Bode 100 - Application Note

Audio Amplifier Frequency Response

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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. 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

This application note explains how to measure frequency dependent characteristics of audio amplifiers with the Bode 100 and additional accessories.
After a short introduction to the measurements we show how to configure the Bode 100 and how to connect the DUT[1] for each measurement.

2 Measurement Tasks

The following measurements are shown in this application note:

- Measurement of the amplifier's gain range (maximum and minimum gain)
- Visualization of the equalizer settings' influence and the 3 dB bandwidth
- Measurement of the input impedance of the sound system with and without a special high impedance bridge[2]
- Measurement of the sound system's output impedance

The measurements are performed on a self-developed sound system.
This sound system was developed by the teacher Dipl.-Päd. Ing. Michael Kvasznicza at the Federal Higher Technical Institute for Education and Experimenting in Bregenz. It was improved and extended with a Bluetooth connection to Android devices during a diploma thesis project.

[1] Device Under Test
[2] Find more details on https://www.omicron-lab.com/bode-100/application-notes-know-how/application-notes/high-impedance-measurements.html

3 Measurement Setup & Results

3.1 Sound System Details

The self-made sound system we are using for the measurements contains a preamplifier (TDA7439) and a self-made power amplifier. The input signal is modified in the preamplifier and can be set as desired via buttons on the housing of the sound system or via Bluetooth on an application for Android devices called "Blue Sound Control"[3].

Figure 1: Front view of the sound system

Figure 2: Rear view of the sound system

[3] This application for android smartphones is only usable with the corresponding sound system like the one we are using

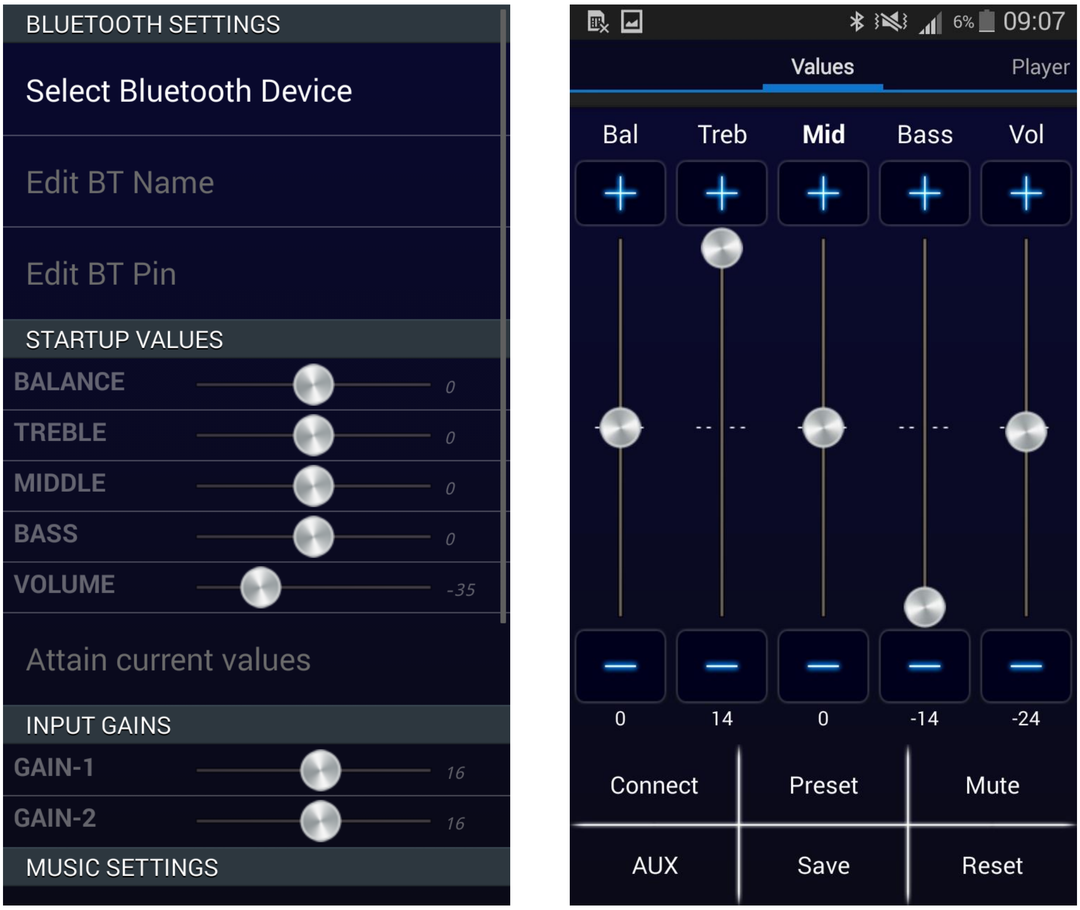

Figure 3: Settings of the sound system in the android app

For reproducibility we use the smartphone app to change the settings as desired since the app directly displays the set values as numbers.

The following settings that can be changed in the smartphone app:

Range	Input Gain	Balance	Treble	Mid-range	Bass	Volume
Maximum	30	R 80	+14	+14	+14	0
Minimum	0	L 80	-14	-14	-14	-47
Step size	2	1	2	2	2	1

3.2 Amplifier Gain Measurements

We can measure the maximum and minimum gain of the amplifier as well as the influence of the equalizer settings on the amplifier's frequency response. Saving of the measurement results in the memory then allows us to quickly see the influence of the different settings.

3.2.1 Bode 100 & Sound System Setup

We actually want to measure the voltage gain from the amplifier input to its output. There are two possibilities how to connect the Bode 100 to the amplifier. One is to use the Bode 100 as a vector network analyzer by using its "internal Reference" (Measurement Type: *Transmission / Reflection* with 1 MΩ at CH2). We then can simply measure the gain by connecting the output of the Bode 100 to the input of the sound system and CH2 to the output of the sound system. However, because the input impedance of the sound system is not 50 Ω we will introduce an error. The error is estimated in the following:

The input impedance of audio systems is generally very high. In our case the input impedance is >70 kΩ (see also 3.3 Input impedance Measurement). As shown below, the real input voltage present at the sound system input will be lower than the internal source voltage of the Bode 100. However, the difference is negligible (0.07% as calculated below). Therefore the measurement type *Transmission / Reflection* can be chosen and CH2 set to 1 MΩ as you can see in the following figures.

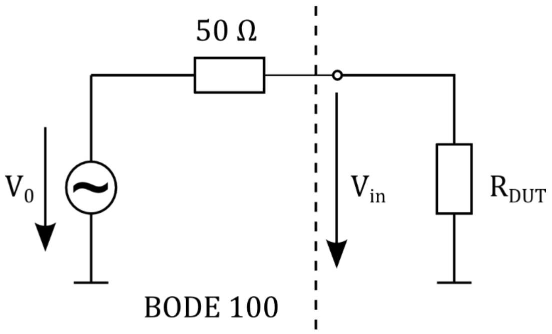

Figure 4: error estimation schematic

$$V_{in} = V_0 \cdot \frac{R_{DUT}}{R_{DUT}+50\ \Omega} = V_0 \cdot \frac{70\ k\Omega}{70\ k\Omega+50\ \Omega} = 0.9993 \cdot V_0 \rightarrow 0.07\%$$

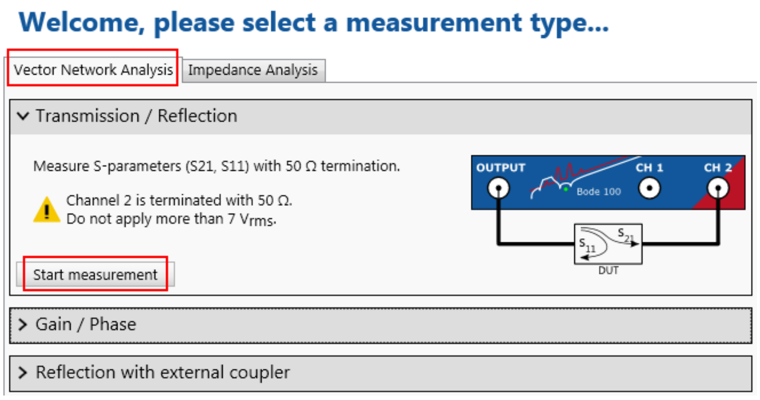

Figure 5: select measurement type transmission / reflection

Figure 6: open hardware setup

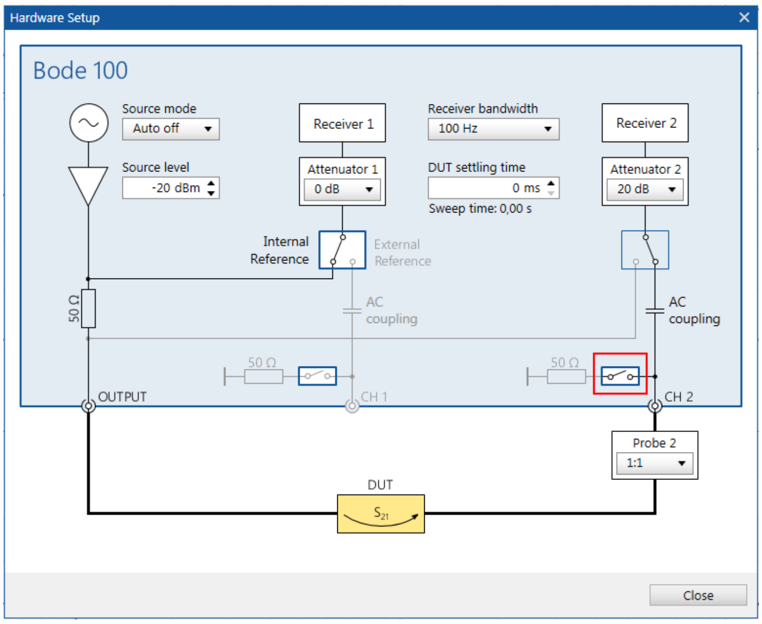

Figure 7: hardware setup window - set CH2 to 50 Ω

The following settings are applied to the Bode 100 in the frequency sweep mode:

- Start Frequency: 10 Hz
- Stop Frequency: 100 kHz
- Sweep Mode: Logarithmic
- Number of Points: 201

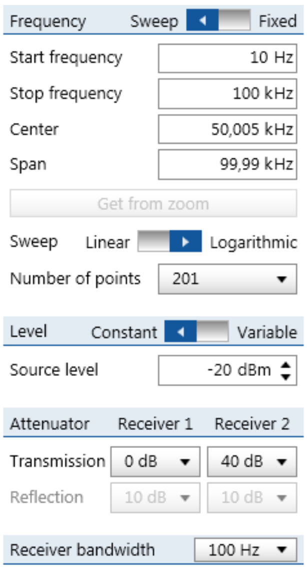

Figure 8: measurement settings

For all gain measurement we set the channel 1 to internal reference, the attenuator CH1 to 0 dB and the receiver bandwidth to 100 Hz.
We connect the loudspeakers for all measurements in order to operate the sound system under normal conditions. Attenuator CH2 is initially set to 40dB to avoid channel overload. In addition, trace 1 and 2 are set to measure *Magnitute (dB)* and *Phase (°)*.

The values that have been set for the following measurements are:

	Bode 100 settings		Sound system settings					
Trace memory	Level in dBm	Attenuator CH2 in dB	Gain	Balance	Treble	Mid-range	Bass	Volume
G30 V0 max 20dB[4]	-27	40	30	0	0	0	0	0
G0 V-47 min	5	0	0	0	0	0	0	-47
G16 V-24 50%	-20	20	16	0	0	0	0	-23
G10 V-24	0	20	10	0	0	0	0	-24
G10 V-24 T14	-20	20	10	0	14	0	0	-24
G10 V-24 M14	-20	20	10	0	0	14	0	-24
G10 V-24 B14	-20	20	10	0	0	0	14	-24
G10 V-24 E14	-20	20	10	0	14	14	14	-24

The Bode 100 source level and the attenuator CH2 are set to a value that the signal is high enough to get a noiseless measurement curve but not too high in order to avoid an overload at CH2. Therefore we always start with a small source level and a high attenuator at CH2 and change it afterwards to fight noise and to get a clean measurement result.

[4] Additional 20 dB attenuator at the Bode 100 output and no loudspeaker connected since the gain is too high without the attenuator

3.2.2 Measurement Setup

For this measurement, we connect the sound system and the loudspeaker as well as the Bode 100 as shown in the picture below.

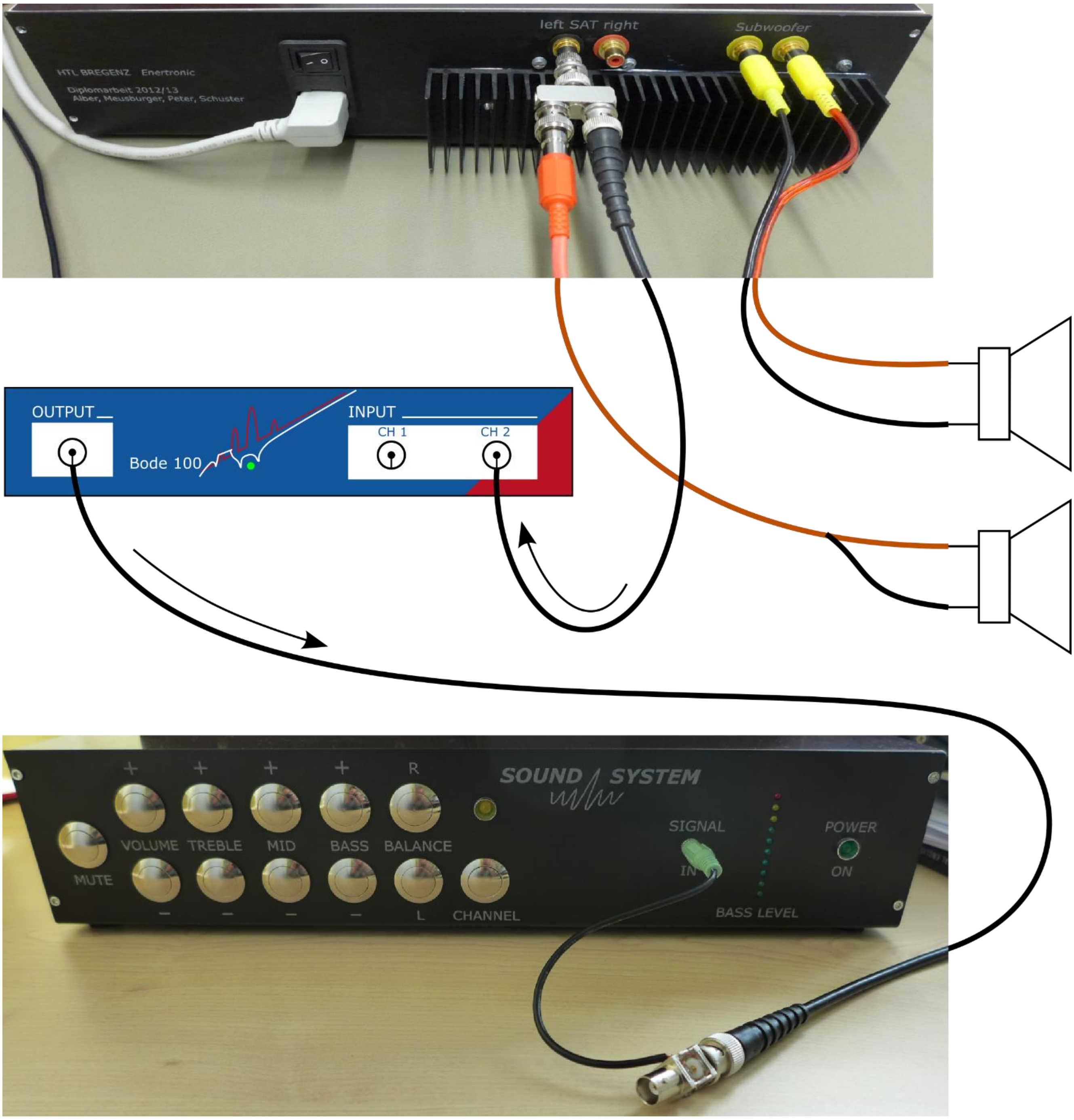

Figure 9: Gain measurement - connection setup

For the connection between the Bode 100 output and the sound system input, we use a BNC cable and a self-made BNC to 3.5 mm stereo audio connector (see Figure 10).
Each of the two BNC-connectors are for either the left or the right input of the sound system.

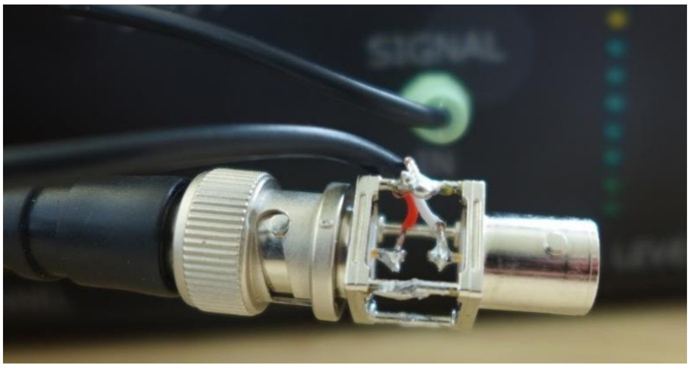

Figure 10: Audio connector to BNC connector

3.2.3 Measurement Results

Before we start a measurement, we perform a THRU calibration.

Maximum, Minimum, Range and 50% of the Gain

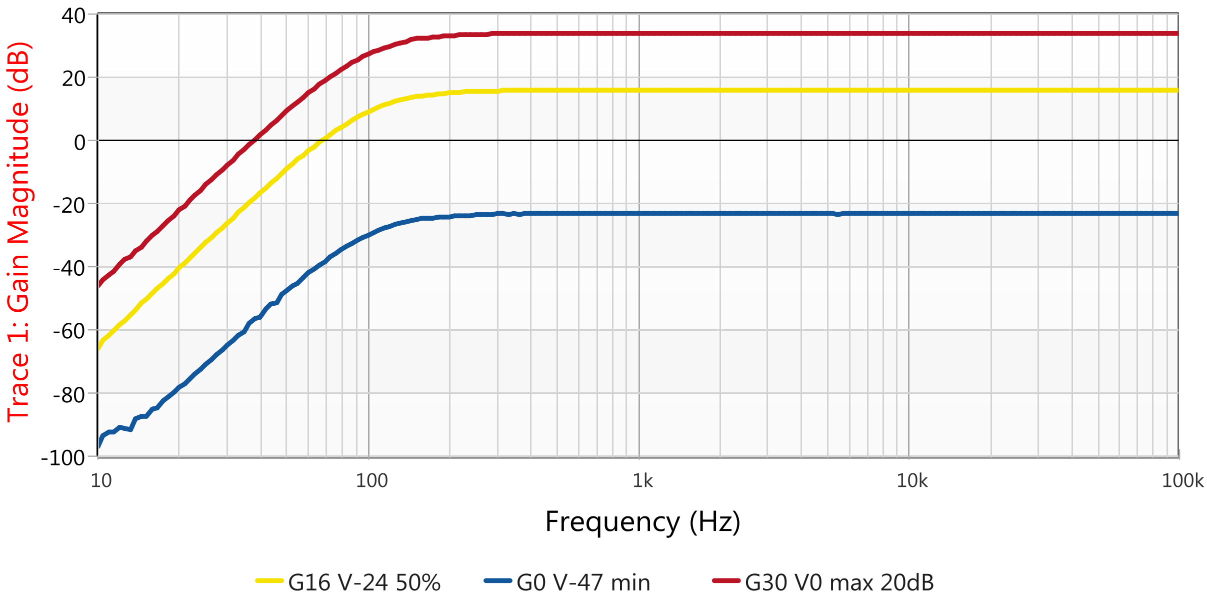

Figure 11: Gain measurement - minimum, maximum and 50 %

In the measurement above, we measure the minimum and maximum amplification of the sound system and then we calculate the values we have to set to get 50 % of the gain.
The minimum amplification at 1 kHz (sound system settings: G0 V-47 min) results in a gain of **-23 dB**.
The maximum amplification at 1 kHz (sound system settings: G30 V0 max 20 dB) results in a gain of **34 dB +20 dB = 54 dB** (we added a 20 dB attenuator at the Bode 100 output)

The gain range of the sound system therefore is: $gain_{max} - gain_{min} = 54\ dB + 23\ dB = 77dB$.

Influence of treble, mid-range and bass level

To visualize the influence of the equalizer settings, a high variety of measurements could be done. As an example, we choose an input gain of 10 and set all equalizer settings (treble, mid-range and bass) to 0.

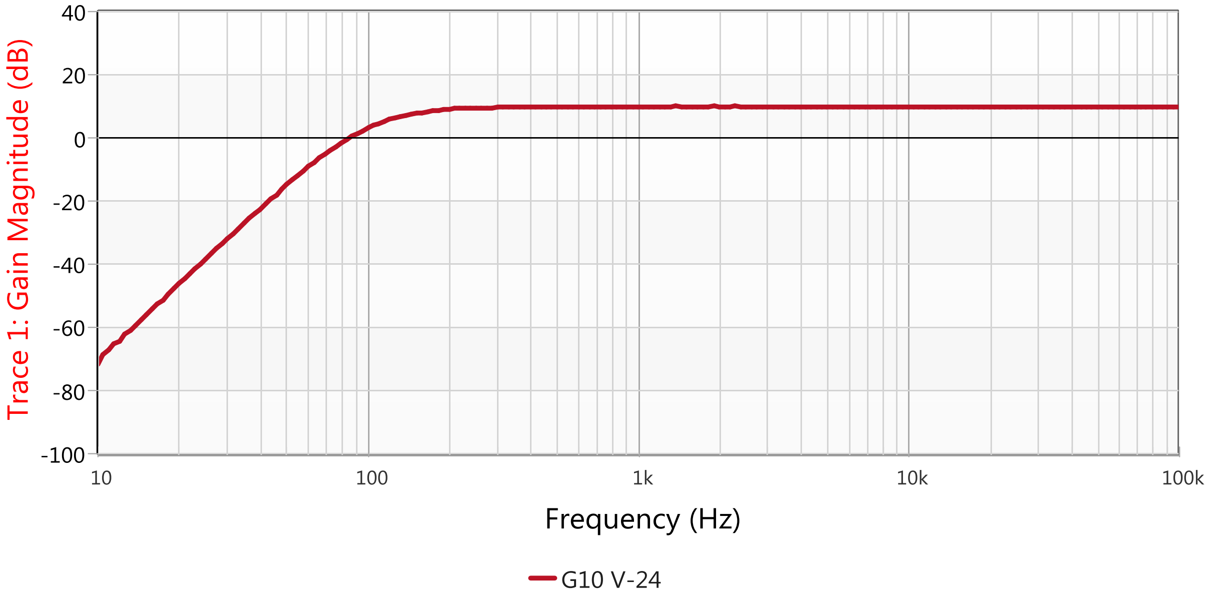

Figure 12: Gain measurement - equalizer neutral

Then, we do four more measurements with different equalizer settings and safe the curves into different memories.

To see the differences of each measurement, we add the other four measurements to the existing curve. The changes we make in the four additional measurement curves are:

1. Treble +14 (G10 V-24 T14)
2. Mid-range + 14 (G10 V-24 M14)
3. Bass + 14 (G10 V-24 B14)
4. Treble, Mid-range and Bass + 14 (G10 V-24 E14)

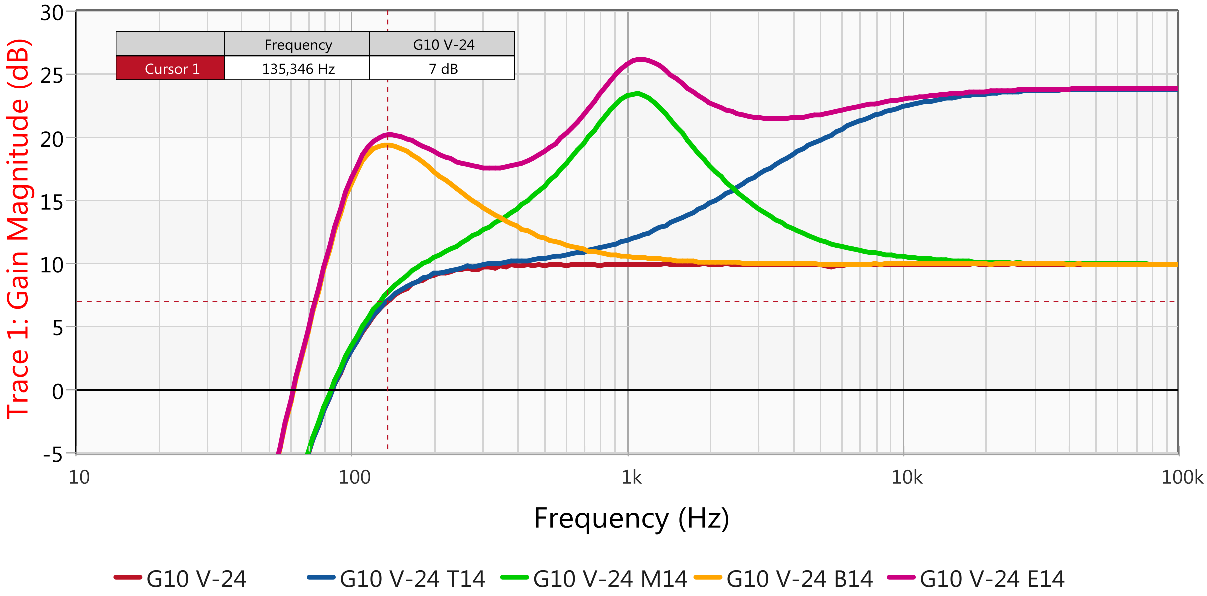

Figure 13: Gain measurement - equalizer maximum

As shown in the diagram above, the 3 dB bandwidth (10 dB of the standard attenuation at higher frequencies – 3 dB) of the curve with all equalizer parameters set to 0 starts at approx. 135 Hz and is very flat until the end of the x-axis at 100 kHz. If we want to improve the low-bandwidth we could increase the bass (see curve G10 V-24 B14).
The curves display quickly in what frequency range the equalizer changes the frequency response of the amplifier and how much the corresponding frequency range (bass, treble and mid-range) is amplified when the equalizer values are set to a maximum (see curve G10 V-24 E14).

3.3 Input impedance Measurement

3.3.1 One-Port Impedance Measurement

3.3.1.1 Bode 100 & Sound System Setup

To measure the input impedance we perform a logarithmic frequency sweep from 10 Hz to 100 kHz and use the maximum Bode 100 output level (13 dBm) for maximum sensitivity and choose at Trace 1 the Format *Magnitude*.
The measurement type *One-Port* is chosen and the other settings are as follows.

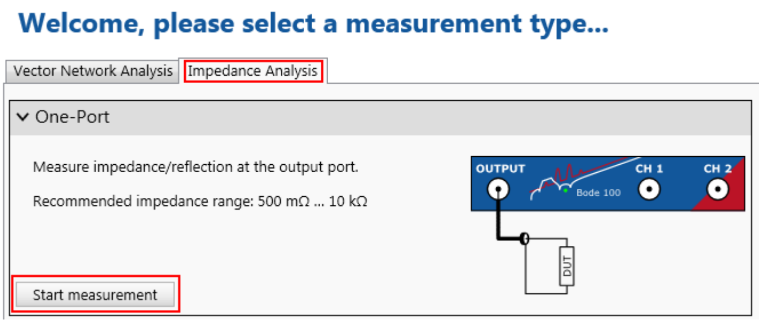

Figure 14: one-port measurement type

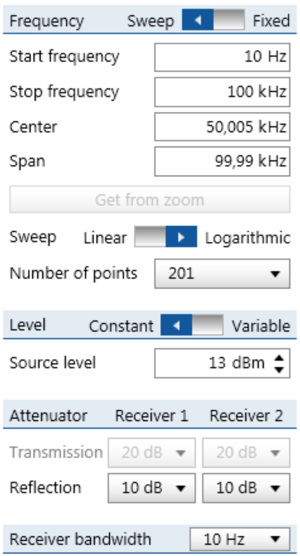

Figure 15: measurement settings – input impedance

Before we start the measurement we perform a User-Range calibration (OPEN, SHORT, LOAD) to get the best possible result. In addition we have to switch the sound system on to ensure that all active components are up and running like during normal operation.

3.3.1.2 Measurement Setup

To measure the input impedance we connect the Output of the Bode 100 to the input of the sound system.

Figure 16: Standard input impedance measurement - connection setup

3.3.1.3 Measurement

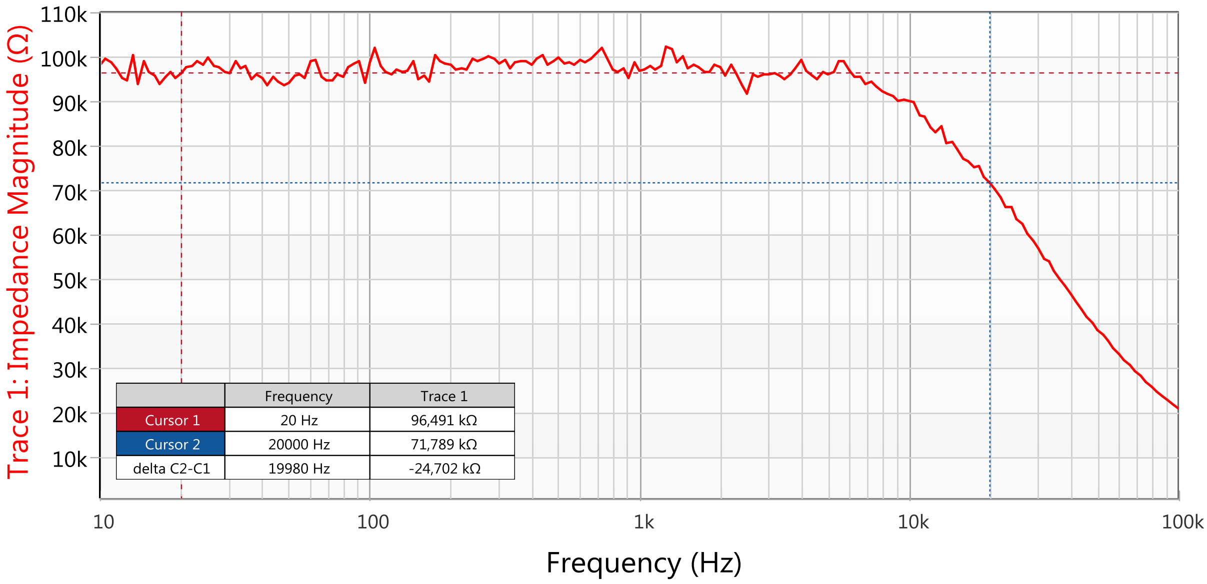

Figure 17: Standard input impedance measurement - frequency sweep

The measurement shows that the input impedance reaches very high values. The one-port impedance measurement method is recommended up to approximately 10 kΩ whereas our sound system has a much higher input impedance. This is the reason for the noise on the measurement that shows the limits of this measurement method.

To improve this measurement we can use a special setup that improves the sensitivity for high impedance values as shown in the next section.

3.3.2 Measurement using a High Impedance Bridge

3.3.2.1 Bode 100 & Sound System Setup

If we use the high impedance bridge[5] we have to select the measurement type *External / Bridge* and apply the same settings like in the measurement before.

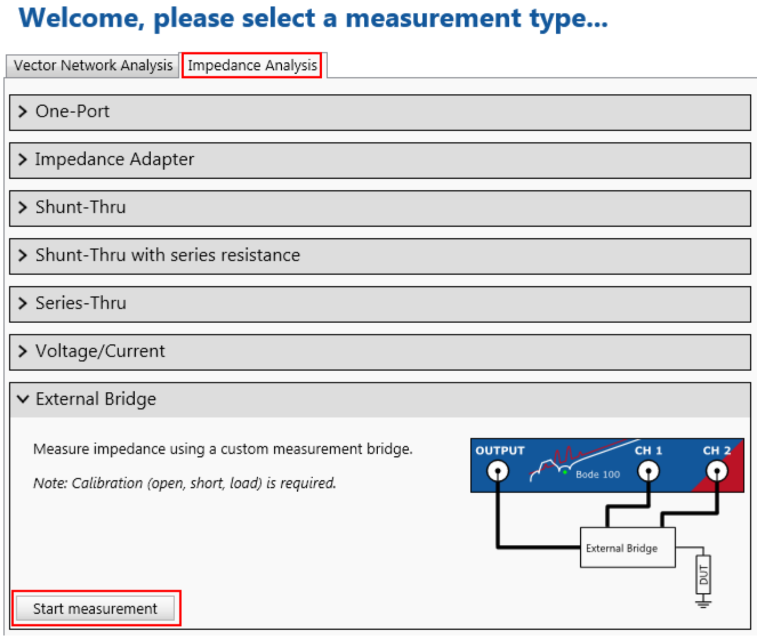

Figure 18: select measurement type external bridge

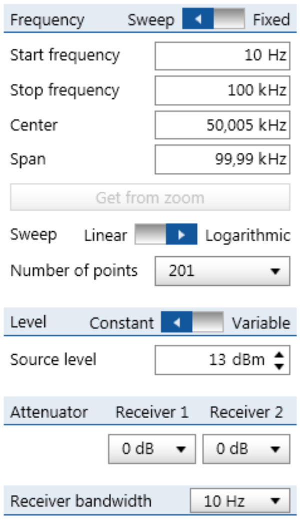

Figure 19: measurement settings external bridge

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[5] Find more details on https://www.omicron-lab.com/fileadmin/assets/customer_examples/Bode_Info_HighImpedance_V1_1.pdf

3.3.2.2 Measurement Setup

For this measurement we use the high impedance bridge and connect it between the Bode 100 and the sound system as we can see in the pictures below.

Figure 20: Input impedance with high impedance bridge - setup front view

3.3.2.3 Measurement Results

Before we could start the measurement, we have to do an OPEN, SHORT and LOAD calibration.

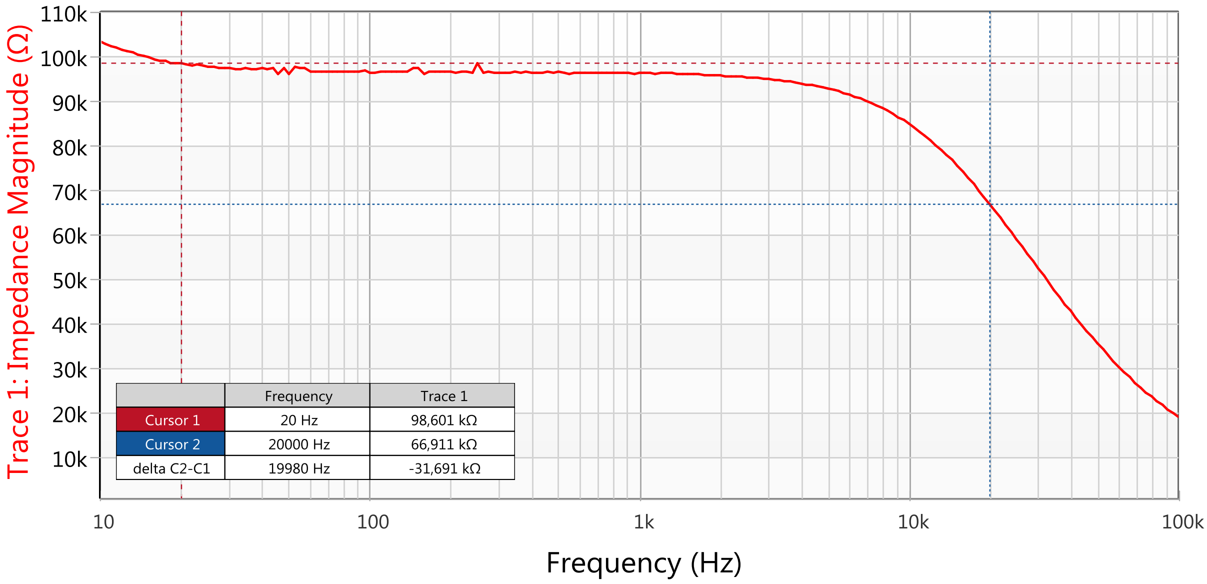

Figure 21: Input impedance with high impedance bridge - frequency sweep

The measurement result shows that the input impedance starts at 98 kΩ at 20 Hz and reduces to 70 kΩ at 20 kHz. Since the input impedance in datasheets are mostly measured at 1 kHz, we also want to know the value at this frequency.

The input impedance of an audio amplifier at 1 kHz should be > 10 kΩ and typically is between 10 kΩ and 100 kΩ for a bridging[6] impedance of the output and the input ($R_{IN} \gg R_{OUT}$). Therefore an input impedance of 96 kΩ at 1 kHz is very good.

3.4 Measuring the Output Impedance

3.4.1 Bode 100 & Sound System Setup

We have to set the Bode 100 to measure the impedance like the way we did in *3.3.1* on page 13.

The Bode 100 is set in the frequency sweep mode as follows:

- Start Frequency: 10 Hz
- Stop Frequency: 100 kHz
- Sweep Mode: Logarithmic
- Number of Points: 201
- Source Level: 13 dBm
- Attenuator CH1: 10 dB
- Attenuator CH2: 10 dB
- Receiver Bandwidth: 10 Hz

3.4.2 Measurement Setup

To measure the output impedance of the sound system, we have to connect the output of the Bode 100 to the output of the sound system. The input of the sound system is short-circuited to reduce noise at the input and to protect the Bode 100 of an output signal from the sound system. Please take care of the maximum reverse power of the Bode 100 which can be seen in the user manual.

Figure 22: Output impedance measurement setup

[6] If the load impedance is 10 times or more the source impedance, this is called a „bridging" impedance.

Figure 23: Output impedance measurement – sound system input

3.4.3 Measurement Results

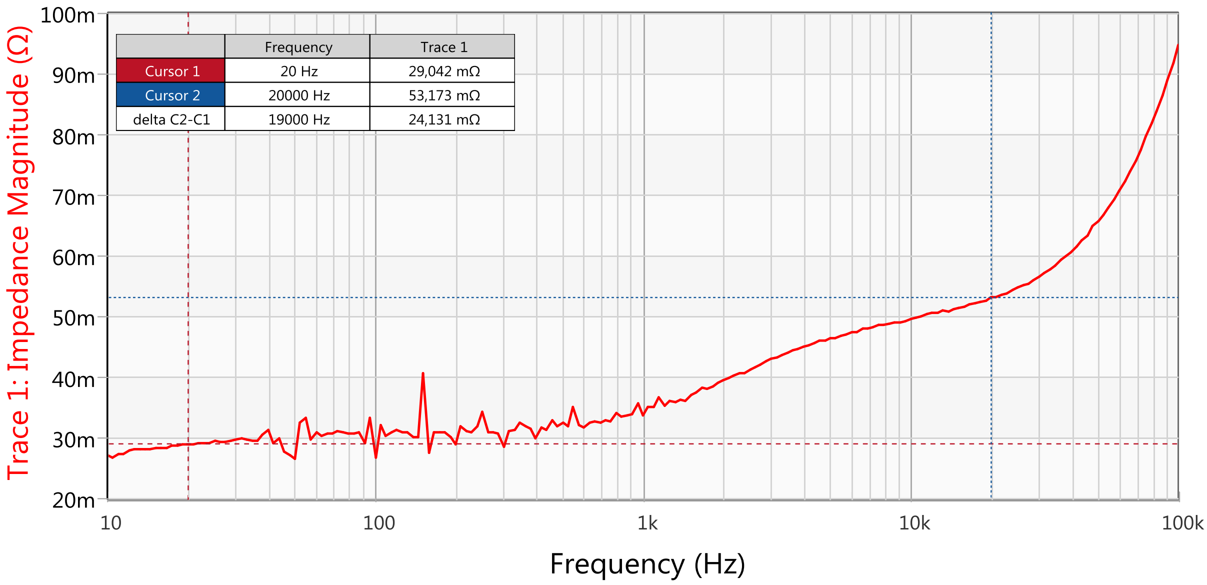

Figure 24: sound system output impedance measurement

The output impedance of the sound system is between 29 mΩ at 20 Hz and 53 mΩ at 20 kHz. Since the impedance of the loudspeakers should be much bigger than the audio output of the sound system they are connected to, the output of the sound system is typically < 100 mΩ and in our case approx. 34 mΩ at 1 kHz.

4 Conclusion

The Bode 100 is a test set that allows to measure a high variety of important sound system parameters in a simple and fast way. Input and output impedances of the sound system or the different settings of the equalizer can be visualized as well as the amplifier's gain range and its 3 dB bandwidth.
If you are interested in sound system measurements, check out our application note "Loudspeaker and Audio Crossover Measurements". In this application note is described how to measure the impedance of loudspeakers and how to characterize audio crossovers.

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