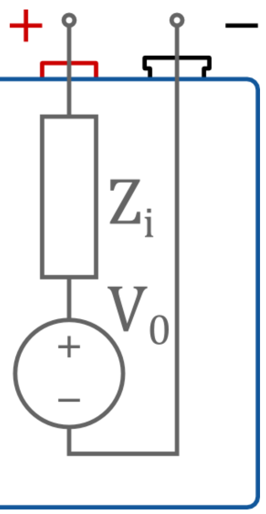
Bode 100 - Application Note

Battery Impedance Measurement



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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

1 Executive Summary

Battery impedance includes information about the internal state of a battery. The impedance depends on many factors such as the chemical properties and mechanical design of the battery. Measuring the battery impedance over frequency helps to identify the characteristics of the battery.

The Bode 100 in conjunction with the Picotest J2111A Current Injector offers an easy way to measure the impedance of a battery in the frequency range from 1 Hz to 10 MHz.

This application note shows the connection setup and the device settings of the Bode 100 necessary to perform the impedance measurement.

2 Measurement Task

The impedance of a lithium ion battery (4.2 V) and an alkaline battery block (9 V) is measured in the frequency range from 1 Hz to 10 MHz. After discharging the batteries to a no load voltage of $V_0 = 3.7\ \mathrm{V}$ and $V_0 = 7.1\ \mathrm{V}$ the impedance spectrum is measured again and compared to the measurement performed on the full charged batteries. We measured both kind of batteries to demonstrate that cells with low and high output resistance can be measured with the presented method.

3 Measurement Setup & Results

The impedance of a battery, Z_i, can be measured by loading the battery with an AC[1] current and measuring the resulting AC output voltage of the battery. Dividing the AC output voltage v_{out} by the AC output current i_{out} leads to the impedance of the battery.

$$Z_i = \frac{v_{out}}{i_{out}}$$

The output current of the battery is modulated by the J2111A current injector, driven by the output signal of the Bode 100.

The output current is then measured by connecting CH1 of the Bode 100 to the current monitor output of the J2111A. The output voltage of the battery is measured directly using a 1:1 voltage probe connected to CH2.

The connection setup is shown in the figure below:

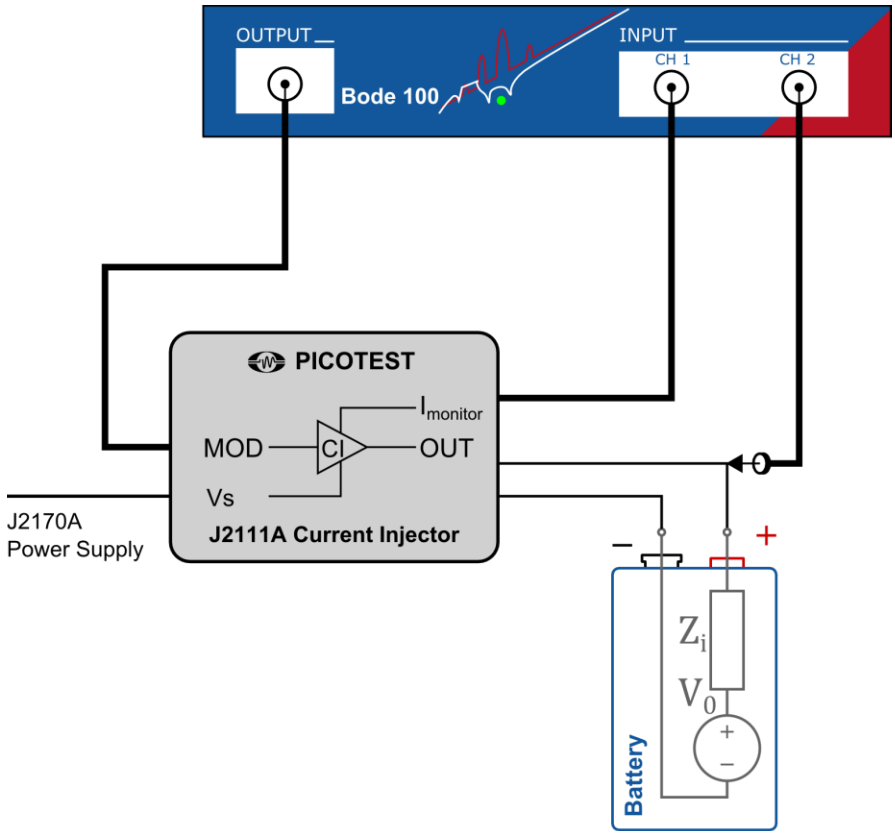

Figure 1: Connection Setup

Note: The maximum allowed battery voltage with this setup is 40 VDC!

[1] Alternating Current (sine-waveform)

3.1 Device Setup

Current Injector J2111A:

The positive bias of the Current Injector must be switched on (+bias) since the Bode 100 output voltage does not have an offset. The positive bias provides a 25 mA offset current, allowing the current injector to operate in class “A” mode. For the best performance, the output wires from the J2111A should be twisted or be coaxial.

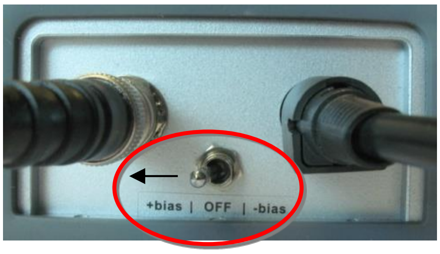

Figure 2: Backside - Current Injector

Bode 100:

The battery impedance measurement can be performed directly with the Bode 100 using the Voltage/Current measurement type.

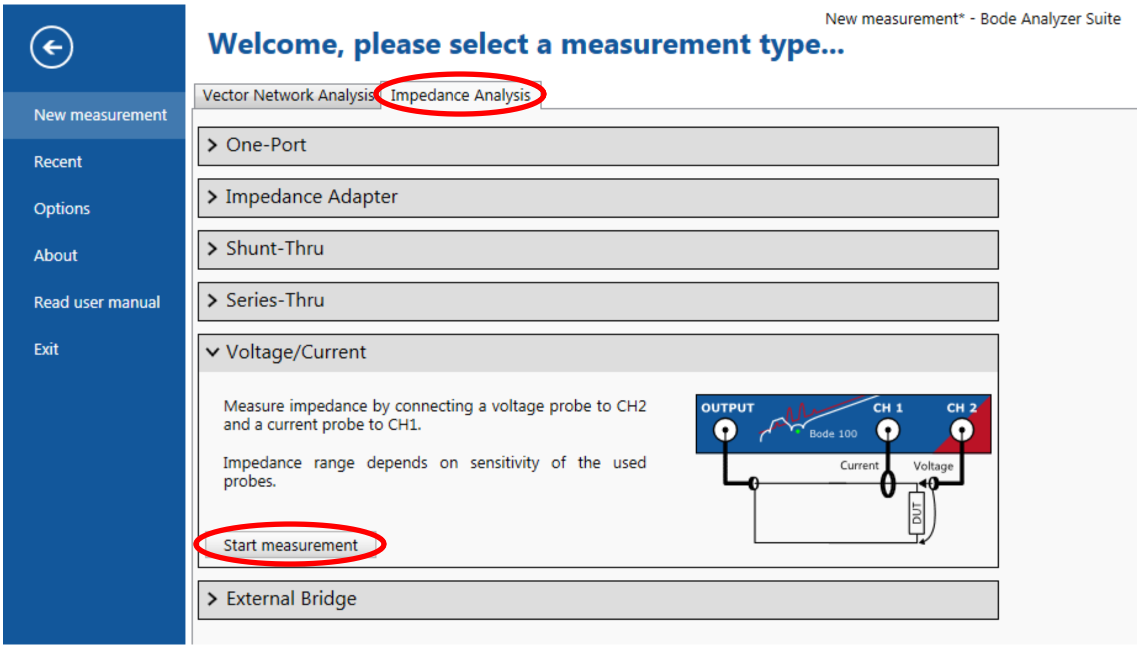

Figure 3: Start menu

The Bode 100 is set up as follows:

Start Frequency:	1 Hz
Stop Frequency:	10 MHz
Sweep Mode:	Logarithmic
Number of Points:	201 or more
Receiver Bandwidth:	100 Hz
Attenuator 1 &2:	0 dB
Level:	0 dBm

To open the Hardware Setup window click on the Impedance / Reflection icon.

Figure 4: hardware setup button

The input impedance of channel 1 must be set to 50Ω, while channel 2 need to remain in high impedance mode:

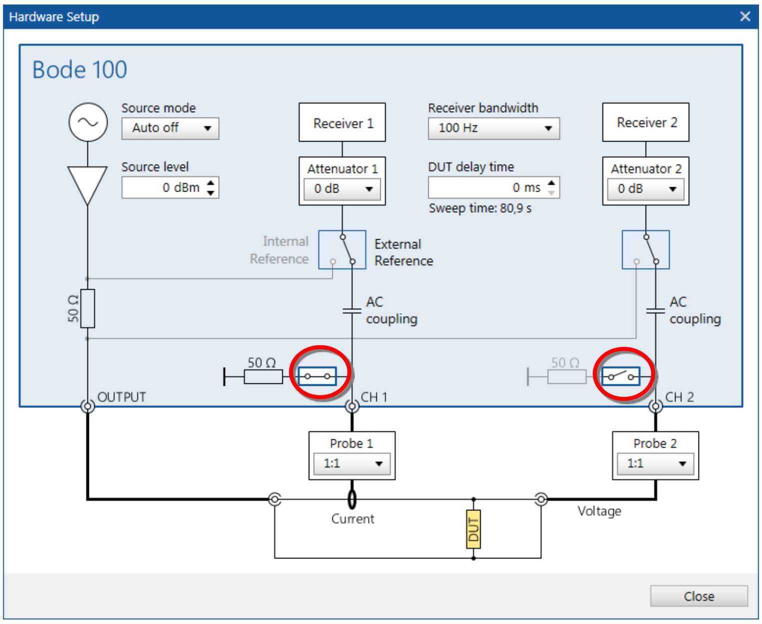

Figure 5: Hardware Setup window

3.2 Calibration

To remove the influence of the voltage probe, we recommended calibrating the setup. To do this the voltage probe at CH2 is connected to the current monitor output of the current injector and a THRU calibration is performed.

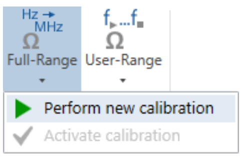

Figure 6: perform full-range calibration

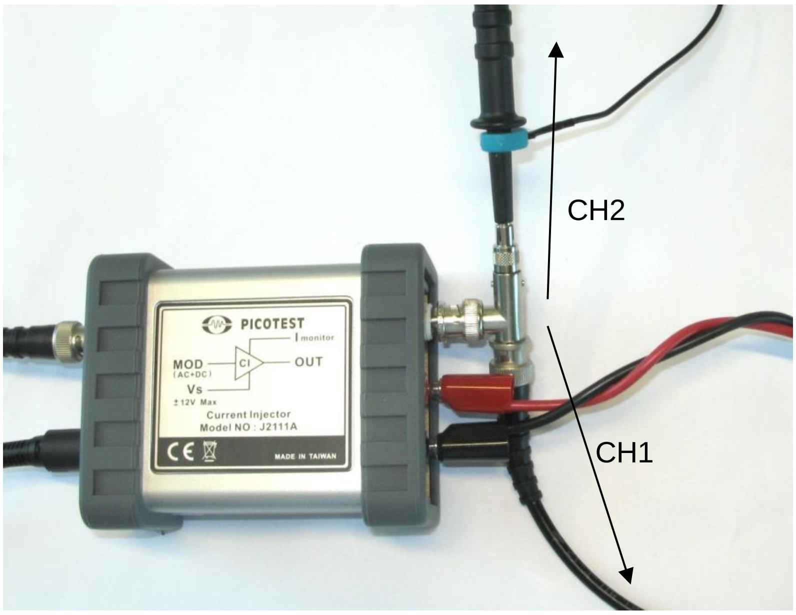

Figure 7: Connection during THRU calibration

3.3 Measurement

For the measurement of the battery impedance, the battery under test (9V alkaline battery block) is connected as shown in the picture below.

Figure 8: Measurement Setup Example

First, we measure impedance of the fully charged battery. Starting a single sweep leads to the following impedance spectrum:

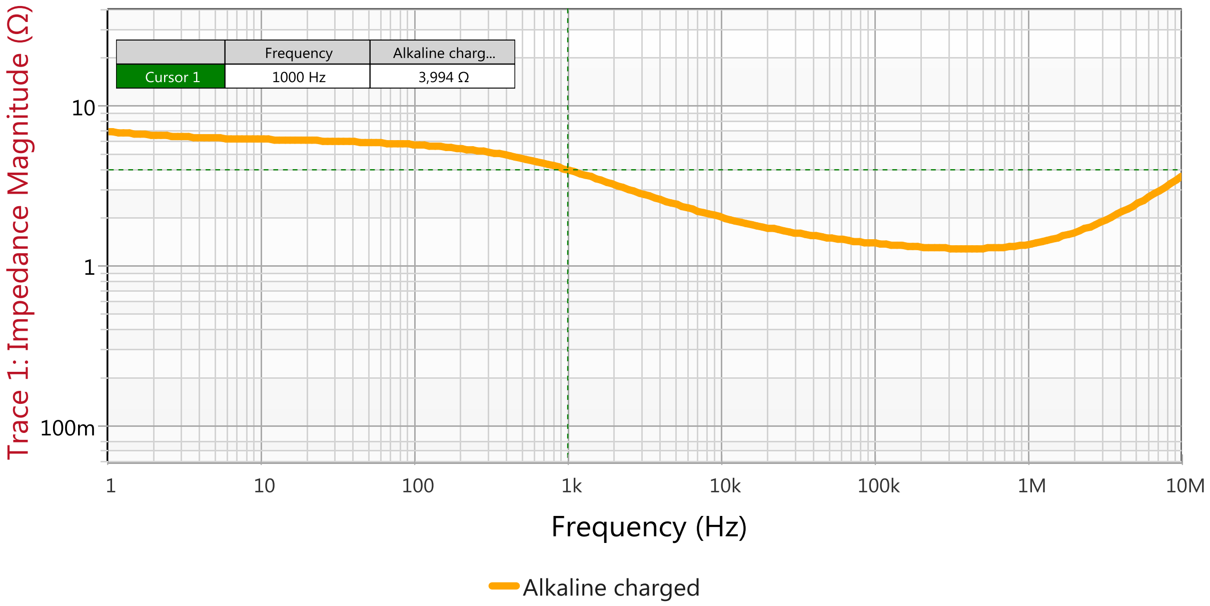

Figure 9: Measurement result of the charged alkaline battery

The Gain magnitude in this case equals the impedance magnitude in Ohm. At $1\ \mathrm{kHz}$ the impedance shows a value of $3.95\ \Omega$.
Now the battery is discharged to a no load voltage of $V_0 = 7.1\ \mathrm{V}$ and a second sweep is performed. This results in a different impedance spectrum (see pink line in the graph below).

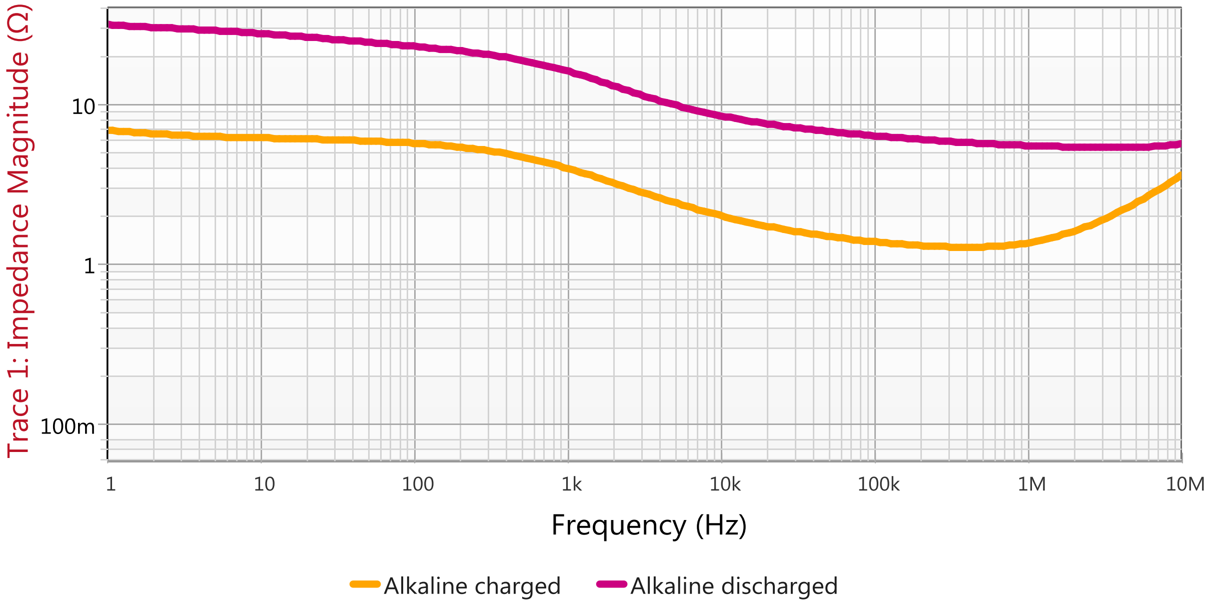

Figure 10: measurement battery charged and uncharged

The battery impedance at $1\ \mathrm{kHz}$ did increase to $\approx 16.2\ \Omega$.

The same measurement setup can be used to measure all types of batteries. As mentioned we measured the impedance of a $3.7\ \mathrm{V}$ lithium ion cell. The impedance of this cell is shown in the graph below in comparison with the alkaline block.

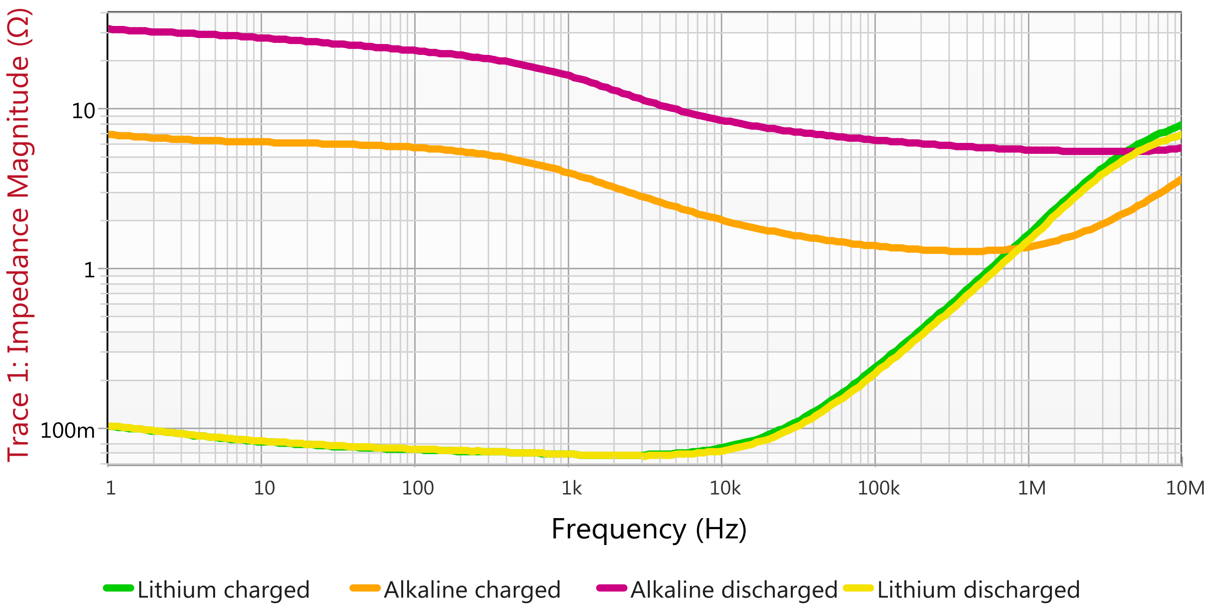

Figure 11: measurement comparison alkaline and lithium

At $1\ \mathrm{kHz}$ the lithium ion cell, charged and discharged, shows an impedance of $\approx 68.6\ \mathrm{m\Omega}$ which is much lower than the impedance of the alkaline battery.

4 Conclusion

The Bode 100 in conjunction with the Picotest J2111A Current Injector offers a test set that enables simple and fast measurement of the battery impedance. The impedance of low and high impedance batteries can be evaluated over the frequency range from 1 Hz to 10 MHz.

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