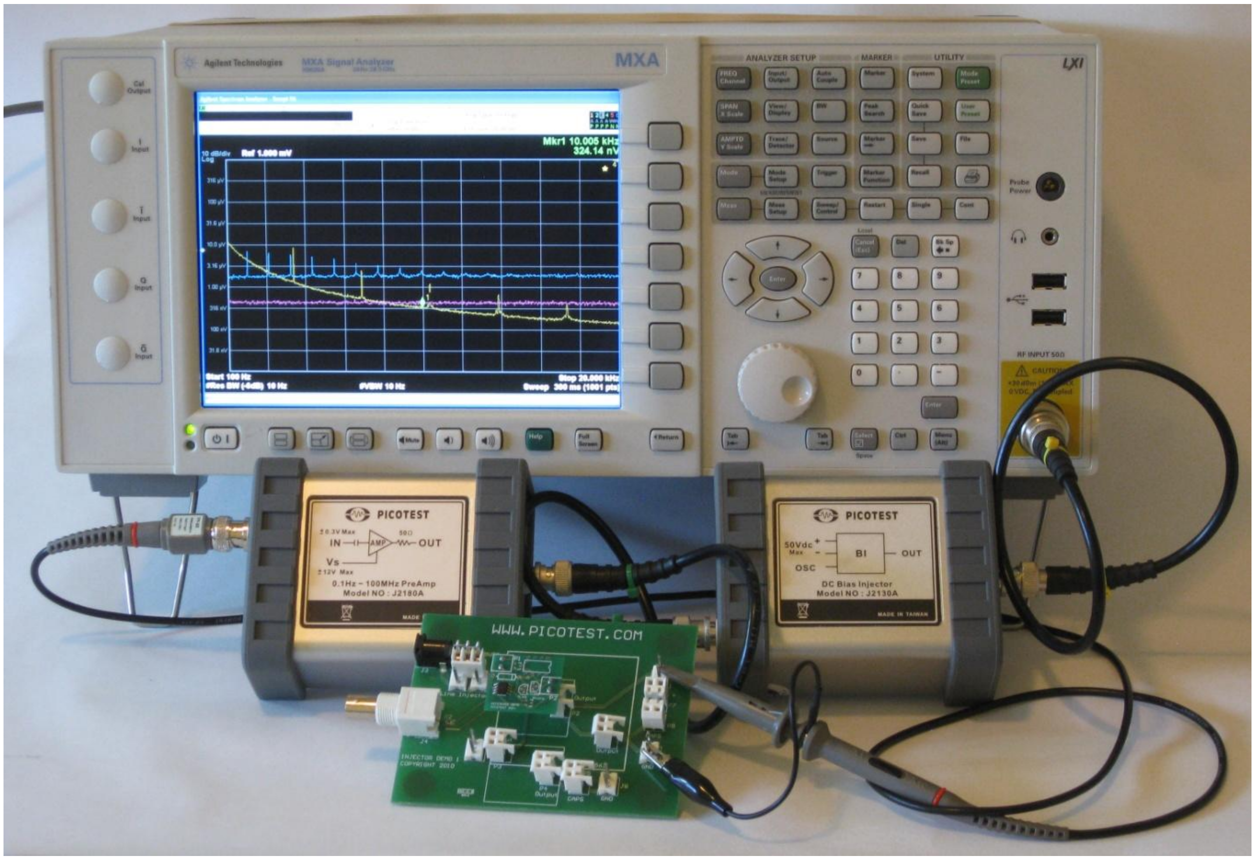
Measuring Power Supply Noise with the Agilent N9020A Signal Analyzer



Noise from power supplies, 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). Low-Noise Amplifiers or 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 voltage reference noise. Since an oscilloscope has a sensitivity in the range of 1-2mV 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 "low-noise" opamps or several cascaded low-noise opamp stages. 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]

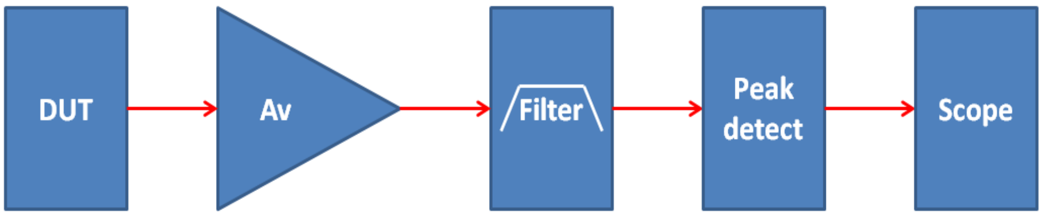


Figure 1 - Typical noise measurement setup using an oscilloscope.

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 their power supply rejection ratio (PSRR), making the circuit sensitive to the supplies that power the circuit. In addition, the amplifier itself contributes noise.

A Signal Analyzer offers better measurement methods

The N9020A Signal Analyzer (w/Option 503) can measure noise over a frequency range of 20Hz to 3.6 GHz, with other models reaching as high as 26.5 GHz. The N9020A also offers an outstanding noise floor and much greater dynamic range and sensitivity than an oscilloscope. The N9020A offers many methods of acquisition and analysis options including direct spectrum measurement and also oscillator phase noise and jitter. The N9020A Signal Analyzer (SA), in conjunction with the Picotest J2180A Signal Injector Preamplifier, offers two ways to measure power supply, voltage regulator, and voltage reference noise.

[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"

Direct measurement of noise

There are two basic methods for measuring voltage regulator/reference noise with a signal analyzer. One method is directly measuring the DUT using the N9020A. In order to demonstrate the validity and the sensitivity of its noise measurement, the noise floor of a typical measurement setup was recorded. The noise floor is measured as a direct measurement, including only the Picotest J2130A DC Bias injector, used as a DC blocker, and also the J2180A preamp. The N9020A external preamp gain is set to 20dB in order to account for the 20dB gain of the J2180A. The J2180A preamp improves the noise floor by nearly 20dB, while also presenting a high impedance connection to the device under test (DUT). This is important since the 50 Ohm termination could easily impact the noise result.

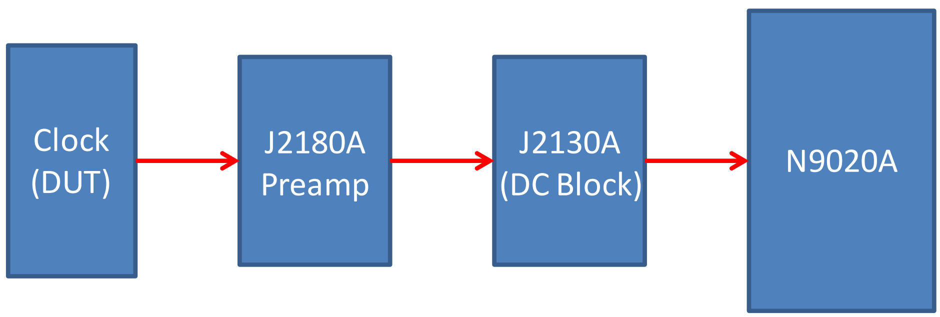


Figure 2 - Test setup to directly connect the DUT to the N9020A for a noise measurement.

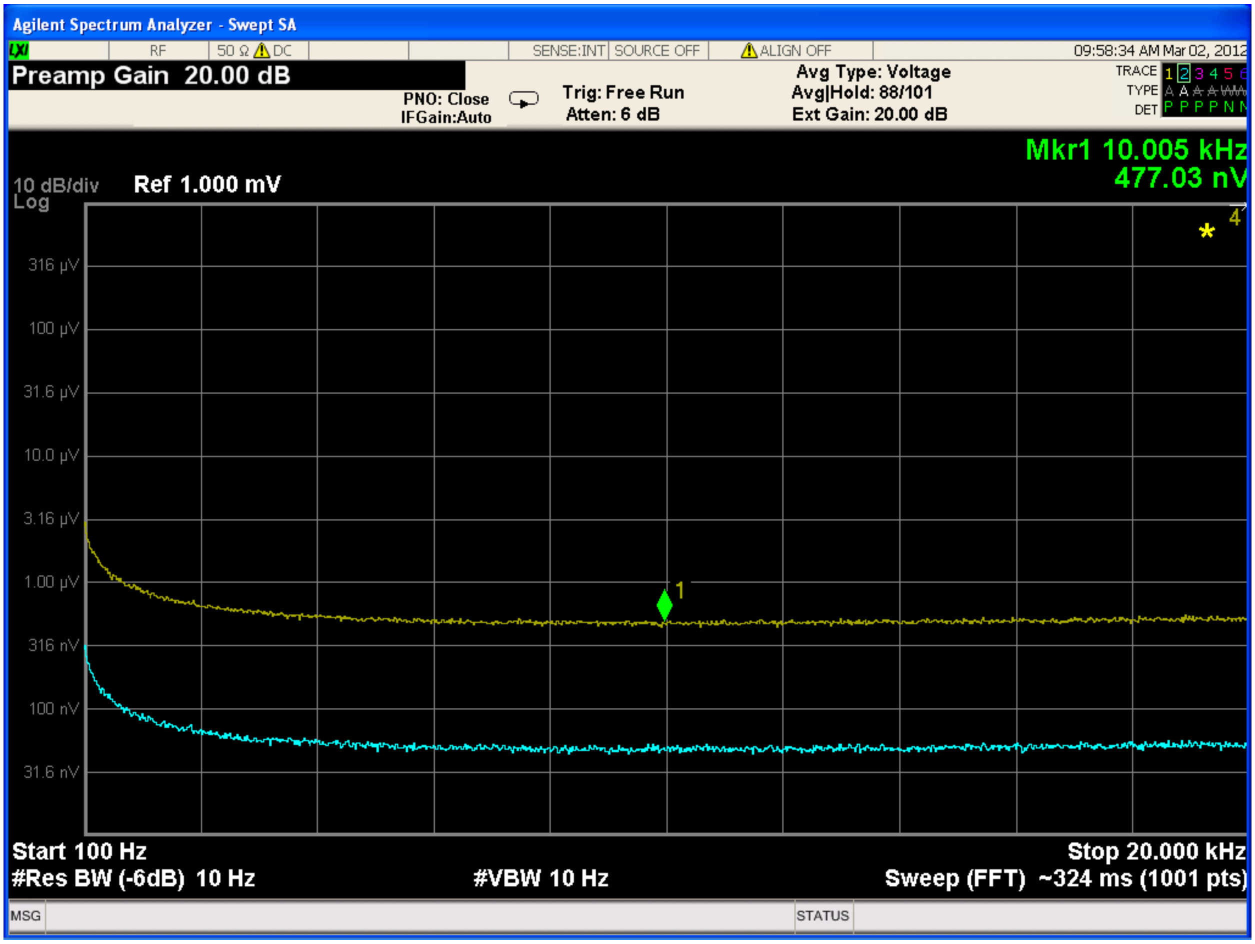


Figure 3 - Low frequency noise floor test using the J2180A preamp (blue trace) and without the preamp (yellow trace). The preamp <u>improves</u> the noise floor by nearly 20dB.

Next, an arbitrary waveform generator (AWG) is set to provide a 1kHz 50mVrms sine output. A pair of Picotest J2140A cascadable attenuators, each configured for an attenuation of 40dB, is connected between the AWG and the N9020A, 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 analyzer, displays 4.56µVavg (5.06µVrms.), which is correct as seen in Figure 5 below.

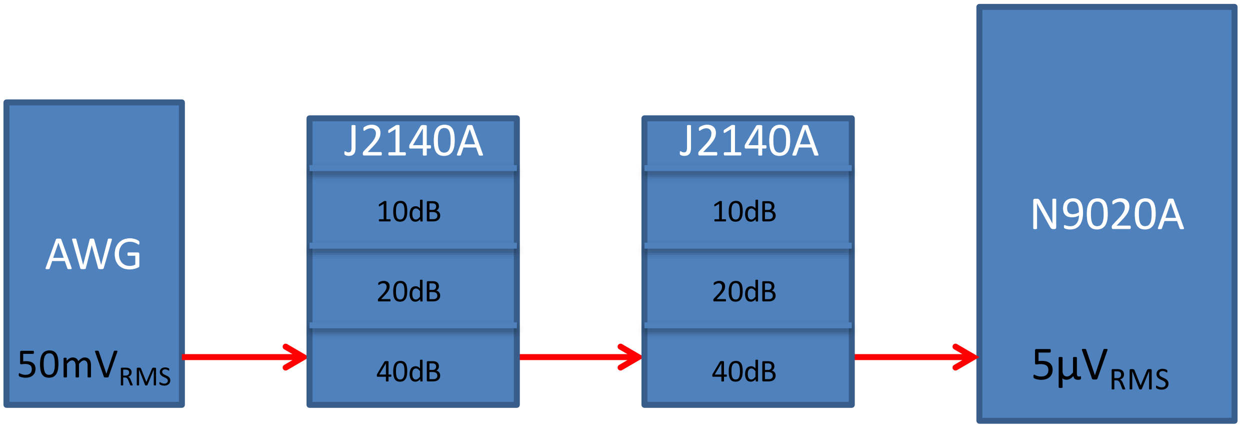


Figure 4 - Test setup to validate the N9020A noise measurement using the J2140A attenuators.

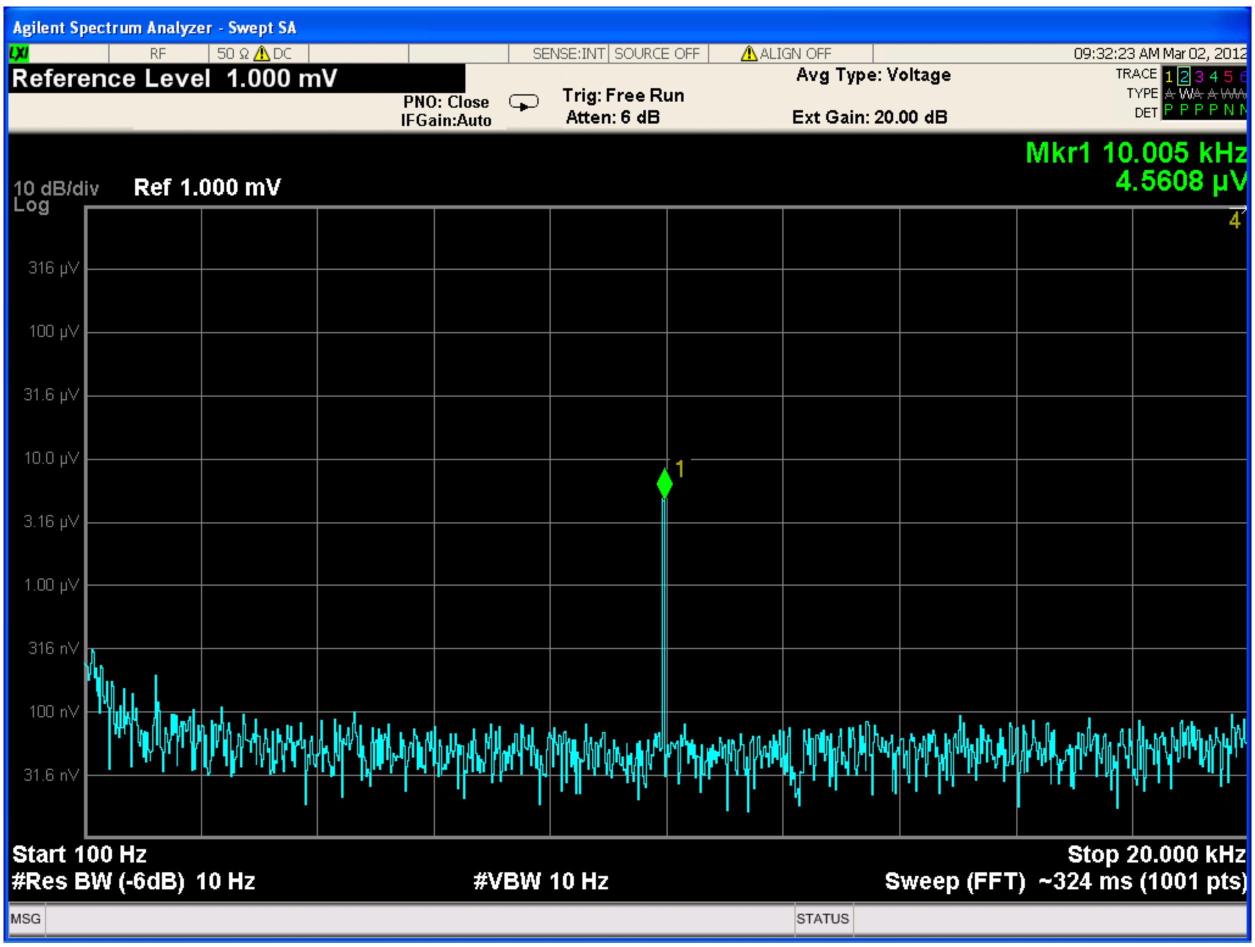


Figure 5 Signal verification using the J2180A preamp with a 1X scope probe and a 20dB gain correction factor. Note the measured 4.6µVavg signal is 40dB above the noise floor of 46nV.

Having shown that the noise floor of the measurement is approximately 45nV and having verified that the setup correctly and accurately measured a 4.6µVavg signal we can now use this setup to directly measure voltage regulator and reference noise.

Measuring phase noise with the N9020A Signal Analyzer

The second method for measuring voltage regulator/reference noise with a signal analyzer 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 precision crystal oscillator offers an effective indirect measurement of regulator noise. The noise signals from the regulator appear as amplitude and/or frequency 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 N9020A phase noise display. An example of oscillator phase noise with a 250kHz power supply noise signal is shown in Figure 6 below. A typical power supply will result in many interference signals; only one example is shown here for clarity.

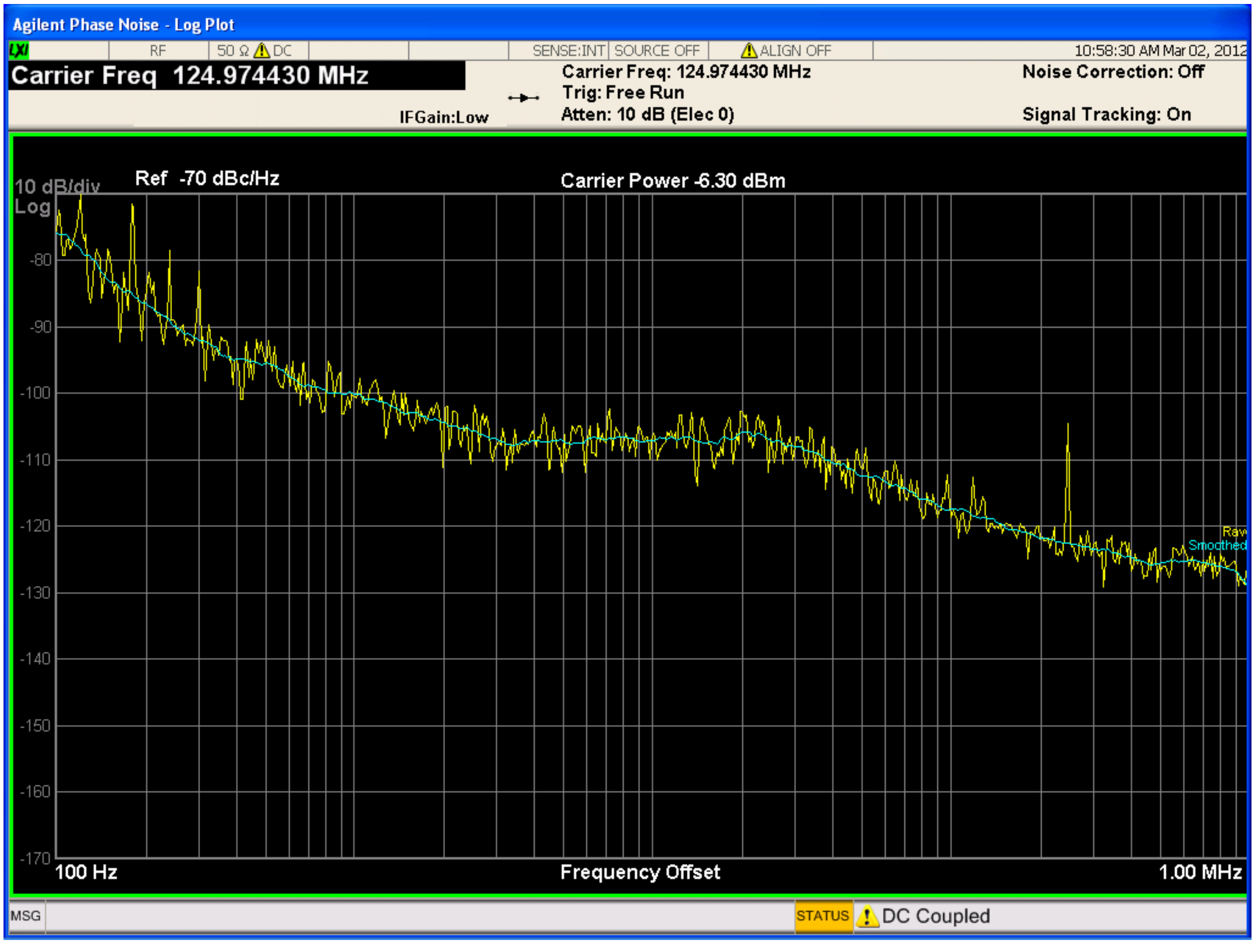


Figure 6 – Phase noise measurement, showing the 250kHz noise representing the power supply.

In order to determine the amplitude of the power supply noise from this phase noise plot, it is necessary to quantify the PSRR of the clock, though in most cases the relative phase noise is an adequate measure of noise.

Example Measurements

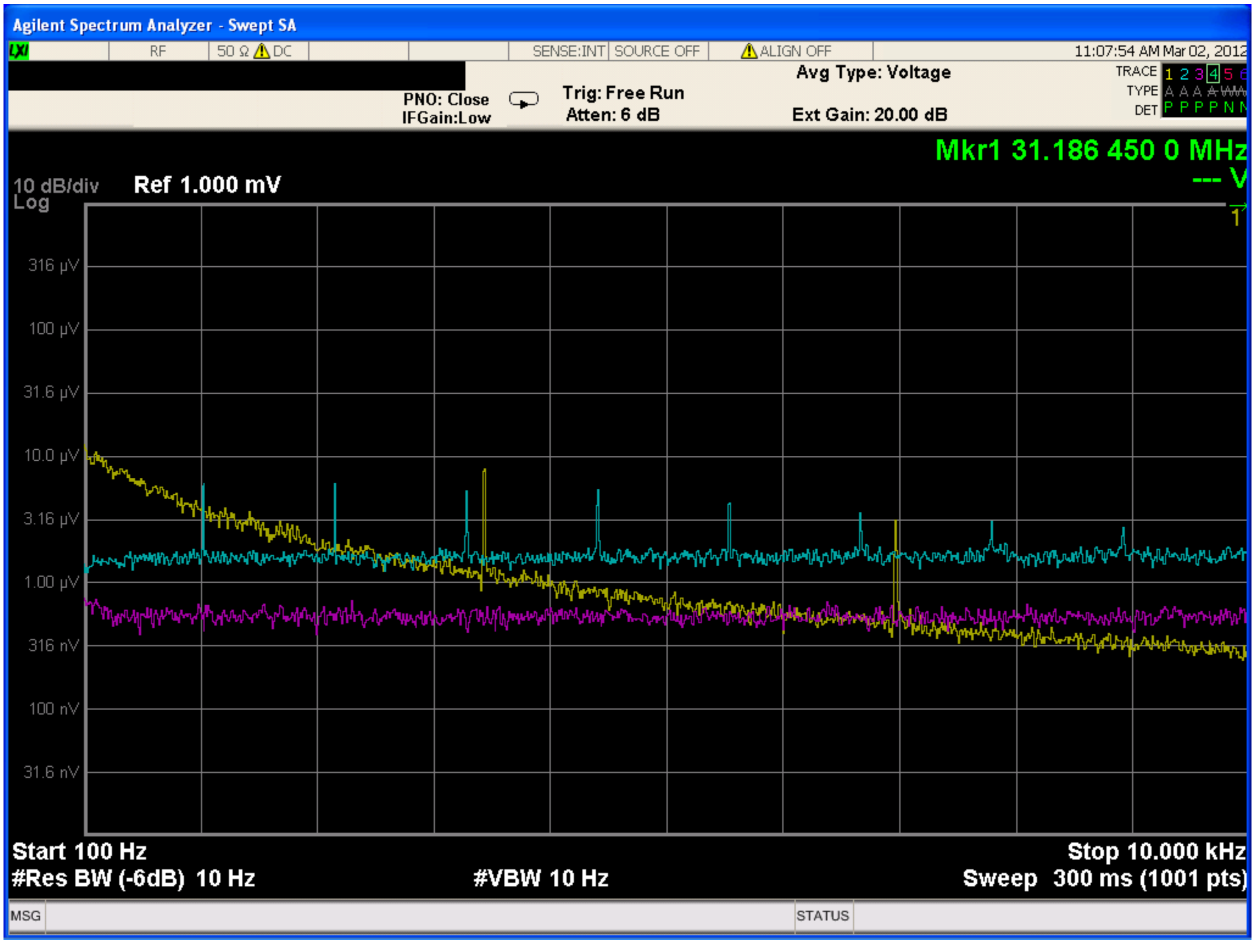


Figure 7 – Typical noise measurements 100Hz -10kHz. The measurements include LDO (yellow), LM317 (blue), REF03 voltage reference (green) and custom regulator (pink).

Conclusions

We have demonstrated two simple methods for measuring power supply and voltage reference noise with a N9020A Signal Analyzer in conjunction with a Picotest J2180A preamp and J2130A DC Bias Injector. Both methods provide significantly more information than the common oscilloscope method, as they offer much greater sensitivity, as well as the particular frequencies that contribute the most noise.