# QC – Air Leak Detection (ALD) S18

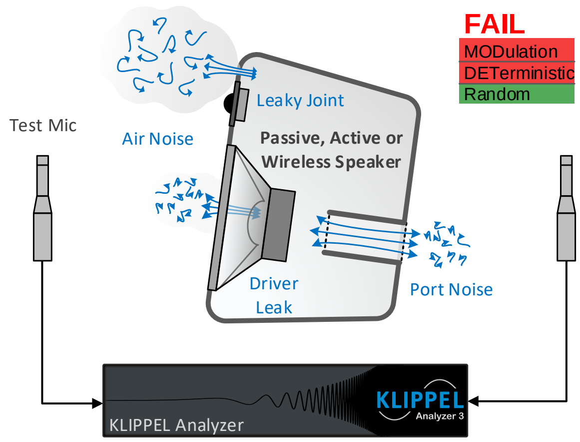
Module of the KLIPPEL ANALYZER SYSTEM

(QC 6, dB-Lab Ver. 210, Document Revision 1.10)

| FEATURES | BENEFITS |
|---|---|
| • Measurement of air leak noise and other triggered noise (e.g. port noise, irregular rubbing) generated in loudspeaker systems<br>• Measurement of systematic rub and buzz defects and air leakage distortion<br>• Measurement of loose particles and other defects producing random symptoms<br>• Ambient noise detection with auto repeat | • Detect small air leaks in drivers and enclosures<br>• Fast measurement<br>• Easy to use<br>• Ambient noise immune<br>• Highest sensitivity using stand-alone ALD task<br>• Highest Speed with integration in QC SPL task |

This add-on module for the QC software framework of the *KLIPPEL Analyzer System* is dedicated to detecting of air leaks in loudspeaker enclosures and drivers.

The acoustical measurement principle provides optimal sensitivity for pulsating noise based on a demodulation technique as well as a dedicated harmonic distortion analysis. This yields unique symptoms of turbulent air noise and leak distortion in order to distinguish this defect from rub and buzz, loose particles and other failures.




The dedicated *Air Leak Detection* measurement task uses single bass tone excitation providing very high sensitivity for extremely small, but audible leaks (Ø < 1 mm) that cannot be detected by other means such as *Rub&Buzz* or impedance testing. The same technology is also available as an integrated solution in the standard Sound Pressure task. A user definable bandwidth of the sine sweep can be used combining high sensitivity with highest possible speed. Both versions allow testing with multiple microphones located around large measurement objects (large enclosures). The powerful tool combines easy handling with high-speed measurement and robustness against ambient noise.

**Applications:**

- End-of-line testing
- Incoming goods inspection (rental companies)
- Diagnostics
- Research & development

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| Article Number | 4000-240 |

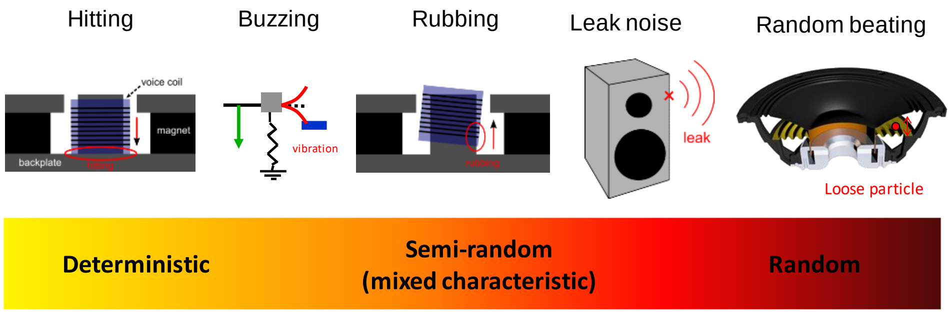
**CONTENT:**



# 1 Overview

**Summary**

**Overview of Loudspeaker Defects**




**Corresponding ALD measures**

| DETerministic | MODulation | Random |
|---|---|---|
| DETabs DETrel<br>DET(L)abs DET(L)rel | MODabs MODrel | **Rand**om |

The reduction of loudspeaker cabinet dimensions and the use of pre-equalizers to enhance the low frequency performance even below the system's resonance frequency results in excessive sound pressure peak levels within loudspeaker enclosures. Driving a bass reflex system near the port resonance frequency leads to similar conditions and port turbulences. In these cases, the performance of a system strongly depends on the mechanical stability and quality of the driver, the enclosure or the bass reflex port.

Even a small air leak can cause pulsating and highly audible air noise and other distortion. A new measurement technique is presented which makes it possible to quickly identify noise caused by air leakage, port turbulences or other and similar defects with a high sensitivity. The symptoms are separated from *rub & buzz* (deterministic) and more random defects such as rattling of loose particles. The single value results are easy to interpret and directly indicate and quantify air leak noise as well as other defect distortion.

**ALD-Task Principle**

The ALD task is based on a dedicated measurement principle. The device under test (DUT) is excited by a low frequency tone to stimulate air leaks and other flow noise. The sound pressure response is measured in the near field of the DUT.

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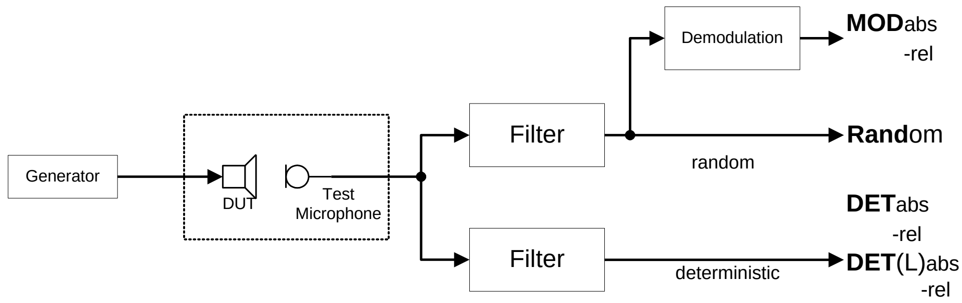
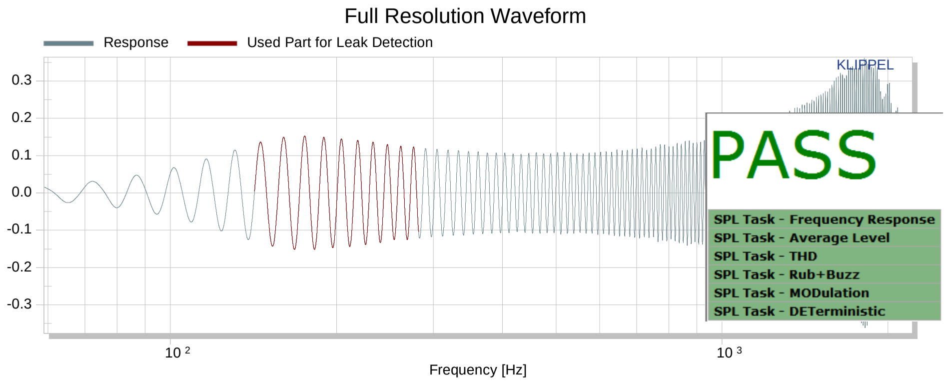
| | The output parameters of the ALD task are calculated by exploiting the unique signal characteristics of amplitude modulated air noise and deterministic leak distortion, which also provide separation from other defects and uncorrelated signals.<br><br> |
| **SPL-Task Integration** | The same analysis methods can be applied to a defined frequency band of the standard SPL sweep for parallel analysis of leak symptoms and standard acoustical properties. A user defined center frequency and bandwidth define a part of the sweep which is analyzed for leak symptoms. The results are identical to the ALD-task with the exception of Random symptoms. Such are detected in the SPL-Task using the standard Rub&Buzz measure.<br><br>Example:<br>$f_{ALD}$ = 200 Hz; $B_{ALD}$ = 1 oct.; $t_{meas}$ = 500 ms<br><br> |
| **QC Requirements** | The ALD was developed to satisfy the following requirements occurring under production conditions:<br>• Reliable detection of air leakage due to mechanical defects of manufactured drivers, ports and loudspeaker systems<br>• Quantifying defect distortion using single value sound pressure levels (**MOD**abs, **DET(L)**abs, **DET**abs, **Rand**om)<br>• Qualitative relative level measures to verify results (**MOD**rel, **DET(L)**rel, **DET**rel)<br>• Ability to work with different QC hardware setups depending on requirements (e.g. multiplexed microphone array)<br>• Reliable detection of ambient noise and automatic test repetition |
| **Ambient Noise Detection ALD-Task** | The ALD Task provides ambient noise detection using an additional ambient noise microphone to prevent false FAIL verdicts caused by external noise. Noise detection is based on parallel signal processing using the tolerance limits, as well as |

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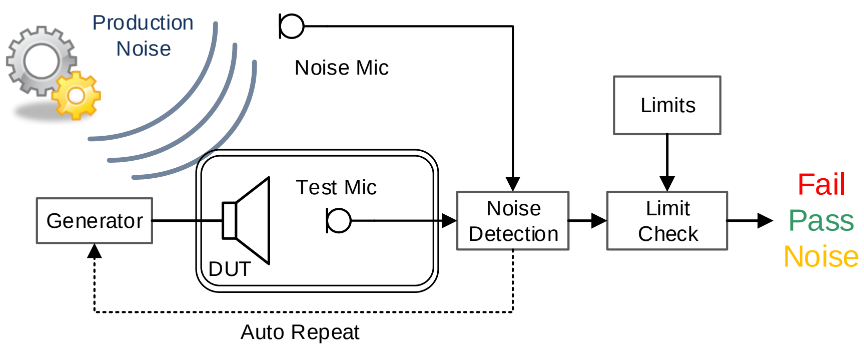
| | time correlation. Additionally, a single microphone noise identification algorithm is provided in case no ambient noise microphone is utilized.<br><br>**Note**: The integrated leak detection in the SPL task may be combined with *the Production Noise Immunity* option. Without this option, ambient noise corruption is still reliably detected. Please see specification *S21 - QC Production Noise Immunity*. |

## 2 Definition of Results

| **MODulation** | |
|---|---|
| **Modulated distortion (absolute)**<br>**“$MOD_{abs}$”** | **DEFINITION:** The **$MOD_{abs}$** describes the <u>absolute</u> level of amplitude-modulated noise as generated by turbulent flow in leakages and other semi-random defects:<br>$$MOD_{abs} = 10\log\frac{\hat{p}_{env}^2}{p_0^2}\,\mathrm{dB}. \qquad (1)$$<br>The modulation envelope peak value is related to the standard reference sound pressure $p_0$ (comparable to SPL). |
| | **Application to end-of-line testing**<br>This measure is optimal for an absolute assessment of air leakage noise and other modulated noise caused by defective devices. If the amplitude of the modulation envelope is below a permissible limit value the DUT may pass the test because the impact on sound quality is negligible. The limit value may be calculated automatically by measuring good units and using the shift algorithm.<br>**Further remarks**<br>There is no general threshold of **$MOD_{abs}$** to indicate a clear defect as the absolute level strongly depends on the DUT and the measurement conditions. A certain signal floor is always present after the demodulation consisting of all kinds of broad-band noise during the measurement. Use the **$MOD_{rel}$** to evaluate the modulation symptom strength. |
| **Modulated distortion (relative)**<br>**“$MOD_{rel}$”** | **DEFINITION:** The **MOD**rel is a <u>relative</u> measure derived from the **MOD**abs measure and is calculated as<br>$$MOD_{rel} = 10\log\frac{\hat{p}_{env}^2}{\bar{p}_{floor}}\,\mathrm{dB}. \qquad (2)$$<br>The peak value of the (squared) modulation envelope is related to the average broadband floor of the modulation spectrum. |
| | **Application to end-of-line testing**<br>**$MOD_{rel}$** describes the modulation symptom strength on a relative scale. The standard value in the optimal case is around or below 0 dB. If **$MOD_{rel}$** exceeds |

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| | this value with a certain tolerance (~5 dB) significant modulation is found. Thus, this threshold can be used as a universally valid limit for end-of-line testing to indicate e.g. leak noise. In contrast to **MOD$_{abs}$** it neglects the absolute amplitude of the distortion, audibility and the impact on sound quality.<br>**Further remarks**<br>The **MOD$_{rel}$** supplements the **MOD$_{abs}$** because it characterizes the modulation symptoms relative to the modulated distortion signal floor. Thus, it represents modulated distortion qualitatively (comparable to SNR). Only values clearly above 0 dB indicate significant symptoms, values below are not indicated. |
| **DETerministic** | |
| **Deterministic Leak Distortion (absolute) "DET(L)$_{abs}$"** | **DEFINITION:** The **DET**(L)$_{abs}$ is an <u>absolute</u> measure for specific deterministic distortion caused by air leaks and is based on averaged long-term spectral analysis. The peak value of the averaged leak distortion is expressed as an SPL:<br>$$DET(L)_{\mathrm{abs}} = 20\log\frac{\hat{p}'_{\mathrm{det,leak}}}{p_0}\,\mathrm{dB}. \quad (3)$$ |
| | **Application to end-of-line testing**<br>The **DET(L)$_{abs}$** only considers deterministic distortion which is very specific for small air leaks which emit no or only little (modulated) turbulent flow noise, especially at low stimulus levels. Thus, it is a very sensitive and independent measure. Combined with the **MOD$_{abs}$** measure it is very powerful for detecting leaks by covering all possibly symptoms of leak noise. |
| **Deterministic Leak Distortion (relative) "DET(L)$_{rel}$"** | **DEFINITION:** The **DET**(L)$_{rel}$ is derived from **DET**(L)$_{abs}$ as a <u>relative</u> level measure. It represents the modified crest factor of deterministic leak distortion using a cleaned RMS value:<br>$$DET(L)_{\mathrm{rel}} = 20\ \log\frac{\hat{p}'_{\mathrm{det,leak}}}{\tilde{p}'_{\mathrm{det,leak}}}\ \mathrm{dB} \quad (4)$$ |
| | **Application to end-of-line testing**<br>The **DET(L)$_{rel}$** describes the impulsiveness of the deterministic leak distortion. Noise and regular distortion in loudspeakers are not impulsive and have a **DET(L)$_{rel}$** < 12 dB. This threshold can be used as a universally valid limit for end-of-line testing. In contrast to **DET(L)$_{abs}$** it neglects the absolute amplitude of the distortion, audibility and the impact on sound quality. |
| **Deterministic Distortion (absolute) "DET$_{abs}$"** | **DEFINITION:** The **DET**$_{abs}$ is an <u>absolute</u> measure for deterministic (strictly periodic) *Rub&Buzz* distortion. Based on long-term spectral analysis it evaluates the averaged high order harmonic distortion. The distortion peak value (using phase and amplitude) is expressed as a sound pressure level:<br>$$DET_{\mathrm{abs}} = 20\log\frac{\hat{p}'_{det}}{p_0}\,\mathrm{dB} \quad (5)$$ |
| | **Application to end-of-line testing**<br>The **DET$_{abs}$** only considers deterministic distortion, which is caused for example by hard limiting of the voice coil movement. Most rub and buzz defects have a strong deterministic component. If the **DET$_{abs}$** value exceeds a predefined limit the deterministic distortion has a strong impact on sound quality and the device fails the test. |

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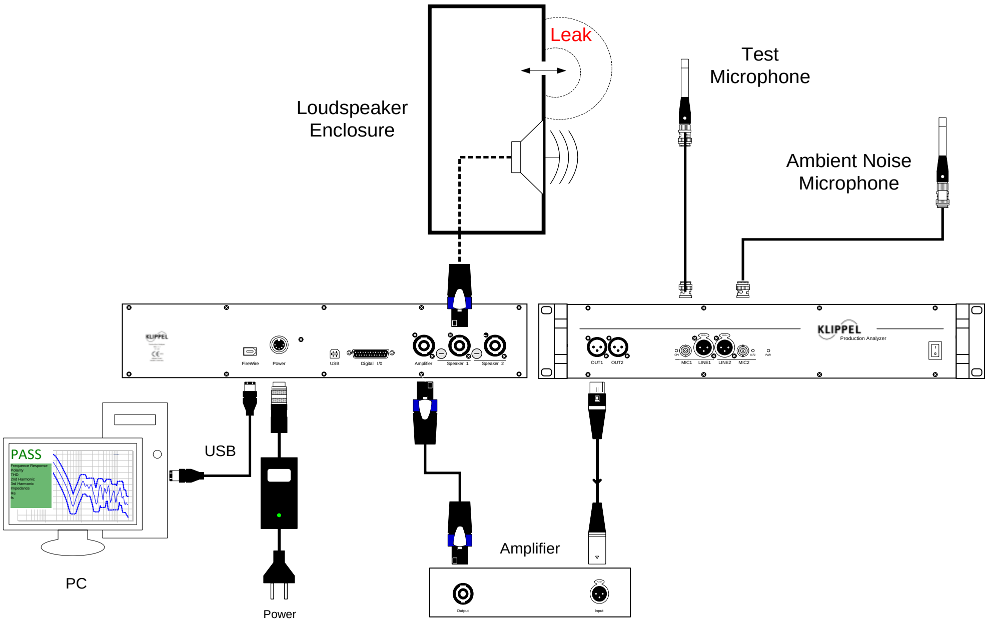
| **Deterministic Distortion (relative) "DET$_{rel}$"** | **DEFINITION:** The **DET**$_{rel}$ is derived from **DET**$_{abs}$ as a <u>relative</u> level measure representing the crest factor of deterministic distortion. It is calculated by relating the distortion peak to the distortion RMS: $$DET_{\mathrm{rel}} = 20\log\frac{\hat{p}'_{\mathrm{det}}}{\tilde{p}'_{\mathrm{det}}}\,\mathrm{dB}. \qquad (6)$$ |
| | **Application to end-of-line testing**<br>The **DET$_{rel}$** describes the impulsiveness of deterministic distortion. Noise and regular distortion in loudspeakers are not impulsive and have a **DET$_{rel}$** < 12 dB. This threshold can be used as a universally valid limit for end-of-line testing but neglects the absolute amplitude of the distortion, audibility and the impact on sound quality. |
| **Random** | |
| **Random Distortion (absolute) "Random"** | **DEFINITION:** The **Rand**om is an absolute measure for randomly occurring distortion. It represents the instantaneous peak SPL of the non-deterministic sound pressure response: $$Random = 20\log\frac{\hat{p}_{\mathrm{rand}}}{p_0}\,\mathrm{dB} \qquad (7)$$ The non-deterministic signal is obtained by removing the deterministic distortion components (fundamental and harmonic distortion). |
| | **Application to end-of-line testing**<br>The **Rand**om describes the peak value of the distortion signal in the time domain exploiting phase and amplitude information. This measure is very sensitive for loose particles producing random symptoms. |

# 3 Hardware

<table>
<tr><td>Minimal Setup</td><td>


The figure above shows the minimal equipment required to run the ALD
<ul>
<li>KLIPPEL Production Analyzer (KLIPPEL Analyzer 3 or 3rd party sound card may be used instead)</li>
<li>measurement microphone</li>
<li>opt: ambient noise microphone (noise detection)</li>
<li>personal computer</li>
<li>for passive speakers: external power amplifier or Amp Card</li>
</ul>
→ more information in the KLIPPEL specification “C3 - QC End of Line Test System”
</td></tr>
<tr><td>Analyzer Hardware</td><td>
For testing active systems, the ALD may be operated with any 3rd party audio interface (sound card).<br>However, for optimal performance or passive systems the<br>KLIPPEL Analyzer 3 - QC or (A)LSX configuration<br>or<br>Production Analyzer<br>is recommended.
Please find more information in the specifications H3 – KA3 and H4 – PA for detailed specification.
</td></tr>
<tr><td>Microphones</td><td>
For best performance of the ALD a high microphone sensitivity and a low microphone noise level is crucial. It is recommended to use high-quality microphones (e.g. MIC255).
Please find more information in A4 – Microphones.
</td></tr>
<tr><td>Power Amplifier</td><td>
Any standard audio amplifier meeting the power and bandwidth requirements of the tests may be used. Please refer to KLIPPEL_Amplifier_Requirements for more information.
The Amplifier Card for KA3 is suitable as well in case the voltage and power requirements of the test are fulfilled.
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| **PC** | Please refer to the general recommendations in: *KLIPPEL QC SYSTEM PC Requirements* |
| **Acoustical Environment** | The ALD detects corrupted measurements caused by ambient noise using an ambient microphone. However, the maximal sensitivity for detecting even smallest air leaks requires a low acoustical noise floor.<br>Therefore, a proper measurement environment or an enclosure is recommended in order to provide high ambient noise attenuation. |

## 4 ALD-Task (stand-alone)

| SETUP PARAMETER LIMITS | | | | | |
|---|---|---|---|---|---|
| **Parameter** | **Symbol** | **Min** | **Typ.** | **Max** | **Unit** |
| ***Category Stimulus*** | | | | | |
| Measurement time (list) without pre-loop | $t_{\mathrm{meas}}$ | 0.17 | 0.68 | 5.46 | s |
| Preloop (pre-excitation time) | $t_{\mathrm{pre}}$ | 0.1 | 0.2 | 20 | s |
| Stimulus frequency (automatically rounded to analysis fitted value | $f_{\mathrm{stim}}$ | var | 50 | 1000 | Hz |
| Stimulus voltage (RMS, stated for rating for Speaker channel routing) | $\tilde{U}_{\mathrm{stim}}$ | 0 | 1 | 200 | V |
| Stimulus level (peak, for digital output device) | $L_{\mathrm{stim}}$ | -inf | -6 | 0 | dBFS |
| ***Category Processing*** | | | | | |
| Minimal analysis frequency (high pass prefilter for MOD and Random) | $f_{\mathrm{HP}}$ | 0 | 2000 | 20000 | Hz |
| Minimal harmonic order for deterministic distortion | $n_{\mathrm{HP}}$ | 10 | 20 | var | - |
| Input gain – preamp gain for analyzer input 1/2 | $G_{\mathrm{pre}}$ | -70 | 0 | 30 | dB |

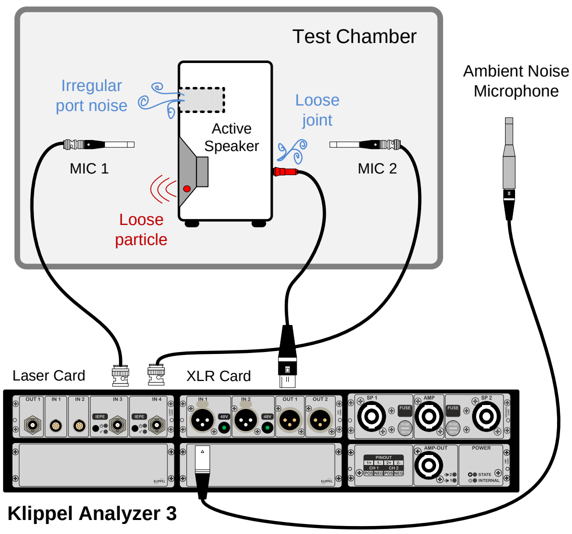
| MEASUREMENT RESULTS | | | | |
|---|---|---|---|---|
| **Measured Quantity** | **Symbol** | **Unit** | **QC limits can be applied** | **Process indices (Cpk/ Ppk) can be applied** |
| Modulated distortion (absolute) | **MOD**abs | dB | x | x |
| Modulated distortion (relative) | **MOD**rel | dB | x | x |
| Deterministic leak distortion (absolute) | **DET**(L)abs | dB | x | x |
| Deterministic leak distortion (deterministic) | **DET**(L)rel | dB | x | x |
| Deterministic distortion (absolute) | **DET**abs | dB | x | x |
| Deterministic distortion (relative) | **DET**rel | dB | x | x |
| Random Distortion | **Random** | dB | x | x |
| Results are grouped in the summary result window. Failed quantities are listed in the verdict table. | | | | |

## 5 ALD integrated in SPL Task

| SETUP PARAMETER LIMITS | | | | |
|---|---|---|---|---|
| **Parameter** | **Symbol** | **Comment** | | |
| ***Category Processing*** | | | | |
| Leak (center) Frequency | $f_{\mathrm{ALD}}$ | Defined range must be within sweep range. | | |
| Leak Bandwidth | $B_{\mathrm{ALD}}$ | | | |
| **MEASUREMENT RESULTS** | | | | |
| **Measured Quantity** | **Symbol** | **Unit** | **QC limits can be applied** | **Process indices (Cpk/ Ppk) can be applied** |
| Modulated distortion (absolute) | **MOD**abs | dB | x | x |
| Modulated distortion (relative) | **MOD**rel | dB | x | x |
| Deterministic leak distortion (absolute) | **DET**(L)abs | dB | x | x |
| Deterministic leak distortion (deterministic) | **DET**(L)rel | dB | x | x |
| Deterministic distortion (absolute) | **DET**abs | dB | x | x |
| Deterministic distortion (relative) | **DET**rel | dB | x | x |
| Results are grouped in the summary result window. Failed quantities are listed in the verdict table. | | | | |

## 6 Applications

**Active System Test with Two Microphones**




The picture shows a typical end-of-line test setup for active speaker systems such as a multimedia, Hi-Fi or portable speakers using *KLIPPEL Analyzer 3* equipped with *Laser Card* and *XLR Card*. The main test microphone is located in the front for testing typical parameters such as frequency response, THD, *Rub&Buzz* distortion etc. using

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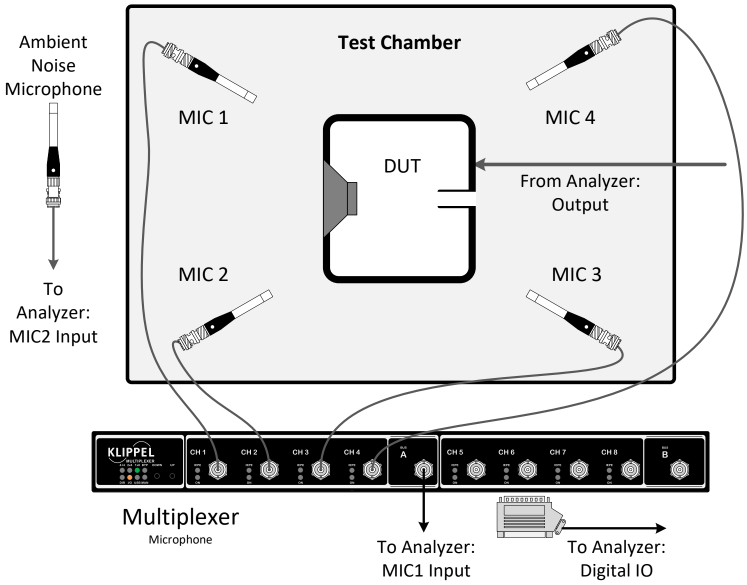
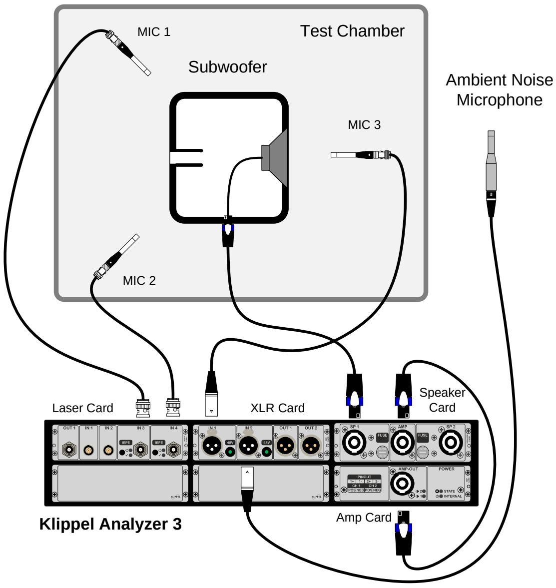
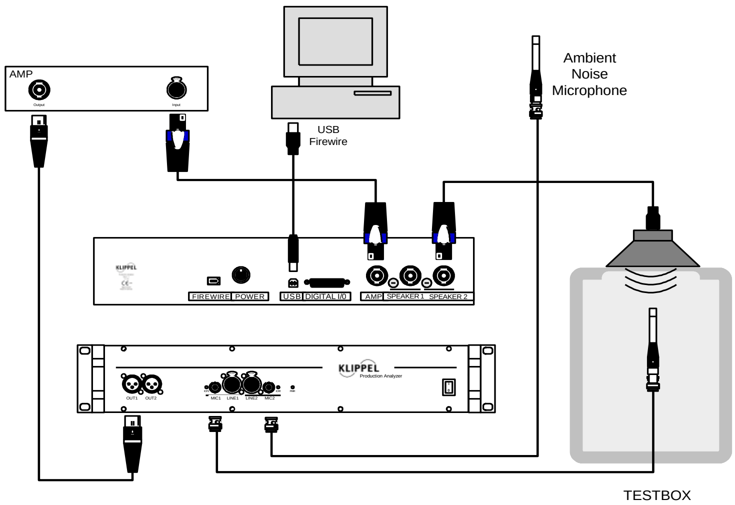
| | *SPL – Sound Pressure Task*. In order to detect loose joints, enclosure defects or irregular port noise, leakage testing can be integrated simply, directly into the sweep test by activating the ALD option in the SPL Task without adding any extra test time. To make sure that also rear defects and leakage problems are detected reliably, another test microphone may be placed at the back of the speaker for an additional ALD test step. Up to four microphones can be used for a single shot test. During the whole test sequence, the ambient microphone outside the test chamber detects ambient noise disturbance reliably and triggers the auto-repeat mechanism for single test steps, if necessary. |
| **Microphone Array for Large Subwoofer** | Detecting air leaks in large speaker systems with only one microphone suffers from acoustical shadowing of the high frequency leak noise. Locating multiple microphones around the device under test overcomes this problem and the complete surface can be covered for optimal leaks detection.<br>**Sequential Test (Production Analyzer + Mic Multiplexer)**<br>The Production Analyzer provides only two simultaneous input channels; therefore, a sequential measurement is required if multiple test microphones are used. In this example, four test microphones are switched by a multiplexer. An additional microphone outside of the test chamber monitors ambient noise in parallel. The test chamber ensures a low average acoustical noise floor for maximal measurement sensitivity.<br><br><br>**Simultaneous Test (KA3 with Input Signal Sharing)**<br>Using the KA3 hardware, a high number of input channels can be measured simultaneously using signal data sharing feature. The QC software currently supports measuring with four acoustical microphones at the same time. In case ambient noise is measured (recommended), three other microphone channels are available that may be connected to the Laser Card (IEPE microphones) or the XLR Card (48V microphones or IEPE using XLR-BNC adaptor). |




The stimulus signal is played back only once by the source ALD task which is recording all input signals. The receiver tasks only process the microphone signals recorded by the source tasks in order to generate the test results and verdicts for all microphones.

**Woofer Leakage**




Gluing errors in drivers are likely to cause air leakage in the surround or the dust cap that may only be audible in the final application when the driver is mounted in a closed or vented enclosure. Such leaks may not be detected under free air conditions due to the lag of air pressure caused by the acoustical short-circuit at low frequencies.
Measuring the driver in an adequately small test box provides the required pressure gradient at low frequencies to stimulate even very small driver leaks. Additionally, the test box offers ambient noise attenuation to go for maximal sensitivity in leak detection and driver testing.

## 7 Patents

| | |
|---|---|
| Germany | 102009033614 |
| USA | 12/819,455 |
| China | 201010228820.8 |

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