Power Supply Tracking for Linear Regulators

by Dan Eddleman

Introduction

The LTC2923 provides simple and versatile control over the power-up and power-down behavior of switching power supplies. It allows several supplies to track the voltage of a master supply, so that their relative voltages meet the stringent specifications for the power up of modern digital semiconductors, such as DSPs, microprocessors, FPGAs and ASICs. The LTC2923 is specifically designed to work with switching power supplies (see "Versatile Power Supply Tracking without MOSFETs" from *Linear Technology* Magazine, February, 2004) but it is easily adapted to linear regulators, including popular low-dropout (LDO) types. Summarized here are several techniques for controlling linear regulators with the LTC2923.

Monolithic Regulators

Table 1 lists three popular monolithic linear regulators that have been tested with the LTC2923. Using these three monolithic LDOs with the LTC2923 is generally very simple:

- The LTC3020 is a 100mA low dropout regulator (LDO) that operates with input supply voltages between 1V and 10V. Since its ADJ pin behaves like the feedback pin on most switching regulators, tracking the LTC3020's output using the LTC2923 is simple. The standard circuits and design procedures shown in the LTC2923 data sheet require no modification when used with the LTC3020 (Figures 1 and 2).
- The LTC3025 is a 300mA monolithic CMOS LDO that regulates input supplies between 0.9V and 5.5V, while a bias supply between 2.5V and 5.5V powers the part. Similar to the LT3020, the LTC3025's ADJ pin is operationally identical to common switchers. For that reason, the LTC3025 combined with an LTC2923 provides a simple supply tracking solution for loads less than 300mA (Figures 1 and 2).
- The LTC1844 CMOS LDO drives loads up to 150mA with input supply voltages between 1.6V and 6.5V. When used in conjunction with the LTC2923, a feedforward capacitor should be included as described in the "Adjustable Operation" section of the LTC1844 data sheet. Otherwise, no special considerations are necessary.

Table 1. New monolithic linear regulators

Regulator	$I_{OUT(MAX)}$ (V)	$V_{IN(MIN)}$ (V)	$V_{IN(MAX)}$ (V)	$V_{DROPOUT}$ (V)
LT3020	100mA	0.9	10	0.15
LTC1844	150mA	1.6	6.5	0.11
LTC3025	300mA	0.9	5.5	0.045

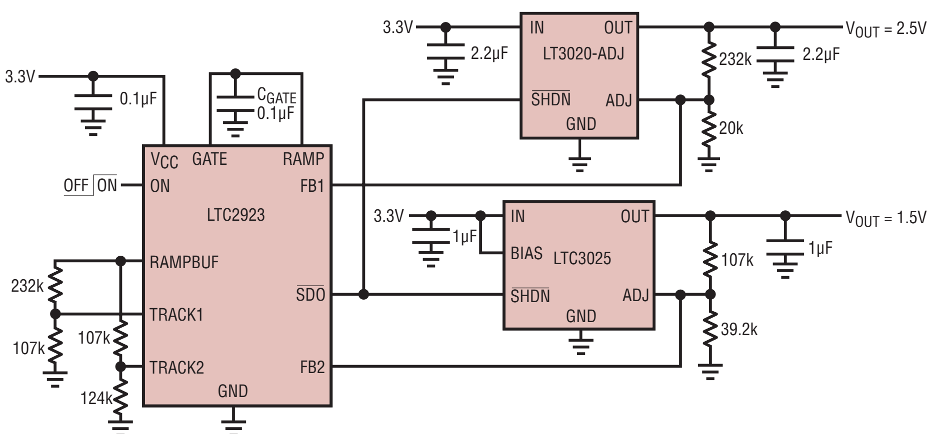

Figure 1. An LTC2923 causes the outputs of the LT3020 and LTC3025 to track during power-up and power-down.

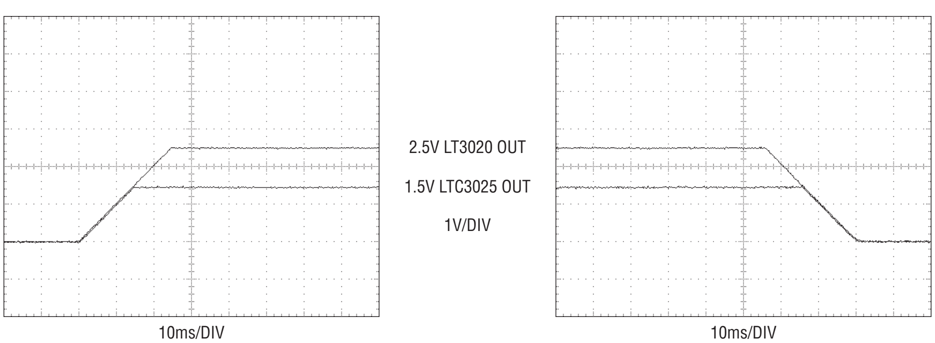

Figure 2. The outputs of the LT3020 and LTC3025 low-dropout linear regulators ramp-up and ramp-down together. (Output of circuit in Figure 1.)

The LTC1761 Family of Monolithic, Bipolar Regulators

Table 2 shows the LTC1761 family of monolithic, bipolar low dropout regulators. These regulators cover a wide range of load currents and offer outstanding transient response and low noise, making them a popular choice for applications with loads less than 3A.

In these regulators, the ADJ pin draws excess current when the OUT

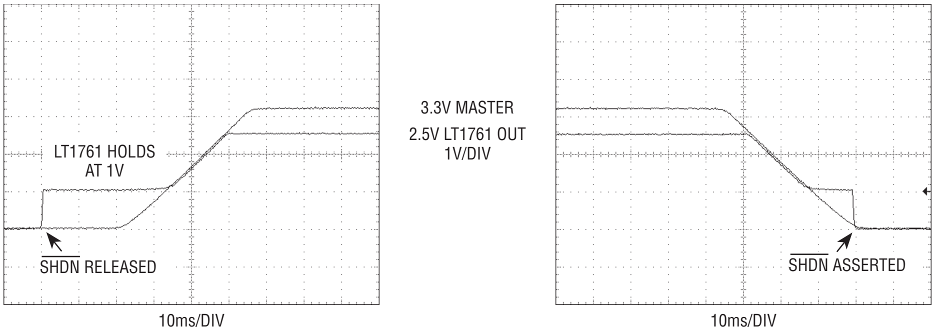

Figure 3. LT1761/LT1962/LT1762/LT1763/LT1963A/LT1764A with adjustable outputs only track above 1V unless modified as discussed in this article. The $\overline{SHDN}$ pin of the LDO is active before the ramp-up and after ramp-down.

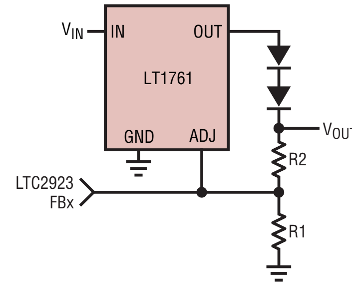

Figure 4. Diodes placed in series with the OUT pin allow the LT1761 to track down to 0V.

pin drops below about 1V, a region of operation that LDOs do not normally experience. Nevertheless, an LDO which tracks another supply, enters this region when the output tracks below 1V (Figure 3). If this excess current is not accounted for, the output of the LDO will be slightly higher than ideal when it tracks below 1V. Three techniques have been used to successfully track outputs of this LDO family below 1V.

If low dropout voltages are not necessary, simply connect two diodes in series with the OUT pin (Figure 4). In this configuration, the OUT pin remains two diode drops above the circuit's output. As a result, the LDO remains in its normal region of operation even when the output is driven near ground. Since the feedback resistors are connected to the output, the LDO regulates the voltage at the circuit output instead of the LDO's OUT pin. Diode voltage varies with both load current and temperature, so verify that the output is low enough at the minimum diode voltage. Likewise, the input voltage must be high enough to regulate the output when the diode drops are at their maximum. This solution effectively increases the dropout voltage of the linear regulator by two diode drops. Therefore, applications that require a low dropout voltage are better served by the solutions that follow.

Consider using the LTC1761, LT1962, LT1762, or LT1763 voltage regulators when the load is less than 500mA and a low dropout voltage is necessary. A fixed output part, (such as the LTC1763A-1.5) can be used as an adjustable LDO if the SENSE pin is treated like an ADJ pin with a feedback voltage of 1.5V (Figure 5). The SENSE pin on the fixed output parts draws about 10µA regardless of the OUT pin's voltage, unlike the ADJ pin on the adjustable parts. When choosing feedback resistors, minimize the output error by compensating for the extra 10µA of current that appears across the upper resistor. Also, use small valued resistors to minimize the error due to the 0µA to 20µA data sheet limits while avoiding values that are so small that the LTC2923's 1mA I_{FB} will be unable to drive the output to ground. To satisfy these constraints, ensure that the parallel combination of the two feedback resistors is slightly greater than 1.5kΩ. For most output voltages, this reduces the output error due to the SENSE pin current to about 1%.

For applications that require higher load currents and a low dropout voltage, the LT1963A and LT1764A may be appropriate. These parts are specified for 1.5A and 3A load currents respectively. Unfortunately, the SENSE pins on these fixed output parts draw about 600µA.

To use these parts, configure an operational amplifier to buffer the voltage from the feedback resistors to the SENSE pin of the 1.5V fixed output versions (Figure 6). If the op amp is configured with a voltage gain of 2, the 1.5V regulator in combination with the op amp behaves as an adjustable output regulator with a 0.75V reference voltage. The input to the op amp now serves as the ADJ input of the new regulator. This technique allows the use of the high current LT1963A/LT1764A where the voltage loss of series diodes would be unacceptable. It also works for the LT1761, LT1962, LT1762, and LT1763 in cases where the 10µA ADJ pin cur-

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Table 2. LT1761 family of low-dropout linear regulators

Regulator	$I_{OUT(MAX)}$ (V)	$V_{IN(MIN)}$ (V)	$V_{IN(MAX)}$ (V)	$V_{DROPOUT}$ (V)
LT1761	100mA	1.8	20	0.30
LT1762	150mA	1.8	20	0.30
LT1962	300mA	1.8	20	0.27
LT1763	500mA	1.8	20	0.30
LT1963A	1.5A	2.1	20	0.34
LT1764A	3A	2.7	20	0.34

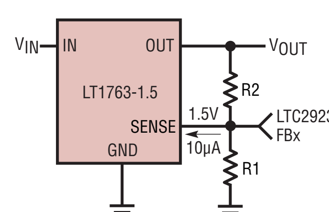

Figure 5. The fixed-output LT1763-1.5 can track down to 0V, has low dropout, and a resistive divider can be used for outputs greater than 1.5V.

Optimizing for Efficiency

While the LT3461A (boost) and LT3462A (inverting) are optimized for small size, the LT3461 (boost) and LT3462 (inverting) are intended for applications requiring higher efficiencies or high conversion ratios. The lower switching frequencies translate to higher efficiencies because of a reduction in switching losses.

The LT3461 (boost) is guaranteed to a maximum switch duty cycle of 92% in continuous conduction mode, and the LT3462 (inverting) is guaranteed to a maximum switch duty cycle of 90%, which enables high conversion ratios at relatively high output currents.

Although high conversion ratios can also be obtained using discontinuous conduction mode (DCM)—where current in the inductor is allowed to go to zero each cycle—the DCM technique requires higher switch currents and larger inductors/rectifiers than a system operating in continuous conduction mode at the same load current. Because the LT3461 can switch at 1.3MHz in continuous conduction mode with up to 92% switch duty cycle, and the LT3462 at 1.2Mhz, 90% duty, they are the most compact solutions available for outputs 5 to 10 times the supply voltage. For example, the LCD bias circuit of Figure 7 provides 18mA at 25V from a 3.3V supply and occupies as little as 50mm^2 of board space. Figure 8 shows that the efficiency of the 25V converter is quite good, peaking at 79% for a 4.2V supply. Figure 9 shows a 3.3V to –25V, 14mA inverter with efficiency above 70% (Figure 10).

Conclusion

The LT3461, LT3461A, LT3462 and LT3462A provide very compact boost and inverter solutions for a wide input voltage range of 2.5V to 16V, and outputs to ±38V, making these devices a good fit in a variety of applications.

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rent produces an unacceptable output voltage error.

Drivers for External, High Current Pass Devices

Table 3 summarizes the characteristics of the LT1575 and LT3150 low dropout regulators. These devices drive external N-channel MOSFET pass devices for high current/high power applications. The LTC3150 additionally includes a boost regulator that generates gate drive for the external FET.

The LTC2923 tracks the outputs of the LT1575 and LT3150 without any special modifications. Because these linear regulators only pull the FET's gate down to about 2.6V, low-threshold FETs may not allow the output to fall below a few hundred millivolts. This is acceptable for most applications.

Table 3. Drivers for external, high current pass devices

Regulator	$I_{OUT(MAX)}$ (V)	$V_{IN(MIN)}$ (V)	$V_{IN(MAX)}$ (V)	$V_{DROPOUT}$ (V)
LT3150	10A*	1.4	10	0.13
LT1575	*	N/A	22	*

*Depends on selection of external MOSFET

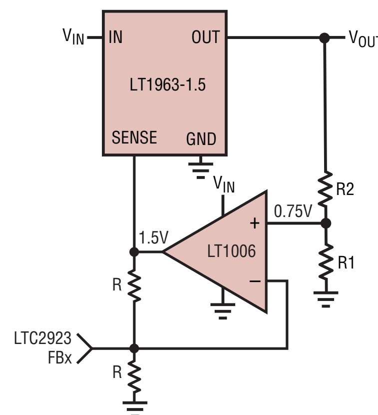

Figure 6. Using an op amp with the LT1963-1.5 allows lower output voltages and removes error due to the SENSE pin current.

Authors can be contacted at (408) 432-1900

LT1990/91/95, continued from page 4

operating-point—and resistors to set gain. High quality resistors consume precious printed circuit board real estate, and test time. In contrast, the LT1995 provides on-chip resistors for voltage division and gain setting in a highly integrated video-speed op amp.

Figure 5 shows a simple way to drive AC-coupled composite video signals over 75Ω coaxial cable using minimum component count. In this circuit, the input resistors form a supply splitter for biasing and a net attenuation of 0.75. The feedback configuration provides an AC-coupled gain of 2.66, so that the overall gain of the stage is 2.0. The output is AC-coupled and series back-terminated with 75Ω to provide a match into terminated video cable and an overall unity gain from signal input to the destination load. An output shunt resistor (10kΩ in this example) is always good practice in AC-coupled circuits to assure nominal biasing of the output coupling capacitor.

Full Bridge Load Current Monitor

Many new motor-drive circuits employ an H-bridge transistor configuration to provide bidirectional control from a single-voltage supply. The difficulty with this topology is that both motor leads "fly," so current sensing becomes problematic. The LT1990 offers a simple solution to the problem by providing an integrated difference amp structure with an unusually high common-mode voltage rating, up to ±250VDC.