Regulating V_{OUT} Below 1.2 V Using an External Reference

Jeff Falin *HPA Portable Power Applications*

ABSTRACT

This application report explains how to use an external reference voltage to regulate the output voltage range of a linear regulator below its internal reference voltage.

Contents

List of Figures

1 Description of the Problem

All dc/dc switching converters and linear regulators regulate their output voltage relative to an internal reference voltage. Therefore, the lowest output voltage that these converters and regulators can provide is the internal reference voltage, which is frequently a 1.2 V bandgap derived reference. This application report explains how to use an external reference voltage to extend the output voltage range of a switching converter or linear regulator below its internal reference voltage. A ±1% accurate linear regulator (TPS736xx) with an enable pin is used as the external reference in order to prevent overshoot at start-up that can occur if the converter/regulator powers up before or powers down after the external reference.

2 Implementation of Solution

The block diagram in Figure 1 shows the general implementation.

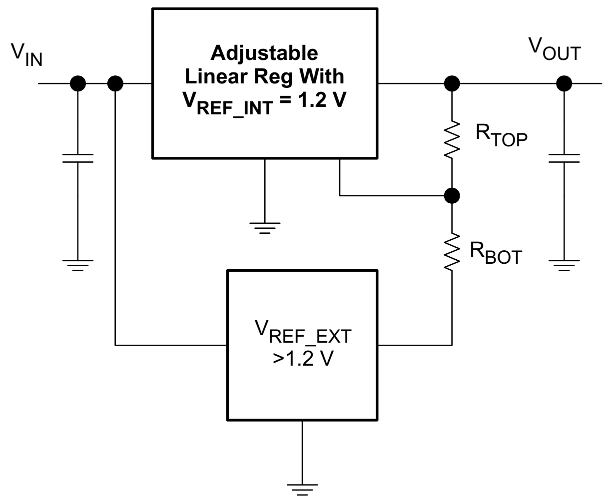

Figure 1. Block Diagram

The dc output voltage is computed by Equation 1:

$$V_{OUT} = V_{REFint} \times \left(1 + \frac{R_{TOP}}{R_{BOT}}\right) - \left(\frac{R_{TOP}}{R_{BOT}} \times V_{REFext}\right) \tag{1}$$

The minimum value occurs when V_{REF_INT} is low, V_{REF_EXT} is high, R_{TOP} is high, and R_{BOTTOM} is low. The maximum value occurs when V_{REF_INT} is high, V_{REF_EXT} is low, R_{TOP} is low, and R_{BOTTOM} is high. Equation 2 computes the maximum output voltage tolerance given the tolerances of each circuit component.

$$\%TOL_{VOUT} = \frac{\%TOL_{VREF\_INT}}{\dfrac{V_{OUT}}{V_{REF\_INT}\left(1 + \dfrac{R_{TOP}}{R_{BOT}}\right)}} - \frac{2 \times \%TOL_{R}}{\dfrac{V_{REF\_INT}}{V_{OUT}\_V_{REF\_INT}} + 1} + \frac{\%TOL_{VREF\_EXT}}{\dfrac{R_{BOT}}{R_{TOP}} \times \dfrac{V_{OUT}}{V_{REF\_EXT}}} \tag{2}$$

A more accurate output voltage can be achieved by using an external reference with higher accuracy and/or external resistors with higher accuracy. The output voltage accuracy worsens as the difference between V_{REF_int} and V_{OUT} increases and improves as the difference between V_{REF_ext} and V_{REF_int} increases.

2.1 Example 1

Figure 2 shows a circuit using the UC382-ADJ 3-A rated linear regulator and the TPS73133 to provide 1.1 V ±1.5%. The UC382-ADJ regulates V_{FB} to V_{REF_INT} =1.20 V ±1% and the TPS73133 provides V_{REF_ext} = 3.3 V ±1%. Additionally, ±1% resistors were used.

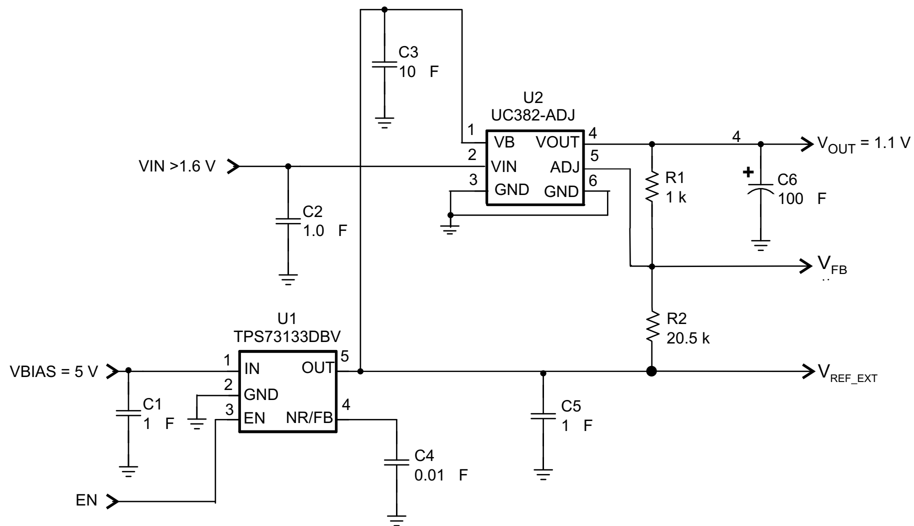

Figure 2. UC382-ADJ Providing 1.1-V Output

By itself, the UC382 is a dual input regulator, requiring a bias voltage, $V_B \geq V_{OUT} + V_{B\_dropout}$, where $V_{B\_dropout}$ is the minimum allowed differential between V_B and V_{OUT} and a power input voltage, $V_{IN} \geq V_{OUT} + V_{IN\_dropout}$, where $V_{IN\_dropout}$ is the minimum allowed differential between V_{IN} and V_{OUT}. In this application, the TPS73133 serves a dual purpose by providing 3.3 V for the external reference and the input bias voltage. When enabled and disabled using the EN pin of the TPS73133, the output voltage from the UC382 rises and falls smoothly with negligible overshoot. Recommended V_{IN} is 1.6 V to 1.8 V for high efficiency and minimal power dissipation through the regulator. The maximum ambient temperature determines the package's maximum power dissipation capability. The power dissipated in the regulator, computed as $Pd = (V_{IN} - 1.1) \times I_{OUT\_max}$, determines the maximum input voltage. A larger capacitor on V_{IN} may be required depending on the regulator's proximity to the V_{IN} power supply. Using the larger 5-A output current rated UC385 device requires moving to the higher current TPS73233 regulator instead of the TPS73133 in order to provide the necessary bias current. For either the UC382 or UC385, there is a 1-mA minimum load for proper regulation and the output capacitor, C6, must be at least 100 µF with at least 50 mΩ of ESR for control loop stability.

2.2 Example 2

Figure 3 shows a circuit using the TPS78601 1.5-A rated linear regulator and the TPS73125 to provide 1.1 V ±2.8%. The TPS78601 regulates V_{FB} to V_{REF_INT} = 1.2246 V ±2% and the TPS73125 provides V_{REF_ext} = 2.5 V ±1%. Additionally, ±0.5% resistors are necessary for R2 and R3.

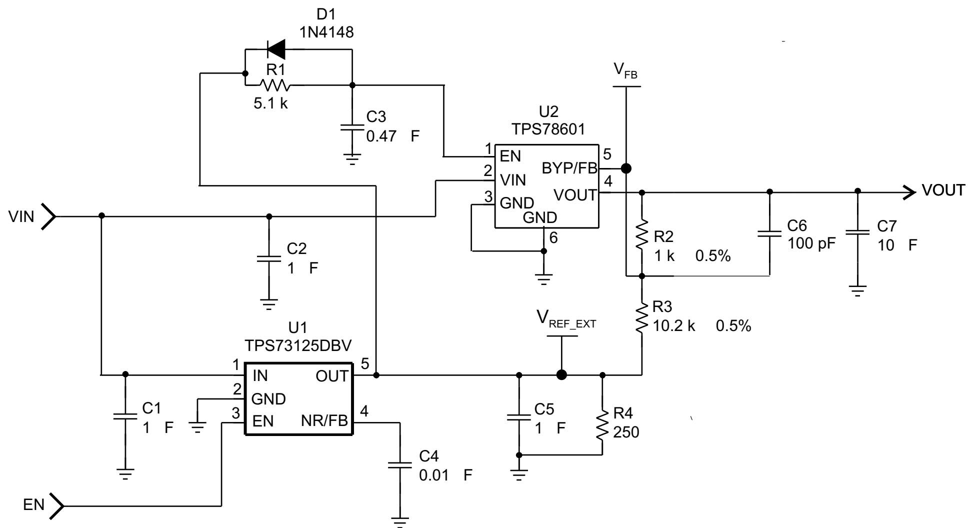

Figure 3. TPS78601 Providing 1.1-V Output

By itself, the TPS78601 has a minimum input voltage of 2.7 V. In this application, the TPS73125 serves a dual purpose by providing 2.5 V for the external reference and the enable signal for the TPS78601. Resistor R1 and capacitor C3 delay the start-up of the fast-starting TPS78601 until the TPS73125 provides the reference and diode D1 removes this delay and pulldown resistor R4 removes V_{REF_ext} at power down. Therefore, when enabled and disabled using the EN pin of the TPS73125, the output voltage from the TPS78601 rises and falls smoothly with negligible overshoot. In order for the TPS73125 to maintain ±1% regulation, the minimum V_{IN} is 3 V and R4 of 250 Ω is required to maintain 10-mA load. The maximum ambient temperature determines the package's maximum power dissipation capability. The power dissipated in the regulator, computed as Pd = $(V_{IN} - 1.1) \times I_{OUT\_max}$, determines the maximum input voltage. A larger capacitor on V_{IN} may be required depending on the regulator's proximity to the V_{IN} power supply. Any of the TPS79x01 family of linear regulators can be substituted if lower output currents are needed. Although only a 2.2-µF ceramic output capacitor, C7, is required for regulator stability, a much larger output capacitance with low ESR is recommended for best PSRR and lowest noise performance.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

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

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

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI 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 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. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

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

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DSP	dsp.ti.com	Broadband	www.ti.com/broadband
Interface	interface.ti.com	Digital Control	www.ti.com/digitalcontrol
Logic	logic.ti.com	Military	www.ti.com/military
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
		Telephony	www.ti.com/telephony
		Video & Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless

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