

Measuring Power Supply Noise with an RSA

Noise from the power supply, linear regulators, and voltage references is a major contributor to the limitations of system performance, especially in instrumentation and communications products. In ADC applications, the noise from regulators and references results in clock jitter, which can significantly degrade the ADC characteristics such as signal-to-noise ratio (SNR), signal-to-noise and distortion ratio (SINAD), and bit error rate (BER). LNAs also suffer from phase noise and modulation effects related to power supply noise.

A common method for measuring noise

An oscilloscope is often used to measure power supply, linear regulator, and reference noise. Since an oscilloscope has a sensitivity in the range of 2mV per division, a substantial voltage gain must be added in order to see the ripple and noise, which is often in microvolts. This gain is usually accomplished using a “low-noise” opamps or several cascaded low-noise opamps. The opamps are followed by an active filter, providing high pass and low pass elements, to meet the desired measurement bandwidth with the entire circuit constructed in a Faraday shield (a paint can can serve this purpose). Several integrated circuit manufacturers have application notes describing the measurement.¹

¹ Linear Technology Application note 124 “775 Nanovolt Noise Measurement for a Low Noise Voltage Reference” and application note 83 “Performance Verification of Low Noise, Low Dropout Regulators”

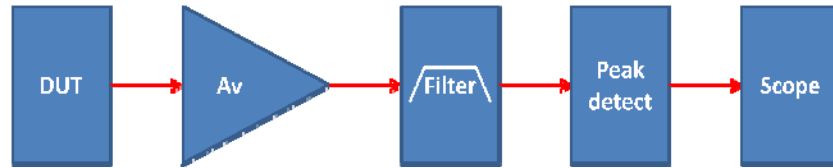
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Figure 1 - Typical noise measurement setup using an oscilloscope.

Several limitations are evident in this setup, the first being that it takes time and effort, not to mention extreme care, to build such a configuration. Next, the high gain required often limits the bandwidth of the measurement, and the amplifiers provide a noise path through PSRR (power supply rejection ratio), making the circuit sensitive to the power supplies that power the circuit. In addition, the amplifier itself contributes noise.

The RSA offers a better way

The Tektronix Real-time Spectrum Analyzer (RSA5103A or RSA5106A), in conjunction with the Picotest Signal Injectors, offers two ways to measure power supply, voltage regulator, and voltage reference noise. These spectrum analyzers can measure over a frequency range of 1Hz to 3GHz (RSA5103A) or 6GHz (RSA5106A) and offer a much greater dynamic range than an oscilloscope. The RSA also offers an outstanding noise floor and much greater sensitivity than an oscilloscope. They provide peak detection, averaging, and high-resolution options for analyzing the results. These two RSA's also offer many other measurements including phase noise and jitter.

Measuring phase noise with an RSA

There are two basic methods for measuring voltage regulator/reference noise with an RSA. One method is to measure the phase noise of a high performance clock, which is powered by the regulator under test. A phase noise measurement of a crystal oscillator offers an effective indirect measurement of regulator noise. The noise signals from the regulator appear as amplitude modulation and as mixing products in the oscillator frequency. The phase noise measurement identifies specific noise frequencies, which can be seen as "spurs."

These spurs include all of the frequencies in the power supply noise, as well as all mixing products of the clock and power supply noise frequencies. All power supply noise contributes to the phase noise and can be seen in the total jitter performance, which is specified directly in

the RSA phase noise display. An example of oscillator phase noise with a 250kHz power supply noise signal is shown in Figure 2 below. A typical power supply will result in many interference signals; only one example is shown here for clarity.

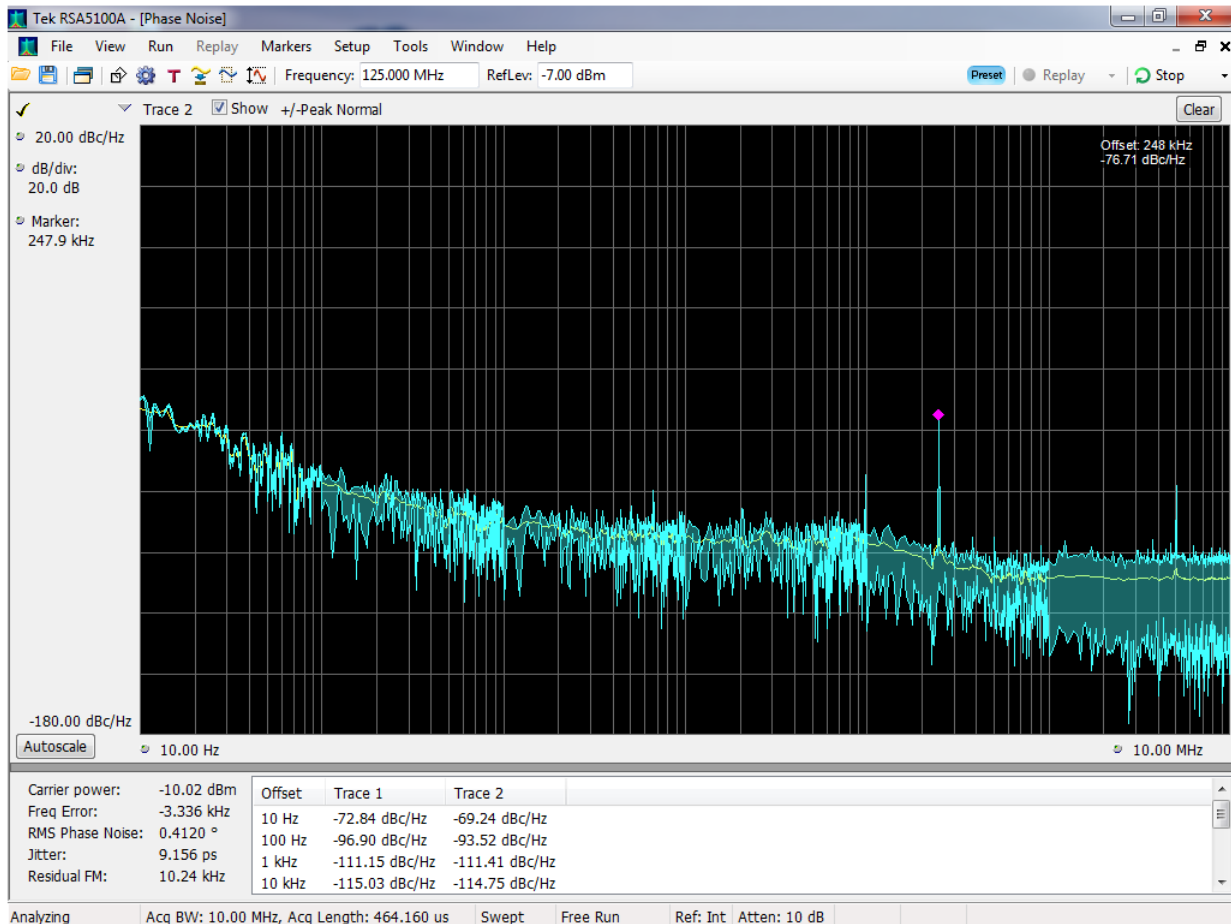


Figure 2 – Phase noise measurement, showing the 250kHz noise representing the power supply.

In order to determine the power supply noise from this phase noise plot, it is necessary to quantify the PSRR of the clock.

Direct measurement of noise

The power supply noise can also be measured directly using the RSA. In order to demonstrate the validity and the sensitivity of the noise measurement, the noise floor of the measurement

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setup is recorded. The 60Hz spur near the center of the screen is approximately $1\mu\text{Vrms}$. This signal is a spurious response related to the AC power input.

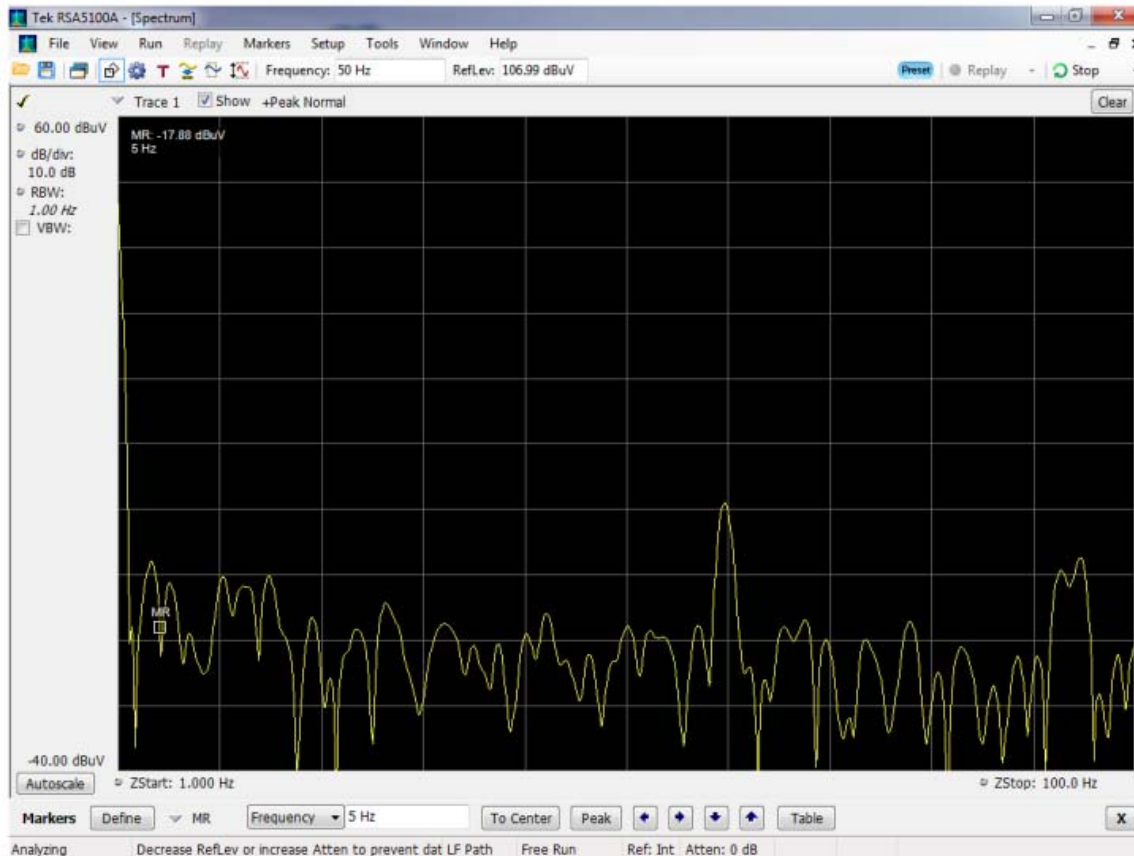


Figure 3 - Low frequency noise floor. The 60Hz spurious response in the center of the screen is approximately $1\mu\text{Vrms}$.

Next, an arbitrary waveform generator (AWG) is set to provide a 5Hz $+80\text{dB}\mu\text{Vrms}$ (10mVrms) sine output. A Picotest J2140 cascaded attenuator, configured for an attenuation of 60dB, is connected between the AWG and the RSA, as shown in Figure 4 below. The attenuator greatly reduces the generator signal level to verify the sensitivity of the measurement. The resulting signal, as measured on the RSA, shows $+20\text{dB}\mu\text{Vrms}$, which is correct ($80\text{dB}\mu\text{V} - 60\text{dB}\mu\text{V} = 20\text{dB}\mu\text{V}$). A $+80\text{dB}\mu\text{Vrms}$ 90Hz sine signal with the attenuator configured for 70dB attenuation (the J2140A maximum) correctly displays $+10\text{dB}\mu\text{Vrms}$ ($80\text{dB}\mu\text{V} - 70\text{dB}\mu\text{V} = 10\text{dB}\mu\text{V}$).

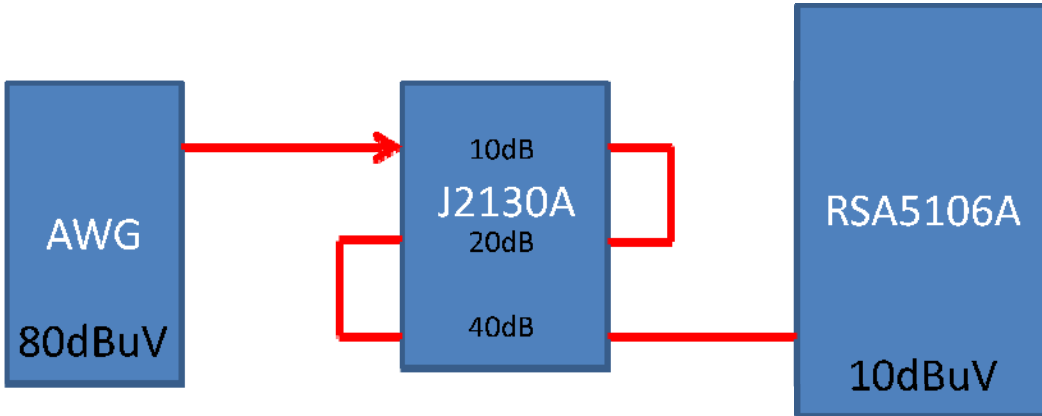


Figure 4 - Test setup to validate the RSA noise measurement.

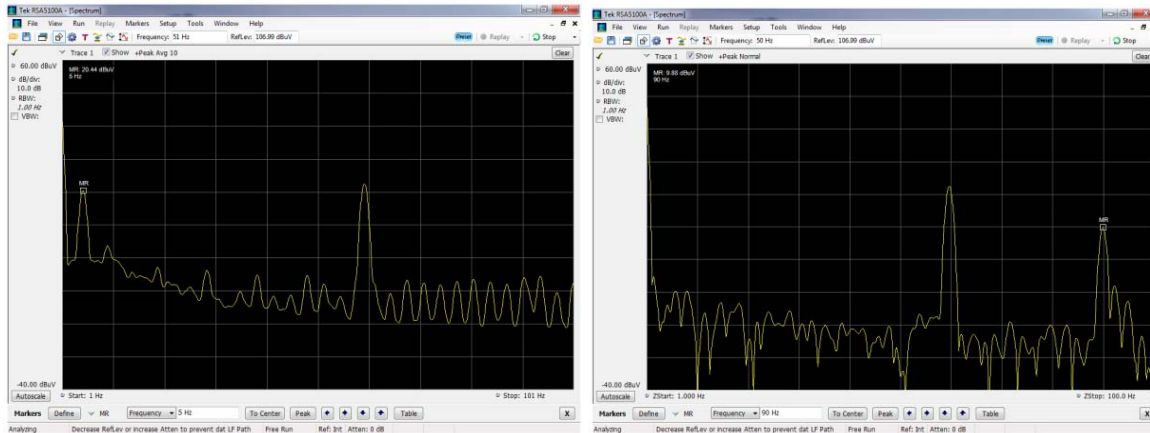


Figure 5 – Test measurements of 5Hz and 90Hz AWG signals with J2140A attenuator.

Having shown in Figure 3 that the noise floor of the RSA is below 0dB μ Vrms (3 μ Vpp), and verified a 90Hz measurement of a 10dB μ Vrms signal from an AWG (the smallest we can generate), we can use this setup to directly measure voltage regulator and reference noise.

Example Measurements

Next, we insert a Picotest J2130A DC Bias injector as a DC blocker. After verifying that the passive DC blocker did not contribute to the noise floor, we connect the DC Bias injector to the output of a regulator in order to measure the regulator noise. Measurements of a typical LDO and a low noise linear regulator (LM7805) were performed. The results are shown in Figure 6 and Figure 7.

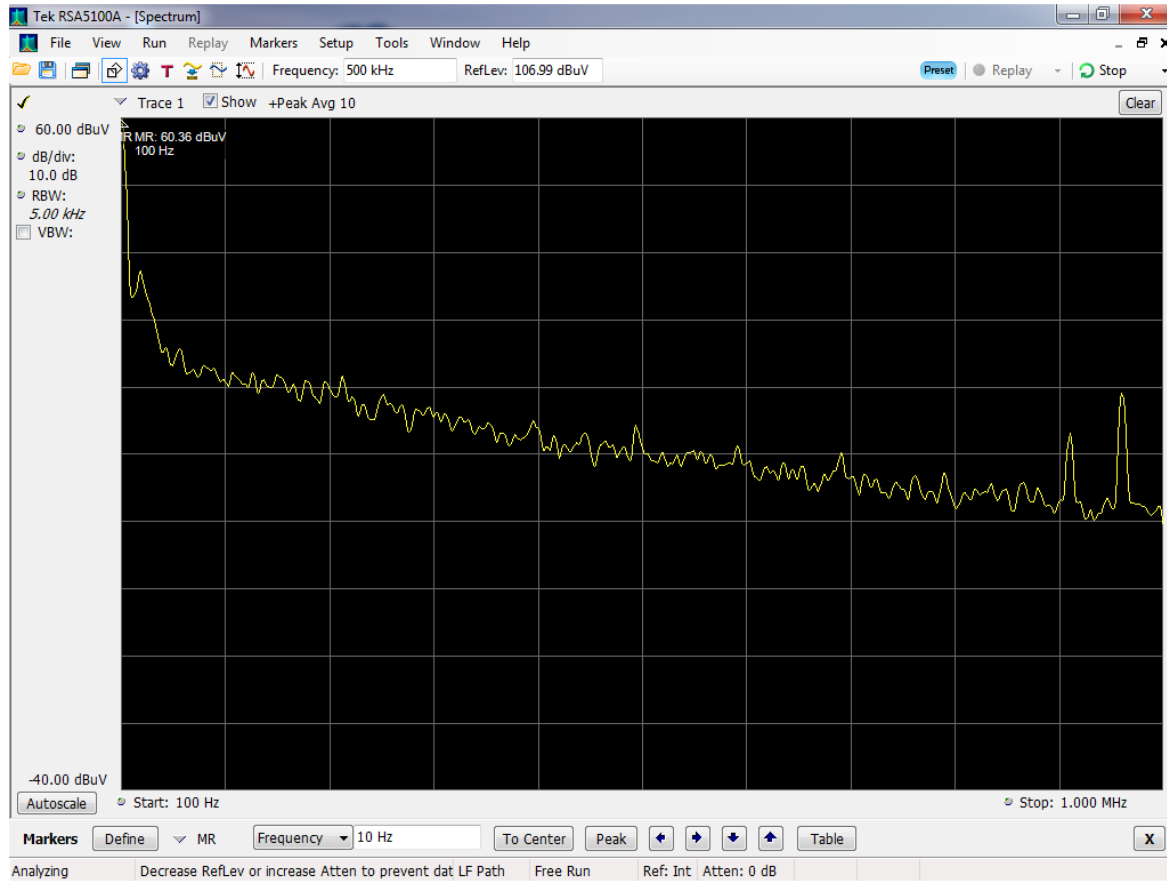


Figure 6 – Typical LDO noise 100Hz -1MHz.

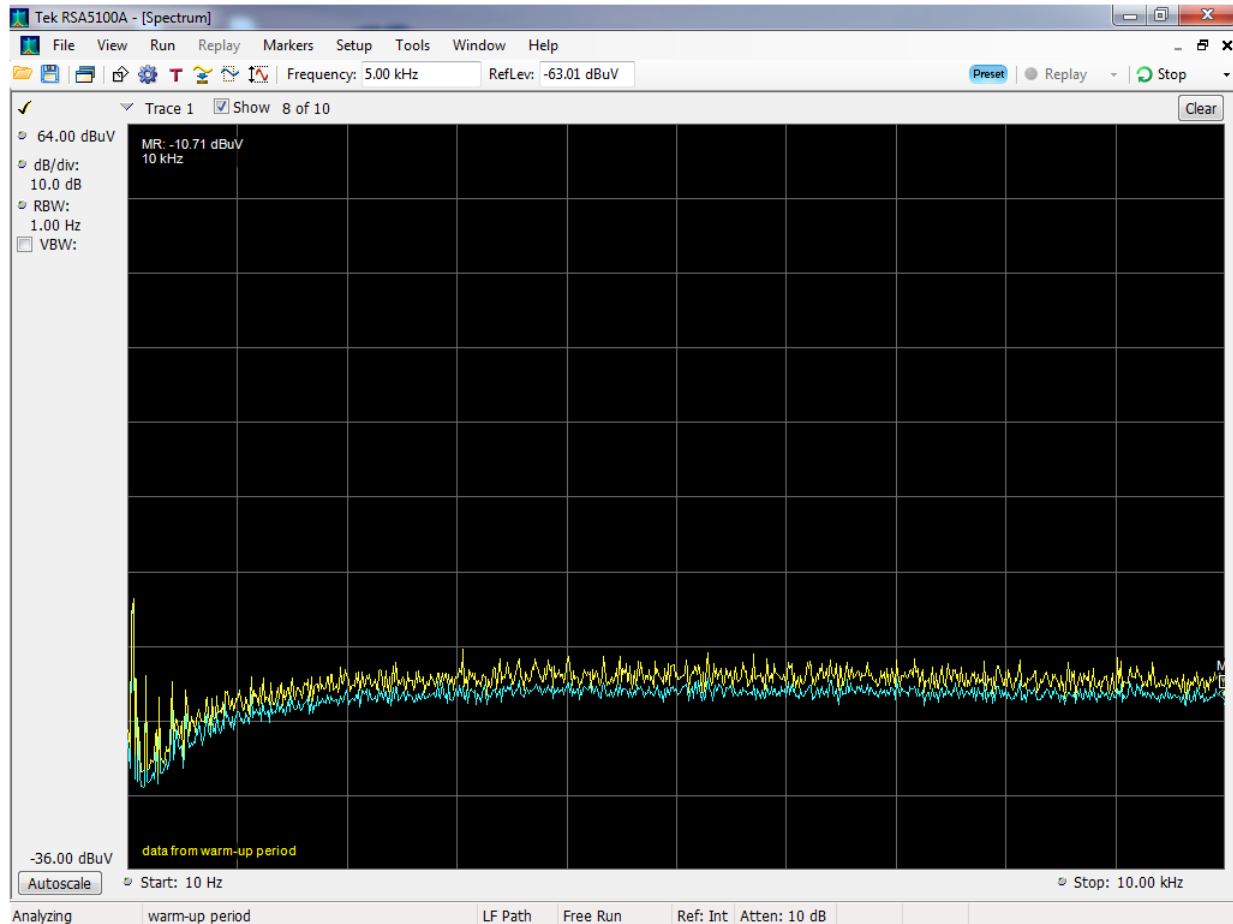


Figure 7 - Typical noise of a low noise voltage regulator (LM7805).

Conclusions

We have demonstrated two simple methods for measuring power supply and reference noise with a Tektronix Real-time Spectrum Analyzer. This method provides significantly more information than the common oscilloscope method, as it offers much greater sensitivity, as well as the particular frequencies that contribute the most noise.

The addition of low noise analog active filters and wideband preamplifiers, coming soon from Picotest, will bring further capabilities to this measurement technique, while further reducing the effective spurious response, particularly evident at 60Hz.