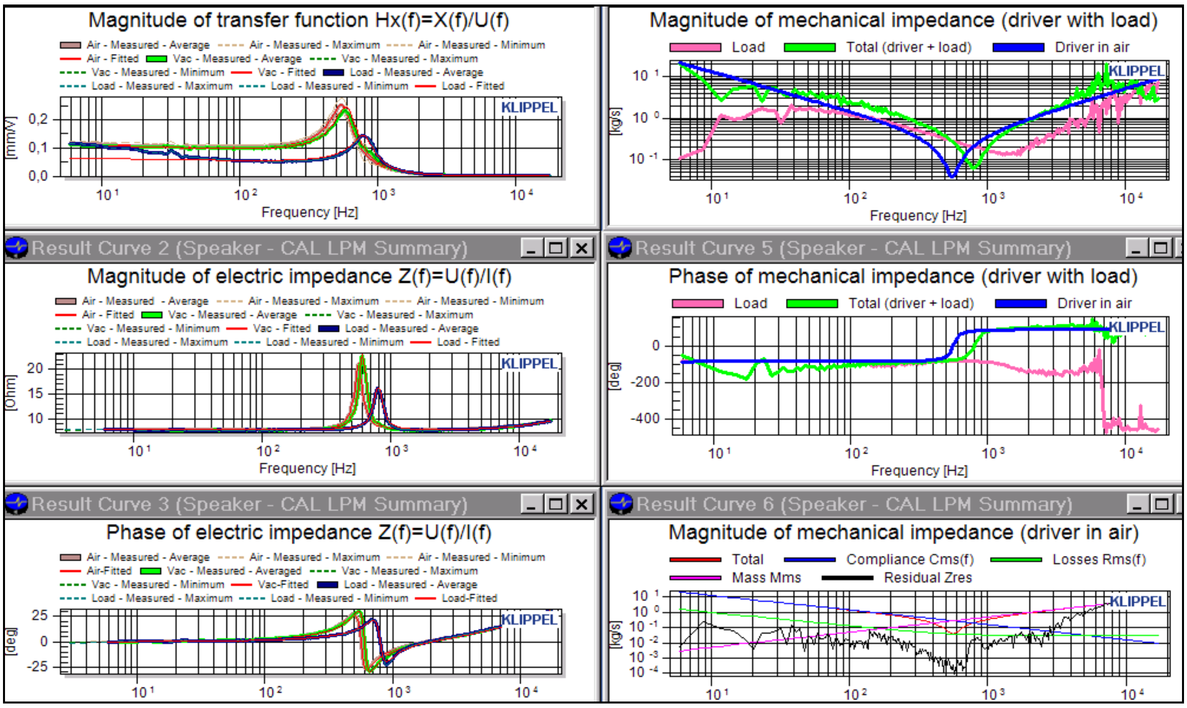
Multipoint Parameter Fitting & Load Separation **AN 50**

Application Note for the Klippel R&D SYSTEM

Identification of Linear parameters of microspeakers can be very hard. Due to rocking, $H_x(f)$ may vary when measuring on different points. Furthermore, due to their low mass and stiffness microspeakers are much more susceptible to load and creep induced fitting errors. This application note will guide through the features of the Microspeaker Multipoint Tool to ease this task.

The Micro-Speaker Multipoint Tool offers acquisition of precise T/S-parameters by evaluating a set of Linear Parameter Measurements taken from one transducer. Measurements taken in vacuum, air and with an attached load (e.g. an enclosure) are used. Thus the load as well as the impact of air to the transducer can be calculated, displayed and evaluated. Displacement measurements taken on different points of the membrane are averaged to improve the accuracy of the measured force factor Bl, and derived parameters.



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Background

Introduction

Distinguishing between measurements in air, vacuum and with load makes it necessary to introduce a model for each technique. These will be introduced in the next paragraphs.

Vacuum Measurement

Measuring a speaker in vacuum neglects all influences of air, thus an estimation of the purely mechanical and purely electrical parameters becomes possible.

Figure 1 shows the electrical equivalent circuit used for vacuum measurements. The classical mechanical parameters R_{ms}, C_{ms} and M_{ms} describe the behavior of the transducer in air and are replaced by the purely mechanical parameters R_{md}, C_{md} and M_{md}.

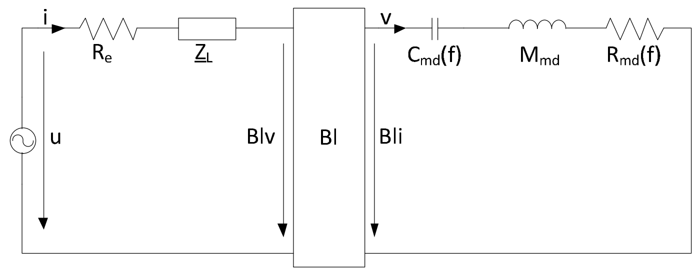

Figure 1 Equivalent electrical circuit for vacuum measurements

Air Measurement

The circuit shown in figure 2 models the transducer measured in air. The mechanical parameters R_{ms}, C_{ms} and M_{ms} represent mechanical as well as acoustical qualities.

The additional impedance $\underline{Z}_{res}$ (residual impedance) represents all effects which are not covered by the three mechanical parameters. This will mainly incorporate frequency dependent effects like air leakage, since the frequency dependence of the compliance and the losses is considered to be purely mechanical due to the creep of the suspension.

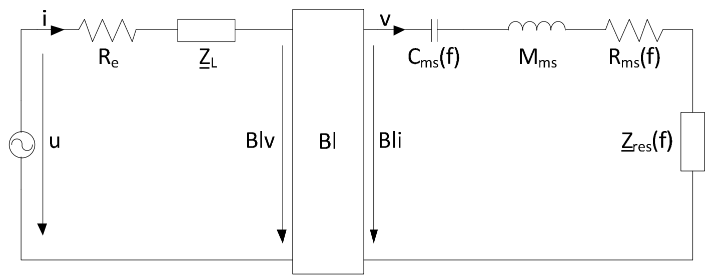

Figure 2 Equivalent electrical circuit for air measurements

Load Measurement

Attaching a load to a transducer can have different meanings. In any case it will add a mechanical (e.g. adding a panel to a shaker) or an acoustical system (e.g. adding a horn to a compression driver) or a mixture of both to the transducer.

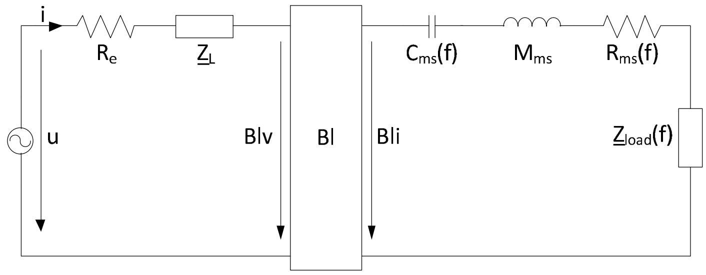

Figure 3 Equivalent electrical circuit for load measurements

Figure 3 shows the circuit used to model the load measurement. The load impedance Z_{load} incorperates all qualities which are not covered by the electrical parameters or the mechanical parameters measured in air. (Note: You may also calculate the load from the difference of the speaker measured in vacuum and with load)

Thus Z_{load} represents a system of arbitrary order depending on the attached load.

Averaging

Especially the estimation of the force factor *Bl* with a laser measurement is very prone to resonant modes of the transducer, since the estimation is directly proportional to the displacement of the membrane.

To get more reliable results it is recommended to measure the displacement with a laser at different points on the membrane. The CAL LPM Micro-Speaker Multipoint Tool will automatically average these measurements for a more robust estimation.

Estimation Order

The following listings display the desired order to estimate the linear transducer parameters.

Vacuum Measurement:

- DC resistance R_e (alternative from air measurement)
- Inductivity model Z_l (alternative from air measurement)
- Creep model (alternative from air measurement)
- Mechanical parameters (R_{md}, C_{md} and M_{md})

Free Air Measurement:

- Mechanical parameters in air (R_{ms}, C_{ms} and M_{ms})
- Residual impedance Z_{res}

Load Measurement:

- Load impedance Z_{load}

Application

Requirements	Running the script requires dB-Lab 206.15 (Or the 206.14 script update) and the KLIPPEL Extraction Tool (ver. 1.302). The CAL LPM Micro-Speaker Multipoint Tool requires a license. The script will summarize and process a set of Linear Parameter Measurements. Thus a KLIPPEL database containing the LPM measurements to be evaluated is mandatory.
Setup	To use the Extended Creep Modeling, create a new object and select the *LPM Microspeaker Multipoint AN50* template. Alternatively you can create a *CAL LPM Microspeaker Multipoint Tool Setup* Operation into an object with existing LPM measurements.
Measurement	The source data will be gained by conducting multiple LPM Measurements. Following steps are recommended Air measurements: 1. Do five measurements in air, on 5 equally distributed points on the membrane. Please mark the measurements with the keyword ‘air’ Vacuum measurement 2. Conduct a measurement in Vacuum, and include the the keyword ‘vac’ in its name. It is necessary, to use the laser for this measurement. However, the inaccuracy of the laser calibration due to the acryl-plate is not critical, as the absolute calibration of the parameters will be done with the laser measurements in air. Load measurement 3. A Measurement with an arbitrary load may be added, to gain information about the impedance of this load. Mark this measurement with the keyword ‘load’ in its name

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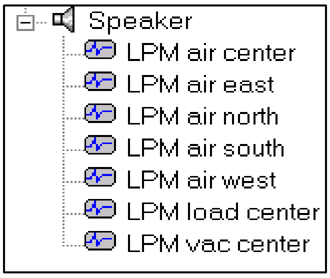
Extracting Data

The Extraction Tool will parse through all LPM operations of a database object and search for keywords in the titles relating the operation to a type measurement.

The following keywords are allowed (there is no case sensitivity):

- vac -> Vacuum Measurement
- air -> Air Measurement
- load -> Load Measurement

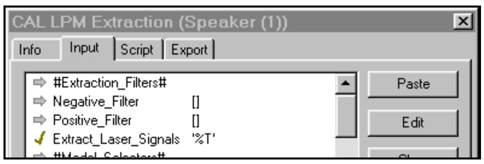


Recommended structure of a database before extraction

All operations which do not contain one of these keywords will be discarded. So labeling the operations in a proper and unique style is very important. The picture on the right shows the recommended scheme.

To prepare the object for extraction select the property page of the *CAL LPM Micro-Speaker Multipoint Tool Setup* operation. Before starting, you may alter the following three input parameters to influence the processing of the extraction. They can be found in the input property page:

- Negative Filter -> allows you to add keywords which will cause the operation containing this word to be discarded
- Positive Filter -> allows to add keywords an operation must contain, all other operations will be discarded
- Extract Laser Signals -> %T activates the extraction of displacement curves; while %F disables it



Start the extraction by pressing the run button. The script will call the Extraction Tool which performs the extraction.

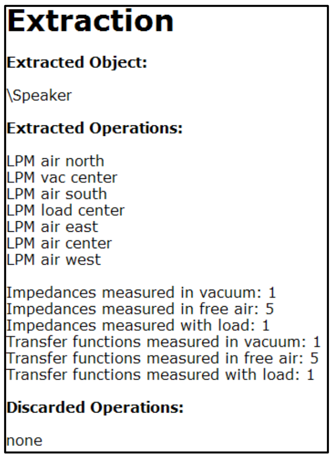
After the extraction is finished a message box will pop up and request a reopening of the database to view the results.

Extraction Results

The Extraction Tool will create a new operation in the database object called LPM Summary (**Warning: If the operation already exists it will be overwritten without request**). Primarily this operation will only contain the summarized and averaged curves of the extracted LPMs.

The Result Variables Window gives an overview of the extraction process. It displays all extracted and all discarded operations as well as many impedance curves and transfer functions have been detected and assigned to a measurement technique.

The windows Result Curve 1 to 3 display the averaged curves as well as the maximum and minimum values of the extracted transfer functions (magnitude) and impedances (magnitude and phase). Thus it is easy to find runaway measurements.



Extraction

Extracted Object:

\Speaker

Extracted Operations:

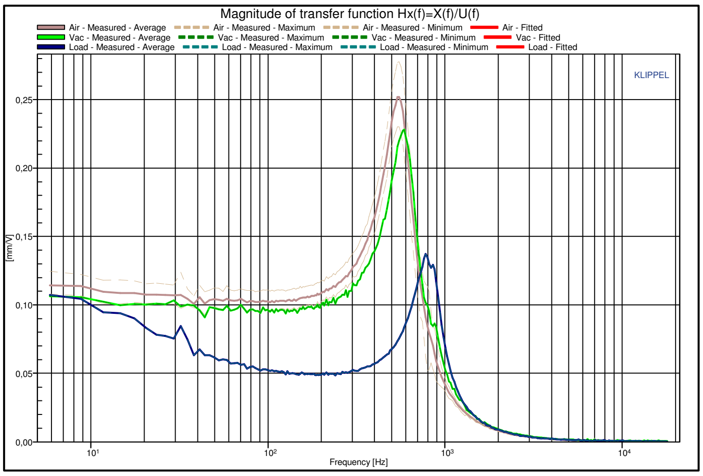
LPM air north
LPM vac center
LPM air south
LPM load center
LPM air east
LPM air center
LPM air west

Impedances measured in vacuum: 1
Impedances measured in free air: 5
Impedances measured with load: 1
Transfer functions measured in vacuum: 1
Transfer functions measured in free air: 5
Transfer functions measured with load: 1

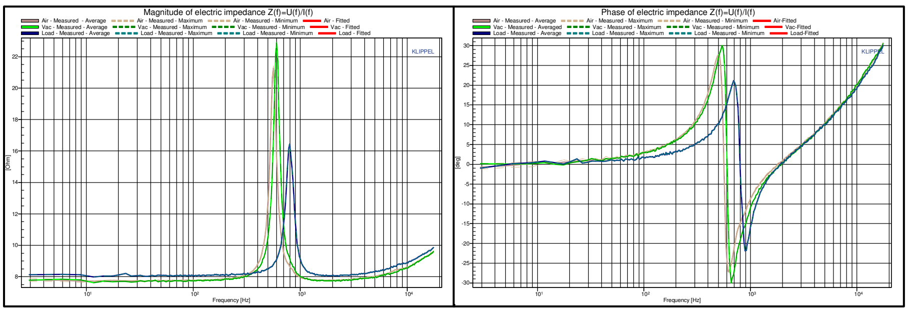
Discarded Operations:

none

Result Variables Window



Result Curve 1 Magnitude of transfer function Hx



Result Curve 2 and 3 Magnitude and Phase of impedance Z

Postprocessing

After extraction, postprocessing has to be started by executing the *CAL LPM Microspeaker Multipoint Tool Results* operation. Before running the operation, you may alter the settings, to select the desired inductance or creep model by changing the following parameters in the Property Page *Input*:

Inductance_Model:

- "none" (considers the inductance to be a constant parameter Le)
- "LR2" (shunted inductor model)
- "Leach" (two parameter model by Leach)
- 'Wright" (four parameter model by Wright)

Creep_Model:

- "none" (compliance is real and constant)
- "Log" (simple, real logarithmic creep model)
- "Knudsen" (complex logarithmic creep model by Knudsen)
- "Ritter" (complex creep model by Ritter)

The script will evaluate the averaged impedances and transfer functions. The estimated parameter sets can be found in the Result Variables window. Result Curves 1-3 will now also contain the estimated curves from the fitted parameters.

All measured curves will be normalized with respect to the estimated values of *Bl* and R_e.

If possible*, Bl* is identified from the air measurement. If Bl cannot be identified in these, the measured Bl from the load measurement is taken (or from the vacuum measurement if the load measurement does not provide a valid Bl).

Apart from that four additional result windows will be filled with data which are described in the next sections.

Measurement

Electrical Parameters

Name	Value	Unit	Comment
Re	7.82	Ohm	electrical voice coil resistance at DC
Le	0.043	mH	frequency independent part of the voice coil inductance
L2	0.0084	mH	para-inductance of the voice coil
R2	0.66	Ohm	electrical resistance due to eddy current losses in the voice coil
Cmes	0.15	mF	electrical capacitance representing moving mass measured in free air
Cmed	0.14	mF	electrical capacitance representing moving mass of driver in vacuum
Lces(fs)	0.52	mH	electrical inductance representing the compliance of the suspension in air at fs
Lced(fd)	0.50	mH	electrical inductance representing the compliance of the suspension in vacuum at fd
Res (fs)	13.49	Ohm	electrical resistance representing mechanical losses measured in free air at fs
Red (fd)	15.28	Ohm	electrical resistance representing mechanical losses in vacuum at fd

Derived Parameters

Name	Value	Unit	Comment
fs	561	Hz	driver resonance frequency in free air
fd	602	Hz	driver resonance frequency in vacuum

Estimated Linear Parameters in the Result Variables Window

In addition the script allows the import of the following parameters:

- R_e – DC Voice Coil Resistance [Ω]
- *Bl* – Force Factor [N/A]
- M_{ms} – Driver Mass [g]

An import of both the force factor and the driver mass will overdetermine the calculations, thus in that case the imported force factor will be ignored.

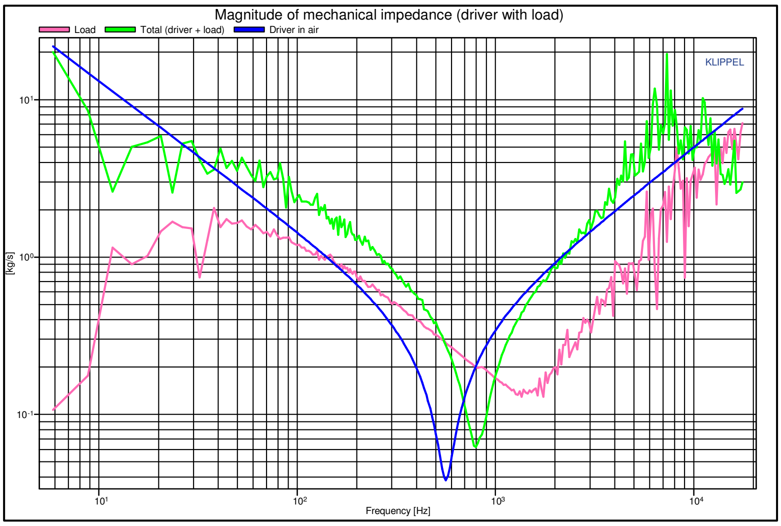
Mechanical Impedance (Driver With Load)

Result Curves 4 and 5 display the magnitude and the phase of mechanical impedances respectively.

Assumed, the corresponding curves are available you may select the domain, the load impedance will be calculated from:

Separate_Load_From

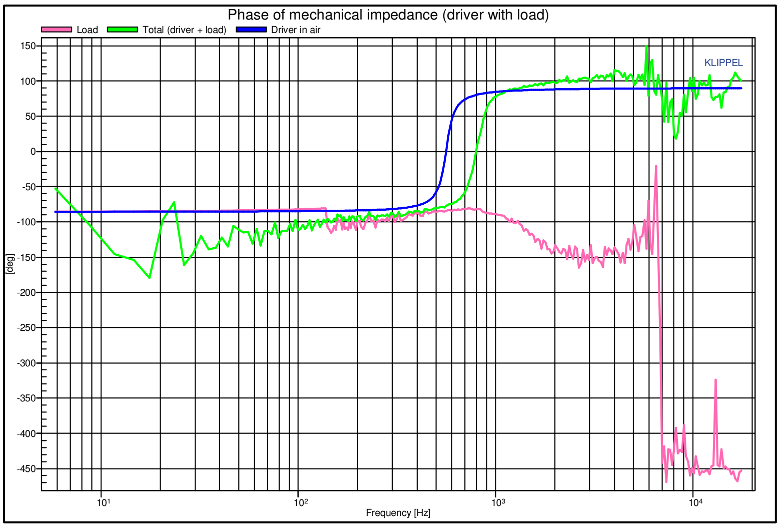
- "VAC" or "VACUUM" calculates the load with the vacuum measurement as basis
- "AIR" calculates the load with the air measurement as basis
- "NONE" deactivates the load separation



Result Curve 4

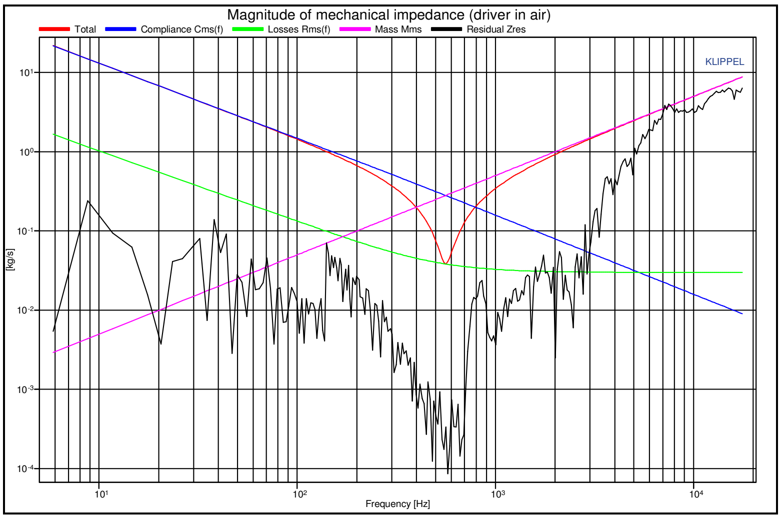
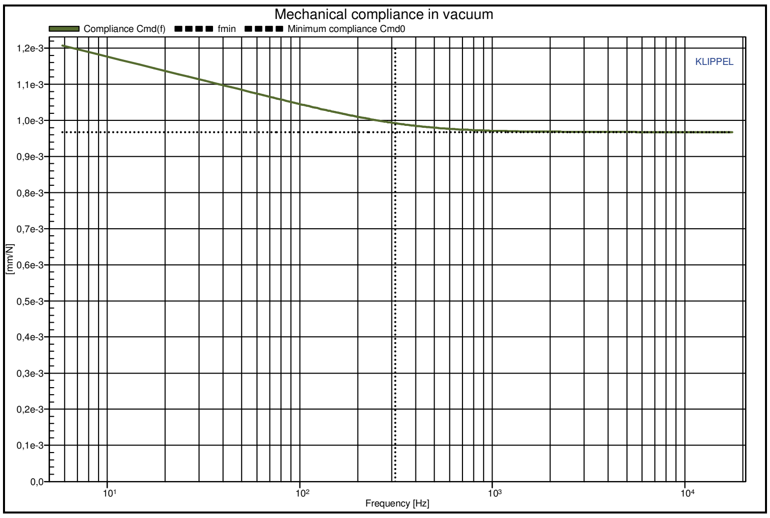
Magnitude of mechanical Impedance (driver with load)

These curves give an outline of the qualities of the connect load and how it influences the behavior of the transducer.



Result Curve 5

Phase of mechanical Impedance (driver with load)

Mechanical Impedance (driver in air)	Result Curve 6 shows the magnitudes of different mechanical impedances related to the driver measured in free air. (If there is no air measurement but a vacuum measurement available, this will be displayed). The figure demonstrates how the mass dominates the total mechanical impedance towards higher and the compliance towards lower frequencies respectively. At the resonance frequency the total impedance becomes real and reaches the value of the losses.  **Result Curve 6** **Magnitude of mechanical Impedance (driver in air)** The residual impedance indicates how much of the transducer behavior in free air is not covered by the rest of the model (Note: This includes effects which aren't modeled (e.g. air leakage) as well as fitting errors).
Mechanical Compliance	The frequency dependence of the mechanical compliance is displayed in Result Curve 8. Depending on the available data it will be taken from the air or vacuum measurement whereat vacuum is preferred. If the Ritter creep model is selected the two parameters C_{md0} (minimum Compliance) and f_{min} are displayed as well.  **Result Curve 7** **Mechanical Compliance**

Parameter Reference

Extraction Filters	This section contains parameters to setup which operations and curves should be extracted. **Negative_Filter** All operations containing one of the input-strings won't be extracted. Example: Setting Negative Filter to '[red,blue]' induces that all operations containing either the word 'red' or the word 'blue' won't be extracted. **Positive_Filter** Only operations containing one of the input-strings will be extracted. Example: Setting Positive Filter to '[yellow]' induces that only operations containing the keyword yellow will be extracted. **Extract_Lasersignals** Setting this parameter to '%T' causes the script to extract the curves of the displacement measurements. All other input values will cause this curves to be discarded.
Model Selectors	Parameters to vary the transducer model. **Inductance_Model** String to select a model for the inductance see Klippel LPM user manual for further information. 'none' – will use just a single inductance Le 'LR2' – LR2 inductance model 'Leach' – Leach inductance model 'Wright' – Wright inductance model **Creep_Model** String to select a model for the viscoelastic behavior of the transducer. See AN49 for further information. 'none' – constant mechanical compliance and losses 'Log' – logarithmic frequency dependence for the mechanical compliance 'Knudsen' – logarithmic model by Knudsen, considering the mechanical compliance and losses as frequency dependent 'Ritter' - model by Ritter, considering the mechanical compliance and losses as frequency dependent

Parameter Import	These parameters allow the import of known model parameters. **Re_import** -> electrical DC-resistance in Ω **Bl_import** -> Force Factor in N/A **Mass_import** -> Mechanical mass in g Note that it is only possible to import either Bl or Mms to keep the calculation of the mechanical parameters consistent.
Load Separation	Parameter considering the arithmetic separation of the load from remaining system of the transducer. **Separate_Load_From** ‘none’ -> deactivates the load separation ‘vac’ -> separates the load from the mechanical system measured in vacuum ‘air’ -> separate the load from the mechanical system measured in air

More Information

Papers	[1] W. Klippel and U. Seidel, “Fast and Accurate Measurement of Linear Transducer Parameters,” presented at the 110th Convention of the Audio Engineering Society, Amsterdam, May 12-15, 2001, preprint 5308 [2] M.H. Knudsen and J.G. Jensen, “Low-Frequency Loudspeaker Models that Include Suspension Creep,” J. Audio Eng. Soc., vol. 41, pp. 3-18, (Jan./Feb. 1993) [3] F. Agerkvist and T. Ritter, “Modelling Viscoelasticity of Loudspeaker Suspensions using Retardation Spectra,” presented at the 129th Convention of the Audio Engineering Society, San Francisco, November 4-7, 2010, preprint 8217
Software	User Manual and online help system of the Klippel R&D System
Application Notes	AN49-Fitting Linear Parameters with CAL LPM Scipt

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