Introduction

For as long as combustion engines have existed, automotive engineers have had to address low-frequency RPM-dependent noise. The most prominent component originates from firing up the cylinders, and if this firing frequency hits the vehicle interior resonance, a prominent booming noise occurs. For fewer cylinders and lower RPM—used for more efficient automotive powertrains in greener vehicles—the engine noise is lower in frequency and more likely to result in booming, which is louder and more disturbing from a customer perspective. Technologies to increase fuel efficiency, such as cylinder deactivation or HEV battery charging, further contribute to this trend.

How can you create a quieter ride?

ANC allows you to use the in-vehicle audio system to reduce unwanted engine noise. By tapping into the engine RPM and additional microphones and utilizing signal processing, either in the radio or amplifiers, you can create the same sound as emitted by the engine in order to counteract it.

Mainstream automotive in-vehicle infotainment systems are commonly adopting active acoustic technologies to influence vehicle sound via electronic means. At the same time, these infotainment systems are moving towards utilizing highly integrated SoCs with high-performance standard CPUs and software infrastructure.

For ANC to work well, you need compute resources that operate in hard real time as they implement feedback control loops that need to be completed in time. Because of these constraints, the approach of integrating a small real-time DSP into your audio subsystem provides a logical choice. This way, you can designate your primary processor to focus on compute-intensive functions such as processing graphics for the interactive screen on the car's center console.
Active Noise Control vs. Active Sound Design

ANC is based on coherent acoustics rather than incoherent acoustics like everyday noise experience. Fundamentally, ANC aims to accurately replicate the original sound field at all relevant locations, for all relevant times, in-time and in counter-phase. Figure 1 shows a typical system design for a passenger car utilizing ANC. Making use of the audio system’s four to five woofers and adding three to six microphones, ANC will work well in a typical cabin within the 30-250Hz range—covering the booming frequencies and all of a typical four-cylinder firing frequency range and reducing noise for all passengers.

Now, in a luxury car, it’s not a big cost impact to utilize a large DSP to run your ANC algorithms, along with the additional amplifiers that are likely there to drive the vehicle’s expansive speaker system. But this approach isn’t cost-effective for, say, an economy car. When cost is a key consideration, you can instead rely on the head unit—the descendant of the good old car radio—to control all of the audio, including the power amplifier and the DSP power for ANC.

ANC for passenger cars: Typical system design

Closely related to ANC is active sound design (ASD), which adds to the audio to create the desired engine sound in the vehicle’s cabin via the audio system (Figure 2). This technique can be considered engine sound enhancement to both showcase the vehicle’s performance and reinforce its automotive brand identity.

For example, the audio system in the sporty BMW M5 features a digital signal processing function that exchanges data with the engine management to deliver sounds that reflect the engine’s revs and torques, as well as the car’s driving speed. If the driver switches to “Sport” or Sport+ mode, the engine’s responsiveness sharpens, as does the acoustic experience inside the car. See Figure 3 for decibel levels of various ASD examples.
Infotainment System At a Glance

Today’s in-vehicle infotainment system is fully digital and highly integrated. Its functionality continues to increase over time, despite limitations in package space and power as well as heat dissipation restrictions. It is a communication hub with multiple interfaces, often wireless. Package space and cost limitations enforce bus-based communication with very high bandwidth at the vehicle interface level. The system is also highly integrated with the vehicle, providing functional sounds for warnings, alerts, and displays.

The design trend for infotainment systems is to use powerful standard processors with an open operating system and middleware. The complexity, then, lies in the software rather than the hardware. Scalability is important, so multi-core processors are typically used. Because software comprises so much of the system, updates can be made in the field and there are generally shorter development and update cycles. Many infotainment system designers are also choosing to use cross-functional SoCs in their designs; for example, such an SoC might support the vehicle’s radio tuners and audio capabilities.

Integrating Active Sound Technologies Via a Dedicated DSP

Infotainment SoC designs must consider the unique requirements of audio signals for active sound technologies and make them match with infotainment audio. Typically, infotainment audio signals have:

- High bandwidth, 48kHz fs
- High dynamic range, ≥16 bit
- A high number of channels, ≥20 source channels, 20 target channels
- Non-synchronous sources and sinks, and different clock domains
- Complex signal processing and block processing
- No interrupts and synchronization capabilities
- Nearly arbitrary latency, with synchronization achieved by delay lines to align with the slowest component (e.g. audio/video lip sync)

In contrast, in application areas such as hands-free voice control and buffering, low latency is a must. This is even more critical for active sound technologies, with their specific low-latency requirements driven by control theory. Therefore, they don’t fit into mainstream audio frameworks.
In the first generation of active sound systems, automotive designers added an extra control unit in the car with a DSP for audio signal control between the power amplifier and the speaker. This approach provided the low latency needed between microphones in the car and the speaker system. In the next generation of systems, designers integrated active noise technology onto very powerful DSP-based amplifiers. However, this approach proved to be very expensive and as a result, effectively banned the technology from economy cars.

Head units in today's vehicles typically run on large embedded CPUs, or even multiple CPUs to support navigation, infotainment, and smartphone apps. Linux is a popular OS for these systems. While this approach provides substantial computational capabilities, it does not support the low latency requirement of audio. Much of this is due to the OS—Linux, for example, guarantees a latency of 100ms for task switching, which is fine for many control tasks, but insufficient for ANC functions.

For the audio component, incorporating a small, dedicated DSP for active sound technologies can be a cost-effective way to meet your system's cost and performance requirements. The DSP could interface with vehicle, microphone and loudspeaker data and run the functional software needed for these applications, offloading your primary processor for more compute-intensive tasks.

Small, Low-Power DSPs for Audio

An example of a small, low-power DSP designed for audio algorithm processing is Cadence’s Tensilica® HiFi DSP for audio, voice, and speech processing. Because the DSP is based upon the customizable Tensilica processor, it supports numerous RTOSs. These RTOSs running on the HiFi DSP can guarantee the low-latency performance not found on general-purpose CPUs running a high-level OS (HLOS) like Linux or Windows. The HiFi DSPs support more than 160 audio, voice, speech recognition, and audio and voice enhancement software packages, as well as proprietary software.

As licensable IP, the Tensilica HiFi DSP can be included in any SoC design, making it easy to integrate low-latency audio signal processing into most any automotive infotainment system. The programmable DSP also provides enough compute resources to support other audio processing algorithms, from acoustic echo cancellation and beamforming to sound-stage widening.

Summary

Active sound technologies including ANC and ASD are enabling automakers to minimize or to brand the engine noise inside their vehicles. Running ANC and ASD algorithms on a small, low-power dedicated DSP can be an effective way to meet the performance, energy consumption, and cost targets for an automotive system. While the dedicated DSP runs low-latency, real-time sound-related algorithms, the primary processor can focus on more compute-intensive functions found in today’s media-rich infotainment systems.

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