AN-2171 Designing Constant-On-Time Buck Regulators for Low Drop-Out Voltage

ABSTRACT

This application note presents a simple scheme to improve the drop-out voltage in constant-on-time buck regulators.

Contents

List of Figures

1 Description

Constant-On-Time (COT) regulators provide a simple, cost-effective way of implementing a step down buck regulator with nearly fixed frequency. Constant-On-Time regulators do not require loop compensation and provide excellent transient performance with minimum design effort and part count.

In a COT buck regulator, the high side switch is controlled by a ‘T_{ON}’ timer. Once the timer expires, the high side switch turns off and does not turn back on again until the voltage at the feedback node falls below the reference voltage. To avoid spurious turn-on caused by switching noise and to allow the bootstrap capacitor to charge, there is a minimum built-in ‘OFF’ time ($T_{OFF\ (min)}$ = 347ns max) in LM5006. This minimum T_{OFF} restricts the maximum duty cycle of the converter for a given switching frequency. This effect is more pronounced at higher switching frequencies as shown in Figure 2 for the circuit of Figure 1. The output voltage (V_{OUT}) drops below 10V for input voltage (V_{IN}) smaller than about 14.0V.

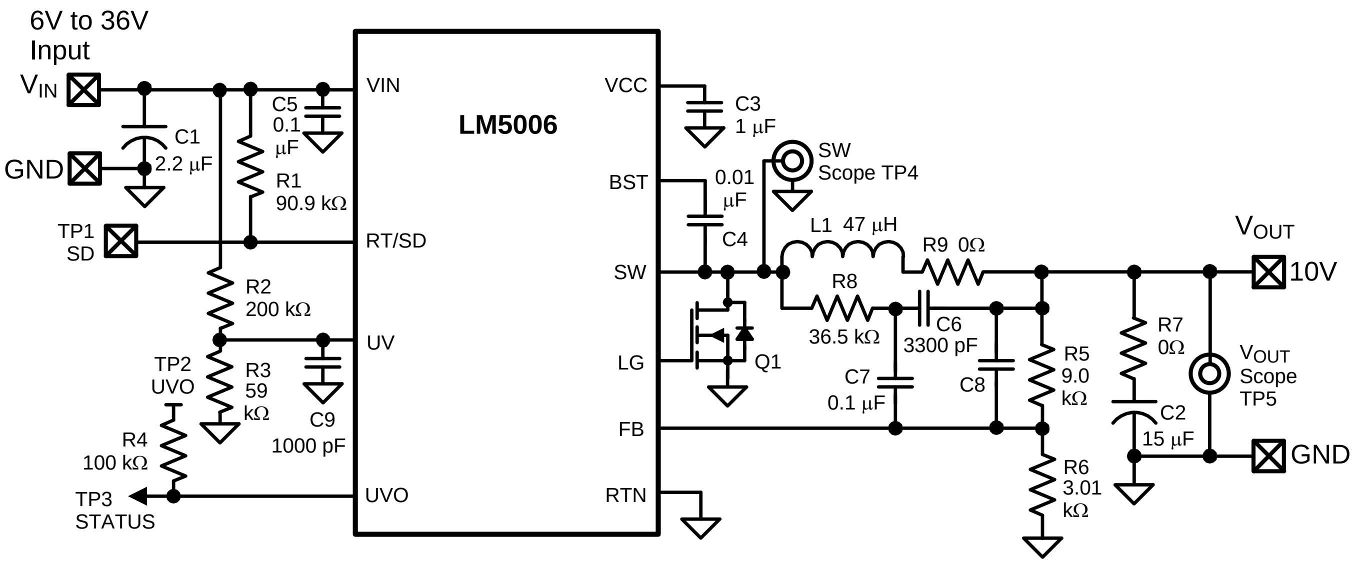

Figure 1. LM5006 Buck Application Circuit, R1 = 90.9kΩ, fsw = 920kHz

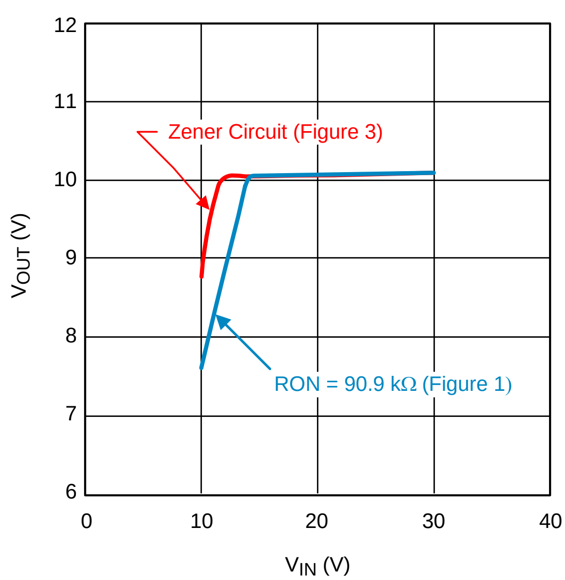

Figure 2. LM5006, V_{IN} vs V_{OUT} (Low V_{IN} Range Extended for Zener Circuit)

In some applications it may be desirable to minimize the dropout voltage in low input voltage condition. One way to minimize the drop out voltage is to reduce the switching frequency. But low frequency operation at high and nominal V_{IN} does not allow the designer to choose smaller filter components. It is, therefore, desirable to keep higher switching frequency for high and nominal V_{IN} range and reduce it only at low V_{IN} to reduce the drop-out voltage. This can be done by modifying adding external components to R_T pin as shown in Figure 3. The parts shown in blue are added to create non-linear R_T resistor. The zener and series resistors are selected so that the NFET turns on at a V_{IN} slightly above 14V where the converter of Figure 1 dropped out of regulation. For V_{IN} > 14V, the external NFET is 'on' and the effective R_T is 90kΩ, the same as in Figure 1. For V_{IN} <14V, the external NFET is 'off' and the effective R_T is 360kΩ. For this higher R_T, the 'T_{ON}' of the converter increases resulting in higher duty cycles. As shown in Figure 2 (red curve), the input voltage range of converter is extended down to V_{IN}=12V for a well regulated output. A low leakage FET (such as BSP123) should be selected to emulate an ideal switch effect. The designer should select the zener and resistor dividers so that the maximum ratings of the components are not exceeded. As always, the design should be verified over the input voltage range.

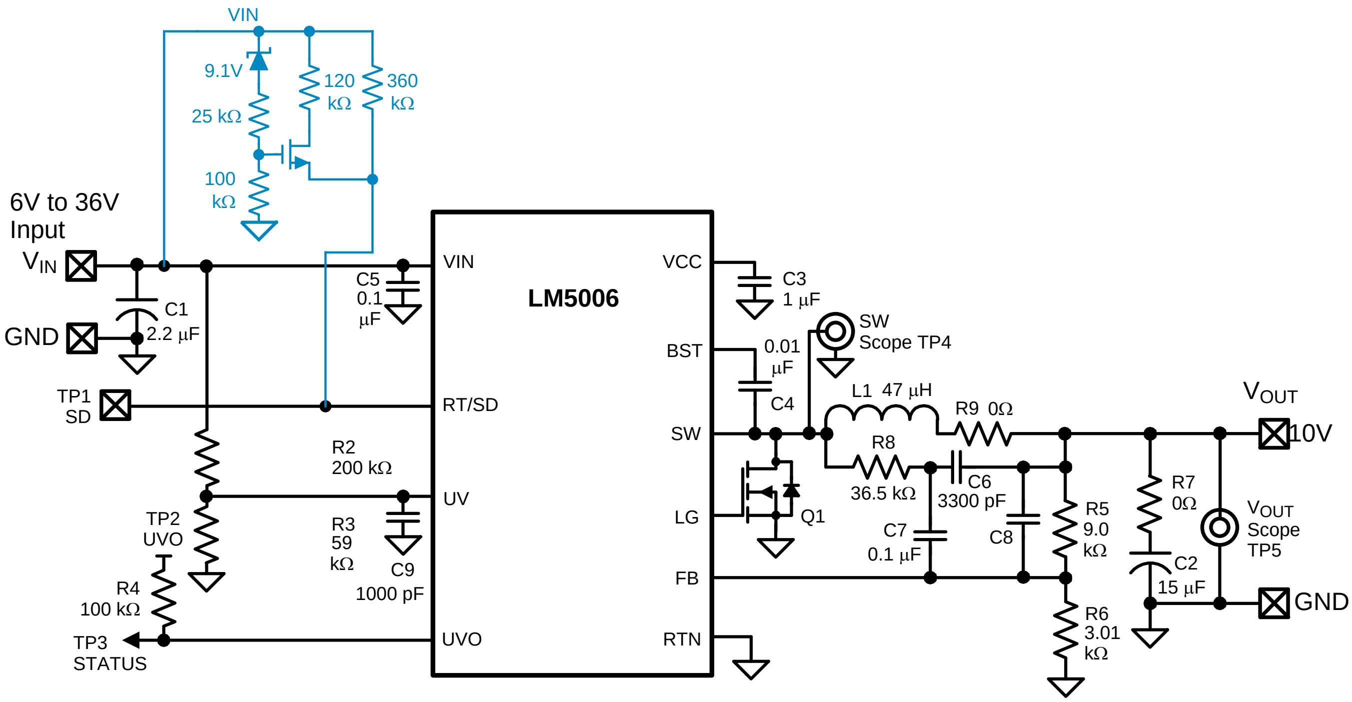

Figure 3. Application Schematic of Figure 1 Modified to Replace R1 With a Non-Linear Zener Circuit

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		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265