Quality Control of Wireless Audio Devices AN76

Application Note for the KLIPPEL ANALYZER SYSTEM

Document Revision 2.2

SCOPE

- Fast quality control in lab or end of production line
- Wireless devices with focus on *Bluetooth*® wireless technology
- Automated pairing, audio profile and volume control
- Windows Bluetooth radio or sound card type Bluetooth interface
- Speaker and microphone test
- Wave file based “open-loop” testing
- KLIPPEL QC software framework (also available in R&D framework)
- KLIPPEL Analyzer 3 or Production Analyzer

APPLICATIONS

- Portable speakers
- Wireless speakers, headphones and true-wireless headsets
- Sound bars
- Smart home devices
- Tablets, smart phones
- TVs
- Car audio system

Most modern audio devices such as portable and wireless speakers and headphones or smart home devices do not provide a traditional analog or digital signal input. Content is played back through a wireless audio link (e.g. *Bluetooth*® wireless technology), from the device’s memory or streamed over *Wi-Fi* using numerous different services and providers. This does not only affect the way music is consumed, but also the way such devices can be tested in the lab and manufacturing.

This application note is dedicated to testing the acoustic performance of wireless audio devices using the *KLIPPEL QC Software* framework. The guide is closely related to *AN72 Testing Wireless Audio Devices with Klippel R&D System.* However, the requirements of end-of-line testing such as automated device pairing and the dedicated features of the QC Standard software and related add-on modules are addressed here. Topics like connectivity, solutions for handling different audio devices and dealing with unknown and varying playback delays are provided.

The application range covers all kinds of audio devices such as portable or smart speakers that may also include one or multiple microphones. This also applies to wireless headphones and headsets that are covered separately by the related Application Note *AN73 QC Headphone Testing*.

CONTENTS

1 Overview

1.1 How to Use This Application Note

This application note addresses two typical test scenarios:

- a “closed-loop” setup with simultaneous playback and recording using *Bluetooth* wireless technology (speaker with integrated microphone)
- “open-loop” setup with audio file-based testing (e.g. tablet or smart speaker)

The information given in the two examples can be applied for a wide range of similar applications. Pick one of the use cases that corresponds best to your device under test (DUT). This document keeps common information for both related scenarios together as far as possible, while application specific information is marked clearly. Only section *Test Settings* is split in two versions.

Before starting with practical testing, follow the instruction given in the sections *Requirements*, *Preparation* and *Hardware Setup* carefully.

Optional related topics are addressed in section *Further Topics*.

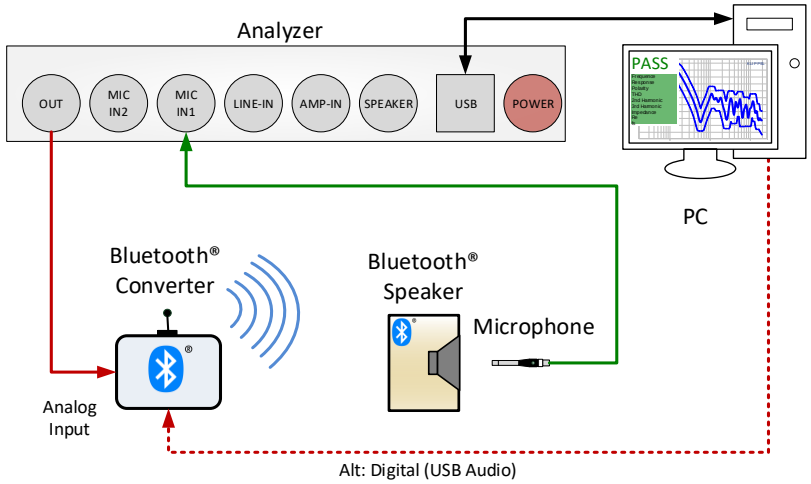
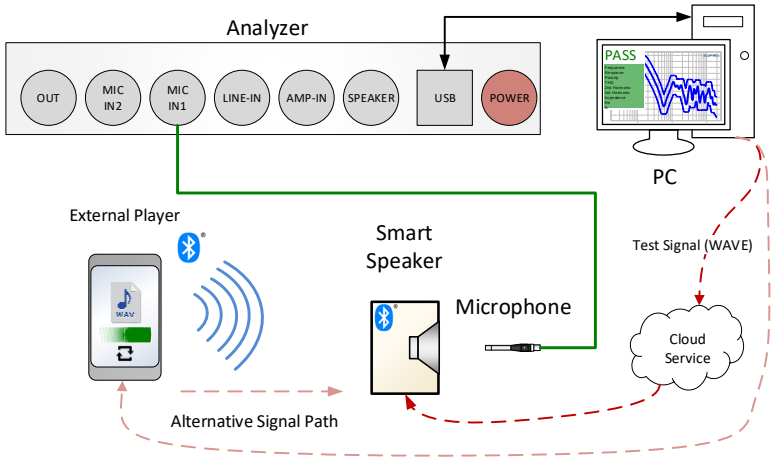
1.2 Results

For quality control, the goal is to provide critical and meaningful test parameters to ensure consistent product quality and specification sheet compliance translated to the EOL test. For digital systems, the results are restricted to acoustical parameters measured with one or multiple microphones.

Speaker Parameters	The speaker response test provides the following results • SPL frequency response of mono or stereo channels • Sensitivity (average level or level at defined frequency) • Polarity • Harmonic distortion (THD, 2^{nd}, 3^{rd}, HI-2, ...) • Rub & buzz distortion (abnormal sound, HOHD) • Optional: absolute and relative MODulation (air leak noise) – SPL or ALD task
Microphone Parameters	In case the device under test (DUT) also contains microphones (e.g. for hands-free telephony or voice assistant interface), the following parameters can be tested using a reference sound source: • SPL frequency response • Sensitivity (average level or level at defined frequency)

	• Harmonic distortion (THD) • Optional: noise/impulsive distortion (*Rub & Buzz*)

1.3 Closed- vs. Open-Loop Testing

Closed Loop (Wireless)	Firstly, the terms of open and closed loop test scenarios shall be defined since understanding the differences is crucial for this app note. A closed loop setup is the most common scenario that also applies to testing analog, wired devices. The test signal is generated and played through the analyzer's signal output. The DUT's response is captured simultaneously by the microphone connected to the signal input of the analyzer.  This basically also applies to most digital (wireless) audio devices. As shown above, the only difference is that the digital test signal is transmitted wirelessly (e.g. Bluetooth) to the DUT. This introduces problems like sample clock mismatch as well as unknown or varying delays that require additional means for synchronizing playback and capture.
Open Loop	An open loop scenario is given when the tested device does not provide any interface for direct audio streaming. In this case the generator is completely decoupled from the capture device.  The test signal sequence is exported to an audio file that can be either copied directly to the DUTs memory or streamed asynchronously using a 3rd party service (e.g. cloud service). For synchronizing the capture device and triggering the measurement, a dedicated trigger signal is prepended to the test signal sequence.

2 Requirements

2.1 Example Set

	The recommended hard- and software components listed in the following paragraph are based on *Example Set for Wireless Speaker Quality Control*.

2.2 Hardware

Analyzer or Audio Interface	The recommend hardware interface for this application note is the KLIPPEL Analyzer 3. However, a 3rd party audio interface may be used for microphone data acquisition and signal output as well. The following options can be used, in general:
	• **KA3 – KLIPPEL Analyzer 3** (Item No. 2000-326) equipped with
	  ○ QC Card (2 x IEPE mic input, 1x balanced output) or Laser Card (IEPE mic input) or/and
	  ○ XLR Card (balanced output and 48 V mic input)
	• PA – Production Analyzer (Item No. 4000-100) or
	• 3rd party USB audio interface (sound card)
	The QC Stand-alone software is required for operation without KLIPPEL analyzer.
	 
	KLIPPEL Analyzer 3

PC	A *Windows* PC is required to operate the KLIPPEL software. See separate document *KLIPPEL PC Requirements* for further information.
Microphone	Up to four microphones may be used with KA3 for testing the acoustical response of the DUT as well as for detecting ambient noise corruption without additional multiplexers. The recommended standard microphone **MIC 255** (Item No. 2400-012) provide best performance-cost value and low self-noise. A cost-efficient alternative is the **MIC 40PP** by G.R.A.S (Item No. 2400-330), especially for ambient noise measurement.  *MIC 255* Additional equipment for multi-channel measurement may be necessary: • XLR-BNC adaptor for use with 48 V XLR input (Item No. 2300-102) • IEPE Supply IV11-S for use with PA Line input (Item No. 2400-301) For use with KA3 XLR Card, also a phantom powered microphone, such as MIC255 48V (Item No. 2400-311) can be used.
Bluetooth Interface	Testing devices with *Bluetooth* wireless technology requires a dedicated transmitter in order to convert and transmit stimulus signals to the DUT or receive response signals from the DUT's microphone(s). Basically, any analog, digital or USB transmitter device can be used that supports basic *A2DP* audio profile and *HFP Hands-free Profile* and the related mandatory audio codecs such (*SBC*, *CVSD*). However, the recommended interface device distributed by KLIPPEL is the **MegaSig U980** (Art. Nr. 2800-406). This professional, converter with analog stereo inputs and one output is directly connected to the analyzer hardware. Device pairing and codec control is realized by the KLIPPEL software via the provided USB control interface. The hardware set includes adaptors and cables  *MegaSig U980* • 3 x BNC cable 1 m (Item No. 2300-108) • 1 x adaptor XLR male to BNC female (Item No. 2300-102) • 2 x adaptor XLR female to BNC female (Item No. 2300-131)  Find more technical information in specification *A6 – Accessories*.

	Using the native Windows Bluetooth e.g. via the integrated radio of the host PC or a dedicated USB dongle is a cost-efficient, though less efficient and flexible alternative option for Bluetooth audio device testing.  *USB Bluetooth® radio*
Sound Source	Testing the DUT microphone response or playing back voice service commands requires a broad-band sound source. For quality control, professional full-range loudspeakers are recommended since artificial mouth devices have very limited peak level and frequency range. Active speakers are connected to the Line outputs of the analyzer, while passive speakers may be operated via an external amplifier or the integrated amplifier of the *KA3 (Amplifier or QC Card)*. KLIPPEL distributes *Genelec* professional speakers. The compact and price-efficient model **Genelec 8010A** (Item No. 2800-500) is suitable for most EoL applications. *VESA* mounting adapters are available for fixed installation. Please refer to specification *A15 – Sound Source*.  *Genelec 8010A*
Input/ Output Switcher	**Microphone Multiplexer** Sensitive testing for air leakage in larger speaker systems usually requires two or more test microphones. In case analyzer input channels are limited, a channel switcher (*Multiplexer BNC*; Item No. 2800-101) can be used to switch up to eight microphones using the *GPIO* of the KLIPPEL analyzer.  **Output Multiplexer** Testing stereo audio with integrated microphones often requires more than two signal outputs in order to provide test signals to the stereo inputs of the Bluetooth converter and one or more reference sound sources. An *XLR-Out Multiplexer* (Item No. 2800-103) is suitable for automated switching between those devices in the test sequence. *Refer to specification A8 Multiplexer for more information.*

2.3 Software

Base: 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 *SPL, SAN*, *Preconditioning* and *PP* among others. For testing exclusively with 3rd party audio interfaces (without KLIPPEL analyzer connected) *QC Stand-alone Software* (Item No. 4004-500) is required. For this application note, the feature set is practically identical to QC Standard since no voltage and current measurements are performed. This document refers to the feature set of QC Version 6.4 which is required to operate *MegaSig U980* Bluetooth interface. However, most of the given information also applies to earlier versions with certain restrictions. Contact support for more information.
Base: QC in R&D Framework	The QC module can also be operated in the KLIPPEL R&D Software distribution. In this case the following requirements apply: • dB-Lab 210.610 or higher • QC SPL – Sound Pressure Task (Item No. 4000-263) • QC SAN – Spectrum Analysis (Item No. 4000-267) – optional for microphone tests with noise or custom signals General restrictions apply compared to QC Standard (see *QC User Manual* section *QC Software in the KLIPPEL R&D Framework*).

Additional Modules	• **QC SYN** – External Synchronization (Item No. 1001-107) – **mandatory** for coping with varying delays and wave file based open-loop testing • **QC EXD Bluetooth** – External Devices (Item No. 4000-251) – **recommended** for automated Bluetooth device pairing and profile control (included in *MegaSig U980* set)
Optional Modules	• QC ALD – Air Leak Detection Devices (Item No. 4000-240) – optional for testing air noise caused by transducer or enclosure leakage and port noise • QC PNI – Production Noise Immunity (Item No. 1001-107) – optional for advanced ambient noise handling (only closed-loop speaker test) • QC EQA – Equalization & Alignment (Item No. 4000-245) – optional for sound source equalization or target SPL adjustment

2.4 Test Environment

Test Enclosure	Optimal sensitivity for rub & buzz and air leakage testing is provided in a silent test environment providing a low acoustical background noise floor. Since this is often not the case in a production environment, random noise disturbance can be detected (*QC Standard*) and handled (*PNI* add-on) reliably using an additional ambient noise microphone. However, additional noise attenuation provided by an insulated test box is still recommended to lower the noise floor as much as possible for optimal defect detection. This is especially crucial when testing the DUT microphones since ambient noise detection feature is usually not applicable for this scenario. Internal damping material and non-parallel walls help reducing peaks and dips in the frequency response related to standing waves.

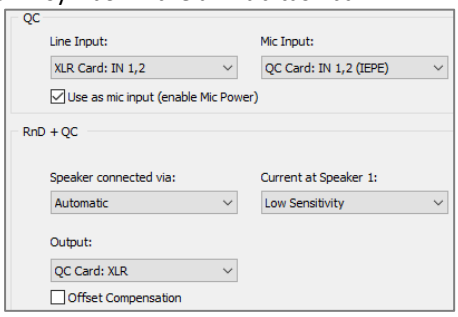
3 Preparation

3.1 Global Signal Routing (only for KA3)

Skip this section in case you are using Production Analyzer or a 3rd party 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* or the instance of *dB-Lab* you would like to use for testing
- 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 *QC 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 analog *Bluetooth* converter (usually *XLR Card)*

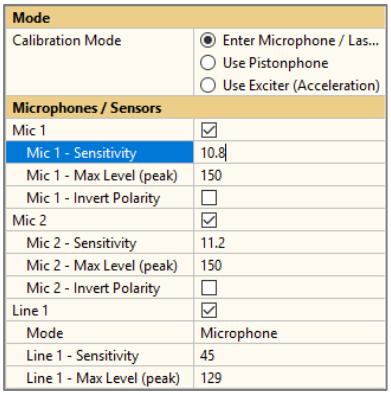
Find more information in *Hardware Manual* section *KA3 Signal Configuration*.

3.2 Calibrate Sound Card Input / Output

This step is only required in case 3rd party audio interface is used for testing and absolute voltages are required (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*. Delay detection may be skipped since testing involves *SYN* add-on taking care of any delays.

3.3 Calibrate Microphones

	For all available test microphones (including external ambient noise mic), calibration data must be available before use. **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) **3rd party 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 *Find more information in QC User Manual section Microphone & Sensor Calibration.*
Using Calibration Sheet Data	• If you just want 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 Sound Calibrator or Pistonphone	• Select *Use Pistonphone* in case you want to measure sensitivity with pistonphone or sound calibrator • 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

3.4 Set up Bar, QR or NFC Code Reader

	• A code reader allows to read either the DUT serial number for data logging and/or the device's Bluetooth address for controlled device pairing using *EXD Bluetooth* feature. Any USB device that is capable of keyboard emulation mode (keyboard wedge) can be used. • Connect the device to the PC and verify with an example tag that the scanned information is entered correctly using a text editor (e.g. *Notepad*). Append *Return* to avoid any additional keyboard interaction. *Find more information in QC Manual section Serial Number Handling – Barcode Input and specification A6 Accessories.*

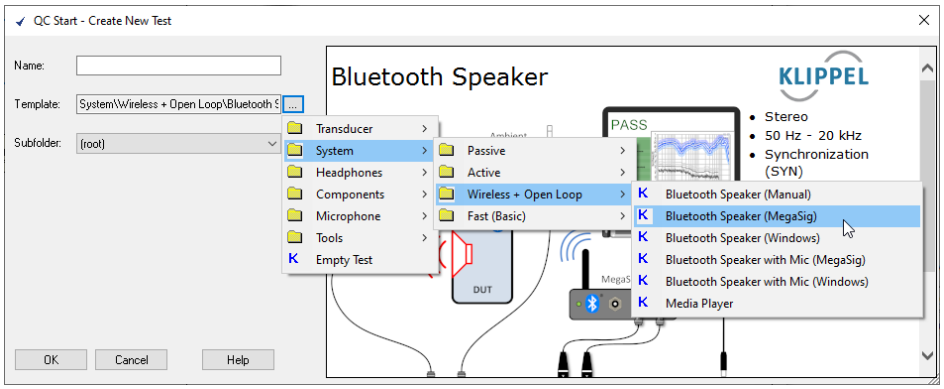
3.5 Install Bluetooth Interface Drivers

The *MegaSig U980* interface requires USB drivers to be controlled through the virtual serial port USB interface. You can access the driver setup from *Qc Install Guide* (*QC Start Engineer – Tool – Check Installation*). Please refer *to EXD Manual* section *Setting up the Hardware* for detailed instructions.

3.6 Find Related Test Templates

QC Test Template

A variety of QC test templates related to wireless and open loop testing are delivered with the QC software. You may access them via *QC Start Engineer – Test – New...* . Most templates can be found in category *System – Wireless + Open Loop* or *Headphones*.

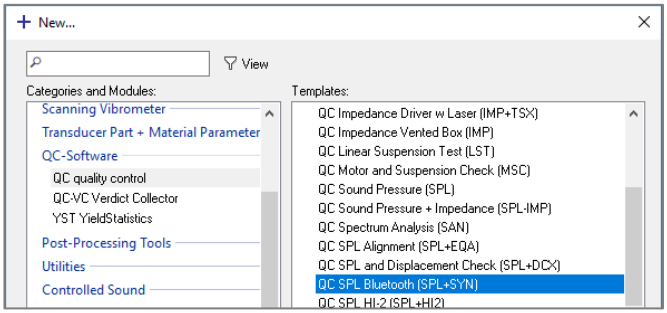


You may modify the settings in the created tests and create your own test templates.

Find more information in the QC User Manual section Organizing Projects using QC-Start.

Template Operations (R&D Framework)

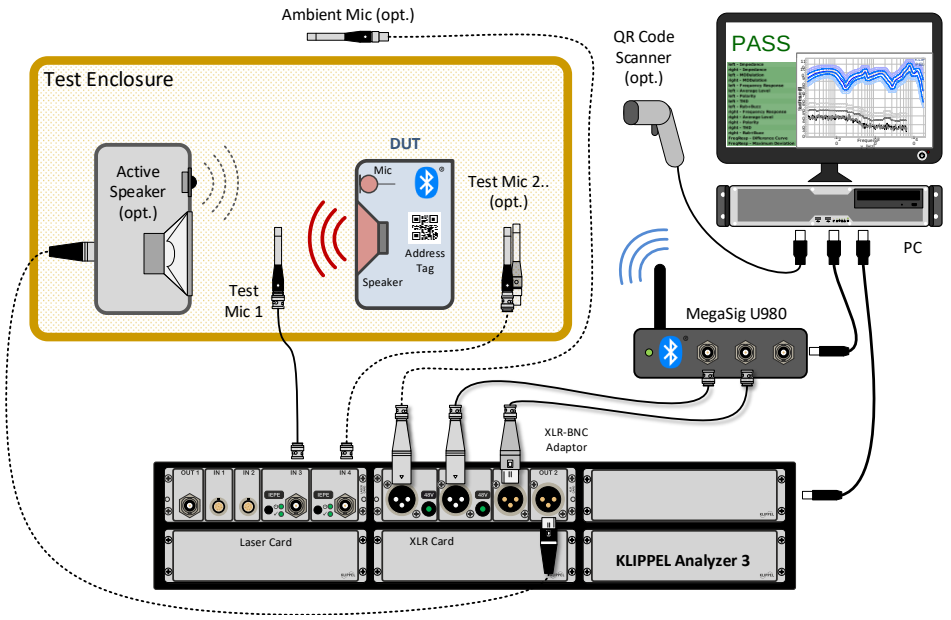
In case the *QC Start* software (part of QC software delivery) is not available, you may work with the provided template operations directly from *dB-Lab*. Create an empty object and add an operation based on template *QC SPL Bluetooth* as a starting point.



Find more information in the dB-Lab User Manual section Creating and Managing Templates.

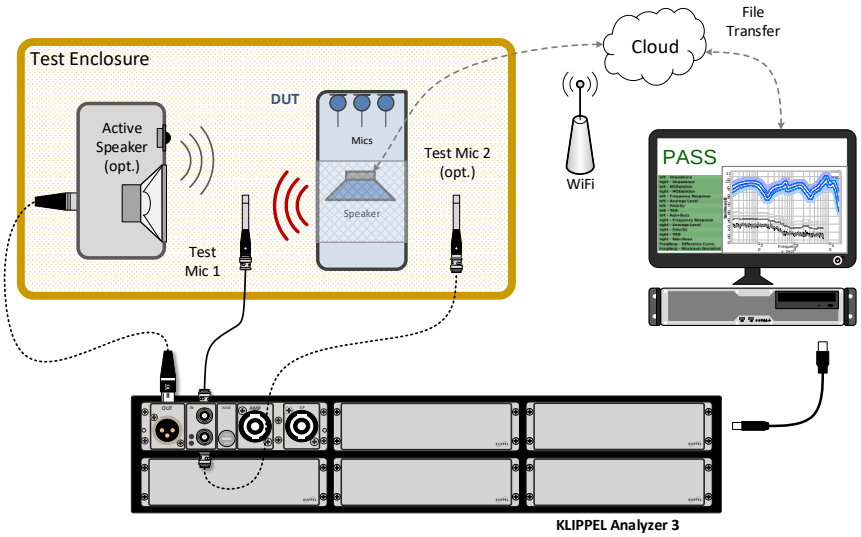
4 Hardware Setup

4.1 Closed-Loop Setup (e.g. Bluetooth Speaker with Microphone)

Overview	 The scheme above shows a typical test setup for a *Bluetooth* enabled mono speaker with hands-free functionality (built-in microphone). The reference speaker is not necessary in case the DUT microphone test shall be skipped. Place the test microphones close to the DUT in order to ensure optimal SNR, especially for detecting rub & buzz or air leakage defects.
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) • Optional: Connect the Bar/QR code reader to another USB port of the PC • Connect the *Bluetooth* interface to a free USB port of the PC and make sure that the drivers are installed • Connect the output(s) of the analyzer (e.g. *XLR Card OUT*) to the *Speaker* input(s) of the *Bluetooth* interface using the BNC cables and optional XLR-BNC adaptors • Connect the *Mic* signal output of the *Bluetooth* interface the analyzer input (e.g. *XLR Card IN*) to using a BNC cable and optional XLR-BNC adaptor • Connect the test microphone(s) to the microphone input(s) of the analyzer (e.g. *IN3/IN4* of the *Laser Card or IN1/IN2* of the *QC Card*) • Connect the optional ambient noise mic located outside of the test box (and/or additional test mics) to *IN1/IN2* of the *XLR Card* (use an XLR-BNC adaptor for microphones with *IEPE* supply) • Connect the active speaker(s) to the balanced output(s) of the analyzer (e.g. *OUT1/OUT2* of the *XLR Card* or *OUT* of *QC Card*); ensure that the speaker(s) are powered and switched on; the main axis of the speaker should face the DUT'S microphone directly, if possible

4.2 Open-Loop Setup (e.g. Smart Speaker via Audio File)

Overview	An open "open-loop" test scenarios applies when the DUT does not provide direct audio streaming interfaces. The test signal sequence is exported to a wave file by the QC software (*SYN* add-on) and played back by the DUT autonomously while the analyzer captures the response signal synchronized by dedicated trigger signals that are automatically added by the *SYN*.



If the DUT has internal memory (e.g. smart phone), the wave files can be simply exchanged e.g. through USB to the host PC. For wireless devices (e.g. smart speaker) as shown above, an audio cloud service may be used to play back the test signal via Wi-Fi. If no software-controlled playback trigger is available, a voice command played back by the sound source can be used to trigger playback through the DUT's integrated voice service.

Note: If the device provides Bluetooth audio, refer to closed-loop setup. For high-volume EoL testing it is recommended to provide simplified wireless or wired access to the DUT (factory mode) to avoid time-consuming Wi-Fi setup.

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 test microphone(s) to the microphone inputs of the analyzer (e.g. *IN1/IN2* of the *QC Card*)
- Connect the optional ambient noise mic located outside of the test box to *IN1/IN2* of the *XLR Card* (not shown)
- For optional microphone testing or sending voice commands, connect the active speaker(s) (reference sound source) to the balanced output(s) of the analyzer (e.g. *OUT* of *QC Card*)
- Make sure that the required audio file transfer infrastructure is set up correctly (e.g. Wi-Fi, cloud service, factory mode, USB, …)

5 Test Settings (Closed-Loop)

5.1 Creating a Test

From Template using QC Start

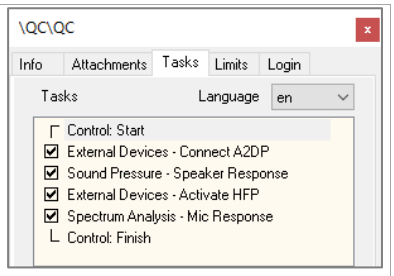
Various test templates are provided for wireless or *Bluetooth* enabled speakers in category *System - Wireless + Open Loop* via *QC Start Engineer – Test – New…*. It is recommended to start with one that fits your test scenario best

- *Bluetooth Speaker (Manual)* – use this template if you use a stand-alone Bluetooth transmitter with manual pairing (either USB audio device type or with analog input)
- *Bluetooth Speaker (MegaSig)* – same as above, but with automatic pairing and profile control using *MegaSig U980* interface (requires *EXD Bluetooth* license)
- *Bluetooth Speaker with Mic (MegaSig)* – same but with extended sequence for additional microphone test (hands-free profile) through a reference sound source

The following guide refers to *Bluetooth Speaker with Mic (MegaSig)* template. Click the *Start* button to login.

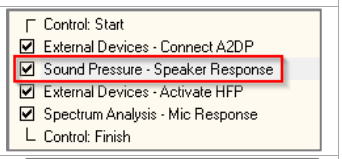
Most templates are created for stereo systems with independent test of left and right channels. Remove one of the Sound Pressure tasks from the sequence if you have a mono device. For headphone templates please refer to the dedicated application note AN73.

Test Sequence	The test sequence contains two *External Devices (EXD)* tasks take care of device pairing and audio profile control while the *Sound Pressure (SPL)* and *Spectrum Analysis (SAN)* tasks performs the actual measurement. *The chirp signal of the SPL task is optimal for speaker testing. For microphone testing, the continuous noise signal of the SAN is more suitable to dynamics introduced by signal processing.* *You may add tasks such as ALD – Air Leak Detection or remove others in the sequence (e.g. for mono operation).*



5.2 Speaker Test Settings

This section refers to the step *Sound Pressure – Speaker Response* for dedicated to speaker output testing via *A2DP* profile.



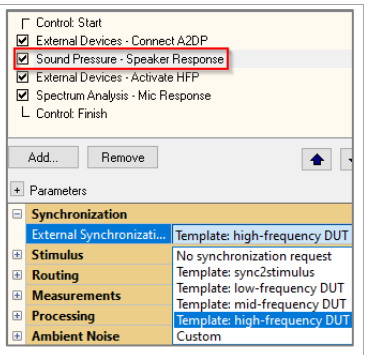
Input & Output Routing	Check the local *Routing* settings and adjust them if necessary. The default settings of provided templates are configured for use with *KA3/PA* and ambient noise microphone. In the *Speaker Response* step • *OUT 1* is used as speaker test *signal Output,* (to Bluetooth interface) • *MIC 1* is used as *test Input* and • *MIC 2* is used for *ambient noise Input.*

Routing	
Output	OUT 1
Speaker 1 Connect	☐
Speaker 2 Connect	☐
Input (Test Sensor)	Mic 1
Input (Noise Sensor)	Mic 2

Stimulus Voltage	• This parameter specifies the *RMS voltage* of the chirp signal fed to the analog input of the *Bluetooth* interface. It is independent of the actual playback level of the DUT that can be controlled by the *Connect A2DP* step (see below). *The maximum sinusoidal RMS input voltage for the MegaSig U980 should not exceed 0.56 V to avoid clipping.* • The overall level should be set high enough to provide sufficient signal-to-noise ratio in the acoustic response as well as sufficient excitation for potential defect and distortion mechanisms. *Note: Parameter Level Profile can be used to boost the stimulus signal and thus improve poor SNR in certain frequency ranges.*

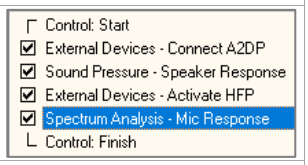
Stimulus	
Start	50
Stop	20000
Time	1
Voltage	0.05
☐ Speed Profile	[1000, 5]
☐ Level Profile	[10, 0; 500, 0;..

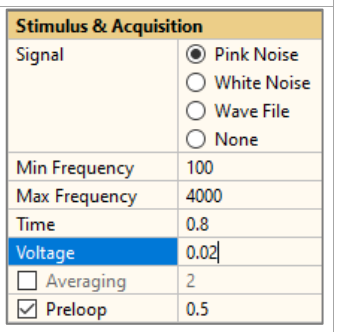
Frequency Range (Start, Stop)	• Adjust *Start* and *Stop* in the *Stimulus* properties of the *Sound Pressure* tasks, if required. • The speaker response test should at least cover the *rated frequency range* of the device under test. The lower frequency may be set below this range as long as sufficient SPL output is provided. *It can be beneficial to sweep downwards (Start > Stop) to reduce phase error at high frequencies due to sample clock jitter and drifts. Also, higher-level codecs such as aptX® can introduce additional temporal variation.*
Ambient Noise Detection	• By default, *Ambient Noise* monitoring is activated. If no ambient noise mic is available, deactivate the option *Noise Monitoring*. • If a *PNI* license is available, further ambient noise settings are available (e.g. *Auto Repeat*) that may be activated/configured. Refer to *PNI Manual* for more information. *For optimal performance, it is strongly recommended to measure the noise attenuation of the test box in order to replace the default setting "in Box Enclosure" that assumes only 15 dB attenuation. Refer to QC Manual section How to Cope with Ambient Noise? for more information.*

Sync. Settings	• Since the delay introduced by the *Bluetooth* audio link is unknown, the *External Synchronization* (*SYN*) should be activated to synchronize the captured response with the generator. In *Control:Start* task, select *Execution Mode - SYN: dynamic* for closed-loop setup. • Each task in the sequence may request synchronization. In most cases, it is sufficient to place only one sync request for the first test task in the sequence. • Choose *high-frequency DUT* or *sync2stimulus* for broadband speakers. If the synchronization fails, use the more robust *mid-frequency* template.  *In sync2stimulus mode the SYN will synchronize directly on the test signal response, while in all other modes, a short noise trigger signal with a unique ID is added before the main test signal.*

5.3 Microphone Test Settings

This section refers to the step *Spectrum Analysis – Mic Response* dedicated to testing the DUT microphone response via *Bluetooth Hands-free (HFP)* profile. The stimulus is played back by the reference speaker.



Routing	In the *Mic Response* step • *OUT 2* is used for mic test *signal Output* (to active speaker) and • *Line 1* is used for the DUT *response Input* (from Bluetooth interface output). *Using HFP profile, only one input channel is provided. Ambient noise monitoring is not applicable due to unknown mic sensitivity.*
Stimulus Signal and Voltage	• First select a suitable test signal for the mic test. Pink noise is suitable in most cases. • Defining excitation voltage depends on the acoustical overload point of the DUT microphone and the sensitivity of the sound source. • The resulting SPL should provide sufficient signal-to-noise ratio in the mic response while avoiding clipping. *Note: Due to the high crest factor of the noise signal, the peak is substantially higher than the RMS level. You may adjust the target SPL with a calibrated reference microphone (see section Adjusting Target SPL and Sound Source Equalization).* 
Min & Max Frequency	• Adjust the test bandwidth of the noise stimulus (*Min Frequency* and *Max Frequency*) considering the specified bandwidth limits of both the sound source and the DUT microphone as well as the used *Bluetooth* codec. • The lowest frequency should be greater than the lower cut-off frequencies of both devices. The upper frequencies are usually limited by the applied codec (8 kHz with *CVSD* or 16 kHz with *mSBC*). *Note: Avoiding low frequencies reduces problems related to standing waves that cause narrow-band SPL peaks and dips in small test boxes.*
Sync. Settings	Refer to the information given for the speaker test setup, but select the *External Synchronization Template* according to the bandwidth of both sound source and microphone (codec). In most cases *mid-frequency DUT* or *sync2stimulus* template are the best choices.

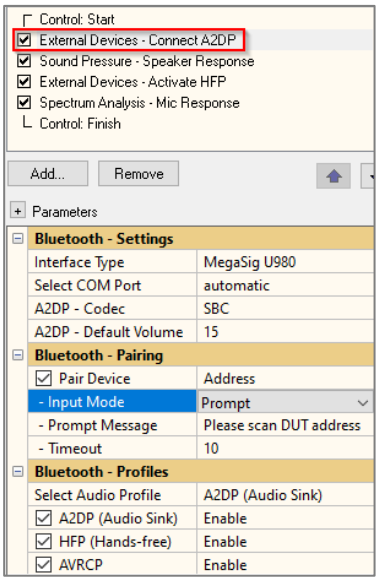
5.4 Bluetooth Settings

This section refers to the *External Devices (EXD)* sequence steps for Bluetooth control. For the selected template, two EXD steps are required to switch audio profiles from *A2DP* to *HFP*. Both use *Bluetooth Audio* preset mode for optimal usability.

Connect A2DP

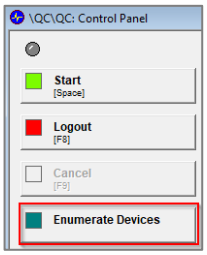
Bluetooth - Settings

- Make sure that the correct *Interface Type* (here *MegaSig U980*) is selected; Set COM port of device manually for optimal timing
- Select *A2DP – Codec* (default: SBC) and change *Default Volume* if necessary



Bluetooth - Pairing

- Select a pairing mode (*Pair Device*) - *Address-based pairing* avoids ambiguity ensures optimal timing; in this case an address must be provided for each DUT
- *Input Mode – Prompt* triggers an operator message box for address input field on each test run. A scanner device with keyboard wedge can be used to fill-in the DUT's address. Alternatively, use *Friendly Name* pairing to connect to the next device with matching name in pairing mode.
- Use the *Enumerate* button in the *QC Control Panel* and take a look at the result table in *Summary* window in order to search and list pairable devices. Make sure that pairing mode of the DUT is active.



Bluetooth device enumeration

Name	Address	Paired	Connected	Service
BTC-4148	20FABB0307E8	F	F	-
JBL GO 2	70991C0E8367	T	T	AudioSink (0x110B), A/V_RemoteContr

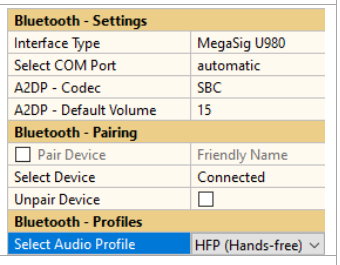
Bluetooth – Profiles

- Select the used *Audio Profile* – *A2DP* for speaker testing
- Enable all *Bluetooth* services (profiles) supported by the device - usually *A2DP*, *AVRCP* for normal audio playback.
- Activate *HFP* only if supported and used for microphone testing

Note: Find more detailed information about using EXD Bluetooth feature in EXD Manual.

Activate HFP

- The second EXD task in the sequence basically only switches the audio profile to *HFP (Hands-free)* in order to test the DUT's microphone
- No pairing is performed, the setting applies to the connected device
- Bluetooth-Settings shall be identical to the *Connect A2DP* step



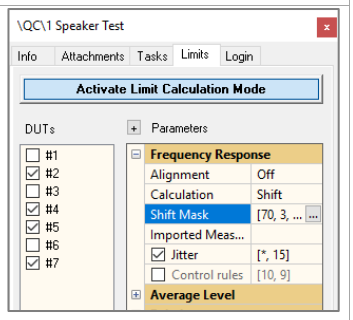
5.5 Trial Run

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*.

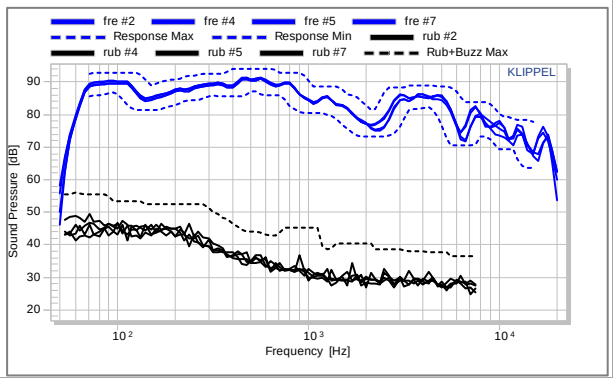
Note: You may deactivate individual tasks in the sequence to skip pairing for adjusting only the test settings and leave the DUT connected.

5.6 Limit Calculation

Relative Limits (Golden DUTs)



- For EoL testing, in most cases limits are defined relative to approved reference units to account for the acoustical properties of the test box and the microphone position in the near field of the DUT. Those *Golden reference DUTs* that have been tested and verified under lab conditions.
- One or more of these physical units can be measured on the QC test station to obtain the reference response in *Limit Calculation Mode* and also used to adjust resulting limits for systematic drifts and changed conditions.
- In addition, parameters like *Frequency Response* can be *normalized* for monitoring only the deviation to the reference average or *Golden DUT*. *Limit Alignment* enables floating limits that are insensitive to absolute level changes (device volume).
- Distortion parameters (e.g. THD, Rub&Buzz) can be tested relative to the frequency response or average level to simplify limit setting.



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

6 Test Settings (Open-Loop)

6.1 Creating a Test

From Template using Qc Start

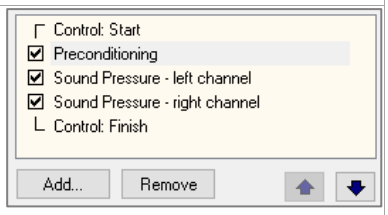
For audio file-based open-loop testing, find a suitable test template using *QC Start Engineer – Test – New…*

- *Media Player* – use this template if you want to test the response of a stand-alone playback device

Click *Measure* to open the test (and login). The following steps refer to the *Media Player* template (speaker test only). The template contains only a single QC operation for exporting the stimulus to a wave file and capturing the DUT's response.

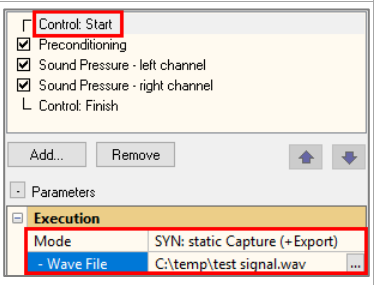
6.2 Task Settings

Test Sequence



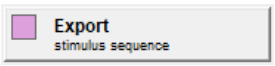
- The task sequence contains two *Sound Pressure* tasks for testing left and right playback channel of the DUT
- add tasks such *ALD – Air Leak Detection* or remove others in the sequence (e.g. for mono operation) using the *Add...* and *Remove…* buttons.
- *Prepending a Wakeup Signal:* some devices require a wakeup signal to power up. Add a *Preconditioning* task (…*Klippel**QC**Standard**precond.0001.task*) at the top of the sequence and set a short test tone to make sure that the synchronization signal of the first test task is played back completely.
- *DUT Control via IO Task* - if test signal transfer and playback can be triggered using a dedicated software interface, you may add an *IO Task* to the test sequence before the first measurement task. Use the *Run batch file* action to copy the stimulus file to the DUT and call any 3rd party application.

Input Routing	• Adjust the input routing individually in each task according to the analyzer and microphone setup used • By default, *MIC 1* is used as *test mic* input, while *MIC2* is used for *ambient noise* channel (if enabled)
Stimulus Level	• For the *Sound Pressure* task(s), this parameter specifies the *digital peak level* of the exported test signal in dBFS. Mind that this affects only the stimulus amplitude, not the actual device playback level that needs to be set manually or using a voice command. • The overall level should be set high enough to provide sufficient signal-to-noise ratio in the acoustic response as well as sufficient excitation for potential defect and distortion mechanisms. Avoid clipping by any chance. *Note: Parameter Level Profile can be used to boost the stimulus signal and thus improve poor SNR in certain frequency ranges.*
Frequency Range	• Adjust *Stimulus – Start* and *Stop* to make sure that the chirp test signal cover at least the *rated frequency range* of the tested device. • Setting a lower start frequency can be beneficial for rub & buzz and air leakage testing, if the DUT is capable of reproducing the signal without interference of high-pass filters
Ambient Noise Detection	• Ambient noise detection is deactivated in this template by default • If an ambient noise microphone is available, it is recommended to activate the option *Noise Monitoring* in the *Sound Pressure* tasks. *The Production Noise Immunity (PNI) add-on cannot be used in open-loop setups since auto repeat cannot be triggered.*
Sync. Settings	• Activate *Execution Mode External Synchronization* (*SYN*) – *Static Capture* in *Control:Start* task. In this mode, the test signal sequence is exported to a wave file. Select a custom export target path and file name (*- Wave File*). • Each task in the sequence may request synchronization. In most cases, it is sufficient to place only one sync request for the first test task (*left channel*) in the sequence. Choose *high-frequency DUT* or *sync2stimulus* for broad-band speakers. If the synchronization fails, use the more robust, but slower *mid-frequency* template. • A unique trigger noise ID signal is prepended to trigger analysis when the DUT plays back the exported sequence



6.3 Trial Run

Export Test Signal	• First export the test signal sequence to the specified location using the *Export button* in *QC Control Panel*.
Convert and Transfer Audio File	• Now copy the exported audio file to the DUT's memory or upload it to a suitable cloud service. • In case 32 Bit Wave file format is not supported by the playback device, you may convert the signal to valid file format with any free format converter software. Preferably, use a lossless format (e.g. FLAC) or a compressed format maximum quality setting.
Start Test	• If the DUT is set and ready for playing back the test sequence, start the measurement using the *Start* button in the *QC Control Panel*. • The data acquisition and analysis stop and stays in idle state before the first task in the sequence that requests synchronization (usually the first *Sound Pressure* task) **Task *Sound Pressure - left channel*: Searching sync ...** • Trigger *DUT playback* (*play* button, voice command or any other trigger) if not handled automatically by an *IO Task*. If the SYN trigger is detected before timeout, the microphone signal is captured and the results are displayed. Otherwise, an error will be generated and you need to repeat. *If case of problems, check the level settings first. If the test signal was clearly audible but not detected, check the microphone setup, the input routing settings or try a different External Synchronization Template*



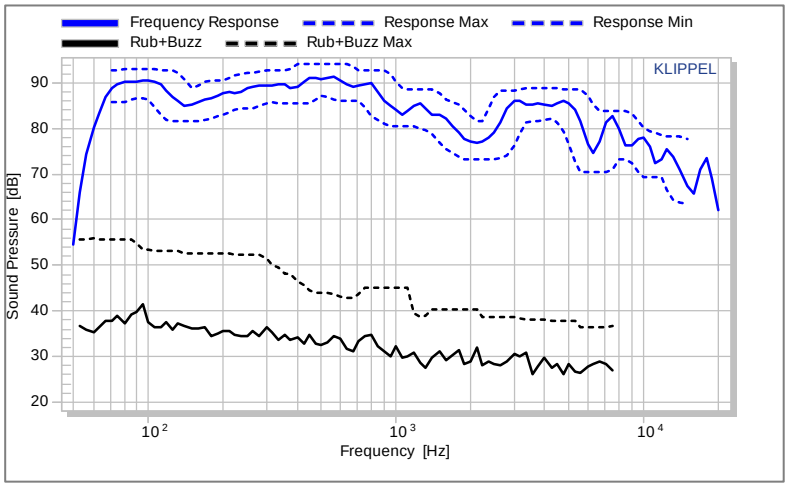
	with longer sync time. Refer to SYN Manual for further information about selecting the right template or for debug information.

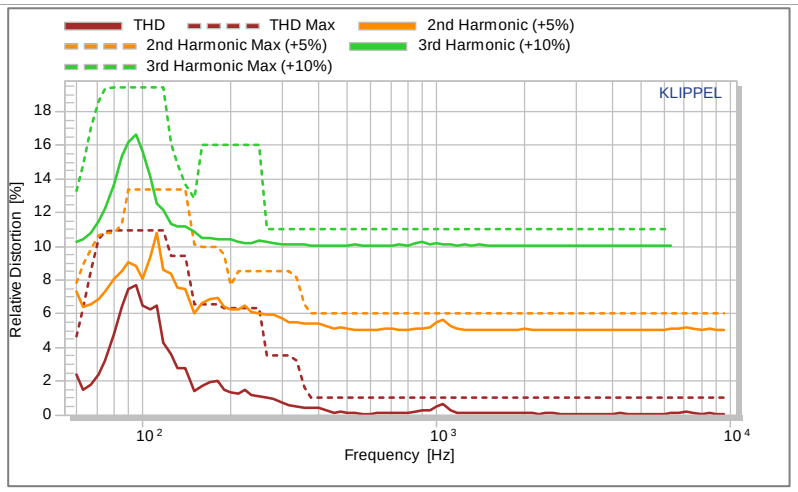
6.4 Limit Calculation

Relative Limits	Refer to section *Limit Calculation.*

7 Results and Limits

7.1 Speaker Test

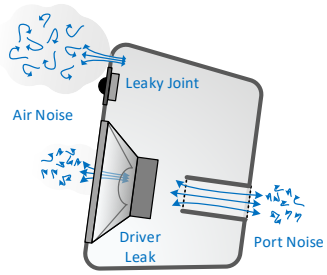
Frequency Response (Speaker)	In the *Frequency Response* window, the smoothed SPL frequency response is displayed. For separate left and right channel testing, the curve colors can be edited in the SPL task's display settings in order to separate the left and right channel results visually.  Limits should be applied only in the pass band range where the SNR is sufficiently high. Use floating limits to neglect absolute level in order to evaluate only curve shape.
Rub & Buzz	*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 (limiter, signal drop outs). The (absolute) result curves in dB SPL are also plotted in *Frequency Response* window. *Since this parameter is sensitive towards to any external noise disturbance, it is recommended to use a well-damped test chamber and activate ambient noise detection feature or Production Noise Immunity (PNI) add-on.*
Average Level (Sensitivity)	The single value result *Average Level* is derived from the *Frequency Response* curve (before smoothing). Using default settings, it 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) using property *Average Level – Frequencies*. [TASK OUTPUT: SOUND PRESSURE] Name | Value | Min Limit | Max Limit | Unit | Description Average Level | 86.5 | 83.2 | 89.2 | dB | average level
Polarity	The polarity check is based on the acoustic phase response at low frequencies, relative to the phase of the reference units. This test is robust towards small phase variation and detects wrong polarity (180° phase shift) reliably.
Harmonic Distortion	Relative harmonic distortion such as *Total Harmonic Distortion* (*THD*), 2nd and 3rd harmonic *is* displayed in result window *Distortion*. For better overview, the curves are shifted by 5 % and 10 % respectively. This can be adjusted or deactivated in the *Display* properties of the *Sound Pressure* task.



Harmonic distortion can be displayed in absolute SPL or relative to the isolated fundamental (IEEE) or total harmonic signal (IEC). In the example above, another relative calculation mode *% (relative to level)* has been 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* stand-alone task or the *ALD in SPL* sweep 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%

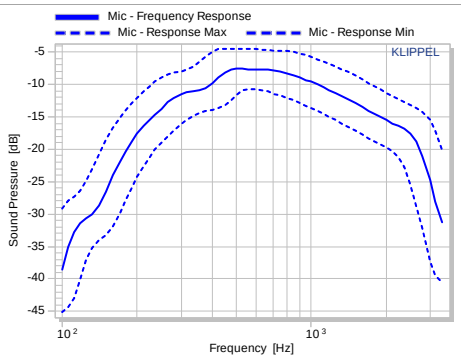
and the measured absolute *MODulation* SPL level and relative modulation index are displayed in the *Summary* window.

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

7.2 Microphone Test

Frequency Response

The DUT microphone's response to the noise signal played back by the reference sound source is displayed in *Frequency Response* window.

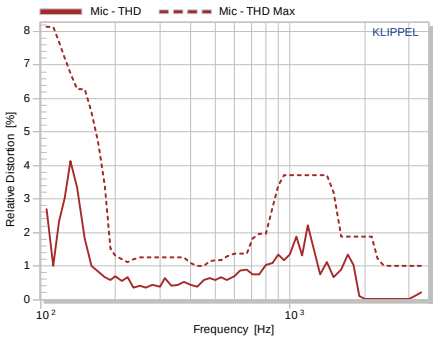


The maximum sample rates supported by *CVSD* (*mSBC*) codec as used in *Bluetooth HFP/HSP* profiles limit the effective bandwidth to 4 kHz (8 kHz) while the lower end is usually limited by the sound source.

Since the DUT microphone sensitivity is usually unknown and different for each DUT, the result data is presented as a voltage level (check that the used Line inputs are calibrated as microphone inputs).

The sound source may be equalized and adjusted to a defined target SPL. See Adjusting Target SPL and Sound Source Equalization for more information.

THD	For the DUT microphone, the *THD* shall be calculated relative to frequency response or average level in percent. Use level reference if the fundamental frequency response is not smooth or shows strong dips. *Note that the THD result reading reflects both the distortion introduced by the sound source and microphone. Make sure that the sound source is operated with sufficient headroom to minimize distortion. However, the SPL should be sufficiently high to test the DUT at critical levels and with sufficient SNR.*



7.3 Test Verdict

Single Operation	For a normal test with only one QC operation the overall test verdict is displayed in *Summary* window (might be hidden in batch run). The verdicts are only available if limits have been calculated previously.
Batch Run	For a full batch run of multiple test steps with different audio devices, the *QC Verdict Collector* operation gathers all results of the preceding QC operations and generates a final overall verdict and a complete verdict list. Any failed parameter and the sub-verdict of the corresponding test step (operation) is highlighted red.

PASS

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

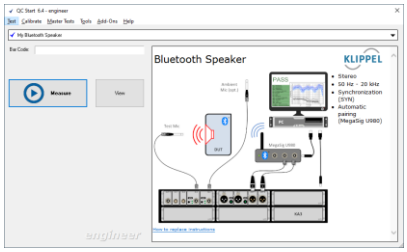
PASS (batch)

1 Speaker Test	
Frequency Response	
Average Level	
Polarity	
THD	
2nd Harmonic	
3rd Harmonic	
Rub+Buzz	
2 Microphone Test	
Frequency Response	
Average Level	
Polarity	
THD	

8 Operator Testing

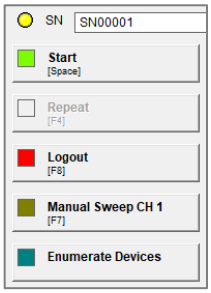
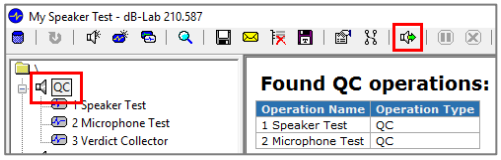
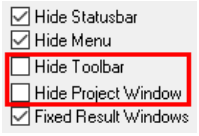
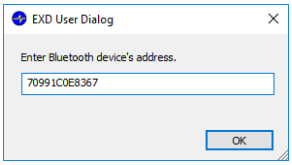
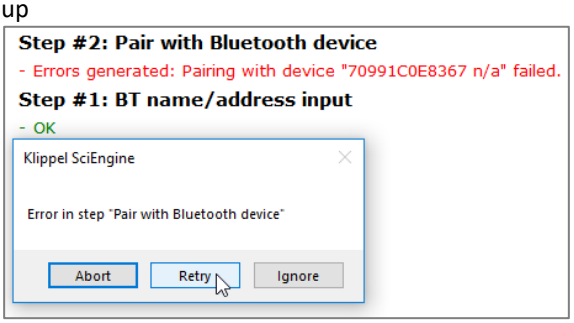
8.1 Select Test

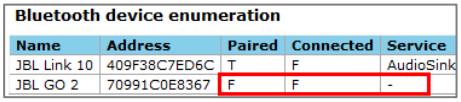
Select & Open Test	1. Start *QC Start – Operator* and find the test that has been set up for your DUT in the drop-down list 2. Click *Measure* to open the test 3. If the test only contains one operation (QC/QC), you will be logged in automatically *Automatic test selection based on masked bar code input is optional (QC Manual – How to Use Bar Code Reader Input).*



8.2 Closed-Loop Test (Bluetooth)

Mounting	1. Place the DUT on the marked position in the test chamber 2. Connect power supply if necessary 3. Switch on the device 4. Activate pairing mode 5. Shut the test chamber (only if no serial number or Bluetooth address needs to be scanned)

<table>
<tr><td>Start Test</td><td>Single Operation
For a normal test with only one QC operation, use the QC Control Panel for test control
If serial number input is activated: use the serial number input field to enter (or scan) the serial number of the DUT; terminate with Enter key
Otherwise use the Start button, Space key or GPIO start trigger pin</td><td> 
</td></tr>
<tr><td></td><td>Multiple Operations (Batch Run) 
To execute the complete operation sequence, select the QC Object and click the Run Batch icon in the task bar (Ctrl-B)
In the following dialog, click 
 tio start the batch</td><td>In order to allow batch run for the operator, make sure that operator screen layout settings (QC Start – Tools – Settings – Operator Start Parameters) are set according to the screenshot below. 
</td></tr>
<tr><td>Pairing</td><td colspan="2">This step only applies if EXD Bluetooth Pairing feature with address prompt input mode is used. Skip this step if the device has been paired manually, a static address/name has been entered or any other automated process is used.
Right after test start, a message box will pop up with a text input field for the device's Bluetooth address 
Make sure that the DUT is in pairing mode
Enter the address manually or use a scanning device (e.g. NFC reader) with keyboard wedge to fill in the device address (may be terminated with line feed to continue)
Confirm with Enter key, if necessary
If the device could not be paired within the specified Timeout limit and EXD Error Handling was set to Notify, an error will be displayed in Summary window and a message box pops up 

Check that the device is in pairing mode and click Retry or Abort in case the reason is not known and Retry repeatedly fails
Use Enumerate button in Control Panel to list all paired and available devices 
</td></tr>
<tr><td>Result</td><td colspan="2">In case the overall verdict is PASS, you may remove the DUT and continue with the next device</td></tr>
</table>

	2. In any other case (NOISE or FAIL) you may use the *Repeat* button or rerun the batch operation to try again and overwrite the current test results; if the device is still paired and connected, the measurement will start immediately

8.3 Open-Loop Test

Mounting	1. Place the DUT on the marked position in the test chamber 2. Connect power supply if necessary 3. Switch on the device 4. Establish data connection (e.g. setup playback device, connect USB or setup Wi-Fi) 5. Make the test signal available (e.g. copy the exported stimulus audio file to the device memory) 6. Set focus to serial number input field in *QC Control Panel* and scan serial number 7. Shut the test chamber
Start Test	1. If not done automatically terminate the entered serial number with *Enter* key 2. Otherwise use the *Start* button, *Space* key or *GPIO* start trigger pin 3. The test sequence stops in idle mode waiting for the synchronization signal 4. Trigger playback of the test signal
Result	1. The test sequence should run until the final verdict is displayed 2. In case the overall verdict is PASS, you may remove the DUT and continue with the next device 3. In case of NOISE or FAIL verdict, you may use the *Repeat* button or rerun the batch operation to try again and overwrite the current test results 4. If the synchronization signal was not detected after some time, no final verdict will be displayed – check the device state and level and repeat playback of the test sequence

9 Further Topics

9.1 Adjusting Target SPL and Sound Source Equalization

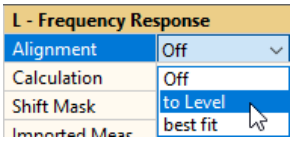
There are different scenarios where it is necessary to adjust playback level or frequency response to a certain target value or curve, such as

- Sound source equalization for microphone test or
- Adjusting consistent test SPL output of digital devices with no analog input.

The optional *Equalization & Alignment (EQA)* task meets those requirements.

It adjusts stimulus voltage/level and *Level Profile* (vs. frequency) in order to meet the target single tone or frequency response automatically. Also assisted manual adjustment is supported (e.g. for manual volume control). The resulting setting can be imported seamlessly into the measurement tasks in the test sequence. The alignment step can be part of the test sequence or an independent off-line operation. See *EQA User Manual* for more information.

9.2 Frequency Response: Level Normalization & Floating Limits



For digital and active playback devices, it may be difficult to ensure consistent playback level among several DUTs. In order to neglect playback level and test only frequency response shape, dedicated limit modes are available in *Limit Calculation Mode*. Using the mode *"to Level"*, the limit curves are shifted by the change of average level relative to the reference measurement(s).

Processing	
Windowing of IR	Off
Result Frequencies	R40 (12 pts/oct)
Response - Smoothi	6
Response - EQU	
Response - Normalize	Average Level

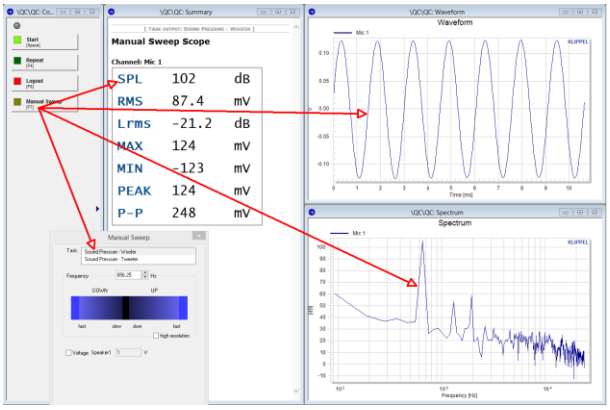
The response normalization mode "Average level" fits well to this limit mode and results in a normalized view as shown below. Find more information in *QC User Manual*.

9.3 Manual Sweep Diagnostics

For digital or wireless devices, the signal chain from the signal source to the microphone inputs is quite complex. During setup phase, a live scope is a helpful tool to check the signal outputs and inputs as well as SPL at certain frequencies.

The *Manual Sweep* feature provides an interactive sine tone generator and input signal scope including spectrum, waveform (total SPL and *Rub&Buzz*) and single value characteristics. The feature can be used if any sweep-based measurement task is used in the test sequence.

The optional *Manual Sweep Controller* allows controlling frequency and level intuitively. In addition, the sound pressure signal of the headphone mounted on the test fixture may be monitored in parallel easily via the PC sound card. For more information, refer to *QC User Manual* sections *Manual Sweep* and *Live-Monitoring of microphone signal.*



9.4 Bluetooth Codec Considerations

A wide variety of basic and proprietary, mostly lossy audio codecs is available in Bluetooth audio. The *MegaSig U980* interface supports mandatory *SBC*, as well as various versions of the *aptX™* codec for *A2DP* as well as narrow *CVSD* and wide-band speech codec *mSBC* for *Hands-free Profile (HFP)*.

If possible, testing should always be performed using *A2DP* profile since it provides superior bandwidth and dynamic range over *HFP* which is dedicated to voice communication. The latter should only be used for basic quality check of the DUT's microphone since the playback channel is also degraded.

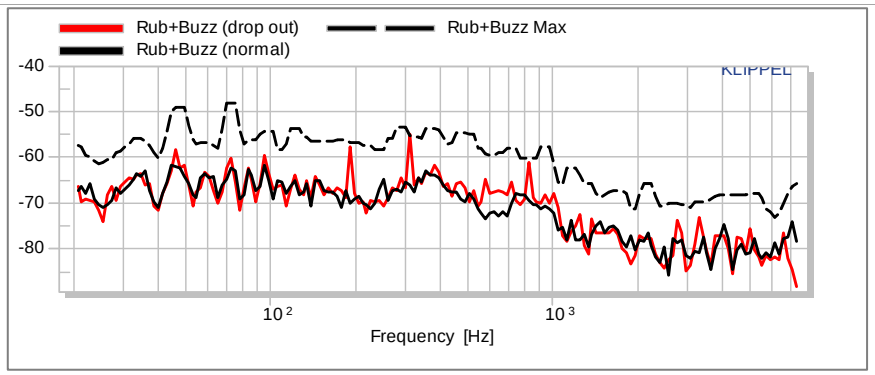
The more advanced audio codecs (*aptX* …) that are not part of the basic Bluetooth audio standard are based on auditory models to provide optimal compression and quality for the listener. This does not necessarily apply to measurements with synthetic, narrow-band test signal since the dynamic range might be reduced by the codec's perceptual processing artifacts.

Therefore, using basic *SBC* codec is recommended for testing, in general. Still, even with this base codec various compression rates are available. Therefore, the actual compression quality is not clearly defined and depends on both source and sink device.

For more information refer to this link with an extensive review of various codecs and its effects (not verified by KLIPPEL): https://habr.com/en/post/456182/

9.5 Handling Drop-outs in Digital & Wireless Devices

Signal dropouts due to packet losses are inherent in wireless transmission channels. In many cases, those transmission errors are hardly audible due to concealment algorithms or masking effects. However, a critical acoustical test will be affected by any signal drop-out and may lead to a false reject, especially when impulsive distortion (*Rub&Buzz*) is tested. The symptoms of a lose particles, random ambient noise and a signal-drop out are very alike as they all cause random impulses as shown in the plot below. The figure shows two impulsive distortion plots of direct signal loopback with *Bluetooth* wireless transmission. The red curve includes signal drop outs that might even lead to a pass/fail limit violation.



To reduce signal drop outs, make sure that

- *Bluetooth* source and sink are as close to each other as possible and
- the *Bluetooth* source has a high transmission power class (e.g. Bluetooth Class 1).

Since packet drop-outs can still not be prevented completely, the following strategies can be applied to avoid false rejects:

- Use ambient noise detection or *PNI* add-on to detect external acoustical disturbance
- In case of a FAIL verdict, repeat the test (step) to identify whether the DUT shows systematic Rub&Buzz (second test also fails) – this can be automatized using *Sequence Control* feature
- If the repeated test passes, the chances are high that the previous test was corrupted by a random signal drop out (or a highly instable lose particle defect)

With this strategy false rejects due to transmission losses can be reduced to a minimum, but there is still a chance that very randomly occurring lose particle defects may pass the test.

10 References

10.1 Manuals	• QC User Manual • SYN User Manual • EXD User Manual • PNI User Manual • SAN User Manual • ALD User Manual • dB-Lab User Manual • Hardware Manual
10.2 Specifications	Software • C3 - QC Set • S18 – QC ALD – Air Leak Detection • S21 - QC PNI – Production Noise Immunity • S31 - QC EXD – External Devices • S32 - QC SYN – External Synchronization • S33 - QC EQA – Equalization & Alignment • S48 - Statistics • S65 - QC SAN - Spectrum Analysis Hardware • A4 - Microphones • A6 – Accessories for the KLIPPEL Analyzer System • A14 - Artificial Ears & Mouths • A15 – Sound Sources • H3 - Klippel Analyzer 3 Other • KLIPPEL QC PC Requirements • KLIPPEL Amplifier Requirements
10.3 Example Set	• Example Set for Wireless Speaker Quality Control • Example Set for Headphone Quality Control All example sets and price lists can be found on the KLIPPEL website.

10.4 Standards	• IEC 60268-21
10.5 Application Notes	• AN46 Test Enclosure for QC • AN72 Testing Wireless Audio Devices with Klippel R&D System • AN73 QC Headphone Testing All KLIPPEL application notes can be downloaded from our website.
10.6 Related Products	• TRF - Transfer Function Measurement Find more related modules in the applications section of our website.

Find explanations for symbols at:
http://www.klippel.de/know-how/literature.html
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