Application Note

Common Problems and Solutions for TAS6424E-Q1 AC Diagnostics

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ABSTRACT

This document was translated from a simplified Chinese source. (ZHCAG73)

The TAS6424E-Q1 is a four-channel high-performance digital-input Class-D audio power amplifier specifically designed by Texas Instruments for automotive audio applications, fully complying with the AEC-Q100 automotive grade standard. Operating within a voltage range of 4.5V to 26.4V, the chip can withstand voltage fluctuations in automotive electrical systems. It integrates an I²S/TDM digital audio interface, supporting sampling rates up to 192kHz, and enables flexible parameter configuration and control via an I²C interface. The AC Load Diagnostics function injects an inaudible high-frequency signal during audio playback to detect the speaker load status—such as open circuit, short circuit, or abnormal impedance—in real time. This achieves non-intrusive, highly reliable fault diagnosis, significantly improving the safety and maintainability of automotive audio systems. This paper primarily reviews and explains the principles, common issues, and solutions related to AC diagnostics. It aims to help developers analyze problems more rapidly and design more optimized power amplifier systems.

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1 Principles of AC Diagnostics

1.1 What is AC Diagnostics

The AC Load Diagnostics function injects an inaudible high-frequency signal during audio playback to detect the speaker load status, such as open circuit, short circuit, or abnormal impedance. This achieves non-intrusive, highly reliable fault diagnosis, significantly improving the safety and maintainability of automotive audio systems. Specifically, AC diagnostics is used to identify whether the tweeter is correctly connected. It achieves this by measuring the impedance and phase shift between the OUTP and OUTN pins. The TAS6424 series amplifiers require an external sine wave as an excitation signal to perform AC measurements, and the impedance and phase shift values can be obtained from the relevant registers. Users must evaluate whether the measured values indicate that the loudspeaker is properly connected.

1.2 Implementation Principle of AC Diagnostics

When the TAS6424 series performs AC diagnostics, the chip enters AC test mode through internal switch configurations (S1 open, S2 and S3 closed), as shown in Figure 1-1 below. Before the test begins, a 19kHz, 0dBFS sine wave must be input as a reference to drive the internal DAC to generate a current signal. After the signal is transmitted and goes through a 20ms stabilization period, the internal 10-bit ADC samples 64 cycles of the output signal. The sampling results are processed by the internal algorithm and automatically stored in the I2C registers for developers to read.

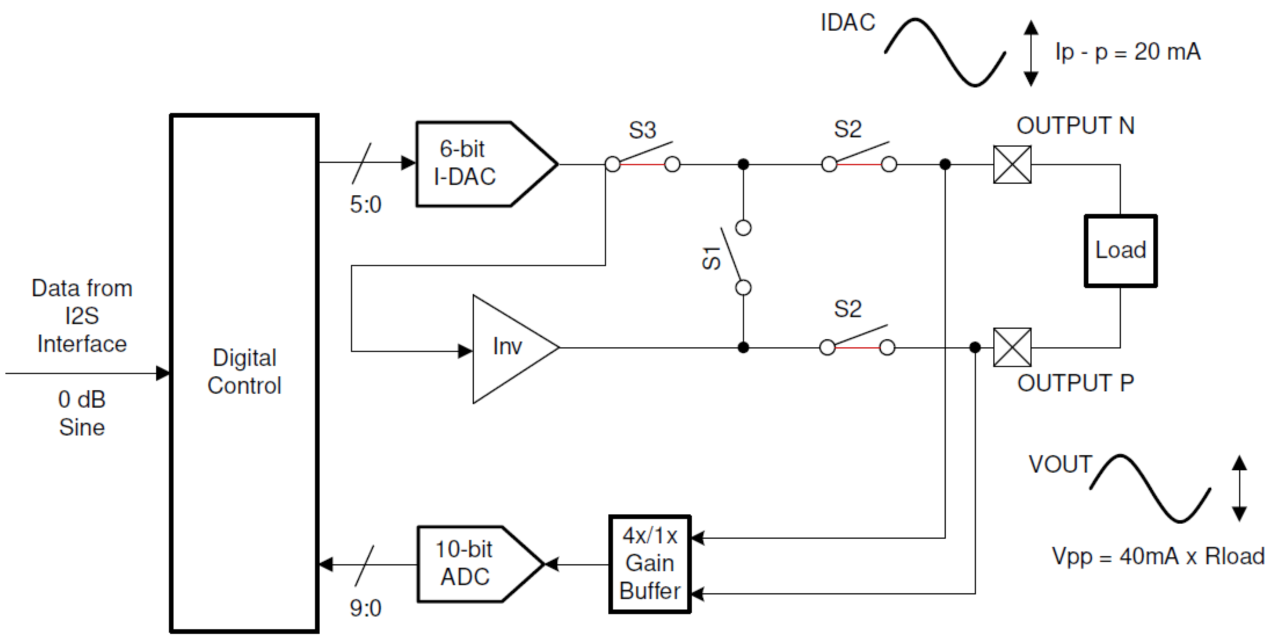

Figure 1-1. Schematic Diagram of AC Diagnostic Principles

2 AC Diagnostic Flow

2.1 Review of the AC Diagnostic Flow

The AC diagnostic workflow is divided into four key stages: first is the pre-preparation, ensuring all channels are in the Hi-Z state and inputting a 19kHz, 0-dBFS sine wave; next is the phase reference calibration, which measures the inherent system error by enabling the internal loopback (0x16 Bit 7); then comes the actual load measurement, where the loopback must be disabled to connect the external loudspeaker, and the chip performs a 32/64-point sampling of the output current (plugging or unplugging the load at this moment will directly cause fluctuations in the sampled current and a spike in the impedance value); finally, during the data reading and calculation stage, the raw data for phase, excitation strength, and impedance are retrieved from the I2C registers and applied to the datasheet formulas to complete the analysis before exiting the diagnostic mode.

Impedance Formula (Impedance):

$$Impedance_{CHx(ohm)} = \frac{(IMP_{CHx}*2.37(mV))}{(Gain*Idac(mA))} \tag{1}$$

Phase Formula (Phase):

$$Phase_{CHx(degree)} = 360*\frac{PHASE_{CHx(LBK)} - PHASE_{CHx(LDM)}}{STI_{CHx(LDM)}} \tag{2}$$

2.2 AC Diagnostics Reference Code

Taking Channel 1 as an example, the reference code is as follows:

```
w d4 04 55     Set ch to Hiz mode
w d4 16 80      Step 1: configure to loop back mode
w d4 15 08      Enable ch1 loop back test
r d4 0f 01              Read 0x0f register, and wait until it go to Hiz mode
r d4 1b 01              Read phase value
r d4 1c 01
w d4 15 00      Disable AC diag
w d4 16 00      Disable loop back test mode
w d4 15 08      Enable ch1 load impedance and phase test
r d4 0f 01              Read 0x0f register, and wait until it go to Hiz mode
r d4 1b 01              Read phase value
r d4 1c 01
r d4 1d 01              Read stimulus value
r d4 1e 01
r d4 17 01              Read impedance value
        w d4 15 00      disable AC diag
```

3 Common Issues and Debugging Strategies in AC Diagnostics

After mastering the basic principles of TAS6424E-Q1 AC diagnostics, debugging details in practical applications often determine system stability. The following sections provide an in-depth analysis of several typical issues and optimization strategies most frequently encountered by engineers during the AC load diagnostics process with this chip.

3.1 Inaccuracy in AC Diagnostics Caused by Excitation Signals

When conducting AC diagnostics, the TAS6424E-Q1 must receive a stable 19kHz, 0dBFS sine wave signal as the excitation source. If the signal frequency output by the front-end DSP or host SoC deviates, or contains excessive harmonic noise, it will directly prevent the chip's internal algorithm from properly locking onto the impedance characteristics. Users must ensure that the 19kHz signal provided by the SoC/DSP is input to the TAS6424E-Q1 via the I2S/TDM interface. The amplitude of the 19kHz excitation signal must be controlled within a reasonable range. If the signal is too weak, the impedance calculation may fluctuate significantly due to an insufficient signal-to-noise ratio (SNR); if the signal is too strong, it may cause output clipping, rendering the diagnostic logic invalid.

It must be ensured that the excitation source frequency is precise and the amplitude is strictly aligned to 0dBFS, while matching the I2S/TDM timing (such as Offset settings) to eliminate digital distortion induced by bit shifts, thereby guaranteeing signal integrity at the source.

Solution: During the initial stage of TAS6424E-Q1 AC diagnostic debugging, it is highly recommended to use a 4.0ohm non-inductive cement resistor (or a precision power resistor) instead of a real loudspeaker for calibration. This is a critical step to ensure the accuracy of the diagnostic algorithm. By accurately verifying the conversion factor between the chip's readback values and the actual ohmic values, developers can adjust the signal frequency and amplitude provided by the DSP, thereby locking in system-level gain accuracy. The correct test results are shown in the table below:

	Load cases	**DC load diag**	**AC load diag**		
			Measured impedance	Measured phase in deg	**Load impedance(ohm)**
TI bench result (for customer reference)	Open load	**Open**	17.5	-82	**110**
	4ohm resistor load	**Normal**	4.3	4	**4.3**
	Woofer only (tweeter open)	**Normal**	19.9	-75	**56.8**
	Tweeter only (woofer open)	**Open**	5	0	**5.1**
	Woofer + tweeter	**Normal**	5	7	**4.8**
	Woofer + tweeter short	**Normal**	0.9	0	**1.3**

Table1_TI AC Diagnostic Test Results (19kHz sine wave signal, 0dBFS as the excitation source)

3.2 Measurement Errors Caused by Unstable Connectors

During the AC diagnostic process, particularly in environments like automotive production lines, poor contact in the loudspeaker connectors or improper wire harness crimping will cause deviations in AC diagnostics. The reason is that AC diagnostics performs 32 or 64-point sampling on the external impedance. Such unstable connections introduce additional contact resistance, which is captured across the 64 samples and incorporated during the averaging calculation. For a precision chip like the TAS6424E-Q1 that calculates impedance by sensing minute current signals, this can lead to significantly larger readback AC impedance values.

Using the TAS6424E-Q1 EVM development board for simulation testing, the 4.0ohm standard load connector was rapidly plugged and unplugged manually while initiating AC diagnostics. By artificially creating unstable instantaneous contact resistance to interfere with the chip's 32/64-point current sampling, the abnormal result where the readback impedance was much higher than the nominal 4.0ohm was successfully reproduced, verifying the direct impact of poor connections on the accuracy of precision AC diagnostics.

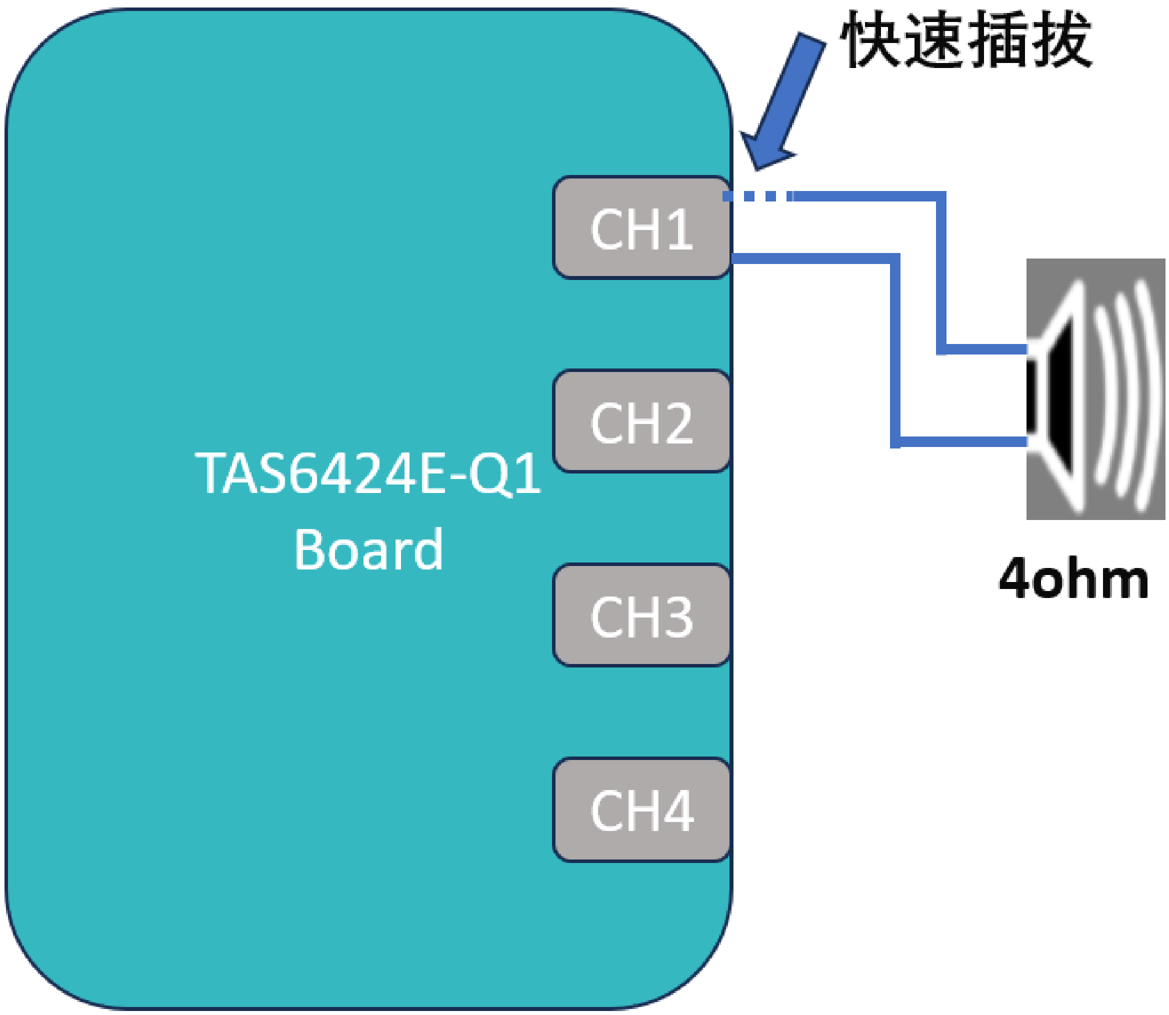

Figure 3-1. TAS6424E-Q1 Manual Testing Rapid Plug and Unplug Diagram

AC Load Diagnostics Report

			Load at Device Output		Load at Filter Output	
	Gain	AC LD Enable	Impedance	Phase	Impedance	Phase
CH1	1	✓	4.3 Ω	7 °	4.2 Ω	11.0 °
CH2	1	✗	0.0 Ω	-	-	-
CH3	1	✗	0.0 Ω	-	-	-
CH4	1	✗	0.0 Ω	-	-	-

Figure 3-2. Channel 1 Normal 4ohm Resistor AC Diagnostic Results

AC Load Diagnostics Report

	Gain	AC LD Enable	Load at Device Output Impedance	Load at Device Output Phase	Load at Filter Output Impedance	Load at Filter Output Phase
CH1	1	✓	17.5 Ω	-81 °	100.8 Ω	34.3 °
CH2	1	✗	0.0 Ω	-	-	-
CH3	1	✗	0.0 Ω	-	-	-
CH4	1	✗	0.0 Ω	-	-	-

Figure 3-3. Channel 1 Open Circuit AC Diagnostic Results

AC Load Diagnostics Report

	Gain	AC LD Enable	Load at Device Output Impedance	Load at Device Output Phase	Load at Filter Output Impedance	Load at Filter Output Phase
CH1	1	✓	16.8 Ω	-13 °	14.0 Ω	37.7 °
CH2	1	✗	0.0 Ω	-	-	-
CH3	1	✗	0.0 Ω	-	-	-
CH4	1	✗	0.0 Ω	-	-	-

Figure 3-4. Channel 1 Rapidly Plugged and Unplugged Connector AC Diagnostic Results

Figure 3-1 shows the test method; for a normal 4.0ohm resistor as Figure 3-2, Channel 1 can measure an impedance of 4.2ohm; when Figure 3-3 is open circuit, Channel 1 will read an impedance greater than 70.0ohm;

Figure 3-4 shows the results obtained when rapidly plugging and unplugging the Channel 1 connector during testing. It can be seen that Channel 1 originally read 4.0ohm, but during rapid plugging and unplugging, the impedance reached 14.0ohm. Different plug/unplug frequencies have a probability of yielding different values, but the AC diagnostic results are all greater than the actually measured impedance value.

It should be noted that this is not a defect of the chip; rather, it is precisely because of AC diagnostics that developers are able to identify issues such as poor connector contact.

3.3 TAS6424E-Q1 Status Register Abnormality

Some users do not execute AC diagnostics only during power-on initialization, but rather run AC diagnostics when the system detects no sound or encounters other anomalies during operation. At this time, the initial state of all channels is not Hi-Z, but Play mode. Since the mode switching of the TAS6424E-Q1 requires a certain amount of time, to ensure the normal operation of AC diagnostics, it is recommended to wait for 10ms after setting the channels to Hi-Z, and confirm that the mode has switched to Hi-Z via status register readback before starting the AC diagnostic flow. For the device, the precondition for the AC diagnostic flow is that all channels must be in the Hi-Z state.

Without state verification, the device might enter the AC diagnostic flow while in Play mode or DC diagnostic mode, causing the device to enter an error state and the AC diagnostic flow to fail. In some scenarios, the system may even erroneously identify the channel status as DC diagnostic mode, as shown in Figure 3-5.

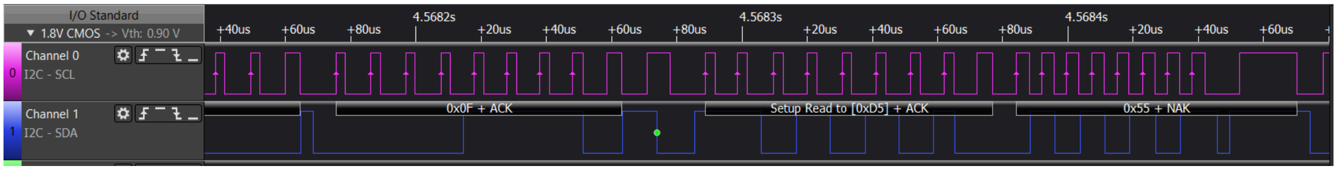

Figure 3-5. System Reads DC Diagnostic Status

3.4 TAS6424E-Q1 AC Diagnostic Debugging Flow

If abnormalities are found in the read values by following the operations in Chapter 2, the conventional debugging methodology is outlined below to help developers quickly locate the problem:

1. Signal Source Verification

   Set the channels to Play state, and first verify whether the 19kHz, 0dBFS sine wave excitation signal is accurate, strictly checking the consistency of its frequency and amplitude. After the excitation check is complete, ensure that the signal continues to be input throughout the entire AC diagnostic period.
2. Standard Load Calibration

   Remove the actual loudspeaker load and connect a high-precision 4.0ohm power resistor for calibration to eliminate interference caused by the speaker's inductive characteristics or frequency response, thereby validating the underlying measurement accuracy of the system.
3. Register Data Verification

   Read the raw register values of channels such as CH1, and fill them into the official companion calculation spreadsheet (such as the yellow highlighted area). The built-in algorithm within the spreadsheet (such as the green area) will automatically calculate the impedance value, allowing a comparison between the calculated result and the deviation of the 4.0ohm standard load.
4. Algorithm Logic Check

   If there is still a discrepancy between the calculated value and the actual value, check whether the register reading sequence is correct, and contact TI to confirm whether the coefficients in the calculation formula match the current hardware platform.

4 Conclusion

This paper provides an in-depth analysis of the AC diagnostic function of the TAS6424E-Q1, spanning from the 19kHz signal injection principle to the standard AC diagnostic workflow. It meticulously reviews the critical elements required to ensure accurate impedance and phase measurements, and provides troubleshooting insights and methodologies for common issues such as signal distortion, unstable connections, and state transitions, aiming to help developers build highly reliable automotive audio load monitoring systems.

5 References

1. TAS6424E-Q1 45W, 2MHz Digital-Input 4-Channel Automotive Class-D Audio Amplifier with Load Dump Protection and I2C Diagnostics Datasheet (Rev. A)
2. Understanding DC and AC Load Diagnostics in Automotive Class-D Amplifiers (SLOA286)

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