QC Multi-Tone Distortion Task S68

Module of the KLIPPEL ANALYZER SYSTEM (QC Ver. 7, dB-Lab Ver. 212)

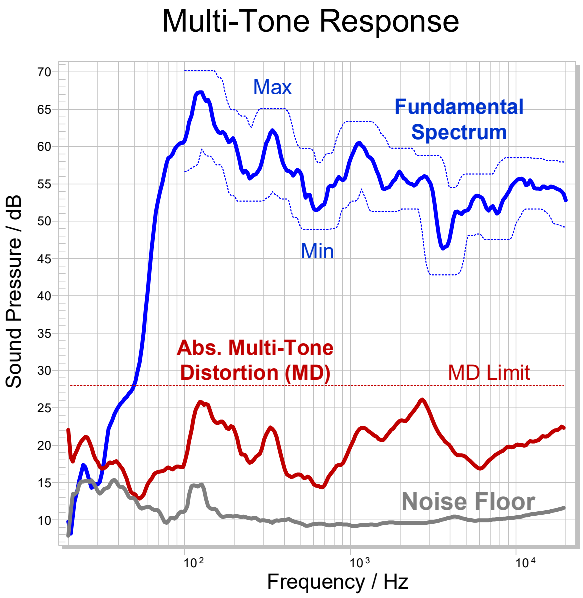
Document Revision 1.3

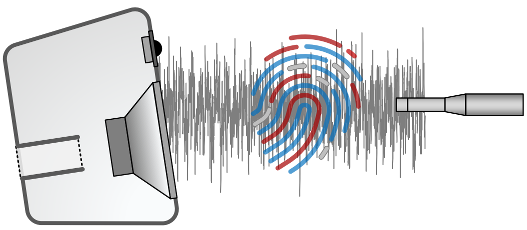
FEATURES

- Multi-tone broad-band stimulus
- Fundamental and transfer function
- Multi-tone distortion (MD) includes all distortion (HD, IMD)
- Relative MD and total MD ratio
- Test output (SPL) and input (current)
- Optional noise floor check
- Compliant to IEC 60268-21

BENEFITS

- Realistic output „finger print“ testing of speakers and audio systems
- Test max SPL capabilities
- Reveals all speaker nonlinearites
- Robust towards room influence
- Ensures overall consistency of production





DESCRIPTION

The multi-tone distortion task is an add-on to the QC end-of-line test system. This module can be inserted as a test step (task) in any existing QC test sequence. Closely related to the *MTON* module with focus on R&D applications, the MTD is based on multi-tone test signals.

In contrast to pure sinusoidal sweep excitation (such as SPL Task), multi-tone stimuli do not only excite harmonic distortion (HD) but also intermodulation distortion (IMD). Therefore, multi-tone distortion provides a much more comprehensive distortion pattern than harmonics alone. Due to the sparse broad band excitation, it is not always possible to identify distinct root causes and symptoms in multi-tone distortion, but it provides a more realistic distortion finger print than pure HD and IMD tests since operation conditions are closer to the final application with music. Therefore, the MTD is highly valuable to verify audio quality and max SPL handling in quality control.

A multi-tone test can be applied to acoustic (sound pressure) and electric (input current) signals using a microphone or a Klippel Analyzer (PA, KA3). This allows to separate symptoms caused by the electro-mechanic part of the audio product (input current) from additional vibration and radiation effects (sound pressure output).

Item Number	4000-003

CONTENT

1 Overview

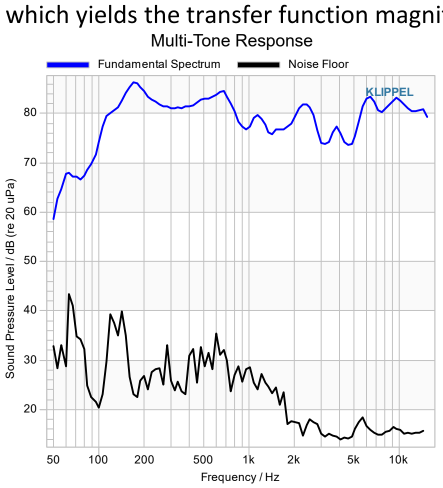
1.1 Principle

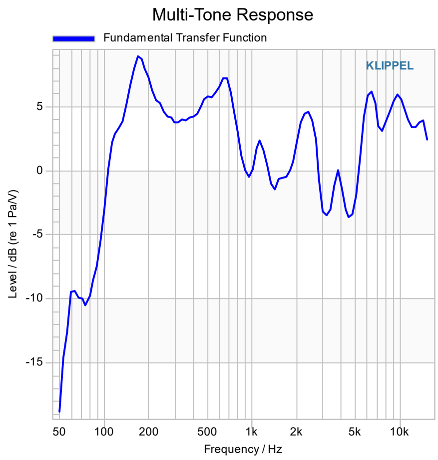
The MTD task is based on a multi-tone stimulus signal. The excited frequencies are used to calculate the multi-tone fundamental spectrum or transfer function curve. The residual response signal measured between the excited frequencies as a result of nonlinear distortion and noise is used to calculate the multi-tone distortion (MD). In addition to absolute spectral MD level, the relative MD (related to fundamental) as well as total multi-tone distortion ratio simplify are robust towards room influence and simplify setting reasonable pass/fail limit.

1.2 Results

Fundamental & Level

The multi-tone **Fundamental** spectrum reflects the level of the excited frequencies' response magnitude in dB (left plot below).
In order to evaluate the transfer behavior instead of output only, the fundamental spectrum can be related to the excitation spectrum (stimulus or voltage at speaker terminals) which yields the transfer function magnitude (right plot).





Note: The fundamental mode can be switched in the MTD task settings. A third mode provides the Frequency Response which is based on the transfer function and emulates the fundamental frequency response as measured by the SPL task (sine sweep) with the same RMS stimulus level.

The total signal **Level** is based on the full AC response waveform and reflects the overall RMS level including fundamental, noise and distortion.

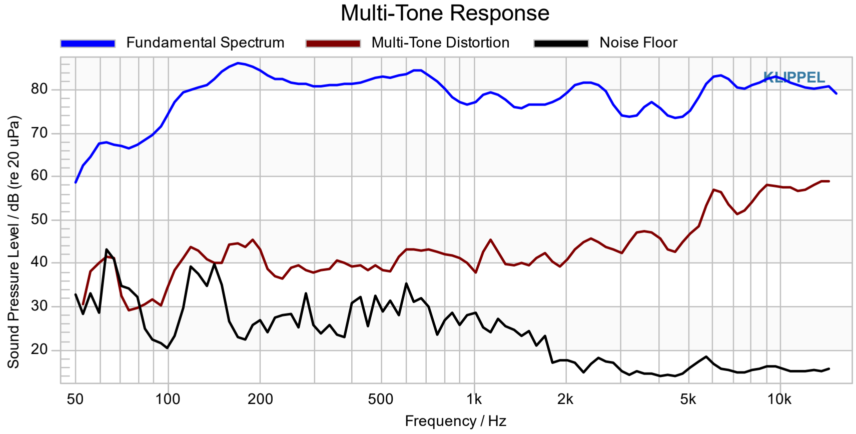
Name	Value	Min Limit	Max Limit	Unit	Description
Level	101.2	98.2	104.2	dB (re 20 uPa)	total response level

Note: The resulting number roughly compares to the average level as measured by the SPL task using the same excitation RMS level.

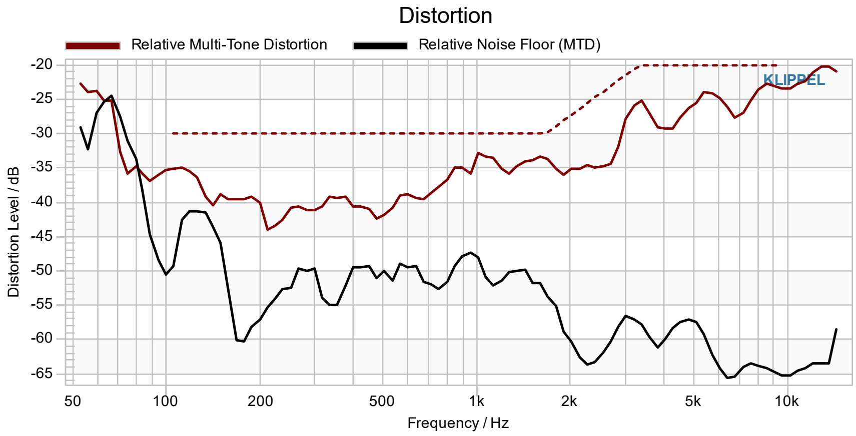
Multi-Tone Distortion (MD)

In contrast to the fundamental spectrum, the multi-tone distortion is based on all spectral components except for the excited frequencies. Thus, it reflects both noise and nonlinear distortion.

For the sake of data reduction, better interpretation and to reduce effects of FFT resolution, the total level of the noise and distortion between the excited frequencies is integrated and plotted over the excited frequencies (average of the adjacent bands). This yields the **absolute MD** plot in result window *Multi-Tone Response* as shown below (red curve).



For even better interpretation and more universal limit setting, it is good practice to relate the distortion band levels to the neighboring fundamental (comparable to THD). This results in the **relative MD** which can be expressed in percent or equivalently as a relative level in dB (“distance” to fundamental). Due to the different scale, the relative MD is plotted in *Distortion* window.



Total Multi-Tone Distortion Ratio

The total MD ratio is a convenient single number that reflects the overall ratio between multi-tone distortion and (fundamental) level. Such as the spectral MD, it can be expressed both in % or dB-

Name	Value	Min Limit	Max Limit	Unit	Description
Total MD Ratio	4.0	-	10.0	%	total multi-tone distortion ratio

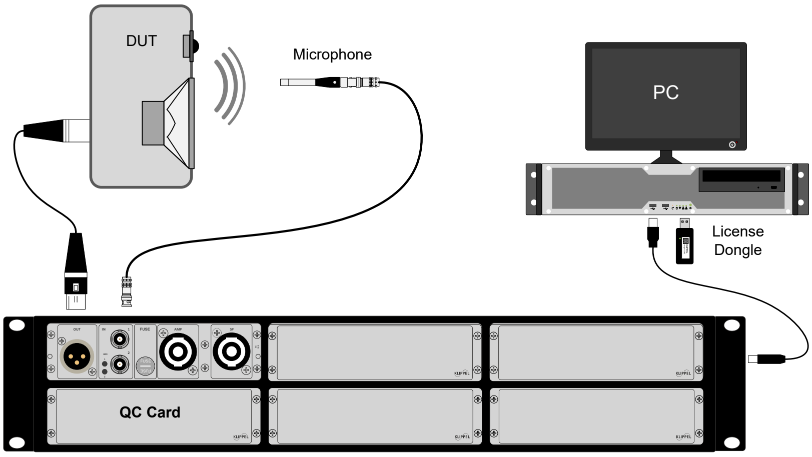
Noise floor

In Qc Engineer mode, a pre-measurement without excitation is performed, optionally. The resulting absolute or relative noise level (comparable to SNR) is plotted together with the spectral MD as shown in the plots above.

This is recommended in order to check for ambient noise and other noise sources that may corrupt the MD or fundamental results. An SNR of > 40 dB is recommended, at least for the fundamental.

2 Examples

2.1 Example 1: Studio Monitor



A studio monitor was measured in a normal room in 1 m distance at high level. The multi-tone spectrum shows the expected, almost flat fundamental response characteristics above 80 Hz.

The relative multi-tone distortion exceeds the -20 dB (10 %) limit relative to the fundamental in a wide frequency band. This also reflects in the Total Multi-Tone Distortion Ratio. According to the relative noise floor, above 60 Hz

In this example the limit was violated and therefor the QC verdict was FAIL. Compared with a THD measurement it is obvious that multi-tone distortion does not decay with frequency (excursion) but are relatively constant in this case due to a dominant amount of intermodulation distortion.

The noise floor was measured as well showing a distance of > 20 dB to the distortion which is an indication for a reliable distortion measurement.

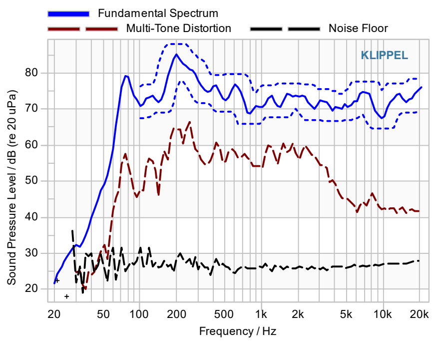
FAIL

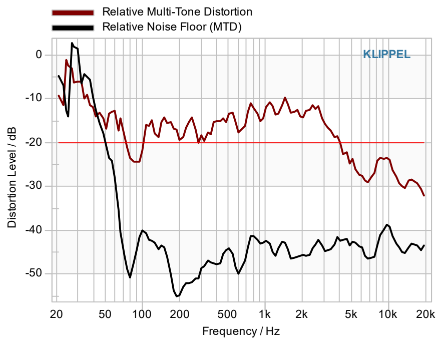
Fundamental
Level
Relative Multi-Tone Distortion
Total MD Ratio

Test: Examples MTD

[TASK OUTPUT: MULTI-TONE DISTORTION]

Name	Value	Min Limit	Max Limit	Unit	Description
Level	97.2	94.2	100.2	dB (re 20 uPa)	total response level
Total MD Ratio	14.2	-	10.0	%	total multi-tone distortion ratio





2.2 Example 2: Transducer Input Current

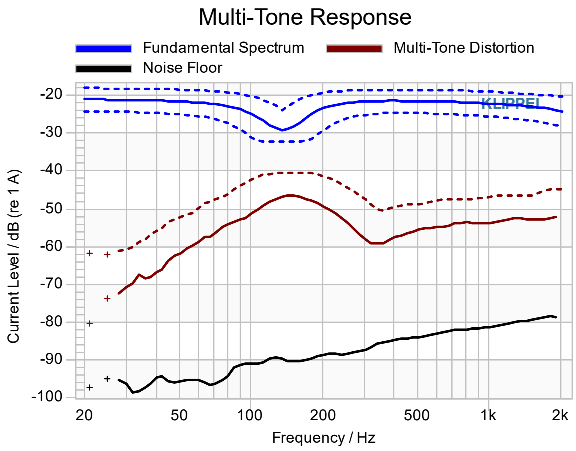
A 8‘‘ woofer shall tested for distortion (IMD, HD) in the input current. The fundamental component shows the typical dip at resonance where the impedance is high and hence the input current is low. However, the highest excursion usually occurs here as well. Since dominant nonlinearities in transducers are depending on excursion, the multi-tone distortion level is often at its maximum here as well.

In this example the distortion level is checked against a reference DUT, which was defining the absolute limit levels (shifted). The DUT depicted in this example does not deviate considerably from the reference and therefore the QC test returned a PASS.

The noise floor is sufficiently low, since acoustic disturbances have virtually no effect on the current noise floor.

PASS

Fundamental
Multi-Tone Distortion



3 Requirements

3.1 Hardware

Analyzer Hardware	The MTD supports the following measurement front-ends • *KA3* - KLIPPEL Analyzer 3 • *PA* - KLIPPEL Production Analyzer • 3rd party audio interface (soundcard) *The actual card configuration of the KA3 depends on the test scenario and DUT type (passive, self-powered).* *For analyzing DUT input current or terminal voltage, a KLIPPEL analyzer (PA, KA3) is recommended. 3rd party front ends capable of voltage and current sensing are suitable as well.*
Mixed Devices Bluetooth Open Loop	For mixed audio device setups (capture device not identical to playback device) the multi-tone task is not recommended. A potential clock mismatch will degrade the results especially at higher frequencies (especially MD). This also applied for open loop tests (e.g. based on wave file playback or capture). If a measurement under such conditions is inevitable, the test time should be chosen as short as possible (e.g. 0.2 s) and the upper bandwidth limit shall restricted to about 1 … 2 kHz.
License Device	A Klippel Dongle (USB) or Klippel Analyzer 3 (KA3) is required as license device.
Microphone	For sound pressure analysis, any hardware compliant microphone such as *MIC255* can be used.
Test Enclosure	For acoustic tests in a production environment, a noise-shielding test chamber is highly recommended to provide a reasonable noise floor for distortion testing. The MTD does not support ambient noise detection using an additional ambient mic. See also *AN-46 Test Enclosures for QC* for further reference.
Device Under Test	The MTD can be used to test audio electronics as well as any acoustic or haptic device that can be actively stimulated by the provided test signal generator.

3.2 Software

QC Framework	To operate the Multi-Tone Distortion Task, the *QC Standard* (Item No. 4005-001) or *QC Stand-alone* (Item No. 4005-500) software as well as an additional MTD license is required.
R&D Framework	From release version 210.560, the MTD may be operated within the KLIPPEL R&D software release. An MTD operation template is included in the normal software setup. An MTD license is required for operation. **Note**: KLIPPEL Analyzer 3 (KA3) hardware is required to operate the MTD in the R&D software framework.

4 Limits

4.1 Setup Parameter Limits

Parameter	Symbol	Min.	Typ.	Max.	Unit
STIMULUS & ACQUISITION					
Frequency range	f_{min}, f_{max}	0.1	-	80 k	Hz
Test time	t_{test}	0.2	0.5	20	s
Multi-tone Resolution (logarithmic)	R	1	12	200	freq. / octave

Preloop (factor of test time)		0	0.5	20	
Averaging (factor of test time)		0	1	20	
Voltage – RMS stimulus voltage (line or amp output)	$u_{\text{rms,stim}}$	>0	-	200	V
Stimulus Level* – digital stimulus peak level rel. to full scale	L_{stim}	-∞	-	0	dBFS
PROCESSING					
Fundamental Smoothing	S_{fund}	1	3	99	Part of octave

**Only available if digital output device is used*

5 Results

5.1 Results

Parameter	Symbol	Unit	QC Limits Applicable
Multi-Tone Fundamental Magnitude Level			
Digital	$L_{\text{FS}}(f)$	dBFS	✓
Voltage	$L_u(f)$	dB (re 1 V)	✓
Sound Pressure	$L_p(f)$	dB (re 20 µPa)	✓
Displacement	$L_x(f)$	dB (re 1 mm)	✓
Acceleration	$L_a(f)$	dB (re 1 µm/s²)	✓
Current	$L_i(f)$	dB (re 1 A)	✓
Level			
Digital	L_{FS}	dBFS	✓
Input Voltage	L_u	dB (re 1 V)	✓
Sound Pressure	L_p	dB (re 20 µPa)	✓
Displacement	L_x	dB (re 1 mm)	✓
Acceleration	L_a	dB (re 1 µm/s²)	✓
Current	L_i	dB (re 1 A)	✓
Transfer Function[1)]			
Sound Pressure - Magnitude (Level)	$\lvert \underline{H}_{p,u}(f)\rvert$	dB (re 1 Pa/V)	✓
Displacement - Magnitude (Level)	$\lvert \underline{H}_{x,u}(f)\rvert$	dB (re 1 mm/V)	✓
Acceleration - Magnitude (Level)	$\lvert \underline{H}_{a,u}(f)\rvert$	dB (re 1 µm/s²/V)	✓
Voltage - Magnitude (Level)	$\lvert \underline{H}_{u,u}(f)\rvert$	dB (re 1 V/V)	✓
Current - Magnitude (Level)	$\lvert \underline{H}_{i,u}(f)\rvert$	dB (re 1 A/V)	✓
Frequency Response (IEC 60268-21, emulated)[1)]			
Sound Pressure Level	$L_p(f)$	dB (re 20 µPa)	✓
Displacement Level	$L_x(f)$	dB (re 1 mm)	✓
Acceleration Level	$L_a(f)$	dB (re 1 µm/s²)	✓
Voltage Level	$L_u(f)$	dB (re 1 V)	✓
Absolute Spectral Multi-Tone Distortion Level			
Digital	$L_{\text{FS,MD}}(f)$	dBFS	✓
Voltage	$L_{u,\text{MD}}(f)$	dB (re 1 V)	✓
Sound Pressure	$L_{p,\text{MD}}(f)$	dB (re 20 µPa)	✓
Displacement	$L_{x,\text{MD}}(f)$	dB (re 1 mm)	✓
Acceleration	$L_{a,\text{MD}}(f)$	dB (re 1 µm/s²)	✓
Current	$L_{i,\text{MD}}(f)$	dB (re 1 A)	✓
Relative Spectral Multi-Tone Distortion			
Ratio	$R_{\text{MD}}(f)$	%	✓
Level	$L_{\text{MD}}(f)$	dB	✓
Total Multi-Tone Distortion Ratio			
Ratio	R_{TMD}	%	✓

Level	L_{TMD}	dB	✓
Absolute Noise Floor Level[2)]			
Digital	$L_{\mathrm{FS,NF}}(f)$	dBFS	
Voltage	$L_{u,\mathrm{NF}}(f)$	dB (re 1 V)	
Sound Pressure	$L_{p,\mathrm{NF}}(f)$	dB (re 20 µPa)	
Displacement	$L_{x,\mathrm{NF}}(f)$	dB (re 1 mm)	
Acceleration	$L_{a,\mathrm{NF}}(f)$	dB (re 1 µm/s^2)	
Current	$L_{i,\mathrm{NF}}(f)$	dB (re 1 A)	
Relative Noise Floor Level[2)]			
Ratio	$R_{NF}(f)$	%	
Level	$L_{NF}(f)$	dB	

[1)]variant for digital output not listed

[2)]only measured in QC Engineer mode

6 References

6.1 Related Products	R&D • Multi-Tone Measurement (MTON) • Live Audio Analyzer (LAA) • Distortion Measurement (DIS) • Transfer Function Measurement (TRF) • Tone Burst Measurement (TBM) QC • Sound Pressure Task (SPL) • Spectrum Analysis Task (SAN) • QC External Synchronization Add-on (SYN)
6.2 Manuals	• MTD User Manual • QC User Manual
6.3 Application Notes	• AN16 Multi-tone Distortion Measurement • AN46 Test Enclosure for QC
6.4 Publications	• W. Klippel: Physical and Perceptual Evaluation of Electric Guitar Loud-speakers • Voishvillo, et. al. , “Graphing, Interpretation, and Comparison of Results of Loudspeaker Nonlinear Distortion Measurements,” J. Audio Eng. Society 52, No. 4 pp. 332-357 (Apr. 2004)
6.5 Standards	• IEC 60268-21
6.6 Videos	• KLIPPEL LIVE Web Seminar Series 1: IEC 60268-21

Find explanations for symbols at:
http://www.klippel.de/know-how/literature.html

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