

Active Sound Design in an NVH Simulator

HiL and SiL Approach

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Abstract

In electric or hybrid vehicles, interior Active Sound Design (iASD) is used to release emotions or provide acoustic feedback that the physical engine sound might not provide. Engine Sound Enhancement (ESE) masks cylinder deactivation or makes the sound of downsized combustion engines more powerful.

With a software-in-the-loop (SiL) or hardware-in-the-loop (HiL) approach, the sound generating device can already be tuned in an NVH simulator, taking the actual driving sound into account. The NVH simulator is an interactive reproduction of wind noise, tire-road noise and physical engine noise. The driver closes the loop by listening to the sound and controlling the pedals.

The advantage of the HiL approach is that the vehicle's hardware platform is used at a very early stage of development. The sound designer can work with the target platform to achieve a faster workflow without compromises from the design to the production phase. The SiL approach allows the use of established tools for sound generation, thus forging links between creative musicians and engineers.

The proposed approach accelerates the process, as the sound is perceived according to the driving dynamics and the masking noise is already taken into account in a prototype phase. The real vehicle is only required for a final tuning.

Introduction

Interior Active Sound Design (iASD) is used to release emotions or provide acoustic feedback that the physical engine sound in electric or hybrid vehicles might not provide. Sound actuators or cabin loudspeakers reproduce artificial engine sounds. It is also used for vehicles with combustion engine. Engine Sound Enhancement (ESE) masks the effect of cylinder deactivation or makes the sound perception of downsized engines more powerful.

The principles of ESE and iASD are similar and the same technology is used in both. The difference is that in the first case there is a significant and relevant real existing powertrain noise which is enhanced by ESE. In the second case the artificial powertrain noise of iASD is dominant while the real noise is secondary.

Workflow – Standard Approach

The process of creating an Active Sound Design can be divided into a concept phase, a design phase and a validation phase (Figure 1). It is an iterative process. If necessary, for example if the result is not satisfactory, the current step is carried out again or the previous phase is repeated.

With the standard approach, the sound designer creates a sound concept at his desk. It contains general ideas about what it is supposed to express and how the targets are to be achieved.



Figure 1: Workflow of Active Sound Design: Standard approach vs. NVH Simulator approach

The designer selects the synthesizer technology according to the capabilities of the target platform in the vehicle. In this creative phase the sound character is defined and first sounds are composed. In the design phase, the sounds are refined according to the concept and based on the decision makers' feedback. In the next step, the sound is transferred to the target system or to evaluation hardware in the vehicle. In the standard approach the sound designer has sufficient access to real vehicles starting from the prototype phase up to the production phase. He can tune the sound in the real vehicles and adjust the parameters to match the interior noise. It is important to take into account the masking of road and wind noise as well as the real powertrain noise. Furthermore, the ASD sound is adapted to the vehicle dynamics. The perception of the same sounds may differ, regardless of whether the change in speed and load is fast or slow. After all, the sound is designed to match the character and target group of the vehicle.

In the validation phase it is checked whether the sound meets all the objectives. If not, re-tuning the sound or even modifying the concept is necessary.

With the challenges of less prototype programs and short development cycles, the conventional standard approach is no longer suitable. The sound designer now has limited access to the vehicles or only at a late stage of development, when less time is available until production starts. Most of the design and tuning must be done at the desk.

Workflow – NVH Simulator Approach

What is an effective and efficient approach to adapting Active Sound Design to the challenges of fewer prototype vehicles and short development cycles?

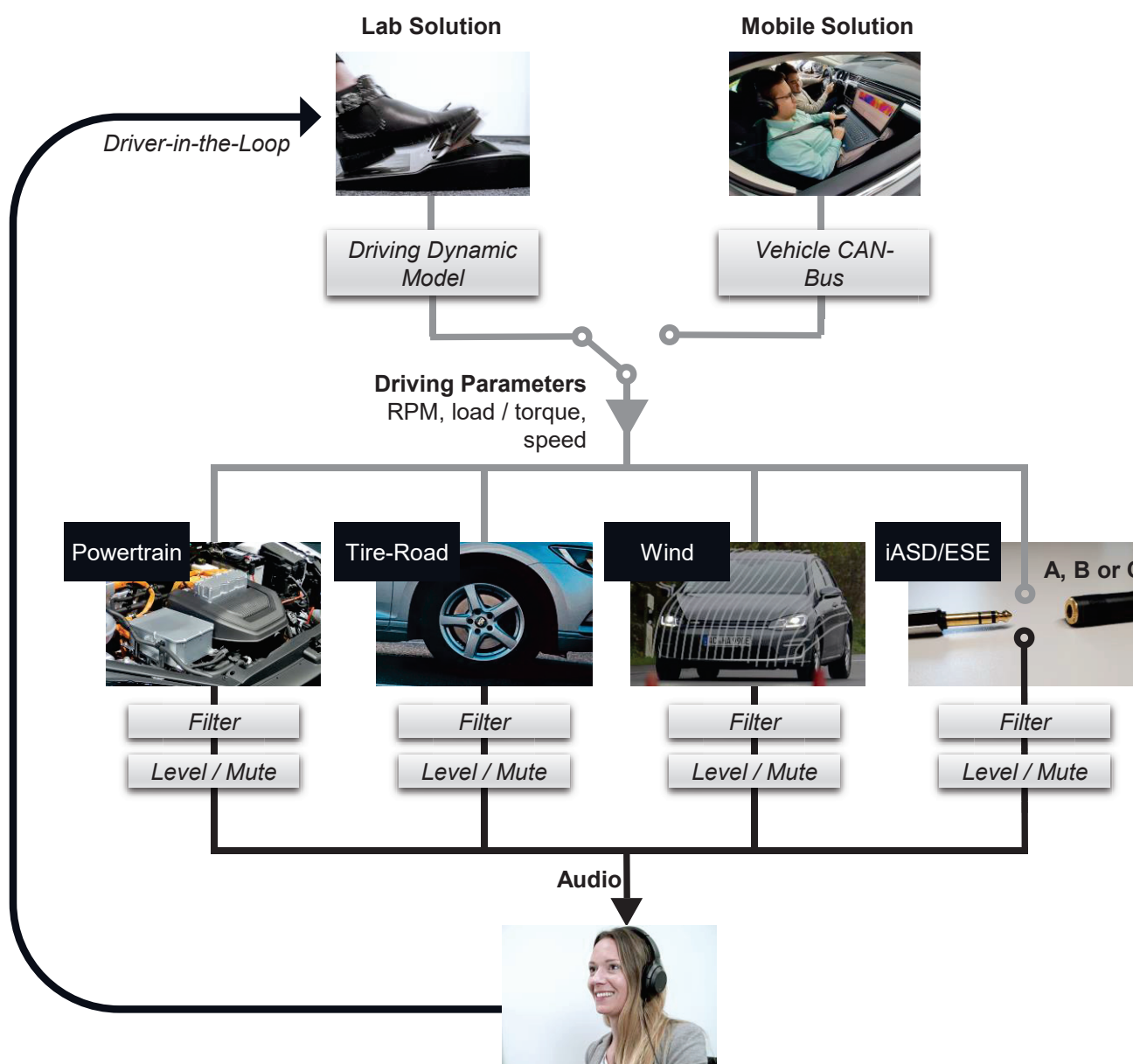


Figure 2: NVH Simulator approach for Active Sound Design

This paper proposes an NVH Simulator approach. The NVH simulator is a computer software that interactively reproduces wind and tire-road noise as well as physical powertrain noise. It is based on measured data at the driver's seat of the target vehicle or a comparable vehicle, e.g., for concept studies.

It is also possible to integrate CAE data and results of the Transfer Path Analysis [1]. Using advanced algorithms, the measured data is processed in real time based on the driver's accelerator and brake pedal commands. The NVH Simulator allows listening to the interior noise according to any speed and rpm profile. The vehicle performance is modelled for a realistic driving experience.

Now the sound designer can add his iASD or ESE to the driving noise of the NVH Simulator. Details are explained in the following section. The important masking by road and wind noise can already be considered in the concept phase (Figure 1, second row). The sound design can be better adapted to the real existing powertrain noise. In addition, the concept can be evaluated as it is perceived according to the driving dynamics of the vehicle.

In the design phase the lack of real vehicles is compensated by a virtual prototype. Colleagues, decision makers or even customers can experience the iASD or ESE as in a real situation to select the best design.

Of course, the Active Sound Design still needs to be applied to the target system in the vehicle. It is also recommended to do a final sound tuning using a real car. That would cover possible gaps between the virtual prototype and a real production vehicle. In contrast to the standard approach, this step takes considerably less time.

The validation phase in the real car is more promising, as with the NVH Simulator approach both the masking noise and the driving experience are considered in the design phase and even in the early concept phase. Unwanted surprises are avoided.

HiL and SiL

In a software-in-the-loop (SiL) or hardware-in-the-loop (HiL) approach, the sound-generating algorithm or device is already tuned in an NVH simulator, taking into account the actual driving sound (Figure 2). The driver closes the loop by listening to the sound and controlling the pedals. The user drives the virtual vehicle using the accelerator, brake pedal and gear lever, while a driving dynamics model of the vehicle calculates the resulting operating conditions consisting of RPM, load and speed. The sound sources powertrain, tire-road and wind can be manipulated by using filters. The level of the sounds can be adjusted or completely muted, e.g., to experience the effect of the masking. The binaural audio signals are played back via headphones.

In the lab solution, pedals of a gaming device, semi-professional or even professional USB devices can be used. In the mobile version, the computer and active noise cancellation headphones are placed in a real vehicle. In this case, a driving dynamics model is not necessary, as the data

(speed, rpm, load) is extracted from the vehicle's CAN bus. It is not necessary to use the target vehicle, since the complete virtual driving sound including ASD is simulated in real time. As a variant, this kind of system could also be used as an evaluation platform in the target vehicle. Here, the NVH simulator only reproduces the ASD sound using cabin loudspeakers or actuators and the real driving sound is generated by the target vehicle.

Three options are proposed to integrate Active Sound Design (iASD / ESE) into the NVH Simulator (Figure 3). With Option A an ASD programming library is integrated using a software interface to transfer the vehicle parameters to the ASD sound synthesizer library. The audio blocks are transferred back to the NVH Simulator and the sound is mixed with the driving sound. An ideal scenario would be to use the same ASD library that is used in the target system, so that the integration into the vehicle does not require any additional effort from the perspective of design. The sound designer creates and tunes the sounds with the tools of the ASD library. No further training is required to become familiar with tuning.

Option B is not to integrate a complete software library but to use a generic software interface based on a network protocol to transmit the driving parameters. In principle, any sound design software allowing for the implementation of this interface can be used. The sound is transmitted via the audio loopback of the computer sound card.

Option C, which is a hardware-in-the-loop approach, means to integrate the hardware of the control unit. The NVH simulator sends the driving parameters to the device using the CAN bus as in the vehicle. It is important that the NVH Simulator also emulates the vehicle, so that the ASD hardware assumes that it is working in the vehicle. Typically, initialization and shutdown messages must be sent to start and stop the sound generation. The programming of the ASD hardware is done with its proprietary tools.

Conclusions

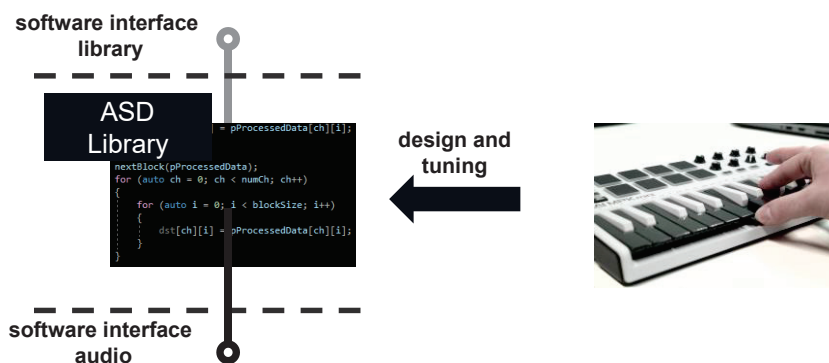
The proposed approach accelerates the process, as the sound is perceived according to the driving dynamics and the masking of the actual driving sound (powertrain, tire-road, wind) is already considered in the concept phase.

A virtual prototype allows for the design and tuning of ASD if there is no access to physical prototypes or if real vehicles are available at a (too) late stage. The real vehicle is only needed for a final tuning and validation.

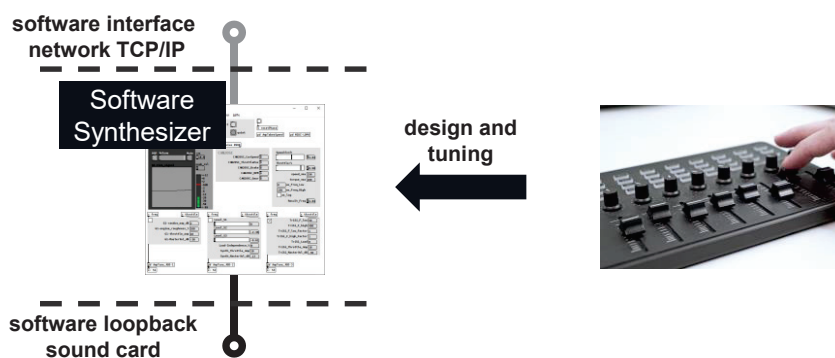
The SiL approach (A, B) allows the use of established tools for sound generation and thus forges a link between creative musicians and engineers.

The advantage of the HiL approach (C) is that the hardware platform of the vehicle is used at a very early stage of development. The sound designer can work with the target platform to achieve a faster workflow without compromises from the design to the production phase.

A) SiL – Software Interface (Programming Library)



B) SiL – Software Interface (Network TCP/IP)



C) HiL – CAN Interface (Sound Control Unit)

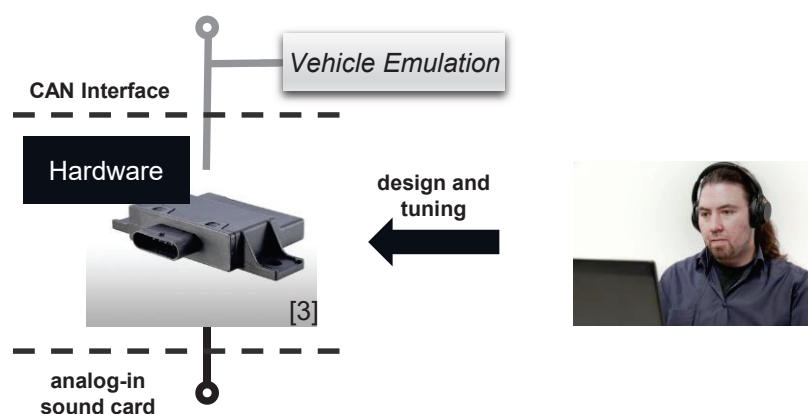


Figure 3: Three different options (A, B, C) are proposed for an integration of Active Sound Design in an SiL or HiL approach with an NVH Simulator (see also Figure 2).

Abbreviations

iASD	interior Active Sound Design
ESE	Engine Sound Enhancement
SiL	Software in the Loop
HiL	Hardware in the Loop

References

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