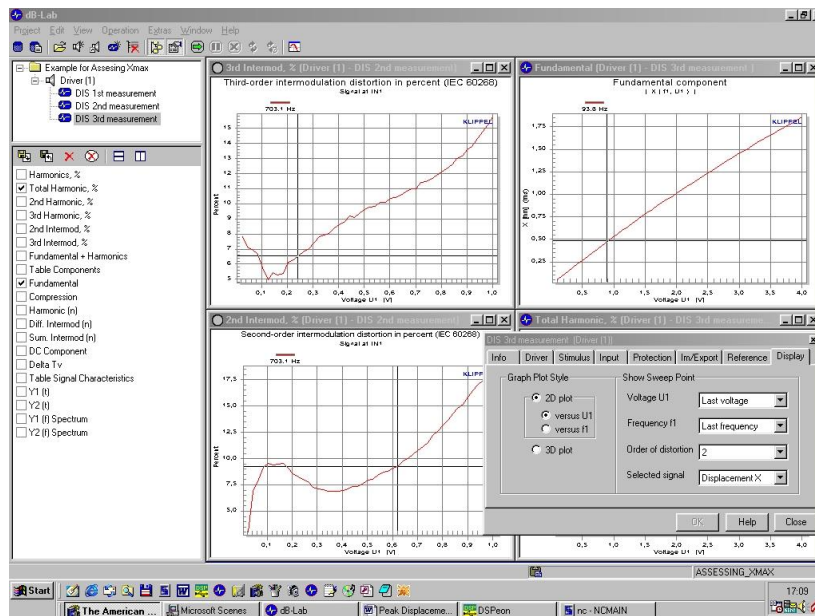


# Measurement of Peak Displacement $X_{max}$ AN 4 (Performance based method)

Application Note to the KLIPPEL R&D System (Document Revision 1.1)

## DESCRIPTION

Using the 3D Distortion Measurement module (DIS) of the KLIPPEL R&D SYSTEM the maximal peak displacement  $X_{max}$  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.




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## 1 Performance based definition of X<sub>max</sub>

<b>Old Definition (AES 2-1984)</b>	<p>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. The manufacturer shall state the method used. The measurement shall be made in free air at f<sub>s</sub>."</p>
<b>What is wrong with AES 2-1984?</b>	<p>The old method of defining the peak displacement X<sub>max</sub></p> <ul style="list-style-type: none"> <li>• Gives no clear definition of peak displacement</li> <li>• Gives multiple or infinite values of X<sub>max</sub></li> <li>• Considers suspension nonlinearity only</li> <li>• Fails in assessing motor linearity</li> </ul>
<b>New Definition (IEC 62458)</b>	<p><i>The voice-coil peak displacement X<sub>max</sub> at which either the total harmonic distortion d<sub>t</sub> or the n<sup>th</sup>-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 f<sub>1</sub>=f<sub>s</sub> and a second tone f<sub>2</sub>=8.5 f<sub>s</sub> with an amplitude ratio of 4:1.</i></p> <p><i>The total harmonic distortion d<sub>t</sub> assesses the harmonics of f<sub>1</sub> and the modulation distortion are measured by the modulation components f<sub>2</sub>± n f<sub>1</sub> according to IEC 60268.</i></p>
<b>Practical Usage</b>	<ol style="list-style-type: none"> <li>1) Measure resonance frequency f<sub>s</sub> of the driver</li> <li>2) Operate driver under free-field condition and excite driver with a two-tone signal f<sub>1</sub>=f<sub>s</sub> and f<sub>2</sub>=8.5 f<sub>s</sub> and amplitude ratio U<sub>1</sub>=4*U<sub>2</sub> and perform a series of measurements with varied amplitudes U<sub>start</sub> &lt; U<sub>1</sub> &lt; U<sub>end</sub>.</li> <li>3) Measure sound pressure in the near-field and perform a spectral analysis to measure the amplitude of the fundamental P(f<sub>1</sub>) and P(f<sub>2</sub>), of the harmonic components P(k*f<sub>1</sub>) with k= 2, 3, ...,K and of the summed-tone component P(f<sub>2</sub>+(n-1)*f<sub>1</sub>) and difference-tone components P(f<sub>2</sub>-(n-1)*f<sub>1</sub>) with n=2, 3 versus amplitude U<sub>1</sub>. Measure the peak displacement X(f<sub>1</sub>) versus amplitude U<sub>1</sub>.</li> <li>4) Calculate the total harmonic distortion <math display="block">d_t = \frac{\sqrt{P(2f_1)^2 + P(3f_1)^2 + \dots + P(Kf_1)^2}}{P_1} * 100\%</math> <p>the second-order modulation distortion</p> <math display="block">d_2 = \frac{P(f_2 - f_1) + P(f_2 + f_1)}{P(f_2)} * 100\%</math> <p>and the third-order modulation distortion</p> <math display="block">d_3 = \frac{P(f_2 - 2f_1) + P(f_2 + 2f_1)}{P(f_2)} * 100\%</math> <p>according to IEC 60268 as a function of U<sub>1</sub>.</p> </li> <li>5) Search for minimal value U<sub>10%</sub> in the range U<sub>start</sub> &lt; U<sub>10%</sub> &lt; U<sub>end</sub> where the harmonic distortion d<sub>t</sub>, the second- or third-order modulation distortion d<sub>2</sub> or d<sub>3</sub>, respectively, reach 10%.</li> <li>6) Search for the peak displacement X<sub>max</sub> corresponding to the amplitude U<sub>10%</sub>.</li> </ol>

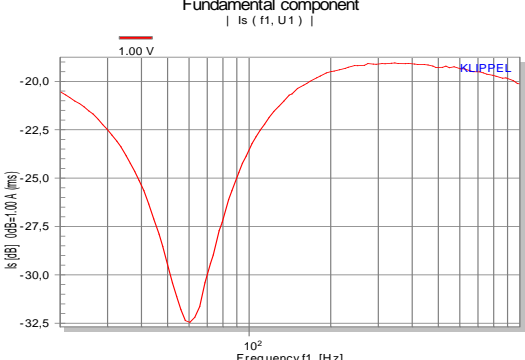
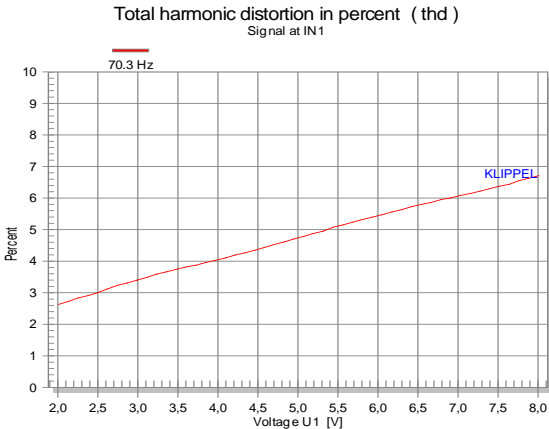
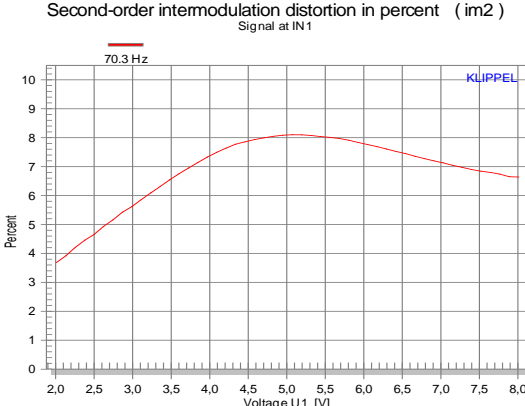
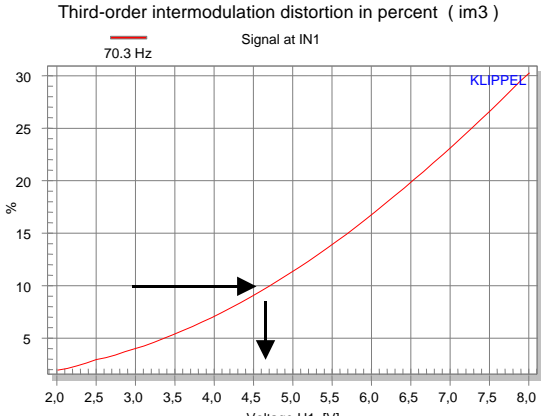
## 2 Using the 3D Distortion Measurement (DIS)

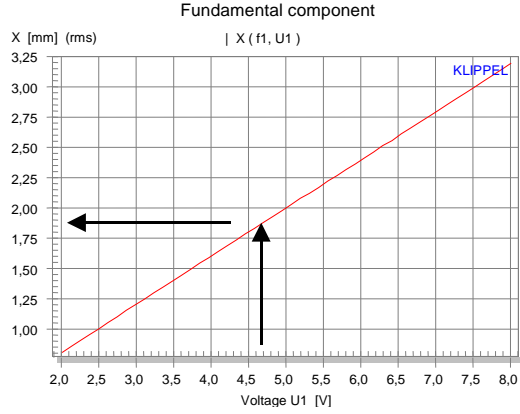
<b>Requirements</b>	<ul style="list-style-type: none"> <li>• Distortion Analyzer + PC</li> <li>• Software module 3D Distortion Measurement (DIS) + dB-Lab</li> <li>• Laser sensor head for measuring the displacement</li> <li>• Microphone for near field measurement</li> </ul>
<b>Setup</b>  	<ul style="list-style-type: none"> <li>• Connect the microphone to the input IN1 at the rear side of the DA.</li> <li>• Mount the driver in the laser stand and connect the terminals with SPEAKER 1.</li> <li>• Switch the power amplifier between OUT1 and connector AMPLIFIER.</li> <li>• Adjust the laser head to the diaphragm and bring the microphone in the near field of the driver.</li> </ul>
<b>Preparation</b>	<ol style="list-style-type: none"> <li>1) Create a new database within dB-Lab or add a new object to your current database.</li> <li>2) Create a new object DRIVER based on the object template "Xmax10% distortion AN4" provided in the dB-Lab object templates.</li> </ol>
<b>1<sup>st</sup> Measurement</b>	<p>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 1<sup>st</sup> measurement for measuring the frequency response of the input current.</p> <ol style="list-style-type: none"> <li>1) Start the measurement "1 DIS Find resonance fs "</li> <li>2) Search for the frequency <math>f_s</math> in window <b>FUNDAMENTAL</b> where the amplitude is minimal.</li> </ol>
<b>2<sup>nd</sup> Measurement</b>	<ol style="list-style-type: none"> <li>1) Start measurement "2 DIS Distortion measurement "</li> <li>2) On property page DISPLAY make sure "Signal at IN 1" is selected as State Signal.</li> <li>3) Window <b>2<sup>nd</sup> INTERMOD, %</b>: Read <math>U_{d2}=U_1</math> where <math>d_2=10\%</math> by using the cross cursor (may be activated by using the right-mouse button).</li> <li>4) Window <b>3<sup>rd</sup> INTETMOD,%</b>: Read <math>U_{d3}=U_1</math> where <math>d_3=10\%</math> by using the cross cursor</li> <li>5) Window <b>TOTAL HARMONIC,%</b>: Read <math>U_{dt}=U_1</math> where <math>d_t=10\%</math> by using the cross cursor</li> <li>6) →If both <math>d_2 &lt; 10\%</math> and <math>d_3 &lt; 10\%</math> and <math>d_t &lt; 10\%</math> then increase <math>U_{end}</math> and start from point 1 of the 2<sup>nd</sup> measurement</li> <li>7) Search for <math>U_{min}=\text{MINIMUM}(U_{dt}, U_{d2}, U_{d3})</math> (see Example)</li> <li>8) Open PP DISPLAY and select signal <b>DISPLACEMENT</b></li> <li>9) Open window <b>FUNDAMENTAL</b></li> <li>10) Read <math>X_{rms}</math> for <math>U_{min}</math> by using the cross cursor</li> <li>11) Calculate peak value <math>X^{max}=1.4*X_{rms}</math></li> </ol>

### 3 Setup Parameters for the DIS Module

<b>Template</b>	Create a new Object, using the object template <b>X<sub>max</sub> 10% distortion AN 4</b> in dB-Lab. Then the two measurements are already customized for the assessment of X <sub>max</sub> . If this template is not available you may generate two 3D distortion measurements (DIS) and modify the setup parameters according to this table.
<b>1<sup>st</sup> Measurement</b>	<ol style="list-style-type: none"> <li>1) Open the PP <b>STIMULUS</b>. Select mode <b>HARMONICS</b>. Switch <b>off</b> Voltage Sweep. Set U to 1 V<sub>rms</sub>. 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.</li> <li>2) Open PP <b>Protection</b>. Disable temperature measurement and any protection.</li> <li>3) Open PP <b>Input</b>. Select <b>US voltage speaker 1 (Y1)</b> and <b>IS current speaker 1 (Y2)</b>.</li> <li>4) Open PP <b>Display</b>. Select <b>CURRENT SPEAKER 1</b> as State signal.</li> </ol>
<b>2<sup>nd</sup> Measurement</b>	<ol style="list-style-type: none"> <li>1) Open the PP <b>STIMULUS</b>. Select mode <b>Harmonics + Intermodulations (f2)</b>. Switch <b>on</b> Voltage Sweep with 50 points spaced <b>linearly</b> between 1 V and 8 V. Make sure the signal level is appropriate for loudspeaker. Set ration <math>U_2/U_1 = -12</math> dB. Switch off the Frequency Sweep and set <math>f_1</math> to <math>f_s</math>. Set ratio <math>f_1/f_2 = 0.118</math>. Activate additional excitation time of 0.1 s before measurement.</li> <li>2) Open PP <b>Protection</b>. 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 %.</li> <li>3) Open PP <b>Input</b>. Select <b>MIC IN 1 (Y1)</b> and <b>X Displacement (Y2)</b>.</li> <li>4) Open PP <b>Display</b>. Select <b>SIGNAL IN1</b> as State signal.</li> </ol>

### 4 Example

<p><b>Resonance frequency <math>f_s</math></b></p>		<p>The fundamental of the input current versus frequency <math>f_1</math>. The minimum of the current shows the resonance frequency <math>f_s</math> of the driver.</p> <p>The minimum of the input current indicates the resonance frequency <math>f_s = 70</math> Hz.</p>
<p><b>Total harmonic distortion <math>d_t</math></b></p>		<p>The total harmonic distortion <math>d_t</math> of sound pressure of the tone <math>f_1=f_s</math> in percent versus amplitude <math>U_1</math>.</p> <p>The total harmonic distortion does not exceed the limit value of 10 %. Thus <math>U_{dt} &gt; 8 V_{rms}</math>.</p>
<p><b>Second-order modulation distortion <math>d_2</math></b></p>		<p>The second-order modulation distortion <math>d_2</math> of the radiated two-tone signal in percent versus amplitude <math>U_1</math>.</p> <p>The second-order distortion does not exceed the limit value of 10 %. Thus <math>U_{d2} &gt; 8 V_{rms}</math>.</p>
<p><b>Third-order modulation distortion <math>d_3</math></b></p>		<p>The third-order modulation distortion <math>d_3</math> of the radiated two-tone signal in percent versus amplitude <math>U_1</math>.</p> <p>For <math>U_{d3} = 4.65 V_{rms}</math> the driver produces 10 % third-order modulation distortion.</p>

<p><b>Voice Coil displacement</b></p>		<p>The minimal voltage <math>U_{\min} = U_{d3}</math> is determined by the third-order modulation distortion. The RMS amplitude of the voice coil displacement of tone <math>f_1</math> versus amplitude <math>U_1</math>. mm.</p> <p>The minimal voltage <math>U_{\min} = U_{d3}</math> is determined by the third-order modulation distortion. For <math>U_{\min} = 4.65 V_{\text{rms}}</math> a displacement of <math>X_{\text{RMS}} = 1.9 \text{ mm}</math> is read. The peak displacement of the driver is <math>X_{\text{max}} = 2.66 \text{ mm}</math>.</p>
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## 5 More Information

<p><b>Papers</b></p>	<p>W. Klippel, "Assessment of Voice Coil Peak Displacement <math>X_{\text{max}}</math>, paper in presented at the 112th Convention of the Audio Engineering Society, 2002 May 10 – 13, Munich, Germany. Updated version on <a href="http://www.klippel.de/know-how/literature/papers.html">http://www.klippel.de/know-how/literature/papers.html</a></p>
<p><b>Application Notes</b></p>	<p>"Measurement of Displacement Limits (parameter-based method)", AN5 of the KLIPPEL R&amp;D SYSTEM</p>
<p><b>Related Specification</b></p>	<p>"DIS", S4</p>
<p><b>Software</b></p>	<p>User Manual for Distortion R&amp;D System.</p>

Find explanations for symbols at:

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

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