Micropower Negative LDO Provides a Quiet Output in SOT-23

by Todd Owen

Introduction

With the myriad of new portable and wireless devices in design today, a multitude of power supply requirements surface. Portable devices run from batteries, requiring low dropout voltage and low quiescent current to maximize battery life. Low noise operation is a key parameter for RF applications, where power supply noise creates unwanted sidebands on RF amplifiers, degrading performance. Another factor is low voltage operation, both on the input and output. Finally, portability requirements dictate strict size constraints on both active devices and passive components. These requirements have been met for many designs with families of low noise, low dropout regulators, but one hole had yet to be filled.

Taking the Flip Side

A wide choice of regulators is available for providing a low noise positive supply voltage. Now, it is possible to provide a similar level of performance for a negative supply. Figure 1 shows a typical application for the LT1964, a new negative low dropout regulator in a 5-lead SOT-23 package. The LT1964 provides the lowest noise available from any negative LDO and it is a micropower device. The LT1964 incorporates features that make it useful for a variety of applications. It is stable with a wide range of output capacitors with an ESR in the range of only a few milliohms up to 3Ω. Small ceramic capacitors can be used without the addition of ESR as is common with other regulators. The output capacitor can be as low as 1µF to maintain a stable output. For low noise operation, the addition of a small bypass capacitor from the output to the BYP pin can reduce output voltage noise to $30\mu V_{RMS}$ over the 10Hz to 100kHz range. However, when using a noise bypass capacitor, we recommend using a minimum of 3.3µF of output capacitance.

The LT1964 delivers 200mA of output current at a dropout voltage of 340mV, making it suitable for many portable designs. The input voltage can range from –2V to –20V, allowing for a wide range of input supplies. The low 30µA operating quiescent current is ideal for battery-powered applications. Quiescent current is well controlled; it does not rise excessively in dropout as happens with many competing regulators. The LT1964 also provides a low power shutdown state: with the shutdown pin pulled to ground, the output is turned off and quiescent operating current is reduced to 3µA. The shutdown pin is bidirectional. Pulling the shutdown pin below –2.1V or above +1.6V will turn the LT1964 on, providing a regulated output. This bidirectional shutdown logic permits easy interfacing to either positive or negative logic, allowing the shutdown pins of both positive and negative supplies to be driven together for easy system management. Figure 2 shows the operational status of the LT1964 based on the shutdown pin voltage. If the shutdown pin is unused, it should be tied to the input to ensure normal operation.

The LT1964 provides many protection features that ease design headaches. The output of the LT1964 can be pulled above ground by several volts without damage; it can be pulled 20V above the input and still allow the device to start and operate. With the input open circuit or grounded, the output of a fixed voltage LT1964 acts like a large resistor, typically 500kΩ or higher, while adjustable LT1964 devices act like an open circuit, with no current flow into the pin. When the input is powered by a voltage source, the output will sink up to the short-circuit current of the device and protect itself by thermal limiting. Like other IC power regulators, the LT1964 provides safe operating area protection. This protection activates at input-to-output differentials greater than –7V, decreasing current limit as the differential increases and keeping the power transistor inside a safe operating region.

The LT1964 is available as a fixed –5V regulator and as two different adjustable versions with a reference voltage of –1.22V. The LT1964-5 brings out all functions, while the addition of the adjust pin on the other versions necessitates sacrificing one of the two functions. For the LT1964-SD, the BYPASS pin is not connected, while the SHUTDOWN pin is brought out. This allows the regulator to be operated normally, with the exception that lowest noise operation cannot be achieved. For the LT1964-BYP, the SHUTDOWN pin has been tied inter-

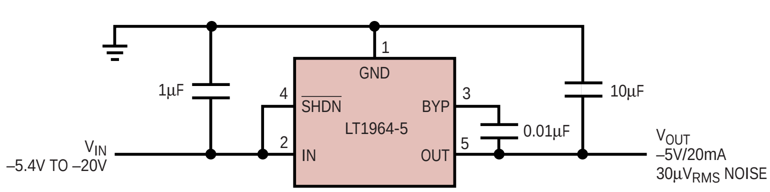

Figure 1. Low noise negative regulator—typical application

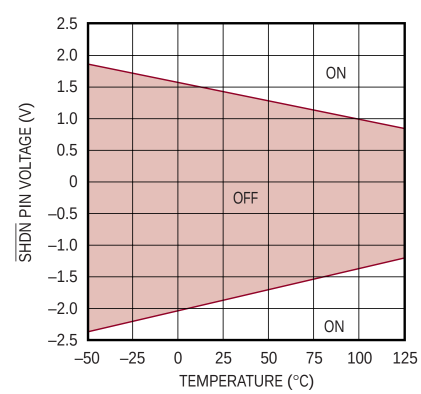

Figure 2. $\overline{\text{SHDN}}$ pin thresholds

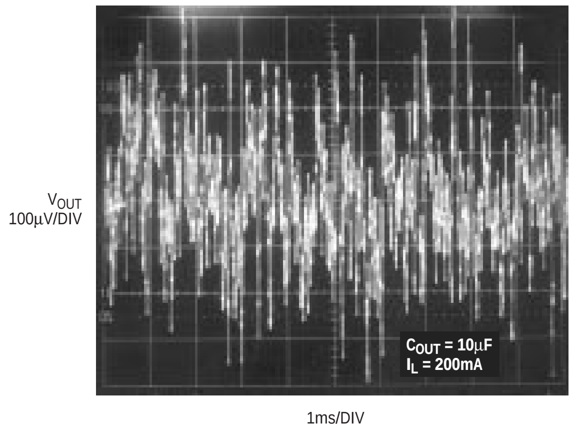

Figure 3. LT1964-5, 10Hz to 100kHz output noise, C_{BYP} = 0

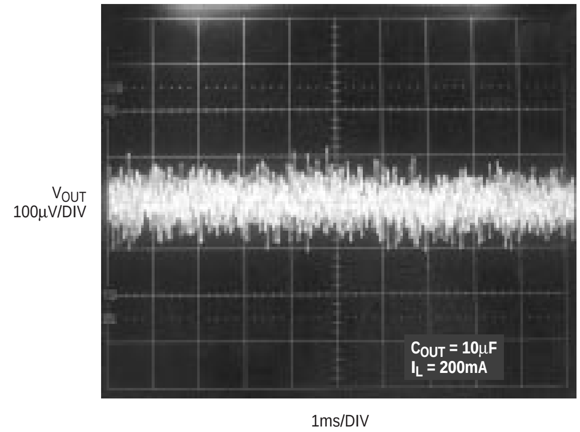

Figure 4. LT1964-5, 10Hz to 100kHz output noise, C_{BYP} = 0.01µF

nally to the input while the BYPASS pin is brought out to allow for low noise operation with the addition of a small reference bypass capacitor.

Measuring Performance

Determining LDO performance is often quite straightforward. Most characteristics are simple to define, with easily obtainable measurements that can be made with DC testing, or pulsed testing to limit power dissipation. Establishing and verifying low noise performance can be quite tricky, particularly when dealing with ultra-low noise outputs. Linear Technology strives to provide accurate, relevant data to customers regarding noise performance. For detailed information on measuring output voltage noise, see Linear Technology Application Note 83, "Performance Verification of Low Noise, Low Dropout Regulators."

When low noise operation is critical, the small reference bypass capacitor provides a significant reduction in output noise. Figures 3 and 4 show the output of the LT1964-5 both with and without the low noise reference bypass capacitor. The LT1964 was tested with 10µF X5R ceramic capacitors on both the input and output, with a 0.01µF used for the reference bypass. Figure 5 shows noise spectral density of the LT1964-BYP and LT1964-5 as varying amounts of reference bypassing is added. Tests were done using a full 200mA load to provide worst-case operating conditions. Four D-cell batteries provided the input voltage to avoid issues with input supply noise feeding through to the output and corrupting noise measurements. This caveat is one that must be considered whenever designing in any low noise linear regulator; devices do not have infinite power supply rejection and will pass through some portion of input ripple to the output. Additionally, care must be exercised with layout and shielding considerations. Proximity to noisy signal traces can induce unwanted crosstalk that can masquerade as increased output voltage noise.

When specifying a regulator for a power supply design, the LT1964 can provide obvious advantages over the competition. The LT1964 can provide lower dropout, lower quiescent current, lower noise, and many other qualities that other regulators lack. All of these characteristics may not be critical to a design, but when any one or two are, the LT1964 becomes an obvious choice.

Applying the LT1964

One of the best uses for the LT1964 is to pair it with the LT1761. Both devices are micropower (LT1761: 20µA I_Q, LT1964: 30µA I_Q), low dropout (LT1761: 300mV at 100mA, LT1964: 340mV at 200mA), low noise (LT1761: 20µV_{RMS}, LT1964: 30µV_{RMS}) regulators in 5-lead SOT-23 packages. Figure 6 shows a ±5V low noise supply designed with both devices. Input,

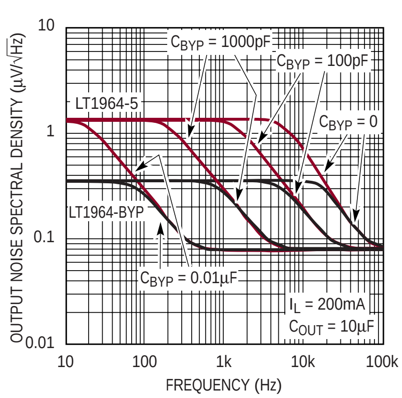

Figure 5. Output noise spectral density

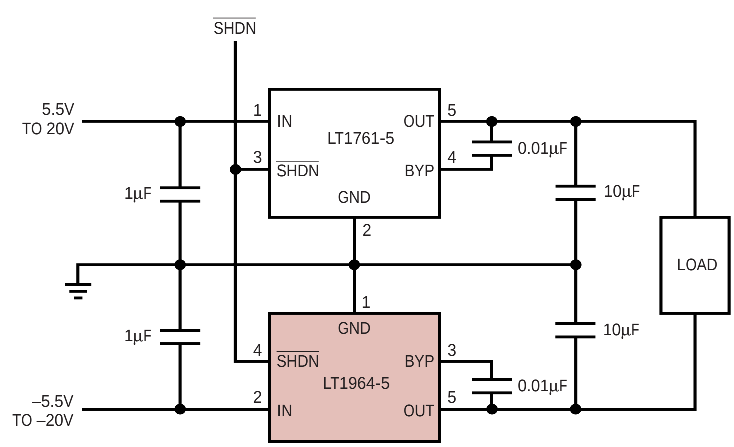

Figure 6. Logic-controlled ±5V low noise supply

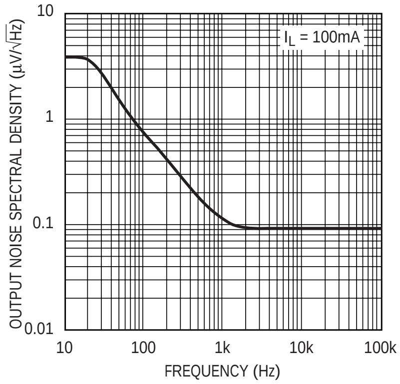

Figure 7. Low noise supply, output noise spectral density

output and reference bypass capacitors are similar on both sides of ground, making for a small bill-of-materials when building a board. Logic control for shutdown of both regulators allows for the shutdown pins of both regulators to be tied together. Pulling the shutdown to ground shuts off both devices and limits total quiescent current to only a few microamperes. With the shutdown pin pulled above 2V, both devices turn on and begin supplying power to the load.

This low noise supply has a good deal of functionality, while leaving little out. One item that is left out is protection diodes, particularly on the outputs of the devices. Many older regulators require reverse protection diodes on the output to prevent the output of the positive regulator from being dragged negative, or vice-versa. Both the LT1761 and LT1964 are designed to allow their respective outputs to be pulled to the wrong side of ground and still allow the parts to start and operate. This is quite useful with a common mode load, such as is shown in Figure 6. The circuit operates with only $40\mu V_{RMS}$ (in the 10Hz to 100kHz bandwidth) of noise, sufficiently quiet for noise-sensitive instrumentation, such as high bit-count A/D and D/A circuits. RF amplifiers will find a minimum amount of power in unwanted sidebands, improving circuit performance.

The performance of this supply is detailed in Figures 7 and 8. Figure 7 shows the spectral noise density seen across the common mode load, whereas Figure 8 shows the peak-to-peak noise on the common mode load. The levels of noise correspond with what would be expected for the sum of the noise from the outputs of the two regulators. Total RMS noise is about $40\mu V_{RMS}$, which is approximately equal to the RMS sum of the output noise of both regulators. Maximum load from the positive side is 100mA, and maximum from the negative is 200mA. Both inputs enter dropout at approximately 300mV above the regulated output voltage at maximum load current, maximizing battery lifetime. Dropout voltage is lower at lighter load currents. Quiescent current is well controlled in dropout, not rising as is common with many other linear regulators. Usually one characteristic of a regulator is not enough to satisfy design requirements. The LT1761 and LT1964 both try to meet any and all needs.

Conclusion

Capable of providing 200mA of output current at 340mV of dropout, the LT1964 draws only 30µA of quiescent current, dropping to 3µA in shutdown. Its small size and ability to work with small, low cost components facilitate portable power supply design. A bidirectional logic shutdown pin allows easy interfacing with existing positive regulators without adding extra external components.

The LT1964 rounds out the offering of low noise regulators from Linear Technology. These regulator families provide a wide range of output currents with low dropout voltage and ultralow output voltage noise. The quiet output is the result of a carefully designed circuit that works with a wide range of external passive components, allowing for a low cost, tightly spaced design. Designing a low noise supply for a new design is no longer a headache.

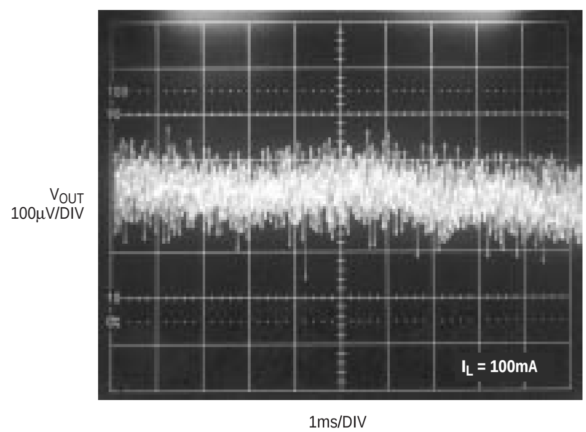

Figure 8. Low noise supply 10Hz to 100kHz output noise

Authors can be contacted at (408) 432-1900