Quality Assurance of Mobile Sound Reinforcement Equipment

AN79

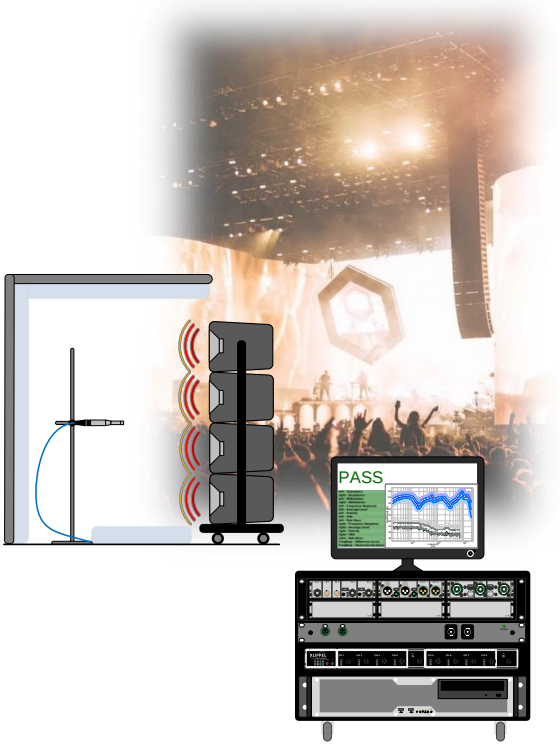
Application Note for the KLIPPEL ANALYZER SYSTEM (Document Revision 1.0)

FEATURES

- Objective, scalable quality control of PA speakers
- Fast and simple to operate
- Suitable for all passive and powered topologies
- Reliable detection of driver, enclosure and electronics defects
- Flexible limits depending on own quality standards and budget
- Full traceability

APPLICATION

- Mobile loudspeakers of any size: line arrays, near-field & stage monitors, subwoofer, full-range speakers
- Event and rental business
- Service station and refurbishment
- Manufacturer



DESCRIPTION

In commercial, public events the audience expects nothing but a flawless performance of the involved audio equipment. Especially in concerts, defects in the most stressed component of the audio system - the loudspeakers - can impair the experience drastically. For most rental houses the required effort and know-how are limiting factors for implementing a critical and objective functionality check for a large number of loudspeaker units. Therefore, simple listening test are common, which are inaccurate, highly subjective, stressful for the operator and can even damage the hearing, while critical sound pressure levels cannot be used at all. Defects may go unnoticed resulting in failure in the worst moment, in front of the audience, where no solution is available.

This application note suggests strategies to overcome these issues by applying objective, electro-acoustic testing to mobile loudspeaker systems using the KLIPPEL QC System. Complete line array stacks can be tested in one fast sequence that can be easily operated for reliable defect detection even beyond the flaws of human hearing. The main step-by-step guide addresses a full featured setup that includes a test box providing controlled conditions and insulation of peak SPL contamination as well as ambient noise disturbance.

The suggested strategies assure that problems are detected as early as possible and that your equipment leaves the door completely functional. Carrying out the tests does not require trained specialists and can be done by any staff member. The guideline includes strategies for setting up robust test limits for reliable defect detection while minimizing false alarms.

Following this guideline helps you maintaining a professional quality level of your audio systems providing a major advantage over your competition and a base for long term trust between you and your clients.

CONTENT

1 Overview

1.1 How to Use this Application Note

This guide focuses on the recommended, full-featured test scenario that includes a controlled and insulated test environment, such as a test box. This is not mandatory, but highly recommended since a free-air test comes with a lot of drawbacks. See *Further* for more details. The given information is scalable and does not have to be followed linearly or completely.

The main aspects covered in this application note are:

- necessary equipment/software and test box design
- creating and preparing tests
- data and limit management
- defect detection and analysis
- operation

For the setup and preparation there should be a dedicated QC engineer while the actual testing can be operated by any staff member.

Before starting with practical measurements, follow the instructions given in the sections *Requirements*, *Measurement Setup*, *Preparation* and *Test Settings,* carefully. After doing so, you can run tests by going through the section *Operator Testing* and interpret the results with the help of *Post-Processing and Data Analysis*.

Other applications concerning QC for rental sound equipment can be found in the *Further* section.

1.2 Test Objects

The application focuses on rental houses and their sound equipment, in particular loudspeakers of all shapes and forms such as

- Subwoofer
- Full-range speaker
- Line array
- Column line array
- Stage monitor

Other PA loudspeaker types like 100 V-speaker can be tested as well, but in this scenario, it is necessary that they are mobile to put them onto a dedicated test stand.

	All of the above can be measured in both active and passive version.
1.3 Principle	
	A single device test consists of the following steps **1 – Setup** The first step includes preparing the device under test (DUT), positioning the microphones, connecting all the necessary cables and selecting the correct test sequence depending on the DUT model type. **2 – Measurement** Next, the electro-acoustic quality check is run. Depending on the used test steps, different stimuli will excite the DUT and the recorded response are processed. This yields the result parameters that are compared against PASS/FAIL limits. The test verdict is displayed to the operator and the result data is stored. **3 – Result check and defect diagnostics** In case of a failed test, diagnostics tools can be used to locate the defect and analyze the root cause. Since the waveforms and result parameters of every single test run are logged, it is possible to review the curves and listen or reprocess to the recorded wavefiles at a later point of time. Principles of other applications are discussed in *Further* .
1.4 Results	
	The goal in quality assurance is to provide critical and meaningful test parameters to ensure consistent product quality and specification sheet compliance as far as applicable.
Basic Acoustical Parameters	The following results are based on measurement with a continuous log sweep: • Sound pressure level magnitude over frequency (fundamental frequency response) • (Phase and polarity) • Impulsive distortion over frequency (Rub & Buzz) • (Total) Harmonic distortion (THD, 2nd, 3rd, HI-2,…) over frequency • Average level (sensitivity and maximum SPL) • Multi-point/band levels • Ambient noise (opt.)
Air Leak Detection (opt.)	A dedicated, optional air leakage test can be integrated with the sweep measurement or added as an individual test using a single low frequency tone. This additionally yields: • Modulated noise (absolute and relative) – leakage and port noise • Deterministic (leak) distortion (absolute and relative) – based on higher order harmonics
Electrical & Mechanical Parameters (Passive DUTs only)	• Impedance (magnitude and phase) • Minimal impedance • T/S parameter (subset) including vented box parameters* • Voice coil offset* • Stiffness asymmetry* *Note:* Impedance and T/S parameter measurement are only available using KLIPPEL analyzer devices. **requires direct access to individual transducer terminals without crossover*
	There are many more useful results, depending on what optional tasks are used. Please refer to *Optional Modules* in the *Software* section. *For result analysis, please see the section Post-Processing and Data Analysis.*

2 Requirements

2.1 Hardware

Analyzer or Audio Interface	• **KA3 – KLIPPEL Analyzer 3 LSX default configuration** (Item No. 2000-300) equipped with: ○ Laser Card (2x BNC mic input with IEPE power) ○ XLR Card (2x XLR input, 2x XLR output) ○ Speaker Card (2x speakON speaker outputs, 1x speakON stereo amplifier input) • alternative: 3rd party audio interface (sound card) – restricted to acoustical and line signal tests  *KLIPPEL Analyzer 3* *Note: The QC Standalone software is required for operation without KLIPPEL analyzer.*
Mobile Rack Mount	To put together the *KA3* and other components listed in this section, a mobile 19-inch rack mount is highly recommended.
PC	A *Windows* PC is required to operate the KLIPPEL software. A laptop or rack mount PC is suitable for this application. See separate document *KLIPPEL PC Requirements* for further information. An internal sound card is highly recommended for diagnostics based on auralizing the microphone and distortion signals.
Microphone	The **MIC 40PP** by G.R.A.S (Item No. 2400-330) is a cost-efficient microphone choice that can be used for all purposes addressed here. Alternatively, rugged microphones like 146AE or 147AX are available for increased mechanical robustness or clip mounting.  *MIC 40PP* For optimal results, you should have 1 microphone on axis for every sub-unit tested in one sequence (e.g. 4 microphones for 4-unit line array stack on a transport dolly). However, for the reason of simplicity and cost, it is possible to have less microphones in use, which is explained in *Hardware Setup*. Three more microphones can be added, optionally • ambient noise microphone • air leak detection microphone (back side for DUT) • hand-held diagnosis tool microphone (can be any existing microphone) Additional equipment for multi-channel measurement may be necessary: • XLR-BNC adaptor for use with 48 V XLR input (Item no. 2300-102) • Microphone multiplexer (see next section) For use with *KA3 XLR Card*, phantom powered microphone can be used.
Input/Output Switcher	In case more than 4 microphones or 2 DUTs are used in one test sequence is needed, additional switchers are available.  **Microphone Multiplexer** A microphone multiplexer (*Multiplexer BNC*; Item No. 2800-101) can switch up to 8 microphones, sequentially. **Output Multiplexer** For testing a stack of line array elements an additional switcher is required (*XLR-Out Multiplexer*, Item No. 2800-103 or *SPEAKON-Out Multiplexer*, item No.2800-104).
Amplifier	Powered loudspeaker systems can be connected directly or with an appropriate adapter to the KA3 or Multiplexer, respectively. Passive systems however do need an

	external amplifier to run the tests. It should meet the required peak power requirements of all tested speaker types. Find more requirements in *KLIPPEL Amplifier Requirements*.
Adaptors, Distributors, Custom Cables	KLIPPEL products listed in this section come with their own cable set. However, if further cables or other lengths are required, KLIPPEL can provide them. However, only cables with BNC, XLR and speakON are available. For any other connector type, a suitable adaptor must be provided. For covering a wide palette of different connectors, an adapter/distributor box or wall terminal might can be a good choice. Further Information can be found in the *Hardware Setup*.
Optional QC System Accessories	**Manual Sweep Controller** (Item No. 2800-005)  For a quick and easy way to control the frequency and voltage in manual sweep mode, KLIPPEL provides a dedicated 3d controller with intuitive and ergonomic handling. Refer to *QC Manual* for more information. **Temperature & Humidity Sensor** (Item No. 2800-011)  Changing climate conditions between seasons in non-controlled environments can have significant impact on the DUT behavior and thus the result data may vary. This may even affect set limits and grades. This optional sensor provides automatic temperature and humidity monitoring with every test for traceability. **QR/Barcode Scanner** (Item No. 2800-004)  A *QR/Barcode Scanner* can be used to scan the DUT serial number label for the purpose of traceability and even for selecting the correct test sequence automatically. This also helps to exclude any potential mistakes by the operator to choose the wrong test.
Diagnostic Tools	 In case a DUT fails the test, usually further diagnostics is required to trace the location and root cause of the failure in order to identify either flaws in the setup or to provide a better error description to the workshop staff. To do so, you can use the in the integrated manual sweep generator in combination with the live monitoring feature. Any cost-efficient available microphone can be used as a hand-held "stethoscope" while an insulated head- or earphone (e.g. drummer headphones) provides hearing protection while playing back the microphone signal at the isolated defect distortion at a safe level. More details about the tools and how to configure and use them, can be found in the *Setting up Manual Diagnostics* and the *Operator Testing* section.
Optional Radio Link	If cables should be avoided during live diagnostics, a radio link for both the microphone and the headphones can ease the handling. For this purpose, any existing radio link may be used (e.g. Bluetooth® wireless technology for the headphone link).

2.2 Software

KLIPPEL QC Software	This application note will mainly address the workflow using the KLIPPEL QC software distribution based on **QC Standard** license (Item No. 4002-010). This set includes test tasks such as *Sound Pressure Level* (*SPL), Impedance (IMP)* and *Spectrum Analysis (SAN)* among others. The framework software *dB-Lab* is the base for any measurements. To get in touch with the software, feel free to use the tutorial provided when starting and see the *dB-Lab Manual* for more information. For testing exclusively with 3rd party audio interfaces (without KLIPPEL analyzer connected) *QC Stand-alone Software* license (Item No. 4004-500) is required.

	In all cases a USB license dongle and the QC Start test management software is provided. See *Test Settings* section for further information.
Additional Modules	• **QC STAT** – Statistical Analysis (Item No. 4000-225) – recommended for data pool statistics and meaningful limit setting. See *Post-Processing and Data Analysis* section for a detailed description. • **QC ALD** – Air Leak Detection (Item No. 4000-240) – **recommended** tool for testing air noise caused by transducer or enclosure leakage and irregular vented box port noise
Optional Modules	• **TFA** – Time-Frequency Analysis – recommended tool for intuitive Rub&Buzz diagnostics based on STFT or wavelet spectrogram • **QC PNI** – Production Noise Immunity (Item No. 1001-107) – for advanced ambient noise handling • **QC ALS** – Air Leak Stethoscope (Item No. 4000-243) – recommended diagnostics tool for localization of air leaks and port noise in loudspeaker systems • **QC MSC** – Motor + Suspension Check (Item No. 4000-230) – for fast measurement of nonlinear driver parameters like voice coil offset and suspension asymmetry • **QC SYN** – External Synchronization (Item No. 1001-107) – to synchronize digital audio and trigger open-loop tests (option for QC tasks)

2.3 Test Enclosure

	A dedicated test enclosure provides major benefits over testing in free air. First of all, it provides a controlled and reproducible mounting and acoustic environment. Furthermore, ambient noise disturbance is lowered and thus defects can be identified with better sensitivity without false rejects. The sound attenuation also allows testing at more critical levels (> 100 dB SPL) while keeping harmful peak SPL and annoyance low for all staff members. The following acoustical effects should be considered when constructing a test enclosure. • Room modes (standing waves) • First reflections • Rattling/parasitical vibration • Pressure chamber effects in small enclosures (increases SPL) Strict guidelines are not required or useful, but here are some practical remarks.
Stability	First of all, it is crucial to have stiff and stable walls without any lose parts in the room to avoid any rattling or parasitical vibrations as good as possible. Especially subwoofer operation can trigger vibration when driven at high SPL which can be misinterpreted as defect symptoms (Rub&Buzz).
Dimensioning	When it comes to size, clearly, there must be enough space to accommodate all required hardware components (e.g. mic stand) and maneuver the DUT freely. The higher the enclosed air volume, the better can acoustical problems be handled (e.g. pressure chamber effect, increasing the SPL at very low frequencies which may result in microphone clipping). A benchmark for subwoofer is a volume of at least 12 m^3. A semi-open enclosure will bypass this effect but also provide poor sound attenuation. More information about how to dimension the volume and other aspects on test enclosures are given in the application note *Test Enclosure for QC* (AN46).
Sound Insulation	Furthermore, sound insulation is a main advantage to lower the test signal SPL outside the enclosure and attenuate ambient noise disturbance. The wall material thickness and mass define the maximum attenuation (the higher the better). Make sure to avoid any holes or gaps in the enclosure construction and use sealing tape. There is a full guide on *How to Measure Box Attenuation?* in the *QC Manual*.

Sound Absorption	In order to achieve free-field-like conditions for mid and high frequencies, sound absorber material such as acoustic foam can be installed inside the enclosure. This can help lowering the first reflections, reverberation time and noise level inside the enclosure. This positively affects the fidelity of the frequency response. The required thickness of the absorber depends on the material and desired cut-off frequency and can usually can be determined by checking the data sheet.
Cable Terminal	The cables necessary to connect the DUT, microphones and the diagnostic tools need to enter the enclosure at some point. A properly sealed, simple cable feedthrough hole is basically sufficient but a wall connector terminal might be a good choice to avoid additional adaptors.
Peripherals	Also, there are some peripherals necessary for the setup like a microphone array stand, a dolly for smaller DUTs and a positioning aid for both the mount and the loudspeaker dolly. Those things will be discussed in detail in the *Test Enclosure Setup* part of the *Measurement Setup* section.

2.4 Environment

Noise Management	In terms of noise there are two major problems when testing: • External noise disturbing the test • Noise emitted by the DUT during the test
External Noise	A major part of the external noise can be attenuated by the enclosure, if well-built and fully closed. Additionally, locating the test station far away from major noise sources helps lowering the noise floor within the test environment. The worst problems are impulsive noise sources (e.g. forklifts) corrupting the measured data. However, if the enclosure insufficiently blocks impulsive noises, this can be managed by the *PNI* add-on mentioned in the *Software* section. Basic ambient noise detection is part of the *QC Standard* software, but either way you need an extra ambient noise microphone outside of the test chamber.
Test Noise	Running speaker tests at realistic application levels, the staff needs to be protected to avoid hearing damage and annoyance. To test maximum SPL output and detect level-dependent defects reliably, the volume rises to levels beyond the permission of occupational safeties from many countries. Again, a good sound insulation of the test enclosure is a major key. If this cannot be applied, ensure that the operator and other staff members close by wear hearing protection. This is especially important during diagnostics inside the test enclosure in presence of high SPL signals (e.g. sound insulating headphones).
Climate Conditions	As mentioned earlier, air temperature and humidity conditions can affect the DUT behavior and thus the test results. Defining reasonably wide test limits to account for the fluctuating climate over the year is not always practical. If available, controlling the temperature in the stock and the test enclosure is recommended to reduce this influence. Also avoid testing speakers right after use (hot state) or after being transported in very cold conditions, is possible.

3 Measurement Setup

3.1 Device Under Test (DUT)

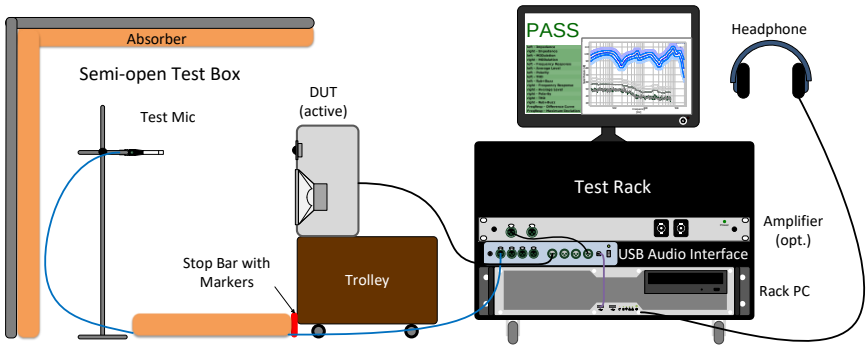
Types	This application note is focused on the quality measurement of the loudspeaker types listed in *Test Objects*. Both powered and passive DUTs can be tested both individually on a test stand or trolley or grouped in arrays on transport dollies as described in more detail below.

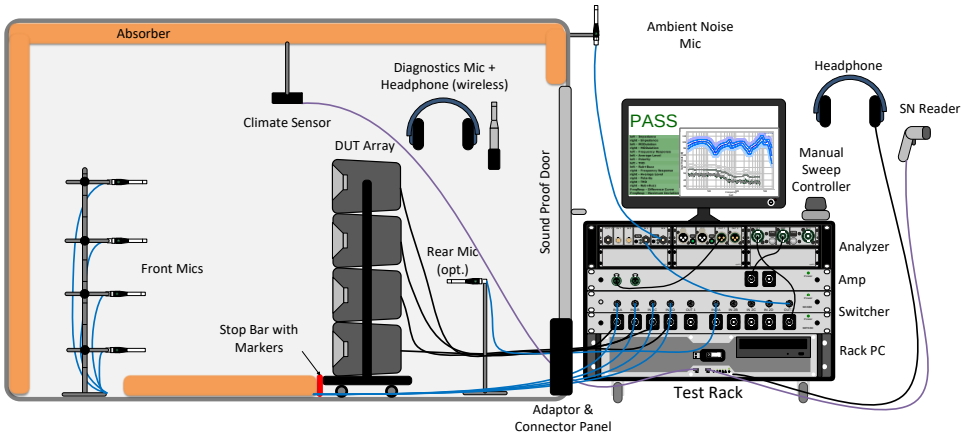
Avoid Rattling	Measuring flown line array stacks would be optimal since it is close to application conditions, performing the tests directly on the transport dolly is desirable since it reduces mounting effort and simplifies handling drastically. However, the test conditions are not fully appropriate since the high SPL during the test can excite vibration in any lose parts such as grid plates and bolts for connecting array elements. The resulting rattling can be misinterpreted as a loudspeaker defect. In doubt, check for parasitic vibration using *Manual Diagnostics* and try to remove or fix those parts using plasticine or tape.

3.2 Test Enclosure Setup

	For information and requirements related to the enclosure construction, see the *Test Enclosure* part of the *Requirements* section.
Microphone Mount	An adjustable microphone stand should be provided to mount the microphone (array) • Microphone height(s) should be adjustable to main radiation axis of the DUT(s) • Mark certain microphone positions for the different DUTs to quickly adjust • Avoid reflective surfaces or flush-mount microphones (absorber material can also lower reflections) • Fix the mount on the ground to prevent any misplacement, vibration or rattling. Use damping material, if necessary *The GRAS 147 AX microphone provides a dedicated mounting system based on magnetic clips that can ease fast and reproducible microphone positioning.*
DUT Mount	A cart or test stand may be required for small DUTs that cannot be placed directly on the floor. • Needs stable wheels to be mobile even with heavier DUTs • Add positioning marks for all DUT types
Positioning Aid	Provide a positioning aid to ensure reproducible DUT placement. • board or rails fixed to the ground • 1-meter horizontal distance between DUT and microphone is mostly used and recommended • Add position marks for all DUT-dolly types and mounts
Additional Absorbers	Extra acoustic absorber material may be put on the ground between the microphones and the DUT to attenuate ground reflections.

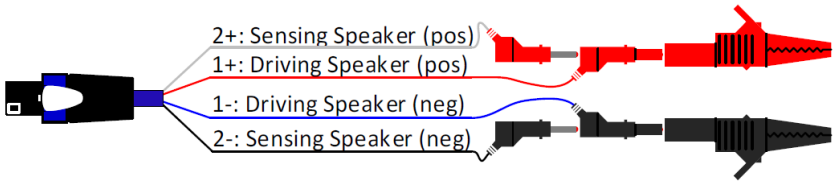
3.3 Hardware Setup

	The test setup for this test application can be created in many different ways, depending on the requirements and capabilities. For general hardware requirements and necessary components, to *Requirements* section.
Minimum Test Setup	To perform a basic test, you need at least the minimum components from the following scheme.  This setup shown above uses only one microphone, an open test enclosure and a USB audio interface instead of a KLIPPEL analyzer. Consequently, the following restrictions apply:

	• Single, fixed or adjustable microphone position – on-axis measurement impossible for stacks/arrays • Poor ambient noise attenuation (noise floor) • Limited test level (wear hearing protection) • No electrical tests for passive DUTs *If you are using a 3rd party audio interface for testing, refer to the Setup with Audio Interface (QC Stand-alone Software) section in the QC Manual before going ahead.*
Recommended Test Setup	This scheme shows the full-featured, optimal test setup.  The mobile test rack contains • PC with monitor or laptop • *KLIPPEL Analyzer 3* • Power amplifier (passive DUTs) • QR/bar code scanner • For more than 4 microphones or 2 DUTs in one test sequence: multiplexers • If there are DUTs with other input plugs than speakON or XLR: adapter box • *Optional:* manual sweep controller • *Optional:* headphones • *Optional:* wireless transmitters for diagnostics tools Inside the enclosure there should be • Front microphones mounted on an array stand • Diagnostic tools (microphone and headphones) • Optional: climate sensor • *Optional:* air leakage test microphone(s) behind the DUT(s) • *Optional:* power supply or power plug/distributor (for speakers) In case the ambient noise detection or *PNI* features are used, place the microphone outside of the enclosure in an exposed position.
Microphones	Regarding microphones there are four different functions to distinguish in this application: • Front microphone (main test microphone) • Rear/side microphone (air leakage test) • Ambient noise microphone • Hand-held diagnostics microphone All of the above but the diagnostics microphone should be professional measurement microphones as those recommended in the *Hardware* section.
Front Microphone	The front microphones are the most important sensors for the QC test. For testing DUT stacks (e.g. line array dolly) it is recommended to have one dedicated on-axis microphone for each element for the following reasons: • Optimal frequency response (no HF off-axis decay) • Better consistency and comparability of the individual responses • Easier limit setting (e.g. possibly identical limit for all units)

	• Optimal sensitivity for defects
Additional Test Microphones	Optional rear/side microphones can be added to detect irregular noise caused by rattling panels, port noise and enclosure leakage using the *Air Leak Detection (ALD)* task with optimal sensitivity at all positions by reducing impact of acoustical shadowing.
Ambient Noise Microphone	Using the ambient noise detection of the *QC Standard* software or the *Production Noise Immunity (PNI)* add-on for auto-repeat and merging requires a dedicated microphone outside of the test enclosure. Refer to *How to Cope with Ambient Noise?* in the *QC Manual* and the specification *S21 – QC PNI – Production Noise Immunity* for more details about the topic.
Diagnostics Microphone	As stated in the *Hardware* section, this hand-held microphone is useful for defect localization and root cause analysis right at the DUT. There are no strict requirements and therefore a cost-efficient stage microphone with sufficiently low self-noise may be used, but it needs an XLR or BNC port (or a suitable adaptor) to connect to the *KA3/Multiplexer*. Also refer to *Setting up Manual Diagnostics* and the *Manual Diagnostics* part of the *Operator Testing* section.

Connecting the Components	• Connect the analyzer (or audio interface) to a USB port of the PC using the USB cable provided by KLIPPEL (avoid hubs or front USB)
	• Connect the output(s) of the analyzer (XLR Card OUT and/or Speaker Card OUT) to the B input(s) of the multiplexer(s)
	• Connect the microphones depending on the total number
	  ○ Up to 4 microphones: use *IN3/IN4* of the *KA3 Laser Card* and the *IN1/IN2* of the *KA3 XLR Card* (also use an XLR-BNC adaptor for microphones with IEPE supply here and activate 48 V phantom power supply)
	  ○ 4-8 microphones: connect the B output of the *BNC Multiplexer* with the *IN3* of the *Laser Card* and use *CH 1-8* of the multiplexer to connect all microphones
	• If available, connect the input of your amplifier with *OUT 1* of the *XLR Card* and the *AMP* in (NL4 stereo) of the *Speaker Card* with the output of your amplifier
	• Connect the USB license dongle to the PC or laptop
	• Optional: Connect the Bar/QR code reader, Temperature & Humidity Sensor and/or Manual Sweep Controller to USB ports of the PC (a hub may be used)

Adaptor Box	In most cases, a custom adaptor box needs to be provided in order to connect DUTs that have other connectors than 3-pole XLR or speakON connectors, as provided by the analyzer hardware outputs and switchers. In addition, the NL4 speakON outputs of the analyzer use a special configuration to realize a 4-wire impedance measurement at the speaker terminals using the second pair of wires as sense line instead if second stereo channel. To measure properly you need to connect the force- (1) and the sense-wires (2) coming from the KA3 or as shown in the figure.  The clamps represent the adaptors terminals. *Find an extended guide in the KLIPPEL Hardware Manual.*
Cable Feedthrough	As mentioned in the *Test Enclosure* section, make sure so seal the cable feedthrough after installing all cables.

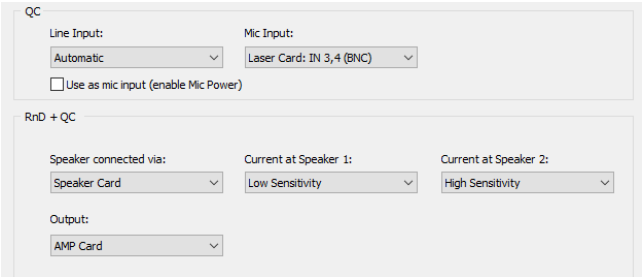
4 Preparation

4.1 Global Signal Routing (only for KA3)

Skip this section if you are using a USB audio interface for testing.

For *KA3* hardware it is required to set the global signal configuration depending on the general test setup and card configuration. In the *Signal Configuration* dialog, the physical hardware channels are assigned to the routing channels available in the QC operation.

- Start *dB-Lab QC*
- Open *KA3 Signal Configuration* dialog via menu *Extras – KA3 – Signal Configuration* or the symbol in the *dB-Lab* task bar



- *Mic Input*: assign the *Mic Input* to *Laser Card* or *XLR Card* depending on your configuration
- *Line Input*: if more than two microphones are used or the microphone response of the DUT shall be tested, assign *Line Input* to *XLR Card*
- *Output:* select the signal output used for connecting the DUT to *XLR Card*

Note: These global settings are bound to the *dB-Lab* version on your PC and will apply to all tests opened by this *dB-Lab* version. However, they can be changed at any time.

Find more information in *Hardware Manual* section *KA3 Signal Configuration*.

4.2 Calibration

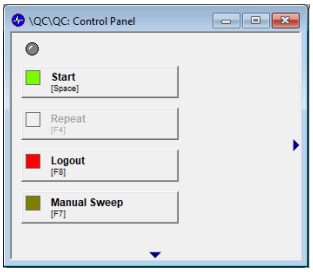
Calibrate Sound Card Input / Output	*This step is only required in case a USB audio interface is used for testing and absolute output voltages need to be used (e.g. to set the correct output voltage for active sound source input). For adjusting correct SPL reading of the sound card inputs with the connected microphones it is recommended to use a microphone calibrator and proceed with the next step.* Please refer to section *3rd Party Audio Device Calibration* in *QC User Manual*.
Calibrate Microphones	For all available test microphones (including external ambient noise mic), calibration data must be available before use (except for the diagnostics microphone). **KLIPPEL Analyzer** • Access microphone calibration via *QC Start – Calibrate – Klippel Analyzer* or *dB-Lab* menu *Extras – KA3 – Calibration for QC Operations* • In the *Property Page – Tasks*, select *Microphone / Sensor Calibration* to set the calibration mode or enter calibration sheet data (sensitivity and max. SPL) **USB audio interface** • Access microphone calibration via *QC Start – Calibrate – 3rd Party Audio Device* or *dB-Lab* menu *Extras – 3rd party audio device – Calibration for QC Operations* • Open *QC Property Page – QC Settings – Configure Hardware* and select your device as Input device, then log in • In case last step has been skipped, using a sound calibrator is mandatory to calibrate the complete input signal chain for correct SPL reading
Using Calibration Sheet Data	• To start with manufacturer calibration data, select *Calibration Mode – Enter Microphone Sensitivity* and enter *sensitivity* and *max. SPL* from the calibration sheet provided by the manufacturer or KLIPPEL

	• Click *Calibrate Mic* button in the *Control Panel* to store the entered data
Using Microphone Calibrator	• If you want to calibrate with a reference device select *Use Pistonphone* • Enter the *Test Frequency* and *Test Level* according to your calibrator device • Select the input channels you want to calibrate one by one, enter max SPL from spec sheet and click *Calibrate Mic* to calibrate the selected channel after activating and attaching the calibrator to the corresponding mic Find a complete guide and more information in QC User Manual section Microphone & Sensor Calibration in the Calibration / Check of Accuracy chapter. *Note that at the time there is no possibility to calibrate single inputs in a microphone multiplexer. Therefore, it is recommended to use the microphone inputs in the laser and/or the XLR card or at least microphones with roughly matching sensitivity.*
Amplifier Gain	• In the same window as for the mic calibration you can find the amplifier gain calibration • Please refer to the section *Amplifier Gain Calibration* in the *Calibration / Check of Accuracy* chapter in the *QC User Manual* for the full guide

4.3 Multiplexer Configuration

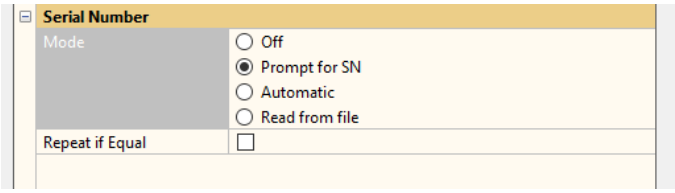
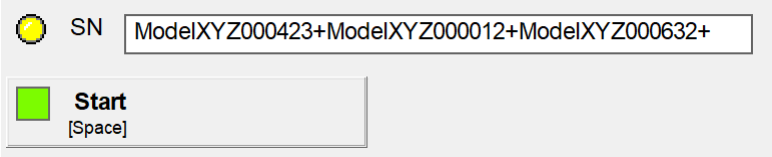
	The multiplexer configuration depends on the use case and hardware setup, but for default application, *single 1 out of 8* (1x8) mode is suitable. If both outputs and inputs (microphones) shall be switched simultaneously (line array stack), all multiplexers may use the same Digital I/O Control Switch setup resulting in matching channel assignment. To understand the multiplexer modes, functionality and how to configure your hardware for QC tests, please Multiplexer Manual. *Note: The ambient noise microphone should always be active, do not connect it to a multiplexer. Air leakage microphones should be used with other inputs for simultaneous measurement together with the front mics.*

4.4 Find Test Templates & First Test

	The *QC Start* software comes with test templates for typical applications that should be used as a base when setting up a new test sequence. For using a template • Start *QC Start - Engineer* • Select *Test - Create New Test…* • Type in a name and press the ··· button in the *Template* line • For testing complete speakers, navigate to *System* category and pick a suitable template for your DUT • In *Subfolder* line you can choose whether you want to store the test sequence in sub-folder of your test root folder for better organization  • Choose a suitable name (Note: if you want to use bar code mask for auto test selection, please make sure that you follow the defined name scheme) • Finish with *OK* and press the *Measure* button to login • In most base templates, two steps (*tasks*) are included: *Sound Pressure* and *Impedance*. (*Note*: The *Impedance* task is only applicable to passive systems; the *Control: Start* and *Control: Finish*-task are beginning and ending of each test and can´t be deleted) • The properties window is where the tasks and test limits can be configured. Access with the button or [Alt] + [Return] • Go to *Tasks* tab, click on the *Control: Start* task and make sure the global *Routing* is correct • Now use the *QC: Control Panel* to start the test by pressing the *Start* button or [Space] (check the voltage settings in the individual tasks first - the default values are relatively low) • All listed tasks will run one after another and the results appear in the charts 

	• Finish the test run by clicking the *Logout* button [F8] With that out of the way, you know the very basics for running a test. See the *Settings* section to learn how to prepare a test on your own.

4.5 Serial Number Management

Overview	A coherent serial number system of all DUTs is crucial to assign the tests results to the correct DUT, for data analysis and traceability. It can also ease test selection for the operator.
Auto Test Selection	You may use the serial number label of your DUT to automatically select the matching test sequence by scanning its bar code. To use this feature, a coherent serial number system for your devices is required where each serial number includes an alphanumeric prefix with fixed number of characters that codes the model type. For more information read *How to Use Bar Code Reader Input* in the *QC Manual* section *Organizing Projects using QC-Start.*
Setup	Also, make sure to have serial number input activated in the *Control: Start* task of every test. This allows to enter or scan the DUT serial number before each test run. Configure your bar code scanner to work as keyboard wedge and do not append "Return" so the test is not started immediately after scanning.  *Note: When testing stacks with more than one DUT at a time, the test procedure differs to having only one. In this case, usually four different serial numbers must be entered, one for each routing block in the test sequence. This is not natively supported, but a strategy is given in the next section.*
Handling DUT Stacks (e.g. line arrays)	• Open *QC Start* • Scan the top DUT in the stack for automatic test identification or, select a suitable test and click *Measure* to login • Scan all the DUTs barcodes from top to bottom separating them with a [+] like in the example for four DUTs (note that [Space] bar starts the test!)  • Run the test by pressing *Start* button or [Space] The data logging will create a test file in the test folder with the entered name of all serial numbers. If results of an individual DUT needs to be monitored or post processed, search the results folder for its serial number to see all test runs with that DUT. This is especially helpful for long-term monitoring.

4.6 Gauge R&R Test

	Gauge R&R is a measurement systems analysis method that analyses the repeatability and reproducibility concerning your complete test setup with all influencing factors. This analysis is not mandatory, but highly recommended in order to know how stable the results in your test setup are an to identify potential flaws that could be fixed. It also crucial for defining the bottom-line variance for defining reasonable test limits to avoid false failed tests. • **Repeatability**: variation in measurements under the same conditions taken by a single person on the same DUT

- **Reproducibility**: variation induced when different operators or instruments measure the same DUT

Though, it is a rather complex topic overall, you can perform these tests meaningful enough in a simple practical manner by

- Running the same test 25 times with a full range speaker and without moving it
- Running tests with 3 different operators and 3 different DUT 25 times each for a total amount of 90 tests, while detaching, removing and reposition the DUT between each test

A possible "serial number" scheme for data logging could be:
Operators-Initials_DUT-Name_Consecutive-Test-Number (Example: *MG_SB15P_1*)

Hint: To prevent re-entering the full string after every test, make sure to always have the current test name in the clipboard by marking the name and press [CTRL + C]. Re-enter by pressing [CTRL + V] and adjust the consecutive number.

When all tests are done you can determine the general deviations of your measurement environment and deviation caused by the operator on basis of the results.

To evaluate the results of Gauge R&R tests it is highly recommended to use the KLIPPEL STAT module described in the Post-Processing and Data Analysis section. However, it is possible to analyze the data with other software tools such as Microsoft Excel.

4.7 Measure Test Enclosure Attenuation

After evaluating the validity of your measurement setup within the enclosure, the effective sound attenuation between the inside and the environment should be characterized. This is important to know for both the limit settings and potential noise monitoring since the effective attenuation curve should be entered in the ambient noise settings for optimal performance.

KLIPPEL provides a full guide on *How to Measure Box Attenuation* in the *QC Manual*.

4.8 Setting up Manual Diagnostics

Manual Sweep

The suggested main tool for manual diagnostics after a DUT has failed the test is the *Manual Sweep* feature, which is a straight-forward sine sweep generator with a simple analyzer and simultaneous audio playback for microphone or *Rub&Buzz* monitoring.

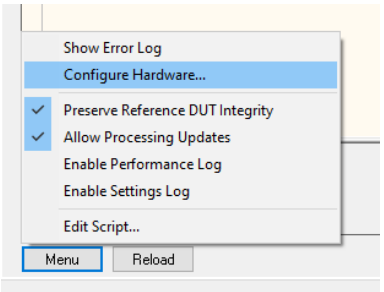
The tool can be started directly from operator *Control Panel* (activate *Configuration / Allow Manual Sweep* in the *Control: Start* task).

For details refer to the section Manual Sweep in the QC Manual.

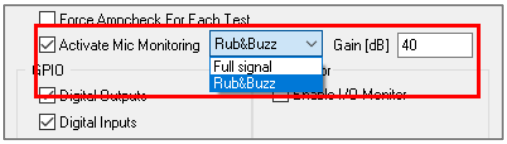
Mic Monitoring

For an intuitive diagnostic using the mic as a stethoscope probe, the mic monitoring feature should be activated to be able to listen to the microphone signal.

- Opening *Menu / Configure Hardware…* in the property page



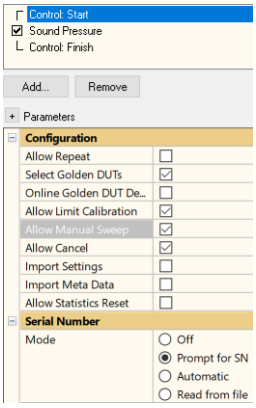
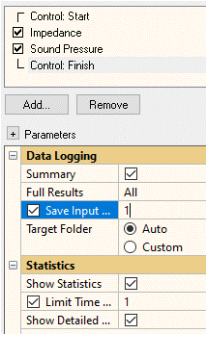
- *Activate Mic Monitoring* for either the *Full Signal* or the *Rub&Buzz* filtered signal
  - It is recommended to use *Rub&Buzz* since it suppresses the main test signal and makes it easier to hear and locate defects
  - Note: *Rub&Buzz* usually needs a gain boost in order to make it audible; also use Windows system volume to adjust playback level

	 • The response signal of any measurement is now played back via the Windows default playback device Find more information in section *Live-Monitoring of Microphone Signal* of the *QC User Manual*

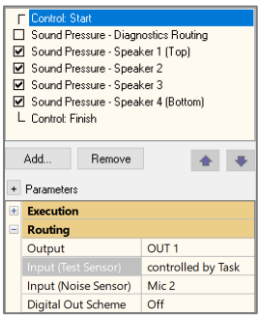
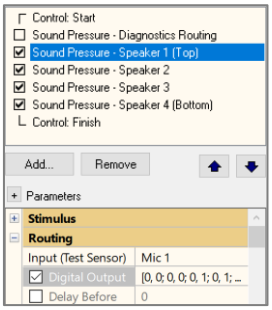
5 Test Settings

5.1 Creating a Test	
	To create your own test, you may either start from scratch or choose a provided template according to your DUT (recommended).
Using a Template	For using a template, follow the steps in the *Find Test Templates & First Test* • Choose the appropriate DUT type in the *PA + Stage* template category • Make sure to follow your global naming scheme for barcode-based test selection or type in the name of the manufacturer and the particular model • Optional: With every created test *QC Start* will create a folder which comes with a HTML file "*testinfo.html*" that can be customized with your company logo, a product photos and operator instruction (refer to *QC User Manual* section *How to Add Test Instructions*) The following base templates have been created for this Application Note (from QC 6.7) • Line Array Stack (Powered) • Line Array Stack (Passive) • Fullrange Speaker (Powered) • Stage Monitor (Passive) • Subwoofer (Passive) • Subwoofer (Powered) Alternatively, choose from the other more general templates in the *System* category. *Note: The general templates are dedicated for different general setup scenarios to get an idea about possible approaches. It is always necessary to adjust settings according to your setup, DUT and requirements.*
Start from Scratch	You can also choose to start from scratch without any presets using the *Empty Test* template. *Note: This requires advanced knowledge in electro-acoustical measurement and is recommended only for experienced users.*
	Before proceeding with modifying individual test settings, make sure both the global and the local signal routing are correct, as described in the Preparation section

5.2 Control Task Settings

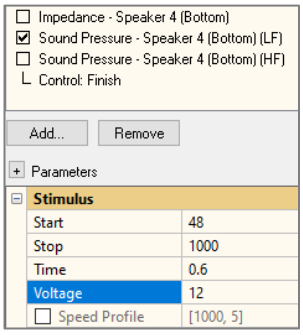
Control Panel Setup	In *Control:Start* you can adjust important settings for the operator interface such as activating serial number input and configuring the available buttons on the *Control Panel*. • *Prompt for SN* should always be activated while the *Configuration* settings may be adjusted according to the requirements. • *Limit Calibration* is a powerful feature to readjust limits based non a selected "golden" DUT which is often not applicable in this application context. • *Allow Manual Sweep* should always be active in order to allow the operator	
Data Logging	In *Control:Finish*, make sure that data logging activated for each individual test sequence. • *Full Results* is mandatory for "lossless" logging of all results and settings and import into the statistics module. • *Summary* is an optional simple log file for overview. • *Save Input Signals* allows storing the recorded sensor responses as wave files which are highly valuable for diagnostics post-processing (e.g. with *TFA*), listening tests and can even be used for reprocessing the result with different analysis settings.	

5.3 Signal Routing

	Setting correct routing is crucial and highly depends on your hardware setup. The provided templates reflect a few use cases so you might have to adjust the settings of the selected templates to adapt it to your setup. Signal routing for the in- and outputs can be set both globally for the complete test sequence or locally for each step.	
Global Routing	The global routing settings can be found in *Control:Start*. Here you can define whether to use a fixed output, test microphone or noise microphone channel or whether it shall be defined by each step (*controlled by task*). A fixed routing is usually required when multiplexers are used to switch channels. *Note: At least one setting must be controlled by task, otherwise the routing parameters (including multiplexer control) will be hidden in the task.*	
Task Routing	The local routing settings in each task can either take care of • Switching input / output channels and/or • Switching multiplexer channels via Digital Output. See the *Routing / Delay / GPIO control* section in the *QC Manual* for more information. *The Digital IO masks set in the templates are dedicated to multiplexers in 1x8 mode using factory default Digital IO setup for QC application.*	

Signal Sharing	When using multiple microphones for one DUT (e.g. front and rear), testing simultaneously can save time. Since most tasks only support one input channel, use the Signal Sharing to measure multiple mics responses at once. Follow the steps of the *Signal Sharing* section in the *QC Manual* to do so.

5.4 Sound Pressure (SPL) Task Settings

	Most defects with acoustic symptoms can be detected by the *Sound Pressure* task, since it covers the most important parameters like frequency response and distortion amongst others based on continuous sweep measurement. This is why most the templates include this task. If you do not use a template, make sure to implement the SPL task first. *Please refer to the Sound Pressure (SPL) section in the QC Manual for a detailed explanation of all the task properties.*
Stimulus Voltage	This parameter specifies the *RMS voltage* of the sinusoidal sweep signal defined at the analyzer output (powered systems) or the amplifier output (passive systems), respectively. It is one of the most critical settings since it defines the SPL output of the DUT during the test which affects signal to noise ratio, distortion mechanisms and trigger conditions for some defects (ensure sufficient pressure or displacement). The preset voltage level of the applications templates is quite low in order to have safe starting values.  However, in most cases the voltage needs to be increased significantly for a critical test. It is good practice to test at typical application sound pressure levels, close to the maximum SPL as stated in the device's datasheet. Carefully step up the voltage until you reach your desired target SPL (check *Average Level* or *Frequency Response*). • Leave a safety headroom of at least 6 dB SPL since the rating conditions as well as your measurement conditions can differ significantly. • In powered speakers avoid clipping by any means and make sure that limiters and other protection systems are not kicking in • Make sure to not exceed the stated max SPL of your microphones. *During setup phase you may deactivate other tasks in the sequence to skip measurement by unchecking the checkboxes next to each step in Property Page – Tasks*
Frequency Range (Start, Stop)	The sweep frequency range is the second most important stimulus setting. • Cover at least the rated frequency range given in the DUT's data sheet. • Setting the minimum below that range can also excite more potential defects since transducer displacement is high.
Results (Measurements)	In parameter group *Measurements* you can activate/deactivate individual test significantly result parameters. Recommended are: • Frequency response • Average Level • (Polarity) • THD • (2nd & 3rd Harmonic) • Rub&Buzz Add-on results (require additional licenses) • HI-2 distortion (HI-2 add-on) – "blat" distortion • MODabs & MODrel (ALD add-on) – air leak detection
Distortion Settings	Single harmonic distortion products and THD (as well as *Rub&Buzz* distortion) can be displayed on an absolute SPL scale or relative to the fundamental frequency response (or its mean). • It is recommended to select *Harmonics – Type: Relative to level* (% or dB) for most robust and comparable results. All other modes are more difficult to interpret

	(affected by Frequency Response peaks/dips) and reduce comparability between different DUTs. • Using *Harmonics- Smoothing* can increase robustness towards narrow peaks related to jitter and noise in the distortion plots
Response Normalization	This feature allows displaying the *Frequency response* relative to the Golden DUT or the average of the reference units in a separate result window. Therefore, it is very helpful to monitor deviation of the DUT vs the reference instead of interpreting absolute SPL plots. *This option is a pure display mode which is tied to the absolute frequency response and therefore not an individual test result.*
Average & Band Level Range	• *Average Level – frequencies* allows to adjust the bandwidth of *Average Level* calculation to the DUT's pass band, independent of the stimulus range (example: 60 Hz to 18 kHz) • Additionally, *Band Levels* allow testing further sub-band levels of e.g. LF, MF or HF range. This simplifies diagnostics for Multi-way systems and is less complicated than testing full Frequency Response. See the *Band Levels* section in the *QC Manual* for more information. Average Level - Frequencies [60, 18000] ☑ Band Levels [60, 2000; 2000, 18000]
Result Frequencies (Resolution)	To adjust result curve resolution, you can set the *Result Frequencies* between 3 and 24 points per octave. Using a low resolution is helpful to reduce result complexity and robustness. *For defect detection (Rub&Buzz), no information is lost when using a low resolution, since always the distortion peak of the corresponding interval will be displayed.*
Noise Monitoring	*Noise Monitoring* should always be activated in case an additional ambient microphone is available and connected in order to detect ambient noise corruption during the test. If you use a closed test box, choose *Microphone – in Box Enclosure* or better *Custom Attenuation*, if known (see *Measure Test Enclosure Attenuation*). For test in large rooms or semi-open boxes, use *in Free Air*. *Refer to Qc Manual section How to Cope with Ambient Noise? for more information*
5.5 Impedance (IMP) Task Settings	
Impedance Task (IMP)	*This task is only applicable to passive DUTs (terminal access required) and if a KLIPPEL analyzer hardware is used.* The *Impedance* (IMP) task is mainly dedicated to testing the impedance magnitude vs. frequency as well as DC (or minimum) resistance. This works for any system topology. Additionally, linear *Thiele/Small (T/S)* have a high diagnostic value since also vented box parameters (port resonance) can be tested, but in this case direct terminal access to individual drivers is required. *Parameter calculation will fail if crossovers are involved, but limiting the upper frequency range can help in this case (see below).*
Voltage	Since the impedance measurement is a "small signal" test, the stimulus *Voltage* should be set with care, typically to a much lower lever than used in the acoustic test. The level should be set as low as possible to avoid distortion, but also high enough to avoid "noisy" impedance magnitude results. *For further directions, refer to Qc Manual section Optimizing Performance.*
Frequency Range (Start, Stop)	The frequency range for the impedance test is not directly related to the *Operating Frequency Range* given in the DUT data sheet. Start with the template range (usually 10 Hz to 5 kHz) which is suitable in most cases. The *Start* frequency may be decreased for Subwoofers in case warnings are displayed or raised for strict HF units. Adjust Stop frequency in order to include or remove parts of the impedance response you are (not) interested in (e.g. for complex multi-way systems).

Results (Measurements)	In Property parameter group *Measurements* you can activate/deactivate individual test result parameters. Recommended are: • Impedance • Re • Current (N+D) – check loose contacts When direct transducer access is available (or range is adjusted to single operation band – see below) • fs, Qts • (Cmes, Lces) + vented box • Fb, Qb
DUT Type	With this parameter you can select your DUT topology required for T/S parameter measurement. Use *Resistive* when testing only impedance magnitude and Re, *Driver* when testing drive units or closed boy speakers. For vented speaker systems use *Driver in Vented Box.*
Max. Fitting Frequency	Testing T/S parameters of multi-way speakers is generally difficult but, in some cases, it is possible to isolate at least the LF unit including the vented box parameters by focusing only on the low frequency part (below crossover frequency) of the measured impedance using this parameter.

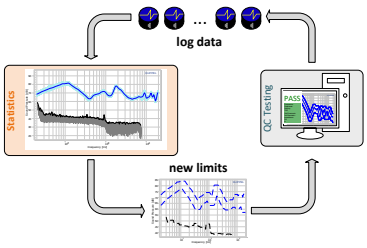
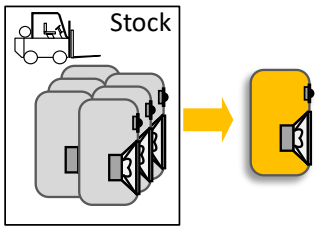
5.6 Trial Run

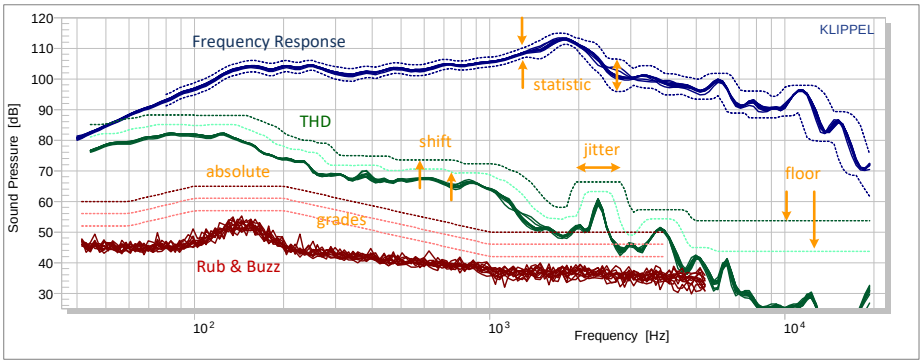
	During setup phase, usually one or more test runs are necessary to verify correct settings. After finishing initial settings, run the test sequence using the *Start* button in the *QC Control Panel*. During this phase you may deactivate all tasks in the sequence that you are currently not investigating using the checkboxes next to the tasks (mind potential multiplexer routing control, though!).  *Refer to the First Measurement section of the QC Manual for a more information about how to create and perform a test.*

6 Limits and Grading

6.1 Limits

Overview	Defining sensible tolerance limits is crucial for quality control. Therefore, it is just as important as setting up critical test parameters. When setting the limits, there is always the trade-off between • having wide and robust tolerances to prevent false alarms and • having tight limits for high quality standard and best failure detection The latter approach makes sense for very well-controlled environments and a very coherent set of DUTs with very similar characteristics. In rental equipment testing however, the main goal is to detect functional degradation and failure with sufficient sensitivity. At the same time false fails shall be prevented since the tolerances must be valid for the full stock of speaker units that may have very different age. In any case, limits must be always defined for one model type and test setup. Therefore, dedicated reference samples can easy limit setup significantly.

Setting Limits Based on Statistics	Knowing the statistical spread of your complete stock takes out the guess work in limit setting and provides a realistic point of view on the effective parameter variation. This is crucial to set reasonable test limits with sufficient tolerance. The *Limit Calculation Mode* of the QC software allows you to measure several reference units and derive shifted limits relative to the average.  The test templates come with recommended, predefined settings but tolerance values or frequency ranges may be adjusted. Find more information in *QC User Manual* section *Limit Calculation.* This is a straight forward approach when the good units are known in advance, but otherwise not very flexible. Therefore, it is recommended to test the full stock in advance using the *Statistics Module (STAT)* for basic statistical analysis and defining suitable limits.
Setting Limits with Golden DUT	This *STAT* also provides the opportunity to determine one or multiple "golden" DUTs that best represent the average, automatically. These golden DUTs are used as a representative reference unit for the whole pool and can be used to calibrate environmental influences. Furthermore, golden units can be used for setup and plausibility checks of the test setup.  Refer to *STAT Manual* section *Detection of Golden Units* for more information.

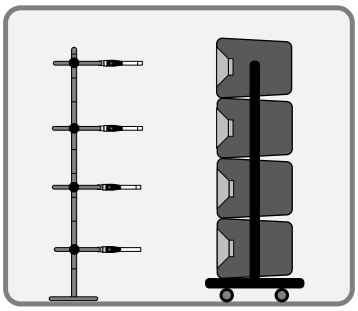
Smart Limit Setting	
	
	For robust and smart limits there are various things to consider:
	• Variance provided by your repeatability test results (see *Gauge R&R Test*)
	• Ambient conditions like temperature and humidity → use sufficiently wide limits, Limit Calibration feature or different sets of limits for different seasons
	• Prefer relative and statistical limit calculation modes over static, absolute limits
	• Consider acoustic noise floor and how it varies over the day → set limits during normal operating hours
	• Use *Jitter* for horizontal tolerance
	  ○ Frequency-selective widening
	  ○ Deal with varying peaks/dips
	• Use *Floating limits*
	  ○ Test curve shape only (test gain/absolute level separately)
	  ○ Either bound to *Average Level* or using
	  ○ *Best fit* mode
	• Frequency selective tolerance
	  ○ Use limits in pass band only (exception: *Rub&Buzz*)
	  ○ Avoid testing resonance nodes
	  ○ Increase tolerance in HF range (position variation)
	• Relative limit floor
	  ○ Define distortion limits relative to total SPL or use relative metrics right away

- Use limit floor option to set bottom line for better robustness

For more information refer to *QC Manual* section *Limit Calculation*.

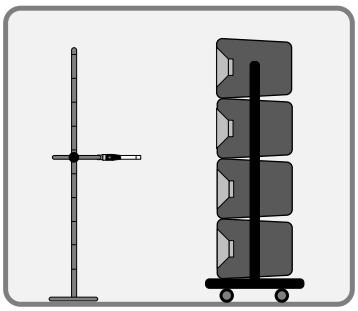
Considerations for Array Stacks

In the recommended test scenario, each DUT is tested with a microphone located on the main radiation axis. Especially in line array stacks this requires a matching number of correctly positioned mics. This provides consistent and comparable results for each sub unit, except for effects related to varying boundary conditions and room acoustics effects (floor reflections, nodes of standing waves).



With sufficiently wide tolerance, limit setup can be simplified by applying identical limits to the whole stack (e.g. imported from *STAT*).

However, if less mics are available or microphone position is fixed, this means that a DUT stack will provide off-axis results at different angles. The effects on frequency response and other parameters degrade comparability and interpretation.



However, smart limit setting can handle the differences:

- Using separate limit settings for every DUT position → more complex setup, takes more effort and time
- Keep one limit for all DUTs, crop range and widen to neglect differences → degrades capability for detecting defects
- Only test parameters that are not affected by mic position → same

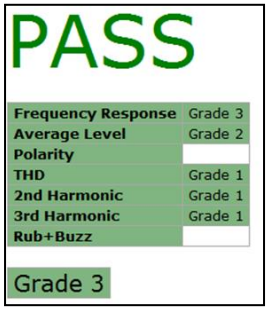
While the HF frequency response is strongly affected by mic positioning, Rub&Buzz is less sensitive towards placement (except for sensitivity loss over distance).

Note: Normalized display modes are available to display the frequency response deviation from a golden reference unit, the reference average or relative to the Average Level. Also, floating limits are applicable to evaluate shape of the response curve instead of absolute level.

Find more information in QC User Manual sections Reference units, Limit Calculation or Golden Unit Handling.

6.2 Grading

In addition to the strict PASS/FAIL limits as discussed above, additional tolerances can be used to distinguish different quality grades or defect severities. This can help to distinguish borderline units or early indications of ageing and reliability problems from real defects with severe symptoms.

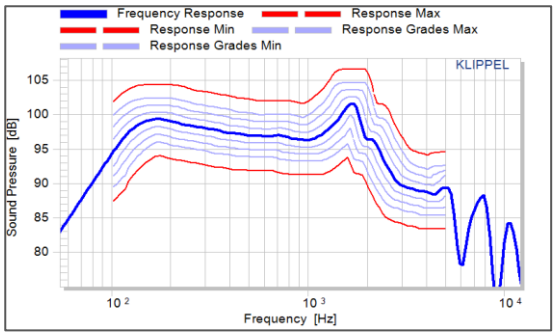


Example:

- Grade 1 – Perfect
- Grade 2 – OK
- Grade 3 – Borderline

Up to ten grades can be defined individually for each tested parameter. The overall grade follows the worst (highest sub-grade).

The image below shows a frequency response plot with three grade limits in light blue as well as Pass/Fail limits in red.

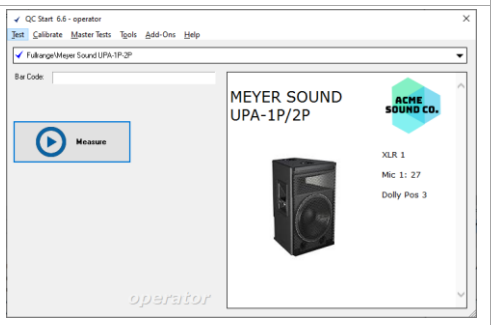


Find more information in *Qc Manual* section *Grading.*

7 Operator Testing

7.1 Select Test

1) Start the QC Start - Operator and choose the right test depending on the device under test in the drop-down list.
   Alternative: scan the barcode of the DUT if bar code test selection was configured.
2) Click the *Measure* button to open the test.



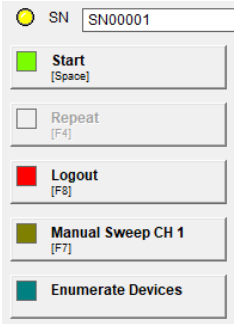
3) If the test only contains one operation (default), you will be logged in automatically. Otherwise log in by clicking the button.
4) Scan the serial number tag again to fil int the SN input filed in *Qc Control Panel*. (Attention: make sure that the reader does not append *Return*, otherwise the test is started immediately)

7.2 Hardware Setup

5) If the DUT is not provided on a dolly, put it on the test cart or stand. Place the DUT on the marked position in the test chamber.
6) *Note*: The HF drivers' main axis should aim directly at the microphone (if there are enough microphones for every DUT within the test). Some DUTs like stage monitor may be put on the side to achieve this.
7) Connect all necessary power and signal cables to the DUT and mind the correct order for speaker stacks. Note that some DUTs may provide separate LF and HF input.
8) If powered, turn on the device(s). If volume controls are available make sure that they are set to a defined default level (e.g. full) and that all DSP is switched off, if possible.
9) Align the microphone positions horizontally on axis with the driver of the DUT and check the microphone channel order.
10) Shut the test chamber or put on hearing protection

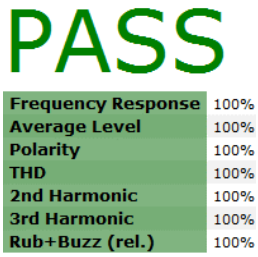
7.3 Start the Test

11) Use the *QC Control Panel* for operation.
12) Type in the serial number of the DUT if not scanned before. *Note*: If there is more than 1 DUT in one test sequence, refer to *Serial Number Management* part of the *Preparation* section
13) Use the **Start** button or press space bar to run the test sequence.



7.4 Check Results

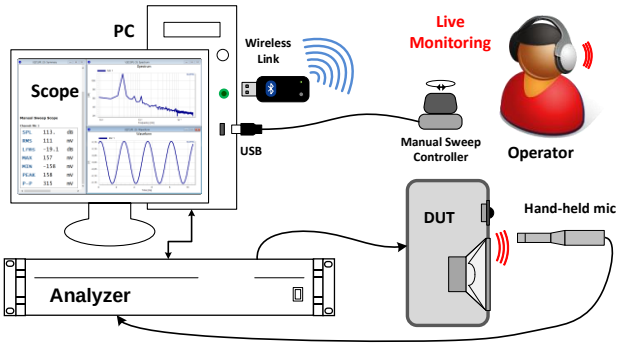
14) If all parameters give a PASS, you may remove the DUT and go ahead with the next device.
15) If one or more values give a FAIL and there is no ambient noise microphone, you may repeat the measurement once by pressing the repeat-button [F4-key] to make sure the data was not corrupted by any coincidence like impulsive noise. Also check for trivial errors (cables not connected, wrong mic position etc.)



16) If it still gives a FAIL, go on with *Manual* Diagnostics.
    If it gives a PASS, you may remove the DUT and go ahead with the next device.
17) If the DUT has passed, but *Grading* is activated and the overall grade has a low rank (high number), follow the instruction provided by the engineer.

7.5 Manual Diagnostics

Preparation

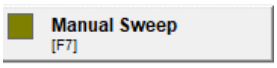
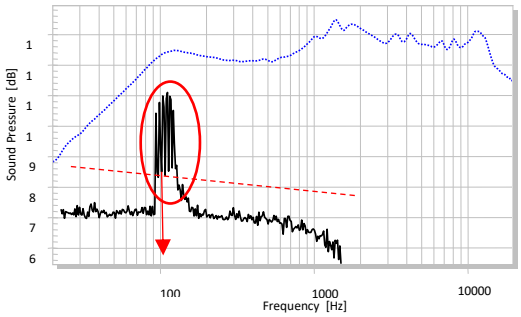
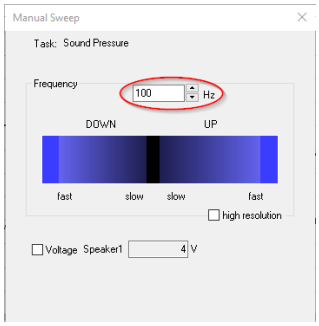


As stated in *Setting up Manual Diagnostics*, in case of a failed test you can use

- a hand-held microphone or any other available microphone (calibration is not relevant) and
- headphones with hearing protection

for tracing the location and root cause of potential defects. The optional *Manual Sweep Controller* eases control of sweep frequency and level but requires a wired USB connection.

18) If multiplexers are used, use the manual switch to select the correct output channel of the failed DUT and/or the correct microphone channel for the
19) Make sure that the headphones are connected to the PC via cable or wireless link. Also check that the required output device is selected as default playback device in *Windows Sound* settings and muting is deactivated.

Running Diagnostics	20) Start up a manual sweep by pressing the *Manual Sweep* button [F7] Note: If two buttons are available, make sure to use the right channel  21) Pick a striking frequency in the results and adjust the manual sweeps frequency to that value (e.g. excessive exceedance of *Rub&Buzz* limit)   22) Put on the headphones with hearing protection 23) Open the test chamber, if available (ensure hearing protection!) 24) Now pick up the microphone and move it closely to the DUT and try to find the origin of irregular noise 25) Most potential defects will be audible over the headphone more and more as you get closer to it *For easier handling you may use a tablet to remote control your PC and adjust the manual sweeps frequency. If you own a Manual Sweep Controller you can also use this as a way to sweep through the frequencies during the diagnostics.*

7.6 Typical Problems

Most systematic failures are related to trivial problems. Here is a list of common issues you can check through before continuing with in-depth diagnostics:

- Wrong/missing connection in the measurement rack (KA3, Multiplexer)
- False microphone position
- Twisted cables and connectors (wrong channel assignment of the DUT or the microphones in the test chamber)
- Powered DUTs are not switched on or controls are set incorrectly
- Lose connectors
- DUT is not lined up completely with markings
- Parasitic vibrations by the dolly or any lose parts in the test enclosure (e.g. forgotten tools, screws)
- Sudden fan noise of powered speakers

8 Post-Processing and Data Analysis

8.1 Data Management

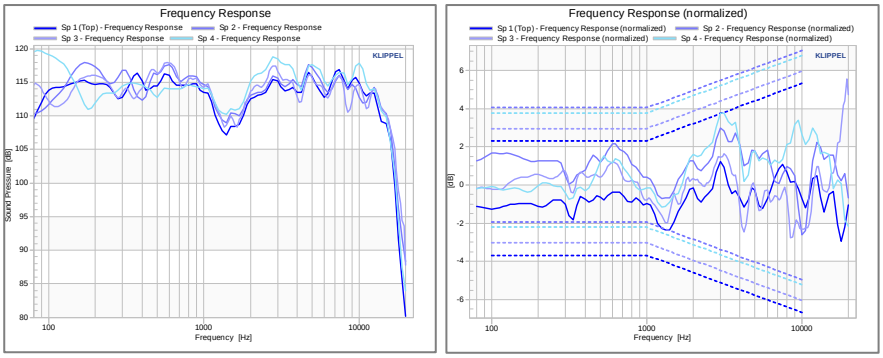
- It is recommended to activate data logging in general to ensure traceability of every tested unit by its serial number.
- For reprocessing conducted tests with different settings or limits or for performing listening tests, it is also highly recommended to activate the input signal logging to store the measured responses in wave files.
- Refer to *Data Logging* for information about setup.
- Structuring your data pool well will help you to analyze (e.g. statistics) or reevaluate them later

- Make sure to always enter a serial number for each test run (*Serial Number Management* section)
- When performing investigative tests (e.g. test run without loudspeaker grill), always add this information to the DUT's serial number (e.g. "SN123_noGrill")
- Data management for stacks that contain multiple units with individual serial numbers is troublesome – refer to section *Handling DUT Stacks (e.g. line arrays)*

8.2 Interpreting Results

Frequency Response

The fundamental frequency response is displayed as an absolute SPL in the *Frequency Response* window, while the relative plot (reference deviation) is available in a separate window as shown below.



For multi-channel or multi-device testing, the curve colors can be edited in the SPL task's *Display* settings for better visual separation. It is one of the most basic and important parameters of audio systems since it reflects spectral balance of the sound reproduction, but it is affected by room acoustics, mic position and many different characteristics of the speaker including electronics and often multiple transducers. Therefore, setting limits and fault diagnostics are difficult tasks in a QC environment.

Average Level (Sensitivity) and Band Levels

To reduce complexity for testing sensitivity/max SPL and tonal balance, *Band Levels* and *Average Level* are suitable alternative test parameters to the Frequency Response.

Both parameters are derived from the Frequency Response curve (before smoothing). Using default settings, Average Level reflects the mean SPL in the complete measured frequency range. However, the frequency range may be restricted (or limited to one or multiple frequency points or bands).

[TASK OUTPUT: SOUND PRESSURE - SP 4]

Name	Value	Min Limit	Max Limit	Unit	Description
Level	115.4	111.6	117.6	dB	average level
Level @ 80-2000 Hz	115.0	112.0	118.0	dB	level of specified frequency point or band
Level @ 2000-20000 Hz	115.8	110.7	116.7	dB	level of specified frequency point or band

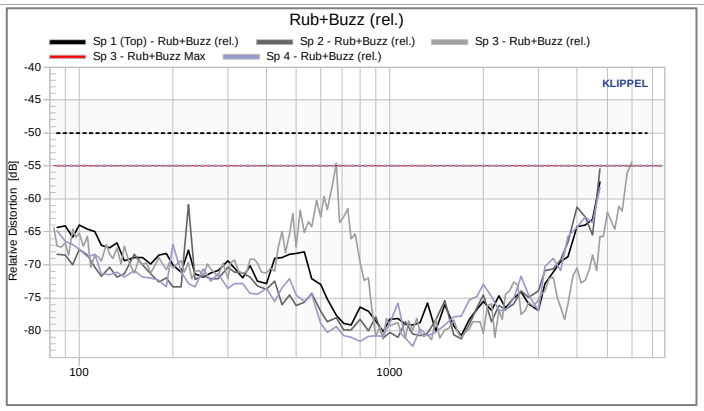
Additionally, an arbitrary number of Band Levels can be tested to check individual frequency bands, e.g. to differentiate woofer from tweeter failure.

Refer to *Average & Band Level Range* for more information about setup.

Rub & Buzz (Impulsive Distortion)

Rub & Buzz reflects higher-order, impulsive noise and distortion as caused by most defects of the transducer, the enclosure and other irregularities in the playback chain (brick-wall limiter, signal dropouts). The (absolute) result curves in dB SPL are plotted in the *Frequency Response* window.

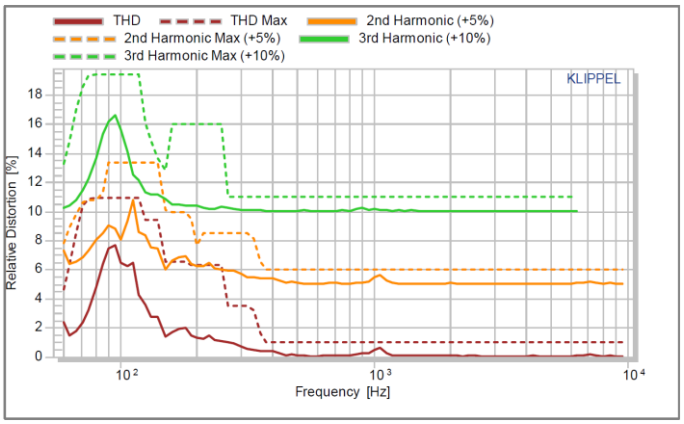
Monitoring this distortion relative to the fundamental frequency response or average level as shown below helps evaluating the severity. Rub&Buzz levels more than 40 dB below the fundamental average level are typically not critical. Still, this is neither an audibility or generally valid limit. Therefore, limits should always be based on approved reference units for each DUT type.



Since this parameter is sensitive towards to any external noise disturbance, it is recommended to use a closed test box to ensure a low noise floor. To identify false fails caused by impulsive external noise, activate ambient noise detection feature or Production Noise Immunity (PNI) add-on using an additional ambient microphone.

Harmonic Distortion

Relative harmonic distortion such as *Total Harmonic Distortion (THD)*, 2nd and 3rd harmonic are displayed in result window *Distortion*. For better overview, the curves can be shifted by a custom percentage (e.g. 5 % and 10 % as shown below). This can be adjusted or deactivated in the *Display* properties of the *Sound Pressure task*.

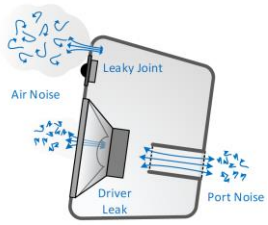


Harmonic distortion indicates mostly problems related to motor and suspension of the transducers (e.g. limiting or asymmetries related to aging or defects), especially for Woofers.

The distortion products can be displayed as an absolute SPL or relative to the fundamental or total signal. In the example above, another relative calculation mode *% (relative to level)* was used since the peaks and dips of the frequency response that normally occur in small test chambers (standing waves) may falsify the relative distortion reading at certain frequencies.

Modulation (Air Leakage)

If an *ALD* license is available, the result parameters of the *Air Leak Detection* can be activated in either the *ALD* standalone task or the *ALD* in *SPL* sweep (SPL task) integration. The most important result is the relative and absolute *MODulation* level that reflects turbulent air noise radiated by driver or enclosure leaks when playing low frequency signals at high levels. When activated, additional test verdicts are available



MODulation	100%

and the measured absolute *MODulation* SPL level and relative modulation index are displayed in the *Summary* window.

Name	Value	Max Limit	Unit	Description
MODabs	29.4	40.2	dB	Absolute modulated distortion
MODrel	0.0	7.5	dB	Relative modulation distortion

The absolute level reflects the severity and is suitable for limit setting based on reference unit while the relative level can indicate leakage problems even without specific limits. Values larger than 5 dB indicate the presence of modulated noise.

Test Verdict

For a normal test with only one QC operation the overall test verdict is displayed in *Summary* window. The verdicts are only available if limits have been calculated previously.

PASS

Frequency Response	100%
Average Level	100%
Polarity	100%
THD	100%
2nd Harmonic	100%
3rd Harmonic	100%
Rub+Buzz	100%
MODulation	100%

8.3 Yield Statistics (YST)

The *Yield Statistics* module processes log files produced by the Klippel QC software for simple statistical analysis of PASS/FAIL rate and single value results. This module is included in the *QC Standard* software.

It gives an overview of verdicts and single value results:

- Verdict overview counter (Pass, Warning, Fail)
- Yield (Y): ratio of number of passed DUTs to total number of measurements
- Invalid measurements
- Mean ($\bar{x}$): ratio of the sum of the single values to the number of samples
- Min/Max: smallest and largest element found in parsed data
- Standard deviation (σ)
- Samples (N): number of valid measurements due to the overall verdict
- Histogram: distribution analysis as a histogram plot

Verdict statistics

	Overall	Resp	Level	Pol
Yield (%)	64.88	97.01	78.72	97.03
Valid	94206	94206	94206	94206
Pass	61119	91389	74156	91409
Warning	0	0	0	0
Fail	33087	2817	20050	2797

Single value statistics

	Level	Re
All	$\bar{x}$: 112.8 Min: 102.8 Max: 123.1 σ: 2.404 N: 94206	$\bar{x}$: 6.951 Min: 5.639 Max: 8.434 σ: 0.3013 N: 94206
Passed	$\bar{x}$: 112.9 Min: 110 Max: 116 σ: 1.56 N: 61119	$\bar{x}$: 7.019 Min: 6.6 Max: 7.799 σ: 0.2448 N: 61119
Limits	[110 .. 116] (94206)	[6.6 .. 7.8] (94206)

Furthermore, the collected data can be filtered by date and time range, operator, serial number or serial number prefix. For easier handling in 3rd party software (e.g. MS Excel), a CSV-file can be exported.

Please check the application note Yield Statistics (YLD) (AN 46) and the specification QC – Yield Statistics (YST) (S 35) for more information.

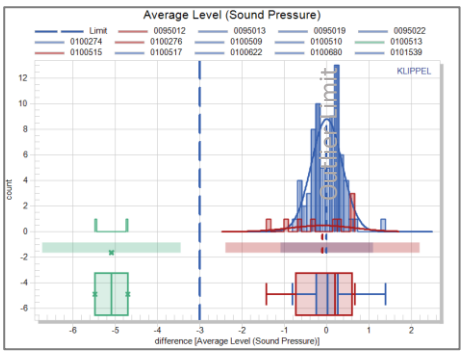
Since the YST is not suitable for detailed analysis of curve data or limit definition, the following section will show a much more comprehensive approach using STAT add-on.

8.4 Statistics Module (STAT)

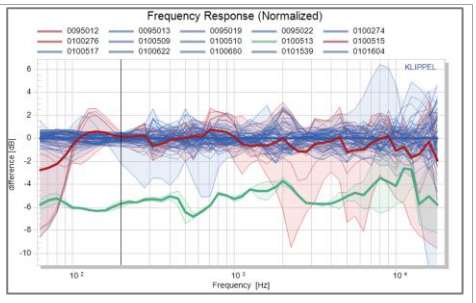
The *Statistical Analysis* (STAT) module is a powerful tool for getting a statistical overview over your collected test results. Logged test data (curve and single value) can be imported, pooled, analyzed and visualized with no effort.

Features:

- Visualization of mean and variances
- Histograms and box plots
- Cross section view of curve data (histogram)
- Pool based test object organization
- Sort out outlier units by point-and-click limits and automatic pooling



- Manual or automatic assignment to pools
- Limit calculation + export
- Automatic “golden” DUT selection



These features are fundamental for analyzing the consistency and state of your speaker pool and helps you to set critical but at the same time not overly sensitive limits. Furthermore, the Gauge R&R measurement can be conducted easily with this tool.

Please check the specification STAT - Statistics (S 48) for more information

8.5 Defect Diagnostics

Typical Defects

Defects come in many shapes and forms with different severity. In many cases the result parameters and violated limits can indicate the root cause, but for complex systems, manual diagnostics as described in section *Running Diagnostics* is often inevitable.

To get an idea, this incomplete list shows typical defects and their symptoms:

Transducer

- Damaged surround or punctured membrane → buzzing, air leakage noise
- Damaged windings → lower impedance and sensitivity, impulsive distortion (crackling)
- Thermal overload → failure, lower impedance and sensitivity
- Bottoming (suspension failure, asymmetry) → impulsive distortion
- Coil rubbing (rocking modes, suspension damage) → impulsive distortion
- Suspension fatigue → harmonic distortion, lower Fs

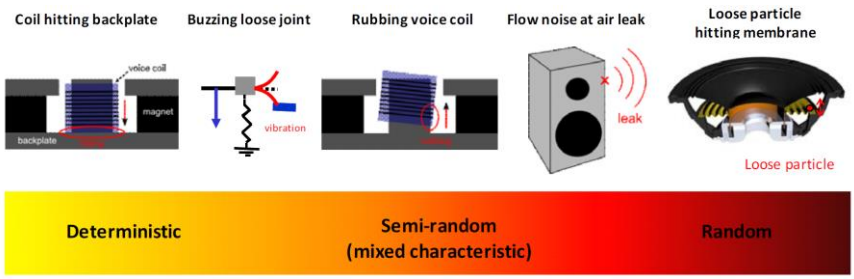
Enclosure

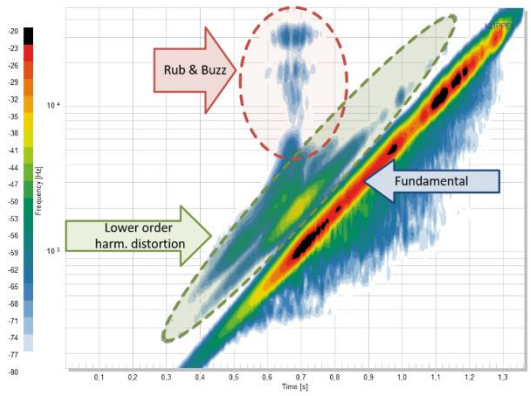
- Loose joints and screws → air leakage noise, buzzing
- Loose grill → buzzing
- Damaged or occluded port → air noise, altered box resonance
- Loose parts inside the box → impulsive distortion

Electronics

- Crossover failure → degraded frequency response (band levels)
- Electronic parts degradation or failure → no output, harmonic distortion, reduced SPL output
- Loose connectors → crackling (impulsive distortion), no output

Most defects that cause impulsive distortion and abnormal noise can be classified according to their symptoms. Some cause very reproducible patterns strictly coupled to the input signal (higher order harmonics) while others are only loosely coupled to the transducer vibration (e.g. broad-band air noise).



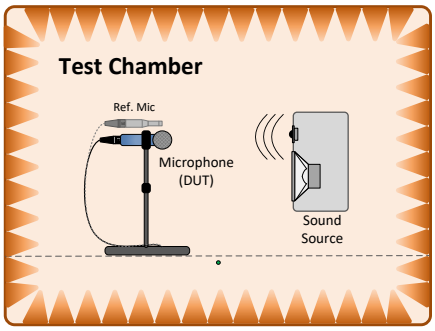
Wave File Analysis (TFA)	As stated, the wave file logging of the microphone input is a valuable tool for the post processing. To analyze wave files created by the QC System, you can simply listen to them using the PLAY module with playback rate adjustment or with any media player for a subjective evaluation. For a more specific analysis, the *Time Frequency Analysis (TFA)* module can process the wave files for a 3D-visualisation of the spectral content and level over time. It makes a quick defect analysis possible by showing an acoustical fingerprint of the test signal including excitation (trigger frequency) and symptom spectrum. 

9 Further Topics

9.1 Mobile Test Stand in Free Air

	Although this application is dedicated to testing speakers under controlled conditions using test enclosures, the given methods can also be applied to tests in an open environment. This comes with some advantages but also major drawbacks, however.
Advantages	• Quality control anywhere (e.g. before loading the truck or before rigging) • More flexibility • Less effort and required space • Cheaper
Drawbacks	• Uncontrolled reflections and potential rattling/parasitical vibrations may spoil the results and can lead to misinterpreted defects • Poor comparability or test results due to different locations → difficult limit setting and less sensibility for actual defects • Full exposure to ambient noise due to missing sound absorption → lowers the quality of the results (lower sensitivity for defects) • No protection from high SPL test signal → damage of operator's hearing and staff annoyance or necessity to lower test level (uncritical test)
Solutions	Some of the drawbacks could be partly compensated by a mobile sound controlling environment (e.g. semi-open test box on wheels with installed microphone or mobile adjustable "chimney" with sound absorbers or heavy curtains). Also, impulsive ambient noise can be monitored and partly removed with an ambient noise microphone using the Production Noise Immunity (PNI) module. However, this does not improve the drawbacks of a poor noise floor for defect detection. *If you are interested in this topic or need further information, don´t hesitate to contact the* KLIPPEL QC support.

9.2 Microphone Testing

	Although not in focus here, stage microphones can also be tested using the KLIPPEL QC System. Using a small test chamber to provide controlled conditions with low noise floor and a neutral, installed reference sound source (e.g. near-field monitor or wall-mount coaxial driver), any microphone can be tested relative to approved references or a neutral reference microphone (insertion technique). 

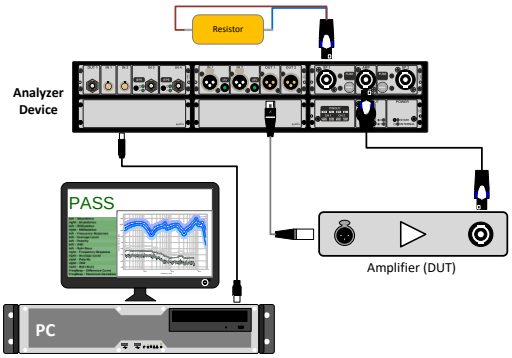
The test results include:

- (relative) fundamental frequency response
- Sensitivity
- Phase
- Harmonic distortion
- Abnormal noise and distortion (Rub&Buzz)

Contact KLIPPEL Support for more information.

9.3 Power Amplifier Testing

Power amplifiers can be tested as well with the QC System using high power dummy load resistors.
The amplifier input is connected to a balanced output of the *KA3 XLR Card* while the amp output is looped through the KA3 Speaker Card for voltage and current measurement. The load resistor(s) are connected to the Speaker Outputs.



He following tests can be performed

- Voltage frequency response, harmonic and impulsive distortion are tested with chirp signal using the *Impedance* task (*IMP*)
- Short-term peak power testing can be performed using multi-tone (*MTD*) or noise signals (*SAN*)

For testing more than two amplifier channels, use a Multiplexer to switch amp output channels.

10 References

Manuals	• QC User Manual • dB-Lab User Manual • Hardware Manual • Multiplexer Manual • PNI User Manual • ALD & ALS User Manual • ALS User Manual • STAT User Manual • TFA User Manual
Application Notes	• AN 46 – Test Enclosure for QC • AN 48 – Yield Statistics (YST) Available on klippel.de.
Standards	• IEC 60268 Part 5 and Parts 21/22
Workshop	• "Quality Assurance of Live Sound Reinforcement Equipment", R. Werner, AES Vienna 2020
Specifications	**Software** • C3 QC Software • S13 QC – Motor and Suspension Check (MSC) • S18 QC – Air Leak Detection (ALD) • S21 QC - Production Noise Immunity (PNI)

	• S35 QC – Yield Statistics (YST)
	• S48 Statistics (STAT)
	• S61 Time Frequency Analysis (TFA)
	• S63 QC – Spectrogram 3D Limits (3DL)
	• S65 QC – Spectrum Analysis (SAN)
	Hardware
	• A4 – Microphones
	• A6 – Accessories for the Klippel Analyzer System
	• A8 – Multiplexer
	• H3 – Klippel Analyzer 3
	  ○ H7 – Laser Card
	  ○ H8 – Speaker Card
	  ○ H9 – XLR Card
	Other
	• Klippel PC Requirements
	• Klippel Amplifier Requirements
	Available on klippel.de.

Find explanations for symbols at:

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

Last updated: October 29, 2020

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