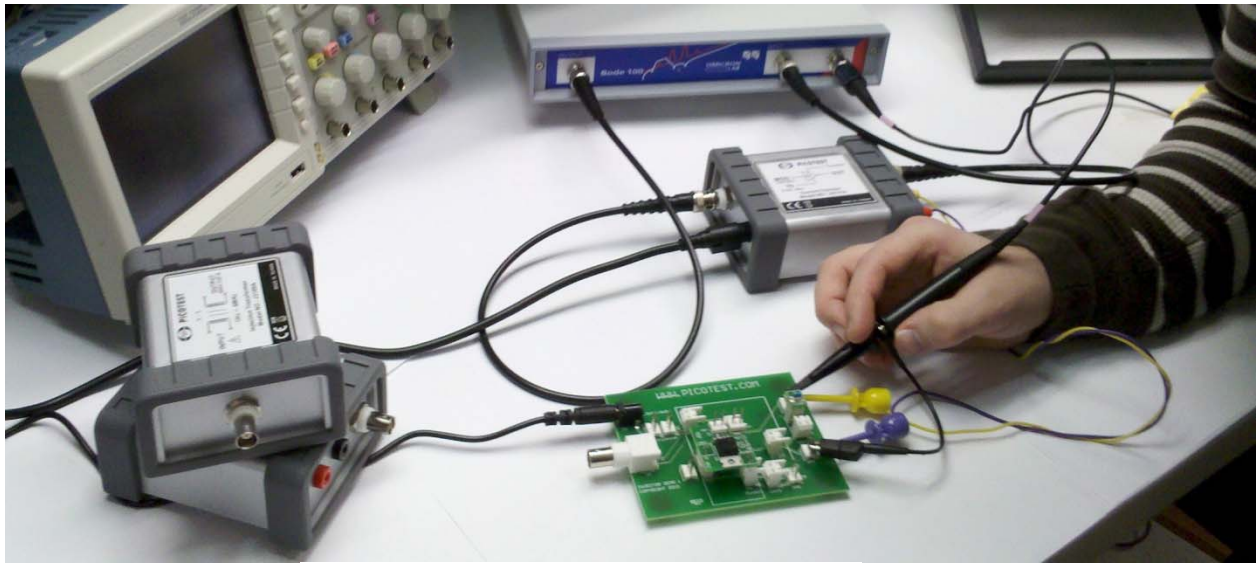


# DC Biased Impedance Measurement

Using the Bode 100 and the  
Picotest J2130A DC Bias Injector



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**Notes:** Basic procedures such as setting-up, adjusting and calibrating the Bode 100 are described in the Bode 100 user manual.

The Picotest J2120A DC Bias Injector does not require calibration.

All measurements in this application note have been performed with the OMICRON Lab Bode 100 Analyzer Suite V2.31. Use this version or a higher version to perform the measurements detailed in this application note.

You can download the latest version at <http://www.omicron-lab.com/downloads.html>.

You can download the latest Picotest Injector manual at <https://www.picotest.com/support.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.

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

Two measurement tasks are performed where the DC offset has a strong influence on the measurement results:

- The Gate Resistance of a MOSFET, depending on the operation point.
- The voltage sensitive capacitance of a ceramic chip capacitor. As result of this measurement we will see that the capacitance value of the DUT<sup>1</sup> is very sensitive to the applied DC voltage.

## 2 Measurement Task

### 2.1 MOSFET Gate Resistance

The Bode 100, used in conjunction with the Picotest J2130A DC Bias Injector, is a perfect combination for measuring the internal gate resistance of a MOSFET. The Bias Injector allows the resistance to be measured with a DC voltage applied from the gate to the source of a MOSFET while leaving the drain floating or connected to the source.

The Bode 100 then measures the vector impedance of the junction. This measurement is very sensitive, since the resistance is very small compared with the capacitive impedance. This measurement requires a very low noise floor and exceptional resolution, both of which are provided by the Bode 100.

We measure the gate resistance of a NMOSFET, type: IRFBF30.

### 2.2 Capacitor Voltage Sensitivity

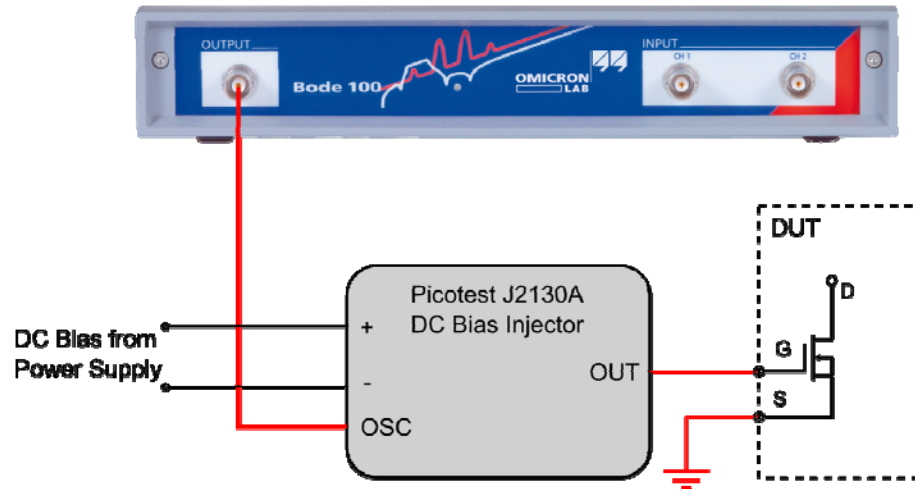
The same method can be used to measure the voltage sensitivity of capacitors. Ceramic capacitors show high voltage sensitivity. This means that the capacitance value changes strongly with the DC voltage applied to the capacitor. Knowing the capacitance value at a specific DC operation point is very important for the correct function of an electronic design. In order to show this measurement we measure the capacitance of a ceramic chip capacitor with 100 $\mu$ F and 35V maximum voltage.

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<sup>1</sup> Device Under Test

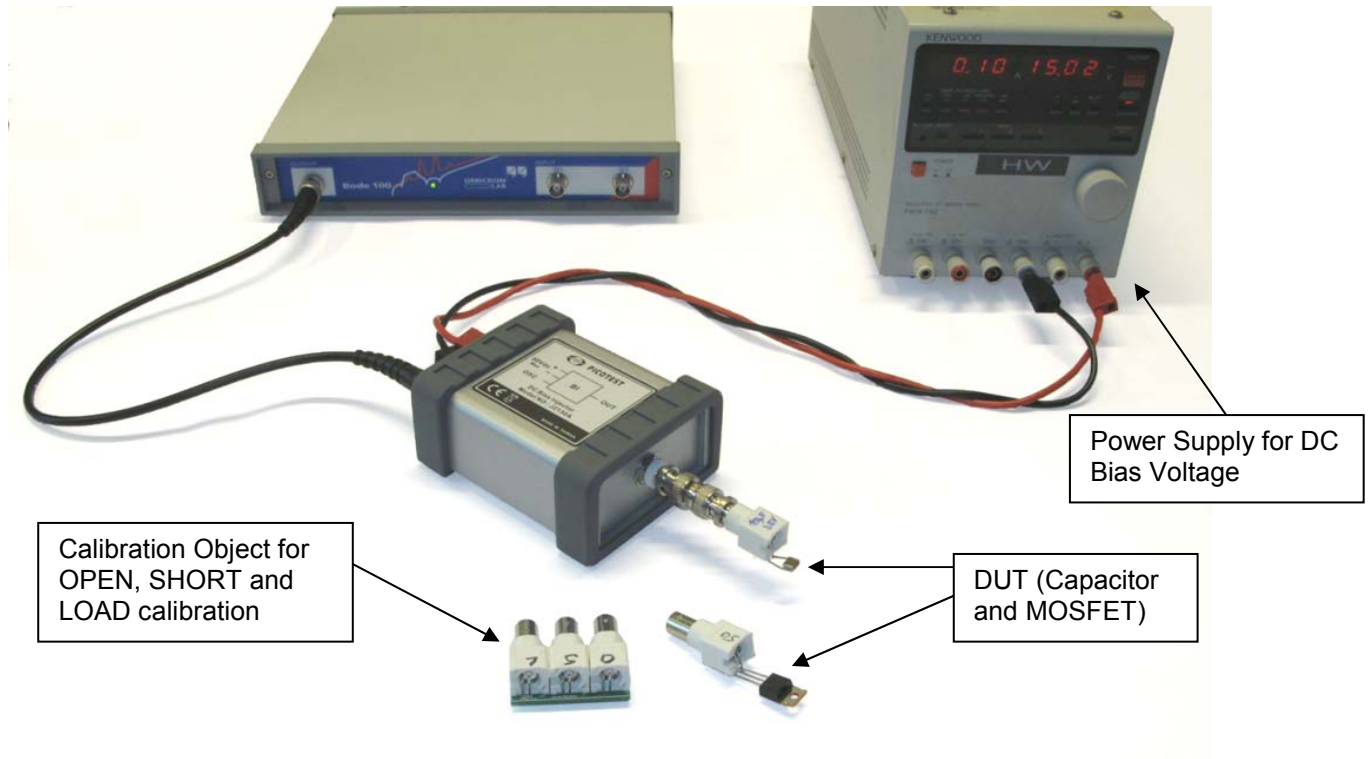
### 3 Measurement Setup

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 MOSFET Gate Resistance measurement.



**Gate Resistance Connection Diagram**

The simplicity of the measurement setup can be seen in the picture below. The J2130A DC Bias Injector is connected to the Bode 100 using a BNC cable. The DC Bias voltage is supplied by a regulated DC power supply. The DUT is soldered to a BNC connector which is a preferable method to keep the connections short and ensure low contact resistance.



Measurement Setup Example

## 4 Device Setup and Calibration

### 4.1 Device Setup

We want to measure the resistance of the gate at a frequency of 1 MHz, biasing the gate to a voltage of 10VDC.

To do so, the Bode 100 has to be configured as follows:

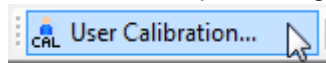
Measurement Mode:	Impedance/Reflection Mode
Source Frequency:	1 MHz
Level:	13 dBm
Attenuator 1 &2:	10 dB
Receiver Bandwidth:	3 Hz



### 4.2 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 49.84Ω 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.

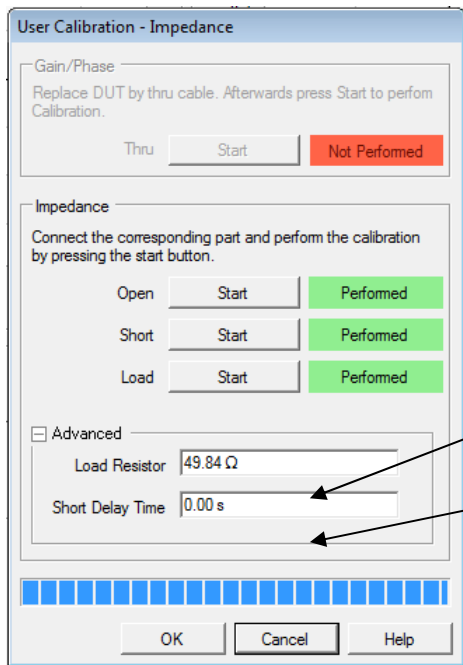
We recommend performing a User Calibration for this measurement setup.



**Note:** The DC Bias Voltage has to 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 prior to calibration using a standard voltmeter.

After applying the DC Bias voltage (we use 10VDC for our measurement) the calibration can be started.

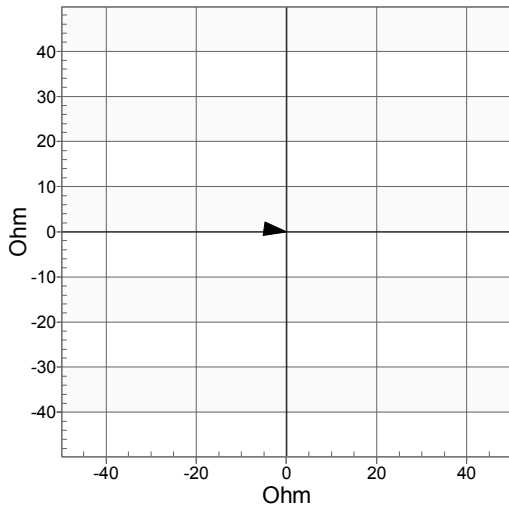


**Note:**

- For precise measurements enter the value of the load resistor in the advanced section
- Set the short delay time to 0s

After calibrating the setup it is advisable to check the calibration points to verify that the calibration points were measured successfully.

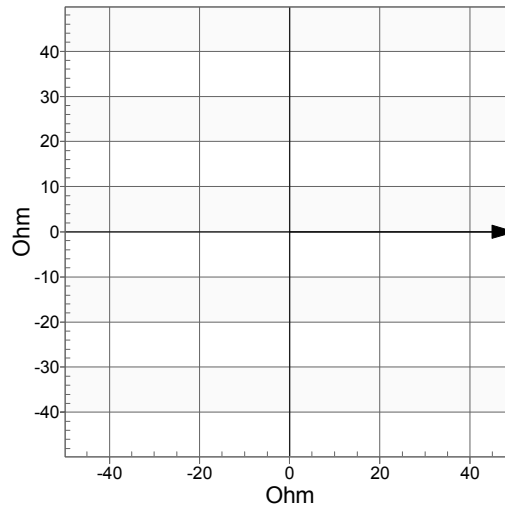
### Short



**Impedance @ 1.000 MHz:**

Real    204.729  $\mu\Omega$   
 Imag    204.631  $\mu\Omega$

### Load



**Impedance @ 1.000 MHz:**

Real    49.840  $\Omega$   
 Imag    -161.771  $\mu\Omega$

**Note:** If the DC Bias Voltage is changed the setup has to be **recalibrated!**

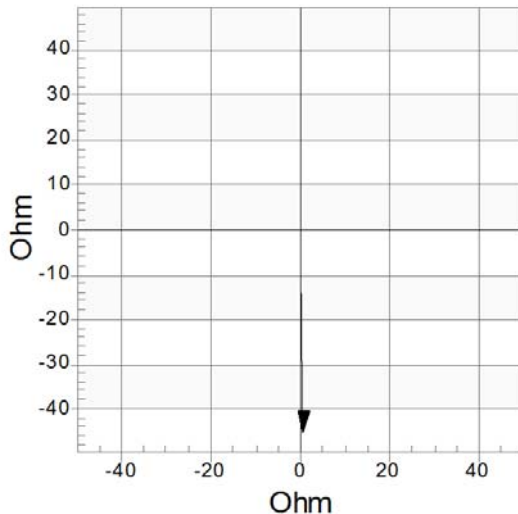
## 5 Measuring the Gate Resistance

Once the setup is calibrated the impedance of the MOSFET can be measured. We measure the impedance of an IRFBF30 N-type MOSFET. The gate is biased with a voltage of 10VDC.

We are measuring the resistance of the gate at 1MHz. This frequency has been chosen because it is an industry standard, though the measurement setup described here works for any frequency from 1Hz to 40MHz. One thing to keep in mind, however, is that at lower frequencies the  $X_p$  portion of the impedance will increase and the real portion will remain the same. This means Q will be significantly higher at lower frequencies, making the measurement much more difficult. Conversely, making the measurement at a higher frequency reduces the Q making the measurement less sensitive.

Keeping the injection signal close to full scale will help to reduce the noise of the measurement, resulting in optimum dynamic range and noise floor

Connecting the MOSFET to the DC Bias Injector leads to the following measurement result:



### Impedance

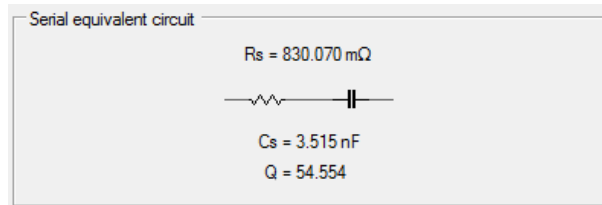
Real	830.070 mΩ
Imag	-45.283 Ω

### Serial equivalent circuit

Rs =	830.070 mΩ
Cs =	3.515 nF
Q =	54.554

From the data we can see that the IRFBF30 MOSFET has an internal gate resistance of  $\approx 830\text{m}\Omega$  and we can also see the gate-source capacitance of the device simultaneously.

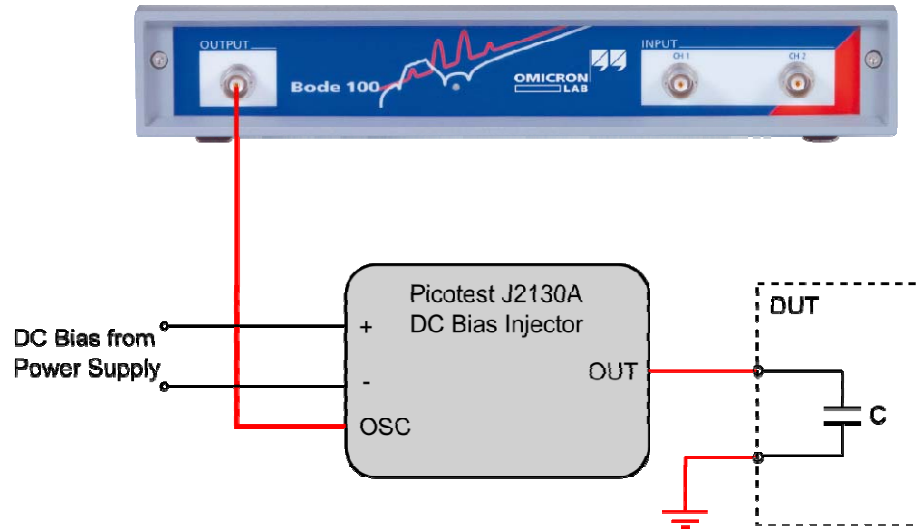
The Bode Analyzer Suite directly displays the equivalent circuits and its calculated values:





## 6 Measuring the Capacitor Voltage Sensitivity

The same setup and settings as described above can be used to measure the capacitance of a capacitor. We use the same setup to measure the voltage dependent capacitance as shown in the following figure:



Capacitance Measurement Connection Diagram

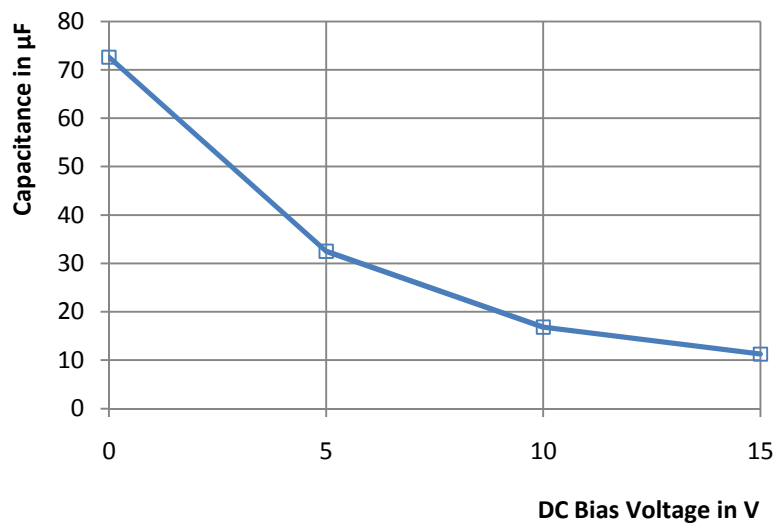
The capacitance of a ceramic 100 $\mu$ F capacitor is measured at a frequency of 1 kHz and at the DC Bias voltages of 0V, 5V, 10V and 15V.

**Note:** Each time changing the **frequency** or DC Bias **voltage** the setup should be **recalibrated** for precise results!

Measuring the capacitance of the capacitor leads to the following results:

Measured Values:

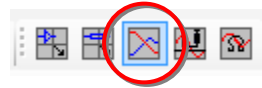
$V_{DC}$	C
V	$\mu$ F
0	72.6
5	32.5
10	16.85
15	11.25



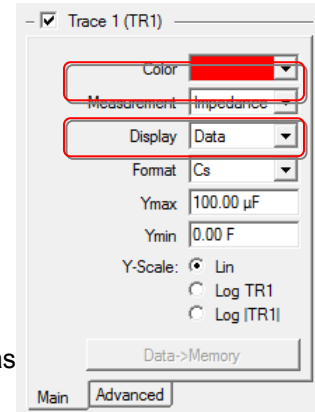
From the measured results we see that the capacitance strongly decreases with increasing DC Bias voltage.

The same measurement setup can be used to perform a frequency sweep measurement.

To do so the following settings have to be applied in the Frequency Sweep Mode:

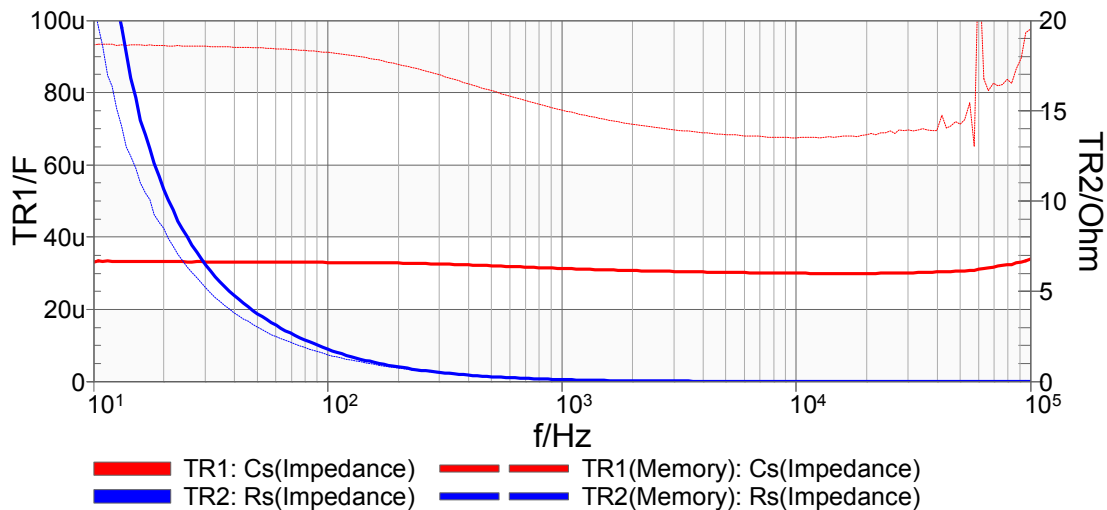


Measurement Mode: Frequency Sweep Mode  
 Start Frequency: 10 Hz  
 Stop Frequency: 100 kHz  
 Sweep Mode: Logarithmic  
 Number of Points: 201  
 Level: 13 dBm  
 Attenuator 1 &2: 10 dB  
 Receiver Bandwidth: 10 Hz



5V

Performing the user calibration as described above and starting a sweep meas Bias leads to the following result:



### Trace 1 (Red):

The thick solid line shows the frequency dependent capacitance of the 5V biased capacitor and the thin dashed line shows the unbiased capacitance values.

### Trace 2 (Blue):

The thick solid line shows the  $ESR^2$  of the 5V biased capacitor and the thin line the ESR of the unbiased capacitor.

<sup>2</sup> Equivalent Series Resistance

## 7 Conclusion

We have demonstrated how you can measure the gate resistance of a MOSFET quickly and accurately using the Bode100 and the Picotest J2130A Bias Injector. A proper fixture should be made to house the MOSFET while keeping cable lengths short and signal levels as low possible. With proper calibration of your equipment this measurement will be repeatable for various MOSFETs and allow production testing to be a simple one-step process.

Furthermore it 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.

## References

1. Picotest. Voltage Regulator Test Standard. Version 1.0d. 2010.
2. Voltage Regulator Test Standard. Version 1.0c. 2010.
3. Signal Injector Documentation. Version 1.0c. 2010.