Minimizing Noise and Power Consumption in Automotive Audio Systems with SigmaDSP

By Ben Wang

Today, more and more digital signal processors (DSPs) are deployed in automotive electrical systems to process audio signals digitally and provide the benefits of multimedia in vehicles. For example, car radio and CD systems can be supplanted by automotive multimedia systems, where DSPs, such as the ADAU1401 SigmaDSP® processor, are used to achieve outstanding audio performance and flexibility, while providing a more powerful multimedia experience for passengers. These DSPs also provide a useful tool for systems engineers, who are concerned with minimizing power consumption and decreasing the effects of system noise on the listening experience. This article introduces a new approach to minimizing noise and power consumption utilizing the SigmaDSP[1] processor and the SigmaStudio™ graphical development tool.[2]

The ADAU1401 complete single-chip audio system includes a fully programmable 28-/56-bit audio DSP, plus analog-to-digital and digital-to-analog converters, and microcontroller-like control interfaces. Signal processing provides equalization, bass enhancement, multiband dynamics, delay compensation, speaker compensation, and stereo image widening. This processing, comparable to that found in high-end studio equipment, can compensate for real-world limitations of speakers, amplifiers, and listening environments—thus providing dramatic improvements in perceived audio quality.

The easy to use SigmaStudio software allows the user to graphically configure a custom signal processing flow using blocks, such as biquad filters, dynamics processors, level controls, and GPIO interface controls.

Noise Floor

Unlike portable devices, automotive audio systems are equipped with high-power amplifiers; each speaker is capable of delivering up to 40 W or 50 W; each vehicle has at least four speakers. The noise floor can easily be amplified to a level that is perceptible by human ears in a quiet environment. For example, 1 mV rms of noise in a 4-Ω speaker can create a *sound-pressure level* (SPL) of about 24 dB (assuming speaker sensitivity is of the order of 90 dB/W)—a level perceptible by human ears in a quiet environment. There are many possible sources of noise. As shown in Figure 1, among the major noise sources are power-supply noise, (V_G), filter/buffer noise, (V_F), and noise created by improper power ground layout, V_E. V_O is the audio signal from the processor, and V_{IN} is the audio signal input to a speaker's power amplifier.

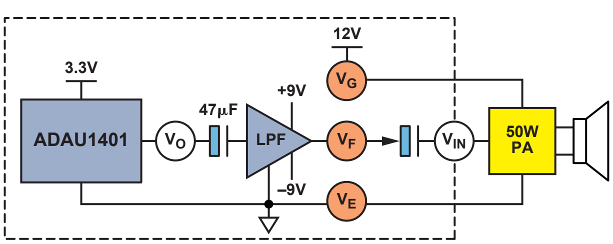

Figure 1. Example of noise sources in an automotive audio system.

Pop Noise During Power On/Off: Automotive audio power amplifiers operate on a single 12-V supply, while DSPs require a lower-voltage supply (for example, 3.3 V), and the filter/buffer operates with a split power supply (for example, ±9 V). Coupling capacitors are required to provide isolation between portions of the circuit operating at these different supply voltages and their differing grounds. During power on/off, capacitors will charge/discharge very quickly, creating a pulse that propagates down the chain, ultimately resulting in pop noise in the speaker. Figure 2 illustrates this process.

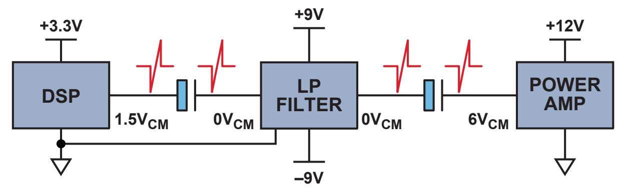

Figure 2. The concept of how pop noise is created in the speaker.

Although the sources of the noise floor and the pop noise are known, and despite efforts to minimize noise at the source through good circuit design and layout techniques—and selection of better devices with lower noise—many uncertainties may appear during design. Designers of automotive multimedia systems must deal with many complex issues, so they must possess a high level of analog/mixed-signal design skill. Even so, the prototype may not perform as originally expected; for example, a noise level of 1 mV rms poses a big challenge. As for pop noise, existing solutions use an MCU to control sequencing of the power amplifier during power on/off, but layout and electromagnetic interference (EMI) are potential problems when the central processor is distant from the power amplifier.

Power Consumption

As more electronics are included in the vehicle, power consumption becomes a bigger challenge. For example, if the audio power amplifier draws quiescent current of up to 200 mA, the power consumption is as much as 2.4 W with a 12-V supply. During times when no sound is required from the speakers, this significant amount of power could be saved if there were a way to detect absence of input signal and shut down the power amplifier without involving a remote processor.

Minimize Noise and Power Consumption of Auto Audio Systems

SigmaDSP technology offers an opportunity to minimize noise, while also saving a significant amount of power, without adding to the hardware cost. Figure 3 is a block diagram of a 4-speaker automotive audio system using an ADAU1401 SigmaDSP processor as the audio post-processor. Besides sampling, converting, digitally processing the audio signal, and generating the additional speaker channels, the SigmaDSP processor has a general-purpose input/output (GPIO) pin that is useful for external control. The microcontroller (MCU) communicates with the SigmaDSP processor via the I^{2}C interface, and the analog outputs drive a low-pass filter/buffer stage employing the ADA4075-2 precision op amp.

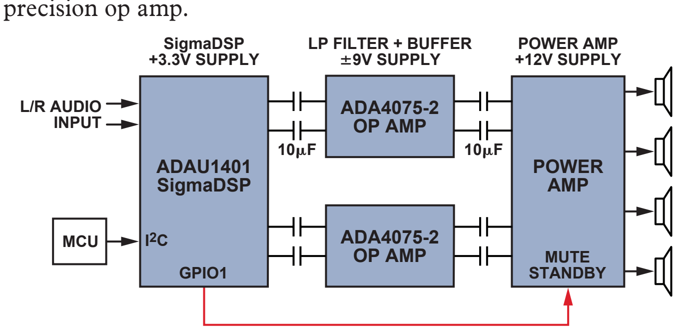

Figure 3. Automotive audio system with four speakers.

The red line between the SigmaDSP processor and the power amplifier controls the mute/standby pin of the power amplifier. In normal default operation, the open-collector GPIO1 pin is set high via a 10-kΩ pull-up resistor. The ADAU1401 has an rms signal detection function, which can be used to determine whether or not there is an input signal. With no input signal, GPIO1 goes low, putting the power amplifier in mute/standby mode, resulting in no amplifier output noise from the speaker, as well as low standby power consumption. When an input signal greater than a predetermined threshold (–45 dB, for example) is detected, GPIO1 goes high, allowing the power amplifier to work normally; the noise floor still exists, but the high signal-to-noise ratio (SNR) masks it, making it imperceptible to human ears.

During power on/off, the SigmaDSP processor, rather than the MCU, has direct control of the *mute/standby* of the power amplifier, but it responds to the MCU. For example, during power on, the I^2C signal from the MCU sets the SigmaDSP processor's GPIO1, keeping it low (mute) until the predetermined capacitor charging process is completed; then the MCU sets the GPIO1 high, thus eliminating pop noise due to start-up transients. On power off, the GPIO is immediately set low, putting the power amplifier in mute/standby, eliminating power off pop noise. By putting the power amplifier under direct control of the SigmaDSP processor, rather than the MCU, layout and EMI control are easier to implement because the SigmaDSP processor is located closer to the power amplifier.

As mentioned earlier, the rms signal level can be determined using a SigmaStudio software algorithm. Using the SigmaStudio graphical development tool, it is easy to set up the rms computation and use it to control the GPIO state, as shown in the example of Figure 4.

RMS detection is achieved by using rms cells and logic cells. The signal threshold includes hysteresis to eliminate chatter of the mute function in response to small changes; for example, the RMS1 threshold is set to –45 dB, and RMS2 is set to –69 dB. When the input signal is greater than –45 dB, GPIO1 is high; when the input signal is less than –69 dB, GPIO1 is low; when the input signal is between the two thresholds, the GPIO1 output signal remains at its previously acquired state (see Figure 5).

Figure 4 also includes compression to further reduce output noise; for example, when the input signal is less than –75 dB, the output signal to the speaker system will be attenuated to –100 dB, thus reducing the noise floor accordingly.

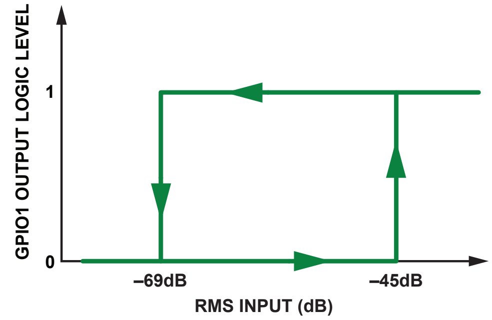

Figure 5. RMS threshold settings and the relationship between input and output.

Summary

Noise and power consumption present great challenges in automotive audio systems. ADI SigmaDSP processors, already widely used in automotive applications for digital audio post-processing, can be easily used to further advantage by employing their rms detection and GPIO control capabilities to minimize noise and reduce power consumption significantly. The SigmaStudio graphical development tool eases the design work by allowing functions to be set up graphically without any need for code writing. Furthermore, since the power amplifier module is physically much closer to the SigmaDSP processor than to the MCU, the use of the SigmaDSP processor to control the mute function makes layout work easier and improves EMI immunity.

References

(*Information on all ADI components can be found at www.analog.com.*)

[1] www.analog.com/en/embedded-processing-dsp/sigmadsp/processors/index.html.

[2] www.analog.com/en/embedded-processing-dsp/sigmadsp/processors/CU_over_SigmaStudio_graphical_dev_tool_overview/fca.html.

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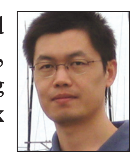

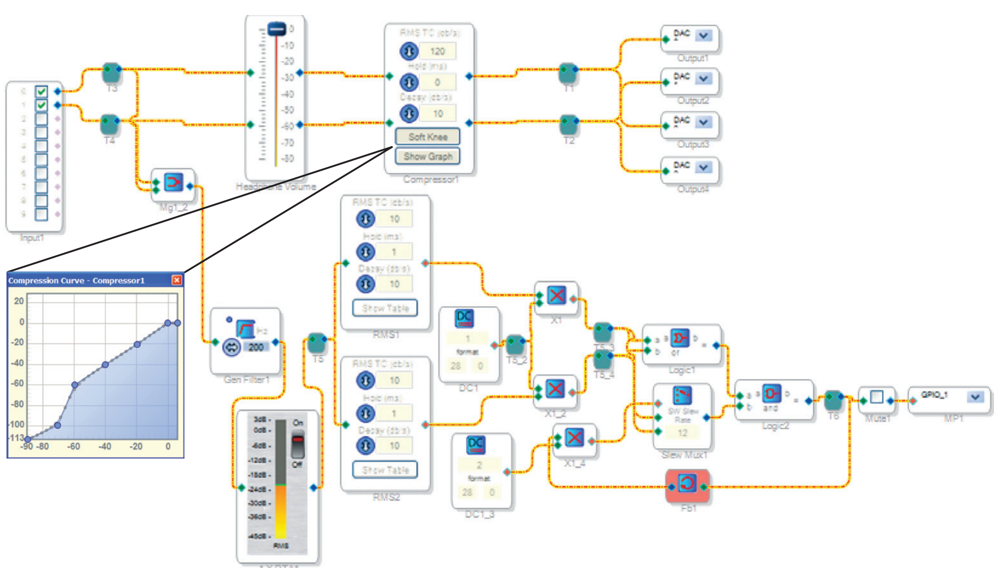

Figure 4. SigmaStudio schematic for rms detection, GPIO control, and compression.