

KLIPPEL ANALYZER SYSTEM

Linear Parameter Measurement (LPM)

*for*

DIYmobileaudio.com

Performed by

Erin Hardison

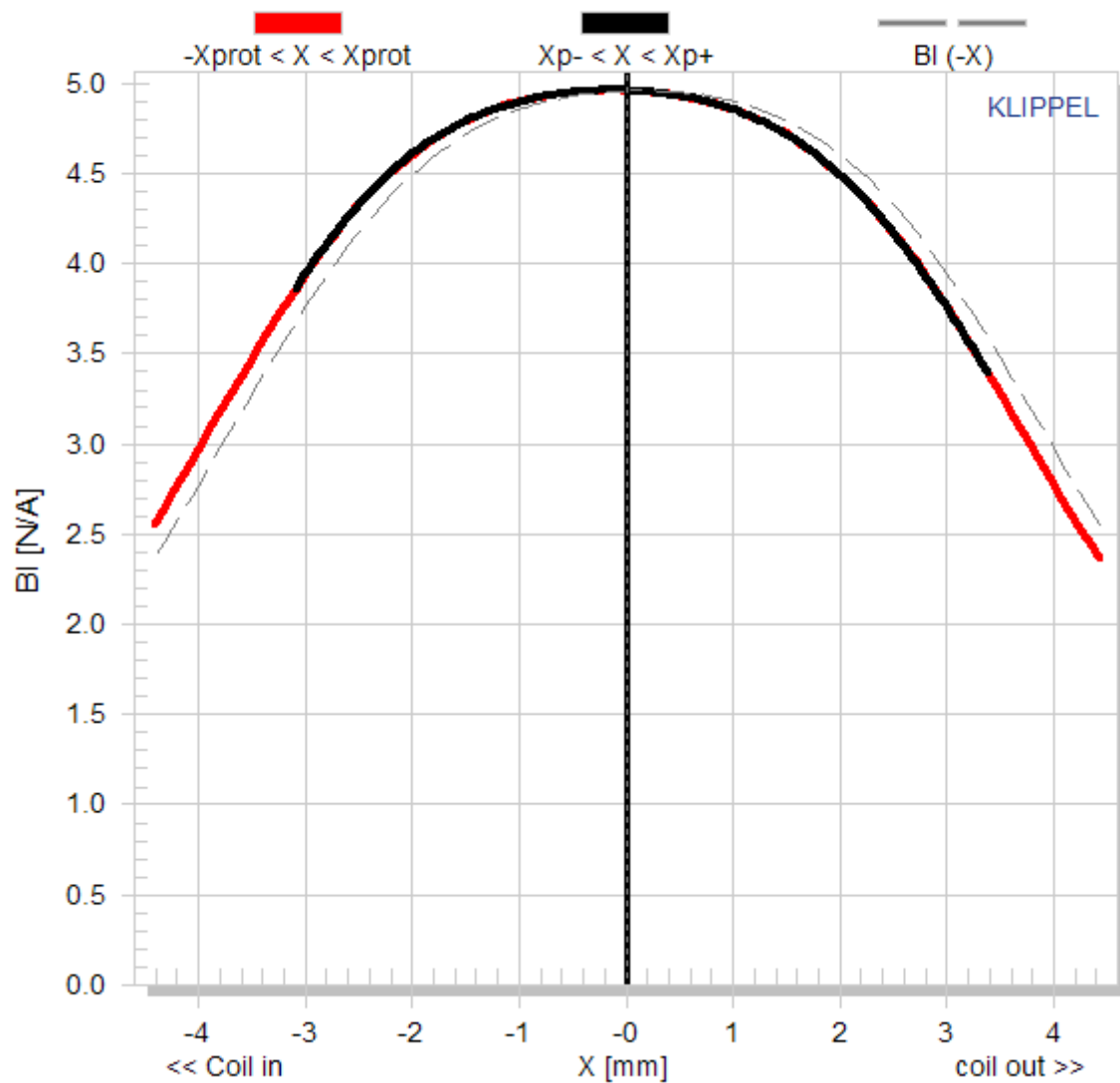
Driver Name: Audible Physics Soul X4

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## Nonlinear Parameters

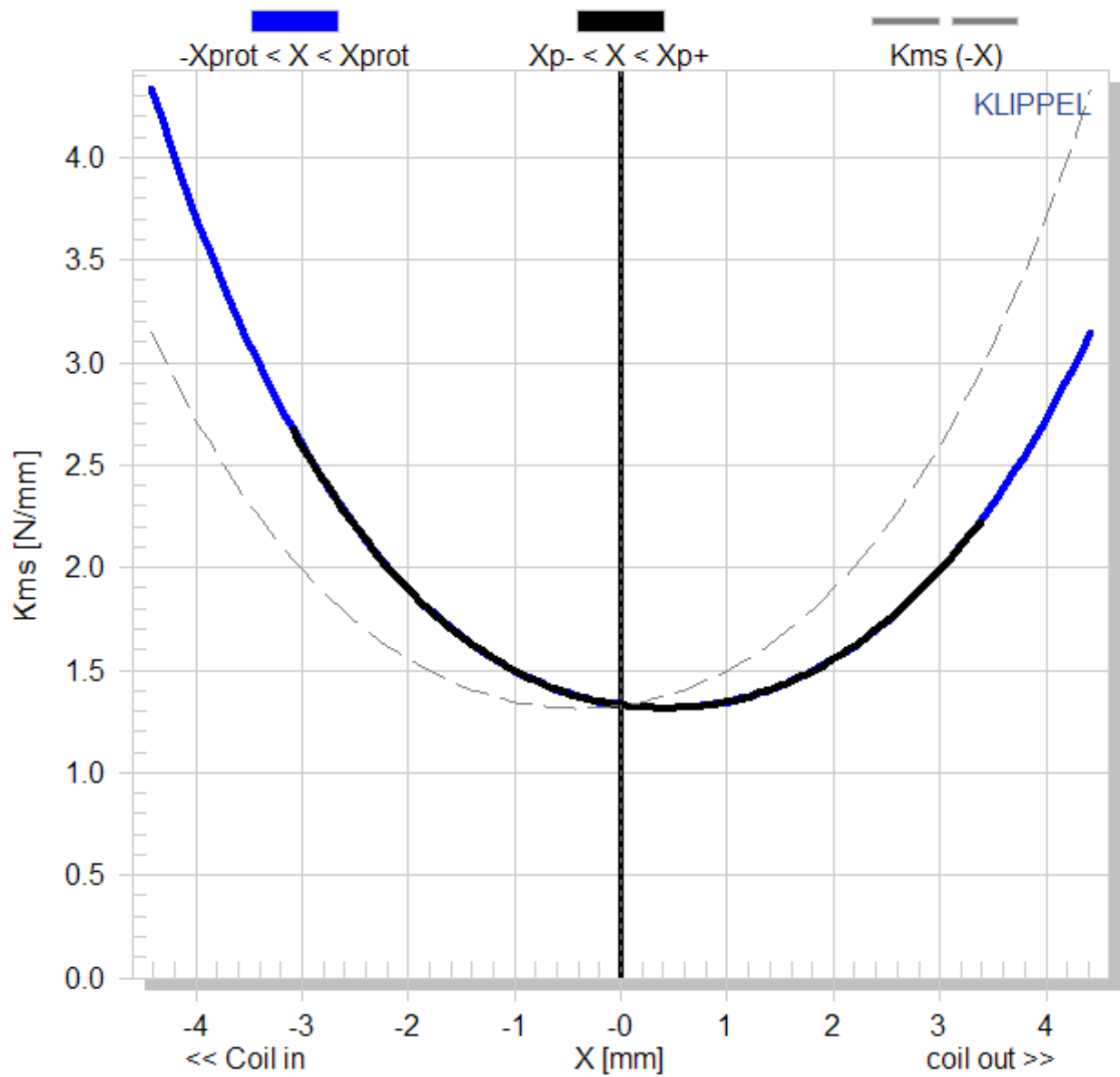
# Force factor BI (X)

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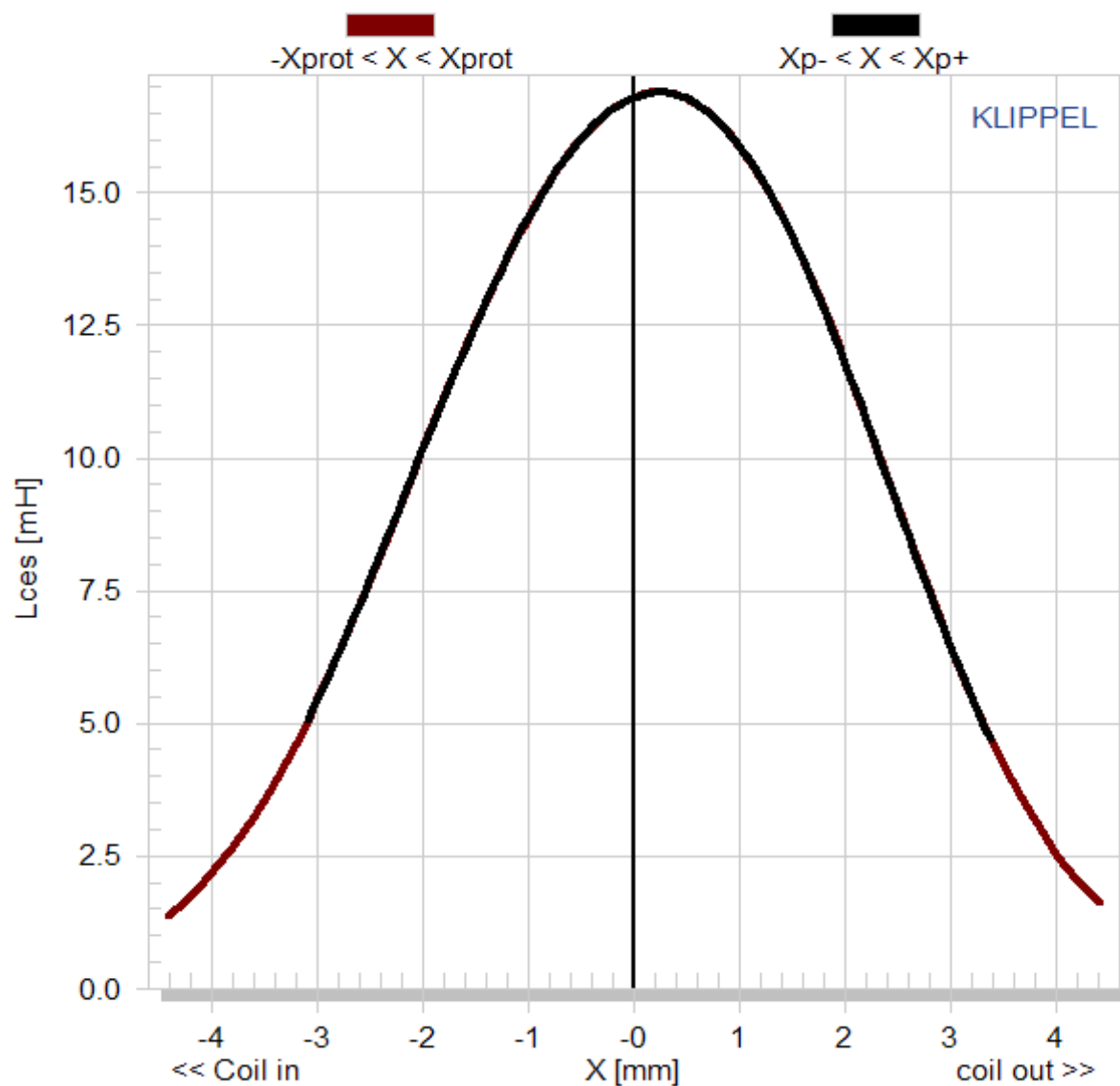


# Stiffness of suspension $K_{ms}(X)$

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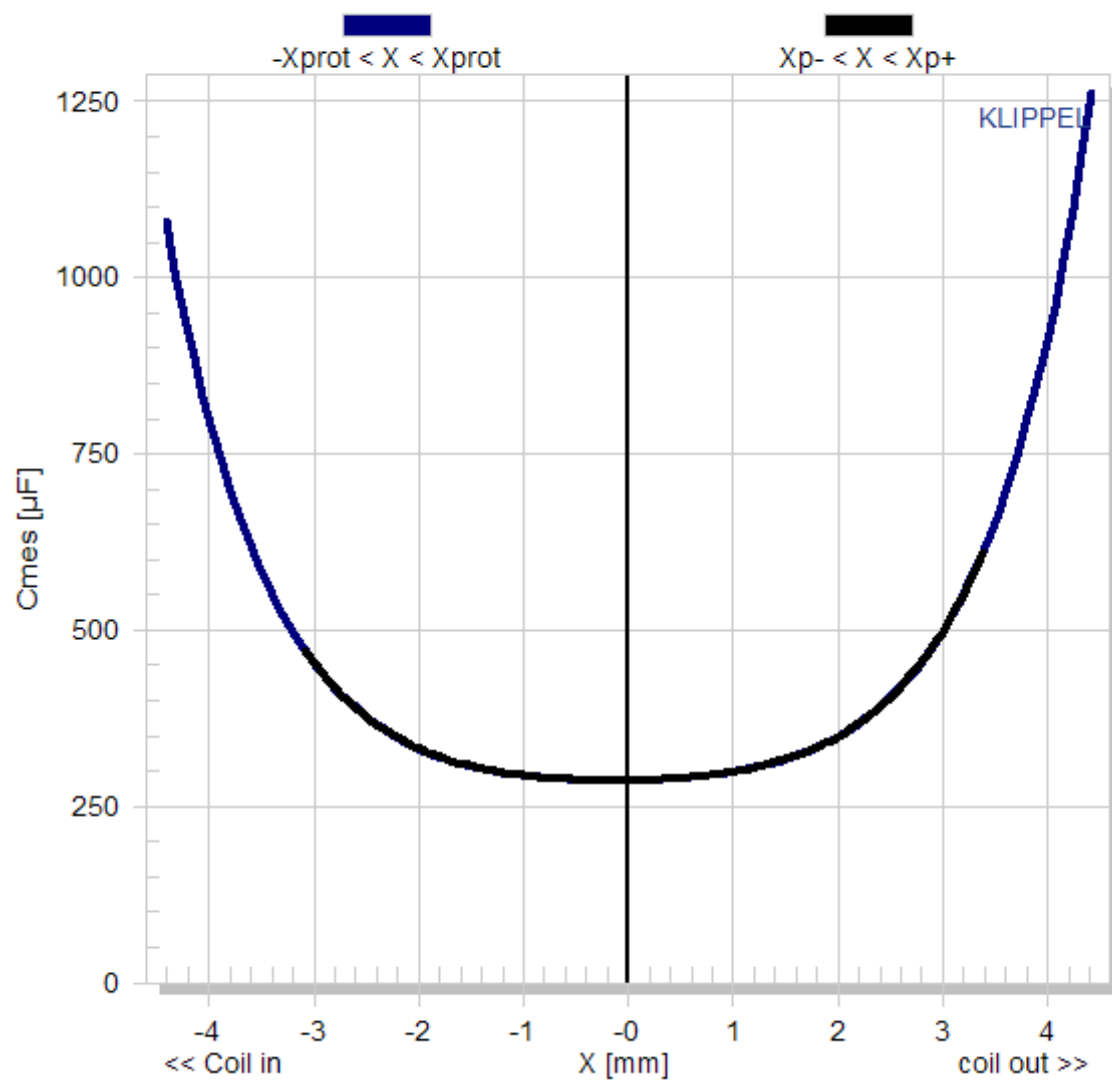


Inductance  $L_{ces}(X)$  corresponds to suspension compliance  
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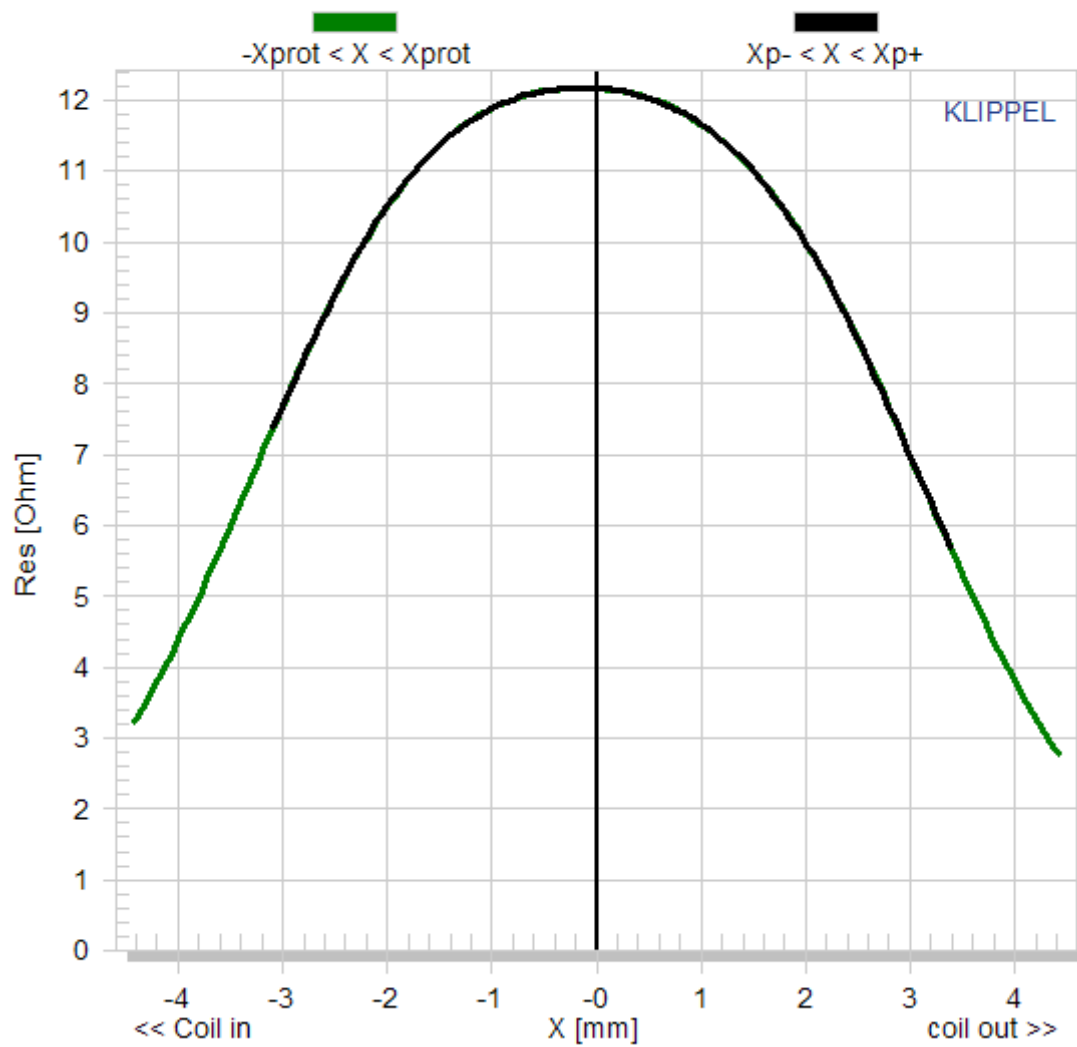


# Capacitance $C_{mes}(X)$ corresponds to driver mass

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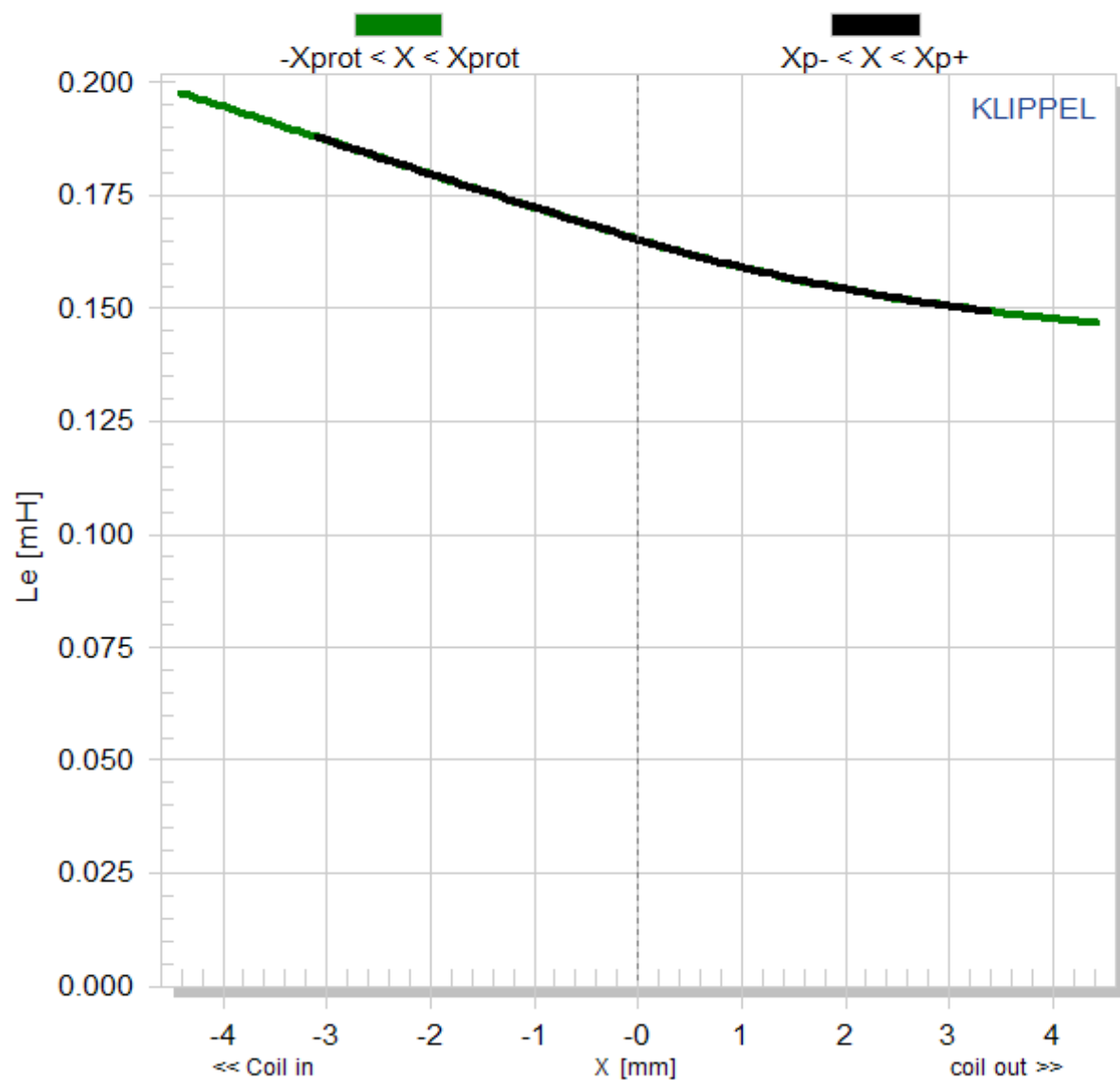


# Resistance Res (X) corresponds to suspension resistance (00:15:27)

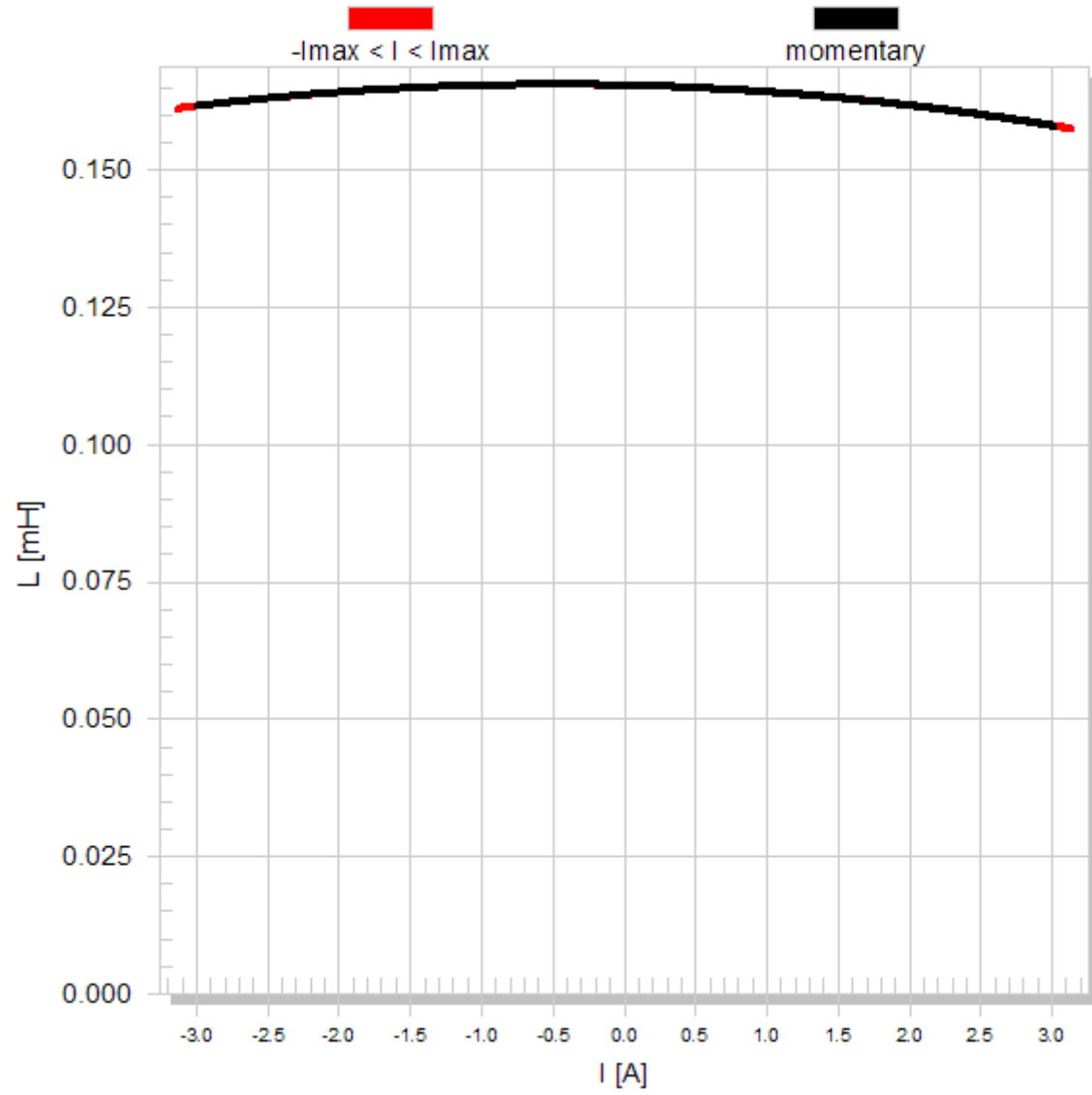


# Electrical inductance $L(X, I=0)$

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# Inductance over current $L(X=0, I)$



# Power Series Expansion

Symbol	Number	Unit	Comment
Displacement Limits			thresholds can be changed in Processing property page
X Bl @ Bl min=82%	2.6	mm	Displacement limit due to force factor variation
X C @ C min=75%	1.7	mm	Displacement limit due to compliance variation
X L @ Z max=10 %	>3.1	mm	Displacement limit due to inductance variation
X d @ d2=10%	12.5	mm	Displacement limit due to IM distortion (Doppler)
alpha			Heating of voice coil by eddy currents
alphaOrg			Heating of voice coil by eddy currents (without limits)
Rtv		K/W	thermal resistance coil ==> pole tips
rv		Ws/Km	air convection cooling depending on velocity
Rtm		K/W	thermal resistance magnet ==> environment
tau m		min	thermal time constant of magnet
Ctm		Ws/K	thermal capacity of the magnet
tau v		s	thermal time constant of voice coil
Ctv		Ws/K	thermal capacity of the voice coil
delta Tw		K	Temperature increase in Warm Resistance Mode
delta Tc		K	Temperature increase in Convection Mode
delta Te		K	Temperature increase in Eddy Mode
Pcoil(warm)		W	Pcoil in warm mode
Pcoil(conv)		W	Pcoil in convection mode
Ptv(mag.beg)		W	power heating the coil at beginning of magnet mode
Ptv(mag.mid)		W	power heating the coil sampled in the middle of magnet mode
Ptv(mag.end)		W	power heating the coil at end of magnet mode
Ptm(mag.beg)		W	power heating the magnet at beginning of magnet mode
Ptm(mag.mid)		W	power heating the magnet sampled in the

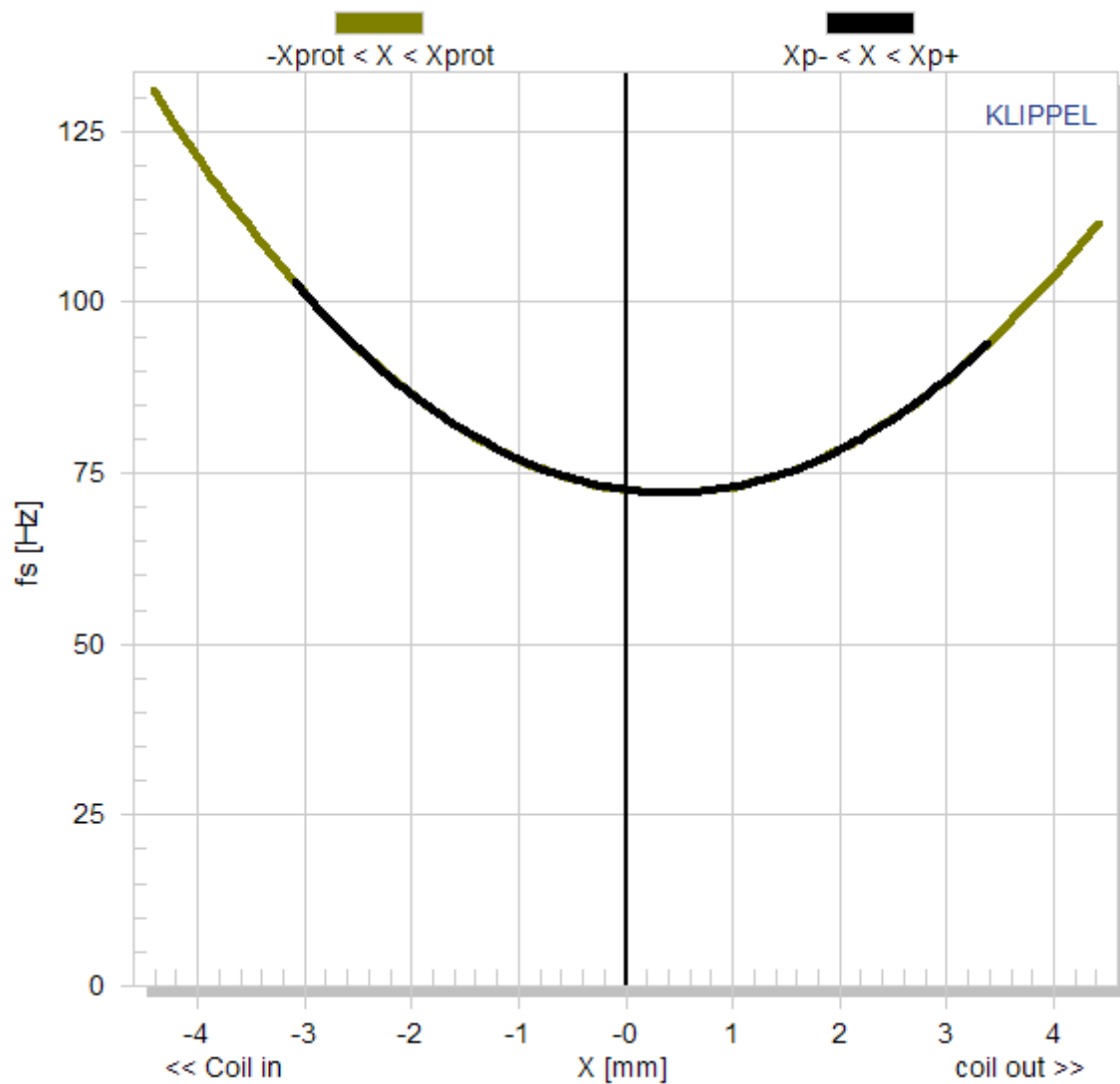
			middle of magnet mode
Ptm(mag.end)		W	power heating the magnet at end of magnet mode
f1	-0.003602	1/A	coefficient (1) of Inductance over current (flux modulation)
f2	-0.003722	1/A^2	coefficient (2) of Inductance over current (flux modulation)
Bl0 = Bl (X=0)	4.9983	N/A	constant part in force factor
Bl1	-0.023117	N/Amm	1st order coefficient in force factor expansion
Bl2	-0.11785	N/Amm^2	2nd order coefficient in force factor expansion
Bl3	-0.00066518	N/Amm^3	3rd order coefficient in force factor expansion
Bl4	-0.00090880	N/Amm^4	4th order coefficient in force factor expansion
Bl5		N/Amm^5	5th order coefficient in force factor expansion
Bl6		N/Amm^6	6th order coefficient in force factor expansion
Bl7		N/Amm^7	7th order coefficient in force factor expansion
Bl8		N/Amm^8	8th order coefficient in force factor expansion
L0 = Le (X=0)	0.16537	mH	constant part in inductance
L1	-0.0065448	mH/mm	1st order coefficient in inductance expansion
L2	0.00041394	mH/mm^2	2nd order coefficient in inductance expansion
L3	4.2797e-005	mH/mm^3	3rd order coefficient in inductance expansion
L4	-2.6017e-006	mH/mm^4	4th order coefficient in inductance expansion
L5		mH/mm^5	5th order coefficient in inductance expansion
L6		mH/mm^6	6th order coefficient in inductance expansion
L7		mH/mm^7	7th order coefficient in inductance expansion
L8		mH/mm^8	8th order coefficient in inductance expansion

C0 = Cms (X=0)	0.74555	mm/N	constant part in compliance
C1	0.032574	1/N	1st order coefficient in compliance expansion
C2	-0.041814	1/Nmm	2nd order coefficient in compliance expansion
C3	-0.0012447	1/Nmm <sup>2</sup>	3rd order coefficient in compliance expansion
C4	0.00091989	1/Nmm <sup>3</sup>	4th order coefficient in compliance expansion
C5		1/Nmm <sup>4</sup>	5th order coefficient in compliance expansion
C6		1/Nmm <sup>5</sup>	6th order coefficient in compliance expansion
C7		1/Nmm <sup>6</sup>	7th order coefficient in compliance expansion
C8		1/Nmm <sup>7</sup>	8th order coefficient in compliance expansion
K0 = Kms (X=0)		N/mm	constant part in stiffness
K1	-0.072864	N/mm <sup>2</sup>	1st order coefficient in stiffness expansion
K2	0.092614	N/mm <sup>3</sup>	2nd order coefficient in stiffness expansion
K3	-0.0031425	N/mm <sup>4</sup>	3rd order coefficient in stiffness expansion
K4	0.0015859	N/mm <sup>5</sup>	4th order coefficient in stiffness expansion
Xpse	4.4	mm	-Xpse < X < Xpse, range where power series is fitted

## Derived Loudspeaker Parameters

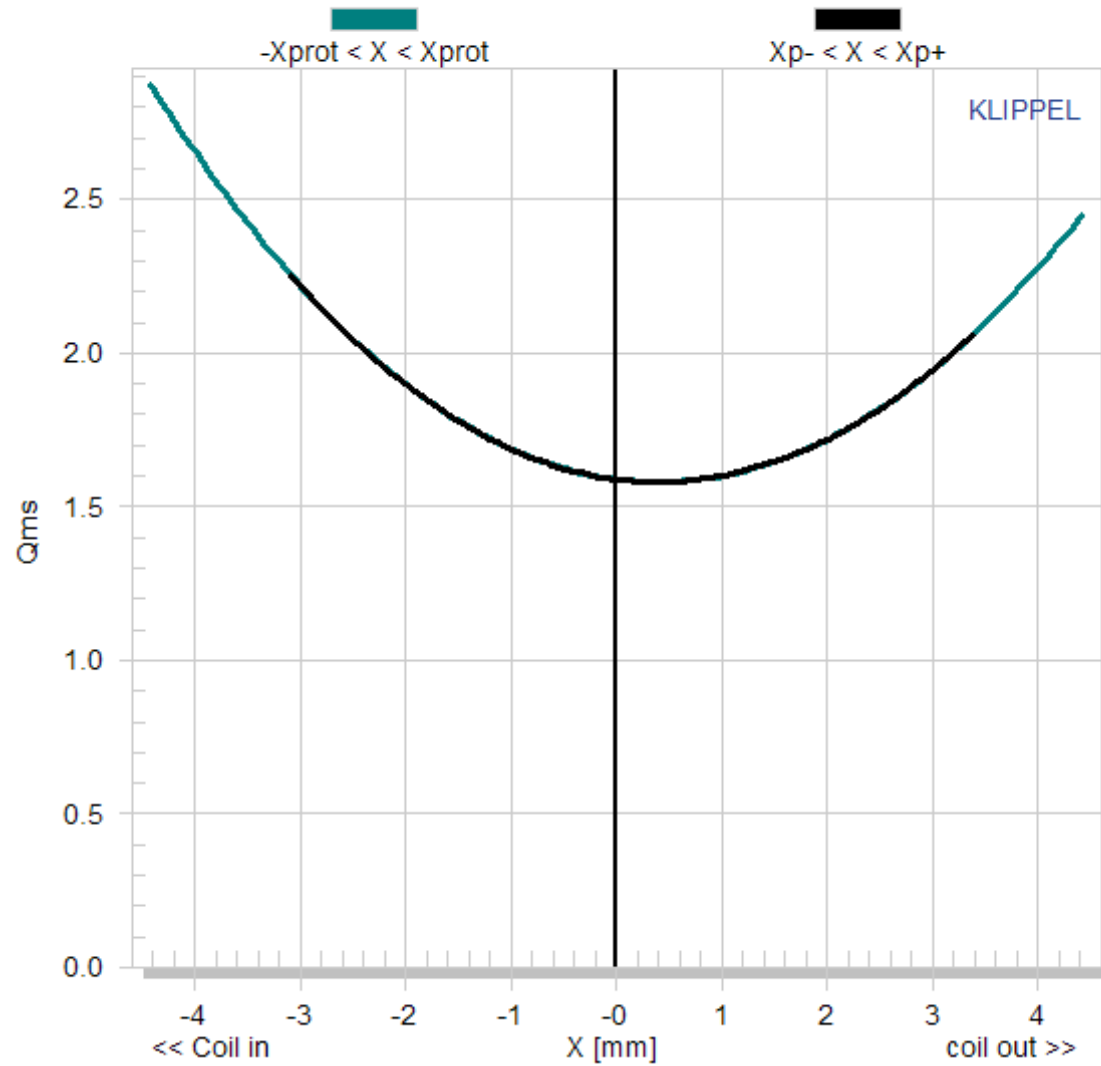
# Resonance frequency $f_s(X)$

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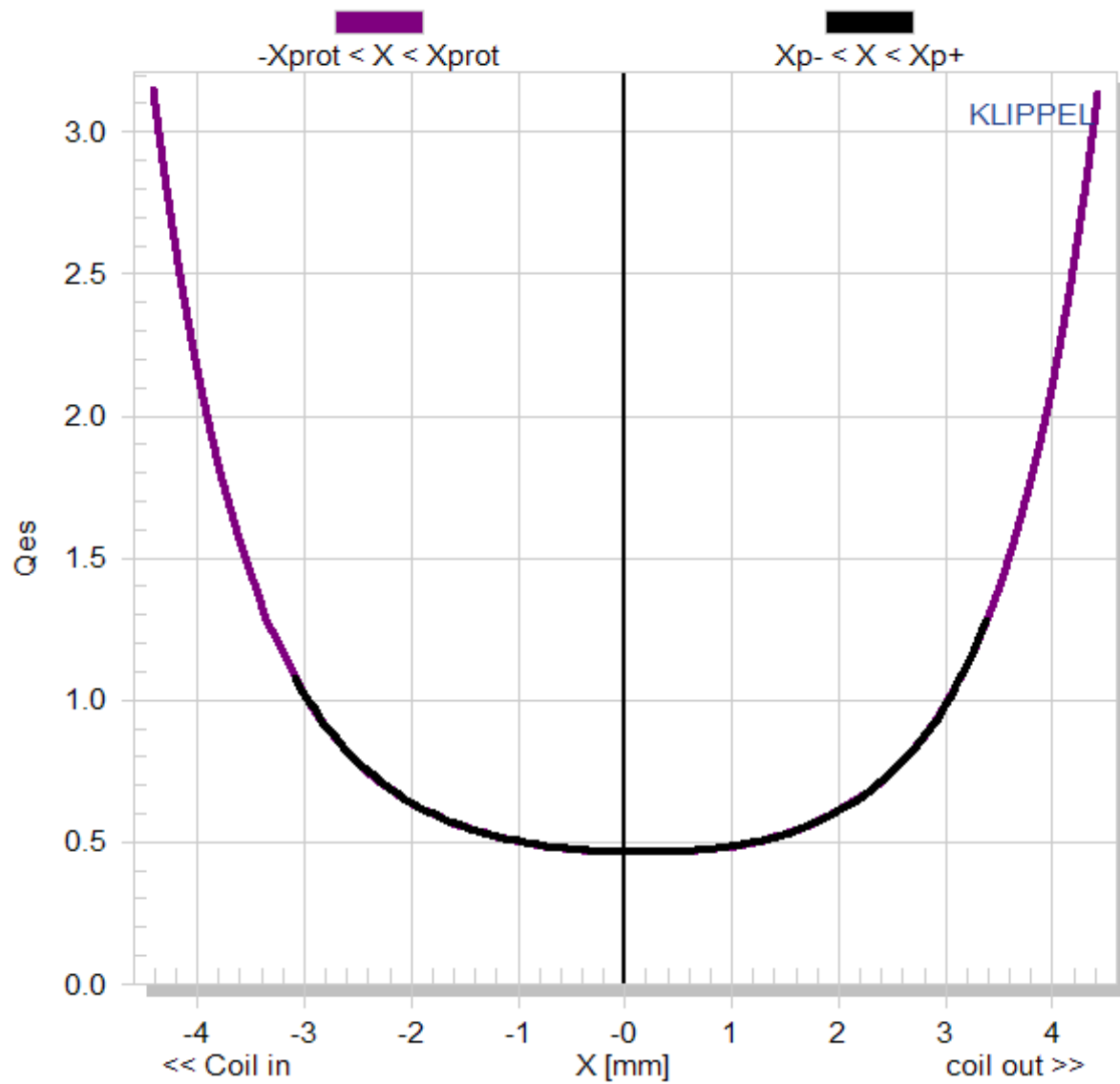
# Mechanical loss factor $Q_{ms}(X)$

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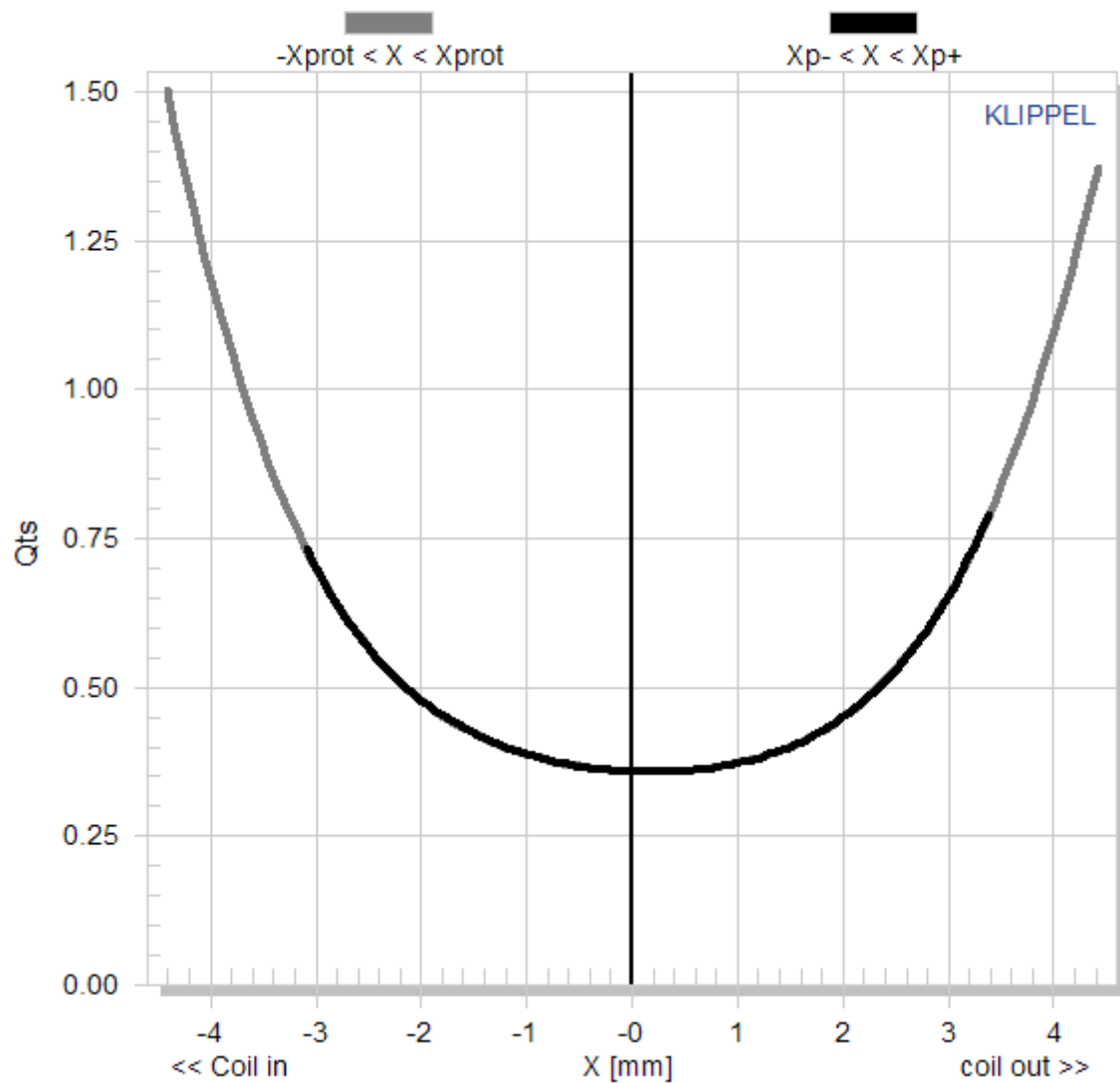
# Electrical loss factor Qes (X)

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# Total loss factor $Q_{ts}(X)$

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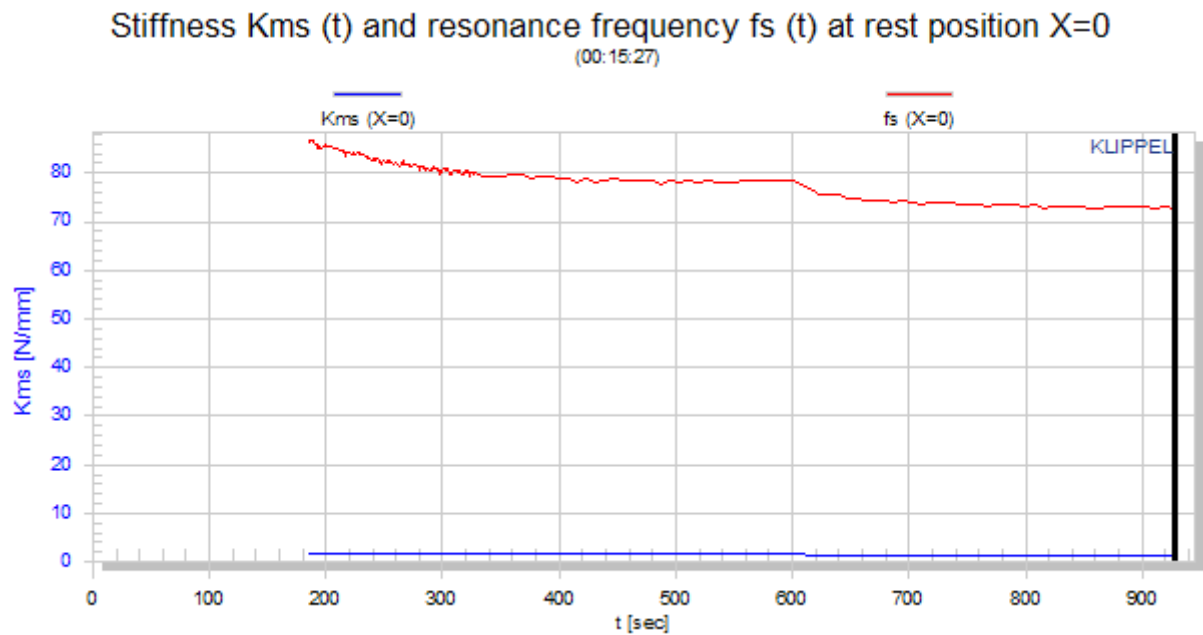


# Linear Parameters

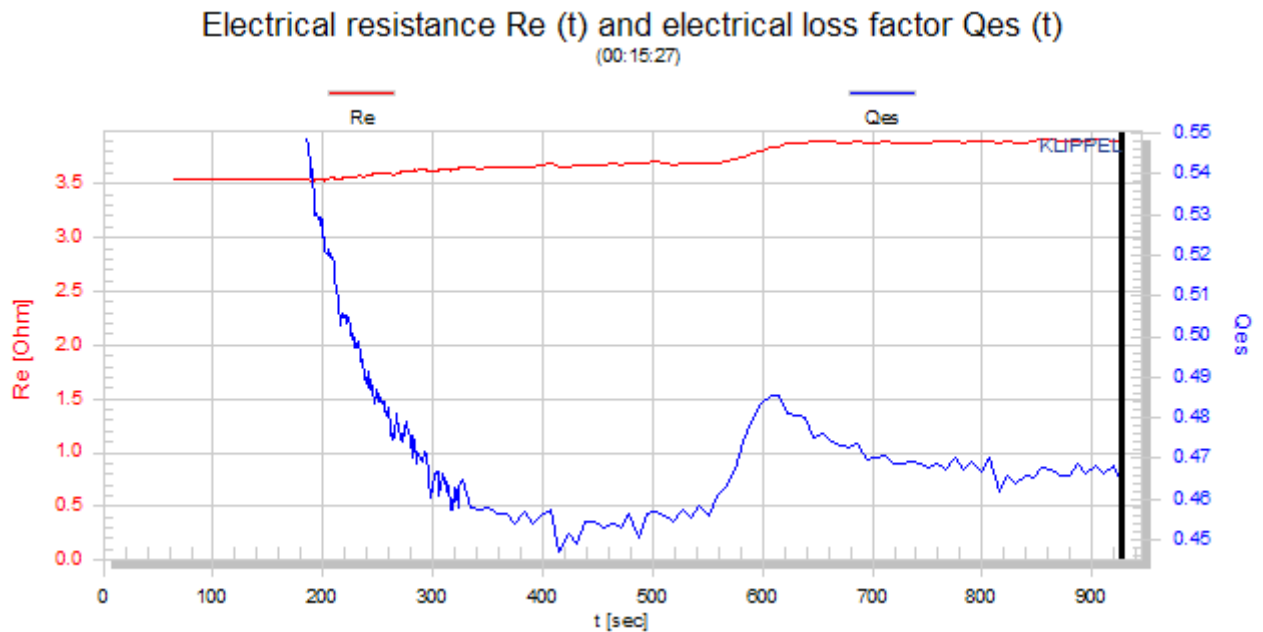
Symbol	Large + Warm	Large + Cold	Small Signal	Unit	Comment
Note:					for accurate small signal parameters, use LPM module
Delta $T_v = T_v - T_a$	26	0	0	K	increase of voice coil temperature during the measurement
Xprot	4.4	4.4	1.0	mm	maximal voice coil excursion (limited by protection system)
Re ( $T_v$ )	3.90	3.55	3.55	Ohm	(imported) voice coil resistance considering increase of voice coil temperature $T_v$
Le ( $X=0$ )	0.17	0.17	0.14	mH	voice coil inductance at the rest position of the voice coil
L2 ( $X=0$ )	0.25	0.25	0.25	mH	para-inductance at the rest position due to the effect of eddy current
R2 ( $X=0$ )	0.75	0.75	0.62	Ohm	resistance at the rest position due to eddy currents
Cmes ( $X=0$ )	287	287	284	$\mu F$	electrical capacitance representing moving mass
Lces ( $X=0$ )	16.81	16.81	11.96	mH	electrical inductance at the rest position representing driver compliance
Res ( $X=0$ )	12.17	12.17	8.73	Ohm	resistance at the rest position due to mechanical losses
Qms ( $X=0$ , $T_v$ )	1.59	1.59	1.35		mechanical Q-factor considering Rms only
Qes ( $T_v$ )	0.46	0.42	0.50		electrical Q-factor considering Re ( $T_v$ ) only
Qts ( $X=0$ , $T_v$ )	0.36	0.33	0.36		total Q-factor considering Re ( $T_v$ ) and Rms only
fs	72.5	72.5	86.3	Hz	driver resonance frequency
Mms	6.400	6.400	6.400	g	(imported) mechanical mass of driver diaphragm assembly including voice-coil and air load
Rms ( $X=0$ )	1.834	1.834	2.578	kg/s	mechanical resistance of total-driver losses
Cms ( $X=0$ )	0.75	0.75	0.53	mm/N	mechanical compliance of driver suspension at the rest position

Bl (X=0)	4.96	4.96	4.96	N/A	(imported) force factor at the rest position (Bl product)
Vas	3.2604	3.2604	2.3015	l	equivalent air volume of suspension
N0	0.257	0.283	0.283	%	reference efficiency (2Pi-sr radiation using Re)
Lm	86.3	86.7	86.7	dB	characteristic sound pressure level
Sd	55.42	55.42	55.42	cm <sup>2</sup>	diaphragm area

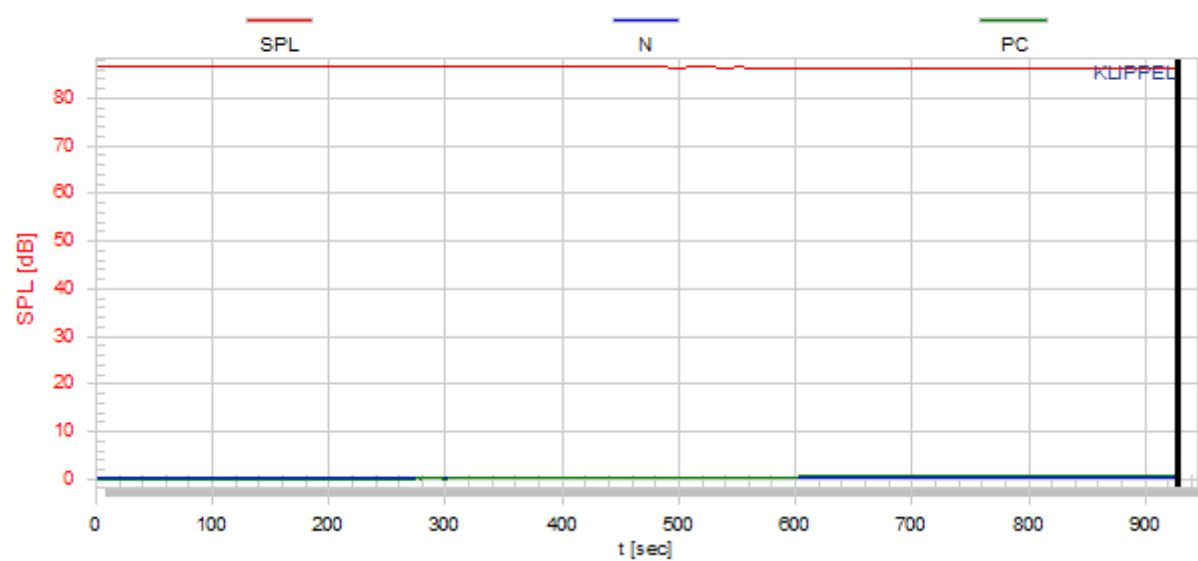
### Temporal Variations of the Stiffness $K_{MS}(t, x=0)$



### Temporal Variations of the Voice Coil Resistance $R_E(t)$



Sound pressure level SPL (t), efficiency N (t) and thermal power compression PC (t)  
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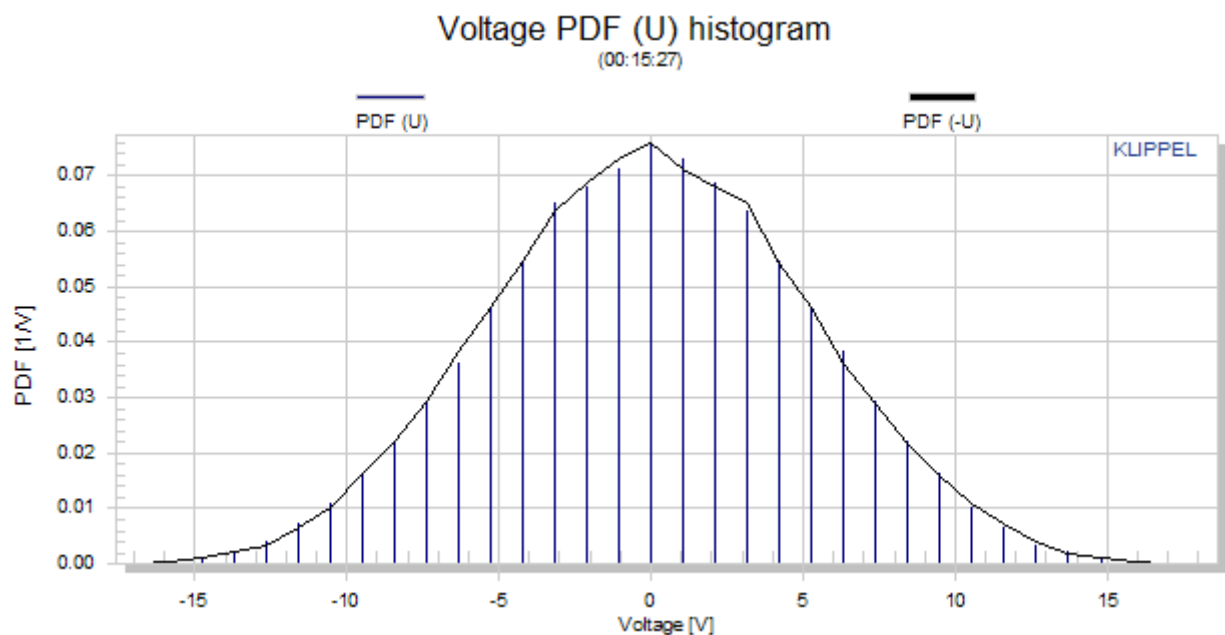


# Transducer State

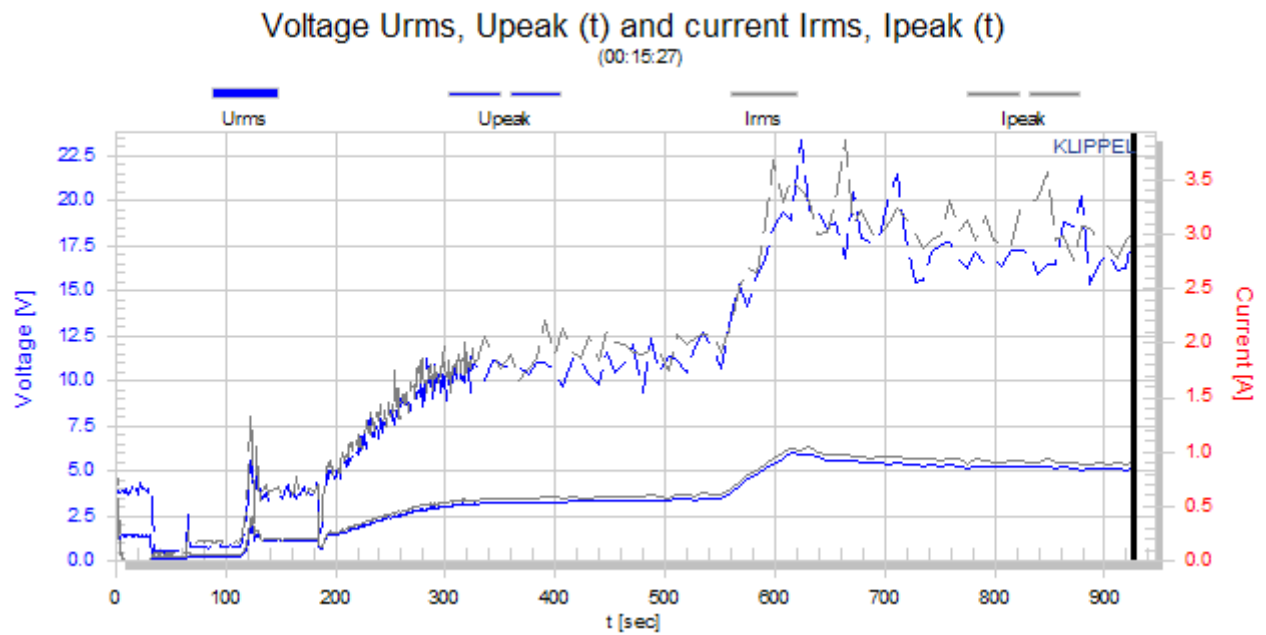
Symbol	Value	Unit	Comment
Date	2011-11-18		
Time	17:26:16		
Serial number	302		
Mode	Nonlinear Mode 5(7)		
Record	363/363		
Laser	signal reliable		
t	00:15:27	h:min:s	measurement time
Time remaining	00:04:33	h:min:s	recalculated at thermal mode(a)
Ei (t)	6.2	%	error current measurement
Ex (t)	100.0	%	error laser measurement
Eu (t)	14.3	%	error amplifier check
Delta Tv (Delta Tlim)	26.1 (90.0)	K	increase of voice coil temperature (limit)
Blmin (Bllim)	50.0 (50.0)	%	minimal force factor ratio (limit)
Cmin (Clim)	32.0 (30.0)	%	minimal compliance ratio (limit)
P (Plim)	3.9968 (10.00)	W	real electrical input power (limit)
Lmin	89.0	%	minimal inductance ratio
Pn		W	IMPORT Zn at Driver page to see nominal electrical input power
P Re	3.159605	W	Power heating voice coil
Irms	0.900	A	rms value of the electrical input current
Urms	5.115	V	rms value of the electrical voltage at the transducer terminals
Ipeak	3.005	A	peak value of the electrical input current
Upeak	18.453	V	peak value of the electrical voltage at the transducer terminals
PC	0.82	dB	thermal power compression factor
Glarge (Gmax)	14.1 (26.0)	dB	gain of the excitation amplitude increased in the large signal domain (maximum)
Mech. system		abs.	import used to identify mechanical system in absolute quantities

Xdc	0.1	mm	dc component of voice coil excursion measured in the last update intervall
Xpeak	3.8	mm	positive peak value of voice coil excursion measured in the last update intervall
Xbottom	-4.3	mm	negative peak value (bottom) of voice coil excursion measured in the last update intervall
Xp+	3.4	mm	upper limit of displacement range (99% probability)
Xp-	-3.1	mm	lower limit of displacement range (99% probability)
Xprot	4.4	mm	maximal voice coil excursion allowed by protection system
v rms	0.48	m/s	voice coil velocity
Db	17.0	%	distortion factors representing contribution of nonlinear force factor
DI	1.4	%	distortion factor representing contribution of nonlinear inductance
Dc	54.2	%	distortion factor representing contribution of nonlinear compliance
R th total	8.27	K/W	Delta Tv / P Re

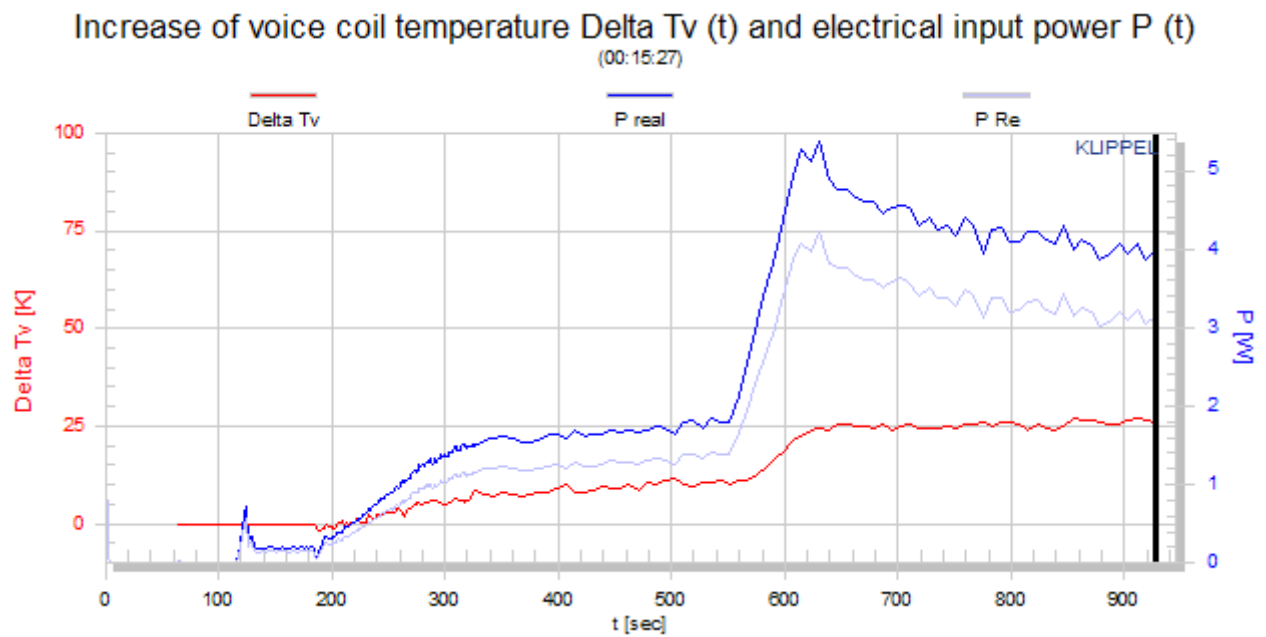
### Voltage Probability Density Function $pdf(u)$



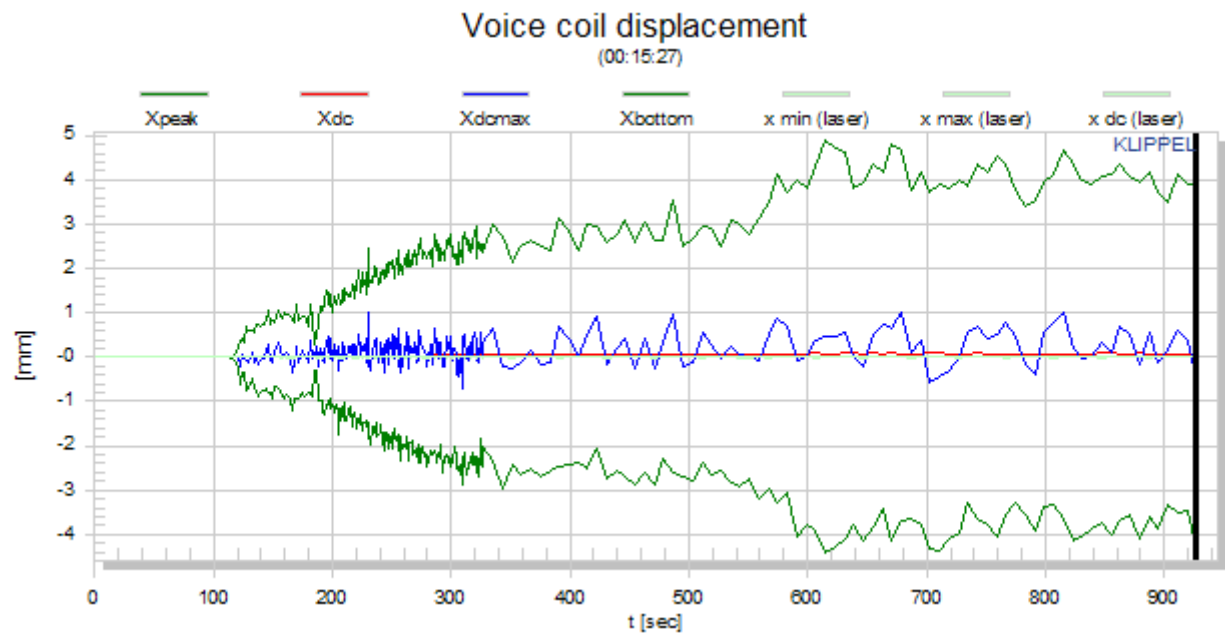
## Voltage $u_{peak}(t)$ and Current $i_{peak}(t)$



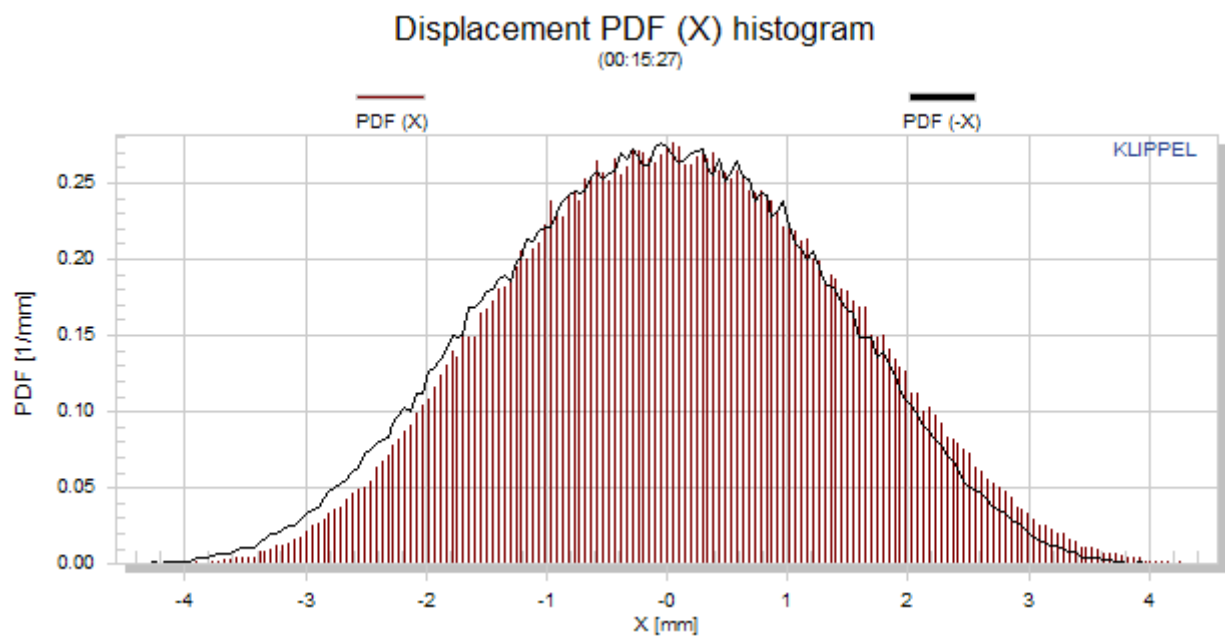
## Voice Coil Temperature $\Delta T_V(t)$ and Power $P(t)$



## Displacement $x(t)$

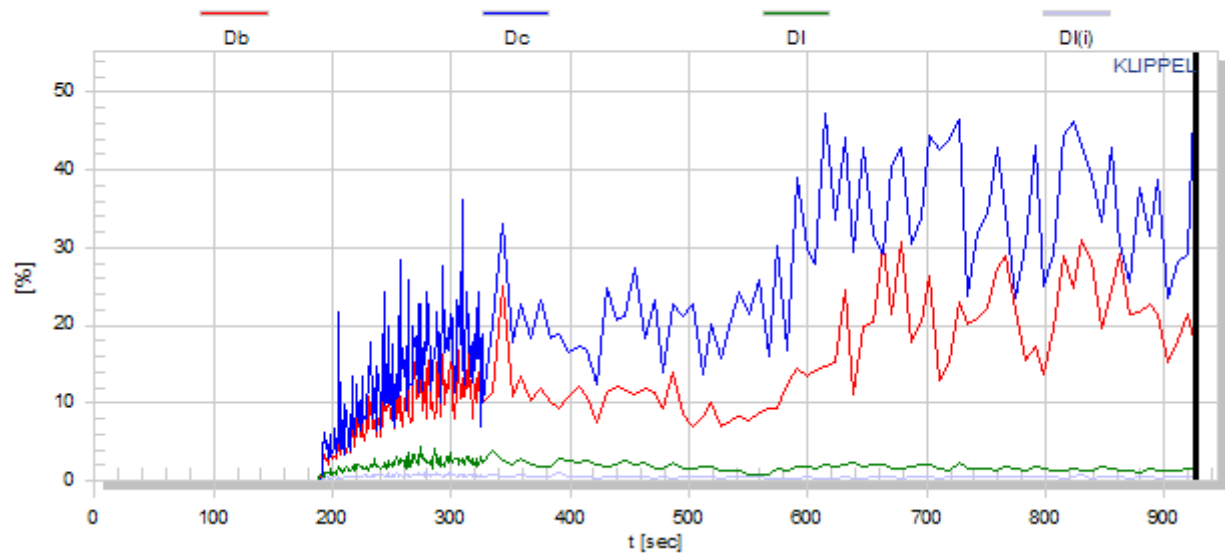


## Displacement Probability Density Function $pdf(x)$



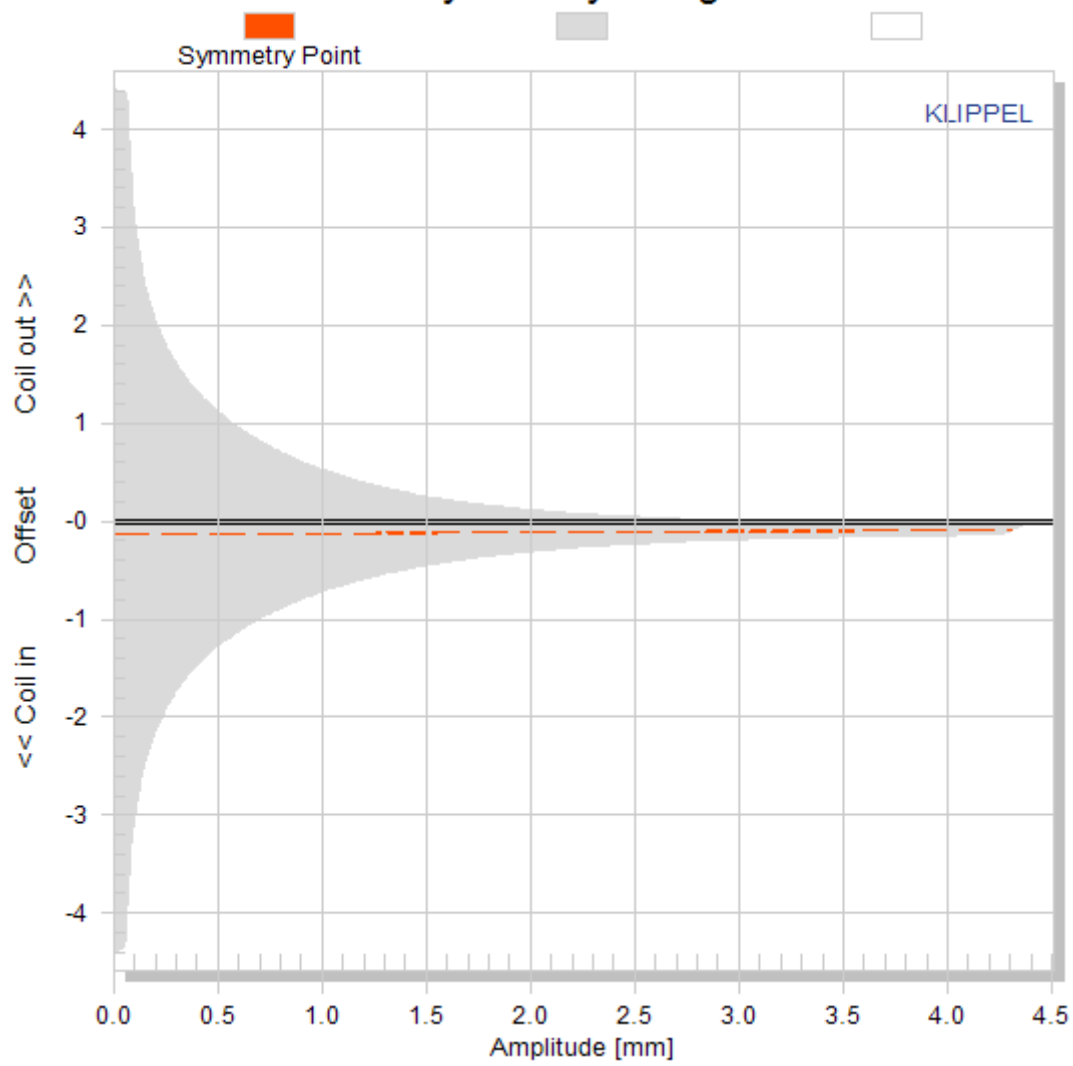
# Distortion Analysis

Distortion analysis : Db (BI-product), Dc (suspension), DI (inductance)  
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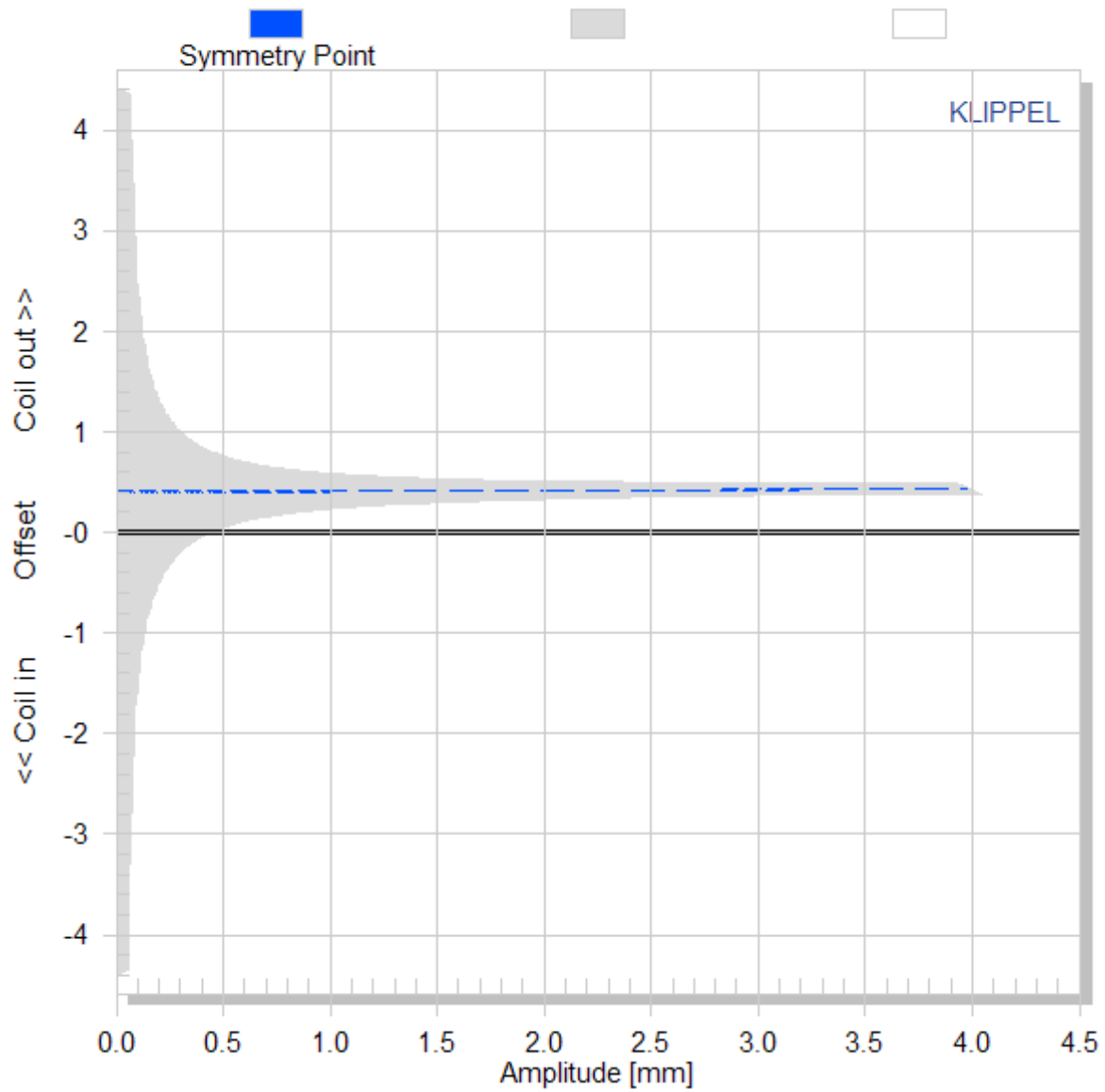


# **Remedies for Transducer Nonlinearities**

## BI Symmetry Range



## Kms Symmetry Range



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