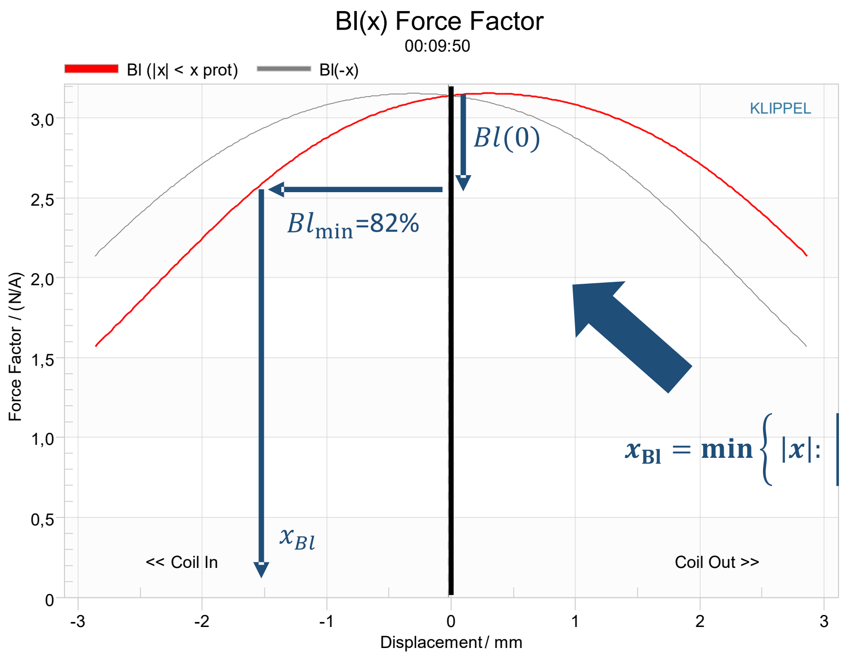
Displacement limits due to driver nonlinearities AN5

Application Note to the KLIPPEL R&D (Document Revision 1.2)

DESCRIPTION

The physical causes limiting the voice coil peak displacement are represented by separate limits corresponding to the dominant driver nonlinearities in the motor, suspension and radiation. These limits are derived from the driver's large-signal parameters, measured under user-defined admissible thresholds for parameter variation. The relationship between the separate displacement limits and the peak displacement determined by the performance-based method is discussed.



$$x_{\mathrm{Bl}} = \min\left\{ |x|: \left|\frac{Bl(x)}{Bl(0)}\right| = Bl_{\min} \right\}$$

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1 Limits of Voice Coil Displacement

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<td>Physical causes</td>
<td>The maximal peak displacement x_{max} is limited by at least three factors:

Excessive decrease in the compliance of the mechanical suspension, often caused by the natural limiting of the spider
Maximum voice coil displacement, mainly limited by hitting the back plate
Signal distortion in the sound pressure output resulting from loudspeaker nonlinearities, depending on the intended application, the characteristics of the excitation signal, and the listener's auditory sensitivity

These limiting factors may be represented by separate displacement limits:

x_{Bl} represents tolerable distortion due to force factor nonlinearity $Bl(x)$
x_C represents tolerable distortion due to compliance nonlinearity $C_{ms}(x)$
x_L represents tolerable distortion due to inductance nonlinearity $L_e(x)$
x_D represents tolerable distortion due to Doppler nonlinearity

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<td>Displacement limits</td>
<td>The calculations of this displacement limits are defined in the IEC 62458 standard. In addition, an explanation of the calculations is provided in the FLSI manual. The most essential principles are described below:

The displacement limit x_{Bl} is determined from the nonlinear $Bl(x)$-characteristic by using a predefined threshold Bl_{min}. The threshold Bl_{min}= 82 % corresponds to approximately 10 % total modulation distortion.
The displacement limit x_C is determined from the nonlinear $C_{ms}(x)$-characteristic by using a predefined threshold C_{min}. The threshold C_{min}= 75 % corresponds to approximately 10 % total harmonic distortion.
The displacement limit x_L is determined as the point at which the ratio of the electrical impedance $Z_E(f_2,x)$ deviates from its value at the rest position by a specified threshold. The threshold $Z_{max}(x_L)$=10% corresponds to approximately 10 % intermodulation distortion. The frequency f_2= 8.5·f_s is defined by IEC 62458 and represents a modulated voice tone.
The displacement limit x_D is determined using the distortion threshold d_2=10% and the reference frequency f_2= 8.5·f_s.

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<td>Practical usage</td>
<td>All displacement limits are automatically calculated by the large signal measurement for the distortion thresholds defined in the IEC 62458 standard. Alternatively, the displacement limits can be changed manually on the property page "Setup".
<table>
<tr><th colspan="2">Display</th></tr>
<tr><td>Distortion Components</td><td>Relative (dB)</td></tr>
<tr><td>Displacement Limits</td><td>Manual</td></tr>
<tr><td>• Bl min</td><td>82</td></tr>
<tr><td>• C min</td><td>75</td></tr>
<tr><td>• Z max</td><td>10</td></tr>
<tr><td>• d2</td><td>10</td></tr>
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<tr>
<td>Relationship to maximal displacement x_{max}</td>
<td>The AES 1984-2 standard suggests a performance-based method for assessing the maximal peak displacement x_{max} based on distortion measurement. The original method is based on assessing the total harmonic distortion only and fails for drivers having significant $Bl(x)$ nonlinearity. An amendment suggests a two-tone signal for the measurement of the harmonics and intermodulation distortion. Although there are fundamental differences between the performance-based and the parameter-based approach, it is possible to keep both methods comparable by choosing corresponding distortion values (described in AN4 Measurement of Peak Displacement Xmax) and thresholds Bl_{min}, C_{min}, Z_{max} and d_2. It is recommended to use the expression "Voice Coil Peak Displacement" and the symbol x_{max} for the results of the performance-based approach.</td>
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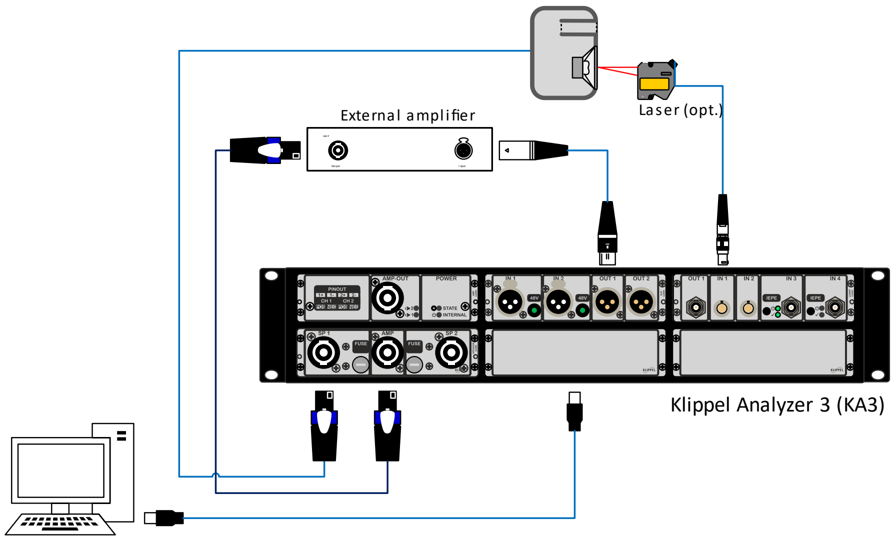
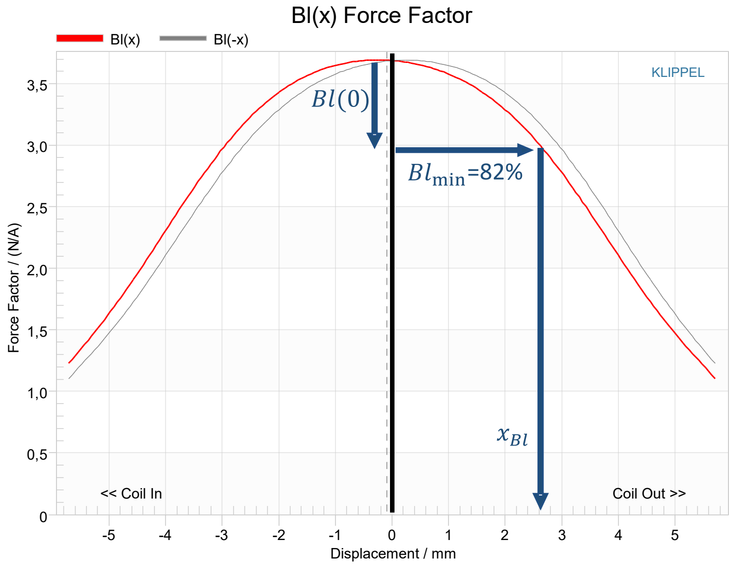
2 Using the KLIPPEL R&D System

Requirements	• Klippel Analyzer (KA3) + PC • Laser sensor • dB-Lab Software • Fast Large Signal Identification (FLSI) or Linear Parameter Measurement (LPM) + Large Signal Identification (LSI)
Setup	• Connect external power amplifier or use internal AMP-Card of KA3 • Mount DUT and connect terminals with speaker output of KA3 • Connect laser with laser input of KA3 and adjust beam to diaphragm of the speaker 
Preparation	Create a new measurement object template "LSI Displacement Limits – AN5" provided in the dB-Lab object templates.
Measurement	• Adjust the setup parameters according to the requirements of your selected DUT (more information in [FLSI manual] or [LSI3 manual]) • Start large signal operation Note: Importing a mechanical parameter into the LSI3 can be more robust and accurate than measuring absolute values by using a laser (more Information in [LSI3 manual]). If necessary, the "1 LPM Measurement" parameter can be used for the measurement of the small signal force factor $Bl(0)$ or moving mass M_{ms}.

3 Example

<table>
<tr><td colspan="2">This example explains how the displacement limits can be calculated manually. The displacement limits calculated automatically by the large signal operation can be found in the window “Table Nonlinear Parameters”.</td></tr>
<tr><td>Limit due to force factor</td><td>

Open the window “Bl(x) Force Factor” and read the peak displacement x_{Bl} where the $Bl(x)$ is reduced to the value Bl_{min} times the value at the rest position $Bl(0)$.



In this example, the peak displacement x_{Bl} = 2.63 mm results from the limit Bl_{min}=82 %.

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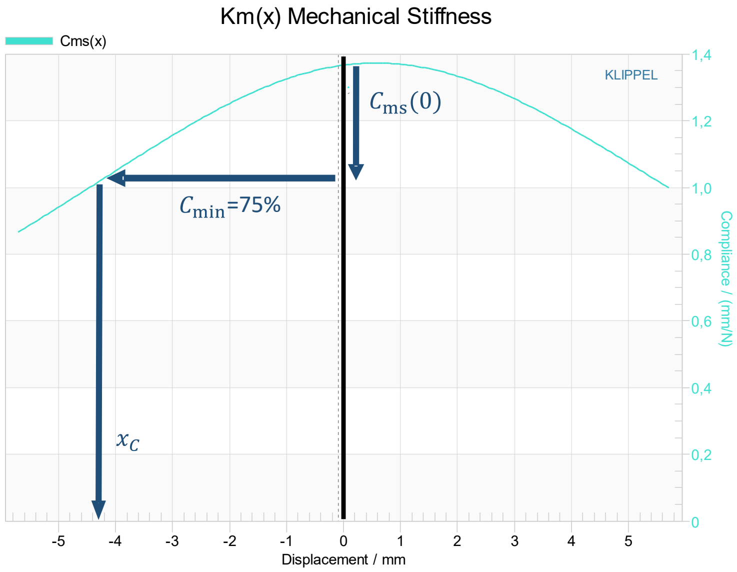
<tr><td>Limit due to compliance</td><td>

For FLSI, open the window “K_{ms}(x) Mechnical Stiffness”, right click and activate “Show All Curves”. Select “Cms(x)” and read the peak displacement x_C where the curve is reduced to the value C_{min} times the value at the rest position $C_{ms}(0)$.



In this example, the peak displacement x_{Bl} = 4.28 mm results from the limit C_{min}=75 %.

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<tr><td>Limit due to inductance</td><td>

In FLSI, open the window “Lossy Inductance Impedance” and select the curve $Z_L(x{,}8.5{\cdot}f_s)$. Shift this (shortcut ‘E’) by the value of the DC resistance R_e to obtain the blocked electrical impedance $Z_E(x,f_2)$. Read the peak displacement x_L where $Z_E(x,f_2)$ deviates the value Z_{max} times the value at the rest position $Z_E(0,f_2)$

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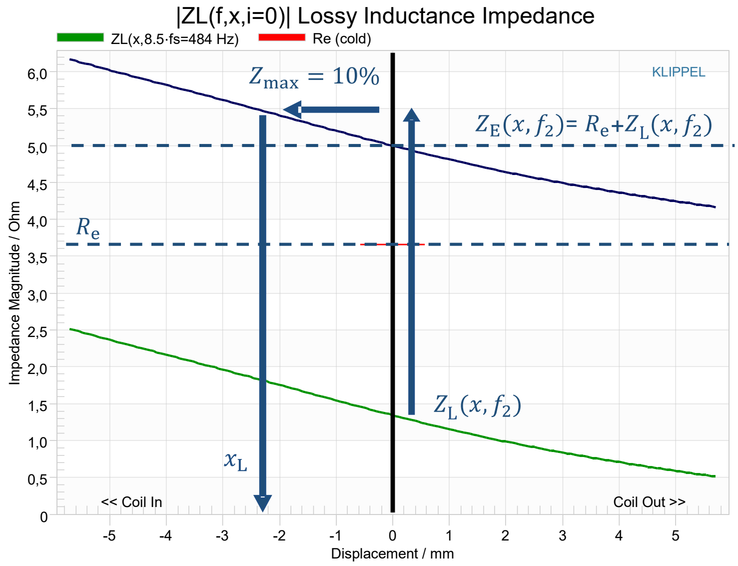
</table>

	 The peak displacement x_L = 2.28 mm results from the limit Z_{max} = 10% Note: 'Lossy Inductance Impedance' window is not included in LSI3 and manual calculation is not possible. An iterative algorithm calculates x_L via the deviation of $Z_e(x,f_2)$.
Limit due to Doppler effect	For a resonance frequency f_s= 57 Hz and a distortion limit d_2= 10 % the Doppler effect will limit the peak displacement to x_D= 15.9 mm.
Peak displacement	The displacements limits due to driver nonlinearities are: x_{Bl}= 2.63 mm @ B_{min}=82 % x_L= 2.28 mm @ Z_{max}= 10 % x_C= 4.28 mm @ C_{min}= 75 % x_D = 15.9 mm @ d_2 = 10 % **The maximal peak displacement is limited by the inductance x_L= 2.28 mm**

4 More Information

Application Notes	Measurement of peak displacement Xmax (Performance based method), Application Note AN4
Related Specification	Fast Large Signal Identification (FLSI), Specification FLSI Linear Parameter Measurement, Specification LPM Large Signal Identification (LSI3), Specification LSI3 Klippel Analyzer 3 (KA3), Specification H3 Laser displacement sensor, Specification A2
Manuals	User Manual Fast Large Signal Identification User Manual Large Signal Identification User Manual Linear Parameter Measurement

Find explanations for symbols at:

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

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