Suspension Part Measurement C2

Software Module of the KLIPPEL ANALYZER SYSTEM

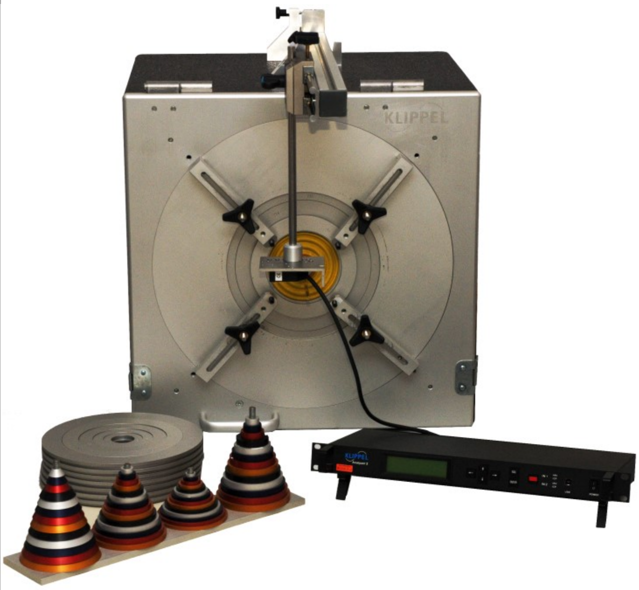
(Document Revision 2.2, dB-Lab 212)

FEATURES

- Linear and nonlinear stiffness $K_{ms}(x)$
- Spiders, surround, cones
- Passive radiators (drones)
- Size from 1 – 8 inch
- Non-destructive, dynamic method
- Fast, robust, simple handling

BENEFITS

- Specification of suspension parts
- Analysis of distortion root cause
- Defining mechanical limits
- Quality control in manufacturing
- Optimal driver design in R&D



DESCRIPTION

The SPM Pro (Suspension Part Measurement) software module and hardware accessory for the KLIPPEL R&D System is designed for the measurement of the large signal stiffness of suspension parts (spiders, surrounds, cones) and passive radiators (drones). A dynamic, nondestructive technique is used to measure the nonlinear stiffness $K(x)$ over the full working range.

Article number	2500-102 (incl. 2500-103) 2500-100

CONTENT

1 Overview

1.1 Principle

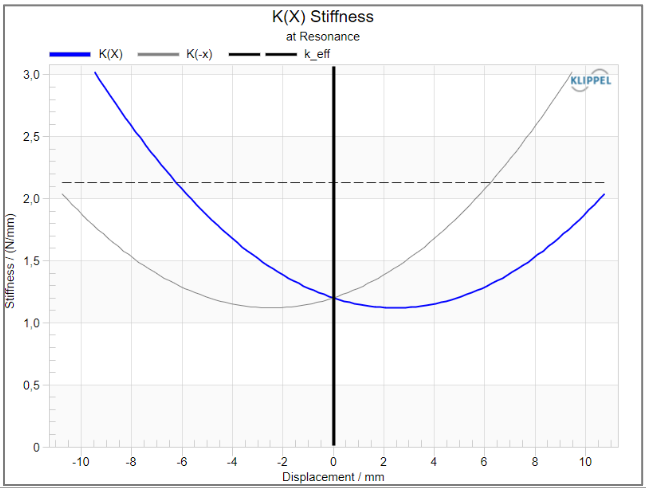
The nonlinear stiffness *K*(*x*) and its reciprocal, the compliance *C*(*x*) of suspension parts (spider, surrounds, cones) and passive radiators (drones) are measured versus displacement *x* over the full range of operation. A dynamic, nondestructive technique is applied to measures the parts under similar condition as operated in the loudspeaker. This guarantees highest precision of the results as well as simple handling and short measurement time. Suspension parts are fixed in the measurement bench by using a set of clamping parts (rings, cones, cups) that fit any size of circular geometries up to a diameter of 222 mm. The working bench excites the suspension pneumatically to vibrate at the resonance frequency related to the stiffness and the mass of the suspension and inner clamping parts. The nonlinear stiffness is calculated by the measured displacement (one-signal-method). It is required to specify the large signal properties of the suspension parts and to detect asymmetrical and symmetrical variations, which are the cause for instable vibration behavior and nonlinear distortion.

Additionally, the SPM Pro software includes the SPM Lite software, which provides linear mechanical parameters of suspension parts and passive radiators (resonance frequency, Q-factor, stiffness, moving mass, mechanical resistance), accurately from the small signal displacement and sound pressure response.

1.2 Results

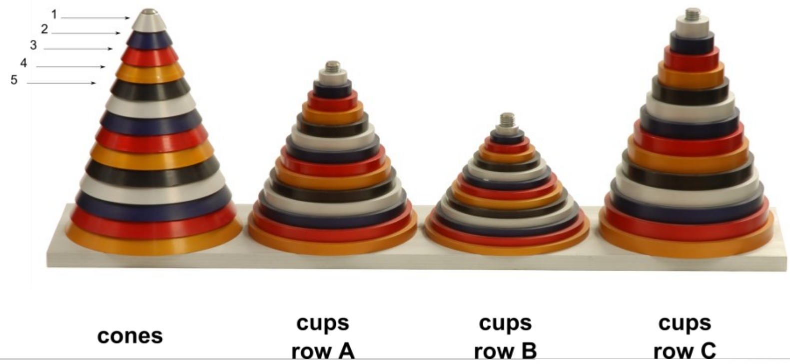
Nonlinear Stiffness Curve

The curve reflects the identified nonlinear stiffness *K*(*x*) depending on the displacement *x*. The inverse compliance *C*(*x*) is available as well.



2 Requirements

2.1 Hardware

SPM Pro Bench (Art. #:2500-101)	The test bench consists of the clamping platform mounted on a sealed enclosure with a volume of 95 liters and a linear, long throw 18" driver which excites the suspension pneumatically. The clamping platform holds the polished center rod for guiding the inner clamping parts (slide, cup, cone and nuts), the fixture for clamping the outer rim by using rings and the laser stand. The clamping platform can easily be folded up into a horizontal position for mounting but is typically used in a vertical position during measurement. The set contains the cable for connecting the measurement bench to KLIPPEL Analyzer hardware. 
Ring Set (Art. #: 2500-302)	Multiple sets of clamping rings allow to attach almost all suspension parts with a circular geometry between 2 and approx. 9 inches. After measuring the outer diameter and the width of the rim, the lower ring set and the upper clamping ring can be easily identified by using a table and nomenclature. The rings are made of 10 mm aluminum. Subsets of rings (to cover only selected sizes) or special forms (elliptic sizes) are available on request. 
Cup & Cone Set (metal) (Art. #: 2500-111)	The cones are used for clamping the inner rim of the suspension part nondestructively. Multiple cones are organized in a set with a simple nomenclature to cover from 14 mm to 111 mm diameters. Single cones are available on request. The counterpart of the cone is the cup which clamps the inner rim. The cups are manufactured in multiple sets to give the user full flexibility over all sizes of suspension parts. Cup Set row A, row B and row C are included in the set. Special cups can be manufactured based on customer's specification. 
Analyzer	The SPM supports the Distortion Analyzer 1 and 2 as well as the Klippel Analyzer 3 (LSX) for providing the stimulus signal and for measuring the sound pressure and displacement response.  

Laser	A displacement laser is required measures the displacement of suspension at the required precision. For large signal operation, the sensors have to have a large linear working range. Recommended types are: • ANR 1282 plus Controller ANR5132 (discontinued) • LK-H082 plus Controller LK-G5001P 
Amplifier	A power amplifier is required for performing the measurement. The amplifier should provide more than 200 W output power at 4 Ohm.
Microphone (opt.)	A ¼ inch microphone is required for the linear suspension parameter measurement (SPM Lite) in order to measure the sound pressure in the test bench.
Computer	A personal computer is required for performing the measurement. Please refer to general PC requirements.

2.2 Software

dB-Lab	From version 210, the SPM is fully integrated as a measurement module in dB-Lab software.
TRF Module	The SPM requires Transfer Function Measurement (TRF) module for performing the actual measurement with the KLIPPEL Analyzer devices.

3 Example

3.1 Measurement Objects

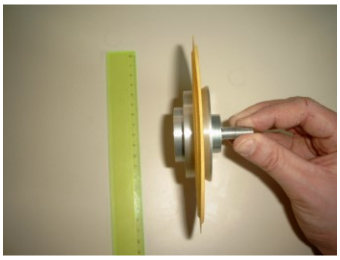
Suspension parts (spiders, suspensions, cone with suspensions) and passive radiators of circular geometries with a diameter of up to 222 mm can be measured by using the small clamping set (rings, cups, cones). For particular objects of larger size or with more complicated shapes, unusual sizes or extremely small rims special clamping parts can be manufactured on customer's request. KLIPPEL may provide service based on detailed drawings.

Although the suspension is pneumatically excited, the technique used can cope with significant air porosity of the suspension.

3.2 Measurement Procedure

Center Clamping

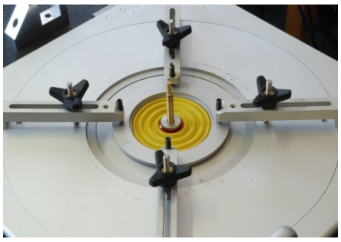
The measurement usually takes 5-10 minutes by performing the following steps:



Measure the inner and outer diameter.

Look at the tables to find the optimal clamping parts using the nomenclature.

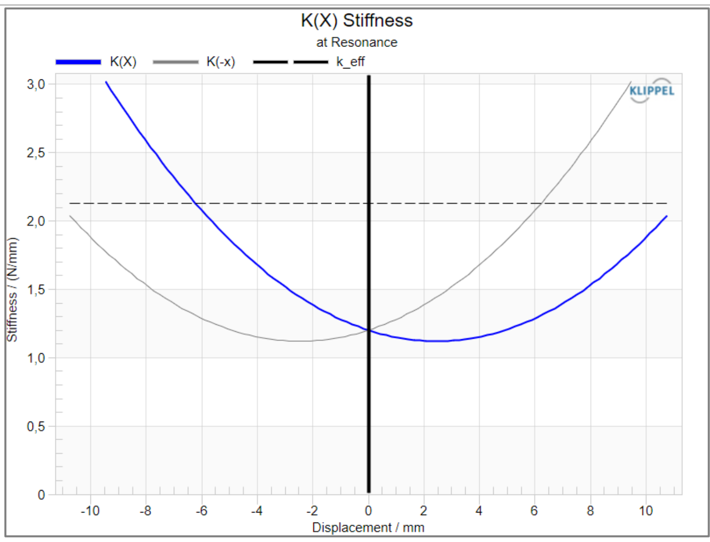
Clamp the inner rim by using the slide, cone, cup and two nuts.

Outer Clamping		Bring the clamping platform into horizontal position for easy handling. Insert the set of lower rings into the clamping platform. Put the slide with the clamped suspension on the guiding rod. Fix the upper ring to clamp the outer rim. Bring the clamping platform into vertical position.
Measurement		Fold down the laser rack and adjust the laser head. Start the measurement which takes a few seconds. Print your report by using your customized template

4 Output

4.1 Result Curves

***Stiffness K(x)* over Displacement**



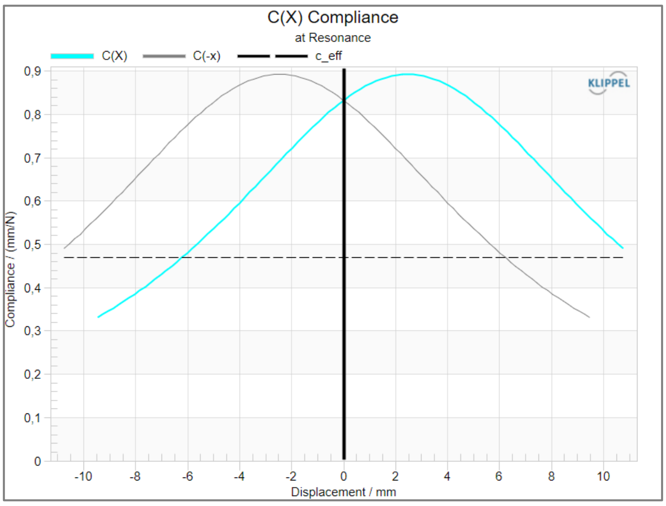
The window shows the identified nonlinear stiffness *K*(*x*) of the DUT. The curve is based on a (regular) power series following the form

$$K(x) = k_0 + k_1 x + k_2 x^2 + k_3 x^3 + \cdots$$

Depending on the number of harmonics used for the calculation a 2nd order power series (parabola) is calculated using three harmonics and a 4th order power series is calculated using five.

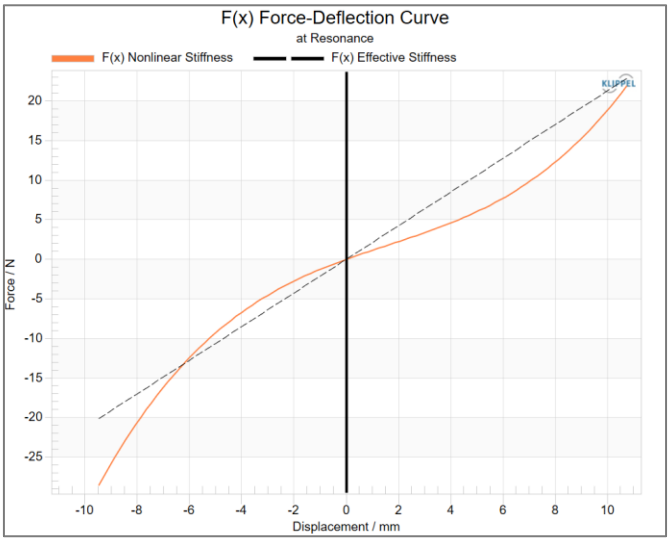
- *K*(*x*) shows the nonlinear stiffness
- *K*(-*x*) shows the nonlinear stiffness mirrored at the rest position $x = 0$
- k_{eff} shows the effective stiffness at the frequency of the displacement maximum

Compliance C(x) over Displacement



This plot shows the compliance $C(x)$. It is the inverse of stiffness $K(x)$.

F(x) Force-Deflection



This result shows the stiffness force depending on the displacement produced by the DUT.

- *F(x) Nonlinear Stiffness* shows the force deflection curve of the force produced by the nonlinear stiffness
- *F(x) Effective Stiffness* shows the effective force deflection curve if the stiffness would be linear and equal to the effective stiffness ($F_{k,eff} = k_{eff}\ x$)

4.2 Result Parameters

k_{eff}	Effective stiffness at resonance frequency
c_{eff}	Effective compliance at resonance frequency
$k_{0...4}$	Stiffness coefficients of power series
W_s	Mechanical work

5 Limitations

5.1 Device Under Test

Parameter	Min	Max	Unit
Dimension			
Outer Diameter	30	222 (490*)	mm
Inner Diameter	13.9	110.7	mm
Resonance Frequency of DUT with Clamping Parts	5	48	Hz

**with custom clamping platform, may not be applicable for SPM Pro*

6 SPM Pro Bench Specification

6.1 Specification for revision 1.4 and below

Physical Dimensions (LxWxH)			
Dimensions of bench only in mm	470x570x570		
Maximum dimensions of bench with attachments in mm	790x720x690		
Maximum/Minimum Ratings	**Min**	**Max**	**Unit**
Driver nominal impedance	4		Ω
Excursion (peak-to-peak)		75	mm
Input voltage in V (RMS, sinusoidal, long term)		60	V
Input voltage in V (RMS, sinusoidal, short term)		120	V
Input voltage in V (RMS, multi-tone stimulus)		35	V

Driver used: AuraSound NS18-992-4A
Possible replacement driver: FaitalPro 18XL1800 (04604223)

6.2 Specification for revision 1.5

Physical Dimensions (LxWxH)			
Dimensions of bench only in mm	500x570x570		
Maximum dimensions of bench with attachments in mm	940x720x790		
Maximum/Minimum Ratings	**Min**	**Max**	**Unit**
Driver nominal impedance	4		Ω
Excursion (peak-to-peak)		75	mm
Input voltage in V (RMS, sinusoidal, long term)		60	V
Input voltage in V (RMS, sinusoidal, short term)		120	V
Input voltage in V (RMS, multi-tone stimulus)		35	V

Driver used: AuraSound NS18-992-4A
Possible replacement driver: FaitalPro 18XL1800 (04604223)

6.3 Specification for 1.6 and above

Physical Dimensions (LxWxH)			
Dimensions of bench only in mm	500x570x570		
Maximum dimensions of bench with attachments in mm	940x720x790		
Maximum/Minimum Ratings	**Min**	**Max**	**Unit**
Driver nominal impedance	4		Ω
Excursion (peak-to-peak)		75	mm
Input voltage in V (RMS, sinusoidal, long term)		60	V
Input voltage in V (RMS, sinusoidal, short term)		120	V
Input voltage in V (RMS, multi-tone stimulus)		35	V
Driver used: FaitalPro 18XL1800 (04604223)			

7 References

7.1 Related Modules	SPM Lite, MSPM Pro/Lite, LST
7.2 Manuals	SPM Manual
7.3 Publications	W. Klippel, "Dynamical Measurement of Loudspeaker Suspension Parts", Convention Paper, 117th AES Convention, October 2004, San Francisco

8 Look up Tables for Small Clamping Set

Color	Number of the cone	Cone diameter D_C (mm)	Name of the cup	Cup diameter D_U (mm)
silver	1	11	A1	13,9
			B1	16,8
			C1	19,7
blue	2	18	A2	20,9
			B2	23,8
			C2	26,7
red	3	25	A3	27,9
			B3	30,8
			C3	33,7
gold	4	32	A4	34,9
			B4	37,8
			C4	40,7
black	5	39	A5	41,9
			B5	44,8
			C5	47,7
silver	6	46	A6	48,9
			B6	51,8
			C6	54,7
blue	7	53	A7	55,9
			B7	58,8
			C7	61,7
red	8	60	A8	62,9
			B8	65,8
			C8	68,7
gold	9	67	A9	69,9
			B9	72,8
			C9	75,7
black	10	74	A10	76,9
			B10	79,8
			C10	82,7
silver	11	81	A11	83,9
			B11	86,8
			C11	89,7
blue	12	88	A12	90,9
			B12	93,8
			C12	96,7
red	13	95	A13	97,9
			B13	100,8
			C13	103,7
gold	14	102	A14	104,9
			B14	107,8
			C14	110,7

Name of the ring	D_R (mm)
A1	30
B1	33
C1	36
D1	39
E1	42
F1	45
G1	48
H1	51
A2	54
B2	57
C2	61
D2	65
E2	69
F2	73
G2	77
H2	81
A3	85
B3	89
C3	93
D3	98
E3	103
F3	108
G3	113
H3	118
A4	124
B4	130
C4	136
D4	142
E4	148
F4	154
G4	160
H4	166
A5	173
B5	180
C5	187
D5	194
E5	201
F5	208
G5	215
H5	222

Find explanations for symbols at:
http://www.klippel.de/know-how/literature.html
Last updated: May 16, 2022
Designs and specifications are subject to change without notice due to modifications or improvements.

KLIPPEL MODULE OVERVIEW FOR MOVING PARTS MEASUREMENT

KLIPPEL

	SPM Lite	SPM Pro	MSPM Lite	MSPM Pro	QC LST Lite	QC LST Pro
R&D System	✓		✓		✓[5]	
QC System	-		-		*QC Basic* or *Standard*	
Base Module	TRF		TRF	LPM	-	
Analyzer Hardware	Distortion Analyzer 2 Klippel Analyzer 3 [5]		Distortion Analyzer 2 Klippel Analyzer 3 [5]		Klippel Analyzer 3 [5] QC Production Analyzer	
Test Bench	SPM or LST	SPM	MSPM[6]		LST, MSPM[6] or SPM[7]	
Laser Sensor (Default) (Measurement Range)	IL-030 (+/- 12.5 mm)	LK-H082 (+/- 18 mm)	LK-H052 (+/- 10 mm)		IL-065 (LK-H052[8]) (+/- 10 mm)	
Laser Sensors (Alternative) (Measurement Range)	LK-H022 LK-H052 LK-H082 LK-H152 LK-G32	LK-H052 (+/- 10 mm) LK-H152 (+/- 40 mm)	LK-H022 (+/- 3 mm) LK-H082 (+/- 18 mm) LK-G32 (+/- 5 mm)		LK-H022 LK-H052 LK-H082 LK-H152 LK-G32	
Microphone	✓	-	✓		Opt.	✓
Linear Parameters f_0, Q, k, c, m, r	✓	- (only k_{eff})	✓ (only effective)		✓ (*m* import, no *r*)	✓ (*m* & *k* relative, no *r*)
Nonlinear Parameters $K(x)$, $C(x)$	-	✓	-	✓	-	
Mass Import	✓	-	✓		✓	
Added Mass	✓	-	✓	-	-	
DUT Ø in mm	30 – 222[1] (490[2])	30 – 222[1]	< 70		30 – 222[1] (490[2]) <70[8]	
Frequency Range in Hz	1 – 100[4] (200[3])	1 – 100	100 - 2500		1 – 100[4] (200[3]) 100 – 2500[8]	

1) *Standard Ring Set*
2) *SPM Bench (with custom ring)*
3) *LST Bench*
4) *SPM Bench*
5) *Min. dB-Lab Release 210*
6) *MSPM Bench requires additional equipment for laser positioning (SCN Vibrometer, LST-Bench or Pro-Stand)*
7) *For DUTs with Ø >= 222 mm / <= 490 mm, customized clamping rings required*
8) *MSPM Bench*