KLIPPEL ANALYZER SYSTEM

Report with comments

Linear Parameter Measurement (LPM)

Driver Name:	w2017 midrange
Driver Comment:	
Measurement:	LPM south free air
Measurement Comment:	Measureslinear parameters of woofers. Driver connected to output SPEAKER 2.

Overview

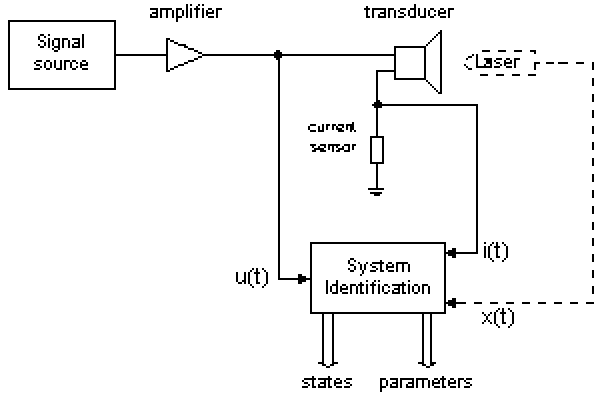
The Introductory Report illustrates the powerful features of the Klippel Analyzer module dedicated to the measurement of the linear speaker parameters. Additional comments are added to the results of a practical measurement applied to the speaker specified above.

After presenting short information to the measurement technique the report comprises the following results

- linear speaker parameters + mechanical creep factor
- electrical impedance response
- mechanical transfer response (voltage to voice coil displacement)
- acoustical transfer response (voltage to SPL)
- time signals of the speaker variables during measurement
- spectra of the speaker variables (fundamental, distortion, noise floor)
- summary on the signal statistics (peak value, SNR, headroom,…).

MEASUREMENT TECHNIQUE

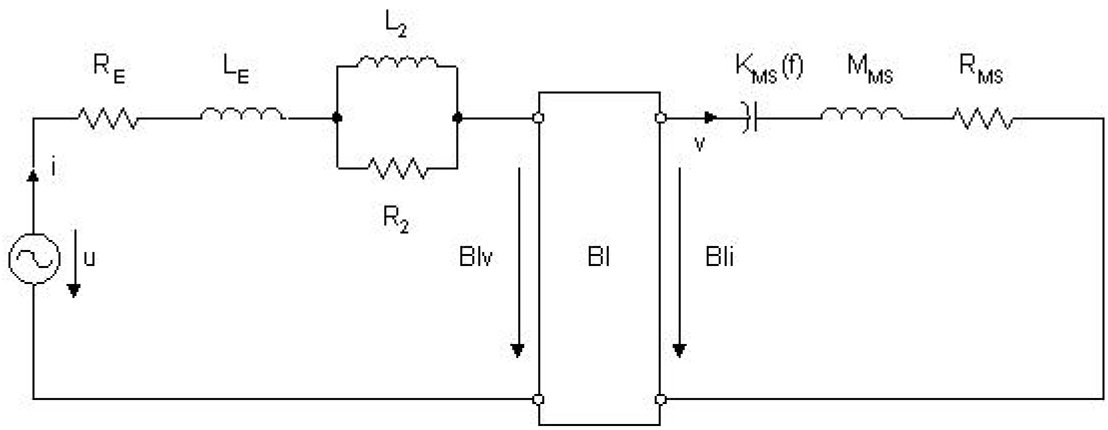
The measurement module identifies the electrical and mechanical parameters (Thiele-Small parameters) of electro-dynamical transducers. The electrical parameters are determined by measuring terminal voltage u(t) and current i(t) and exploiting the electrical impedance Z(f)=U(f)/I(f). The mechanical parameters can either be identified using a laser displacement sensor or by a second (comparative) measurement where the driver is placed in a test enclosure or an additional mass is attached to it. For the first method the displacement of the driver diaphragm is measured in order to exploit the function Hx(f)= X(f)/U(f). So the identification dispenses with a second measurement and avoids problems due to leakage of the test enclosure or mass attachment. Furthermore the suspension creep of the driver is identified giving more accuracy of the loudspeaker model at low frequencies.



Measurement Results

Linear electrical and mechanical parameters

The measurement module determines the components (Thiele-Small Parameters) of the linear loudspeaker model below describing the small signal behaviour of the driver.



The table below shows the electrical and mechanical parameters of the linear driver model, the derived parameters (resonance frequency, loss factors etc.) and the parameter of the suspension creep factor.

Name	Value	Unit	Comment
Electrical Parameters			
Re	6.33	Ohm	electrical voice coil resistance at DC
Le	0.277	mH	frequency independent part of voice coil inductance
L2	0.430	mH	para-inductance of voice coil
R2	4.28	Ohm	electrical resistance due to eddy current losses

Cmes	245.61	µF	electrical capacitance representing moving mass
Lces	92.16	mH	electrical inductance representing driver compliance
Res	44.18	Ohm	resistance due to mechanical losses
fs	33.5	Hz	driver resonance frequency
Mechanical Parameters			
(using laser)			
Mms	14.348	g	mechanical mass of driver diaphragm assembly including air load and voice coil
Mmd (Sd)	13.036	g	mechanical mass of voice coil and diaphragm without air load
Rms	1.322	kg/s	mechanical resistance of total-driver losses
Cms	1.578	mm/N	mechanical compliance of driver suspension
Kms	0.63	N/mm	mechanical stiffness of driver suspension
Bl	7.643	N/A	force factor (Bl product)
Lambda s	0.007		suspension creep factor
Loss factors			
Qtp	0.286		total Q-factor considering all losses
Qms	2.281		mechanical Q-factor of driver in free air considering Rms only
Qes	0.327		electrical Q-factor of driver in free air considering Re only
Qts	0.286		total Q-factor considering Re and Rms only
Other Parameters			
Vas	27.2288	l	equivalent air volume of suspension
n0	0.300	%	reference efficiency (2 pi-radiation using Re)
Lm	86.97	dB	characteristic sound pressure level (SPL at 1m for 1W @ Re)
Lnom	87.99	dB	nominal sensitivity (SPL at 1m for 1W @ Zn)
rmse Z	2.54	%	root-mean-square fitting error of driver impedance Z(f)
rmse Hx	1.37	%	root-mean-square fitting error of transfer function Hx (f)
Series resistor	0.00	Ohm	resistance of series resistor
Sd	110.44	cm^2	diaphragm area

Suspension creep factor

Some loudspeaker suspension materials exhibit significant creep (continued slow displacement under sustained force) in their dynamic behaviour. Therefore the traditional low-frequency loudspeaker model is expanded to incorporate suspension creep by replacing the simple linear compliance by the dynamic transfer function [1].

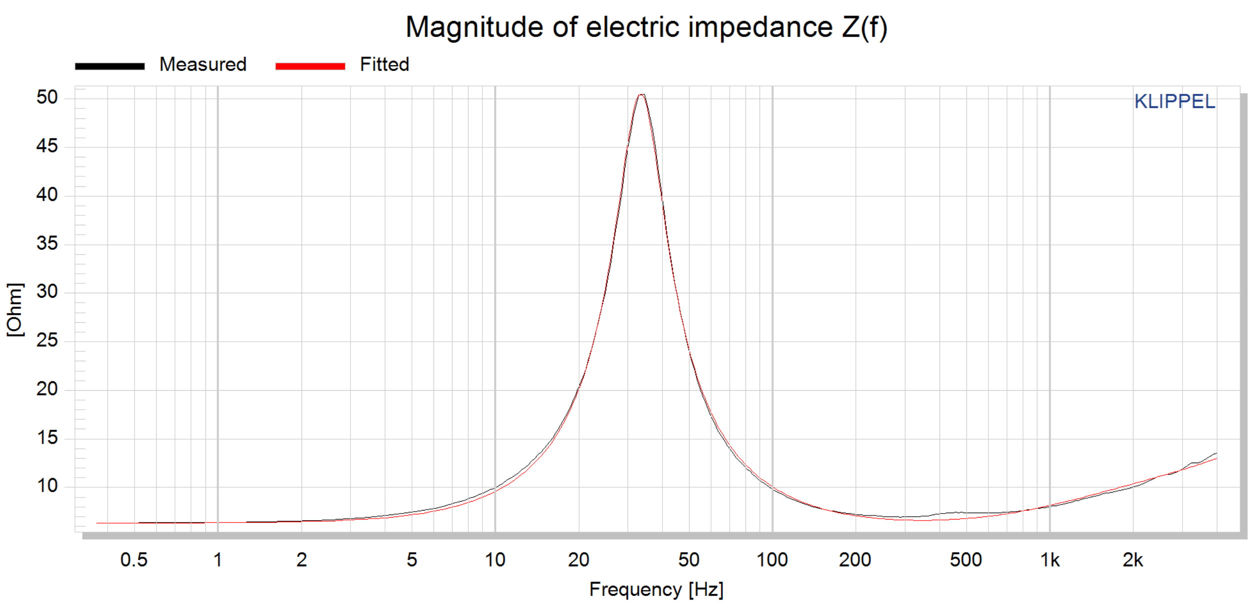
$$C_{MS}(f) = C_{MS}(f_s)\left[1 - \lambda \log 10\left(\frac{f}{f_s}\right)\right]$$

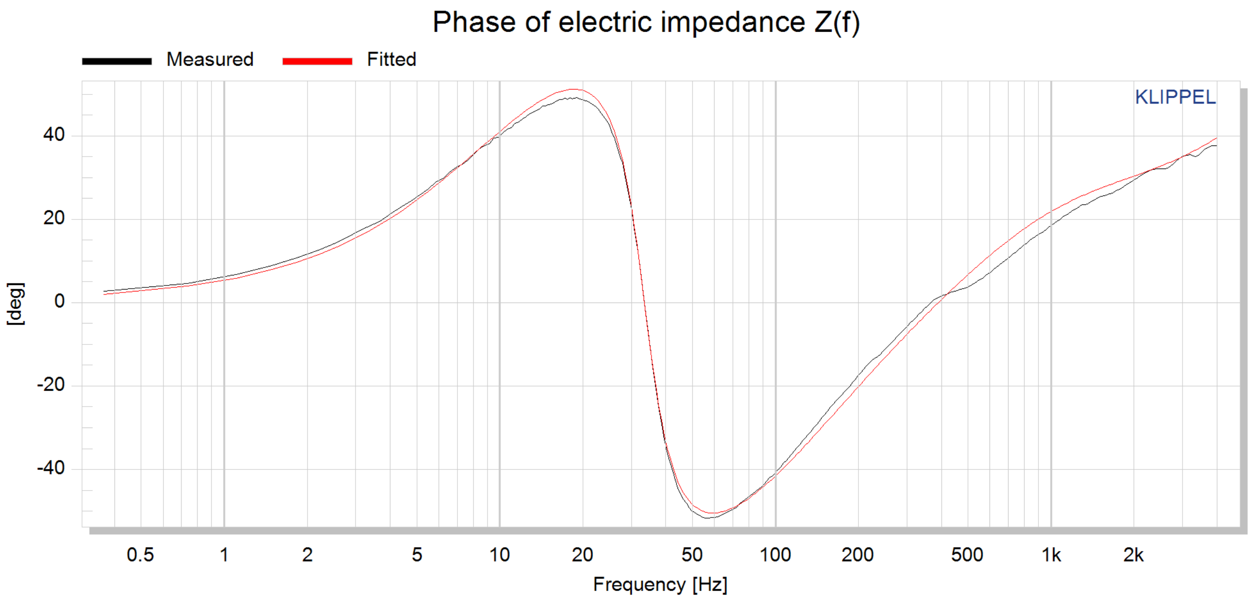
where C_{MS} is the linear compliance and f_s is the driver resonance frequency. There is a straight forward interpretation of the creep factor λ . The quantity λ 100% indicates the decrease of the compliance $C_{MS}(f_s)$ in percentages at low frequencies. For a frequency one decade below the resonance frequency f_s the compliance $C_{MS}(f_s)$ is decreased by λ 100% .

[1] Knudsen, M. H. and Jensen, J. G. *Low-frequency loudspeaker models that include suspension creep.* J. Audio Eng. Soc., Vol. 41, No. 1 / 2, 1993

Electrical Impedance

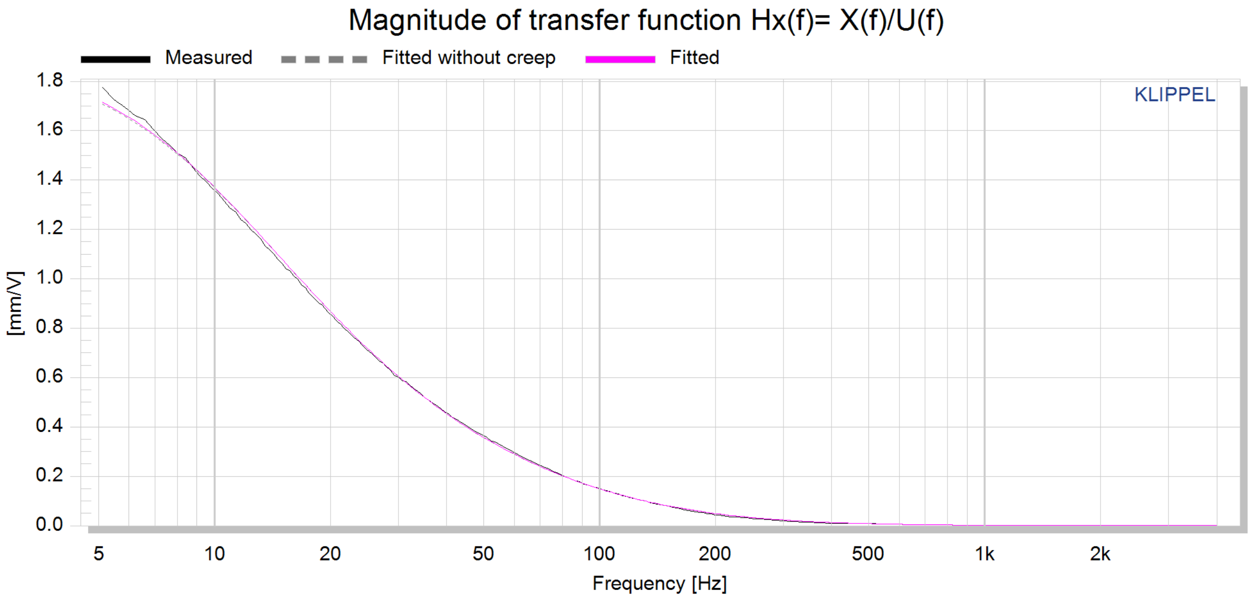
The two figures below show the magnitude and the phase response of the measured and estimated transfer function Z(f)= U(f)/I(f) where U is the terminal voltage and I is the current. The **solid** curve is the ratio of the measured spectra U(f), I(f) while the *thin* curve is the impedance of the linear driver equivalent circuit using the linear model and the identified electrical parameters shown





Displacement Transfer Function

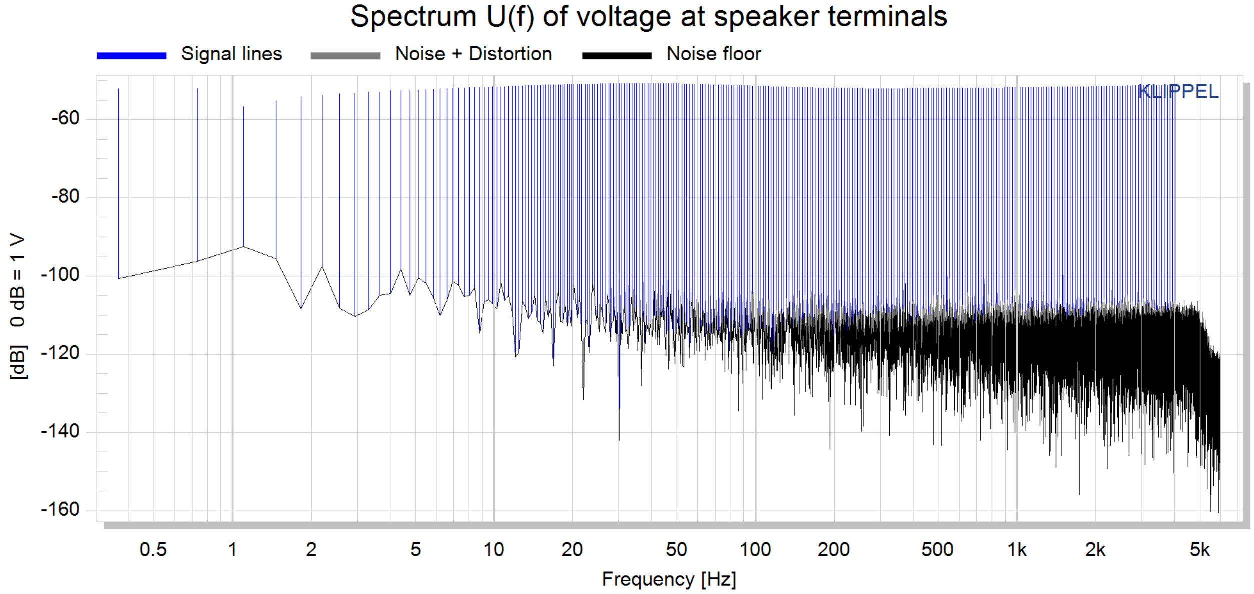
The figure below shows the magnitude of the measured and estimated transfer function Hx(f)= X(f)/U (f) between the voice coil displacement X and the terminal voltage U. The **solid black curve** is the ratio of the measured spectra X(f), U(f) while the ***thin black curve*** is the transfer function based on the linear driver equivalent circuit using the identified electrical and mechanical parameters as well as the creep parameter. The dashed red curve is based on the conventional model without considering the creep factor.



Spectra of measurement signals

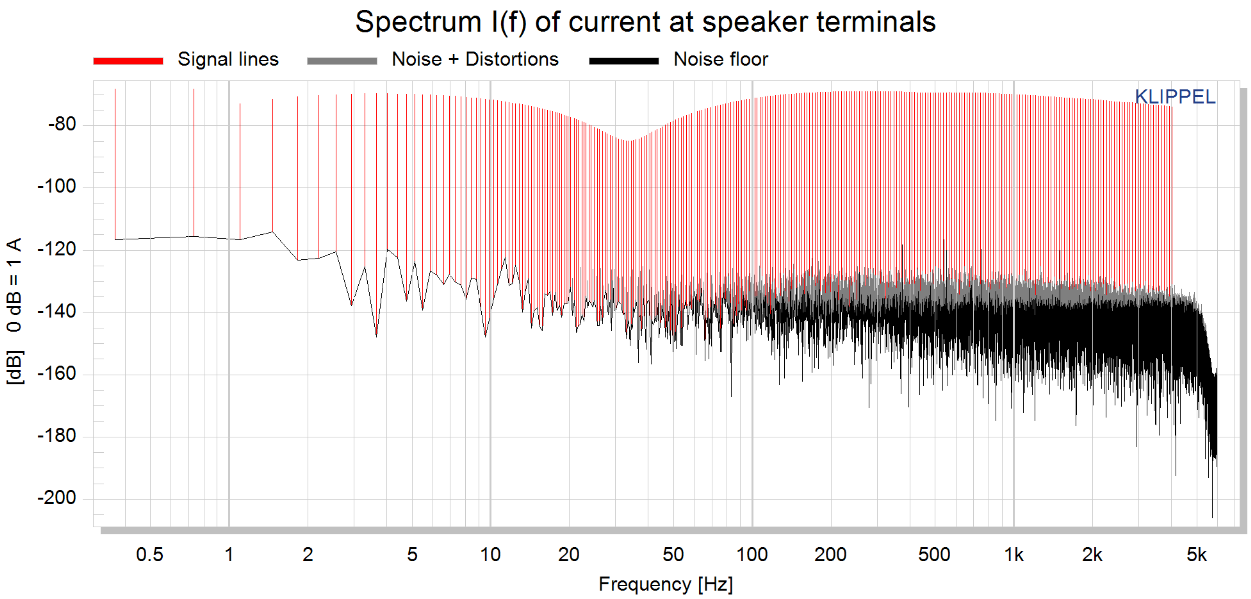
Voltage Spectrum

The diagram shows the multi-tone spectrum of the voltage at the terminals. The blue lines represent the fundamental components excited by the stimulus. The **black "noise floor"** lines represent the residual measurement noise caused by the voltage sensor. If the grey **"noise + distortions"** exceeds the residual noise floor we see the distortions generated by the nonlinearities of the power amplifier. This information is important for assessing the distortion of the speaker in the current, displacement and sound pressure below.



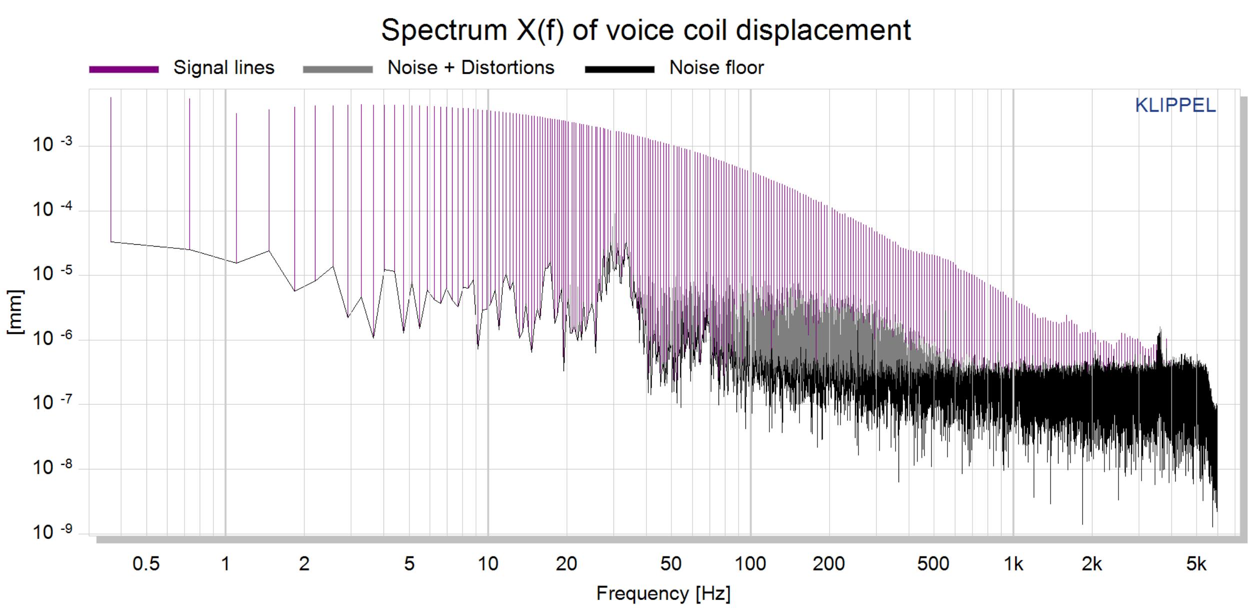
Current Spectrum

The diagram below shows the multi-tone spectrum of the current at the terminals. The red lines represent the fundamental components excited by the stimulus. Note the notch of the spectrum at the resonance frequency of the driver. The black **"noise floor"** lines indicate the residual noise caused by the measurement system (current sensor). If the grey **"noise + distortions" lines** exceeds the residual noise floor we see the distortions generated by the nonlinearities of the speaker (assuming that the power amplifier is sufficiently linear).



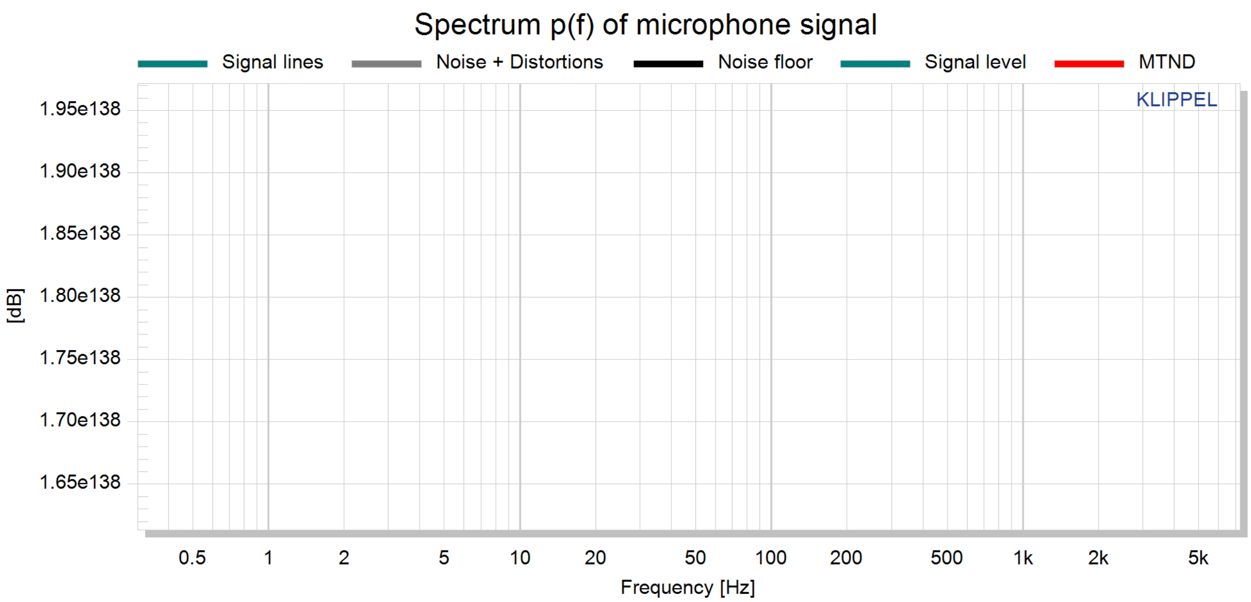
Displacement Spectrum

The diagram below shows the multi-tone spectrum of the voice coil displacement measured with the laser sensor. The **violet lines** represent the fundamental components excited by the stimulus. Note the 12 dB/octave decay of the displacement spectra above the resonance frequency of the laser. The black **"noise floor"** lines indicate the measurement noise caused by the resolution of the used Laser Sensor Head. Increasing the number of averaging will further reduce the residual noise line. If the grey **"noise + distortions"** exceeds the residual noise floor we see the distortions generated by the nonlinearities of the speaker. These components are independent on the number of averaging.



Sound Pressure Spectrum

The diagram shows the multi-tone spectrum of the sound pressure measured with the microphone. The **green lines** represent the fundamental components excited by the stimulus.The black **“noise floor”** lines indicate the ambient noise during the measurement. The grey **“noise + distortions”** are the nonlinear distortion components generated by the speaker.



Signal Characteristics

The table below summarizes important statistical characteristics (peak values, head rooms, SNR ratio, …) of the state variables (voltage, current, displacement and sound pressure). This information is helpful for assessing the working point of the driver (Small - Large Signal Domain) and to detect any malfunction operation (microphone or laser not connected).

Name	Value	Unit	Comment

Reduce Fmax to 20* fs to improve impedance fitting			
Voltage			
U pp	0.35	V	peak to peak value of voltage at terminals
U ac	0.04	V rms	AC part of voltage signal
U dc	0.00	V	
U head	63.7	dB	digital headroom of voltage signal
U SNR+D	35.4	dB	ratio of signal to noise+distortion in voltage signal
fu noise	302.1	Hz	frequency of noise+distortion maximum in voltage signal
gain	23.87		Amplifier gain measured
Current			
I pp	0.04	A	peak to peak value of current at terminals
I ac	0.00	A rms	AC part of current signal
I dc	0.00	A	
I head	43.8	dB	digital headroom of current signal
I SNR+D	35.9	dB	ratio of signal to noise+distortion in current signal
fi noise	302.1	Hz	frequency of noise+distortion maximum in current signal
Displacement			
X pp	0.20	mm	peak to peak value of displacement signal
X ac	0.03	mm rms	AC part of displacement signal
X dc	-0.00	mm	
X head	46.8	dB	digital headroom of displacement signal
X SNR+D	25.6	dB	ratio of signal to noise+distortion in displacement signal
fx cutoff	2009.0	Hz	frequency of highest valid line in displacement signal
SPL			
p pp		mV	peak to peak value of microphone signal
p ac		mV rms	AC part of microphone signal
p head		dB	digital headroom of microphone signal
p sum level		dB	sum level of microphone signal

p mean level		dB	mean level of microphone signal
Measurement			
f sample	12000	Hz	sample frequency
N stim	32768	samples	stimulus length
cal x laser	0.024503		Laser calibration factor

This report is generated by the report generator in the frame software *dB-Lab* in the Klippel Analyzer System. Using an existing report as template, the old data are replaced by the results of the current measurement automatically.

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