Diagnostics and Protections in Automotive Audio Systems

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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](image)

Another form of enhanced protection is TI’s overtemperature protection by channel. Overtemperature protection traditionally uses a single temperature sensor near the center of the device. When the sensors measure the temp as exceeding the threshold, the entire amplifier shuts down, and audio playback ceases. Overtemperature protection by channel features sensors at the output of each channel, where more localized temperature events may occur. Overtemperature at a single output causes just that channel to shut down, which allows for playback to continue via other channels.

DC offset protection in TI’s Class-D automotive amps is also implemented independently by 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 amps like the TAS6424-Q1 family 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 amplifier family 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 WARN pin, and through the I2C 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.
Diagnostics are typically required during manufacturing for test and validation purposes. Diagnostics results are available via I²C 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.

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 I²C 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

<table>
<thead>
<tr>
<th>DEVICE</th>
<th>INPUT TYPE</th>
<th>CHANNELS</th>
<th>OPERATING RANGE (V)</th>
<th>CURRENT LIMIT (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAS6421-Q1</td>
<td>Digital</td>
<td>1</td>
<td>4.5 V to 26.4 V</td>
<td>6.5 A</td>
</tr>
<tr>
<td>TAS6422-Q1</td>
<td>Digital</td>
<td>2</td>
<td>4.5 V to 26.4 V</td>
<td>6.5 A</td>
</tr>
<tr>
<td>TAS6424-Q1</td>
<td>Digital</td>
<td>4</td>
<td>4.5 V to 26.4 V</td>
<td>6.5 A</td>
</tr>
<tr>
<td>TAS6424M-Q1</td>
<td>Digital</td>
<td>4</td>
<td>4.5 V to 18 V</td>
<td>6.5 A</td>
</tr>
<tr>
<td>TAS6424L-Q1</td>
<td>Digital</td>
<td>4</td>
<td>4.5 V to 18 V</td>
<td>4.8 A</td>
</tr>
<tr>
<td>TPA6404-Q1</td>
<td>Analog</td>
<td>4</td>
<td>4.5 V to 18 V</td>
<td>6.5 A</td>
</tr>
</tbody>
</table>
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