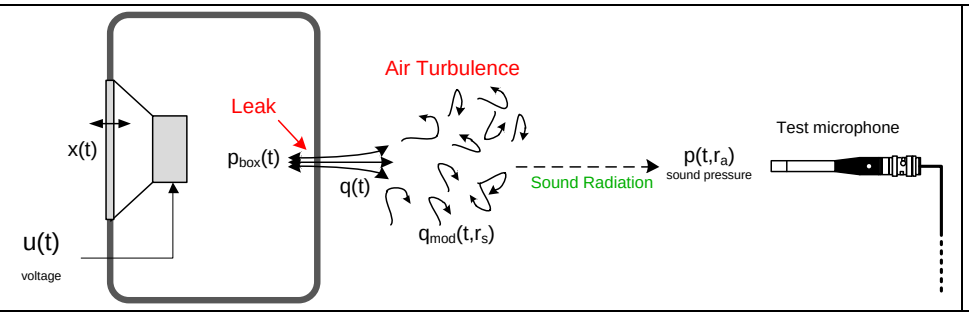
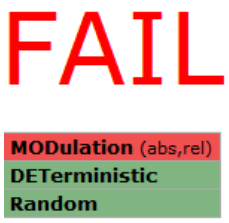
QC – Air Leak Detection (ALD) **S18**

QC Version 5

FEATURES	BENEFITS
• Detection of air leak noise and other modulated noise (e.g. port noise, irregular rubbing) generated in loudspeaker systems • Detection of systematic rub and buzz defects and deterministic distortion caused by air leakage • Detection of loose particles and other defects producing random symptoms • Ambient noise detection with auto repeat • Production indices (Cpk, Ppk)	• Detect air leakage borderline defects • Fast measurement • Easy to use • Reduce number of defect units • Ensure consistency of production • Highest sensitivity using stand-alone ALD task • Highest Speed with integration in SPL task





This module of the QC system is dedicated to the detection of air leaks in enclosures, dust caps, and other parts of loudspeaker systems.

The analysis is based on a demodulation technique and a specific harmonic distortion analysis providing unique symptoms of turbulent air noise and leak distortion to distinguish this defect from rub and buzz, loose particles and other failures. This ensures high detection sensitivity even in some distance from the source.

The dedicated Air Leak Detection measurement task uses a fixed tone excitation providing very high sensitivity for extremely small leaks (Ø<1mm). The same technology is also available as an integrated solution in the standard SPL task. A user definable bandwidth of the sine sweep can be used combining high sensitivity with high speed.

Both implementations support multiplexing multiple microphones located around large measurement objects (large enclosures). The powerful tool combines easy handling with high-speed measurement and robustness against ambient noise.

Application:

- End-of-line testing
- Incoming goods inspection
- Diagnostics

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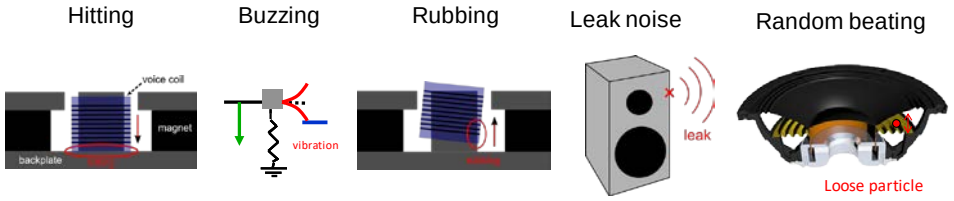
Classification of Loudspeaker Defects

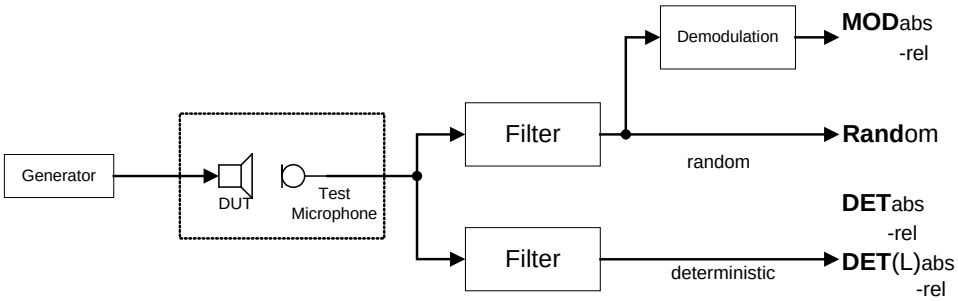
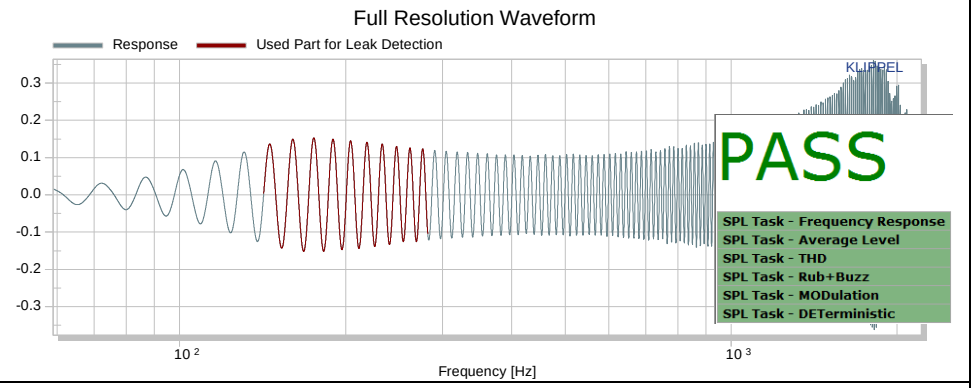


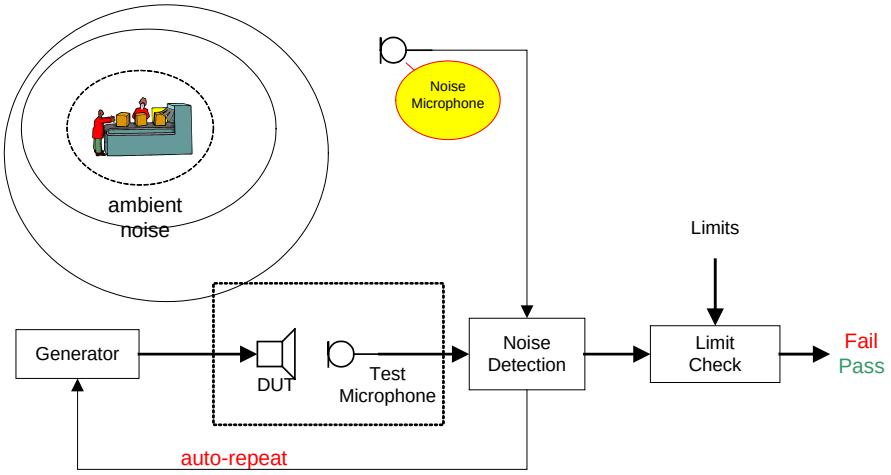
Deterministic — **Semi-random (mixed characteristic)** — **Random**

Corresponding ALD measures

DETerministic	MODulation	Random
DETabs **DET**rel **DET(L)**abs **DET(L)**rel	**MOD**abs **MOD**rel	**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 amplitude modulated and highly audible broadband air noise and specific deterministic distortion. A new measurement technique is presented which makes it possible to quickly identify noise due to air leak, port turbulences or other modulated defect symptoms with a high sensitivity due to the separation from strongly periodic (deterministic) and randomly occurring driver defects such as rub and buzz and loose particles. The derived single valued data is easy to interpret and directly indicates and quantifies air leak noise as well as other defect distortion.

ALD-Task Principle	The ALD task is based on a new identification technique. The system is excited by a single sine tone at low frequencies (e.g. below driver resonance) to stimulate air leaks and other flow noise. Only acoustical signals are measured in the near field of the DUT. 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. 
SPL-Task Integration	The same analysis methods are applied to a defined bandwidth 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 octave; t_{meas} = 500ms 
QC requirements	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 • Quantification of the defect distortion using derived and easily interpretable single valued measures (**MOD**abs, **DET(L)**abs, **DET**abs, **Rand**om) • Robustness 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 measurement array); for basic functionality only the standard QC system setup is necessary • Reliable detection of ambient noise through ambient noise measurement and post-processing

Ambient noise immunity **ALD-Task**	The ALD Task optionally offers ambient noise detection with auto repeat via an additional ambient noise microphone to prevent false test verdicts due external noise. Noise detection is based on parallel signal processing based on tolerance limits, as well as 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 reliably detected. Please see specification *S21 - QC Production Noise Immunity*.

Definition of Measures

MODulation

Modulated distortion (absolute)

- **MOD**$_{abs}$

DEFINITION: The **MOD**$_{abs}$ describes the absolute level of amplitude-modulated noise as generated by turbulent flow in leakages and other semi-random defects:

$$\mathrm{MOD}_{abs} = 10 \lg \frac{\hat{p}_{env}^2}{p_0^2} \mathrm{dB}. \qquad (1)$$

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 relative measure derived from the **MOD**abs measure and is calculated as $$\mathrm{MOD}_{\mathrm{rel}} = 10\lg\frac{\hat{p}^2_{\mathrm{env}}}{\tilde{P}_{\mathrm{floor}}}\,\mathrm{dB}. \qquad (2)$$ The peak value of the (squared) modulation envelope is related to the average broad-band 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.

DETerministic

Deterministic Leak Distortion (absolute)

- **DET**(L)abs

DEFINITION: The **DET**$(L)_{abs}$ is an absolute 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:

$$\mathrm{DET(L)_{abs}} = 20\lg\frac{\hat{p}'_{\mathrm{det,leak}}}{p_0}\,dB\,. \qquad (3)$$

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 relative level measure. It represents the modified crest factor of deterministic leak distortion using a cleaned RMS value:

$$\mathrm{DET(L)_{abs}} = 20\lg\frac{\hat{p}'_{\mathrm{det,leak}}}{\tilde{p}'_{\mathrm{det,leak}}}\,\mathrm{dB}\,. \qquad (4)$$

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 absolute 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:

$$\mathrm{DET_{abs}} = 20\lg\frac{\hat{p}'_{\mathrm{det}}}{p_0}\,dB \qquad (5)$$

Application to end-of-line testing

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.

Deterministic Distortion (relative)

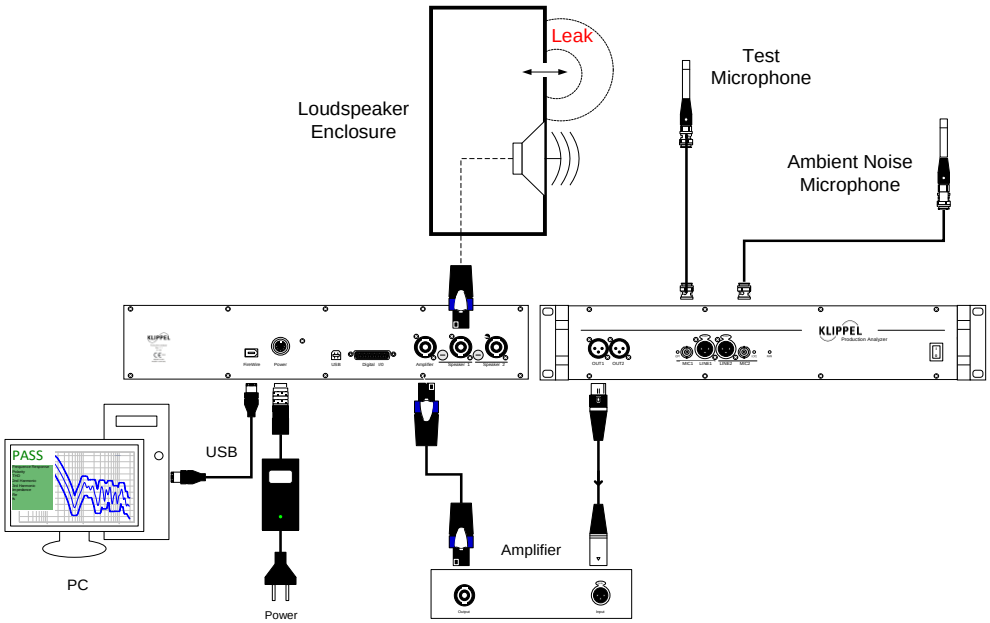
- **DET**$_{rel}$

DEFINITION: The **DET**$_{rel}$ is derived from **DET**$_{abs}$ as a relative level measure representing the crest factor of deterministic distortion. It is calculated by relating the distortion peak to the distortion RMS:

$$\mathrm{DET_{rel}} = 20\lg\frac{\hat{p}'_{\mathrm{det}}}{\tilde{p}'_{\mathrm{det}}}\,\mathrm{dB}\,. \qquad (6)$$

	Application to end-of-line testing 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) - **Rand**om	**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: $$\text{Random} = 20\lg\frac{\hat{p}_{\text{rand}}}{p_0}\,\text{dB} \qquad (7)$$ The non-deterministic signal is obtained by removing the deterministic distortion components (fundamental and harmonic distortion).
	Application to end-of-line testing 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.

Hardware

Minimal Setup	 The figure above shows the minimal equipment required to run the ALD • QC Production Analyzer • measurement microphone • opt: ambient noise microphone (noise detection) • personal computer • Power amplifier and cables → more information in the KLIPPEL specification “C3 - QC End of Line Test System”
Production Analyzer	Please find more information in *H4 – Production Analyzer Hardware* for detailed specification.
Microphones	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*.
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.
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. Therefore a proper measurement environment or an enclosure is recommended in order to provide high ambient noise attenuation.

ALD-Task (stand-alone)

Input Parameters (Setup)

Parameter	Symbol	Min	Typ.	Max	Unit
Category Synchronization Only shown if the external synchronization *ExtSync* is enabled in the *ControlTask*. Please refer to the *QC user manual* for a detailed description of the available parameters.					
Category Stimulus					
Measurement Time (list) including default pre-loop time to achieve steady state conditions	*Time*	0.45	0.97	5.75	s
Stimulus frequency (automatically rounded to analysis fitted value	*Frequency*	var	50	1000	Hz
RMS stimulus voltage (different ranges for passive and active use)	*Voltage (rms)*	0	1 (0.1)	200 (6)	V
Category Routing					
activates parallel measurement mode with two test microphones; ambient noise measurement with a dedicated microphone is not available in this mode	*Two channel mode*				
Select output of the Production analyzer to be used (test voltage is specified at selected port) Only available if output routing is *controlled by task*	*Output*	• Speaker 1 • Speaker 2 • OUT 1 • OUT 2			
Connect speaker 1 to amplifier output Only available if output routing is *controlled by task*	*Speaker 1 connect*				
Connect speaker 2 to amplifier output Only available if output routing is *controlled by task*	*Speaker 2 connect*				
Select PA hardware input for measurement channel 1 Only available if output routing is *controlled by task* or *two channel mode* is activated	*Input Channel 1*	• Mic1 • Line1 • Mic 2 • Line 2			
Select PA hardware input for measurement channel 2 (available in *Two channel mode*) Only available if output routing is *controlled by task* or *two channel mode* is activated	*Input Channel 2*	• Mic2 • Line2			
Select PA hardware input for ambient noise channel (available if *Ambient Noise* is activated) Only available if *ambient noise monitoring* is activated	*Ambient Noise Channel*	• off • Mic2 • Line2			
Bit mask for digital output GPIO of PA (e.g. for multiplexer control), pins are set before test.	*Digital Output*	rows correspond to pins 24, (11), 5, 17, 4, 16, 3, 15, 2 Format 1: [Value1, Mask1; Value2, Mask2; ...] Format 2: [Value1; Value2; ...]			
Set delay before measurement starts (after GPIO setting, if requested)	*Delay Before*	0	0	10000	ms
Set delay after measurement (after GPIO setting, if requested)	*Delay After*	0	0	10000	ms
Category Measurement					
Measure “Absolute modulated distortion”	*MOD -abs*				
Measure “Relative modulated distortion”	*MOD -rel*				
Measure “Absolute deterministic leak distortion”	*DET -(L)abs*				
Measure “Relative deterministic leak distortion”	*DET -(L)rel*				
Measure “Absolute deterministic distortion”	*DET -abs*				

Measure “Relative deterministic distortion”	*DET -rel*				
Measure “Random distortion”	*Random*				
Category Ambient Noise					
Activate noise monitoring (using ambient noise microphone and/or noise post-processing)	*Noise monitoring*				
Location of test microphone	*Microphone*	• In Free Air • In Box • Custom			
Acoustical shielding of test enclosure (should be specified above 2kHz, respectively 10 times stimulus frequency, see ALD Manual for further details) Only available if *Microphone – Custom* is selected	*Shielding*	*Format:* Frequency1, Attenuation1; Frequency2, Attenuation2; : :			[Hz], [dB]
Repeat measurement automatically in case of noise corruption (if limits available), specify maximal number of repetitions	*Auto Repeat*	0 (unchecked)	3	10	
Activate single channel noise post-processing for ambient noise detection (MODulation measures have to be activated)	*Noise Post-processing*				
Declare all failed measures as corrupted, if at least one measure is corrupted by ambient noise	*Generalize corruption*				
Category Processing					
Input gain for PA inputs MIC 1/ Line 1	*Input Gain 1*	-70	0	30	dB
Input gain for PA inputs MIC 2/ Line 2	*Input Gain 2*	-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	**Rand**om	dB	x	x

Results are grouped in the summary result window. Failed quantities are listed in the verdict table.

ALD integrated in SPL Task

Input Parameters (Setup)

Parameter	Symbol	Comment
Category Measurement		
Measure “Absolute modulated distortion”	*MOD -abs*	On / Off
Measure “Relative modulated distortion”	*MOD -rel*	On / Off
Measure “Absolute deterministic leak distortion”	*DET -(L)abs*	On / Off
Measure “Relative deterministic leak distortion”	*DET -(L)rel*	On / Off
Measure “Absolute deterministic distortion”	*DET -abs*	On / Off
Measure “Relative deterministic distortion”	*DET -rel*	On / Off
Category Processing		
Leak (center) Frequency	f_{ALD}	Defined range must be within sweep range.
Leak Bandwidth	B_{ALD}	

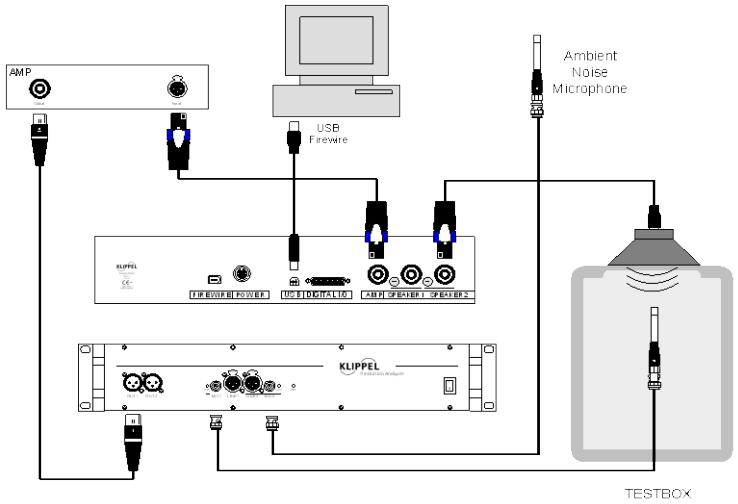
Measurement Results

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.

Applications

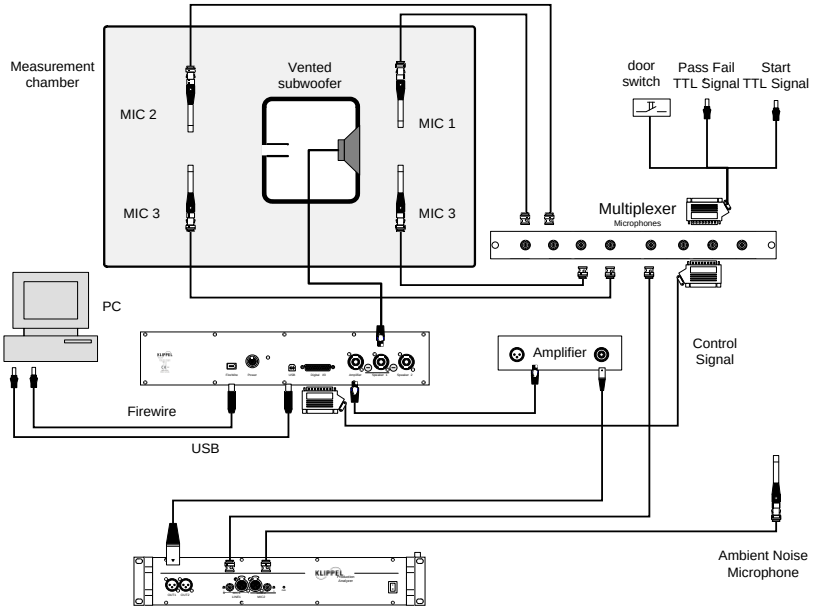
Driver testing



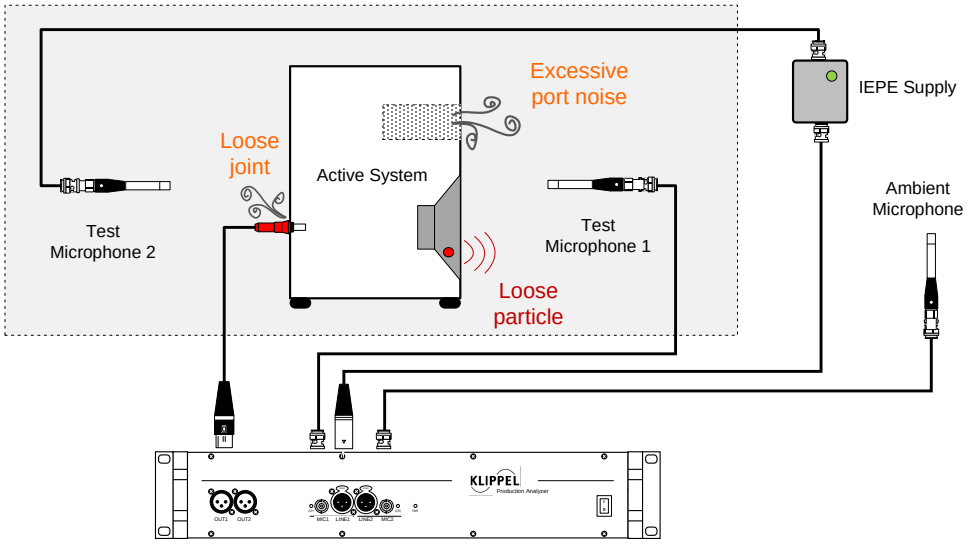
Gluing errors in drivers are likely to cause air leakage in the surround or the dust cap that may only be audible in the final application when the driver is mounted in a closed or vented enclosure. Such leaks may not be detected under free air conditions due to the lag of air-pressure caused by the 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.

Detecting leaks in large loudspeaker enclosures



Detecting air leaks in large speaker systems with only one microphone leads to physical problems due to shadowing of high frequency leak noise. Locating multiple microphones around the device under test solves this problem by measuring the speaker from different sides and thus covering the whole surface. The four test microphones are switched by a signal multiplexer for sequential measurement. An additional far-field microphone always monitors ambient noise parallely while the measurement chamber guarantees proper ambient noise attenuation for maximal measurement sensitivity.

System Testing	Test enclosure  For high speed, comprehensive system testing the leak detection technology integrated in the standard SPL task shall be used. The standard SPL checks are extended by a dedicated test for air leakage symptoms (modulated noise) in one single sweep test. Air noise due to loose joints or even irregular port noise due to manufacturing errors (e.g. burr) in vented systems are detected. Two test microphones are located at opposing sides of the DUT to cover a wide surface. The second test microphone may be connected to the Line input of the Production Analyzer using an external microphone power supply. An ambient microphone in the far field detects ambient noise corruption during the tests and triggers the auto-repeat mechanism.

Patents

Germany	102009033614
USA	12/819,455
China	201010228820.8

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