Diagnostics and Protections in Automotive Audio Systems

Jayson Johnston

In automotive audio systems, a reliable audio amplifier has a large impact on system performance. That is why TI's Class-D automotive amplifiers have integrated protections and diagnostics, which ensure amplifier and system reliability. To differentiate the two, protections typically refer to features which actively step-in during fault conditions, while diagnostics are used to search for fault conditions.

Protection

Traditional protection features almost always cause the amplifier to shut down. TI has made several advancements that allow the amplifier to remain active during manageable fault conditions. One example of enhanced protections is Cycle-by-Cycle Current Control, or CBC. CBC is activated in overcurrent situations when the current limit threshold is met. As shown in Figure 1, the current output is actively limited by reducing the duty cycle of the output PWM over several switching cycles, which protects the amplifier from overcurrent damage.

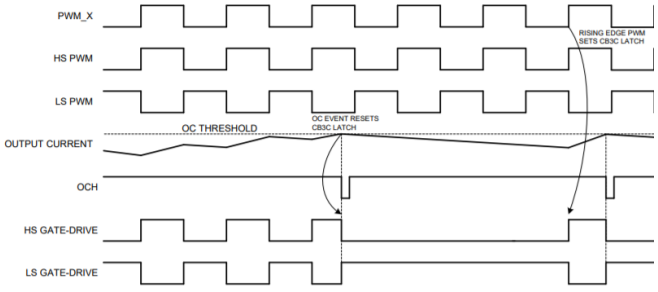

Figure 1. CBC Timing Diagram for Automotive Class-D Audio Amps

Overtemperature protection traditionally uses a single "global" temperature sensor near the center of the amplifier. When the global sensor measures the temperature as exceeding a set warning threshold, then a global temperature warning signal is activated. If the temperature continues to rise until it reaches the global overtemperature shutdown threshold, then the amplifier will automatically shut down, and audio playback for all four channels ceases. Overtemperature warning and protection measures can be further enhanced by allowing for thermal monitoring on a "per channel" basis. Overtemperature monitoring and protection on a per channel basis features additional temperature sensors at the output of each channel, where more localized temperature events may occur (such as an event where there is a shorted load on a single output). Temperature warning and protection measures for each channel operate in the same manner as the global warning and protection measures, but the primary difference is that a single channel can be shut down and audio can continue playback via the remaining channels.

New 2-MHz automotive Class-D audio amplifiers like TI's TPA6304-Q1 are able to protect themselves from excessive temperatures by limiting the gain to reduce output power. This is triggered by either the global or per channel temperature threshold being exceeded. The attack and release time, which corresponds to the rate of change in the gain, are programmable. This allows for the engineer to choose their level of aggressiveness in limiting gain and thermal exposure. The attack and release times are selectable from 100 ms to 1600 ms, and the maximum attenuation is 12 dB.

DC offset protection in TI's Class-D automotive amps is also implemented independently per channel.

Undervoltage and overvoltage protections are, of course, implemented and improved. TI has revolutionized this feature with industry-leading operating range for Class-D amplifiers. TI's automotive Class-D amplifiers like the new TPA6304-Q1 operate down to 4.5 V, as opposed to competitors which require 5 V to 6 V. Low operating voltage is very important in automotive applications, as audio is required in start/stop conditions for information, in the form of chimes originating from the cluster.

Another protection important to the automotive industry is load dump protection. TI's automotive Class-D amplifiers all feature load dump protection up to 40 V.

While clipping is sometimes desired when recording music, audio engineers typically try to minimize clipping in the audio amplifier. Warnings for clipping and overtemperature are provided via the external $\overline{\text{WARN}}$ pin, and through the I^2C bus.

Diagnostics

Diagnostics can be split into two subsections: DC and AC diagnostics. TI offers fully integrated diagnostic abilities in automotive Class-D amplifiers.

DC diagnostics function by sending a low-current DC signal to test for fault conditions. These conditions are:

- Short to supply
- Short to ground
- Short across load

- Open load

This prevents the amp from delivering full power to a faulty load, which protects the amplifier and speaker from damage. The load resistance can also be measured in this manner.

Some speaker configurations use a passive crossover network to separate the high- and low-frequency components of a signal, allowing for a woofer and tweeter to be connected on the same channel. This is opposed to connecting the woofer and tweeter on two separate channels. Figure 2 illustrates a simplified passive crossover network. The coupling capacitor between the tweeter and amplifier blocks DC signals, so an AC signal must be used instead. This is called AC diagnostics. Using AC diagnostics allows for speaker detection in a passive crossover and impedance measurement.

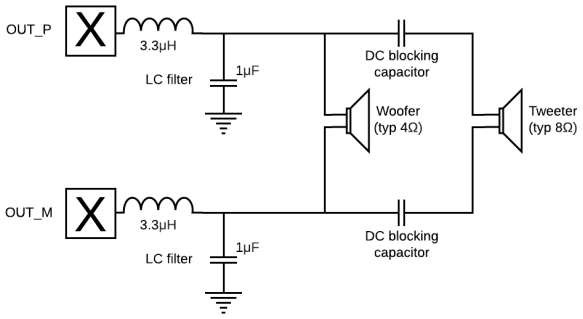

Figure 2. Simplified Passive Crossover Network

An internal signal generator can be found in devices like TI's new 2-MHz audio amplifier, TPA6304-Q1. This internal signal generator provides the AC signal for diagnostics. The signal can range from 1 kHz to 20 kHz, and is selectable via I^2C.

Diagnostics are typically required during manufacturing for test and validation purposes. Diagnostics results are available via I^2C for quick validation. TI also offers a powerful audio design tool, PurePath™ Console, which makes evaluation easy by providing a simple, and easily understandable, GUI. Figure 3 shows the interface and results of the AC diagnostics test used to detect a properly connected load.

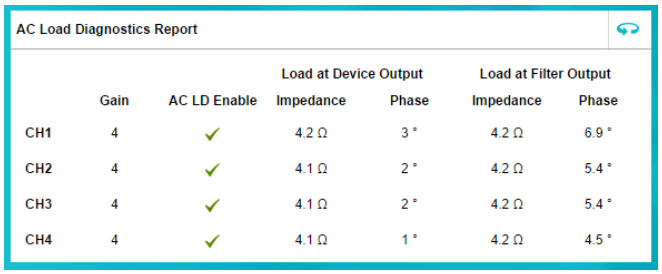

Figure 3. PurePath™Console Diagnostic Interface

As automobiles become more connected, more data is being sent over the air (OTA) to manufacturers. Load diagnostics, both AC and DC, let auto OEMs understand what is happening to speakers on the road through OTA data, and can notify the driver of issues that require attention. For example, virtual engine sound systems (VESS) and telematics applications are improved when speaker connectivity is monitored, due to the potentially lifesaving nature of the feature. Diagnostics can be used to test for a connected load by initiating the test via I^2C when audio is not in use. The impedance and phase measurement can then be transmitted OTA for OEMs to characterize speakers over a product lifetime. Results are also valuable to alert drivers of any problems. This is just one way diagnostics can be used to improve system reliability and safety on the road.

Table 1 below lists the newest automotive audio amplifiers which feature integrated diagnostic and protection features outlined in this note.

Resources

- Texas Instruments, *DC and AC Load Diagnostics Using 75-W TAS6424-Q1 Class-D Audio Amplifier*
- Texas Instruments, *Instrument clusters: moving beyond chimes and dings*
- *PurePath™Console graphical development suite for audio system design and development*

Table 1. Automotive Audio Amplifiers With Load Diagnostics and Protections

DEVICE	INPUT TYPE	CHANNELS	OPERATING RANGE (V)	CURRENT LIMIT (A)
TAS6421-Q1	Digital	1	4.5 V to 26.4 V	6.5 A
TAS6422-Q1	Digital	2	4.5 V to 26.4 V	6.5 A
TAS6424-Q1	Digital	4	4.5 V to 26.4 V	6.5 A
TAS6424M-Q1	Digital	4	4.5 V to 18 V	6.5 A
TAS6424L-Q1	Digital	4	4.5 V to 18 V	4.8 A
TPA6404-Q1	Analog	4	4.5 V to 18 V	6.5 A
TPA6304-Q1	Analog	4	4.5 v to 18 V	6.5 A

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265