TPA2011D1 3.2-W Mono Filter-Free Class-D Audio Power Amplifier
With Auto-Recovering Short-Circuit Protection

1 Features
• Powerful Mono Class-D Amplifier
  – 3.24 W (4 Ω, 5 V, 10% THDN)
  – 2.57 W (4 Ω, 5 V, 1% THDN)
  – 1.80 W (8 Ω, 5 V, 10% THDN)
  – 1.46 W (8 Ω, 5 V, 1% THDN)
• Integrated Feedback Resistor of 300 kΩ
• Integrated Image Reject Filter for DAC Noise Reduction
• Low Output Noise of 20 μV
• Low Quiescent Current of 1.5 mA
• Auto Recovering Short-Circuit Protection
• Thermal Overload Protection
• 9-Ball, 1.21 mm x 1.16 mm 0.4 mm Pitch DSBGA

2 Applications
• Wireless or Cellular Handsets and PDAs
• Portable Navigation Devices
• General Portable Audio Devices

3 Description
The TPA2011D1 is a 3.2-W high efficiency filter-free class-D audio power amplifier (class-D amp) in a 1.21 mm x 1.16 mm wafer chip scale package (DSBGA) that requires only three external components.

Features like 95% efficiency, 86-dB PSRR, 1.5 mA quiescent current and improved RF immunity make the TPA2011D1 class-D amp ideal for cellular handsets. A fast start-up time of 4 ms with no audible turn-on pop makes the TPA2011D1 ideal for PDA and smart-phone applications. The TPA2011D1 allows independent gain while summing signals from separate sources, and has a low 20 μV noise floor.

Device Information

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PACKAGE</th>
<th>BODY SIZE (NOM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPA2011D1</td>
<td>DSBGA</td>
<td>1.60 mm x 1.21 mm</td>
</tr>
</tbody>
</table>

(1) For all available packages, see the orderable addendum at the end of the data sheet.

An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.
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4 Revision History
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision A (May 2010) to Revision B  Page

• Added Pin Configuration and Functions section, Handling Rating table, Feature Description section, Device Functional Modes, Application and Implementation section, Power Supply Recommendations section, Layout section, Device and Documentation Support section, and Mechanical, Packaging, and Orderable Information section ................................................. 1

Changes from Original (December 2009) to Revision A  Page

• Changed the Package Dimensions table. D was Max = 1244μm, Min = 1184μm. E was Max = 1190μm, Min = 1130μm ................................................. 1
## 5 Device Comparison Table

<table>
<thead>
<tr>
<th>DEVICE NUMBER</th>
<th>SPEAKER CHANNELS</th>
<th>SPEAKER AMP TYPE</th>
<th>OUTPUT POWER (W)</th>
<th>PSRR (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPA2011D1</td>
<td>Mono</td>
<td>Class D</td>
<td>3.2</td>
<td>86</td>
</tr>
<tr>
<td>TPA2005D1</td>
<td>Mono</td>
<td>Class D</td>
<td>1.4</td>
<td>75</td>
</tr>
<tr>
<td>TPA2010D1</td>
<td>Mono</td>
<td>Class D</td>
<td>2.5</td>
<td>75</td>
</tr>
</tbody>
</table>
6 Pin Configuration and Functions

![YFF Package 9-Pin DSBGA Top View](image)

### Pin Functions

<table>
<thead>
<tr>
<th>PIN NAME</th>
<th>PIN NO.</th>
<th>I/O</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN</td>
<td>C2</td>
<td>I</td>
<td>Shutdown terminal. When terminal is low the device is put into Shutdown mode.</td>
</tr>
<tr>
<td>GND</td>
<td>A2</td>
<td>I</td>
<td>Analog ground terminal. Must be connected to same potential as PGND using a direct connection to a single point ground.</td>
</tr>
<tr>
<td>IN–</td>
<td>C1</td>
<td>I</td>
<td>Negative differential audio input</td>
</tr>
<tr>
<td>IN+</td>
<td>A1</td>
<td>I</td>
<td>Positive differential audio input</td>
</tr>
<tr>
<td>PGND</td>
<td>B3</td>
<td>I</td>
<td>High-current Analog ground terminal. Must be connected to same potential as GND using a direct connection to a single point ground.</td>
</tr>
<tr>
<td>PV_D0</td>
<td>B2</td>
<td>I</td>
<td>High-current Power supply terminal. Must be connected to same power supply as V_DD using a direct connection. Voltage must be within values listed in Recommended Operating Conditions table.</td>
</tr>
<tr>
<td>V_D0</td>
<td>B1</td>
<td>I</td>
<td>Power supply terminal. Must be connected to same power supply as PV_D0 using a direct connection. Voltage must be within values listed in Recommended Operating Conditions table.</td>
</tr>
<tr>
<td>V_O–</td>
<td>A3</td>
<td>O</td>
<td>Negative BTL audio output</td>
</tr>
<tr>
<td>V_O+</td>
<td>C3</td>
<td>O</td>
<td>Positive BTL audio output</td>
</tr>
</tbody>
</table>

### 7 Specifications

#### 7.1 Absolute Maximum Ratings

over operating free-air temperature range, $T_A = 25°C$ (unless otherwise noted)$^{(1)}$

<table>
<thead>
<tr>
<th>V_DD, PV_DD Supply voltage</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>In active mode</td>
<td>$-0.3$</td>
<td>6</td>
<td>V</td>
</tr>
<tr>
<td>In shutdown mode</td>
<td>$-0.3$</td>
<td>6</td>
<td>V</td>
</tr>
<tr>
<td>V_I Input voltage</td>
<td>$-0.3$</td>
<td>$V_D0 + 0.3$</td>
<td>V</td>
</tr>
<tr>
<td>R_L Minimum load resistance</td>
<td>3.2</td>
<td></td>
<td>Ω</td>
</tr>
</tbody>
</table>

(1) Stresses beyond those listed under **absolute maximum ratings** may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under **recommended operating conditions** is not implied. Exposure to absolute–maximum–rated conditions for extended periods may affect device reliability.
7.2 ESD Ratings

<table>
<thead>
<tr>
<th>VALUE</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>±2000</td>
<td>V</td>
</tr>
<tr>
<td>±1000</td>
<td></td>
</tr>
</tbody>
</table>

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

7.3 Recommended Operating Conditions

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{DD}$</td>
<td>2.5</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>$V_{IH}$</td>
<td>1.3</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$V_{IL}$</td>
<td>0.35</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$R_I$</td>
<td>15</td>
<td></td>
<td>kΩ</td>
</tr>
<tr>
<td>$V_{IC}$</td>
<td>0.75</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$T_A$</td>
<td>−40</td>
<td>85</td>
<td>°C</td>
</tr>
</tbody>
</table>

7.4 Thermal Information

<table>
<thead>
<tr>
<th>THERMAL METRIC(1)</th>
<th>TPA2011D1</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{JA}$</td>
<td>107</td>
<td>°C/W</td>
</tr>
<tr>
<td>$R_{JC(top)}$</td>
<td>0.9</td>
<td>°C/W</td>
</tr>
<tr>
<td>$R_{JB}$</td>
<td>18.1</td>
<td>°C/W</td>
</tr>
<tr>
<td>$\psi_{JT}$</td>
<td>3.8</td>
<td>°C/W</td>
</tr>
<tr>
<td>$\psi_{JB}$</td>
<td>18</td>
<td>°C/W</td>
</tr>
<tr>
<td>$R_{JC(bot)}$</td>
<td>N/A</td>
<td>°C/W</td>
</tr>
</tbody>
</table>

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application report, SPRA953.

7.5 Electrical Characteristics

$T_A = 25°C$ (unless otherwise noted)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$</td>
<td>V_{OS}</td>
<td>$</td>
<td>Output offset voltage (measured differentially)</td>
<td>$V_I = 0 V, A = 2 V/V, V_{DD} = 2.5 V to 5.5 V$</td>
<td>1</td>
</tr>
<tr>
<td>$</td>
<td>I_{IH}</td>
<td>$</td>
<td>High-level input current</td>
<td>$V_{DD} = 5.5 V, V_{EN} = 5.5 V$</td>
<td>50</td>
</tr>
<tr>
<td>$</td>
<td>I_{IL}</td>
<td>$</td>
<td>Low-level input current</td>
<td>$V_{DD} = 5.5 V, V_{EN} = 0 V$</td>
<td>1</td>
</tr>
<tr>
<td>$I_Q$</td>
<td>Quiescent current</td>
<td>$V_{DD} = 5.5 V, no load$</td>
<td>1.8</td>
<td>2.5</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>$V_{DD} = 3.6 V, no load$</td>
<td>1.5</td>
<td>2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$V_{DD} = 2.5 V, no load$</td>
<td>1.3</td>
<td>2.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{SD}$</td>
<td>Shutdown current</td>
<td>$V_{EN} = 0.35 V, V_{DD} = 2.5 V to 5.5 V$</td>
<td>0.1</td>
<td>2</td>
<td>µA</td>
</tr>
<tr>
<td>$R_{O,SD}$</td>
<td>Output impedance in shutdown mode</td>
<td>$V_{EN} = 0.35 V$</td>
<td>2</td>
<td></td>
<td>kΩ</td>
</tr>
<tr>
<td>$f_{SW}$</td>
<td>Switching frequency</td>
<td>$V_{DD} = 2.5 V to 5.5 V$</td>
<td>250</td>
<td>300</td>
<td>350</td>
</tr>
<tr>
<td>$A_V$</td>
<td>Gain</td>
<td>$V_{DD} = 2.5 V to 5.5 V, R_I$ in kΩ</td>
<td>285/R_I</td>
<td>300/R_I</td>
<td>315/R_I</td>
</tr>
<tr>
<td>$R_{EN}$</td>
<td>Resistance from EN to GND</td>
<td></td>
<td>300</td>
<td></td>
<td>kΩ</td>
</tr>
</tbody>
</table>
### 7.6 Operating Characteristics

\( V_{DD} = 3.6 \text{ V}, \ T_A = 25^\circ\text{C}, \ AV = 2 \text{ V/V}, \ R_L = 8 \Omega \) (unless otherwise noted)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>( V_{DD} = 5 \text{ V} )</th>
<th>( V_{DD} = 3.6 \text{ V} )</th>
<th>( V_{DD} = 2.5 \text{ V} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_O )</td>
<td>Output power</td>
<td>3.24 W</td>
<td>1.62 W</td>
<td>0.70 W</td>
</tr>
<tr>
<td>THD + N = 10%</td>
<td>( f = 1 \text{ kHz}, \ R_L = 4 \Omega )</td>
<td>2.57 W</td>
<td>1.32 W</td>
<td>0.57 W</td>
</tr>
<tr>
<td>THD + N = 10%</td>
<td>( f = 1 \text{ kHz}, \ R_L = 8 \Omega )</td>
<td>1.80 W</td>
<td>0.91 W</td>
<td>0.42 W</td>
</tr>
<tr>
<td>THD + N = 1%</td>
<td>( f = 1 \text{ kHz}, \ R_L = 8 \Omega )</td>
<td>1.46 W</td>
<td>0.74 W</td>
<td>0.33 W</td>
</tr>
</tbody>
</table>

\( V_n \) Noise output voltage

\[
\begin{align*}
V_{DD} &= 3.6 \text{ V}, \ \text{Inputs AC grounded} & \text{A-weighting} & 20 \\
& \text{with} \ C_I = 2 \mu \text{F}, \ f = 20 \text{ Hz to 20 kHz} & \text{No weighting} & 25
\end{align*}
\]

**THD+N** Total harmonic distortion plus noise

- \( V_{DD} = 5.0 \text{ V}, \ P_O = 1.0 \text{ W}, \ f = 1 \text{ kHz}, \ R_L = 8 \Omega \) 0.11\%
- \( V_{DD} = 3.6 \text{ V}, \ P_O = 0.5 \text{ W}, \ f = 1 \text{ kHz}, \ R_L = 8 \Omega \) 0.05\%
- \( V_{DD} = 2.5 \text{ V}, \ P_O = 0.2 \text{ W}, \ f = 1 \text{ kHz}, \ R_L = 8 \Omega \) 0.05\%
- \( V_{DD} = 5.0 \text{ V}, \ P_O = 2.0 \text{ W}, \ f = 1 \text{ kHz}, \ R_L = 4 \Omega \) 0.23\%
- \( V_{DD} = 3.6 \text{ V}, \ P_O = 1.0 \text{ W}, \ f = 1 \text{ kHz}, \ R_L = 4 \Omega \) 0.07\%
- \( V_{DD} = 2.5 \text{ V}, \ P_O = 0.4 \text{ W}, \ f = 1 \text{ kHz}, \ R_L = 4 \Omega \) 0.06\%

**PSRR** AC power supply rejection ratio

\( V_{DD} = 3.6 \text{ V}, \ \text{Inputs AC grounded} \) with \( C_I = 2 \mu \text{F}, \ 200 \text{ mVpp} \) ripple, \( f = 217 \text{ Hz} \) 86 dB

**CMRR** Common mode rejection ratio

\( V_{DD} = 3.6 \text{ V}, \ V_{IC} = 1 \text{ Vpp}, \ f = 217 \text{ Hz} \) 79 dB

**T_{SU}** Startup time from shutdown

\( V_{DD} = 3.6 \text{ V} \) 4 ms

**I_{OC}** Overcurrent protection threshold

- \( V_{DD} = 3.6 \text{ V}, \ V_{O+} \text{, shorted to} \ VDD \) 2 A
- \( V_{DD} = 3.6 \text{ V}, \ V_{O-} \text{, shorted to} \ VDD \) 2 A
- \( V_{DD} = 3.6 \text{ V}, \ V_{O+} \text{, shorted to} \ GND \) 2 A
- \( V_{DD} = 3.6 \text{ V}, \ V_{O-} \text{, shorted to} \ GND \) 2 A
- \( V_{DD} = 3.6 \text{ V}, \ V_{O+} \text{, shorted to} \ V_{O-} \) 2 A

**T_{SD}** Time for which output is disabled after a short-circuit event, after which auto-recovery trials are continuously made

\( V_{DD} = 2.5 \text{ V} \) to 5.5 V 100 ms

### 7.7 Dissipation Ratings

<table>
<thead>
<tr>
<th>PACKAGE</th>
<th>DERATING FACTOR(1)</th>
<th>( T_A &lt; 25^\circ\text{C} )</th>
<th>( T_A = 70^\circ\text{C} )</th>
<th>( T_A = 85^\circ\text{C} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>YFF (DSBGA)</td>
<td>4.2 mW/°C</td>
<td>525 mW</td>
<td>336 mW</td>
<td>273 mW</td>
</tr>
</tbody>
</table>

(1) Derating factor measure with high K board.
7.8 Typical Characteristics

$V_{DD} = 3.6\, V, \, C_I = 0.1\, \mu F, \, C_{S1} = 0.1\, \mu F, \, C_{S2} = 10\, \mu F, \, T_A = 25^\circ C, \, R_L = 8\, \Omega$ (unless otherwise noted)
Typical Characteristics (continued)

\[ V_{DD} = 3.6 \, V, \, C_1 = 0.1 \, \mu F, \, C_{S1} = 0.1 \, \mu F, \, C_{S2} = 10 \, \mu F, \, T_A = 25^\circ C, \, R_L = 8 \, \Omega \] (unless otherwise noted)

**Figure 7. Supply Current vs Supply Voltage**

**Figure 8. Supply Current vs EN Voltage**

**Figure 9. Output Power vs Load Resistance**

**Figure 10. Output Power vs Load Resistance**

**Figure 11. Output Power vs Supply Resistance**

**Figure 12. THD + Noise vs Output Power**
Typical Characteristics (continued)

\(V_{DD} = 3.6 \text{ V}, \ C_i = 0.1 \ \mu \text{F}, \ C_{S1} = 0.1 \ \mu \text{F}, \ C_{S2} = 10 \ \mu \text{F}, \ T_A = 25^\circ \text{C}, R_L = 8 \ \Omega \) (unless otherwise noted)
Typical Characteristics (continued)

\[ V_{DD} = 3.6 \text{ V}, \ C_I = 0.1 \mu \text{F}, \ C_{G1} = 0.1 \mu \text{F}, \ C_{G2} = 10 \mu \text{F}, \ T_A = 25^\circ \text{C}, \ R_L = 8 \Omega \text{ (unless otherwise noted)} \]

![Figure 19. THD + Noise vs Frequency](image)

![Figure 20. THD + Noise vs Common Mode Input Voltage](image)

![Figure 21. Power Supply Rejection Ratio vs Frequency](image)

![Figure 22. Power Supply Rejection Ratio vs Frequency](image)

![Figure 23. Power Supply Rejection Ratio vs Common Mode Input Voltage](image)

![Figure 24. Common Mode Rejection Ratio vs Frequency](image)
Typical Characteristics (continued)

\( V_{DD} = 3.6 \text{ V, } C_1 = 0.1 \mu \text{F, } C_{S1} = 0.1 \mu \text{F, } C_{S2} = 10 \mu \text{F, } T_A = 25^\circ \text{C, } R_L = 8 \Omega \) (unless otherwise noted)

![Figure 25. Common Mode Rejection Ratio vs Common Mode Input Voltage](image)

![Figure 26. GSM Power Supply Rejection vs Time](image)

![Figure 27. GSM Power Supply Rejection vs Frequency](image)
8 Parameter Measurement Information

All parameters are measured according to the conditions described in the Specifications section.

1. Input resistor $R_I = 150k\Omega$ gives a gain of 6 dB which is used for all the graphs.
2. $C_I$ was shorted for any common-mode input voltage measurement. All other measurements were taken with $C_I = 0.1\mu F$ (unless otherwise noted).
3. $C_{S1} = 0.1\mu F$ is placed very close to the device. The optional $C_{S2} = 10\mu F$ is used for datasheet graphs.
4. The 30-kHz low-pass filter is required even if the analyzer has an internal low-pass filter. An RC low-pass filter ($1k\Omega, 4700pF$) is used on each output for the data sheet graphs.

Figure 28. Test Setup for Typical Application Graphs
9 Detailed Description

9.1 Overview
The TPA2011D1 is a high-efficiency filter-free Class-D audio amplifier capable of delivering up to 3.2W into 4-Ω load with 5-V power supply. The fully-differential design of this amplifier avoids the usage of bypass capacitors and the improved CMRR eliminates the usage of input-coupling capacitors. This makes the device size a perfect choice for small, portable applications as only three external components are required. The advanced modulation used in the TPA2011D1 PWM output stage eliminates the need for an output filter.

9.2 Functional Block Diagram

9.3 Feature Description
9.3.1 Fully Differential Amplifier
The TPA2011D1 is a fully differential amplifier with differential inputs and outputs. The fully differential amplifier consists of a differential amplifier and a common-mode amplifier. The differential amplifier ensures that the amplifier outputs a differential voltage on the output that is equal to the differential input times the gain. The common-mode feedback ensures that the common-mode voltage at the output is biased around VDD/2 regardless of the common-mode voltage at the input. The fully differential TPA2011D1 can still be used with a single-ended input; however, the TPA2011D1 should be used with differential inputs when in a noisy environment, like a wireless handset, to ensure maximum noise rejection.

9.3.1.1 Advantages of Fully Differential Amplifiers
- Input-coupling Capacitors Not Required
  - The fully differential amplifier allows the inputs to be biased at voltage other than mid-supply. For example, if a codec has a midsupply lower than the midsupply of the TPA2011D1, the common-mode feedback circuit will adjust, and the TPA2011D1 outputs will still be biased at midsupply of the TPA2011D1. The inputs of the TPA2011D1 can be biased from 0.5 V to VDD –0.8 V. If the inputs are biased outside of that range, input-coupling capacitors are required.
- Midsupply Bypass Capacitor, C(BYPASS), Not Required
  - The fully differential amplifier does not require a bypass capacitor. This is because any shift in the midsupply affects both positive and negative channels equally and cancels at the differential output.
- Better RF-Immunity
  - GSM handsets save power by turning on and shutting off the RF transmitter at a rate of 217 Hz. The
Feature Description (continued)

transmitted signal is picked-up on input and output traces. The fully differential amplifier cancels the signal much better than the typical audio amplifier.

9.3.2 Eliminating the Output Filter With the TPA2011D1

This section focuses on why the user can eliminate the output filter with the TPA2011D1.

9.3.2.1 Effect on Audio

The class-D amplifier outputs a pulse-width modulated (PWM) square wave, which is the sum of the switching waveform and the amplified input audio signal. The human ear acts as a band-pass filter such that only the frequencies between approximately 20 Hz and 20 kHz are passed. The switching frequency components are much greater than 20 kHz, so the only signal heard is the amplified input audio signal.

9.3.2.2 When to Use an Output Filter

Design the TPA2011D1 without an Inductor / Capacitor (LC) output filter if the traces from the amplifier to the speaker are short. Wireless handsets and PDAs are great applications for this class-D amplifier to be used without an output filter.

The TPA2011D1 does not require an LC output filter for short speaker connections (approximately 100 mm long or less). A ferrite bead can often be used in the design if failing radiated emissions testing without an LC filter; and, the frequency-sensitive circuit is greater than 1 MHz. If choosing a ferrite bead, choose one with high impedance at high frequencies, but very low impedance at low frequencies. The selection must also take into account the currents flowing through the ferrite bead. Ferrites can begin to lose effectiveness at much lower than rated current values. See the TPA2011D1 EVM User’s Guide for components used successfully by TI. Figure 29 shows a typical ferrite-bead output filter.

9.3.3 Short Circuit Auto-Recovery

When a short-circuit event occurs, the TPA2011D1 goes to shutdown mode and activates the integrated auto-recovery process whose aim is to return the device to normal operation once the short-circuit is removed. This process repeatedly examines (once every 100ms) whether the short-circuit condition persists, and returns the device to normal operation immediately after the short-circuit condition is removed. This feature helps protect the device from large currents and maintain a good long-term reliability.

9.3.4 Integrated Image Reject Filter for DAC Noise Rejection

In applications which use a DAC to drive Class-D amplifiers, out-of-band noise energy present at the DAC’s image frequencies fold back into the audio-band at the output of the Class-D amplifier. An external low-pass filter is often placed between the DAC and the Class-D amplifier in order to attenuate this noise.

The TPA2011D1 has an integrated Image Reject Filter with a low-pass cutoff frequency of 130 kHz, which significantly attenuates this noise. Depending on the system noise specification, the integrated Image Reject Filter may help eliminate external filtering, thereby saving board space and component cost.
9.4 Device Functional Modes

9.4.1 Summing Input Signals With the TPA2011D1

Most wireless phones or PDAs need to sum signals at the audio power amplifier or just have two signal sources that need separate gain. The TPA2011D1 makes it easy to sum signals or use separate signal sources with different gains. Many phones now use the same speaker for the earpiece and ringer, where the wireless phone would require a much lower gain for the phone earpiece than for the ringer. PDAs and phones that have stereo headphones require summing of the right and left channels to output the stereo signal to the mono speaker.

9.4.1.1 Summing Two Differential Input Signals

Two extra resistors are needed for summing differential signals (a total of 5 components). The gain for each input source can be set independently (see Equation 1 and Equation 2, and Figure 30).

\[
\text{Gain 1} = \frac{\Delta V_O}{\Delta V_{I1}} = \frac{2 \times 150 \, \text{k}\Omega}{R_{I1}} \quad (V/V)
\]

\[
\text{Gain 2} = \frac{\Delta V_O}{\Delta V_{I2}} = \frac{2 \times 150 \, \text{k}\Omega}{R_{I2}} \quad (V/V)
\]

If summing left and right inputs with a gain of 1 V/V, use \( R_{I1} = R_{I2} = 300 \, \text{k}\Omega \).

If summing a ring tone and a phone signal, set the ring-tone gain to Gain 2 = 2 V/V, and the phone gain to gain 1 = 0.1 V/V. The resistor values would be:

\( R_{I1} = 3 \, \text{M}\Omega \), and \( R_{I2} = 150 \, \text{k}\Omega \).

![Figure 30. Application Schematic With TPA2011D1 Summing Two Differential Inputs](image_url)

9.4.1.2 Summing a Differential Input Signal and a Single-Ended Input Signal

Figure 31 shows how to sum a differential input signal and a single-ended input signal. Ground noise can couple in through IN+ with this method. It is better to use differential inputs. The corner frequency of the single-ended input is set by \( C_{I2} \), shown in Equation 5. To assure that each input is balanced, the single-ended input must be driven by a low-impedance source even if the input is not in use.

\[
\text{Gain 1} = \frac{\Delta V_O}{\Delta V_{I1}} = \frac{2 \times 150 \, \text{k}\Omega}{R_{I1}} \quad (V/V)
\]

\[
\text{Gain 2} = \frac{\Delta V_O}{\Delta V_{I2}} = \frac{2 \times 150 \, \text{k}\Omega}{R_{I2}} \quad (V/V)
\]
Device Functional Modes (continued)

\[ C_{I2} = \frac{1}{2\pi R_{I2} f_{c2}} \]  

If summing a ring tone and a phone signal, the phone signal should use a differential input signal while the ring tone might be limited to a single-ended signal. Phone gain is set at gain 1 = 0.1 V/V, and the ring-tone gain is set to gain 2 = 2 V/V, the resistor values would be...

\[ R_{I1} = 3 \, \text{M} \Omega, \quad \text{and} \quad R_{I2} = 150 \, \text{k}\Omega. \]

The high pass corner frequency of the single-ended input is set by \( C_{I2} \). If the desired corner frequency is less than 20 Hz...

\[ C_{I2} > \frac{1}{2\pi 150 \, \text{k}\Omega 20 \, \text{Hz}} \]

\[ C_{I2} > 53 \, \text{nF} \]

\( \text{Figure 31. Application Schematic With TPA2011D1 Summing Differential Input and Single-Ended Input Signals} \)

9.4.1.3 Summing Two Single-Ended Input Signals

Four resistors and three capacitors are needed for summing single-ended input signals. The gain and corner frequencies \( (f_{c1} \text{ and } f_{c2}) \) for each input source can be set independently (see Equation 8 through Equation 11, and Figure 32). Resistor, \( R_P \), and capacitor, \( C_P \), are needed on the IN+ terminal to match the impedance on the IN– terminal. The single-ended inputs must be driven by low impedance sources even if one of the inputs is not outputting an ac signal.

\[ \text{Gain 1} = \frac{V}{V_{I1}} = \frac{2 \times 150 \, \text{k}\Omega}{R_{I1}} \]

\[ \text{Gain 2} = \frac{V}{V_{I2}} = \frac{2 \times 150 \, \text{k}\Omega}{R_{I2}} \]

\[ C_{I1} = \frac{1}{2\pi R_{I1} f_{c1}} \]

\[ C_{I2} = \frac{1}{2\pi R_{I2} f_{c2}} \]

\[ C_P = C_{I1} + C_{I2} \]
Device Functional Modes (continued)

\[ R_P = \frac{R_{I1} \times R_{I2}}{R_{I1} + R_{I2}} \]  

Figure 32. Application Schematic With TPA2011D1 Summing Two Single-Ended Inputs

9.4.2 Shutdown Mode

The TPA2011D1 can be put in shutdown mode when asserting SHUTDOWN pin to a logic LOW. While in shutdown mode, the device output stage is turned off and set into high impedance, making the current consumption very low. The device exits shutdown mode when a HIGH logic level is applied to SHUTDOWN pin.
10 Application and Implementation

NOTE
Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI’s customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

10.1 Application Information
These typical connection diagrams highlight the required external components and system level connections for proper operation of the device in several popular use cases. Each of these configurations can be realized using the Evaluation Modules (EVMs) for the device. These flexible modules allow full evaluation of the device in the most common modes of operation. Any design variation can be supported by TI through schematic and layout reviews. Visit e2e.ti.com for design assistance and join the audio amplifier discussion forum for additional information.

10.2 Typical Applications

10.2.1 TPA2011D1 with Differential Input

![Typical TPA2011D1 Application Schematic with Differential Input](image)

Figure 33. Typical TPA2011D1 Application Schematic with Differential Input

10.2.1.1 Design Requirements
For this design example, use the parameters listed in Table 1.

<table>
<thead>
<tr>
<th>DESIGN PARAMETER</th>
<th>EXAMPLE VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power supply</td>
<td>5 V</td>
</tr>
<tr>
<td>Enable input</td>
<td>High &gt; 2 V</td>
</tr>
<tr>
<td>Speaker</td>
<td>8 Ω</td>
</tr>
</tbody>
</table>

Table 1. Design Parameters
10.2.1.2 Detailed Design Procedure

10.2.1.2.1 Input Resistors (\(R_I\))

The input resistors (\(R_I\)) set the gain of the amplifier according to the following equation.

\[
\text{Gain} = \frac{2 \times 150k\Omega}{R_I} \left( \frac{V}{V} \right)
\]  

(14)

Resistor matching is very important in fully differential amplifiers. The balance of the output on the reference voltage depends on matched ratios of the resistors. CMRR, PSRR, and cancellation of the second harmonic distortion diminish if resistor mismatch occurs. Therefore, it is recommended to use 1% tolerance resistors or better to keep the performance optimized. Matching is more important than overall tolerance. Resistor arrays with 1% matching can be used with a tolerance greater than 1%.

Place the input resistors very close to the TPA2011D1 to limit noise injection on the high-impedance nodes.

For optimal performance, the gain should be set to 2 V/V or lower. Lower gain allows the TPA2011D1 to operate at its best, and keeps a high voltage at the input making the inputs less susceptible to noise.

10.2.1.2.2 Decoupling Capacitor (\(C_S\))

The TPA2011D1 is a high-performance class-D audio amplifier that requires adequate power supply decoupling to ensure the efficiency is high and total harmonic distortion (THD) is low. For higher frequency transients, spikes, or digital hash on the line, a good low equivalent-series-resistance (ESR) ceramic capacitor, typically 1 \(\mu\)F, placed as close as possible to the device VDD lead works best. Placing this decoupling capacitor close to the TPA2011D1 is very important for the efficiency of the class-D amplifier, because any resistance or inductance in the trace between the device and the capacitor can cause a loss in efficiency. For filtering lower-frequency noise signals, a 10 \(\mu\)F or greater capacitor placed near the audio power amplifier would also help, but it is not required in most applications because of the high PSRR of this device.

10.2.1.3 Application Curves

For application curves, see the figures listed in Table 2.

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>FIGURE NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Power vs Supply Resistance</td>
<td>Figure 11</td>
</tr>
<tr>
<td>GSM Power Supply Rejection vs Time</td>
<td>Figure 26</td>
</tr>
<tr>
<td>GSM Power Supply Rejection vs Frequency</td>
<td>Figure 27</td>
</tr>
</tbody>
</table>
10.2.2 TPA2011D1 with Differential Input and Input Capacitors

Figure 34. TPA2011D1 Application Schematic with Differential Input and Input Capacitors

10.2.2.1 Design Requirements
For this design example, use the parameters listed in Table 1.

10.2.2.2 Detailed Design Procedure
For the design procedure see Input Resistors ($R_I$) and Decoupling Capacitor ($C_S$).

10.2.2.2.1 Input Capacitors ($C_I$)
The TPA2011D1 does not require input coupling capacitors if the design uses a differential source that is biased from 0.5 V to VDD –0.8 V. If the input signal is not biased within the recommended common mode input range, if needing to use the input as a high pass filter, or if using a single-ended source, input coupling capacitors are required.

The input capacitors and input resistors form a high-pass filter with the corner frequency, $f_C$, determined in the following equation.

$$f_C = \frac{1}{2\pi R_I C_I}$$

The value of the input capacitor is important to consider as it directly affects the bass (low frequency) performance of the circuit. Speakers in wireless phones cannot usually respond well to low frequencies, so the corner frequency can be set to block low frequencies in this application.

The equation below is reconfigured to solve for the input coupling capacitance.

$$C_I = \frac{1}{2\pi f_C R_I}$$

(16)

If the corner frequency is within the audio band, the capacitors should have a tolerance of ±10% or better, because any mismatch in capacitance causes an impedance mismatch at the corner frequency and below.

For a flat low-frequency response, use large input coupling capacitors (1μF). However, in a GSM phone the ground signal is fluctuating at 217 Hz, but the signal from the codec does not have the same 217 Hz fluctuation. The difference between the two signals is amplified, sent to the speaker, and heard as a 217 Hz hum.

10.2.2.3 Application Curves
For application curves, see the figures listed in Table 2.
10.2.3 TPA2011D1 with Single-Ended Input

10.2.3.1 Design Requirements
For this design example, use the parameters listed in Table 1.

10.2.3.2 Detailed Design Procedure
For the design procedure see Input Resistors ($R_I$), Decoupling Capacitor ($C_S$), and Input Capacitors ($C_I$).

10.2.3.3 Application Curves
For application curves, see the figures listed in Table 2.

11 Power Supply Recommendations
The TPA2011D1 is designed to operate from an input voltage supply range between 2.5-V and 5.5-V. Therefore, the output voltage range of power supply should be within this range and well regulated. The current capability of upper power should not exceed the maximum current limit of the power switch.

11.1 Power Supply Decoupling Capacitors
The TPA2011D1 requires adequate power supply decoupling to ensure a high efficiency operation with low total harmonic distortion (THD). Place a low equivalent-series-resistance (ESR) ceramic capacitor, typically 0.1 μF, within 2 mm of the VDD pin. This choice of capacitor and placement helps with higher frequency transients, spikes, or digital hash on the line. In addition to the 0.1 μF ceramic capacitor, is recommended to place a 2.2 μF to 10 μF capacitor on the VDD supply trace. This larger capacitor acts as a charge reservoir, providing energy faster than the board supply, thus helping to prevent any drop in the supply voltage.
12 Layout

12.1 Layout Guidelines

In making the pad size for the DSBGA balls, TI recommends that the layout use nonsolder mask defined (NSMD) land. With this method, the solder mask opening is made larger than the desired land area, and the opening size is defined by the copper pad width. Figure 36 shows the appropriate diameters for a DSBGA layout.

Place all the external components close to the TPA2011D1 device. Placing the decoupling capacitors as close as possible to the device is important for the efficiency of the class-D amplifier. Any resistance or inductance in the trace between the device and the capacitor can cause a loss in efficiency.

An on-pad via is not required to route the middle ball B2 (PV_DD) of the TPA2011D1. Just short ball B2 (PV_DD) to ball B1 (V_DD) and connect both to the supply trace as shown in Figure 37. This simplifies board routing and saves manufacturing cost.

![Figure 36. Land Pattern Dimensions](image)

Table 3. Land Pattern Dimensions

<table>
<thead>
<tr>
<th>SOLDER PAD DEFINITIONS</th>
<th>COPPER PAD</th>
<th>SOLDER MASK OPENING</th>
<th>COPPER THICKNESS</th>
<th>STENCIL OPENING</th>
<th>STENCIL THICKNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonsolder mask defined (NSMD)</td>
<td>0.23 mm</td>
<td>0.310 mm</td>
<td>1 oz max (0.032 mm)</td>
<td>0.275 mm x 0.275 mm Sq. (rounded corners)</td>
<td>0.1 mm thick</td>
</tr>
</tbody>
</table>

(1) Circuit traces from NSMD defined PWB lands should be 75 μm to 100 μm wide in the exposed area inside the solder mask opening. Wider trace widths reduce device stand-off and impact reliability.

(2) Best reliability results are achieved when the PWB laminate glass transition temperature is above the operating range of the intended application.

(3) Recommend solder paste is Type 3 or Type 4.

(4) For a PWB using a Ni/Au surface finish, the gold thickness should be less than 0.5 mm to avoid a reduction in thermal fatigue performance.

(5) Solder mask thickness should be less than 20 μm on top of the copper circuit pattern.

(6) Best solder stencil performance is achieved using laser cut stencils with electro polishing. Use of chemically etched stencils give inferior solder paste volume control.

(7) Trace routing away from DSBGA device should be balanced in X and Y directions to avoid unintentional component movement due to solder wetting forces.
12.2 Layout Example

Figure 37. TPA2011D1 Layout Example

- Top Layer Ground Plane
- Top Layer Traces
- Pad to Top Layer Ground Plane
- Via to Bottom Layer Ground Plane
- Via to Power Supply

Decoupling capacitor placed as close as possible to the device

Input Resistors placed as close as possible to the device
13 Device and Documentation Support

13.1 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community  **TI's Engineer-to-Engineer (E2E) Community.** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

**Design Support**  **TI's Design Support** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

13.2 Trademarks

E2E is a trademark of Texas Instruments. All other trademarks are the property of their respective owners.

13.3 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

13.4 Glossary

**SLYZ022 — TI Glossary.** This glossary lists and explains terms, acronyms, and definitions.

14 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.
### Packaging Information

<table>
<thead>
<tr>
<th>Orderable Device</th>
<th>Status (1)</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>Package Qty</th>
<th>Eco Plan (2)</th>
<th>Lead finish/Ball material</th>
<th>MSL Peak Temp (3)</th>
<th>Op Temp (°C)</th>
<th>Device Marking (4/5)</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPA2011D1YFFR</td>
<td>ACTIVE</td>
<td>DSBGA</td>
<td>YFF</td>
<td>9</td>
<td>3000</td>
<td>RoHS &amp; Green</td>
<td>SNAGCU</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 85</td>
<td>OEW</td>
<td>Samples</td>
</tr>
<tr>
<td>TPA2011D1YFFT</td>
<td>ACTIVE</td>
<td>DSBGA</td>
<td>YFF</td>
<td>9</td>
<td>250</td>
<td>RoHS &amp; Green</td>
<td>SNAGCU</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 85</td>
<td>OEW</td>
<td>Samples</td>
</tr>
</tbody>
</table>

(1) The marketing status values are defined as follows:

**ACTIVE**: Product device recommended for new designs.

**LIFEBUY**: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND**: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW**: Device has been announced but is not in production. Samples may or may not be available.

**OBsolete**: TI has discontinued the production of the device.

(2) **RoHS**: TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substances do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt**: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green**: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) **MSL, Peak Temp.**: The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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**TAPE AND REEL INFORMATION**

![Reel Dimensions Diagram](image)

**TAPE DIMENSIONS**

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A0</td>
<td>Dimension designed to accommodate the component width</td>
</tr>
<tr>
<td>B0</td>
<td>Dimension designed to accommodate the component length</td>
</tr>
<tr>
<td>K0</td>
<td>Dimension designed to accommodate the component thickness</td>
</tr>
<tr>
<td>W</td>
<td>Overall width of the carrier tape</td>
</tr>
<tr>
<td>P1</td>
<td>Pitch between successive cavity centers</td>
</tr>
</tbody>
</table>

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**

![Quadrant Assignments Diagram](image)

*All dimensions are nominal.*

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Reel Diameter (mm)</th>
<th>Reel Width W1 (mm)</th>
<th>A0  (mm)</th>
<th>B0  (mm)</th>
<th>K0  (mm)</th>
<th>P1  (mm)</th>
<th>W  (mm)</th>
<th>Pin1 Quadrant</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPA2011D1YFFR</td>
<td>DSBGA</td>
<td>YFF</td>
<td>9</td>
<td>3000</td>
<td>180.0</td>
<td>8.4</td>
<td>1.34</td>
<td>1.34</td>
<td>0.81</td>
<td>4.0</td>
<td>8.0</td>
<td>Q1</td>
</tr>
<tr>
<td>TPA2011D1YFFT</td>
<td>DSBGA</td>
<td>YFF</td>
<td>9</td>
<td>250</td>
<td>180.0</td>
<td>8.4</td>
<td>1.34</td>
<td>1.34</td>
<td>0.81</td>
<td>4.0</td>
<td>8.0</td>
<td>Q1</td>
</tr>
</tbody>
</table>
### TAPE AND REEL BOX DIMENSIONS

<table>
<thead>
<tr>
<th>Device</th>
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<th>Package Drawing</th>
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<th>Width (mm)</th>
<th>Height (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPA2011D1YFFR</td>
<td>DSBGA</td>
<td>YFF</td>
<td>9</td>
<td>3000</td>
<td>182.0</td>
<td>182.0</td>
<td>20.0</td>
</tr>
<tr>
<td>TPA2011D1YFFT</td>
<td>DSBGA</td>
<td>YFF</td>
<td>9</td>
<td>250</td>
<td>182.0</td>
<td>182.0</td>
<td>20.0</td>
</tr>
</tbody>
</table>

*All dimensions are nominal*
NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
NOTES: (continued)

3. Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. For more information, see Texas Instruments literature number SNVA009 (www.ti.com/lit/syva009).
4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.
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