ABSTRACT

With high power Class-D audio amplifiers, layout is often critical for achieving maximum power and optimal performance. For this reason, a ground plane on two layers is recommended to provide a solid ground reference for the amplifier and to minimize ground voltage differentials across the die of the monolithic amplifier. However, as found with the TPA32xx family of amplifiers, referencing the analog input grounds directly to the ground plane can cause issues, especially when using single ended op-amps.

NOTE: This applications report discusses the grounding recommendations for analog inputs only. It is always recommended to use a ground plane for high power and switching nodes with all Class-D amplifiers.

Contents

1 Single Ended to Differential Input Stage
2 Input Stage with Ground Plane
   2.1 Testing Ground Plane Configuration
   2.2 Ground Plane Results
3 Input Stage with Star Ground
   3.1 Testing Star Ground Configuration
4 TPA32xx Ground Pin Reference

List of Figures

1 Cost Effective SE to Diff Input Stage
2 SE to Diff Input Stage Ground Plane Noise
3 TPA3244 THD+N vs Power 1 KHz Ground Plane
4 TPA3244 THD+N vs Power 100 Hz Ground Plane
5 TPA3245 THD+N vs Power 100 Hz Ground Plane
6 SE to Diff Input Stage Star Ground
7 TPA3244 THD+N vs Power 100 Hz Star Ground

Trademarks

All trademarks are the property of their respective owners.
1 Single Ended to Differential Input Stage

Figure 1 shows the basic setup for a Single-Ended (SE) to Differential (Diff) input stage used with the TPA32xx amplifier. In this use case, the amplifier is configured for BTL output and requires “Input_A” and “Input_B” to be driven differentially. A pair of inverting Op-amps is used where the Op-amp gain is set to -1. By cascading the operational-amplifiers as shown, the analog signal from the RCA jack labeled “SE Input” appears on both “Input_A” and “Input_B” of the TPA32xx amplifier out of phase with each other.

These operational-amplifiers also run from a single 12 V supply rail to reduce cost. In order to pass analog signals that swing below ground, the operational-amplifiers are biased to the mid rail (6 V) using a resistor divider and filter. Then DC blocking capacitors are used to isolate the Op-amp bias voltage from a ground referenced analog input.

This cost effective SE to Diff converter works quite well; however, since this design is not using a truly differential operational-amplifier stage, there will always be some imbalance between “Input_A” and “Input_B” with this configuration and less than ideal common mode (CM) rejection.

Note: Only one channel of TPA32xx Class-D Amplifier is shown

Figure 1. Cost Effective SE to Diff Input Stage
2 Input Stage with Ground Plane

Now suppose that all of the ground points for the input stage are tied to the ground plane at the most convenient locations, as typically done in PCB layout (Figure 2).

At high output power, the ground plane used for the TPA32xx amplifier will start to see heavy current flow and switching noise. This is generally worse at lower audio frequencies where the sustained amplitude of the audio signal peaks is longer when compared to higher frequency signals. This can cause lots of noise on the ground plane.

Due to the heavy current flow into the ground plane as represented by the arrow “I_{power}”, noise voltages \( V_{n1} \), \( V_{n2} \), and \( V_{n3} \) develop across the ground plane. Therefore, the ground nodes for the input stage G2, G3, and G4 will all be at different potentials relative to the TPA32xx amplifier analog ground reference G1.

Since our Op-amp input stage is not truly differential with poor CM rejection, signal imbalance is inevitable. It is likely that a differential noise voltage due to \( V_{n1} \), \( V_{n2} \), and \( V_{n3} \) develop between “Input_A” and “Input_B” and is amplified by the TPA32xx amplifier.

This results in degraded low frequency audio performance.
2.1 Testing Ground Plane Configuration

THD+N vs output power of the TPA3244 amplifier was tested using the SE to Diff input stage where the signal grounds were tied to the ground plane of the PCB as shown in Figure 2. The TPA3244 was setup to run stereo channels in BTL with 4 Ω loads, so our input stage is copied for the other channel.

In Figure 3, the THD+N audio performance looks quite good at 1 KHz. However, as shown by Figure 4, at 100 Hz the THD+N is quite different between channels.

A PCB with the TPA3245 was also tested at 100 Hz and the results were even worse. Channel 1 has a THD+N of 0.013% whereas Channel 2 is 0.0049% at 20 Watts of output power.

2.2 Ground Plane Results

The reason for different THD+N results between stereo channels at 100 Hz is simply ground plane noise. At low audio frequencies and high output power, ground noise is being injected into our SE to Diff analog input stage and reducing performance. However since we cannot control the currents in the ground plane and it is unlikely that the layout is 100% symmetric, the SE to Diff input stage of Channel 1 has been affected more by our ground noise.
3 Input Stage with Star Ground

To fix this issue, G2, G3, and G4 input stage ground nodes were connected with separate traces directly to the TPA32xx amplifier analog ground reference, G1. With this star ground connection scheme, G1 G2 G3 and G4 are well coupled and share the same ground potential. Therefore, no noise voltage can be developed between the input stage grounds and the TPA32xx analog ground. Figure 6 shows this connection scheme.

![Figure 6. SE to Diff Input Stage Star Ground](Image)

**NOTE:** The supply grounds of the two operational-amplifiers are not shown to connect to specific point on the grounding scheme. The high PSRR offered by the op-amp means that ground noise on the supply pins will have little impact on the audio performance. Generally it is acceptable to tie the operational-amplifier supply ground to a convenient location.

3.1 Testing Star Ground Configuration

Using this star ground topology of Figure 7, the THD+N vs output power of the TPA3244 amplifier was again tested by running 2 channels in BTL with 4 Ω loads at 100 Hz.

Not only is the amplifier channel performance now matched, but the overall THD+N has improved. Ground noise is no longer affecting our input stage.

![Figure 7. TPA3244 THD+N vs Power 100 Hz Star Ground](Image)
4  TPA32xx Ground Pin Reference

For reference, the pinout of the analog and power ground pins on the TPA32xx devices are listed in Table 1.

Table 1. TPA32xx Ground Pins

<table>
<thead>
<tr>
<th>Amplifier</th>
<th>Analog Ground Pins</th>
<th>Power Ground Pins</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPA3244</td>
<td>10, 11</td>
<td>25, 26, 33, 34, 41, 42</td>
</tr>
<tr>
<td>TPA3245</td>
<td>12, 13</td>
<td>25, 26, 33, 34, 41, 42</td>
</tr>
<tr>
<td>TPA3250</td>
<td>10, 11</td>
<td>25, 26, 33, 34, 41, 42</td>
</tr>
<tr>
<td>TPA3251</td>
<td>12, 13</td>
<td>25, 26, 33, 34, 41, 42</td>
</tr>
<tr>
<td>TPA3255</td>
<td>12, 13</td>
<td>25, 26, 33, 34, 41, 42</td>
</tr>
</tbody>
</table>
IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated (‘TI’) technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, “TI Resources”) are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI’s provision of TI Resources does not expand or otherwise alter TI’s applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT. AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED “AS IS” AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include: without limitation, TI’s standard terms for semiconductor products http://www.ti.com/sc/docs/stdterms.htm), evaluation modules, and samples (http://www.ti.com/sc/docs/sampterms.htm).

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2018, Texas Instruments Incorporated