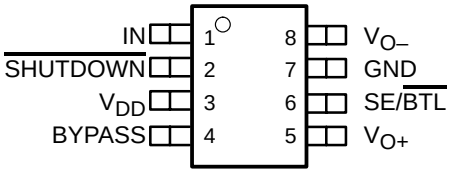
- **Ideal for Wireless Communicators, Notebook PCs, PDAs, and Other Small Portable Audio Devices**
- **2 W Into 4 Ω From 5-V Supply**
- **0.6 W Into 4 Ω From 3-V Supply**
- **Wide Power Supply Compatibility 3 V to 5 V**
- **Low Supply Current**
  - **4 mA Typical at 5 V**
  - **4 mA Typical at 3 V**
- **Shutdown Control . . . 1 μA Typical**
- **Shutdown Pin Is TTL Compatible**
- **–40°C to 85°C Operating Temperature Range**
- **Space-Saving, Thermally-Enhanced MSOP Packaging**

DGN PACKAGE
(TOP VIEW)



description

The TPA0211 is a 2-W mono bridge-tied-load (BTL) amplifier designed to drive speakers with as low as 4-Ω impedance. The device is ideal for small wireless communicators, notebook PCs, PDAs, anyplace a mono speaker and stereo headphones are required. From a 5-V supply, the TPA0211 can deliver 2 W of power into a 4-Ω speaker.

The gain of the input stage is set by the user-selected input resistor and a 50-kΩ internal feedback resistor ($A_V = – R_F/R_I$). The power stage is internally configured with a gain of –1.25 V/V in SE mode, and –2.5 V/V in BTL mode. Thus, the overall gain of the amplifier is –62.5 kΩ/ R_I in SE mode and –125 kΩ/R_I in BTL mode. The input terminals are high-impedance CMOS inputs, and can be used as summing nodes.

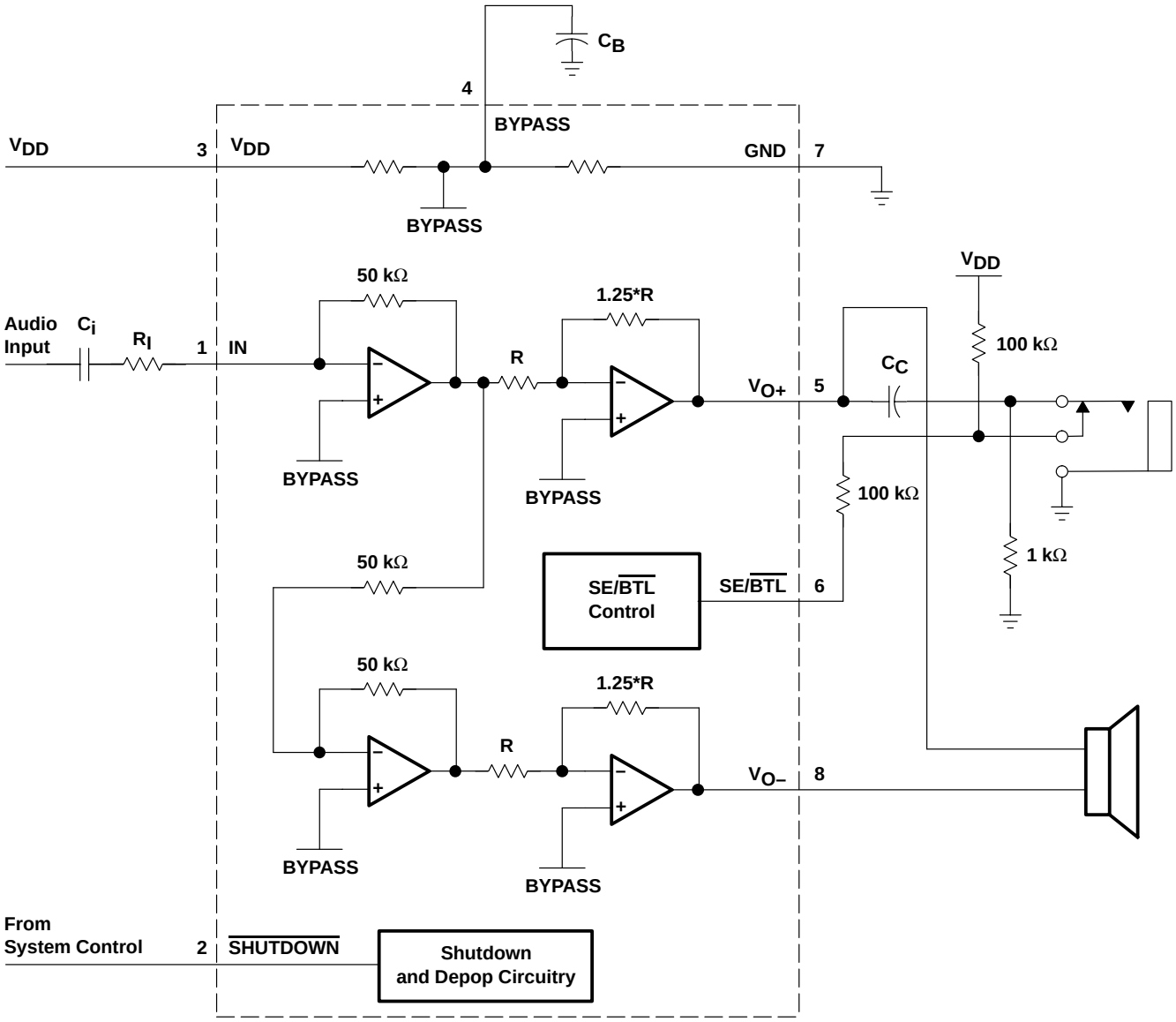
The TPA0211 is available in the 8-pin thermally-enhanced MSOP package (DGN) and operates over an ambient temperature range of –40°C to 85°C.

AVAILABLE OPTIONS

T_A	PACKAGED DEVICES	MSOP SYMBOLIZATION
	MSOP† (DGN)	
–40°C to 85°C	TPA0211DGN	AEG

† The DGN package are available taped and reeled. To order a taped and reeled part, add the suffix R to the part number (e.g., TPA0211DGNR).

functional block diagram



Terminal Functions

TERMINAL NAME	TERMINAL NO.	I/O	DESCRIPTION
BYPASS	4	I	BYPASS is the tap to the voltage divider for internal mid-supply bias. This terminal should be connected to a 0.1-µF to 1-µF capacitor.
GND	7		GND is the ground connection.
IN	1	I	IN is the audio input terminal.
SE/$\overline{\text{BTL}}$	6	I	When SE/$\overline{\text{BTL}}$ is held low, the TPA0211 is in BTL mode. When SE/$\overline{\text{BTL}}$ is held high, the TPA0211 is in SE mode.
$\overline{\text{SHUTDOWN}}$	2	I	$\overline{\text{SHUTDOWN}}$ places the entire device in shutdown mode when held low. TTL compatible input.
V_{DD}	3		V_{DD} is the supply voltage terminal.
V_{O+}	5	O	V_{O+} is the positive output for BTL and SE modes.
$V_{O–}$	8	O	$V_{O–}$ is the negative output in BTL mode and a high-impedance output in SE mode.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V_{DD} . . . . . 6 V
Input voltage range, V_I . . . . . –0.3 V to V_{DD} +0.3 V
Continuous total power dissipation . . . . . internally limited (see Dissipation Rating Table)
Operating free-air temperature range, T_A . . . . . –40°C to 85°C
Operating junction temperature range, T_J . . . . . –40°C to 150°C
Storage temperature range, T_{stg} . . . . . –65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . . 260°C

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

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$	DERATING FACTOR	$T_A = 70°C$	$T_A = 85°C$
DGN	2.14 W‡	17.1 mW/°C	1.37 W	1.11 W

‡See the Texas Instruments document, *PowerPAD Thermally Enhanced Package Application Report* (SLMA002), for more information on the PowerPAD™ package. The thermal data was measured on a PCB layout based on the information in the section entitled *Texas Instruments Recommended Board for PowerPAD* on page 33 of that document.

recommended operating conditions

			MIN	MAX	UNIT
Supply voltage, V_{DD}			2.5	5.5	V
High-level input voltage, V_{IH}	SE/$\overline{BTL}$	V_{DD} = 3 V	2.7		V
		V_{DD} = 5 V	4.5		
	$\overline{SHUTDOWN}$		2		
Low-level input voltage, V_{IL}	SE/$\overline{BTL}$	V_{DD} = 3 V		1.65	V
		V_{DD} = 5 V		2.75	
	$\overline{SHUTDOWN}$			0.8	
Operating free-air temperature, T_A			–40	85	°C

electrical characteristics at specified free-air temperature, V_{DD} = 3 V, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$\lvert V_{OO}\rvert$	Output offset voltage (measured differentially)	SE/$\overline{BTL}$ = 0 V, $\overline{SHUTDOWN}$ = 2 V, R_L = 8 Ω, Inputs floating				30	mV
$I_{DD(BTL)}$	Supply current, BTL mode	SE/$\overline{BTL}$ = 1.375 V, $\overline{SHUTDOWN}$ = 2 V, V_{DD} = 2.5 V			4	6	mA
$I_{DD(SE)}$	Supply current, SE mode	SE/$\overline{BTL}$ = 2.25 V, $\overline{SHUTDOWN}$ = 2 V, V_{DD} = 2.5 V			2	4	mA
$I_{DD(SD)}$	Supply current, shutdown mode	$\overline{SHUTDOWN}$ = 0 V, SE/$\overline{BTL}$ = 3 V			1	10	µA
$\lvert I_{IH}\rvert$	High-level input current	$\overline{SHUTDOWN}$	V_{DD} = 3.3 V, $V_I = V_{DD}$			1	µA
		SE/$\overline{BTL}$	V_{DD} = 3.3 V, $V_I = V_{DD}$			1	
$\lvert I_{IL}\rvert$	Low-level input current	$\overline{SHUTDOWN}$	V_{DD} = 3.3 V, V_I = 0 V			1	µA
		SE/$\overline{BTL}$	V_{DD} = 3.3 V, V_I = 0 V			1	
R_F	Feedback resistor	V_{DD} = 2.5 V, $\overline{SHUTDOWN}$ = 2 V, SE/$\overline{BTL}$ = 0 V, R_L = 4 Ω		45	50	60	kΩ

PowerPAD is a trademark of Texas Instruments.

operating characteristics, V_{DD} = 3 V, T_A = 25°C, R_L = 4 Ω

PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
P_O	Output power	THD = 1%,	BTL mode,	f = 1 kHz		660		mW
		THD = 0.1%,	SE mode, f = 1 kHz,	R_L = 32 Ω		33		
THD + N	Total harmonic distortion plus noise	P_O = 500 mW,	f = 20 Hz to 20 kHz			0.3%		
B_{OM}	Maximum output power bandwidth	Gain = 2,	THD = 2%			20		kHz
SNR	Signal-to-noise ratio					88		dB
V_n	Output noise voltage	C_B = 0.47 µF, f = 20 Hz to 20 kHz	BTL mode, R_L = 8 Ω,	A_V= 8 dB		65		μV_{RMS}
			SE mode, R_L = 32 Ω,	A_V= 2 dB		25		

electrical characteristics at specified free-air temperature, V_{DD} = 5 V, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$\lvert V_{OO}\rvert$	Output offset voltage (measured differentially)	SE/$\overline{\text{BTL}}$ = 0 V, $\overline{\text{SHUTDOWN}}$ = 2 V, R_L = 8 Ω, Inputs floating				30	mV
$I_{DD(BTL)}$	Supply current, BTL mode	SE/$\overline{\text{BTL}}$ = 2.75 V, $\overline{\text{SHUTDOWN}}$ = V_{DD}			4	6	mA
$I_{DD(SE)}$	Supply current, SE mode	SE/$\overline{\text{BTL}}$ = 4.5 V, $\overline{\text{SHUTDOWN}}$ = V_{DD}			2	4	mA
$I_{DD(SD)}$	Supply current, shutdown mode	SE/$\overline{\text{BTL}}$ = 5 V, $\overline{\text{SHUTDOWN}}$ = 0 V			1	10	µA
$\lvert I_{IH}\rvert$	High-level input current	$\overline{\text{SHUTDOWN}}$	V_{DD} = 5.5 V, V_I = V_{DD}			1	µA
		SE/$\overline{\text{BTL}}$	V_{DD} = 5.5 V, V_I = V_{DD}			1	
$\lvert I_{IL}\rvert$	Low-level input current	$\overline{\text{SHUTDOWN}}$	V_{DD} = 5.5 V, V_I = 0 V			1	µA
		SE/$\overline{\text{BTL}}$	V_{DD} = 5.5 V, V_I = 0 V			1	

operating characteristics, V_{DD} = 5 V, T_A = 25°C, R_L = 4 Ω

PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
P_O	Output power	THD = 1%,	BTL mode,	f = 1 kHz		2		W
		THD = 0.1%,	SE mode, f = 1 kHz,	R_L = 32 Ω		92		mW
THD + N	Total harmonic distortion plus noise	P_O = 1.5 W,	f = 20 Hz to 20 kHz			0.2%		
B_{OM}	Maximum output power bandwidth	Gain = 2.5,	THD = 2%			20		kHz
SNR	Signal-to-noise ratio					93		dB
V_n	Output noise voltage	C_B = 0.47 µF, f = 20 Hz to 20 kHz	BTL mode, R_L = 8 Ω,	A_V= 8 dB		65		μV_{RMS}
			SE mode, R_L = 32 Ω,	A_V= 2 dB		25		

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
	Supply ripple rejection ratio	vs Frequency	1, 2
I_{DD}	Supply current	vs Supply voltage	3
P_O	Output power	vs Supply voltage	4, 5
		vs Load resistance	6, 7
THD+N	Total harmonic distortion plus noise	vs Frequency	8, 9, 10, 11
		vs Output power	12, 13, 14, 15, 16, 17
V_n	Output noise voltage	vs Frequency	18, 19
	Closed loop gain and phase		20, 21

TYPICAL CHARACTERISTICS

SUPPLY RIPPLE REJECTION RATIO vs FREQUENCY

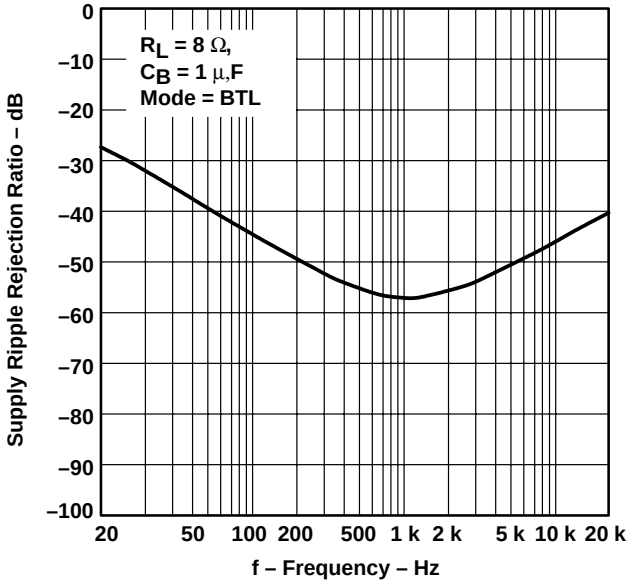


Figure 1

SUPPLY RIPPLE REJECTION RATIO vs FREQUENCY

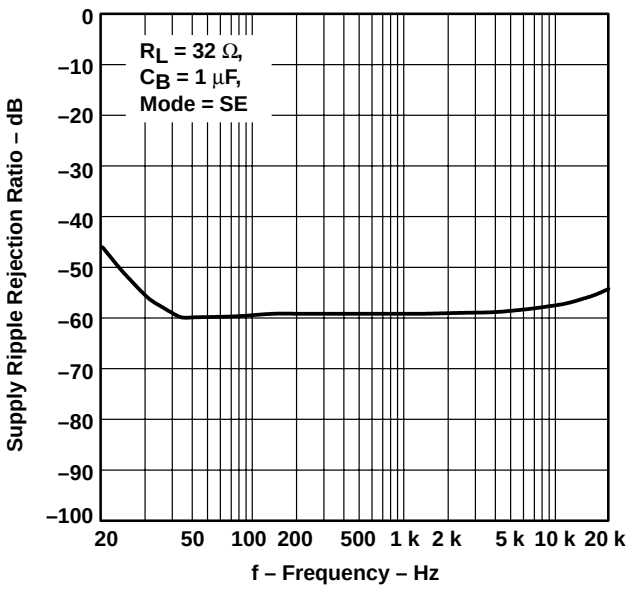


Figure 2

SUPPLY CURRENT vs SUPPLY VOLTAGE

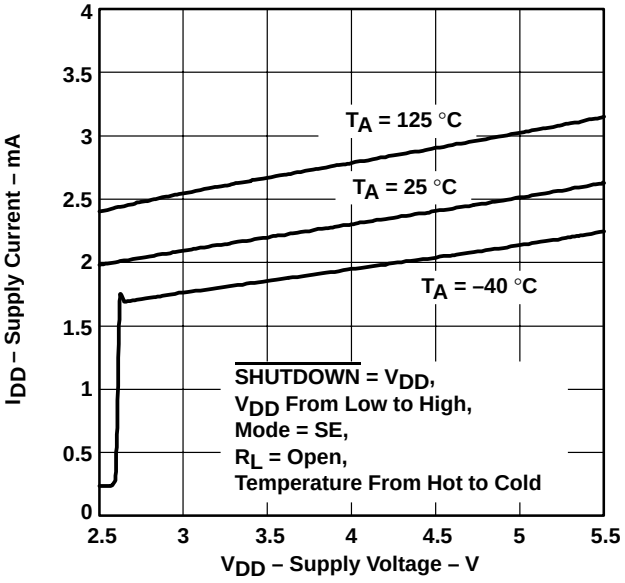


Figure 3

OUTPUT POWER vs SUPPLY VOLTAGE

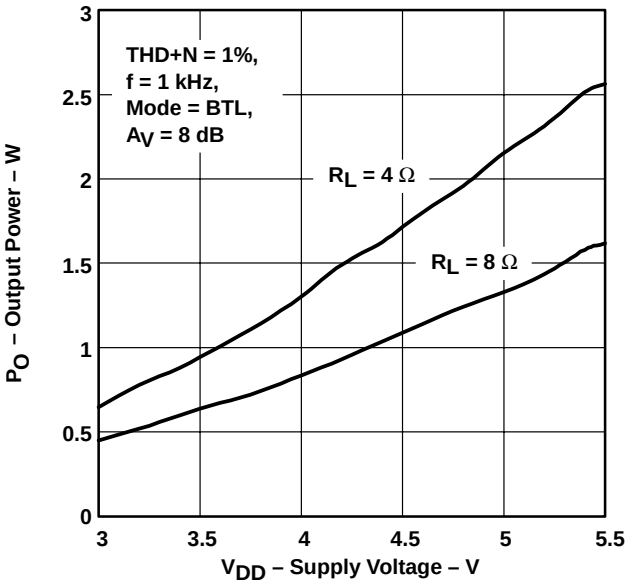


Figure 4

TYPICAL CHARACTERISTICS

OUTPUT POWER vs SUPPLY VOLTAGE

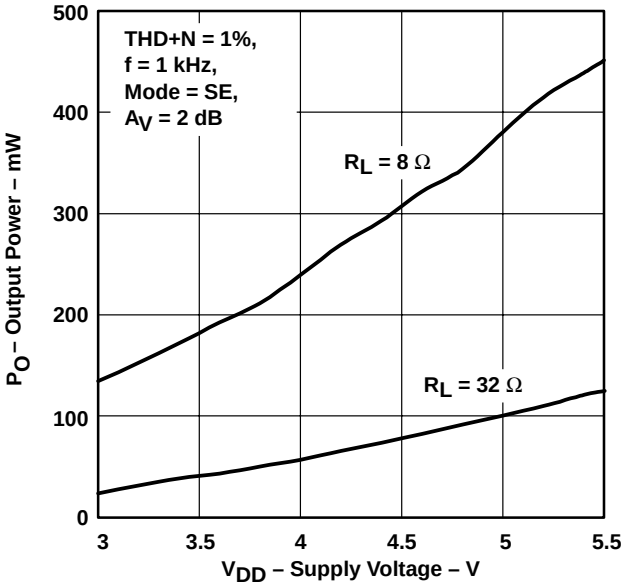


Figure 5

OUTPUT POWER vs LOAD RESISTANCE

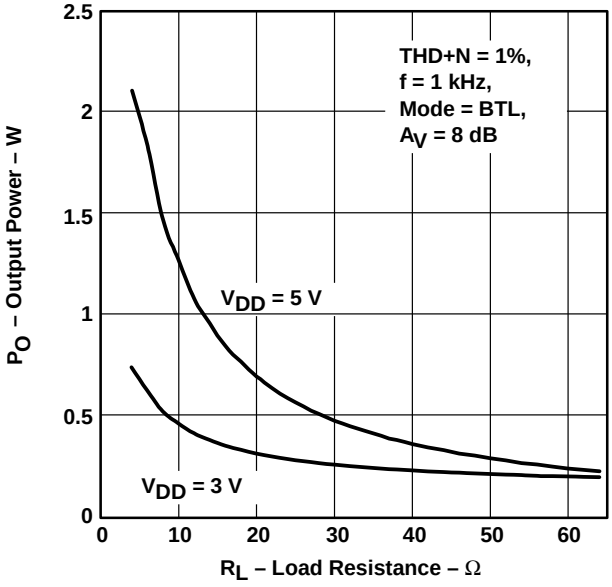


Figure 6

OUTPUT POWER vs LOAD RESISTANCE

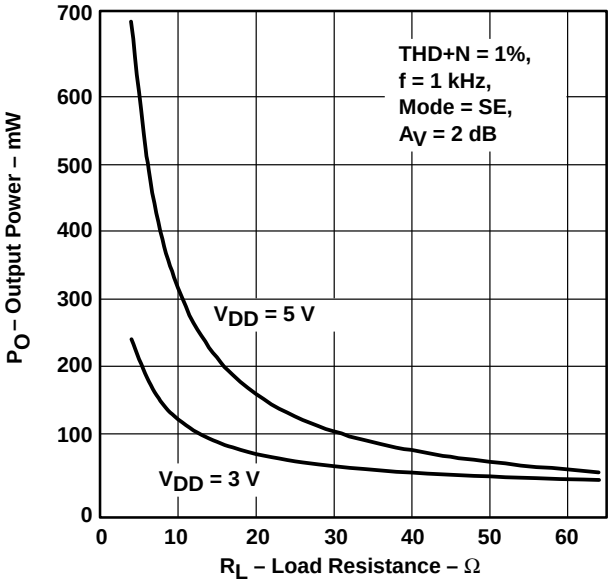


Figure 7

TYPICAL CHARACTERISTICS

TOTAL HARMONIC DISTORTION PLUS NOISE
vs
FREQUENCY

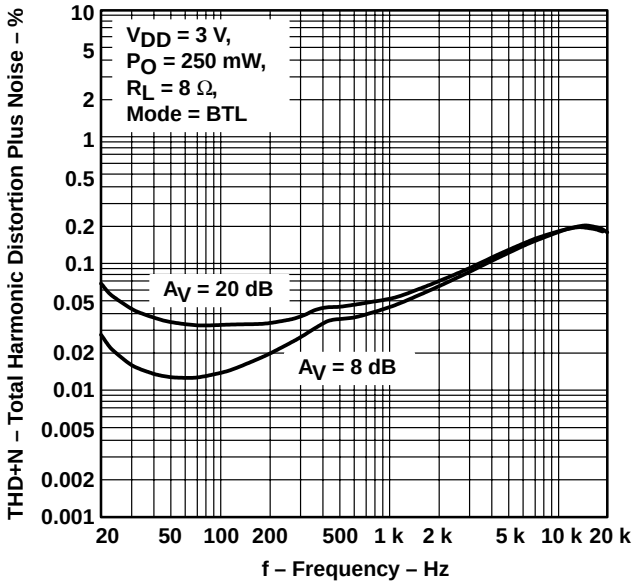


Figure 8

TOTAL HARMONIC DISTORTION PLUS NOISE
vs
FREQUENCY

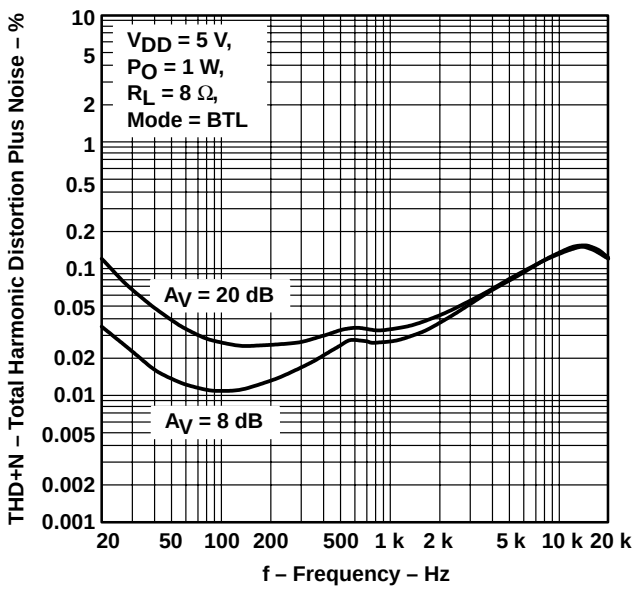


Figure 9

TOTAL HARMONIC DISTORTION PLUS NOISE
vs
FREQUENCY

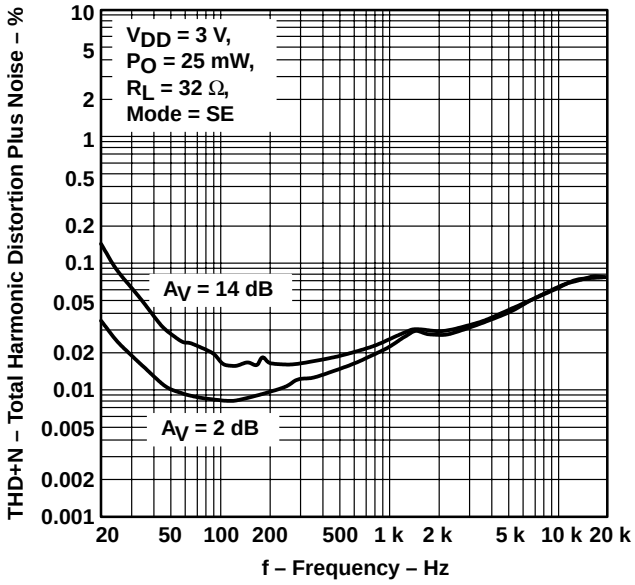


Figure 10

TOTAL HARMONIC DISTORTION PLUS NOISE
vs
FREQUENCY

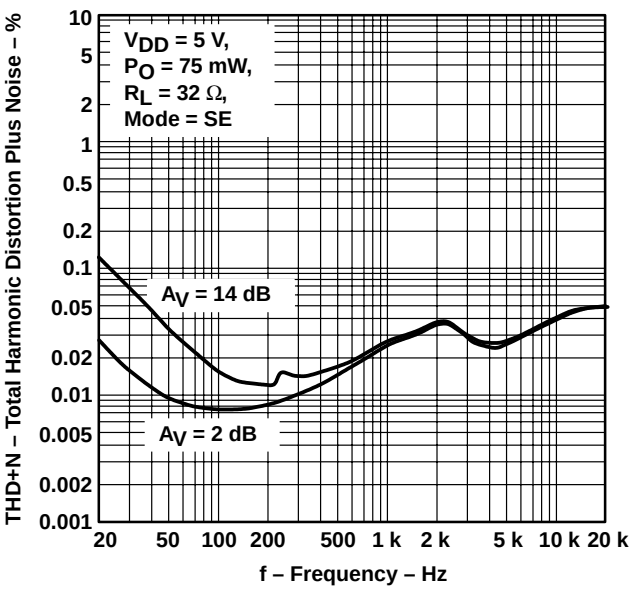


Figure 11

TYPICAL CHARACTERISTICS

TOTAL HARMONIC DISTORTION PLUS NOISE
vs
OUTPUT POWER

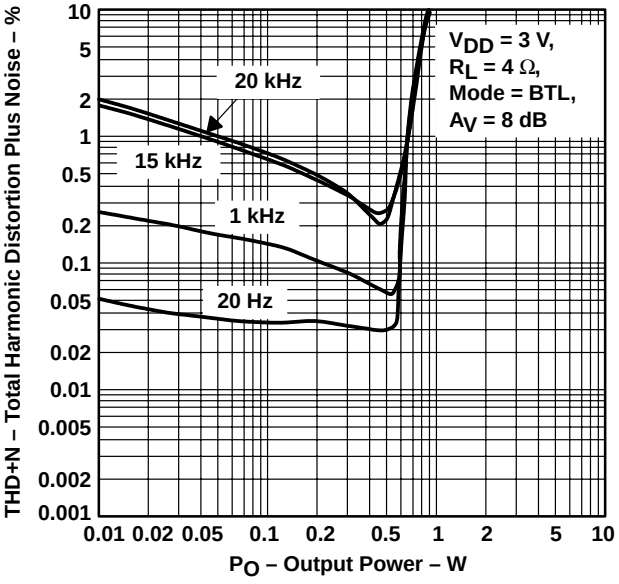


Figure 12

TOTAL HARMONIC DISTORTION PLUS NOISE
vs
OUTPUT POWER

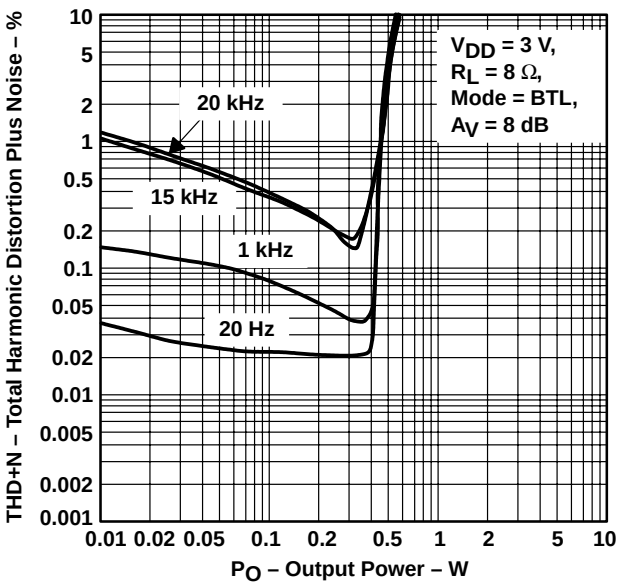


Figure 13

TOTAL HARMONIC DISTORTION PLUS NOISE
vs
OUTPUT POWER

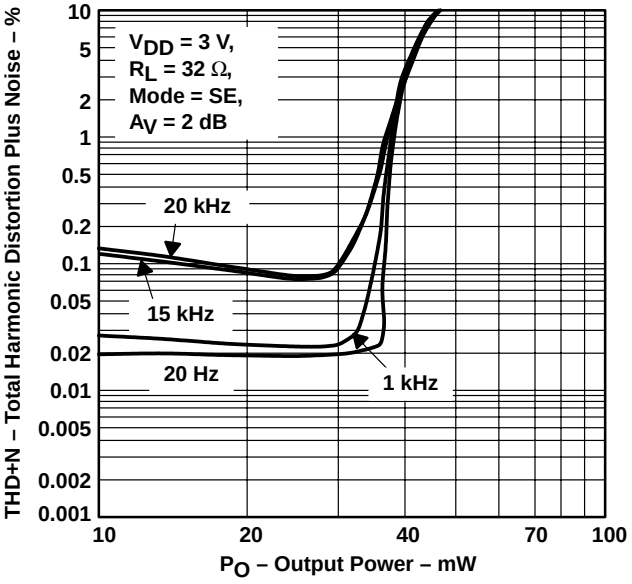


Figure 14

TOTAL HARMONIC DISTORTION PLUS NOISE
vs
OUTPUT POWER

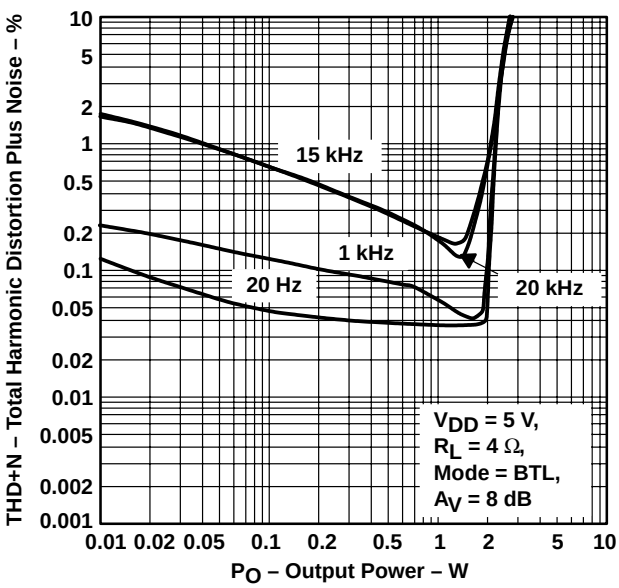


Figure 15

TYPICAL CHARACTERISTICS

TOTAL HARMONIC DISTORTION PLUS NOISE vs OUTPUT POWER

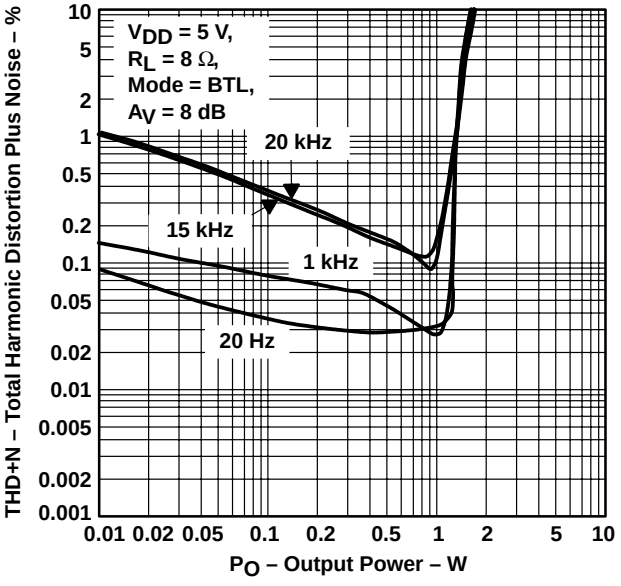


Figure 16

TOTAL HARMONIC DISTORTION PLUS NOISE vs OUTPUT POWER

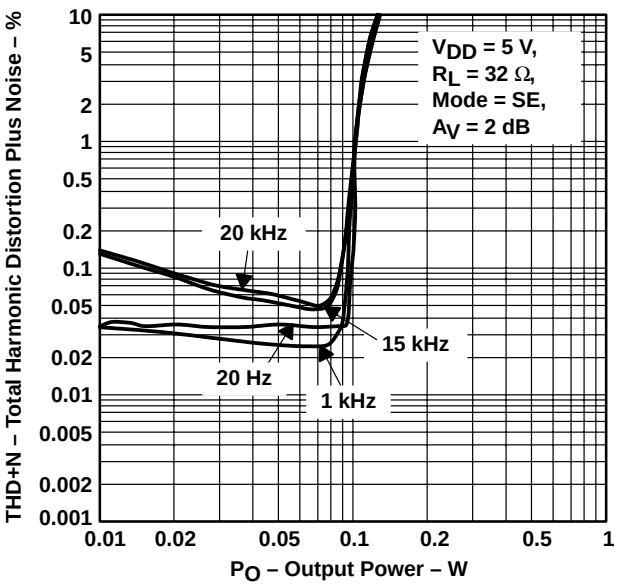


Figure 17

OUTPUT NOISE VOLTAGE vs FREQUENCY

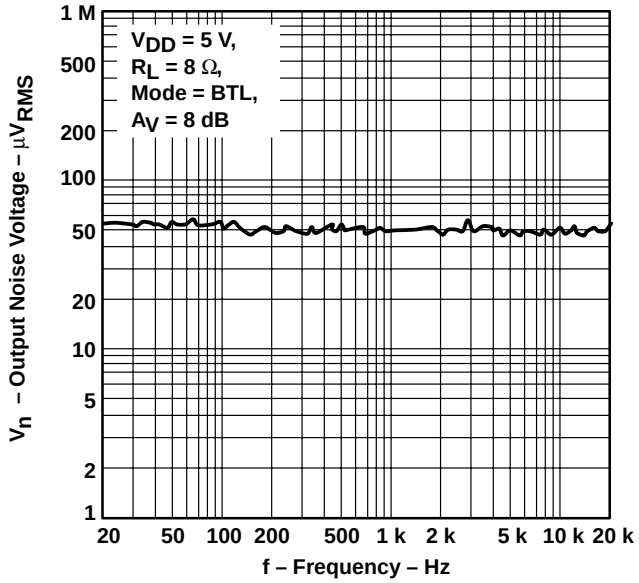


Figure 18

OUTPUT NOISE VOLTAGE vs FREQUENCY

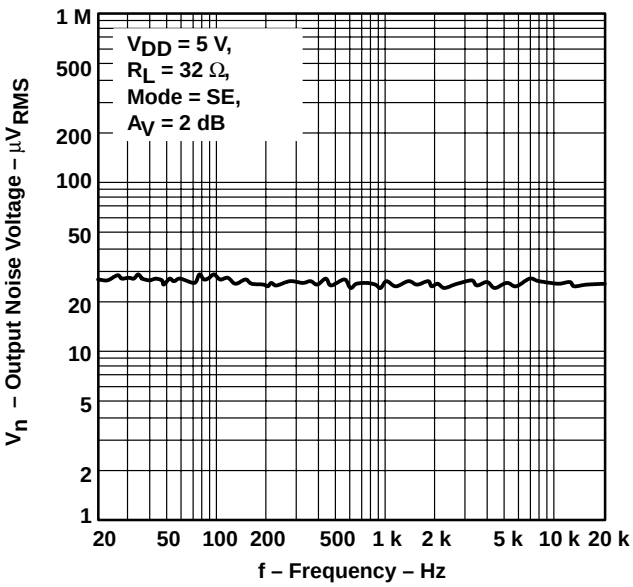


Figure 19

TYPICAL CHARACTERISTICS

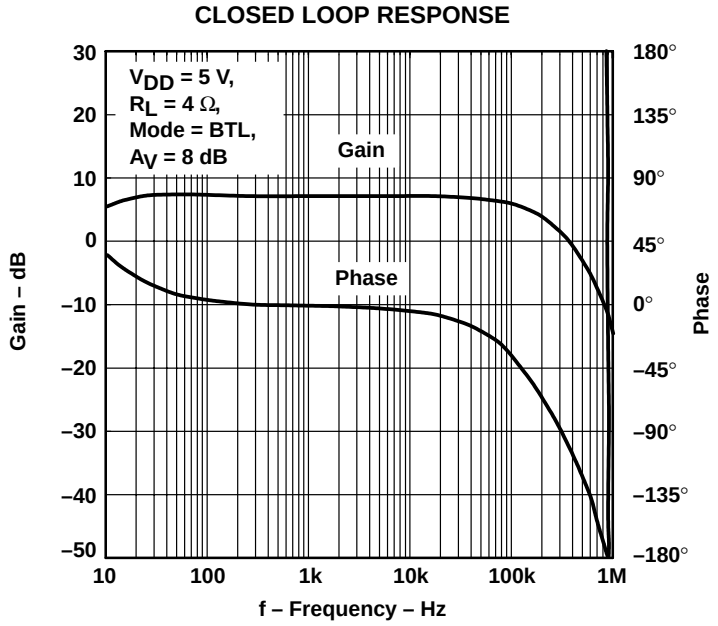


Figure 20

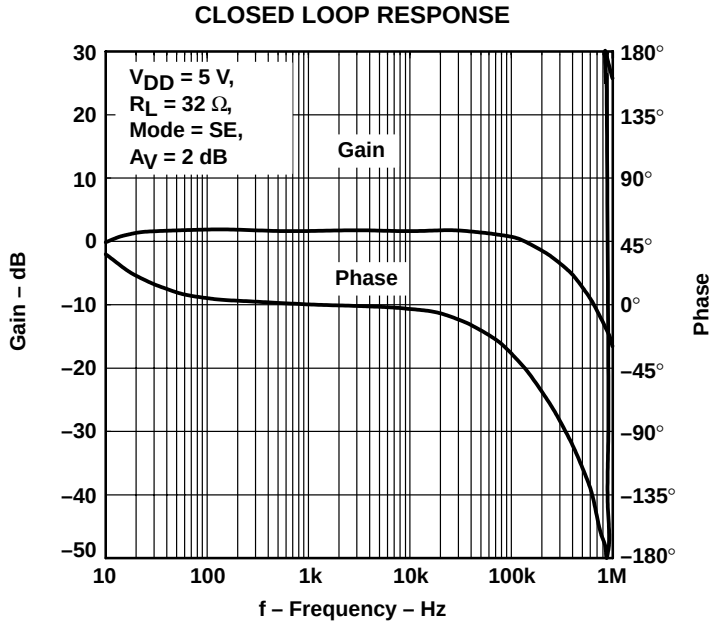


Figure 21

APPLICATION INFORMATION

gain setting via input resistance

The gain of the input stage is set by the user-selected input resistor and a 50-kΩ internal feedback resistor.

However, the power stage is internally configured with a gain of –1.25 V/V in SE mode, and –2.5 V/V in BTL mode. Thus, the feedback resistor (R_F) is effectively 62.5 kΩ in SE mode and 125 kΩ in BTL mode. Therefore, the overall gain can be calculated using equations (1) and (2).

$$A_V = \frac{-125\ k\Omega}{R_I} \quad \text{(BTL)} \tag{1}$$

$$A_V = \frac{-62.5\ k\Omega}{R_I} \quad \text{(SE)} \tag{2}$$

The –3 dB frequency can be calculated using equation 3:

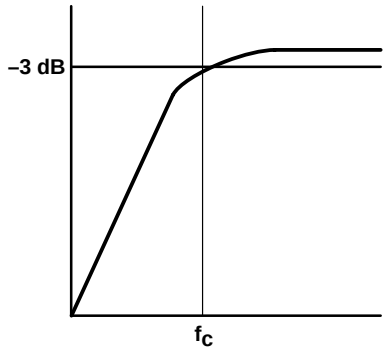
$$f_{-3\ dB} = \frac{1}{2\pi R_I C_i} \tag{3}$$

If the filter must be more accurate, the value of the capacitor should be increased while the value of the resistor to ground should be decreased. In addition, the order of the filter could be increased.

input capacitor, C_i

In the typical application an input capacitor, C_i, is required to allow the amplifier to bias the input signal to the proper dc level for optimum operation. In this case, C_i and the input resistance of the amplifier, R_I, form a high-pass filter with the corner frequency determined in equation 4.

$$f_{c(highpass)} = \frac{1}{2\pi R_I C_i} \tag{4}$$



The value of C_i is important to consider 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 40 Hz. Equation 2 is reconfigured as equation 5.

$$C_i = \frac{1}{2\pi R_I f_c} \tag{5}$$

In this example, C_I is 0.4 μF so one would likely choose a value in the range of 0.47 μF to 1 μF. A further consideration for this capacitor is the leakage path from the input source through the input network (C_i) and the feedback network to the load. This leakage current creates a dc offset voltage at the input to the amplifier that reduces useful headroom, especially in high gain applications. For this reason a low-leakage tantalum or ceramic capacitor is the best choice. When polarized capacitors are used, the positive side of the capacitor should face the amplifier input in most applications as the dc level there is held at $V_{DD}/2$, which is likely higher than the source dc level. Note that it is important to confirm the capacitor polarity in the application.

APPLICATION INFORMATION

power supply decoupling, $C_{(S)}$

The TPA0211 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. The optimum decoupling is achieved by using two capacitors of different types that target different types of noise on the power supply leads. For higher frequency transients, spikes, or digital hash on the line, a good low equivalent-series-resistance (ESR) ceramic capacitor, typically 0.1 μF placed as close as possible to the device V_{DD} lead, works best. For filtering lower-frequency noise signals, a larger aluminum electrolytic capacitor of 10 μF or greater placed near the audio power amplifier is recommended.

midrail bypass capacitor, $C_{(BYP)}$

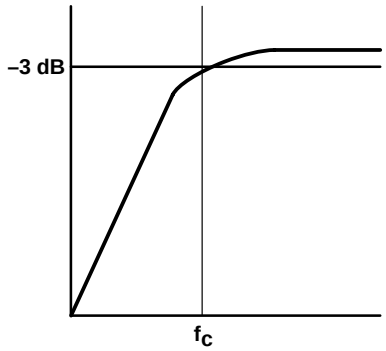
The midrail bypass capacitor, $C_{(BYP)}$, is the most critical capacitor and serves several important functions. During start-up or recovery from shutdown mode, $C_{(BYP)}$ determines the rate at which the amplifier starts up. The second function is to reduce noise produced by the power supply caused by coupling into the output drive signal. This noise is from the midrail generation circuit internal to the amplifier, which appears as degraded PSRR and THD+N.

Bypass capacitor, $C_{(BYP)}$, values of 0.47 μF to 1 μF ceramic or tantalum low-ESR capacitors are recommended for the best THD and noise performance.

output coupling capacitor, $C_{(C)}$

In the typical single-supply SE configuration, an output coupling capacitor ($C_{(C)}$) is required to block the dc bias at the output of the amplifier thus preventing dc currents in the load. As with the input coupling capacitor, the output coupling capacitor and impedance of the load form a high-pass filter governed by equation 6.

$$f_{c(high)} = \frac{1}{2\pi R_L C_{(C)}} \quad (6)$$



The main disadvantage, from a performance standpoint, is that the load impedances are typically small, which drives the low-frequency corner higher, degrading the bass response. Large values of $C_{(C)}$ are required to pass low frequencies into the load. Consider the example where a $C_{(C)}$ of 330 μF is chosen and loads vary from 3 Ω, 4 Ω, 8 Ω, 32 Ω, 10 kΩ, to 47 kΩ. Table 1 summarizes the frequency response characteristics of each configuration.

APPLICATION INFORMATION

Table 1. Common Load Impedances vs Low Frequency Output Characteristics in SE Mode

R_L	$C_{(C)}$	Lowest Frequency
3 Ω	330 μF	161 Hz
4 Ω	330 μF	120 Hz
8 Ω	330 μF	60 Hz
32 Ω	330 μF	15 Hz
10,000 Ω	330 μF	0.05 Hz
47,000 Ω	330 μF	0.01 Hz

As Table 1 indicates, most of the bass response is attenuated into a 4-Ω load, an 8-Ω load is adequate, headphone response is good, and drive into line level inputs (a home stereo for example) is exceptional.

Furthermore, the total amount of ripple current that must flow through the capacitor must be considered when choosing the component. As shown in the application circuit, one coupling capacitor must be in series with the mono loudspeaker for proper operation of the stereo-mono switching circuit. For a 4-Ω load, this capacitor must be able to handle about 700 mA of ripple current for a continuous output power of 2 W.

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.

bridged-tied load versus single-ended mode

Figure 22 shows a Class-AB audio power amplifier (APA) in a BTL configuration. The TPA0211 BTL amplifier consists of two Class-AB amplifiers driving both ends of the load. There are several potential benefits to this differential drive configuration, but initially consider 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, where voltage is squared, yields 4× the output power from the same supply rail and load impedance. (See equation 7.)

$$V_{(RMS)} = \frac{V_{O(PP)}}{2\sqrt{2}} \qquad (7)$$

$$\text{Power} = \frac{V_{(RMS)}^2}{R_L}$$

APPLICATION INFORMATION

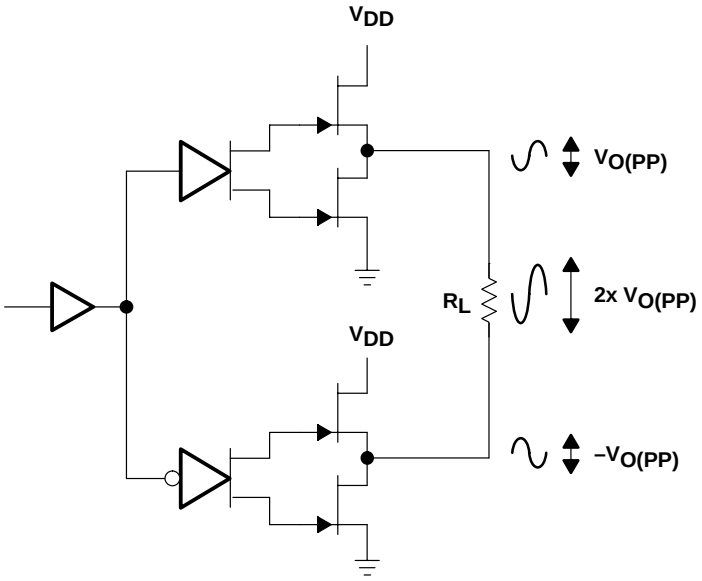


Figure 22. Bridge-Tied Load Configuration

In a typical computer sound channel operating at 5 V, bridging raises the power into an 8-Ω speaker from a singled-ended (SE, ground reference) limit of 250 mW to 1 W. In sound power, that is a 6-dB improvement—which is loudness that can be heard. In addition to increased power, there are frequency response concerns. Consider the single-supply SE configuration shown in Figure 23. A coupling capacitor is required to block the dc offset voltage from reaching the load. These capacitors can be quite large (approximately 33 μF to 1000 μF) so they tend to be expensive, heavy, occupy valuable PCB area, and have the additional drawback of limiting low-frequency performance of the system. This frequency limiting effect is due to the high pass filter network created with the speaker impedance and the coupling capacitance and is calculated with equation 8.

$$f_c = \frac{1}{2\pi R_L C_{(C)}} \quad (8)$$

APPLICATION INFORMATION

bridged-tied load versus single-ended mode (continued)

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.

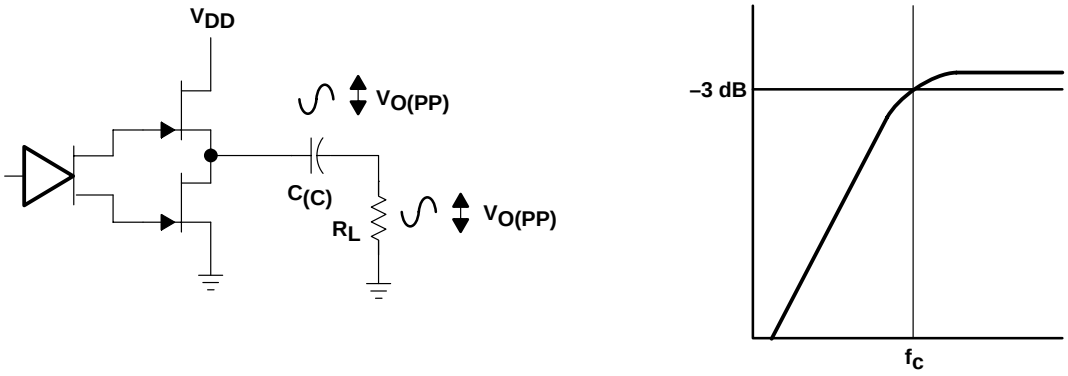


Figure 23. Single-Ended Configuration and Frequency Response

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 4× the output power of the SE configuration. Internal dissipation versus output power is discussed further in the *crest factor and thermal considerations* section.

single-ended operation

In SE mode (see Figure 22 and Figure 23), the load is driven from one amplifier output (V_{O+}, terminal 5).

The amplifier switches to single-ended operation when the SE/$\overline{\text{BTL}}$ terminal is held high.

BTL amplifier efficiency

Class-AB amplifiers are inefficient. The primary cause of inefficiencies is the voltage drop across the output stage transistors. There are two components of the internal voltage drop. One is the headroom or dc voltage drop that varies inversely to output power. The second component is due to 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 RMS value of the supply current, I_{DD}rms, determines the internal power dissipation of the amplifier.

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 24.

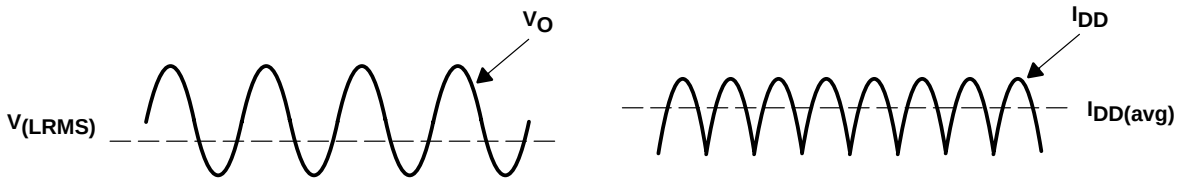


Figure 24. Voltage and Current Waveforms for BTL Amplifiers

APPLICATION INFORMATION

BTL amplifier efficiency (continued)

Although the voltages and currents for SE and BTL are sinusoidal in the load, currents from the supply are very different between SE and BTL configurations. In an SE application the current waveform is a half-wave rectified shape, whereas in BTL it 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. The following equations are the basis for calculating amplifier efficiency.

$$\text{Efficiency of a BTL amplifier} = \frac{P_L}{P_{SUP}} \tag{9}$$

where

$$P_L = \frac{V_{LRMS}^2}{R_L}, \text{ and } V_{LRMS} = \frac{V_P}{\sqrt{2}}, \text{ therefore, } P_L = \frac{V_P^2}{2R_L}$$

and $P_{SUP} = V_{DD}\, I_{DD}avg$ and $I_{DD}avg = \frac{1}{\pi}\int_0^{\pi} \frac{V_P}{R_L} \sin(t)\, dt = \frac{1}{\pi} \times \frac{V_P}{R_L} [\cos(t)]_0^{\pi} = \frac{2V_P}{\pi R_L}$

therefore,

$$P_{SUP} = \frac{2\, V_{DD}\, V_P}{\pi\, R_L}$$

substituting P_L and P_{SUP} into equation 9,

$$\text{Efficiency of a BTL amplifier} = \frac{\frac{V_P^2}{2\, R_L}}{\frac{2\, V_{DD}\, V_P}{\pi\, R_L}} = \frac{\pi\, V_P}{4\, V_{DD}}$$

where

$$V_P = \sqrt{2\, P_L\, R_L}$$

therefore,

$$\eta_{BTL} = \frac{\pi \sqrt{2\, P_L\, R_L}}{4\, V_{DD}} \tag{10}$$

P_L = Power devilered to load
P_{SUP} = Power drawn from power supply
V_{LRMS} = RMS voltage on BTL load
R_L = Load resistance
V_P = Peak voltage on BTL load
$I_{DD}avg$ = Average current drawn from the power supply
V_{DD} = Power supply voltage
η_{BTL} = Efficiency of a BTL amplifier

APPLICATION INFORMATION

BTL amplifier efficiency (continued)

Table 2 employs equation 10 to calculate efficiencies for four different output power levels. Note that 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. Note that 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.

Table 2. Efficiency Vs Output Power in 5-V 8-Ω BTL Systems

Output Power (W)	Efficiency (%)	Peak Voltage (V)	Internal Dissipation (W)
0.25	31.4	2.00	0.55
0.50	44.4	2.83	0.62
1.00	62.8	4.00	0.59
1.25	70.2	4.47†	0.53

† High peak voltages cause the THD to increase.

A final point to remember about Class-AB amplifiers (either SE or BTL) is how to manipulate the terms in the efficiency equation to utmost advantage when possible. Note that in equation 10, V_{DD} is in the denominator. This indicates that as V_{DD} goes down, efficiency goes up.

crest factor and thermal considerations

Class-AB power amplifiers dissipate a significant amount of heat in the package under normal operating conditions. A typical music CD requires 12 dB to 15 dB of dynamic range, or headroom above the average power output, to pass the loudest portions of the signal without distortion. In other words, music typically has a crest factor between 12 dB and 15 dB. When determining the optimal ambient operating temperature, the internal dissipated power at the average output power level must be used.The TPA0211 data sheet shows that when the TPA0211 is operating from a 5-V supply into a 4-Ω speaker 4-W peaks are available. Converting watts to dB:

$$P_{dB} = 10\,\text{Log}\frac{P_W}{P_{ref}} = 10\,\text{Log}\frac{4\ W}{1\ W} = 6\ dB \qquad (11)$$

Subtracting the headroom restriction to obtain the average listening level without distortion yields:

6 dB – 15 dB = –9 dB (15-dB crest factor)
6 dB – 12 dB = –6 dB (12-dB crest factor)
6 dB – 9 dB = –3 dB (9-dB crest factor)
6 dB – 6 dB = 0 dB (6-dB crest factor)
6 dB – 3 dB = 3 dB (3-dB crest factor)

APPLICATION INFORMATION

crest factor and thermal considerations (continued)

Converting dB back into watts:

$$P_W = 10^{PdB/10} \times P_{ref} \quad (12)$$

$$= 63 \text{ mW (18-dB crest factor)}$$
$$= 125 \text{ mW (15-dB crest factor)}$$
$$= 250 \text{ mW (9-dB crest factor)}$$
$$= 500 \text{ mW (6-dB crest factor)}$$
$$= 1000 \text{ mW (3-dB crest factor)}$$
$$= 2000 \text{ mW (15-dB crest factor)}$$

This is valuable information to consider when attempting to estimate the heat dissipation requirements for the amplifier system. Comparing the absolute worst case, which is 2 W of continuous power output with a 3 dB crest factor, against 12 dB and 15 dB applications drastically affects maximum ambient temperature ratings for the system. Table 3 shows maximum ambient temperatures and TPA0211 internal power dissipation for various output-power levels.

Table 3. TPA0211 Power Rating, 5-V, 4-Ω, Mono

PEAK OUTPUT POWER (W)	AVERAGE OUTPUT POWER	POWER DISSIPATION (W)	MAXIMUM AMBIENT TEMPERATURE
4	2 W (3-dB crest factor)	1.7	–3°C
4	1000 mW (6-dB crest factor)	1.6	6°C
4	500 mW (9-dB crest factor)	1.4	24°C
4	250 mW (12-dB crest factor)	1.1	51°C
4	125 mW (15-dB crest factor)	0.8	78°C
4	63 mW (18-dB crest factor)	0.6	96°C

As a result, this simple formula for calculating P_{Dmax} may be used for an 4-Ω application:

$$P_{Dmax} = \frac{2V_{DD}^2}{\pi^2 R_L} \quad (13)$$

However, in the case of a 4-Ω load, the P_{Dmax} occurs at a point well above the normal operating power level. The amplifier may therefore be operated at a higher ambient temperature than required by the P_{Dmax} formula for a 4-Ω load.

The maximum ambient temperature depends on the heat sinking ability of the PCB system. The derating factor for the DGN package is shown in the dissipation rating table. Converting this to Θ_{JA}:

$$\Theta_{JA} = \frac{1}{\text{Derating Factor}} = \frac{1}{0.0171} = 58.48°C/W \quad (14)$$

APPLICATION INFORMATION

crest factor and thermal considerations (continued)

To calculate maximum ambient temperatures, first consider that the numbers from the dissipation graphs are per channel so the dissipated power needs to be doubled for two channel operation. Given Θ_{JA}, the maximum allowable junction temperature, and the total internal dissipation, the maximum ambient temperature can be calculated with the following equation. The maximum recommended junction temperature for the TPA0211 is 150°C. The internal dissipation figures are taken from the Power Dissipation vs Output Power graphs.

$$T_A \text{ Max} = T_J \text{ Max} - \Theta_{JA} P_D = 150 - 58.48(0.8 \times 2) = 56°\text{C (15-dB crest factor)} \quad (15)$$

NOTE:
Internal dissipation of 0.8 W is estimated for a 2-W system with 15-dB crest factor per channel.

Table 3 shows that for some applications no airflow is required to keep junction temperatures in the specified range. The TPA0211 is designed with thermal protection that turns the device off when the junction temperature surpasses 150°C to prevent damage to the IC. Table 3 was calculated for maximum listening volume without distortion. When the output level is reduced the numbers in the table change significantly. Also, using 8-Ω speakers dramatically increases the thermal performance by increasing amplifier efficiency.

SE/$\overline{\text{BTL}}$ (stereo/mono) operation

The ability of the TPA0211 to easily switch between mono BTL and stereo SE modes is one of its most important cost saving features. This feature eliminates the requirement for an additional headphone amplifier in applications where an internal speaker is driven in BTL mode but an external headphone must be accommodated. When SE/$\overline{\text{BTL}}$ is held high for SE mode, the V_{O-} output goes into a high impedance state while the V_{O+} output operates normally. When SE/$\overline{\text{BTL}}$ is held low, the V_{O-} output operates normally, placing the amplifier in BTL mode.

APPLICATION INFORMATION

ST/$\overline{\text{BTL}}$ operation (continued)

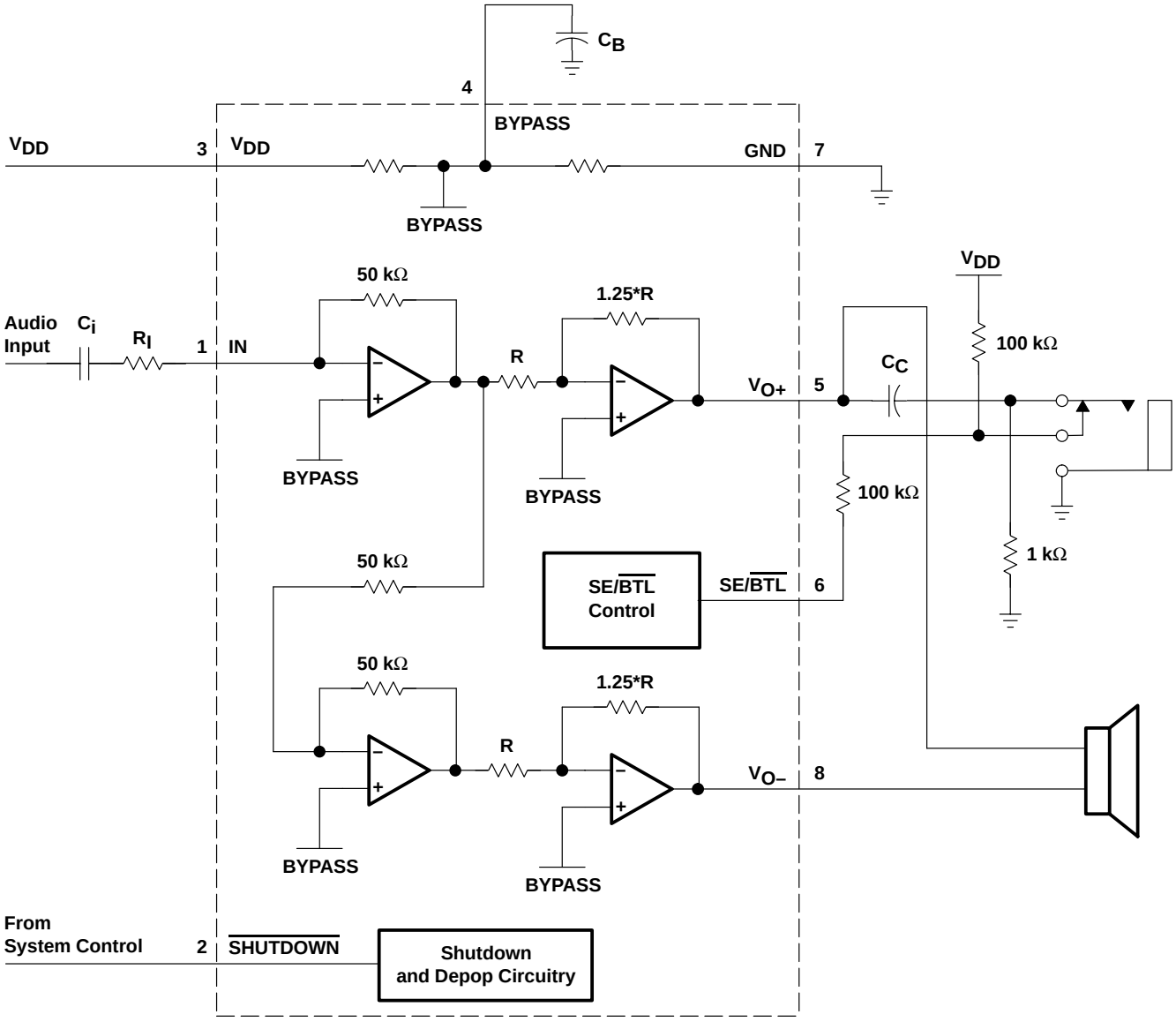


Figure 25. TPA0211 Resistor Divider Network Circuit

Using a readily available 1/8-in. (3,5 mm) mono headphone jack, the control switch is closed when no plug is inserted. When closed, the 100-kΩ/1-kΩ divider pulls the SE/$\overline{\text{BTL}}$ input low. When a plug is inserted, the 1-kΩ resistor is disconnected and the SE/$\overline{\text{BTL}}$ input is pulled high.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
TPA0211DGN	ACTIVE	MSOP-PowerPAD	DGN	8	80	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	AEG	Samples
TPA0211DGNG4	ACTIVE	MSOP-PowerPAD	DGN	8	80	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	AEG	Samples
TPA0211DGNR	ACTIVE	MSOP-PowerPAD	DGN	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	AEG	Samples

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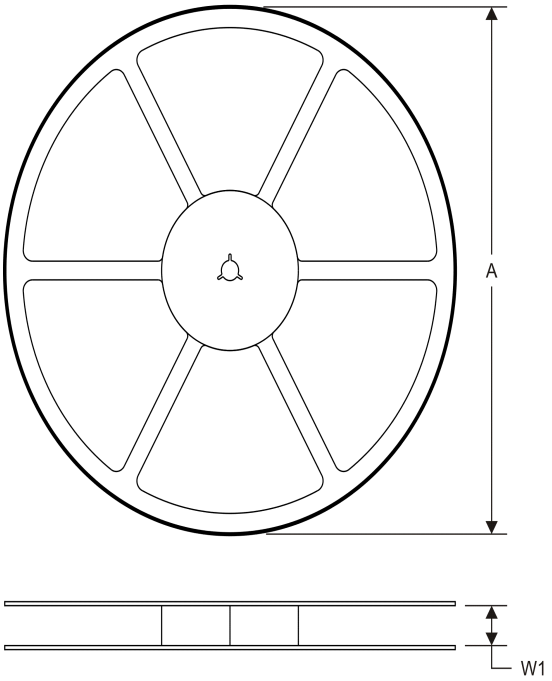
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS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

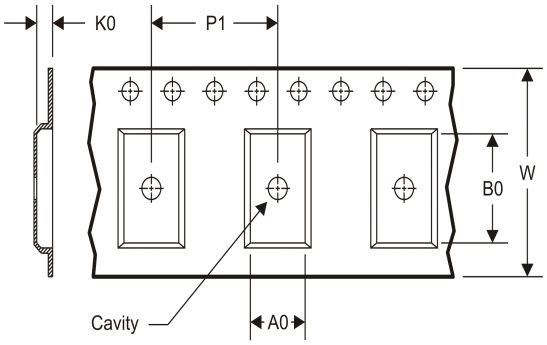
(4) Only one of markings shown within the brackets will appear on the physical device.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



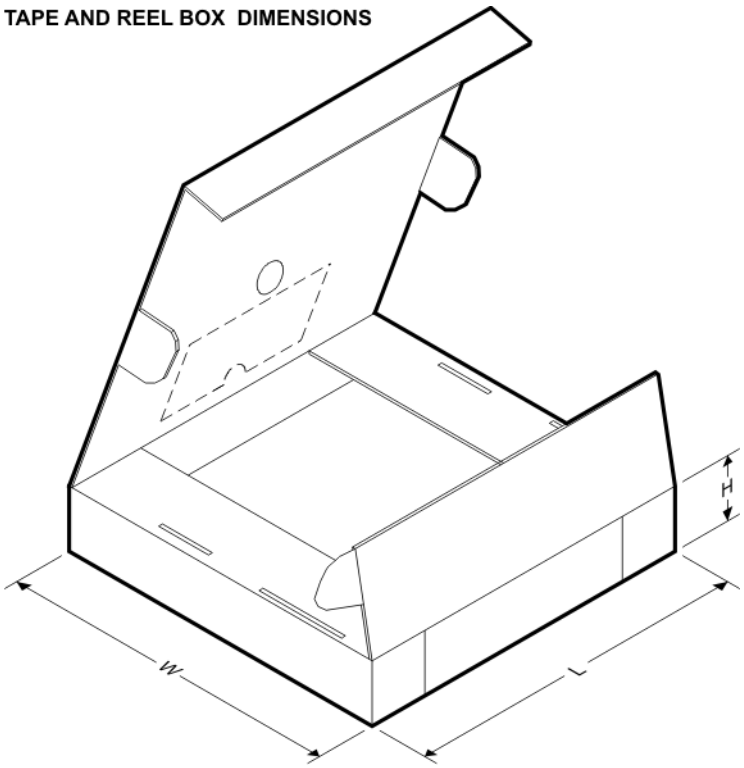
A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

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
TPA0211DGNR	MSOP-Power PAD	DGN	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
TPA0211DGNR	MSOP-Power PAD	DGN	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1

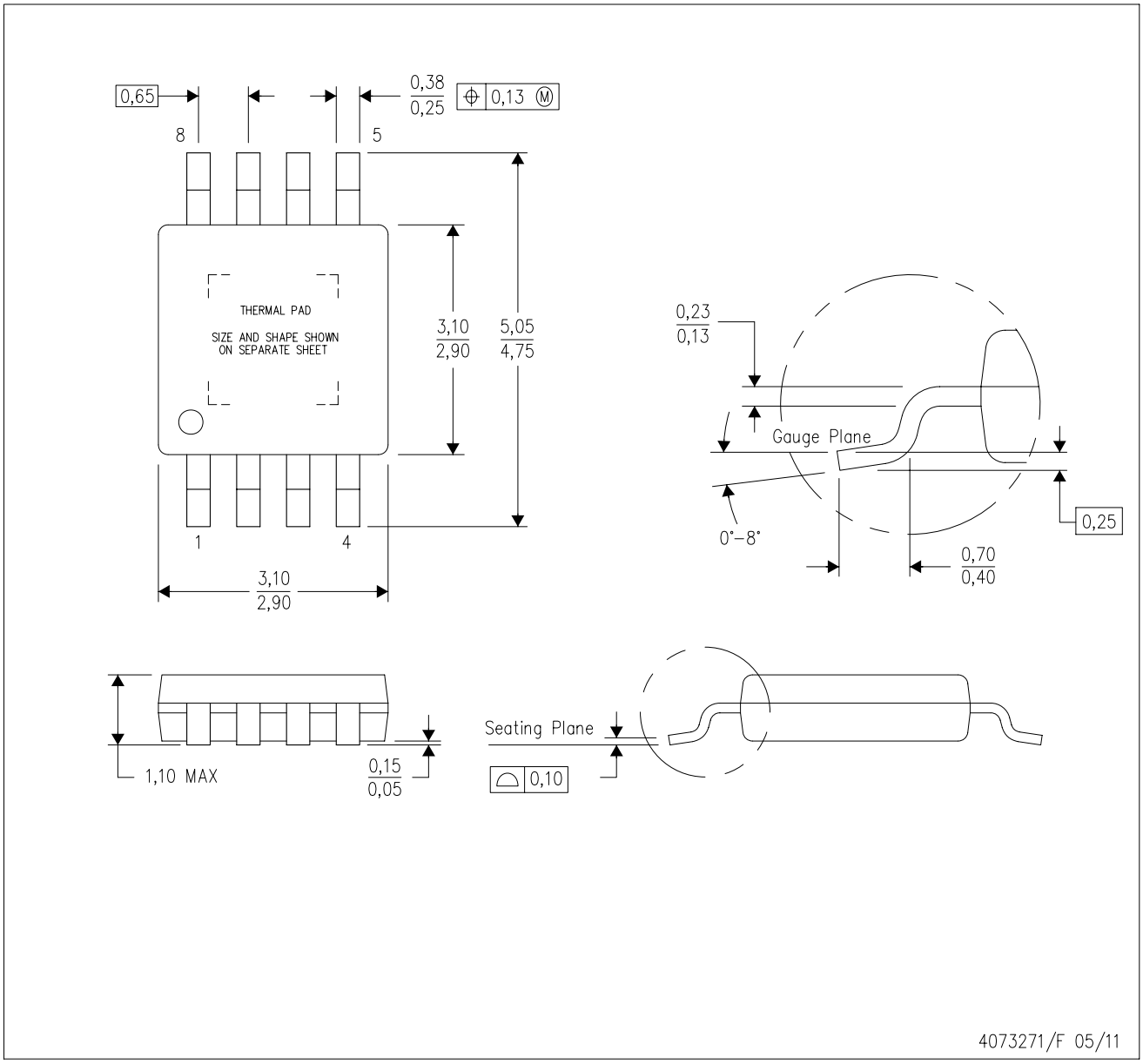
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPA0211DGNR	MSOP-PowerPAD	DGN	8	2500	364.0	364.0	27.0
TPA0211DGNR	MSOP-PowerPAD	DGN	8	2500	358.0	335.0	35.0

DGN (S–PDSO–G8) PowerPAD™ PLASTIC SMALL OUTLINE



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. 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>.
E. See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
F. Falls within JEDEC MO–187 variation AA–T

PowerPAD is a trademark of Texas Instruments.

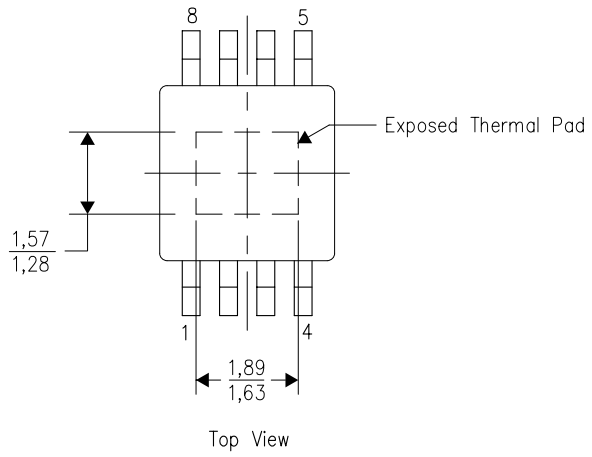
DGN (S–PDSO–G8) PowerPAD™ PLASTIC SMALL OUTLINE

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.

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



Top View

Exposed Thermal Pad Dimensions

4206323–2/I 12/11

NOTE: All linear dimensions are in millimeters

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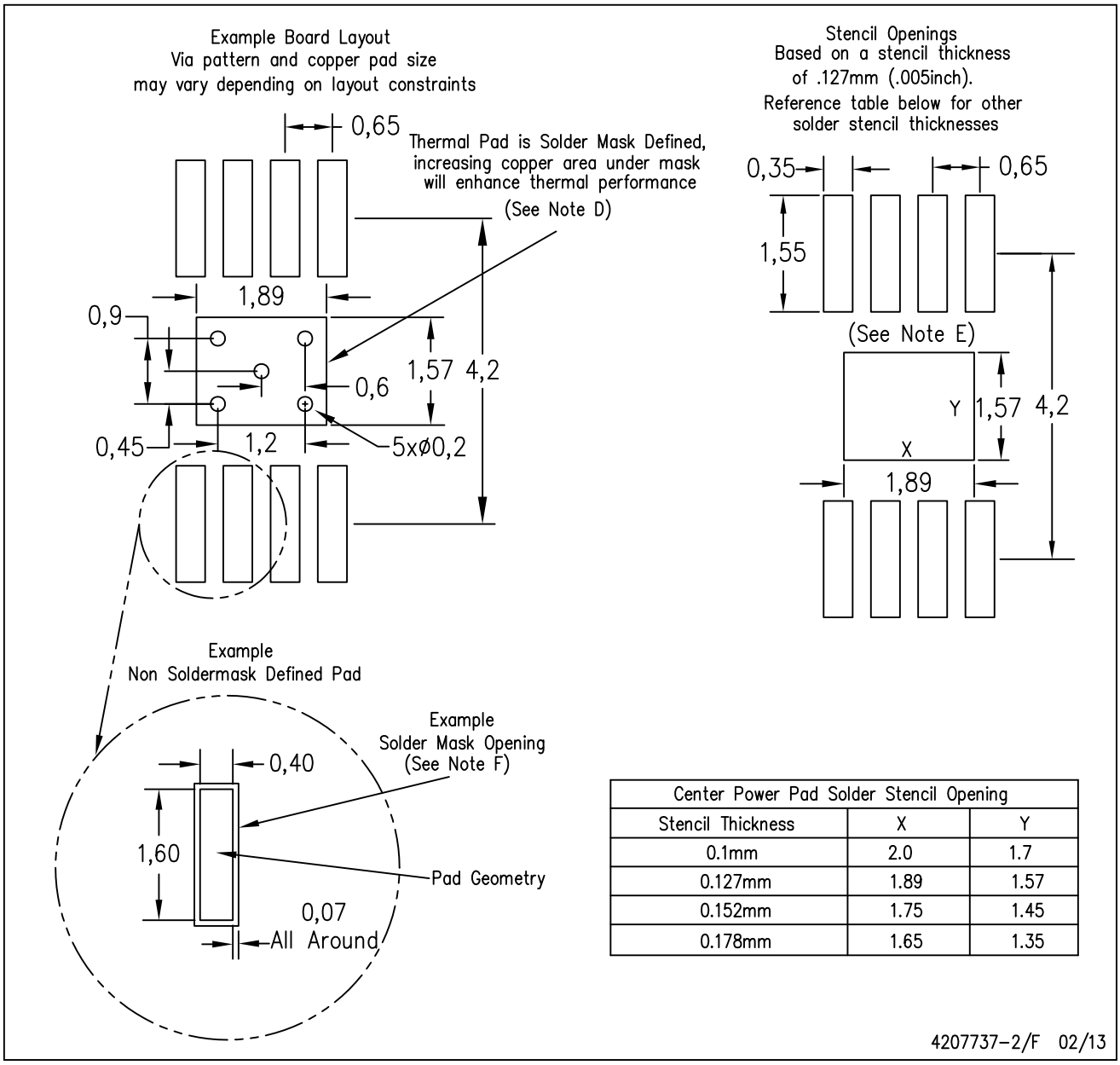
DGN (R–PDSO–G8) PowerPAD™ PLASTIC SMALL OUTLINE



Center Power Pad Solder Stencil Opening		
Stencil Thickness	X	Y
0.1mm	2.0	1.7
0.127mm	1.89	1.57
0.152mm	1.75	1.45
0.178mm	1.65	1.35

4207737–2/F 02/13

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
D. 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>.
E. 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.
F. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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