AN-1815 LDOs Ease the Stress of Start-Up

Krista Pavlakos

ABSTRACT

The LP38851/52/53 devices, with soft-start, provide a reliable way to ensure that start-up into high capacitive loads is uneventful and stress free.

Contents

List of Figures

1 Introduction

Typical low-dropout (LDO) linear voltage regulators do not provide a method of limiting the in-rush current during start up conditions. Using the LP38851, LP38852, and LP38853 adjustable LDO linear regulators, with nominal current levels of 800 mA, 1.5A, and 3A, respectively, eliminates this problem by including user-programmable, soft-start circuitry with the device.

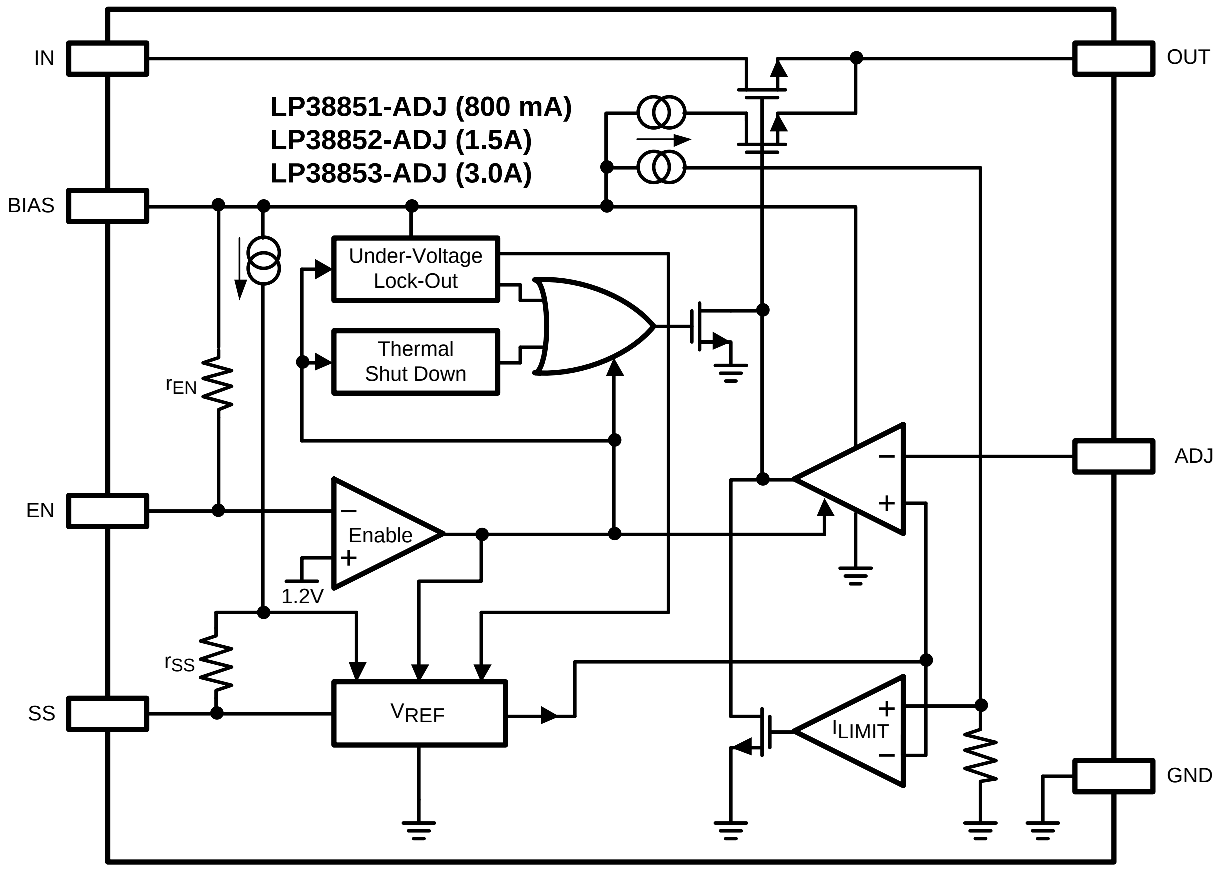

Figure 1. LP38851/52/53-ADJ Block Diagram

When power is first applied to a linear LDO regulator, a finite setting of time is needed for the internal circuitry (Figure 1), including the band-gap reference voltage to stabilize. This internal electrical uncertainty can be addressed by the use of under-voltage lock-out (UVLO) circuitry and an external enable logic control.

When V_{IN} has risen above the UVLO threshold and the enable logic command is valid, the LDO becomes active, the error amplifier (EA) senses the output voltage is low and, in response, drives the pass element fully on. The pass element then allows a large in-rush current to charge the output capacitance. This in-rush current is initially limited only by the pass element $R_{DS(ON)}$.

Figure 2 shows a typical application schematic of the LP38853-ADJ. Note the C_{SS} capacitor is connected to the (SS) soft-start pin. Next, the start up behavior will be compared without utilizing the soft-start feature versus start up behavior with a 0.01 μF capacitor for C_{SS}.

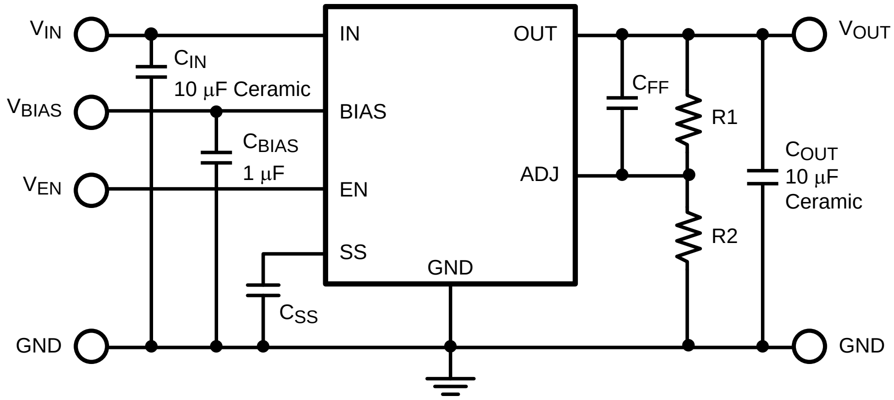

Figure 2. LP38851/52/53-ADJ Typical Application

Figure 3 shows the in-rush current and the V_{IN} disturbance for the LP38853 without a soft-start capacitor, which represents a typical behavior of many linear regulators. In this example, V_{IN} is set to 2.5 V, V_{OUT} is set to 1.0 V, the R_{LOAD} value is 0.5 Ω, and C_{OUT} is 330 µF.

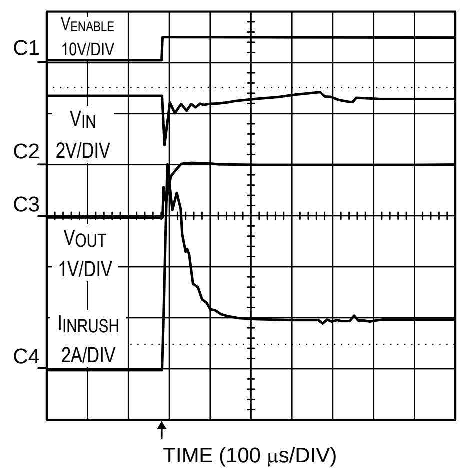

Figure 3. Startup In-Rush Current Produces a V_{IN} and V_{OUT} Disturbance, C_{OUT} = 330uF

V_{OUT} exhibits a slight disturbance where the input current demand (8A peak) and the voltage drop at V_{IN} causes V_{OUT} to drop momentarily. This non-monotonic start-up for V_{OUT} is not suitable behavior for many digital sub-systems, and this excessive inrush current can cause several problems. Three of the more common problems are:

- If the in-rush current exceeds the threshold of the LDO current limit circuit, it may cause the output voltage to fall. Only when the output capacitor is sufficiently charged, and the current demand falls below the current limit threshold, will the output voltage begin to rise again.
- If the LDO in-rush current is greater than the current capacity of the main power supply, or if the source impedance of the main power supply is high enough, the voltage at the LDO V_{IN} pin will drop back below the UVLO threshold, shutting down the LDO. This result can affect any voltage-sensitive circuits on the main power supply line.
- Small amounts of in-rush current can cause voltage and current ringing on the input voltage line if the line is sufficiently inductive. This ringing can couple between traces on a printed circuit board causing problems that may be difficult to debug.

Figure 4 demonstrates the in-rush current for the LP38853 under identical electrical conditions as Figure 3, except the soft-start capacitor (C_{SS}) is set to 0.01 µF. This provides an RC time constant for V_{OUT} of 140 µs, with V_{OUT} within 99% of the final value in typically 700 µs (that is, 5RC). Here, the soft-start feature has reduced the peak in-rush current to 3A and provides a monotonic V_{OUT} start-up characteristic.

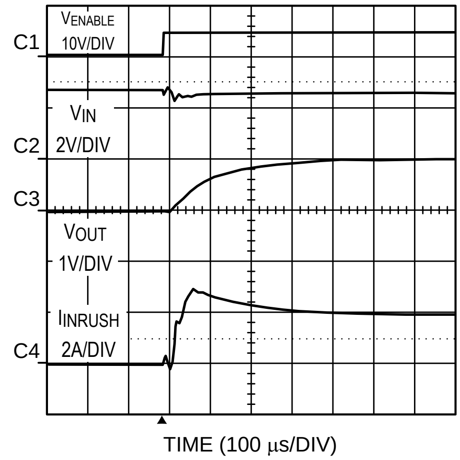

Figure 4. Startup In-Rush Current With Soft-start, C_{OUT} = 330 µF

The soft-start circuitry of the LP38851/52/53 consists of an internal resistor and a user-selectable external capacitor. These two components form a low-pass RC filter providing a reference voltage to the Error Amplifier that at power-up starts at zero volts and rises at a defined rate. This defined rise time of the reference voltage controls the rise time of the output voltage and the reduced dV/dt demands less in-rush current.

With this simple RC filter, the highest inrush current occurs during the first time constant where V_{REF} has the largest dV/dt. The resistor is built into the circuit and, therefore, you only need to select an appropriate external soft-start capacitor to control the rise time.

The ideal choice for the soft-start capacitor value is one that will limit the in-rush current to a value no more than the rated current. A practical value for the soft-start capacitor is one that provides an acceptably controlled startup characteristic with minimal disruption to the main power supply.

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