Measuring the Output Impedance of Voltage References and Zener Diodes

In this article we examine the process of measuring a key performance characteristic, output impedance, using the Picotest J2130 DC Bias Injector and the OMICRON-Lab Bode 100 VNA

There are many types of voltage references, including series references, shunt references and several that can perform as either series or parallel devices. The requirements vary greatly from application to application, though the general performance drivers remain the same. The general performance metrics include DC voltage accuracy, temperature coefficient, noise, output impedance, PSRR and stability.

The output impedance is of significant concern for high speed A/D converters, especially sigma-delta converters that see a capacitor charge at each clock event. The stability of the reference can be evaluated through the output impedance, and so that will be addressed in this application note. PSRR and reference noise, two other important parameters, will be addressed in separate article.

Figure 1 – Connection diagram for the DC Bias Injector, VNA and shunt voltage reference.

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For convenience, we used one of the spare component printed circuit boards for the VRTS kit[1] and soldered in a shunt reference. We have also created a PC board that allows the mounting of both series and shunt references in many common packages. While these measurement can certainly be made without these "fixtures", we will use them to keep the measurement setups both simple and parasitic free.

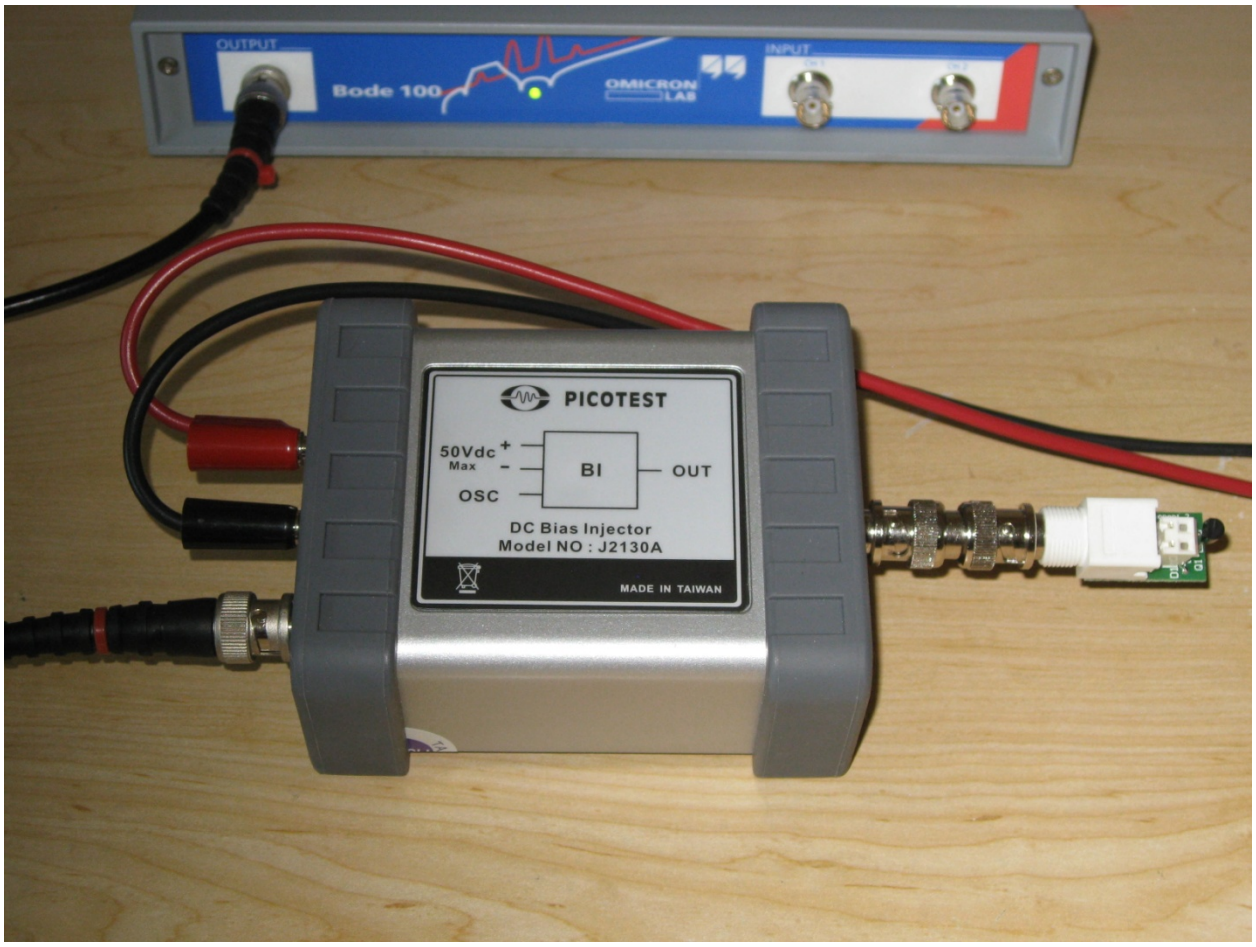

Figure 2 – Combining DC and AC. Photo showing a LT1009 reference device mounted in a VRTS component PCB. The red and black wires connect to a variable DC bench power supply. The VNA oscillator output is connected to the injector where it combines with a DC offset signal controlled by the bench power supply.

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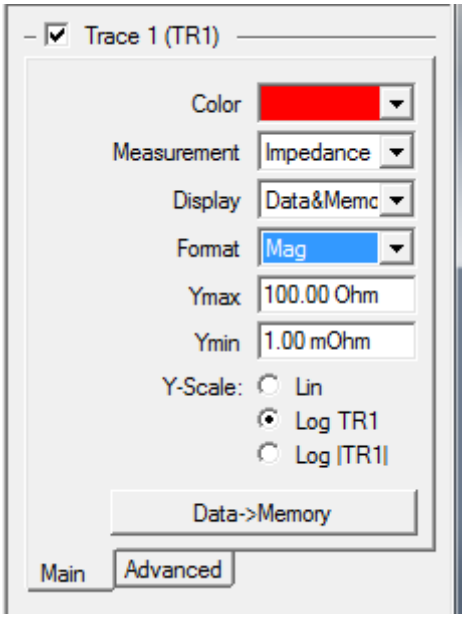
Calibrating the Measurement

Make sure to apply the bias to the Bias Injector PRIOR to doing the calibration (we'll use 10V for this example). This step will not always change the results, but it does assure that the power supply is active, and therefore, presenting a low impedance source.

Set the Bode-100 for "Frequency Sweep" and Trace 1 set to measure "Impedance".



With the measurement configured as in Figure 2 and the DC bench supply turned on and set to zero volts, remove the LT1009 component PC board and perform an Open, Short, Load calibration, at the J2130A output, in accordance with the Bode-100 User Manual. Note that some power supplies will have a negative voltage when the adjustment is turned fully counterclockwise. **We do not want a negative voltage for this measurement so make sure there isn't one**.

Making the Measurement

While monitoring the bench supply current with a multimeter, increase the DC bias current to 4mA. Save the measurement to memory using the "Trace 1(TR1) Data->Memory" button, reduce the DC bias current to 1mA and display "Data&Memory."

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You can display the results either in Mag dB Format with Y-Scale set to Lin or as Mag using a Y-Scale Log TR1, as we have chosen. This option displays the results in Ohms, while maintaining the log scale desired for this measurement.

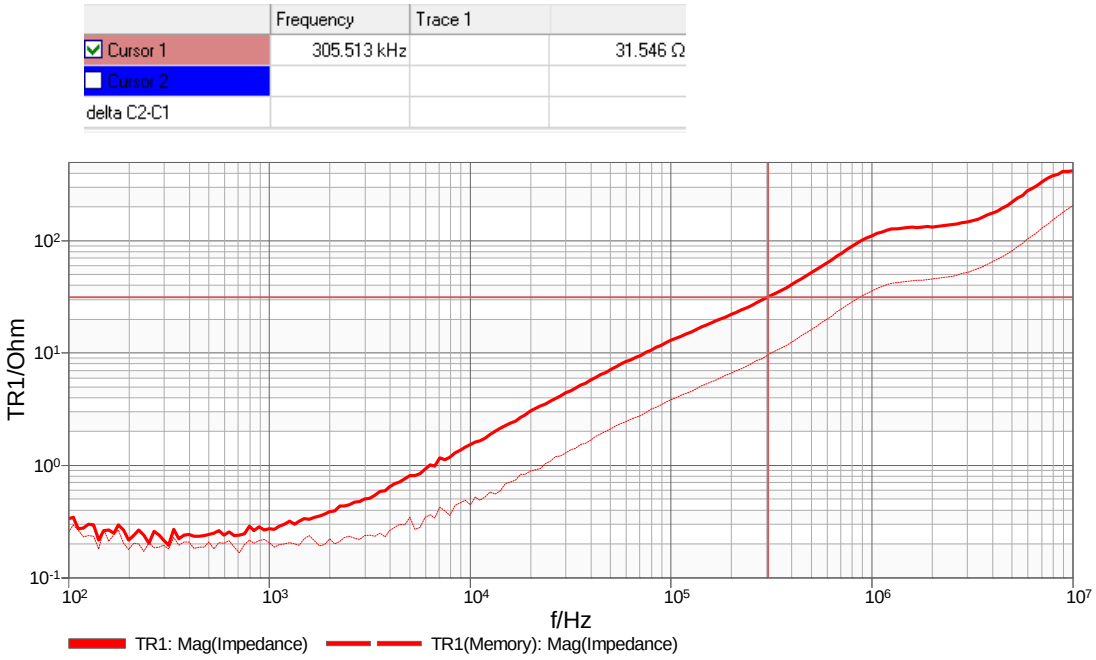

Figure 3 – LT1009 Output impedance at 1mA and 4mA DC bias currents. Note that 31.5 Ω at 305kHz with a +6dB/octave slope reflects 16.4uH. At bias current of 4mA the impedance reduces to approximately 9Ω or 4.7uH.

Note that the output impedance appears as a series RL network with an additional parallel resistor at 1MHz. This is very similar to the voltage regulator output impedance we described previously[2]. As is the case with a typical voltage regulator, the "inductance" is dependent on the operating current.

With 1mA DC bias current measurement now saved to memory we add a 0.1uF capacitor from the VRTS kit, via the 2 pin receptacle on the component PC Board. The output impedance curves for these two measurements are shown in Figure 4.

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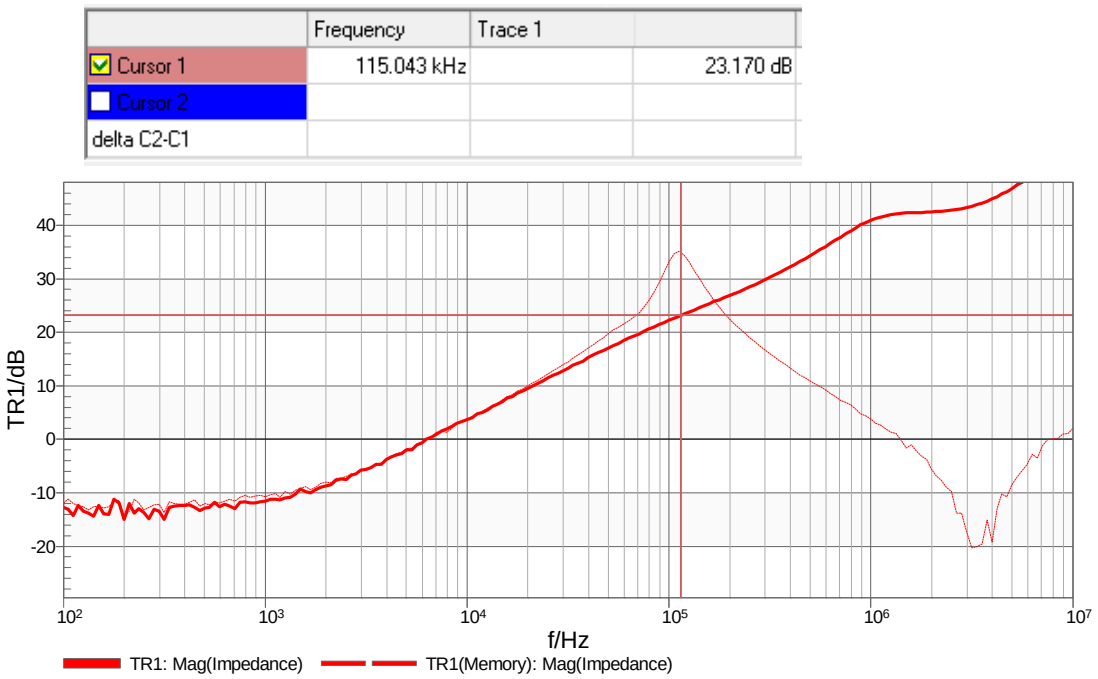

Figure 4 – the LT1009 output impedance measurement at 1mA DC bias current with no capacitor and with a 0.1uF X7R ceramic capacitor. Note that at the 115kHz impedance peak the difference between the two curves is 12dB which relates to a magnitude of 4, which is the Q of the impedance. A Q of 4 corresponds to approximately 15 degrees of phase margin.

Conclusion

The OMICRON Lab Bode100 Vector Network Analyzer, combined with the Picotest J2130A DC Bias Injector makes measuring the output impedance of reference devices simple. While the addition of a bypass capacitor reduces the impedance at higher frequencies, there is a penalty at the bandwidth due to poor phase margin. While not a direct measurement, the phase margin can be determined using the same methods used in our non-invasive phase margin measurement[3]. Using the methods in reference 2, the ESR or series resistance, required for stable performance, can easily be determined for any operating current, thereby improving the dynamic performance of the reference.

[1] VRTS Reference
[2] Simple Method to Determine ESR Requirements for Stable Regulators, Steven M. Sandler, Power Electronics Technology, Aug 2011
[3] New Technique for Non-Invasive Testing of Regulator Stability , Steven M. Sandler, Power Electronics Technology, Sept 2011

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