DESIGN NOTES

µPower Buck Regulator Safely Rides Through Automotive Load Dumps – Design Note 475

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Introduction

When a buck regulator is used in applications where output short-circuit and overload conditions occur, the duty cycle required to keep the inductor current under control can be lower than the regulator's minimum duty cycle when operating at full speed. Therefore, to effectively protect a traditional regulator under such conditions, its switching frequency must be reduced to a speed that can safely handle the maximum expected input voltage.

In some cases, frequency foldback can help reduce the effective duty cycle by reducing the switching frequency as the output voltage falls out of regulation. However, this technique might not provide enough protection if the *folded* frequency is not low enough. In the end, the duty cycle problem imposes a limit on the maximum switching frequency at which the regulator can be safely operated, especially in automotive applications where the input supply can see positive voltages several times higher than the normal 12V operating voltage.

The LT®3682 is a new 1A buck regulator that overcomes the duty cycle limitation by monitoring the current through the external catch diode, and delaying the generation of new switch pulses if this current exceeds a defined value. The LT3682 safely accommodates output shorts and overload conditions up to its maximum adjustable operating frequency of 2.2MHz regardless of input voltage. This added level of protection allows automotive systems designers to take advantage of the maximum

switching frequency of the regulator without concern for transients on the input supply.

The LT3682 accepts input voltages from 3.6V to 36V and transients up to 60V. Additional features such as soft-start, power good flag, frequency foldback and thermal shutdown are all included in the thermally enhanced 12-lead 3mm × 3mm DFN package.

Minimum Switch On-Time

Under normal load conditions the internal switch current limit is regulated to meet the required peak inductor current. Due to internal delays, the power switch does not turn off immediately when the internal current limit is reached, but instead takes the minimum on-time ($t_{ON(MIN)}$) to do so. This delay allows the inductor current to continue rising to values that depend on the current slope and the value of $t_{ON(MIN)}$. During positive input voltage transients the slope of the rising inductor current is greatly increased, thus raising its peak value. A well designed buck converter must skip switch pulses to maintain regulation if the new duty cycle requirements cannot be met due to minimum on-time limitations.

Overload conditions during the input transients may aggravate the situation further. Under extreme overloads the internal current limit is ultimately clamped to its maximum value, I_{LIM}, and the output voltage falls out of regulation, reducing the negative slope of the inductor
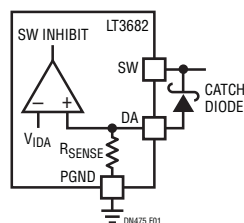
Figure 1. The LT3682 Monitors the Current Flowing Through the External Catch Diode at the DA Pin
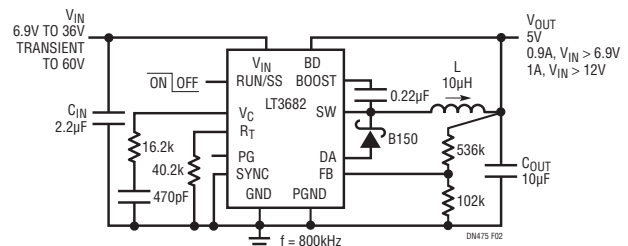

Figure 2. A Typical 800kHz Application

current accordingly. If during the switch off-time the inductor current does not return to the same or smaller values it had at the end of the previous cycle, its peak value will ratchet higher in every cycle and increase to unacceptably high levels.

Monitoring Current Via the DA Pin

The LT3682 constantly monitors the inductor current during the switch off-time by looking at the current flowing through the external catch diode via the DA (diode anode) pin (see Figure 1) and delays the generation of new switch pulses if this current does not fall below a defined threshold, I_{DA}, thus reducing the regulator's effective duty cycle.

Thus, it is now possible to use the small footprint inductors found in high frequency applications without sacrificing robustness during a number of fault conditions. Figures 2 and 5 show how to configure the LT3682 in a $5V_{OUT}$ application with a 800kHz and 1.7MHz programmed switching frequency, respectively. The resistive load at V_{OUT} is increased until the regulator hits its maximum current limit. Figures 3, 4, 6 and 7 show the DA pin current sense protection for input voltages of 12V and 36V for both applications. In all cases the lowest value of the inductor current is pinned to about 1.1A, which keeps its peak value well under control. By delaying the generation of new switch pulses the switching frequency is effectively reduced to satisfy the new duty cycle requirements introduced by the fault condition.
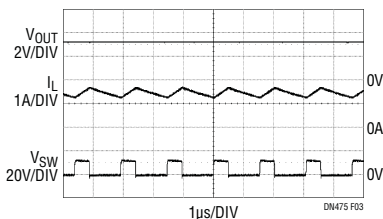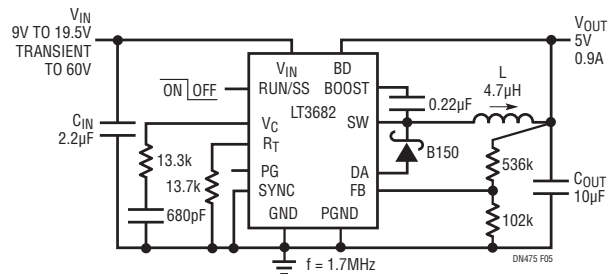
Figure 3. The 800kHz Application with V_{IN} = 12V. Overload Condition Forces V_{OUT} to Drop to About 3.2V
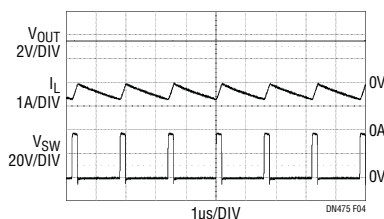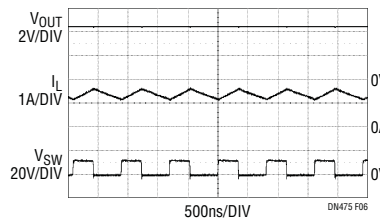
Figure 4. The 800kHz Application with V_{IN} = 36V. Overload Condition Forces V_{OUT} to Drop to About 3.5V

Conclusion

The LT3682 is a 1A monolithic buck switching regulator that accepts input voltages from 3.6V to 36V and transients up to 60V. It features an adjustable and synchronizable switching frequency from 250kHz to 2.2MHz. It also has the ability to monitor the current flowing through the external catch diode, thus providing an extra level of protection against output fault conditions over the entire operating frequency range, regardless of input voltage. These features, together with its typical 75µA no load quiescent current makes the LT3682 the right choice in high frequency automotive and battery-powered applications.

Figure 5. A Typical 1.7MHz Application

Figure 6. The 1.7MHz Application with V_{IN} = 12V. Overload Condition Forces V_{OUT} to Drop to About 4.4V
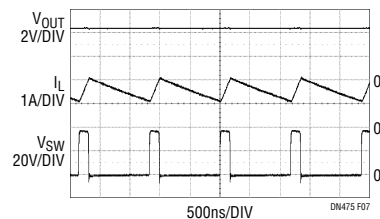
Figure 7. The 1.7MHz Application with V_{IN} = 36V. Overload Condition Forces V_{OUT} to Drop to About 4.4V

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