

## TPA2012D2 2.1-W/Channel Stereo Filter-Free Class-D Audio Power Amplifier

### 1 Features

- Output Power By Package:
  - WQFN:
    - 2.1 W/Ch Into 4  $\Omega$  at 5 V
    - 1.4 W/Ch Into 8  $\Omega$  at 5 V
    - 720 mW/Ch Into 8  $\Omega$  at 3.6 V
  - DSBGA:
    - 1.2 W/Ch Into 4  $\Omega$  at 5 V (Thermally Limited)
    - 1.3 W/Ch Into 8  $\Omega$  at 5 V
    - 720 mW/Ch Into 8  $\Omega$  at 3.6 V
- Only Two External Components Required
- Power Supply Range: 2.5 V to 5.5 V
- Independent Shutdown Control for Each Channel
- Selectable Gain of 6, 12, 18, and 24 dB
- Internal Pulldown Resistor on Shutdown Pins
- High PSRR: 77 dB at 217 Hz
- Fast Start-Up Time (3.5 ms)
- Low Supply Current
- Low Shutdown Current
- Short-Circuit and Thermal Protection
- Space-Saving Packages
  - 2.01-mm  $\times$  2.01-mm NanoFree™ DSBGA (YZH)
  - 4-mm  $\times$  4-mm Thin WQFN (RTJ) With PowerPAD™

### 2 Applications

- Wireless or Cellular Handsets and PDAs
- Portable DVD Players
- Notebook PCs
- Portable Radios
- Portable Gaming
- Educational Toys
- USB Speakers

### 3 Description

The TPA2012D2 is a stereo, filter-free, Class-D audio amplifier (Class-D amp) available in a DSBGA or WQFN package. The TPA2012D2 only requires two external components for operation.

The TPA2012D2 features independent shutdown controls for each channel. The gain can be selected to 6, 12, 18, or 24 dB using the G0 and G1 gain select pins. High PSRR and differential architecture provide increased immunity to noise and RF rectification. In addition to these features, a fast start-up time and small package size make the TPA2012D2 class-D amp an ideal choice for both cellular handsets and PDAs.

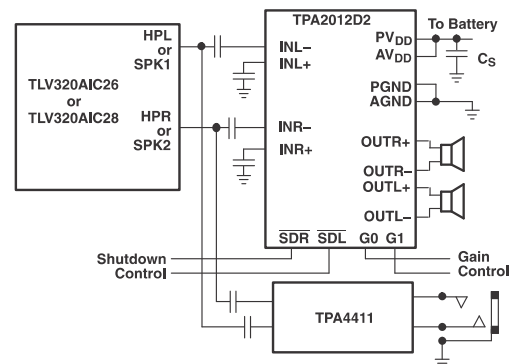
The TPA2012D2 is capable of driving 1.4 W/Ch at 5 V or 720 mW/Ch at 3.6 V into 8  $\Omega$ . The TPA2012D2 is also capable of driving 4  $\Omega$ . The TPA2012D2 is thermally limited in DSBGA and may not achieve 2.1 W/Ch for 4  $\Omega$ . The maximum output power in the DSBGA is determined by the ability of the circuit board to remove heat. Figure 33 shows thermally limited region of the DSBGA in relation to the WQFN package. The TPA2012D2 provides thermal and short-circuit protection.

**Device Information<sup>(1)</sup>**

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TPA2012D2	DSBGA (16)	2.01 mm $\times$ 2.01 mm
	WQFN (20)	4.00 mm $\times$ 4.00 mm

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

### Simplified Application Schematic



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## 4 Revision History

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

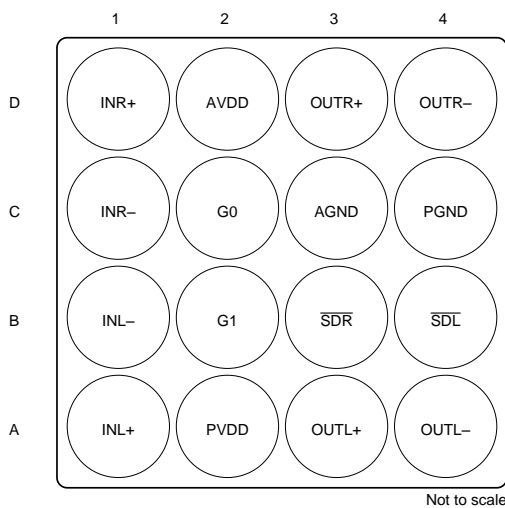
<b>Changes from Revision E (September 2016) to Revision F</b>	<b>Page</b>
<ul style="list-style-type: none"> <li>Switched the BODY SIZE values in the <i>Device Information</i> table: DSBGA From: 4.00 mm × 4.00 mm To: 2.01 mm × 2.01 mm and WQFN From: 2.01 mm × 2.01 mm To: 4.00 mm × 4.00 mm .....</li> </ul>	<b>1</b>
<b>Changes from Revision D (June 2008) to Revision E</b>	<b>Page</b>
<ul style="list-style-type: none"> <li>Added <i>ESD Ratings</i> table, <i>Feature Description</i> section, <i>Device Functional Modes</i>, <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, and <i>Mechanical, Packaging, and Orderable Information</i> section .....</li> <li>Deleted Available-Options table; see POA at the end of the data sheet .....</li> <li>Deleted previous application schematics: Typical Application Circuit (previously Figure 33), TPA2012D2 Application Schematic With Differential Input and Input Capacitors (previously Figure 34), and TPA2012D2 Application Schematic With Single-Ended Input (previously Figure 35) .....</li> </ul>	<b>1</b> <b>1</b> <b>16</b>

## 5 Device Comparison Table

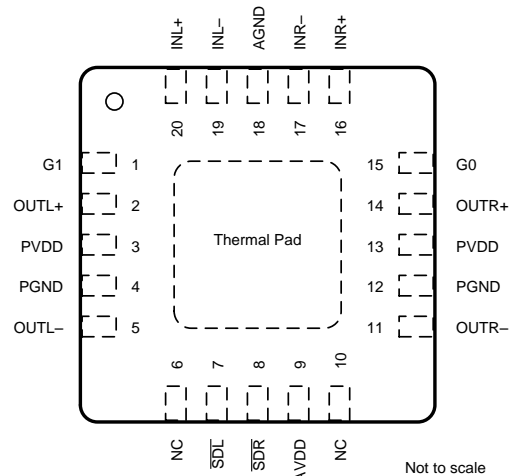
DEVICE NO.	SPEAKER AMP TYPE	SPECIAL FEATURE	OUTPUT POWER (M)	PSRR (dB)
TPA2012D2	Class D	—	2.1	71
TPA2016D2	Class D	AGC/DRC	2.8	80
TPA2026D2	Class D	AGC/DRC	3.2	80

## 6 Pin Configuration and Functions

**YZH Package  
16-Pin DSBGA  
Top View**



**RTJ Package  
20-Pin WQFN  
Top View**



### Pin Functions

NAME	PIN		I/O	DESCRIPTION
	DSBGA	WQFN		
AGND	C3	18	I	Analog ground
AVDD	D2	9	I	Analog supply (must be same voltage as PVDD)
G0	C2	15	I	Gain select (LSB)
G1	B2	1	I	Gain select (MSB)
INL–	B1	19	I	Left channel negative input
INL+	A1	20	I	Left channel positive input
INR–	C1	17	I	Right channel negative input
INR+	D1	16	I	Right channel positive input
NC	—	6, 10	—	No internal connection
OUTL–	A4	5	O	Left channel negative differential output
OUTL+	A3	2	O	Left channel positive differential output
OUTR–	D4	11	O	Right channel negative differential output
OUTR+	D3	14	O	Right channel positive differential output
PGND	C4	4, 12	I	Power ground
PVDD	A2	3, 13	I	Power supply (must be same voltage as AVDD)
SDL	B4	7	I	Left channel shutdown terminal (active low)
SDR	B3	8	I	Right channel shutdown terminal (active low)
Thermal Pad	—	—	—	Connect the thermal pad of WQFN package to PCB GND

## 7 Specifications

### 7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

		MIN	MAX	UNIT
Supply voltage, $V_{SS}$ (AVDD, PVDD)	Active mode	−0.3	6	V
	Shutdown mode	−0.3	7	
Input voltage, $V_I$		−0.3	$V_{DD} + 0.3$	V
Continuous total power dissipation		See <a href="#">Dissipation Rating Table</a>		
Operating junction temperature, $T_J$		−40	150	°C
Storage temperature, $T_{stg}$		−65	150	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

### 7.2 ESD Ratings

		VALUE	UNIT
$V_{(ESD)}$ Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	±2000	V
	Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup>	±1500	

- (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

over operating free-air temperature range (unless otherwise noted)

		MIN	MAX	UNIT
$V_{SS}$	Supply voltage, AVDD, PVDD	2.5	5.5	V
$V_{IH}$	High-level input voltage, $\overline{SDL}$ , $\overline{SDR}$ , G0, G1	1.3		V
$V_{IL}$	Low-level input voltage, $\overline{SDL}$ , $\overline{SDR}$ , G0, G1		0.35	V
$T_A$	Operating free-air temperature	−40	85	°C

### 7.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		TPA2012D2		UNIT
		YZH (DSBGA)	RTJ (WQFN)	
		16 PINS	20 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	71.4	34.6	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	0.4	34.3	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	14	11.5	°C/W
$\psi_{JT}$	Junction-to-top characterization parameter	1.8	0.4	°C/W
$\psi_{JB}$	Junction-to-board characterization parameter	13.3	11.6	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	—	3.2	°C/W

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

## 7.5 Electrical Characteristics

 $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V <sub>ool</sub>	Output offset voltage (measured differentially)	Inputs ac grounded, A <sub>V</sub> = 6 dB, V <sub>DD</sub> = 2.5 to 5.5 V			5	25	mV
PSRR	Power supply rejection ratio	V <sub>DD</sub> = 2.5 to 5.5 V			−75	−55	dB
V <sub>icm</sub>	Common-mode input voltage			0.5	V <sub>DD</sub> − 0.8		V
CMRR	Common-mode rejection ration	Inputs shorted together, V <sub>DD</sub> = 2.5 to 5.5 V			−69	−50	dB
I <sub>IH</sub>	High-level input current	V <sub>DD</sub> = 5.5 V, V <sub>I</sub> = V <sub>DD</sub>				50	μA
I <sub>IL</sub>	Low-level input current	V <sub>DD</sub> = 5.5 V, V <sub>I</sub> = 0 V				5	μA
I <sub>DD</sub>	Supply current	V <sub>DD</sub> = 5.5 V, no load or output filter			6	9	mA
		V <sub>DD</sub> = 3.6 V, no load or output filter			5	7.5	
		V <sub>DD</sub> = 2.5 V, no load or output filter			4	6	
		Shutdown mode				1.5	μA
r <sub>DS(on)</sub>	Static drain-source on-state resistance	V <sub>DD</sub> = 5.5 V			500		mΩ
		V <sub>DD</sub> = 3.6 V			570		
		V <sub>DD</sub> = 2.5 V			700		
	Output impedance in shutdown mode	V <sub>(SDR, SDL)</sub> = 0.35 V			2		kΩ
f <sub>(sw)</sub>	Switching frequency	V <sub>DD</sub> = 2.5 V to 5.5 V		250	300	350	kHz
	Closed-loop voltage gain	G0, G1 = 0.35 V		5.5	6	6.5	dB
		G0 = V <sub>DD</sub> , G1 = 0.35 V		11.5	12	12.5	
		G0 = 0.35 V, G1 = V <sub>DD</sub>		17.5	18	18.5	
		G0, G1 = V <sub>DD</sub>		23.5	24	24.5	
OPERATING CHARACTERISTICS, R <sub>L</sub> = 8 Ω							
P <sub>O</sub>	Output power (per channel)	R <sub>L</sub> = 8 Ω	V <sub>DD</sub> = 5 V, f = 1 kHz, THD = 10%	1.4		W	
			V <sub>DD</sub> = 3.6 V, f = 1 kHz, THD = 10%	0.72			
		R <sub>L</sub> = 4 Ω	V <sub>DD</sub> = 5 V, f = 1 kHz, THD = 10%	2.1			
THD+N	Total harmonic distortion plus noise	P <sub>O</sub> = 1 W, V <sub>DD</sub> = 5 V, A <sub>V</sub> = 6 dB, f = 1 kHz		0.14%			
		P <sub>O</sub> = 0.5 W, V <sub>DD</sub> = 5 V, A <sub>V</sub> = 6 dB, f = 1 kHz		0.11%			
	Channel crosstalk	f = 1 kHz		−85		dB	
k <sub>SVR</sub>	Supply ripple rejection ratio	V <sub>DD</sub> = 5 V, A <sub>V</sub> = 6 dB, f = 217 Hz		−77		dB	
		V <sub>DD</sub> = 3.6 V, A <sub>V</sub> = 6 dB, f = 217 Hz		−73			
CMRR	Common mode rejection ratio	V <sub>DD</sub> = 3.6 V, V <sub>IC</sub> = 1 V <sub>pp</sub> , f = 217 Hz		−69		dB	
	Input impedance	A <sub>v</sub> = 6 dB		28.1		kΩ	
		A <sub>v</sub> = 12 dB		17.3			
		A <sub>v</sub> = 18 dB		9.8			
		A <sub>v</sub> = 24 dB		5.2			
	Start-up time from shutdown	V <sub>DD</sub> = 3.6 V		3.5		ms	
V <sub>n</sub>	Output voltage noise	V <sub>DD</sub> = 3.6 V, f = 20 to 20 kHz, inputs are ac grounded, A <sub>V</sub> = 6 dB	No weighting	35		μV	
			A weighting	27			

## 7.6 Dissipation Rating Table

PACKAGE	$T_A = 25^\circ\text{C}$ POWER RATING <sup>(1)</sup>	DERATING FACTOR	$T_A = 75^\circ\text{C}$ POWER RATING	$T_A = 85^\circ\text{C}$ POWER RATING
RTJ	5.2 W	41.6 mW/ $^\circ\text{C}$	3.12 W	2.7 W
YZH	1.2 W	9.12 mW/ $^\circ\text{C}$	690 mW	600 mW

(1) This data was taken using 2-oz trace and copper pad that is soldered directly to a JEDEC standard 4-layer 3 in  $\times$  3 in PCB.

## 7.7 Typical Characteristics

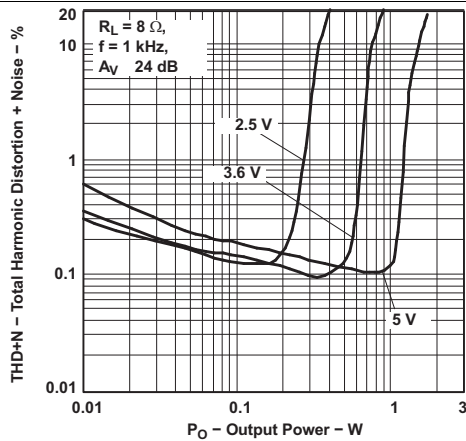


Figure 1. Total Harmonic Distortion vs Output Power

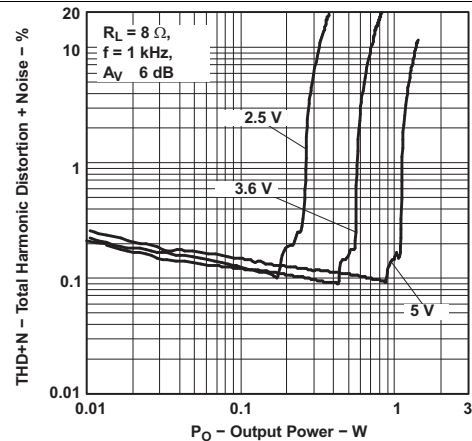


Figure 2. Total Harmonic Distortion vs Output Power

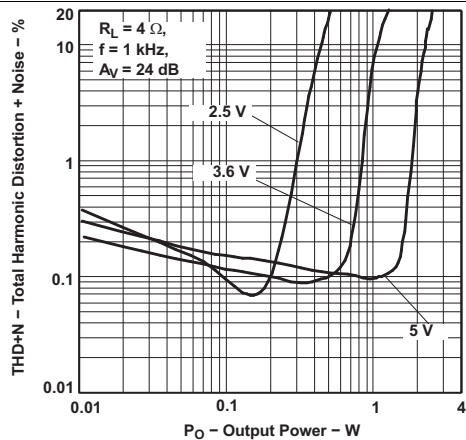


Figure 3. Total Harmonic Distortion vs Output Power

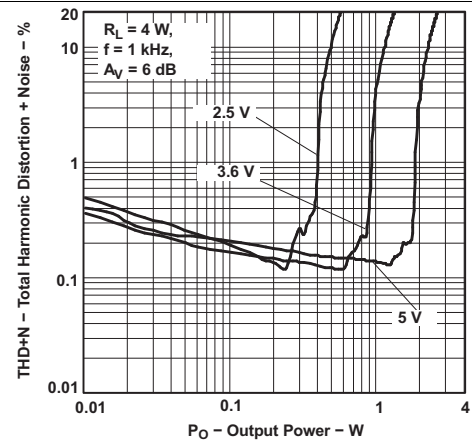


Figure 4. Total Harmonic Distortion vs Output Power

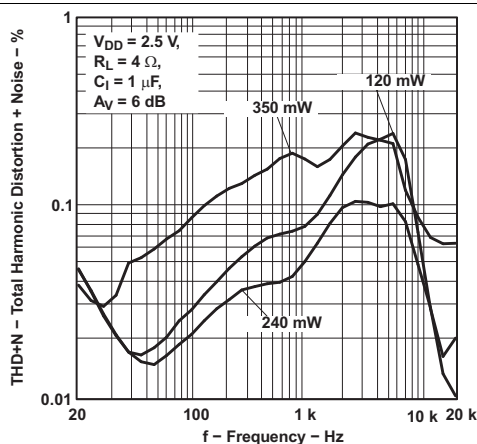


Figure 5. Total Harmonic Distortion vs Frequency

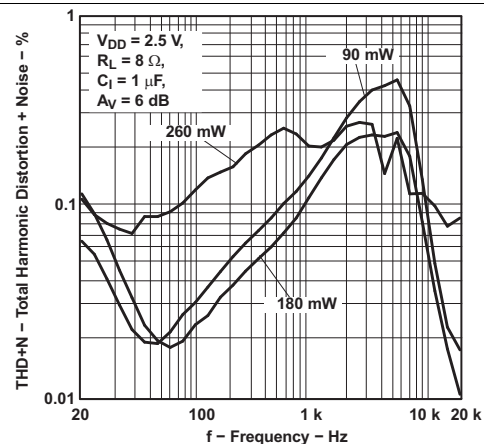
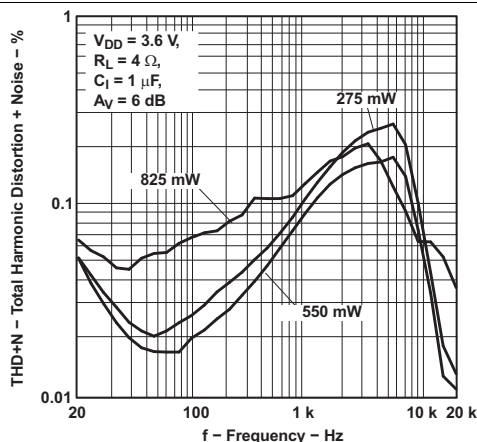
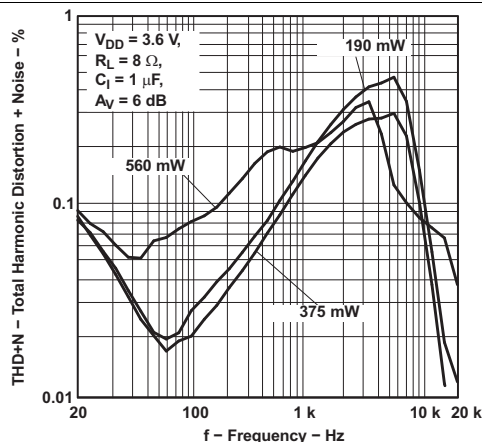


Figure 6. Total Harmonic Distortion vs Frequency

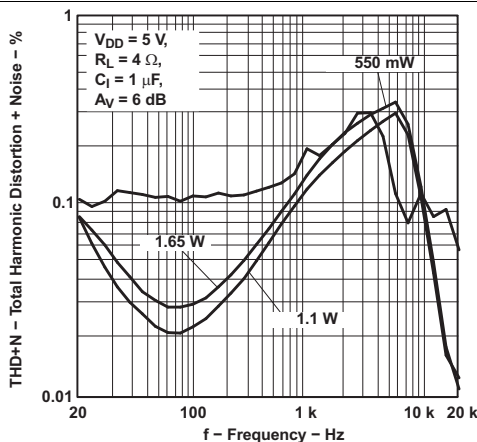
## Typical Characteristics (continued)



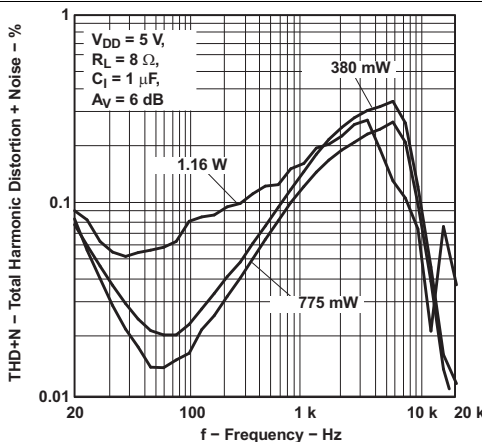
**Figure 7. Total Harmonic Distortion vs Frequency**



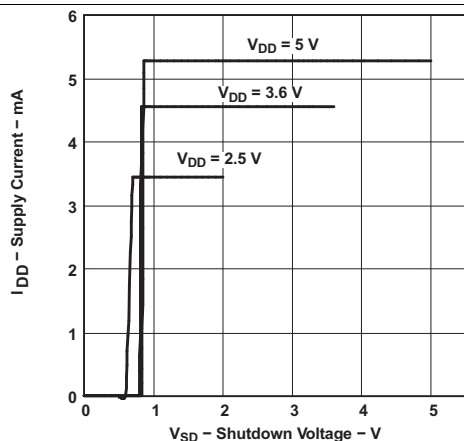
**Figure 8. Total Harmonic Distortion vs Frequency**



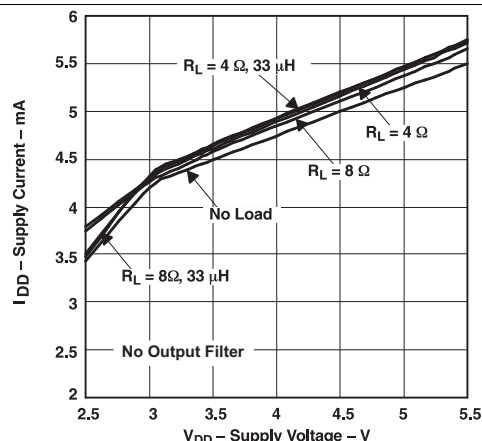
**Figure 9. Total Harmonic Distortion vs Frequency**



**Figure 10. Total Harmonic Distortion vs Frequency**

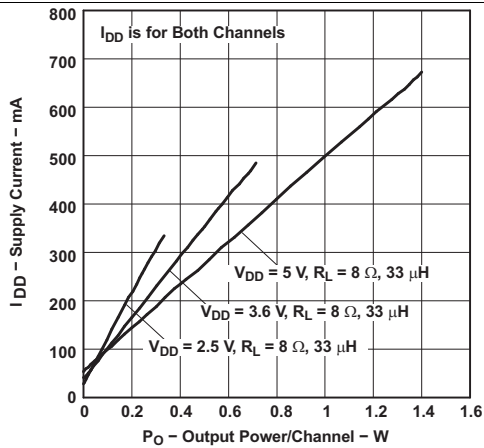
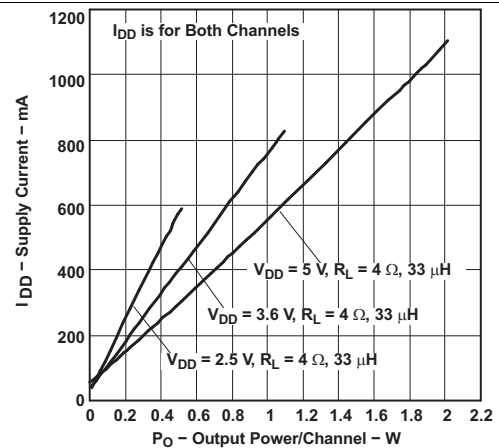
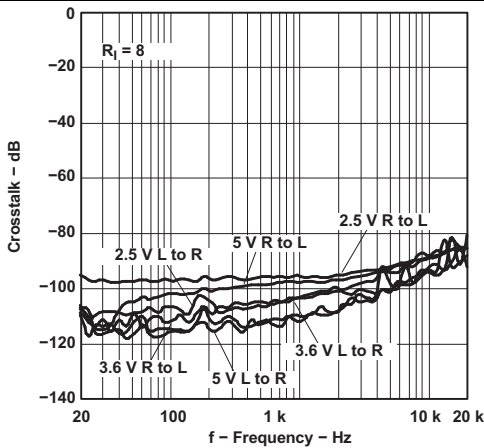
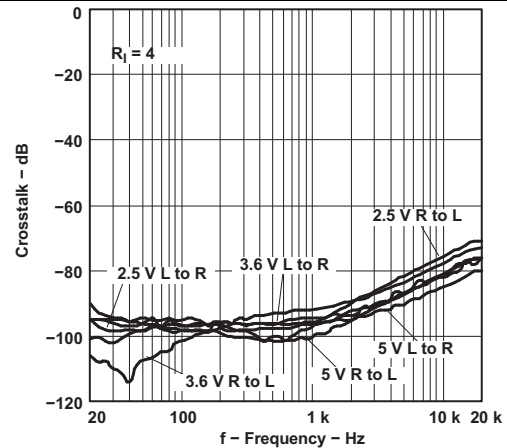
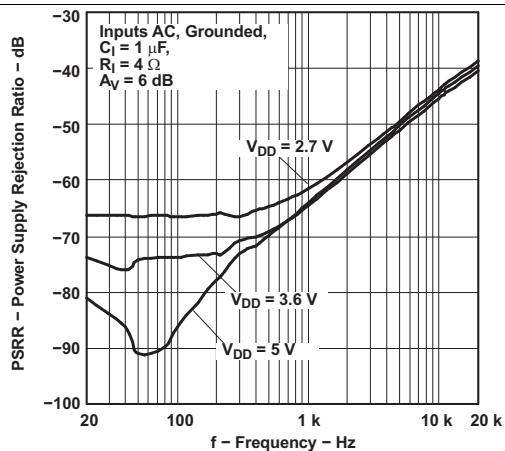
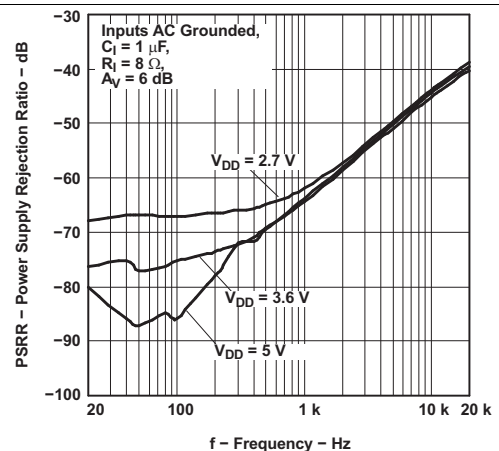


**Figure 11. Supply Current vs Shutdown Voltage**



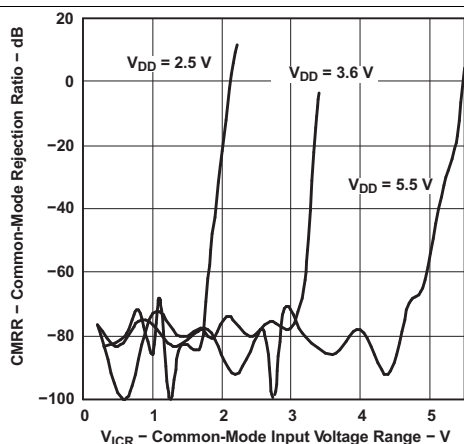
**Figure 12. Supply Current vs Supply Voltage**

## Typical Characteristics (continued)

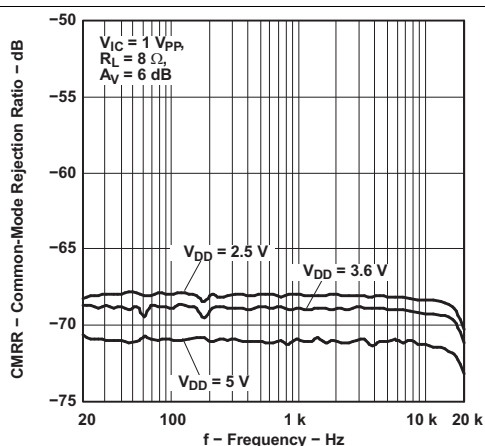

**Figure 13. Supply Current vs Output Power**

**Figure 14. Supply Current vs Output Power**

**Figure 15. Crosstalk vs Frequency**

**Figure 16. Crosstalk vs Frequency**

**Figure 17. Power Supply Rejection Ratio vs Frequency**

**Figure 18. Power Supply Rejection Ratio vs Frequency**



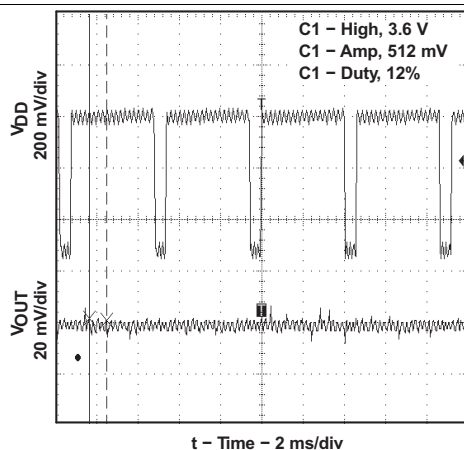
## Typical Characteristics (continued)



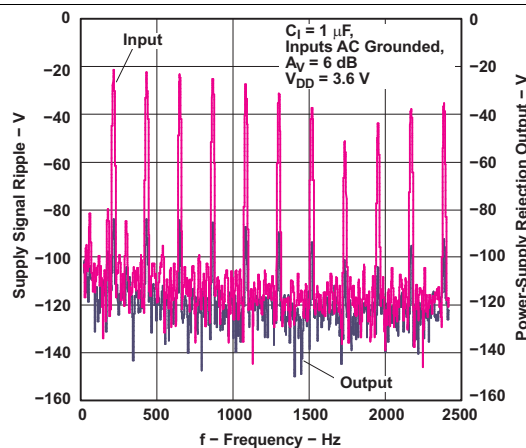
**Figure 19. Common-Mode Rejection Ratio vs Common-Mode Input Voltage**



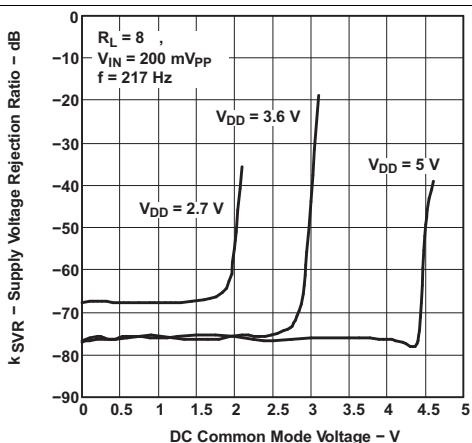
**Figure 20. Common-Mode Rejection Ratio vs Frequency**



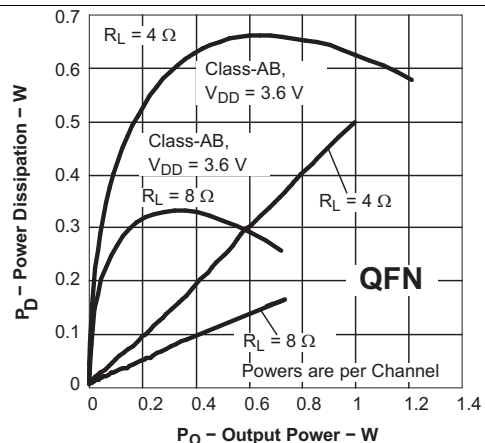
**Figure 21. GSM Power Supply Rejection vs Time**



**Figure 22. Power Supply Rejection vs Frequency**



**Figure 23. Supply Voltage Rejection Ratio vs DC Common-Mode Voltage**



**Figure 24. Power Dissipation vs Output Power**

## Typical Characteristics (continued)

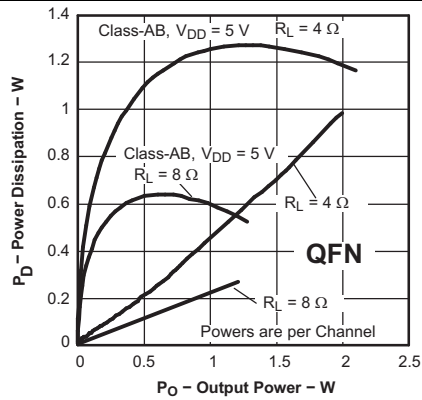


Figure 25. Power Dissipation vs Output Power

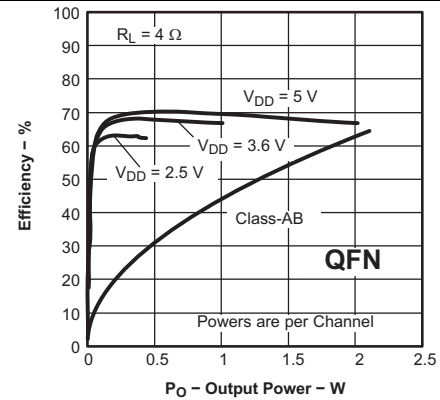


Figure 26. Efficiency vs Output Power

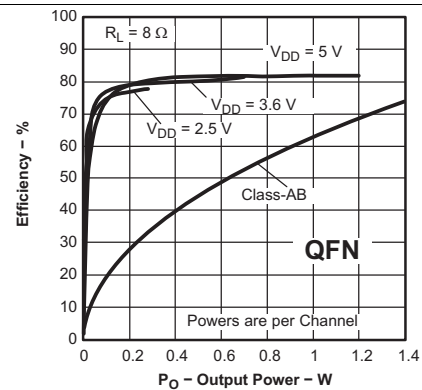


Figure 27. Efficiency vs Output Power

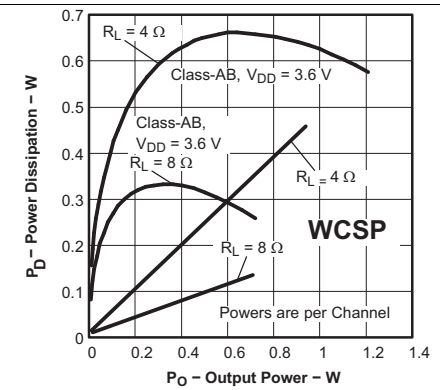


Figure 28. Power Dissipation vs Output Power

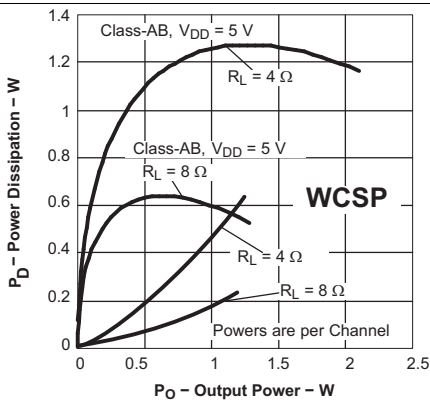


Figure 29. Power Dissipation vs Output Power

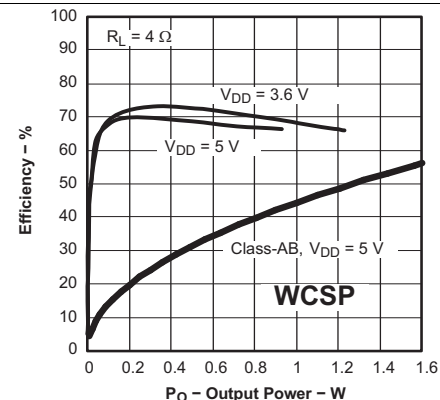
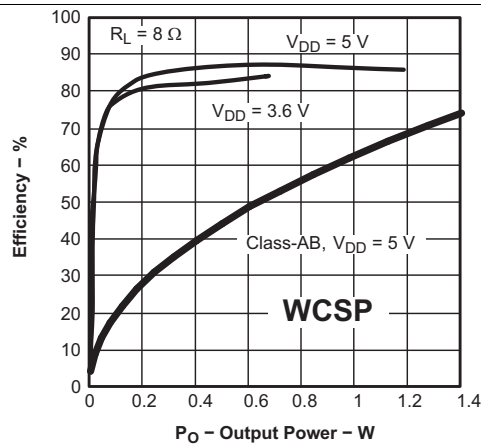
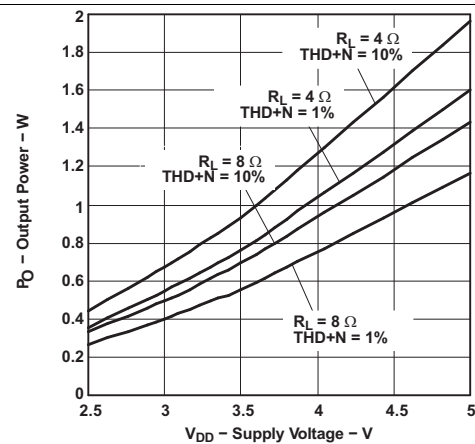


Figure 30. Efficiency vs Output Power

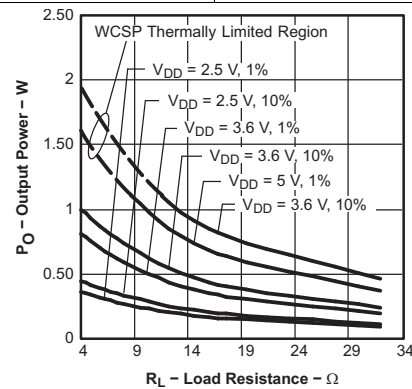
## Typical Characteristics (continued)



**Figure 31. Efficiency vs Output Power**



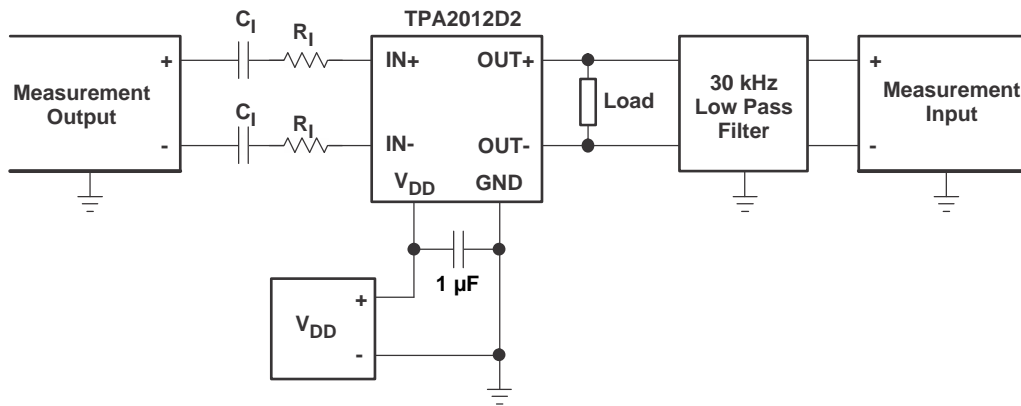
**Figure 32. Output Power vs Supply Voltage**



**Figure 33. Output Power vs Load Resistance**

## 8 Parameter Measurement Information

All parameters are measured according to the conditions described in the [Specifications](#). [Figure 34](#) shows the setup used for the typical characteristics of the test device.



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- (1)  $C_I$  was shorted for any common-mode input voltage measurement.
- (2) A 33- $\mu$ H inductor was placed in series with the load resistor to emulate a small speaker for efficiency measurements.
- (3) The 30-kHz low-pass filter is required even if the analyzer has an internal low-pass filter. An RC low-pass filter (100  $\Omega$ , 47 nF) is used on each output for the data sheet graphs.

**Figure 34. Test Setup For Graphs (Per Channel)**

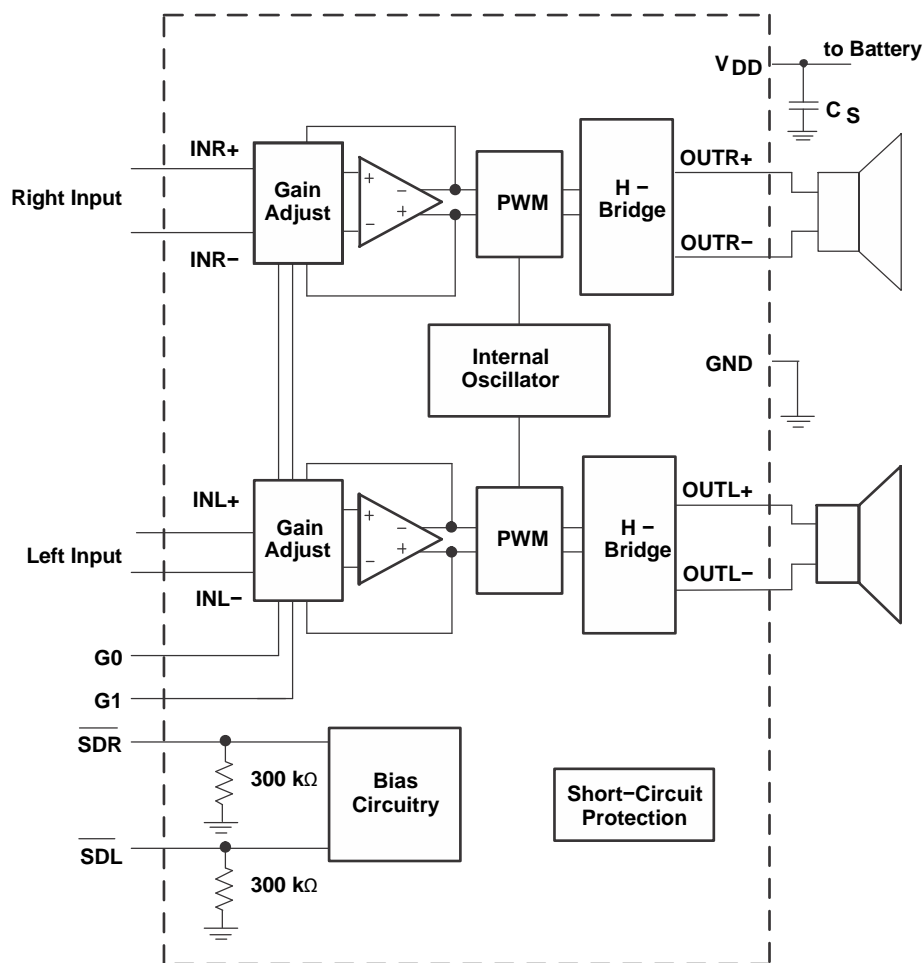
## 9 Detailed Description

### 9.1 Overview

The TPA2012D2 is capable of driving 1.4 W/Ch at 5-V or 720 mW/Ch at 3.6-V into 8  $\Omega$ . The TPA2012D2 is also capable of driving a load of 4  $\Omega$ .

The TPA2012D2 feature independent shutdown controls for each channel. High PSRR and differential architecture provide increased immunity to noise and RF rectification. The TPA2012D2 provides thermal and short-circuit protection.

### 9.2 Functional Block Diagram



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### 9.3 Feature Description

#### 9.3.1 Fixed Gain Setting

The TPA2012D2 has 4 selectable fixed gains: 6 dB, 12 dB, 18 dB, and 24 dB. Connect the G0 and G1 pins as shown in [Table 1](#).

**Table 1. Gain Setting**

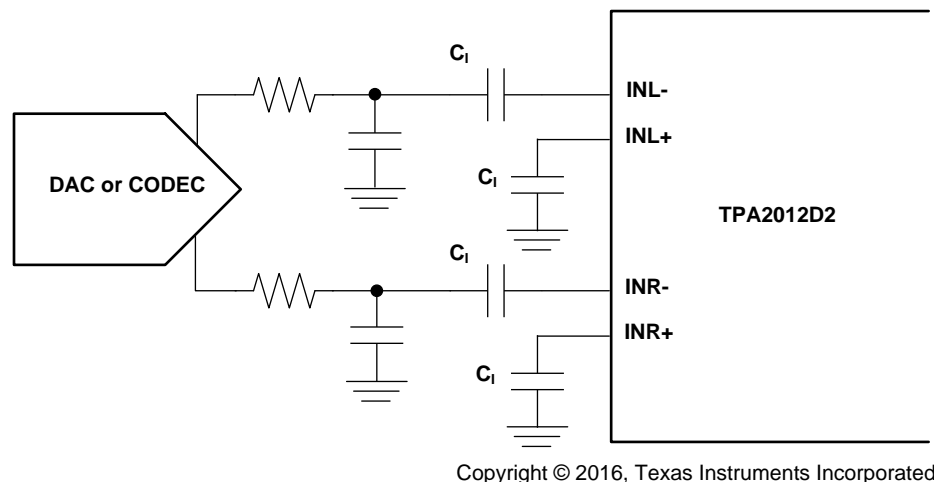
G1	G0	GAIN (V/V)	GAIN (dB)	INPUT IMPEDANCE ( $R_i$ , k $\Omega$ )
0	0	2	6	28.1
0	1	4	12	17.3
1	0	8	18	9.8
1	1	16	24	5.2

### 9.3.2 Short-Circuit Protection

TPA2012D2 goes to low duty cycle mode when a short-circuit event happens. To return to normal duty cycle mode, the device must be reset. The shutdown mode can be set through the SDL and SDR pins, or the device can be turned off and turned on to return to normal duty cycle mode. This feature protects the device without affecting long-term reliability.

### 9.3.3 Operation With DACs and CODECs

In using Class-D amplifiers with CODECs and DACs, sometimes there is an increase in the output noise floor from the audio amplifier. This occurs when mixing of the output frequencies of the CODEC and DAC mix with the switching frequencies of the audio amplifier input stage. The noise increase can be solved by placing a low-pass filter between the CODEC, DAC, and audio amplifier. This filters off the high frequencies that cause the problem and allow proper performance. The recommended resistor value is 100  $\Omega$  and the capacitor value of 47 nF. [Figure 35](#) shows the typical input filter.

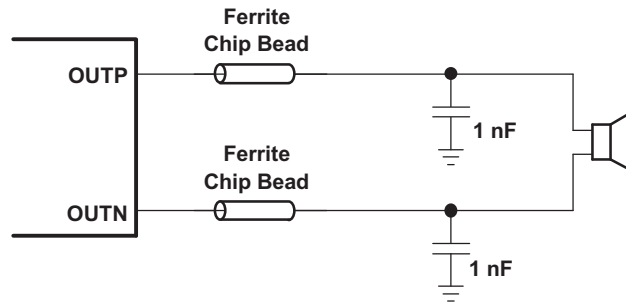

**Figure 35. Reducing Out-of-Band DAC Noise With External Input Filter**

### 9.3.4 Filter-Free Operation and Ferrite Bead Filters

A ferrite bead filter can often be used if the design is failing radiated emissions without an LC filter and the frequency sensitive circuit is greater than 1 MHz. This filter functions well for circuits that just have to pass FCC and CE because FCC and CE only test radiated emissions greater than 30 MHz. When choosing a ferrite bead, choose one with high impedance at high frequencies, and very low impedance at low frequencies. In addition, select a ferrite bead with adequate current rating to prevent distortion of the output signal.

Use an LC output filter if there are low frequency (< 1 MHz) EMI sensitive circuits and/or there are long leads from amplifier to speaker.

[Figure 36](#) shows typical ferrite bead and LC output filters.



**Figure 36. Typical Ferrite Chip Bead Filter (Chip Bead Example: TDK – MPZ1608S221A)**

## 9.4 Device Functional Modes

### 9.4.1 Shutdown Mode

The TPA2012D2 amplifier can be put in shutdown mode when asserting SDR and SDL pins to a logic LOW. While in shutdown mode, the device output stage is turned off and the current consumption is very low.

## 10 Application and Implementation

### NOTE

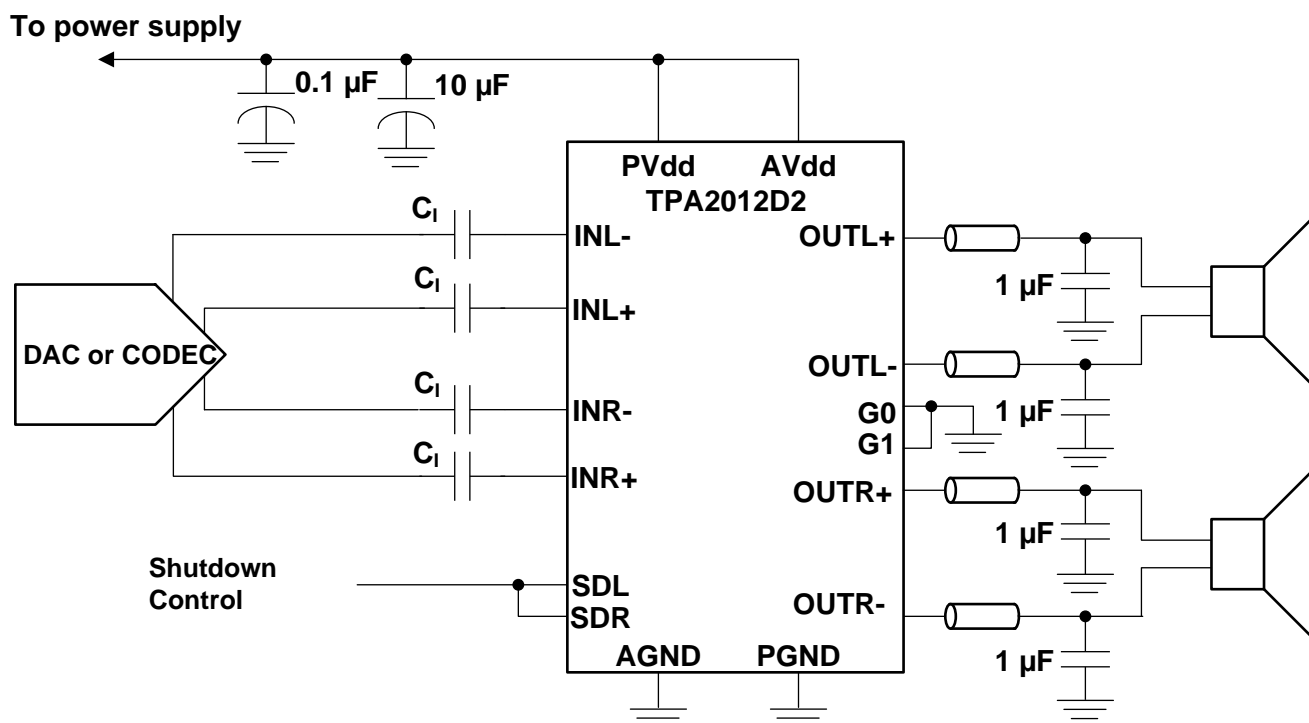
Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation 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. 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](http://e2e.ti.com) for design assistance and join the audio amplifier discussion forum for additional information.

### 10.2 Typical Applications

#### 10.2.1 TPA2012D2 With Differential Input Signal



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**Figure 37. Typical Application Schematic With Differential Input Signals**



## Typical Applications (continued)

### 10.2.1.1 Design Requirements

For this design example, use the parameters listed in [Table 2](#).

**Table 2. Design Parameters**

PARAMETER	VALUE
Power supply	5 V
Enable inputs	High > 1.3 V
	Low < 0.35 V
Speaker	8 $\Omega$

### 10.2.1.2 Detailed Design Procedure

#### 10.2.1.2.1 Surface Mount Capacitors

Temperature and applied DC voltage influence the actual capacitance of high-K materials. [Table 3](#) shows the relationship between the different types of high-K materials and their associated tolerances, temperature coefficients, and temperature ranges. Notice that a capacitor made with X5R material can lose up to 15% of its capacitance within its working temperature range.

In an application, the working capacitance of components made with high-K materials is generally much lower than nominal capacitance. A worst-case result with a typical X5R material might be –10% tolerance, –15% temperature effect, and –45% DC voltage effect at 50% of the rated voltage. This particular case would result in a working capacitance of 42% ( $0.9 \times 0.85 \times 0.55$ ) of the nominal value.

Select high-K ceramic capacitors according to the following rules:

1. Use capacitors made of materials with temperature coefficients of X5R, X7R, or better.
2. Use capacitors with DC voltage ratings of at least twice the application voltage. Use minimum 10-V capacitors for the TPA2012D2.
3. Choose a capacitance value at least twice the nominal value calculated for the application. Multiply the nominal value by a factor of 2 for safety. If a 10- $\mu$ F capacitor is required, use 20  $\mu$ F.

The preceding rules and recommendations apply to capacitors used in connection with the TPA2012D2. The TPA2012D2 cannot meet its performance specifications if the rules and recommendations are not followed.

**Table 3. Typical Tolerance and Temperature Coefficient of Capacitance by Material**

MATERIAL	COG/NPO	X7R	X5R
Typical tolerance	$\pm 5\%$	$\pm 10\%$	80% to –20%
Temperature	$\pm 30$ ppm	$\pm 15\%$	22% to –82%
Temperature range ( $^{\circ}$ C)	–55 $^{\circ}$ C to 125 $^{\circ}$ C	–55 $^{\circ}$ C to 125 $^{\circ}$ C	–30 $^{\circ}$ C to 85 $^{\circ}$ C

#### 10.2.1.2.2 Decoupling Capacitor ( $C_S$ )

The TPA2012D2 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  $PV_{DD}$  lead works best. Placing this decoupling capacitor close to the TPA2012D2 is 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 4.7  $\mu$ 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.

#### 10.2.1.2.3 Input Capacitors ( $C_I$ )

The TPA2012D2 does not require input coupling capacitors if the design uses a differential source that is biased from 0.5 V to  $V_{DD} - 0.8$  V. If the input signal is not biased within the recommended common-mode input range, if high-pass filtering is needed (see [Figure 37](#)), or if using a single-ended source (see [Figure 38](#)), input coupling capacitors are required.

The input capacitors and input resistors form a high-pass filter with the corner frequency,  $f_c$ , determined in Equation 1.

$$f_c = \frac{1}{(2\pi R_I C_I)} \quad (1)$$

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. Not using input capacitors can increase output offset.

Equation 2 is used to solve for the input coupling capacitance.

$$C_I = \frac{1}{(2\pi R_I f_c)} \quad (2)$$

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

### 10.2.1.3 Application Curves

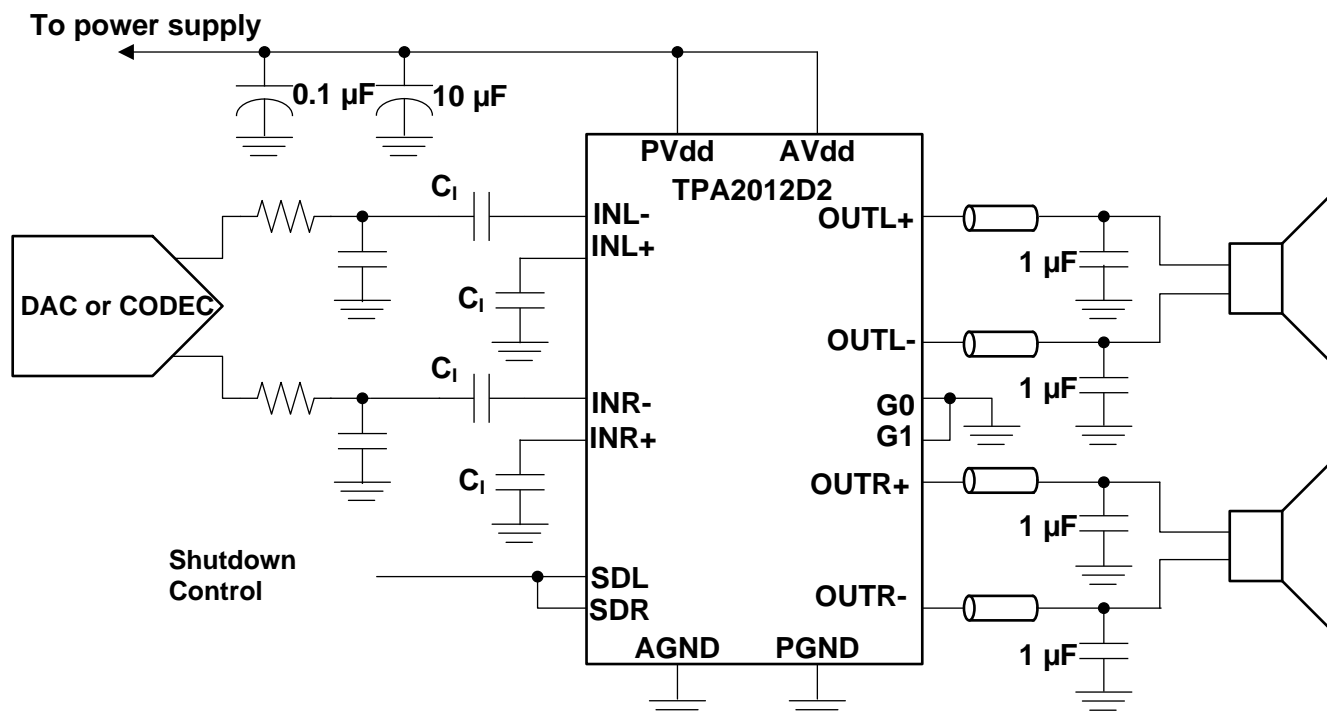
For application curves, see the figures listed in Table 4.

**Table 4. Table of Graphs**

DESCRIPTION	FIGURE NO. <sup>(1)</sup>
THD+N vs Output power	<a href="#">Figure 1</a>
THD+N vs Frequency	<a href="#">Figure 5</a>
Power dissipation vs Output power	<a href="#">Figure 24</a>
Output power vs Supply voltage	<a href="#">Figure 32</a>

(1) All figure numbers have a hyperlink to a figure in the [Typical Characteristics](#).

### 10.2.2 TPA2012D2 With Single-Ended Input Signal



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**Figure 38. Typical Application Schematic With Single-Ended Input Signal**

### 10.2.2.1 Design Requirements

For this design example, use the parameters listed in [Table 2](#).

### 10.2.2.2 Detailed Design Procedure

For the design procedure, see [Detailed Design Procedure](#) from the previous example.

### 10.2.2.3 Application Curves

For application curves, see the figures listed in [Table 4](#).

## 11 Power Supply Recommendations

The TPA2012D2 is designed to operate from an input voltage supply range from 2.5 V to 5.5 V. Therefore, the output voltage range of the power supply must be within this range. The current capability of upper power must not exceed the maximum current limit of the power switch.

### 11.1 Power Supply Decoupling Capacitor

The TPA2012D2 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- $\mu$ F, within 2 mm of the PVDD/AVDD pins. This choice of capacitor and placement helps with higher frequency transients, spikes, or digital hash on the line. In addition to the 0.1- $\mu$ F ceramic capacitor, TI recommends placing a 2.2- $\mu$ F to 10- $\mu$ F capacitor on the PVDD/AVDD supply trace. This larger capacitor acts as a charge reservoir, providing energy faster than the board supply, thus helping to prevent any droop in the supply voltage.

## 12 Layout

### 12.1 Layout Guidelines

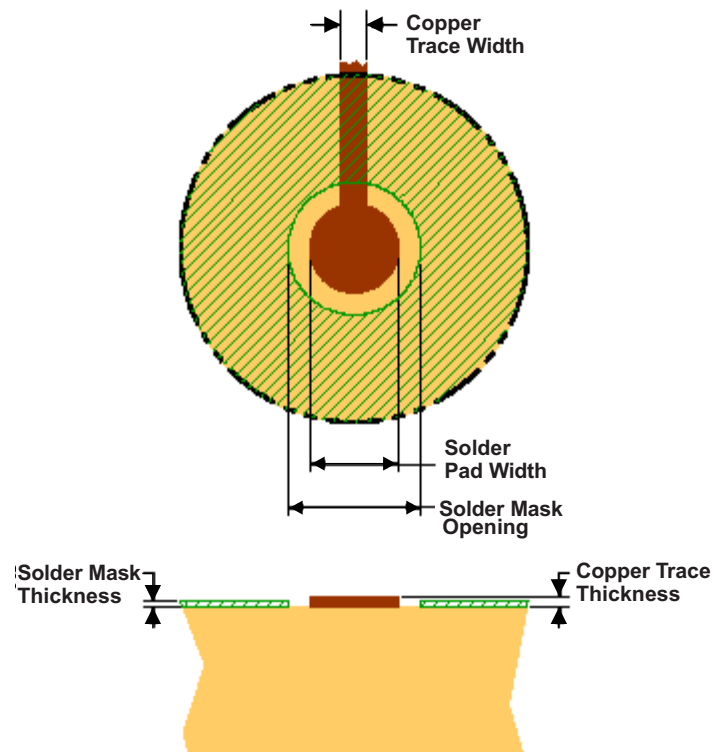
#### 12.1.1 Pad Side

In making the pad size for the DSBGA balls, TI recommends that the layout use non-solder 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 39](#) and [Table 5](#) shows the appropriate diameters for a DSBGA layout. The TPA2012D2 evaluation module (EVM) layout is shown in the next section as a layout example.

**Table 5. Land Pattern Dimensions<sup>(1)(2)(3)(4)</sup>**

SOLDER PAD DEFINITIONS	COPPER PAD	SOLDER MASK <sup>(5)</sup> OPENING	COPPER THICKNESS	STENCIL <sup>(6)(7)</sup> OPENING	STENCIL THICKNESS
Nonsolder mask defined (NSMD)	275 $\mu$ m (+0.0, -25 $\mu$ m)	375 $\mu$ m (+0.0, -25 $\mu$ m)	1 oz max (32 $\mu$ m)	275 $\mu$ m $\times$ 275 $\mu$ m (square) (rounded corners)	125 $\mu$ m

- (1) Circuit traces from NSMD defined PWB lands should be 75  $\mu$ m to 100  $\mu$ m 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 the 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 0.5  $\mu$ m to avoid a reduction in thermal fatigue performance.
- (5) Solder mask thickness should be less than 20  $\mu$ m 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 results in 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.



**Figure 39. Land Pattern Dimensions**

### 12.1.2 Component Location

Place all the external components very close to the TPA2012D2. Placing the decoupling capacitor,  $C_S$ , close to the TPA2012D2 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.

### 12.1.3 Trace Width

Recommended trace width at the solder balls is 75  $\mu\text{m}$  to 100  $\mu\text{m}$  to prevent solder wicking onto wider PCB traces.

For high current pins ( $PV_{DD}$ , PGND, and audio output pins) of the TPA2012D2, use 100- $\mu\text{m}$  trace widths at the solder balls and at least 500- $\mu\text{m}$  PCB traces to ensure proper performance and output power for the device.

For the remaining signals of the TPA2012D2, use 75- $\mu\text{m}$  to 100- $\mu\text{m}$  trace widths at the solder balls. The audio input pins ( $INR_{\pm}$  and  $INL_{\pm}$ ) must run side-by-side to maximize common-mode noise cancellation.

## 12.2 Layout Examples

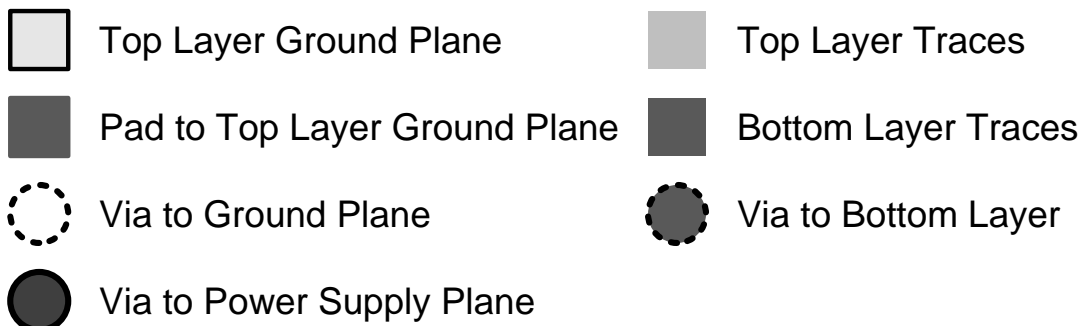
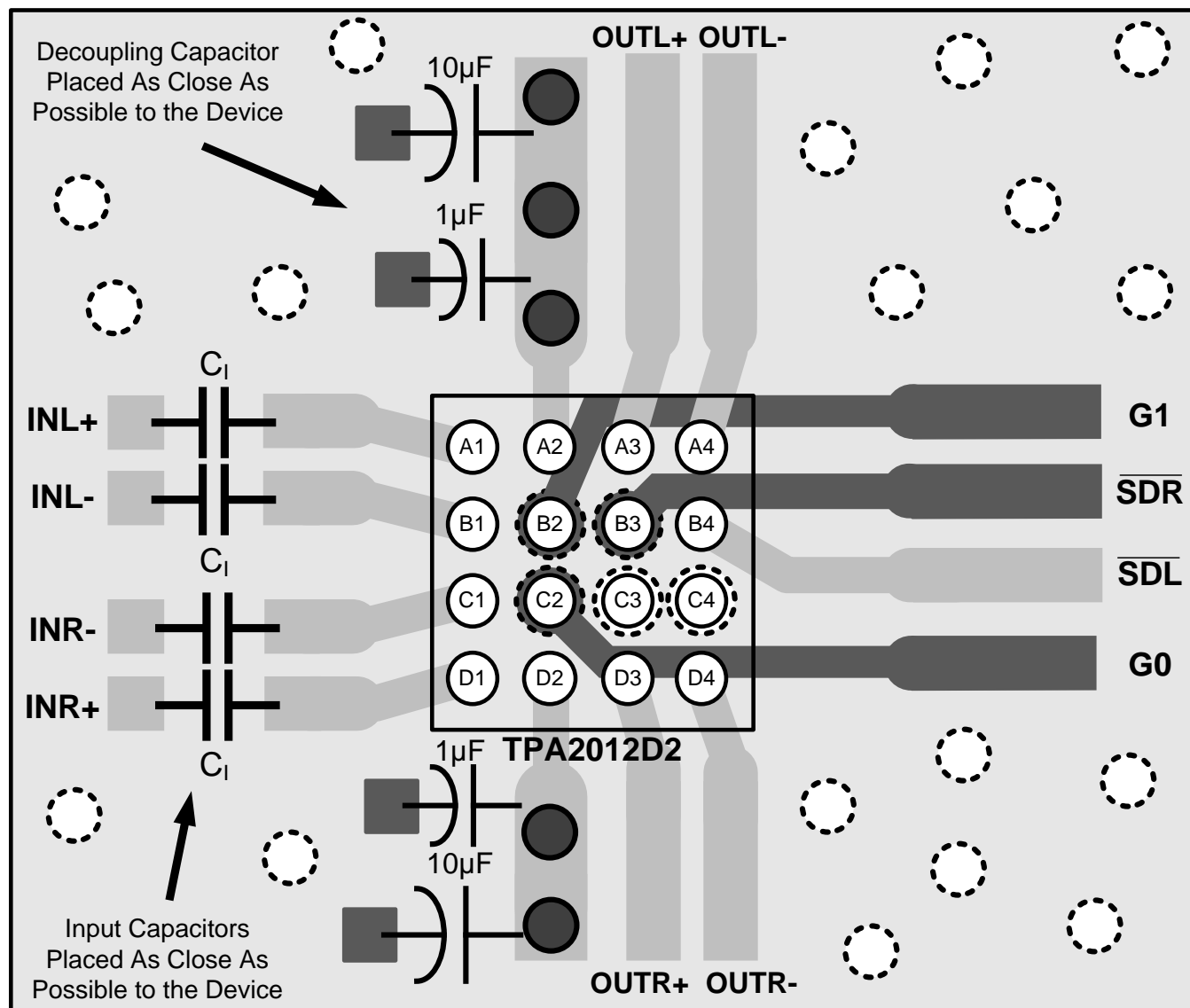
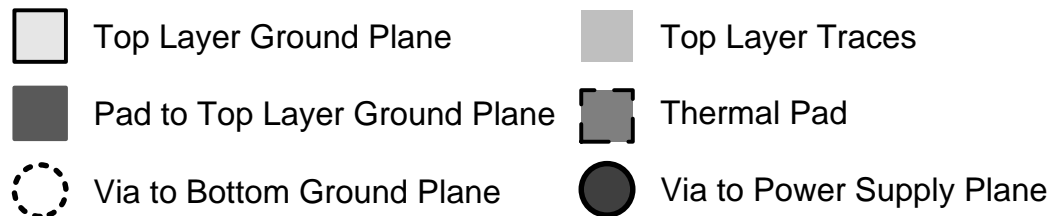
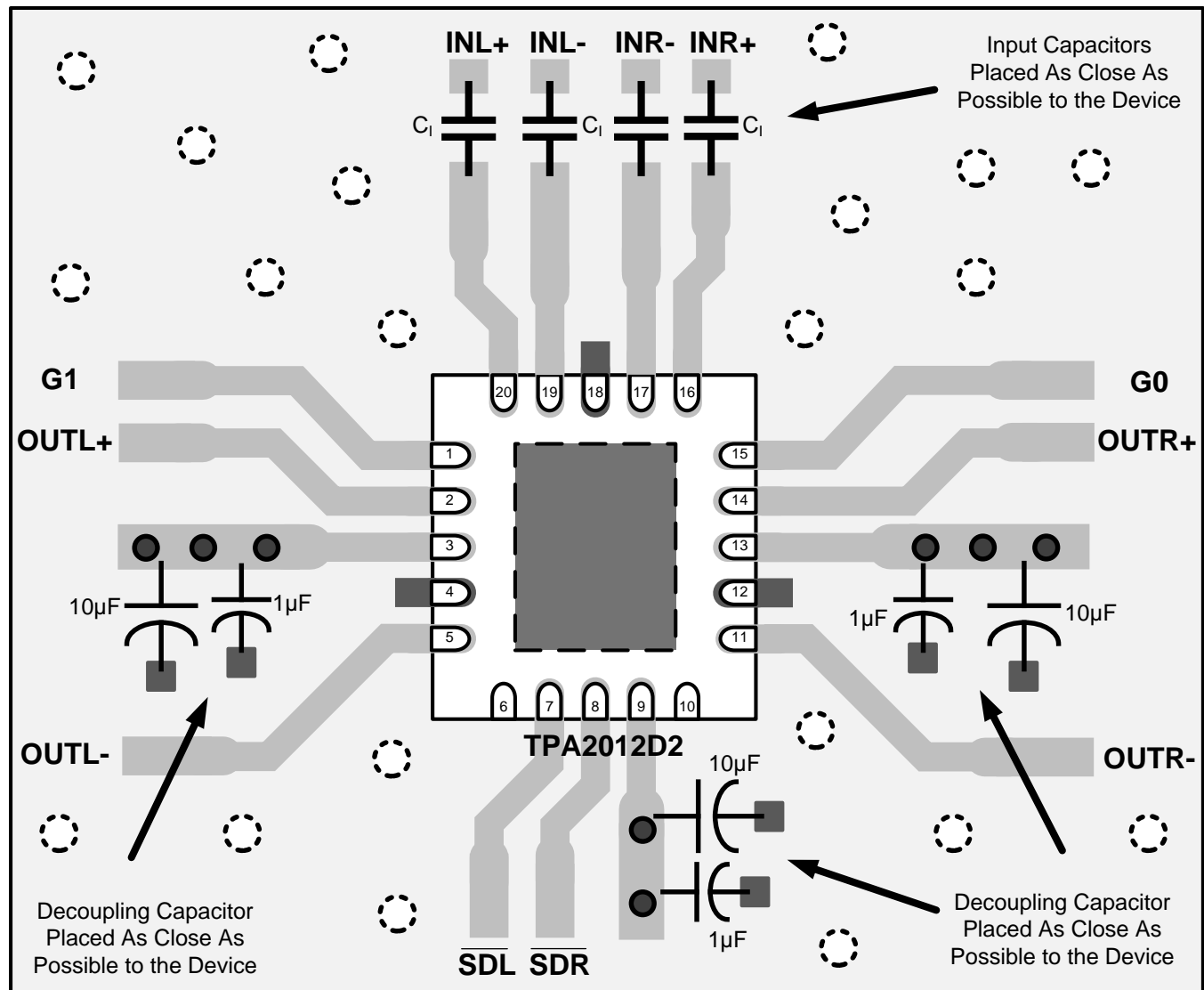


Figure 40. TPA2012D2 DSBGA Layout Example

## Layout Examples (continued)



**Figure 41. TPA2012D2 WQFN Layout Example**

## 12.3 Efficiency and Thermal Considerations

The maximum ambient temperature depends on the heat-sinking ability of the PCB system. The derating factor for the packages are shown in the dissipation rating table. Converting this to  $\theta_{JA}$  for the WQFN package with [Equation 3](#).

$$\theta_{JA} = \frac{1}{\text{Derating Factor}} = \frac{1}{0.041} = 24^{\circ}\text{C} / \text{W} \quad (3)$$

Given  $\theta_{JA}$  of  $24^{\circ}\text{C}/\text{W}$ , the maximum allowable junction temperature of  $150^{\circ}\text{C}$ , and the maximum internal dissipation of 1.5 W (0.75 W per channel) for 2.1 W per channel, 4- $\Omega$  load, 5-V supply, from [Figure 25](#), the maximum ambient temperature can be calculated with [Equation 4](#).

$$T_{A\text{Max}} = T_{J\text{Max}} - \theta_{JA}P_{D\text{max}} = 150 - 24(1.5) = 114^{\circ}\text{C} \quad (4)$$

[Equation 4](#) shows that the calculated maximum ambient temperature is  $114^{\circ}\text{C}$  at maximum power dissipation with a 5-V supply and a 4- $\Omega$  load. The TPA2012D2 is designed with thermal protection that turns the device off when the junction temperature surpasses  $150^{\circ}\text{C}$  to prevent damage to the IC. Also, using speakers more resistive than 4- $\Omega$  dramatically increases the thermal performance by reducing the output current and increasing the efficiency of the amplifier.

## 13 Device and Documentation Support

### 13.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](http://ti.com). In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 13.2 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](http://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.

### 13.3 Trademarks

NanoFree, PowerPAD, E2E are trademarks of Texas Instruments.  
All other trademarks are the property of their respective owners.

### 13.4 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.

### 13.5 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

Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
<a href="#">TPA2012D2RTJR</a>	Active	Production	QFN (RTJ)   20	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	AKS
<a href="#">TPA2012D2RTJT</a>	Active	Production	QFN (RTJ)   20	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	AKS
<a href="#">TPA2012D2YZHR</a>	Active	Production	DSBGA (YZH)   16	3000   LARGE T&R	Yes	SNAGCU	Level-1-260C-UNLIM	-40 to 85	AKR
<a href="#">TPA2012D2YZHT</a>	Active	Production	DSBGA (YZH)   16	250   SMALL T&R	Yes	SNAGCU	Level-1-260C-UNLIM	-40 to 85	AKR

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts 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.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

## TAPE AND REEL INFORMATION



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TPA2012D2RTJR	QFN	RTJ	20	3000	330.0	12.4	4.25	4.25	1.15	8.0	12.0	Q2
TPA2012D2RTJR	QFN	RTJ	20	3000	330.0	12.4	4.25	4.25	1.15	8.0	12.0	Q2
TPA2012D2RTJT	QFN	RTJ	20	250	180.0	12.4	4.25	4.25	1.15	8.0	12.0	Q2
TPA2012D2YZHR	DSBGA	YZH	16	3000	180.0	8.4	2.18	2.18	0.81	4.0	8.0	Q1
TPA2012D2YZHT	DSBGA	YZH	16	250	180.0	8.4	2.18	2.18	0.81	4.0	8.0	Q1

## TAPE AND REEL BOX DIMENSIONS



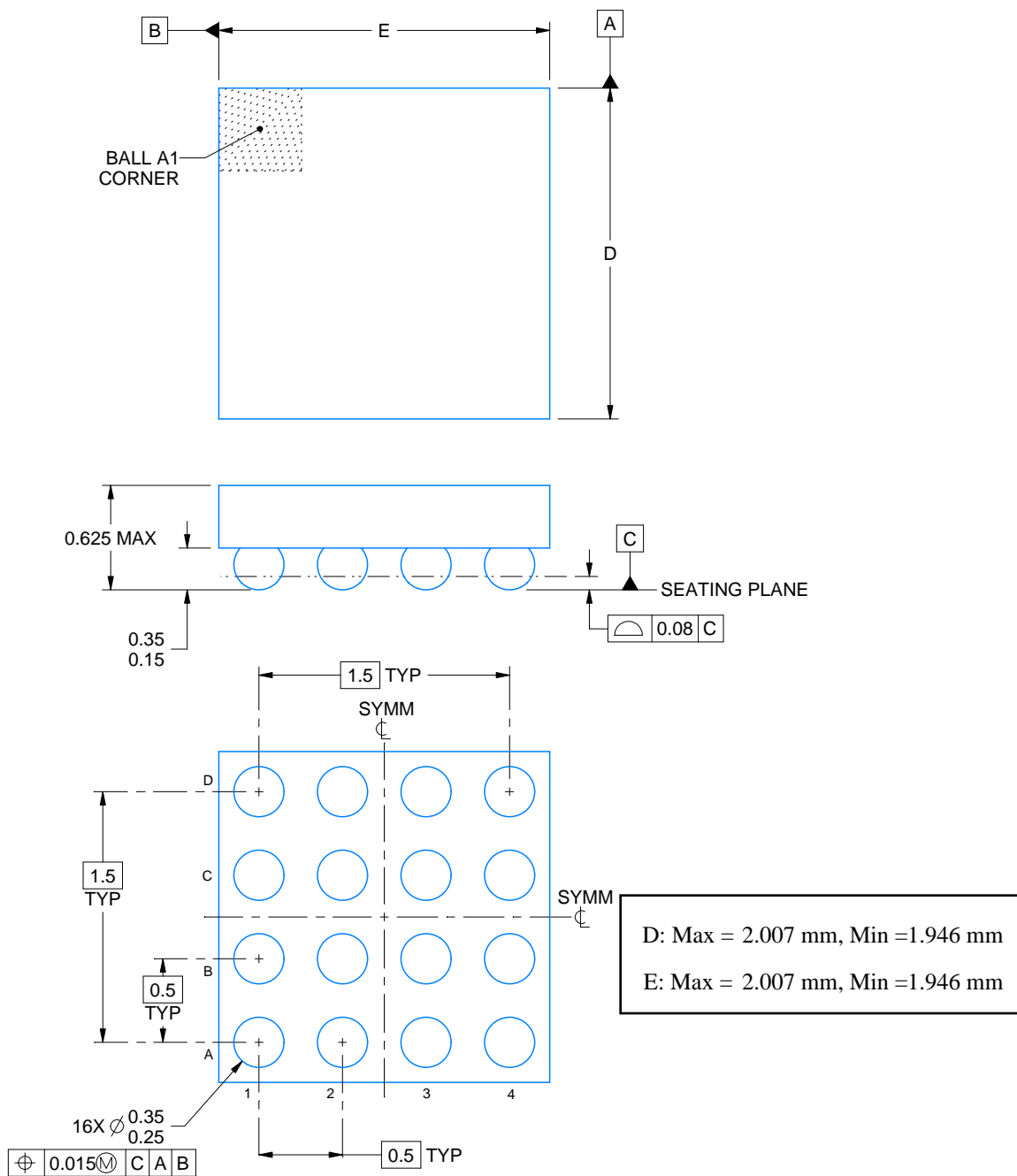
\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPA2012D2RTJR	QFN	RTJ	20	3000	367.0	367.0	36.0
TPA2012D2RTJR	QFN	RTJ	20	3000	346.0	346.0	33.0
TPA2012D2RTJT	QFN	RTJ	20	250	182.0	182.0	20.0
TPA2012D2YZHR	DSBGA	YZH	16	3000	182.0	182.0	20.0
TPA2012D2YZHT	DSBGA	YZH	16	250	182.0	182.0	20.0



## DSBGA - 0.625 mm max height

## DIE SIZE BALL GRID ARRAY



4226617/A 03/2021

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.

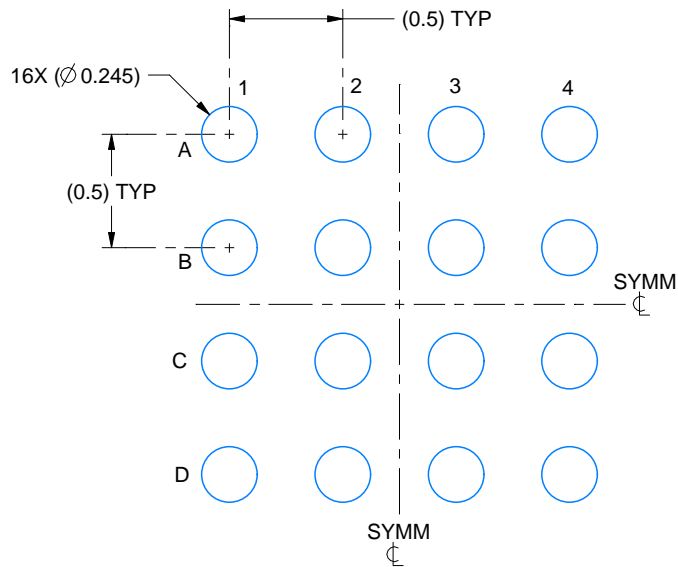
2. This drawing is subject to change without notice.

# EXAMPLE BOARD LAYOUT

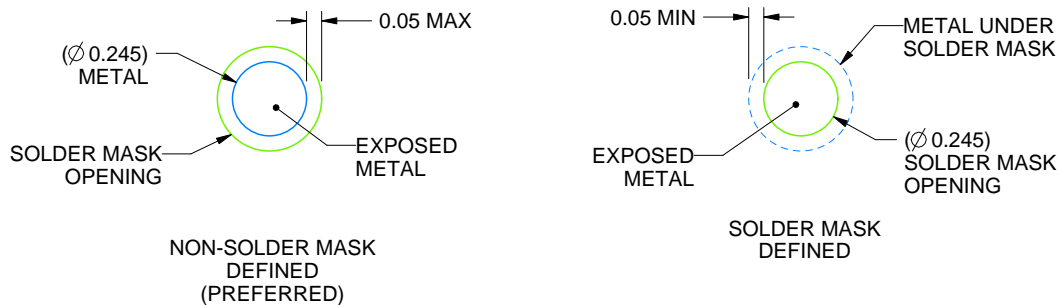
YZH0016

DSBGA - 0.625 mm max height

DIE SIZE BALL GRID ARRAY



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 30X



SOLDER MASK DETAILS  
NOT TO SCALE

4226617/A 03/2021

NOTES: (continued)

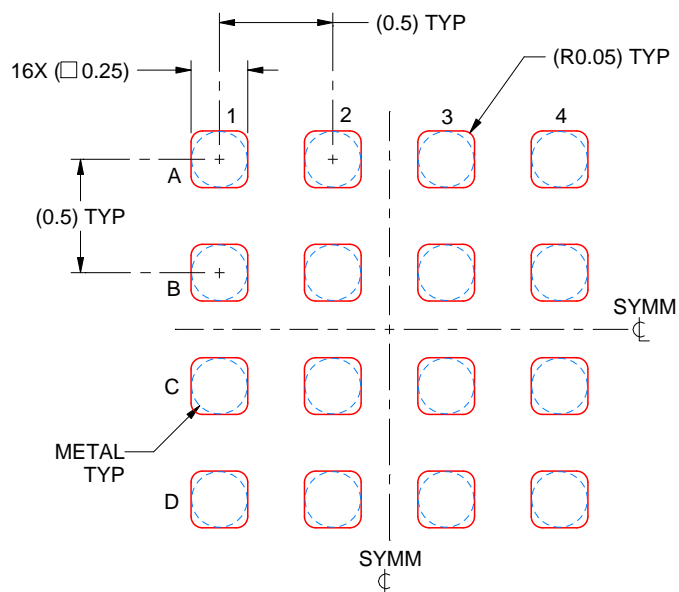
- Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. See Texas Instruments Literature No. SNVA009 ([www.ti.com/lit/snva009](http://www.ti.com/lit/snva009)).

# EXAMPLE STENCIL DESIGN

YZH0016

DSBGA - 0.625 mm max height

DIE SIZE BALL GRID ARRAY



SOLDER PASTE EXAMPLE  
 BASED ON 0.075 mm THICK STENCIL  
 SCALE: 30X

4226617/A 03/2021

NOTES: (continued)

4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.

## GENERIC PACKAGE VIEW

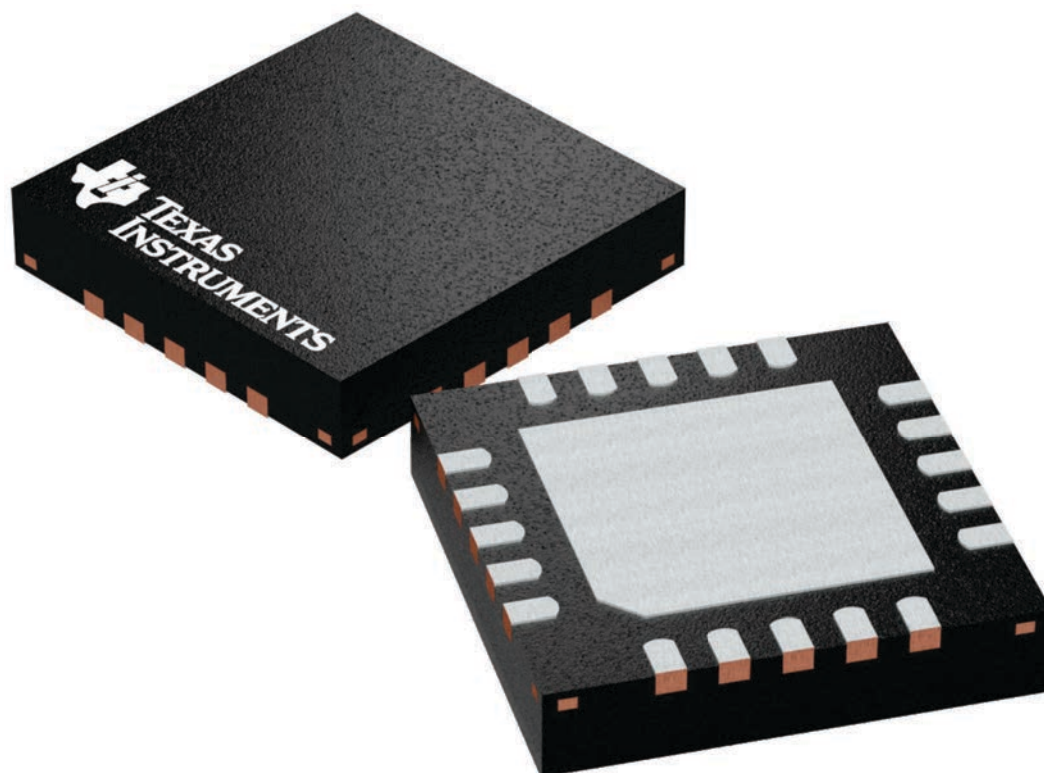
**RTJ 20**

**WQFN - 0.8 mm max height**

4 x 4, 0.5 mm pitch

PLASTIC QUAD FLATPACK - NO LEAD


This image is a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.



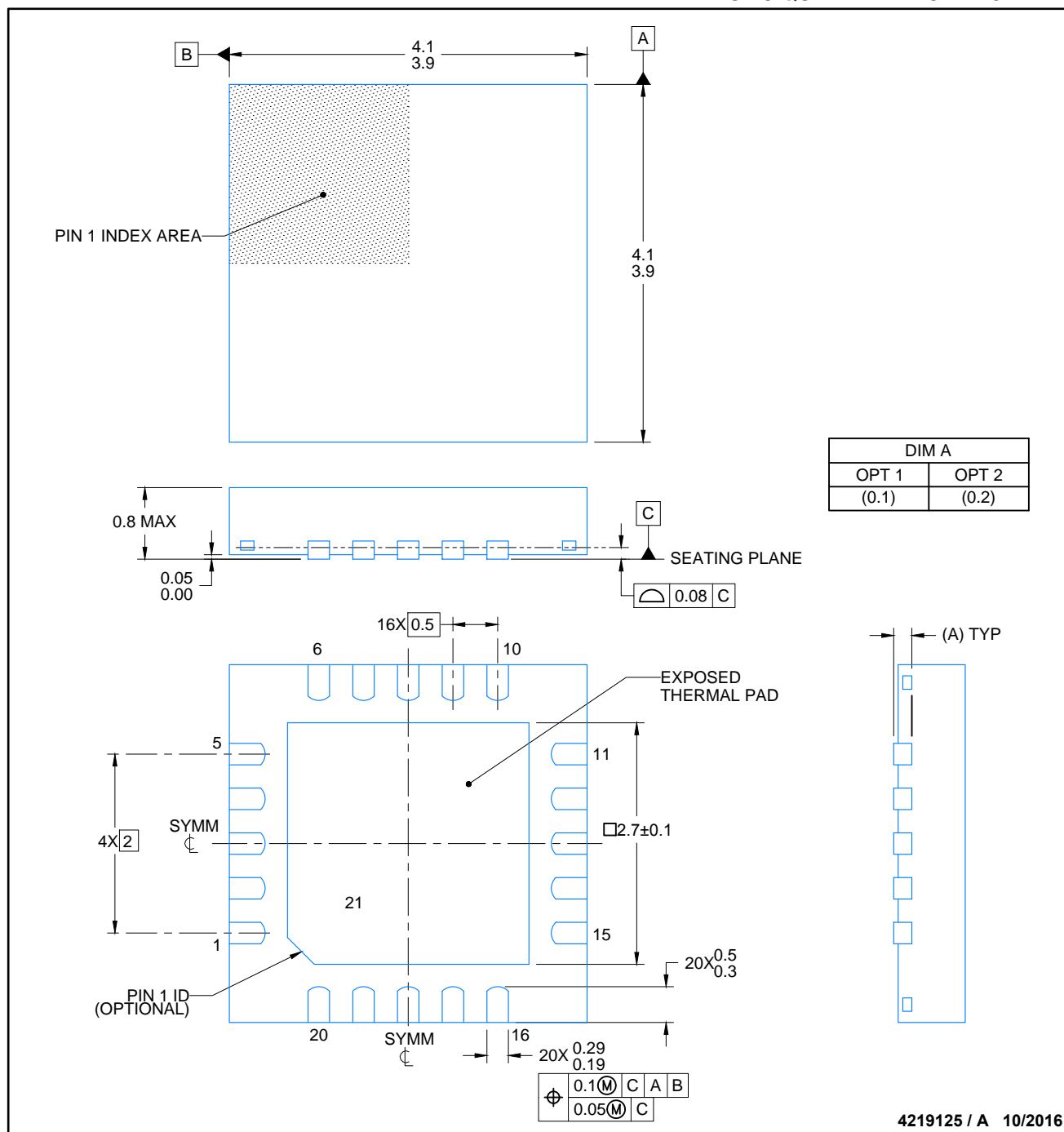
4224842/A

DATA BOOK  
PACKAGE OUTLINE

LEADFRAME EXAMPLE
4222370

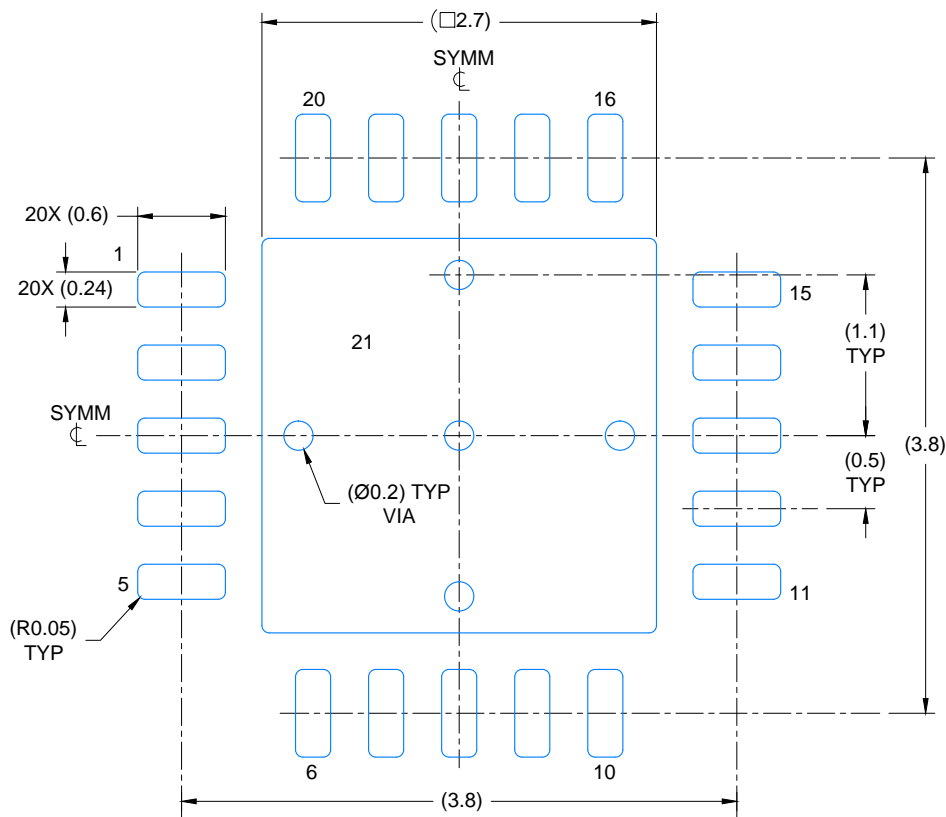
DRAFTSMAN: H. DENG		DATE: 09/12/2016			DIMENSIONS IN MILLIMETERS		
DESIGNER: H. DENG		DATE: 09/12/2016	<div> <b>TEXAS INSTRUMENTS</b> SEMICONDUCTOR OPERATIONS</div> <div>CODE IDENTITY NUMBER 01295</div> <div>ePOD, RTJ0020D / WQFN, 20 PIN, 0.5 MM PITCH</div>				
CHECKER: V. PAKU & T. LEQUANG		DATE: 09/12/2016					
ENGINEER: T. TANG		DATE: 09/12/2016					
APPROVED: E. REY & D. CHIN		DATE: 10/06/2016					
RELEASED: WDM		DATE: 10/24/2016					
TEMPLATE INFO: EDGE# 4218519		DATE: 04/07/2016	SCALE 15X	SIZE A	4219125	REV A	PAGE 1 OF 5



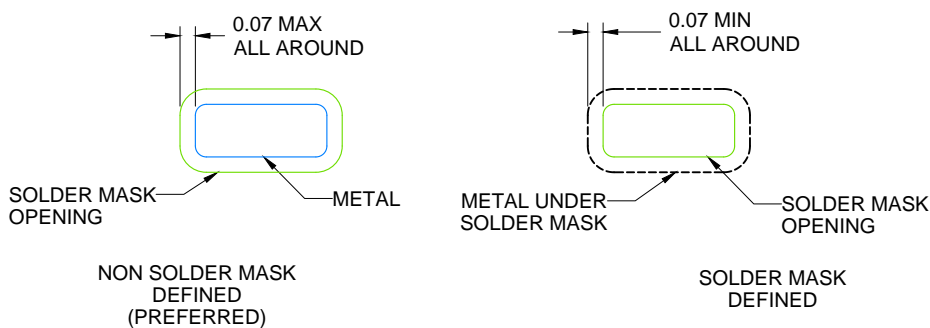


## NOTES:

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.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.



LAND PATTERN EXAMPLE  
SCALE: 20X

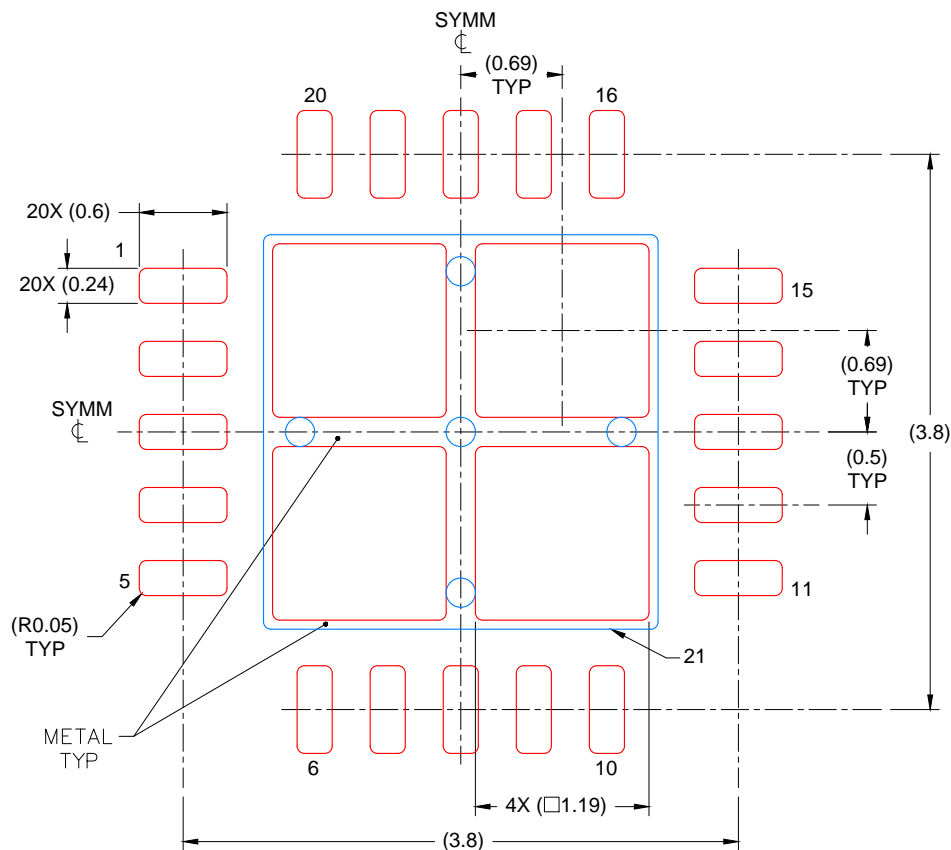


SOLDER MASK DETAILS

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NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/slue271](http://www.ti.com/lit/slue271)).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.



SOLDER PASTE EXAMPLE  
 BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD  
 78% PRINTED COVERAGE BY AREA  
 SCALE: 20X

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NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations..

# REVISIONS

REV	DESCRIPTION	ECR	DATE	ENGINEER / DRAFTSMAN
A	RELEASE NEW DRAWING	2160736	10/24/2016	T. TANG / H. DENG

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