

LDOs Ease the Stress of Start-Up

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National Semiconductor
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Don Jones
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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

800mA, 1.5A, and 3A, respectively, will eliminate this problem by including user-programmable, soft-start circuitry with the device.

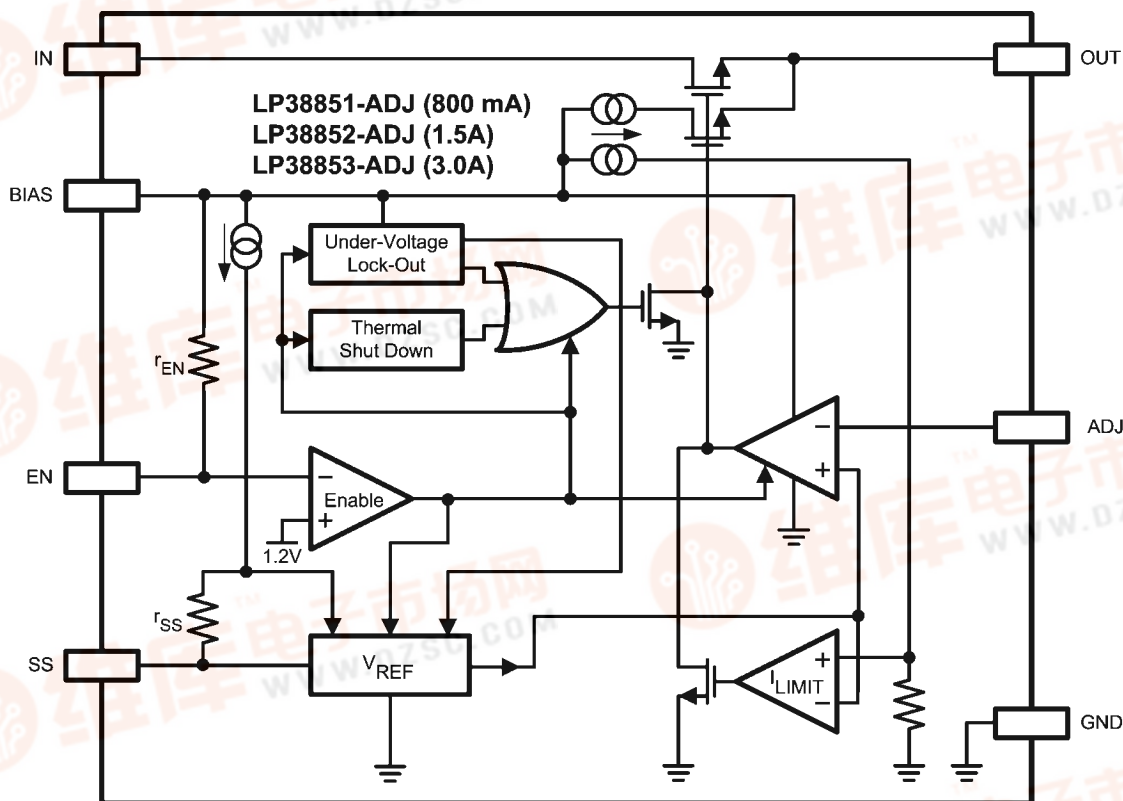


FIGURE 1. LP38851/52/53-ADJ Block Diagram

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 re-

sponse, 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, we'll compare start up behavior without utilizing the soft-start feature versus start up behavior with a $0.01\mu F$ capacitor for C_{SS} .

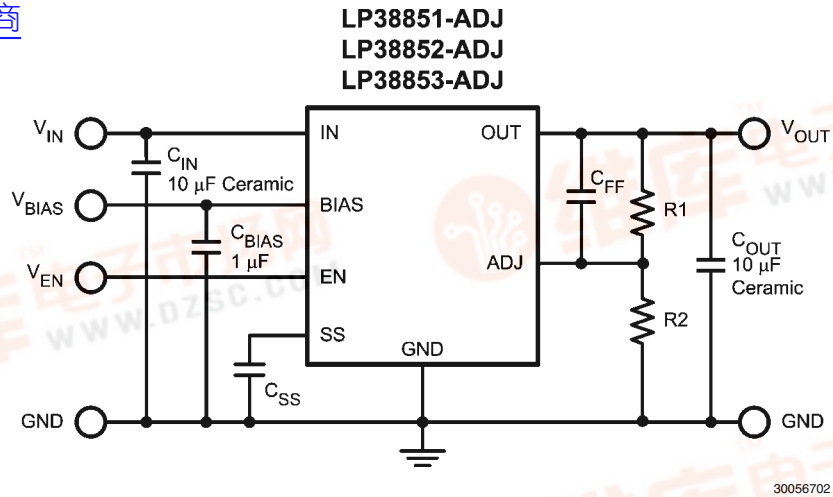
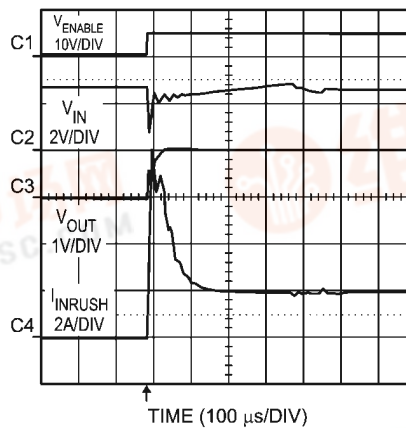
**FIGURE 2. LP38851/52/53-ADJ Typical Application**

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 2.5V, V_{OUT} is set to 1.0V, the R_{LOAD} value is 0.5 ohm, and C_{OUT} is 330 μ F.

**FIGURE 3. Startup In-rush Current Produces a V_{IN} and V_{OUT} Disturbance, $C_{OUT} = 330\mu$ F**

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:

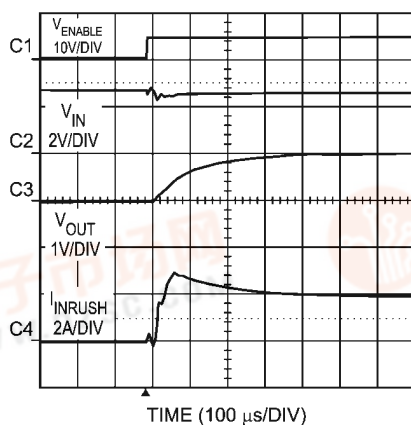
1. If the in-rush current exceeds the threshold of the LDO current limit circuit, it may cause the output voltage to fall. Only when the output capacitor is sufficiently charged, and the current demand falls below the current limit threshold, will the output voltage begin to rise again.
2. If the LDO 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.

3. 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 μ F. This provides an RC time constant for V_{OUT} of 140 μ s, with V_{OUT} within 99% of the final value in typically 700 μ s (i.e. 5RC). Here the soft-start feature has reduced the peak in-rush current to 3A and provides a monotonic V_{OUT} start-up characteristic.

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FIGURE 4. Startup In-rush Current with Soft-start, $C_{OUT} = 330\mu F$

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 will control the rise time of the output voltage and the reduced dV/dt will demand less in-rush current.

With this simple RC filter, the highest inrush current will occur during the first time constant where V_{REF} has the largest dV/dt . The resistor is built into the circuit and therefore the user

only needs 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.

In summary, 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.

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