# Micropower LDO Has the Lowest Noise and Quiescent Current in SOT-23

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## Introduction

A cell phone rings, a pager beeps. Wireless communications devices are everywhere. These RF circuits have a myriad of power supply requirements. Most important in many applications is low noise operation, to prevent unwanted sidebands on RF amplifiers. Second is low power operation, which translates directly to extended operating time in battery-powered devices. In addition, portability requires small size, which makes small packages for regulators and stability with small surface mount ceramic capacitors a plus. Another factor that can weigh in is low voltage operation, both for the input and output. Satisfying all of these needs at once can be a difficult challenge.

Table 1. Evaluation of available SOT-23 low noise, low dropout regulators

| Part | Quiescent Operating Current | Output Voltage Noise (Specified with Bypass Cap) | Output Voltage Noise (Measured with Bypass Cap) | Output Voltage Noise (Measured, No Bypass Cap) |
|---|---|---|---|---|
| Competitor 1 (5V Output) | 80µA | 260nV/√Hz[1] | $100\mu V_{RMS}$ | $245\mu V_{RMS}$ |
| Competitor 2 (5V Output) | 95µA | $30\mu V_{RMS}$ | $55\mu V_{RMS}$[2] | $340\mu V_{RMS}$ |
| Competitor 3 (3.3V Output) | 85µA | $30\mu V_{RMS}$ | $30\mu V_{RMS}$ | $265\mu V_{RMS}$ |
| Linear Technology LT1761 | 20µA | $20\mu V_{RMS}$ (1.22V) | $15\mu V_{RMS}$ (1.22V) | $56\mu V_{RMS}$ (1.22V) |
| | | $20\mu V_{RMS}$ (3.3V) | $16\mu V_{RMS}$ (3.3V) | $110\mu V_{RMS}$ (3.3V) |
| | | $20\mu V_{RMS}$ (5V) | $18\mu V_{RMS}$ (5V) | $135\mu V_{RMS}$ (5V) |

1. The data sheet specification is 260nV/√Hz, with no spot frequency given.
2. Measurement on the bench is over the 10Hz–100kHz frequency range, where $30\mu V_{RMS}$ is specified in the data sheet over the 300Hz–50kHz frequency range.

## New LDO Makes a Quiet Entrance

Figure 1 shows a typical application for the LT1761, a new micropower low dropout regulator in a 5-lead SOT-23 package with the lowest noise available from any LDO regulator. Designed into the regulator are many other features that make it useful in a variety of applications. It is stable with a wide range of output capacitors. Small ceramic capacitors can be used without the necessary addition of series resistance as is common with other regulators. The output capacitor can be as low as 1µF, with an ESR in the range from milliohms up to 3 ohms. For low noise operation, the addition of a small bypass capacitor from the output to the BYPASS pin can reduce output voltage noise to $20\mu V_{RMS}$ over the 10Hz to 100kHz frequency range. However, when using a noise bypass capacitor, it is recommended that a minimum output capacitor of 3.3µF be used.

Designed to deliver 100mA of output current at a dropout of 300mV, the LT1761 fits well in many portable designs. The input voltage can range from 2V to 20V, allowing for a wide range of input supplies. Its low 20µA operating quiescent current is ideal for battery-powered applications. This quiescent current is well controlled; it does not rise excessively in dropout as happens with many competing regulators. The part also has a low power shutdown state: with the shutdown pin pulled high, the LT1761 will provide a regulated output; when the shutdown pin is pulled to ground, all quiescent current from the input and shutdown pins is reduced to the leakage currents of the internal transistors. This leakage current, typically a few nanoamperes at room temperature, stays below 1µA over the operating temperature range. Competing devices may be able to match the shutdown quiescent current, but operating quiescent current is improved by a factor of four.

The LT1761 has a number of protection features to safeguard itself and sensitive load circuits. The device is protected against reverse input voltages, which is useful in situations where a battery might be connected backwards. No external protection diodes are needed when using the LT1761. With a reverse voltage from output to input, the LT1761 acts as if it has a diode in series with its output and prevents reverse current flow. In dual-supply applications where the regulator load is returned to a nega-

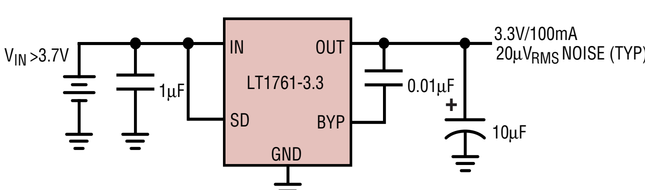


Figure 1. New low noise, low dropout, micropower regulator

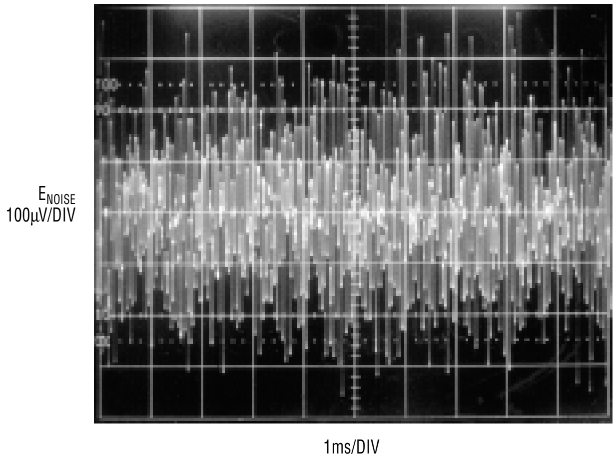


Figure 2. Competitor #1's peak-to-peak output voltage noise (5V output)

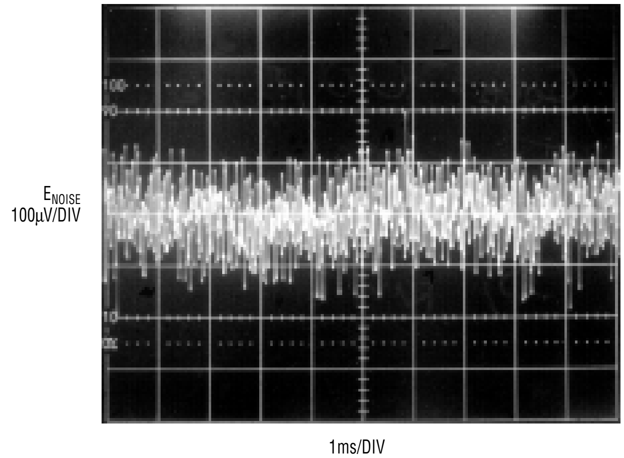


Figure 3. Competitor #2's peak-to-peak output voltage noise (5V output)

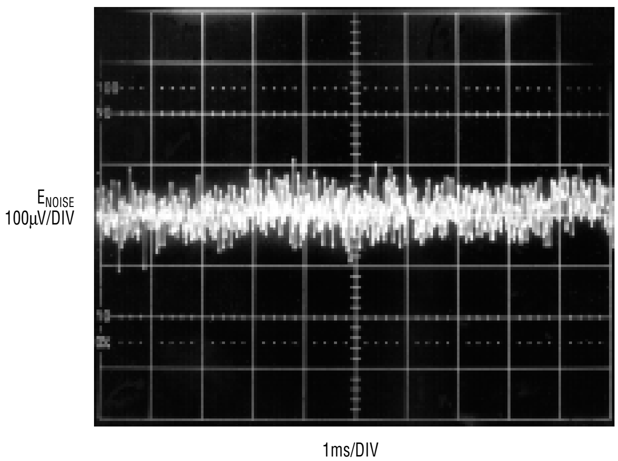


Figure 4. Competitor #3's peak-to-peak output voltage noise (5V output)

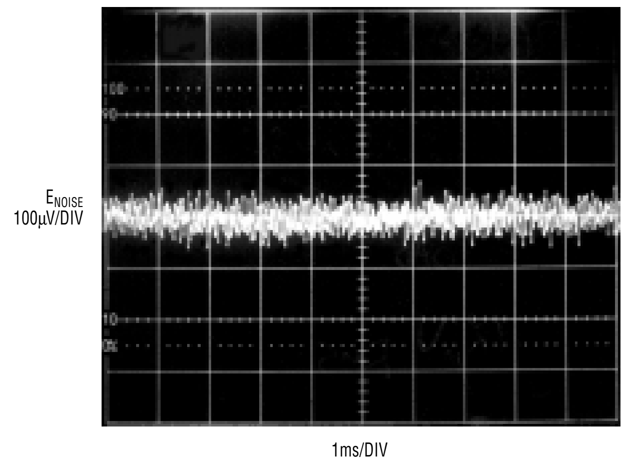


Figure 5. LT1761-5 output voltage noise

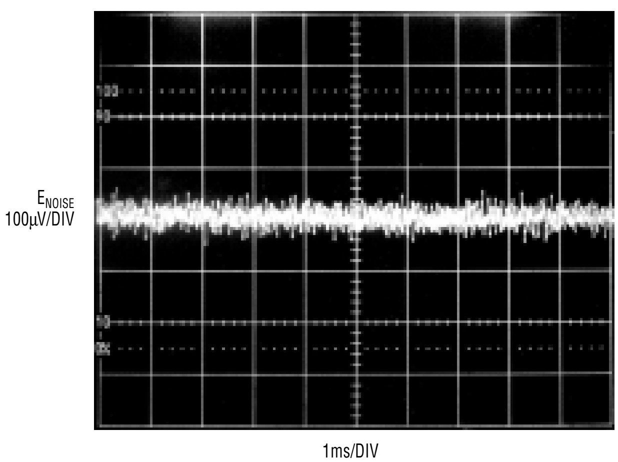


Figure 6. LT1761-3.3 output voltage noise

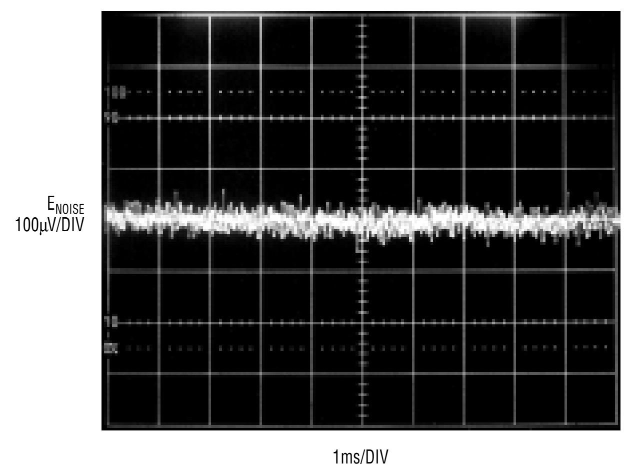


Figure 7. LT1761-BYP output voltage noise ($V_{OUT}$ = 1.22V)

tive supply, the output can be pulled below ground by several volts and the device will still start and operate. These features are in addition to standard protection features for linear regulators, such as current limiting and thermal limiting.

The LT1761 regulators are available in several fixed voltage options as well as two different adjustable versions. Fixed voltage options include 2.5V, 3V, 3.3V and 5V. The adjustable versions of the LT1761 are available with a reference voltage of 1.22V and a minimum input operating voltage of 2V. The adjustable LT1761 has to sacrifice one of the function pins to bring out the adjust pin. For the LT1761-SD, the SHUTDOWN pin remains while the BYPASS pin has been removed. This allows the regulator to be

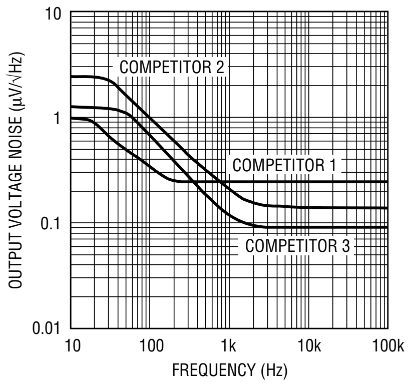


**Figure 8. Competing devices' noise spectral density**

operated normally, with the exception that noise reduction cannot be achieved. For the LT1761-BYP, the BYPASS pin has been brought out to allow for low noise operation with the addition of a small capacitor. The shutdown pin is internally tied to the input to ensure that the regulator will operate normally with the minimum operating voltage.

## How Does It Measure Up?

There are a number of low noise, low dropout regulators in SOT-23 packages on the market. The LT1761 gives many performance advantages over the competition. Comparisons based on data sheet specifications can be difficult and confusing, since many manufacturers specify different measurement methods and frequency ranges. Table 1 summarizes the distinctions between the parts to help designers make a quick comparison.

These parts were compared on the bench side by side. This A/B comparison eliminates any variations in test equipment or measurement methods. All measurements were taken with a 50mA load, 10µF output capacitor and the manufacturer's maximum recommended noise capacitor (0.01µF). Noise was measured using a noise amplifier with a gain of 60dB (the amplifier adds $0.5\mu V_{RMS}$ of noise into the measurement, providing accuracy within 0.5% for a $20\mu V_{RMS}$ noise signal). The noise was amplified to eliminate any noise added by the instrumentation used for measurements.

Noise measurements given as RMS values over a frequency bandwidth may often not provide enough information to decide on a regulator for your design. Figures 2 through 7 show peak-to-peak noise for the regulators showcased in the article. Again, the devices were tested with identical 10µF output capacitors, the manufacturer's recommended maximum 0.01µF bypass capacitor and identical 50mA loads. The difference in performance is readily apparent.

Finally, Figures 8 and 9 show noise spectral density over the 10Hz to 100kHz range for the parts. These curves show the dramatic difference that the LT1761's unique architecture makes in reducing output voltage noise. Noise over the entire frequency range is reduced, providing an exceptionally quiet output. By any of these measurement methods, the LT1761 offers the lowest noise available.

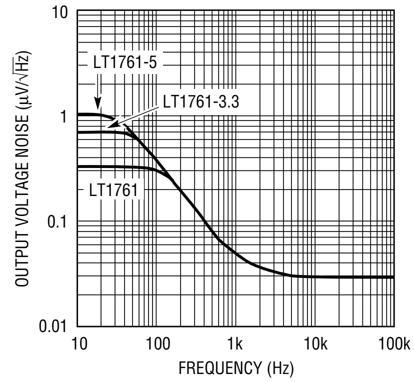


**Figure 9. LT1761 noise spectral density**

## Other Performance Advantages

The unique internal architecture of the LT1761 provides other performance advantages. For transient performance, Figure 10 shows two photos of a 10mA to 100mA transient load step on the 5V output of the LT1761. This test was done with 6V on the input and 10µF capacitors on both input and output. The only difference in test conditions between the two is the addition of a 0.01µF bypass capacitor to lower the output voltage noise. The difference in circuit response is readily apparent. The LT1761 also allows for direct connection of the output to the adjust pin, which provides a minimum 1.22V regulated output. Competing devices are either unavailable in adjustable versions or require some minimum

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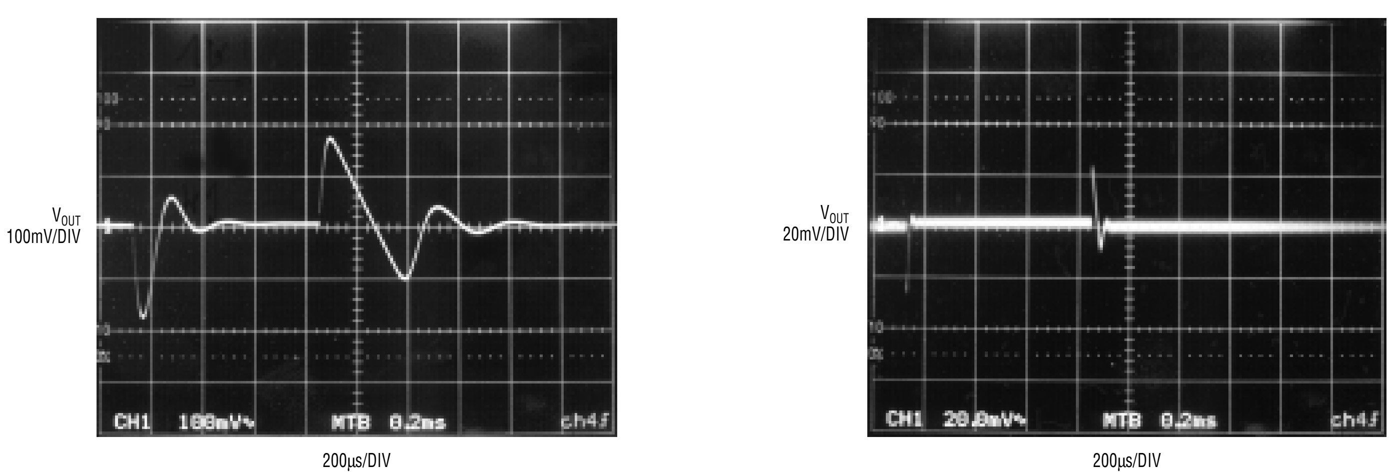


**Figure 10. Before and after photos show dramatic improvement in transient response after the addition of a 0.01µF bypass capacitor. Note the change in voltage scale**

*LT1761, continued from page 7*

output voltage above the reference, rendering them unusable in some applications.

## Conclusion

The LT1761 provides excellent performance in a small package. With a maximum of 100mA output current at a dropout of 300mV, it operates with only 20µA of quiescent current. This current drops to less than 0.1µA in shutdown, perfect for battery powered applications that need to be miserly with every joule. It is stable with a wide range of output capacitors, including small ceramics. With the addition of a small bypass capacitor from the output to the reference, output voltage noise can be reduced to as low as $20\mu V_{RMS}$. Adding a bypass capacitor also realizes a benefit in improved transient response. Competing devices can't come close to the advantages that the LT1761 offers in the world of SOT-23 regulators.