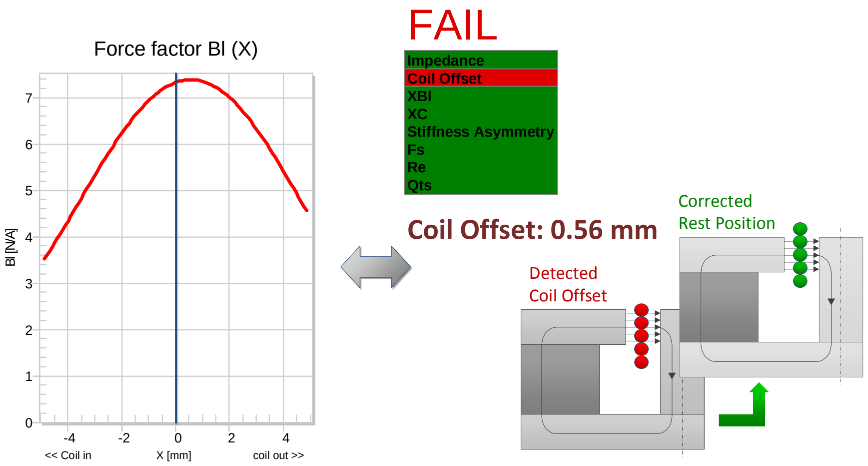
Linking Large Signal Testing Between QC and R&D

AN 65

Application Note for the KLIPPEL R&D and QC SYSTEM

(Document Revision 1.2)

The large signal performance of loudspeakers is limited by nonlinear and thermal mechanisms. Transducer nonlinearities limit the acoustical output, affect the speaker system alignment, cause unstable behavior and create audible nonlinear distortions such as intermodulation and harmonic distortion. The nonlinear characteristics depend on important parameters, such as voice coil offset, which can vary during the production process. Therefore, it is important to optimize the nonlinear speaker parameters during the design and test for conformity in production. However, these processes can be very different. To help provide consistent and comparable results, this document explains the link between the KLIPPEL *R&D* (*LSI*) and *QC* (*MSC*) systems which provide measurements, such as large signal identification and voice coil offset testing, respectively.



CONTENTS

1 Scope

Motivation	Different measurement principles and conditions exist between R&D and QC resulting in different ways to present the nonlinear transducer parameters. While QC requires speed, robustness and simplicity, R&D requires a more in-depth detailed analysis. Linking both processes is crucial for successful consistency and meaningful testing.
Objectives	In addition to understanding and handling differences between R&D and QC, the objectives are: • Setting up end-of-line testing (MSC) based on R&D measurement results using reference speaker(s) • Ensuring comparable and reproducible results • Optimal balance of accuracy and test speed on the production line • Dealing with different motor geometries.
Device Under Test	Electrodynamic transducers operated in free air or mounted in a sealed or vented enclosure.
Requirements	Both KLIPPEL *R&D* and *QC* systems are prerequisites. The following lists represent the minimal (though complete) configurations: **KLIPPEL R&D System** • Distortion Analyzer • Power amplifier • Laser sensor (optional) • LPM - Linear Parameter Measurement • LSI – Large Signal Identification (Woofer, Tweeter, or Box depending on DUT type); from version 206.x (for derived nonlinear asymmetry parameters) **KLIPPEL QC System** • QC Standard • Production Analyzer • Power amplifier • MSC – Motor & Suspension Check
Parameters	The following relevant large signal design and end-of-line testing parameters are related to suspension (spider, surround) and motor (B-field distribution and voice coil) and can be separated into base and derived parameters: **Motor Parameters** • Force factor at rest position $Bl(0)$* • Nonlinear Force Factor $Bl(x)$* • Bl Symmetry Point x_{sym} • Coil Offset x_{offset} • Peak displacement limited by motor x_{Bl} **Suspension Parameters** • Nonlinear Stiffness $K_{\mathrm{ms}}(x)$* • Stiffness Asymmetry A_{kms} • Peak displacement limited by suspension x_{C} All listed measures comply with *IEC 62458*. Other parameters such as nonlinear inductance and losses are mainly defined by design and are not considered as relevant for end-of-line testing. For parameter definitions please refer to the references in the module's user manual. **Note:** implementation of derived nonlinear parameters may differ slightly between *MSC* and *LSI* (i.e. due to different reference peak displacements). *Base parameters

2 Step-by-Step Guide

The following procedure outlines the general approach for setting up and evaluating the results of a *QC MSC* test based on *R&D* measurements from one or more reference speakers. These instructions mainly focus on finding an optimal test setup (generating testing limits is not covered). Please refer to the *MSC Manual* for more information.

The device under test (DUT) does not necessarily have to be a “good” reference unit when used for relative limit calculations. You are encouraged to test multiple units for assessing variations and double checking the settings applied.

The speaker used in this example is a conventional woofer with an overhung coil configuration.

2.1 Linear Parameter Identification (R&D)

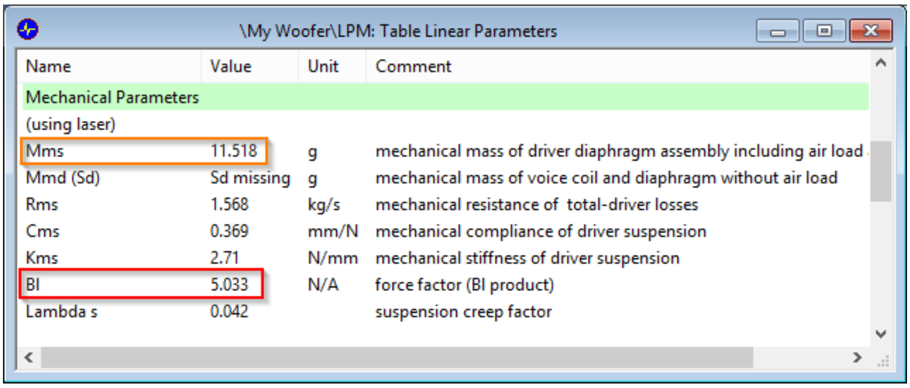
LPM Measurement

The *Linear Parameter Measurement* is accurately identifying the lumped parameters of the transducer’s linear equivalent circuit (T/S parameters, etc.).

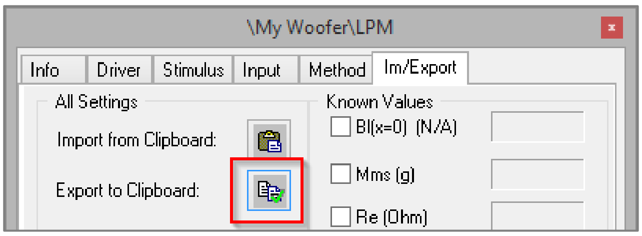
Both *LSI* and *MSC* require a mechanical calibration factor to display the result in absolute mechanical units (mm). Either the moving mass M_{ms} or the force factor at the coil rest position $Bl(x = 0)$ can be used for this purpose. Both can be measured with optimal accuracy using *LPM*. Please refer to *LPM - Tutorial* for detailed instructions about setting up an *LPM* measurement. Either the laser or the added mass method can be used with LPM.

LPM Results

After the *LPM* has finished successfully, the resulting Bl and M_{ms} can be found in the result window *Table Linear Parameters*.



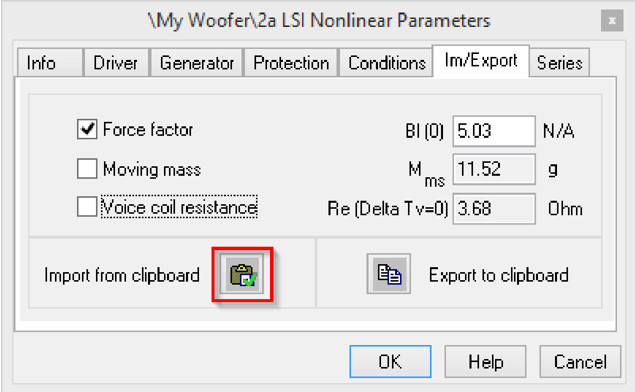
These parameters may be exported to the clipboard as shown below:



2.2 Large Signal Parameter Identification (R&D)

1. LSI Measurement

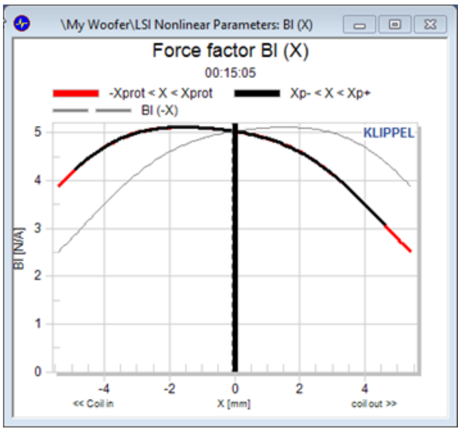
Import the mechanical calibration parameters $Bl(0)$ or M_{ms} as shown below:

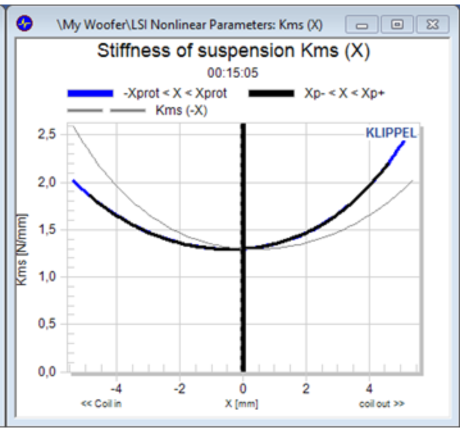


This is required to display the results in absolute mechanical units (e.g. mm). Using a laser sensor with *LSI* is optional. When using a laser sensor with *LSI*, importing *LPM* parameters is not required but recommended for better accuracy. Please refer to *LSI-Tutorial* for detailed instructions on how to setup a new *LSI* operation. To obtain the nonlinear parameter set, define suitable *Protection Parameters* and perform the *LSI* measurement according to *LSI-Tutorial*.

2. Nonlinear Curves

The relevant *LSI* result windows, nonlinear force factor $Bl(x)$ and the nonlinear stiffness $K_{ms}(x)$, are shown below in the final state of the measurement (time cursor in *Temperature, Power* result window is located in the final position).





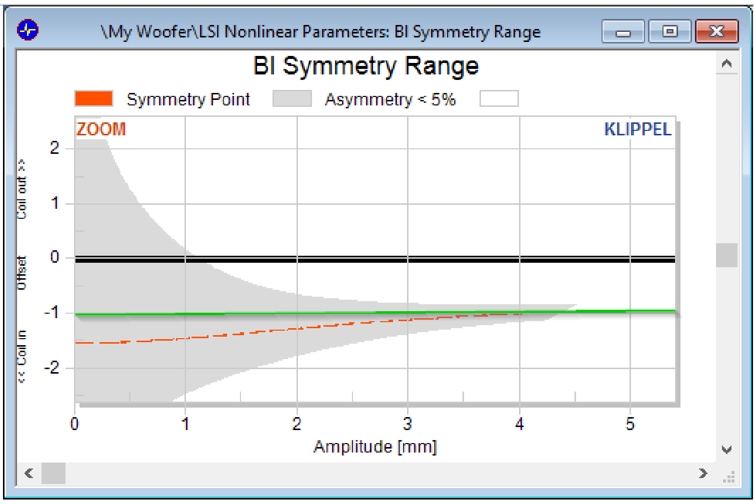
The colored lines represent the nonlinear parameters within the displacement range $\pm x_{prot}$ defined by the protection parameters. The black lines indicate the displacement range $x_{p-} < x < x_{p+}$ with a 99 % probability of occurrence (only for time cursor located in final position).

The $Bl(x)$ plot in this example shows a visible offset from the rest position at $x = 0$ along with a slight field asymmetry. The suspension tends to be asymmetric as well.

Note: The orientation of these curves depends on the polarity connection during the measurement. In case a laser sensor is used, “coil in” and “coil out” markers indicate the actual physical orientation of the parameters. However, for consistent comparability reasons, it is recommended to always connect the speaker with correct polarity.

3. Bl Symmetry Point

The window below shows the *Bl Symmetry Range* and *Symmetry Point* plot which provide additional diagnostic information about Bl asymmetry and coil positioning.



At low displacement amplitudes the field asymmetry is dominant because the *symmetry point* $x_{\mathrm{sym}}(x_{\mathrm{ac}})$ (red dashed curve) varies with rising amplitude. At higher excursions the *symmetry point* $x_{\mathrm{sym}}(x_{\mathrm{ac}})$ @ $x_{\mathrm{p-}}$ approaches a stable value of approx. -1 mm (green line) indicating a non-optimal voice coil rest position which significantly limits the working range of the driver.

Due to the field asymmetry, the voice coil offset can only be estimated correctly at very high displacement amplitudes. This must be considered when setting up *MSC* because using the symmetry point measured at lower displacement amplitudes would be misleading.

Note: Some motor designs require special attention when testing voice coil offset. For details about the most common voice coil configurations and the corresponding Bl Symmetry Range and Symmetry Point plots, please refer to application note *AN1 - Optimal Voice Coil Rest Position.*

4. Derived Single Value Parameters

The *LSI* result window *Nonlinear Parameters* contains single values that have been derived from the relevant nonlinear curves. These single values may be used for comparing with the *QC MSC* module's output.

\My Woofer\LSI Nonlinear Parameters: Nonlinear Parameters

Symbol	Number	Unit	Comment
Displacement Limits			thresholds can be changed in Processing
X Bl @ Bl min=82%	3.0	mm	Displacement limit due to force factor va
X C @ C min=75%	3.3	mm	Displacement limit due to compliance va
X L @ Z max=10 %	2.0	mm	Displacement limit due to inductance var
X d @ d2=10%	16.7	mm	Displacement limit due to IM distortion (
Asymmetry (IEC 62458)			
Ak	-24.65	%	Stiffness asymmetry Ak(Xpeak)
Xsym	-1.03	mm	Symmetry point of Bl(x) at maximal excu

The value of x_{sym} corresponds to the observations made in the *Symmetry Point* plot at higher displacement amplitudes. To optimize the rest position, the voice coil should be shifted approx. 1 mm towards the back plate.

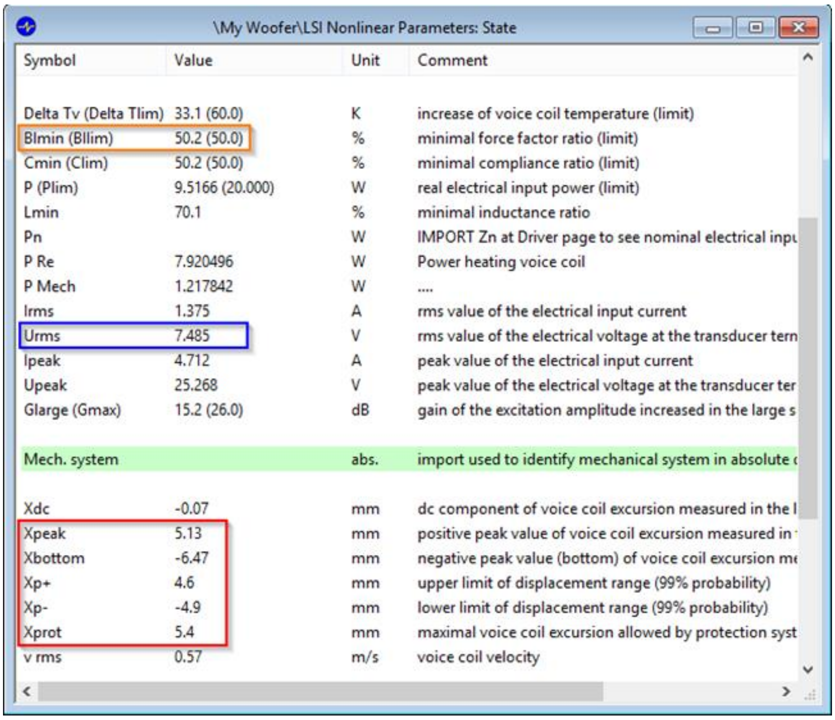
Parameter A_K indicates an asymmetry in the suspension of approx. 25 % as shown in the $K_{\mathrm{ms}}(x)$ curve.

The displacement limits show the amount of displacement required for each nonlinearity to produce 10% distortion. Only x_{Bl} and x_C are tested in production by *MSC*.

Note: in this case, the dominant nonlinearity is the inductance $L(x)$ represented byx_L. This is a coil design problem that will not be evaluated during the QC test.

5. State Conditions

The *LSI* result window *State* provides auxiliary information reflecting the state conditions during the measurement.



\My Woofer\LSI Nonlinear Parameters: State

Symbol	Value	Unit	Comment
Delta Tv (Delta Tlim)	33.1 (60.0)	K	increase of voice coil temperature (limit)
Blmin (Bllim)	50.2 (50.0)	%	minimal force factor ratio (limit)
Cmin (Clim)	50.2 (50.0)	%	minimal compliance ratio (limit)
P (Plim)	9.5166 (20.000)	W	real electrical input power (limit)
Lmin	70.1	%	minimal inductance ratio
Pn		W	IMPORT Zn at Driver page to see nominal electrical inpu
P Re	7.920496	W	Power heating voice coil
P Mech	1.217842	W	....
Irms	1.375	A	rms value of the electrical input current
Urms	7.485	V	rms value of the electrical voltage at the transducer tern
Ipeak	4.712	A	peak value of the electrical input current
Upeak	25.268	V	peak value of the electrical voltage at the transducer ter
Glarge (Gmax)	15.2 (26.0)	dB	gain of the excitation amplitude increased in the large s
Mech. system		abs.	import used to identify mechanical system in absolute
Xdc	-0.07	mm	dc component of voice coil excursion measured in the l
Xpeak	5.13	mm	positive peak value of voice coil excursion measured in
Xbottom	-6.47	mm	negative peak value (bottom) of voice coil excursion me
Xp+	4.6	mm	upper limit of displacement range (99% probability)
Xp-	-4.9	mm	lower limit of displacement range (99% probability)
Xprot	5.4	mm	maximal voice coil excursion allowed by protection syst
v rms	0.57	m/s	voice coil velocity

Displacement amplitude information, such as the protection displacement limit x_{prot}, should be stated along with the derived nonlinear parameters, A_K or x_{sym} (x_{offset}). This ensures comparability between results since A_K and x_{sym} (x_{offset}) are determined at high displacements.

In addition, these state conditions help estimate the start and target values (terminal voltage, peak displacement, required Bl decay) to set up the *QC MSC* test for comparable results.

2.3 Setting up the QC Test

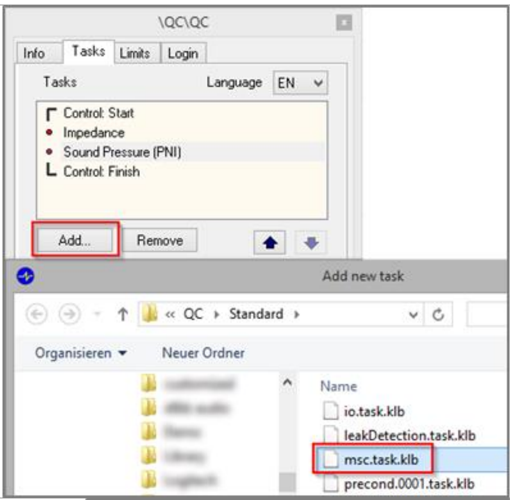
The *LSI* results can be used to set up the *QC MSC* test in an end-of-line test environment. The test setup may be different because the QC measurement is usually performed with the DUT inside or attached to a test box instead of free air. For best comparability of the results, it is recommended to keep the same mounting orientation and load (large test box) as used during the *LSI* test.

Note: It is important to connect the DUT with correct polarity. Otherwise, some nonlinear parameters and states will have the wrong sign when compared to *LSI*.

1. Create/Select Test

Open *QC Start – Engineer* and create a new test based on a suitable template or select an existing test which shall be enhanced by the *MSC* for large signal testing

Click *Measure* to login for setup.

<table>
<tr>
<td>2. Add MSC Task</td>
<td>
Click Add.. under Property Page - Tasks to add the MSC to the test sequence. Use the arrow buttons to change the order of the test sequence.
In a reverberant test environment it is not recommended to place MSC right before an acoustic test step like Sound Pressure, as its high-level acoustical decay may falsify the Rub&Buzz test.
Note: For minimal overall test time the MSC should be placed early in the test sequence. Signal processing for MSC is performed in parallel with subsequent measurements.


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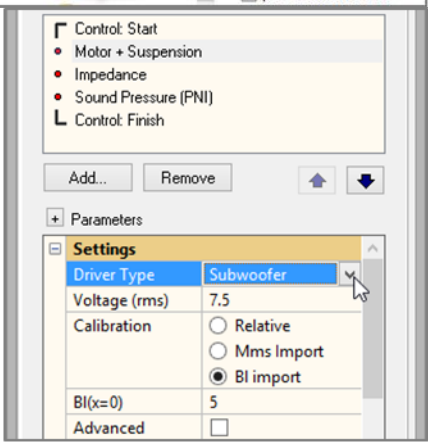
<tr>
<td>3. Set Driver Type</td>
<td>
Set up MSC by selecting one of the predefined Driver Type templates. Select the template according to the specified resonance frequency range of the DUT. See the MSC Tutorial section - Find the Optimal Driver Type for more information.
The present DUT's resonance frequency is below 80 Hz, thus the Subwoofer template is recommended. The Woofer template would be applicable as well but it is recommended to use the "lower" template as it uses more reliable settings such as longer measurement time for better low frequency resolution.


Settings, such as measurement time, frequency range and resolution are set automatically in the background. The complete set of available settings is shown by selecting Advanced parameter. In most cases the template settings are suitable or a good starting point.
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<td>4. Set Initial Test Voltage</td>
<td>
One of the most critical setup parameters is the excitation Voltage since it defines the peak displacement during the measurement.
Although the excitation signals of LSI (noise) and MSC (multitone) differ, both have comparable characteristics. Therefore, U_{rms}, as displayed in the LSI State window (see section State Window), may be used as a reasonable test voltage for the first run of MSC.
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<tr>
<td>5. Mechanical Calibration</td>
<td>
For mechanical calibration either $Bl(x = 0)$ or M_{ms} can be copied from the LPM measurement. Select the corresponding parameter in Settings – Calibration.
It is recommended to use the most stable parameter (i.e. the parameter which exhibits the least amount of variation amongst a series of sample drivers in production). Importing moving mass may be preferable as it is independent of the coil rest position. Further aspects are discussed in section
Root Causes of Result Deviation.
If Relative calibration is selected, all results will be displayed in % of peak displacement. This is not recommended due to the lack of diagnostic information in the result.
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<tr>
<td>6. First Run</td>
<td>
After selecting the desired results such as Coil Offset in parameter category Measurements, start a first measurement to verify the setup parameters by clicking the Start button in Control Panel.
The Summary window shows the results of the MSC with the estimated Coil Offset printed at the top. The value is a close match to the x_{sym} value measured by LSI, even when just using the standard QC template settings. In addition, Stiffness Asymmetry
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shows good agreement with A_K.

[TASK OUTPUT: MOTOR + SUSPENSION]

Coil Offset: -1.010 mm

Nonlinear working range not reached symmetrically (force factor dropped to 70.8%, target: <70%), increase voltage

Name	Value	Unit	Description
Coil Offset	-1.01	mm	recommended shift to compensate voice coil offset
Stiffness Asymmetry	-19.8	%	stiffness asymmetry
fs	57.8	Hz	resonance frequency
Re	3.75	Ohm	electrical voice coil resistance at DC
Qts	0.43		total Q-factor

Name	Value	Unit	Description
Xpeak	6.82	mm	peak displacement during measurement
Xprot	-	mm	peak displacement of reference Duts
Xac	5.81	mm	ac displacement at coil offset
Xdc	-0.74	mm	dc displacement (at maximum peaks)
Bl min	48.5	%	minimal force factor ratio during measurement (related to rest pc
Cms min	42.4	%	minimal compliance ratio during measurement (related to rest po:

The state variables shown in the second table should be checked to verify that the *MSC* measurement conditions are the same as *LSI* measurement conditions.

Peak displacement x_{peak} in *MSC* refers to the maximal absolute displacement* which should be to the *LSI* reference displacement x_{prot} which has been identified according to the user defined protection limits. Therefore, it is recommended to reduce the *MSC* stimulus voltage in order to decrease the peak displacement by ≈ 1.4 mm.

Bl_{min} is an indicator of the “degree of nonlinearity” because it describes the force factor variation $Bl(x)$ related to the Bl at the rest position $Bl(x = 0)$. In this example, Bl_{min} is below the *LSI* protection limit of $50\ \%$ which is another indication that the *MSC* stimulus voltage should be reduced.

Note: To estimate a valid voice coil offset, the *MSC* measurement looks for a symmetrical force factor reduction of 70% or greater. In some cases, when *Bl*(*x*) is highly asymmetric, the warning message *“Nonlinear working range not reached..”* will be displayed. However, if the results can be validated by comparing *MSC* state variables to *LSI*, the warning can be ignored.

**Separate $\mathrm{x}_{\mathrm{peak}}$ and $\mathrm{x}_{\mathrm{bottom}}$ available from version QC4.0d.*

7. Modify Advanced Settings

In some cases, it may be necessary to edit additional parameters to improve the agreement between results. Selecting the *Advanced* option activates the following additional hidden parameters:

Advanced	☑
F start	2
F stop	750
Resolution	20
Time	2.73
Preloop	0.5
Compensate Amplifier	☐
Inductance Model	Leach (2)
Consider thermal heating	☐
Consider nonlinear dam...	☐

- If linear parameter estimation of the MSC fails or *LPM* shows a clear preference for a specific **Inductance Model**, adjust the *MSC* parameter to match.
- To increase accuracy, consider increasing the measurement **Time**, especially for low frequency transducers. To find the optimal test time, start the measurement using the maximal measurement time (for best accuracy) and then reduce the time, step-wise, until the results start to deviate.
- **Preloop** defines the additional time spent to bring the speaker into steady-state conditions.
- **Compensate Amplifier** accounts for the amplifier roll off at very low frequencies. In some cases results may be impaired if the applied boost is high. Amplifier compensation may be deactivated in most cases.
- Microspeakers or tweeters may heat up even during a short MSC test. The resulting variation of R_{e} may impair the MSC results. Consider activating **Consider thermal heating**. However, this will result in a significantly longer test time to identify the thermal characteristic. Therefore only use it if the results im-

prove.

- **Consider nonlinear damping** will account for the effect of nonlinear damping as a function of velocity $R_{\text{ms}}(v)$. This effect is relevant for micro speakers and should be activated for this transducer type.

More related information can be found in the section

Root Causes of Result Deviation and in the MSC – Tutorial section Customize your MSC Task.

8. Final Setup Check

The screenshot below shows the results with optimized setup parameters. A lower voltage has been used to reduce the peak displacement and the measurement time was increased to improve accuracy.

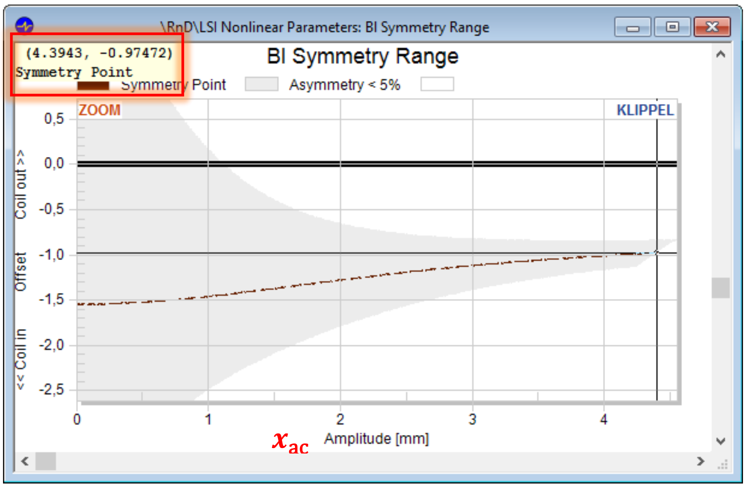
Coil Offset: -0.9829 mm

Nonlinear working range not reached symmetrically

Name	Value	Unit	Description
Coil Offset	-0.98	mm	recommended shift to c
Stiffness Asymmetry	-30.4	%	stiffness asymmetry
fs	61.2	Hz	resonance frequency
Re	3.74	Ohm	electrical voice coil res
Qts	0.46		total Q-factor

Name	Value	Unit	Description
Xpeak	5.37	mm	peak displacement during measurem
Xprot	-	mm	peak displacement of reference Dut
Xac	4.38	mm	ac displacement at coil offset
Xdc	-0.38	mm	dc displacement (at maximum peaks
Bl min	53.3	%	minimal force factor ratio during me
Cms min	52.6	%	minimal compliance ratio during mea

Now, the *Coil Offset* is slightly less than the x_{sym} value stated in the *LSI Nonlinear Parameters* table. However, using the cross cursor in *LSI*'s *Bl Symmetry Range* plot shows a very good agreementwith the x_{ac} value provided in *MSC's* parameter table.



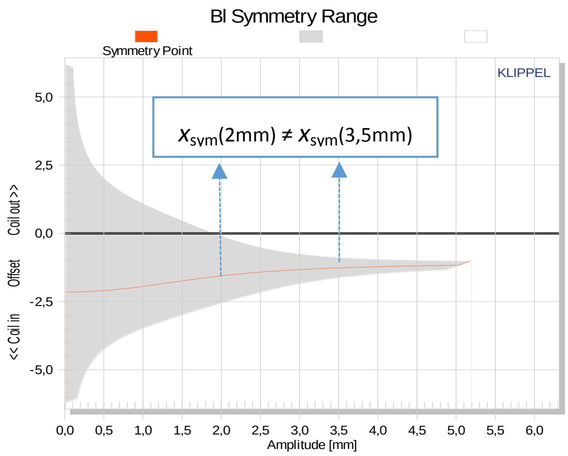
9. Verify Setup

In order to verify the test setup parameters when multiple speaker samples are available, it is recommended to run the QC test on the complete sample lot. This helps verify typical variations, accuracy, stability and limit settings.

3 Root Causes of Result Deviation

3.1 Peak Displacement

Comparing derived nonlinear parameters such as voice coil offset or stiffness asymmetry may heavily depend on the peak displacement achieved during the measurements. This is especially the case for nonlinear characteristics with a dominant inherent asymmetry.



Therefore, the maximum displacement during both measurements should be the same.

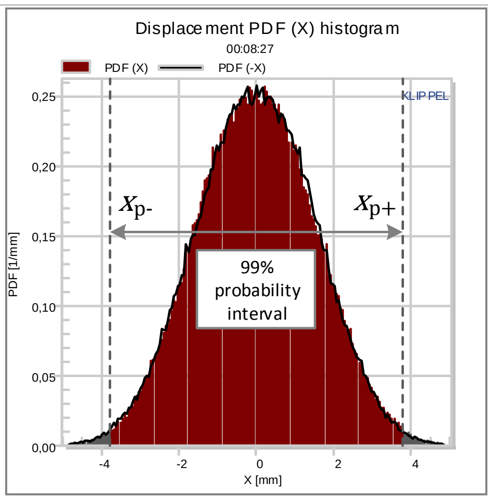
Note: there are different parameters referring to peak displacement which should be distinguished, such as $x_{\text{peak}}, x_{\text{bottom}}, x_{\text{ac}}, x_{\text{prot}}, x_{\text{p}}$.

For very linear motor designs, always check that displacement is high enough to produce flanks on both sides of the nonlinear curve, even when assuming high offset. This policy of producing flanks should also be followed when the nonlinear curve has two sub-maxima and a local minima. See AN1 for more details.

In order to be determine displacement limit parameters, such as x_{C} and x_{Bl}, a certain amount of variation is required.

3.2 Measurement Duration and Excitation Signal

The *LSI* measurement takes significant time to adaptively determine the nonlinear parameters with a broad band noise signal. The *LSI* displacement PDF histogram shows low voice coil displacement most of the time. Relatively speaking, there are very few incidents of high excursions. However, especially high amplitude information is required for nonlinear identification purposes.



Contrast to *LSI*, *MSC* must acquire all information in only a few seconds. Therefore, a dedicated multitone signal is used to ensure symmetric peak displacement and a low crest factor at minimal test time. During this short test time, peak displacement is only achieved a few times. Therefore, increasing time is recommended to improve the result agreement. The default settings of the Driver Type templates may not be time optimal for your transducer, especially when the resonance frequency of the DUT is in the lower recommended range of the selected template.

3.3 Orientation

Due to a soft suspension or a large moving mass, the effects of gravity may impair the results by causing a significant shift in the coil rest position. Therefore, It is recommended to always keep the DUT orientation similar to the target application and maintain consistency throughout all the measurements.

The influence of gravity on the coil rest position can be estimated by the following equation:

$$\Delta x_{\mathrm{offset}} = \mathrm{g} \cdot m_{\mathrm{ms}} \cdot c_{\mathrm{ms}}$$

The offset is given relative to vertical orientation.

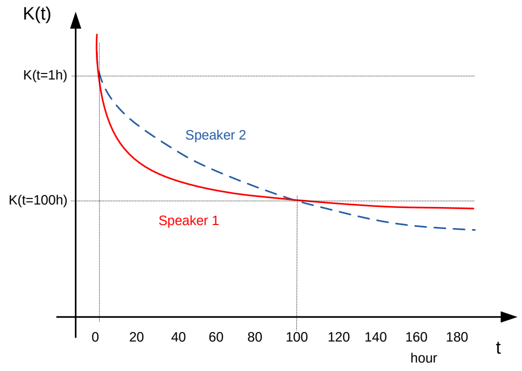
3.4 Polarity

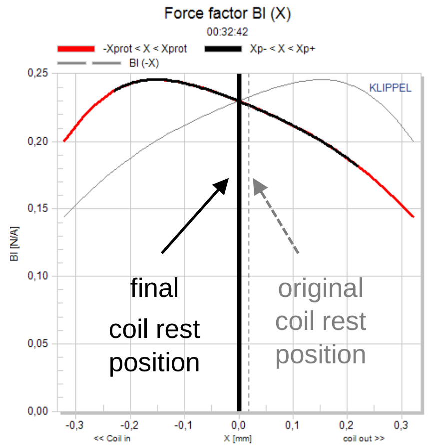
Although it is not relevant towards determining the actual nonlinear identification, polarity is important to correctly orient an outward coil movement with a positive voltage on the positive terminal of the speaker.

If a laser sensor is used during the LSI measurement, the polarity is automatically determined. However, a correct polarity connection is recommended to have consistent orientation of the nonlinear curve abscissa. Due to the lack of mechanical sensors, *MSC* relies on correct connections. The wrong polarity connection during *MSC* can be detected as an inverted sign in the offset result.

3.5 Time Variance & Ageing

The material properties of the suspension change with the amount of mechanical work performed (i.e. stress and strain during operation). As a result, the mechanical parameters (small and large signal) vary with time as shown in the example $K(t)$ plot below. The changes can be irreversible. For example, the quick stiffness decay during the "break-in" period of new transducers. A change in suspension stiffness may produce a change in coil rest position. Therefore, LSI should be performed before MSC. In *LSI*, both the initial and final coil rest position is indicated by vertical lines in the nonlinear parameter charts.





3.6 Self-Heating

In order to identify the large signal parameters during LSI, the device under test is usually operated close to its mechanical or thermal protection limits. As a result, the measurement is compensated for an increase in D.C. resistance R_e due to voice coil heating.

Voice coil heating may also occur during *MSC*. The setup parameter *Consider thermal heating* may be used to compensate but this increases measurement time significantly (by factor 3) and it is not required in most cases. Typically, only micro speakers or tweeters may suffer from heating during the *MSC* test because the thermal time constant of the voice coil τ_v is relatively fast. Therefore, keep the measurement time as short as possible or activate thermal mode when the results are not reliable.

Note: LSI provides an optional *Thermal Mode* which is performed after nonlinear parameter identification to identify thermal parameters such as τ_v.

3.7 Variance of Mechanical Calibration

To calibrate the result parameters in absolute mechanical units (e.g. mm), *LSI* facilitates importing a reference value such as the force factor at the rest position $Bl(x = 0)$ or the total moving mass M_{ms}. These parameters are measured accurately with high precision by *LPM*.

During end-of-line testing, $Bl(x = 0)$ or M_{ms} are usually not updated for each unit tested. Therefore, to calibrate the variations between samples, MSC also facilitates the entry of a typical (reference) value. This means that any deviation between the measured and typical values indirectly affect the results such as x_{Bl} or *voice coil offset*. The relative error between measured displacement x' and typical displacement x is described by the following relations:

$$\frac{x'}{x} = \frac{Bl_{typ}}{Bl_{DUT}} = \sqrt{\frac{M_{ms,DUT}}{M_{ms,typ}}}$$

As shown, a Bl deviation causes a linear error while a moving mass deviation has less of an impact (square root). In terms of typical production processes, force factor is often more stable than moving mass. However, $Bl(x = 0)$ strongly depends on the rest position by definition, importing mass may be more robust.

Note: A typical end-of-line test includes small signal parameter and acoustical response measurements. Parameters, such as resonant frequency or average sound pressure level, will indicate a significant deviation in $Bl(x = 0)$ or M_{ms}.

3.8 Test Setup (Load)

During, end-of-line testing, test boxes are commonly used to provide consistent measurement conditions and ambient noise isolation. Because R&D tests are typically performed in free air or in a baffle, the acoustical load conditions during a QC test may be different.

The enclosed air acts as an additional spring which increases the total measured stiffness and limits peak displacement. The actual impact depends on the DUTs radiating surface area and the volume of the test box. In most cases, increasing stimulus voltage is sufficient to compensate for the drop in peak displacement.

In some cases, even large signal parameters may be corrupted. For example, in very small test boxes, air compression becomes nonlinear. At the same time a dominant air stiffness may linearize the total $K_{ms}(x)$.

3.9 Ambient Conditions

Since temperature and humidity variations may have significant effects on suspension parameters and other characteristics, all tests should be performed under the same climatic conditions. Although factory conditions can be drastically different from laboratory conditions, it is important to at least provide the same climate conditions during setup and evaluation stages.

4 Related Information

Application Notes	• AN1: "Optimal Voice Coil Rest Position" • AN2: "Separating Spider and Surround" • AN3: "Adjusting the Mechanical Suspension" • AN5: "Displacement Limits due to Driver Nonlinearities" • AN21: "Reduce Distortion by Shifting Voice Coil" • AN24: "Measuring Telecommunication Drivers" You may download all KLIPPEL application notes here.
Specifications	• S13 QC - Motor and Suspension Check (MSC) • S1 – Large Signal Identification (LSI) • S2 - Linear Parameter Measurement (LPM)
Manuals	• Tutorial & Manual MSC • Tutorial & Manual LSI • Tutorial & Manual LPM
Standards	• IEC 62458 – Sound System Equipment – Electroacoustical Transducers – Measurement of Large Signal Parameters
Papers	• W. Klippel "Mechanical Fatigue and Load-Induced Aging of Loudspeaker Suspension" • W. Klippel "Nonlinear Modeling of Heat Transfer" • W. Klippel "Loudspeaker Nonlinearities – Causes, Parameters, Symptoms" • W. Klippel "Assessing Large Signal Performance of Transducers " • W. Klippel "Assessment of Voice Coil Peak Displacement Xmax" • W. Klippel "Nonlinear Damping in Micro Speakers" • S. Hutt, L. Fincham; "Loudspeaker Production Variance", presented at the 125th convention of the Audio Engineering Society 2008 (San Francisco) Most of the listed papers and many more related may be downloaded here.

Find explanations for symbols at:

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

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