Starting Up A Buck Regulator With a Voltage Present At V_{OUT}

National Semiconductor
Application Note 1634
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May 2007

The Problem

The problem described in this application note is that of a buck regulator's inability to startup when there is a voltage already present at the regulator's output (V_{OUT}). The voltage at V_{OUT} may be due to active load circuitry (powered from a different source) providing a voltage at V_{OUT} through leakage, or because the buck regulator's output capacitor has not completely discharged due to a momentary shutdown.

The problem is inherent in non-synchronous buck regulators implemented with a high side N-Channel MOSFET. This configuration incorporates a "boost" circuit to provide a voltage above the input voltage necessary to enhance the MOSFET gate during the on-time.

Although the LM5007 is used in this application note, the same discussion applies to the LM50xx and LM349xx series of buck regulators.

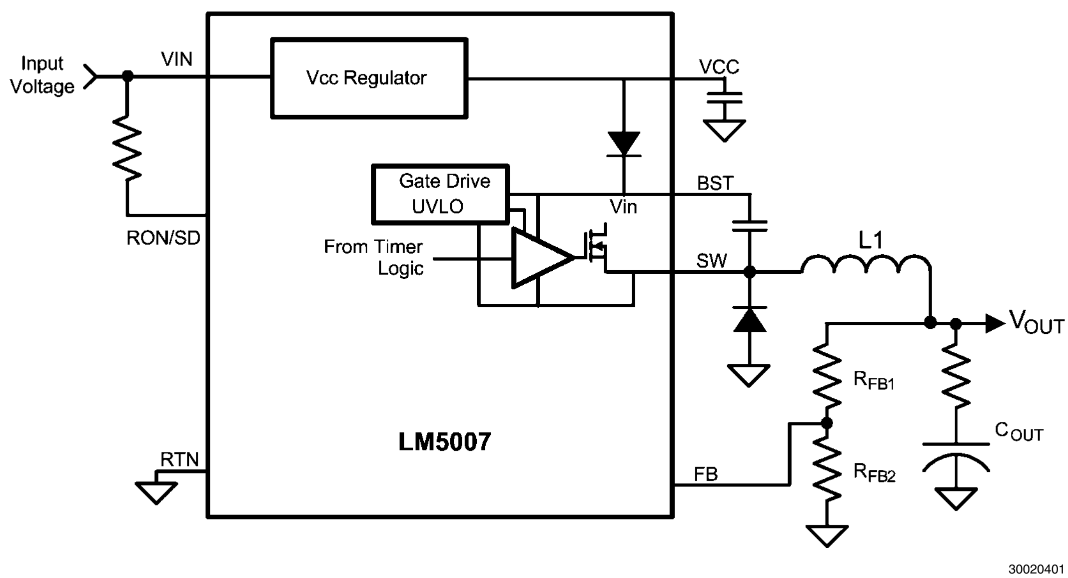

FIGURE 1. Partial Block Diagram

Referring to *Figure 1*, the voltage across the boost capacitor (between the BST and SW pins) provides the voltage to power the Gate Drive circuit, and the charge to turn-on the internal buck MOSFET at the beginning of each on-time. If the voltage across the capacitor is low – less than the Gate Drive Under-Voltage Lock-Out (UVLO) level - the buck switch will not be turned on in order to prevent a partial turn-on situation which may damage the MOSFET.

In normal operation, the boost capacitor is recharged every off-time from the internal Vcc regulator (7V) when the free-wheeling diode is conducting. During this time the SW pin is at approximately -0.6V. The voltage across the boost capacitor is therefore approximately 7V at the beginning of each on-time.

In a typical application, if the circuit is shutdown by removing the input voltage, the boost capacitor voltage decays to 0 volts. When the input voltage is reapplied, the boost capacitor is then recharged to 6.5V (if the output voltage had dropped to 0 volts). Alternately, if the regulator is disabled by grounding the Ron/SD pin, the voltage at the SW pin tracks V_{OUT} as the output voltage falls. When Vout decays to 0 volts the voltage across the boost capacitor is at approximately 6.5V. In both cases, when the regulator is again enabled, the buck switch is able to be turned on since the Gate Drive UVLO is satisfied, and startup proceeds normally.

But if a voltage is present at V_{OUT} (and therefore at the SW pin) at the time a restart is initiated the voltage across the boost capacitor is less than 7 volts. If the external voltage at V_{OUT} is high enough, such that the voltage across the boost capacitor is less than the Gate Drive UVLO threshold, the gate driver is disabled. In this situation the voltage across the boost capacitor is:

$$V_{BST} = Vcc - Vd - V_{OUT} \qquad (1)$$

where Vd is the voltage drop across the internal diode (typically 0.5V).

Rearranging the above equation to calculate the maximum allowed value of the externally applied voltage at V_{OUT}:

$$V_{OUT(max)} = Vcc - Vd - GD_{(UVLO)}$$

where $GD_{(UVLO)}$ is the gate drive UVLO threshold. Using typical values for the LM5007:

$$V_{OUT(max)} = 7.0V - 0.5V - 4.5V = 2V$$

Using min/max limits from the LM5007 data sheet to determine the worst case situation:

$$V_{OUT(max)} = 6.6V - 0.6V - 5.5V = 0.5V$$

Therefore, the externally applied voltage must not exceed 2V (0.5V worst case) to ensure the circuit restarts. This limitation is independent of the voltage at VIN.

The Solution

Two suggested solutions are provided for this problem – which one is appropriate depends upon the specifics of the application.

1) Ensure the initial value of V_{OUT} is low enough so the voltage across the boost capacitor is above the $GD_{(UVLO)}$ threshold. This may be accomplished by allowing sufficient time for the output capacitor to discharge, or by manually discharging V_{OUT} if waiting is not an option. Discharging V_{OUT} can be accomplished by switching in a low value resistor from V_{OUT} to ground, starting up the regulator circuit, and then switching out the resistor once the circuit is functioning.

2) Apply a pull-up voltage to the VCC pin. Referring to equation 1, increasing the Vcc voltage increases the voltage across the boost capacitor. Equation 1 can be used to determine the required voltage at VCC for each application. The following cautions must be observed if this solution is used:

a) The maximum voltage applied to the VCC pin cannot exceed 14V. Therefore, this solution is suitable only if the externally applied voltage at V_{OUT} is less than 9V (7.9V worst case).

b) The Vcc regulator has an inherent internal body diode connected between the VCC pin and the VIN pin. If the Vcc voltage is greater than the VIN voltage this diode will conduct, and if the current is not limited the regulator may be damaged. Therefore if an external voltage is applied to Vcc, and a condition may exist where it exceeds the voltage at V_{IN}, it is imperative that the external Vcc voltage source be current limited to less than 50 mA.

Summary

The problem described above is inherent in the configuration of a non-synchronous buck regulator employing a high side N-Channel buck switch with a gate driver UVLO feature. Two suggested solutions are provided which may be fairly simple to implement in many applications. However, each application must be evaluated to determine if this issue will limit the operation of the regulator.

Notes

Notes

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