MEASURING LOUDSPEAKER MAXIMUM LINEAR SOUND LEVEL ACCORDING TO AES75 WITH CLIO

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Introduction

The AES75-2023 standard[1] outlines a procedure for evaluating the maximum linear sound level generated by a loudspeaker system or driver using a standard test signal known as Music-Noise. This test signal is a pink-shaped random noise with a crest factor that increases with frequency, a characteristic typically found in music programs[2].

The standard employs a live transfer function measurement with coherency calculation to assess the impact of both thermal compression and distortion on the device under test. The driving level is progressively increased until a specified compression or distortion threshold is reached. Subsequently, the test mandates recording the peak sound pressure level produced by the device, using it as a metric for the maximum attainable linear sound level.

Although the essential measurement functions were already present in the CLIO system in earlier software versions, the release of software version CLIO 13 introduces specific features tailored for adopting the AES75-2023 standard. This document will describe these features, along with a step-by-step guide for testing loudspeakers according to the standard using CLIO.

Standard Test Requirements

We assume here that the reader is already familiar with the AES75-2022 standard, which is available from the AES Standards website[1].

Here we will show how to perform the test with the CLIO system using a typical setup.

Basically the AES75 test needs three devices to be carried out:

- Media Player capable of reproducing 48 kHz or 96 kHz wave files
- Transfer Function Analyzer (TFA) with coherency calculation
- IEC 61672-1 Class I Sound Level Meter (SLM)

The CLIO system, using a Class I microphone front end for the SLM measurement, can be used for all roles[2].

CLIO as Media Player

The CLIO hardware can run at 48, 96 or 192 kHz and the CLIO generator is able to reproduce the Music-Noise wave file provided with the standard and act as a Media Player.

The Music-Noise files are freely available for download from the AES Standards

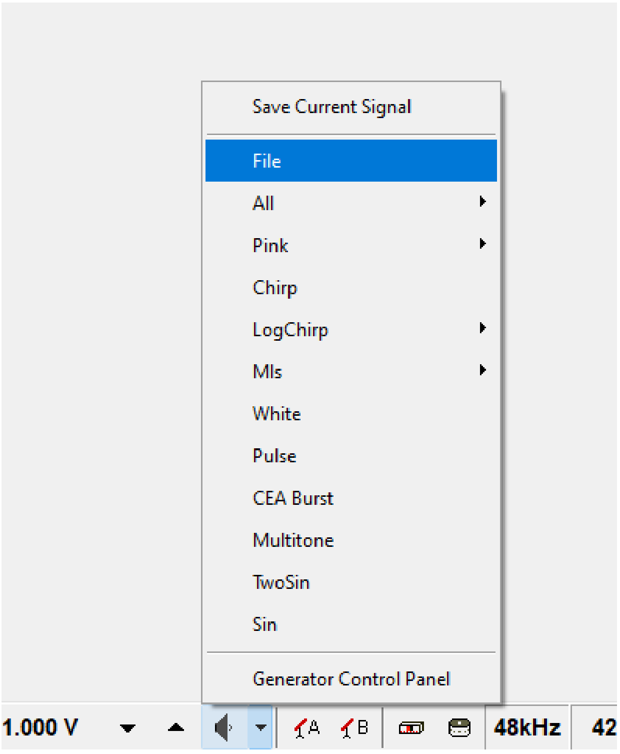
1 https://www.aes.org/standards/AES75/
2 The only drawback is that CLIO hardware has two input channels, and since one channel is already used for the TFA reference signal, the user must switch microphones at the other available CLIO box input when performing SLM measurements.

Website at the following link:

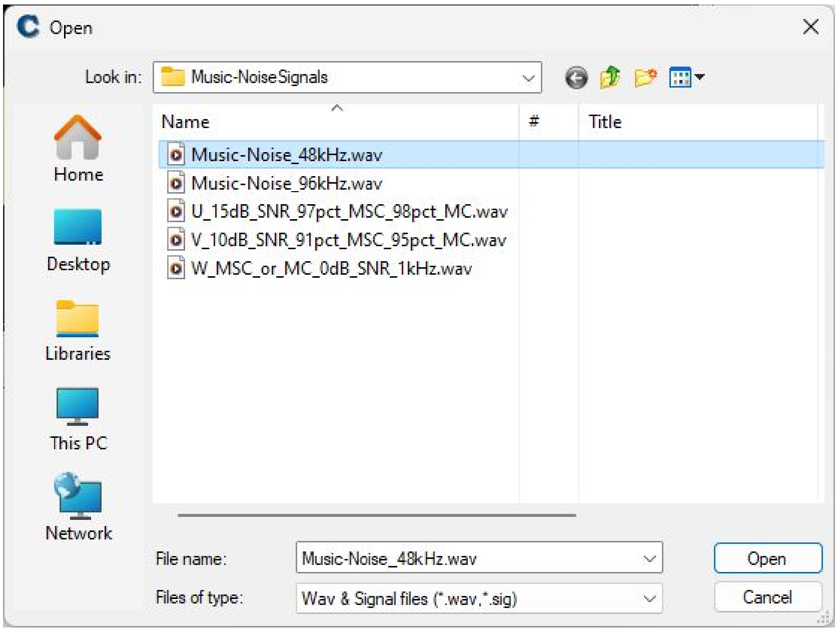
https://www.aes.org/standards/models/Music-NoiseSignals-download.cfm

The download contains a .zip archive with Music-Noise wave files at 48 kHz and 96 kHz plus three other test tracks which can be used to test the TFA. We will use these tracks later to check CLIO TFA implementation and settings.

The Music-Noise can be simply reproduced by CLIO generator using the File option.



And selecting the Music-Noise file:

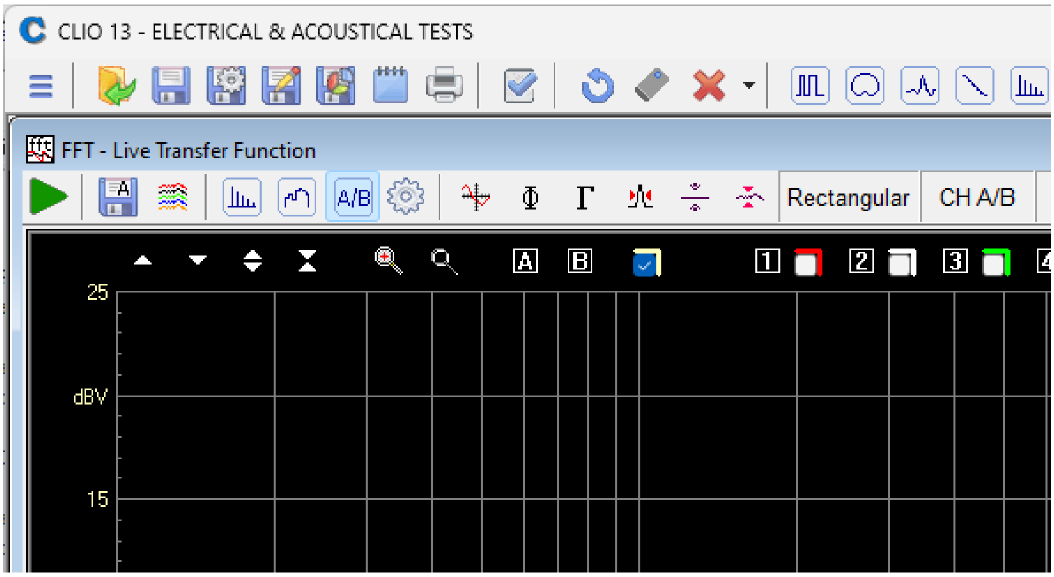


The CLIO generator can source an output level up to 18 dBu (referred to a sinusoidal signal RMS level). When testing professional audio equipment, such as medium to large scale sound reinforcement systems devices, the CLIO output level might not be sufficient to reach the limits of the device under test. In these case it is advisable to use a pre-amplifier stage between CLIO output and the DUT or amplifier input.

The AES75 standard also allows to bandlimit the Music-Noise signal to suit the DUT band limits characteristics. This calls for the need of loudspeaker dedicated signal processor such as a DSP. The device can both provide pre-amplification, lowpass and highpass filtering if needed.

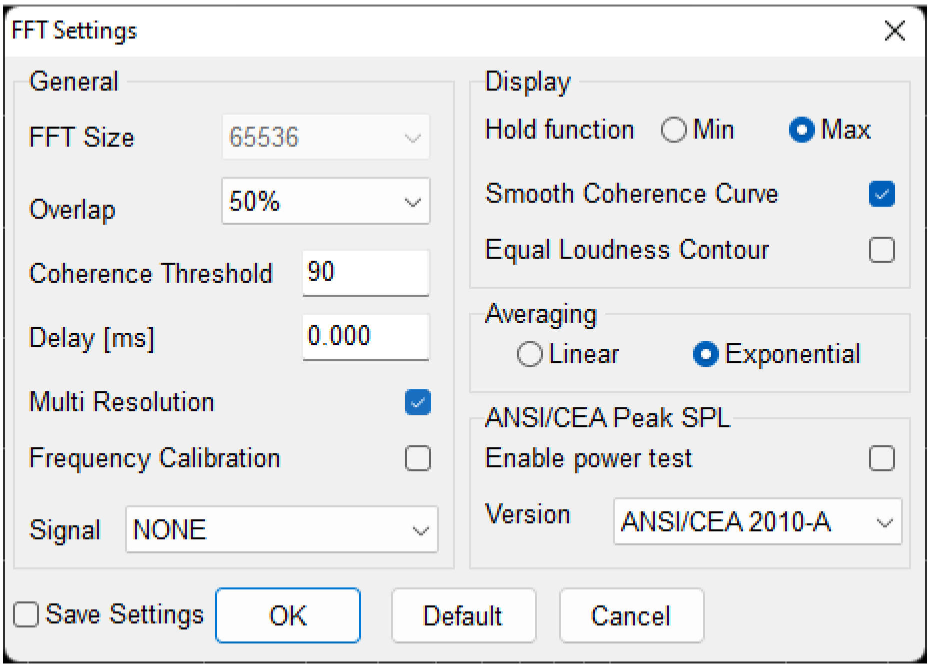
CLIO Live Transfer Function settings

The CLIO FFT measurement menu features a powerful Live Transfer Function analyzer which can be used as TFA.



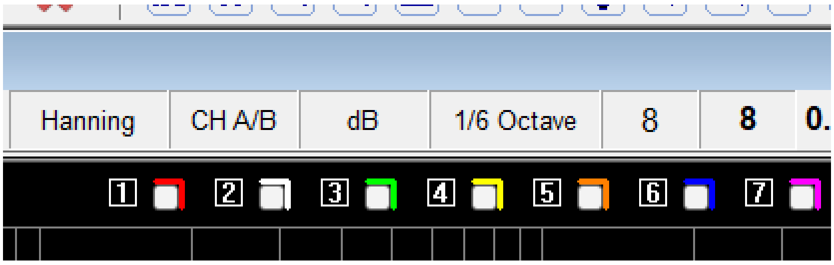
Unlike other software packages on the market, the CLIO TFA implementation is very general purpose; therefore, it has many settings. Some of these settings have been specifically added to support AES75.

The following settings in CLIO FFT – Live Transfer Function, which comply with the AES75 standard, are suggested:



For a proper interpretation of coherency as a distortion detector, it is necessary to choose the Multi-Resolution option in CLIO FFT. This selection ensures that CLIO FFT operates similarly to other standard TFA implementations, utilizing a shorter FFT size for high-frequency bands as envisioned by the standard[2].

The **Overlap** 50% setting has been specifically added to enable coherence in detecting non-linearity. Additionally, the **Hanning window** for the time data must be chosen, along with **8 target averages** and smoothing set to 1/6 of an octave.



According to the AES75 standard, it is recommended to use the 50% overlap and 8 averages settings to accurately detect distortion through coherence while simultaneously capturing time variations in the magnitude frequency response of the device under test.

The total integration time can be calculated from the following formulae:

$$T_{TOTAL} = T \times N - T \times OL \times (N-1)$$

where:

- $T = FFT_{POINTS} \times \frac{1}{F_{SAMPLING}}$ is the analysis time interval length
- OL is the percentage overlap
- N is the number of averages

With the previously shown settings the total integration time with CLIO TFA implementation using 8 averages is 6.14 s at 48 kHz and 3.07 s at 96 kHz.

The analysis time interval length is also in line with the standard's requirement for 1/6 octave resolution at the lowest analysis frequency. With the aforementioned settings, this resolution is achieved from 20 Hz onwards.

CLIO employs the **magnitude squared coherence** calculation for coherence, and this can be confirmed using the Coherence Regime Test Tracks, which are available for download along with the Music-Noise tracks[3]. As outlined in Appendix A of the AES standard, there are three test tracks featuring the reference Music-Noise in the right channel and a distorted signal with specific characteristics in the left channel.

As an example we can try to reproduce and analyze with CLIO TFA the track:

U_15dB_SNR_97pct_MSC_98pct_MC.wav

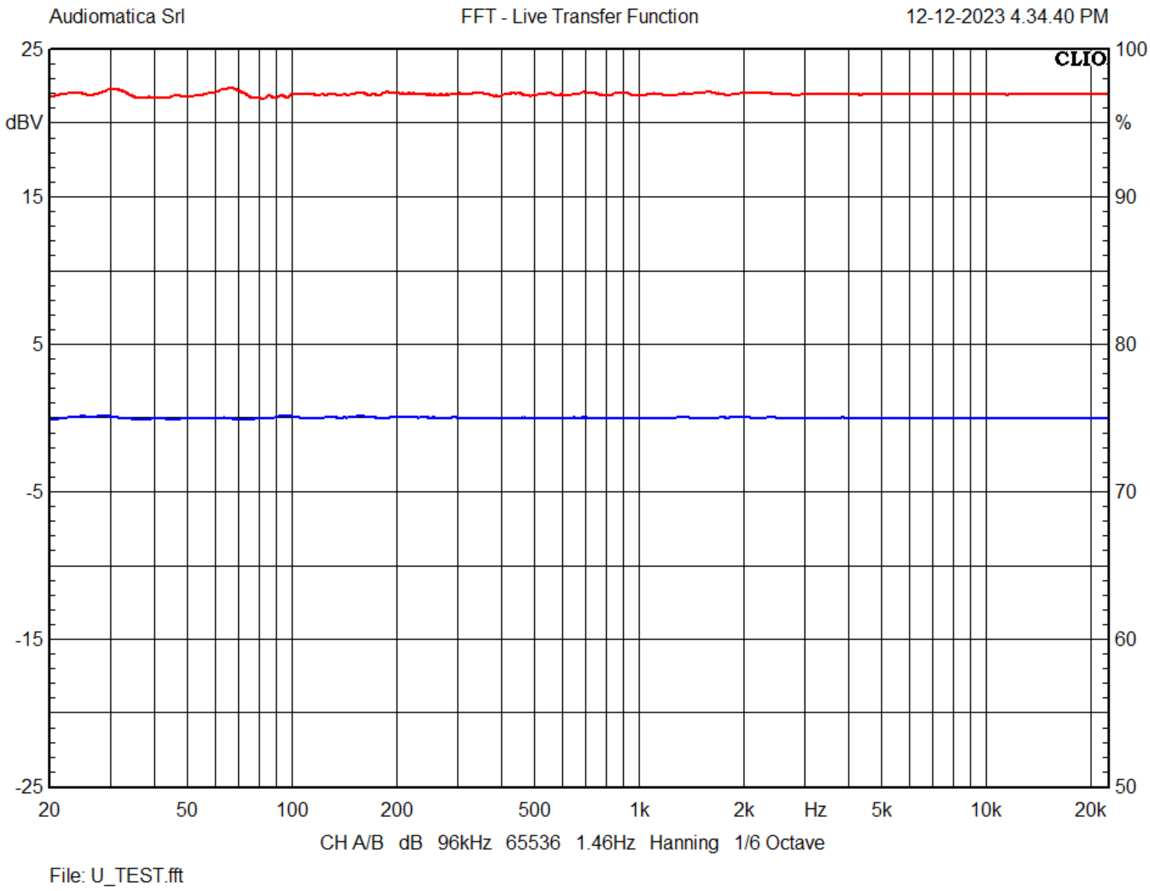
This track should give a 97% coherence reading in CLIO TFA.

We suggest the following steps:

- disconnect any cable from CLIO box inputs and outputs
- set CLIO output level to 0 dBV
- set CLIO input levels of both CHA and CHB to 0 dBV
- put both CHA and CHB channels in loop

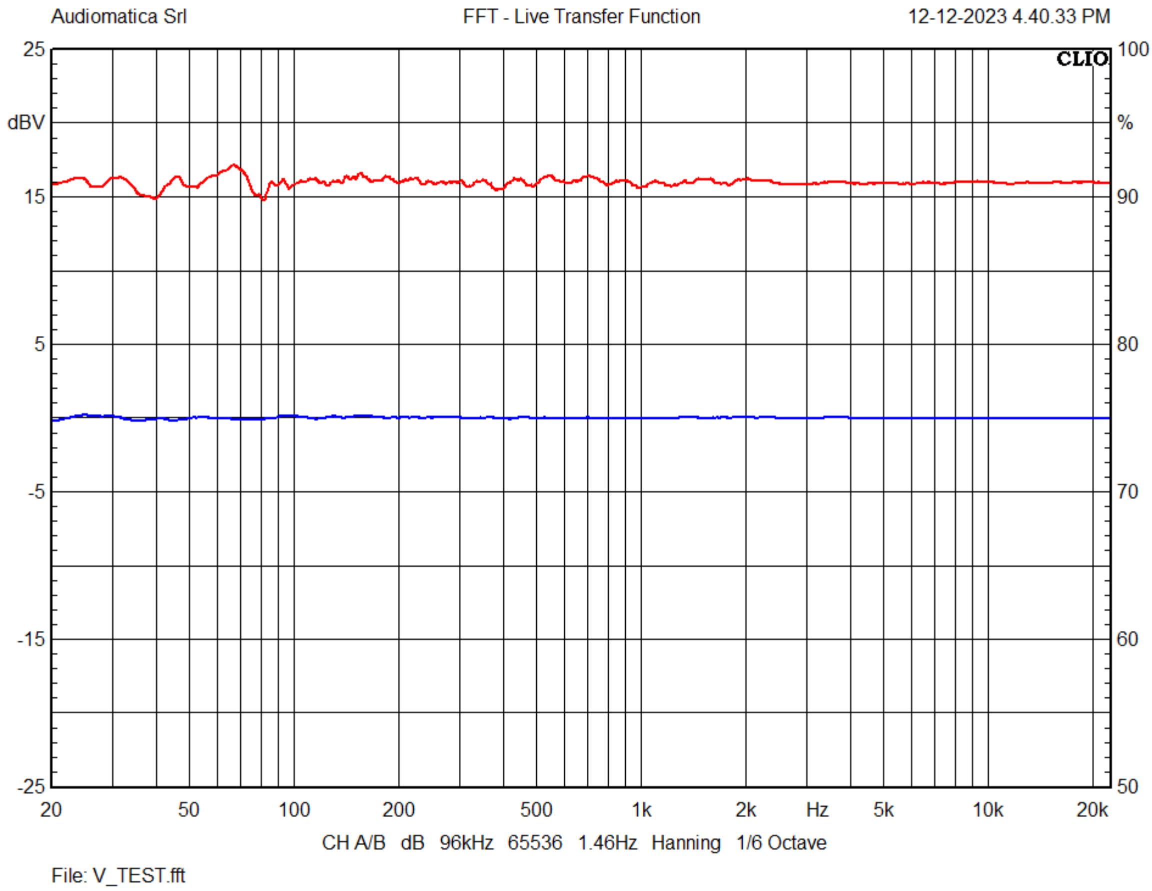
3 The coherence test tracks downloaded from the link https://www.aes.org/standards/models/Music-NoiseSignals-download.cfm are in 24 bit fixed point format which CLIO could not read and have to be converted to a .wav format readable by CLIO. You can download a set of coherence test tracks we already converted to 32 floating point format clicking on the CLIO software menu Help->On Line Resources Download https://www.audiomatica.com/downloadresources.htm.

At this point, the TFA can be run with the coherence reading activated, and you should obtain the following result:

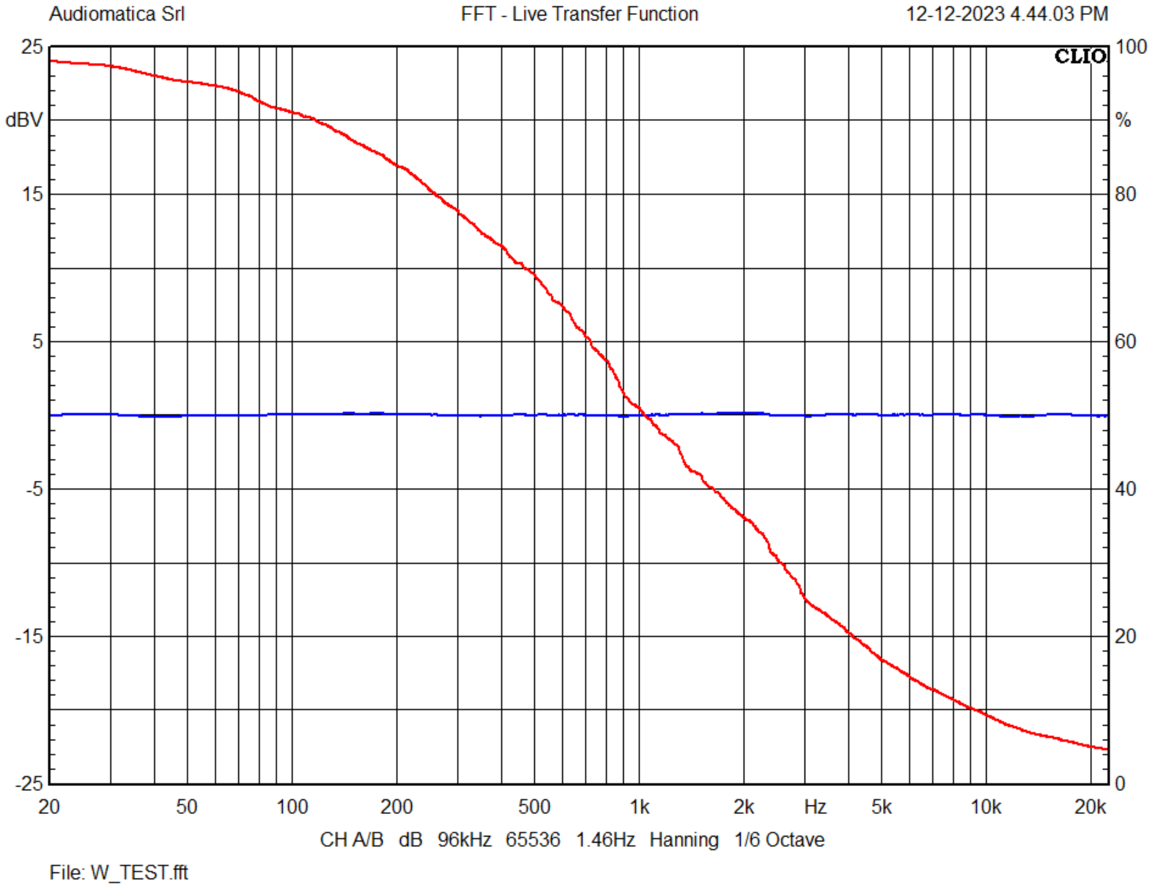


with coherency curve at 97% level.

The file V_10dB_SNR_91pct_MSC_95pct_MC.wav confirms that CLIO uses Magnitude Squared coherence as it reads a coherence around 91%:



And finally the file W_MSC_or_MC_0dB_SNR_1kHz.wav:



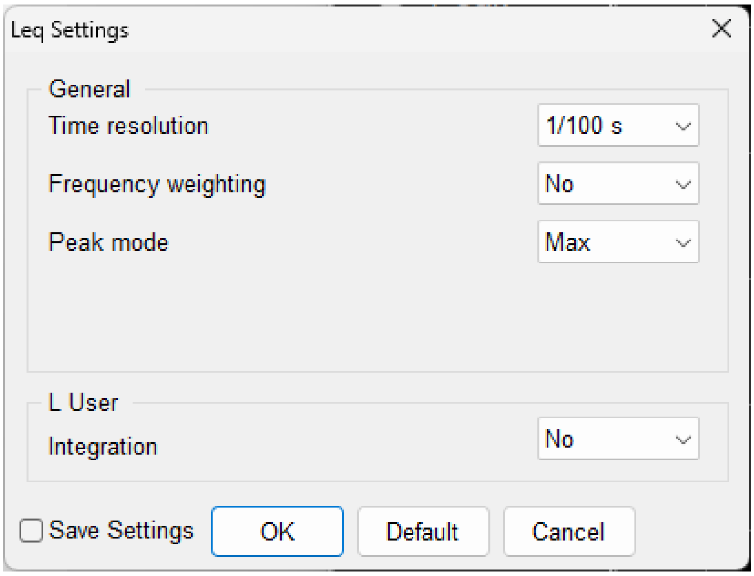
correctly shows 50% coherence at 1 kHz.

We can now proceed with a real world measurement of an electro-acoustical device.

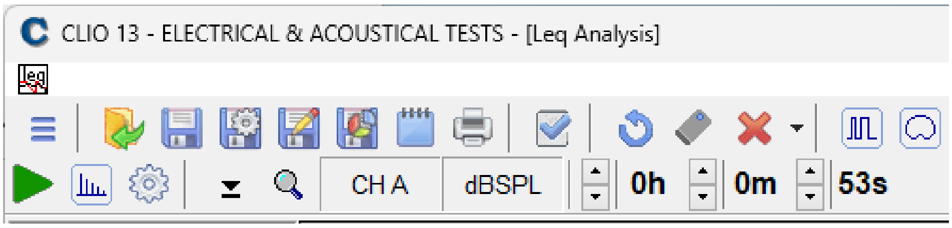
CLIO Leq settings

The AES75 tests require recording the maximum sound pressure level produced by the DUT at the SLM microphone. The maximum non-weighted (Z) sound pressure level with "slow" integration constant L_{ZSmax} and the non weighted (Z) sound pressure peak level L_{Zpeak} shall be recorded for the entire duration of the Music-Noise signal (53 seconds).

The CLIO Leq module can be used to record the sound pressure levels at the SLM microphone. The following options should be used:



The Leq analysis can be setup to last exactly 53 seconds. Selecting the Lslow and peak curves shall directly give the reading of the quantities that need to be recorded for the test.



The only drawback of using the Leq module is its limitation to a 48 kHz sampling rate. If CLIO is employed as both TFA and SLM, we should accept using 48 kHz sampling for the whole AES75 test procedure.

AES75 Test Setup

According to the standard, the test can be conducted without the need for an anechoic chamber. This is possible because the distortion analyzer microphone is in the near field of the source, effectively minimizing the impact of room reflections by the predominance of the direct sound. Addionally, the TFA implementation with multi-resolution FFT further enhances rejection of reflections by employng a shorter time window in the higher frequency bands.

Nevertheless, it is crucial to conduct the test in an environment with low noise levels and low reverberation. The accuracy of distortion detection, which relies on coherence, needs a good signal-to-noise ratio. Even when the loudspeaker operates within its lineare range, the presence of background noise can still impact coherence readings. This concern is especially relevant in small-scale systems, where efforts should be made to minimeze ambient background noise.

The acoustic characteristics of the test environment are crucial, as strong ambient reflections can hinder the identification of an optimal position for the near-field microphone.

Therefore, it is advisable to carry out the AES75 test in a suitable quiet environment and deploy local acoustical absorption around the device under test. This precautionary measure helps mitigating strong reflections from nearby large objects or boundaries.

Furthermore, it's crucial to acknowledge that the sound pressure level in the testing environment may surpass safety thresholds.

It is recommended to utilize appropriate personal protective equipment, such as protective headsets, during the test.

Additionally, careful consideration should be given to the potential disturbance of noise to surrounding environments.

In this example we will show the AES75 test of a small Hi-Fi passive two-way loudspeaker box.

We are going to use a very simple setup with a CLIO Standard system and a single class I 1/2 inch microphone directly powered from CLIO fw-02 phantom power.

The same microphone will be used as Transfer-Function microphone and Sound Level Meter microphone. This will require to move the microphone during the various phases of the tests, which is an inconvience, but will also reduce hardware costs by using a single microphone.

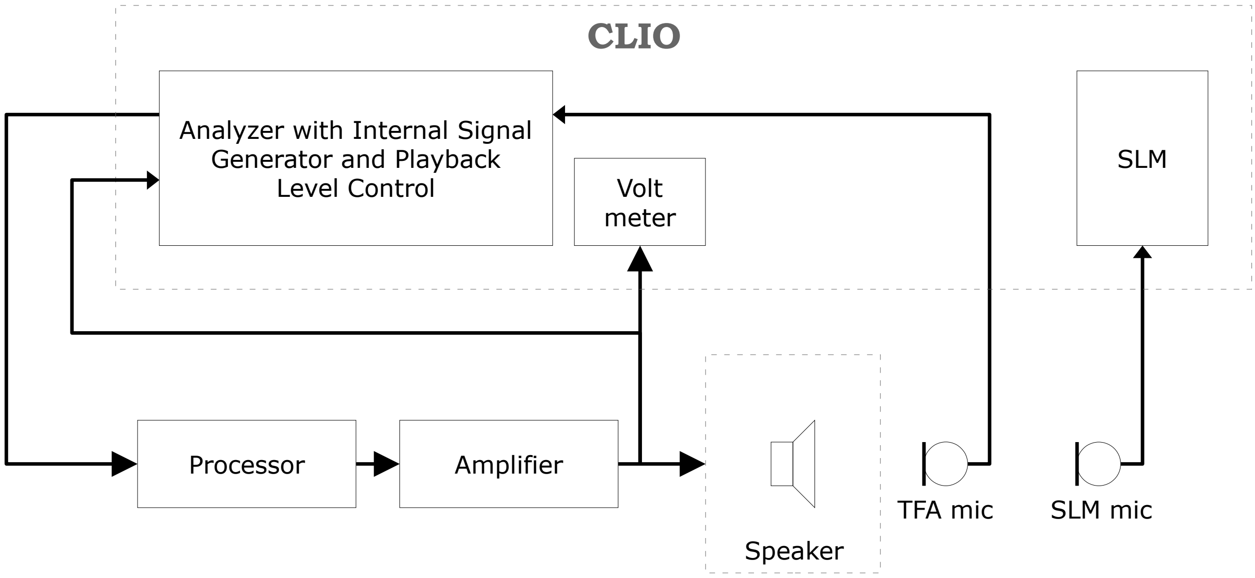
Our test setup is as follows:

- CLIO fw-02 system with CLIO standard software
- Class I 1/2 inch measurement microphones
- DSP Loudspeaker Processor
- Two way loudspeaker DUT

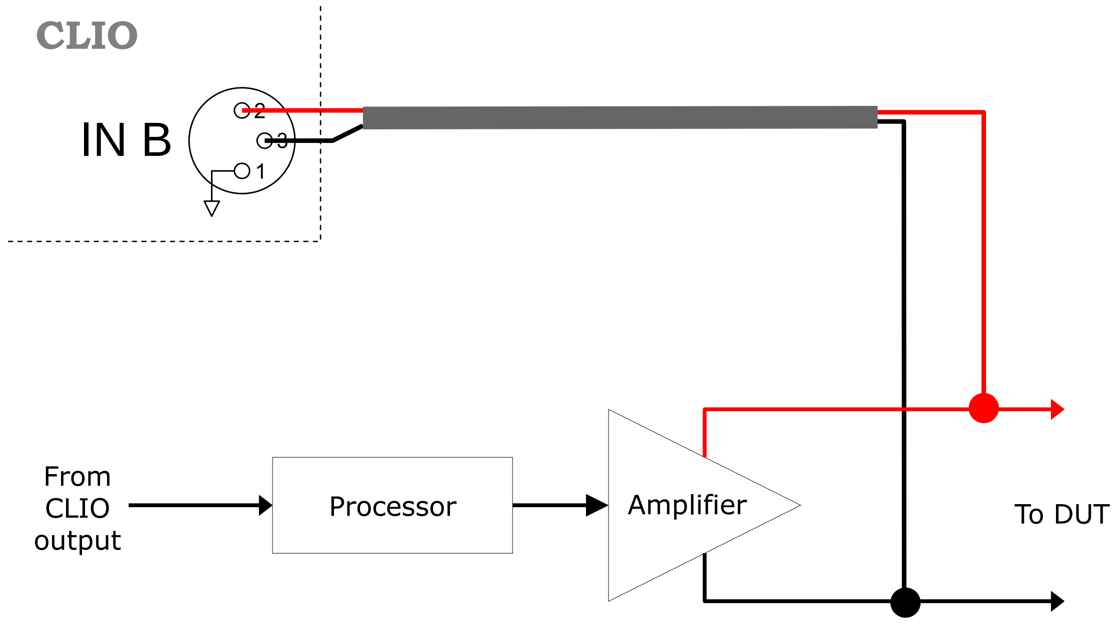
The test has been carried out in an office with limited space available, as previously stated the example shown here is just a proof-of-concept of how to perform an AES75 test using CLIO. A proper laboratory scenario with a larger footprint is advisable.

A schematic of the test connections is reported in the next figure. CLIO here acts as:

- Generator
- TFA Transfer Function Analyzer
- SLM Sound Level Meter
- Voltmeter



It is recommended to use a cable with the following scheme to connect CLIO IN B to the amplifier output:



This setup helps avoid ground loops and provides a differential input, which allows measuring amplifier with various output stages topologies.

The DUT is mounted on a standard loudspeaker pole at about 150 cm from the floor. The TFA microphone is placed at a close distance (10 cm), whilst the SML microphone is placed at 1 meter. Both TFA and SLM microphones are placed at the height of the DUT's tweeter. As instructed by the standard both TFA and SLM should be able to handle the sound pressure levels expected by the DUT at their respective locations.

The devices we are using in this example to pilot the passive loudspeaker DUT are a t.racks DSP 204 processor and t.amp S100 mk2 amplifier. Both devices are capable to drive our specific DUT up to its limits, before running an AES75 test of an active or passive device you should check that there are no bottlenecks which can limit the signal fed to the DUT. In our case, since we are testing a passive device, we should check that the amplifier linear range is sufficient to reach the AES75 stop conditions. This is not trivial because of the high crest factor of the Music-Noise test signal.

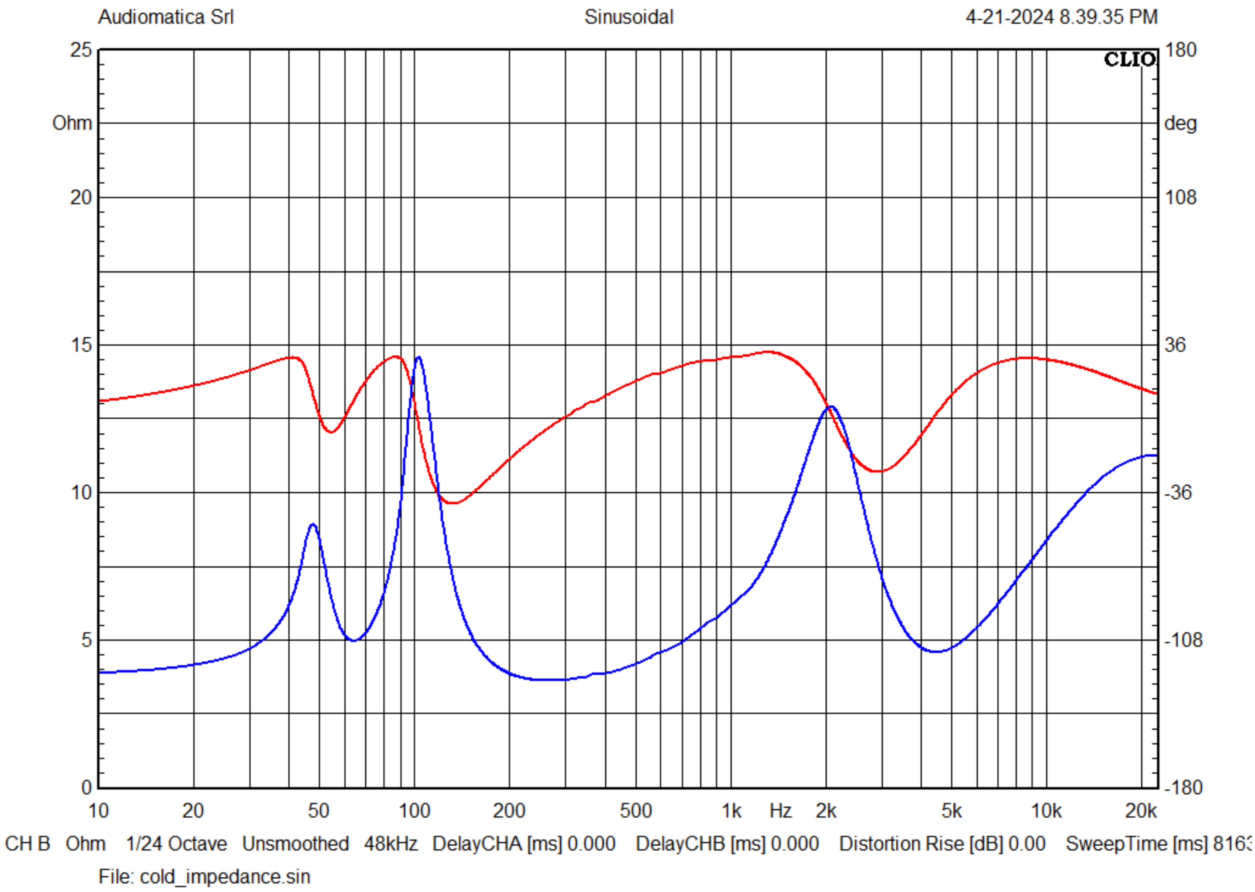
The specs of the DUT which will be tested in this example, as declared by the manufacturer, are:

- Two-way passive system with bottom bass-reflex port
- 4 inch woofer and 1 inch dome tweeter
- 8 ohm nominal impedance
- 86 dB peak SPL
- 20-60 W power handling

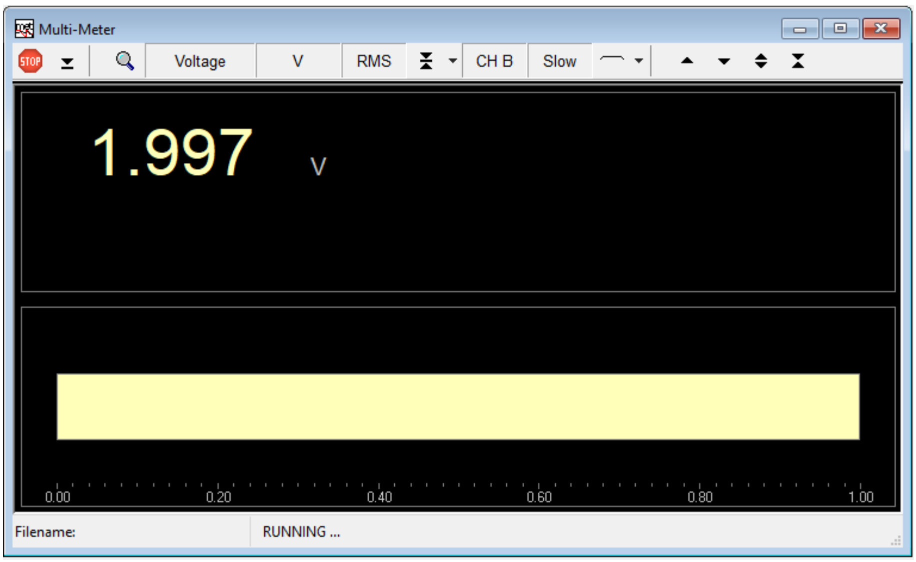
The data sheet does not report any information on how the declared peak SPL is specified and what does the 20-60 W power handling means. Nevertheless we should rely on this data to figure out which starting level to use for our AES75 test and which are the levels we expect to measure at the end of the test.

Following is a picture of the DUT and TFA microphone, red lines are projected from a laser level which is useful to setup and move the single microphone we are using between the TFA and SLM positions.

We can begin by measuring the DUT impedance at rest and in thermal equilibrium with room temperature (20 °C) before proceeding with the AES75 test.



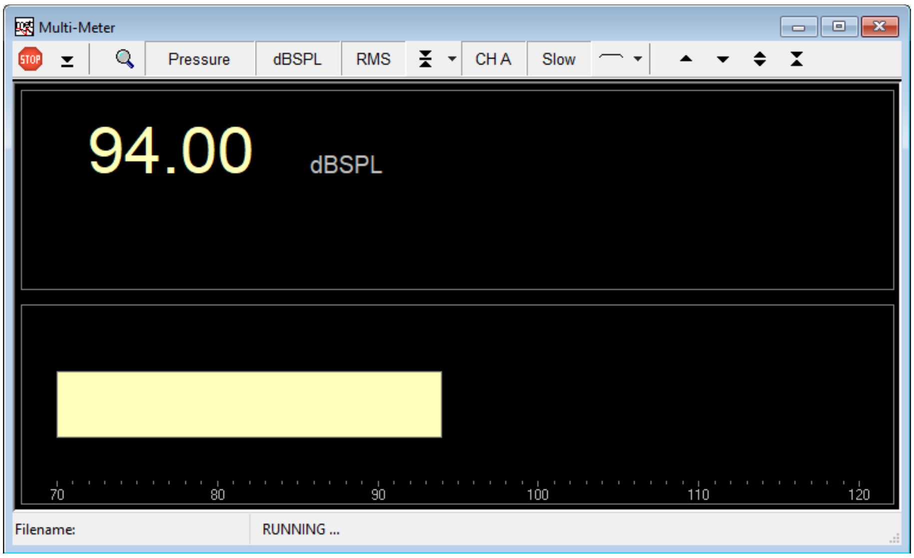
We should also characterize the gain of the amplifier and DSP processor chain. This can be done by generating a 100 mV 1 kHz sinusoidal tone and measuring the amplifier output using the CLIO Multimeter on input CH B.



The processor plus amplifier gain is 20 (26 dB).

In this example we will use the 48 kHz Music-Noise signal, although the preferred sampling rate according to the AES75 standard is 96 kHz. While the CLIO generator and TFA can operate at 96 kHz, the CLIO Leq module is limited to a sampling rate of 48 kHz. To streamline the procedure and avoid switching sampling rates during the test, we have opted to mantain a consistent 48 kHz sampling rate throughout the process.

Using a Class I microphone calibrator we ensure that the microphone sensitivity is properly configured in CLIO.



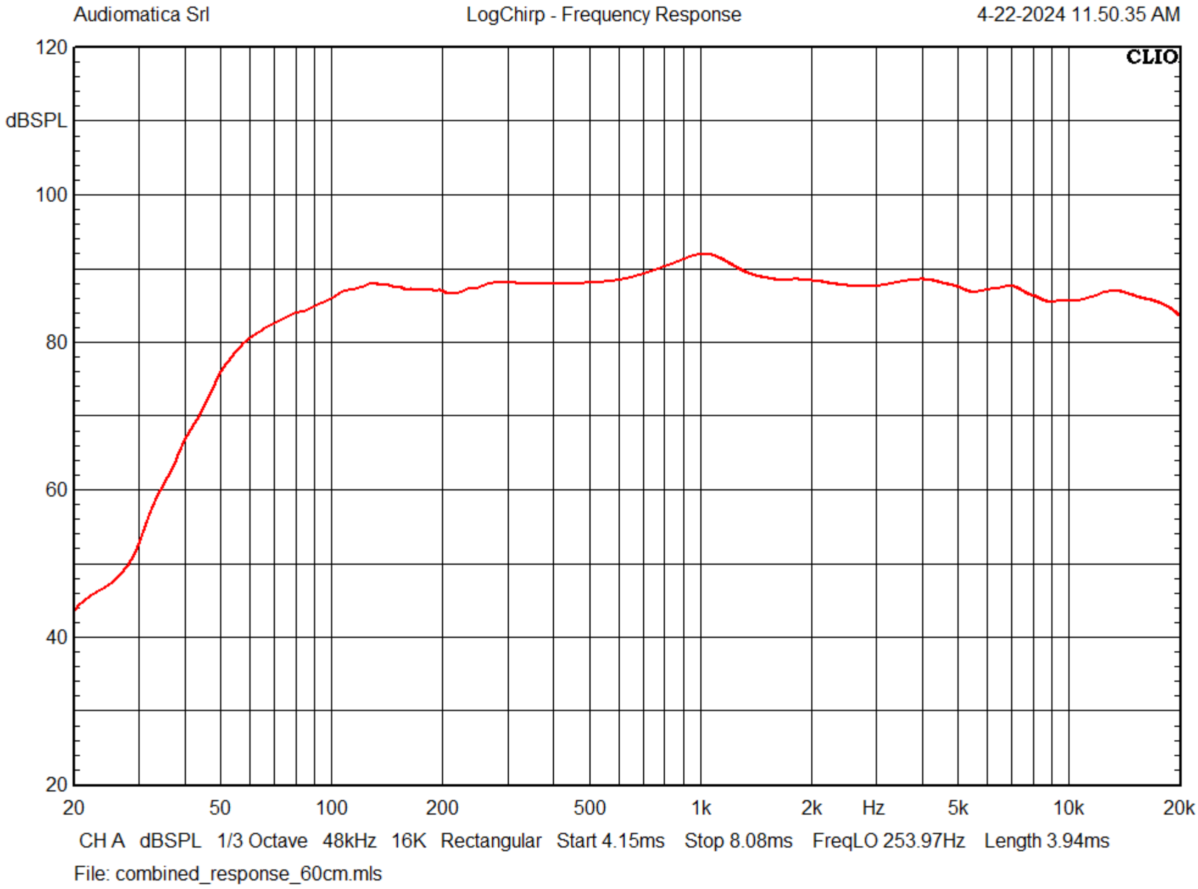
At this stage, we are nearly ready to start the AES75 test procedure. One decision we need to make is whether to apply a band-limiting filter to the Music-Noise signal or not. The standard allows for some flexibility to tailor the test to different scenarios. Since the DUT in this example is intended to be used as a full-range device, we have decided to not apply any band-limiting. However, if the same device is intended to be used with the addition of a subwoofer and would normally be high-pass filtered, then in that case, a more representative figure for maximum output might be obtained by AES75 test using an high-pass filtered version of the Music-Noise signal.

Running the AES75 test

The procedure requires to place the near field TFA microphone in a close position in respect to the DUT in order to meet the 97% coherence and 15 dB SNR criteria.

To determine the correct position, the far field anechoic response of the DUT needs be measured. Due to the limitation of our office environment, we conducted an on-axis measurement at a distance of 1 meter using a combination of a far field (1 m) and a near field frequency response measurement. This approach is detailed in Joe D'Appolito's paper "Measuring Loudspeaker Low-Frequency Response", which is freely available on Audiomatica's website [3].

The on-axis response at 1 meter, using the tweeter position as a reference point, of the DUT loudspeaker with a 2.83 V sinusoidal stimulus is depicted in the following figure:



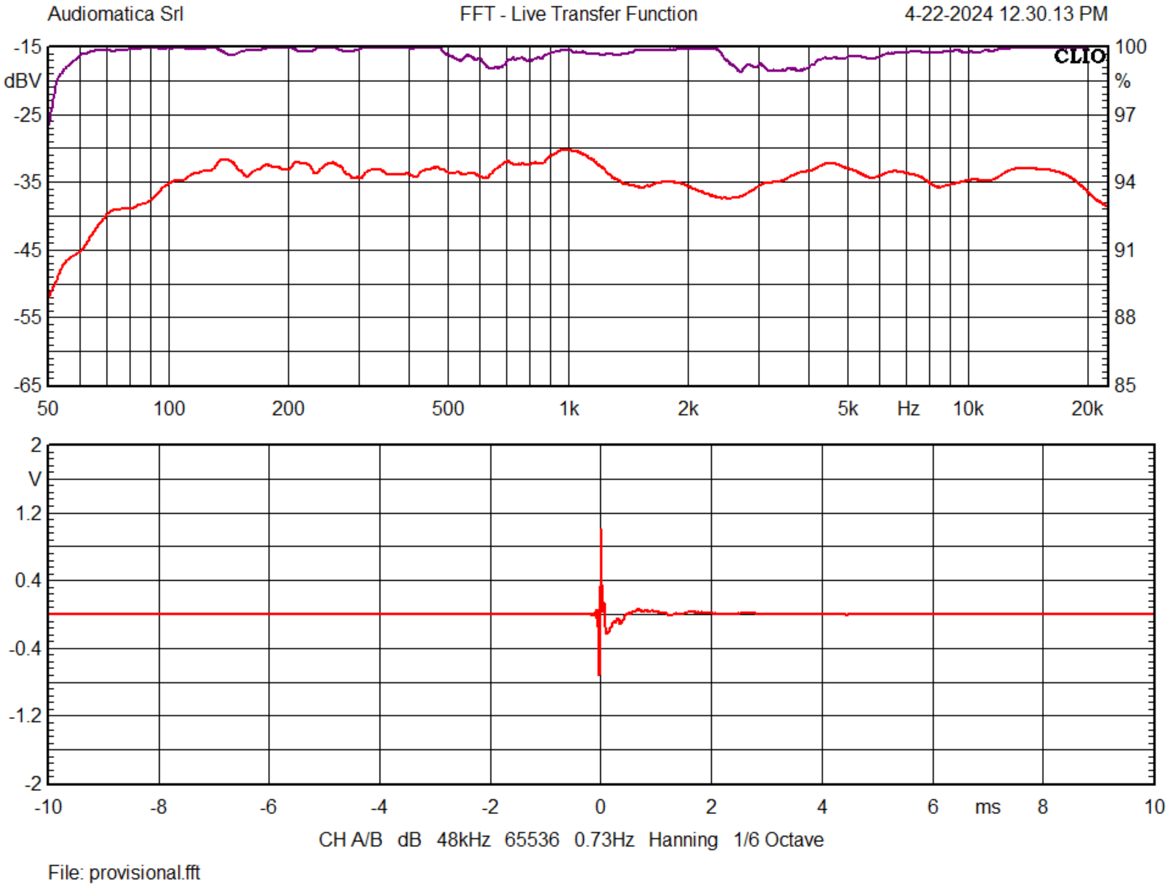
Now we place the microphone back to the TFA poisition. Next, we can activate the FFT Transfer Function measurement using the settings described earlier for the TFA, ensuring compliance with the AES75 standard.

After activating the coherence plot, we should set the y-scale limits from 85 to 100%. The graph will display grid lines also at the points of interest: 97% and 91% coherence.

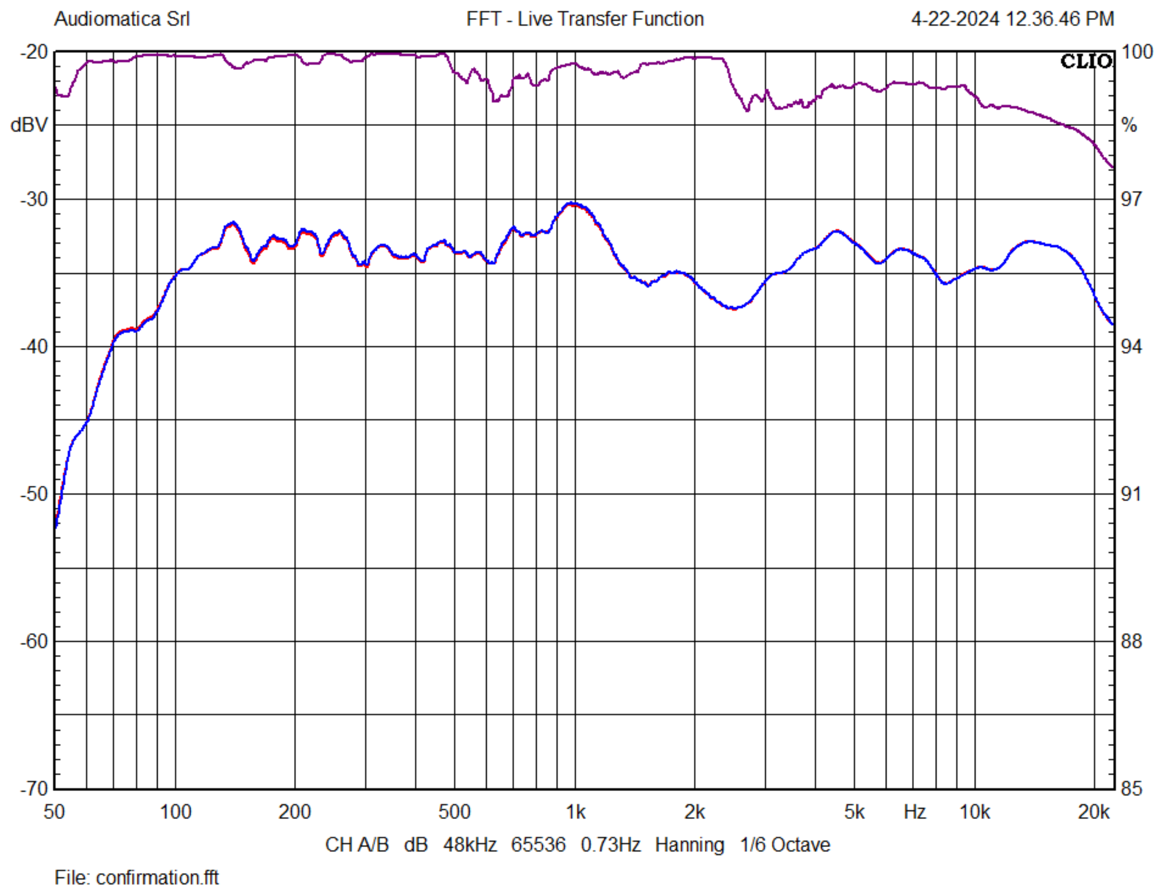
Selecting the 48 kHz Music-Noise signal, we can activate the CLIO generator with a 0.2 V amplitude output level. Considering that the Music-Noise signal has an overall crest factor of about 18 dB, the RMS level at the DUT will be approximately 0.5 V. This voltage level is considered safe for the DUT and ensures that the SPL output is sufficiently above the ambient noise level.

We can now capture the Interchannel Delay and check the resulting frequency response.

After testing several positions for the TFA microphone, we settled on a position 15 cm in front of the DUT tweeter. This positioning provides a response that closely matches the far-field response, with a coherence greater than 97%.

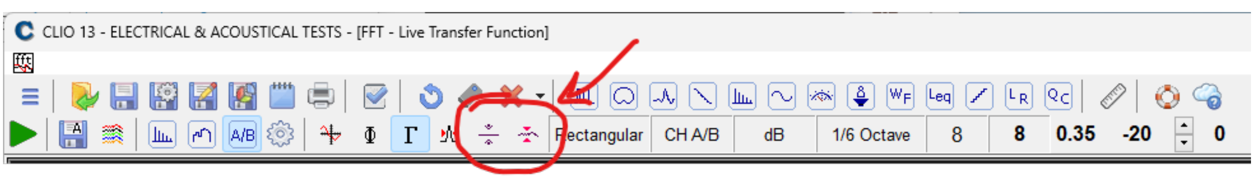


We can save this measurement as "provisional.fft". Next, we can then increase the level by 6 dB (as the standard requires at least a 3 dB increase) and continue measuring the transfer function. Finally, we can save the measurement as "confirmation.fft".



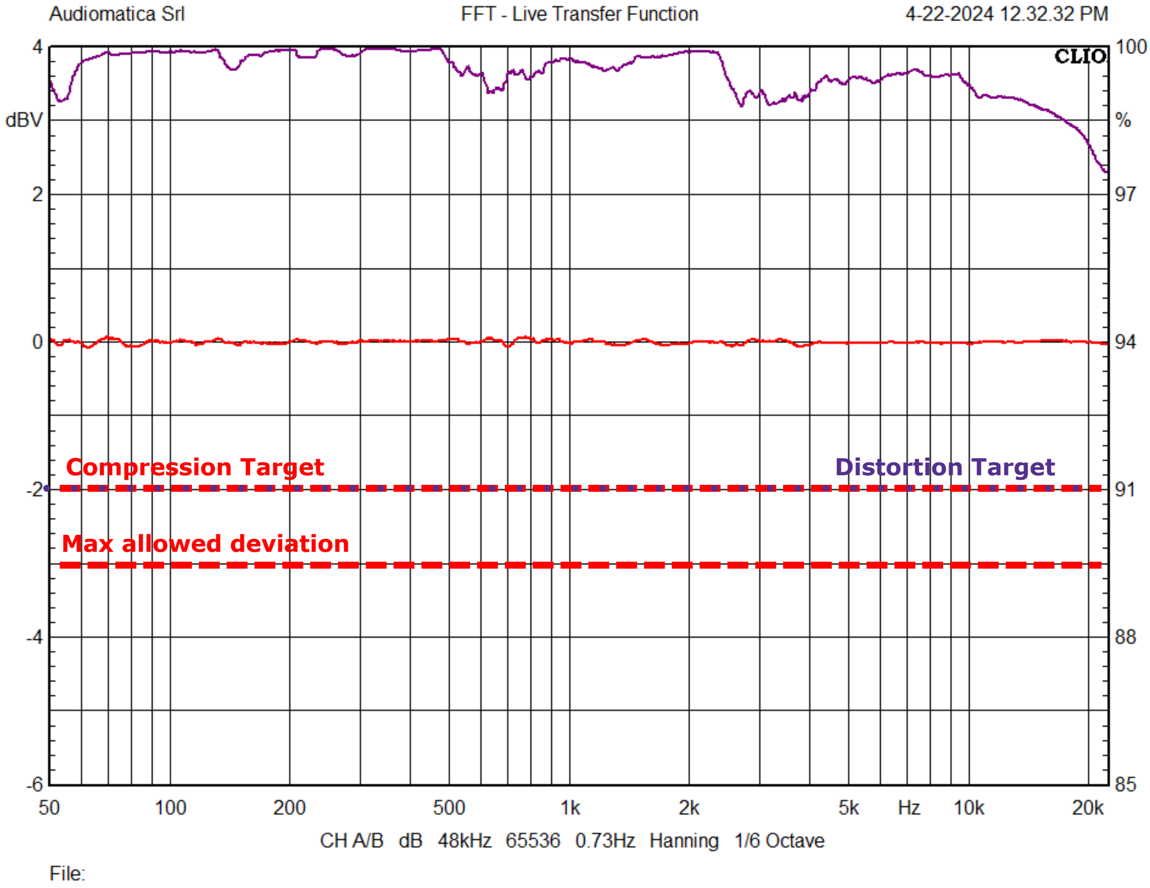
This measurement serves as the starting point and reference for the entire procedure. It's important to ensure that the responses of the provisional and confirmation measurements do not deviate by more than 1 dB, and that the coherence remains above 97%.

Since both conditions are met, we can proceed. The confirmation measurement represents the "linear" response of the DUT. We can now use the "Get Reference Curve" and "Show Relative Curve" buttons to acquire this linear response and then focus on the deviation of the response from the linear condition (confirmation measurement).



Now, we can adjust the y-axis zoom to examine small deviations from the linear response. One option is to select a 10 dB range from -6 dB to 4 dB. This setting ensures that all the stop conditions of the AES75 test are easily visible:

- A 2 dB deviation from the linear response of the DUT over at least two octaves
- A 3 dB deviation from the linear response of the DUT anywhere
- Coherence falling below 91% anywhere



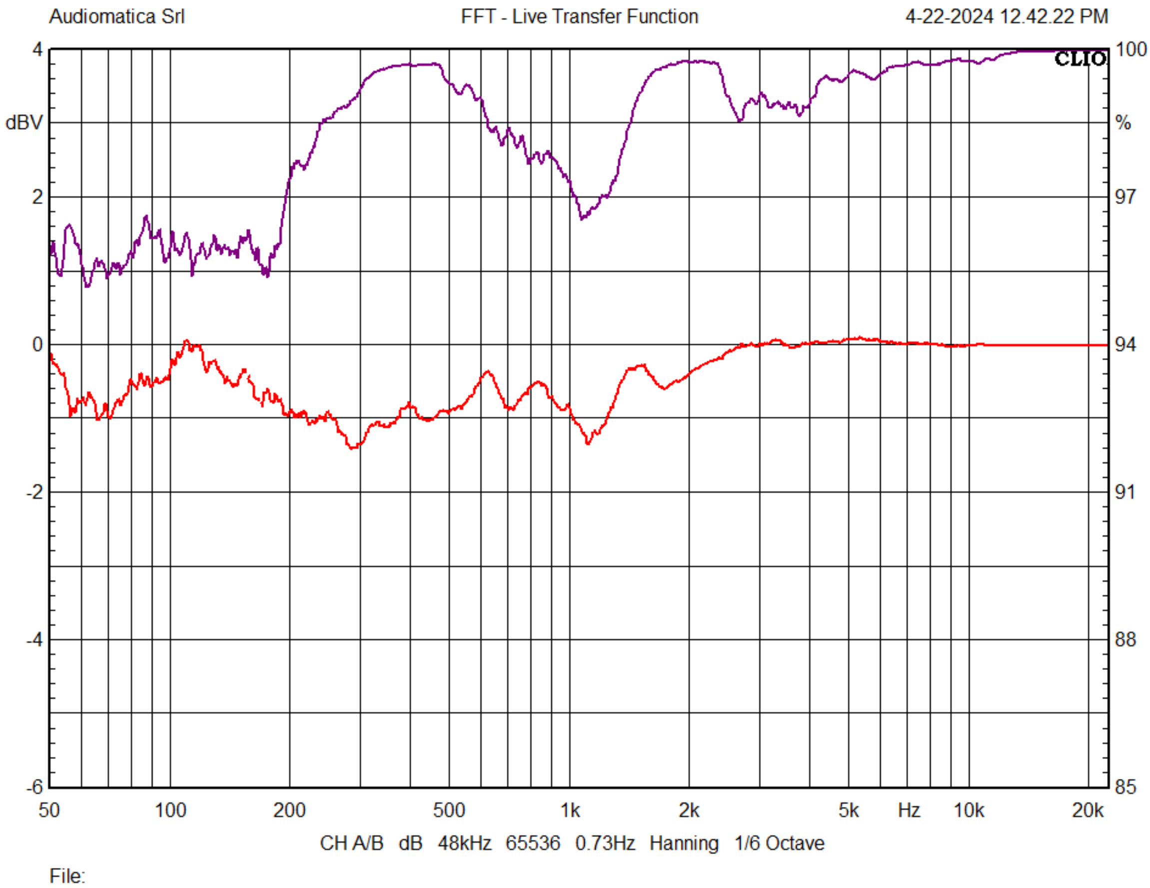
The AES75 test ramp-up process can now commence. Initially, the driving level is stepped back 2 dB from the confirmation level, and then increased at a rate not exceeding 1 dB per minute, particularly when within 10 dB from the stop condition

The CLIO generator level can be increased in 1 dB steps using the F8 key shortcut. During the test, attention should be given to checking the input level of both CH A and CH B. If there is any overload detected in either the CH A and/or CH B input, the channel input full scale should be increased by 10 dB. This adjustment can also be made using keyboard shortcuts F9 and Shift+F9.

Action	Keyboard Shortcut
Increase output level by 1 dB	F8
Increase output level by 0.1 dB	Shift+F8
Reduce output level by 1 dB	F7
Reduce output level by 0.1 dB	Shift+F7
Increase CH A Input Full Scale +10 dB	F9
Reduce CH A Input Full Scale -10 dB	F10
Increase CH B Input Full Scale +10 dB	Shift+F9
Reduce CH B Input Full Scale -10 dB	Shift+F10

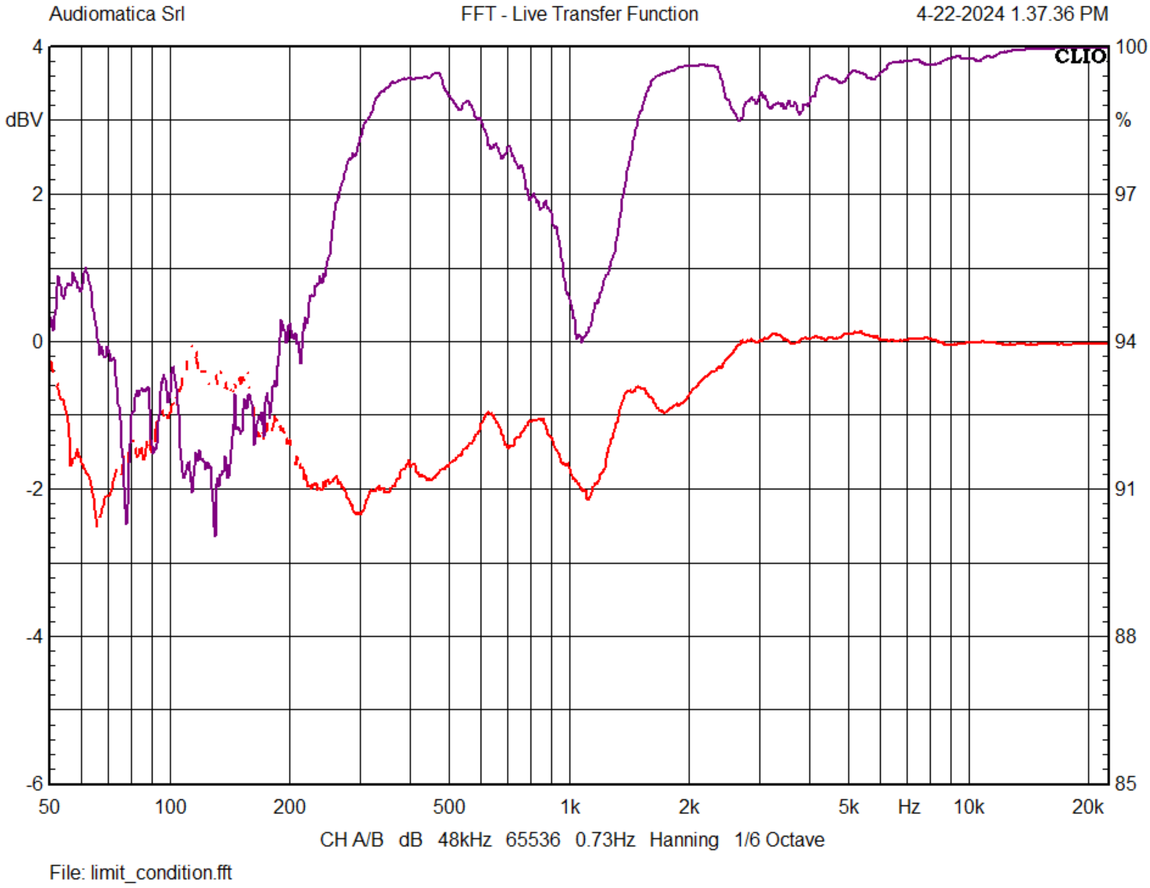
During the AES75 test, it is advisable not to use Input level autorange, as the crest factor of the Music-Noise signal could potentially induce endless limit cycles in input level control.

This is the situation about 10 minutes into the AES75 test, with the CLIO output level increased by 15 dB over the confirmation level.



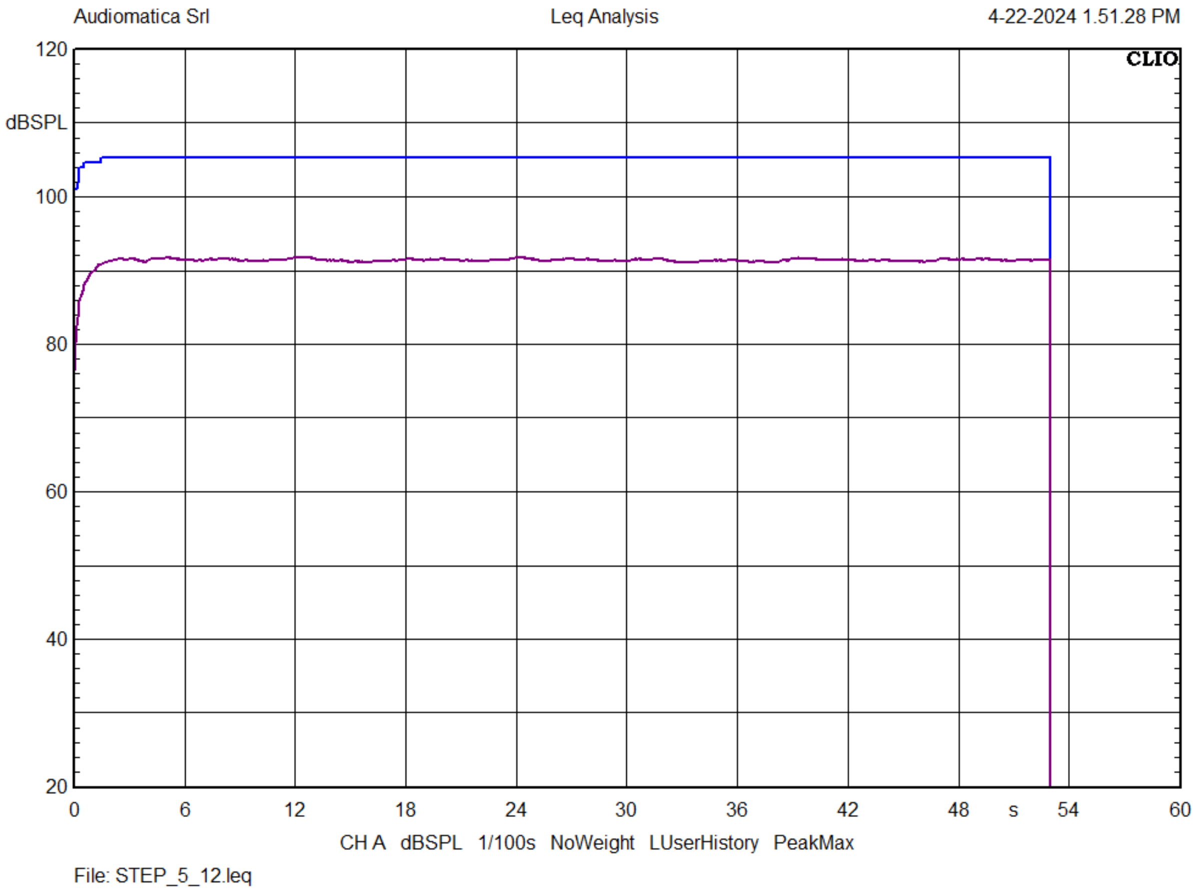
The power compression of the woofer driver is clearly evident in the deviation of the frequency response compared to the provisional "linear" level. Additionally, distortion is increasing in the low-frequency region.

After three more dB of level increase, the limit condition is reached:

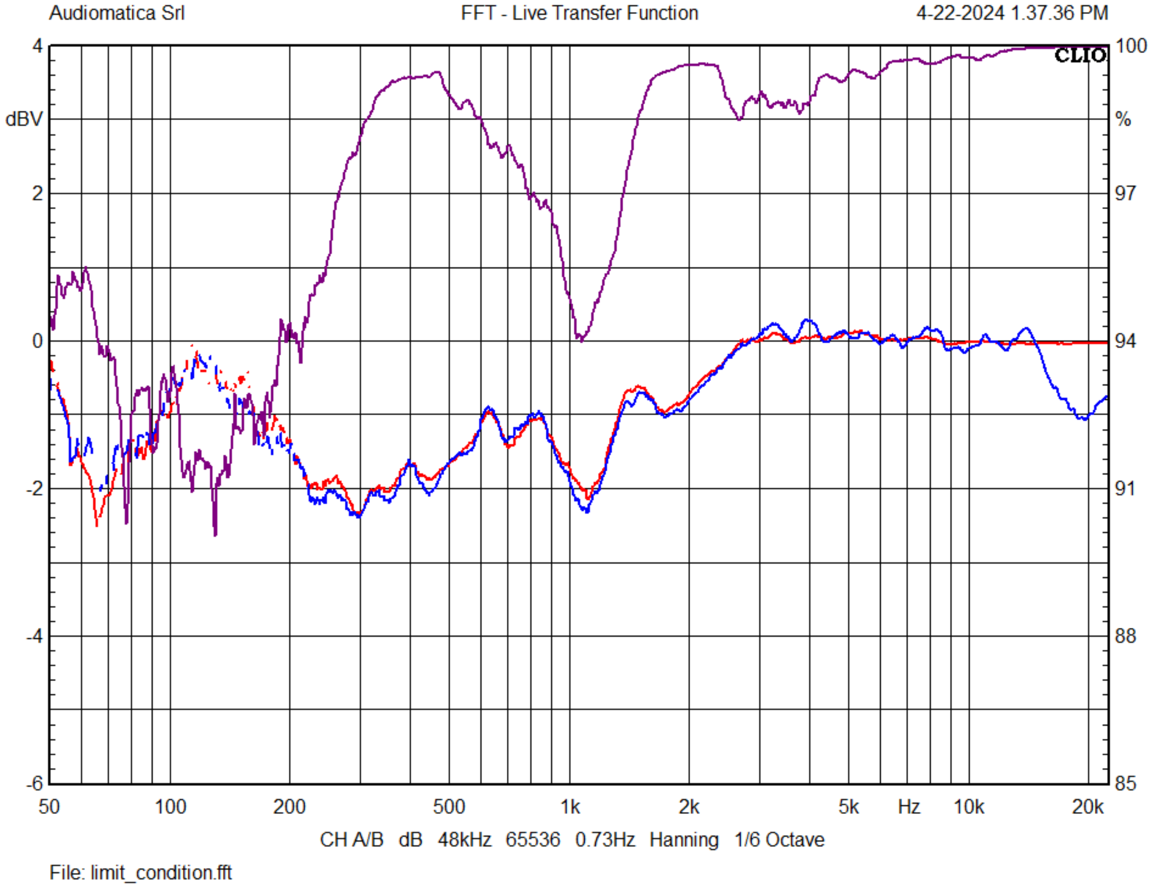


It appears that while the coherence reduction target is being met, the 2 dB power compression stop condition is also about to be reached.

Now we can move the microphone at 1 m, which is our position for the SLM microphone. Using CLIO Leq menu, we can measure the L_{ZSmax} and L_{Zpeak}. The measurement lasts for exaclty 53 seconds, which matches the period of the Music-Noise signal, ensuring that we do not miss any peaks in the signal.

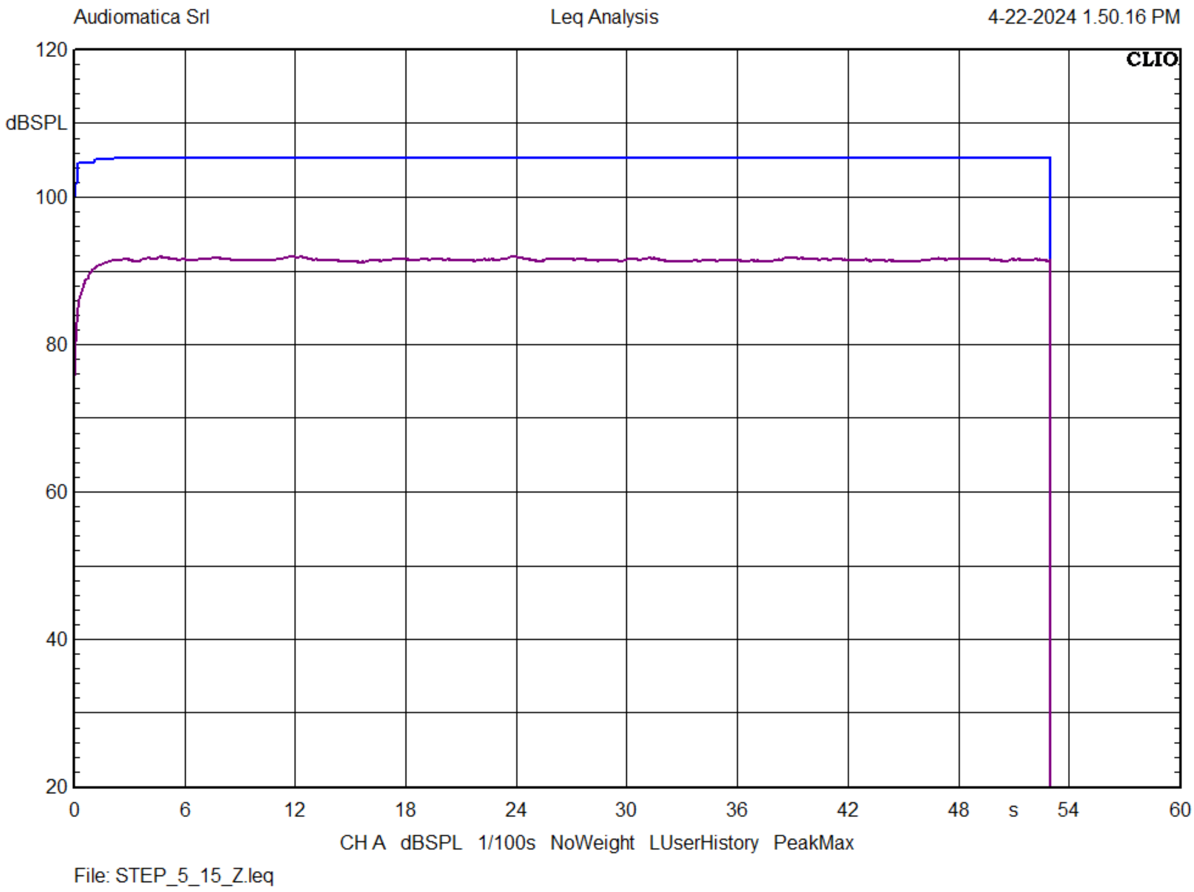


At this point, the AES75 procedure requires us to continue reproducing the Music-Noise at the same level and check for any deviation from the previously measured frequency response at the stop condition. After five minutes, we can compare the curves.

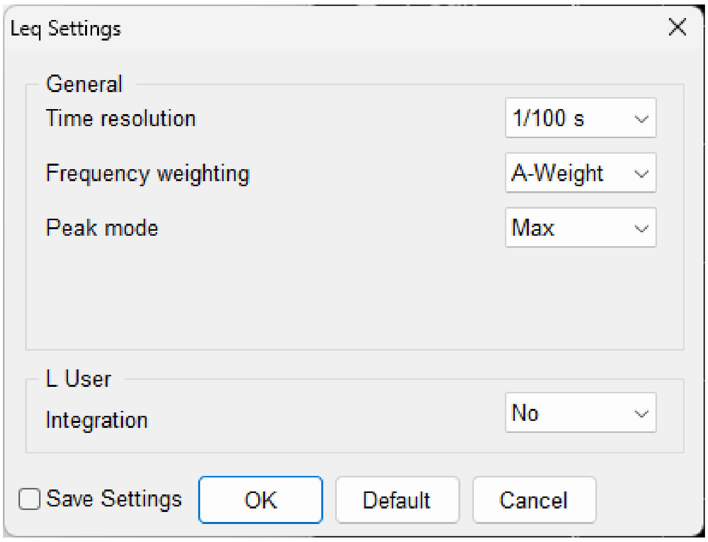


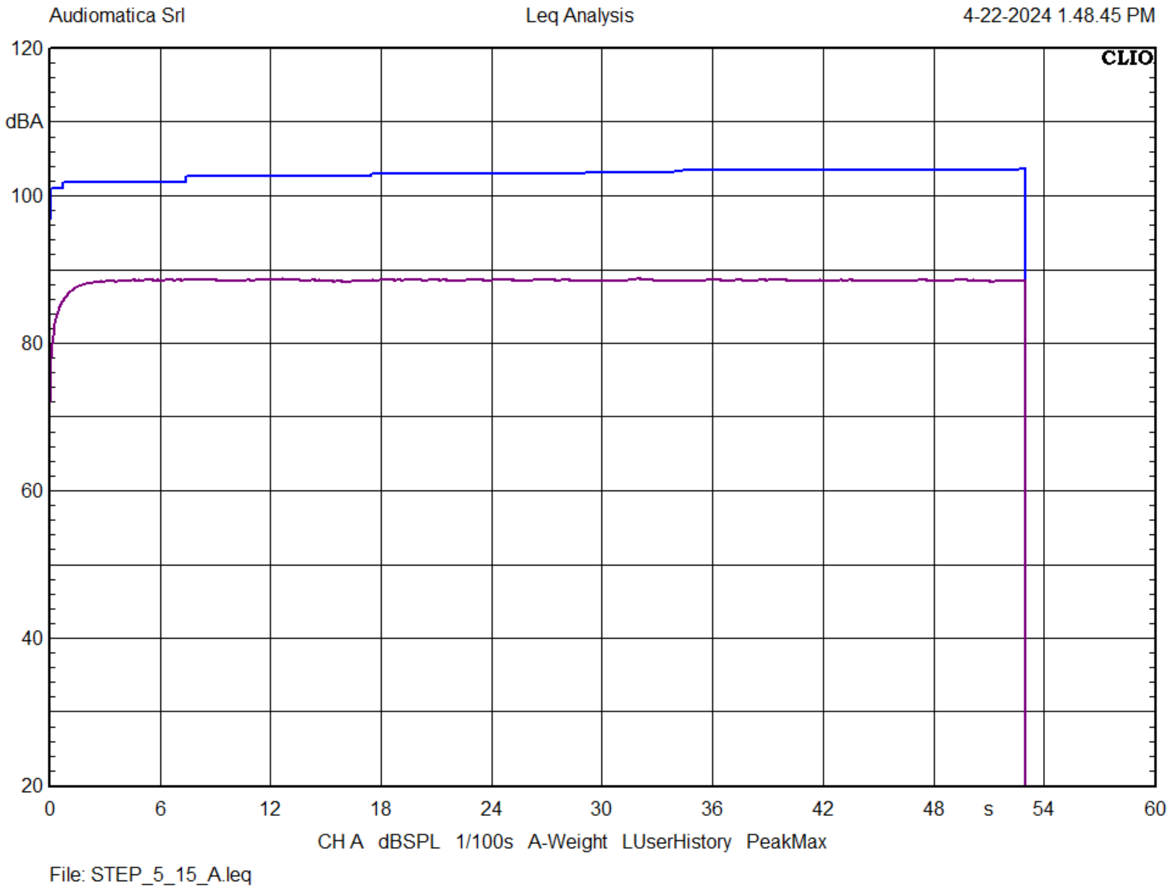
The deviation remains within the accepted limit of ±1 dB. However, we notice a slight deviation above 16 kHz. This is likely due to the imperfect repositioning of the TFA microphone, which we previously moved to measure the maximum sound pressure level at 1 m. This minor inconvenience is a consequence of using a single microphone for both TFA and SLM measurements.

At this point we can measure again at SLM position the L_{ZSmax} and L_{Zpeak}:

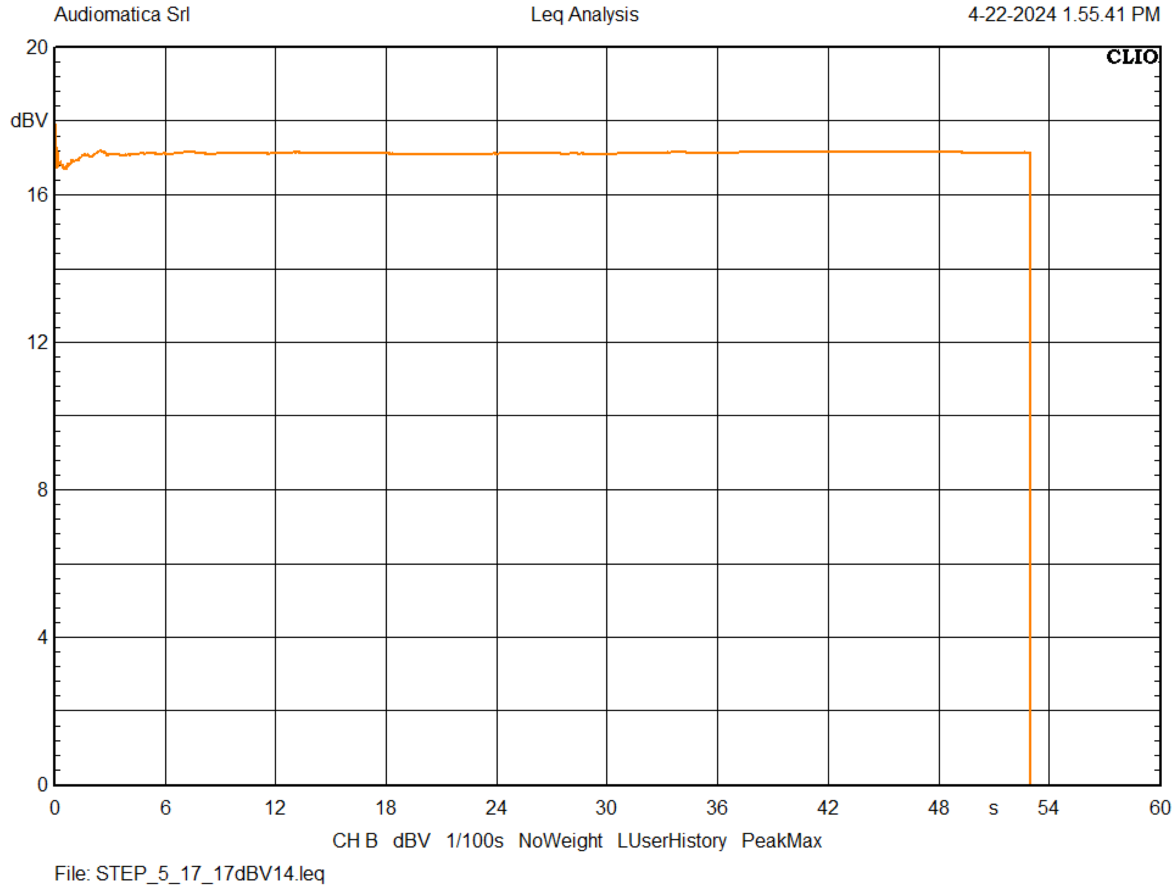


And slightly modifying the Leq settings to include A-Weighting we can measure the L_{ASmax} and L_{Apeak} values:





We can then finally measure the RMS level of the excitation signal, this can be done also using the Leq analysis module, using non-weighted among the Leq options and selecting LEq as a curve.



The test results can be summarized in a compact form as shown in the standard. Our device under test performs as follows:

AES75 max. linear sound levels: 92 dBZ, 105 dBZpk, 89 dBA
at an RMS input level of 17.2 dBV (7.2 V)

It should be noted that the test has been carried out without band limiting the test signal, with the hypotesis that the system under test is a full range system without a subwoofer.

Measurement have been collected in a non anechoic environment, this should be considered and noted when declaring levels as the room reverberation contributes to the measured SPL levels.

Conclusion

We have demonstrated the completion of an AES75 test of a passive loudspeaker using CLIO software and a single Class I microphone.

We conducted our test in an office room, and while this is feasible, we recommend utilizing a suitable laboratory environment if not an anechoic chamber. Key considerations include having a quiet room with minimal reverberation, sufficient space and/or acoustic treatment to mitigate near acoustical reflections. Additionally, evaluating distortion using coherence necessitates minimizing the background noise in the environment.

At the same time, the test itself can generate potentially harmful very high sound pressure levels. It's important to implement ear protection measures and carefully evaluate any noise impact on other activities taking place nearby.

In this example, CLIO has been utilized as a generator, TFA and SLM. Additionally, there is the option to utilize CLIO only as a generator and TFA, supplemented by a handheld SLM in the setup. The test can be conducted interactively and the procedure can be efficiently documented using CLIO.

References

[1] AES75-2022, “AES standard for acoustics – Measuring loudspeaker maximum linear sound levels using noise”

[2] Van Veen, Schwenke, “Coherence as an Indicator of Distortion for Wide-Band Audio Signals such as M-Noise and Music”, Convention E-Brief, presented at 147th AES Convention, New York, 2019

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