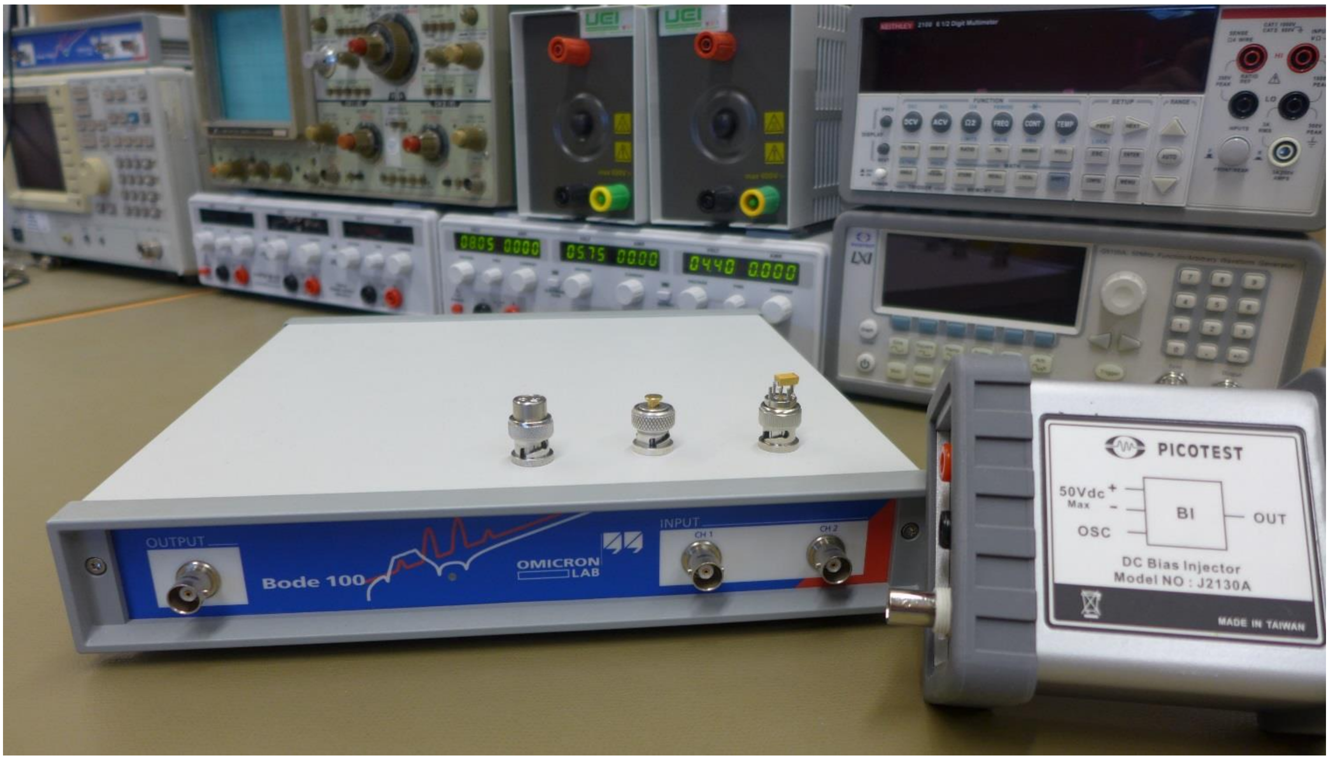
Bode 100 - Application Note

DC Biased Impedance Measurements Capacitors



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Visit www.omicron-lab.com for more information.
Contact support@omicron-lab.com for technical support.

Table of Contents

Note: Basic procedures such as setting-up, adjusting and calibrating the Bode 100 are described in the Bode 100 user manual. You can download the Bode 100 user manual at www.omicron-lab.com/bode-100/downloads#3

Note: All measurements in this application note have been performed with the Bode Analyzer Suite V3.0. Use this version or a higher version to perform the measurements shown in this document. You can download the latest version at www.omicron-lab.com/bode-100/downloads

You can download the latest Picotest Injector manual at http://www.picotest.com/products_injectors.html.

1 Executive Summary

Measuring the impedance of electronic parts or devices can be a challenging task as the impedance often depends on many external parameters.

One of these parameters is the DC Bias or DC offset. The Bode 100 generally measures impedances using an AC signal with zero DC offset.

But in this application note we show how the Bode 100 impedance measurement capabilities are extended with the Picotest J2130A DC Bias Injector.

One measurement task is performed where the DC offset has a strong influence on the measurement results:

- The voltage sensitive capacitance of a ceramic chip capacitor. As result of this measurement we will see that the capacitance value of the DUT[1] is very sensitive to the applied DC voltage.

2 Measurement Task

2.1 Capacitor Voltage Sensitivity

The same method can be used to measure the voltage sensitivity of capacitors. Some ceramic capacitors, especially X5R dielectric, show high voltage sensitivity. This means that the capacitance value changes strongly with the DC voltage applied to the capacitor. Knowing the capacitance value at a specific DC operation point is very important for the correct function of an electronic design. In order to show this measurement we measure the capacitance of some ceramic chip and a tantalum capacitor.

3 Measuring the Capacitor Voltage Sensitivity

The measurement setup for the DC biased impedance measurement is simple when using the Bode 100 in combination with the Picotest J2130A. The following figure shows the connection setup for the Capacitor Voltage Sensitivity measurement.

[1] Device Under Test

3.1 Measurement Setup

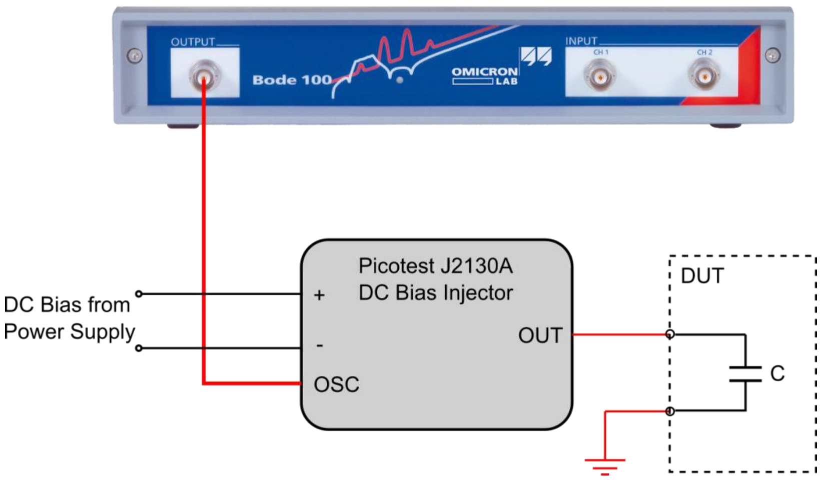


Figure 1: Capacitance Measurement Connection Diagram

The capacitance of a ceramic 100 µF capacitor is measured at a frequency of 1 kHz and at the Bias voltages of 0 VDC, 5 VDC, 10 VDC and 15 VDC.

Note: Each time changing the **Bias voltage**, the setup should be **recalibrated**.

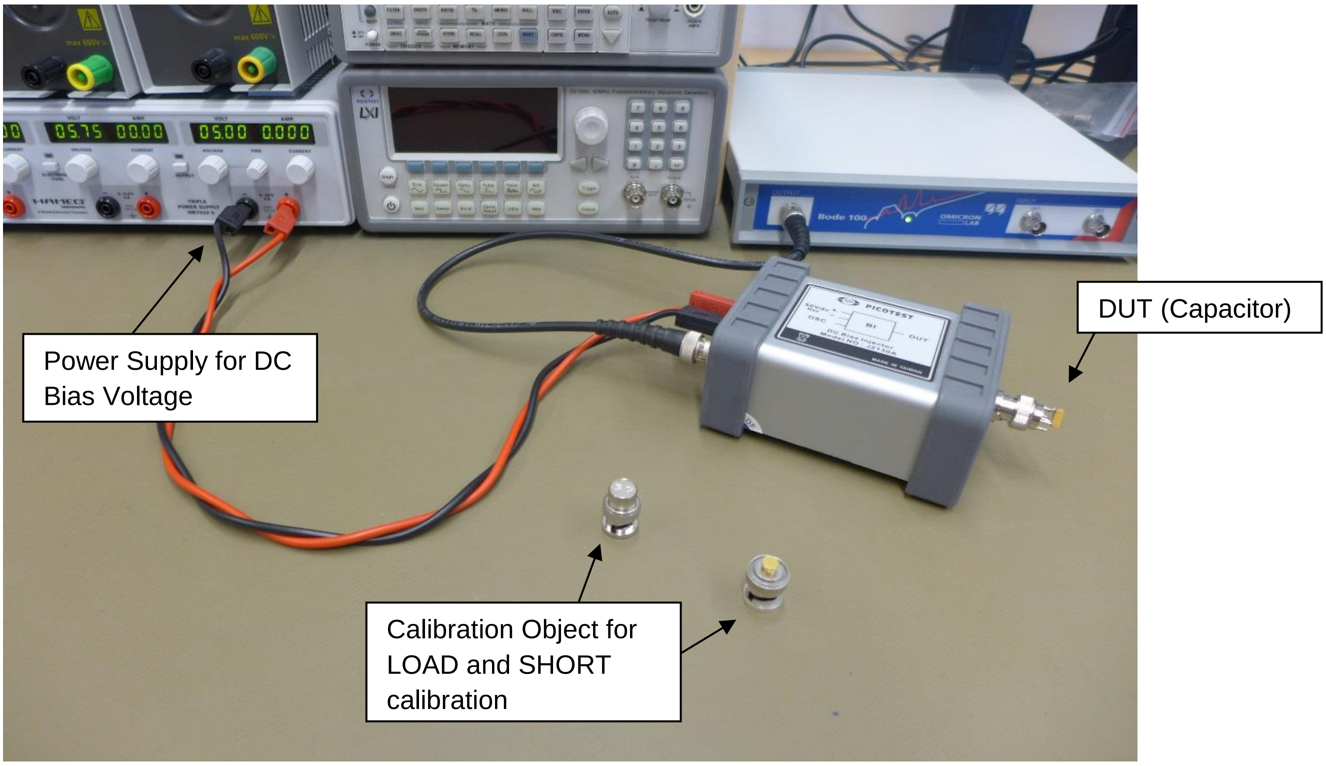


Figure 2: Measurement Setup Example

3.2 Device Setup

Start the measurement by selecting the One-Port measurement type:

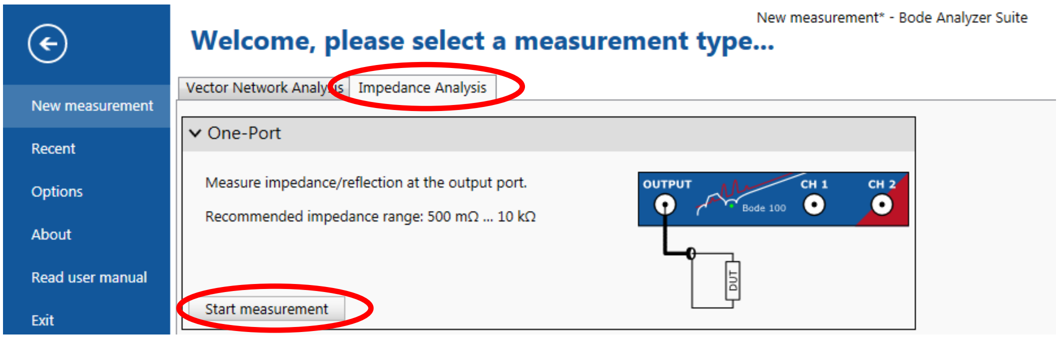


Figure 3: Start menu

To measure the capacitance, we setup the Bode Analyzer Suite like in the following pictures.

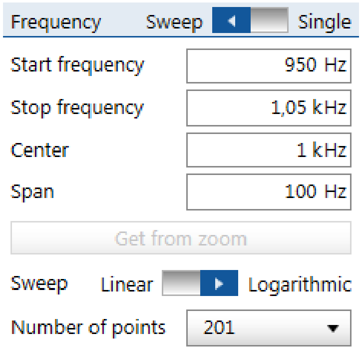


Figure 4: Measurement settings

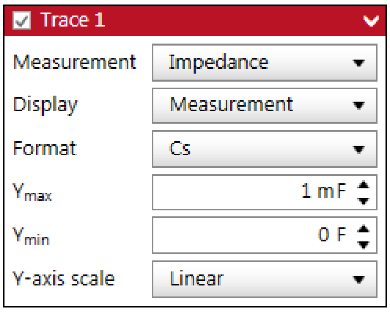


Figure 5: Settings Trace 1

3.3 Calibration

One of the most critical aspects of the measurement is calibrating out the parasitics from the cables and the Bias Injector. Open, Short and Load calibration has to be performed to ensure measurement accuracy. For this measurement, we are using 3 BNC connectors with the leads shorted, open and with a 50 Ω resistor to calibrate the Bode 100. The DUT is soldered to the same BNC connector in order to minimize parasitics outside of the calibration. In this case, the calibration and measurements are all referenced to the BNC connector leads.

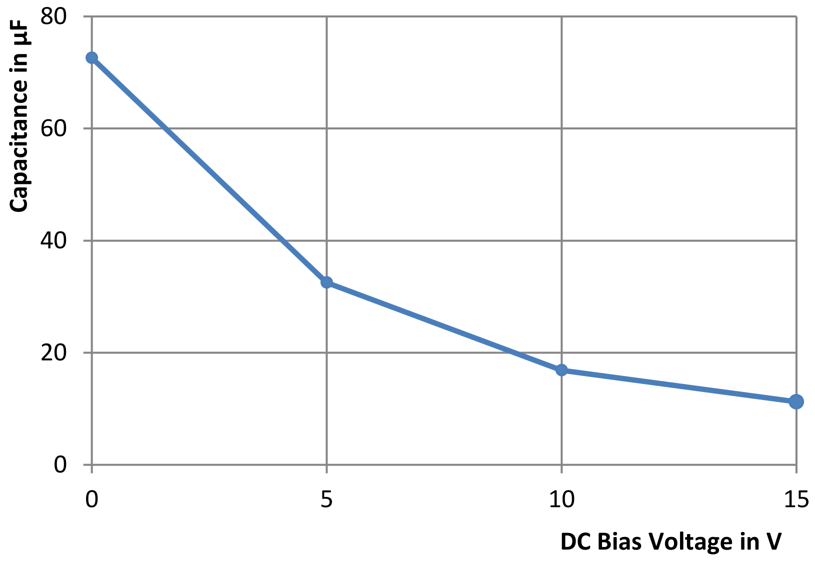
We recommend performing a User Calibration for this measurement setup.

Note: The DC Bias voltage should be applied **prior to** the calibration!

Note: When connecting a DC-conductive DUT, the 10 kΩ injection resistor of the J2130A and the DC-resistance of the DUT form a voltage divider! The DC voltage at the DUT can be checked using a standard voltmeter.

3.4 Measurement Results

Measuring the capacitance at several voltages at 1 kHz leads to the following results:



V_{DC} in V	C in µF
0	72,6
5	32,5
10	16,85
15	11,25

Figure 6: Change of the capacitance's with DC voltage

From the measured results we see that the capacitance strongly decreases with increasing DC Bias voltage. Furthermore the capacitance does not reach the nominal value of 100 µF at 0 VDC bias.

Different capacitor types show different voltage sensitivity. In the following diagram the voltage sensitivity of a X5R and a X7R ceramic capacitor is compared to a tantalum capacitor. To make the different capacitors comparable, the applied DC voltage V_{DC} is normalized to the maximum voltage V_{max} of the particular capacitor. The measured capacitance C_{DC} is normalized to the measured capacitance without DC voltage applied ($C_{0_{DC}}$).

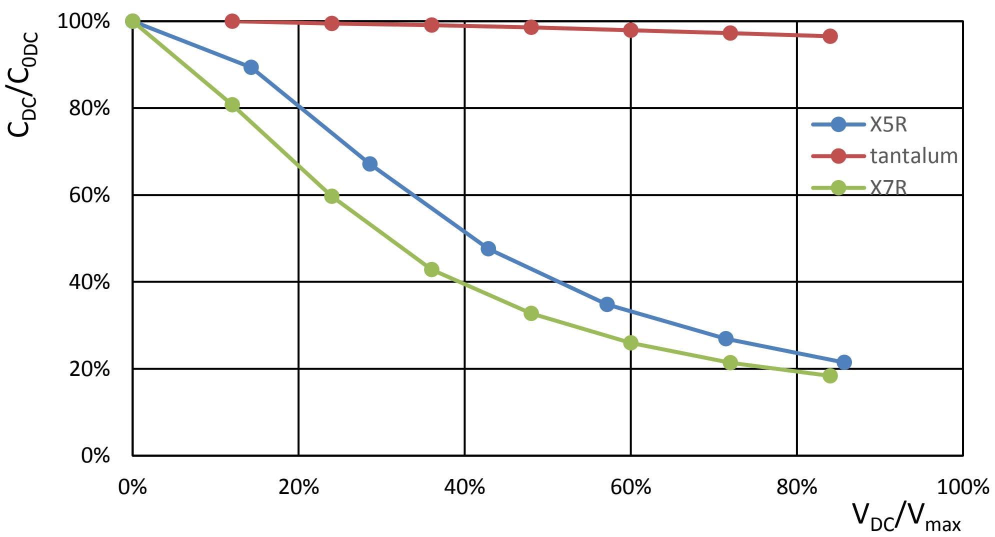


Figure 7: Comparison of the capacitance's DC voltage dependency of different capacitor types

The measurement results show that the capacitance of tantalum capacitors is not depending on the applied DC voltage whereas the two ceramic capacitors are strongly influenced. At 80% of the maximal voltage the capacitance of the X5R ceramic capacitors is decreased to only 20% of the nominal capacitance value.

The data measured with the Bode 100 matches well with the DC Bias Charge diagram from the manufacturer's datasheet. Below the diagrams for the used X5R capacitor are shown:

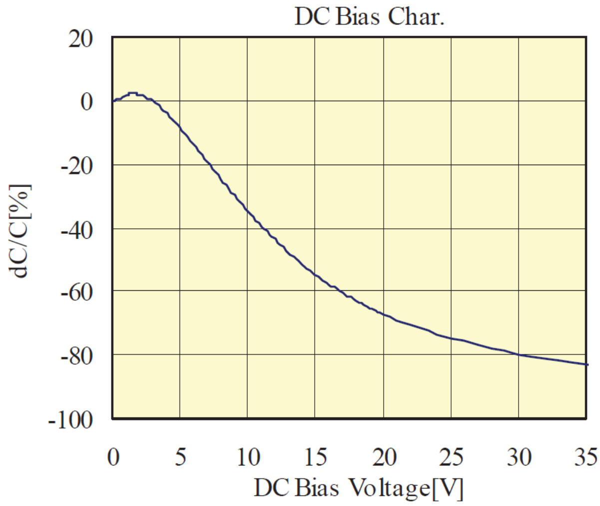


Figure 7: DC biased capacitance from datasheet.

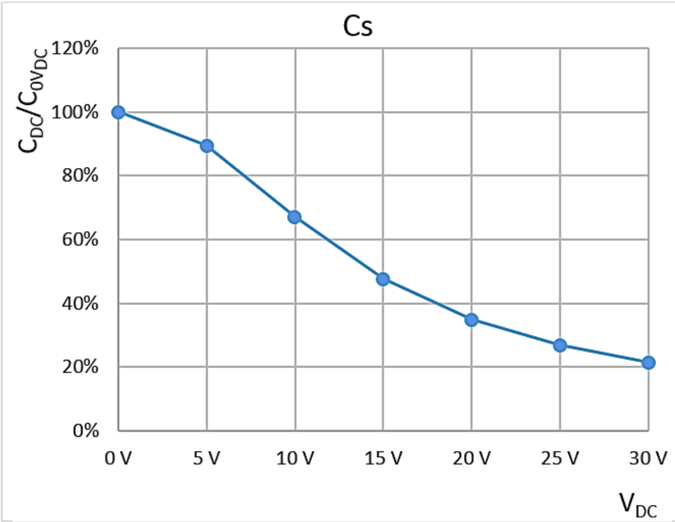


Figure 8: Measured DC biased capacitance

Note: The capacitance of class 2 ceramic capacitors (X7R, X5R and Y5V) is decreasing at a constant percentage in a decade hour. That means that the capacitance is decreasing strongly directly after their manufacturing and gets more constant over the time. By heating up the capacitor over 150°C a de-aging process starts. Therefore soldering a capacitor also increases its capacitance. This capacitance will decrease afterwards. The measurement can be strongly influenced by this degrading. Hence it is advisable to conduct the measurement after the capacitance drop slows down:

Capacitance drop:	X7R & X5R:	-2.5% per decade hour
	Y5V:	-7% per decade hour

The same measurement setup can be used to perform a frequency sweep measurement.
To do so the following settings have to be applied within the One-Port measurement type:

Start Frequency:	10 Hz
Stop Frequency:	100 kHz
Sweep Mode:	Logarithmic
Number of Points:	201
Level:	13 dBm
Attenuator 1 &2:	10 dB
Receiver Bandwidth:	10 Hz

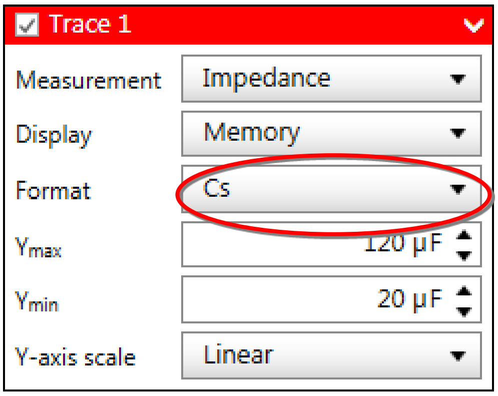


Figure 8: Settings Trace 1

Performing the user calibration as described above and starting a sweep measurement with 0 VDC Bias (green line) and 5 VDC Bias (red line) leads to the following result:

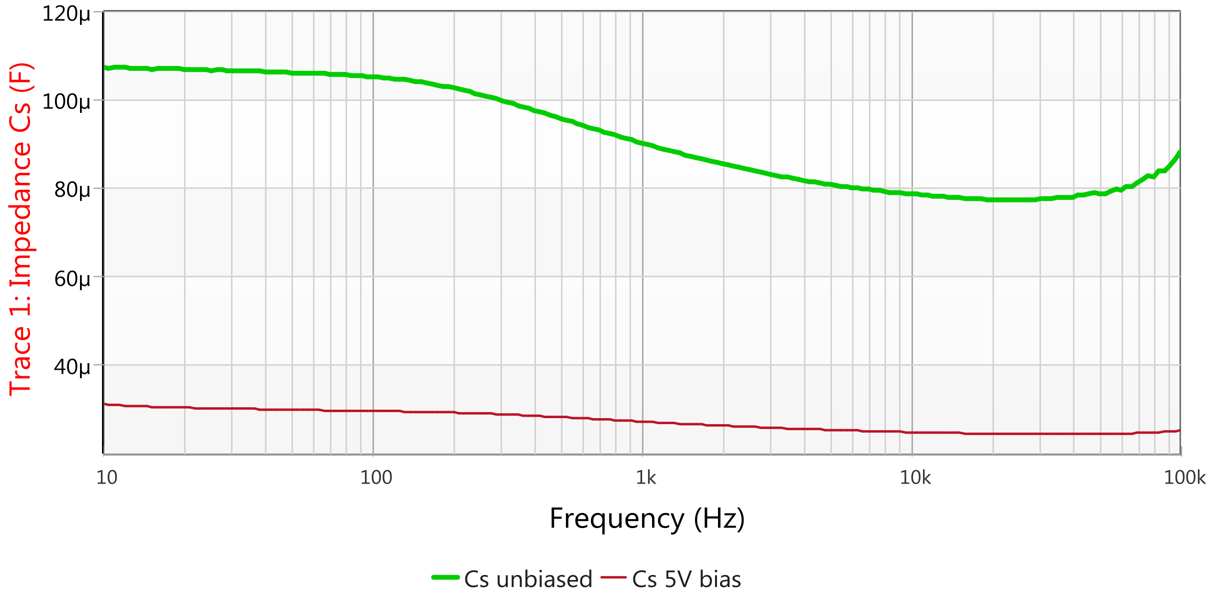


Figure 9: Trace 1 - Capacitance frequency sweep

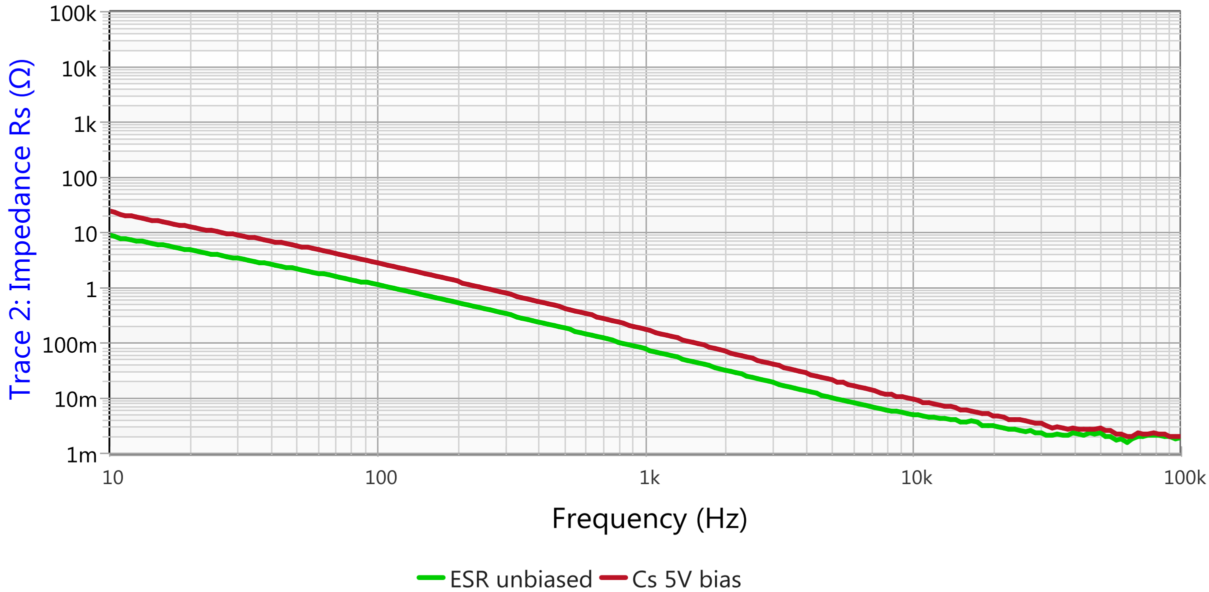


Figure 10: Trace 2 - ESR frequency sweep

4 Conclusion

This measurement has shown how the Bode 100 in combination with the J2130A Bias Injector can be used to characterize capacitors depending on frequency and DC Bias voltage. Due to the large variation of capacitance, it is important to measure this characteristic in order to assure stable voltage regulator performance.

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