

New DC/DC Controller Enables High Step-Down Ratios

by Greg Dittmer

Importance of Minimum On-Time

As processor voltage requirements are pushed lower and lower, input supply voltages remain high, forcing DC/DC converters to operate at lower and lower duty cycles. Since operating frequencies also remain high to minimize noise and the size of components, the on-time of the topside switch in a constant-frequency converter must continue to decrease to regulate the lower and lower output voltages. The required on-time is given by $T_{ON} = V_{OUT}/(V_{IN} \cdot f)$

Unfortunately, there is a limit to how small this time can be. In a typical current mode DC/DC converter, once the main switch is turned on at the beginning of each switching cycle, the speed at which it can be turned off is limited by the response time of the current comparator, the time required for the turn-off command to propagate through the logic and output driver and the time required to discharge the capacitance of the topside gate. These delays add up to a few hundred nanoseconds and constitute the minimum time the topside switch must stay on during each switching cycle. If the maximum V_{IN} and frequency are fixed, this minimum on-time sets a lower limit on

output voltage. If an output voltage below this limit is required, the only choice is to lower the operating frequency, which is usually not desirable. Figure 1 shows the on-times required with $V_{IN} = 22V$ as a function of output voltage for various frequencies.

Capabilities of the LTC1435

The LTC1435 high efficiency synchronous DC/DC controller has been extremely popular for notebook computers and other battery-powered equipment due to its low noise, constant-frequency operation and its dual N-channel drive for outstanding high current efficiency without sacrificing low dropout operation. However, its 400ns–500ns minimum on-time requires lower operating frequencies (<150kHz) to regulate output voltages below 2.0V if V_{IN} is high.

What happens if minimum on-time is violated in the LTC1435? If V_{IN} is increased so that the on-time falls below $T_{ON(MIN)}$, the LTC1435 will begin to skip cycles to remain in regulation. During this “cycle-skipping” mode, the output remains in regulation but the operating frequency decreases, causing the inductor ripple current and output ripple voltage to increase.

Enter the LTC1435A

The operating envelope has been substantially expanded with the introduction of the new LTC1435A DC/DC controller, which has all the outstanding features of the LTC1435 with a reduced minimum on-time of 300ns or less and improved noise immunity at low output voltages. With these improvements, high performance at output voltages down to 1.3V can be achieved with operating frequencies in excess of 250kHz from input supply voltages above 22V. Figure 2 shows the resulting improvement of maximum V_{IN} vs output voltage as a result of the reduced minimum on-time.

The LTC1435A's minimum on-time is dependent on the speed of the internal current comparator, which in turn is dependent on the amplitude of the signal the comparator is monitoring: inductor ripple current. Thus, the higher the ripple current, the lower the minimum on-time. Figure 3 shows how minimum on-time varies as a function of the inductor ripple amplitude. At higher amplitudes, $T_{ON(MIN)}$ is less than 250ns; at low amplitudes it can be 350ns or more. This means that for low duty cycle applications where the on-time

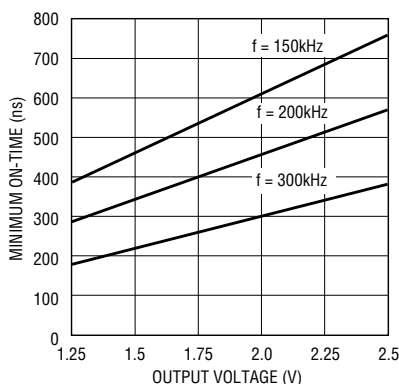


Figure 1. Minimum on-time required for $V_{IN} = 22V$

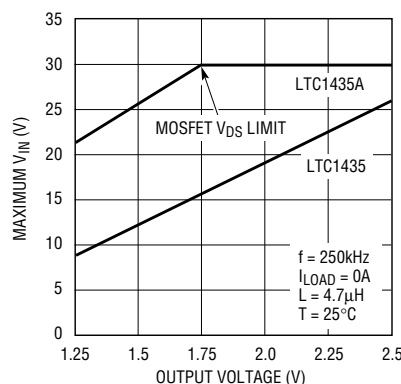


Figure 2. LTC1435/LTC1435A maximum V_{IN} comparison

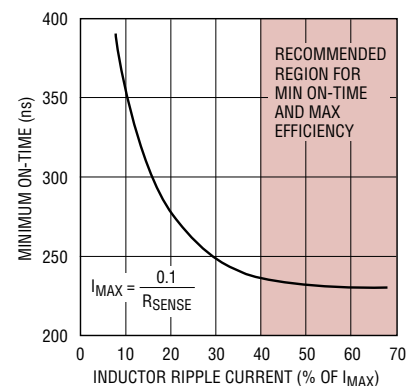


Figure 3. LTC1435A minimum on-time vs inductor ripple current

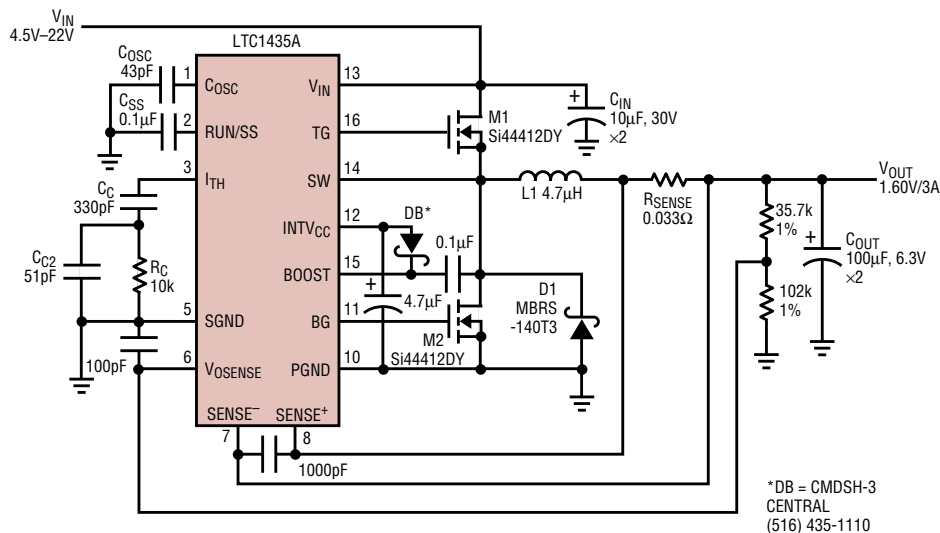


Figure 4. LTC1435A 22V to 1.6V/3A converter (f = 250kHz)

is approaching $T_{ON(MIN)}$, there may be a minimum ripple current amplitude, and hence, a maximum inductance necessary to prevent cycle skipping. Or, expressed differently, the lower the inductance, the higher the maximum V_{IN} that can be achieved before the minimum on-time is violated and cycle skipping occurs. For most applications, 40% ripple not only reduces the minimum on-time but also optimizes efficiency.

22V to 1.6V Converter at 250kHz

Figure 4 shows the LTC1435A configured in an all N-channel synchronous buck topology as a 22V to 1.6V/3A converter running at 250kHz. The 43pF C_{OSC} capacitor sets the internal

oscillator frequency at 250kHz and the 33mΩ sense resistor sets the maximum load current at 3A. For a 22V to 1.6V converter, the on-time required is:

$$T_{ON} = 1.6 / (22 \times 250\text{kHz}) = 291\text{ns}$$

Can the LTC1435A do this? At maximum V_{IN} the inductor ripple is

$$\Delta I_L = \frac{V_{OUT} \cdot (1 - V_{OUT}/V_{IN})}{F \cdot L}$$

$$= \frac{1.6 \cdot (1 - 1.6/22)}{250\text{kHz} \cdot 4.7\mu\text{H}} = 1.3\text{A}$$


which is 43% of the 3A maximum load. From Figure 3, 43% ripple gives a minimum on-time of 235ns, which is well below the 291ns required by

this application, so no cycle skipping will occur. If a 10μH inductor is used, the ripple amplitude drops to 0.6A or 20% and the minimum on-time increases to 280ns. This does not provide much margin below the 291ns on-time required, and thus the 4.7μH inductor is a better choice.

Intel Mobile Processor VID Power Converter

Figure 5 shows the LTC1435A used with an LTC1706-19 to implement an Intel Mobile Pentium® II Processor VID power converter. This DC/DC converter provides digitally selectable output voltages over the range of 1.3V to 2.0V in 50mV increments at 250kHz and a 7A load current. The selectable output voltage is implemented by replacing the conventional feedback resistor network with the LTC1706-19, which provides the appropriate feedback resistor ratios internally (see the accompanying article in this issue). The proper ratio is selected with the 4-bit digital input pins.

Conclusion

The LTC1435A retains all the outstanding features of the LTC1435, such as constant-frequency operation, dual N-channel MOSFET drive and low dropout, while adding enhancements such as reduced minimum on-time and improved performance at low output. With these enhancements, the LTC1435A is a perfect fit for notebook computers and battery-powered equipment requiring high frequency, low duty cycle DC/DC converters. 

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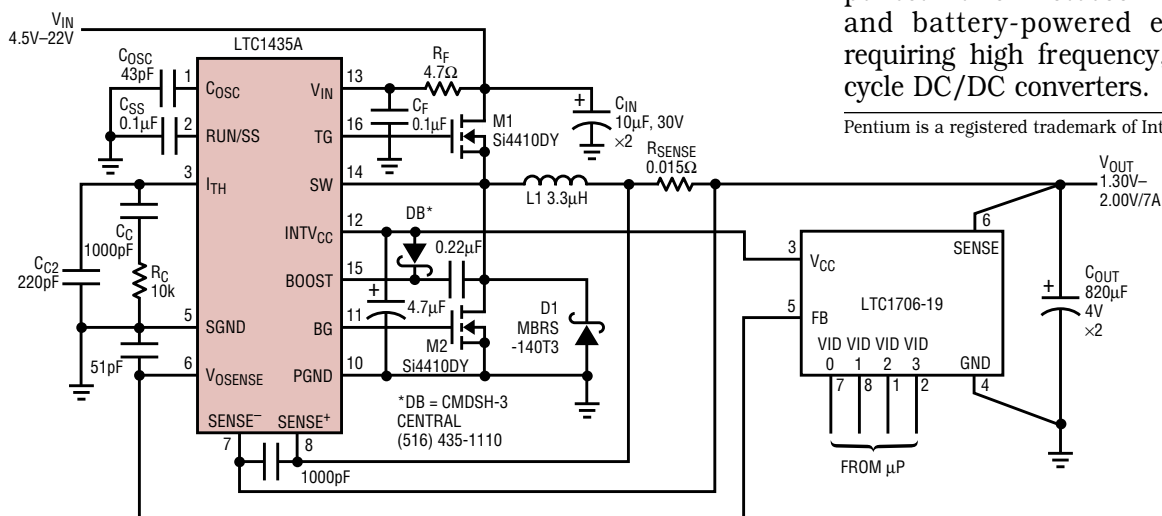


Figure 5. Intel Mobile Pentium II processor VID power converter