Application Report
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TPA32xx Analog Input Grounding for Single Ended Inputs

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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.

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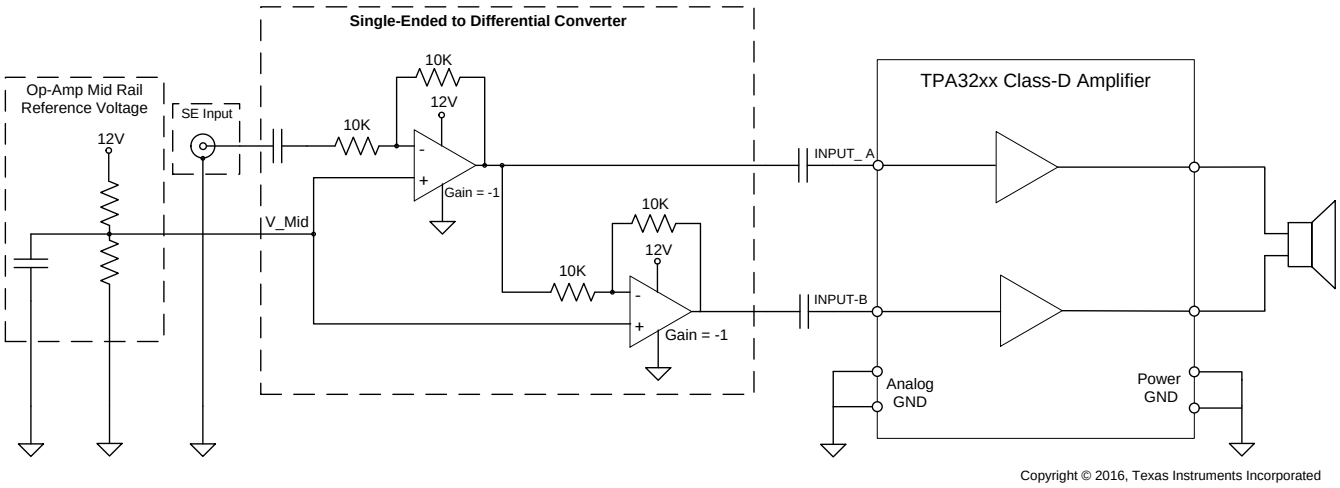
Trademarks

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.

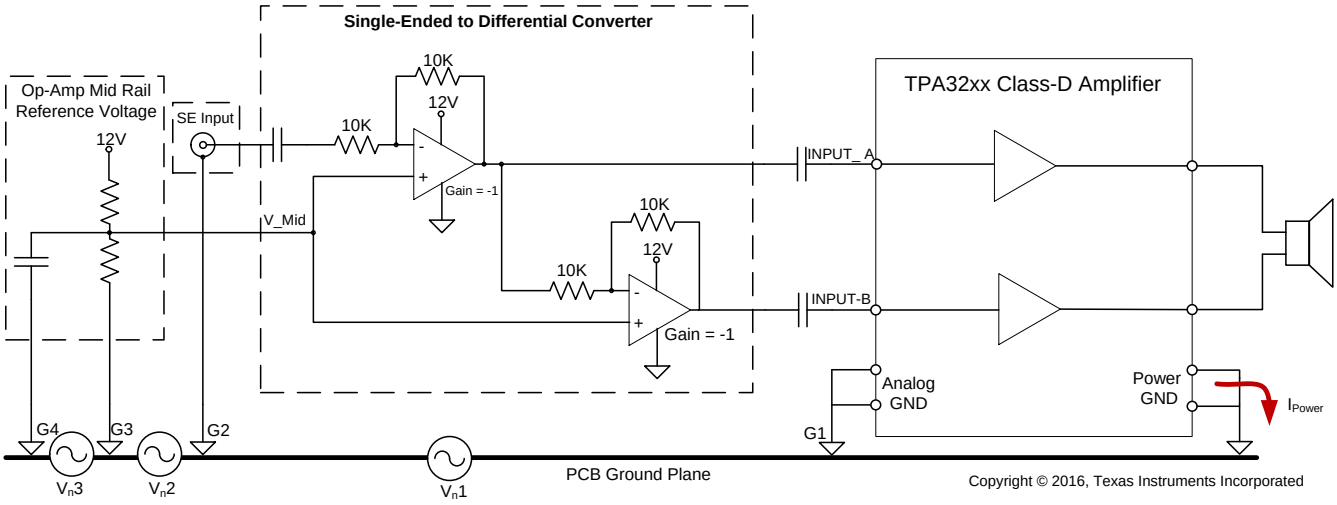


Figure 2. SE to Diff Input Stage Ground Plane Noise

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.

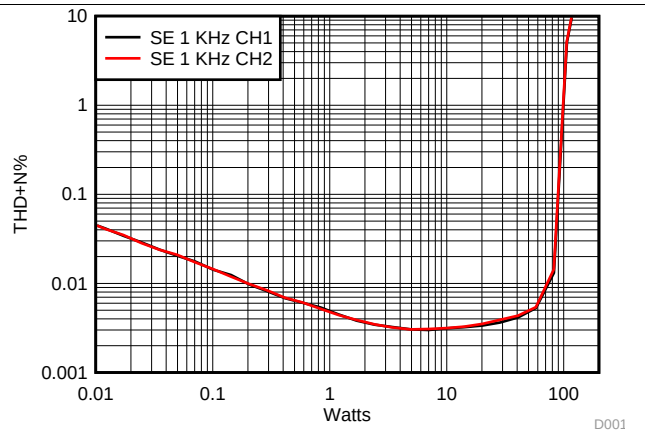


Figure 3. TPA3244 THD+N vs Power 1 KHz Ground Plane

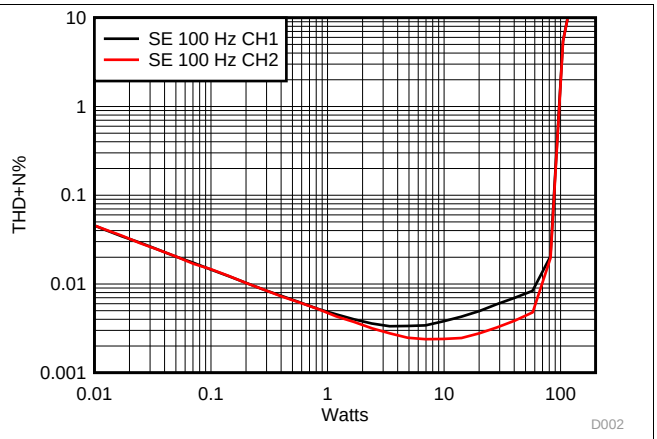


Figure 4. TPA3244 THD+N vs Power 100 Hz Ground Plane

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.

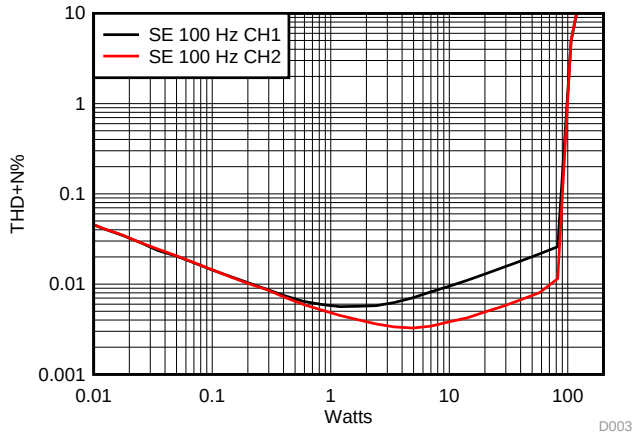


Figure 5. TPA3245 THD+N vs Power 100 Hz Ground Plane

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.

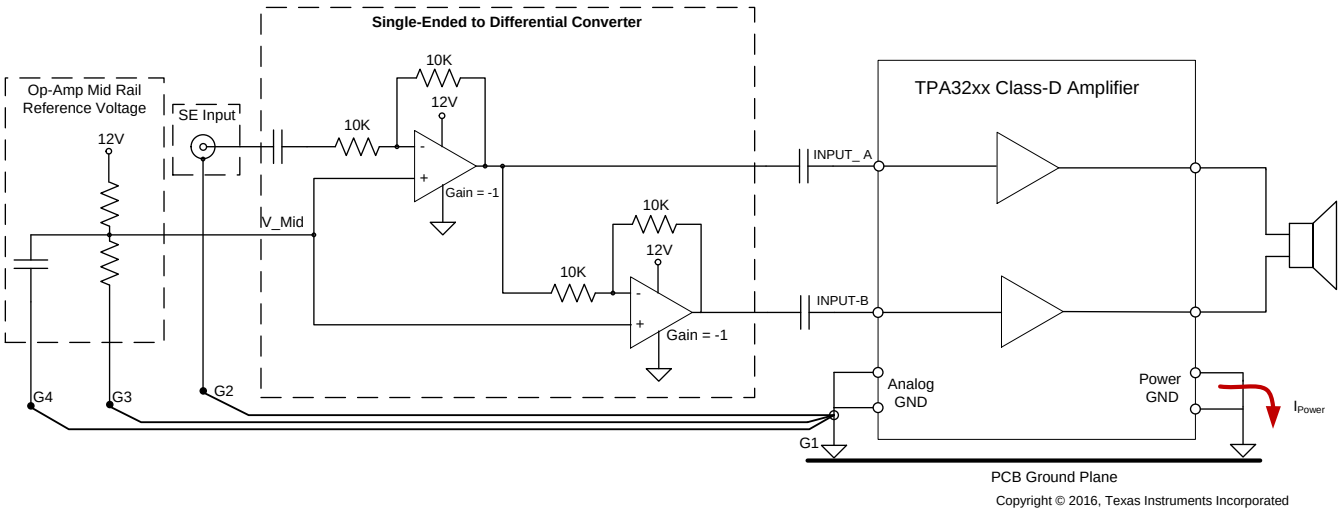


Figure 6. SE to Diff Input Stage Star Ground

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.

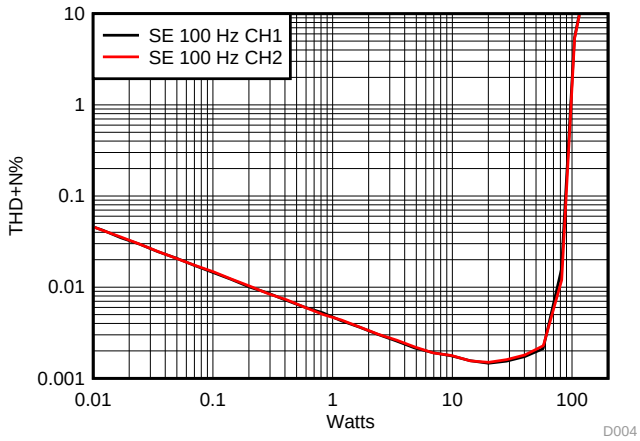


Figure 7. TPA3244 THD+N vs Power 100 Hz Star Ground

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

TPA32xx Class-D Amplifier Ground Pins		
Amplifier	**Analog Ground Pins**	**Power Ground Pins**
TPA3244	10, 11	25, 26, 33, 34, 41, 42
TPA3245	12, 13	25, 26, 33, 34, 41, 42
TPA3250	10, 11	25, 26, 33, 34, 41, 42
TPA3251	12, 13	25, 26, 33, 34, 41, 42
TPA3255	12, 13	25, 26, 33, 34, 41, 42

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