# Motor and Suspension Check (MSC) S13

Specification for the KLIPPEL ANALYZER SYSTEM (QC Ver. 6, dB-Lab Ver. 210)

Document Revision 1.8

## FEATURES

- Large signal parameters for QC
- Voice coil offset in mm
- Relative to Reference DUT or Bl Symmetry
- Suspension asymmetry in %
- No additional sensor required
- Effective small signal parameter (T/S)
- Ultra-fast testing at physical limit

## BENEFITS

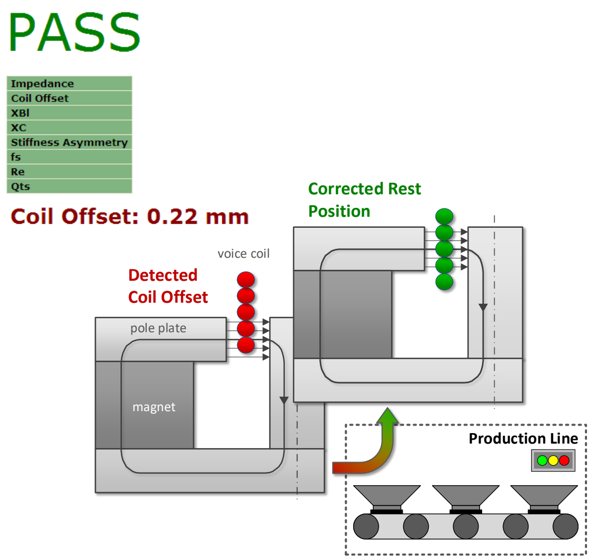
- Maximum output and reliability
- Simplify diagnostics of defective units (root cause analysis)
- Control production process with QC results
- Reduce number of defective units (early defect detection)
- Ensure consistency of production
- Use the same data in QC and R&D

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 an extremely short measurement time. The parameters are easy to interpret and give feedback for process control to avoid manufacturing 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




| Article Number: | 4000-230 |
|---|---|

## CONTENT

# 1 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. The measurement technique of the MSC 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. |
| **Targets** | The QC- Motor and Suspension Check (MSC) was developed to satisfy the following requirements occurring under production conditions:<br>• Objective and reliable detection of defects in motor and suspension within the shortest possible measurement time (<1 s – 3 s).<br>• Although performing the measurement at high amplitudes, the MSC shall also provide the parameters at the rest position, such as Kms(x=0), which correspond to the small signal parameters (T/S).<br>• Large signal parameters information is reduced to single values to support limit setting and statistics (cpk, ppk) for assessing the process stability.<br>• 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.<br>• QC requires a robust and cost-effective hardware solution. The MSC uses only voltage and current sensors of the analyzer, no additional sensors are required.<br>• The purely electrical measurement principle provides high robustness against ambient noise.<br>• Extremely short training period for the MSC.<br>• 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) module of the KLIPPEL R&D system. |
| **Principle** | The MSC is based on a patent-protected identification technique. 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 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** | Although the loudspeaker is operated at higher amplitudes and the loudspeaker nonlinearities produce significant distortion the parameters (fs, $Q_{ts}$, $K_{ms}$, …) at the rest position x=0 can be calculated. Those parameters are comparable with the |

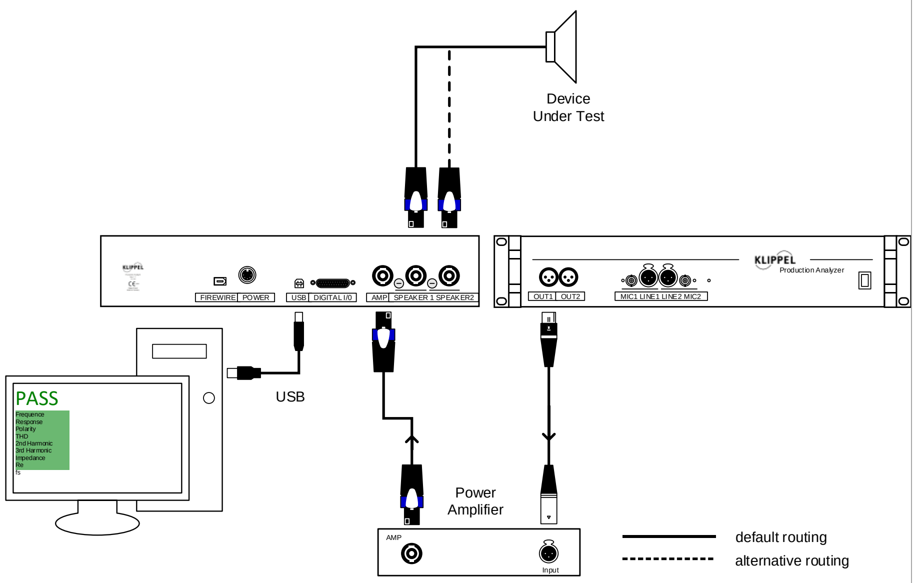
linear Thiele-Small parameters usually measured in the small signal domain. The electrical impedance curve $Z_{el}(f)$ is also measured at the rest position of the coil and the artifacts generated by loudspeaker nonlinearities are suppressed.

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). This can be explained by visco-elastic effects caused by temporal deformation of the fiber structure of the suspension material.

## 2 Requirements

### 2.1 Hardware

Minimal Setup (with PA)

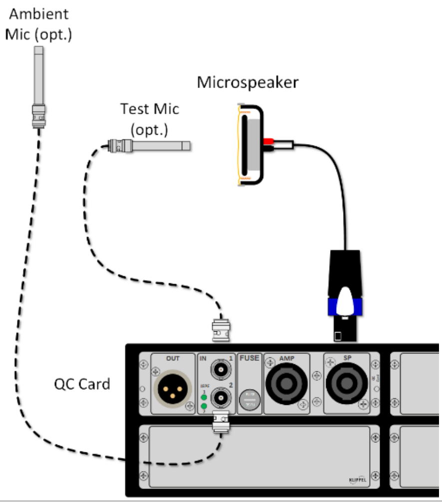



The figure above shows the minimal equipment required to run the MSC with KLIPPEL Production Analyzer:

- KLIPPEL Production Analyzer
- Power amplifier and cables
- PC

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

| | |
|---|---|
| Production Analyzer | The Production Analyzer hardware provides current and voltage sensors for two speaker channels. This allows performing 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.<br>Different sensitivities of current sensors are available, depending on the nominal impedance of the DUT. However, for large signal testing, the default version is suitable in most cases.<br>Please find more information in *H4 – Production Analyzer Hardware* for detailed specification. |
| Alternative Setup (with KA3 QC) | The figure on the rigth shows an alternative test setup with *KLIPPEL Analyzer 3 QC Card.* For test objects with lower power requirements like microspeakers or small woofers, the internal amplifier of the QC Card is highly suitable also for MSC large signal test.<br>The additional microphones are optional for acoustic tests (QC SPL Task) with ambient noise detection, they are not relevant for the MSC test.<br><br> |
| KLIPPEL Analyzer 3 | In order to use the MSC with the KLIPPEL R&D System (from version 210), the KA3 hardware is required. The analyzer is also supported from QC Version 6. No external amplifier is required in case the *Amplifier Card* or *QC Card* meets the peak voltage and power requirements.<br><br>The required minimal card configuration for use with external amplifier is:<br>*XLR Card + Speaker Card*<br>In case no external amplifier is required, the following cards are required:<br>*QC Card*<br>or<br>*Speaker Card + Amplifier Card*<br>Please refer to the *KA3 and extension card specifications* for more information. |
| Power Amplifier | Any standard audio amplifier meeting the power and bandwidth requirements of the tests may be used. A power amplifier may be omitted in case a KA3 equipped with an Amplifier Card or QC Card is used and it fulfils the peak voltage and power requirements.<br>Find more details in *KLIPPEL Amplifier Requirements* |
| PC | Please refer to the general recommendations in *KLIPPEL QC SYSTEM PC Requirements*.<br>The signal processing algorithms of the MSC may affect the total test time, therefore a fast CPU is recommended. |

### 2.2 Software

| | |
|---|---|
| QC Framework | The MSC requires QC Standard software. MSC is installed with the QC software, no additional setup is required. A dedicated license is required to operate the module. |
| RnD Framework | From release version 210, the MSC may be operated within the KLIPPEL RnD software release. No additional setup, only an MSC license is required for operation.<br>**Note**: KLIPPEL Analyzer 3 (KA3) hardware is required to operate the MSC in the RnD software framework. |

### 2.3 Further Requirements

| | |
|---|---|
| Test Fixture | The transducer may be measured in free air, attached to a test chamber or mounted in a sealed or vented loudspeaker enclosure.<br>Note that the orientation may influence coil position and any additional air volume may affect stiffness asymmetry and peak displacement. Correct polarity must be ensured (e.g. by additional acoustical test). |
| Test Environment | There are no special requirements for the test environment, the measurement is immune against ambient noise. However, temperature and humidity should be controlled and well-defined for consistent behavior of the device under test. |

# 3 Limits

### 3.1 Transducer

| Parameter | Symbol | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|
| Voice coil resistance [1] | $R_e$ | 0.1 | 4 - 120 | | Ω |
| Resonance frequency | $f_s$ | 20 | | 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 2nd-order mechanical system, also in vented enclosure (4th-order system) | | | | |
| Types | subwoofer, woofer, midrange, tweeter, micro-speaker, headphones, compression driver | | | | |

[1] Maximal resistance depends on the selected current sensitivity

### 3.2 Input Parameters (Setup)

| Parameter | Symbol | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|
| Stimulus voltage (RMS) | $U_{rms}$ | 0.1 | 4 | 200 | V |
| Driver Type | *Type* | • subwoofer<br>• woofer<br>• midrange driver | | | |

| | | | | | |
|---|---|---|---|---|---|
| | | • micro-speaker<br>• headphone<br>• tweeter<br>• subwoofer in vented box<br>• woofer in vented box<br>• general (advanced mode) | | | |
| Calibration of mechanical units [2] | *Calibration* | • Relative (no import required)<br>• Bl(x=0) imported<br>• Mass $M_{ms}$ imported, | | | |
| Force factor (if Bl(x=0) import selected) | *Bl(x=0)* | 0.01 | | | N/A |
| Moving mass (if Mms 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 |
| test frequency for Re measurement (pilot tone) | $f_{Re}$ | 375 | | 12000 | Hz |
| Excitation density (number of tones in multi-tone complex) | *Resolution* | 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 | $T_{pre}$ | 0 | 0.5 | 20 | |
| Inductance Model used to consider Para-inductance | *Inductance Model* | • Leach Model (2 parameters)<br>• LR-2 Model (3 parameters)<br>• Wright Model (4 parameters) | | | |

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

## 4 Measurement Results*

| **Measured Quantity** | **Symbol** | **Unit** | **QC limits applicable** |
|---|---|---|---|
| **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] | $M_{ms}$ | g | |
| 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 |
| Enclosure resonance frequency[2] | $f_b$ | Hz | x |
| Enclosure 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 displacement[1] | $X_{peak}$ | mm | |
| Bottom displacement[1] | $X_{bottom}$ | mm | |
| Absolute peak displacement of Reference DUT during limit setting[1] | $X_{prot}$ | mm | |
| Symmetrical AC displacement at Bl(x) max[1] | $X_{ac}$ | mm | |
| DC displacement (average and peak-to-peak) | $X_{dc}$, $X_{dc,max}$ | mm | |
| Lowest ratio of nonlinear force factor during measurement related to rest position | $Bl_{min}$ | % | |
| Lowest ratio of nonlinear compliance during measurement related to rest position | $C_{ms,min}$ | % | |

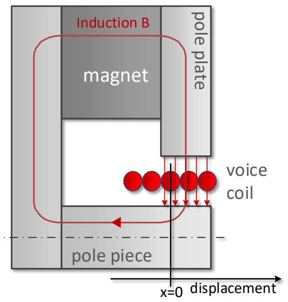
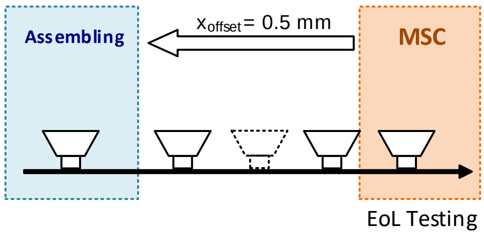
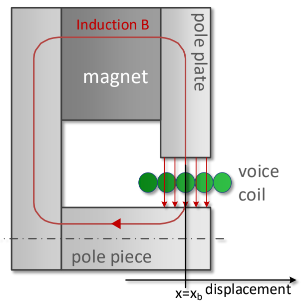
* This parameter is defined in MSC Manual.

[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

# 5 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 significant harmonic distortion. However, the harmonic distortion does not show the physical cause and will reduce yield until the root cause is identified and fixed. |   Badly centered coil rest position |
| 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 $X_{offset}$ stated in mm is transmitted to the assembling station and used as a shift recommendation to correct the voice coil rest position. |   |
| 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 rest position |

# 6 References

| | |
|---|---|
| **6.1 Related Products** | • QC BAC Task (Balanced Armature Check)<br>• QC TSX add-on for Impedance Task (laser-based T/S parameters)<br>• LSI Module (Large Signal Identification)<br>• LPM Module (Linear Parameter Identification) |
| **6.2 Manuals** | • QC User Manual<br>• MSC User Manual<br>• Hardware Manual |
| **6.3 Application Notes** | • AN1 Optimal Voice Coil Rest Position<br>• AN3 Adjusting the Mechanical Suspension<br>• AN5 Displacement Limits due to Driver Nonlinearities<br>• AN21 Reduce distortion by shifting Voice Coil<br>• AN65 Linking Large Signal Testing Between QC and R&D<br>Find more on http://www.klippel.de/know-how/literature/application-notes.html |
| **6.4 Papers** | Fast Measurement of Motor and Suspension Nonlinearities in Loudspeaker Manufacturing<br>Find more on http://www.klippel.de/know-how/literature/papers.html |
| **6.5 Standards** | IEC62458 Sound System Equipment – Electroacoustic Transducers - Measurement of Large Signal Parameters |
| **6.6 Patents** | **Germany**<br>102007005070; 1020120202717; 19714199; 43340407; 4332804.0<br>**USA**<br>8,078,433; 14/436,222; 6,058,195; 5815585<br>**China**<br>ZL200810092055.4; 201380054458.9; 981052849<br>**Japan**<br>5364271; 2972708<br>**Europe**<br>13786635.6<br>**Taiwan**<br>102137485<br>**India**<br>844/MUMNP/2015<br>**Great Britain**<br>2324888 |

*ACKNOWLEDGEMENT:*

The research on this project has been funded by the Federal Ministry of Economics and Technology of Germany. (BMWi).

Find explanations for symbols at:

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

Last updated: February 05, 2020