Audio synthesis and noise reduction in modern vehicles

Rafael A. Barkas, Gerhard Pfaffinger, Harman - March 29, 2013

Audio optimization has become a mainstream issue for today's auto designers. From compensating for the absence of engine noise to keeping sound levels down in the vehicle interior, audio synthesis and noise suppression solutions can help.

In seeking ways to counter rising fuel prices and lessen environmental impacts, the auto industry is staking out two key trajectories. One is the industry's commitment to lightweight design. The new VW Golf, for instance, weighs in at over 100 kg lighter than its predecessor. The other is the trend toward hybrid and electric vehicles that can complete at least part of a journey solely on electric power.

What both developments have in common is the challenge they present for vehicle noise optimization. The lower the vehicle’s target weight is, the less material can be installed to reduce noise, meaning that noise penetrates the vehicle interior (and passenger ears) unmitigated.

Electric motor-powered vehicles, on the other hand, by their very nature emit little or no noise at all. As a result, pedestrians are unable to hear an electric vehicle until it is virtually upon them – or worse still, they fail to hear the car at all. Moreover, the lack of engine sound exacerbates the impact of other vehicle noise, meaning that road or wind noise, or wind may be perceived as relatively loud in the vehicle interior.

To counteract these effects, auto manufacturers need effective systems which can synthesize sound in electric vehicles to warn pedestrians, and that can also suppress interior noise successfully. A solution that excels at both, external sound synthesis and internal noise suppression, is HALOsonic, a joint development of HARMAN and the British developer Lotus Engineering.
Protection through sound
The acoustic pedestrian safety feature in HALOsonic works according to a relatively simple principle. A loudspeaker is mounted to the front of the vehicle. This has the effect of projecting sound forward to the front of the car. The audio source is supplied with signals that correspond to the driving situation, ensuring that the synthesized sound is consistent with the vehicle’s speed and acceleration.

One challenge is to design and position the speaker and its electronics such that they will not be damaged by the extreme conditions in the engine compartment. In addition to the intense heat that
can occur here – temperatures of 120 °C are common – the highly sensitive components are exposed to a multitude of environmental impacts. When the vehicle is travelling at speed, wind, rain, dust, small rocks – all pose risk to the loudspeaker which has to be designed to withstand these elements. The electronics themselves are easier to protect. Since the electronic componentry does not have to be in a particular location, it can easily be mounted in the interior of the vehicle.

The sound produced in external sound synthesis is optimized for audibility. With frequencies between 50 Hz and 3 to 4 Kilohertz, it is right in the middle of the human auditory field, which ranges from about 16 Hertz to - in infants - 20,000 Hertz.

**Sound as a brand signature**
While safety is the primary interest, external sound synthesis also creates opportunities for automakers to reinforce their brand by creating unique audio signatures for their vehicles. Cars with internal combustion engines already routinely make use of sound engineering to “soundscape” the brand.

A Ferrari, for instance, sounds different to a BMW, and each has an audio signature which is in turn distinct from that of a Renault. This differentiation is now also possible with electric and hybrid vehicles. A Toyota Prius, for example, and an Opel Ampere each have their own particular audio signatures.

**Fighting noise with noise**

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HALOsonic can also influence sound inside the vehicle by optimizing the audio signals that passengers hear. As cars become lighter, insulation material becomes thinner, and considerably more unwanted noise gets through to the passengers' ears. The HARMAN solution counteracts this with two systems: Engine Order Cancellation (EOC) and Road Noise Cancellation (RNC). Both work based on the same principle that employs anti-noise to counteract engine or road noise.

![Figure 2: External sound synthesis allows for more focused sound emission and less noise pollution.](image-url)
EOC helps to control engine noise. This type of noise is called narrowband because at a given time, it occurs over a narrow frequency range whose value depends on the engine's rotational speed (RPM). HALOsonic analyzes the sound signature of the engine throughout the relevant RPM range. Thus, the HALOsonic system “knows” what sound waves an engine will produce at a certain RPM. These sounds include the primary sounds created by combustion and the motion of the major engine components, and also the harmonics of those frequencies. EOC is capable of achieving a peak noise reduction of up to 20 dB.

Cancellation of the engine sounds is not perfect, largely because the engine and the speakers are in different physical locations. In order to help correct for this imperfection, microphones are positioned above the seating locations. These microphones pick up any residual engine sound that is not cancelled. The HALOsonic processor then creates an inverted version of the residual engine noise and sends it out through the audio system, which increases the overall efficacy of the noise cancellation.

![Figure 3: Thanks to EOC, a reduction of up to 20 dB is possible over a wide rpm range.](image)

RNC works similarly to engine noise cancellation and ensures that unwanted noise caused by the road surface and tire resonance is less audible in the interior. It senses vibration coming from the road, and then creates an inverse sound wave through the car’s audio system to cancel out the noise caused by the road-induced vibration.

To implement RNC, each wheel assembly is typically fitted with a pair of accelerometers. By comparing the output of the two accelerometers, the HALOsonic processor can measure the activity of the suspension at each wheel, and thus knows when, where, and at what intensity road vibration – and thus, road noise – is occurring in the vehicle.

The HALOsonic processor then creates an inverse sound wave through the car’s audio system to cancel out the noise caused by the road-induced vibration. However, the nature of this noise is different in that, unlike engine noise, road noise is very broadband, extending over a wide range of frequencies. Therefore, the system is able to reduce the peaks of this noise by 10dB and 4-5dB.
across the target frequency range. This level of performance significantly improves the perceived quality and comfort of the car’s interior.

As with EOC, RNC does not perfectly cancel road noise because the road noise and the cancelling sound wave from the audio system come from different physical locations. To enhance the efficacy of RNC, the same type of small overhead microphones used for EOC are used to provide feedback to the HALOsonic processor. The microphones pick up any remaining road noise, then the HALOsonic processor produces additional sound waves to cancel out the residual road noise.

The power of sound

At present, sound synthesis and noise suppression technology is still in its infancy (so far there are only a few manufacturers developing the systems, let alone installing them in vehicles). Yet development is moving ahead at a brisk pace.

The more vehicles are equipped with quiet hybrid or electric motors, the greater need there is for solutions to make the engines more audible to pedestrians. And interior noise reduction has been an industry focus for decades already. So we can expect to hear more - or hear less, depending on the objective - from these two areas in the future.

About the authors:
Rafael A. Barkas is Director of Business Development, Harman Lifestyle Division – Automotive Audio SBU. Gerhard Pfaffinger is Senior Manager, Harman Lifestyle Division – Automotive Audio SBU.

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