DC Biased Impedance Measurements

Using the Bode 100 and the Picotest J2130A DC Bias Injector

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

Note: All measurements in this application note have been performed with the Bode Analyzer Suite V2.31. Use this version or a higher version to perform the measurements outlined 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 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.

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[1] is very sensitive to the applied DC voltage.

[1] Device Under Test

2 Measurement Tasks

2.1 MOSFET Gate Resistance

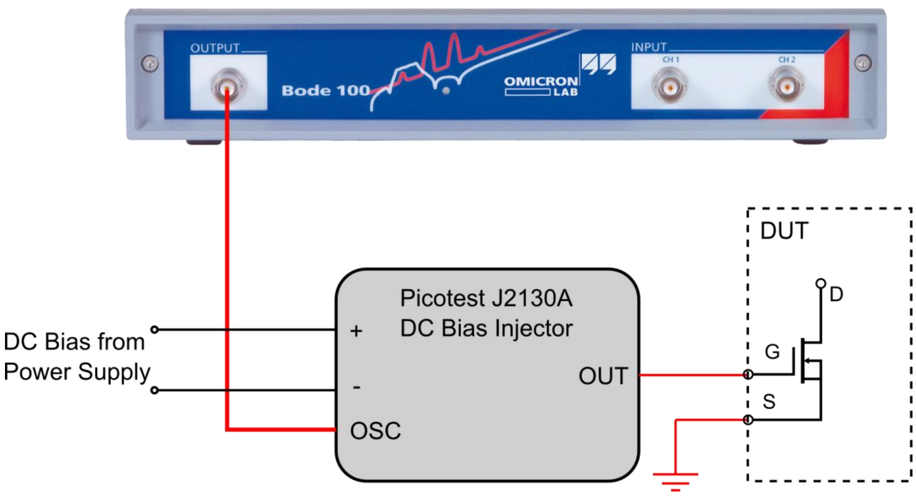
The Bode 100, used in conjunction with the Picotest J2130A DC Bias Injector, is a perfect combination for measuring the internal gate resistance of a MOSFET. The Bias Injector allows the resistance to be measured with a DC voltage applied from the gate to the source of a MOSFET while leaving the drain 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. 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 a ceramic chip capacitor with 100µF and 35V maximum voltage.

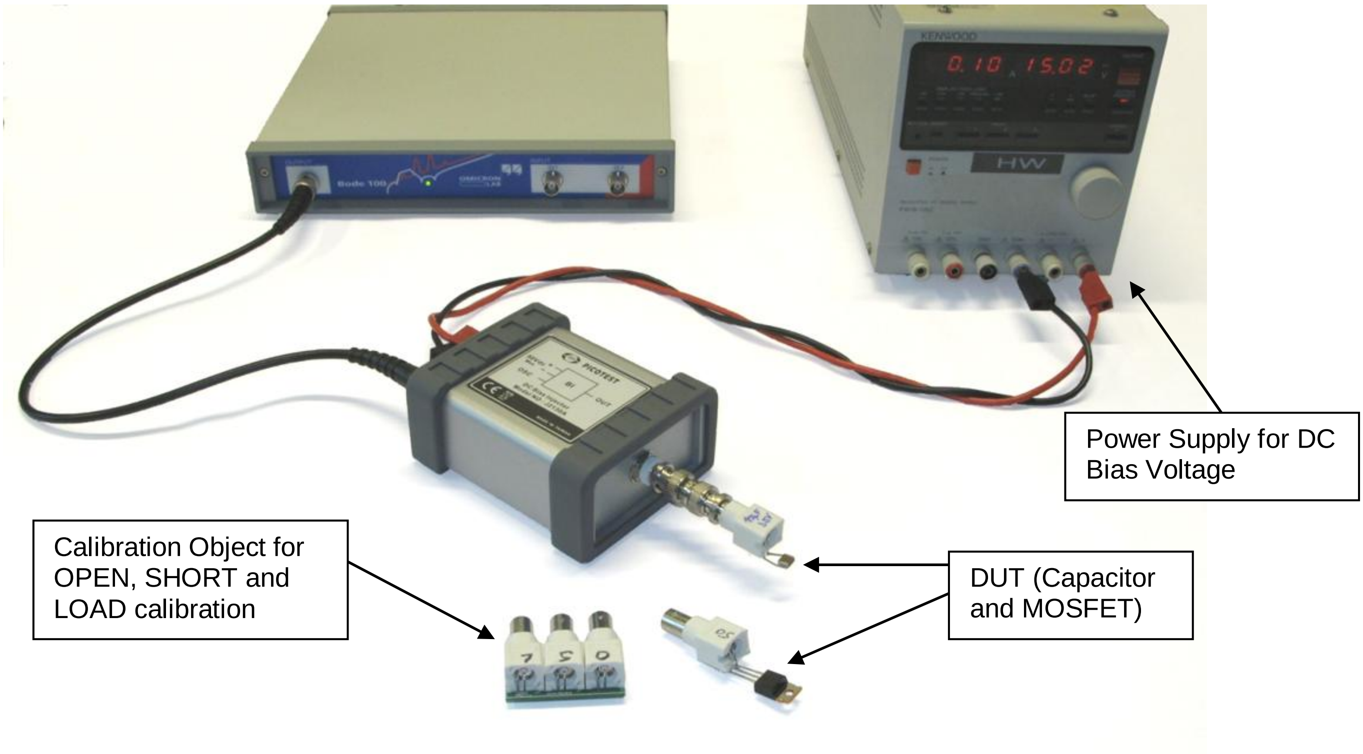
3 Measurement Setup

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.



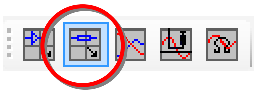
Measurement Setup Example

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:

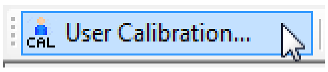
Measurement Mode:	Impedance/Reflection Mode
Source Frequency:	1 MHz
Level:	13 dBm
Attenuator 1 &2:	10 dB
Receiver Bandwidth:	3 Hz



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 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.

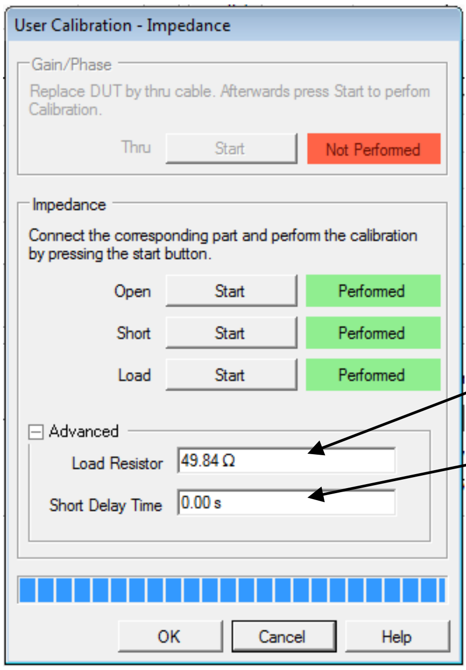
We recommend performing a User Calibration for this measurement setup.



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 J130A and the DC-resistance of the DUT form a voltage divider! The DC voltage at the DUT can be checked using a standard voltmeter.

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

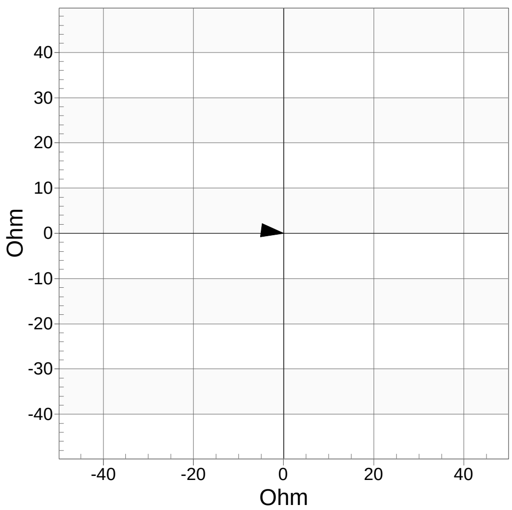


Note:

- For precise measurements enter the measured 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.

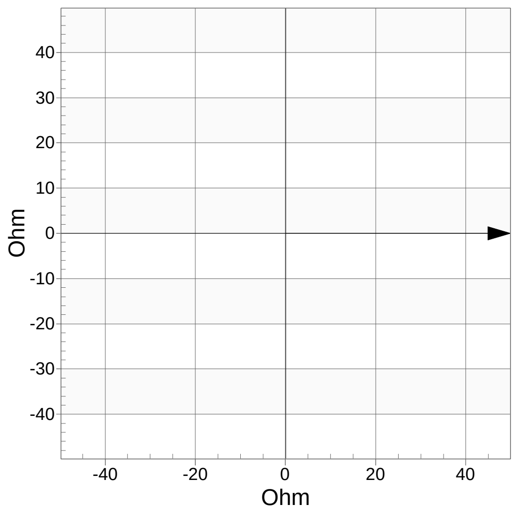
Short



Impedance @ 1.000 MHz:

Real	204.729 µΩ
Imag	204.631 µΩ

Load



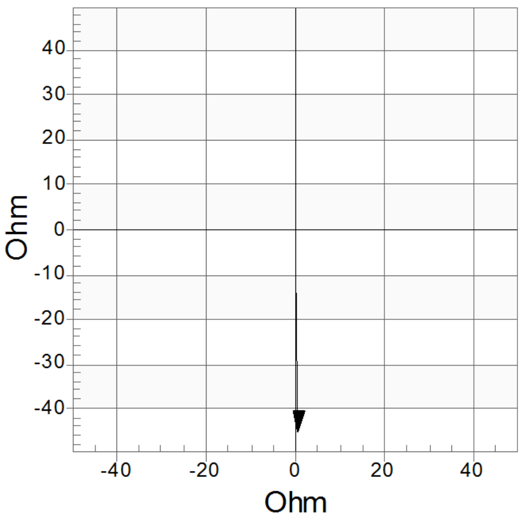
Impedance @ 1.000 MHz:

Real	49.840 Ω
Imag	-161.771 µΩ

5 Measuring the Gate Resistance

Once the setup is calibrated the impedance of the MOSFET can be measured. We measure the impedance of a 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:

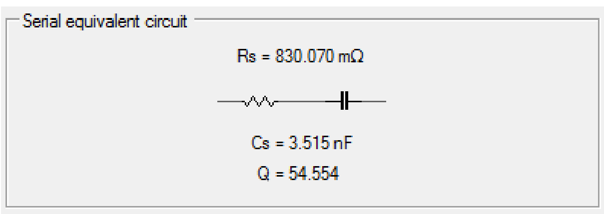


Impedance	
Real	830.070 mΩ
Imag	-45.283 Ω

Serial equivalent circuit	
Rs =	830.070 mΩ
Cs =	3.515 nF
Q =	54.554

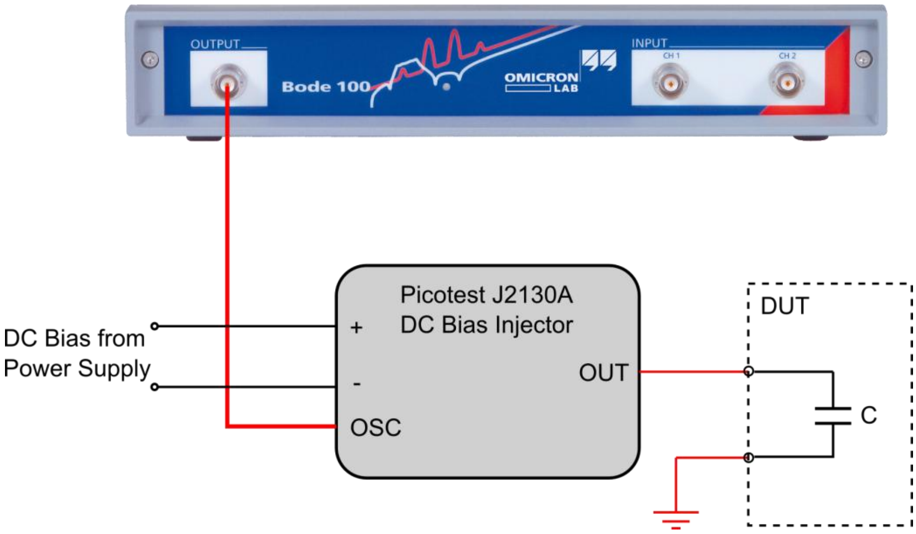
From the data we can see that the IRFBF30 MOSFET has an internal gate resistance of $\approx 830\text{m}\Omega$ and we can also see the gate-source capacitance of the device simultaneously.

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

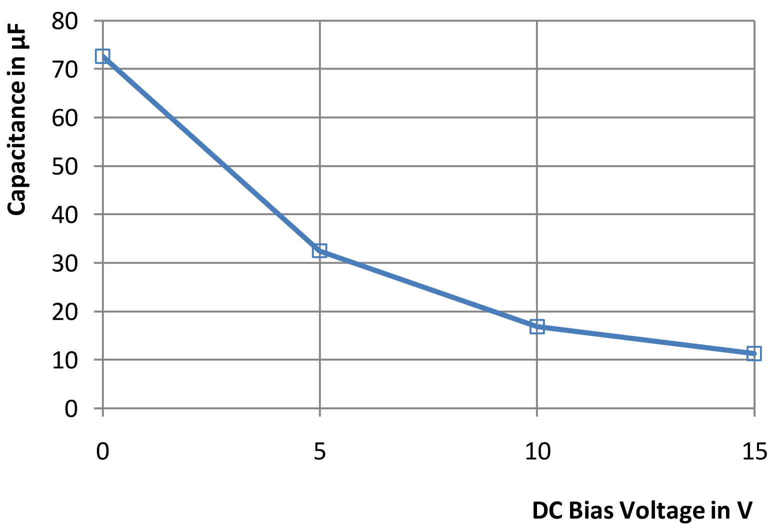
The capacitance of a ceramic 100µF capacitor is measured at a frequency of 1 kHz and at the DC Bias voltages of 0V, 5V, 10V and 15V.

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

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

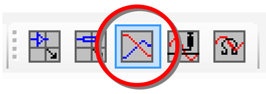
Measured capacitance at 1 kHz:

V_{DC}	C
V	µF
0	72.6
5	32.5
10	16.85
15	11.25

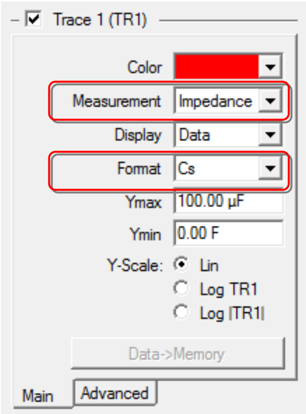


From the measured results we see that the capacitance strongly decreases with increasing DC Bias voltage. Furthermore the capacitance does not reach the nominal value of 100 µF at 0 V DC bias.

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

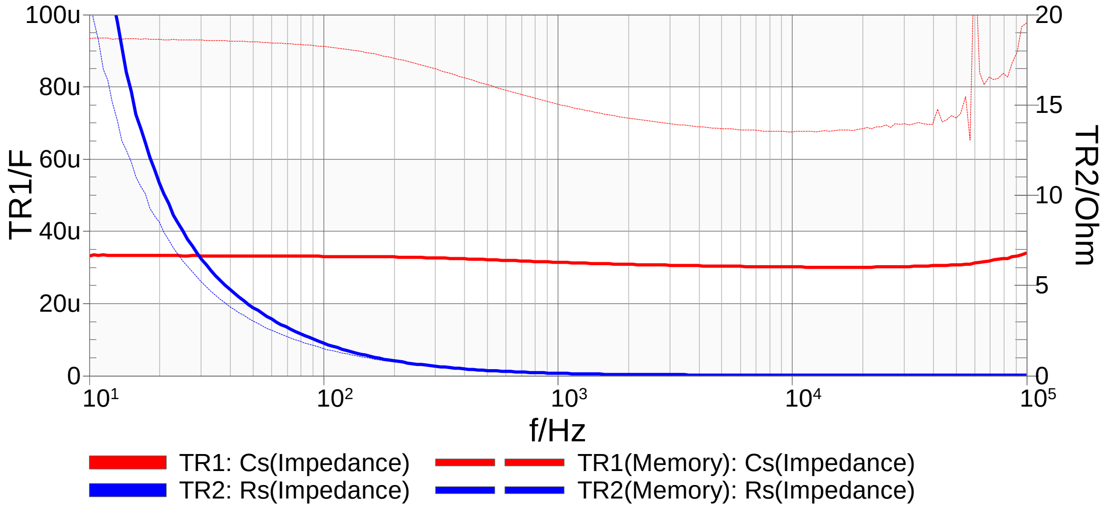


To do so the following settings have to be applied in the Frequency Sweep Mode:



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

Performing the user calibration as described above and starting a sweep measurement with 0V Bias and 5V 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.

[2] 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. Due to the large variation of capacitance, it is important to measure this characteristic in order to assure stable voltage regulator performance.