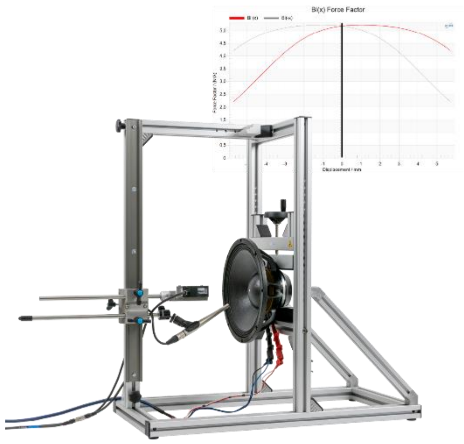
Fast Large Signal Identification Professional (FLSI Pro) S75

Module of the KLIPPEL R&D SYSTEM (Document Revision 0.3)

PRELIMINARY SPECIFICATION – PRODUCT IS STILL AWAITING FORMAL RELEASE
This specification is preliminary and is subject to change.

FEATURES

- Small and large signal lumped speaker parameter measurement
- For electrodynamic transducers of all kind
- Supports drivers in free air, closed, vented and passive radiator systems
- Minimal measurement time (20 sec … 3 min)
- Fully automatic measurement
- Finds the root causes of distortion
- Creates accurate linear and nonlinear parameters for simulations
- Fast thermal characterization



DESCRIPTION

The *FLSI Pro* software module identifies the elements of the nonlinear lumped parameter model of woofers, microspeakers, tweeters, and other electrodynamic transducers. The transducer might be mounted in a closed or ported enclosure and operates under normal working conditions. It is excited with a multi-tone signal. Starting in the small-signal domain, the amplitude is gradually increased up to limits admissible for the particular transducer. The maximum amplitude can be determined automatically using the identified transducer parameters and general protection parameters describing the thermal and mechanical load.

The identification of the model parameters is based on the voltage *u(t)* and current signal *i(t),* measured at the electrical terminals. The identified model allows locating the sources of the nonlinear distortion and their contribution to the radiated sound. , and other nonlinear effects can be investigated in detail.

Article number	1000-100

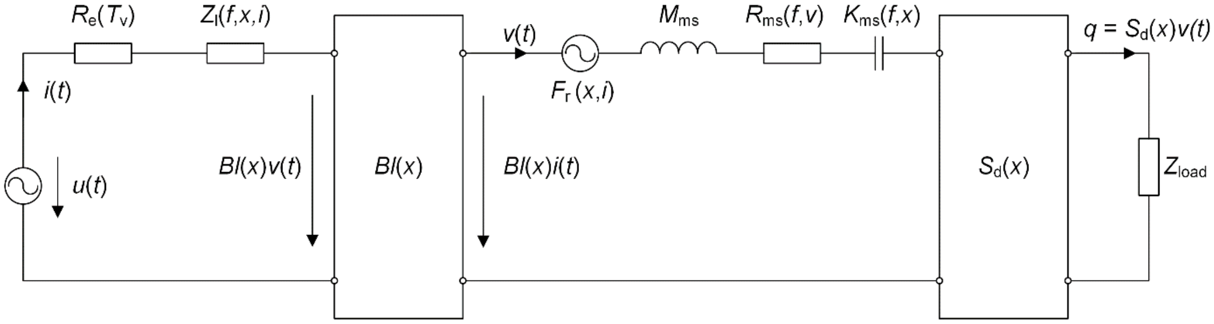
CONTENT

1 Overview

1.1 Principle

The transducers considered here have a moving-coil assembly performing an electro-dynamical conversion of the electrical quantities (current and voltage) into mechanical quantities (velocity and force) and vice versa.

Equivalent Circuit



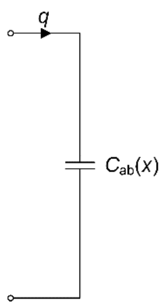
The lumped parameter model shown above is used to describe the large signal behavior of electro-dynamical drivers at high amplitudes. In contrast to the well-known linear model, most elements cannot be assumed to be constant but they depend on one or more speaker states (e.g. displacement *x*, voice coil velocity *v*, input current *i*, voice coil temperature T_v):

- Resistance of the voice coil at DC represented by $R_e(T_v)$
- Voice coil inductance represented by the nonlinear impedance $Z_l(f,x,i)$,
- Electrodynamic force factor $Bl(x)$,
- Stiffness of the mechanical suspension $K_{ms}(f, x)$,
- Mechanical losses $R_{ms}(f, v)$
- Effective radiation area $S_d(x)$

The additional impedance Z_{load}, which represents any additional acoustical load such as an additional resonance caused by a vented enclosure or passive radiator might contain nonlinear parameters as well (see section *Acoustical Load Impedance* below).

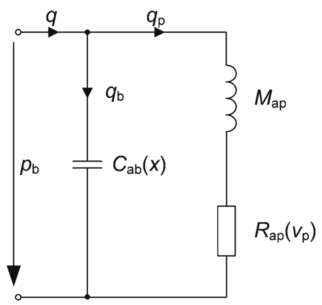
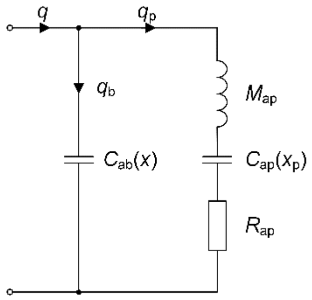
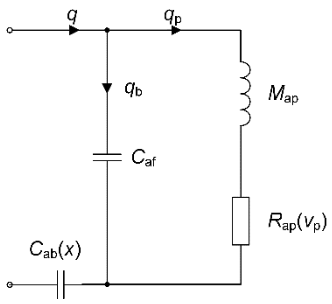
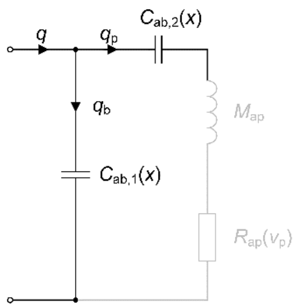
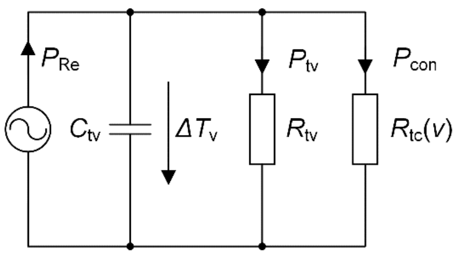
Acoustical Load Impedance

The acoustical load has a significant impact on the performance the loudspeaker system. For instance, a closed box adds a stiffness that has to be compressed when the transducer and highly changes the frequency response, efficiency and sensitivity compared to the transducer in free air. The acoustical load can also create additional nonlinear distortion, e.g. due to the nonlinear port resistance in vented speaker systems. Therefore it is highly recommended to not only perform nonlinear parameter measurements on the transducer, but also on the transducer mounted in the enclosure that shall be used in the end product. In addition to the free air measurement, the following speaker system types are supported by the FLSI Pro:



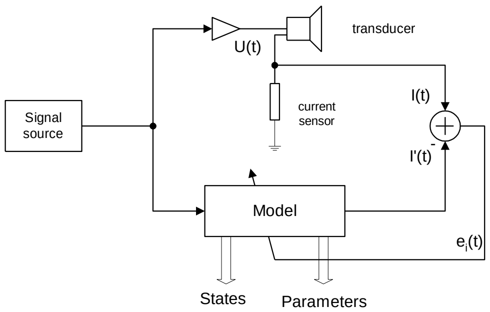
Closed Box:

The loudspeaker cabinet is closed and adds a nonlinear acoustical stiffness $K_{ab}(x) = 1/C_{ab}(x)$ to the transducer's suspension stiffness. The stiffness is nonlinear because the volume of the air in the cabinet is modulated by the voice coil displacement *x*.

		**Vented Box:** The vented box uses a port that, together with the stiffness of the enclosed air $1/C_{ab}(x)$, creates a Helmholtz resonance. The port is modeled with an acoustic mass M_{ap} and a nonlinear acoustical resistance $R_{ap}(q_p)$, which depends on the volume velocity $q_p=S_p v_p$, with v_p being the mean particle velocity in the port which has an effective opening surface area S_p.
		**Passive Radiator System:** The passive radiator is a passive element comprising a moving mass, a mechanical suspension and a mechanical resistance. Similarly to the suspension of an electrodynamic transudcer, the passive radiator's stiffness $K_{mp}(x_p)$ is nonlinear and depends on the passive radiator displacement x_p.
		**4th order Bandpass/Sidefire System:** In a fourth order bandpass system, the electrodynamic transducer is mounted in an enclosure with a closed back chamber. A port is located at the front side of the transducer.
		**Tweeter:** The FLSI module assumes tweeters to be electrodynamic transducers with a closed back chamber. Some tweeters have a small port that separates the back chamber into two. This port has to be considered in the model to accurately predict the voice coil movement. It can also create nonlinear distortion. The FLSI Pro automatically determines whether it considers any port parameters and deactivates them if they cannot be identified.
Thermal Model		The FLSI Pro identifies a short-term thermal model which equivalent circuit is shown on the left. The model comprises three parameters: 1. Thermal capacitor C_{tv}: Related to the voice coil mass 2. Thermal resistor R_{tv}: Related to the voice coil surface area 3. Nonlinear thermal resistor $R_{tc}(v)$ describing convection cooling: Related to the voice coil surface area and the air velocity around the coil This model can be used to estimate and compare the power handling capabilities of voice coils (see manual for more information).

1.2 Identification Technique

Principle



The transducer is excited by a broadband multi-tone signal delivered to the DUT (*device under test*) by a power amplifier. A nonlinear system identification algorithm estimates the voice coil current *i*(*t*)' which is then compared with the measured current *i*(*t*). The amplitude of the difference signal is minimized by adjusting the model parameters adaptively. The output parameters are the optimal linear and nonlinear parameter estimates, the instantaneous state variables (displacement) and statistical values (RMS and peak values).

Supported Speaker Systems

The FLSI measures and identifies the nonlinear lumped parameter model of electrodynamic transducers described above. It only supports the measurement of single electrodynamic transducers without any passive crossovers. The transducer might be mounted in an enclosure, such as closed, vented, bandpass or passive radiator. Measuring the transducer mounted in an enclosure that is similar to the one used in the end product additionally to the free air measurement is highly recommended to get performance characteristics not only of the transducer, but of the full physical passive system.

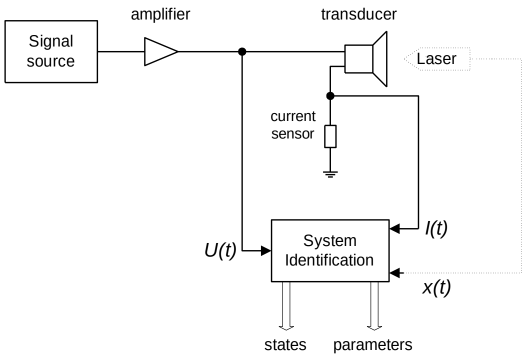
See a description of the supported speaker systems above (*Acoustical Load Impedance*).

Import Parameter

The minimal setup measures the electrical impedance at the transducer terminals and identifies the electrical system in absolute quantities, whereas the mechanical system is identified in relative quantities only. A calibration of the mechanical system is required to calculate the estimated state variables and mechanical parameters in physical units.

The calibration is done by measuring the voice coil excursion using a laser sensor. Comparing the estimated and measured excursion signals, the calibration factor *Bl*(*x*=0) can be identified. If a laser is not available or the transducer's membrane is covered, the calibration can be done by importing *Bl*(*x*=0), max(*Bl*(*x*)),the moving mass M_{ms}) or performing an added mass method. Note that the calibration using the laser sensor usually gives the most precise result.

Laser



A laser sensor based on triangulation principle (see *A2 Laser Displacement Sensor*) can be used for measuring the voice coil displacement during the test. This information is used for identifying the force factor *Bl*(*x*=0). This is required to calibrate the mechanical parameters in absolute terms.

Microphone

A microphone can optionally be used for measuring impulsive distortion (Rub&Buzz). Impulsive distortion metrics are used to identify a reasonable transducer's working range and to prevent mechanical overload.

In addition, the microphone is required to identify the nonlinear distortion caused by $S_d(x)$.

Measurement Procedure

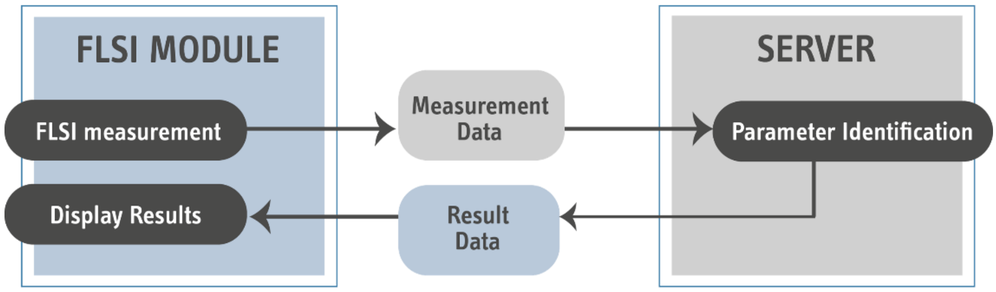
The estimation of the linear and nonlinear parameters consists of a series of steps processed sequentially:

- LINEAR MODE
  - Amplifier check (cables, gain control, limiting)
  - Measurement of resistance R_e at DC
  - Finding the optimal excitation settings (level, bandwidth, number of averages) for the linear parameter measurement
  - Identification of the linear lumped parameters
- ENLARGEMENT MODE (optional)
  - Identification of the admissible amplitude
- NONLINEAR MODE
  - Identification of the nonlinear parameters describing the transducer over its whole working range
- THERMAL MODE (optional)

	○ Voice coil heating (only required if the minimum required temperature was reached during the NONLINEAR MODE) ○ Voice coil cooling measurement ○ Identification of Thermal Parameters
Acoustical Environment	The influence of the room acoustics on the driver parameters may be neglected having a normal room size (volume > 30 m³) and keeping a distance of about 1 m to the walls.

1.3 Parameter Identification

Klippel Server	The parameter identification requires an internet connection because the parameter identification happens on a Klippel server. The communication with the server happens automatically during the measurement.



2 Requirements

2.1 Hardware			SPEC
Analyzer		Klippel Analyzer 3 The *High Power Speaker Card* is not supported yet.	H3
Amplifier	KA3 Amp-Card or external audio amplifier with a flat frequency response over the desired measurement bandwidth		H6
Microphone	*[optional]* Free field microphone with omnidirectional directivity characteristic over the desired measurement bandwidth.		A4
Laser Displacement Sensor	*[optional]* A high precision laser displacement sensor may be used to capture the membrane movement.		A2
Computer	A Windows PC with Internet access is required.		
Klippel Server Access	The parameter identification is performed on a KLIPPEL server. If a firewall is used, it needs to allow outgoing connections to ***https://klippel.services*** and its subdomains ***https://<SUB_DOMAIN_NAME>.klippel.services***. See the privacy policy here.		

2.2 Software	

dB-Lab	Project Management Software of the KLIPPEL R&D SYSTEM. Requires the latest version of dB-Lab 212.	
Permissions	In addition to dB-Lab, the user also needs permissions to run the software *curl*. curl is installed together with dB-Lab.	

3 Limitations

3.1 Device Under Test

Parameter	Symbol	Min	Typical	Max	Unit
Voice coil resistance	R_e	1	2-20	300	Ω
Resonance frequency	f_s	15		2000	Hz

3.2 Power Amplifier

Parameter	Symbol	Min	Typical	Max	Unit
Frequency response Ref. 1kHz @ 5 Hz … 20 kHz	$\Delta G_{amp}(f)$	-1	0	+1	dB
Frequency response Ref. 1kHz @ 2 Hz	$\Delta G_{amp}(f_{Re})$	-20	0	+1	dB

3.3 Input Parameters

Parameter	Symbol	Min	Typical	Max	Unit
DRIVER					
Effective area of the driver diaphragm	S_d	0.01		10000	cm²
Force factor at rest position[1]	$Bl(x{=}0)$	0.01		1000	N/A
Maximum force factor over the full voice coil excursion range	Bl_{max}	0.01		1000	N/A
Moving mass	M_{ms}	0.0001		10000	g
Box volume	V_b	0.0001		1000	Liter

4 Output

PARAMETERS AT THE REST POSITION (X=0) IN THE SMALL AND LARGE SIGNAL DOMAIN	
Electrical transducer parameters	R_e, L_e, L_2 , R_2, L_3 , R_3, C_{mes}, L_{ces}, R_{es}
Mechanical transducer parameters	M_{ms}, R_{ms}, K_{ms}, C_{ms}, Bl
Derived parameters transducer parameters	Q_{ts} , Q_{ms}, Q_{es}, f_s, V_{as}, η_0, L_m
Vented box/Passive Radiator/Bandpass parameters	Q_b, f_b, α
Closed Box parameters	K_{mt}, C_{mt}, L_{cet}, Q_{tc} , Q_{mc}, Q_{ec}, f_c
TRANSFER FUNCTIONS	
Measured Impedance	$Z(f)$, arg($Z(f)$),
Impedances based on small and large signal lumped parameters	$Z_{small}(f)$, arg($Z_{small}(f)$), $Z_{large}(f)$, arg($Z_{large}(f)$),
Predicted Lossy Inductance Parameters	$\|Z_l(f)\|$, arg($Z_l(f)$), $L_{app}(f)$, $R_{l,app}(f)$
Displacement Frequency Response Magnitudes	Measured and predicted small and large signal frequency responses
WAVEFORMS	
Measured time signals	$u(t)$, $i(t)$, $x(t)$, $p(t)$
Modeled time signals	$x(t)$

[1] Absolute identification of the mechanical parameters without laser sensor requires import of *Bl(x=0)* or M_{MS}

SPECTRA	
Measured spectra	*U*(*f*), *I*(f), *X*(*f*), *P*(*f*)
Modeled spectra	*X*(*f*), *P*(*f*)
Modeled distortion components	Total Distortion, Force Factor, Stiffness, External Resistance, Internal Mechanical Damping, Inductance (*x*), Inductance (*i*), Reluctance Force, Radiation Area $S_d(x)$, Port
STATES	
Modeling and Measurement Errors	E_{lin}, $E_{x,lin}$, E_{nonlin}, $E_{x,nonlin}$
Nonlinear Parameter Variation	Bl_{min}, C_{min}, L_{min}
Displacement	x_{peak}, x_{bottom}, x_{dc}, x_{prot}
Maximum estimated port velocity	$\|v_p\|_{max}$
Electrical signals	u_{peak}, i_{peak}, u_{rms}, i_{rms}, P_{real}, P_{Re}, P_{mech}, , P_{eddy}
Effective distortion components	D_{total}, D_{bl}, D_k, $D_{r,int}$, $D_{r,ext}$, D_{lx}, D_{li}, D_{reluct}, D_{sd}, D_{port}
NONLINEAR PARAMETERS (CURVES)	
Force factor (*Bl*-product)	$Bl(x)$
Suspension characteristics	$K_{ms}(x)$, $K_{mt}(x)$, $K_{mb}(x)$
Displacement varying Inductance	$L(f,x)$
Current varying Inductance	$L(i)$
Mechanical losses	$R_{ms}(v)$
Symmetry Ranges	$Bl(x)$, $K_{ms}(x)$, $K_{mt}(x)$
NONLINEAR PARAMETERS (SINGLE VALUES)	
Maximum Force factor	Bl_{max}
Displacement Limits (IEC 62458)	$x_{Bl}(Bl_{min})$, $x_C(C_{min})$, $x_L(Z_{max})$, $x_d(d_2)$
Minimal parameter ratios	Bl_{min}, C_{min}
Asymmetry metrics	x_{sym}, a_{bl}, a_{kms}, a_{rp} (only vented box)
THERMAL PARAMETERS	
Thermal resistance of heat transfer from voice coil to pole tips	R_{tv}
Instantaneous thermal resistance of heat transfer from voice coil to ambience by convection cooling	$R_{tc}(v)$
Instantaneous thermal resistance of heat transfer from voice coil to pole tips and ambience	$R_t(v)$
Thermal capacitance of voice coil	C_{tv}
Thermal time constants	τ_v, $\tau_h(v)$
EXPORT	
Graphics to Clipboard	
Parameters for Simulation	

5 References

5.1 Related Modules	[S3] SIM2 [S2] LPM – Linear Parameter Measurement [S52] LSI3 Large Signal Identification
5.2 Manuals	https://www.klippel.de/manuals/docs/transducer-parameter-identification/fastlsi/fastlsi.html

6 Patents

Germany	102007005070, 1020120202717, 102014005381.4, 19714199, 4111884.7, 4336608.2, 43340407, 4332804.0, 102013012811, 102013021599.4, 102013000684, 102009033614, 102009033614, P10214407

USA	8,078,433; 14/436,222; 14/683,351; 6,058,195; 5,438,625; 6005952; 5.577.126; 5815585; 5,528,695; 14/499,379; 577,604; 8,964,996; 14/152,556; 12/819,455; 12/819,455; 7,221,167
China	ZL200810092055.4; 201380054458.9; 201510172626.5; 981062849; 2014103769646; 2014107954970; 2014100795121; 201010228820.8; 201010228820.8; 03108708.6
Japan	5364271; 2972708
Europe	13786635.6; 0508392A2
Taiwan	102137485
India	844/MUMNP/2015
GB	2324888
Hong Kong	1020403
Korea	1020140095591

Find explanations for symbols at:

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

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Designs and specifications are subject to change without notice due to modifications or improvements.