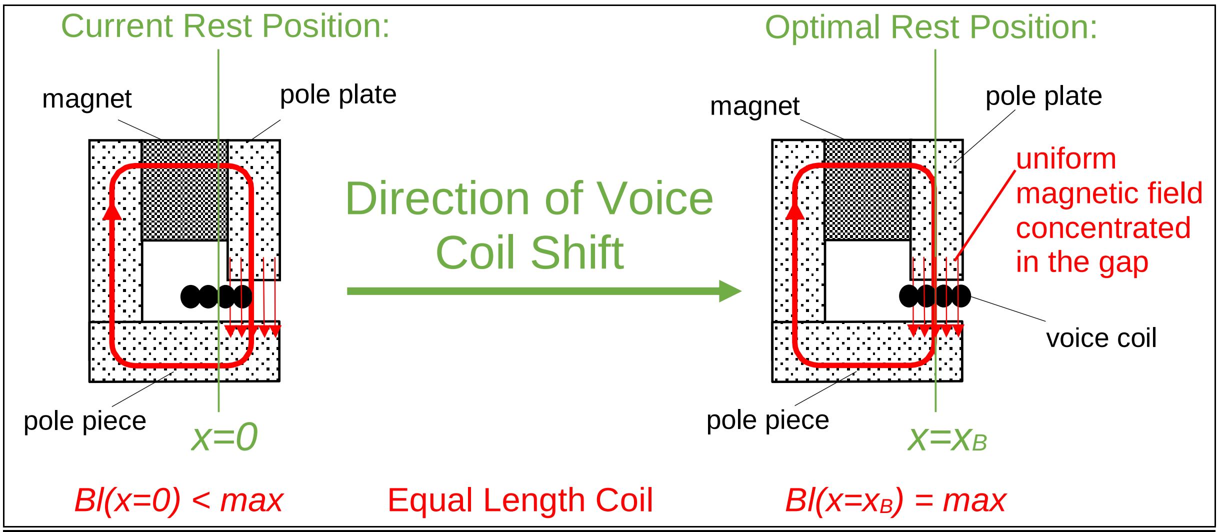
Optimal Voice Coil Rest Position AN 1

Application Note to the KLIPPEL R&D SYSTEM - Revision 1.2

The location of the voice coil in the magnetic gap is a very critical parameter of dynamic transducers used in loudspeakers, shakers, headphones, etc. An offset from the perfect symmetrical rest position in the magnetic field may produce unwanted signal distortion and generate a dynamic DC-displacement, which degrades the stability of the driver by moving the coil's rest position towards the gap edges. As a solution, shifting the voice coil into the optimal rest position in the magnetic field may fully or partially compensate for the asymmetries. The optimal rest position may be found by measuring the symmetry of the force factor *Bl* versus displacement *x*. The large signal identification module (LSI) determines the *Bl(x)* parameter dynamically by operating the driver under normal working conditions. In addition, the LSI results include data analysis tools to help assess the asymmetry in the *Bl(x)* curve and to find the amount of shift required x_B to obtain the optimal voice coil rest position.



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Measurement of the Nonlinear Force Factor

Requirements

To measure the nonlinear characteristics of the force factor, the following hardware and software is required:

- Hardware platform Distortion Analyzer (DA)
- Software module LSI installed within dB-Lab on the PC
- A driver stand or similar clamping
- Laser displacement sensor (recommended)

Procedure

Don't forget ear protection!

1) Operate the DUT in free air (or in a box).
2) Create a new object *Driver* and add a new LSI operation based on the ***Default*** template. Adjust the measurement set up parameters according to the requirements of your selected DUT. Use caution not to overload the DUT. To calibrate the displacement axis to the highest precision, import the force factor at the rest position *Bl(x=0)* or the moving mass M_{MS} from a previous LPM or other measurement.
3) Ensure that the DUT polarity and laser calibration are correct.
4) Start the measurement.
5) Open the results windows ***Bl(x)*** and ***Bl Symmetry Range***.

Post Processing and Interpretation

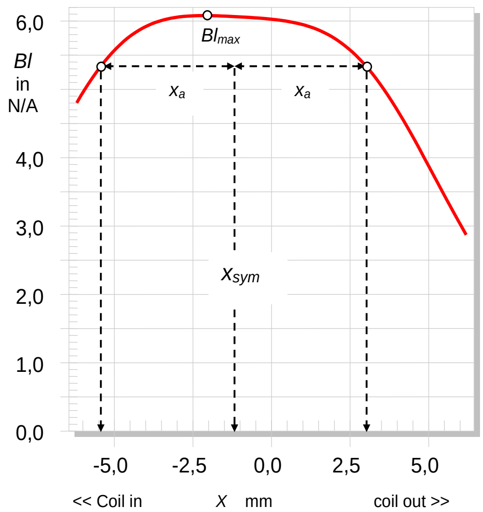
Bl(x)

The force factor *Bl* is not a constant as assumed in linear modeling but varies with the voice coil displacement *x*. Clearly, *Bl(x)* decreases when the coil moves out of the gap. In addition, there are symmetrical and asymmetrical variations of the *Bl(x)* curve. The asymmetrical variations may be caused by an offset in the voice coil's rest position or by an asymmetry in the magnetic B field. In the case of a voice coil offset, the asymmetries can be fully compensated by shifting the voice coil into the optimal rest position. However, when a magnetic field asymmetry exists, the asymmetry can only be partially compensated with shift of the voice coil rest position. Finding the optimal voice coil shift (in mm) can be tricky. For instance, the optimal voice coil shift is not always identical with the maximum in the *Bl(x)* curve. A coil shift to the *Bl(x)* maximum may help at smaller displacements but will make things worse at larger displacements. To assess the asymmetry quantitatively and to find the optimal shift value, use the result window ***Bl Symmetry Range*** as described in the "Examples" section of this app note.

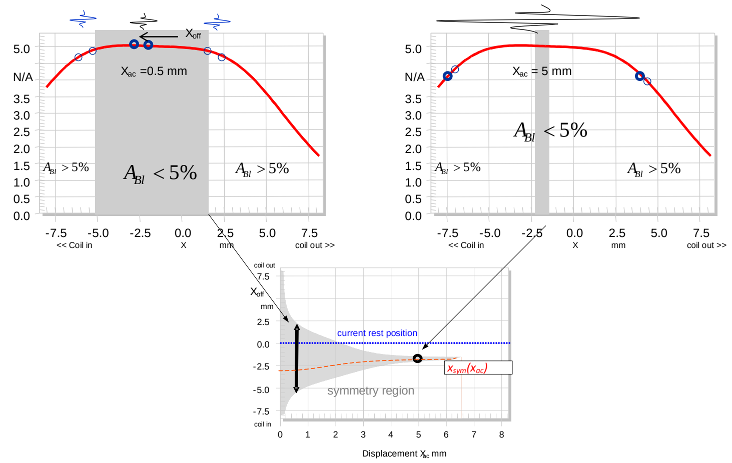
Symmetry Point

The symmetry point x_{sym} in the asymmetrical Bl(x) curve is the centre point between two points having the same *Bl* value for negative and positive displacements x_{ac} from the symmetry point:

$$Bl(x_{sym}\, x_{ac})+ x_{ac}) = Bl(x_{sym}(x_{ac})- x_{ac})$$



The displacement x_{ac} represents the amplitude of sinusoidal signal generating the peak displacement $x_{sym}(x_{ac})+ x_{ac}$ and bottom displacement $x_{sym}(x_{ac})- x_{ac}$. The force factor curve would be perfectly symmetrical if the symmetry point $(x_{sym}(x_{ac})$ =const.) is constant for any amplitude x_{ac}. In general, the symmetry point $x_{sym}(x_{ac})$ depends on the amplitude x_{ac} as shown as the red line in the lower diagram:



Operating a transducer in the small signal domain where the amplitude AC signal is negligible the symmetry point $x_{sym}(x_{ac}\approx 0)$ is identical with the location at maximum force factor. However, the symmetry point $x_{sym}(x_{ac}\approx x_{max})$ measured in the large signal domain where the amplitude is close to the maximum displacement x_{max} is more relevevant for loudspeaker diagnostics and should be used for compensating an offset in the voice coil rest position. For example, the left diagram shows a symmetry point $x_{sym}(x_{ac}\approx 0.5\text{mm}) = 3$ *mm* deviating significantly from the current voice coil rest position x=0. However, the maximum is on the plateau region of the Bl(x) where a constant number of windings is in the gap and the large deviation of the symmetry point from the current rest position is caused by the B field asymmetry and should not be compensated by shift of the voice coil rest position. In large large signal domain the symmetry point $x_{sym}(x_{ac}\approx 6\text{mm}) = 1.6$ *mm* is much closer to the current position. Here the force factor curve has steeper slopes because coil windings leave the gap for positive and negative displacement.

Bl-Asymmetry and Symmetry Region

The “Bl Asymmetry” is an important characteristic for finding the optimal voice coil rest position by considering the symmetry point x_{sym} and the steepness of the Bl(x) curve. This “Bl Asymmetry” defined as

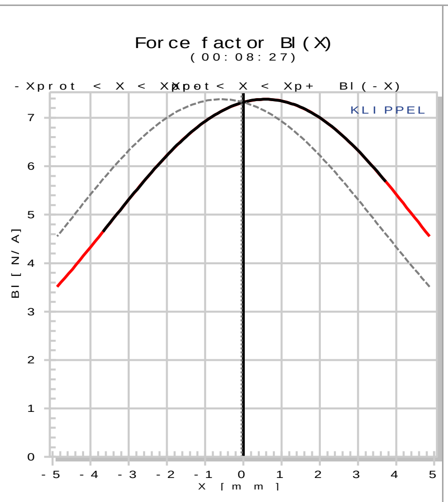
$$A_{Bl}(x_{ac}, x_{off}) = \frac{Bl(x_{off} + x_{ac}) - Bl(x_{off} - x_{ac})}{Bl(x_{off} + x_{ac}) + Bl(x_{off} - x_{ac})} 100\%$$

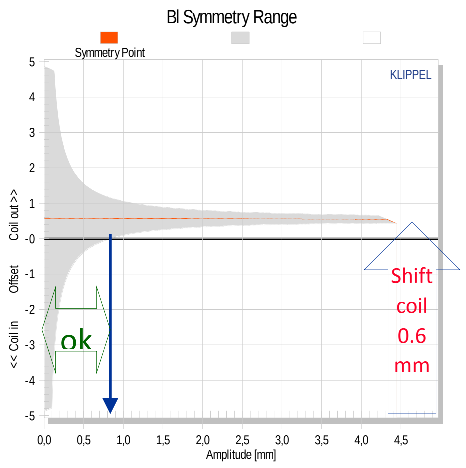
depends on virtual shift X_{off} of the coil and the amplitude displacement x_{ac}. If the Bl Asymmetry $|A_{Bl}(x_{off}, x_{ac})| < 5\%$ than the offset between current rest position and symmetry point is negligible. This case is represented by a grey symmetry region in the upper diagram. In the small signal domain ($x_{ac}\approx 0.5$mm) the current rest position ($X_{off}=0$) is in the grey symmetry region and no correction of the voice coil position is required. However, the Bl Asymmetry $|A_{Bl}(x_{off}, x_{ac})$ exceeds the 5 percent threshold at 2 mm amplitude of the displacement. In the large signal domain ($x_{ac}\approx 6$ mm) the symmetry region is far away from the current rest position ($X_{off}=0$) and a voice coil shift inwards to symmetry point $x_{sym}(x_{ac}\approx 6\text{mm}) = 1.6$ *mm* is recommended.

Examples

Equal-length Configuration

An equal-length configuration is very sensitive to an offset in the voice coil’s rest position. In most of these cases, the impact from the magnetic field asymmetries plays a secondary role.





As shown in the result window ***Force factor Bl(x)***, the overlay of the measured *Bl(x)* curve (red solid line) with the derived *Bl(-x)* curve (grey dotted line) mirrored at *x=0* reveals the asymmetry in the *Bl*-characteristic.

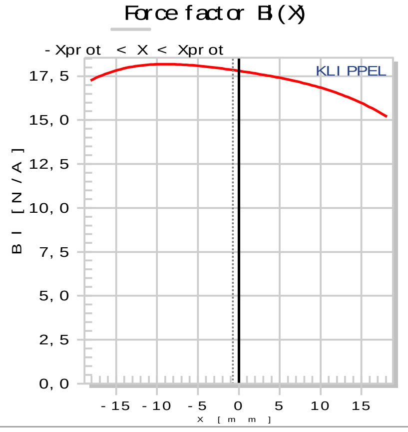
As shown in the result window ***Bl Symmetry Range***, the shaded area is the range where the *Bl* asymmetry is below 5% as a function of displacement amplitude (horizontal axis) and voice coil offset x_{off} (vertical axis). The current rest position of the voice coil is indicated by the voice coil offset zero reference (*Y=0*).

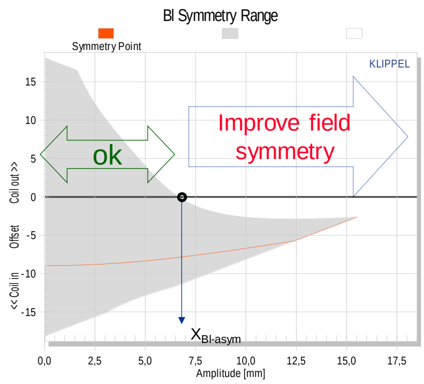
The displacement where the border of the shaded area crosses the zero reference in the voice coil offset is an important value. It is the displacement where *Bl(x)* has decreased to 82 % of the static *Bl* value, which also corresponds to a THD level of 10 %. As shown in this example, a displacement working range of +/- 0.8 mm satisfies this condition. This is a very small displacement for a woofer application. To increase the displacement working range, while maintaining the same distortion tolerance, it is recommended to have the zero reference of the voice coil offset x_{off}=0 located completely within the *Bl* symmetry range (shaded area).

This can be accomplished by assessing the Bl-symmetry point x_{sym}, which is the red dashed line in the result window ***BL Symmetry Range***. Ideally, x_{sym} should coincide with the voice coil offset zero reference. In this example, x_{sym} is +0.6 mm and it is constant over the displacement range from 0 < x_{ac} <4.4 mm. Therefore, a shift of the voice coil 0.6 mm in the positive direction (outwards) will completely compensate for the asymmetry in the Bl-characteristic and improve the stability of the driver, thereby reducing the generation of DC displacement and distortion.

Overhang Configuration

A large overhang of the voice coil gives more robustness against an offset in the voice coil's rest position but is more sensitive to asymmetries in the magnetic field.





	In this example, an amplitude 6.5 mm of the AC displacement or less will result in acceptable Bl intermodulation distortion corresponding to an Bl asymmetry $\|A_{Bl}(x_{off}, x_{ac})\| < 5\,\%$. To increase the displacement working range it is recommended to improve the magnetic field symmetry in the gap. Shifting the voice coil rest inwards by 2 mm will partly compensate for the B field asymmetry up to 15 mm amplitude but not at larger negative displacements where the Bl curve decays rapidly. Note: a FEM analysis will provide further information regarding the cause of the stray magnetic field.	

More Information

Related Application Notes	"Separating Spider and Surround", Application Note AN 2 "Adjusting the Mechanical Suspension", Application Note AN3 "Measurement of Peak Displacement", Application Note AN4
Related Specification	"LSI", S1
Software	User Manual for KLIPPEL R&D SYSTEM.
References	W. Klippel, "Diagnosis and Remedy of Nonlinearities in Electro-dynamical Transducers," presented at the 109th Convention of the Audio Engineering Society, Los Angeles, September 22-25, 2000, preprint 5261.

Find explanations for symbols at:

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

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