Techniques for accurate PSRR measurements

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Introduction

In theory, measuring the power-supply-rejection ratio (PSRR) is relatively simple. A variable-frequency signal modulates the power-supply input, and the attenuation of that signal is measured at the output. However, the measurement is highly sensitive to setup noise, including noise from the probe-loop area and the layout of the printed circuit board (PCB). This article explores commonly encountered setup issues that limit PSRR measurement and offers a method to overcome them using high-fidelity signal injectors and a highly sensitive/selective vector network analyzer (VNA).

Input-signal modulation

The easiest way to modulate the input to a regulator is with a line injector, such as the Picotest J2120A. This device accommodates 50 V at the input and an input current of 5 A. Coupled with a VNA, the J2120A directly modulates the input voltage while the VNA measures the input/output attenuation. The drawbacks of this method are the need to break into the input lines and the need to accommodate a voltage drop across the injector. While these drawbacks are generally not issues for bench testing, they can be troublesome when the measurement is performed in circuit.

An alternative way to modulate the input is to capacitively connect the VNA to the device under test by using a low-frequency DC blocker, such as the J2130A DC bias injector. The amplitude of the signal at the input is limited by the VNA's 50-Ω source impedance, but the signal is usually large enough to be measured by the VNA. This method does not require breaking into the input connection and therefore can be performed in circuit without adding any DC loading to the voltage bus being modulated.

Calibration

Before performing a PSRR measurement, it is important to correct for any probe variations. It is also important to measure the noise floor of the setup to determine measurement limitations. The image in Figure 1 shows the test board setup for calibration. The black and white wires are the input from the J2120A line injector. The red and black clips on the right are connected to a J2111A current injector that serves as a 25-mA load. The two probes are connected to a common output ground; and both probe tips are connected to the same input so they see the same modulation signal. A THRU calibration is then performed on the VNA in order to correct for any probe or cable-related imperfections. A flat gain response should be seen on the VNA over the frequency band of interest.

Figure 1. Test board setup for THRU calibration

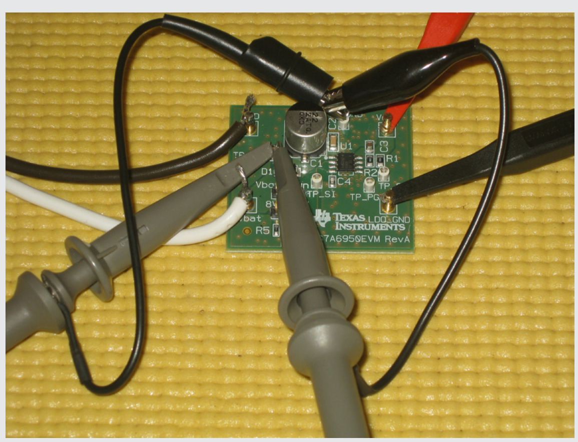


Figure 2. Noise-floor measurement with setup using scope probes

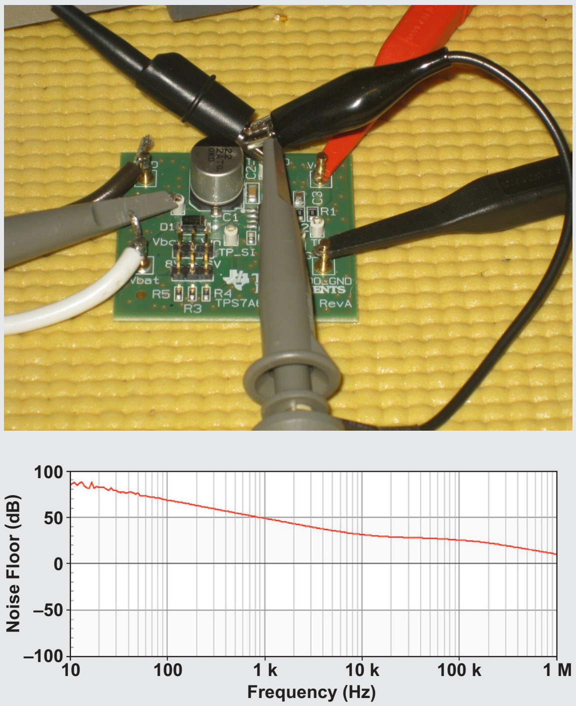
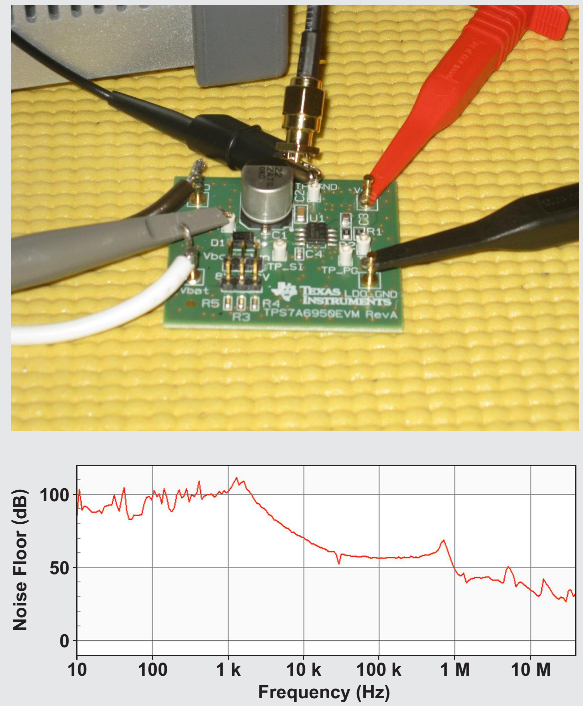


Figure 3. Noise-floor measurement with output scope probe replaced by 50-Ω coaxial cable



Assessing the noise floor

With the probe calibration completed, the noise floor can be assessed by shorting the output sense probe to the ground connection (Figure 2). It is clear from this measurement that this noise floor is far too high in relationship to the PSRR of most regulators today and that a better setup is required to ascertain the actual PSRR. In general, high-fidelity measurements like PSRR necessitate the use of carefully terminated connections with minimal probe-loop area. In fact, the low-fidelity measurement in Figure 2 is largely a result of induced noise in the wire loop created by the scope probe's ground clips.

In the next measurement setup, shown in Figure 3, the output scope probe is replaced with a 50-Ω coaxial cable via an SMA adapter soldered directly to the output capacitor. The cable is connected to the VNA through a J2130A DC blocker and a J2102A common-mode transformer. The probe is shorted at the output ground to assess the noise floor. From Figure 3 it is clear that the noise floor has been improved with over 90 dB out to 1 kHz. However, since most quiet power regulators from Texas Instruments (TI) have good PSRR out beyond 1 MHz, this noise floor is still unacceptable.

Next, the input-side scope probe is replaced with a 50-Ω coaxial cable soldered directly to the input capacitor (Figure 4). The complete setup (two 50-Ω coaxial cables

Figure 4. Input scope probe replaced by 50-Ω coaxial cable

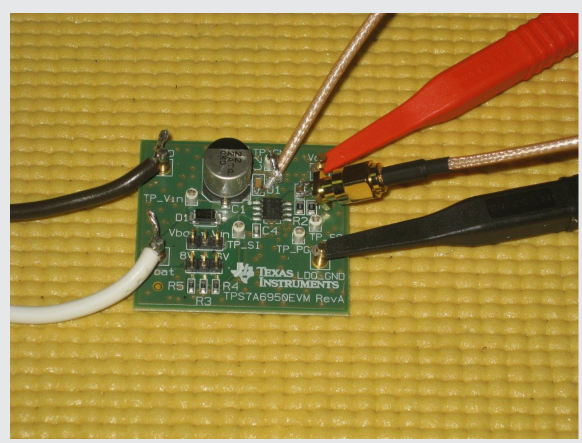


Figure 5. Complete setup and noise-floor/PSRR measurements

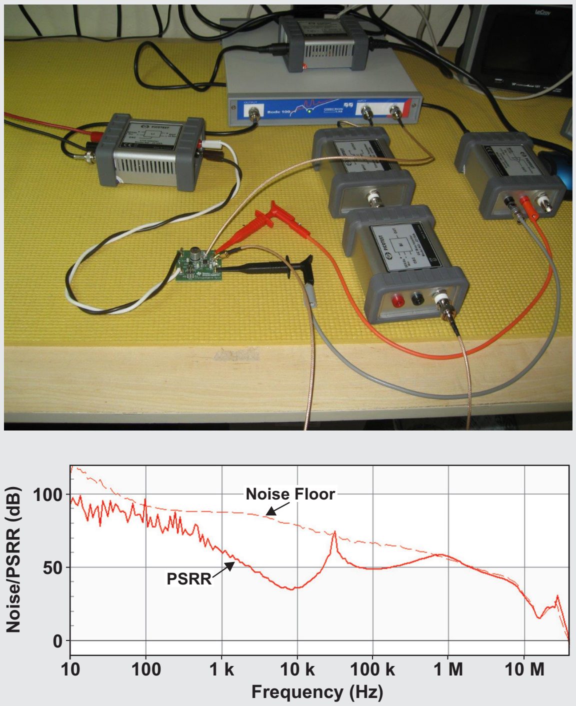


Figure 6. Optimized high-fidelity PSRR and noise-floor measurements

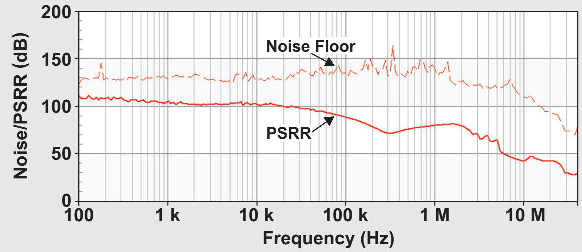
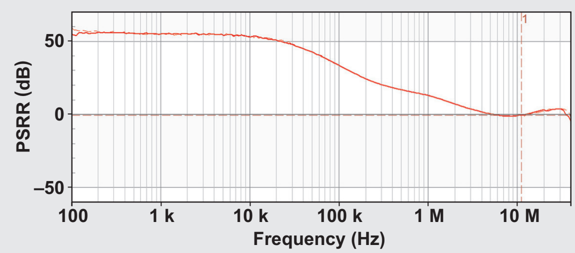


Figure 7. LM317's PSRRs measured with J2120A and J2130A



and the J2102A, J2130A, J2120A, and J2111A) and the noise-floor/PSRR measurements are shown in Figure 5. The setup has a much lower noise floor, facilitating a PSRR measurement to 1 MHz and a low-frequency PSRR over 90 dB. The PSRR resonance near 30 kHz is likely a result of the PCB layout or component parasitic interaction.

To illustrate the significance of a good setup, the PSRR of a carefully designed regulator, PCB layout, and setup is shown in Figure 6. This measurement shows that with careful setup and appropriate measurement equipment, it is possible to obtain a significantly lower noise floor, enabling very accurate PSRR measurements. Lastly, to validate the injection methods discussed earlier, the PSRR of TI's LM317 adjustable regulator was measured using a J2120A line injector (method 1) and a J2130A DC bias injector (method 2). Figure 7 shows nearly perfect overlapping plots, which means there is a very good correlation between the two injection methods.

Conclusion

This article illustrates that although PSRR measurement is simple in concept, the setup is of great significance in achieving an accurate result. A methodology for lowering the noise floor has also been presented.

Reference

1. Masashi Nogawa, "A topical index of TI LDO application notes," Application Report. Available: www.ti.com/sbva026-aaj

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