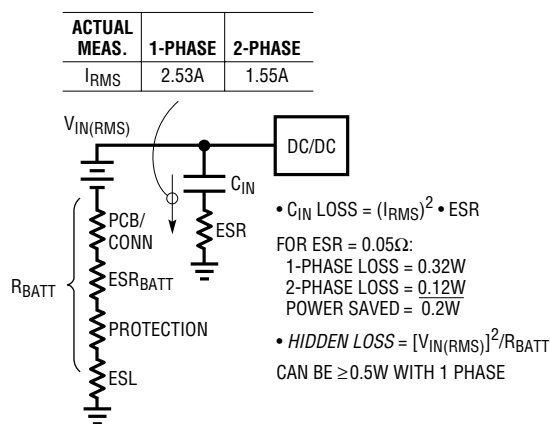


Figure 4. The Lower RMS Ripple Current of the 2-Phase Solution Increases System Efficiency by Reducing Power Losses Inside the Battery

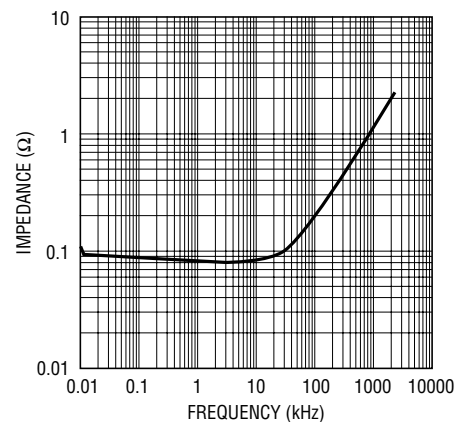


Figure 5. Typical Li-Ion Battery Impedance

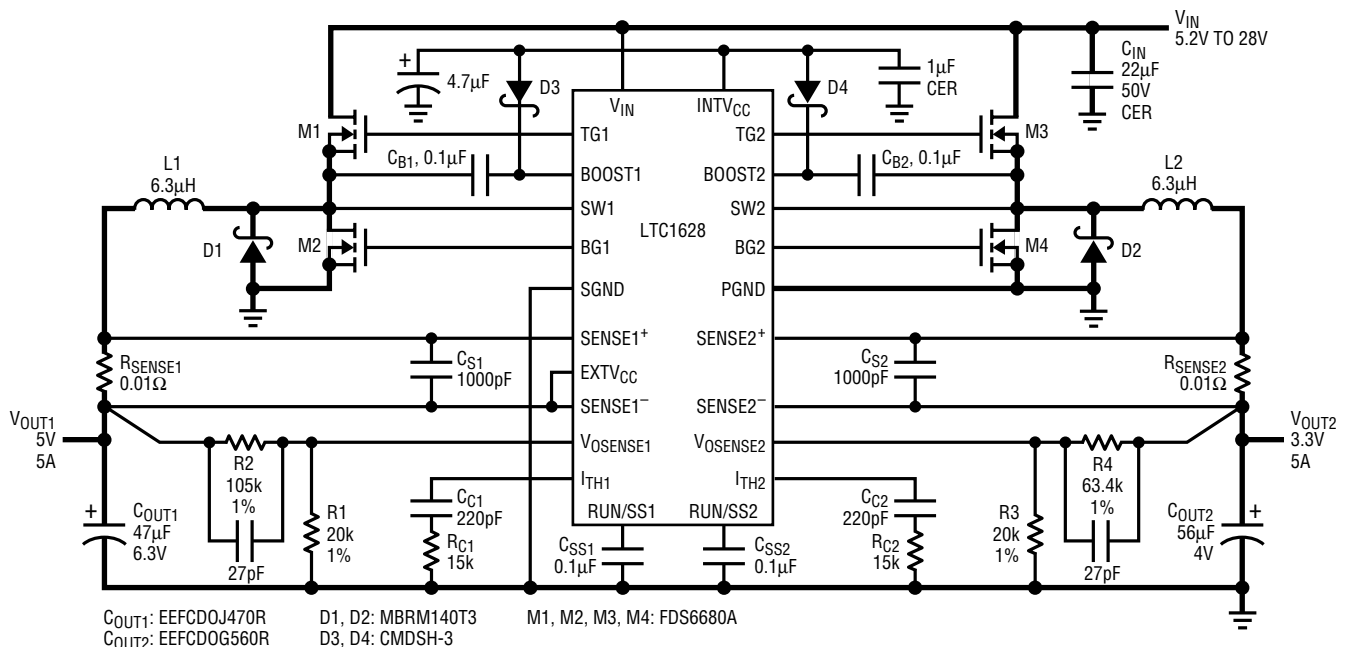


Figure 6. LTC1628 High Efficiency Dual 5V/3V Step-Down Converter

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input capacitance requirement. Reducing peak currents and doubling the radiated frequency significantly reduces EMI related problems. Figure 6 illustrates a typical 5V/3.3V dual output step-down converter circuit using the LTC1628.

The internal oscillator frequency is set by the voltage applied to the FREQSET pin. The frequency can be continuously varied over a 140kHz to 300kHz range by applying an external voltage of 0V to 2.4V to the FREQSET pin.

High efficiency is made possible by selecting either of two low current modes: 1) Burst Mode™ operation for maximum efficiency and 2) low noise, constant frequency, burst disable mode for only slightly less efficiency. Constant frequency is desirable in applications requiring minimal electrical noise. Figure 7 shows the LTC1628 efficiency with Burst Mode operation enabled.

Burst Mode operation allows the output MOSFETs to “sleep” between several PWM switching cycle periods of normal MOSFET activity. Bursting starts at approximately 20% of maximum designed load current.

The burst disable mode allows heavily discontinuous, low audio noise, constant-frequency operation down to approximately 1% of maximum designed load current. This mode results in the elimination of switching frequency subharmonics over 99% of the output load range. Switching cycles start to be dropped at approximately 1% of maximum designed load current in order to maintain proper output voltage.

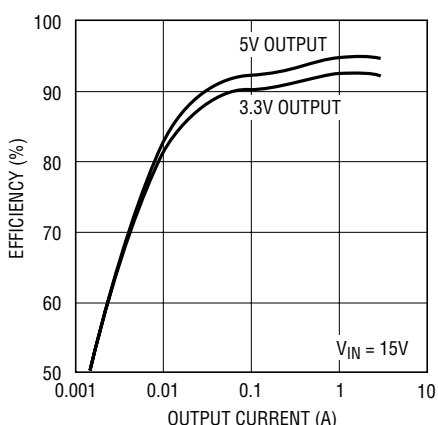


Figure 7. Efficiency for Both Outputs Exceeds 90% Over a Wide Range of Load Currents

The FCB input pin allows the selection of the low current operating mode of both switching regulator controllers. Burst disable mode is selected when the FCB pin is tied to INTV_{CC}. Tying the FCB pin to ground potential forces controller 1 into PWM or forced continuous mode. Both controllers can be forced into PWM mode by tying the FCB pin to ground and tying the FLT_{CPL} pin to INTV_{CC}. In forced continuous mode, the output MOSFETs are always driven, regardless of output loading conditions.

As portable instruments continue to push for increased functionality and longer run times, concerns regarding board space and battery life become more dominant. 2-Phase operation allows the LTC1628 dual output DC/DC controller to address both of these concerns by eliminating input filter capacitors and reducing the power lost in the battery and the input power path. The LTC1628 can be combined with the LTC1735/LTC1735-1 or LTC1736 DC/DC controllers to form a high efficiency multiple output notebook PC power supply that uses a minimum of board space. The LTC1628 can also be combined with the LTC1702 or LTC1703 dual output DC/DC controllers to form a similar notebook power supply using a 2-Step system architecture with the CPU core and I/O supplies derived from the 5V and 3.3V rails for faster transient response and less heat generated near the CPU.

For a complete list of Linear Technology's solutions for Notebook PCs, visit www.linear-tech.com/ads/nbook.html.

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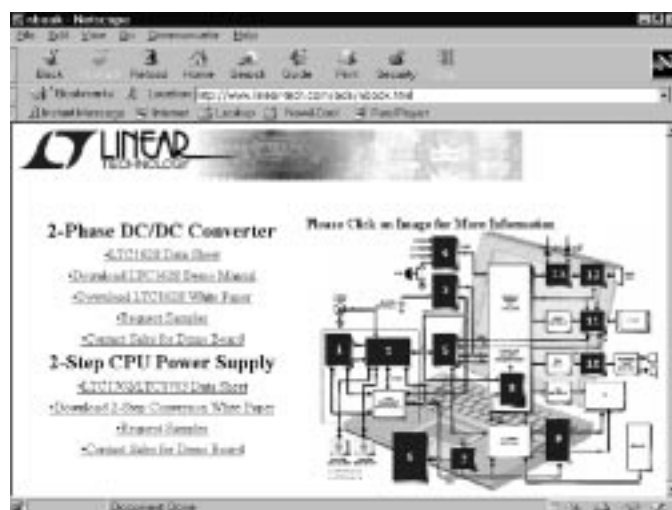


Figure 8. Additional Information Regarding Linear Technology's 2-Phase DC/DC Controllers and Other Power Solutions for Notebook PCs Can be Found at www.linear-tech.com/ads/nbook.html