QC – Air Leak Detection (ALD) S18

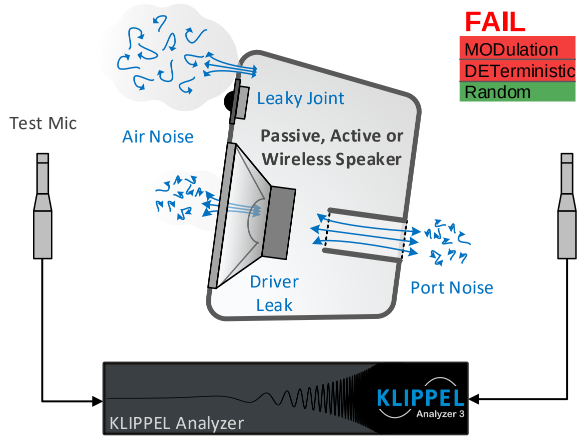
Module of the KLIPPEL ANALYZER SYSTEM

(QC 7, dB-Lab Ver. 212, Document Revision 1.13)

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

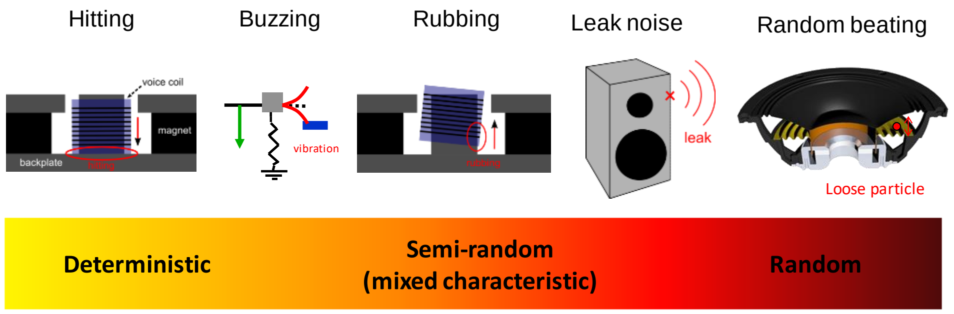
Article Number	4000-240

CONTENTS

1 Overview

Summary

Overview of Loudspeaker Defects



Corresponding ALD measures

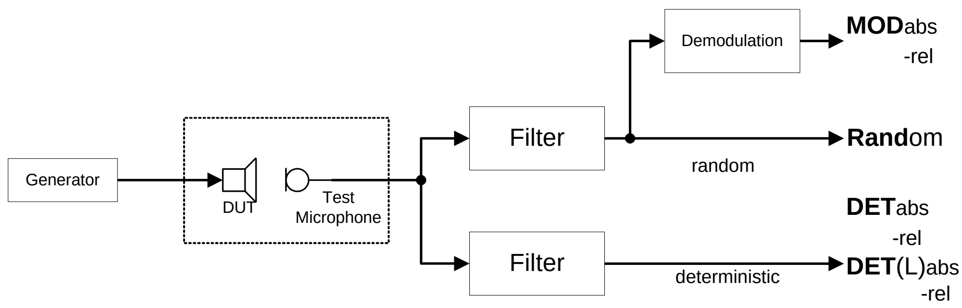
DETerministic	MODulation	Random
DETabs DETrel DET(L)abs DET(L)rel	MODabs MODrel	**Rand**om

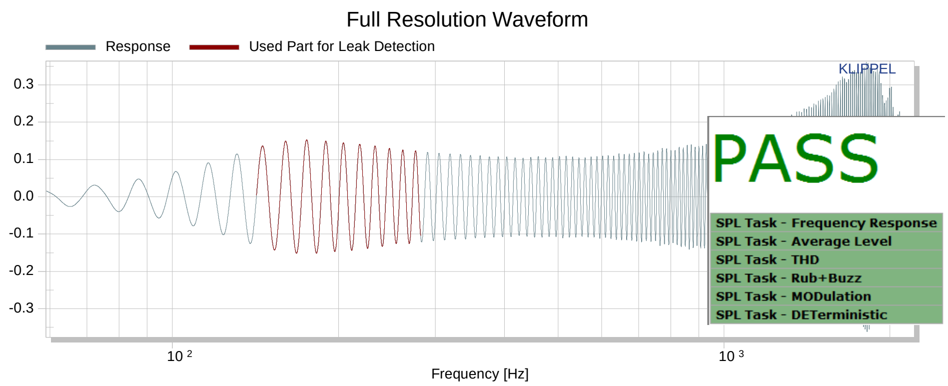
The reduction of loudspeaker cabinet dimensions and the use of pre-equalizers to enhance the low frequency performance even below the system's resonance frequency results in excessive sound pressure peak levels within loudspeaker enclosures. Driving a bass reflex system near the port resonance frequency 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

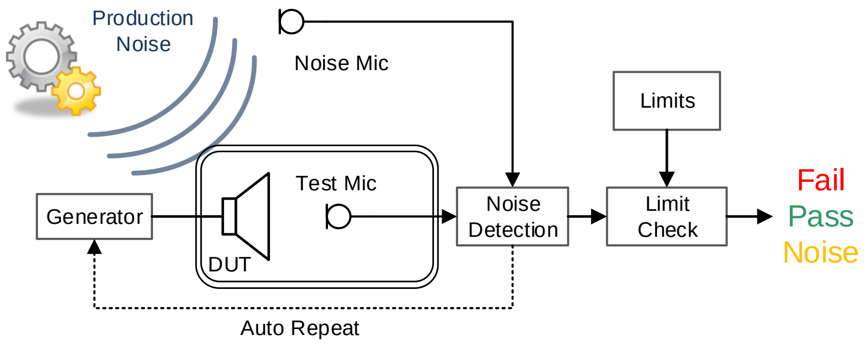
The ALD task is based on a dedicated measurement principle. The device under test (DUT) is excited by a low frequency tone to stimulate air leaks and other flow noise. The sound pressure response is measured in the near field of the DUT.

<table>
<tr><td></td><td>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.

</td></tr>
<tr><td>SPL-Task Integration</td><td>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.

Example:
f_{ALD} = 200 Hz; B_{ALD} = 1 oct.; t_{meas} = 500 ms

</td></tr>
<tr><td>QC Requirements</td><td>The ALD was developed to satisfy the following requirements occurring under production conditions:
• Reliable detection of air leakage due to mechanical defects of manufactured drivers, ports and loudspeaker systems
• Quantifying defect distortion using single value sound pressure levels (**MOD**abs, **DET(L)**abs, **DET**abs, **Rand**om)
• Qualitative relative level measures to verify results (**MOD**rel, **DET(L)**rel, **DET**rel)
• Ability to work with different QC hardware setups depending on requirements (e.g. multiplexed microphone array)
• Reliable detection of ambient noise and automatic test repetition</td></tr>
<tr><td>Ambient Noise Detection

ALD-Task</td><td>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</td></tr>
</table>

time correlation. Additionally, a single microphone noise identification algorithm is provided in case no ambient noise microphone is utilized.



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

2.1 MODulation

Modulated distortion (absolute) "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: $MOD_{abs} = 10 \log \frac{\hat{p}_{env}^2}{p_0^2} \text{ dB}.$ (1) The modulation envelope peak value is related to the standard reference sound pressure p_0 (comparable to SPL).
	Application to end-of-line testing 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. **Further remarks** 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) "MOD_{rel}"	**DEFINITION:** The **MOD**rel is a <u>relative</u> measure derived from the **MOD**abs measure and is calculated as $MOD_{rel} = 10 \log \frac{\hat{p}_{env}^2}{\tilde{p}_{floor}} \text{ dB}.$ (2) 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 **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 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. **Further remarks** 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.

2.2 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: $$DET(L)_{\mathrm{abs}} = 20\log\frac{\hat{p}'_{\mathrm{det,leak}}}{p_0}\,\mathrm{dB}. \quad (3)$$
	Application to end-of-line testing 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: $$DET(L)_{\mathrm{rel}} = 20\ \log\frac{\hat{p}'_{\mathrm{det,leak}}}{\tilde{p}'_{\mathrm{det,leak}}}\ \mathrm{dB} \quad (4)$$
	Application to end-of-line testing 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: $$DET_{\mathrm{abs}} = 20\log\frac{\hat{p}'_{det}}{p_0}\,\mathrm{dB} \quad (5)$$

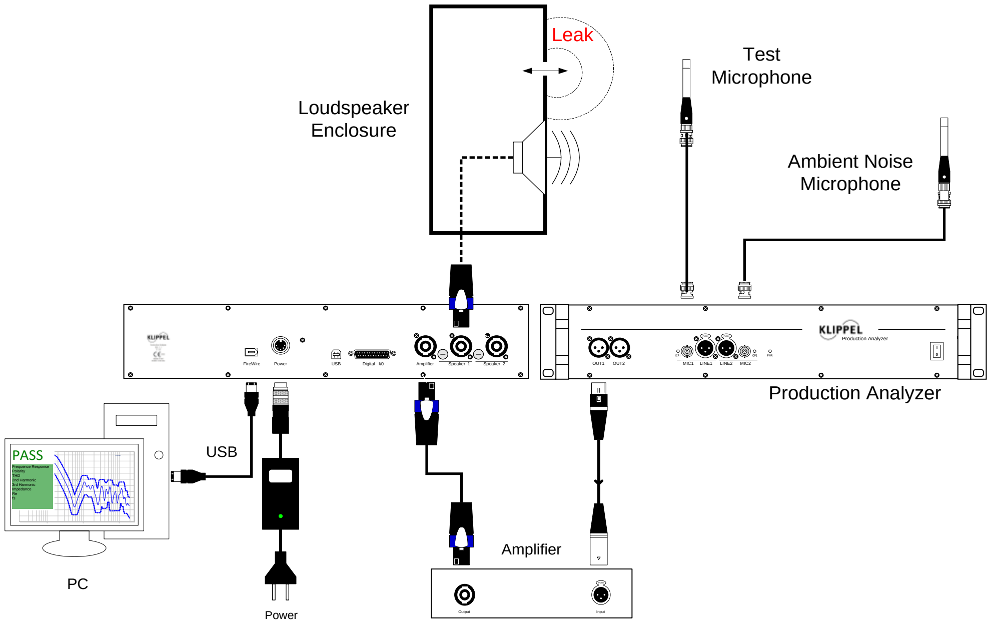
	Application to end-of-line testing The **DETabs** only considers deterministic distortion, which is caused for example by hard limiting of the voice coil movement. Most rub and buzz defects have a strong deterministic component. If the **DETabs** value exceeds a predefined limit the deterministic distortion has a strong impact on sound quality and the device fails the test.
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: $$DET_{\mathrm{rel}} = 20\log\frac{\hat{p}'_{\mathrm{det}}}{\tilde{p}'_{\mathrm{det}}}\,\mathrm{dB}. \quad (6)$$
	Application to end-of-line testing The **DETrel** describes the impulsiveness of deterministic distortion. Noise and regular distortion in loudspeakers are not impulsive and have a **DETrel** < 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.

2.3 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: $$Random = 20\log\frac{\hat{p}_{\mathrm{rand}}}{p_0}\,\mathrm{dB} \quad (7)$$ The non-deterministic signal is obtained by removing the deterministic distortion components (fundamental and harmonic distortion).
	Application to end-of-line testing 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 Requirements

3.1 Hardware

Scheme (Passive DUT)	
	
	The figure above shows the minimal equipment required to run the ALD
	• *Analyzer device*
	  ○ Production Analyzer (shown above) or
	  ○ KLIPPEL Analyzer 3 (e.g. QC or LSX configuration) or
	  ○ 3rd party sound card (*QC Stand-alone*)
	• one or more measurement microphones
	• opt: ambient noise microphone (noise detection)
	• personal computer
	• for passive speakers: external power amplifier or KA3 Amplifier or QC Card
	→ more information in the KLIPPEL specification "C3 - QC End of Line Test System"

Analyzer Hardware	For optimal performance and passive DUTs the KLIPPEL Analyzer 3 - QC or (A)LSX configuration or Production Analyzer is recommended. Please find more information in the specifications *H3 – KA3* and *H4 – PA* for detailed specification. *For testing self-powered DUTs, the ALD may be operated with any 3rd party audio interface (sound card). Amplifiers with a digital audio streaming interface are suitable as well.*
Microphones	For best performance a high microphone sensitivity and a low microphone noise floor level is beneficial. It is recommended to use high-quality microphones (e.g. MIC255). Please find more information in *A4 – Microphones*.

Power Amplifier	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* or *QC Card* for KA3 are highly suitable as well in case the voltage and power requirements of the test are fulfilled (see card specifications).
PC	Please refer to the general recommendations in: *KLIPPEL QC SYSTEM Computer Requirements*

3.2 Software

QC Framework	• KLIPPEL QC software
	  ○ *QC Standard* (Item No. 4005-001) or
	  ○ *QC Stand-alone* (Item No. 4005-500)
	• *Air Leak Detection* license
	No additional setup is required

R&D Framework	• KLIPPEL dB-Lab Release 210 or higher • *Air Leak Detection* license *No additional setup is required* **Note**: KLIPPEL Analyzer 3 (KA3) hardware is required to operate the ALD in the R&D software framework.

3.3 Acoustics

Acoustical Environment	The ALD detects corrupted measurements caused by ambient noise using a dedicated ambient microphone. However, in order to maximize sensitivity for detecting even smallest air leaks a low acoustical noise floor, is required. Therefore, a silent test environment or a well-sealed test enclosure is recommended in order to provide high ambient noise attenuation.

4 ALD-Task (stand-alone)

4.1 Setup Parameter Limits

Parameter	Symbol	Min	Typ.	Max	Unit
CATEGORY STIMULUS					
Measurement time (list) without preloop	t_{meas}	0.17	0.68	5.46	s
Preloop (pre-excitation time)	t_{pre}	0.1	0.2	20	s
Stimulus frequency (automatically rounded to analysis fitted value	f_{stim}	var	50	1000	Hz
Voltage – RMS stimulus voltage (line or amp output)	$u_{\mathrm{rms,stim}}$	0	1	200	V
Stimulus level (peak, for digital output device)	L_{stim}	-inf	-6	0	dBFS
CATEGORY PROCESSING					

Minimal analysis frequency (high pass prefilter for MOD and Random)	f_{HP}	0	2000	200 00	Hz
Minimal harmonic order for deterministic distortion	n_{HP}	10	20	var	-
Input gain – preamp gain for analyzer input 1/2	G_{pre}	-70	0	30	dB

4.2 Measurement Results

Measured Quantity	Symbol	Unit	QC limits can be applied	Process indices (Cpk/ Ppk)
Modulated distortion (absolute)	**MOD**abs	dB (re 20 µPa)	x	x
Modulated distortion (relative)	**MOD**rel	dB	x	x
Deterministic leak distortion (absolute)	**DET**(L)abs	dB (re 20 µPa)	x	x
Deterministic leak distortion (deterministic)	**DET**(L)rel	dB	x	x
Deterministic distortion (absolute)	**DET**abs	dB (re 20 µPa)	x	x
Deterministic distortion (relative)	**DET**rel	dB	x	x
Random Distortion	**Rand**om	dB (re 20 µPa)	x	x
Results are grouped in the summary result window. Failed quantities are listed in the verdict table.				

5 ALD Integrated in Sound Pressure (SPL) Task

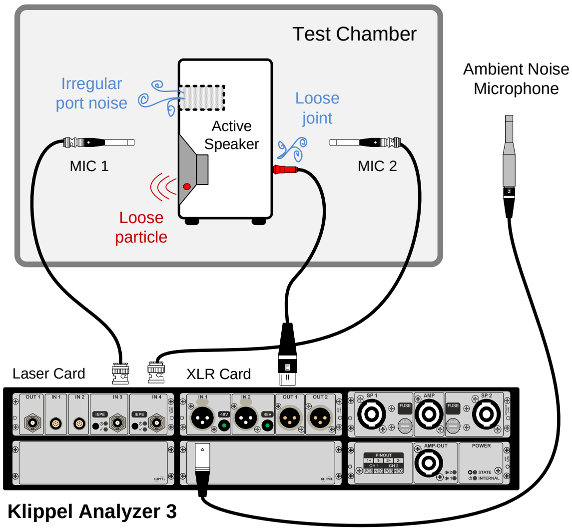
5.1 Setup Parameter Limits

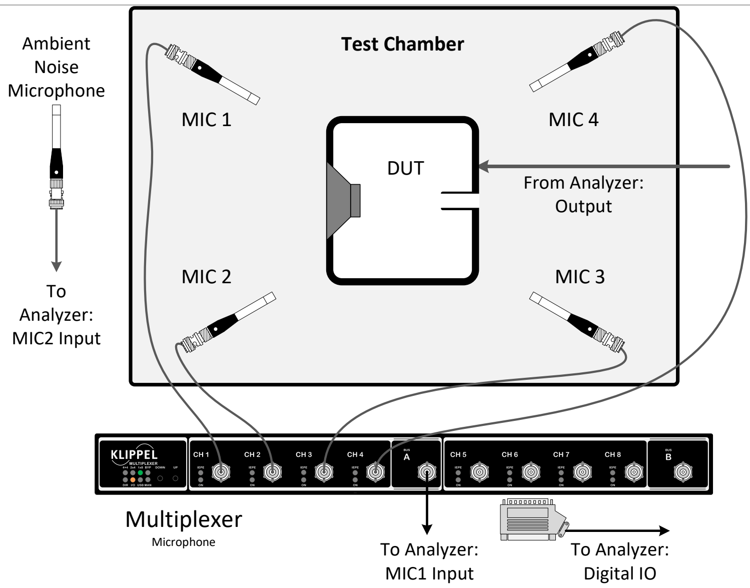
Parameter	Symbol	Comment
CATEGORY PROCESSING		
Leak (center) Frequency	f_{ALD}	Defined range must be within sweep range.
Leak Bandwidth	B_{ALD}	

5.2 Measurement Results

Measured Quantity	Symbol	Unit	QC limits can be applied	Process indices (Cpk/ Ppk)
Modulated distortion (absolute)	**MOD**abs	dB (re 20 µPa)	x	x
Modulated distortion (relative)	**MOD**rel	dB	x	x
Deterministic leak distortion (absolute)	**DET**(L)abs	dB (re 20 µPa)	x	x
Deterministic leak distortion (deterministic)	**DET**(L)rel	dB	x	x
Deterministic distortion (absolute)	**DET**abs	dB (re 20 µPa)	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.				

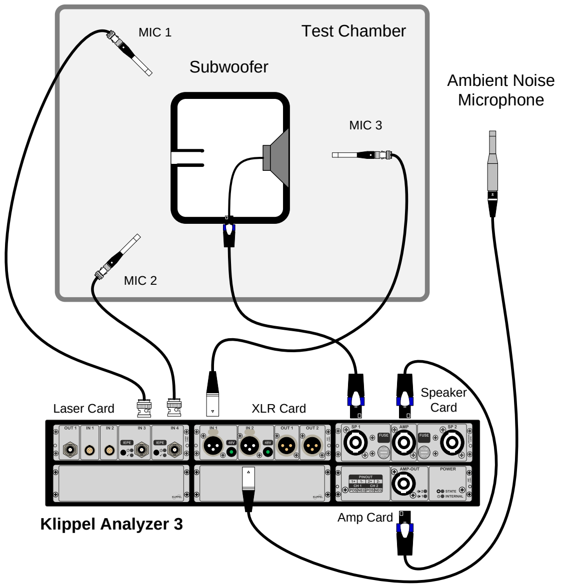
6 Applications

Powered Speaker System with Two Microphones	 The picture shows a typical end-of-line test setup for powered 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 front of the DUT for testing typical parameters such as frequency response, THD, *Rub&Buzz* distortion etc. using *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 is placed behind the speaker for an additional ALD test step. Up to four microphones can be used for a single shot test. For the complete test sequence, the ambient microphone next to 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 occlusion 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 optimum sensitivity. **Sequential Test (Production Analyzer + Mic Multiplexer)** 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.

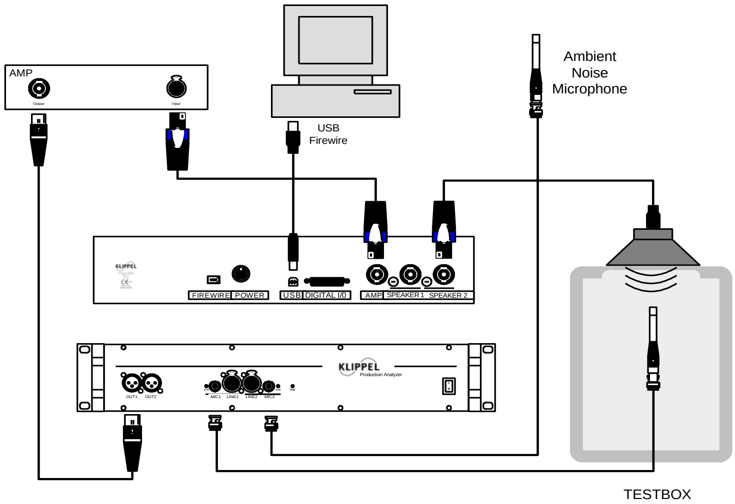


Simultaneous Test (KA3 with Input Signal Sharing)

Using the KA3 hardware or a multi-channel sound card, a higher number of input channels can be measured simultaneously using signal data sharing feature. With KA3, for inputs can be measured simultaneously. In case ambient noise is measured (recommended), three test microphone channels are available that may be connected to the Laser Card (IEPE powered microphones) or the XLR Card (48 V microphones or IEPE using XLR-BNC adaptor).



The stimulus signal is played back only once by the source ALD task that simultaneously captures all other microphone 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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