Electronic Design

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Creating the Immersive Automotive Audio Experience

Sponsored by Texas Instruments: As components such as Class-D audio amps, processors, and microcontrollers become more advanced and integrated, car audio will continue to soar to new heights.

From car audio's fledgling beginnings in the 1930s as a simple AM in-dash noise source to today's fully immersive, multi-speaker, hundreds (even thousands) of watt theater-like environment, it's been a remarkable journey.

Early high-end automotive audio was a niche market driven by a handful of audiophiles seeking to bring a much better sound experience to the wheeled environment. Eventually, as audio technology advanced, the niche audio market quickly adopted it. Today, nearly entry-level vehicles boast some form of premium audio environment.

However, the journey was not without its challenges. As system power ramped up, audio amplifier footprints became unwieldy. Class AB amplifiers demanded obscene amounts of vehicle power and increasingly larger heat-management solutions. So, designers started looking for new directions that would reel in the power monster, especially for electric vehicles, where every watt is precious.

Some components, such as RF front ends and preamps, are highly integrated and have relatively small footprints and power requirements. They don't particularly challenge space or power constraints. However, high-power Class AB audio amplifiers do. They're relatively inefficient devices and the largest audio system components (other than speakers) are the primary challenge to more efficient audio system designs.

A second challenge is the cabin environment. Along with these high-power systems came a mandate to improve the cabin with better acoustic properties.

Applying physical acoustic solutions had its limitations. Physical materials only add weight and take up space, which is impractical. Therefore, designers again looked to technology for solutions.

And they found them in the way of Class-D amplifiers and highly integrated microcontrollers. Let's drill down a bit on how designers evolved car audio into today's immersive systems.

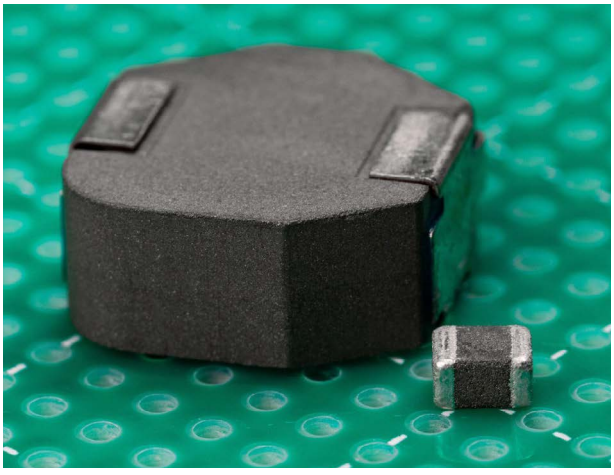
First and Foremost, the Audio Amplifier

The staple, for many years, was the Class-AB audio amplifier. Its analog output design allows the device to connect directly to speakers with nothing in the circuit except maybe a capacitor. However, as power demands ramped up, Class AB became unwieldy. The cooling and supply power requirements for high-wattage systems made for a large footprint that required robust heat management, i.e., large heatsinks, good ventilation, and lots of available power–all precious commodities in many wheeled environments.

Designers decided to replace the well-entrenched, moderately efficient (typically 50% to 70%), Class-AB circuitry with Class-D circuitry. Class D was an ideal solution. It's a switching platform and much more efficient (over 90%). Class D's efficiency meant the amplifier uses less power and generates less heat, resulting in a smaller, less power-hungry footprint.

There was, however, a gotcha (of course). While Class-D circuits have overcome early sound-quality issues, their digital signal can't be connected directly to speakers. Moreover, the signal contains an unacceptable amount of ripple. That meant additional components were required between the output of the amplifier and the speakers. A simple, cost-effective solution was to couple the speakers via an L/C filter. This filter provides the proper output signal and filtering.

However, the high power output from the amplifier made the L/C components large, particularly the series inductor. And each audio channel requires two inductors. A better so-



1. Eliminating one inductor and redesigning the remaining inductor led to this more compact Class-D amplifier.

lution was needed.

The design came in the form of a new Class-D audio amplifier with a slower switching speed (2.1 MHz) and proprietary single inductor (1L) modulation technology. By eliminating one inductor and redesigning the remaining inductor, this innovative design allows for the use of a smaller, more cost-effective circuit *(Fig. 1)*. This met the high power demands of premium audio, optimizing space and cost.

Managing the Cabin

Designers next addressed the cabin environment. As was previously mentioned, adding physical medium for acoustic environment management wasn't an acceptable solution. There was little space for such material, and it simply added more weight.

Therefore, the only option was to compensate for the environment with technology. This came in the form of state-of-the art, highly integrated, automotive processors such as the AM62D-Q1 processor and AM275x-Q1 microcontrollers (MCUs).

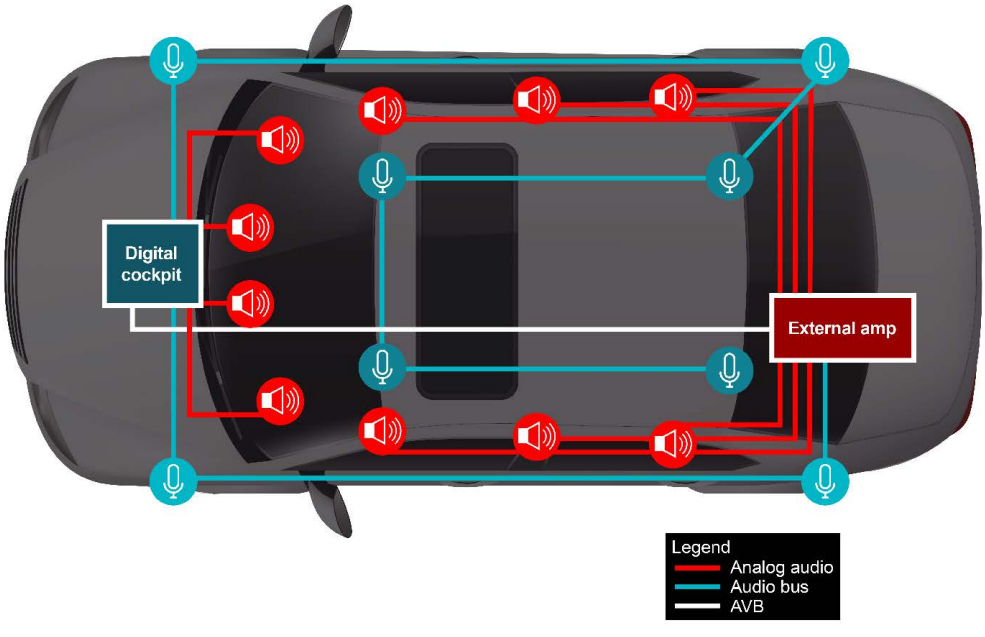
Microcontrollers have been used in high-end audio systems for some time. Typical designs employed multiple ICs, MCUs, and digital processors (DSPs) spread across multiple transducers and microphones *(Fig. 2)*. While achieving the desired results, this resulted in increased system complexity, footprint, and costs.

To address this distributed architecture, designers turned to next-generation MCUs enhanced with both traditional and AI-based algorithms. These designs, coupled with high-performance audio amplifier ICs (TAS6754-Q1) and power-management ICs (TPS65224-Q1) achieve the goal of reducing cost and complexity *(Fig. 3)*.

Such single-chip architectures significantly streamline audio system design by consolidating multiple high-end audio features into a single integrated circuit. This innovation reduces the reliance on multiple chip components, which both complicate manufacturing and increase costs. Single-chip solutions enhance performance, minimize power consumption, and simplify the overall system architecture.

Real-World Visibility

Implementing the system design with these integrated components not only makes it simpler, it also offers a number of features and enhancements across vehicle perfor-



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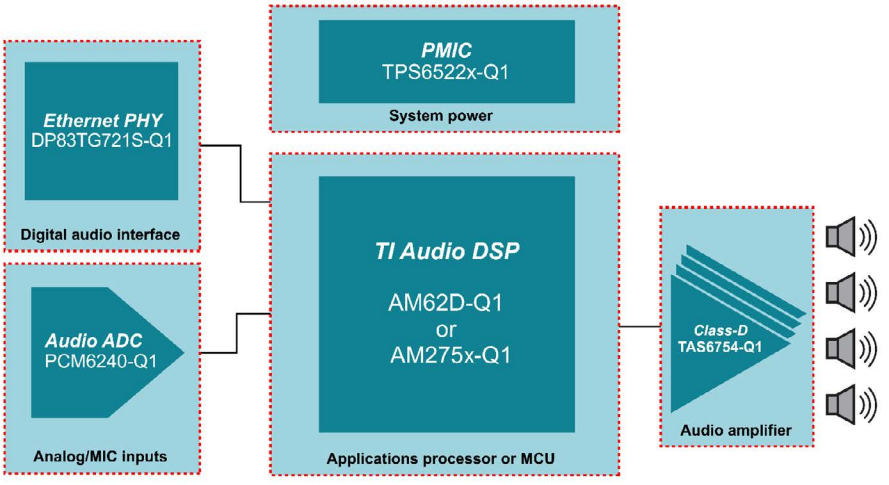

3. Developing an advanced distributed architecture generally involves incorporation of next-generation MCUs enhanced with both traditional and AI-based algorithms plus high-performance audio amplifier ICs (TAS6754-Q1) and power-management ICs (TPS65224-Q1).

mance and functionality.

First, it can improve safety. Such AI-based systems are capable of analyzing the vehicle's environment, both inside and outside. External speakers can alert pedestrians that a vehicle is nearby. And, especially for electric vehicles, they emulate engine sounds inside the cabin.

Another capability is the system can tailor where sounds emanate from, such as reducing external speakers and routing sound to a headrest behind the driver for a phone call.

Scalability is another benefit. Integrated systems make it much simpler to add features or upgrades. There's only one central component to deal with.

Conclusion

As components become more advanced and integrated, car audio will continue to soar to new heights. Vehicles are already integrated with communications, wireless networks, the transportation infrastructure, satellites, and more. The vehicle audio will become more immersive, while monitoring the environment, inside and out and offering a cabin audio environment intimately connected across many different elements.