Using the J2110A Solid State Signal Injector

Introduction

Most of us have experience using a wideband signal injection transformer to introduce a modulation signal into our loop stability test. While a high quality injection transformer, such as the Picotest J2100A or J2101A often provides more than adequate results, there are applications where higher fidelity, lower noise and even wider bandwidth are required. This application note shows some applications that can benefit from the J2110A Solid State Injector, also sometimes referred to as a “Bode Box.”

A block diagram of the J2110A Solid State Injector is shown in Figure 1.

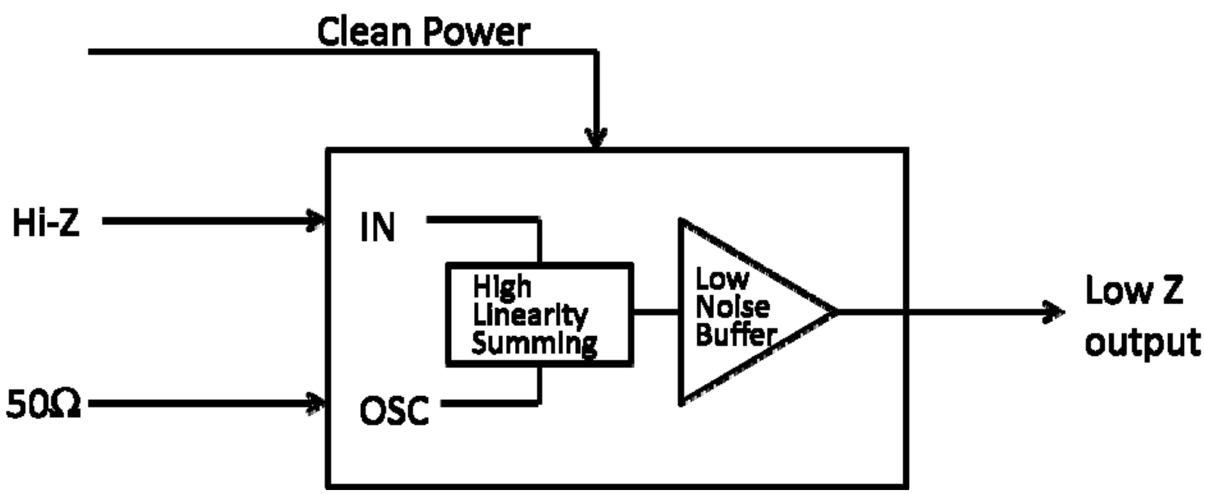

Figure 1, Block Diagram of the J2110A Solid State Signal Injector.

The J2110A provides a bandwidth of DC to more than 100MHz and is designed to have very low noise and very high linearity so that the oscillator (OSC) signal and the input are summed with minimal mixing products. This feature allows the J2110A to be used for IMD testing of audio, ultrasonic and other low frequency RF signals, in addition to higher fidelity measurements of control loops, such as in power supplies and opamp circuits. Figure 2 shows the high frequency bandwidth of the J2110A, exceeding 100MHz.

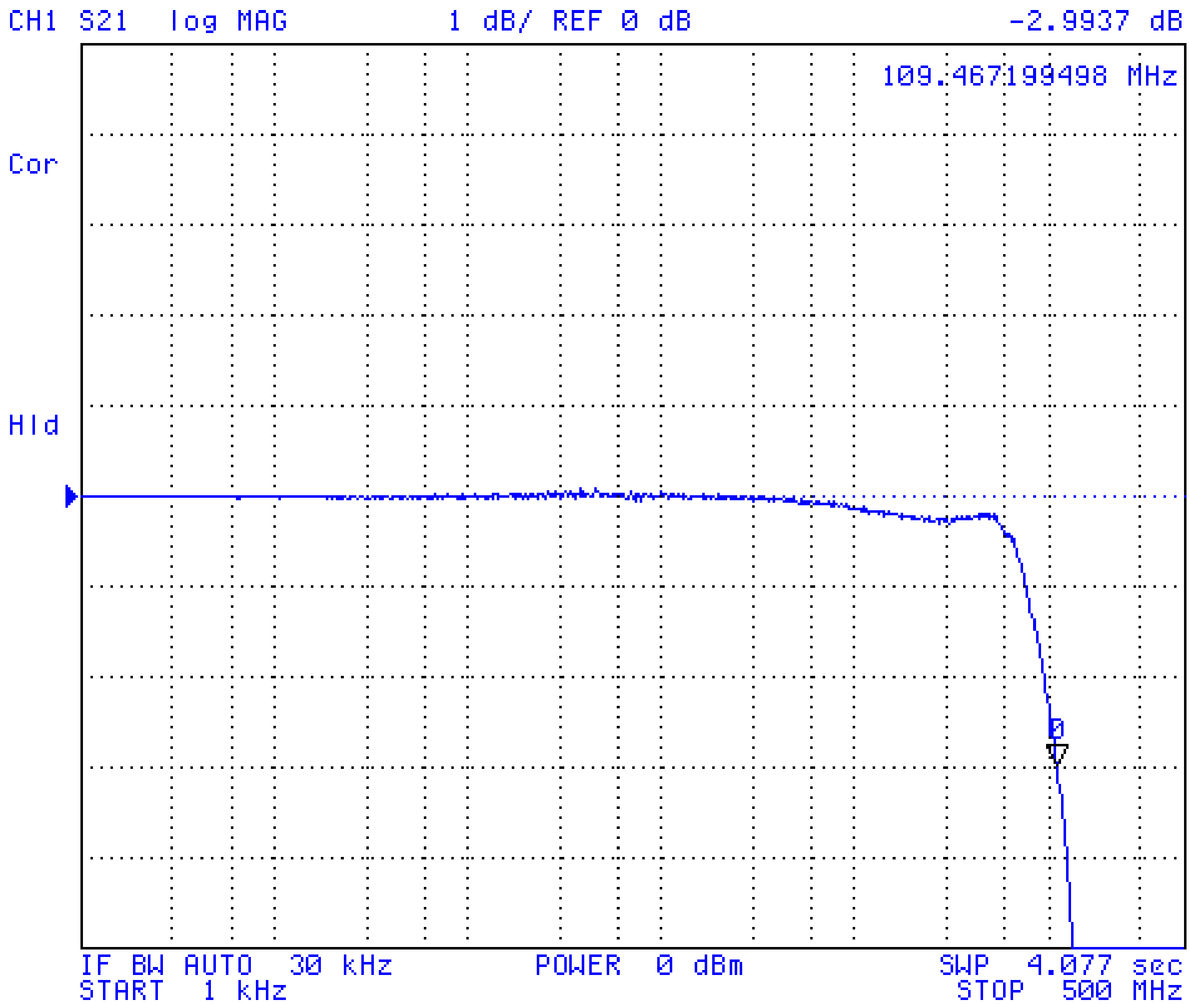

Figure 2 High frequency response of the J2110A Solid State Signal Injector.

Measuring Opamp Open Loop Gain

In order to demonstrate the low noise and wideband performance of the J2110A we can insert it into the feedback loop of an opamp in order measure the open loop gain. Since the low frequency loop gain of the opamp is very high, this measurement is extremely sensitive to noise, especially at the opamp input.

An existing application describing a minimum noise method of making the opamp open loop gain measurement can be found at http://www.omicron-lab.com/bode-100/application-notes-know-how/application-notes/op-amp-open-loop-gain.html.[i]

It is our goal in this application note to show the low noise performance of the J2110A and the dynamic range and noise performance of the OMICRON Lab Bode 100 network analyzer, therefore, no special precautions are taken to minimize noise. Since this opamp test board is also used to demonstrate opamp PSRR[ii], the circuit does not even include bypass capacitors on the opamp supply voltage pins.

Figure 3 shows the connections o f the J2110A with the Bode 100 and the opamp being tested. In this application, the J2110A provides a 0dB DC path from the output of the opamp to the input of the opamp, creating a buffer circuit. Due to the 0dB gain configuration, the opamp output amplitude during the sweep is equal to the signal injection level, while the opamp input level is reduced by the open loop opamp gain. In rough numbers, if the opamp has a low frequency gain of 95dB and the signal level is set to 1Vrms, then the opamp input level is 17uVrms.

The open loop gain measurement result using this setup is shown in Figure 4. Note that even with these very small signal levels, the Bode 100 has sufficient dynamic range and signal-to-noise ratio (SNR) to measure nearly 100dB of open loop gain with minimal noise.

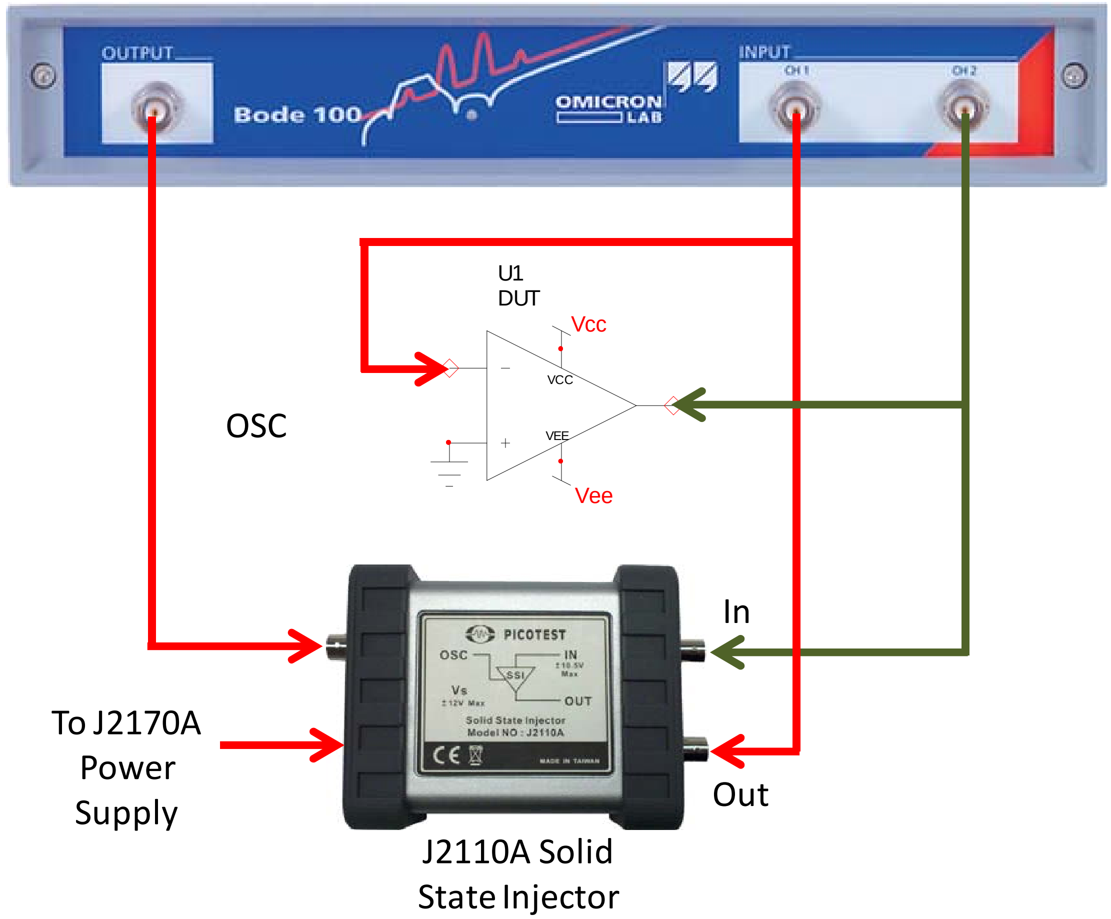

Figure 3 Connection Diagram using the J2110A Solid State Signal Injector to measure open loop opamp gain.

TIP: This measurement is very sensitive to the signal level at the inverting input of the opamp and it is, therefore, important to make the probe ground wires as short as possible and as close to the non-inverting input as possible.

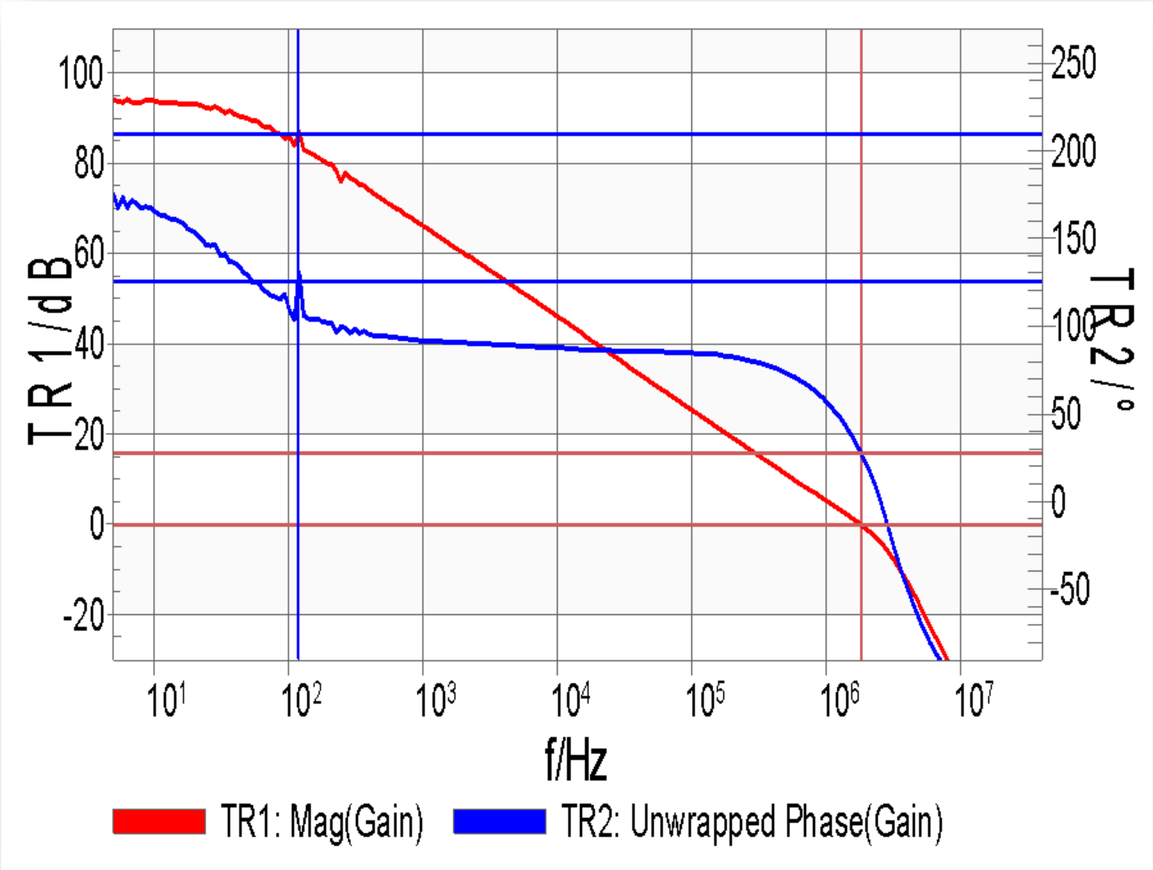

Figure 4 Measurement results using the J2110A Solid State Signal Injector to measure open loop opamp gain.

Calibrating the Measurement

This measurement uses two oscilloscope probes which, for optimum results, require a through calibration with the analyzer in order to eliminate any imbalance between the two probes. During the thru calibration both probes are connected to the Bode 100 source signal and a thru calibration is executed. The detailed instructions for the calibration are described in the Bode 100 user manual.

Due to the wide bandwidth of the J2110A injector, it is possible to make this measurement with opamps having up to approximately 20MHz gain bandwidth product. At higher frequencies the J2110A will begin to introduce additional phase shift that could cause the opamp to oscillate.

Measuring Voltage Regulator Converter Open Loop Gain

In the second example, a voltage regulator Bode plot is measured using a J2100A high fidelity injection transformer and also using the J2110A Solid State Signal Injector. The results with the injection transformer are shown in Figure 5 while the results with the J2110A are shown in Figure 6. Note the significantly reduced noise at low frequency and the improvement in fidelity above a few hundred kHz. In applications with low frequencies, such are thermal control loops, motor controls and power factor corrected controller (PFC) solid state injection offers a significant fidelity improvement. Similarly in applications with very high bandwidth solid state injection also offers a significant fidelity improvement, while in most typical applications the injection transformer is more than adequate.

It is important to provide an suitable injection point for solid state injection. For applications with high voltages, such as PFCs and other applications with high impedance sense networks, it is generally advisable to buffer the divider in the circuit with an opamp in order to provide a high quality injection point. An example is shown in Figure 7. The opamp buffers the voltage divider while reducing the voltage levels to be compatible with the J2110A.

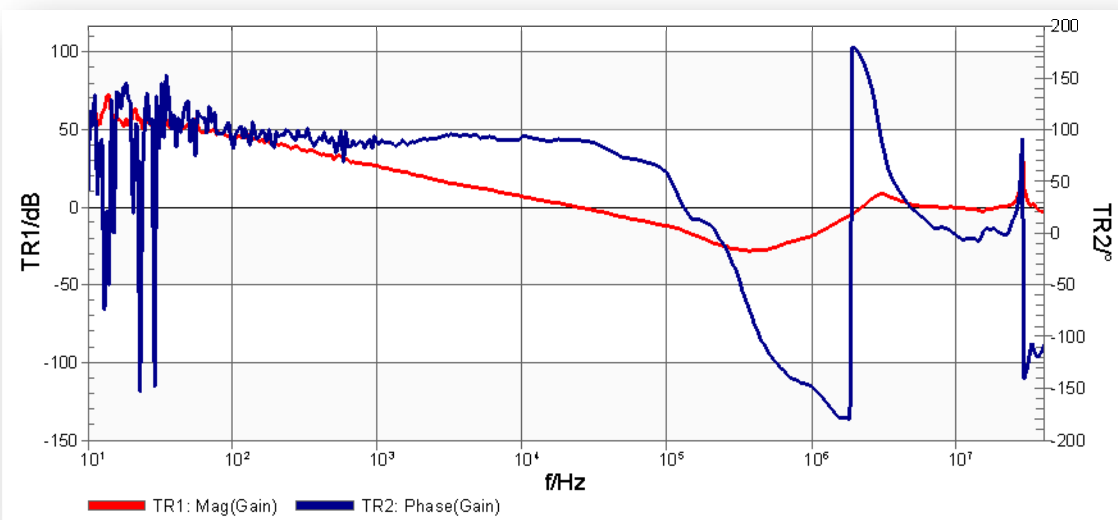

Figure 5 Bode Measurement results using the J2100A injection transformer.

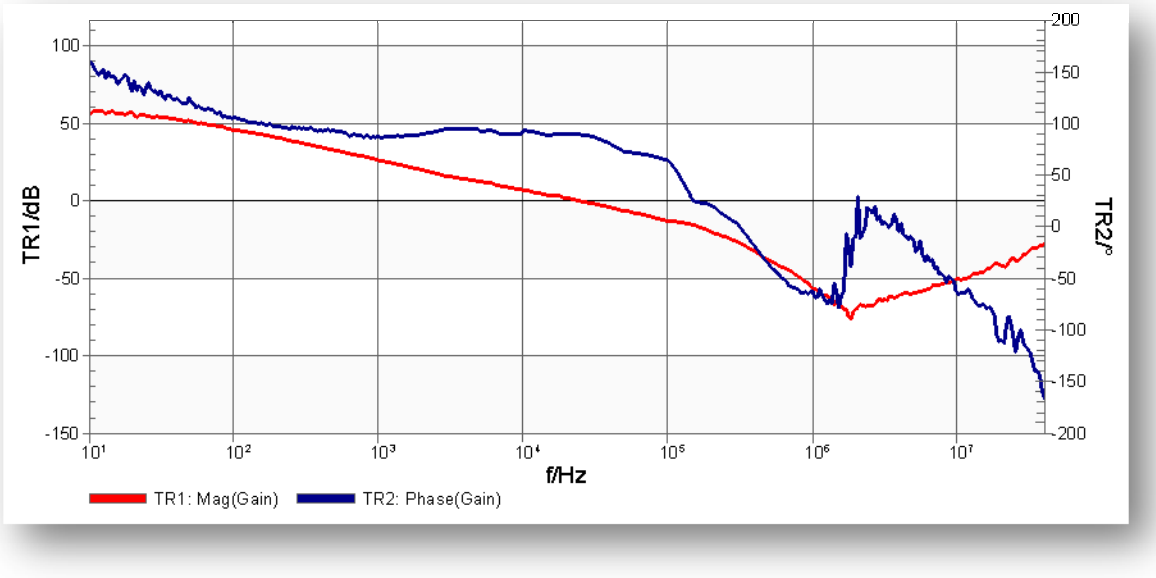

Figure 6 Bode Measurement results using the J2110A Solid State Signal Injector

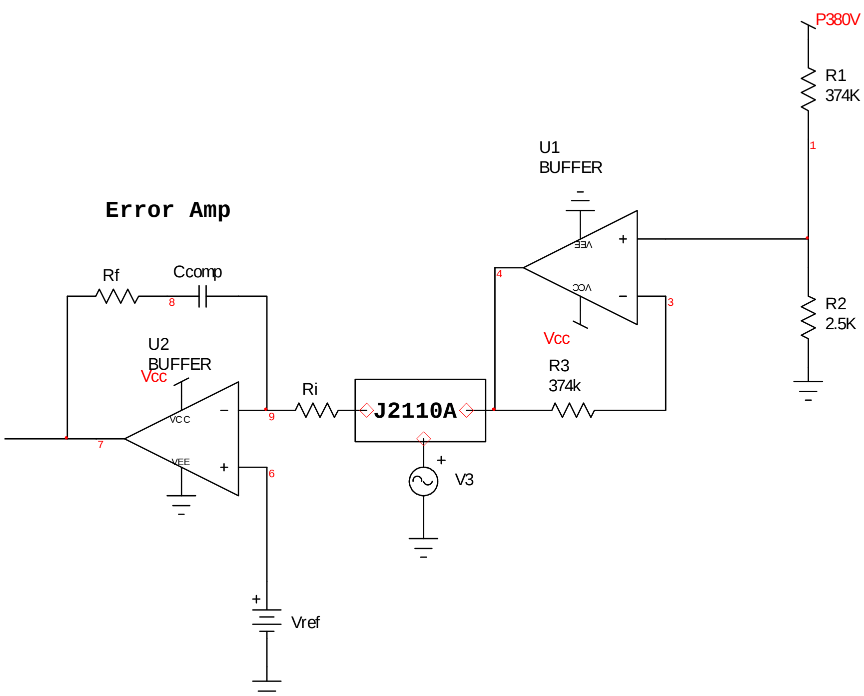

Figure 7 Typical configuration for measuring PFC using the J2110A Solid State Signal Injector.

Measuring the Spectral Purity of the J2110A Solid State Signal Injector

The wide bandwidth of the J2110A also supports low frequency RF, ultrasonic and audio applications. The high linearity of the J2110A can be seen in the spectrum and time domain plot in Figure 8. A 50MHz sine wave from a signal generator is used to modulate the input of the J2110A while the output is monitored on an oscilloscope and a spectrum analyzer. Note the lack of spurious signals or harmonics, as well as, the noise free response.

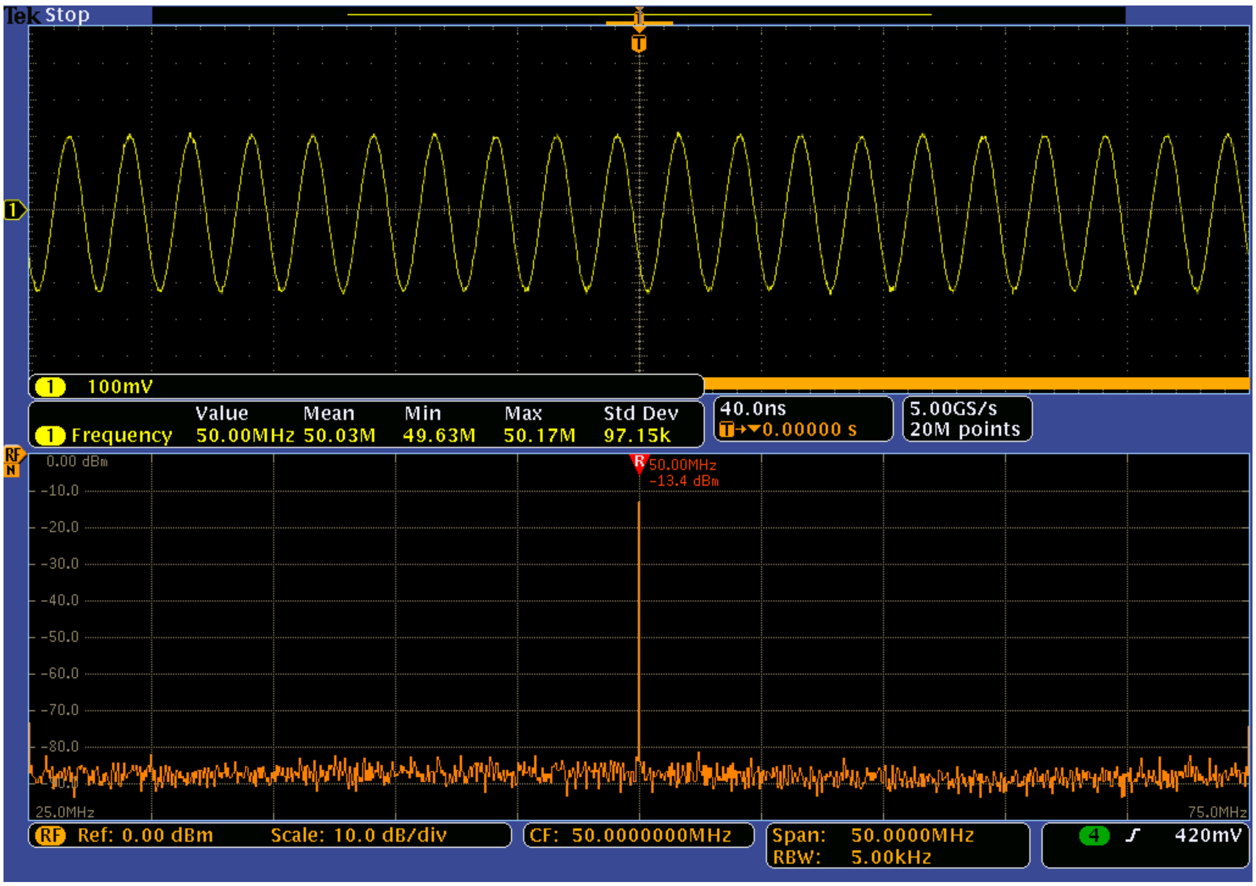

Figure 8 Spectral purity of the J2110A Solid State Signal Injector due to its high linearity.

Next, two non-related signals are presented to the OSC and IN connections of the J2110A. The signals are arbitrarily chosen as 1.112MHz and 1.998MHz. The resulting spurious signals due to mixing products can be seen in Figure 9. Note that all of the mixing products are suppressed approximately 60dBm allowing this injector to be used for modulation and IMD measurements.

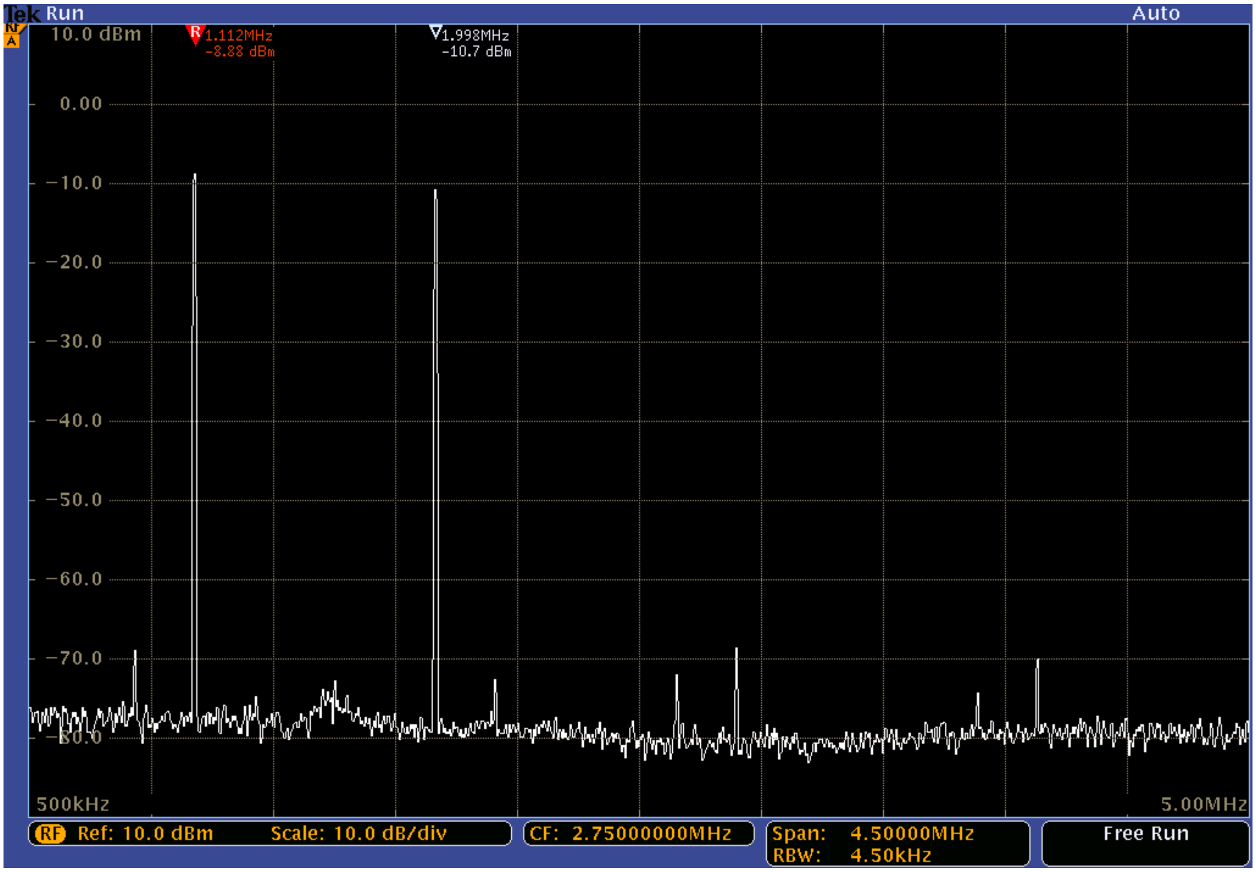

Figure 9 Spectral plot showing the non-mixing capability of the J2110A.

Conclusion

Some of the special features of the J2110A Solid State Signal Injector have been demonstrated, including the high linearity minimal mixing performance, ultra wide, DC-100MHz+ bandwidth and very low noise. For more information on the J2110A and other signal injectors, please visit www.picotest.com.

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[i] Operational Amplifier Measurements with Bode100, Lukas Heinzle, ©2008 Omicron Lab
[ii] "Measuring Op Amp PSRR", https://www.picotest.com/blog/