



## TPA6211A1-Q1 3.1-W Mono Fully Differential Audio Power Amplifier

### 1 Features

- Qualified for Automotive Applications
- AEC-Q100 Qualified With the Following Results:
  - Device Temperature Grade 2:  $-40^{\circ}\text{C}$  to  $105^{\circ}\text{C}$  Ambient Operating Temperature Range
  - Device HBM ESD Classification Level 3A
  - Device CDM ESD Classification Level C6
- 3.1 W Into 3  $\Omega$  From a 5-V Supply at THD = 10% (Typical)
- Low Supply Current: 4 mA (Typical) at 5 V
- Shutdown Current: 0.01  $\mu\text{A}$  (Typical)
- Fast Startup With Minimal Pop
- Only Three External Components
  - Improved PSRR ( $-80$  dB) and Wide Supply Voltage (2.5 V to 5.5 V) for Direct Battery Operation
  - Fully Differential Design Reduces RF Rectification
  - $-63$ -dB CMRR Eliminates Two Input Coupling Capacitors

### 2 Applications

- Automotive Audio
- Emergency Calls
- Driver Notifications
- Cluster Chimes

### 3 Description

The TPA6211A1-Q1 device is a 3.1-W mono fully-differential amplifier designed to drive a speaker with at least 3- $\Omega$  impedance while consuming only 20-mm<sup>2</sup> total printed-circuit board (PCB) area in most applications. The device operates from 2.5 V to 5.5 V, drawing only 4 mA of quiescent supply current. The TPA6211A1-Q1 device is available in the space-saving 8-pin MSOP (DGN) PowerPAD™ package.

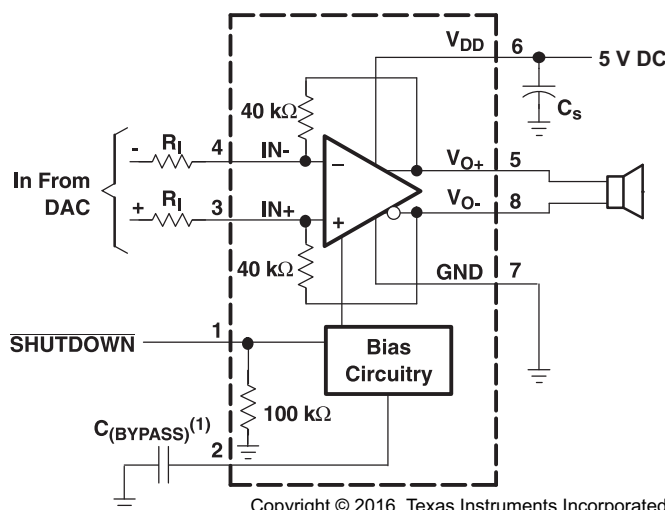
The device includes features such as a  $-80$ -dB supply voltage rejection from 20 Hz to 2 kHz, improved RF-rectification immunity, small PCB area, and a fast start-up with minimal pop makes the TPA6211A1-Q1 device ideal for emergency call applications. Additionally, the device supports low-power needs in infotainment and cluster applications, such as cluster chimes or driver notification.

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

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TPA6211A1-Q1	MSOP-PowerPAD (8)	3.00 mm × 3.00 mm

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

#### Application Circuit



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(1)  $C_{\text{(BYPASS)}}$  is optional



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## 4 Revision History

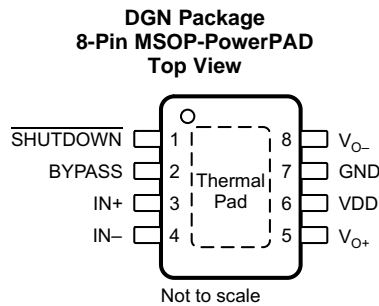
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

<b>Changes from Revision B (January 2014) to Revision C</b>	<b>Page</b>
• Added <i>Device Information</i> table, <i>ESD Ratings</i> table, <i>Feature Description</i> section, <i>Device Functional Modes</i> section, <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. ....	<b>1</b>
• Added missing Max Ambient Temperature values to <a href="#">Table 2</a> .....	<b>14</b>
• Changed 45.9 to 71.7, 1.27 to 1.25, and 91.7 to 60 in <a href="#">Equation 12</a> .....	<b>15</b>

<b>Changes from Revision A (November 2013) to Revision B</b>	<b>Page</b>
• Added three new equations to the <i>DIFFERENTIAL OUTPUT VERSUS SINGLE-ENDED OUTPUT</i> section in order to show difference between single-ended and differential output .....	<b>15</b>

<b>Changes from Original (June 2011) to Revision A</b>	<b>Page</b>
• Deleted <i>Designed for Wireless or Cellular Handsets and PDAs</i> from <i>Features</i> list.....	<b>1</b>
• Deleted <i>Ordering Information</i> table .....	<b>3</b>
• Changed reference from "equation 6" to <a href="#">Equation 25</a> in the <i>High-Pass Filter</i> section.....	<b>20</b>

## 5 Pin Configuration and Functions



### Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
BYPASS	2	I	Mid-supply voltage, adding a bypass capacitor improves PSRR
GND	7	I	High-current ground
IN–	4	I	Negative differential input
IN+	3	I	Positive differential input
SHUTDOWN	1	I	Shutdown pin (active low logic)
Thermal Pad	—	—	Connect to ground. Thermal pad must be soldered down in all applications to properly secure device on the PCB.
V <sub>DD</sub>	6	I	Power supply
V <sub>O+</sub>	5	O	Positive BTL output
V <sub>O–</sub>	8	O	Negative BTL output

## 6 Specifications

### 6.1 Absolute Maximum Ratings

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

	MIN	MAX	UNIT
Supply voltage, V <sub>DD</sub>	–0.3	6	V
Input voltage, V <sub>I</sub>	–0.3	V <sub>DD</sub> + 0.3 V	V
Continuous total power dissipation	See <a href="#">Dissipation Ratings</a>		
Lead temperature 1.6 mm (1/16 Inch) from case for 10 s	DGN		260 °C
Operating free-air temperature, T <sub>A</sub>	–40	105	°C
Junction temperature, T <sub>J</sub>	–40	150	°C
Storage temperature, T <sub>stg</sub>	–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.

### 6.2 ESD Ratings

	VALUE	UNIT
V <sub>(ESD)</sub> Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	±4000
	Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup>	±1000

- (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.

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### 6.3 Recommended Operating Conditions

		MIN	MAX	UNIT
V <sub>DD</sub>	Supply voltage	2.5	5.5	V
V <sub>IH</sub>	High-level input voltage	SHUTDOWN	1.55	V
V <sub>IL</sub>	Low-level input voltage	SHUTDOWN	0.5	V
T <sub>A</sub>	Operating free-air temperature	–40	105	°C

### 6.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		TPA6211A1-Q1	UNIT
		DGN (MSOP-PowerPAD)	
		8 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	71.7	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	55.9	°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	44.9	°C/W
Ψ <sub>JT</sub>	Junction-to-top characterization parameter	3.7	°C/W
Ψ <sub>JB</sub>	Junction-to-board characterization parameter	44.7	°C/W
R <sub>θJC(bot)</sub>	Junction-to-case (bottom) thermal resistance	19.6	°C/W

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

### 6.5 Electrical Characteristics

T<sub>A</sub> = 25°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
V <sub>OS</sub>	Output offset voltage (measured differentially) V <sub>I</sub> = 0-V differential, Gain = 1 V/V, V <sub>DD</sub> = 5.5 V	–9	0.3	9	mV
PSRR	Power supply rejection ratio V <sub>DD</sub> = 2.5 V to 5.5 V		–85	–60	dB
V <sub>IC</sub>	Common mode input range V <sub>DD</sub> = 2.5 V to 5.5 V	0.5		V <sub>DD</sub> – 0.8	V
CMRR	Common mode rejection ratio V <sub>DD</sub> = 5.5 V, V <sub>IC</sub> = 0.5 V to 4.7 V		–63	–40	dB
	V <sub>DD</sub> = 2.5 V, V <sub>IC</sub> = 0.5 V to 1.7 V		–63	–40	
Low-output swing	R <sub>L</sub> = 4 Ω, V <sub>IN+</sub> = V <sub>DD</sub> , V <sub>IN+</sub> = 0 V, Gain = 1 V/V, V <sub>IN–</sub> = 0 V or V <sub>IN–</sub> = V <sub>DD</sub>	V <sub>DD</sub> = 5.5 V	0.45		V
		V <sub>DD</sub> = 3.6 V	0.37		
		V <sub>DD</sub> = 2.5 V	0.26	0.4	
High-output swing	R <sub>L</sub> = 4 Ω, V <sub>IN+</sub> = V <sub>DD</sub> , V <sub>IN–</sub> = V <sub>DD</sub> , Gain = 1 V/V, V <sub>IN–</sub> = 0 V or V <sub>IN+</sub> = 0 V	V <sub>DD</sub> = 5.5 V	4.95		V
		V <sub>DD</sub> = 3.6 V	3.18		
		V <sub>DD</sub> = 2.5 V	2	2.13	
I <sub>IH</sub>	High-level input current, shutdown V <sub>DD</sub> = 5.5 V, V <sub>I</sub> = 5.8 V		58	100	μA
I <sub>IL</sub>	Low-level input current, shutdown V <sub>DD</sub> = 5.5 V, V <sub>I</sub> = –0.3 V		3	100	μA
I <sub>Q</sub>	Quiescent current V <sub>DD</sub> = 2.5 V to 5.5 V, no load		4	5	mA
I <sub>(SD)</sub>	Supply current V <sub>SHUTDOWN</sub> ≤ 0.5 V, V <sub>DD</sub> = 2.5 V to 5.5 V, R <sub>L</sub> = 4 Ω		0.01	1	μA
Gain	R <sub>L</sub> = 4 Ω	$\frac{38 \text{ k}\Omega}{R_I}$	$\frac{40 \text{ k}\Omega}{R_I}$	$\frac{42 \text{ k}\Omega}{R_I}$	V/V
Resistance from shutdown to GND			100		kΩ

## 6.6 Operating Characteristics

 $T_A = 25^{\circ}\text{C}$ , Gain = 1 V/V

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
$P_O$ Output power	THD + N = 1%, f = 1 kHz, $R_L = 3\ \Omega$	$V_{DD} = 5\ \text{V}$		2.45		W
		$V_{DD} = 3.6\ \text{V}$		1.22		
		$V_{DD} = 2.5\ \text{V}$		0.49		
	THD + N = 1%, f = 1 kHz, $R_L = 4\ \Omega$	$V_{DD} = 5\ \text{V}$		2.22		
		$V_{DD} = 3.6\ \text{V}$		1.1		
		$V_{DD} = 2.5\ \text{V}$		0.47		
	THD + N = 1%, f = 1 kHz, $R_L = 8\ \Omega$	$V_{DD} = 5\ \text{V}$		1.36		
		$V_{DD} = 3.6\ \text{V}$		0.72		
		$V_{DD} = 2.5\ \text{V}$		0.33		
THD+N Total harmonic distortion plus noise	f = 1 kHz, $R_L = 3\ \Omega$	$P_O = 2\ \text{W}$ , $V_{DD} = 5\ \text{V}$		0.045%		
		$P_O = 1\ \text{W}$ , $V_{DD} = 3.6\ \text{V}$		0.05%		
		$P_O = 300\ \text{mW}$ , $V_{DD} = 2.5\ \text{V}$		0.06%		
	f = 1 kHz, $R_L = 4\ \Omega$	$P_O = 1.8\ \text{W}$ , $V_{DD} = 5\ \text{V}$		0.03%		
		$P_O = 0.7\ \text{W}$ , $V_{DD} = 3.6\ \text{V}$		0.03%		
		$P_O = 300\ \text{mW}$ , $V_{DD} = 2.5\ \text{V}$		0.04%		
	f = 1 kHz, $R_L = 8\ \Omega$	$P_O = 1\ \text{W}$ , $V_{DD} = 5\ \text{V}$		0.02%		
		$P_O = 0.5\ \text{W}$ , $V_{DD} = 3.6\ \text{V}$		0.02%		
		$P_O = 200\ \text{mW}$ , $V_{DD} = 2.5\ \text{V}$		0.03%		
$k_{SVR}$ Supply ripple rejection ratio	$V_{DD} = 3.6\ \text{V}$ , Inputs AC-grounded with $C_1 = 2\ \mu\text{F}$ , $V_{RIPPLE} = 200\ \text{mV}_{pp}$	f = 217 Hz		–80		dB
		f = 20 Hz to 20 kHz		–70		
SNR Signal-to-noise ratio	$V_{DD} = 5\ \text{V}$ , $P_O = 2\ \text{W}$ , $R_L = 4\ \Omega$			105		dB
$V_n$ Output voltage noise	$V_{DD} = 3.6\ \text{V}$ , f = 20 Hz to 20 kHz, Inputs AC-grounded with $C_1 = 2\ \mu\text{F}$	No weighting		15		$\mu\text{V}_{RMS}$
		A weighting		12		
CMRR Common mode rejection ratio	$V_{DD} = 3.6\ \text{V}$ , $V_{IC} = 1\ \text{V}_{pp}$	f = 217 Hz		–65		dB
$Z_I$ Input impedance			38	40	44	k $\Omega$
Start-up time from shutdown	$V_{DD} = 3.6\ \text{V}$ , No $C_{BYPASS}$			4		$\mu\text{s}$
	$V_{DD} = 3.6\ \text{V}$ , $C_{BYPASS} = 0.1\ \mu\text{F}$			27		ms

## 6.7 Dissipation Ratings

PACKAGE	$T_A \leq 25^{\circ}\text{C}$ POWER RATING	DERATING FACTOR <sup>(1)</sup>	$T_A = 70^{\circ}\text{C}$ POWER RATING	$T_A = 85^{\circ}\text{C}$ POWER RATING
DGN	2.13 W	17.1 mW/ $^{\circ}\text{C}$	1.36 W	1.11 W

(1) Derating factor based on High-k board layout.

## 6.8 Typical Characteristics

**Table 1. Table of Graphs**

		FIGURE
Output power	vs Supply voltage	<a href="#">Figure 1</a>
	vs Load resistance	<a href="#">Figure 2</a>
Power dissipation	vs Output power	<a href="#">Figure 3</a> , <a href="#">Figure 4</a>
Total harmonic distortion + noise	vs Output power	<a href="#">Figure 5</a> , <a href="#">Figure 6</a> , <a href="#">Figure 7</a>
	vs Frequency	<a href="#">Figure 8</a> , <a href="#">Figure 9</a> , <a href="#">Figure 10</a> , <a href="#">Figure 11</a> , <a href="#">Figure 12</a>
	vs Common-mode input voltage	<a href="#">Figure 13</a>
Supply voltage rejection ratio	vs Frequency	<a href="#">Figure 14</a> , <a href="#">Figure 15</a> , <a href="#">Figure 16</a> , <a href="#">Figure 17</a>
Supply voltage rejection ratio	vs Common-mode input voltage	<a href="#">Figure 18</a>
GSM Power supply rejection	vs Time	<a href="#">Figure 19</a>
GSM Power supply rejection	vs Frequency	<a href="#">Figure 20</a>
Common-mode rejection ratio	vs Frequency	<a href="#">Figure 21</a>
	vs Common-mode input voltage	<a href="#">Figure 22</a>
Closed loop gain/phase	vs Frequency	<a href="#">Figure 23</a>
Open loop gain/phase	vs Frequency	<a href="#">Figure 24</a>
Supply current	vs Supply voltage	<a href="#">Figure 25</a>
	vs Shutdown voltage	<a href="#">Figure 26</a>
Start-up time	vs Bypass capacitor	<a href="#">Figure 27</a>

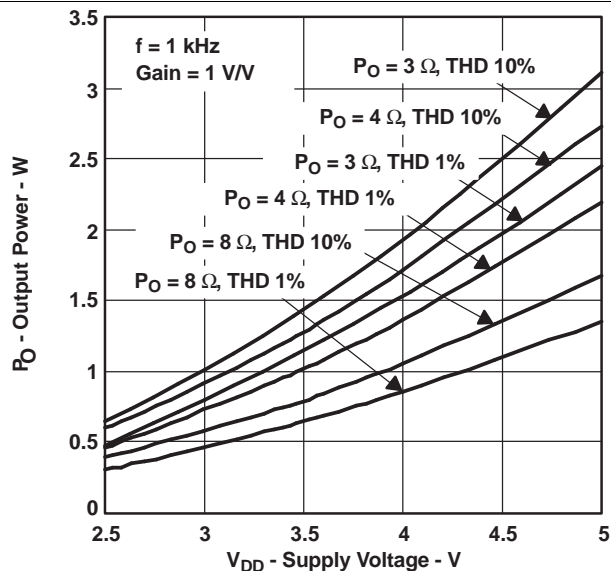


Figure 1. Output Power vs Supply Voltage

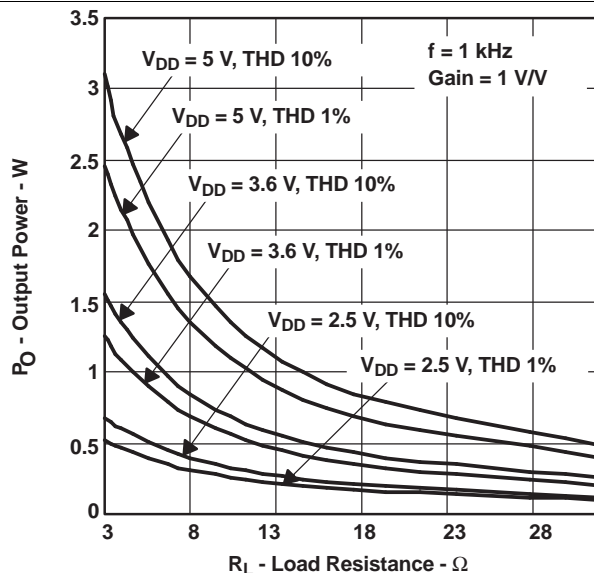


Figure 2. Output Power vs Load Resistance

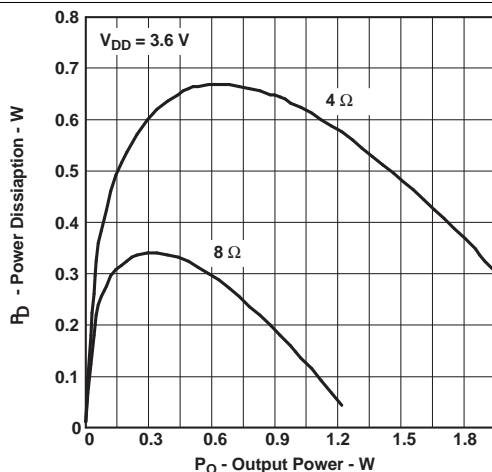


Figure 3. Power Dissipation vs Output Power

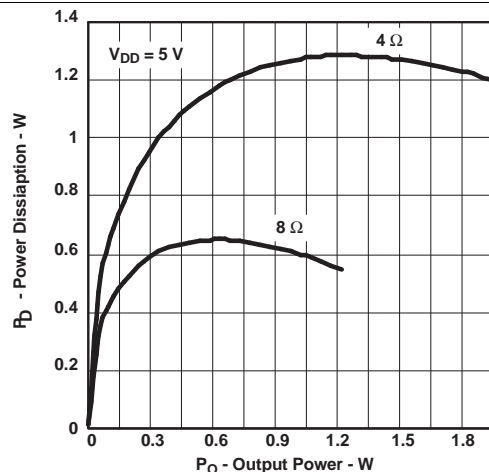


Figure 4. Power Dissipation vs Output Power

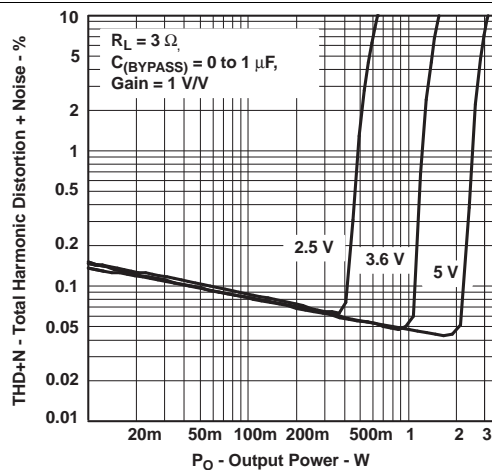


Figure 5. Total Harmonic Distortion + Noise vs Output Power

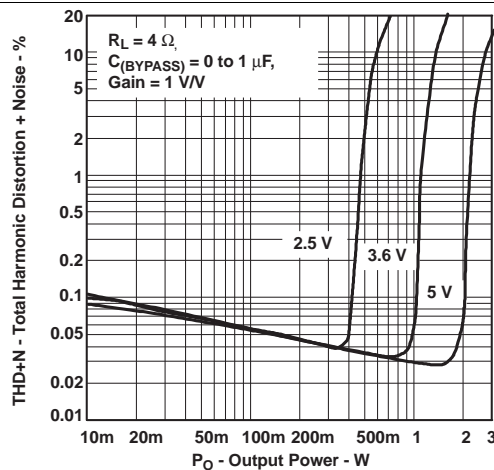
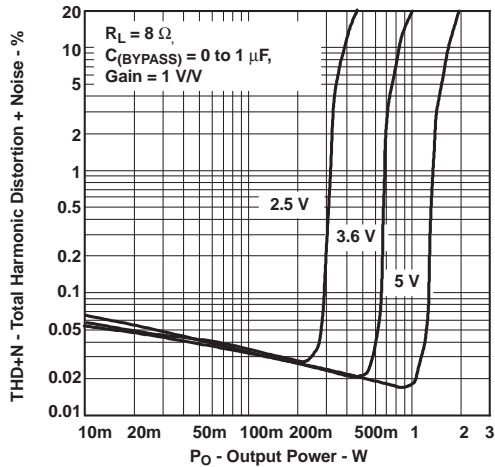
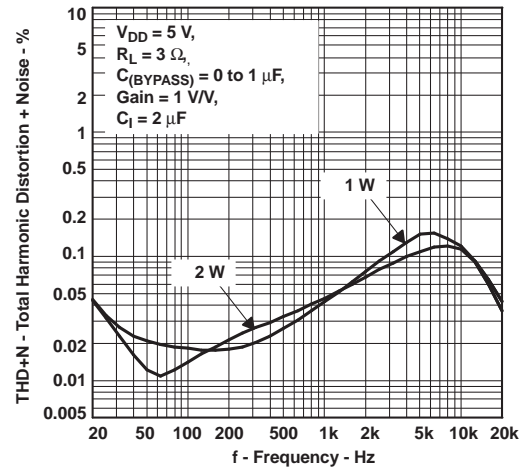
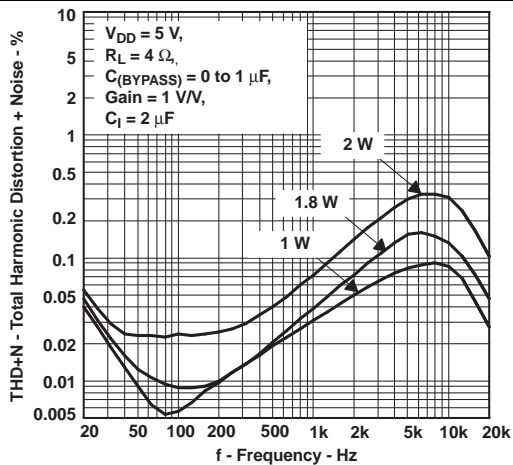
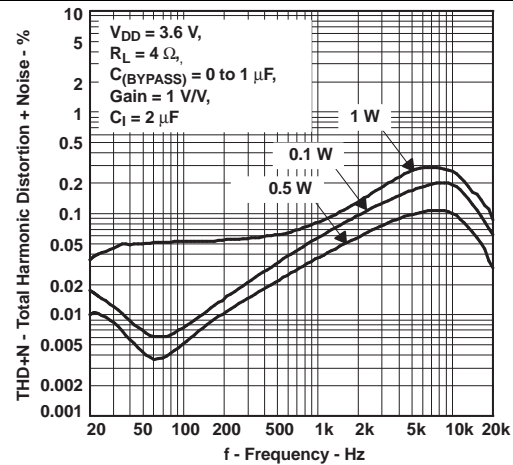
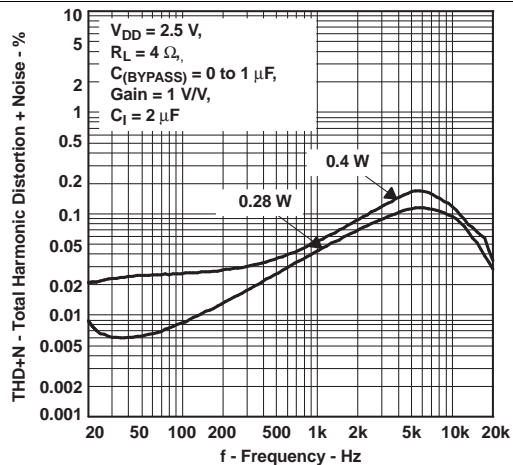
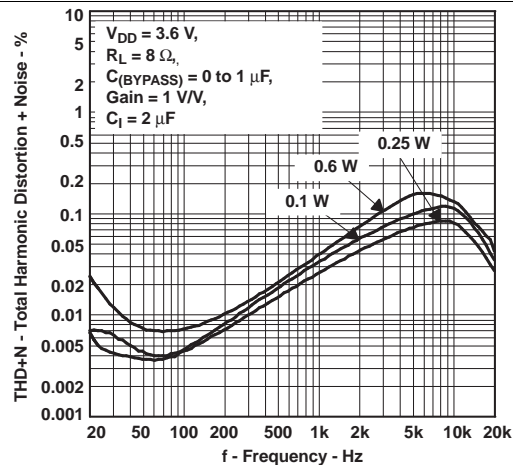


Figure 6. Total Harmonic Distortion + Noise vs Output Power

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**Figure 7. Total Harmonic Distortion + Noise vs Output Power**

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

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

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

**Figure 11. Total Harmonic Distortion + Noise vs Frequency**

**Figure 12. Total Harmonic Distortion + Noise vs Frequency**



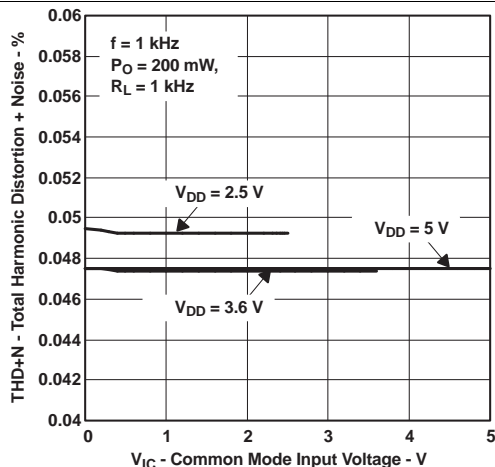


Figure 13. Total Harmonic Distortion + Noise vs Common-Mode Input Voltage

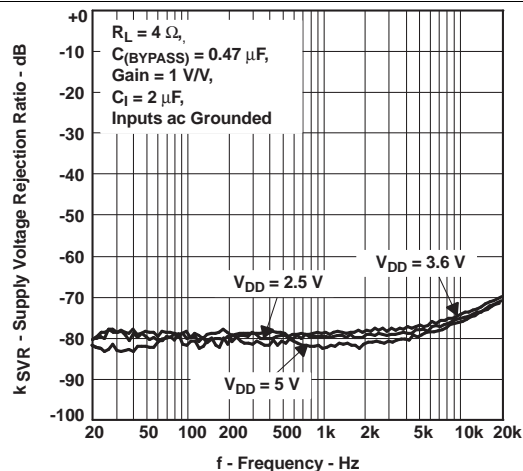


Figure 14. Supply Voltage Rejection Ratio vs Frequency

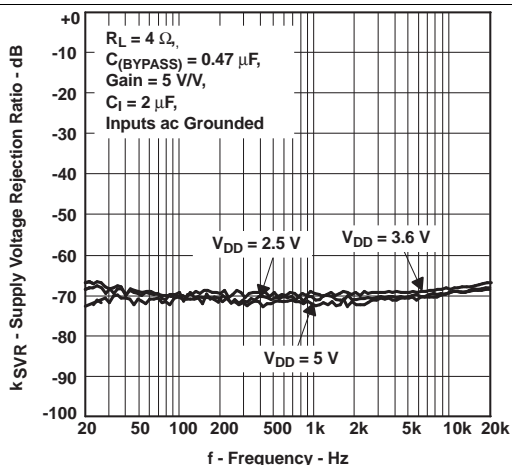


Figure 15. Supply Voltage Rejection Ratio vs Frequency

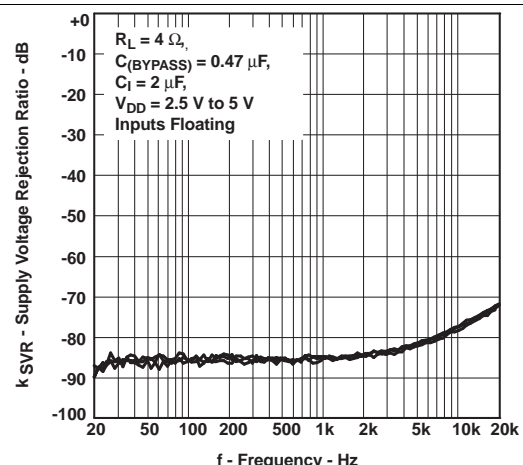


Figure 16. Supply Ripple Rejection Ratio vs Frequency

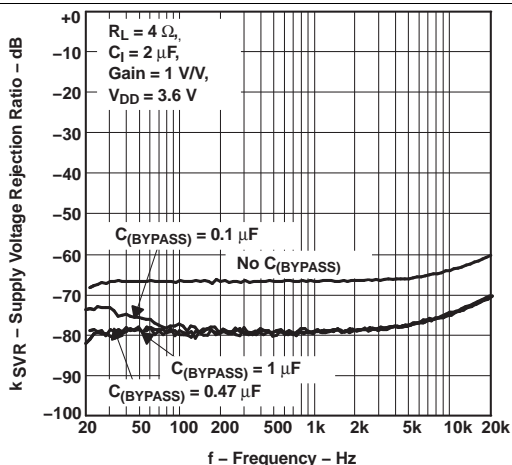


Figure 17. Supply Voltage Rejection Ratio vs Frequency

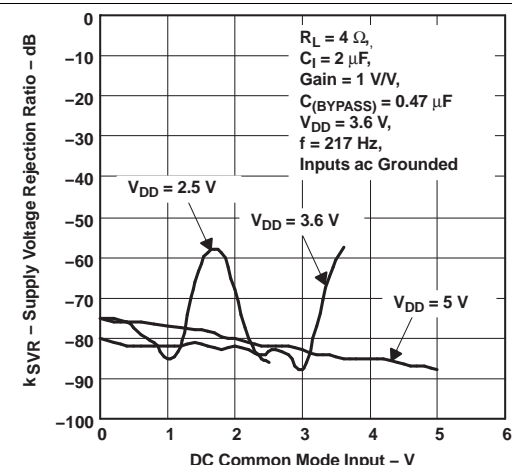
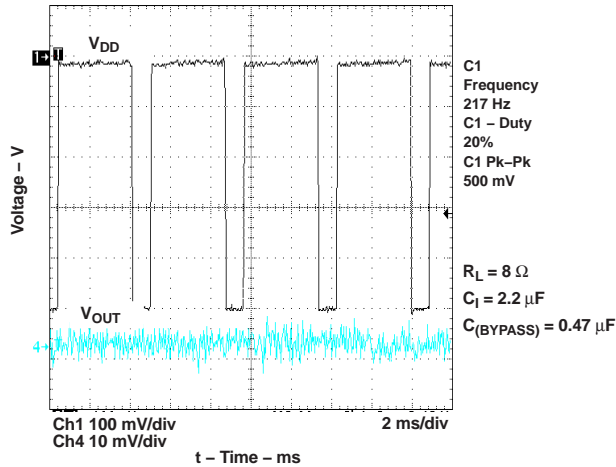
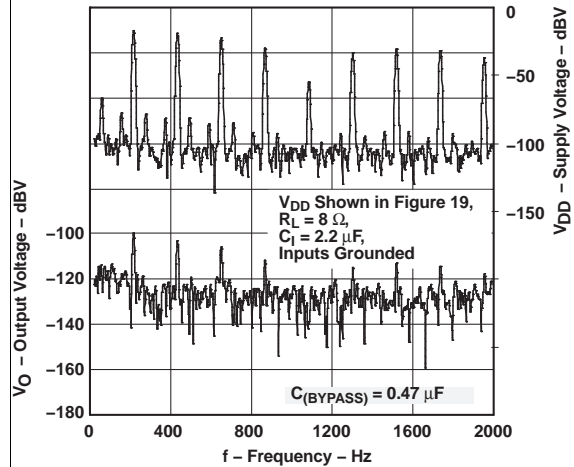
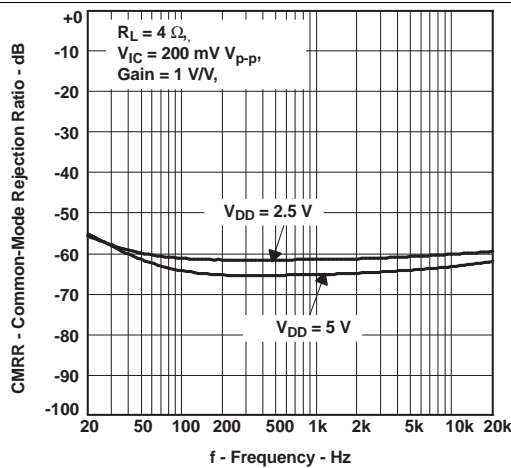
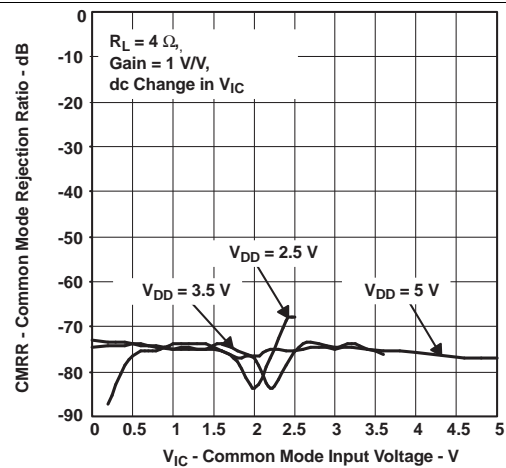
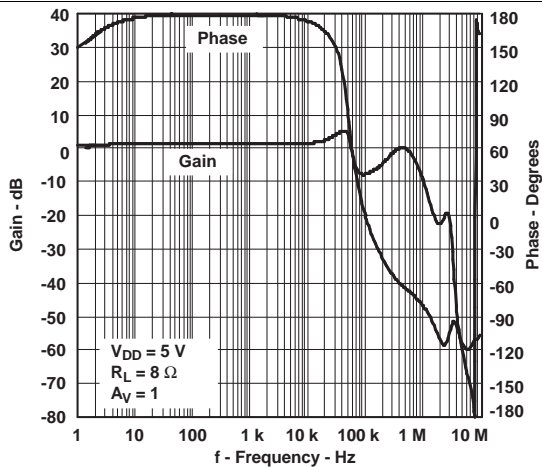
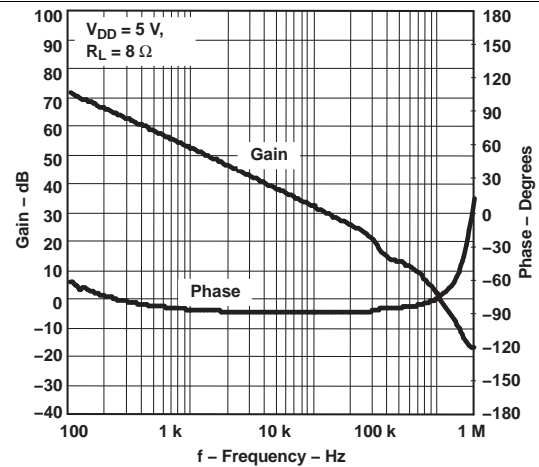
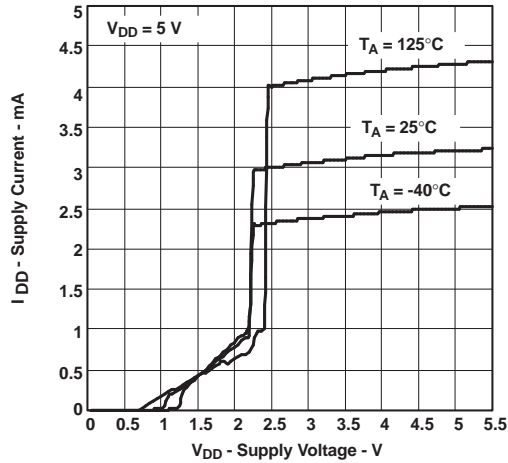


Figure 18. Supply Voltage Rejection Ratio vs DC Common-Mode Input

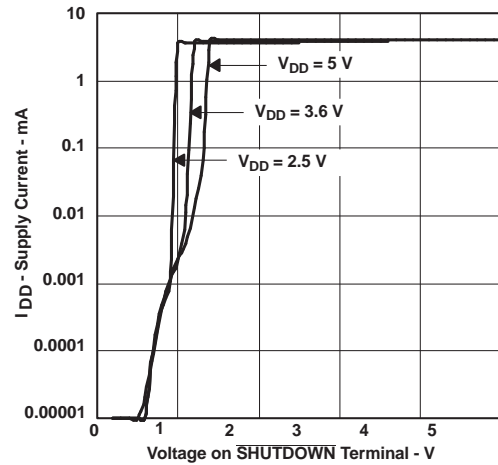
**TPA6211A1-Q1**

SBOS555C – JUNE 2011 – REVISED AUGUST 2016

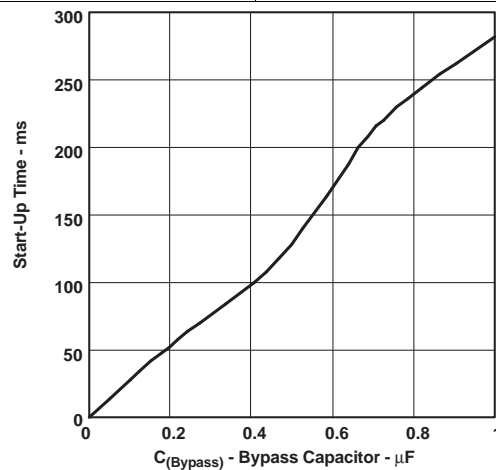
[www.ti.com](http://www.ti.com)

**Figure 19. GSM Power Supply Rejection vs Time**

**Figure 20. GSM Power Supply Rejection vs Frequency**

**Figure 21. Common-Mode Rejection Ratio vs Frequency**

**Figure 22. Common-Mode Rejection Ratio vs Common-Mode Input Voltage**

**Figure 23. Closed Loop Gain/Phase vs Frequency**

**Figure 24. Open Loop Gain/Phase vs Frequency**



**Figure 25. Supply Current vs Supply Voltage**



**Figure 26. Supply Current vs Shutdown Voltage**



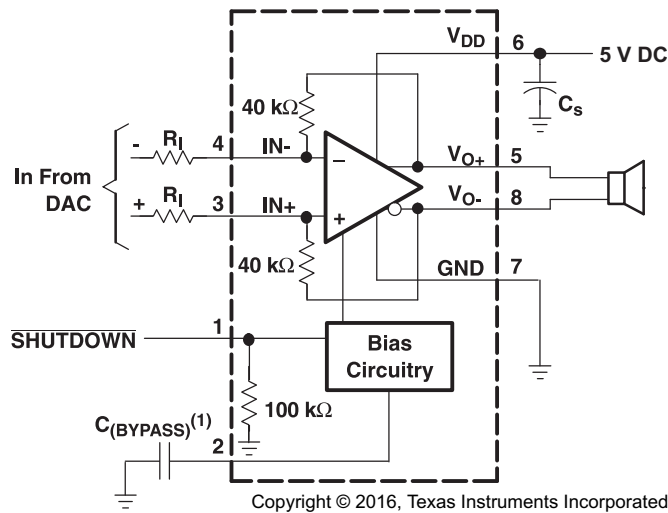
**Figure 27. Start-up Time vs Bypass Capacitor**

## 7 Detailed Description

### 7.1 Overview

The TPA6211A1-Q1 device 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 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  $V_{DD} / 2$  regardless of the common-mode voltage at the input.

### 7.2 Functional Block Diagram



(1)  $C_{BYPASS}$  is optional

### 7.3 Feature Description

#### 7.3.1 Advantages of Fully Differential Amplifiers

Input coupling capacitors are not required. A fully differential amplifier with good CMRR, such as the TPA6211A1-Q1 device, allows the inputs to be biased at voltage other than mid-supply. For example, if a DAC has a lower mid-supply voltage than that of the TPA6211A1-Q1 device, the common-mode feedback circuit compensates, and the outputs are still biased at the mid-supply point of the TPA6211A1-Q1 device. The inputs of the TPA6211A1-Q1 device can be biased from 0.5 V to  $V_{DD} - 0.8$  V. If the inputs are biased outside of that range, input coupling capacitors are required.

A Mid-supply bypass capacitor,  $C_{BYPASS}$ , is not required. The fully differential amplifier does not require a bypass capacitor. Any shift in the mid-supply voltage affects both positive and negative channels equally, thus canceling at the differential output. Removing the bypass capacitor slightly worsens power supply rejection ratio ( $k_{SVR}$ ), but a slight decrease of  $k_{SVR}$  can be acceptable when an additional component can be eliminated (see Figure 17).

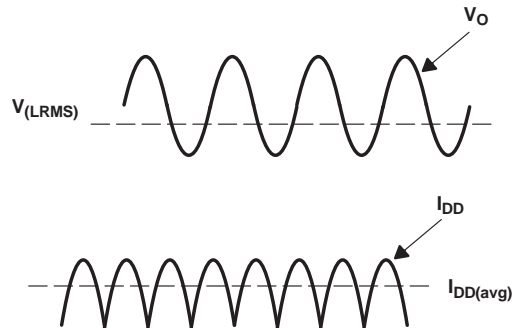
The RF-immunity is improved. A fully differential amplifier cancels the noise from RF disturbances much better than the typical audio amplifier.

#### 7.3.2 Fully Differential Amplifier Efficiency and Thermal Information

Class-AB amplifiers are inefficient, primarily because of voltage drop across the output-stage transistors. The two components of this internal voltage drop are the headroom or DC voltage drop that varies inversely to output power, and the sinewave nature of the output. The total voltage drop can be calculated by subtracting the RMS value of the output voltage from  $V_{DD}$ . The internal voltage drop multiplied by the average value of the supply current,  $I_{DD(avg)}$ , determines the internal power dissipation of the amplifier.

## Feature Description (continued)

An easy-to-use equation to calculate efficiency starts out as being equal to the ratio of power from the power supply to the power delivered to the load. To accurately calculate the RMS and average values of power in the load and in the amplifier, the current and voltage waveform shapes must first be understood (see [Figure 28](#)).



**Figure 28. Voltage and Current Waveforms for BTL Amplifiers**

Although the voltages and currents for SE and BTL are sinusoidal in the load, currents from the supply are different between SE and BTL configurations. In an SE application the current waveform is a half-wave rectified shape, whereas in BTL the current waveform is a full-wave rectified waveform. This means RMS conversion factors are different. Keep in mind that for most of the waveform both the push and pull transistors are not on at the same time, which supports the fact that each amplifier in the BTL device only draws current from the supply for half the waveform. [Equation 1](#) to [Equation 10](#) are the basis for calculating amplifier efficiency.

$$\eta_{\text{BTL}} = \frac{P_L}{P_{\text{SUP}}}$$

where

- $\eta_{\text{BTL}}$  is the efficiency of a BTL amplifier
- $P_L$  is the power delivered to load
- $P_{\text{SUP}}$  is the power drawn from power supply

$P_L$  is calculated with [Equation 2](#), and  $V_{\text{LRMS}}$  is calculated with [Equation 3](#).

$$P_L = \frac{V_{\text{LRMS}}^2}{R_L}$$

where

- $V_{\text{LRMS}}$  = RMS voltage on BTL load
- $R_L$  is load resistance

$$V_{\text{LRMS}} = \frac{V_P}{\sqrt{2}}$$

where

- $V_P$  is peak voltage on BTL load

Therefore,  $P_L$  can be given as [Equation 4](#).

$$P_L = \frac{V_P^2}{2 \times R_L}$$

$P_{\text{SUP}}$  is calculated with [Equation 5](#).

$$P_{\text{SUP}} = V_{\text{DD}} \times I_{\text{DDavg}}$$

where

- $V_{\text{DD}}$  is power supply voltage
- $I_{\text{DDavg}}$  is average current drawn from the power supply

## Feature Description (continued)

$I_{DDavg}$  is calculated with Equation 6.

$$I_{DDavg} = \frac{1}{\pi} \int_0^{\pi} \frac{V_P}{R_L} \times \sin(t) \times dt = -\frac{1}{\pi} \times \frac{V_P}{R_L} \times \cos(t) \Big|_0^{\pi} = \frac{2 \times V_P}{\pi \times R_L} \quad (6)$$

Therefore,  $P_{SUP}$  can be given as Equation 7.

$$P_{SUP} = \frac{2 \times V_{DD} \times V_P}{\pi \times R_L} \quad (7)$$

Substituting for  $P_L$  and  $P_{SUP}$ , Equation 1 becomes Equation 8

$$\eta_{BTL} = \frac{\frac{V_P^2}{2 \times R_L}}{\frac{2 \times V_{DD} \times V_P}{\pi \times R_L}} = \frac{\pi \times V_P}{4 \times V_{DD}} \quad (8)$$

$V_P$  is calculated with Equation 9.

$$V_P = \sqrt{2 \times P_L \times R_L} \quad (9)$$

And substituting for  $V_P$ ,  $\eta_{BTL}$  can be calculated with Equation 10

$$\eta_{BTL} = \frac{\pi \sqrt{2 \times P_L \times R_L}}{4 \times V_{DD}} \quad (10)$$

A simple formula for calculating the maximum power dissipated ( $P_{Dmax}$ ) can be used for a differential output application:

$$P_{Dmax} = \frac{2V_{DD}^2}{\pi^2 R_L} \quad (11)$$

**Table 2. Efficiency and Maximum Ambient Temperature vs Output Power**

OUTPUT POWER	EFFICIENCY	INTERNAL DISSIPATION	POWER FROM SUPPLY	MAX AMBIENT TEMPERATURE
<b>5-V, 3-Ω SYSTEMS</b>				
0.5 W	27.2%	1.34 W	1.84 W	54°C
1 W	38.4%	1.6 W	2.6 W	35°C
2.45 W	60.2%	1.62 W	4.07 W	34°C
3.1 W	67.7%	1.48 W	4.58 W	44°C
<b>5-V, 4-Ω BTL SYSTEMS</b>				
0.5 W	31.4%	1.09 W	1.59 W	72°C
1 W	44.4%	1.25 W	2.25 W	60°C
2 W	62.8%	1.18 W	3.18 W	65°C
2.8 W	74.3%	0.97 W	3.77 W	80°C
<b>5-V, 8-Ω SYSTEMS</b>				
0.5 W	44.4%	0.625 W	1.13 W	105°C (limited by maximum ambient temperature specification)
1 W	62.8%	0.592 W	1.6 W	105°C (limited by maximum ambient temperature specification)
1.36 W	73.3%	0.496 W	1.86 W	105°C (limited by maximum ambient temperature specification)
1.7 W	81.9%	0.375 W	2.08 W	105°C (limited by maximum ambient temperature specification)

**Equation 10** is used to calculate efficiencies for four different output power levels, see **Table 2**. The efficiency of the amplifier is quite low for lower power levels and rises sharply as power to the load is increased resulting in a nearly flat internal power dissipation over the normal operating range. The internal dissipation at full output power is less than in the half power range. Calculating the efficiency for a specific system is the key to proper power supply design. For a 2.8-W audio system with 4-Ω loads and a 5-V supply, the maximum draw on the power supply is almost 3.8 W.

A final point to remember about Class-AB amplifiers is how to manipulate the terms in the efficiency equation to the utmost advantage when possible. In **Equation 10**,  $V_{DD}$  is in the denominator. This indicates that as  $V_{DD}$  goes down, efficiency goes up.

The maximum ambient temperature depends on the heat sinking ability of the PCB system. Given  $R_{\theta JA}$  (junction-to-ambient thermal resistance), the maximum allowable junction temperature, and the internal dissipation at 1-W output power with a 4-Ohm load, the maximum ambient temperature can be calculated with **Equation 12**. The maximum recommended junction temperature for the TPA6211A1-Q1 device is 150°C.

$$T_A(\text{Max}) = T_J(\text{Max}) - R_{\theta JA} \times P_D = 150 - 71.7 \times 1.25 = 60^\circ\text{C} \quad (12)$$

**Equation 12** shows that the maximum ambient temperature is 60°C at 1-W output power and 4-Ohm load with a 5-V supply.

**Table 2** shows that the thermal performance must be considered when using a Class-AB amplifier to keep junction temperatures in the specified range. The TPA6211A1-Q1 device is designed with thermal protection that turns the device off when the junction temperature surpasses 150°C to prevent damage to the IC. In addition, using speakers with an impedance higher than 4 Ω dramatically increases the thermal performance by reducing the output current.

### 7.3.3 Differential Output Versus Single-Ended Output

**Figure 29** shows a Class-AB audio power amplifier (APA) in a fully differential configuration. The TPA6211A1-Q1 amplifier has differential outputs driving both ends of the load. One of several potential benefits to this configuration is power to the load. The differential drive to the speaker means that as one side is slewing up, the other side is slewing down, and vice versa. This in effect doubles the voltage swing on the load as compared to a ground-referenced load. Plugging  $2 \times V_{O(PP)}$  into the power equation (**Equation 13**) yields four-times the output power (as the voltage is squared) from the same supply rail and load impedance (see **Equation 15** and **Equation 16**).

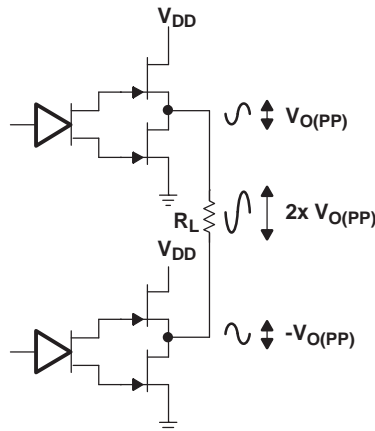
$$V_{(rms)} = \frac{V_{O(PP)}}{2\sqrt{2}}$$

$$\text{Power} = \frac{V_{(rms)}^2}{R_L} \quad (13)$$

$$\text{Power}_{(S-E)} = \frac{V_{(rms)}^2}{R_L} = \frac{\left(\frac{V_{O(PP)}}{2\sqrt{2}}\right)^2}{R_L} = \frac{V_{O(PP)}^2}{8R_L} \quad (14)$$

$$\text{Power}_{(Diff)} = \frac{V_{(rms)}^2}{R_L} = \frac{\left(\frac{2 \times V_{O(PP)}}{2\sqrt{2}}\right)^2}{R_L} = \frac{V_{O(PP)}^2}{2R_L} \quad (15)$$

$$\text{Power}_{(Diff)} = 4 \times \text{Power}_{(S-E)} \quad (16)$$

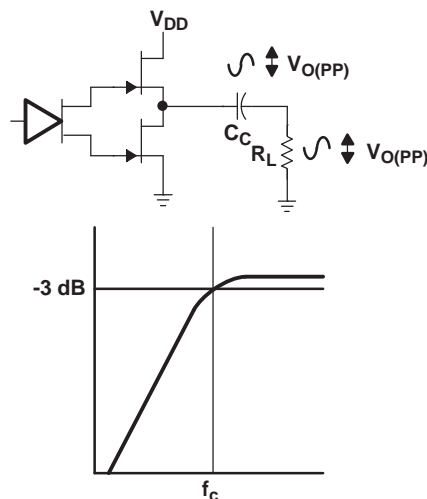


**Figure 29. Differential Output Configuration**

In a typical automotive application operating at 5 V, bridging raises the power into an 8-Ω speaker from a singled-ended (SE, ground reference) limit of 390 mW to 1.56 W. This is a 6-dB improvement in sound power, or loudness of the sound. In addition to increased power, there are frequency-response concerns. Consider the single-supply SE configuration shown in [Figure 30](#). A coupling capacitor ( $C_C$ ) is required to block the DC-offset voltage from the load. This capacitor can be quite large (approximately 33 μF to 1000 μF) so it tends to be expensive, heavy, occupy valuable PCB area, and have the additional drawback of limiting low-frequency performance. This frequency-limiting effect is due to the high-pass filter network created with the speaker impedance and the coupling capacitance. This is calculated with [Equation 17](#).

$$f_c = \frac{1}{2\pi R_L C_C} \quad (17)$$

For example, a 68-μF capacitor with an 8-Ω speaker would attenuate low frequencies below 293 Hz. The BTL configuration cancels the DC offsets, which eliminates the need for the blocking capacitors. Low-frequency performance is then limited only by the input network and speaker response. Cost and PCB space are also minimized by eliminating the bulky coupling capacitor.



**Figure 30. Single-Ended Output and Frequency Response**

Increasing power to the load does carry a penalty of increased internal power dissipation. The increased dissipation is understandable considering that the BTL configuration produces four-times the output power of the SE configuration.



## 7.4 Device Functional Modes

The TPA6211A1-Q1 device 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.

## 8 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.

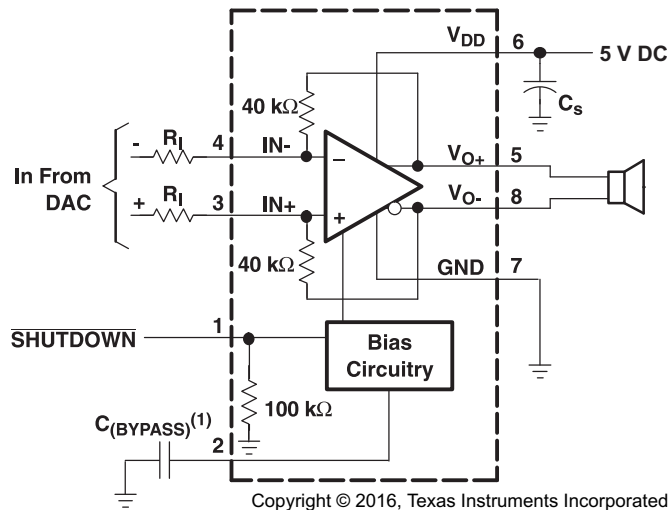
### 8.1 Application Information

The TPA6211A1-Q1 is a fully-differential amplifier designed to drive a speaker with at least 3-Ω impedance while consuming only 20-mm<sup>2</sup> total printed-circuit board (PCB) area in most applications.

### 8.2 Typical Applications

Figure 31 shows a typical application circuit for the TPA6211A1-Q1 with a speaker, input resistors, and supporting power supply decoupling capacitors.

#### 8.2.1 Typical Differential Input Application



(1)  $C_{BYPASS}$  is optional

**Figure 31. Typical Differential Input Application Schematic**

Typical values are shown in Table 3.

**Table 3. Typical Component Values**

COMPONENT	VALUE
$R_I$	40 kΩ
$C_{BYPASS}^{(1)}$	0.22 μF
$C_S$	1 μF
$C_I$	0.22 μF

(1)  $C_{BYPASS}$  is optional.

#### 8.2.1.1 Design Requirements

For this design example, use the parameters listed in Table 4 as the input parameters.

**Table 4. Design Parameters**

PARAMETER	EXAMPLE VALUE
Power supply voltage	2.5 V to 5.5 V
Current	4 mA to 5 mA
Shutdown	High > 1.55 V
	Low < 0.5 V
Speaker	3 Ω, 4 Ω, or 8 Ω

## 8.2.1.2 Detailed Design Procedure

### 8.2.1.2.1 Resistors ( $R_I$ )

The input resistor ( $R_I$ ) can be selected to set the gain of the amplifier according to [Equation 18](#).

$$\text{Gain} = \frac{R_F}{R_I} \quad (18)$$

The internal feedback resistors ( $R_F$ ) are trimmed to 40 kΩ.

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 the cancellation of the second harmonic distortion diminishes if resistor mismatch occurs. Therefore, TI recommends 1%-tolerance resistors or better to optimize performance.

### 8.2.1.2.2 Bypass Capacitor ( $C_{\text{BYPASS}}$ ) and Start-Up Time

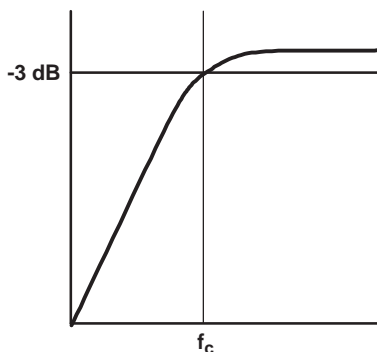
The internal voltage divider at the BYPASS pin of this device sets a mid-supply voltage for internal references and sets the output common mode voltage to  $V_{\text{DD}} / 2$ . Adding a capacitor filters any noise into this pin, increasing  $k_{\text{SVR}} \cdot C_{\text{BYPASS}}$  also determines the rise time of  $V_{\text{O+}}$  and  $V_{\text{O-}}$  when the device exits shutdown. The larger the capacitor, the slower the rise time.

### 8.2.1.2.3 Input Capacitor ( $C_I$ )

The TPA6211A1-Q1 device does not require input coupling capacitors when driven by a differential input source biased from 0.5 V to  $V_{\text{DD}} - 0.8$  V. Use 1% tolerance or better gain-setting resistors if not using input coupling capacitors.

In the single-ended input application, an input capacitor ( $C_I$ ) is required to allow the amplifier to bias the input signal to the proper DC level. In this case,  $C_I$  and  $R_I$  form a high-pass filter with the corner frequency defined in [Equation 19](#).

$$f_c = \frac{1}{2\pi R_I C_I} \quad (19)$$



**Figure 32. Input Filter Cutoff Frequency**

The value of  $C_I$  is an important consideration, as it directly affects the bass (low frequency) performance of the circuit. Consider the example where  $R_I$  is 10 kΩ and the specification calls for a flat bass response down to 100 Hz. [Equation 19](#) is reconfigured as [Equation 20](#).

$$C_I = \frac{1}{2\pi R_I f_c} \quad (20)$$

In this example,  $C_I$  is 0.16  $\mu\text{F}$ , so the likely choice ranges from 0.22  $\mu\text{F}$  to 0.47  $\mu\text{F}$ . TI recommends the use of ceramic capacitors because they are the best choice in preventing leakage current. When polarized capacitors are used, the positive side of the capacitor faces the amplifier input in most applications. The input DC level is held at  $V_{DD} / 2$ , typically higher than the source DC level. Confirming the capacitor polarity in the application is important.

#### 8.2.1.2.4 Band-Pass Filter ( $R_I$ , $C_I$ , and $C_F$ )

Having signal filtering beyond the one-pole high-pass filter formed by the combination of  $C_I$  and  $R_I$  can be desirable. A low-pass filter can be added by placing a capacitor ( $C_F$ ) between the inputs and outputs, forming a band-pass filter.

An example of when this technique might be used would be in an application where the desirable pass-band range is between 100 Hz and 10 kHz, with a gain of 4 V/V. Equation 21 to Equation 28 allow the proper values of  $C_F$  and  $C_I$  to be determined.

##### 8.2.1.2.4.1 Step 1: Low-Pass Filter

$$f_{c(\text{LPF})} = \frac{1}{2\pi R_F C_F} \quad (21)$$

$$f_{c(\text{LPF})} = \frac{1}{2\pi 40\text{k}\Omega C_F} \quad (22)$$

Therefore,

$$C_F = \frac{1}{2\pi 40\text{k}\Omega f_{c(\text{LPF})}} \quad (23)$$

Substituting 10 kHz for  $f_{c(\text{LPF})}$  and solving for  $C_F$ :

$$C_F = 398\text{ pF} \quad (24)$$

##### 8.2.1.2.4.2 Step 2: High-Pass Filter

$$f_{c(\text{HPF})} = \frac{1}{2\pi R_I C_I} \quad (25)$$

Because the application in this case requires a gain of 4 V/V,  $R_I$  must be set to 10 k $\Omega$ .

Substituting  $R_I$  into Equation 25.

$$f_{c(\text{HPF})} = \frac{1}{2\pi 10\text{k}\Omega C_I} \quad (26)$$

Therefore,

$$C_I = \frac{1}{2\pi 10\text{k}\Omega f_{c(\text{HPF})}} \quad (27)$$

Substituting 100 Hz for  $f_{c(\text{HPF})}$  and solving for  $C_I$ :

$$C_I = 0.16\text{ }\mu\text{F} \quad (28)$$

At this point, a first-order band-pass filter has been created with the low-frequency cutoff set to 100 Hz and the high-frequency cutoff set to 10 kHz.

The process can be taken a step further by creating a second-order high-pass filter. This is accomplished by placing a resistor ( $R_a$ ) and capacitor ( $C_a$ ) in the input path.  $R_a$  must be at least 10 times smaller than  $R_I$ ; otherwise its value has a noticeable effect on the gain, as  $R_a$  and  $R_I$  are in series.

##### 8.2.1.2.4.3 Step 3: Additional Low-Pass Filter

$R_a$  must be at least ten-times smaller than  $R_I$ . Set  $R_a = 1\text{ k}\Omega$

$$f_{c(LPF)} = \frac{1}{2\pi R_a C_a} \quad (29)$$

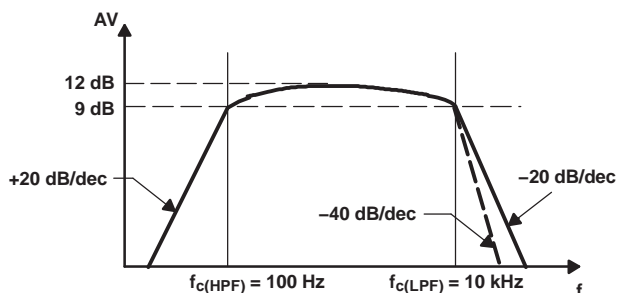
Therefore,

$$C_a = \frac{1}{2\pi \cdot 1k\Omega \cdot f_{c(LPF)}} \quad (30)$$

Substituting 10 kHz for  $f_{c(LPF)}$  and solving for  $C_a$ :

$$C_a = 160 \text{ pF} \quad (31)$$

Figure 33 is a bode plot for the band-pass filter in the previous example. Figure 38 shows how to configure the TPA6211A1-Q1 device as a band-pass filter.



**Figure 33. Bode Plot**

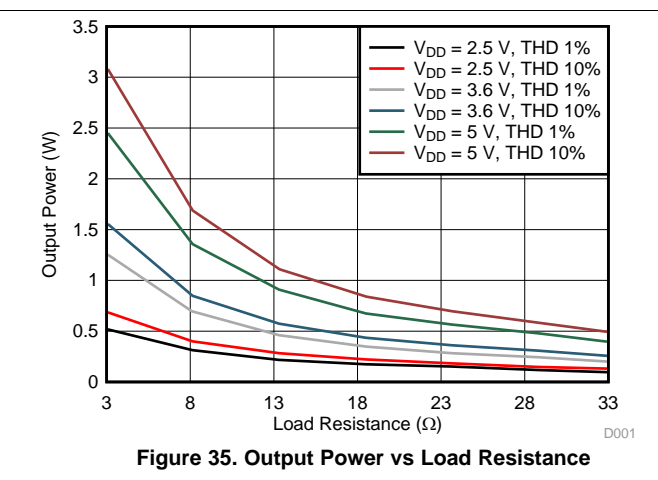
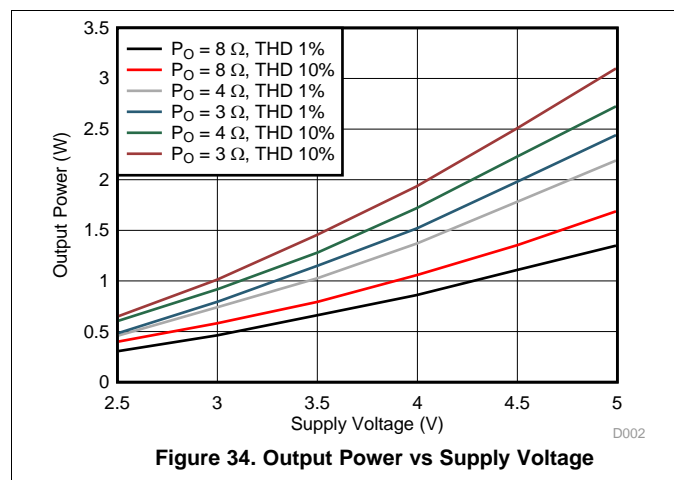
#### 8.2.1.2.5 Decoupling Capacitor ( $C_s$ )

The TPA6211A1-Q1 device is a high-performance CMOS audio amplifier that requires adequate power supply decoupling to ensure the output total harmonic distortion (THD) is as low as possible. Power-supply decoupling also prevents oscillations for long lead lengths between the amplifier and the speaker. For higher frequency transients, spikes, or digital hash on the line, a good low equivalent-series-resistance (ESR) ceramic capacitor, typically 0.1  $\mu\text{F}$  to 1  $\mu\text{F}$ , placed as close as possible to the device  $V_{DD}$  lead works best. For filtering lower frequency noise signals, a 10- $\mu\text{F}$  or greater capacitor placed near the audio power amplifier also helps, but is not required in most applications because of the high PSRR of this device.

#### 8.2.1.2.6 Using Low-ESR Capacitors

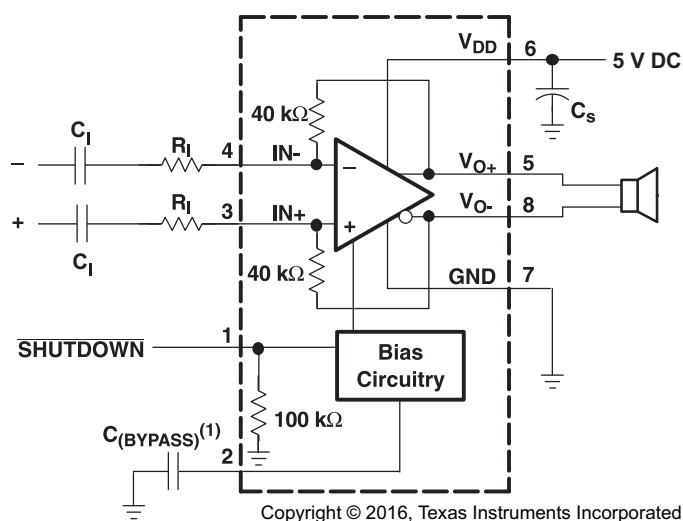
Low-ESR capacitors are recommended throughout this applications section. A real (as opposed to ideal) capacitor can be modeled simply as a resistor in series with an ideal capacitor. The voltage drop across this resistor minimizes the beneficial effects of the capacitor in the circuit. The lower the equivalent value of this resistance the more the real capacitor behaves like an ideal capacitor.

### 8.2.1.3 Application Curves



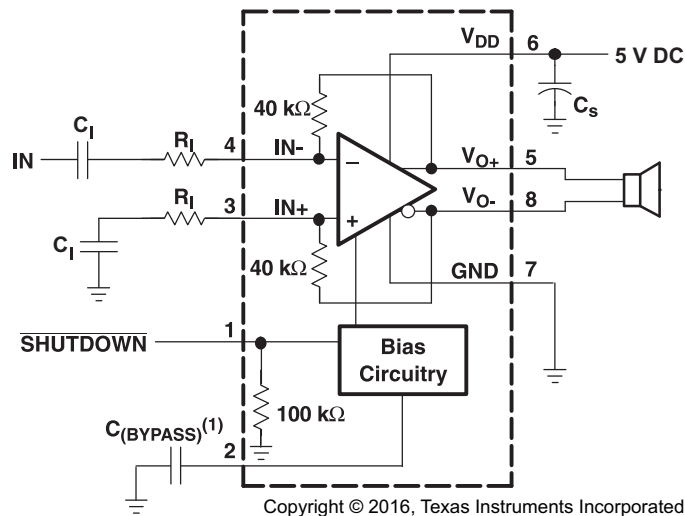
### 8.2.2 Other Application Circuits

Figure 36, Figure 37, and Figure 38 show example circuits using the TPA6211A1-Q1 device.



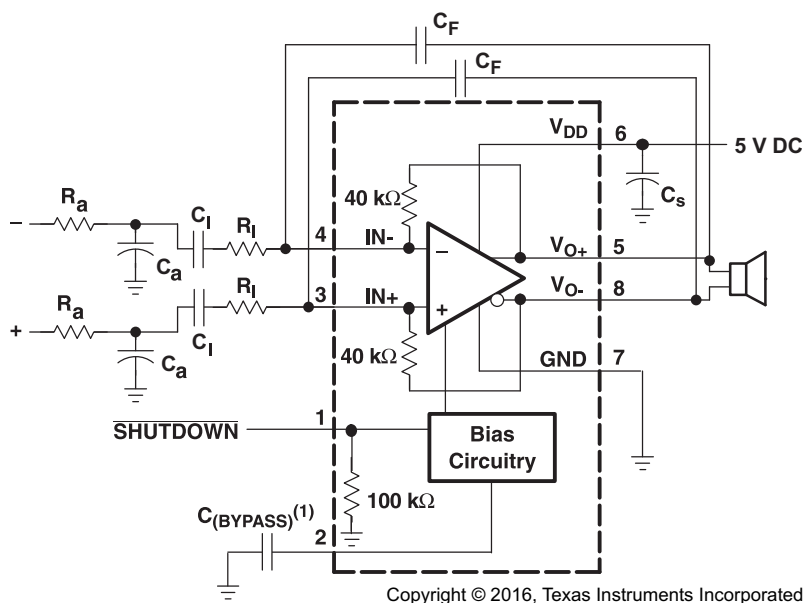
(1)  $C_{(BYPASS)}$  is optional

Figure 36. Differential Input Application Schematic Optimized With Input Capacitors



(1)  $C_{(BYPASS)}$  is optional

**Figure 37. Single-Ended Input Application Schematic**



(1)  $C_{(BYPASS)}$  is optional

**Figure 38. Differential Input Application Schematic With Input Bandpass Filter**

## 9 Power Supply Recommendations

The TPA6211A1-Q1 device 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 must be within this range and well regulated. The current capability of upper power should not exceed the maximum current limit of the power switch.

## 9.1 Power Supply Decoupling Capacitor

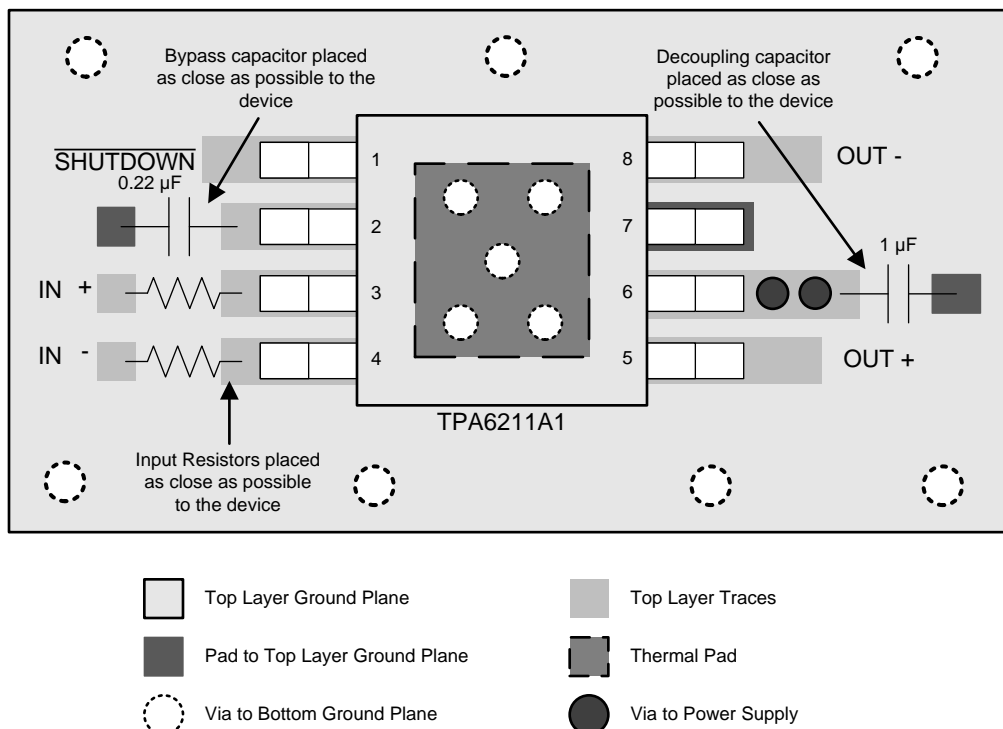
The TPA6211A1-Q1 device requires adequate power supply decoupling to ensure a high efficiency operation with low total harmonic distortion (THD). Place a low equivalent series resistance (ESR) ceramic capacitor, typically 0.1  $\mu\text{F}$ , as close as possible of the  $V_{\text{DD}}$  pin. This choice of capacitor and placement helps with higher frequency transients, spikes, or digital hash on the line. TI recommends placing a 2.2- $\mu\text{F}$  to 10- $\mu\text{F}$  capacitor on the  $V_{\text{DD}}$  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.

## 10 Layout

### 10.1 Layout Guidelines

Place all the external components close to the TPA6211A1-Q1 device. The input resistors need to be close to the device input pins so noise does not couple on the high impedance nodes between the input resistors and the input amplifier of the device. Placing the decoupling capacitors,  $C_{\text{S}}$  and  $C_{\text{BYPASS}}$ , close to the TPA6211A1-Q1 device is important for the efficiency of the amplifier. Any resistance or inductance in the trace between the device and the capacitor can cause a loss in efficiency.

### 10.2 Layout Example



**Figure 39. TPA6211A1-Q1 8-Pin MSOP-PowerPAD™ (DGN) Board Layout**



## 11 Device and Documentation Support

### 11.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on 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.

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

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All other trademarks are the property of their respective owners.

### 11.4 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.

### 11.5 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

## 12 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 Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TPA6211A1TDGNRQ1	ACTIVE	MSOP- PowerPAD	DGN	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 105	6211Q	<a href="#">Samples</a>

(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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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**OTHER QUALIFIED VERSIONS OF TPA6211A1-Q1 :**

- Catalog: [TPA6211A1](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

**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
TPA6211A1TDGNRQ1	MSOP-Power PAD	DGN	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1

## TAPE AND REEL BOX DIMENSIONS

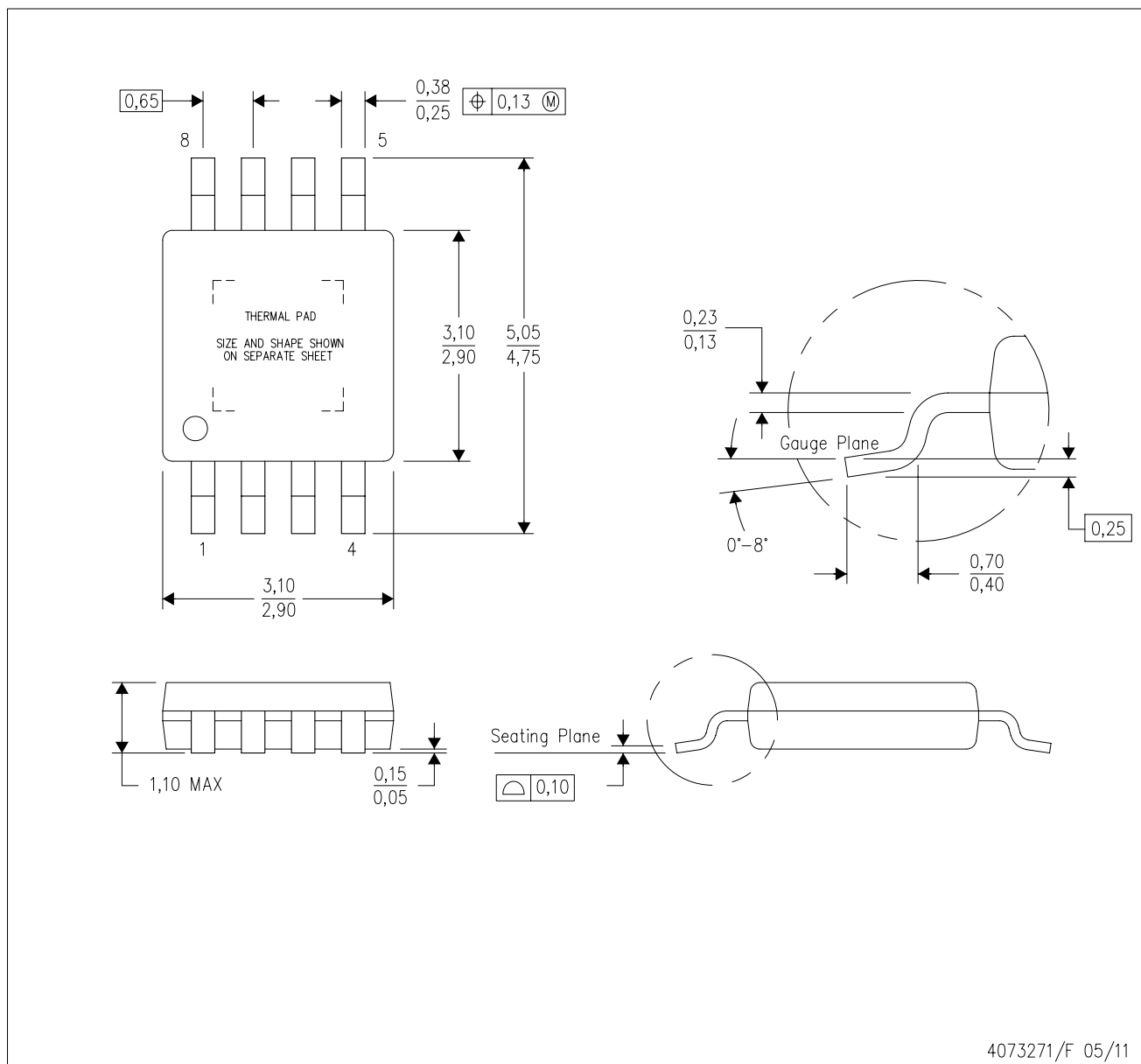


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPA6211A1TDGNRQ1	MSOP-PowerPAD	DGN	8	2500	358.0	335.0	35.0

DGN (S-PDSO-G8)

PowerPAD™ PLASTIC SMALL OUTLINE



4073271/F 05/11

- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Body dimensions do not include mold flash or protrusion.
  - This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
  - Falls within JEDEC MO-187 variation AA-T

PowerPAD is a trademark of Texas Instruments.

DGN (S-PDSO-G8)

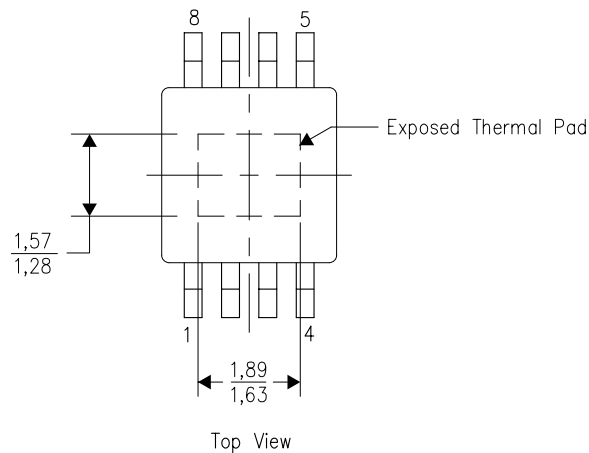
PowerPAD™ PLASTIC SMALL OUTLINE

## THERMAL INFORMATION

This PowerPAD™ package incorporates an exposed thermal pad that is designed to be attached to a printed circuit board (PCB). The thermal pad must be soldered directly to the PCB. After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For additional information on the PowerPAD package and how to take advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 and Application Brief, PowerPAD Made Easy, Texas Instruments Literature No. SLMA004. Both documents are available at [www.ti.com](http://www.ti.com).

The exposed thermal pad dimensions for this package are shown in the following illustration.



Exposed Thermal Pad Dimensions

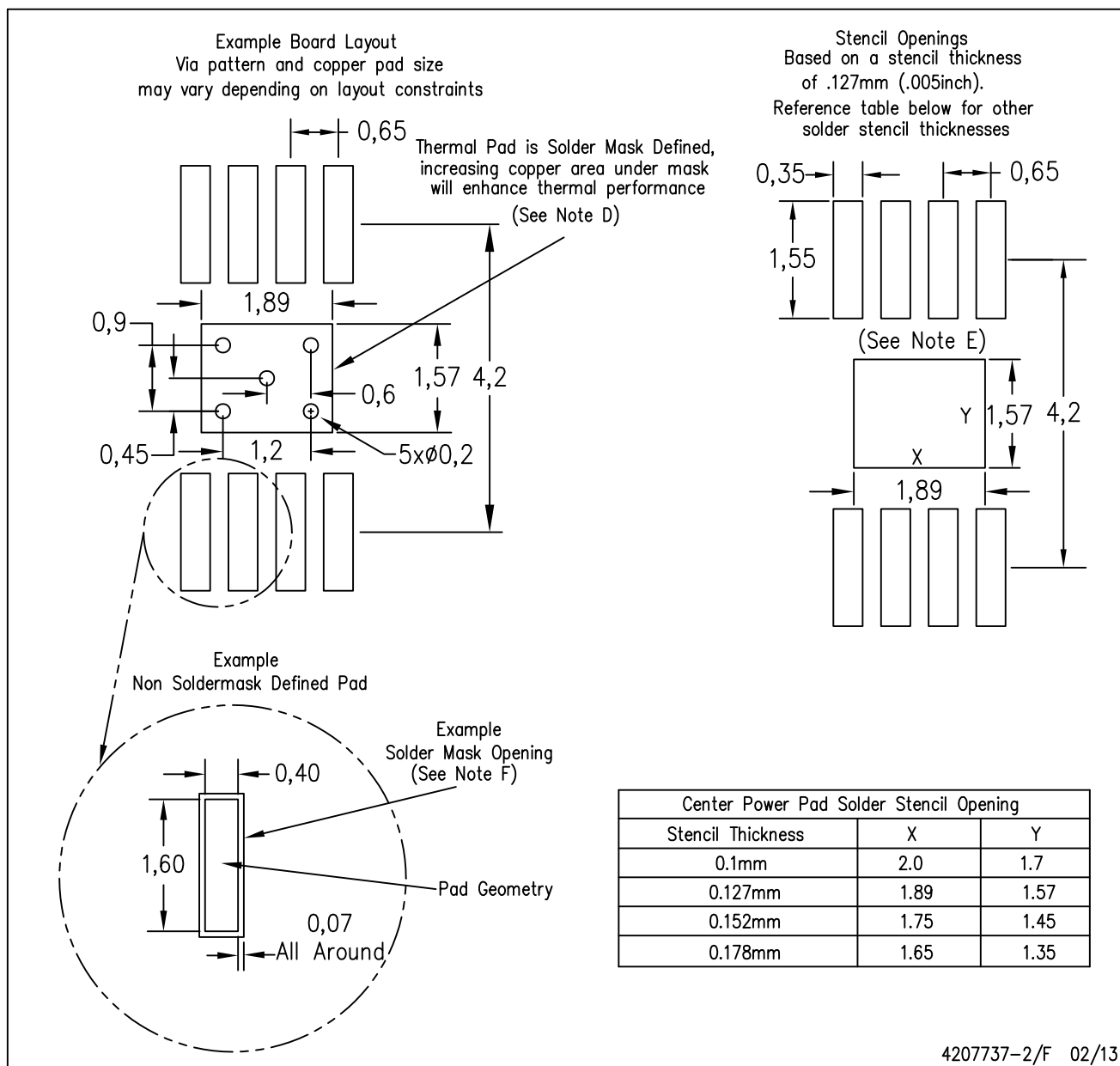
4206323-2/1 12/11

NOTE: All linear dimensions are in millimeters

PowerPAD is a trademark of Texas Instruments

DGN (R-PDSO-G8)

PowerPAD™ PLASTIC SMALL OUTLINE



4207737-2/F 02/13

- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
  - This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002, SLMA004, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

PowerPAD is a trademark of Texas Instruments



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Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
OMAP Applications Processors	<a href="http://www.ti.com/omap">www.ti.com/omap</a>
Wireless Connectivity	<a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a>

### Applications

Automotive and Transportation	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
Computers and Peripherals	<a href="http://www.ti.com/computers">www.ti.com/computers</a>
Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Space, Avionics and Defense	<a href="http://www.ti.com/space-avionics-defense">www.ti.com/space-avionics-defense</a>
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