

Comparison of Different Playback Systems in a Vehicle Environment



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HEAD acoustics is offering a number of binaural systems for the playback of vehicle interior sounds.

The range of products reaches from high-quality headphone playback via digital equalizers with electrodynamic or electrostatic headphones to technically sophisticated systems for the simultaneous reproduction of airborne sound and vibrations corresponding to real driving situations.

These systems are based on the philosophy that the subjective judgement of sounds should be regarded as a multi-dimensional task:

- Sounds in the interior of vehicles are almost always accompanied by vibrations that have a direct influence on the judgement of the sound.
- Psychological and cognitive aspects must be taken into account regarding subjective sound evaluation.
- The judgement of sounds is affected by the individual sensitivity of the judging person and is subject to that person's general attitude towards the respective sound event.



These experiences show that the judgement of vehicle interior sounds is highly context-sensitive.

In order to do justice to such context effects in listening tests, HEAD acoustics offers the possibility to transfer the sound playback from the laboratory environment into a real vehicle environment.

Different expansion stages of systems for the authentic playback of sounds and vibrations in a vehicle are presented and compared in this document.

Advantages of the Multi-dimensional Playback System SoundCar



Many years of experience with binaural high-quality recordings in the interior of vehicles have shown that for an authentic playback it is not sufficient to provide only the airborne sound components via a headphone in an arbitrary listening environment. Especially persons usually not dealing with acoustic development (decision makers, customers) often have difficulties in putting the sound they are hearing into the corresponding context.

The discrepancy between a headphone-only playback and the original impression is caused by complex physical and psychological processes:

- A human being unconsciously adapts to the sound field (volume, diffuseness etc.) of his or her current location. The acoustic properties of a vehicle cabin are so different from those of a typical listening studio that a realistic judgement of vehicle interior sounds in a laboratory environment is hardly possible without special training of the listener.
- In a natural sound field, a person will never experience high sound pressure levels at the eardrum without corresponding structure-borne sounds in the cranial bone and in the body. If vehicle interior sounds in a simulation are played back via a headphone only, the absence of the bone- and body vibrations causes a subjective shift of the sound spectrum towards lower frequencies in the perception of many test persons.
- Many test persons unconsciously blame unpleasant vibrations in a vehicle on the sound they are hearing. Therefore, the absence of these vibrations in a headphone-only playback often leads to a different, normally more positive judgement of the vehicle interior sound.

The solution for these problems is the SoundCar from HEAD acoustics:

- The listening environment is a real vehicle cabin, the sound field is as realistic as possible. The hardware required for the playback is mounted in the engine compartment of the vehicle (with the engine removed).
- Low-frequency airborne sound is generated by a subwoofer located, for example, in the trunk, to restore the realistic sound balance.
- Vibrations of the engine and the steering wheel (e.g. caused by the tires) are reproduced by actuators on the driver's seat and the steering wheel.



Experience reports from users show that SoundCar allows the judgement of vehicle interior sounds by decision makers and customers to be put on a firmer basis. Especially the judgement of simulated vehicle sounds by less experienced persons was found to match their judgement of the real vehicle sound much better.

The system allows different test configurations, each with its own realistic sound and vibration scenarios, to be compared to each other without any need for time-consuming and expensive modifications of the vehicle components. Furthermore, the tests can be performed independently of the weather.

Advantages of the Interactive Sound Simulation System H3S As an Expansion of the SoundCar Playback System



Furthermore, experience with the playback of vehicle sounds and vibrations has shown that the judgement is easier if the test person is in an interactive simulation environment, where the vehicle is actually controlled (accelerating, braking, shifting gears), while sound and vibrations dynamically adapt to the current driving situation (speed, gear, engine load). With such a system, target sounds can be defined more easily in a dialog with decision makers and selected potential customers even before the construction of a prototype.

The aurally accurate sound simulation system H3S allows an interactive, realistic simulation of driving situations. This system is a fundamental advancement beyond the mere playback of realistic sounds of fixed operating states predefined during the recording. H3S plays the sound of an engine recorded on a test bench as well as tire and wind noise. At the same time, vibrations of the driver's seat and the steering wheel are generated by actuators. Optionally, it is also possible to add spatially accurate sounds of passing vehicles, adding even more realism to the immersive simulation of the driving situation.



The interactive sound and vibration simulation in the SoundCar has the following advantages:

- Often the test person has a different notion and wants to experience the sound with his or her very own driving style. This is made possible by H3S, which dynamically creates a realistic driving soundscape based on engine load, transmission, RPM and speed from a pool of real-life recordings made at a number of predefined operating states.
- The simulation is performed separately for engine, wind and rolling sounds, which also allows these sound components to be experienced individually.
- Established filtering techniques (some of them RPM-dependent) allow the individual sound components to be manipulated separately. That way, changes can be evaluated immediately, and target sounds can be defined in the early stages of development in discussions with decision makers.
- If the binaural transfer paths of the car body, e.g. the transmission system, are known, even engine types not yet implemented in this car body, of which only test bench measurements exist, can be tested and judged in a realistic driving situation.



H3S is an ideal complement for the SoundCar playback system. With this platform, the virtual driving experience is simulated extremely realistically. The "user interface" consists of the accelerator pedal, brake pedal, gearshift lever and the dashboard instruments of the vehicle.

The effort for the construction of prototypes and real test drives for the judgement of vehicle interior sounds can be widely minimized, resulting in considerable cost savings. Furthermore, the tests are independent of the weather.

Advantages of the Interactive Sound Simulation System H3S as a Mobile Variant in an Operative Vehicle



H3S can now also be used in a mobile variant, where the SoundCar as a playback platform is replaced by an actual drive in a real vehicle. The original sounds of the vehicle are covered up by simulated sounds (e.g. from a different engine or a competitor's car). The simulated airborne sound components are played back through headphones with a high absorption of external sound.

In the mobile variant of H3S, virtual driving sounds are played back in a real driving situation. The "user interface" consists of the accelerator pedal, brake pedal, gearshift lever and the dashboard instruments of the vehicle. Vibrations as well as the driving dynamics are provided by the real base vehicle used for the test drive.

With such a system, only sounds of vehicle types similar to the actual base vehicle used can be reasonably compared to each other.

The advantages of this method are obvious:

- The test person is experiencing a real driving situation. It is therefore not necessary to simulate the situational context, but only the driving sounds, which considerably facilitates the judgement.
- The simulation is performed separately for engine, wind and rolling sounds, which also allows these sound components to be experienced individually.
- The required hardware can be installed without expensive modifications to the vehicle. The system can be easily transferred from one vehicle to another and installed there.
- The simulation can also include "customer-actuated sounds": Instead of the real sound caused by the use of a vehicle component, such as the turn signal, any simulated sound can be made audible.



The system is suitable for benchmarking as well as for the definition of target sounds or for the comparison of different model variants of a vehicle.