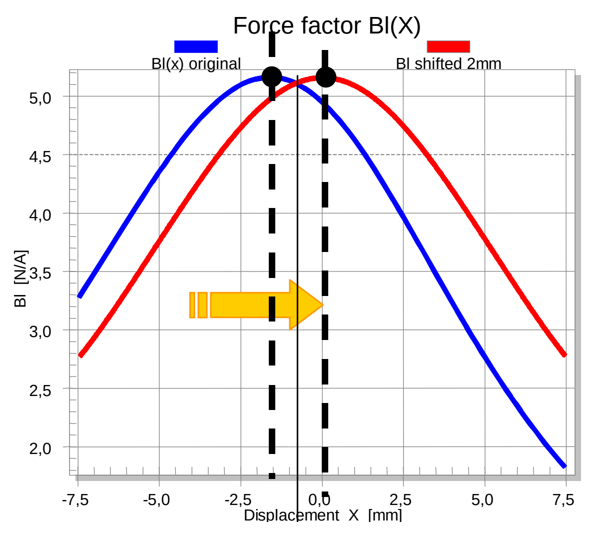
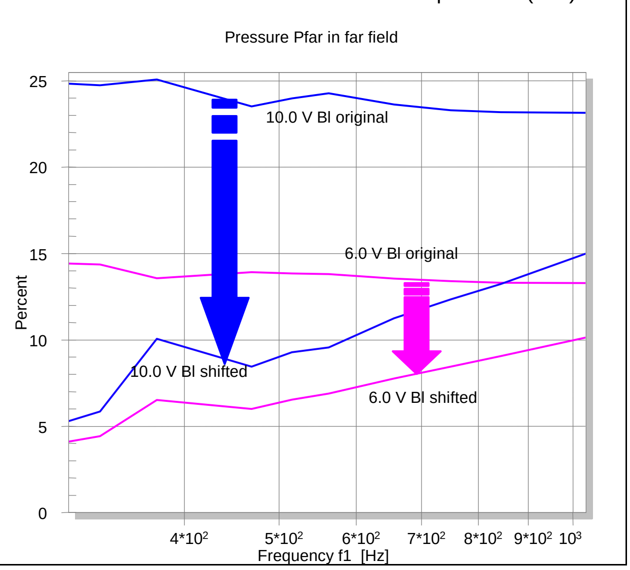
Reduce distortion by shifting Voice Coil **AN 21**

Application Note to the KLIPPEL R&D SYSTEM

Asymmetric *Bl(x)* shapes cause critical, instable DC offsets at about twice the resonance frequency. High 2nd order intermodulation in the pass band in presence of a bass tone of this frequency tone will be generated.
Using the simulation module (SIM), the original, asymmetric *Bl* shape can be modified and the resulting distortion for a virtually shifted, now symmetrical *Bl* shape can be predicted. The original *Bl*-characteristic defined by the magnet structure is maintained but the only rest position of the voice coil is shifted.
The intermodulation distortion of a driver with first an asymmetrical and later a shifted *Bl(x)* shape are simulated and compared to each other. A considerable reduction of 2nd order intermodulation can be achieved.





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Theory

Driver characteristics	The driver under test should have an asymmetry in the shape of *Bl(x).* The Bl(x)-maximum is shifted out- or inside. As known from Application Note AN13 this may cause at about twice the resonance frequency a considerable DC offset in the displacement. We assume a symmetrical compliance of the suspension and a low L_e value or a negligible L_e-asymmetry.
below fs	A so designed driver will have at low frequencies f<fs a minor DC offset caused by the Bl(x) shape. Below fs a DC component will be generated to drive the speaker into the Bl(x) maximum as well as into the Cms(x) maximum. Since Cms(x) should be symmetrical and have its maximum at x=0 but Bl(x) does not, both nonlinearities attempt to work against each other and generate a minor DC component in direction of the Bl maximum. However, this effect is stable since the driver seeks to go to the maximal values.
above fs	Above fs the influence of the compliance becomes less but the Bl asymmetry generates now a DC component in opposite direction, away from the Bl-maximum. This effect is in contrast to f<fs instable. The working point slides down the Bl shape starting at x=0 until the compliance is strong enough to generate a force equilibrium. The resulting working point is also dependent on the creep effect of the suspension. The effective DC part above fs will be considerable higher than below fs.
Critical tests	Critical tests for this kind of drivers are - Motor asymmetry test to find out where the maximum DC part is generated (see also Application Note AN14). Usually 1.5 – 2 fs will generate the highest DC part. - 2^{nd} order Intermodulation distortion as a measure for asymmetries with the bass tone at the highest DC part generating frequency. Although the compliance is symmetrical in the rest position it becomes dynamically asymmetrical due to the shift of the working point by the DC displacement.
Shift Bl shape to become symmetrical	With the nonlineare Simulation tool SIM a virtual shift of the voice coil can be performed. The effect on the resulting intermodulation distortion will show, how much a real shifting would improve the driver. In further investigations simulations can be perfromed to find out, where possible remaining distortion are coming from. Depending on the unit specific parameters reduction of 2nd order intermodultaion distortion by 4 to 6 dB are possible.
Simulation technique	The SIM module bases on the solution of the differential equation in time domain. The dominant nonlinearities Bl(x), Cms(x) and Le(x) as well as radiation nonlinearities (Doppler) and thermal interactions are considered. The user may modify all nonlinearities and may define the enclosure and thermal conditions.
Orientation	The sign of the DC displacement determines the direction of the voice coil shift. In this application note positive displacements *x* denote shifts that move the coil away from the backplate (coil out).
Overhang Coils	

Performing the Simulation

Requirements	The following hardware and software is required : - Distortion Analyzer - PC - Software modules (SIM, dB-Lab pro, LSI pro)
Preparation	To perform simulations as outlined in this application note you should have measured a driver with a nonlinear characteristic similar to the one specified above (with LSI pro). You can also get the database used for this application note to get nonlinear data.

	Please note that effects may vary considerably if nonlinearities change. - Ensure that the database Default_Database.mdb (coming with each software update after release 76) is available in the folder ~/KLIPPEL/DA/DATA. - Create a new database (a copy of the Default_Database will be generated) - Open the database within dB-Lab - Create a new object - Create a LSI measurement and perform a LSI with protection parameters (Blim=40%, Cmin=40%). - Create two new operations based on the template *SIM Intermod. high f2 (AN21).* Label the first one *SIM original Bl shape*, the second one *SIM adjusted Bl shape*.
Setup	- Import nonlinear parameter of a measured loudspeaker from the LSI pro module. Use the Export function in the LSI and the Import function in the SIM module. - Set the bass tone level to U2/U1=0 dB and f2 to the frequency where the DC part is maximal, which is typically twice the resonance frequency 2 f_s.
Measurement	1. Start the measurement " *SIM original Bl* ". 2. Open the result windows Bl(x), 2nd Intermod., 3rd Intermod. and X(t) 3. modify the Bl shape of the second *SIM adjusted Bl shape* operation. See the chapter *Shifting Nonlinear Shape* for details. 4. Compare the intermodulation distortion from both simulation as well as the displacement information X(t).

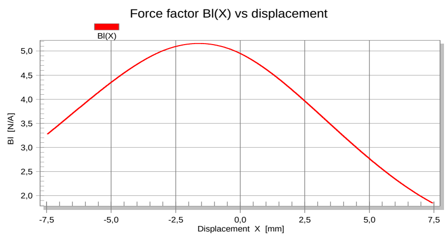
Shifting Nonlinear Shape vs. displacement

Nonlinear Coefficients	Please open the Property Page Nonlinear and open the Bl(x) coefficients. The values b1 – b8 are coefficients of a power series $Bl(x) = Bl(x=0) + b_1 x + b_2 x^2 + b_3 x^3 + \ldots + b_8 x^8$ (*b* stands for (*Bl*)) The Bl asymmetry is caused by the position of the voice coil and by the construction of the magnetic structure. In this application note we want to fix only the voice coil position but not the shape caused by the magnet structure. This would require a complete new magnet design. Here a simple shift of the voice coil position shall be simulated which can be done for real drivers with some but not too high effort.
Keep original Bl	Before changing the Bl shape by modifying the coefficients it is always good practice to keep the original curve. Copy the Bl(x) curve (right mouse button context menu while pointing to the Bl(x) labe) and paste it to the same curve. All modifications are now visible in contrast to the original curve.
Modifying b1	For a Bl shape where the Bl maximum is at the voice coil rest position, set b1 to zero.
Adjust Bl(x=0)	Since the b1 coefficient also changes the absolute Bl value at the rest position, this value has to be adjusted. Open the Im/Export Page and set the Bl(x=0) value that both Bl curves have identical maximum values.

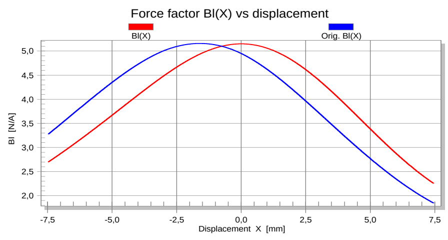
Example

Comparison	**Original Bl Shape**	**Shifted Bl-Shape**

Bl shape

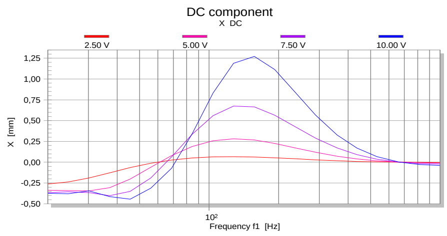


The original Bl(x) shape has an offset of –2mm.

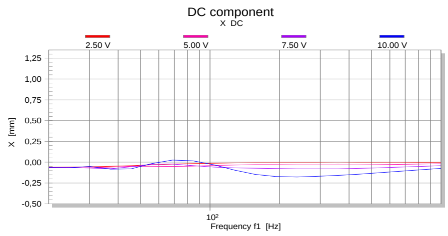


The shifted Bl-curve has the same shape but the maximum is shifted by +2mm. Note that the Bl(x=0) value must be set to get identical maximum values.

DC Part

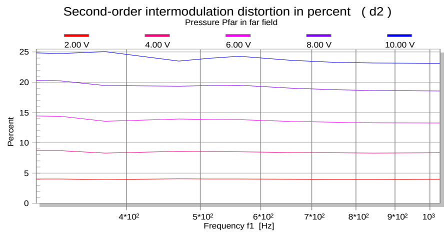


The DC part of the Displacement starts at low frequencies with negative offsets but has the highest part at twice the resonance frequency.

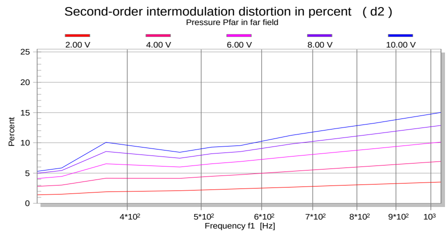


Using the same scaling the decrease of DC components is obvious. Note that even with symmetric *Bl* and C_{ms} a smaller offset exist (in this example due to $L_e(x)$ nonlinearity).

2nd order intermodulation

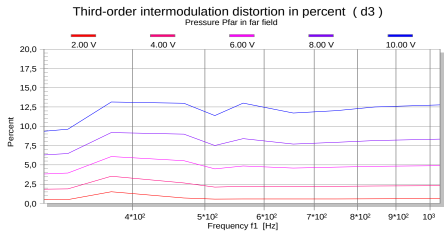


2nd order intermodulation are up to 25% and almost independent on frequency. This is typical for Bl caused distortion.

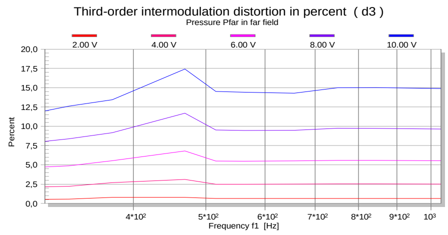


The symmetrized driver shows a considerably reduced 2nd order component. Mainly the inductance Le(x) asymmetry causes the increasing distortion level with frequency.

3rd order intermodulation



3rd order intermodulation are caused by the symmetric part (even Bl-coefficients) of the nonlinear shape. Characteristic for Bl caused distortion is again the broadband flat distortion level.



By symmetrizing Bl(x) the driver sees now a more symmetrical Bl(x) shape. This causes a slight increase of 3rd order distortion. However, this increase is almost negligible in contrast to the reduction of 2nd order distortion.

More Information	
Documents	*AN01 - Optimal voice coil rest position* *AN08 - 3D Intermodulation measurement* *AN13 – Dynamic generation of DC displacement* *AN14 - Motor Stability*
Software	User Manual for the KLIPPEL R&D SYSTEM.

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