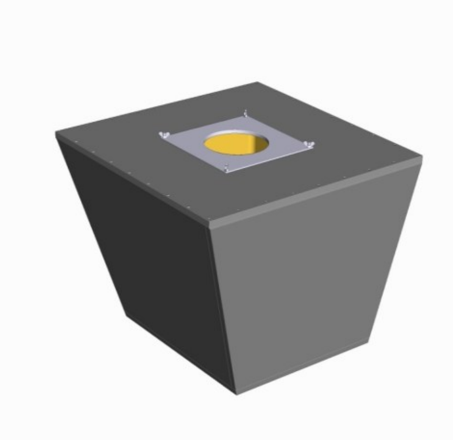
Test Enclosures for QC AN46

Application Note for the KLIPPEL ANALYZER SYSTEM

Document Revision 1.8

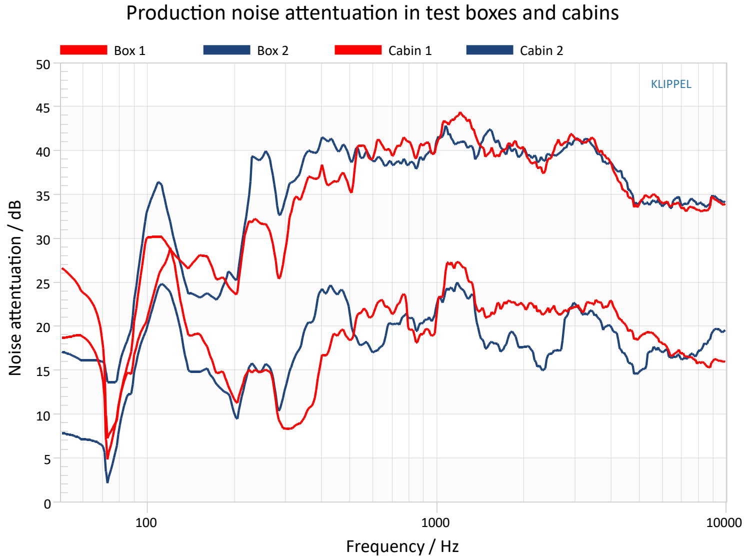
BENEFITS



- reproducible results
- attenuation of ambient noise
- attenuated standing waves
- minimized rattling
- cost-effective construction
- match with test microphone specification for the highest Rub&Buzz sensitivity

OVERVIEW

A robust and stable test enclosure should be used for the online test of transducers and audio systems. The guidelines described in this document outline the state of the art used in loudspeaker production for full-range drivers and woofers. For tweeters as well as complete loudspeaker enclosures, tailored concepts and procedures are required, since additional tests - such as leakage tests - are often performed in parallel.



CONTENT

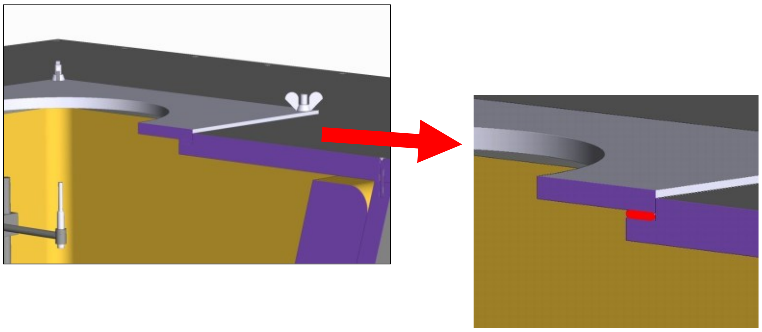
1 Background

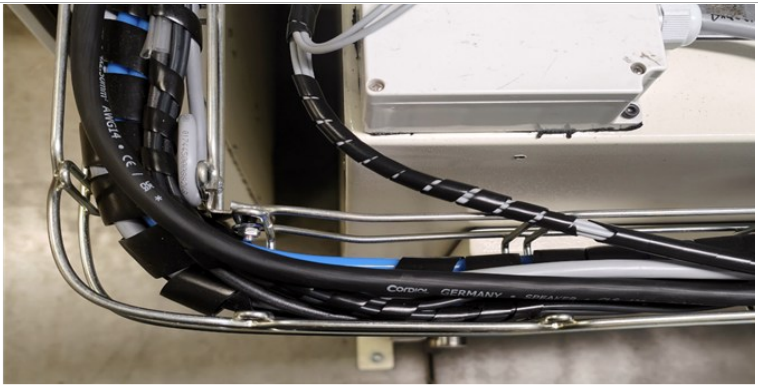
The problem	In contrast to the R&D system, which is operated in acoustically controlled environments, the QC system is located directly within the production line – typically at the end of the manufacturing process. This setup entails numerous challenges that affect the quality of the end-of-line (EOL) measurement. The production line itself represents a significant source of noise: • Workstations, conveyor belts, as well as adjacent machines or parallel production lines (e.g., for magnet assembly) continuously generate disruptive sounds. • In addition, multiple EOL test cabins positioned side by side or open sweep test stations contribute further noise. • Transport systems, manual material handling, and pallet shuttle systems also create considerable operational and transit noise, squeak and rattle. The objective of this document is to outline measures that minimize external impact on measurement quality, and at the same time reduce test duration. As a result, cycle times can be shortened, measurement results across different test stations can be made more consistent, comparable and interchangeable, and the yield rate can be sustainably improved. A shorter cycle time lowers production costs per unit and increases net profit. Improved production yield reduces scrap within the line and warranty claims, directly contributing to profitability by lowering quality-related costs.
Defined test conditions	Typical QC applications in the first place require test results, which are highly reproducible. Hence, a fixed environment including a defined microphone and DUT position is crucial for quality control to ensure comparability. Note: The absolute results may be different from R&D measurements according to standards, which typically require very specific and complex measurement conditions.
Repeatability and Reproducibility (R&R)	Standardized “Reproducibility and Repeatability Studies” (R&R) identify the most significant causes of production variation. Typical causes under investigation are different product samples, different operators, repetition of measurements, environmental conditions, and the production process itself. R&R studies on acoustical measurements show the highest impact caused by the fixture, the operation, and the “soft” parts of loudspeakers themselves. The influence of the actual measurement device is rather negligible. A well-designed box and dedicated test adapters improve the R&R result considerably. If the aspects of this note are considered for designing a new test station, the remaining dominant variable for an R&R test will likely be the soft parts of the test object itself. This topic is complex and requires a careful analysis by domain experts (R&D or consultants, see section More Information).
Noise attenuation	Audible Rub&Buzz distortion may be 80 dB below the fundamental (frequency response). Production noise can easily exceed those low Rub&Buzz defects and thus needs to be attenuated for maximal sensitivity. Although a good test box can have >40 dB noise attenuation, it is not sufficient to provide 100 % noise immunity. Especially high-level impulsive noise events (falling parts, driving nails) will distort the test and hence reduce the yield rate (classifying good DUTs as bad). A combination of a good test enclosure and the Production Noise Immunity (PNI) feature of the Klippel QC Framework will provide 100 % noise immunity. Excessive ambient noise events are reliably detected using a second microphone, and tests are repeated and merged to ensure minimal testing time. Note that the feature without a properly designed test enclosure cannot provide fast and reliable QC due to an unreasonably high number of test repetitions. The key is the combination of both.

2 Test enclosure

The test enclosure is defined as a structure that provide defined test conditions (load) for the DUT and shielding the measurement from production noise. The DUT is either fixed inside the test enclosure or mounted on the test enclosure (as illustrated below). If more production noise shielding is required, an additional shell may be applied, in most cases as a test cabin.

2.1 Mechanics

Wall material	MDF (Medium density fiberboard) of sufficient thickness (>=30 mm) or metal is recommended for the outer walls of the body. The mass and stiffness of the box walls are the dominant properties to attenuate low frequencies. Vibrations of walls should be minimized. Struts or profiles may be applied internally or externally. All edges should be carefully sealed. Use screws every 10 cm to ensure stable connections. For optimal sealing, all connections should be glued and screwed together. Check the reference at the end of this note for recommended sealing tape for reversible sealing of small holes (e.g. cable outlets).
Size/Volume	The volume of the test box depends on the test objects and can be derived using a two-step chart-based procedure. Please refer to the section "How to calculate the peak SPL inside the box?" below. The optimal size depends on the displaced volume of the test object and the peak SPL capability of your test microphone.
DUT Adapter	To test different types of drivers, an adaptor board is recommended. Make sure that the adaptor can be tightened onto the box without any leakage. This adaptor should be stiff and robust for reproducible tests and frequent exchange. Metal or thick MDF is recommended. Between the box and adaptor, a sealing tape should be used. 
Geometry	The best results can be obtained when any parallel walls are avoided. Thus, standing waves are attenuated, and mechanical vibration is reduced. It is sufficient to design 10°-15° off. The minimal volume requirement is defined by the low frequencies, where the displacement of the DUT is high. Note that a too small volume has a pretty high stiffness and may affect the operation of the test object as a non-typical load condition. Especially faint defects (by buzzing, rocking, leaks) may be missed. Since the wavelength is usually larger than the geometrical dimensions, the volume can be shaped according to usability and space restrictions. It does not need to be a cube-like box.
Microphone holder	Make sure that the holder is not vibrating or rattling. If larger in size, bandage the parts with a damping material. Make sure that the microphone cable outlet is sealed. Mounting the microphone using a (shock absorbing) spider is recommended to attenuate structure-borne noise coupling into the microphone.
Usability	Design the test box to be compliant with safety restrictions and allow an efficient mode of operation (manually or by a robot).
Decoupling from the factory floor (structure born noise)	It is highly recommended to decouple the test box from the factory floor (or test cabin) by shock absorbers or other means. Parts of the system that are in contact with the test box during the measurement need to be insulated. These are essentially cables, connectors, and robots. Cable ducts must not create secondary transmission paths and must therefore not be firmly fixed to the test box.



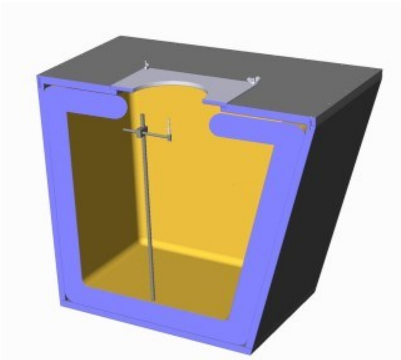
Double shielding by a test cabin

For better isolation from air- and structure born noise a second environment (chamber, larger box) can be used. The same ideas on decoupling noise from the test box apply. Minimize potential rattling sources inside the chamber (see section Test cabin).

2.2 Acoustics

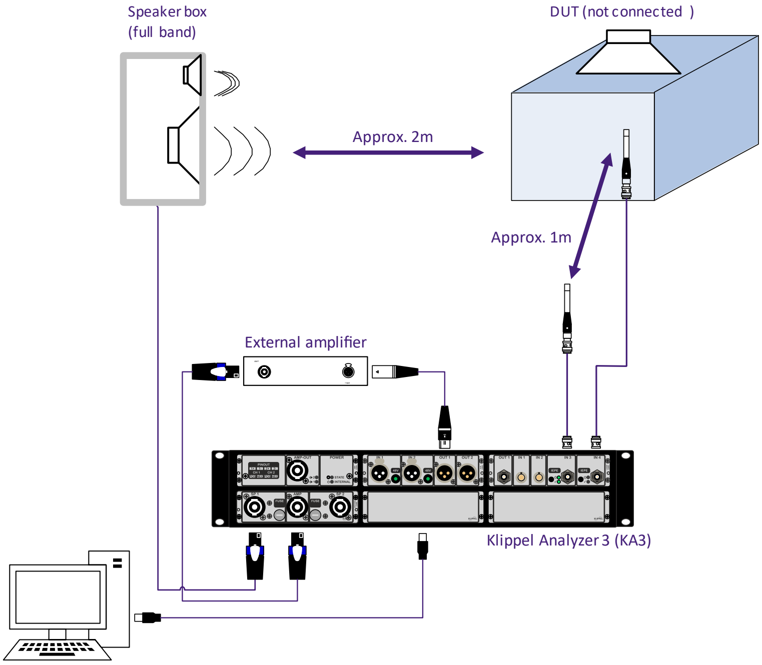
Damping material

Ideally, all walls should be equipped with absorber material. The purpose of this is to minimize reflections, reducing peaks and dips of the acoustic amplitude frequency response. The absorber material should have an absorbing coefficient of $\alpha > 0{,}7$. Between the microphone and DUT shall not be any damping material.



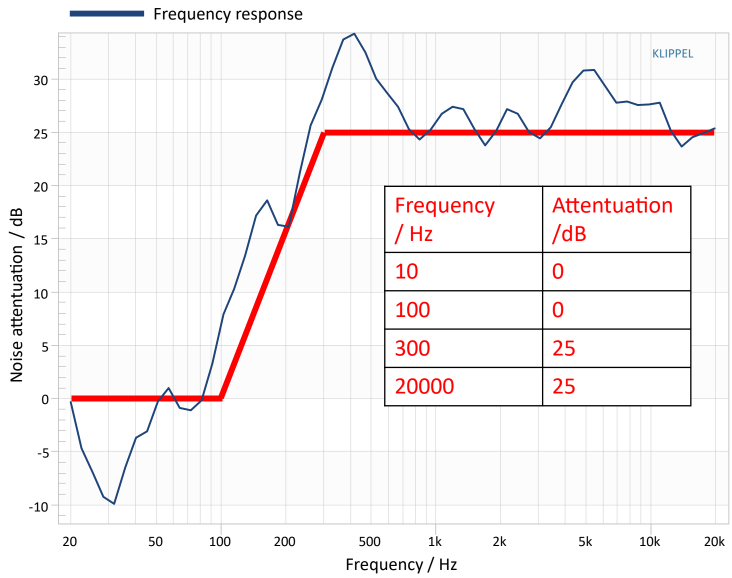
Measure ambient noise attentuation

Following the instructions in this application note will guide you to a robust test enclosure. However, it is highly recommended to measure the achieved attenuation by a simple measurement. The hardware setup could consist of the following components:



- Klippel Analyzer (KA3 or PA) + PC
- External Amplifier or internal AMP-Card of KA3
- Measurement microphone + Ambient microphone
- Speaker box + Test enclosure
- QC Standard Software + Production Noise Immunity Add-on

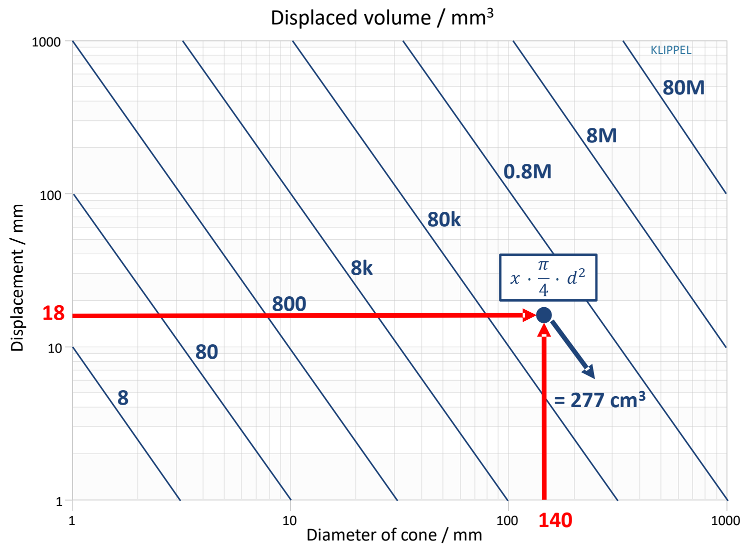
A full-band speaker is required (not the DUT!) to emulate external production noise and a typical DUT for this production line. If a test cabin is used, the full-band speaker shall be operated within the cabin and outside the test enclosure. The 2 m distance may be reduced in this case. This is a typical attenuation curve for a larger test enclosure:

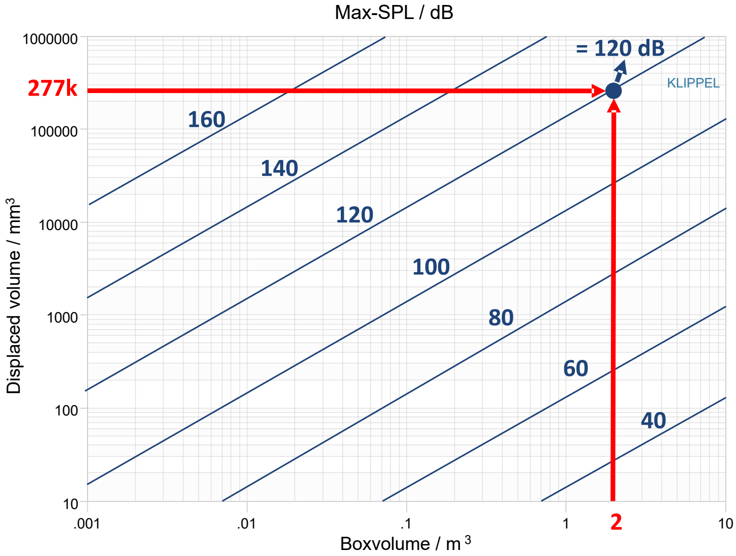


More Information can be found in the QC Online Manual on how to calculate the specific ambient noise attenuation of the test box and how to set up the test setup considering this attenuation.

How to calculate the peak SPL inside the box?

Using the following charts, you can calculate the peak SPL for a given volume or also calculate the volume for a specified peak SPL. You may also use the Excel sheet that is available as an appendix to this note. The figures show an example of testing a subwoofer with a diameter of 140 mm and 18 mm peak displacement. The resulting peak SPL is about 120 dB.





Microphone position	The microphone should be positioned on axis and facing toward the DUT. If multiple test stations exist, the position of the measurement microphone must be identically in all test stations. Position of the microphone itself also plays a major role and influences the quality of the measurement. The distance should be approximately the same as the dimension of the DUT. Special microphone positions or multiple microphones may be chosen to assess spots of potential defects and to avoid dips due to cancellation effects in the fundamental response.
Microphone selection	The microphone type should be selected according to the peak SPL inside the box. Please refer to specification A4 Microphones for available microphones from Klippel and an application guide at the end of this specification. Select a microphone with sufficient but not too large headroom (6-15 dB) for all expected test levels. Thus, the dynamic range can be fully used for the most accurate and sensitive detection of the smallest Rub&Buzz defects. If drivers of very different sizes and displacements are to be tested, consider making two test boxes or using dedicated microphones. Note: The specified peak levels by the microphone manufacturer usually refer to clipping the fundamental component. A considerable increase in THD and Rub&Buzz (higher harmonic distortion) starts at about 10 dB or even more below this specified level. Klippel specifies and checks each microphone for the peak SPL level that ensures full sensitivity for even faint distortion. Thus, Klippel specified peak SPL level may be lower than the max SPL specified by the manufacturer.

2.3 Electrical domain

Connection	Loose connections in the electrical domain (broken cables) are reliably detected using the Rub&Buzz analysis. However, to avoid those rejects, which are not related to the quality of the DUT, the plugs/sockets for the electrical connection to the DUT should be replaced regularly and before they become brittle or broken. Special care must be taken to not damage the contact area for sensitive applications (micro speaker, automotive). In those cases, spring contact probes may be used.
4-wire Cables	Klippel provides 4 wire speaker cables for accurate voltage monitoring of the DUT directly at the terminals. This requires a true 4-wire connection close to the connection point of the DUT. **Do not extend the speaker cable with a 2-wire cable!**

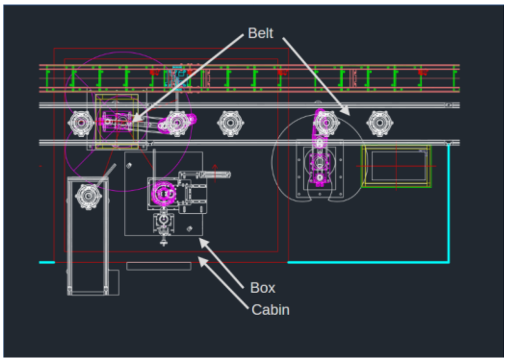
3 Test enclosure

Where feasible, a robust EOL setup should include both a loudspeaker test box and an enclosing cabin. This configuration provides significantly better shielding from background noise, which directly improves measurement quality and overall process reliability. The result is a box in a box design, where the outer shell is mostly made as a test cabin.

3.1 Building acoustics

Example

The EOL station is close to production, where noise will affect measurements. A cabin around the test box reduces sound transmission, ensuring reliable results and supporting quality and efficiency. There are two main approaches to address challenges in building acoustics, both focusing on reducing structure-borne vibrations and improving airborne sound insulation.

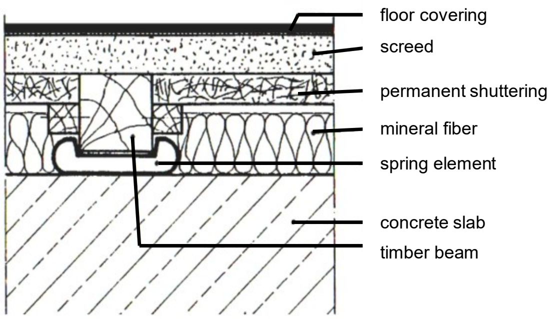


Structure-born noise decoupling

Structure-borne decoupling prevents vibrations from traveling through floors, walls, and ceilings. These challenges are typically addressed in one of two ways:

Room-in-Room-Design

The room-in-room design offers the best performance, but it is also the most complex and costly. Relocating the cabin due to changes in the production line is difficult. In this approach, the entire test cabin is structurally decoupled from the surrounding room and floor. The construction essentially forms a spring-mass system, where the mass (screed slab) rests on an elastic layer (spring), and the test cabin sits on top. All necessary connections, such as cable ducts or conveyor interfaces, must be designed to avoid rigid attachment to the cabin, ensuring the decoupling remains effective.

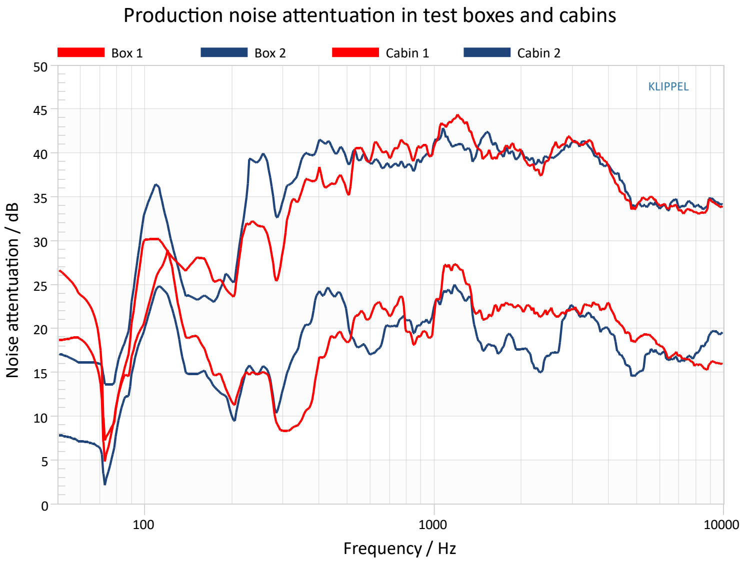


Device and machine decoupling

Device or machine decoupling addresses individual system components separately. Only components that are in contact with the test box during measurement require acoustic isolation. These typically include the test box itself, the cabin, a robot stand, other system components, such as the automatic connector, unless they are mounted directly to the test box. Also, cable ducts, which must not form secondary transmission paths must not be rigidly connected to the test box. A cabin with the test box is usually free-standing within the production area, meaning that structure-borne sound transmission needs to be considered primarily through the floor. All system components shall be isolated from the floor using sound-absorbing mats or spring-based systems. Anchoring points, such as floor-mounted screw connections (see below left), must be equipped with appropriate decoupling elements. In addition, all cable ducts, conveyor belts (see below right), and similar interfaces must be designed to avoid any direct contact with the test box.

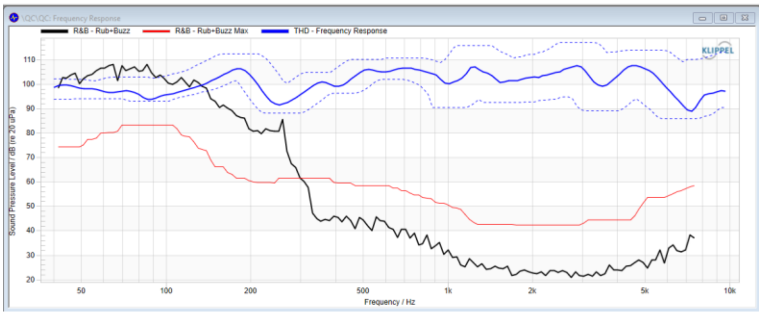
Production noise attenuation

The diagram below illustrates an example of 2 test cabins including a test box each. SPL measurements were taken from outside the cabin, inside the cabin and inside the box. The attenuation is the difference in the measured SPL. The data shows that below 100 Hz there is low attenuation. This behavior is primarily caused by structure-borne sound transmission and limited acoustic absorption at low frequencies. In practice, this is typically not a concern for Rub&Buzz detection, as defect-related signals occur at higher frequencies. From 200 Hz until 500 Hz the attenuation gradually increases. From there it is almost constant, which is the important range of defect analysis. Note, that even a professional test cabin attenuates the production noise by not more than 40 dB. For high impulsive noise therefore the additional add-on [Production Noise Immunity (PNI)] for acoustic tests is highly recommend to avoid false rejects and to increase the yield.



The noise inside the cabin originates from two main sources:

- Sound transmission through the cabin walls. This makes it essential to design the walls with adequate airborne sound insulation
- Openings in the cabin structure. These are primarily required for conveyor belts and other material interfaces and can act as acoustic leakage paths if not properly designed

<table>
<tr><td>Example measurements</td><td>The next figure shows an example of a measurement taken during a massive disturbance caused by structure-borne noise. While the frequency response is not necessarily affected, the THD curve is completely abnormal. In practical production, this results in a failure due to THD, even though the loudspeaker is actually OK.

</td></tr>
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4 QC employee training

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<tr><td>Benefit</td><td>An equally important measure is employee training. The QC process provides a range of critical information about the condition of the overall production line. It therefore makes a lot of sense to train quality personnel in production accordingly so that they can recognize deviations in line quality and intervene before problems arise. A basic prerequisite for this is that employees learn to understand the product and are able to recognize trends that indicate deviations from normal parameters at an early stage.</td></tr>
<tr><td>Checks</td><td>The EOL test station should be checked regularly for the following:
Regular check with the golden samples
Tune the necessity to tests manually for training and double checks
Regular calibration of the measurement microphones, the amplifier, cleanliness and loose parts
Check the noise emissions and, if necessary, optimize the max. number of repetitions for the test
Check for changes in the environment with regard to new noise or vibration sources. Keep test stations clean, remove any non-mandatory stuff</td></tr>
<tr><td>Feedback to R&D</td><td>Communicate regularly with the R&D department and discuss conclusions from production for optimization of the production process and the product itself. R&D is a good source for training, it is a win-win.</td></tr>
</table>

5 More Information

References	QC Standard Software Production Noise Immunity (PNI) KA3 – Klippel Analyzer 3 Microphones – Specification A4 QC Quality Control – User Manual KLIPPEL, Wolfgang. End-of-line testing. Assembly Line-Theory and Practice, Prof. Waldemar Grzechca (Ed.), 2011, S. 181-206.
Consultancy	Mr. Andreas Lartz, Test specialist for automotive applications: **office@audiosquare.de** Assist in the selection and implementation of effective acoustic measures and provide targeted training to help quality team detect errors early and refine processes.
Automation	XENON: German supplier of automated equipment. You may also contact your local distributor for recommendations.
Professional Test Box	ADMESS: German distributor of test equipment provides self-designed test enclosures CRYSOUND: Manufacturer of acoustic test chambers and test enclosures for R&D and QC Contact Klippel Support to configure complete test solutions for your audio devices.
Sealing	To temporary seal holes (e.g., for cable outlets) we recommend sealing tape for vehicles.
Testing probes	INGUN: German supplier of high-quality test probes. Also doing customized, automated probes for speaker/system testing as well as standard connectors (USB, Ethernet).

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