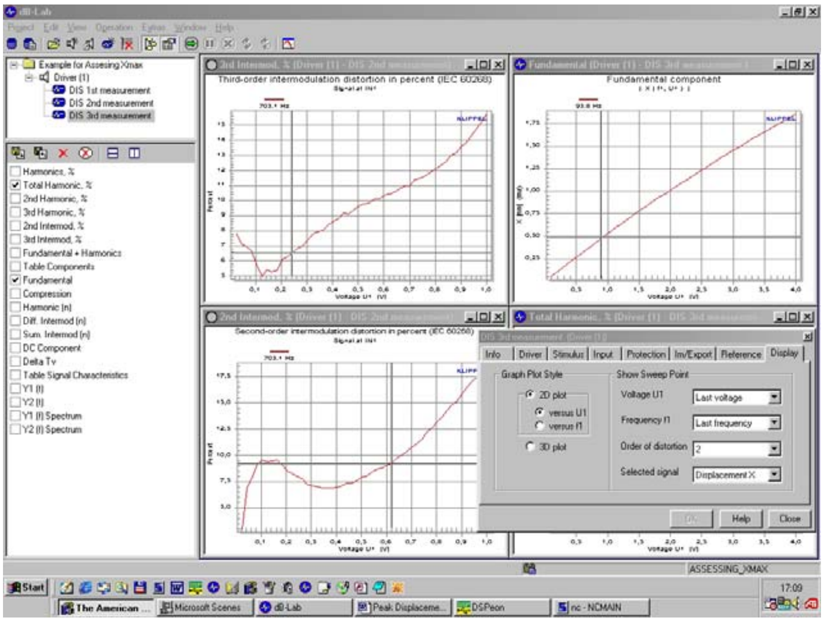
Measurement of Peak Displacement Xmax
(performance-based method)

AN 4

Application Note to the KLIPPEL R&D SYSTEM

Using the 3D Distortion Measurement module (DIS) of the KLIPPEL R&D SYSTEM the maximal peak displacement Xmax of a driver is determined by assessing the harmonic and intermodulation distortion in the radiated sound pressure (near field). The new performance-based method is an amendment of the technique AES 2 (1984) and subject of current discussion. It can be accomplished by straightforward techniques defined in the IEC 60268.



CONTENTS:

KLIPPEL
Klippel GmbH
Mendelssohnallee 30
01309 Dresden, Germany
www.klippel.de
info@klippel.de
TEL: +49-351-251 35 35
FAX: +49-351-251 34 31

Performance based definition of Xmax

Current Definition	The current standard defines "*the voice-coil peak displacement at which the "linearity" of the motor deviates by 10%. Linearity may be measured by percent distortion of the input current or by percent deviation of displacement versus input current. Manufacturer shall state method used. The measurement shall be made in free air at f_S.*"
What is wrong with AES 2-1984	The old method of defining the peak displacement Xmax • gives no clear definition of peak displacement • gives multiple or infinite values of Xmax • considers suspension nonlinearity only • fails in assessing motor linearity
Suggested Amendment	*The voice-coil peak displacement Xmax at which either the total harmonic distortion d_t or the nth-order modulation distortion (where n=2 or 3) exceeds 10% in the sound pressure radiated by the driver in free air excited by the linear superposition of a first tone at the resonance frequency f1=f_S and a second tone f_2=8.5 f_S with an amplitude ratio of 4:1.* *The total harmonic distortion d_t assesses the harmonics of f_1 and the modulation distortion are measured by the modulation components $f_2 \pm nf_1$ according to IEC 60268.*
Practical Usage	1. Measure resonance frequency f_S of the driver 2. Operate driver under free-field condition and excite driver with a two-tone signal $f_1=f_S$ and $f_2=8.5\ f_S$ *and* amplitude ratio $U_1=4*U_2$ *and* perform a series of measurements with varied amplitudes $U_{start} < U_1 < U_{end}$. 3. Measure sound pressure in the near field and perform a spectral analysis to measure the amplitude of the fundamental $P(f_1)$ and $P(f_2)$, of the harmonic components $P(k*f_1)$ with k= 2, 3, ...,K and of the summed-tone component $P(f_2+(n-1)*f_1)$ and difference-tone components $P(f_2-(n-1)*f_1)$ with n=2, 3 versus amplitude U_1. Measure the peak displacement $X(f_1)$ versus amplitude U_1. 4. Calculate the total harmonic distortion $$d_t = \frac{\sqrt{P(2f_1)^2 + P(3f_1)^2 + ... + P(Kf_1)^2}}{P_t} * 100\ \%$$ the second-order modulation distortion $$d_2 = \frac{P(f_2 - f_1) + P(f_2 + f_1)}{P(f_2)} * 100\ \%$$ and the third-order modulation distortion $$d_3 = \frac{P(f_2 - 2f_1) + P(f_2 + 2f_1)}{P(f_2)} * 100\ \%$$ according IEC 60268 as a function of U_1. 5. Search for minimal value $U_{10\%}$ in the range $U_{start} < U_{10\%} < U_{end}$ where either the harmonic distortion d_t, the second- or third-order modulation distortion d_2 or d_3, respectively, equals 10%. 6. Search for the peak displacement Xmax corresponding to the amplitude $U_{10\%}$.

Using the 3D Distortion Measurement (DIS)

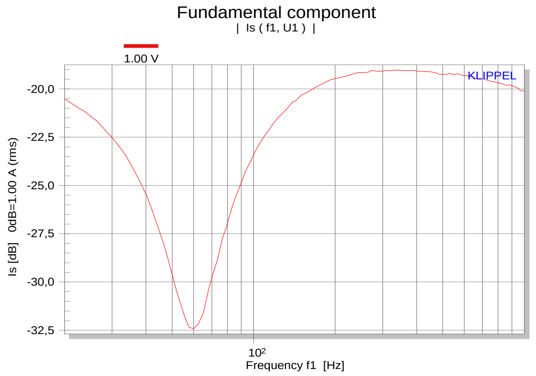
Requirements	• Distortion Analyzer + PC • Software module 3D Distortion Measurement (DIS) + dB-Lab • Laser sensor head for measuring the displacement • Microphone for near field measurement
Setup  Don't forget ear protection!	Connect the microphone to the input IN1 at the rear side of the DA. Mount the driver in the laser stand and connect the terminals with SPEAKER 1. Switch the power amplifier between OUT1 and connector AMPLIFIER. Adjust the laser head to the diaphragm and bring the microphone in the near field of the driver.
Preparation	1. Create a new database within dB-Lab or add a new object to your current database. 2. Create a new object DRIVER based on the object template “Xmax10% distortion AN4” provided in the dB-Lab object templates.
1st Measurement	If you know the resonance frequency of the driver (from LPM or LSI) you may skip the first measurement. Alternatively you may use the DIS measurement 1st measurement for measuring the frequency response of the input current. 1. Start the measurement "1 DIS Find resonance fs " 2. Search for the frequency f_s in window **fundamental** where the amplitude is minimal.
2nd Measurement	1. Start measurement "2 DIS Distortion measurement " 2. On property page DISPAY make sure “Signal at IN 1” is selected as State Signal. 3. Window **2nd INTERMOD,%:** Read $U_{d2}=U_1$ where d_2=10% by using the cross cursor (may be activated by using the right-mouse button). 4. Window **3rd INTETMOD,%:** Read $U_{d3}=U_1$ where d_3=10% by using the cross cursor 5. Window **TOTAL HARMONIC,%:** Read $U_{dt}=U_1$ where d_t=10% by using the cross cursor 6. →If both d_2 < 10 % and d_3 < 10% and d_t < 10 % then increase U_{end} and start from point 1 of the 2nd measurement 7. Search for U_{min}=MINIMUM(U_{dt}, U_{d2}, U_{d3}) (see Example) 8. Open PP DISPLAY and select signal **DISPLACEMENT** 9. Open window **FUNDAMENTAL** 10. Read X_{rms} for U_{min} by using the cross cursor 11. Calculate peak value Xmax=1.4*X_{rms}

Setup Parameters for the DIS Module

Template	Create a new Object, using the object template **Xmax10% distortion AN 4** in dB-Lab. Then the two measurements are already customized for the assessment of Xmax. If this template is not available you may generate two 3D distortion measurements (DIS) and modify the setup parameters according to this table.
1st Measurement	1. Open the PP **STIMULUS**. Select mode **HARMONICS**. Switch **off** Voltage Sweep. Set U to 1 V_{rms}. Switch on the Frequency Sweep with 100 points spaced logarithmically between 20 Hz and 1000 Hz. Activate additional excitation time of 0.1 s before measurement. 2. Open PP **Protection**. Disable temperature measurement and any protection. 3. Open PP **Input**. Select **US voltage speaker 1 (Y1)** and **IS current speaker 1 (Y2)**. 4. Open PP **Display**. Select **CURRENT SPEAKER** 1 as State signal.
2nd Measurement	1. Open the PP **STIMULUS**. Select mode **Harmonics + Intermodulations (f2)**. Switch **on** Voltage Sweep with 50 points spaced **linearly** between 1 V and 8 V. Make sure the signal level is appropriate for loudspeaker. Set ration U_2/U_1= -12 dB. Switch off the Frequency Sweep and set f_1 to f_s. Set ratio f_1/f_2 = 0.118. Activate additional excitation time of 0.1 s before measurement. 2. Open PP **Protection**. Enable temperature measurement and set threshold of maximal increase of voice coil temperature to 50 K. Enable mechanical protection in IN 1 and Laser and set threshold of total harmonic distortion to 10.5 %. 3. Open PP **Input**. Select **MIC IN 1 (Y1)** and **X Displacement (Y2)**. 4. Open PP **Display**. Select **SIGNAL IN1** as State signal.

Example

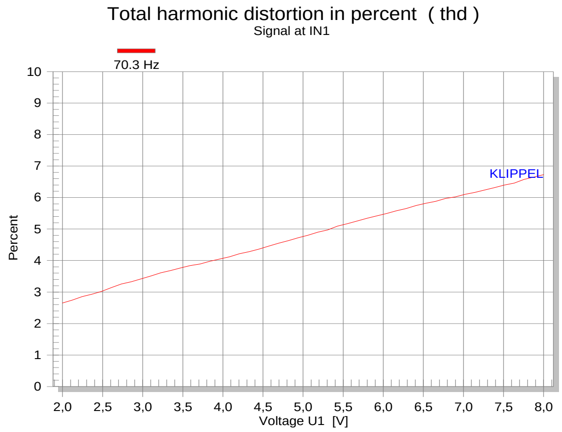
resonance frequency f_s



The fundamental of the input current versus frequency f_1. The minimum of the current shows the resonance frequency f_s of the driver.

The minimum of the input current indicates the resonance frequency f_s = 70 Hz.

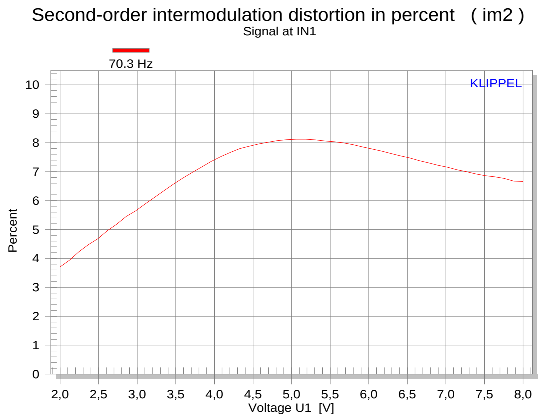
Total harmonic distortion d_t



The total harmonic distortion d_t of sound pressure of the tone f_1=f_s in percent versus amplitude U_1.

The total harmonic distortion does not exceed the limit value of 10 %. Thus U_{dt} > 8 $V_{rms.}$

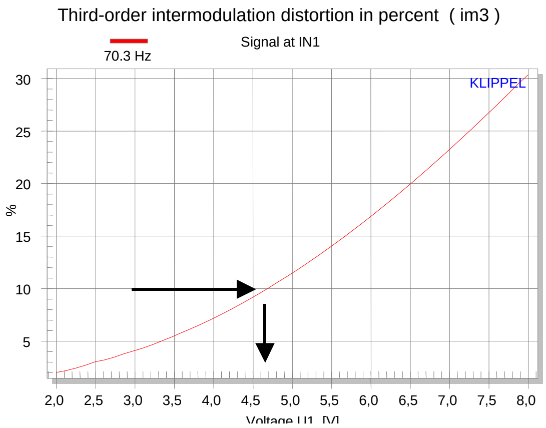
Second-order modulation distortion d_2



The second-order modulation distortion d_2 of the radiated two-tone signal in percent versus amplitude U_1.

The second-order distortion does not exceed the limit value of 10 %. Thus U_{d2} > 8 $V_{rms.}$

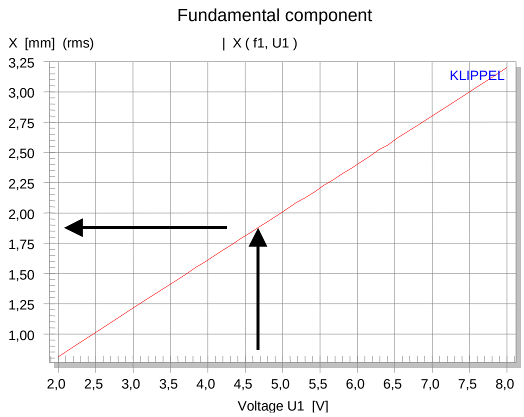
Third-order modulation distortion d_3



The third-order modulation distortion d_3 of the radiated two-tone signal in percent versus amplitude U_1.

For U_{d3} = 4.65 V_{rms} the driver produces 10 % third-order modulation distortion.

Voice Coil displacement



The minimal voltage $U_{min} = U_{d3}$ is determined by the third-order modulation distortion. The RMS amplitude of the voice coil displacement of tone f_1 versus amplitude U_1. mm.

The minimal voltage $U_{min} = U_{d3}$ is determined by the third-order modulation distortion. For $U_{min} = 4.65\ V_{rms}$ we read a $X_{RMS} = 1.9$ mm. The peak displacement of the driver is $X_{max} = 2.66$ mm.

More Information

Papers	W. Klippel, "Assessment of Voice Coil Peak Displacement X_{max}, paper in presented at the 112th Convention of the Audio Engineering Society, 2002 May 10 – 13, Munich, Germany. Updated version on http://www.klippel.de/know-how/literature/papers.html
Application Notes	"Measurement of Displacement Limits (parameter-based method)", AN 5 of the KLIPPEL R&D SYSTEM
Related Specification	“DIS”, S4
Software	User Manual for Distortion R&D System.

updated April 4, 2012

KLIPPEL

Klippel GmbH
Mendelssohnallee 30
01309 Dresden, Germany

www.klippel.de
info@klippel.de

TEL: +49-351-251 35 35
FAX: +49-351-251 34 31