

# 50-mW ULTRALOW-VOLTAGE, FIXED-GAIN STEREO HEADPHONE AUDIO POWER AMPLIFIER

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- Minimal External Components Required
- 1.6-V to 3.6-V Supply Voltage Range
- 50-mW Stereo Output
- Low Supply Current . . . 0.75 mA
- Low Shutdown Current . . . 50 nA
- Gain Set Internally to 2 dB
- Pop Reduction Circuitry
- Internal Mid-Rail Generation
- Thermal and Short-Circuit Protection
- Surface-Mount Packaging
  - MSOP
  - SOIC

D or DGK PACKAGE  
(TOP VIEW)



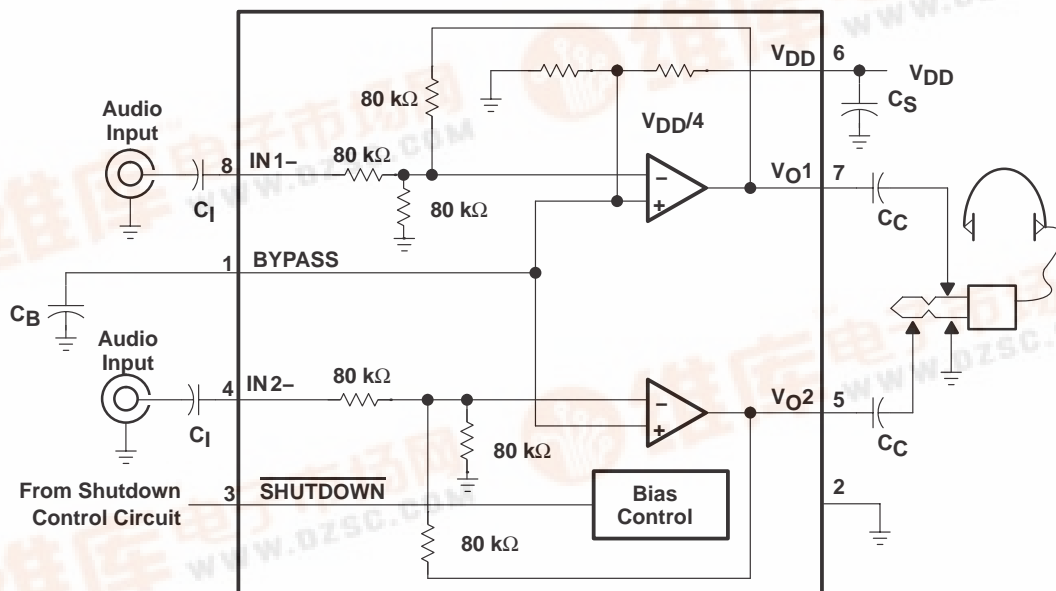
## description

The TPA6101A2 is a stereo audio power amplifier packaged in either an 8-pin SOIC package or an 8-pin MOSP package capable of delivering 50 mW of continuous RMS power per channel into 16-Ω loads. Amplifier gain is internally set to 2 dB (inverting) to save board space by eliminating six external resistors.

The TPA6101A2 is optimized for battery applications because of its low-supply current, shutdown current, and THD+N. To obtain the low-supply voltage range, the TPA6101A2 biases BYPASS to  $V_{DD}/4$ .

When driving a 16-Ω load with 40-mW output power from 3.3 V, THD+N is 0.08% at 1 kHz, and less than 0.2% across the audio band of 20 Hz to 20 kHz. For 30 mW into 32-Ω loads, the THD+N is reduced to less than 0.06% at 1 kHz, and is less than 0.3% across the audio band of 20 Hz to 20 kHz.

## typical application circuit



NOTE: All internal resistor values are  $\pm 20\%$ .

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.



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**AVAILABLE OPTIONS**

T <sub>A</sub>	PACKAGED DEVICE		MSOP SYMBOLIZATION
	SMALL OUTLINE (D)	MSOP (DGK)	
-40°C to 85°C	TPA6101A2D	TPA6101A2DGK	AJM

**Terminal Functions**

TERMINAL NAME	NO.	I/O	DESCRIPTION
BYPASS	1	I	Tap to voltage divider for internal mid-supply bias supply. BYPASS is set at V <sub>DD</sub> /4. Connect to a 0.1-μF to 1-μF low-ESR capacitor for best performance.
GND	2	I	GND is the ground connection.
IN1-	8	I	IN1- is the inverting input for channel 1.
IN2-	4	I	IN2- is the inverting input for channel 2.
SHUTDOWN	3	I	Active-low input. When held low, the device is placed in a low-supply current mode.
V <sub>DD</sub>	6	I	V <sub>DD</sub> is the supply voltage terminal.
V <sub>O1</sub>	7	O	V <sub>O1</sub> is the audio output for channel 1.
V <sub>O2</sub>	5	O	V <sub>O2</sub> is the audio output for channel 2.

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

Supply voltage, V <sub>DD</sub>	4 V
Input voltage, V <sub>I</sub>	-0.3 V to V <sub>DD</sub> + 0.3 V
Continuous total power dissipation	Internally Limited
Operating junction temperature range, T <sub>J</sub>	-40°C to 150°C
Storage temperature range, T <sub>stg</sub>	-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 <sub>A</sub> ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T <sub>A</sub> = 25°C	T <sub>A</sub> = 70°C POWER RATING	T <sub>A</sub> = 85°C POWER RATING
D	710 mW	5.68 mW/°C	454 mW	369 mW
DGK	469 mW	3.75 mW/°C	300 mW	244 mW

**recommended operating conditions**

	MIN	MAX	UNIT
Supply voltage, V <sub>DD</sub>	1.6	3.6	V
High-level input voltage, V <sub>IH</sub> (SHUTDOWN)	60% x V <sub>DD</sub>		V
Low-level input voltage, V <sub>IL</sub> (SHUTDOWN)		25% x V <sub>DD</sub>	V
Operating free-air temperature, T <sub>A</sub>	-40	85	°C

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**dc electrical characteristics at  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 3.6\text{ V}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{OO}$	Output offset voltage	$A_V = 2\text{ dB}$		5	40	mV
PSRR	Power supply rejection ratio	$V_{DD} = 3\text{ V to }3.6\text{ V}$		72		dB
$I_{DD}$	Supply current	$\overline{\text{SHUTDOWN}} = 3.6\text{ V}$		0.75	1.5	mA
$I_{DD}(\text{SD})$	Supply current in SHUTDOWN mode	$\overline{\text{SHUTDOWN}} = 0\text{ V}$		50	250	nA
$ I_{IH} $	High-level input current ( $\overline{\text{SHUTDOWN}}$ )	$V_{DD} = 3.6\text{ V}$ , $V_I = V_{DD}$			1	$\mu\text{A}$
$ I_{IL} $	Low-level input current (SHUTDOWN)	$V_{DD} = 3.6\text{ V}$ , $V_I = 0\text{ V}$			1	$\mu\text{A}$
$Z_I$	Input impedance			80		k $\Omega$

**ac operating characteristics,  $V_{DD} = 3.3\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_L = 16\ \Omega$**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
G	Gain			2		dB
$P_O$	Output power (each channel)	THD $\leq 0.1\%$ , $f = 1\text{ kHz}$		50		mW
THD+N	Total harmonic distortion + noise	$P_O = 45\text{ mW}$ , $20\text{--}20\text{ kHz}$		0.4%		
B <sub>OM</sub>	Maximum output power BW	THD $< 0.5\%$		$> 20$		kHz
$k_{SVR}$	Supply ripple rejection ratio	$f = 1\text{ kHz}$		47		dB
SNR	Signal-to-noise ratio	$P_O = 50\text{ mW}$		86		dB
$V_n$	Noise output voltage (no-noise weighting filter)			45		$\mu\text{V}(\text{rms})$

**ac operating characteristics,  $V_{DD} = 3.3\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_L = 32\ \Omega$**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
G	Gain			2		dB
$P_O$	Output power (each channel)	THD $\leq 0.1\%$ , $f = 1\text{ kHz}$		35		mW
THD+N	Total harmonic distortion + noise	$P_O = 30\text{ mW}$ , $20\text{--}20\text{ kHz}$		0.4%		
B <sub>OM</sub>	Maximum output power BW	THD $< 0.4\%$		$> 20$		kHz
$k_{SVR}$	Supply ripple rejection ratio	$f = 1\text{ kHz}$		47		dB
SNR	Signal-to-noise ratio	$P_O = 30\text{ mW}$		86		dB
$V_n$	Noise output voltage (no-noise weighting filter)			50		$\mu\text{V}(\text{rms})$

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## 50-mW ULTRALOW-VOLTAGE, FIXED-GAIN STEREO HEADPHONE AUDIO POWER AMPLIFIER

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### dc electrical characteristics at $T_A = 25^\circ\text{C}$ , $V_{DD} = 1.6\text{ V}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{OO}$	Output offset voltage	$A_V = 2\text{ dB}$		5	40	mV
PSRR	Power supply rejection ratio	$V_{DD} = 1.4\text{ V to }1.8\text{ V}$		80		dB
$I_{DD}$	Supply current	$\overline{\text{SHUTDOWN}} = 1.6\text{ V}$		0.65	1.2	mA
$I_{DD}(\text{SD})$	Supply current in $\overline{\text{SHUTDOWN}}$ mode	$\overline{\text{SHUTDOWN}} = 0\text{ V}$		50	250	nA
$ I_{IH} $	High-level input current ( $\overline{\text{SHUTDOWN}}$ )	$V_{DD} = 1.6\text{ V}, V_I = V_{DD}$			1	$\mu\text{A}$
$ I_{IL} $	Low-level input current ( $\overline{\text{SHUTDOWN}}$ )	$V_{DD} = 1.6\text{ V}, V_I = 0\text{ V}$			1	$\mu\text{A}$
$Z_I$	Input impedance			80		k $\Omega$

### ac operating characteristics, $V_{DD} = 1.6\text{ V}$ , $T_A = 25^\circ\text{C}$ , $R_L = 16\ \Omega$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
G	Gain			2		dB
$P_O$	Output power (each channel)	THD $\leq 0.5\%$ , $f = 1\text{ kHz}$		10		mW
THD+N	Total harmonic distortion + noise	$P_O = 9.5\text{ mW}$ , $20\text{--}20\text{ kHz}$		0.06%		
B <sub>OM</sub>	Maximum output power BW	THD $< 1\%$		$> 20$		kHz
k <sub>SVR</sub>	Supply ripple rejection ratio	$f = 1\text{ kHz}$		47		dB
SNR	Signal-to-noise ratio	$P_O = 10\text{ mW}$		82		dB
$V_n$	Noise output voltage (no-noise weighting filter)			32		$\mu\text{V}(\text{rms})$

### ac operating characteristics, $V_{DD} = 1.6\text{ V}$ , $T_A = 25^\circ\text{C}$ , $R_L = 32\ \Omega$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
G	Gain			2		dB
$P_O$	Output power (each channel)	THD $\leq 0.5\%$ , $f = 1\text{ kHz}$		7.5		mW
THD+N	Total harmonic distortion + noise	$P_O = 6.5\text{ mW}$ , $20\text{--}20\text{ kHz}$		0.05%		
B <sub>OM</sub>	Maximum output power BW	THD $< 1\%$		$> 20$		kHz
k <sub>SVR</sub>	Supply ripple rejection ratio	$f = 1\text{ kHz}$		47		dB
SNR	Signal-to-noise ratio	$P_O = 7.5\text{ mW}$		84		dB
$V_n$	Noise output voltage (no-noise weighting filter)			32		$\mu\text{V}(\text{rms})$

## TYPICAL CHARACTERISTICS

### Table of Graphs

		FIGURE
THD+N	Total harmonic distortion plus noise	vs Frequency
		1, 3, 5, 7, 9, 11
		vs Output power
		2, 4, 6, 8, 10, 12
		vs Output voltage
		13, 14
$P_O$	Output power	vs Load resistance
		15, 16
k <sub>SVR</sub>	Supply ripple rejection ratio	vs Frequency
		17, 18
$V_n$	Output noise voltage	vs Frequency
		19, 20
	Crosstalk	vs Frequency
		21, 22
	Closed-loop gain and phase	vs Frequency
		23, 24, 25, 26
$I_{DD}$	Supply current	vs Supply voltage
		27
$P_D$	Power dissipation	vs Output power
		28

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**TYPICAL CHARACTERISTICS**

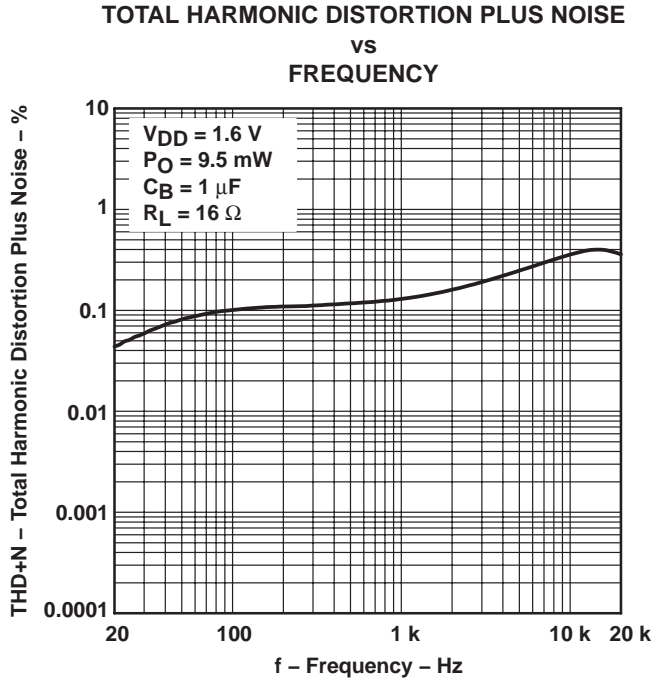


Figure 1

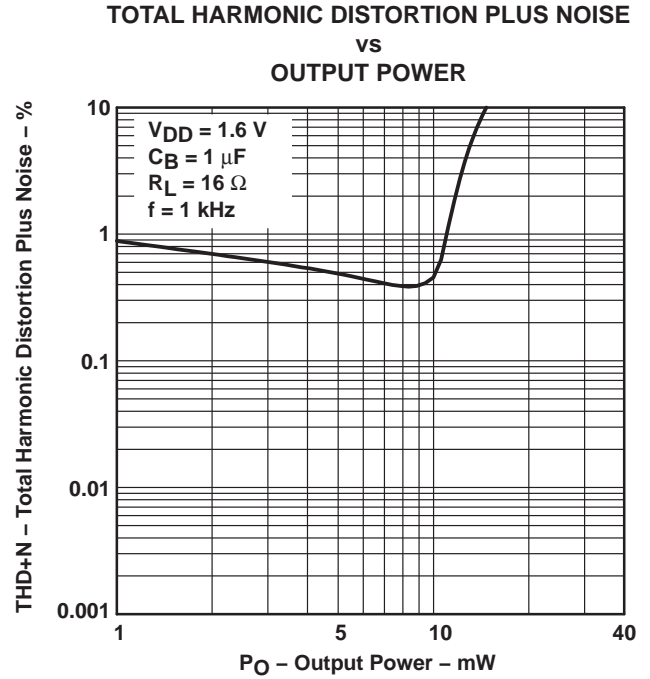


Figure 2

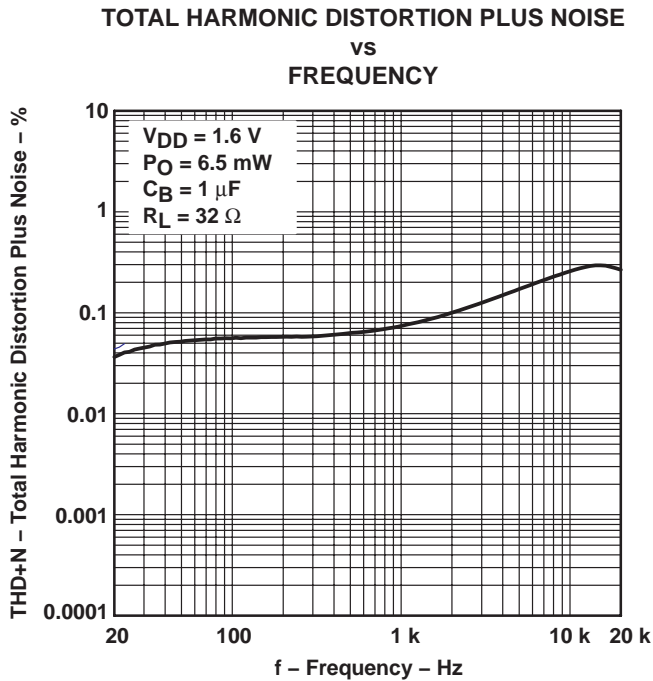


Figure 3

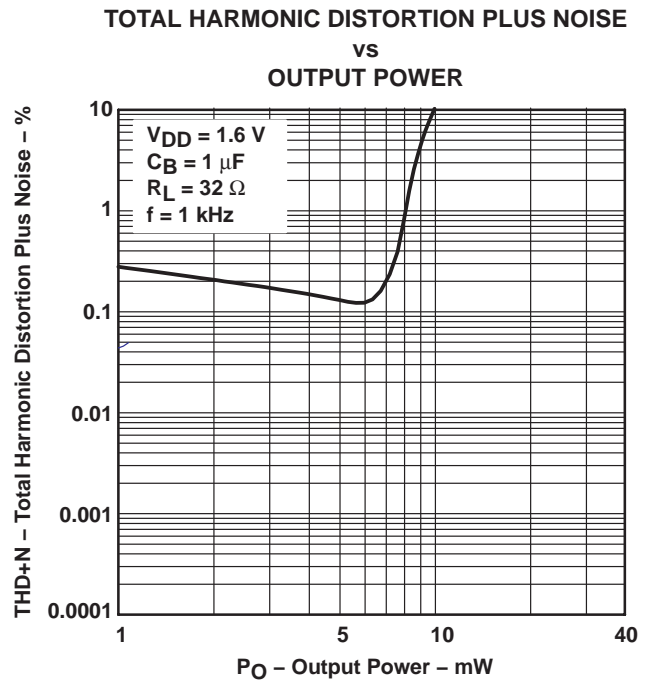


Figure 4

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### TYPICAL CHARACTERISTICS

TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
FREQUENCY

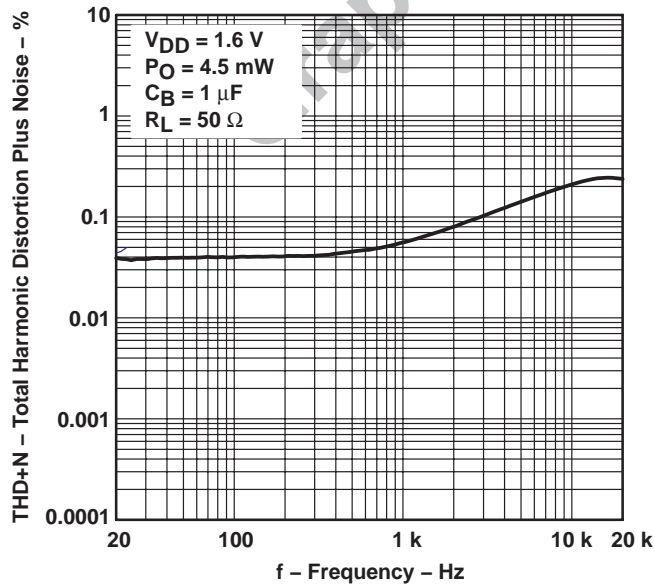


Figure 5

TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
OUTPUT POWER

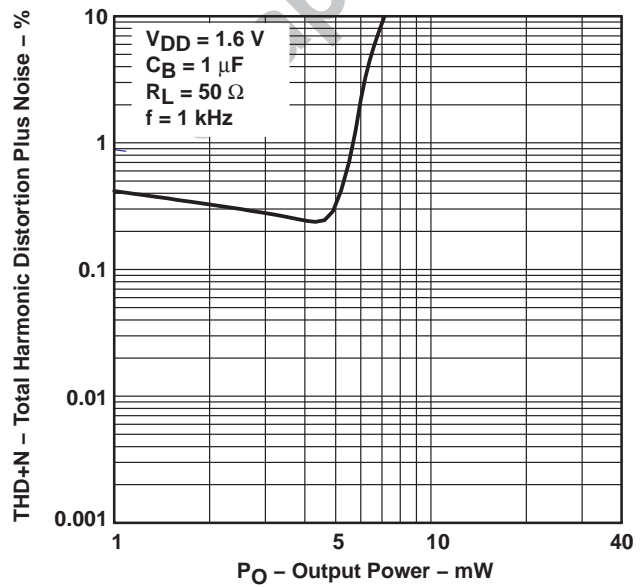


Figure 6

TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
FREQUENCY

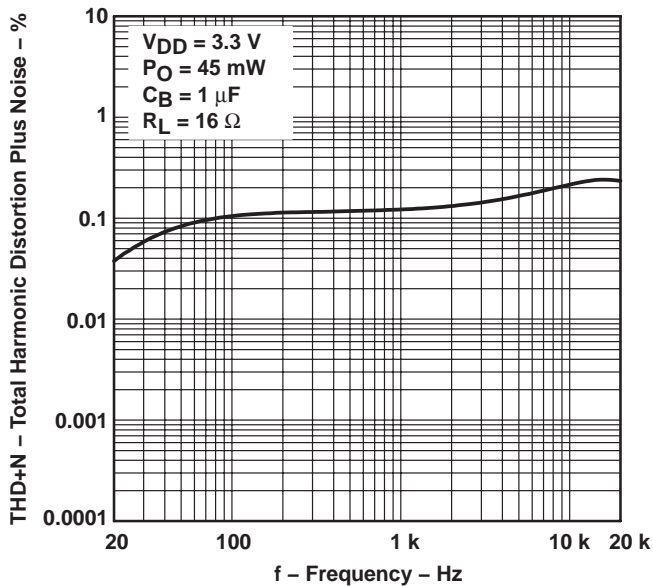


Figure 7

TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
OUTPUT POWER

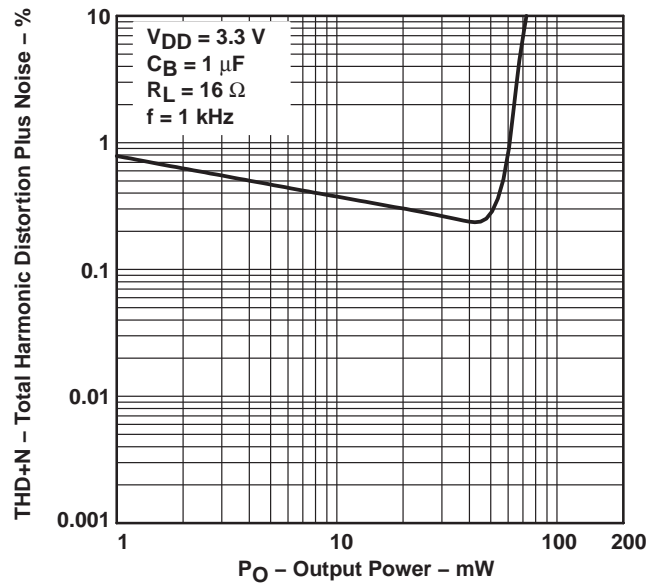


Figure 8

**TPA6101A2**  
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**TYPICAL CHARACTERISTICS**

**TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
FREQUENCY**

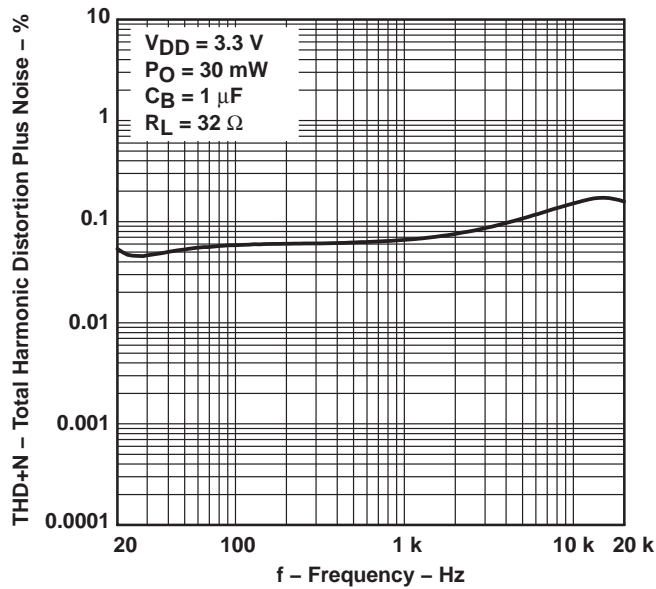


Figure 9

**TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
OUTPUT POWER**

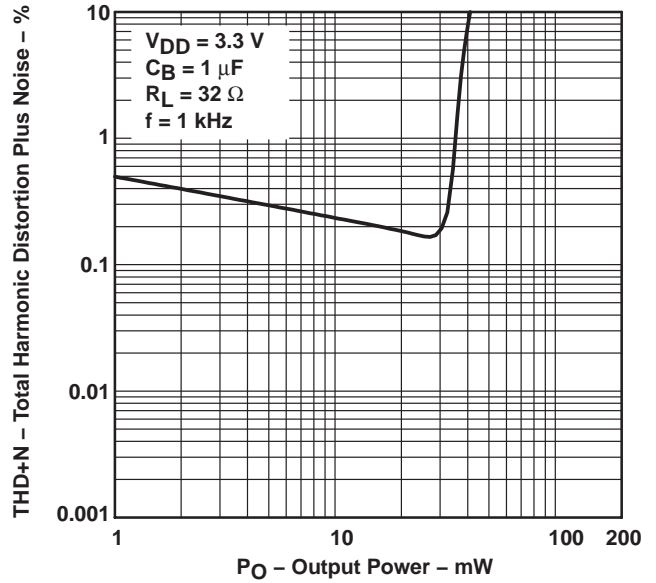


Figure 10

**TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
FREQUENCY**

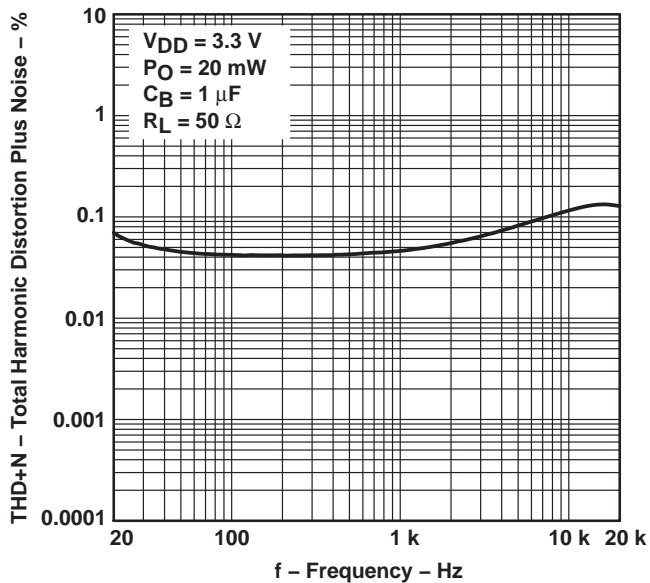


Figure 11

**TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
OUTPUT POWER**

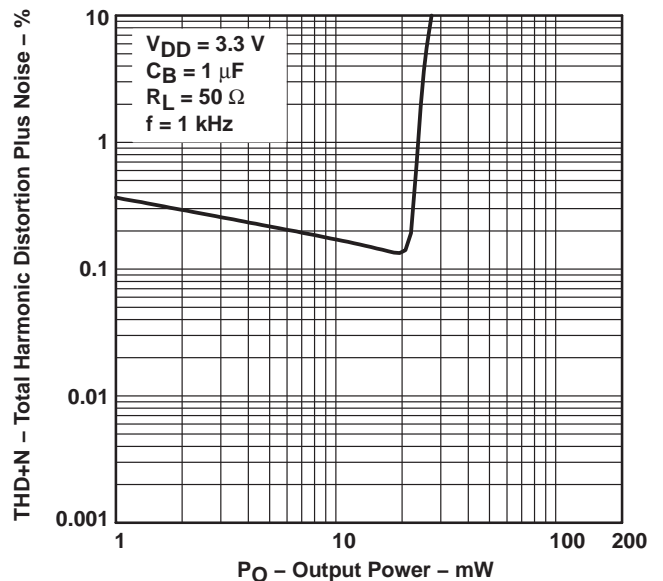


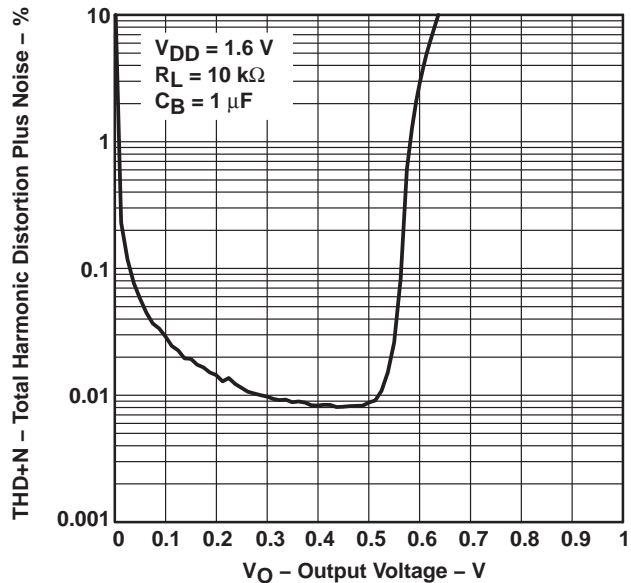
Figure 12

**TPA6101A2**  
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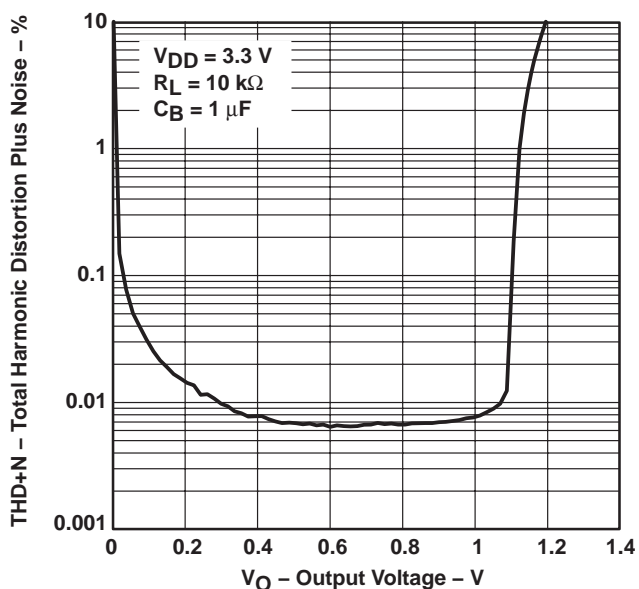
**TYPICAL CHARACTERISTICS**

**TOTAL HARMONIC DISTORTION PLUS NOISE**  
**vs**  
**OUTPUT VOLTAGE**



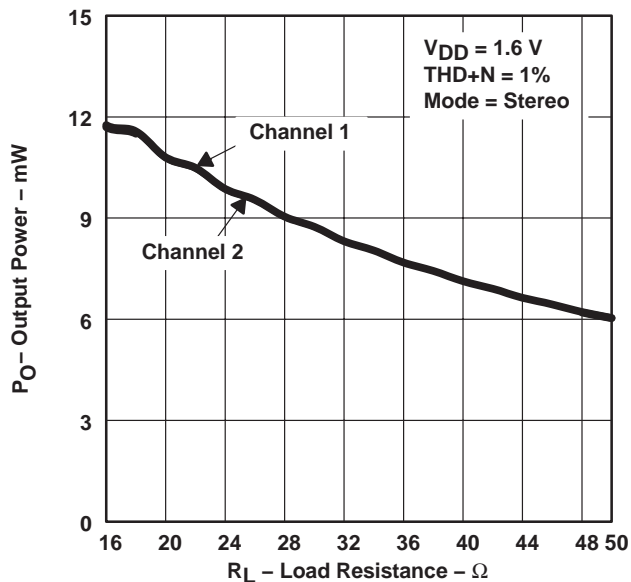
**Figure 13**

**TOTAL HARMONIC DISTORTION PLUS NOISE**  
**vs**  
**OUTPUT VOLTAGE**



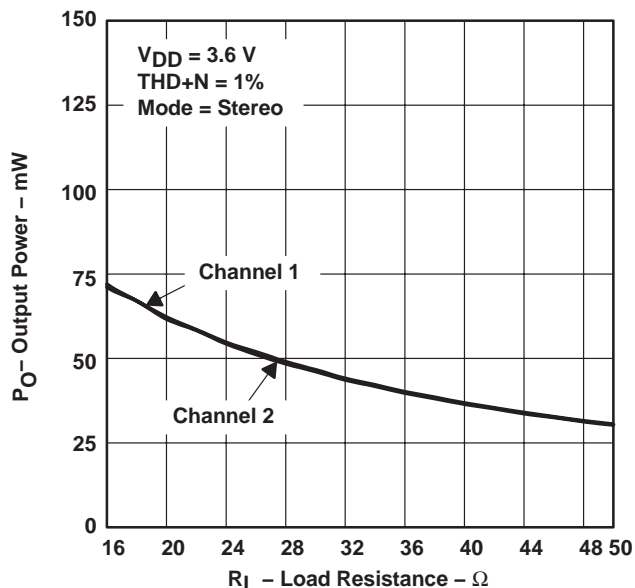
**Figure 14**

**OUTPUT POWER**  
**vs**  
**LOAD RESISTANCE**



**Figure 15**

**OUTPUT POWER**  
**vs**  
**LOAD RESISTANCE**



**Figure 16**

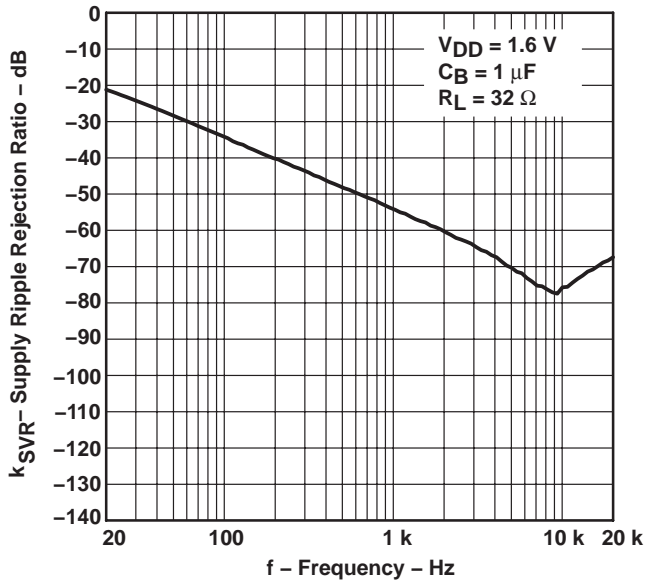


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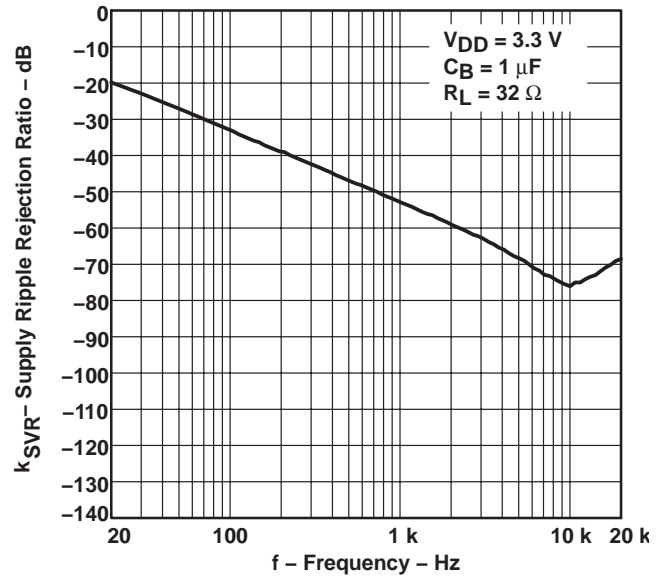
**TYPICAL CHARACTERISTICS**

**SUPPLY RIPPLE REJECTION RATIO  
vs  
FREQUENCY**



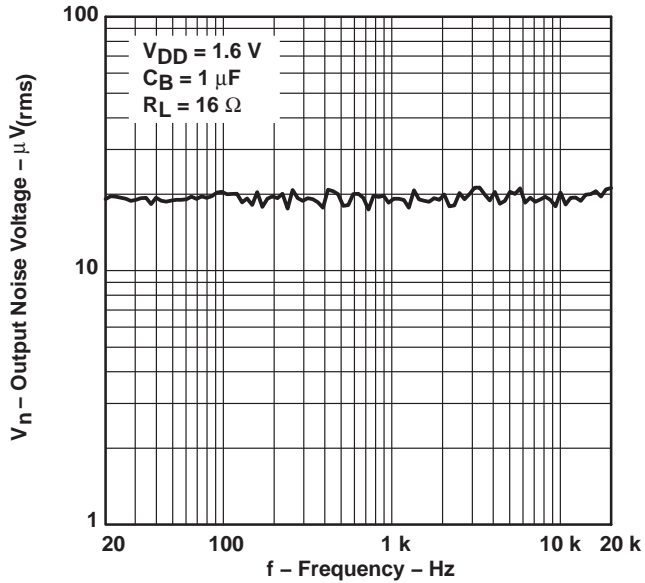
**Figure 17**

**SUPPLY RIPPLE REJECTION RATIO  
vs  
FREQUENCY**



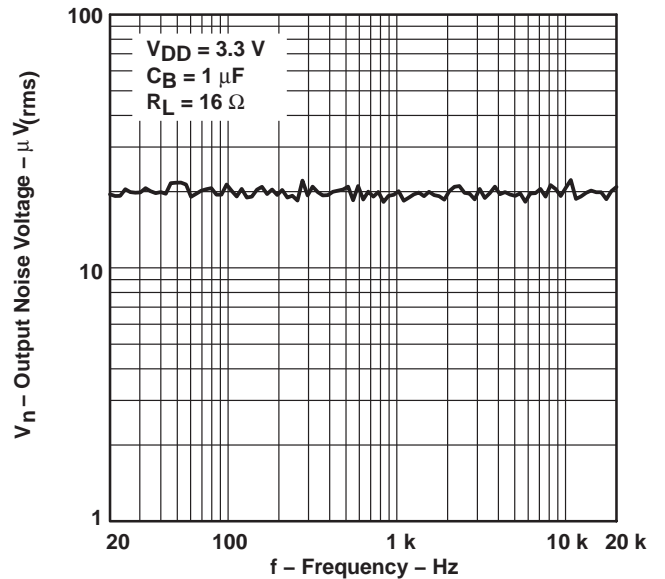
**Figure 18**

**OUTPUT NOISE VOLTAGE  
vs  
FREQUENCY**



**Figure 19**

**OUTPUT NOISE VOLTAGE  
vs  
FREQUENCY**



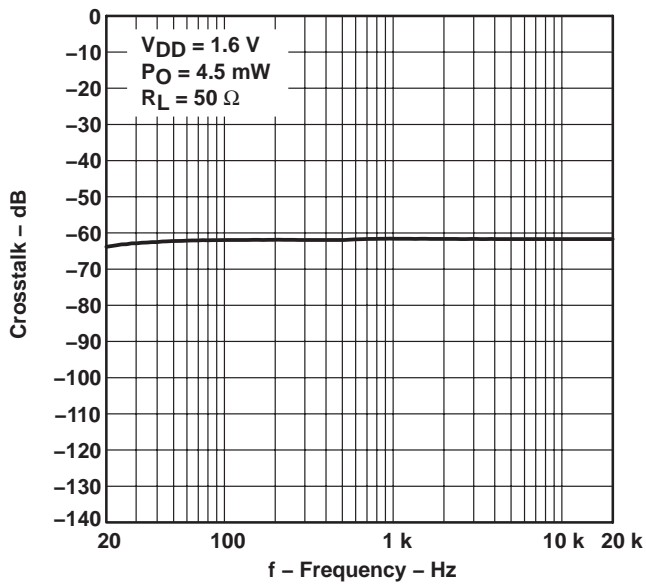
**Figure 20**

**TPA6101A2**  
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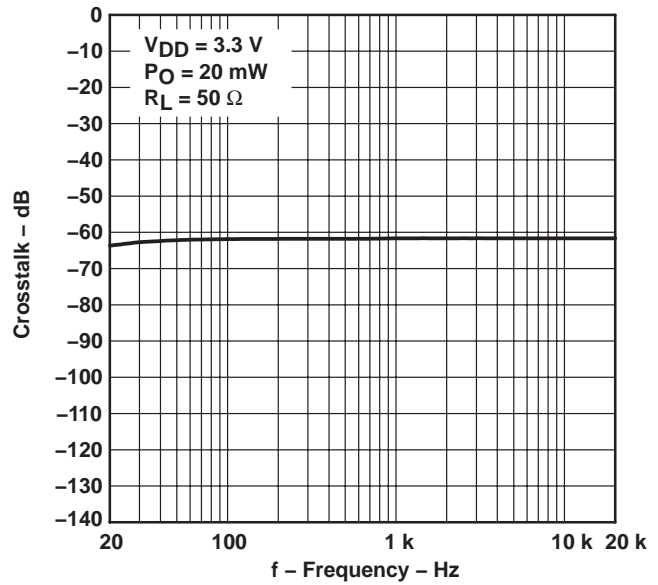
**TYPICAL CHARACTERISTICS**

**CROSSTALK**  
**vs**  
**FREQUENCY**



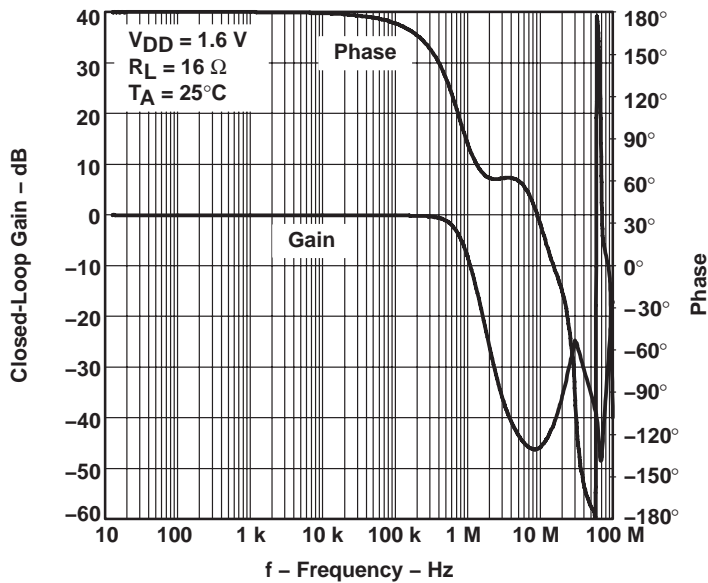
**Figure 21**

**CROSSTALK**  
**vs**  
**FREQUENCY**



**Figure 22**

**CLOSED-LOOP GAIN AND PHASE**  
**vs**  
**FREQUENCY**



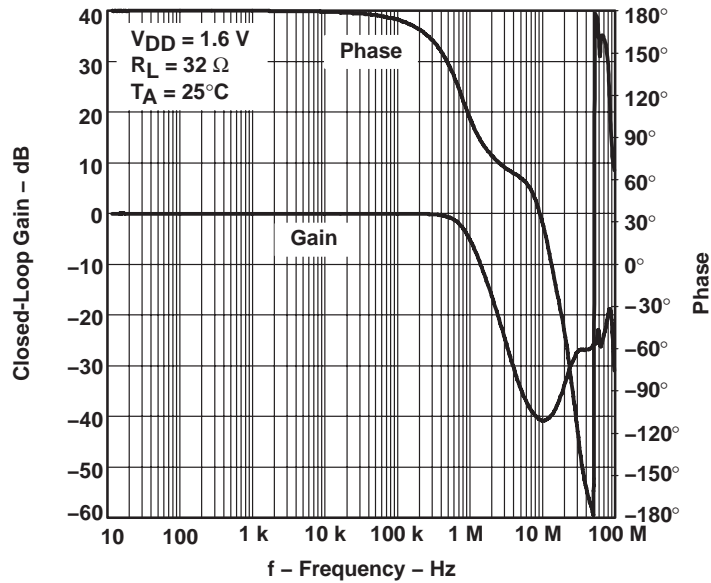
**Figure 23**

**TPA6101A2**  
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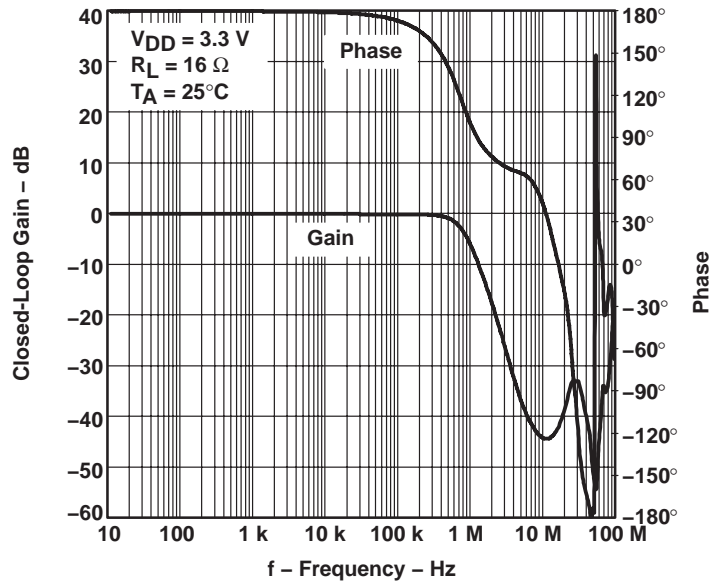
**TYPICAL CHARACTERISTICS**

**CLOSED-LOOP GAIN AND PHASE**  
**vs**  
**FREQUENCY**



**Figure 24**

**CLOSED-LOOP GAIN AND PHASE**  
**vs**  
**FREQUENCY**



**Figure 25**

**TPA6101A2**  
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**TYPICAL CHARACTERISTICS**

**CLOSED-LOOP GAIN AND PHASE**  
**vs**  
**FREQUENCY**

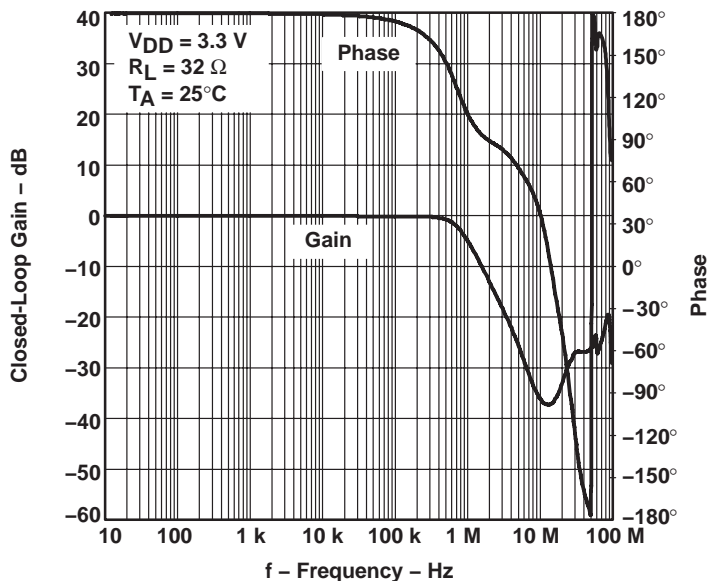


Figure 26

**SUPPLY CURRENT**  
**vs**  
**SUPPLY VOLTAGE**

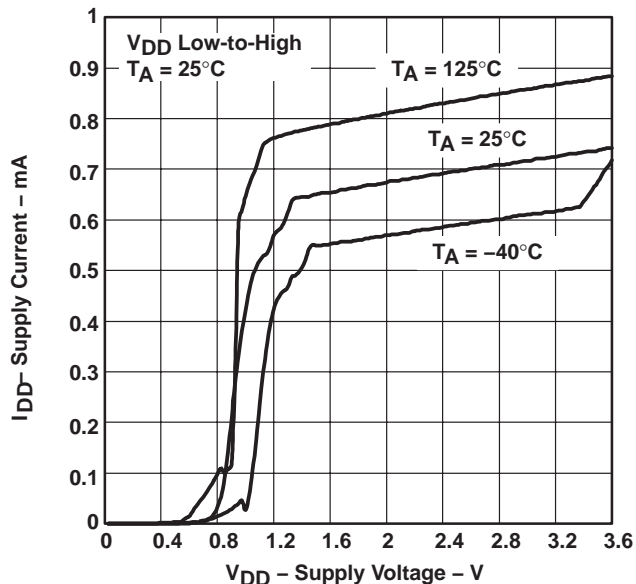


Figure 27

**POWER DISSIPATION**  
**vs**  
**OUTPUT POWER**

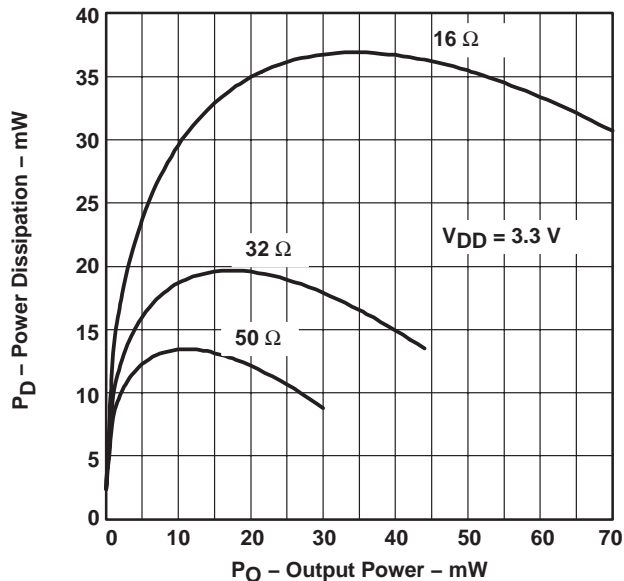


Figure 28

**TPA6101A2**  
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## APPLICATION INFORMATION

### 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  $R_I$  form a high-pass filter with the corner frequency determined in equation 1.  $R_I$  is set internally and is fixed at 80 k $\Omega$ .

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

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 the specification calls for a flat-bass response down to 20 Hz. Equation 1 is reconfigured as equation 2.

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

In this example,  $C_I$  is approximately 0.1  $\mu$ F. A further consideration for this capacitor is the leakage path from the input source through the input network ( $R_I$ ,  $C_I$ ) and the feedback resistor ( $R_F$ ) to the load. This leakage current creates a dc-offset voltage at the input to the amplifier that reduces useful headroom. 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  $V_{DD}/4$ , which is likely higher than the source dc level. It is important to confirm the capacitor polarity in the application.

### power supply decoupling, $C_S$

The TPA6101A2 is a high-performance CMOS audio amplifier that requires adequate power supply decoupling to ensure that 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  $\mu$ F, 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  $\mu$ F or greater placed near the power amplifier is recommended.

### midrail bypass capacitor, $C_B$

The midrail bypass capacitor ( $C_B$ ) serves several important functions. During start-up,  $C_B$  determines the rate at which the amplifier starts up. This helps to push the start-up pop noise into the subaudible range (so low it can not be heard). 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. The capacitor is fed from a 55-k $\Omega$  source inside the amplifier. To keep the start-up pop as low as possible, the relationship shown in equation 3 should be maintained.

$$\frac{1}{(C_B \times 55 \text{ k}\Omega)} \leq \frac{1}{(C_I R_I)} \quad (3)$$

As an example, consider a circuit where  $C_B$  is 1  $\mu$ F,  $C_I$  is 0.1  $\mu$ F, and  $R_I$  is 80 k $\Omega$ . Inserting these values into the equation 3 results in:  $18.18 \leq 125$  which satisfies the rule. Bypass capacitor ( $C_B$ ) values of 0.47- $\mu$ F to 1- $\mu$ F ceramic or tantalum low-ESR capacitors are recommended for the best THD and noise performance.

## TPA6101A2

# 50-mW ULTRALOW-VOLTAGE, FIXED-GAIN STEREO HEADPHONE AUDIO POWER AMPLIFIER

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## APPLICATION INFORMATION

### output coupling capacitor, $C_C$

In the typical single-supply, single-ended (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 from a high-pass filter is governed by equation 4.

$$f_c = \frac{1}{2\pi R_L C_C} \quad (4)$$

The main disadvantage, from a performance standpoint, is that the typically small-load impedances drive the low-frequency corner higher. Large values of  $C_C$  are required to pass low-frequencies into the load. Consider the example where a  $C_C$  of 68  $\mu\text{F}$  is chosen and loads vary from 32  $\Omega$  to 47 k $\Omega$ . Table 1 summarizes the frequency response characteristics of each configuration.

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

$R_L$	$C_C$	LOWEST FREQUENCY
32 $\Omega$	68 $\mu\text{F}$	73 Hz
10,000 $\Omega$	68 $\mu\text{F}$	0.23 Hz
47,000 $\Omega$	68 $\mu\text{F}$	0.05 Hz

As Table 1 indicates, headphone response is adequate and drive into line level inputs (a home stereo for example) is very good.

The output coupling capacitor required in single-supply SE mode also places additional constraints on the selection of other components in the amplifier circuit. With the rules described earlier still valid, add the following relationship:

$$\frac{1}{(C_B \times 55 \text{ k}\Omega)} \leq \frac{1}{(C_I R_I)} \ll \frac{1}{R_L C_C} \quad (5)$$

### using low-ESR capacitors

Low-ESR capacitors are recommended throughout this application. A real 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.

### 3.3-V versus 1.6-V operation

The TPA6101A2 was designed for operation over a supply range of 1.6 V to 3.6 V. There are no special considerations for 1.6-V versus 3.3-V operation as far as supply bypassing, gain setting, or stability. Supply current is slightly reduced from 0.75 mA (typical) to 0.65 mA (typical). The most important consideration is that of output power. Each amplifier can produce a maximum output voltage swing within a few hundred millivolts of the rails with a 10-k $\Omega$  load. However, this voltage swing decreases as the load resistance decreases and the  $r_{DS(on)}$  as the output stage transistors becomes more significant. For example, for a 32- $\Omega$  load, the maximum peak output voltage with  $V_{DD} = 1.6$  V is approximately 0.7 V with no clipping distortion. This reduced voltage swing effectively reduces the maximum undistorted output power.

**TPA6101A2**  
**50-mW ULTRALOW-VOLTAGE, FIXED-GAIN STEREO HEADPHONE**  
**AUDIO POWER AMPLIFIER**

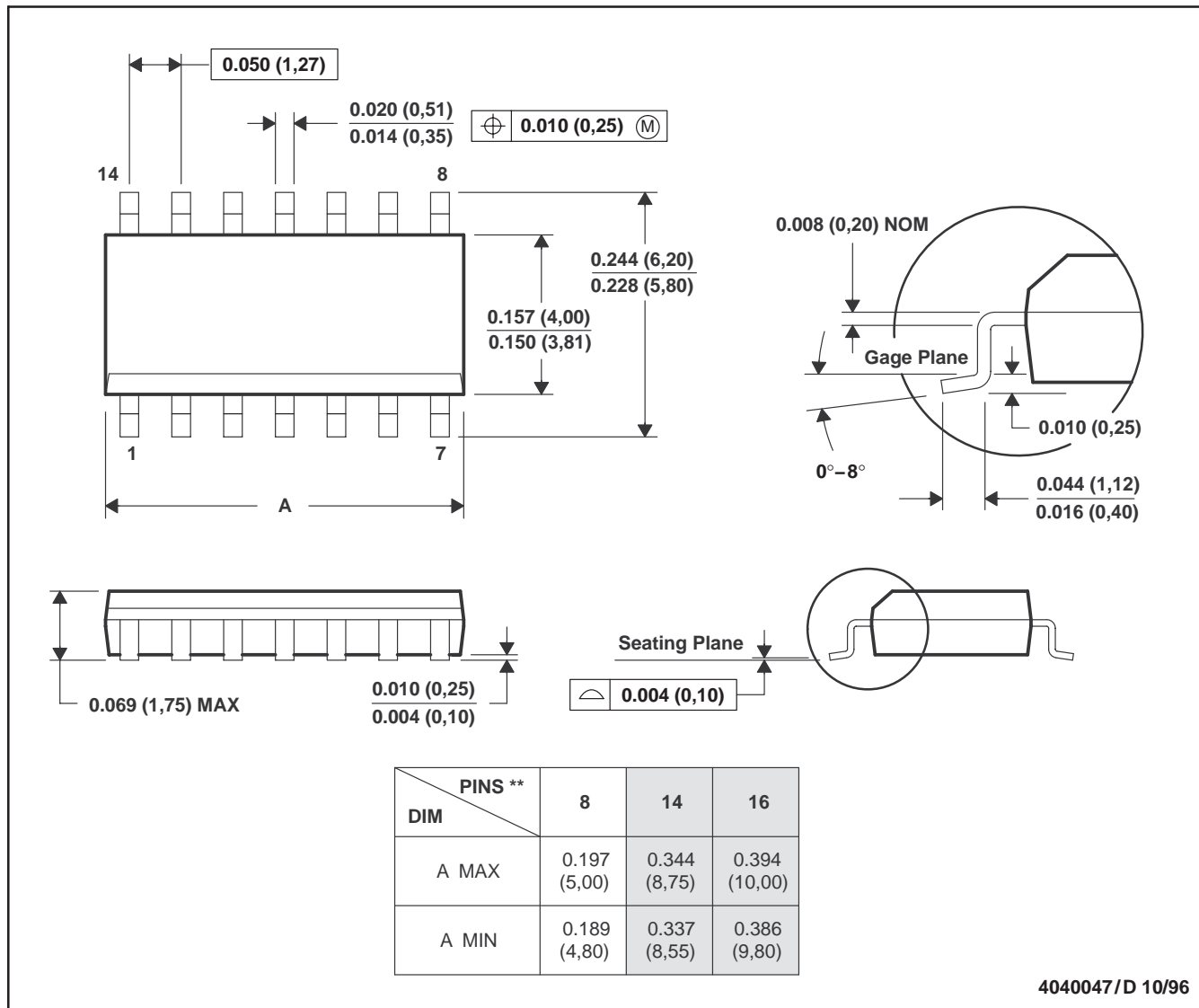
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**MECHANICAL DATA**

**D (R-PDSO-G\*\*)**

**PLASTIC SMALL-OUTLINE PACKAGE**

14 PIN SHOWN



- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).

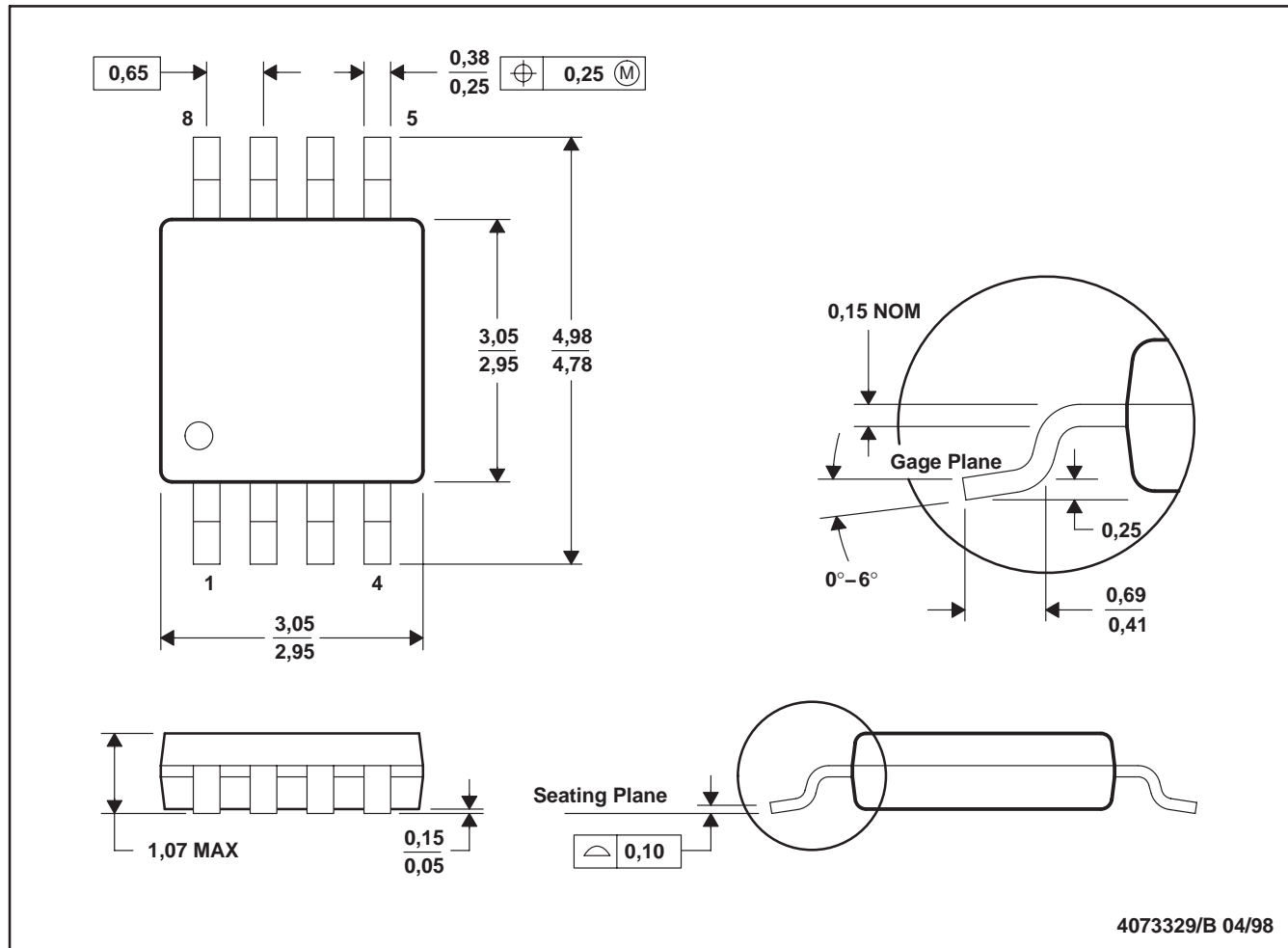
**TPA6101A2**  
**50-mW ULTRALOW-VOLTAGE, FIXED-GAIN STEREO HEADPHONE**  
**AUDIO POWER AMPLIFIER**

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**MECHANICAL INFORMATION**

**DGK (R-PDSO-G8)**

**PLASTIC SMALL-OUTLINE PACKAGE**



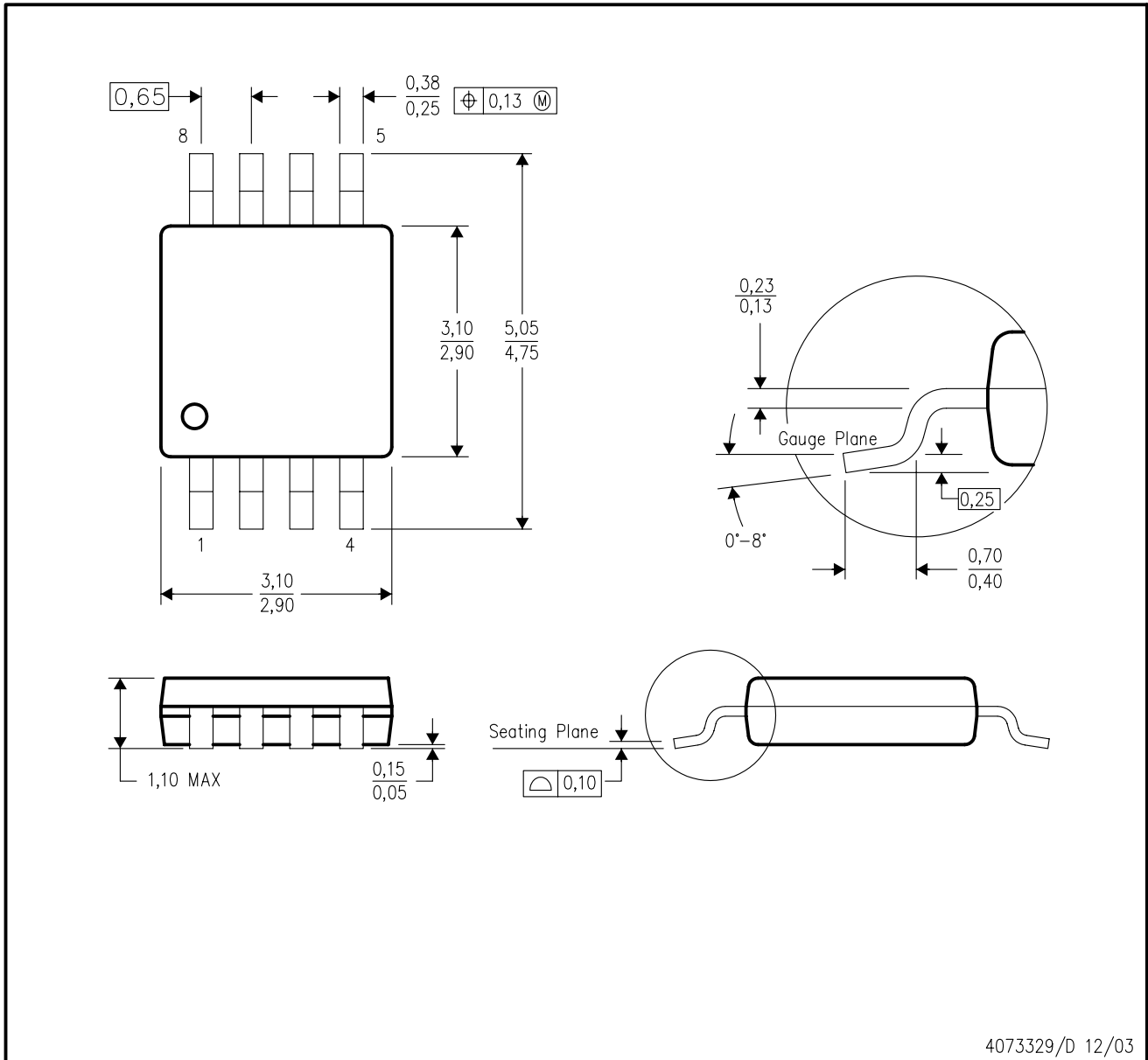
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# MECHANICAL DATA

DGK (S-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE

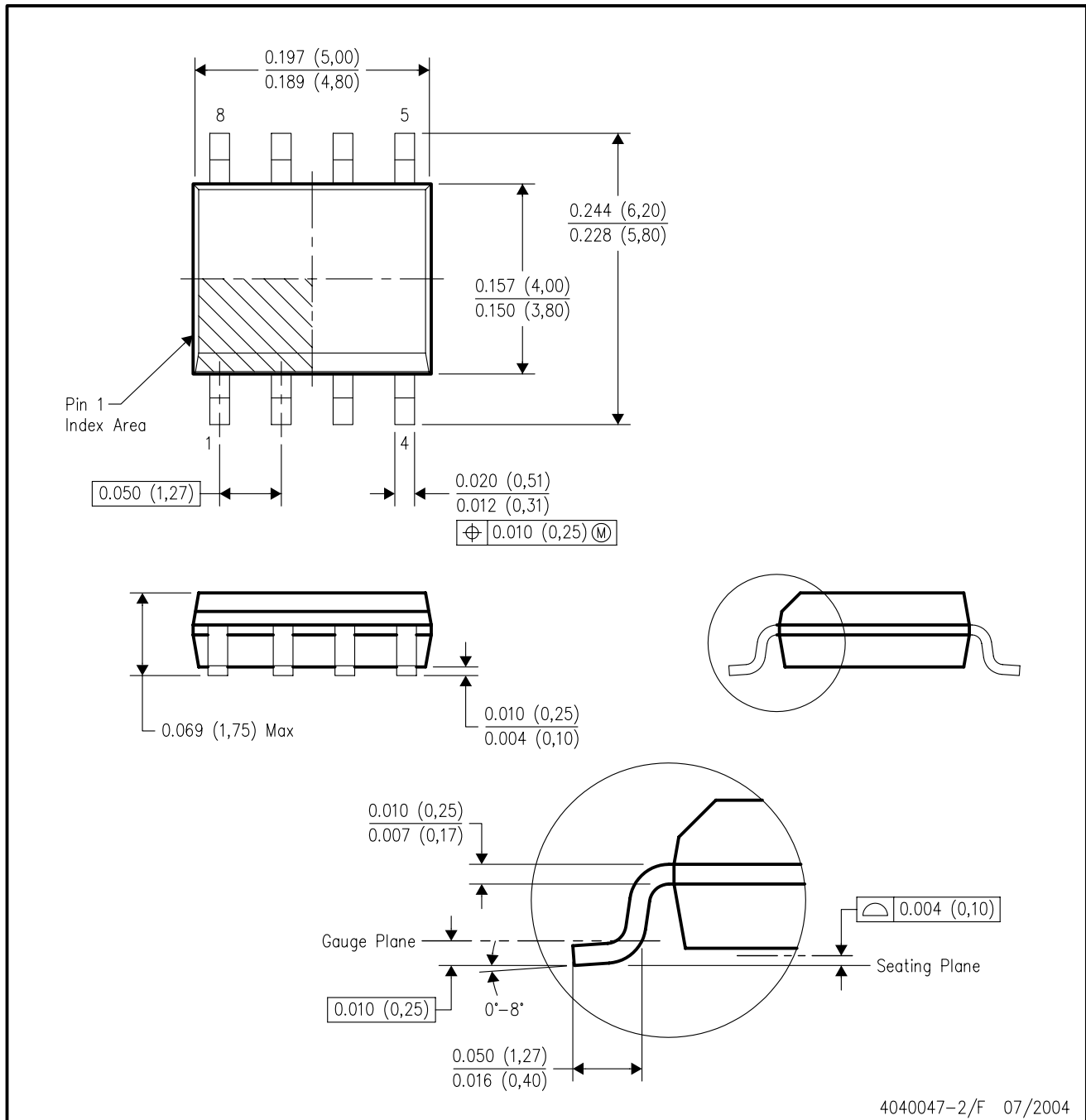


- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion.
  - D. Falls within JEDEC MO-187 variation AA.

# MECHANICAL DATA

D (R-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
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