# *Electric vehicle warning sound system*

*Analog Devices (AD) developed two solutions that can synthesize in-cabin engine sounds as well as external engine sounds and adjust them on the traveling speed.*

Traditional combustion engine vehicles emit engine sound, even at low travel speeds. Typically, pedestrians and other traffic participants recognize an approaching or departing vehicle through sight and auditory identification of tire sounds and other emitted noise when the vehicle is out of sight.

Electric vehicles (EVs) do not emit engine sound. Hybrid electric vehicles (HEVs) or plug-in hybrid electric vehicles (PHEVs) move almost silently when traveling at low speeds and before the conventional internal combustion engine kicks in. These vehicles are difficult to hear when travelling at speeds less than 30 km/h. At greater speeds, the tire sound becomes dominant.

Global governing bodies are exploring legislation that seeks to establish a minimum level of sound for EVs so that visually impaired people, pedestrians, and cyclists can hear these vehicles approach and determine from which direction these vehicles are approaching. An example of this legislation can be found on the National Highway Traffic Safety Administration (NHTSA, United States) website.

An electric vehicle warning sound system (EVWSS) produces a series of sounds designed to alert pedestrians to the presence of EVs, HEVs, and PHEVs. The driver can initiate warning sounds (similar to the sound from a car horn, but less urgent); however, the sounds must automatically be enabled at low speeds. These sounds vary from artificial tones to realistic sounds that mimic engine noise and tires moving over gravel.

Analog Devices offers two different solutions for applications with an in-cabin engine sound and an external engine sound. The advanced engine sound system solution is based on the ADSP-BF706 Blackfin+ processor. For entry-level systems, a solution based on the ADAU1450 SigmaDSP was developed. These solutions can synthesize sound and adjust frequency, sound volume, and other parameters depending on the traveling speed. Then the audio signal is sent to an audio power amplifier. The warning sound can be simulated using combustion engine sounds or any other synthesized tones.
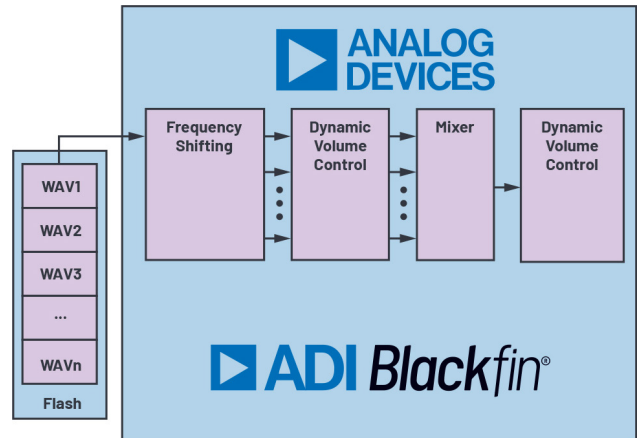


*Figure 1: Processing blocks on Blackfin+ processor (Source: AD)*

## Blackfin-based solution

The ADSP-BF706 Blackfin+ processor provides a single-chip solution for audio processing and interfacing to the CAN network. AD developed a CAN software stack that runs on the ADSP-BF706, which enables users to build automotive-grade demonstrations using ▷
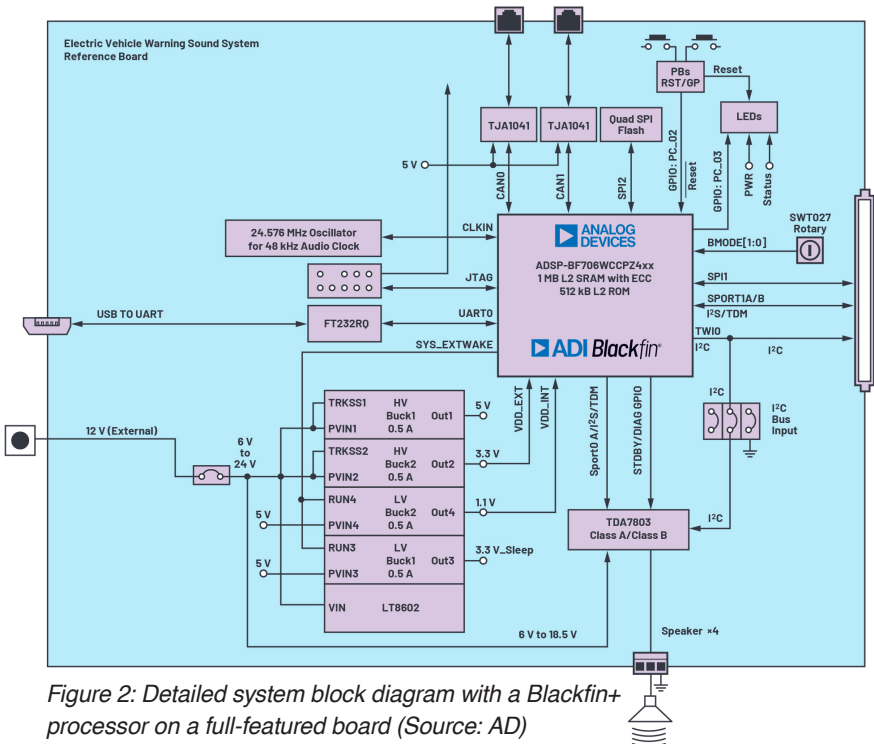


*Figure 2: Detailed system block diagram with a Blackfin+ processor on a full-featured board (Source: AD)*
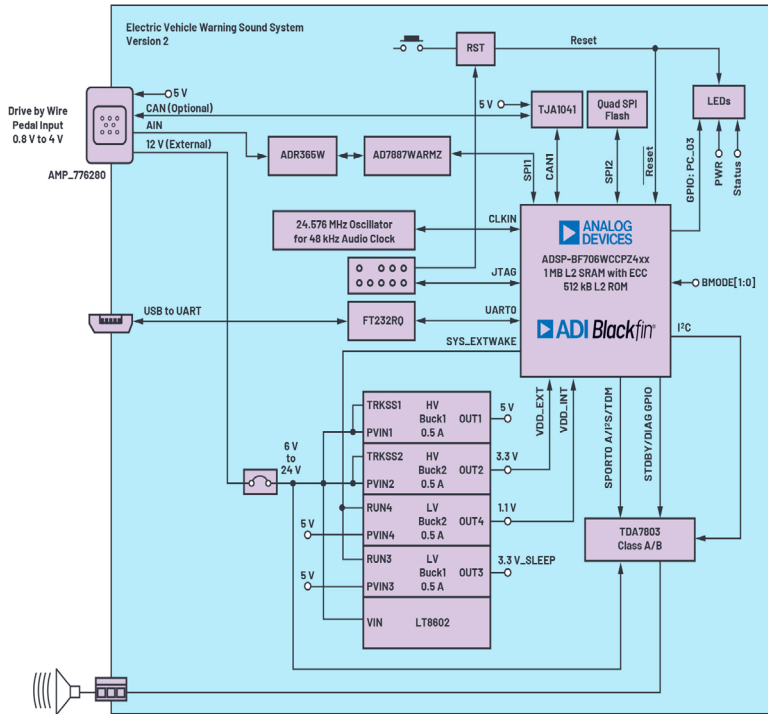
*Figure 3: Detailed system block diagram with a Blackfin+ processor on a board with reduced components (Source: AD)*

e.g., a CAN stack by Vector. Additionally, AD provides a hardware and software reference design and Sigmastudio compatibility for the live tuning of parameters.

Figure 1 shows the different processing blocks inside the ADSP-BF706. External waveform audio files (WAVs, up to 25) store signature engine sounds or audio tones. These files are frequency-shifted and mixed internally in the digital signal processor (DSP) before adding the dynamic volume control.

The ADSP-BF706 utilizes a memory-mapped SPI (serial peripheral interface) interface that provides access to the external memory, which eliminates the need for an external double data-rate (DDR) memory for this application. Up to 25 WAV files can be accessed simultaneously from the SPI flash memory. The large number of accessible WAV files helps to create more realistic engine sounds.

The ADSP-BF706 can also implement up to 16 pitch shifting variants (recommended from NHTSA), which increases the frequency of the output sound as the vehicle speed increases. The ADSP-BF706 can dynamically control the volume as the vehicle speed increases. The vehicle speed value is provided from the in-vehicle CAN network.

Figure 2 shows a detailed system block diagram. A power-by-linear LT8602 step-down regulator provides all voltage rails required in the system supplied by the 12-$V_{DC}$ car battery. The 2-MHz switching frequency allows users to avoid critical, noise-sensitive frequency bands. The 3-$V_{DC}$ to 42-$V_{DC}$ input voltage makes the LT8602 suitable for automotive applications, which must regulate through cold crank and start/stop scenarios with minimum 3-$V_{DC}$ input voltages and load dump transients more than 40 $V_{DC}$.

Figure 3 shows an alternative system block diagram with connectors, a reduced set of peripherals, and one ▷
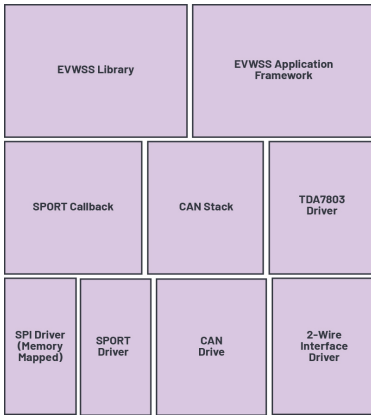
*Figure 4: EVWSS software architecture block diagram (Source: AD)*

automotive connector carrying all relevant signals. This configuration allows the design of a smaller form factor board and results in a reduced system cost because the ADSP-BF706 acts as a micro-controller and an audio processor.

The solution details can be seen in the demo manuals, which are provided by AD on request in the software download package.

## Blackfin solution software architecture

The EVWSS software architecture (see figure 4) is based on the ADSP-BF706 processor hardware architecture. The CAN interface reads directly from the flash memory using the memory mapped SPI. This reduces the complexity of the EVWSS library and makes the memory access efficient for warning sound generation.

The Sport callback feature maps to the audio data sample rate and runs in the Sport transceiver interrupt service routine (ISR) context, reading flash files, performing audio manipulation, and sending out modified audio on the Sport transceiver interface. The EVWSS library holds the different functions to synthesize the warning sound. It also receives the vehicle speed input from the CAN stack (or the UART interface for debugging). The TDA7803 driver controls the external power amplifier to generate the warning sound. The EVWSS application framework configures the system peripherals, the CAN stack, and the TDA7803 driver.

In this application, the base pitch (audio signal spectrum) of the WAV file is shifted depending on the vehicle speed input. The engine sound depends on the engine strokes (intake, compression, expansion, and exhaust). These strokes create frequency modulated tones instead of pure tones. Varying the pitch shift parameters allows to achieve frequency modulation. Two kinds of modulation are included in this application. In the sawtooth modulation, the frequency ramps from the lowest to the highest and then back to the lowest with a jump. In the triangular modulation, the frequency ramps from the lowest to the highest and then ramps back down to the lowest.

For audio mixing the various gains can be configured with respect to the vehicle speed. Although the required WAV files are present in the flash, the user can play or stop some of the WAV files, depending on the dynamic conditions.

## SigmaDSP-based solution

For entry-level applications, an ADAU1450 SigmaDSP processor can be used as an alternative to the ADSP-BF706.

ADAU1450 supports the Sigmastudio graphical programming environment for automotive applications. The software features include multiple tone generation, dynamic volume control with up to 64 ranges, sound mixing, limiter function, pitch shifting, and a simultaneous playback of up to five WAV files from the SPI flash memory. The Sigmastudio cannot support a CAN software stack i.e., an external micro-processor is required. Sigmastudio can be downloaded from the company's website.

## Conclusion

Analog Devices offers solutions for an entry-level system and for an advanced engine sound system that supports in-cabin engine sounds and external engine sounds. The solutions include the necessary software components for rapid prototyping and product development. ◄
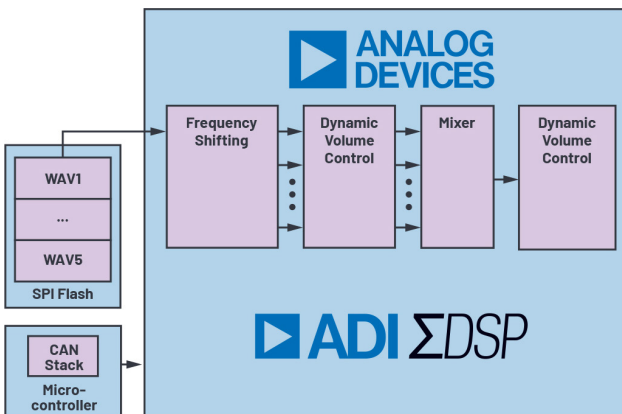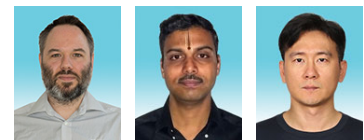


*Figure 5: Processing blocks on the SigmaDSP processor (Source: AD)*

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