Josey Angili

ABSTRACT
This document details automotive diagnostics and the benefits it brings to automotive system design and reliability. It clearly defines how to implement diagnostics in the TAS2505-Q1 system design. Some of the features discussed here are native to the device and others will be shown how to solve externally at minimal size/cost impact to the design.

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1 1. What are Diagnostics and Why are They Important?
Diagnostics are the ability of a system to identify an issue and communicate it back to the central host to decide what next steps need to be taken. This capability is important for automotive audio applications to ensure both the speaker and the amplifier are performing as expected. Below are some common diagnostics features:

Open Load—Verifies that the speaker connection to the amplifier is secure

Short Circuit—Identifies when a short to ground, short to power, or short between speaker terminals occurs in the system

Over-Temperature—Highlights when the temperature surpasses a set limit that could cause damage

All of these features are used commonly in applications such as Automotive Cluster and Emergency Call (eCall) to ensure quality and reliability of design. The remainder of this document will specifically highlight how to implement these features in the TAS2505-Q1.

2 Diagnostics Features in TAS2505

2.1 Short Circuit Detection
TAS2505 detects and self protects against the following faults:
- Short to Ground
- Short to Power
• Short between Speaker terminals
  When the amplifier detects these above errors, it shuts down and an internal flag is raised. This flag can be read via I²C by looking at the register map as seen below in Table 1. When any of the above mentioned faults occur, Page1, 0x2D bit 1 is cleared to “0”. The host processor can monitor this bit during normal operation to detect the presence of a fault condition.

Table 1. Page 1, Register 45: Speaker Amplifier Control 1 – 0x01/0x2D

<table>
<thead>
<tr>
<th>Bit</th>
<th>Type</th>
<th>Reset</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>D7–D2</td>
<td>R</td>
<td>0000 00</td>
<td>Reserved. Write only reset values.</td>
</tr>
</tbody>
</table>
| D1 | R/W | 0 | Speaker Power Driver  
  0: SPK output driver is powered down (Bit Clear during normal operations indicates fault).  
  1: SPK output driver is powered up. |
| D0 | R | 0 | Reserved. Write only reset values. |

2.2 Over-Temperature Detection

The TAS2505-Q1 has an over-temperature protection feature for the speaker driver. The over-temperature protection feature is intended to protect the device and ensure reliable operation, and is always enabled. If the device exceeds the set temperature limit, then the output stops switching and an error flag is set as a read-only bit on page 0, register 45, bit D7.

3 External Diagnostics

3.1 Open Load Detection

Diagnostics to detect an open load can be done externally with minimal impact to size and cost of the design. The external load diagnostic circuit is shown below in Figure 1.

Figure 1. External Load Diagnostics Circuit
The circuit detects load faults by monitoring the positive speaker line (SP+) and the negative speaker line (SP-) of each channel. Abnormal voltages on each output line are identified by comparing the voltages to the reference voltages created by a resistor network. The circuit shows one amplifier output (SP+ and SP-), a speaker represented by a 4-Ω load (R2) and load diagnostics consisting of a resistor network (R1, R2, R3, R4, R5, R6, R7) and two LM2901-Q1 comparator. Outputs of both comparators are labeled as O1 and O2 respectively.

To limit power draw during operation and minimize effects on audio performance, R1, R3, R5, R6, and R7 are high impedance resistors. The purpose of R4 is to define the range for open load fault detection (OL). Its value determines the reference voltages that SP+ and SP- are compared to and thus the threshold of the resistance value of R2 to be detected as open load. This reference window is crucial for open load detection and needs to be adjusted to the voltage levels at SP+ and SP- as well as voltage variations caused by resistor tolerances and internal resistance on the amplifier outputs.

During speaker load open error, both O1 and O2 goes high. Depending on SPKVDD, a resistor divider may be used to bring the level compatible to IOVDD being used and then feed one of them (O1 or O2) to the GPIO pin of TAS2505-Q1 to get registered into an I2C register for the external controller (host) to read (refer to the Section 3.2 section).

### 3.2 Communication to Host & Action

Information regarding short and open load fault conditions for the TAS2505-Q1 amplifier’s speakers can be accessed through two integrated registers via I2C. External host can poll the 2 registers (register 62 and 46) to see if an error occurred. See Table 2 below to interpret the error. There is no requirement on how often to poll these registers as the device self protects on the event of an error.

To determine whether or not a short has occurred, host reads register 45 of page 1. If bit D1 of this register is low, then a short condition exists in the amplifier and has caused it to shut down. The fault condition will need to be fixed and the device will need to be reset before it will operate again. If this bit is high, then no short circuit condition has been detected.

The other primary type of output fault condition, open load, can also be read through I2C. To do this, the first output of the LM2903 dual comparator is routed back to the GPIO/DOUT pin. Additionally, the user should first mute the amplifier to stop switching at the outputs. To do, set bit D1 of register 45 from page 1 to "0." The user should then write "00001000" or "0x08" to register 52 of page 0. This sets the GPIO/DOUT control register to its general input setting. The first output of the comparator is then automatically written to this register and stored in bit “D1” as a high or low bit. The user can then read back register 52 of page 0 at any time and, comparing its D1 bit with the D1 bit of register 46 on page 1, determine if an open load fault has occurred. Once diagnostic reading is complete, make sure to reset D1 of register 45, page 1 back to "1" to re-enable the amplifier. If a fault was detected, it needs to be corrected and the amplifier reset before sound can be played again. Table 2 demonstrates the register information that corresponds to each primary state of amplifier operation.

#### Table 2. Primary Operation States and Fault Detection: I2C

<table>
<thead>
<tr>
<th>Amplifier State</th>
<th>Page 0, Register 52, Bit D1</th>
<th>Page 1, Register 46, Bit D1</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Fault</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Short Circuit</td>
<td>X</td>
<td>0</td>
</tr>
<tr>
<td>Open Load</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

In addition, LEDs are added on the board to reflect if an error happened. The state of the 2 LEDs can also reveal the state of the amplifier’s fault conditions. This is only used for indication.

#### Table 3. Complete Operation States and Fault Detection: I2C and LEDs

<table>
<thead>
<tr>
<th>Amplifier State</th>
<th>Comparator Out 1</th>
<th>LED 1</th>
<th>Comparator Out 2</th>
<th>LED 2</th>
<th>Page 1, Reg 46, Bit 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Fault</td>
<td>1</td>
<td>OFF</td>
<td>1</td>
<td>OFF</td>
<td>1</td>
</tr>
<tr>
<td>Short to GND</td>
<td>1</td>
<td>OFF</td>
<td>0</td>
<td>ON</td>
<td>0</td>
</tr>
<tr>
<td>Short to Power</td>
<td>0</td>
<td>ON</td>
<td>1</td>
<td>OFF</td>
<td>0</td>
</tr>
<tr>
<td>Shorted Load</td>
<td>1</td>
<td>OFF</td>
<td>1</td>
<td>OFF</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 3. Complete Operation States and Fault Detection: I²C and LEDs (continued)

<table>
<thead>
<tr>
<th>Amplifier State</th>
<th>Comparator Out 1</th>
<th>LED 1</th>
<th>Comparator Out 2</th>
<th>LED 2</th>
<th>Page 1, Reg 46, Bit 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Load</td>
<td>0</td>
<td>ON</td>
<td>0</td>
<td>ON</td>
<td>1</td>
</tr>
</tbody>
</table>
### Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

<table>
<thead>
<tr>
<th>Changes from Original (July 2017) to A Revision</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Updated the 'External Load Diagnostics Circuit' diagram</td>
<td>2</td>
</tr>
<tr>
<td>• Added information about the new R7 resistor</td>
<td>3</td>
</tr>
<tr>
<td>• Added additional information to Communication to Host &amp; Action section</td>
<td>3</td>
</tr>
</tbody>
</table>
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