

AN-2129 Boot Capacitor Regulation in LM25007 Constant-On-Time (COT) Converter

ABSTRACT

This application report discusses boot capacitor regulation in the Texas Instruments LM25007 constant-on-time (cot) converter.

Contents

| | | |
|-----|--|---|
| 1 | The Issue | 2 |
| 2 | The Solution | 3 |
| 2.1 | Increasing Boot Capacitor (CBST) | 3 |
| 2.2 | Reducing Feedback Resistors (RFB1, RFB2) | 3 |
| 2.3 | Raising V_{BST} Using External Circuit | 4 |

List of Figures

| | | |
|---|---|---|
| 1 | LM25007 Application with Prebiased Output..... | 2 |
| 2 | Startup with Prebiased Output | 2 |
| 3 | Hiccup Mode Operation at No Load | 3 |
| 4 | Raising Boot Capacitor Voltage Using External Circuit | 4 |

1 The Issue

LM25000 series of constant-on-time (COT) integrated regulators provide a simple, cost-effective way of implementing a step down buck regulator with nearly fixed frequency. Non-synchronous operation reduces switching frequency at very light load resulting in higher efficiency than a comparable fixed frequency converter. The non-synchronous operation, however, causes two problems related to boot capacitor regulation under certain operating conditions.

Bootstrap capacitor (C_{BST}) may have insufficient voltage during startup if a voltage is present at the output of the converter see [Figure 1](#). This voltage is usually referred to as prebias. Since, at startup, there is no current in the inductor (L), the prebias voltage at the output appears at the switch node. If this prebias voltage is high such that the boot capacitor voltage ($V_{BST} = V_{CC} - V_{SW}$) is lower than the threshold voltage (V_{TH}) of high side gate, the high side switch fails to turn 'on' and the converter fails to startup see [Figure 2](#). This condition persists until prebias is removed. A prebias is often caused by some leakage path in downstream circuits, e.g., a logic circuit or FPGA with a pin pulled high, or leftover charge from a previous power down.

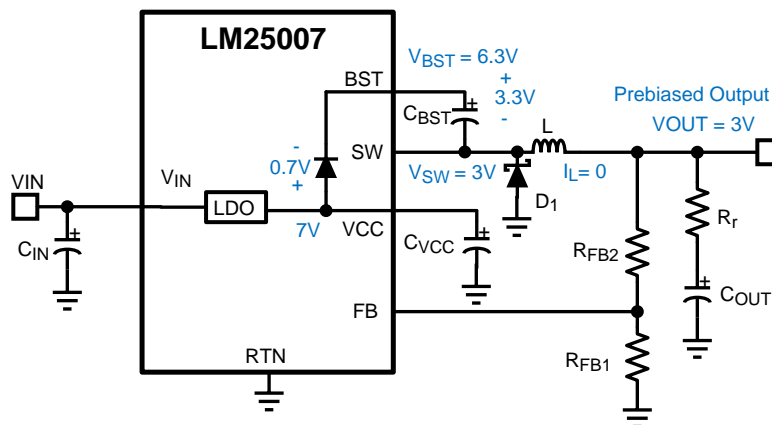


Figure 1. LM25007 Application with Prebiased Output

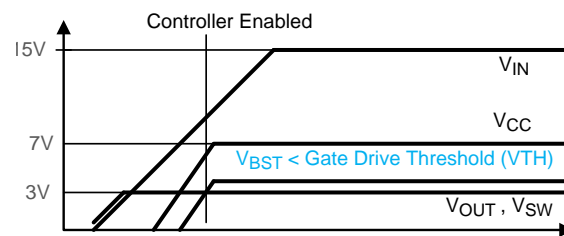


Figure 2. Startup with Prebiased Output

A similar situation may occur under light load or no load conditions see [Figure 3](#). At light load/no load, the inductor current is discontinuous causing the diode (D1) to turn off for a relatively long off time. During this time the bootstrap capacitor (C_{BST}) may discharge to a level below the top side FET gate drive threshold (V_{TH}), which is normally around 5V. Under these conditions the top side FET fails to turn on and the output voltage is no longer regulated. Since there is no current in the inductor, this output voltage appears at the switch node ($V_{SW}=V_{OUT}$). As V_{OUT} , and therefore V_{SW} , drops, the bootstrap capacitor voltage rises and is given by $V_{BST} = V_{CC} - V_{OUT}$. When $V_{CC} - V_{OUT} > V_{TH}$, the hi-side FET turns on again and the switching resumes bringing the V_{OUT} to the target level. At that time, if the low load condition persists, the whole cycle will repeat itself, causing a hiccup mode operation in which V_{OUT} fall to $V_{CC} - V_{TH}$ and rises back to the target level. This loss of regulation is undesirable in many applications.

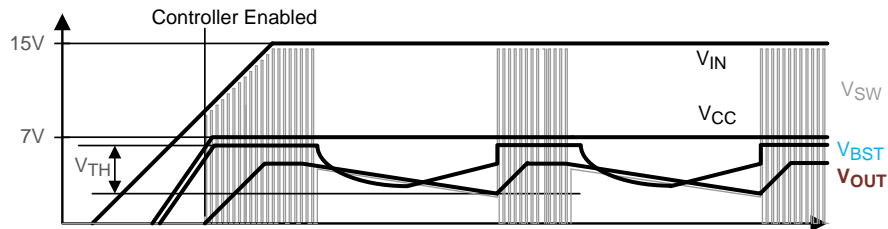


Figure 3. Hiccup Mode Operation at No Load

2 The Solution

For prebiased startup problem, the source of prebias should be removed if possible. If the prebias source is some leakage path in the downstream logic circuit, the system designer should consider the option of tying unused logic pin, which is the source of leakage, low. In some cases, this leakage path may be difficult to identify, or a necessary part of design. In other cases, the source of prebias may be a stiff source, e.g., a battery or super capacitor at the output of the converter. The system designer can choose from the techniques described below depending on the constraints of his design.

2.1 Increasing Boot Capacitor (CBST)

The designer can increase the boot capacitor value so that during no load boot capacitor is not discharged below the gate threshold of high side switch before V_{OUT} , and hence V_{FB} , falls below the reference. The hiccup free operation should be verified for whole input voltage (V_{IN}) range. The designer should not exceed the recommended boot capacitor value in the datasheet. This method does not help in case of prebiased output.

2.2 Reducing Feedback Resistors (RFB1, RFB2)

In no load condition, feedback Resistors, FB1 and FB2, constitute the total load at the output of the converter. These should be chosen so that V_{OUT} and hence V_{FB} fall below the reference level faster than V_{BST} falls below the gate threshold (V_{TH}). The hiccup free operation should be verified for whole input voltage (V_{IN}) range.

For prebiased outputs during startup, reducing the feedback resistors effectively pulls the V_{OUT} and V_{SW} closer to ground, thereby raising the boot capacitor (C_{BST}) voltage. The extent of this pull down however depends on the strength and voltage level of the prebias source. This method of counteracting prebias is limited to weak prebias sources or leftover charge on output capacitor (C_{OUT}) from previous power cycle.

2.3 Raising V_{BST} Using External Circuit

If none of the simpler solutions previously presented are sufficient, an external pull up circuit can be used to raise the boot capacitor voltage (V_{BST}) above gate threshold (V_{TH}) of high side switch. An example circuit is shown in Figure 4. The 50k Ω pull up resistor pulls BST pin up while limiting the current drawn from V_{IN} . The 10V zener prevents the boot capacitor voltage from exceeding the maximum voltage rating between BST and SW pins. This method is effective for no load as well as prebiased output conditions. The designer should select the pull up resistor to optimize the voltage drop across it and the power dissipation in the pull up resistor and the zener.

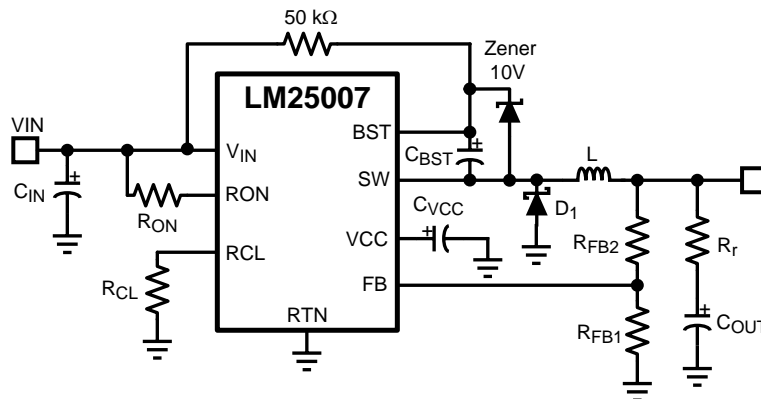


Figure 4. Raising Boot Capacitor Voltage Using External Circuit

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products

| | |
|------------------------------|--|
| Audio | www.ti.com/audio |
| Amplifiers | amplifier.ti.com |
| Data Converters | dataconverter.ti.com |
| DLP® Products | www.dlp.com |
| DSP | dsp.ti.com |
| Clocks and Timers | www.ti.com/clocks |
| Interface | interface.ti.com |
| Logic | logic.ti.com |
| Power Mgmt | power.ti.com |
| Microcontrollers | microcontroller.ti.com |
| RFID | www.ti-rfid.com |
| OMAP Applications Processors | www.ti.com/omap |
| Wireless Connectivity | www.ti.com/wirelessconnectivity |

Applications

| | |
|-------------------------------|--|
| Automotive and Transportation | www.ti.com/automotive |
| Communications and Telecom | www.ti.com/communications |
| Computers and Peripherals | www.ti.com/computers |
| Consumer Electronics | www.ti.com/consumer-apps |
| Energy and Lighting | www.ti.com/energy |
| Industrial | www.ti.com/industrial |
| Medical | www.ti.com/medical |
| Security | www.ti.com/security |
| Space, Avionics and Defense | www.ti.com/space-avionics-defense |
| Video and Imaging | www.ti.com/video |

TI E2E Community

e2e.ti.com