-- USER GUIDE ---

ModeCompensator 01

1. TABLE OF CONTENTS

----

2. PURPOSE OF THE EQUIPMENT

This equipment is foreseen for precise and high-resolution Room-Mode-Free Measurements of the Frequency Response of Loudspeakers in a standard laboratory environment.
It is intended to be used in combination with a measurement equipment as e.g., a computer with audio inputs and an appropriate evaluation software.

3. SAFETY NOTES

- Install this unit in a well ventilated, cool, dry, clean place in a standard laboratory environment.
- Use the supply voltage specified on this unit only. AudioChiemgau will not be held responsible for any damage resulting from the use of this unit with a voltage other than specified.
- Do not attempt to modify or fix this unit by yourself. Contact customer service when any service is needed.
- Please check regularly all connectors and cables and do not use the equipment for your own safety in case of any damages.
- When not planning to use this unit for long periods of time, disconnect the wall plug power supply from the wall outlet.
- Storage of all components should take place in the transportation case which is the scope of delivery. This avoids any damage or contamination of the sensible equipment and especially of the MEMS microphones.
- The product specifications and information in this manual are for reference only. The content of this manual is subject to change without notice.

4. GUIDELINES

- Europäische Norm EN 60730-1, 60730-2-7, 60730-2-9
- RoHs Richtlinien 2002/95/EC
- Niederspannungsrichtlinie 2006/95/EC
- Elektromagnetische Verträglichkeit 89/336/EEC, 93/68/EEC

5. SYSTEM REQUIREMENTS

5.1. PACKAGE CONTENT

The equipment comprises:

- ModeCompensator,
- Two calibrated MEMS-microphones with cables
- Wall-plug power supply
- Operation Instructions (User Guide)
- Transportation case

5.1.1. NECESSARY SUPPORTING EQUIPMENT

The following equipment is required for frequency response and harmonic distortion measurements:

- Personal Computer
  Example: Apple Mac Book, iMac or Windows based Computer
- External audio interface
  Example: USB audio interface Focusrite Scarlett 2i2, or Clarett 2pre USB
- Evaluation software
  Example: FuzzMeasure (Mac OS) or
  EQ Wizard (Windows, MacOS and Linux)

There are many commercial evaluation software alternatives for Apple or Windows computers on the market.

The frequency plots in the chapter "Examples" were generated with an iMac running FUZZ Measure and Clarett 2pre audio Interface.

6. INTRODUCTION

The usual method of measuring the frequency response of the Sound pressure level (SPL) of a loudspeaker chassis (device under test, DUT) uses time gating. The time window (time gate) in which the sound pressure is recorded is set such, that reflections of the sound from the walls, which arrive after their distance depending traveling time are excluded from the measurement.

The time domain measurement is then usually transformed into the frequency domain by an appropriate evaluation software in order to get the frequency response of the SPL. The time window determines the achievable frequency resolution of the measurement, as time window duration and frequency resolution are reciprocal parameters.

In most laboratories the distance from the DUT to the next wall is below 2 meters. As the sound travels 343 Meters per Second, the first reflection from the wall arrives after about 11 Milliseconds. A corresponding time window set to 10 Milliseconds results in a frequency resolution of 100 Hz. In addition, standing waves between hard room boundaries (e.g., walls, ground, ceiling) develop.

It becomes clear from the above example that SPL frequency response measurements below 1 kHz are not possible with acceptable frequency resolution and accuracy.

The AudioChiemgau ModeCompensator enables the measurement of the SPL frequency response with very high frequency resolution and accuracy between 10 Hz and 1000 Hz.

Its basic principle eliminates the sound pressure reflections from the walls and room resonances from the time domain measurement. For this purpose, two microphones are used to distinguish the direct sound from the DUT from the unwanted room reflections and room resonances a.k.a. room modes.

Such the time window of the evaluation software can be set according to the desired frequency resolution of the SPL frequency response measurement. Usually, a 10 seconds duration Log-Sweep with a time window of 10 Seconds is used in order to get 0.1 Hz frequency resolution down to 10 Hz (lower frequency limit of the MEMS microphones).

7. THEORY OF OPERATION

AudioChiemgau offers a simple technology solving the discussed measurement problem:

The loudspeaker is measured in the near field (approximately 5 cm between membrane and measurement microphone) and simultaneously the room modes are measured with a second microphone (mode microphone) in exactly 5 cm distance to the measurement microphone.

Both microphones record the direct sound pressure from the chassis and the room modes according to the 1/distance law.

The SPLs of the direct sound are about 6 dB different for both microphones, as the relative distances from the source (loudspeaker membrane) have the ratio one to two.

The SPLs of the modes are practically equal, as the sound wave traveled already quite some distance before arriving at the microphones.

The Mode-Compensator uses this physical relationship and derives in real time a mode free SPL signal from the loudspeaker under test.

More information on this subject can be found at *www.AudioChiemgau.de*

8. INITIAL OPERATION AND CONTROLS

MAKE SURE THAT THE SUPPLIED WALL PLUG POWER SUPPLY IS ONLY CONNECTED TO A WALL OUTLET WITH A VOLTAGE RATING BETWEEN 100 VAC AND 240 VAC

8.1. FRONT PANALE CONTROLS AND TERMINALS

Front Panel of the ModeCompensator

M1/M2:
Phone Jacks for the active MEMS Microphones 1 and 2

Phase 1 and Phase 2:
Setting of the signal phases of channel 1 and 2 to 0° or 180°

Gain:
3-position-switch for simultaneous gain setting for channel 1 and 2 (0 dB / +10 dB / +20 dB).

Compensation:
10-turn potentiometer for accurate mode compensation.

ON:
Control LED to display the status of the internal power supplies.

8.2. REAR PANEL TERMINALS

Connectors on the rear side of the control unit

Power IN:
DC Power from **12 VDC to 28 VDC**. To be used with the supplied 24 VDC wall plug power supply. The internal circuitry and the metal enclosure of the ModeCompensator are connected to the negative side of the floating external low voltage power supply.

Out 1 and Out 2:
Balanced monitoring audio outputs for amplified and frequency response corrected signals from channel 1 and 2.

Out:
Balanced output for the mode compensated measurement signal.

GND – GND Lift
It is well known that only one instrument in a measurement chain should be connected to protective ground in order to avoid ground loops.

Even when the ModeCompensator uses a floating wall plug power supply there may be capacitive interfering currents, which may disturb precise measurements.

The negative primary supply of the ModeCompensator is connected to the enclosure. Inside the ModeCompensator a floating power supply isolates the primary supply from the secondary internal power supply.

A Ground Lift switch on the backside of the enclosure allows connecting primary ground and enclosure with the secondary measurement ground, or to separate the two grounds (GND Lift). In case there are interferences visible in the measured signals, the activation of Ground Lift may help to reduce them.

8.3 SETTING UP OF THE MODECOMPENSATOR

a) Connect the two active MEMS microphones to the two inputs (M1 / M2) of the ModeCompensator.
Attention: The ModeCompensator supplies power to the calibrated active MEMS microphones. Do not plug in other microphones.

b) Connect the low voltage power cable to the rear side power input of the ModeCompensator. Use the supplied wall plug power supply.

c) Plug the wall plug power supply into a wall outlet supplying 100 ... 240 V AC. A green LED on the front of the ModeCompensator will indicate the presence of the internal power

d) Connect the ModeCompensator Outputs to your measurement equipment. **Attention**: All outputs of the mode compensator are **balanced outputs** with respect to the negative side of the low voltage external power supply and the metal enclosure. Use appropriate (balanced / stereo) plugs and cables to avoid shortening of one of the outputs.

e) Set the Compensation dial to the calibrated compensation value, which is marked on the ModeCompensator type plate on the bottom of the unit.

f) You are now ready for accurately measuring the frequency response of the DUT following the next steps

8.4 OPERATION OF THE MODE-COMPENSATOR

1. Locate both microphones in the near field of the membrane (see picture below). Microphone 1 (the direct microphone) should be placed about 5 cm above/from the membrane. Microphone 2 (the mode microphone should be placed exactly 5 cm above/from the direct microphone on an axis perpendicular to the chassis. The distance of the two microphones needs to be adjusted accurately in order to get an accurate frequency response up to 1000 Hz (±0.1 dB).

Location of the microphones on an axis perpendicular to the membrane

2. Use Output 1 and/or Output 2 and adjust the Audio Interface to a convenient level. Use a gain setting of the ModeCompensator as required with both phase switches set to 0 degree. Do not overdrive (stay below 120 dB SPL respectively 3 V output amplitude at any channel.

3. Use the Mode Compensated Output (Out) and switch the phase of the „Mode“ microphone to 180 degrees.

4. Perform, if required, a fine adjustment with the 10-turn potentiometer either while repeating fast (e.g., 1 second) SPL frequency measurements until a perfect cancellation of the room modes is achieved. An under-compensation, or an over-compensation is easily visible from the SPL frequency responses, as the mode

excitations invert their sign at exact compensation (see the examples in chapter 14)

Alternatively use a two-channel oscilloscope. Connect the direct microphone output to one channel and the mode compensated output (Out) to the second channel. Watch the waveform of the output (Out) during frequency sweeps. An under-compensation, or an over-compensation is easily visible as the mode amplitude changes during a frequency sweep from a dip to a peak or vice versa at exact compensation

5. Perform a long duration SPL frequency measurement (e.g., 10 seconds duration with 10 seconds time window) in order to get the final result with 0.1 Hz frequency resolution down to 10 Hz.

Remarks:

One can use any of the two microphones as the „Direct" or the „Mode" microphone. But always plug the right microphone to the corresponding input, as the microphone frequency responses are individually calibrated.
Switch the phase of the „Direct" microphone to 0 degrees and the phase of the „Mode" microphone to 180 degrees for cancellation of the room modes.

A mode free highly accurate SPL frequency response measurement can be performed within minutes in any laboratory environment at very high frequency resolution (e.g. 0.1 Hz) between 10 Hz and 1000 Hz).

9. PHYSICAL LIMITS FOR MEASUREMENTS

With increasing frequency, a proportional increasing phase difference between the two microphone signals needs to be considered. The corresponding frequency response is corrected up to 1000 Hz within ±0.1 dB **for distances of 5 cm between the two MEMS microphones**. If required an accurate calibration of the high-end frequency response can be achieved by slightly modifying the distance between the two microphones.

At higher frequencies it is recommended to measure with only one microphone and sufficient short time gate values of the evaluation software. For this purpose, the respective output Out 1 or OUT 2 of the ModeCompensator should be used.

10. DAMAGE OR IMPROPER FUNCTIONING

In case the ModeCompensator with the supplied equipment does not work as specified please contact the supplier and return the equipment for repair or exchange.

11. TRADEMARKS

Microsoft and Windows, as well as Apple and Focusrite are registered trademarks. All other trademarks are property of their respective holders.

----

12. SPECIFICATION

ModeCompensator (Control Unit):

Rated supply voltage:	12 – 28 VDC
Nominal Supply Voltage:	24 VDC
Power Consumption @24V:	1,5 W
Operating temperature:	+10°C ... +40°C
Non-operating temperature:	0°C ... +50°C
Humidity (non condensing):	30% ... 80%
Weight:	378g
Size in mm (B x T x H):	120 x 135 x 44
Mode Compensator Outputs:	balanced and referenced to chassis
Output impedance:	120 Ohms,
Output amplitude limit:	< 10 V

Two calibrated active MEMS microphones:

Type: (Balanced Outputs)	Analog MEMS
Frequency range:	10 Hz – 20 kHz
Maximum Acoustic Input:	133 dB (SPL)
Signal to noise ratio:	70 dB (A)

Wall plug power supply (MW GST18E24-P1J):

Rated input voltage:	100 ... 240VAC
Frequency:	50/60 Hz
Output:	24 VDC @ 0.75A

Complete Equipment:

Shipping Weight:	2200g

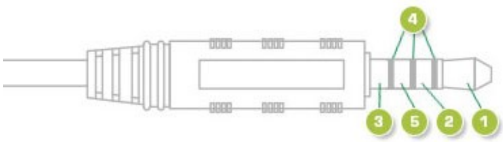
13. CONNECTORS

DC-Input: Round Ø5,5mm (negative) / Ø2,1mm (positive)

Audio-Out: Phone Jack Ø 6,3mm
- Tip: + OUT
- Ring: - Out
- Sleeve: GND

(balanced and **referenced to chassis** and negative low voltage power supply)

2 Mic Inputs: 4 pol Phone Jack Ø3,5mm

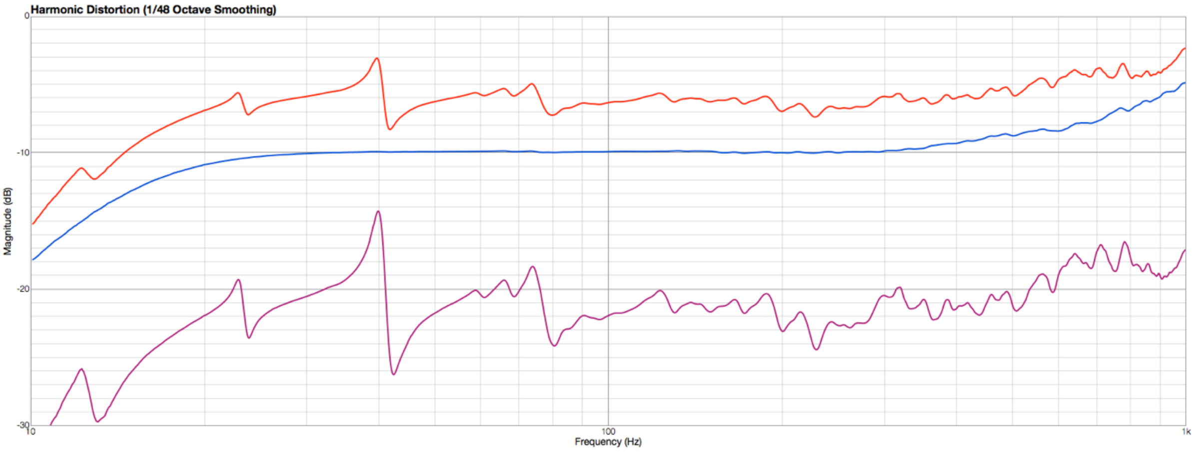


1 – Supply +3,0 VDC
2 – neg. Signal from Mic
5 – pos. Signal from Mic
3 – GND/Shield

14. EXAMPLES

14.1. EXAMPLE FOR A SPL FREQUENCY RESPONSE

The measurement below shows the SPL frequency responses of a chassis with ± 0.1 dB SPL accuracy and 0.1 Hz frequency resolution measured in a standard laboratory (sweep time 10 Seconds and time gate 10 Seconds corresponding to a frequency resolution of 0.1 Hz).



Red is the measured SPL of the “direct” microphone with approximately 5 cm distance from the membrane. This is what one would usually measure in a standard laboratory.

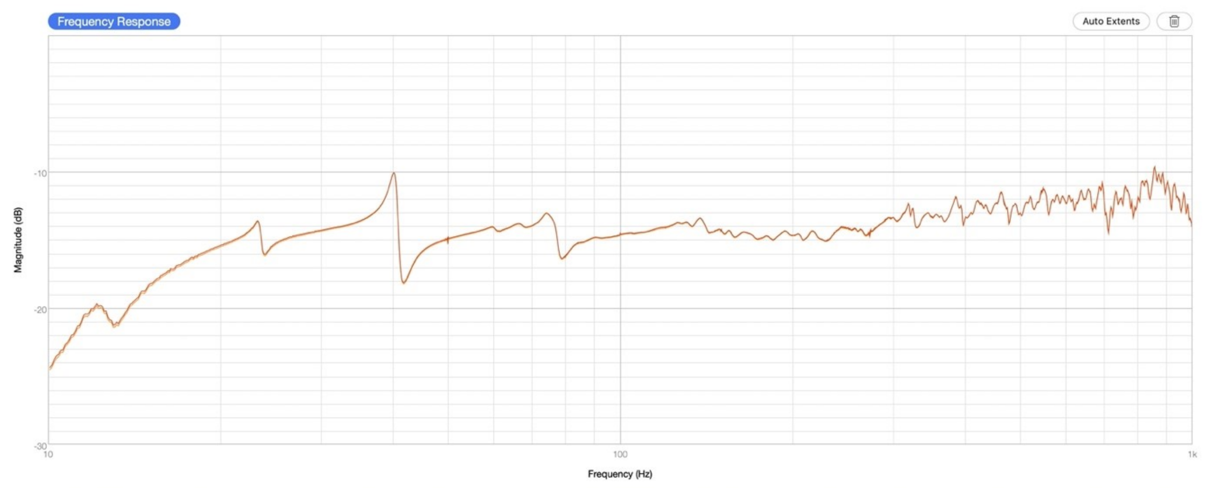
Violet is the measured SPL of the “mode” microphone with exact 5 cm distance to the direct microphone.

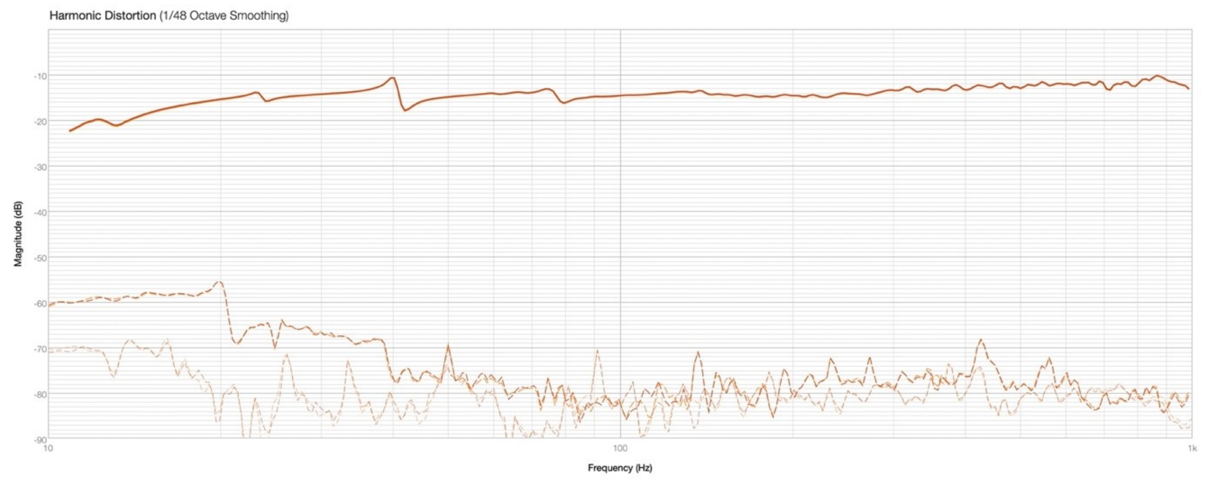
Blue is the mode free SPL frequency response derived from the above two measurements using the ModeCompensator.

Remarks:

- *The visible low-end frequency response is resulting from the loudspeaker under test (15 Hz @ -3dB)*

Calibrated frequency response of the microphones: The SPL frequency response of a Bruel&Kjaer reference microphone is recorded in comparison to the two MEMS microphone channels. Deviations are typically below ± 0.1 dB between 10 Hz and 1 kHz. No smoothing is applied in the below example for the Frequency response plot of the two MEMS microphones.



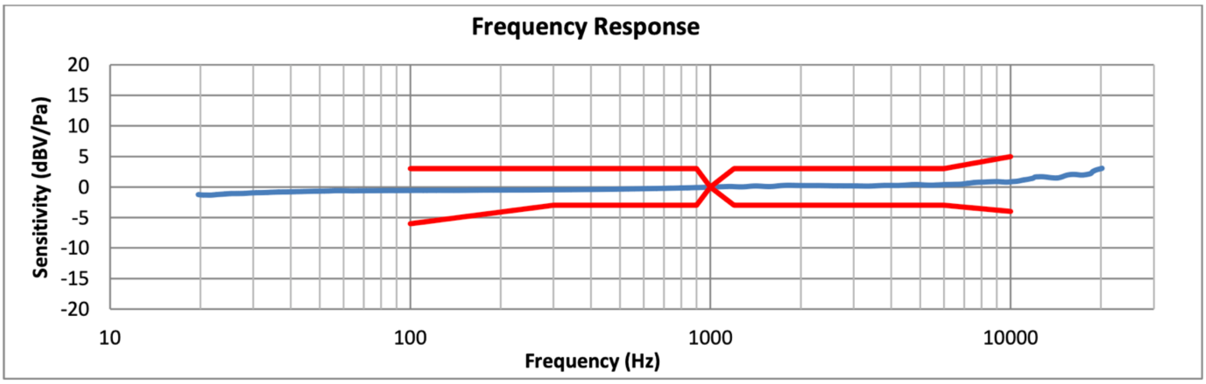


Remarks:

The Frequency responses of the two measurement channels are accurately calibrated with respect to each other. There is no absolute calibration foreseen, as this would be done via the Audio Interface of the measurement system if required.

Do not mix the microphones as each measurement channel frequency response is calibrated individually to its microphone. Always plug microphone 1 to channel one and microphone 2 to channel 2.

The chart below shows for information only the frequency response of the MEMS microphone before calibration of their low-end frequency response



14.2. DIFFERENT COMPENSATION LEVELS

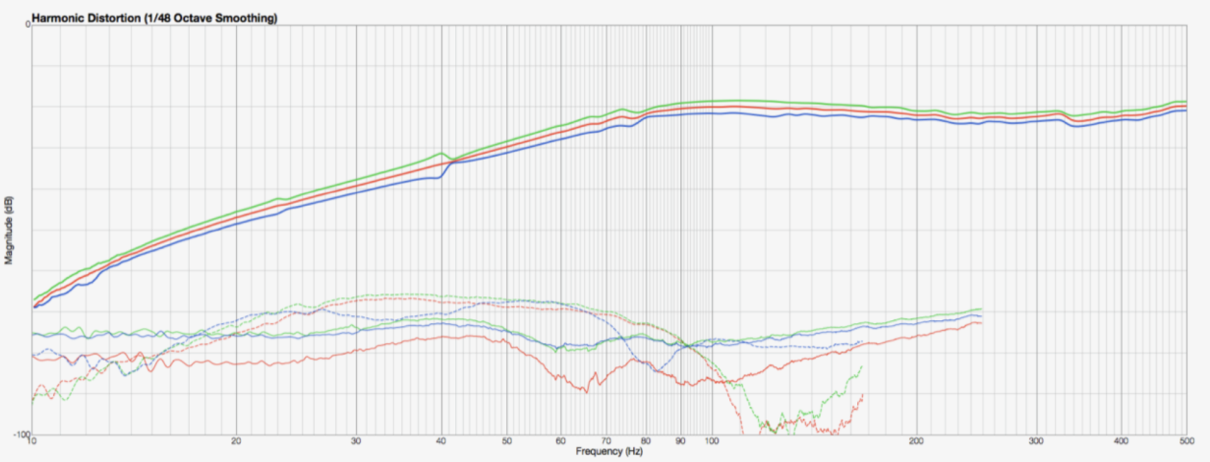
The three SPL frequency response curves show different levels of compensation of the room modes.

Settings: 10 Seconds sweep time, 10 seconds time window resulting in 0.1 Hz frequency resolution.

- **Green** shows an **under-compensation** of the room modes (e.g., at @40 Hz)
  The shape of the room mode shows the same phase as the uncompensated room modes

- **Blue** shows an **over-compensation**.
  The shape of the room mode shows a phase / sign flip compared to the uncompensated room modes

- **Red** shows the **correct compensation** of the room modes.
  Because of the Phase flip the exact compensation can be determined very easily and accurately.



Remarks:

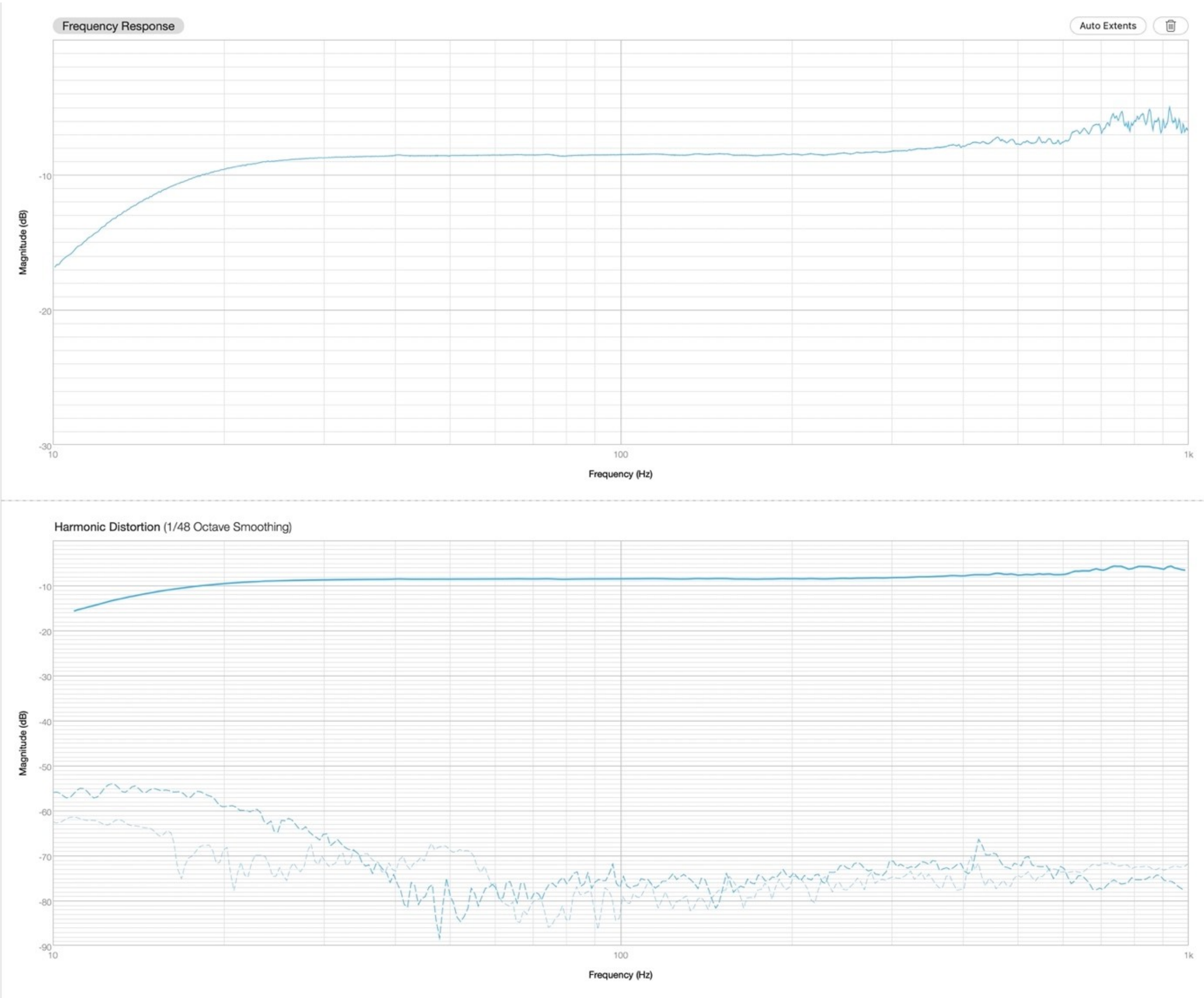
The lines at the bottom of the chart show the harmonic components k2 and k3 of the device under test. Harmonic frequency components are accurately measured up to 1000 Hz too.

In case phase frequency response measurements should be made, the accuracy is within 5 degrees at 400 Hz and 12 degrees at 1000 Hz*.*

14.3. HIGH-END LOUDSPEAKER MEASUREMENT

This example shows the measurement of an AudioChiemgau motion-controlled loudspeaker with a lower frequency limit of 15 Hz @ -3 dB in a standard laboratory

The SPL frequency response is shown in the top chart below at 10 seconds sweep time and 10 seconds time window (0.1 Hz frequency resolution, no smoothing applied). The second harmonics and the third harmonics are accurately measured as well.



Remarks:

The second harmonics is exaggerated at large membrane excursions in every near field measurement because of physics. The phase modulation (Doppler effect), but mainly the Nonlinear Amplitude Modulation (NLAM) due to the relative movement of the membrane with respect to the microphone generate mainly second harmonics in a single frequency measurement. More frequencies would lead additionally to intermodulation products between the frequency components.

The accuracy of a single measurement of the harmonic content may be limited by the dynamic range and by the linearity of the MEMS microphones. See table below, right column for maximum values.

Total harmonic distortion	THD_{NM}	1KHz At 94 dB SPL, Differential		0.03	0.06	%
		1KHz At 110 dB SPL, Differential			0.1	%
		1KHz At 120 dB SPL, Differential			0.3	%
		1KHz At 130 dB SPL, , Differential			2	%
		THD<1% @ 1kHz, Differential		128		dB SPL

For more accurate measurements in presence of noise, averaging may be used. One can expect a reduction of the noise floor by the square root of the number of averages. However, the ModeCompensator eliminates also most of the ambient noise. Such an increased measurement dynamics of about 20 dB can be expected at low frequencies.

15. BLOCK DIAGRAM AND I/O SPECIFICATION

The following figure shows a block diagram and an Input/Output Specification of the Mode-Compensator