

FEATURES

- Large Signal Parameter for QC
- Voice coil offset in mm
- Suspension asymmetry in %
- No additional sensor required
- Small Signal Parameter (T/S)
- Ultra fast testing at physical limit
- Automatic limit calculation

BENEFITS

- Simplify diagnostics of defect units
- Control production process with QC results
- Reduce number of defect units
- Ensure consistency of production
- Use the same data in QC and R&D
- Exploit ambient noise immunity
- Go for 100% testing

The Motor and Suspension Check (MSC) is an add-on to the QC end-of-line test system. This module measures selected large signal parameters such as voice coil offset and suspension asymmetry within a extremely short measurement time (1- 3 s). The parameters are easy to interpret and give feedback for process control to avoid manufacturing of bad units. The MSC can be applied to all kinds of transducers such as woofers, tweeters, headphones, micro-speakers and compression drivers.

Application:

- End-of-line testing
- Incoming goods inspection
- Diagnostics

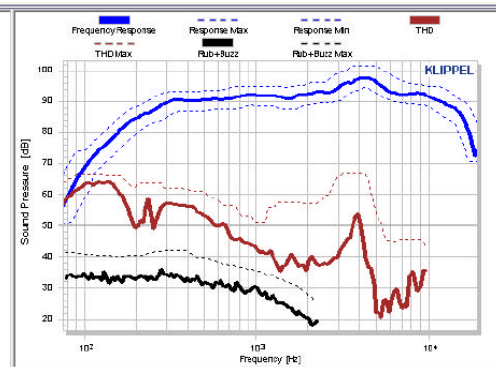
Coil Offset: 1.52 mm

Name	Value	Unit	Description
Coil Offset	1.52	mm	voice coil offset
Suspension Asymmetry	8.95	mm	asymmetry of the driver suspension
Kms ($x=0$)	0.229	N/mm	stiffness at rest position
Kms ($-xlin$)	0.199	N/mm	stiffness at inner bound of linear working range
Kms ($+xlin$)	0.403	N/mm	stiffness at outer bound of linear working range
Bl Variation	79.0	%	maximal variation of force factor during measurement

[show signal characteristics \(motor + suspension\)](#)

PASS

Impedance
Re
Lces
fs
Frequency Response
Average Level
Rub+Buzz
Ambient Noise
Polarity
THD
2nd Harmonic
3rd Harmonic
4th Harmonic



Article Number:

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Overview

Summary	The maximal output, distortion and motor stability of a transducer highly depend on the suspension properties which vary significantly from batch to batch due to material uncertainties, climate and storage conditions. A new measurement technique is presented which makes it possible to measure voice coil offset in mm, suspension asymmetries in percent and other large signal parameters useful for quality control during end-of-line testing. This data is easy to interpret and directly indicates defects of motor and suspension. Exploiting this information in process control reduces the number of failed units and ensures consistent properties of the manufactured drive units and loudspeaker systems.
QC requirements	<p>The QC- Motor and Suspension Check (MSC) was developed to satisfy the following requirements occurring under production conditions:</p> <ul style="list-style-type: none"> • Objective and reliable detection of defects in motor and suspension within the shortest possible measurement time (1 – 3 s). • Although performing the measurement up to high amplitudes the MSC shall also provide the parameters at the rest position, such as $K_{ms}(x=0)$, which correspond with the small signal parameters (T/S). • Large signal parameters are expressed as single values to support limit setting and statistics (cpk, ppk) for assessing the process stability. • The interpretation of the large signal parameters is simple and supports loudspeaker diagnostics. For example using a new batch of spiders may cause an offset of the voice coil position. Since the MSC measures this offset in mm this information can directly be used as a feedback to process control to correct the coil position. • QC requires a robust and cost effective hardware solution. The MSC uses the Production Analyzer which already provides current and voltage sensors for small and high amplitudes. No additional sensor is required for MSC ! • The MSC dispenses with measurements of mechanical or acoustical quantities such as displacement or sound pressure. This gives high robustness of the measurement against ambient noise. • Extremely short training period for the MSC. • The large signal parameters (coil offset, suspension asymmetry, ...) measured with the MSC can directly be compared with the data measured by the Large Signal Identification (LSI) which is a module of the KLIPPEL R&D system.
Principle	The MSC is based on a new identification technique which is patent protected. The loudspeaker is excited by a multi-tone signal of sufficient bandwidth and amplitude. Only electrical signals (voltage and current) are measured at the terminals of the transducer. The output parameters of the MSC are calculated by exploiting the nonlinear information found in the current signal. The MSC can identify 2 nd -order mechanical systems comprising a stiffness, moving mass and losses and also 4 th -order systems with additional acoustical resonances as caused by a vented enclosure.
Parameters at x=0	<p>Although the loudspeaker is operated at higher amplitudes and the loudspeaker nonlinearities produce significant distortion the parameters (f_s, Q_{ts}, K_{ms}, ...) at the rest position $x=0$ can be calculated. Those parameters are comparable with the linear Thiele-Small parameters usually measured in the small signal domain. The electrical impedance curve $Z_{el}(f)$ is also measured at the rest position of the coil and the artifacts generated by loudspeaker nonlinearities are suppressed.</p> <p>Note that the stiffness K_{ms} of the suspension at $x=0$ depends highly depends on the peak displacement (also in the small signal domain where the nonlinearities are not active).</p>

Definition of Motor Parameters

BI-limited peak displacement

DEFINITION: The decrease of the BI-value caused by a movement of the coil away from the rest position $x=0$ limits the maximal peak displacement. This value called *force factor limited displacement* X_{BI} is implicitly defined by the condition that the minimal force factor ratio

$$\min_{-X_{BI} < x < X_{BI}} \left(\frac{Bl(x)}{Bl(0)} \right) \cdot 100\% = Bl_{\min} \quad (1)$$

equals a threshold Bl_{\min} .

The definition is illustrated in Fig. 1 showing a $Bl(x)$ -curve measured by the Large Signal Identification (LSI) module of the KLIPPEL R&D system (curve not available in MSC):

1. Read the value $Bl(x=0)$ at the rest position and multiply this value with the threshold of the minimal force factor ratio ($Bl_{\min} = 82\%$).
2. Search for the smallest X_{BI} where the $Bl(x)$ equals $Bl(x=0) \cdot 82\%$.
3. The peak value X_{BI} shall be reported with the used minimal force factor ratio, Bl_{\min} for example: $x_{BI} = 3 \text{ mm}$ (@ $Bl_{\min} = 82\%$)

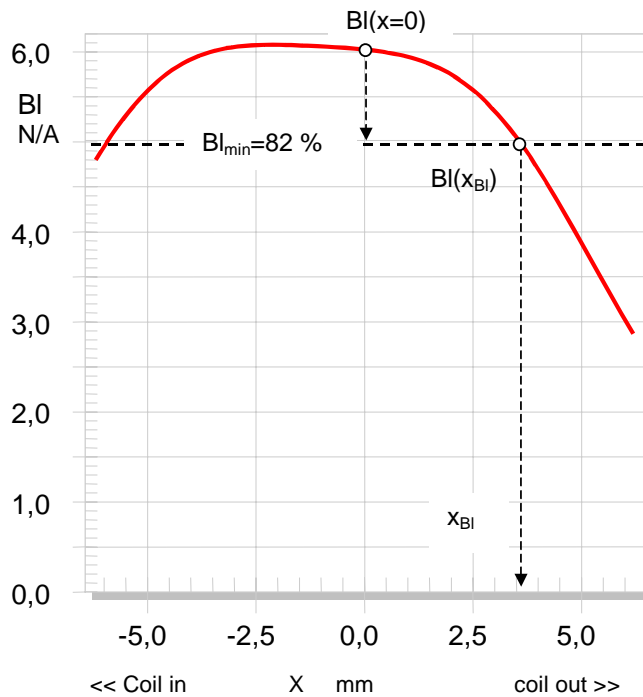


Fig. 1: Reading the maximal peak displacement X_{BI} limited by force factor nonlinearity

Application to end-of-line testing

The force factor limited displacement X_{BI} is a useful characteristic for finding a motor defect causing excessive harmonic distortion. However, harmonic distortion is not a unique symptom but may be caused by other nonlinearities. X_{BI} considers symmetrical and asymmetrical variation of the force factor only. Minimal or maximal QC limits may be applied to check X_{BI} and to make a PASS/FAIL decision.

BI Symmetry Point

DEFINITION: The symmetry point in the BI-curve describes the centre point between two points on the BI-curve producing the same BI-value

$$Bl(X_{sym}(x_{ac}) - x_{ac}) = Bl(x_{sym}(x_{ac}) + x_{ac}) \quad (2)$$

which are separated by $2x_{ac}$.

The definition is illustrated in Fig. 2 showing a $Bl(x)$ -curve measured by the Large Signal Identification (LSI) module of the KLIPPEL R&D system (curve not available in MSC):

1. Select a BI-value which is smaller or equal than Bl_{max} as illustrated in Fig. 2.
2. Read the corresponding displacement values x_1 and x_2 on both sides of the BI maximum giving $Bl(x_1)=Bl(x_2)$.
3. Calculate the symmetry point $X_{sym}=(x_1+x_2)/2$ and the displacement $X_{ac}=|x_2-x_1|/2$. Repeat the procedure for other BI-values.
4. Report the dependency of the symmetry point $x_{sym}(x_{ac})$ versus displacement x_{ac} as a curve

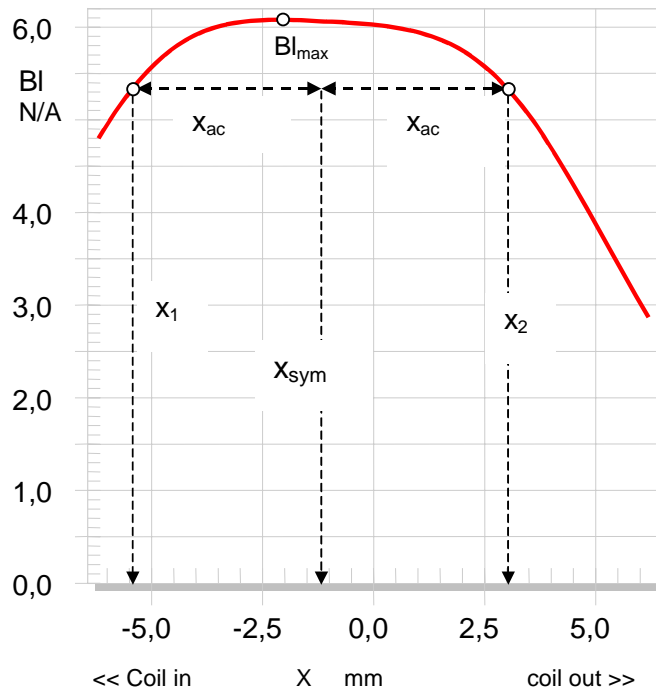


Fig. 2: Definition of the symmetry point X_{sym} in the nonlinear force factor characteristic $Bl(x)$.

Application to end-of-line testing

The symmetry point is the basis for assessing the voice coil offset which is a more useful characteristic for QC tests. See below for the definition of X_{offset} .

Voice Coil Offset

X_{offset}

DEFINITION: The voice coil offset X_{offset} is the symmetry point $x_{sym}(x_{ac})$ for a high value of X_{ac} ($X_{ac} > X_{Bl}$) to assess the symmetry at the steep slopes of the BI-curve.

The definition is illustrated in Fig. 3 showing the symmetry point measured by the Large Signal Identification (LSI) module of the KLIPPEL R&D system (curve not available in MSC) :

1. Calculate the symmetry point $x_{sym}(x_{ac})$ as a function of displacement X_{ac} .
2. Read the voice coil offset at high displacement X_{Bl} .
3. Report the the voice coil offset X_{offset} together with the amplitude x_{ac} for example: $X_{offset} = 0.4 \text{ mm}$ (@ $X_{ac} = 5.2 \text{ mm}$)

Note: If the symmetry point varies significantly with the displacement ($x_{sym}(x_{ac}) \neq \text{constant}$), the asymmetry of the BI-curve is caused by the magnetic field geometry and can not be compensated by a coil shift.

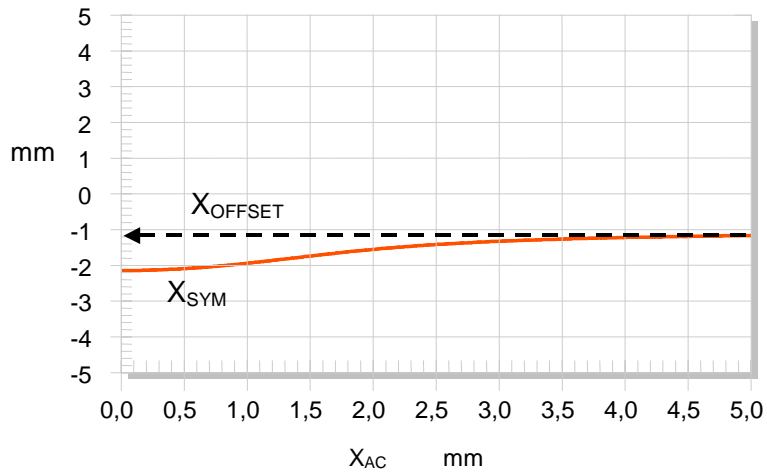


Fig. 3: Reading the voice coil offset from the symmetry point $X_{SYM}(X_{AC})$ curve.

Application to end-of-line testing

Voice coil offset X_{offset} is a useful characteristic for assessing the asymmetry of the motor which can be compensated by a voice coil shift. A coil offset generates 2nd-order harmonic distortion, a d.c. part in the displacement and may initiate a motor instability. The voice coil offset X_{offset} should be close to zero.

A permissible range defined by minimal or maximal QC limits may be applied to X_{Bl} to check for a PASS/FAIL decision.

Definition of Suspension Parameters

C_{ms} -limited peak displacement

X_C

DEFINITION: The decrease of the compliance value C_{MS} - caused by a movement of the coil away from the rest position $x=0$ limits the maximal peak displacement. This value called *compliance limited peak displacement* X_C is implicitly defined by the condition that the minimal compliance ratio

$$\min_{-X_C < x < X_C} \left(\frac{C_{MS}(x)}{C_{MS}(0)} \right) \cdot 100\% = C_{min} \quad (3)$$

equals a threshold C_{min} .

The definition is illustrated in Fig. 4 showing a $C_{MS}(x)$ -curve measured by the Large Signal Identification (LSI) module of the KLIPPEL R&D system (curve not available in MSC):

1. Read the value $C_{ms}(x=0)$ at the rest position and multiply this value with the threshold of the minimal compliance ratio (e.g. $C_{min} = 75\%$).
2. Search for the smallest X_C where the $C_{ms}(x)$ equals $C_{MS}(x=0) \cdot C_{min}$.

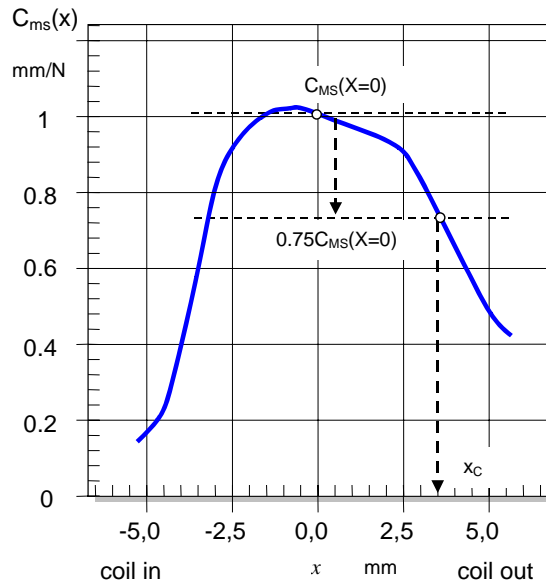


Fig. 4: Reading the compliance limited peak displacement X_C .

Application to end-of-line testing

The compliance limited displacement X_C is a useful characteristic for finding a defect suspension part such as a spider or surround causing excessive harmonic distortion (THD). However, harmonic distortion is not a unique symptom of suspension problems but may also be caused by a voice coil offset. X_C considers symmetrical and asymmetrical variation of the suspension nonlinearity only.

Minimal or maximal QC limits may be applied to check X_C and to make a PASS/FAIL decision.

Stiffness asymmetry

$A_K(x_{peak})$

DEFINITION: The asymmetry of the $K_{ms}(x)$ -curve is the ratio

$$A_K(x_{peak}) = \frac{2(K_{MS}(-X_{peak}) - K_{MS}(X_{peak}))}{K_{MS}(-X_{peak}) + K_{MS}(X_{peak})} 100\%, \quad (4)$$

using the stiffness at the negative and positive limits $\pm X_{peak}$.

The definition is illustrated in Fig. 5 showing a $K_{MS}(x)$ -curve measured by the Large Signal Identification (LSI) module of the KLIPPEL R&D system (curve not available in MSC):

1. Read the stiffness values at positive and negative peak displacement X_{peak} in the measured $K_{ms}(x)$ curve as illustrated in Fig. 5.
2. Calculate the stiffness asymmetry using Eq. (4).
3. Report the peak displacement X_{peak} together with the asymmetry value:
 $A_K=90\%$ ($X_{peak}=5.5\text{ mm}$)

Note: It is recommended to calculate Stiffness asymmetry A_K for $X_{peak} > X_C$.

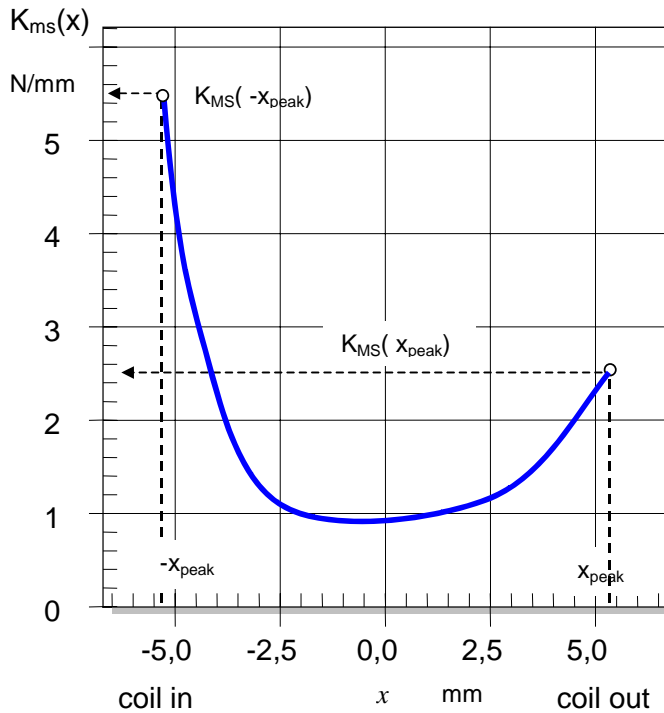


Fig. 5: Reading the stiffness asymmetry A_K .

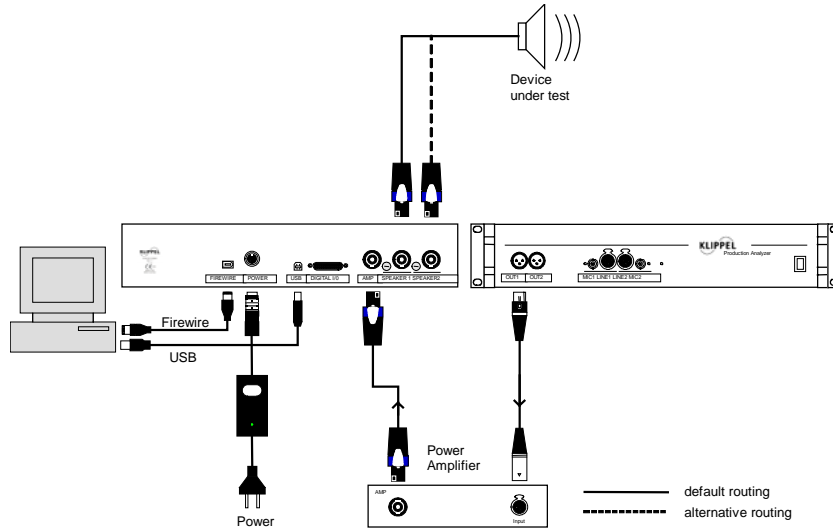
Application to end-of-line testing

The stiffness asymmetry A_K is a useful characteristic for assessing the asymmetry of the suspension part which generates 2nd-order harmonic distortion. Stiffness asymmetry A_K only considers asymmetrical variation of the suspension nonlinearity separated from other nonlinearities. The stiffness asymmetry A_K should be close to zero. The sign of A_K corresponds with the sign of the d.c. displacement generated by an asymmetrical suspension.

A permissible range defined by minimal or maximal QC limits may be applied to A_K to check for a PASS/FAIL decision.

Hardware

Minimal Setup



The figure above shows the minimal equipment required to run the MSC:

- QC Production Analyzer
- personal computer (IBM compatible, Windows)
- Power amplifier and cables

Of course the MSC can be combined with traditional tests such as SPL, THD, Rub&Buzz, polarity using optional equipment

- microphones,
- barcode reader, switches, assembly line control via digital I/O connector

→ more information in the KLIPPEL specification "C3 - QC End of Line Test System"

Production Analyzer

The production analyzer hardware provides current and voltage sensors for two speaker channels. This allows to perform an alternative testing of drive units. While a first drive unit is measured on connector SPEAKER 1 a second drive unit will be connected to connector SPEAKER 2.

The current sensors can be customized to the transducer type to handle the maximal peak current (100 mA for a microspeaker or 60 A for a subwoofer).

Please find more information in *H4 – Production Analyzer Hardware* for detailed specification.

Power Amplifier

Any standard audio amplifier meeting the power and bandwidth requirements of the tests may be used.

PC

MSC performs significant signal processing and puts the following requirements on the computer:

P4 (2 GHz) or equivalent, 1024 MByte RAM, USB and Firewire (IEEE1394) port; 1 GB space on harddisk drive for programme and additional harddisk space for measurement data (depends on task); Windows XP Service Pack 1 or higher, Vista compatible.

Fixture

The transducer may be measured in free air or connected to a sealed enclosure. Additional resonances close to the fundamental resonance frequency should be avoided.

Acoustical Environment

The MSC is very robust against ambient noise.

Limits					
TRANSDUCER					
Parameter	Symbol	Min	Typ	Max	Unit
Voice coil resistance ¹	R_e	0.1	4 - 120		Ω
Resonance frequency	f_s	15		3000	Hz
Total loss factor	Q_t	0.3		6	
Voice coil inductance	L_e	0.05		5	mH
Principle	electro-dynamical transducer with a 2 nd -order mechanical system, also in vented enclosure (4 th -order system)				
Types	subwoofer, woofer, midrange, tweeter, micro-speaker, headphones, compression driver				

¹ Maximal resistance depends on the current sensor used in the Production Analyzer (customization is possible)

REQUIREMENTS FOR POWER AMPLIFIER					
Maximal input level				15	dBu
Frequency response ref. 1 KHz @ 5Hz ... 20 kHz				1	dB
Input sensitivity at rated output power			0 (775)		dBu (mV)

INPUT PARAMETERS (SETUP)					
Parameter	Symbol	Min	Typ	Max	Unit
rms voltage	U_{rms}	0.1	4	200	V
Driver Type	<i>Type</i>	<ul style="list-style-type: none"> • subwoofer • woofer • midrange driver • micro-speaker • headphone • tweeter • subwoofer in vented box • woofer in vented box • general (advanced mode) 			
Calibration of mechanical units ²	<i>Calibration</i>	<ul style="list-style-type: none"> • Relative (no import required) • $Bl(x=0)$ imported • Mass M_{ms} imported, 			
Force factor (if $Bl(x=0)$ import selected)	$Bl(x=0)$	0.01			N/A
Moving mass (if M_{ms} import selected)	M_{ms}	0.01			gram
Optional Input Parameters (if advanced mode selected)					
lowest frequency of multi-tone complex	f_{start}	2	2	20	Hz
highest frequency of multi-tone complex	f_{stop}	375		12000	Hz
Excitation Density (number of tones in multi-tone complex)	<i>Resolution</i>	1	20	200	tones/ octave
Duration of stimulus	T	0.17	0.7	5.46	s
Number of loops repeated the stimulus before measurement to get steady-state	<i>Pre-loop</i>	0	0.5	20	
Compensation of cut-off frequency of the power amplifier	<i>Compensate Amplifier</i>	on /off			
Inductance Model used to consider Para-inductance	<i>Inductance Model</i>	<ul style="list-style-type: none"> • Leach Model (2 parameters) • LR-2 Model (3 parameters) • Wright Model (4 parameters) 			

² Absolute identification of the mechanical parameters without laser sensor requires import of $Bl(x=0)$ and/or M_{ms}

Measurement Results			
Measured Quantity	Symbol	Unit	QC limits can applied
LARGE SIGNAL PARAMETERS (ABSOLUTE) ¹			
Voice coil offset	X_{offset}	mm	x
Force factor limited displacement	X_{Bl}	mm	x
Compliance limited displacement	X_C	mm	x
RELATIVE LARGE SIGNAL PARAMETERS (RELATIVE)			
Relative voice coil offset	X_{offset}/X_{peak}	%	x
Force factor limited displacement (relative)	X_{Bl}/X_{peak}	%	x
Compliance limited displacement (relative)	X_C/X_{peak}	%	x
Stiffness Asymmetry	A_{SYM}	%	x
PARAMETERS AT THE REST POSITION (X=0)			
Voice coil resistance	R_e	Ohm	x
Moving mass ¹	M_{ms}	grams	
Stiffness ¹	K_{ms}	N/mm	
Force Factor ¹	Bl	N/A	
Resonance frequency	f_s	Hz	x
Total loss factor	Q_{ts}		x
Electrical loss factor	Q_{es}		
Mechanical loss factor	Q_{ms}		
Impedance curve	$Z_{el}(f)$	Ohm	x
Port resonance frequency ²	f_b	Hz	x
Port loss factor ²	Q_b		x
Mechanical resistance ¹	R_{ms}	Ns/m	
Inductance of the LR2 Model	L_e	mH	
Electrical capacitance representing moving mass	C_{mes}	μF	
Electrical inductance representing driver compliance	L_{ces}	mH	
Electrical resistance representing mechanical losses	R_{es}	Ohm	
STATE INFORMATION			
Peak Current	I_{peak}	A	
Peak Voltage	U_{peak}	V	
Peak Displacement ¹	X_{peak}	mm	
rms Displacement ¹	X_{ac}	mm	
Headroom Current	H_i	dB	
Distortion Current	D_i	dB	
Lowest value of nonlinear force factor in used working range	Bl Variation	%	
Lowest value of nonlinear compliance in used working range	Cms Variation	%	
Peak displacement of Reference DUT during Limit setting ¹	X_{prot}	mm	

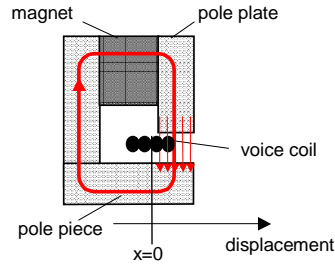
¹ Additional information about the mechanical system is required (import Bl or Mms value at x=0)

² only for Driver Types in vented box

Example: Voice coil position under process control

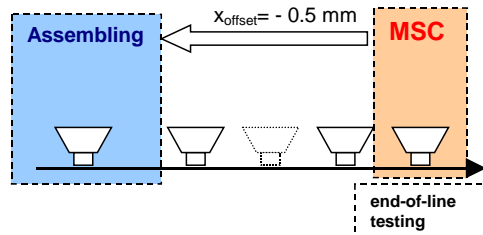
Problem:

An offset in the voice coil position may be caused by using a new batch of spiders. This offset generates excessive harmonic distortion. However, the harmonic distortion does not show the physical cause.



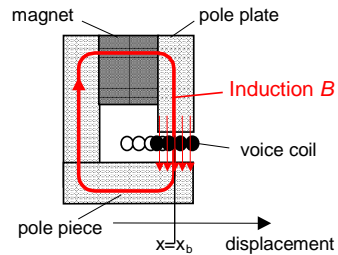
Solution:

As soon as the first device using the new spider part arrives at the end of line the voice coil offset is detected by MSC. The parameter X_{offset} expressed in mm is transmitted to the assembling station and used as a feedback to correct the voice coil offset.



Result:

100 % -testing of the voice coil position can be realized by MSC within a few seconds. MSC combined with process control makes it possible to produce transducers at high quality even if the properties of the parts and the production condition vary.



→ coil at optimal position

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