LTC1622: Low Input Voltage, Current Mode PWM Buck Converter

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Introduction

The push for 2.5V system supplies continues unabated as manufacturers introduce more parts that operate at this low voltage. The rewards are great, especially for battery-powered equipment, since the lower voltage reduces power consumption and thereby extends the time between battery replacements or recharges. With a 2.5V system supply, operation from a single lithium-ion battery becomes highly attractive, because its end-of-charge voltage is 2.7V and it has the most energy per volume compared to NiCd and NiMH.

The 8-pin LTC1622 step-down DC/DC controller is designed to help system designers harness all of the available energy from lithium-ion batteries in several ways. Its wide operating input-voltage range (2.0V to an absolute maximum of 10V) and 100% duty cycle allows low dropout for maximum energy extraction from the battery. The part's low quiescent current, 400µA, with a shutdown current of 15µA, extends battery life. Its user-selectable Burst Mode operation enhances efficiency at low load current.

For portable applications where board space is a premium, the LTC1622 operates at a constant frequency of 550kHz and can be synchronized to frequencies of up to 750kHz. High frequency operation allows the use of small inductors, making this part ideal for communications products. The LTC1622 comes in a tiny 8-lead MSOP package, providing a complete power solution while occupying only a small area.

The LTC1622 uses a pulse-width, current mode architecture, which provides excellent AC and DC load and line regulation. Peak inductor current is set by an external sense resistor. This allows the design to be optimized for each application. A soft-start pin allows the LTC1622 to power up gently.

A Detailed Look at the LTC1622

The LTC1622 is a constant-frequency, pulse-width-modulated, current mode switching regulator. In normal operation, the external P-channel power MOSFET is turned on during each cycle when the oscillator 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 I_{TH} pin, which is the output of the error amplifier, g_m. An external resistive divider connected between V_{OUT} and ground allows g_m to receive an output feedback voltage, V_{FB}. When the load current increases, it causes a slight decrease in V_{FB} relative to the 0.8V reference, which, in turn, causes the I_{TH} voltage to increase until the average inductor current matches the new load current. (For a more detailed description, please refer to the LTC1622 data sheet.)

The value of the R_{SENSE} is chosen based on the required output current. The LTC1622 current comparator has a maximum threshold of 100mV/R_{SENSE}. The current-comparator threshold sets the peak of the inductor current, yielding a maximum average output current equal to the peak value minus one-half the peak-to-peak inductor ripple current. For applications where the duty cycle is

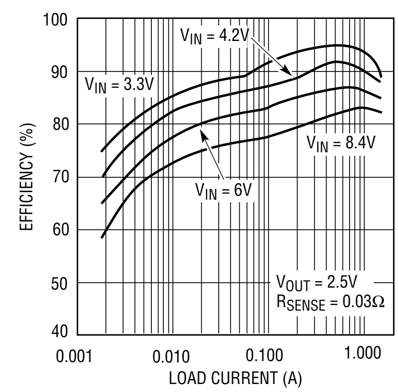


Figure 2. Efficiency vs load current for Figure 1's circuit (Burst Mode enabled)

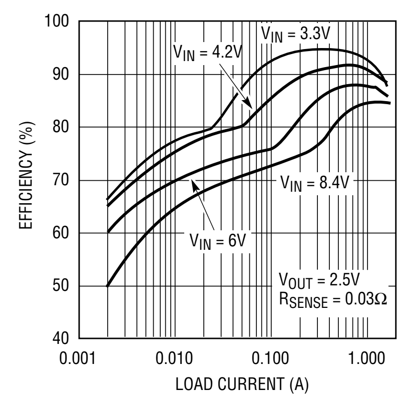


Figure 3. Efficiency vs load current for Figure 1's circuit (Burst Mode disabled)

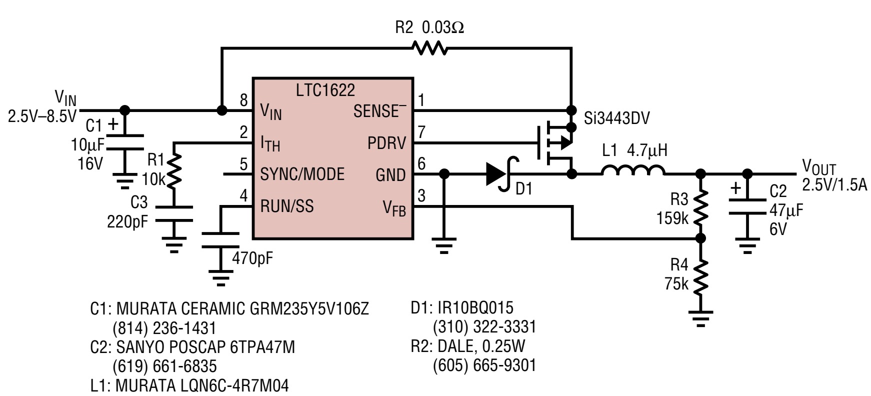


Figure 1. LTC1622 typical application: 2.5V/1.5A converter

high (> 80%), the value of the sense resistor is set to approximately 50mV/I_{OUTMAX} to account for the effect of slope compensation. Under short-circuit conditions, the frequency of the oscillator will be reduced to about 120kHz. This low frequency allows the inductor current to safely discharge, thereby preventing current runaway.

The LTC1622 includes protection against output overvoltage conditions or transients. An overvoltage comparator monitors the output voltage and forces the external MOSFET off when the feedback voltage has risen to 8% above the reference voltage (0.8V).

Burst Mode Operation

The LTC1622's Burst Mode operation is enabled at low load currents simply by connecting the SYNC/MODE pin to V_{IN} or letting it float. In this mode, the minimum peak current of the inductor is set to 0.36V/R_{SENSE} even though the voltage at the I_{TH} pin would indicate a lower value. If the inductor's average current is greater than the load requirement, the voltage at the I_{TH} pin will drop as V_{OUT} rises slightly. When the I_{TH} voltage goes below 0.12V, a sleep signal is generated, turning off the external MOSFET. The load current is now supported by the output capacitor. The LTC1622 will resume normal operation when the I_{TH} voltage goes above 0.22V. For frequency-sensitive applications, Burst Mode operation is inhibited by connecting the SYNC/MODE pin to ground. In this case, constant-frequency operation will be maintained at a lower load current together with lower output ripple. If the load current is low enough, cycle skipping will occur to maintain regulation.

Frequency Synchronization

The LTC1622 can be externally driven by a clock signal of up to 750kHz. Synchronization is inhibited when the feedback voltage is below 0.3V. This is done to prevent inductor current build-up under short-circuit conditions. Burst Mode operation is inhibited when the LTC1622 is driven by an external clock.

Undervoltage Lockout and Dropout Operation

An undervoltage lockout circuit is incorporated into the LTC1622. When the input voltage drops below 2.0V, most of the LTC1622 circuitry will be turned off, reducing the quiescent current from 400µA to several microamperes and forcing the external MOSFET off.

The LTC1622 is capable of turning the external P-channel MOSFET on continuously (100% duty cycle) when the input voltage falls to near the output voltage. In dropout, the output voltage is determined by the input voltage minus the voltage drop across the MOSFET, the sense resistor and the inductor resistance.

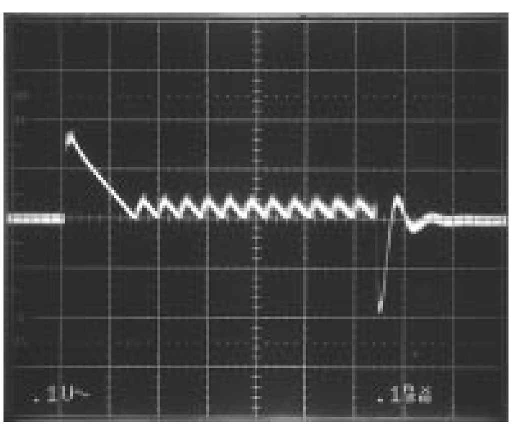
RUN/Soft-Start Pin

The RUN/SS pin is a dual-function pin that provides the soft-start function and a means to shut down the LTC1622. An internal current source charges an external capacitor. When the voltage on the Run/SS pin reaches 0.65V, the LTC1622 begins operating. As the voltage on the RUN/SS continues to increase linearly from 0.65V to 1.8V, the internal current limit also increases proportionally. The current limit begins at 0A (at $V_{RUN/SS}$ = 0.65V) and ends at 0.10V/R_{SENSE} ($V_{RUN/SS}$ > 1.8V); therefore, this pin can be used for power supply sequencing.

2.5V/1.5A Step-Down Regulator

A typical application circuit using the LTC1622 is shown in Figure 1. This circuit supplies a 1.5A load at 2.5V with an input supply between 2.7V up to 8.5V. The 0.03Ω sense resistor is selected to ensure that the circuit is capable of supplying 1.5A at a low input voltage. In addition, a sublogic threshold MOSFET is used, since the circuit operates at input voltages as low as 2.7V. The circuit operates at the internally set frequency of 550kHz. A 4.7µH inductor is chosen so that the inductor's current remains continuous during burst periods at low load current. For low output voltage ripple, a low ESR capacitor (100mΩ) is used.

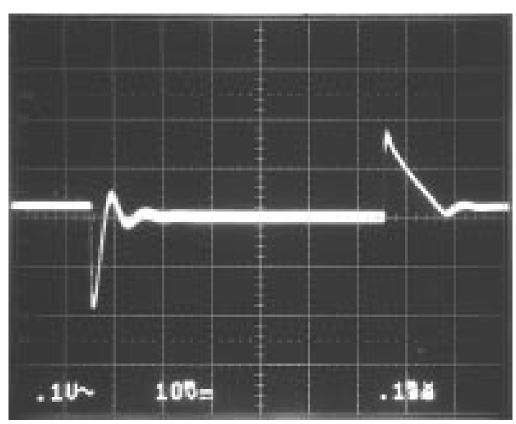
OUTPUT VOLTAGE
(AC COUPLED)
0.1V/DIV



0.1ms/DIV

Figure 4. Transient response with Burst Mode enabled; load step = 50mA to 1.2A

OUTPUT VOLTAGE
(AC COUPLED)
0.1V/DIV



0.1ms/DIV

Figure 5. Transient response with Burst Mode inhibited; load step = 50mA to 1.2A

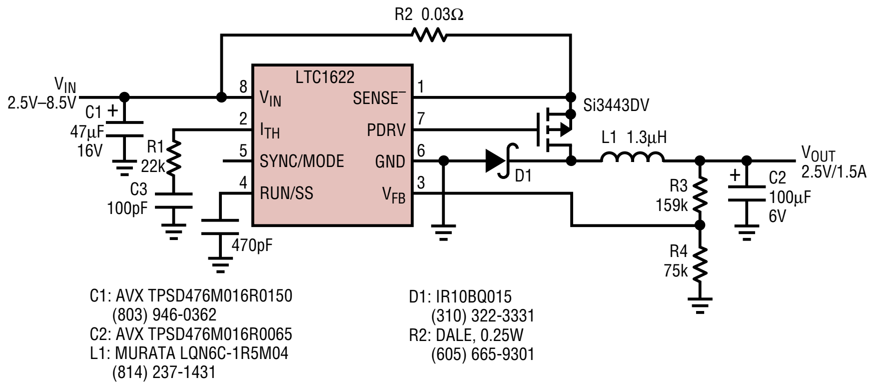


Figure 6. 2.5V/1.5A converter with improved transient response

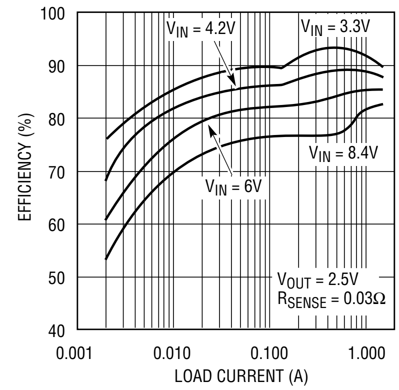


Figure 9. Efficiency vs load current for Figure 6's circuit (Burst Mode enabled)

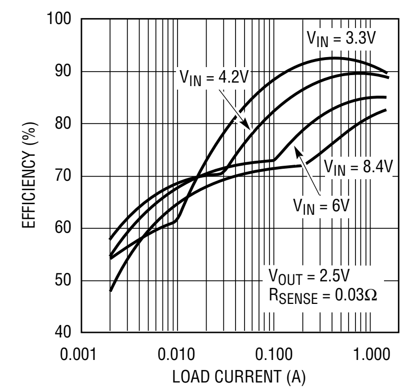


Figure 10. Efficiency vs load current for Figure 6's circuit (Burst Mode disabled)

Efficiency Considerations

The efficiency curves for Figure 1's circuit are shown in Figures 2 and 3. Figure 2 shows the efficiency with Burst Mode enabled, whereas Figure 3 has Burst Mode defeated. Note that, at low load currents, the efficiency is higher with Burst Mode operation. However, constant frequency operation is still achievable at a lower load currents with Burst Mode operation defeated. The kinks in the efficiency curves indicate the transition out of Burst Mode operation.

The components of Figure 1 have been carefully chosen to provide the amount of output power using a minimum of board space. Efficiency is also a prime consideration in selecting the components, as illustrated in Figures 2 and 3. Figures 4 and 5 show the transient response of V_{OUT} with a load step from 50mA to 1.2A. Figure 4 has Burst Mode enabled, while Figure 5 has it defeated. Note that the output voltage ripple (in the middle portion of the photographs) is higher for Burst Mode operation than with Burst Mode disabled at 50mA load current.

Applications that require better transient response can use the circuit in Figure 6, whose components are selected specifically for this requirement. Figures 7 and 8 show the response with and without Burst Mode operation, respectively. Note that the transient response has been enhanced significantly. However, this comes at the expense of slightly reduced efficiency at low load currents, as indicated by the efficiency curves of Figures 9 and 10.

Conclusion

Although the LTC1622 comes in a tiny 8-pin MSOP, it is packed with features that are not normally found in other DC/DC converters. Its ability to operate from input voltages as low as 2.0V makes it attractive for single lithium-ion battery-powered applications. Features like Burst Mode and 100% duty cycle ensure that energy from the battery is used efficiently and charge is extracted down to the last coulomb. For telecommunications products, where noise generated by a switching regulator may spell trouble, the synchronizable LTC1622 can operate at a constant frequency, making noise a nonissue for system designers.

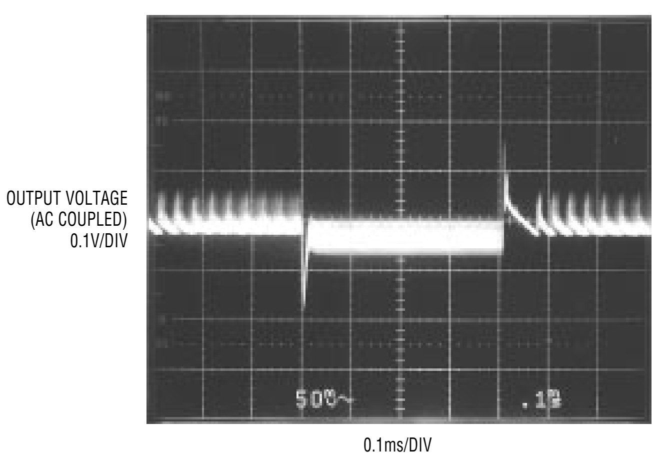


Figure 7. Transient response with Burst Mode enabled; load step = 50mA to 1.2A

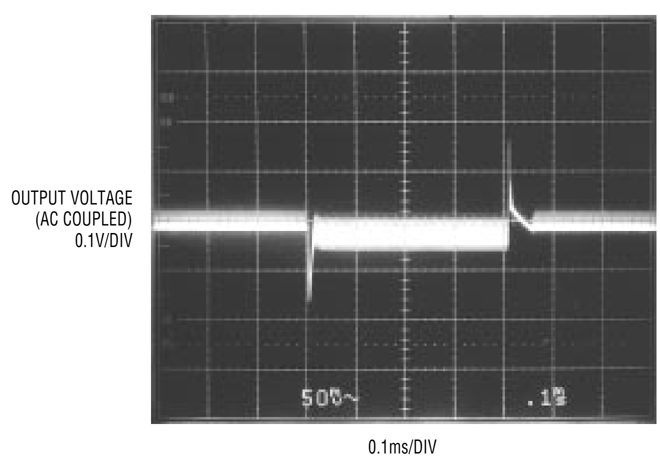


Figure 8. Transient response with Burst Mode inhibited; load step = 50mA to 1.2A