3D Distortion Measurement (DIS) S4

Software Module of the KLIPPEL ANALYZER SYSTEM (Document Revision 1.3)

FEATURES	BENEFITS
• Voltage and frequency sweep • Steady-state measurement • Single-tone or two-tone excitation signal • DC-component, magnitude and phase of fundamental, harmonic and intermodulation components • High spectral resolution • Two channel data acquisition • High SNR due to synchronous data acquisition • Signal components up to 96 kHz[1]	• Optimal for transducer measurements • Considers mechanical, electrical, acoustical signals • Measures voice coil temperature • Visualizes amplitude compression • Detects critical speaker distortion • Assesses admissible output amplitude • Proves driver stability (DC-offset) • Thermal and mechanical protection • Adjusts voltage at speaker terminals

DESCRIPTION

The DIS module performs a series of steady-state measurements by using a single- or two-tone excitation signal varied in frequency **and** voltage. Two signals may be measured simultaneously (e.g. current, voltage, displacement, SPL). Due to high quality converters and synchronous data acquisition the spectral components (fundamental, harmonic and intermodulation distortions, DC part) can be obtained with high signal to noise ratio up to 96 kHz signal frequency[1]. After performing the measurement (voltage and frequency sweep) the magnitude of the spectral components is displayed in a 2D or 3D plot versus voltage and frequency of the excitation tone.

The 3D Distortion Measurement provides features especially valuable for transducer measurements. By measuring the electrical input signals directly at the terminals of the speaker, a given excitation level can be ensured and the instantaneous voice coil temperature can be monitored. The transducer may be protected against mechanical and thermal overload by pausing the measurement automatically if the total harmonic distortion or the increase of the voice coil temperature violates user defined limits. The 3D Distortion Measurement (DIS) uses the same graphical output format and a similar user interface as the simulation module (SIM2) to facilitate comparisons between modeling and reality. The data measured by this module are the basis for assessing the maximal output amplitude considering thermal and nonlinear compression effects and the stability of the driver (dynamic DC generation).

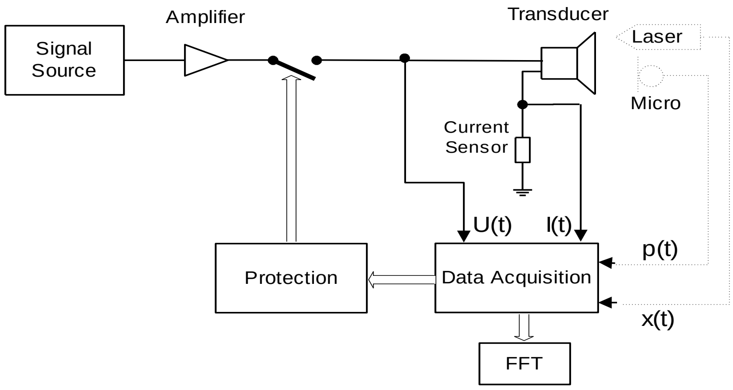
Article Number:	1000-800, 1000-810, 1000-811

[1] Requires Klippel Analyzer 3. Klippel Distortion Analyzer 2 allows measurement of signal components up to 48 kHz.

CONTENT

1 Overview

1.1 Signal Generation & Acquisition

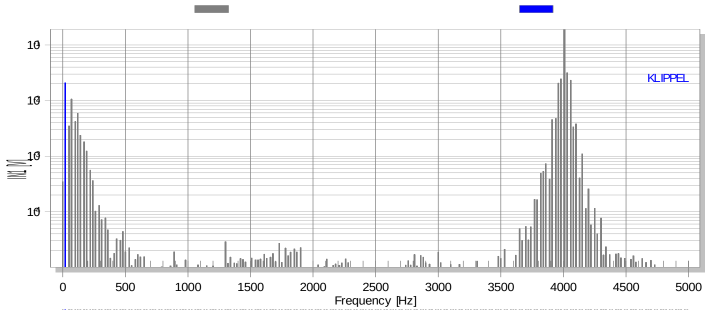
Principle	 The generated excitation signal is applied to OUT 1, and may be amplified and linked via the high-power path of the analyzer unit to the transducer under test. Voltage and current sensors measure the amplifier output (at connector AMPLIFIER) and the electrical signals at the transducer terminals (at connector SPEAKER 1 or SPEAKER 2). At the beginning of the measurement the transducer is disconnected from the amplifier output to determine the amplifier gain automatically. Two external signals may be provided via input IN1 and IN2 from microphones or laser displacement meter. The user has the option to select two input signals $Y_1(t)$ and $Y_2(t)$, which are recorded at the same time. To provide a maximum of protection of the measurement object, the electrical signals can be measured independently from the routing of the input signals Y_1 and Y_2.
Stimulus	A two-tone signal defined by $$U(t) = U_1 \cdot \sin(2\pi f_1 \cdot t) + U_2 \cdot \sin(2\pi f_2 \cdot t)$$ is an optimal excitation signal to measure fundamental, harmonic, difference-tone and summed-tone intermodulation components. The frequencies f_1 and f_2, as well as the voltages U_1 and U_2 may be specified by the user explicitly, or may be varied automatically to perform frequency or voltage sweeps. The duration of the stimulus depends on the sample rate and is adjusted by the module automatically.

Amplifier Gain	If the voltage of the stimulus refers to the transducer terminals, the gain of the power amplifier connected between generator output and transducer is determined automatically at 375, 750 or 2250 Hz without load and the stimulus signal will be adjusted accordingly. The user will be informed if major variations of the amplifier gain occur during the measurement.
Frequency Sweep	The user may choose between measurements performed with a constant frequency f_1 or a series of sequential measurements performed for different values of f_1. The user can specify the start value f_{start} and the end value f_{end} for the frequency f_1, as well as the number of intermediate points spaced linearly or logarithmically.
Voltage Sweep	The user may choose between measurements performed with constant voltage U_1 or a series of sequential measurements performed for different values of U_1. The user can specify the start value U_{start} and the end value U_{end} for the voltage U_1, as well as the number of intermediate points spaced linearly or logarithmically. The voltage U_2 of the second tone is coupled to the voltage U_1 of the first tone and the user specifies the ratio U_2/U_1.
Measurement of Harmonics	The user can choose between four measurement modes, i.e. • Harmonics, • Harmonics + Intermodulations (f1), • Harmonics + Intermodulations (f2), • Intermodulations (f1), • THDN
Measurement of Harmonic Components	The *Harmonics* mode is used to measure the harmonic components of tone f_1. The second excitation tone is switched off. This reduces the amplitude of the excitation signal *U(t)* and avoids interferences between harmonic and intermodulation components.
Measurement of Intermodulations	In the *Harmonics + Intermodulation (f1)* and *Harmonics + Intermodulation (f2)* modes summed-tone and difference-tone intermodulation components (centred around f_1 and f_2 respectively) are measured additionally to the harmonic components of f_1. No harmonic components are measured if *Intermodulations (f1)* is selected. There are three different ways to specify the frequency f_2 of the second tone: • **f_2 = const.** The user specifies the frequency f_2 which is held constant during frequency sweep of f_1. This mode allows to generate a very critical stimulus for most transducers. Selecting $f_2 < f_1$, f_2 may represent a bass tone producing large voice coil displacement and f_1 represents any audio component (voice) in the pass band of the transducer. • **f_2/f_1 = const.** The user specifies the frequency ratio between both excitation tones. Selecting $f_2 > f_1$, and using a fractional ratio (e.g. 5.5) this mode avoids interferences between the harmonic and intermodulation distortion components. • **f_2-f_1 = const.** The user specifies the distance between both excitation frequencies. This mode produces difference intermodulation at the same frequency independent of f_1.

Measurement of total harmonics + noise	The *THDN* mode is for measuring the harmonics and the total harmonics + noise. The measurement is excited by tone f_1. The second excitation tone is switched off. The sample rate is hold constant for all sweep points to get comparable measurement conditions.
Additional excitation before measurement	Prior the measurement of the distortion components the transducer is excited to reach steady state for each voltage-frequency point. The duration of this pre-excitation is adjusted automatically. The user may specify an additional pre-excitation time to investigate the thermal behavior of the transducer and to compensate time delays.
Procedure	The measurement consists of an initial part to identify • gain of the power amplifier, • amplifier limiting, as well as • initial voice coil temperature. The following kernel routine is processed periodically for all samples of the voltage and frequency sweep, comprising the following four steps: • pre-excitation to reach steady-state conditions, • additional pre-excitation of user specified duration, • acquisition of Signal Y_1 and Y_2, • measurement of voice coil temperature.
Signal Y_1	The first signal Y_1 may be selected from the following choices: • Signal at input IN 1 (microphone or external Laser), • Voltage at terminals SPEAKER 1 or SPEAKER 2.
Signal Y_2	The second signal Y_2 may be selected from the following choices: • Signal at input IN 2 (microphone or external Laser), • Current at terminals SPEAKER 1 or SPEAKER 2, • Internal laser displacement signal.
Sample Rate	The signals Y_1 and Y_2 are sampled at various rates (48, 96, 192 kHz) adjusted to the maximal frequency of fundamental or distortion components which are of interest to the user. In case of a conflict between signal components and maximal Nyquist frequency suggestions are provided to the user such as to reduce maximal order of analyzed distortion components or f_{end}. Noise and distortion components of higher order are attenuated by a low-pass filter to avoid aliasing effects.

1.2 Spectral Analysis

FFT	The steady-state responses of Y_1 and Y_2 are subject of an FFT analysis having the same size as of the stimulus to dispense with additional windowing of the time signal. This reveals the spectra at maximal resolution without any smearing effects.
Pause	During a frequency and voltage sweep the measurement may be paused to view details of the waveform and the spectrum.
Spectrum	The fundamental frequencies f_1 and f_2 are represented by distinct colors to facilitate the identification of the distortion components.

	 In the example above the harmonics of the lower frequency tone f_2 may be easily distinguished from the intermodulation components centered around the higher tone f_1.
Data Compression	The magnitudes and phases of spectral components that are of particular interest such as fundamental, DC-component and the harmonic and intermodulation components up to the specified order *n* are stored in the database and are may be listed.

1.3 Protection of the Transducer

Principle	Performing measurements at high voltages may damage the transducer. Permanent monitoring of the electrical signals at the terminals and the measurement of a mechanical state variable (displacement) or acoustical output (sound pressure) is the basis for protecting the transducer against thermal and mechanical overload. The protection system may be activated by the user by defining limit values (increase of voice coil temperature, total harmonic distortion). If one of the monitored variables exceeds the allowed limits the measurement will be interrupted automatically. The user may activate a voltage sweep with sufficiently fine steps starting at low voltages to detect an overload situation in time.
Voice Coil Temperature	The increase of the voice coil temperature during a measurement is the criterion for the thermal protection. Before staring the voltage-frequency measurement sweep the voice coil resistance is determined and stored as a reference value. During the sweep the voice coil resistance is measured after each step. The voice coil temperature is calculated from the increase of voice coil resistance and stored in the database.
Harmonic Distortion	The total harmonic distortion in the analyzed signals Y_1 and Y_2 is the criterion for detecting the mechanical load.

2 Requirements

2.1 Hardware

Analyzer	The Distortion Analyzer or the Klippel Analyzer 3 is used as the hardware to perform the measurement.	
Laser Displacement Sensor	A high precision laser displacement sensor is required to measure the transducer displacement during measurement. See *A2 Laser Displacement Sensors* for more details.	
Amplifier	A power amplifier is required for performing the measurement. **Note:** The measurement may lead to very high peak voltages. Please ensure that the amplifier unit is able to provide these.	

2.2 Software

DIS Software	Measurement module performing the DIS measurements and analysis
dB-Lab	Project Management Software of the KLIPPEL R&D SYSTEM

3 Limitations

3.1 Hardware

Distortion Analyzer	The maximum sample rate is 96 kHz, thus only signal components up to 48 kHz can be measured. Use a *Klippel Analyzer 3* to measure signal components up to 96 kHz.

4 Setup

Parameter	Symbol	Min.	Typ.	Max.	Unit
Spectral Analysis					
Stimulus Length		64			samples
Sample Rate[2]	f_{sample}	48		192	kHz
Resolution	Δf	0.73			Hz
Order of Distortion Analysis	n	2	4	16	
Excitation Tone					
Frequency of First Tone[2]	f_1	0.19		80000/n	Hz
Frequency of Second Tone					
Constant Frequency	f_2	0.73		3)	Hz
Constant Difference	$f_1 - f_2 = d$	0.73		4)	Hz
Constant Ratio	$f_1 / f_2 = r$	5)	5.5	5)	
Voltage First Tone at SPEAKER 1 [6)]	U_1	0		300	V

[2] Depending on the measurement device, maximum value reflects capabilities of *Klippel Analyzer 3*

[3] *Klippel Analyzer 3:* $f_1 + (n-1) \cdot f_2 < 80\ \mathrm{kHz}$ | *Distortion Analyzer:* $f_1 + (n-1) \cdot f_2 < 40\ \mathrm{kHz}$

[4] *Klippel Analyzer 3:* $f_1 + (n-1)(f_1 - d) < 80\ \mathrm{kHz}$ | *Distortion Analyzer:* $f_1 + (n-1)(f_1 - d) < 40\ \mathrm{kHz}$

[5] *Klippel Analyzer 3:* $f_1 + (n-1)(f_1/r) < 80\ \mathrm{kHz}$ | *Distortion Analyzer:* $f_1 + (n-1)(f_1/r) < 40\ \mathrm{kHz}$

[6] @ $U_2/U_1 = 1$

Parameter	Symbol	Min.	Typ.	Max.	Unit
Voltage First Tone at OUT1 [6)]	U_1	0		3	V
Voltage Ratio Between Tones	U_2/U_1	-1000	0	20 lg(300V/U_1)	dB
Frequency Sweep					
Points		1		500	
Start Value of Frequency Sweep f_1	f_{start}	0.73		f_{end}	Hz
Final Value of Frequency Sweep f_1 [2]	f_{end}	f_{start}		96000/n	Hz
Voltage Sweep					
Points		1		500	
Start Value of Voltage Sweep U_1 at SPEAKER Connector [6)]	U_{start}	0		U_{end}	V
Final Value of Voltage Sweep U_1 at SPEAKER Connector [6)]	U_{end}	U_{start}		300	V
Start Value of Voltage Sweep U_1 at OUT 1 [6)]	U_{start}	0		U_{end}	V
Final Value of Voltage Sweep U_1 at OUT 1 [6)]	U_{end}	U_{start}		3	V
Duration of additional excitation before measurement	multiples of t_{meas}	t_{meas}		$t_{meas} \cdot 131072$	s

5 Results

5.1 Windows

Signals (only displayed during measurement)
Signal Y_1 vs. time
Signal Y_2 vs. time
Spectrum of signal Y_1
Spectrum of signal Y_2
Spectral Components of Y_1 or Y_2
DC component vs. frequency f_1 and voltage U_1 of excitation
Fundamental component vs. frequency f_1 and voltage U_1 of excitation
n^{th}-order harmonic distortion component vs. frequency f_1 and voltage U_1 of excitation
n^{th}-order summed frequency modulation distortion component vs. frequency f_1 and voltage U_1 of excitation
n^{th}-order difference frequency modulation distortion component vs. frequency f_1 and voltage U_1 of excitation
Compression (= Fundamental · U_{start} / U_1) vs. frequency f_1 of excitation
Distortion (IEC 60268) of Y_1 or Y_2
Relative total harmonic distortion vs. frequency f_1 and voltage U_1 of excitation
Relative second-order harmonic distortion in vs. frequency f_1 and voltage U_1 of excitation
Relative third-order harmonic distortion vs. frequency f_1 and voltage U_1 of excitation

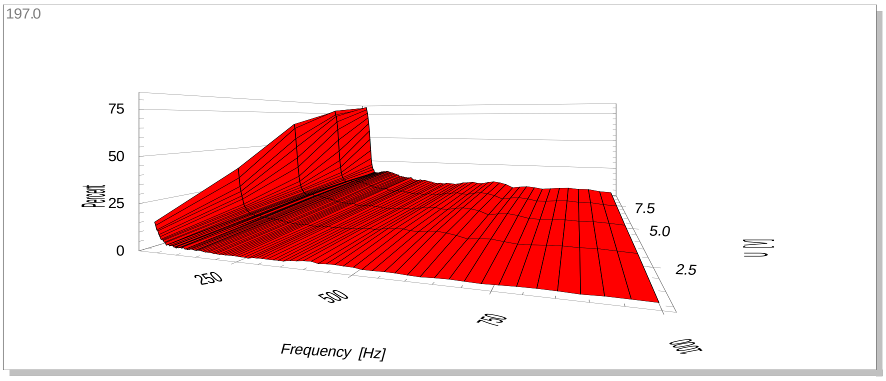
Relative second-order modulation distortion vs. frequency f_1 and voltage U_1 of excitation
Relative third-order modulation distortion vs. frequency f_1 and voltage U_1 of excitation
Relative total harmonic distortion + noise vs. frequency f_1 and voltage U_1 of excitation
Additional Distortion Measures available in DIS Pro (1000-810)
Weighted harmonic distortion (Hi-2, Blat) distortion
Amplitude modulation distortion (called IMD in automotive applications) given as RMS, top and bottom value
Summaries
Peak values, headroom, RMS-value of AC-part

5.2 Graphical Representation

Example: Total harmonic distortion (THD) in the radiated sound pressure.

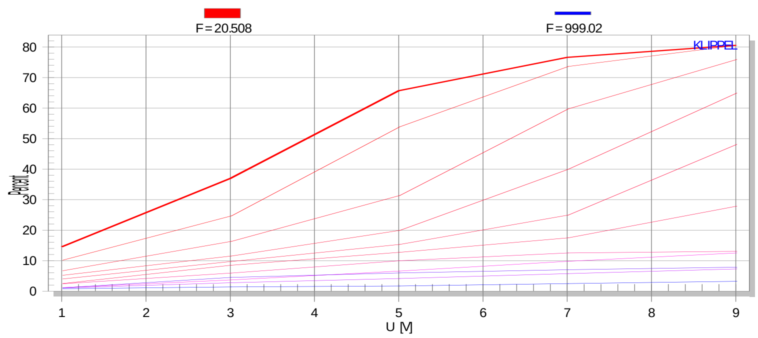
3D-Graphic

Performing a measurement with voltage and frequency sweep the magnitude of the spectral and distortion components may be displayed in a 3D-plot versus frequency f_1 and voltage U_1 of the first excitation tone. Viewing the plot from different perspectives is convenient for interpreting the data. An additional contour plot may be activated.



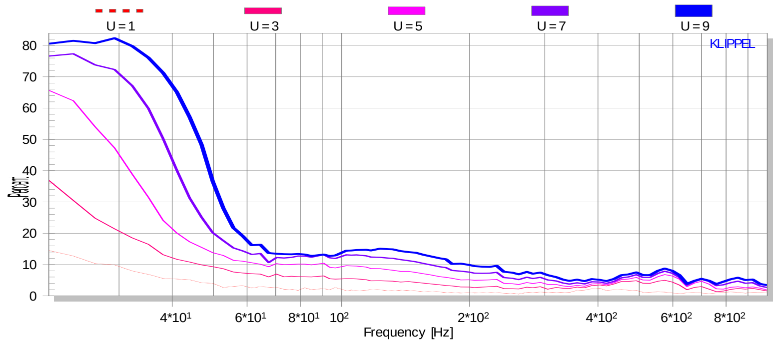
2D-Graphic (versus U)

Measurements performed with a voltage sweep may be displayed as a 2D-plot of output variables versus voltage U_1 of the first excitation tone. This representation shows the nonlinear relationship between input and output amplitude (compression and expansion). Performing a measurement with a frequency sweep additional curves represent the individual frequencies f_1.



2D-Graphic (versus f)

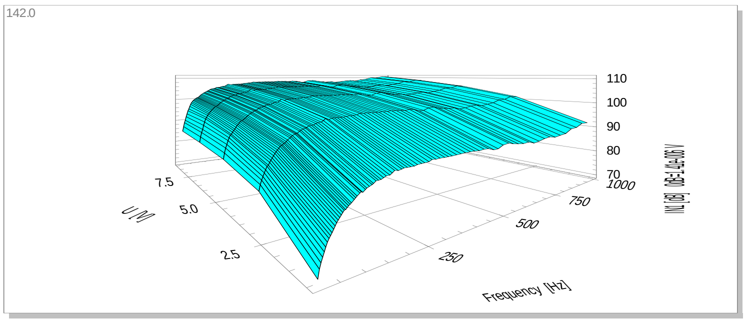
Measurements performed with a frequency sweep may be displayed as a 2D-plot of output variables versus frequency f_1 of the first excitation tone (frequency response). Variations of the voltage U_1 of the first excitation tone are represented as additional curves. The scaling of the y-axis is chosen by default according to the spacing of the voltage sweep samples (linear or logarithmic). In this representation the frequency responses of a linear system measured at different voltages will always appear as multiple equally spaced. Compression and expansion of the amplitude transfer function due to thermal and nonlinear mechanisms can so easily be detected.



6 Application

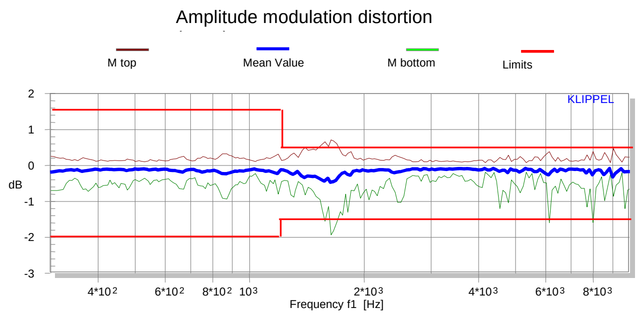
Maximal Output

In the large signal domain, there is no linear relationship between input and output amplitude. Thermal and nonlinear mechanisms limit the maximal output of the driver. This module allows assessing the maximal displacement and maximal SPL for admissible distortion values.



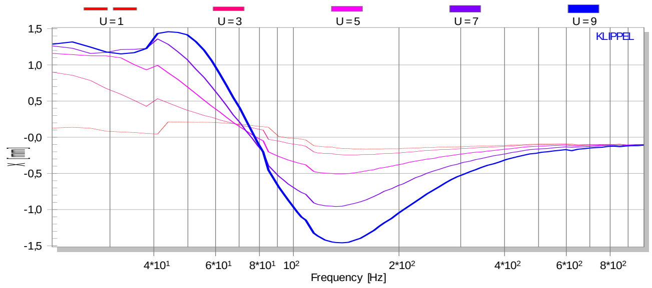
Intermodulation Distortion

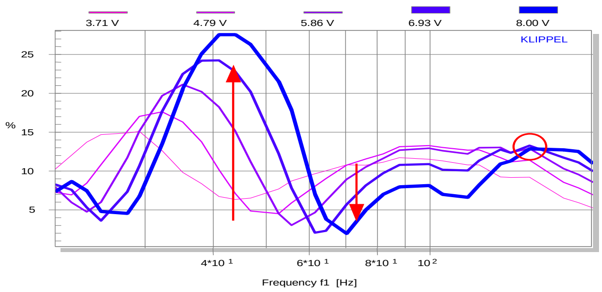
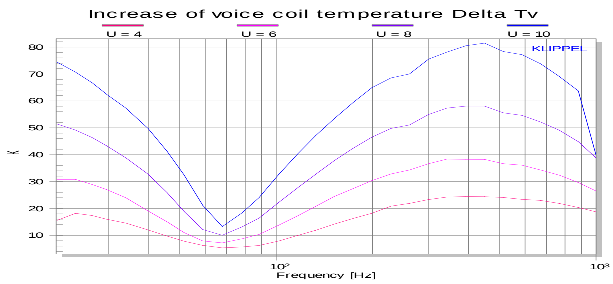
Nonlinearities of the speaker generate additional spectral components in the output signal. The measurement of harmonic distortion is not sufficient to describe the large signal behavior adequately. A fixed tone at resonance frequency f_s (representing a bass) and a second tone f_1 varied over the audio band (representing a voice) produce audible summed-tone and difference-tone intermodulation in the pass band. By examining intermodulation components, the dominant sources of distortion (suspension, motor, radiation) can be revealed.



Stability

A driver with asymmetrical nonlinearities rectifies an AC-input and will generate a DC-component in the displacement dynamically. In some cases, the driver might become instable causing excessive distortion and reducing the output of the driver. Measurements of the DC-component are required to show the stability of the driver at high amplitudes.

<table>
<tr><td></td><td>

The diagram shows the response of a driver with a coil offset causing an asymmetry in the Bl(x)-curve. At frequencies below the resonance (< 80 Hz) the coil will shifted dynamically to 1.4 mm which is the maximum of the Bl(x)-curve (self-centering capability). However, at 150 Hz the DC-displacement rises rapidly showing an instability of the motor (coil jump out effect).</td></tr>
<tr><td>Compression, Expansion</td><td>The amplitude of the nonlinear distortion depends very much on the amplitude of the stimulus. For example, the picture below shows the amplitude of the 2nd-order harmonic distortion of a woofer with measured between 20-200 Hz at 5 amplitudes increased linearly. At 40 Hz the distortion increases but at 75 Hz the distortion decreases with the amplitude of the stimulus. At 150 Hz the distortion converges to a constant value. Thus the "natural" compression or expansion effects have to be considered in the interpretation of the nonlinear distortion measurements.

</td></tr>
<tr><td>Voice Coil Temperature</td><td>The heating of the voice coil will reduce the acoustical output (thermal power compression) and may damage the speaker. Monitoring of the voice coil temperature is the basis for predicting the instantaneous or final voice coil temperature if the coil and/or magnet is in thermal equilibrium. In order to investigate the heating up of the voice coil and its impact on the speaker performance in detail the user can specify an additional pre-excitation that is performed before the main measurement is started.

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7 References

7.1 Related Modules	SIM Simulation

7.2 Manuals	DIS User's Manual

Find explanations for symbols at:

http://www.klippel.de/know-how/literature.html

Last updated: November 26, 2020

Designs and specifications are subject to change without notice due to modifications or improvements.