Siemens Digital Industries Software

Leveraging active sound design for automotive

Defining and shaping the soundscape of urban areas in the coming decades

Executive summary

Low emission and autonomous strategies have changed the noise, vibration and harshness (NVH) and acoustic landscape. Engineering departments have reinvented the vehicle NVH development process to better control all noise sources. Simcenter™ software is used to integrate simulation and testing tools and expertise. Its solutions are built for designing premium NVH and acoustic quality. In this white paper we discuss new technological solutions for vehicle sound enhancements, focusing on active design and describing the engineering process for adding meaningful sounds that meet both brand sound and engineering targets. In a related white paper entitled, “Active noise cancellation technology,” we explain how to implement innovative active noise canceling technology to reduce unwanted noise sources and improve the driver experience.

Contents

Introduction

As the automotive market continues to evolve, manufacturers are being confronted with emissions legislation that is forcing them to reduce the amount of carbon dioxide (CO^2) emitted into the air. Therefore, some new technologies are already in place or are in the process of being developed to achieve these new goals.

In addition to engine downsizing, which has been the main focus over the past decade, there is now an accelerating trend toward hybrids and fully electric vehicles (EVs). This prevents new challenges to vehicle NVH development. Completely new sounds are present in these vehicles. By contrast, in current vehicles the lack of a masking effect of internal combustion engines (ICEs) makes existing noise sources a lot more audible and annoying to the driver. The sound of next-generation vehicles will no longer be dominated by the powertrain, but largely influenced by road and wind noise.

Improving the NVH experience for the driver

There is an increasing amount of time spent on engineering efforts to control and/or reduce all noise sources. This requires the manufacturer to re-invent the vehicle NVH development process and pay attention to all noise sources. New innovative methods in NVH engineering enables engineers to build and evaluate virtual vehicle assemblies long before physical prototypes exist. These virtual vehicles or the digital twin is being driven on a driving simulator while assessing sounds. There are important limits to reducing the sound in the vehicle. Also, a lot of measures that reduce noise sources require expensive trim material and add overall weight to the vehicle.

This is where additional sound enhancement techniques become important to further impact vehicle sound. What those techniques have in common is they induce sound into the vehicle through the infotainment system. Here two complementary methods exist: First, adding active sounds to the vehicle that resonate with the driver's expectation of that vehicle. Secondly, using innovative active noise cancellation technology to remove the unwanted noise sources. Both technologies go hand-in-hand in impacting the overall in-vehicle sound experience, and the engineering solutions that can help to implement both of those are covered in this white paper.

We further discuss engineering solutions for implementing active sounds into the vehicle, including the entire process from design into the design studio, in-vehicle testing and implementation in production vehicles. It is also explained how the same technology is used for acoustic vehicle alerting systems (AVAS) for exterior sound generation, which is especially important for electric vehicles.

End-to-end active sound design

Active sound design technology for automotive applications

Active sound design (ASD) is a methodology to improve the driver's experience by giving acoustic feedback on the vehicle's performance, as well as ensuring the safety of other road users by emitting exterior warning sounds.

Thanks to acoustic treatments, ICE vehicles can become quieter and more comfortable. However, the downsizing of the powertrain could negatively impact the interior sound. Reducing the number of cylinders has a direct impact on the noise signature of the car. Going from an eight-cylinder engine, for instance, to a four-cylinder or less completely changes the driving experience and brand sound. ASD can be used in such cases to add engine orders to the sound and keep up with the brand sound of the vehicle. ASD techniques are applied in these vehicles to overcome the bad sound signature in different driving scenarios.[1] In addition, ASD creates the opportunity to make it sound better, improving the driving experience.

In hybrid and fully electric vehicles, at low speeds it is also mandatory for the AVAS to emit an exterior sound to alert pedestrians and other "weaker" traffic participants about the presence of the approaching vehicle. The minimum noise level of the AVAS system is strictly regulated, but the characteristics of the sound are not. The AVAS sound largely impacts the brand sound of the vehicle as it is perceived by any pedestrian around the vehicle. As a consequence, it is critical to design a sound with the right characteristics.

Full electric vehicles are largely silent at low speeds and provide little noise feedback to the driver. At higher speeds, a lot of annoying noise sources, such as wind and road noise, are no longer masked by the combustion engine. ASD can be used to enhance interior sound to compensate for the lack of acoustic feedback and increase driving pleasure. Secondly, new noise sources that have become apparent can be partially masked by enhancing the sound with ASD and while providing the right driving experience. This allows you to create the perception of driving a sporty car just by playing the right active sound over the speaker system.[2]

There are already several vehicles on the market with artificial interior sounds and AVAS systems in place as they are becoming mandatory in different parts of the world.

Several ASD techniques are applied for the different types of vehicles. Together they enable auto original equipment manufacturers (OEMs) to take the great opportunity to design a sound that represents their brand's signature for the next decades. Figure 1 illustrates the mandatory and optional ASD challenges for both exterior and interior sounds.

ASD sounds are easier in theory than in practice. But what exactly should a vehicle sound like? How should the sound change for different driving scenarios and different vehicle speeds or loads? How can you generate creative, authentic sound models that improve the driving experience without being perceived as artificial? There are many aspects to consider and tests that need to be done.

How do you create active sounds from a vehicle's dynamic parameters? The examples in this paper were used for the design of the active sounds, making use of two main methods: granular synthesis and order-based synthesis.

Granular synthesis

Granular synthesis is a sound sampling method that originated in the music industry in the 1970s, and was first described by Xenakis.[3] It is a sound synthesis method by which an original sound sample is broken down into short time segments called grains, which are then reorganized to compose a new sound. The grains can be as short as 10 milliseconds (ms).

This work has been extended into computer-based real-time synthesis methods by Truax,[4] making it more available to musicians. New sounds are composed by synthesizing grains with a certain window to ensure smooth transitions. In doing so, composers will change the pitch, duration and position of grain in the sample, thereby creating original, rich and lively sounds that will reflect more or less of their base sample.

Applying granular synthesis to automotive vehicle sound requires these composers' parameters are tied to vehicle dynamics parameters.[5] While the vehicle cycles through its operational condition, the granular synthesis changes the pitch of the sound in function of speed or torque.

The original sound sample used as input for the granular synthesis is the starting point of the design process. To obtain the final sound, the grain parameters will be tuned, such as the grain location in function of vehicle parameters and the grain duration, overlap and pitch. As such, granular synthesis allows you to create innovative and creative sounds that deviate from the more traditional order-based sounds present in classical vehicle NVH sounds.

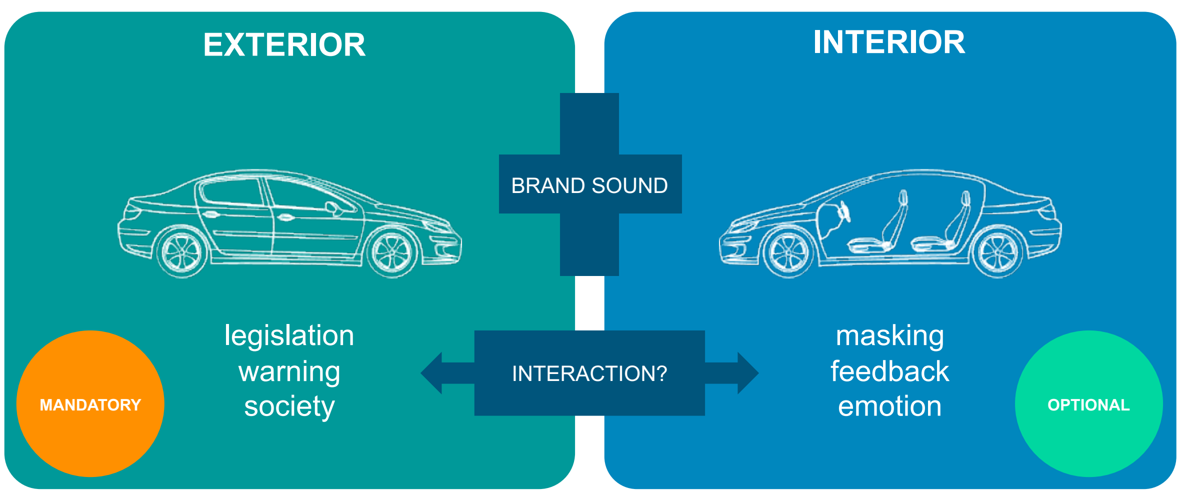

Figure 1. Interior versus exterior vehicle sound.

Order-based synthesis

Order-based synthesis is a technique to synthesize a combustion-engine sound based on its physical properties. Combustion-based sounds usually are low-frequency centered, consisting of a combination of lower engine orders.[6] Under load condition, a significant roughness contribution can be observed. The character strongly depends on the number of cylinders defining the main order. Synthesis is done by modeling engine orders in function of engine speed, where the frequency of the sound is equal to the order number multiplied by the revolutions per minute (RPM). See Janssens[7] for an application in vehicle sound synthesis.

The phase relationships between the orders can be taken from measured data or can be randomized. For a specific engine speed, the synthesis engine will generate sine tones for each order of frequency, amplitude and phase. Modeling more engine orders will make the synthesis more natural and refine as it will be able to invoke roughness between the orders; but it also puts a higher load on the synthesis engine. This technique has been applied for years in ICE vehicles to keep their good sound perception and to increase their interior sound quality. The order synthesis process needs to be followed by some steps to ensure sound satisfaction. That is mainly about adding a certain amount of dirtiness, roughness and variation in the order synthesis so the orders sound natural instead of synthetic.

Typical applications of active sound design

Active sound design is applied for several reasons. First, to comply with legislation for minimum exterior pass-by noise (PBN). And second, because ASD is an effective technology for vastly improving the driver's experience in an affordable way.

Exterior warning sounds to comply with legal requirements

All electric and hybrid vehicles in the market will need to comply with pass-by noise regulation. These regulations describe minimum noise level for a warning sound at low speeds, less than 30 kilometers (km)/per hour (h), and standstill conditions to warn pedestrians that a vehicle is approaching. This is necessary because of the low noise emissions intrinsic to these vehicles. The main tests are United Nations Economic Commission for Europe (UN ECE) Regulation 138 for Europe and other ECE regions,[10] and Federal Motor Vehicle Safety Standards (FMVSS) 141 for the U.S.,[11] and Guobiao standards (GB/T) 37153 for China.[12] During the tests referred to in the regulations, the AVAS needs to be operational.

OEMs need to design this sound and ASD is commonly used for that. Granular synthesis is an advanced method and is usually preferred to develop these sounds.[5]

In addition to designing the AVAS sounds, other aspects need to be considered. The AVAS sound is acting in parallel with other exterior sounds of the vehicle. Also, its sound can possibly be perceived inside the vehicle. Integrating a loudspeaker behind the front bumper also requires taking the transfer from the speaker to the side of the road into account. The sound quality inside the vehicle can be investigated and above all compliance to the legal evaluation (based on local regulations) is required. Therefore, AVAS sound design and implementation requires a flexible set of tools, allowing both the design and the full in-vehicle validation and tuning. That includes the validation of the designed AVAS sound against the different regulations while designing and tuning.

As opposed to sounds for interior active sound design, implementing AVAS sounds is not optional for the manufacturers. The AVAS sound will be heard outside the vehicle in a soundscape that is different than other urban sounds and will predominantly determine the brand image.

Enhancing interior combustion engine sound with active sound design

The main reason for using ASD in ICE vehicles is the signature of downsized engines changed significantly and, in many cases, no longer represented vehicle brand sounds. A three-cylinder engine just doesn't sound like a four-cylinder engine and certainly not like an eight-cylinder engine. Main contributors to the sound are the so-called engine orders, which are directly influenced by the number of cylinders firing per combustion cycle. The roughness of the sound increases with the load and this gives the correct impression to the driver. With reducing engine size and cylinders, this relationship between load and sound is not evident anymore.

The most used ASD technique for ICE vehicles is order-based synthesis. This technique is implemented by synthesizing artificial engine orders – the ones that are missing for that specific engine – to make it sound like a bigger or more powerful engine.

This method is extremely efficient and provides real-time sound feedback, making the synthesis easy. One can achieve more complex and vivid sounds with a less complex sound parameter structure. See Bodden[8] and Belschner.[9]

Order synthesis also allows the user to do additional sound manipulations, which enables the direct parametrization of more complex and required perceptions. One can add noise variances into the synthesis, increasing the liveliness and naturalness of the final sound.

This allows you to use more complex sound signatures that contribute to a better harmonization of sound and gives the possibility of generating a powerful brand identity. Lastly, synthesizing additional cylinders addresses emotions like giving a "sport" or a "race" feeling during the driving experience.

Figure 2(a) shows the frequency spectrum maps of a vehicle that originally had a three-cylinder engine, and by using ASD with order synthesis, was converted into a four- and eight-cylinder vehicle.

The order-based synthesis technique has proven to be efficient for ICE vehicles and since engine downsizing is still a trend these systems will remain present in the market. This technique is also applied to electrified powertrains, in applications where the OEMs want their EV to sound like ICE vehicles (for example, sportive brands moving toward electrification).

One of the aspects of a flexible and easy-to-edit toolchain is the possibility to use both techniques (order-based and sample-based) at the same time to design a unique sound.

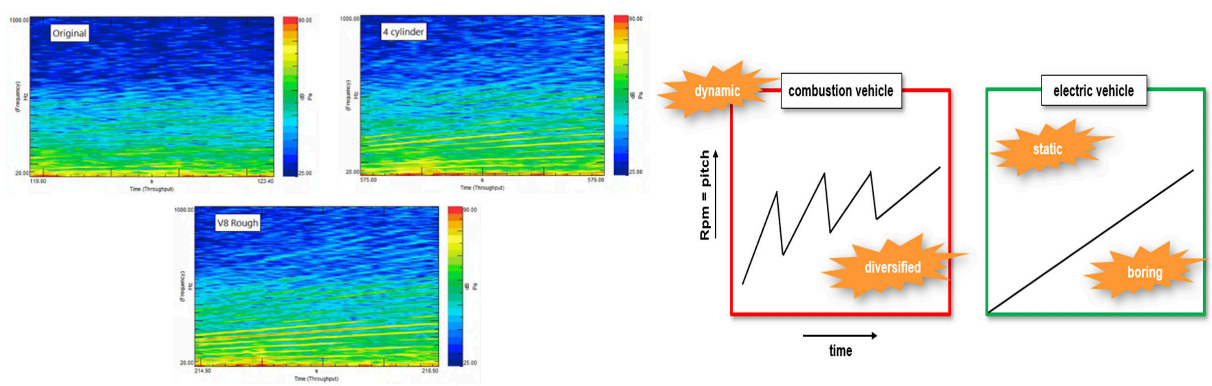

Figure 2. (a) Order synthesis applied to a three-cylinder vehicle, perceiving it as a four- or eight-cylinder engine. (b) Pitch profile of ICE (left) versus EV (right) and their sound perceptions.

Sample-based sound design applied to electrified powertrains

As mentioned, hybrids and fully electric vehicles have different acoustic behavior. More advanced techniques need to be considered to make them sound pleasant or even mimic the sound to make them appear similar to an ICE vehicle.

Electric powertrains have a single gear and their rotational speeds have a linear relation to vehicle speed. This behavior can give a static and boring sensation to the driver who may miss the sound feedback. This is the main motivation to use ASD in hybrids and EVs. See figure 2(b).

Granular synthesis is a sample-based technique generating rich and dense sounds from short and simple samples. Every variation in the selection of the grain creates different sensations, which makes this technique quite advanced. It can be used to design exterior AVAS sounds as well as interior sounds. See further details in Bodden.[6] In complicated scenarios, as in the transition from ICE to electric motor in hybrid vehicles, it can overcome acoustic issues by adding sounds based on vehicle parameters.

Granular synthesis can be applied in parallel to other synthesis methods. In Simcenter Testlab™ Sound Designer software, part of the Xcelerator™ portfolio, the comprehensive and integrated portfolio of software and services from Siemens Digital Industries Software, it's applied in multiple layers. The final sound is a combination of three main layers. Each layer is responsible for giving a group of perceptions to the final sound. The combination of the layers is an essential and important part of the design phase for achieving a high-quality sound.

For hybrid vehicles, the scenario is even more complex as the design is a combination of order-based synthesis (ICE engine) and sample-based synthesis (EV mode).

The resulting sound design will pass through a final phase of integration and tuning. Normally, this is done directly in the vehicle as it needs to be validated when acting together with the other interior sounds like road noise, wind noise and auxiliary noise.

An extra layer is used to overcome monotonic pitch increase with speed. This layer, called Shepard Layer, uses the Shepard tone technique to keep some low-frequency content in the sound at higher speeds.

When applied in a fully electric vehicle, we get results such as in figure 3. It shows a runup from 0 to 70 km/h followed by a rundown. The same interior sound was enhanced with order-based as well granular synthesis. These sounds were created by using an order-based layer in combination with one or more sample-based layers (and the Shepard Layer as complement). The completeness of the toolchain makes it possible to bring this design to a higher level and make an EV vehicle sound completely different.

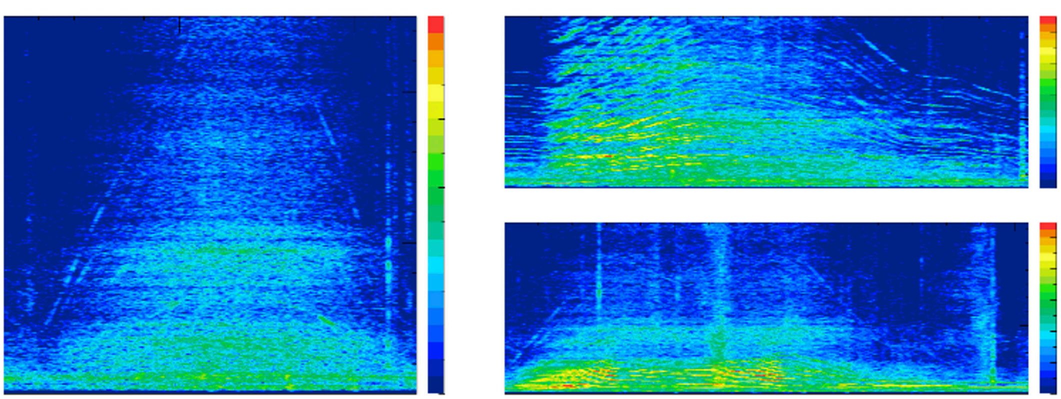

Figure 3. Active sound design example in a fully electric vehicle. Frequency map of the original sound (left), granular synthesis (right top) and order synthesis (right bottom).

Active sound design is a process

Active sound design for interior sound enhancement can be considered a creative task, but it is also part of a process. That process follows three mains steps: design, validation and deployment. This is quite similar to AVAS sound design, however, there are a few differences in the design, validation and deployment phase.

Design phase

In this phase the sound designer starts with a tabula rasa, aiming to define the brand definition of the auto OEM, the portfolio of vehicles and the individual models.

Even though sound design is a creative process, there is a step-by-step process to go through the design of active sounds. This brand sound exploration is a process that defines which attributes should fit a vehicle. This can be laid down in a rule-based approach and is typically the result of several iterations based on interviews with key stakeholders such as designers, but also potential future buyers and drivers (using jury testing). These rules can at first instance be subjective, such as it should sound Zen, “I want to feel free when driving the car,” or, “it should sound sporty,” or simply, “it should not sound like a combustion engine vehicle.”

With further follow up sessions playing different sound samples, these subjective descriptions can be made more specific. Sometimes as objective as ”I want to hear order 5.5 modulate with order 6 between 40 and 70 km/h,” or ”Zen is perceived closest to sound sample nr. x, which is a rolling ocean.”

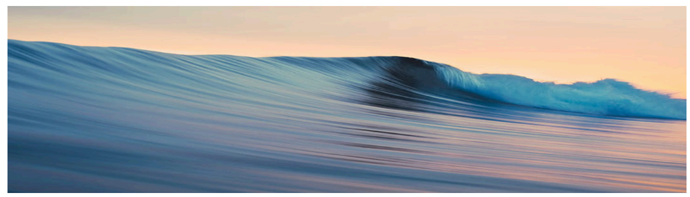

Figure 5. Samples from nature that match a brand sound serve well as input for sound signatures.

Sound models cannot be designed independently of the vehicle in which they will be used. First, it is important to think about which vehicle parameters should influence the generated sounds. Typical examples are vehicle or engine speed, or throttle and vehicle load. Those parameters together define a driving profile, which is the input for the sound model.

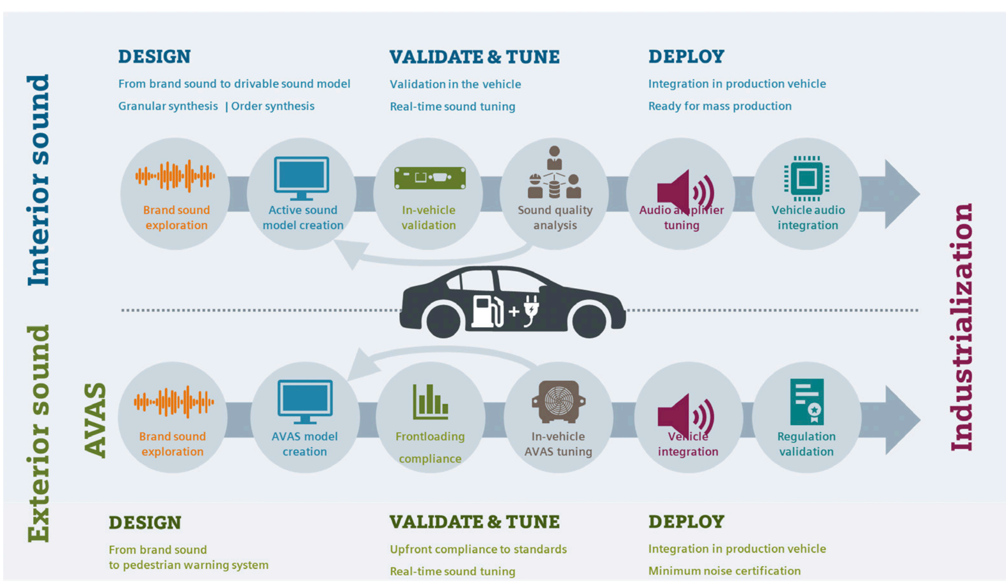

Figure 4. Active sound design process for interior and exterior sound.

In the early stage, before having a prototype or vehicle simulator available, a first evaluation of the designed sound models against driving performance can be done. With this approach, the driving profiles that represent certain scenarios are used as input for the active sound models while a first evaluation of the sounds during those scenarios can be done. Different approaches can be used to create the driving profiles. In the simplest way, the driving profiles are created from historic data or basic simulations. Alternatively, Simcenter Amesim™ software models can be used to generate the profiles. This allows the possibility to evaluate different driveline designs or alternative control parameters and their impact on active sounds at an early stage. Another efficient way is to record dynamic data of equivalent test vehicles without any active sound. Typically, such datasets contain CAN bus parameters, and the sound at the driver's left and right ear is recorded with a binaural headset. By including the original road, wind and electric motor noise, the active sound signature can be evaluated in a very realistic way.

To further optimize the sound models, they need to be tuned further on the vehicle sound simulator or vehicle prototype, which is done in the validation phase.

Validation phase

In this phase, the designer takes the sounds in the studio to the target vehicle. Because whatever you design in the studio must be validated in the vehicle. It interacts with the existing noise sources and is validated against vehicle driving behavior.

The sound models will need to be tested on a vehicle sound simulator or the vehicle prototype. This is crucial, as a developed sound model at the design table will still not be what you want once used in the vehicle. The driver interaction with the generated sound can only be tested in its real environment. At that moment, real-time interaction with the vehicle CAN bus is required to access the parameters that influence the active sound.

Taking the sound signature and connecting it to the CAN bus requires dedicated hardware. The Tier 1 audio hardware for mass production is most probably not available yet (if even selected). So, a development unit is required that contains the same components as we find on a real Tier 1 audio system. For that, Simcenter Testlab Sound Designer uses a vehicle unit that has four analog outputs, a CAN bus interface and an onboard audio digital signal processing (DSP). The audio outputs are connected to the vehicle's speaker system, an external speaker system (less intrusive) or an onboard audio amplifier. The software then allows it to dump up to four sound signatures on the device. All parameters can be tuned in real time. Once done, the final candidate signatures are stored on the vehicle unit for longer term evaluation by the different stakeholders. See figure 7.

Figure 7. The Simcenter Testlab Sound Designer vehicle unit connected to a vehicle's CAN bus through a CAN gateway. In this setup the audio output of the vehicle unit is connected to an external speaker system. Simcenter Testlab Sound Designer controls the sound signature and all its parameters in real time while the dynamic driving data comes directly from the vehicle.

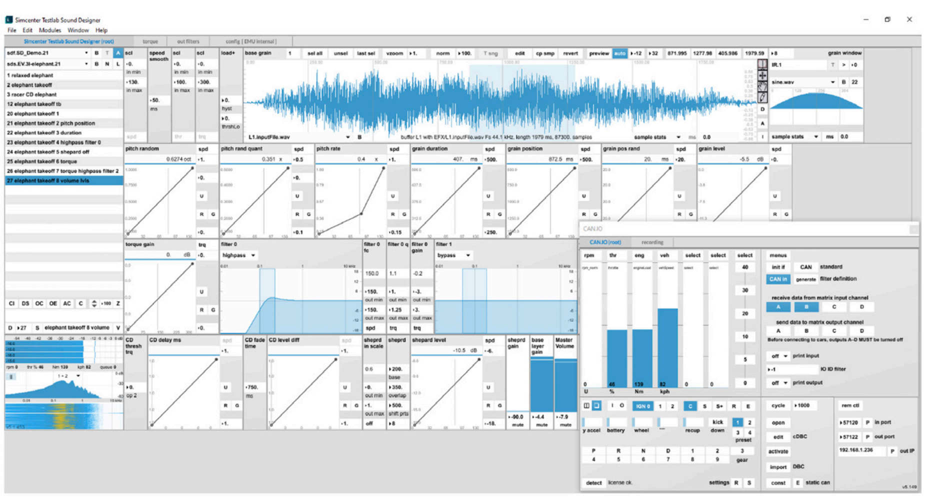

Figure 6. Granular synthesis with Simcenter Testlab Sound Designer. The wave sample is a recording of a natural elephant sound, while all parameters make it become a smooth, powerful and drivable ASD.

At this point it is also important to assess if the sound quality (SQ) of the interior active sound design matches the vehicle's SQ targets. It can be assessed in two classic ways: by subjective and objective assessment. Taking both assessment results into account will give an advanced view on the final SQ assessment and to whether the NVH SQ targets of the vehicle are met.

The subjective assessment is typically a jury testing evaluation. To quantify the preference of experienced drivers to the different sounds, sound recordings are replayed in a listening test. Listening, or jury tests, allow you to collect subjective preferences and opinions of the jurors in a controlled environment and use that result for further correlation with objective analysis.

The jurors can be internal engineers, designers and management, or selected as part of the target group that should buy a certain vehicle model. A paired comparison jury test with forced answers option enabled and A-B replication results in a number of pairs of sounds can be used. The jurors then have to answer the question, "Which of the interior sounds do you prefer?" The A-B replication resulted in the doubling of the length of the test but was considered advantageous in rating the consistency of the jurors. Prior to the listening phase, jurors typically have to answer several statistical questions that splits them into different groups. This can be age, gender, current type of vehicle, any attribute that is useful to correlate the answers of the jury test to. So, jury testing is about identifying groups that assess sounds in the same way, and their preference. See figure 8.

Objective assessment is to use sound quality metrics for analysis. Sound quality metrics aim to quantify subjective criteria such as loudness, sharpness or roughness. These include psychoacoustics features mimicking our physiological hearing mechanism, like the fact that we evaluate sounds per bands (critical bands), spectral masking (frequency components hiding others) and other temporal effects (continuity preference, pre- and post-masking, etc.).

The models behind psychoacoustic metrics are built to fit subjective evaluations from listening tests. Therefore, these metrics represent the perception of an average human listener. To assess active sound design signatures, metrics like loudness, sharpness, articulation index and prominence ratio are good candidates to build a model on which to fit the listening test ratings. See figure 9.

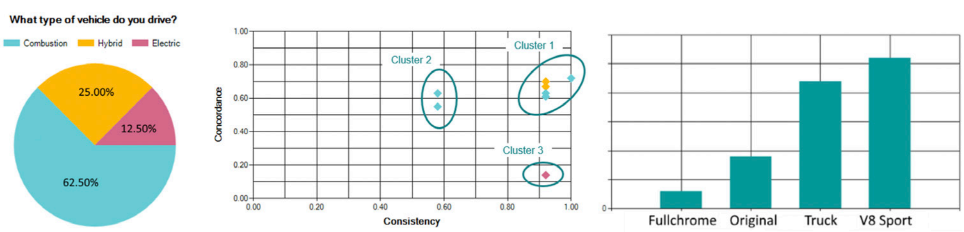

Figure 8. Statistical groups, clusters of consistency and concordance and preference of a certain cluster.

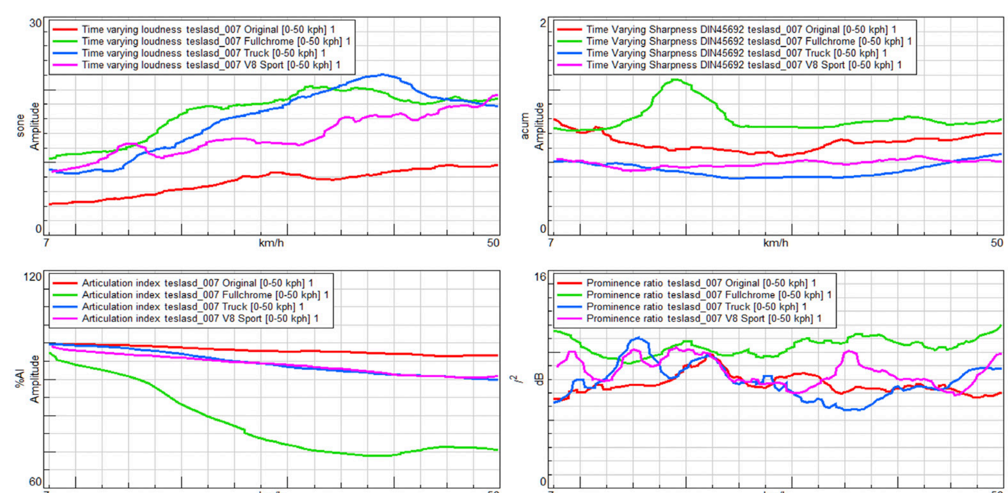

Figure 9. Loudness, sharpness, articulation index and prominence ratio metrics in ASD.

Deployment phase

It is always a good idea to start a project with the end in mind. For active sound design that means that one should start to design ASD with the ultimate goal to deploy the sound to mass production of the target vehicle. More specifically, it needs to run on the Tier 1 audio hardware selected by the auto OEM. Such hardware does not only manage ASD, but it also integrates all other audio processes running in the vehicle, such as infotainment, Bluetooth for cell phones, navigation, warning sounds and active noise cancelation.

To understand deployment of ASD it is required to understand how such hardware works. First, it typically has several audio DSP chips, from chip suppliers such as Analog Device, NXP Semiconductors and Texas Instruments. These chips typically have a small internal random access memory (RAM). They are integrated on a hardware audio board that also has flash memory that can store some audio samples and be loaded into the audio DSP RAM when used. Finally, there are also USB/UTP interfaces to communicate with the device, audio buses and audio input/output. See figure 10.

This application runs on hardware called a framework. The framework is made by a programming tool for embedded hardware devices, such as Code Composer Studio[13] or AUTOSAR.[14] The code needs to be compiled with a certain compiler for the programming tool and then flashed on the hardware.

There are two major challenges when it comes to deploying sound signatures on such hardware systems. First, the sound signature needs to run on the framework. It would be a waste of resources if the perfectly designed sound needs to be reprogrammed again from scratch in the framework. Also, it's neither the job nor the skill of the sound designer to program embedded hardware code.

The second challenge with deploying ASD is that a sound signature needs to be validated and tuned with the vehicle. It would not be an efficient process if every change to the sound results in first programming the changes, then recompiling the code, flashing it on a chip, putting the hardware board back in the vehicle and only then having the designer test it.

The solution to both challenges, as employed by Simcenter Testlab Sound Designer, is the sound synthesis library is integrated with the framework. Integration means the library is compiled with the framework so it runs on the audio DSP, can access the flash memory and an interface is agreed upon to communicate with it. This will allow the sound design tool (Simcenter Testlab Sound Designer) to communicate with that library via USB or UTP to dump an entire new signature to the audio hardware without having to recompile the code. Furthermore, an update of a couple of parameters can be done in real time and the effect will be audible instantly.

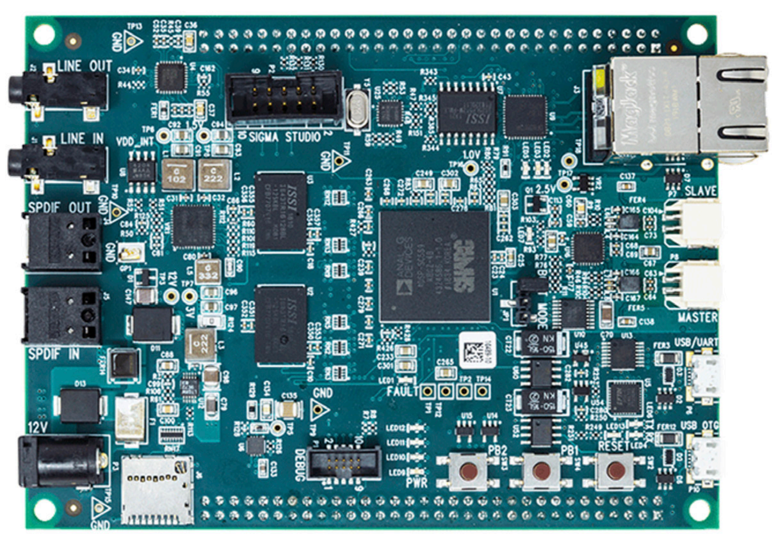

Figure 10. Typical Tier 1 audio hardware board with audio DSP, SPDIF and analog audio input/output and USB/UTP interfaces.

AVAS design, validation and deployment

For validation of AVAS sound it is important to know if it passes the PBN minimum regulations. Globally, the most important standards are UN ECE Regulation 138 covering most of Europe but also other regions, FMVSS 141 covering the United States and GB/T 37153 covering China. The European and Chinese standards are exactly the same, except the Chinese standard has 2 decibels (dBs) higher minimum noise limits.

In the design of the AVAS sound, several characteristics from the standards should be considered. First, a minimum sound level should be made at its required speed point. Depending on the standards, that's idle, reverse, 6 /10/20/30 km/h. Second, legislators have also included requirements to have a certain number of specific third-octave bands that exceed a minimum level. Finally, a criterion is included that will help pedestrians detect approaching vehicles and their speed and acceleration: the pitch shift (ECE, GB/T) and the volume change (FMVSS141). So the ASD for AVAS should comply with these requirements and within those boundaries it should also address the brand sound design.

In the validation stage, the most important part is to predict if the design also complies to these standards. Several steps of the vehicle design still have to be done, such as determining the exact speaker location, selecting the AVAS audio hardware and performing the final PBN testing for compliance. That is a lot of potentially lengthy steps before doing the final validation. A lot of cost can be avoided by front loading the compliance check. To be able to do so, applying transfer functions between the AVAS amplifier's output (the input into the AVAS speaker) and the PBN microphones, which are standing 2 meters away from the vehicle, are required. The impulse response of these transfer functions can be convoluted with the synthesized AVAS sounds to predict the real levels later measured during compliance test, and all criteria of the PBN minimum noise standards can then be assessed accordingly. See figure 12.

This AVAS compliance check can then be done for several projected speaker locations behind the front bumper. In theory there are an infinite number of speaker locations possible, and acoustic simulation can be done to determine the ideal location. However, in practice there are only a handful of speaker locations possible, as AVAS speakers have a certain dimension and front bumpers are mainly designed with other constraints in mind such as safety and aesthetic design.

One may wonder, "So what?" If you don't comply, why not just tune the AVAS by increasing the volume? Well, that's a last-minute possibility late in the design cycle, but it will always mean that the AVAS speaker is more likely audible inside the vehicle as well. With the absence of combustion engines, also the firewall of the vehicle, which is traditionally designed to absorb a lot of the acoustic radiation of an engine, will have fewer design specifications and focus more on road noise. By assessing transfer functions from the AVAS unit to the vehicle's interior, this aspect can be front loaded as well.

Figure 11. Simcenter Testlab AVAS unit mounted on the outside of the bumper for development purposes. It includes the amplifier and the speaker, connects to the CAN bus and runs the AVAS sound signature. The personal computer application can be connected for tuning and evaluation.

In the deployment phase, the vehicle undergoes its final PBN certification. For ECE R138 and GB/T 37153 that can be done either in-room in a semi-anechoic test facility, or outdoors on the test track. For FMVSS141, it is only allowed outdoors.

The test setup consists of two microphones positioned at only 2 meters(m) from the center of the vehicle and requires cruising tests at low speeds in forward and reverse. Additionally, it requires frequency shift tests to ensure that acceleration or deceleration of a vehicle can be detected. The cruising speeds are not allowed to exceed a certain sound pressure level. Several runs are required per conditions, which means a lot of bookkeeping has to be done to be able to apply all the calculations and checks from the standards, and finally produce a report that can be accepted by a homologation authority.

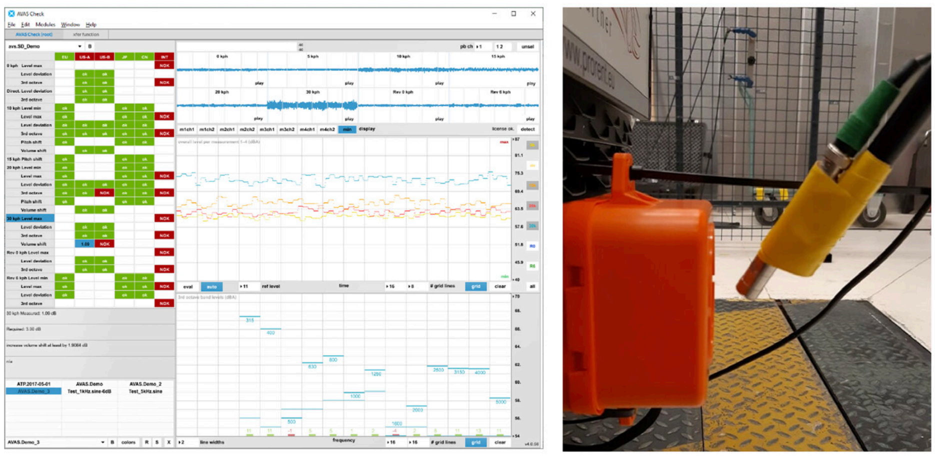

Figure 12. AVAS check predict compliance to PBN minimum noise standards. It uses transfer functions measured on prototypes.

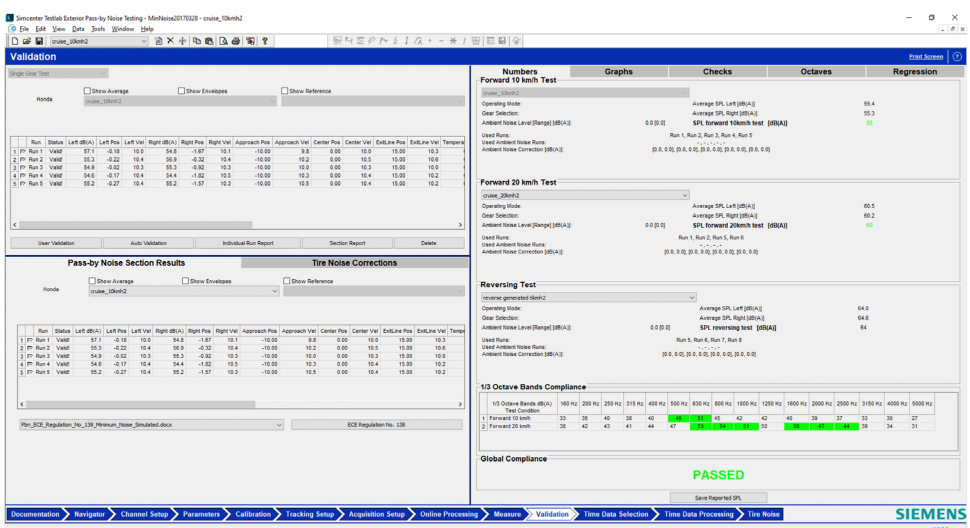

Figure 13. Simcenter Testlab: minimum noise testing according to UN ECE R138: make it green!

Conclusion

Active sound design is about adding meaningful sounds to the vehicle, both on the inside and outside. Vehicle manufacturers need to build the ASD process into their vehicle development programs, where the creative design part meets both the brand sound and the engineering targets. Key elements are the ability to design sound in function of automotive vehicle dynamics, validate ASD directly in the vehicle and deploy the ASD for mass production independently of the Tier 1 audio hardware platform of choice.

AVAS design largely follows the same steps but has the prerequisite that it needs to comply to known PBN minimum noise legislation. Compliance as well as the audibility to the interior vehicle can be front loaded.

Simcenter Testlab[15] includes a full solution for active sound design, with several sound design methods and validation using real-time synthesis in the office, in-vehicle or on a driving simulator. Finally, you will have the possibility of deploying for mass production.

Simcenter Testlab also supports PBN minimum noise standards for UN ECE R138, the preceding ISO 16254, GB/T 37153 and FMVSS 141.

AVAS and active sound design will define and shape the soundscape of urban areas in the next decades, laying the foundation for the driving experience of the near future.

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