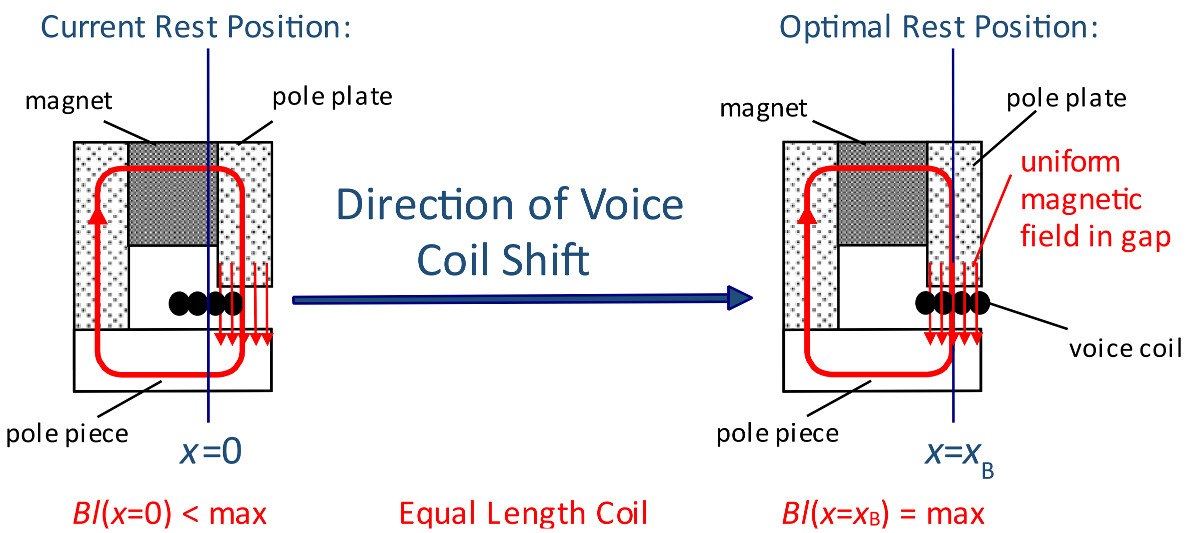
Optimal voice coil rest position

AN1

Application Note for the KLIPPEL ANALYZER SYSTEM (Document Revision 1.0)

DESCRIPTON

The location of the voice coil in the magnetic gap is a very critical parameter of dynamic transducers (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. This 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 determines the *Bl*(*x*) parameter dynamically by operating the driver under normal working conditions. In addition, the results include data analysis tools to help assess the asymmetry in the force factor curve and to find the amount of shift required to obtain the optimal voice coil rest position.



CONTENT

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1 Measurement Setup

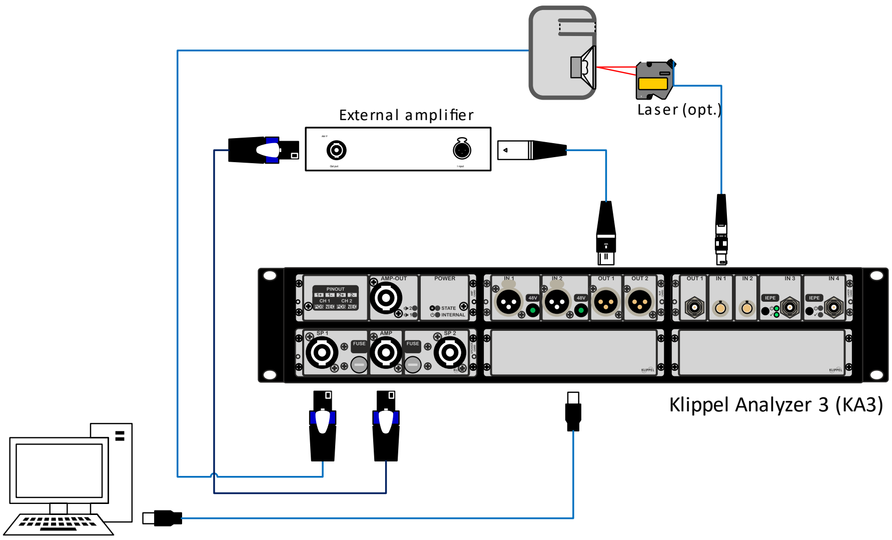
1.1 Requirements

Klippel Analyzer (KA3 or DA2)	Hardware platform for the measurement modules performing the signal generation, acquisition and digital signal processing
Laser displacement Sensor (optional)	High resolution laser sensor with low noise floor for reliable results also at higher frequencies with low displacement
Amplifier	External amplifier with a flat frequency response over the desired measurement bandwidth or internal AMP-Card of KA3
dB-Lab	Frame software of the Klippel Analyzer system
Large Signal Identification (FLSI or LSI)	Large signal identification module for measurement of large signal parameters including nonlinearities of loudspeakers

1.2 Hardware Setup

Connect hardware

- Connect external power amplifier or use internal AMP-Card of KA3
- Mount DUT and connect Klippel Analyzer with speaker terminals
- Connect laser to Klippel Analyzer and adjust laser head to the diaphragm



1.3 Software Setup

Preparation	• Open dB-Lab and select large signal identification operation (FLSI or LSI) • Use default setup parameters (If no laser is connected, the force factor value at the rest position *Bl*(x=0) or the moving mass M_{ms} has to be imported to calibrate the displacement axis) • Ensure that the DUT polarity is correct
Measurement	• Start operation • After measurement open result windows “Bl(x) Force Factor” and “Bl Symmetry Range”

2 Results

2.1 Interpretation

Force factor *Bl*(x)

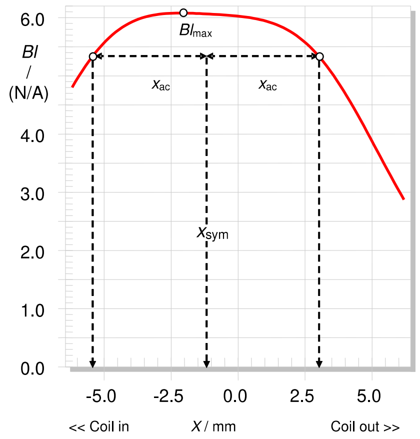
The force factor *Bl* is not a constant as assumed in linear modeling but varies with the voice coil displacement x. The force factor *Bl*(x) decreases when the coil moves out of the gap. In addition, there are symmetrical and asymmetrical variations of the *Bl*(x) curve. The asymmetrical variations may be caused by an offset in the voice coil 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, it 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”.

Symmetry point x_{sym}

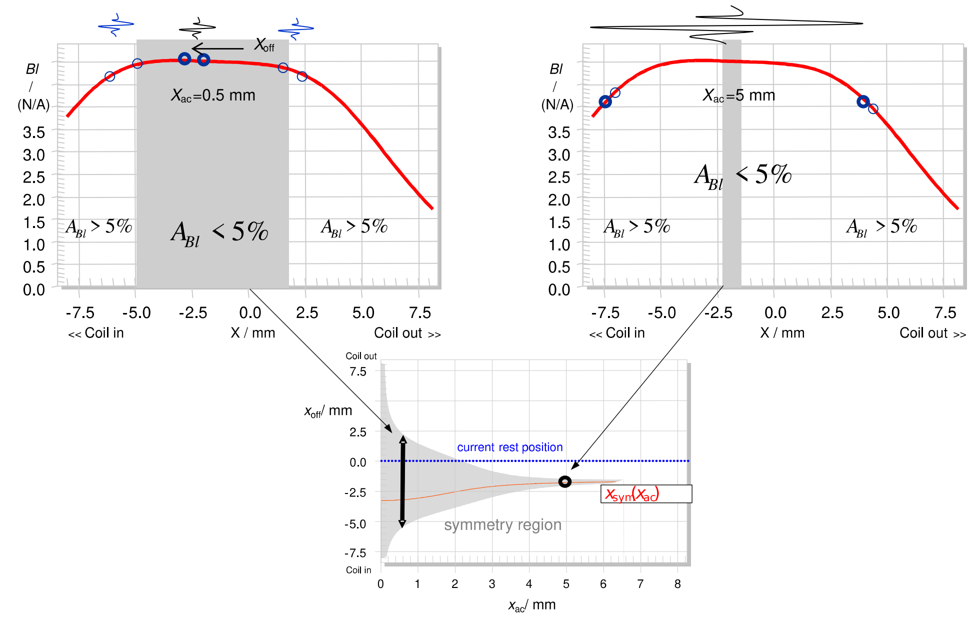
The symmetry point x_{sym} in *Bl*(x) curve is the center point between two points having the same *Bl* value for negative and positive displacements x_{ac} from the symmetry point:

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

The displacement x_{ac} represents the amplitude of sinusoidal signal generating the peak displacement and bottom displacement. The force factor curve would be perfectly symmetrical if the symmetry point $x_{sym}(x_{ac})$ is constant for any amplitude.



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:



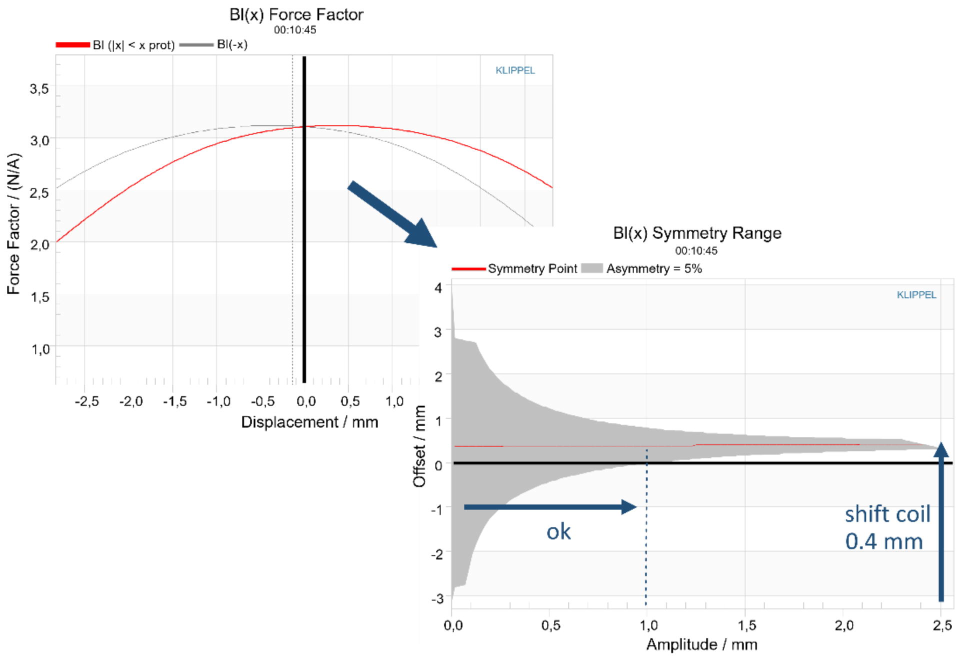
When operating a transducer in the small signal domain, where the amplitude AC signal is negligible, the symmetry point $x_{sym}(x_{ac} \approx 0)$ is identical with the location at maximum force factor. However, the symmetry point $x_{sym}(x_{ac} \approx x_{max})$ measured in the large signal domain where the amplitude is close to the maximum displacement x_{max} is more relevant 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 $x_{sym}(x_{ac} \approx 0.5mm) = -3$ 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 signal domain the symmetry point $x_{sym}(x_{ac} \approx 6mm) = -1.6$ 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. The *Bl*-asymmetry is defined as: $$A_{\mathrm{Bl}}(x_{\mathrm{ac}}, x_{\mathrm{off}}) = 2\frac{Bl(x_{\mathrm{off}} + x_{\mathrm{ac}}) - Bl(x_{\mathrm{off}} - x_{\mathrm{ac}})}{Bl(x_{\mathrm{off}} + x_{\mathrm{ac}}) + Bl(x_{\mathrm{off}} - x_{\mathrm{ac}})} 100\%$$ depends on virtual shift x_{off} of the coil and the amplitude displacement x_{ac}. If the *Bl*-asymmetry $\lvert A_{Bl}(x_{off},x_{ac})\rvert < 5\%$ then 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 ($x_{ac} \approx 0.5mm$) the current rest position ($x_{off} = 0$) is in the grey symmetry region and no correction of the voice coil position is required. In the upper example the *Bl*-asymmetry $\lvert A_{Bl}(x_{off},x_{ac})\rvert$ exceeds the 5% threshold at 2 mm amplitude of displacement. In the large signal domain ($x_{ac} \approx 6mm$) the symmetry region is far away from the current rest position ($x_{off} = 0$) and a voice coil shift inwards to symmetry point $x_{sym}(x_{ac} \approx 6mm) = -1.6mm$ is recommended.

2.2 Example

As shown in the result window "Bl(x) Force Factor", 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 value, which also corresponds to a THD level of 10 %. As shown in this example, a displacement working range of +/- 1 mm satisfies this condition. 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 +0.4 mm and it is constant over the displacement range from 0 < x_{ac} <2.5 mm. Therefore, a shift of the voice coil 0.4 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.

3 References

Related Specifications	Fast Large Signal Identification (FLSI), Specification FLSI 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 dB-Lab
Publications	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

Last updated: October 21, 2025

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