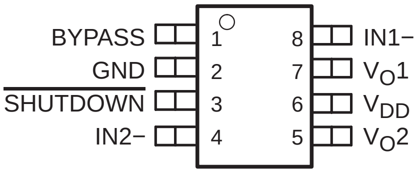
TPA6102A2
50-mW ULTRALOW-VOLTAGE, FIXED-GAIN STEREO HEADPHONE AUDIO POWER AMPLIFIER

SLOS324B − JUNE 2000 − REVISED SEPTEMBER 2004

- **50-mW Stereo Output**
- **Low Supply Current . . . 0.75 mA**
- **Low Shutdown Current . . . 50 nA**
- **Minimal External Components Required**
- **Gain Set Internally to 14 dB**
- **Pop Reduction Circuitry**
- **Internal Mid-Rail Generation**
- **Thermal and Short-Circuit Protection**
- **Surface-Mount Packaging**
  - **MSOP**
  - **SOIC**
- **1.6-V to 3.6-V Supply Voltage Range**

D or DGK PACKAGE
(TOP VIEW)



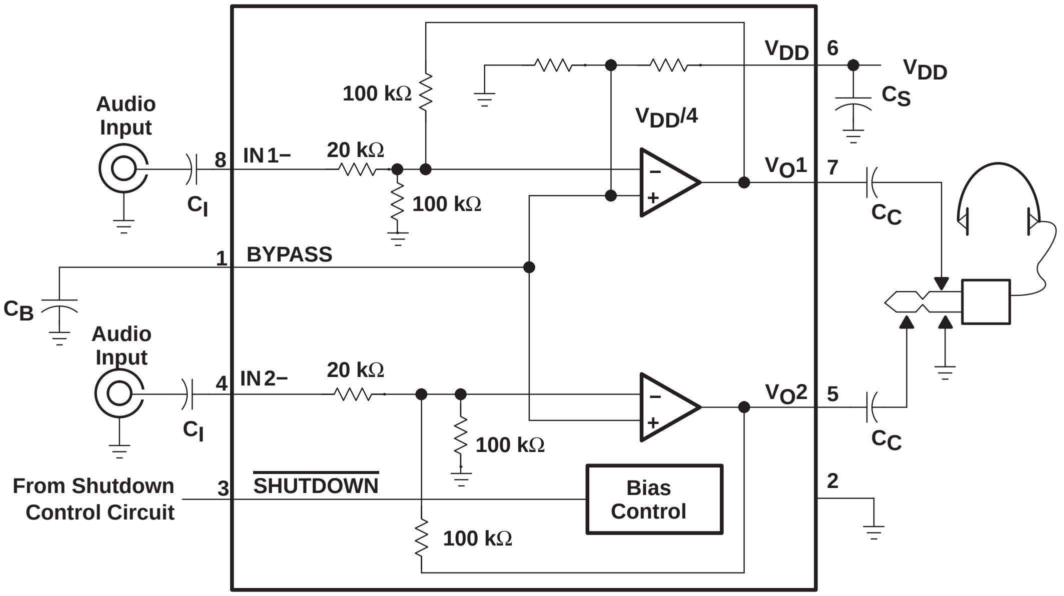
description

The TPA6102A2 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 14 dB (inverting) to save board space by eliminating six external resistors.

The TPA6102A2 is optimized for battery applications because of its low-supply current, shutdown current, and THD+N. To obtain the low-supply voltage range, the TPA6102A2 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



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.

AVAILABLE OPTIONS

T_A	PACKAGED DEVICE		MSOP SYMBOLIZATION
	SMALL OUTLINE (D)	MSOP (DGK)	
−40°C to 85°C	TPA6102A2D	TPA6102A2DGK	AJN

Terminal Functions

TERMINAL		I/O	DESCRIPTION
NAME	NO.		
BYPASS	1	I	Tap to voltage divider for internal mid-supply bias supply. BYPASS is set at $V_{DD}/4$. 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.
$\overline{\text{SHUTDOWN}}$	3	I	Active-low input. When held low, the device is placed in a low supply current mode.
V_{DD}	6	I	V_{DD} is the supply voltage terminal.
V_O1	7	O	V_O1 is the audio output for channel 1.
V_O2	5	O	V_O2 is the audio output for channel 2.

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

Supply voltage, V_{DD}	4 V
Input voltage, V_I	−0.3 V to V_{DD} + 0.3 V
Continuous total power dissipation	Internally Limited
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	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ 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_{DD}		1.6	3.6	V
High-level input voltage, V_{IH} ($\overline{\text{SHUTDOWN}}$)		60% x V_{DD}		V
Low-level input voltage, V_{IL} ($\overline{\text{SHUTDOWN}}$)			25% x V_{DD}	V
Operating free-air temperature, T_A		−40	85	°C

dc electrical characteristics at T_A = 25°C, V_{DD} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{OO}	Output offset voltage	A_V = 14 dB		5	40	mV
PSRR	Power supply rejection ratio	V_{DD} = 3 V to 3.6 V		72		dB
I_{DD}	Supply current	$\overline{\text{SHUTDOWN}}$ = 3.6 V		0.75	1.5	mA
$I_{DD(SD)}$	Supply current in $\overline{\text{SHUTDOWN}}$ mode	$\overline{\text{SHUTDOWN}}$ = 0 V		50	250	nA
$\lvert I_{IH}\rvert$	High-level input current ($\overline{\text{SHUTDOWN}}$)	V_{DD} = 3.6 V, $V_I = V_{DD}$			1	µA
$\lvert I_{IL}\rvert$	Low-level input current ($\overline{\text{SHUTDOWN}}$)	V_{DD} = 3.6 V, V_I = 0 V			1	µA
Z_I	Input impedance			20		kΩ

ac operating characteristics, V_{DD} = 3.3 V, T_A = 25°C, R_L = 16 Ω

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
G	Gain			14		dB
P_O	Output power (each channel)	THD ≤ 0.1%, f = 1 kHz		50		mW
THD+N	Total harmonic distortion + noise	P_O = 45 mW, 20−20 kHz		0.4%		
B_{OM}	Maximum output power BW	THD < 0.5%		> 20		kHz
k_{SVR}	Supply ripple rejection ratio	f = 1 kHz		47		dB
SNR	Signal-to-noise ratio	P_O = 50 mW		86		dB
V_n	Noise output voltage (no noise weighting filter)			45		µV(rms)

ac operating characteristics, V_{DD} = 3.3 V, T_A = 25°C, R_L = 32 Ω

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
G	Gain			14		dB
P_O	Output power (each channel)	THD ≤ 0.1%, f = 1 kHz		35		mW
THD+N	Total harmonic distortion + noise	P_O = 30 mW, 20−20 kHz		0.4%		
B_{OM}	Maximum output power BW	THD < 0.4%		>20		kHz
k_{SVR}	Supply ripple rejection ratio	f = 1 kHz		47		dB
SNR	Signal-to-noise ratio	P_O = 30 mW		86		dB
V_n	Noise output voltage (no noise weighting filter)			50		µV(rms)

dc electrical characteristics at T_A = 25°C, V_{DD} = 1.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{OO}	Output offset voltage	A_V = 14 dB		5	40	mV
PSRR	Power supply rejection ratio	V_{DD} = 1.4 V to 1.8 V		80		dB
I_{DD}	Supply current	$\overline{\text{SHUTDOWN}}$ = 1.6 V		0.65	1.2	mA
$I_{DD(SD)}$	Supply current in $\overline{\text{SHUTDOWN}}$ mode	$\overline{\text{SHUTDOWN}}$ = 0 V		50	250	nA
$\|I_{IH}\|$	High-level input current ($\overline{\text{SHUTDOWN}}$)	V_{DD} = 1.6 V, $V_I = V_{DD}$			1	µA
$\|I_{IL}\|$	Low-level input current ($\overline{\text{SHUTDOWN}}$)	V_{DD} = 1.6 V, V_I = 0 V			1	µA
Z_I	Input impedance			20		kΩ

ac operating characteristics, V_{DD} = 1.6 V, T_A = 25°C, R_L = 16 Ω

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
G	Gain			14		dB
P_O	Output power (each channel)	THD ≤ 0.5%, f = 1 kHz		10		mW
THD+N	Total harmonic distortion + noise	P_O = 9.5 mW, 20−20 kHz		0.06%		
B_{OM}	Maximum output power BW	THD < 1%		> 20		kHz
k_{SVR}	Supply ripple rejection ratio	f = 1 kHz		47		dB
SNR	Signal-to-noise ratio	P_O = 10 mW		82		dB
V_n	Noise output voltage (no noise weighting filter)			32		µV(rms)

ac operating characteristics, V_{DD} = 1.6 V, T_A = 25°C, R_L = 32 Ω

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
G	Gain			14		dB
P_O	Output power (each channel)	THD ≤ 0.5%, f = 1 kHz		7.5		mW
THD+N	Total harmonic distortion + noise	P_O = 6.5 mW, 20−20 kHz		0.05%		
B_{OM}	Maximum output power BW	THD < 1%		>20		kHz
k_{SVR}	Supply ripple rejection ratio	f = 1 kHz		47		dB
SNR	Signal-to-noise ratio	P_O = 7.5 mW		84		dB
V_n	Noise output voltage (no noise weighting filter)			32		µV(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_{SVR}	Supply ripple rejection ratio	vs Frequency	17, 18
Vn	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

TYPICAL CHARACTERISTICS

TOTAL HARMONIC DISTORTION PLUS NOISE
vs
FREQUENCY

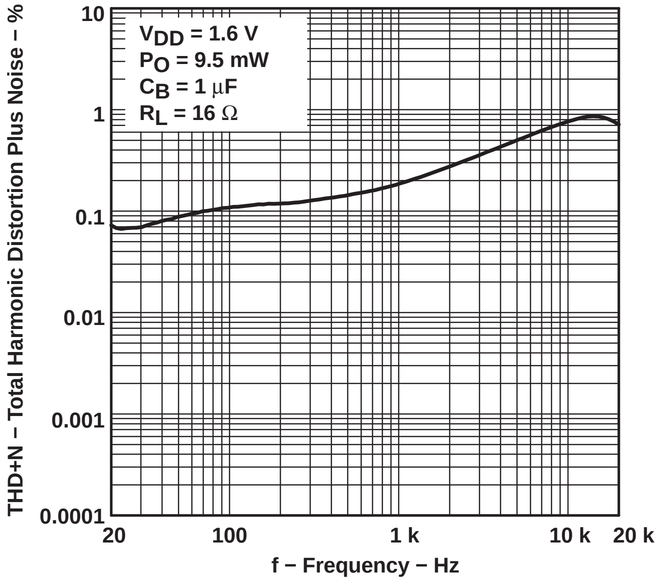


Figure 1

TOTAL HARMONIC DISTORTION PLUS NOISE
vs
OUTPUT POWER

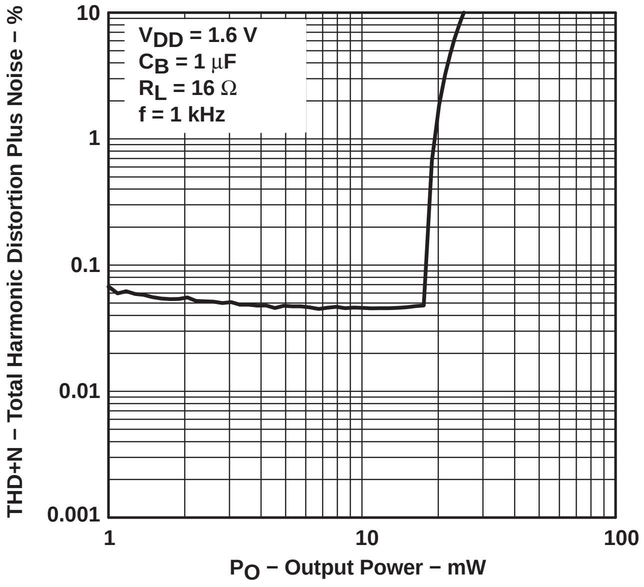


Figure 2

TOTAL HARMONIC DISTORTION PLUS NOISE
vs
FREQUENCY

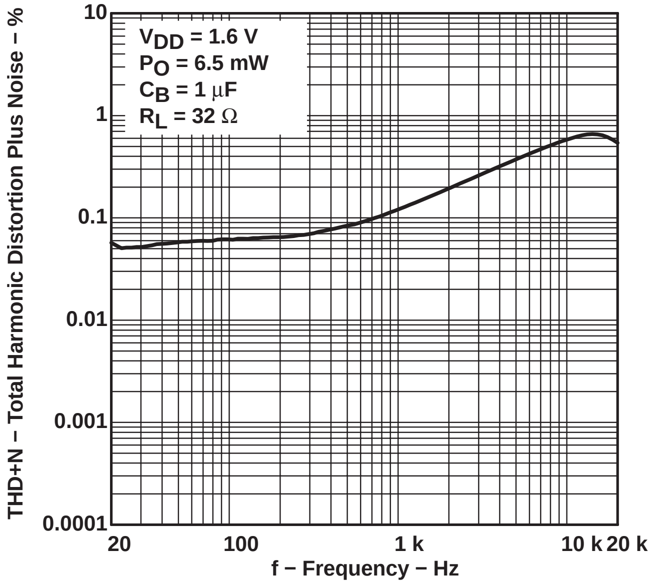


Figure 3

TOTAL HARMONIC DISTORTION PLUS NOISE
vs
OUTPUT POWER

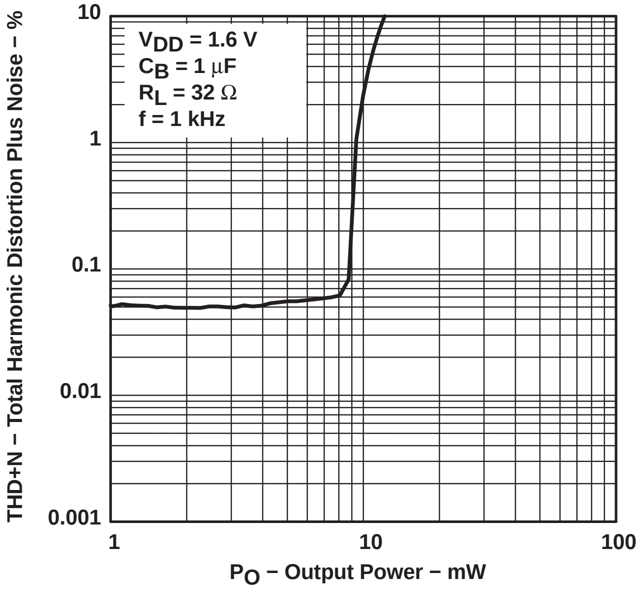


Figure 4

TYPICAL CHARACTERISTICS

TOTAL HARMONIC DISTORTION PLUS NOISE vs FREQUENCY

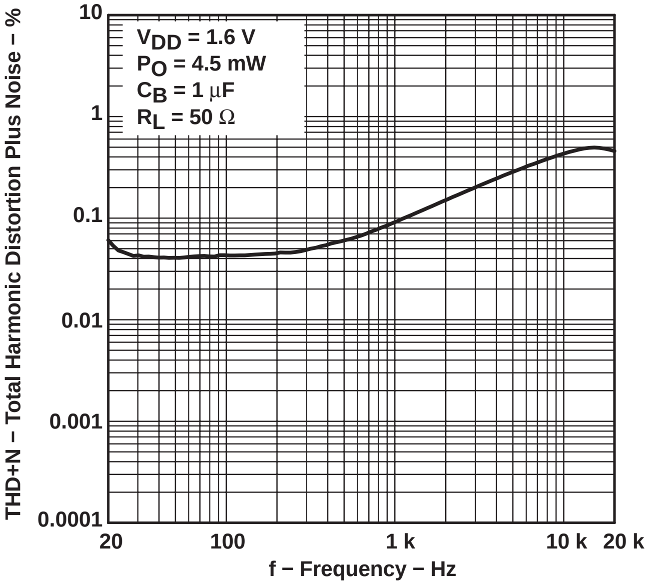


Figure 5

TOTAL HARMONIC DISTORTION PLUS NOISE vs OUTPUT POWER

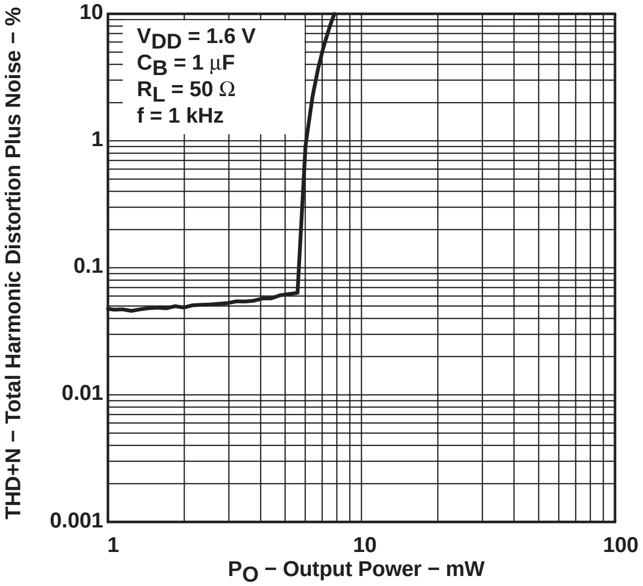


Figure 6

TOTAL HARMONIC DISTORTION PLUS NOISE vs FREQUENCY

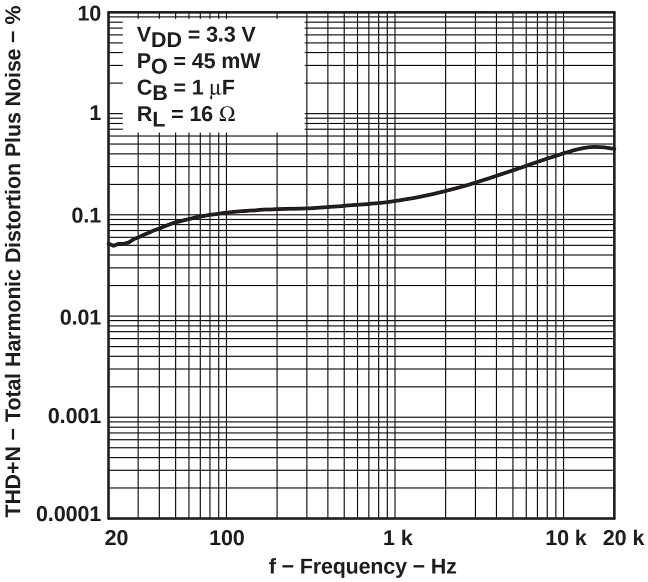


Figure 7

TOTAL HARMONIC DISTORTION PLUS NOISE vs OUTPUT POWER

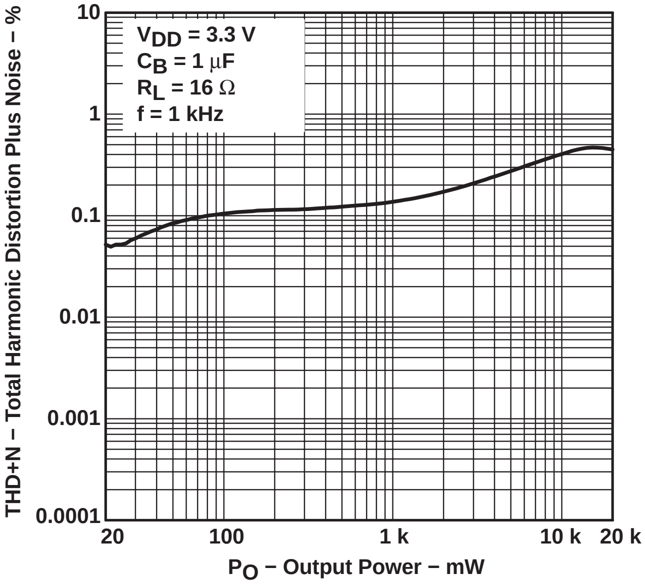


Figure 8

TYPICAL CHARACTERISTICS

TOTAL HARMONIC DISTORTION PLUS NOISE vs FREQUENCY

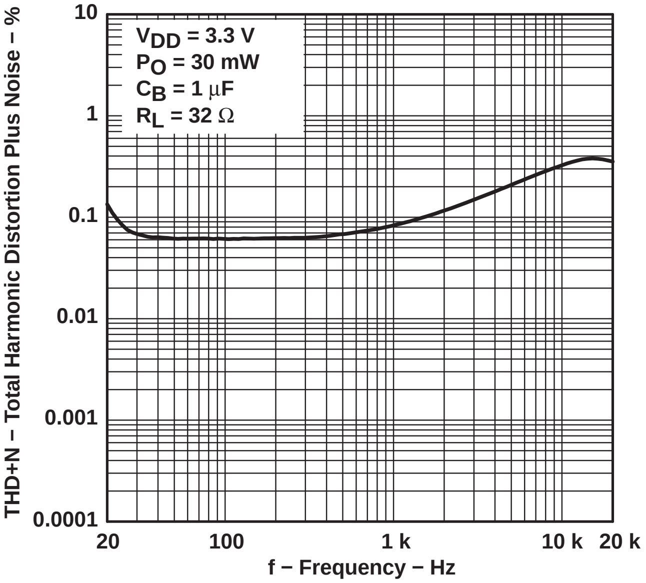


Figure 9

TOTAL HARMONIC DISTORTION PLUS NOISE vs OUTPUT POWER

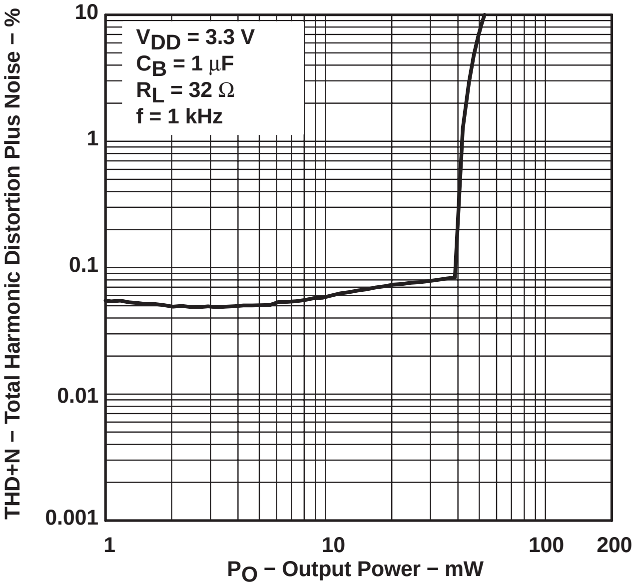


Figure 10

TOTAL HARMONIC DISTORTION PLUS NOISE vs FREQUENCY

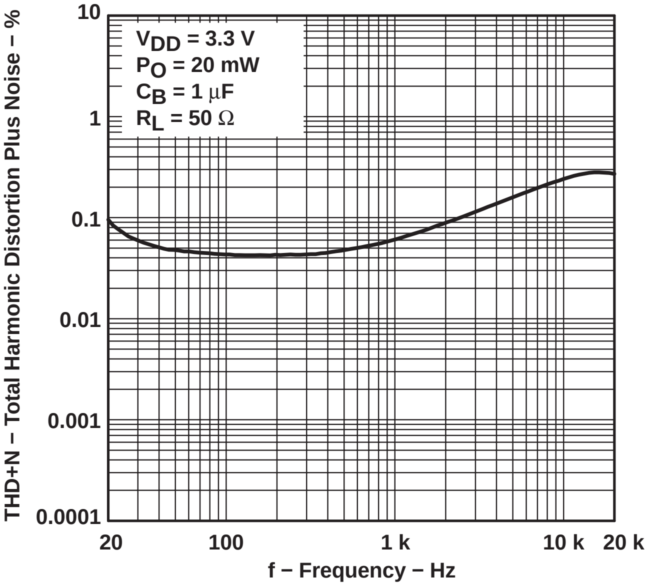


Figure 11

TOTAL HARMONIC DISTORTION PLUS NOISE vs OUTPUT POWER

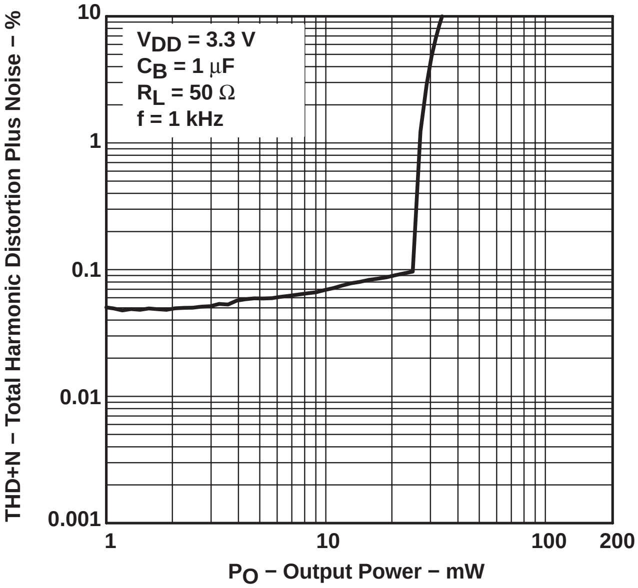


Figure 12

TYPICAL CHARACTERISTICS

TOTAL HARMONIC DISTORTION PLUS NOISE
vs
OUTPUT VOLTAGE

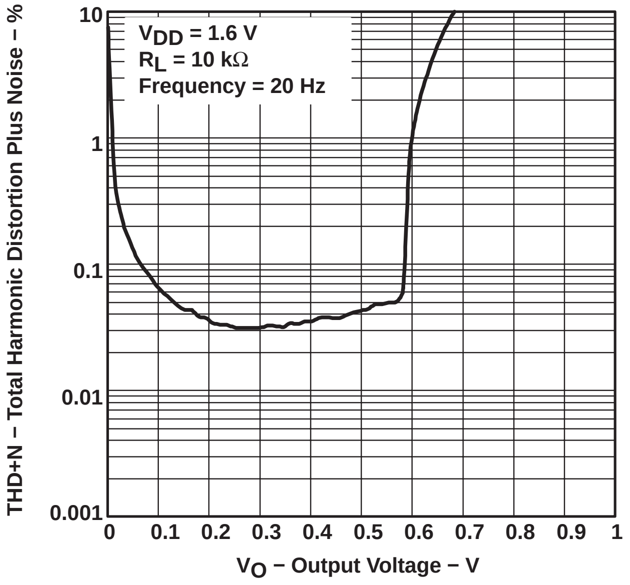


Figure 13

TOTAL HARMONIC DISTORTION PLUS NOISE
vs
OUTPUT VOLTAGE

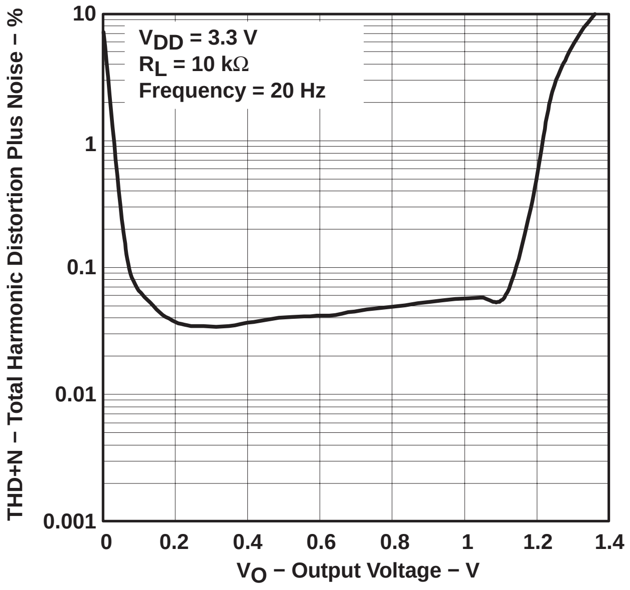


Figure 14

OUTPUT POWER
vs
LOAD RESISTANCE

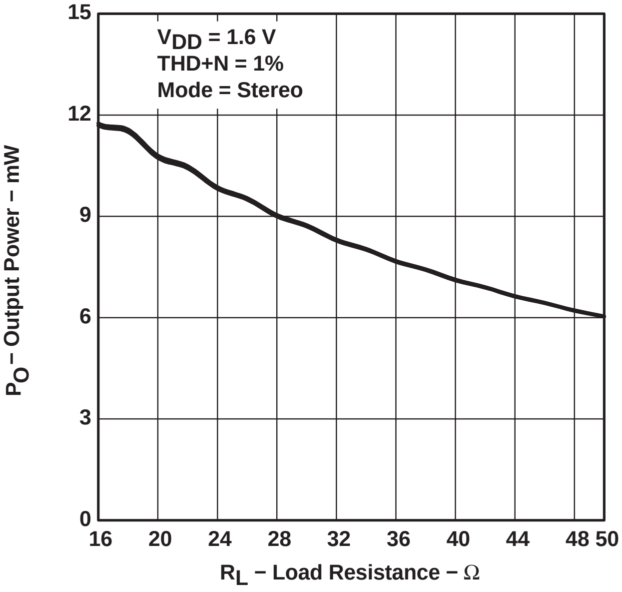


Figure 15

OUTPUT POWER
vs
LOAD RESISTANCE

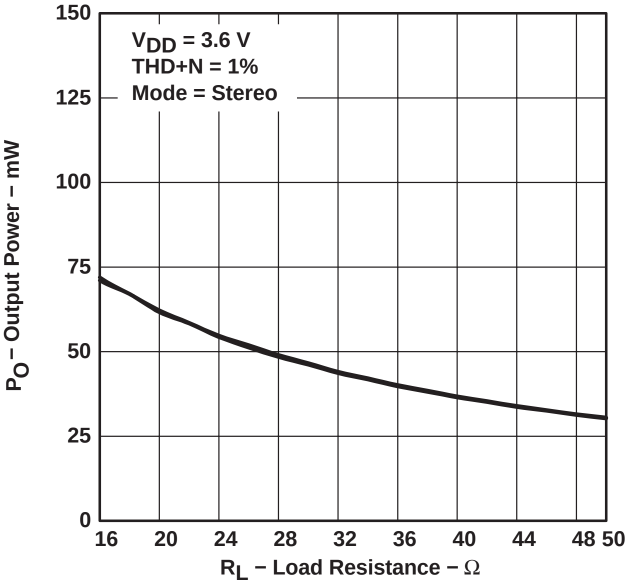


Figure 16

TYPICAL CHARACTERISTICS

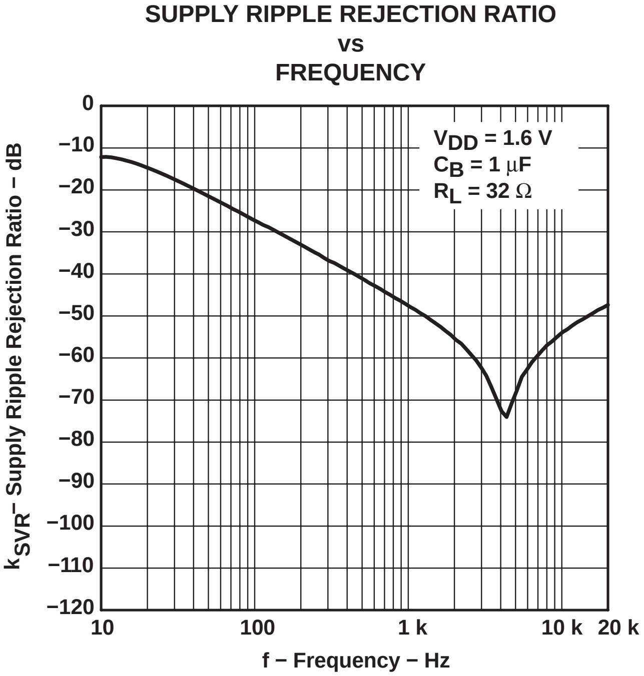


Figure 17

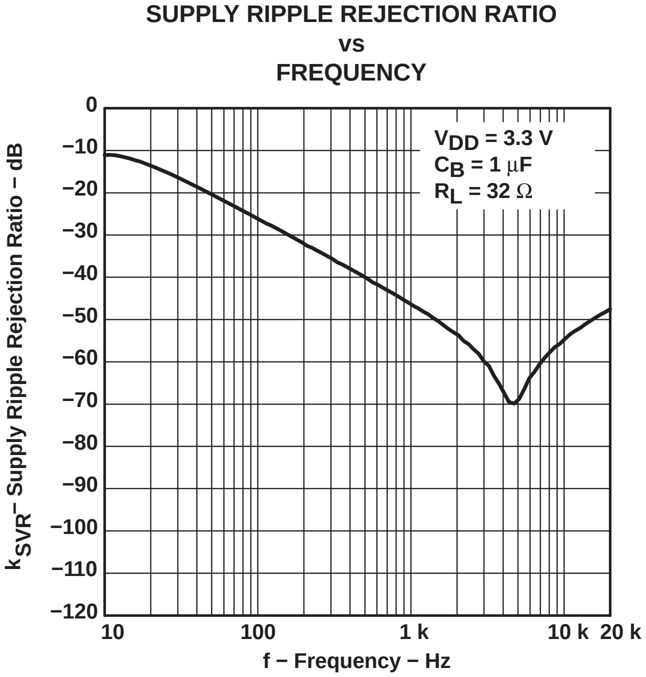


Figure 18

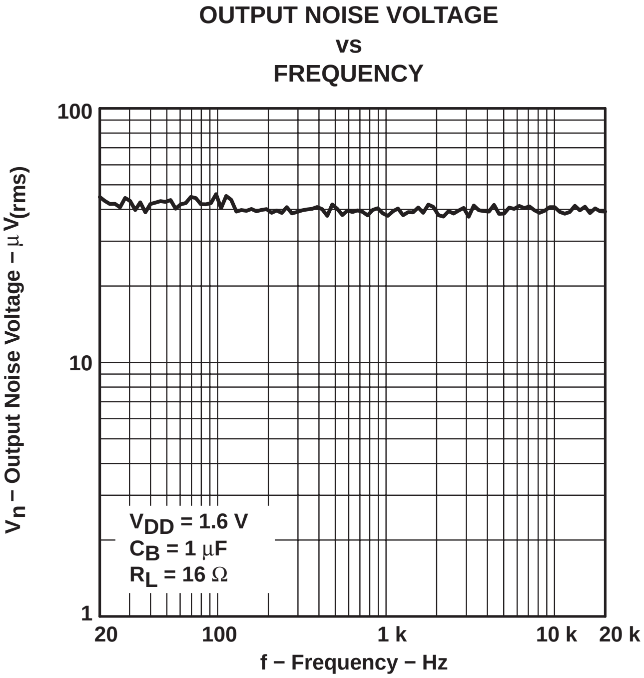


Figure 19

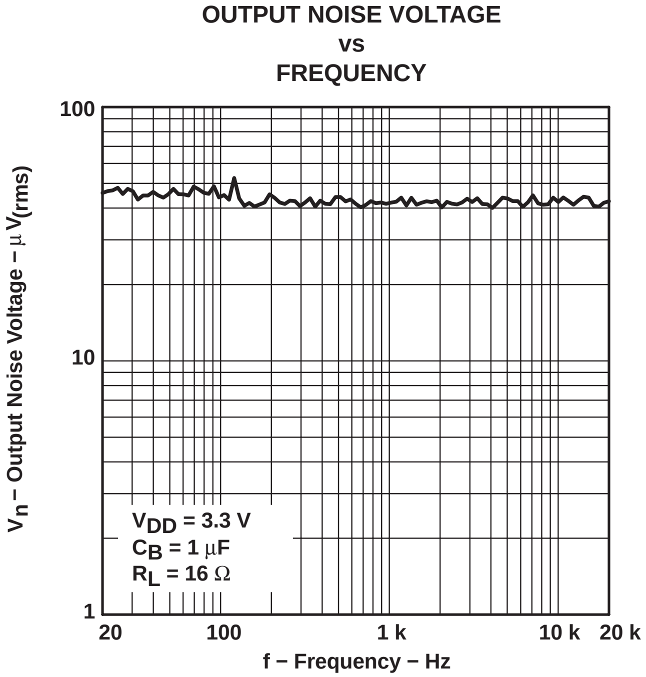


Figure 20

TYPICAL CHARACTERISTICS

CROSSTALK
vs
FREQUENCY

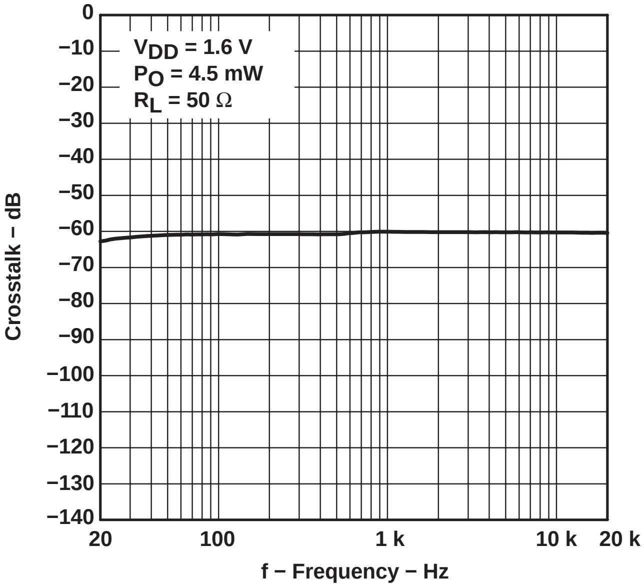


Figure 21

CROSSTALK
vs
FREQUENCY

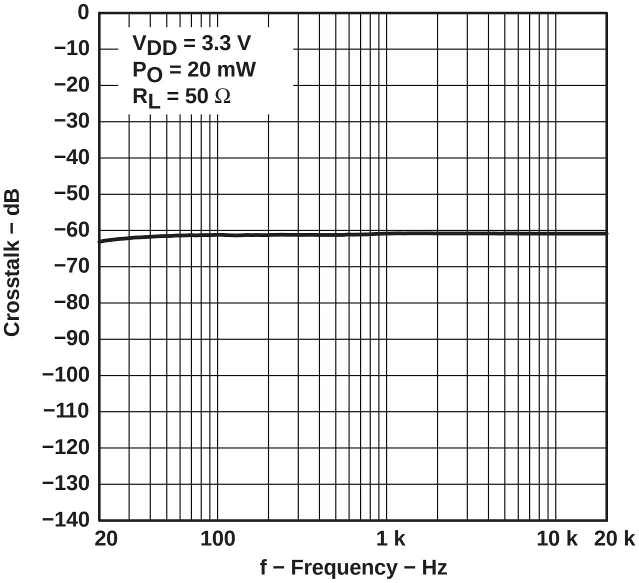


Figure 22

CLOSED-LOOP GAIN AND PHASE
vs
FREQUENCY

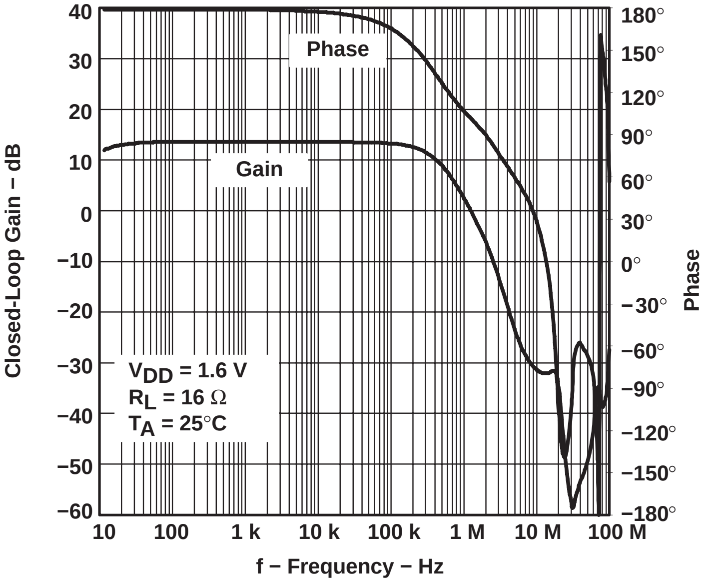


Figure 23

TYPICAL CHARACTERISTICS

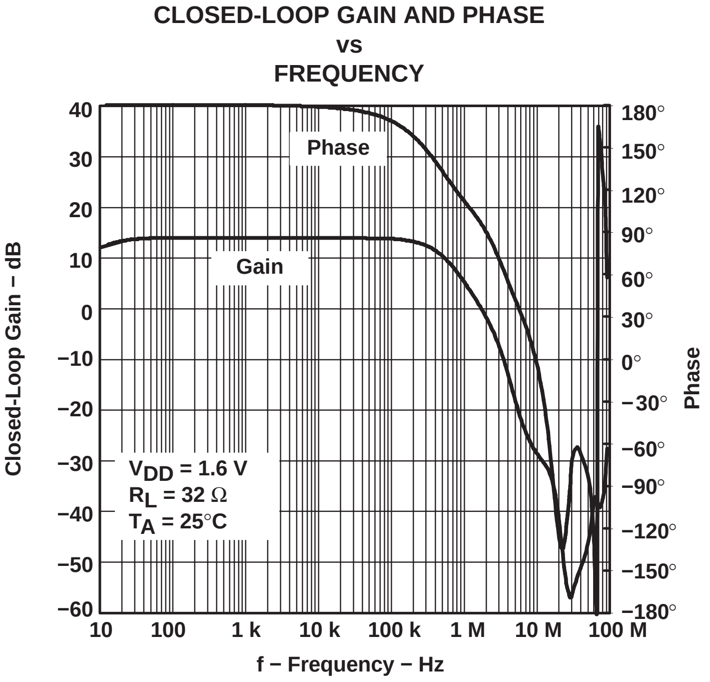


Figure 24

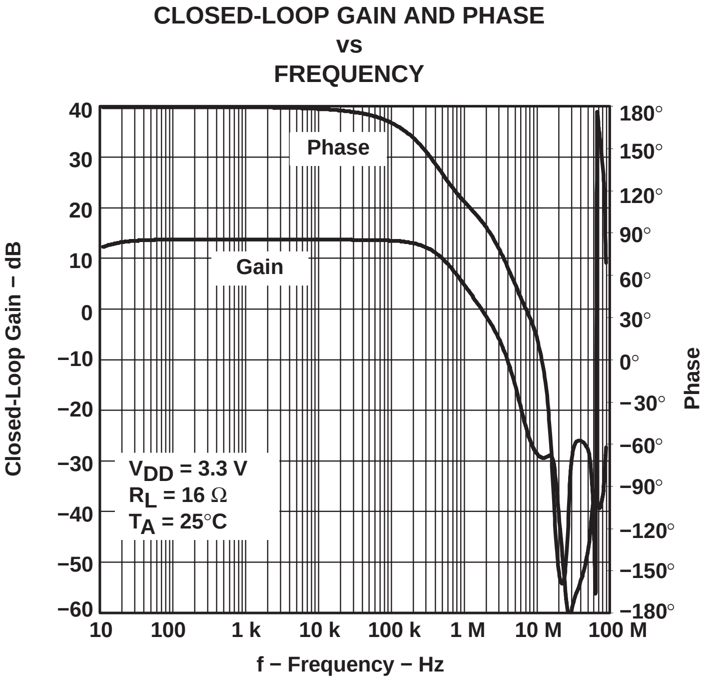


Figure 25

TYPICAL CHARACTERISTICS

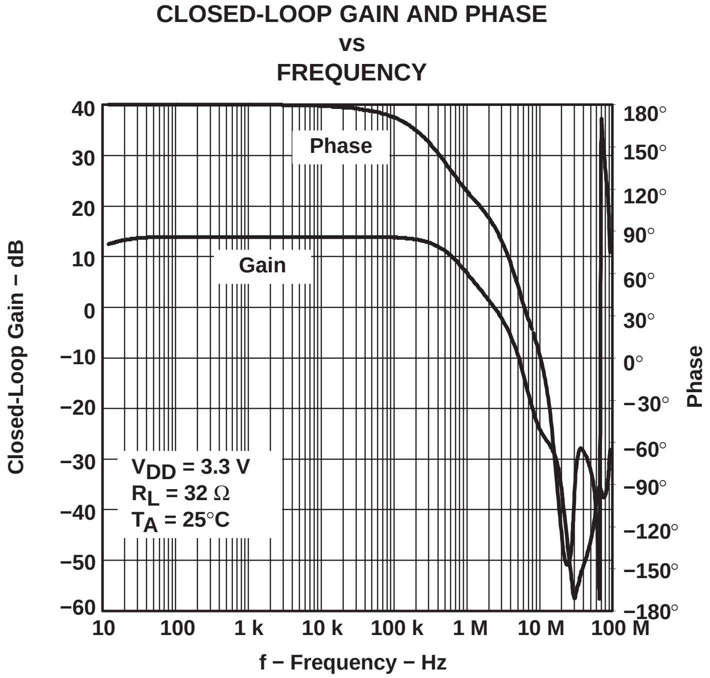


Figure 26

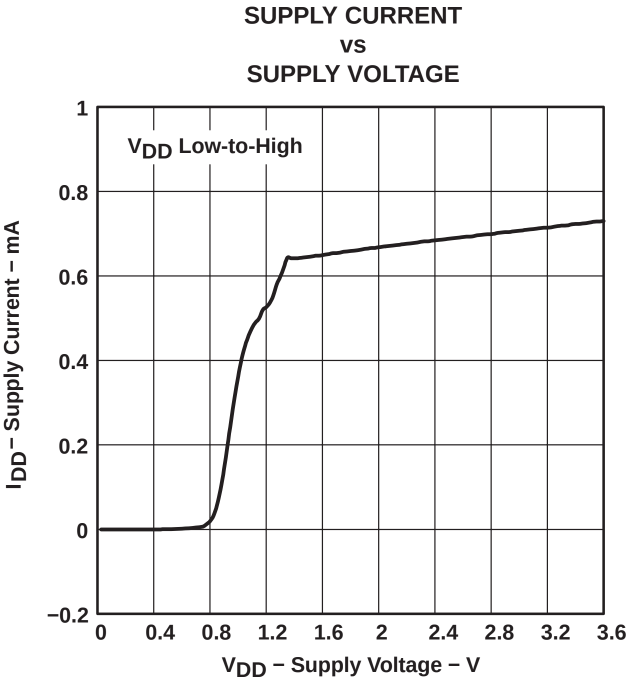


Figure 27

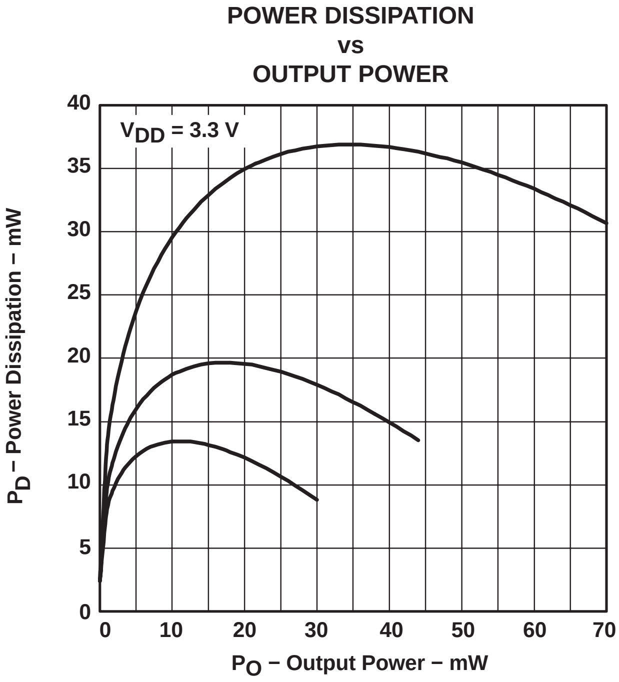


Figure 28

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 20 kΩ.

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

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.

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

In this example, C_I is 0.40 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 (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 TPA6102A2 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 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 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-kΩ source inside the amplifier. To keep the start-up pop as low as possible, the relationship shown in equation 3 should be maintained.

$$\frac{1}{\left(C_B \times 55\ \text{k}\Omega\right)} \le \frac{1}{\left(C_I R_I\right)} \tag{3}$$

As an example, consider a circuit where C_B is 1 µF, C_I is 1 µF, and R_I is 20 kΩ. Inserting these values into the equation 3 results in: 18.18 ≤ 50 which satisfies the rule. Bypass capacitor (C_B) with values of 0.47-µF to 1-µF ceramic or tantalum low-ESR capacitors are recommended for the best THD and noise performance.

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 form a high-pass filter governed by equation 4.

$$f_c = \frac{1}{2\pi R_L C_C} \tag{4}$$

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 µF is chosen and loads vary from 32 Ω to 47 kΩ. 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 Ω	68 µF	73 Hz
10,000 Ω	68 µF	0.23 Hz
47,000 Ω	68 µF	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:

$$\frac{1}{\left(C_B \times 55\ \text{k}\Omega\right)} \le \frac{1}{\left(C_I R_I\right)} \ll \frac{1}{R_L C_C} \tag{5}$$

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.

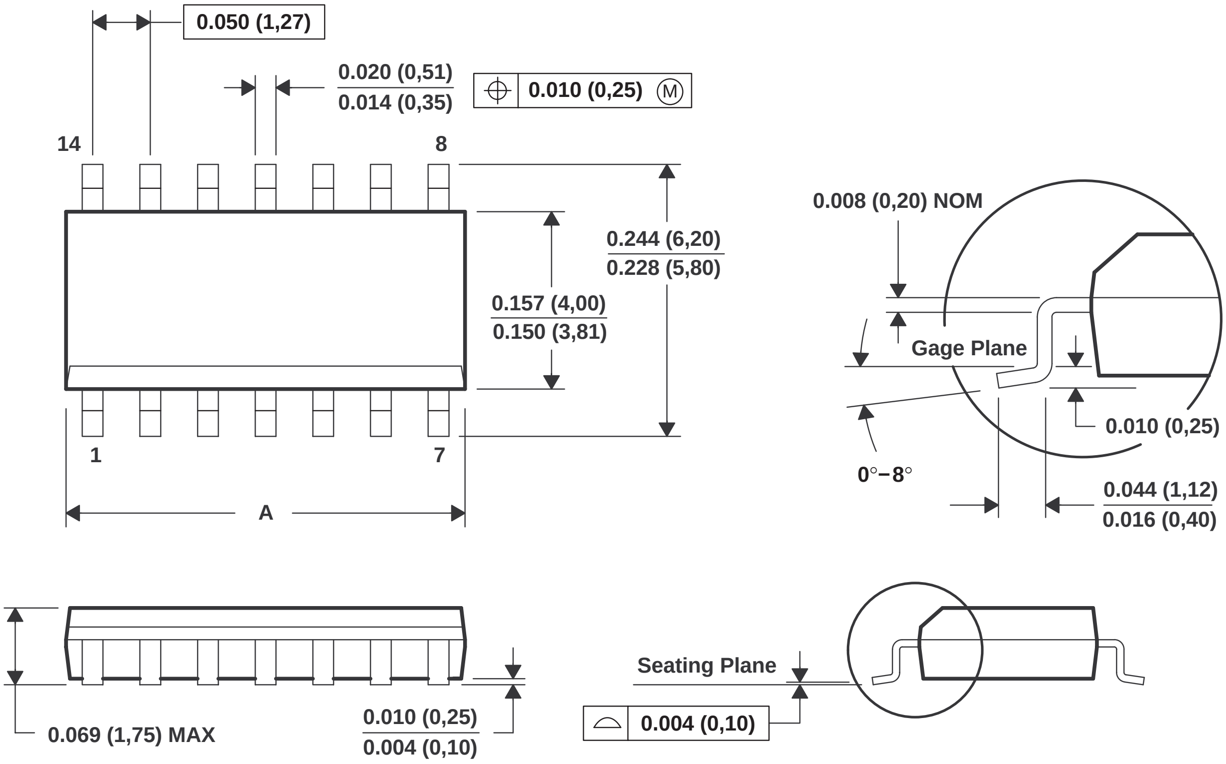
3.3-V versus 1.6-V operation

The TPA6102A2 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 maxium output voltage swing within a few hundred millivolts of the rails with a 10-kΩ 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-Ω 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.

MECHANICAL DATA

D (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14 PIN SHOWN



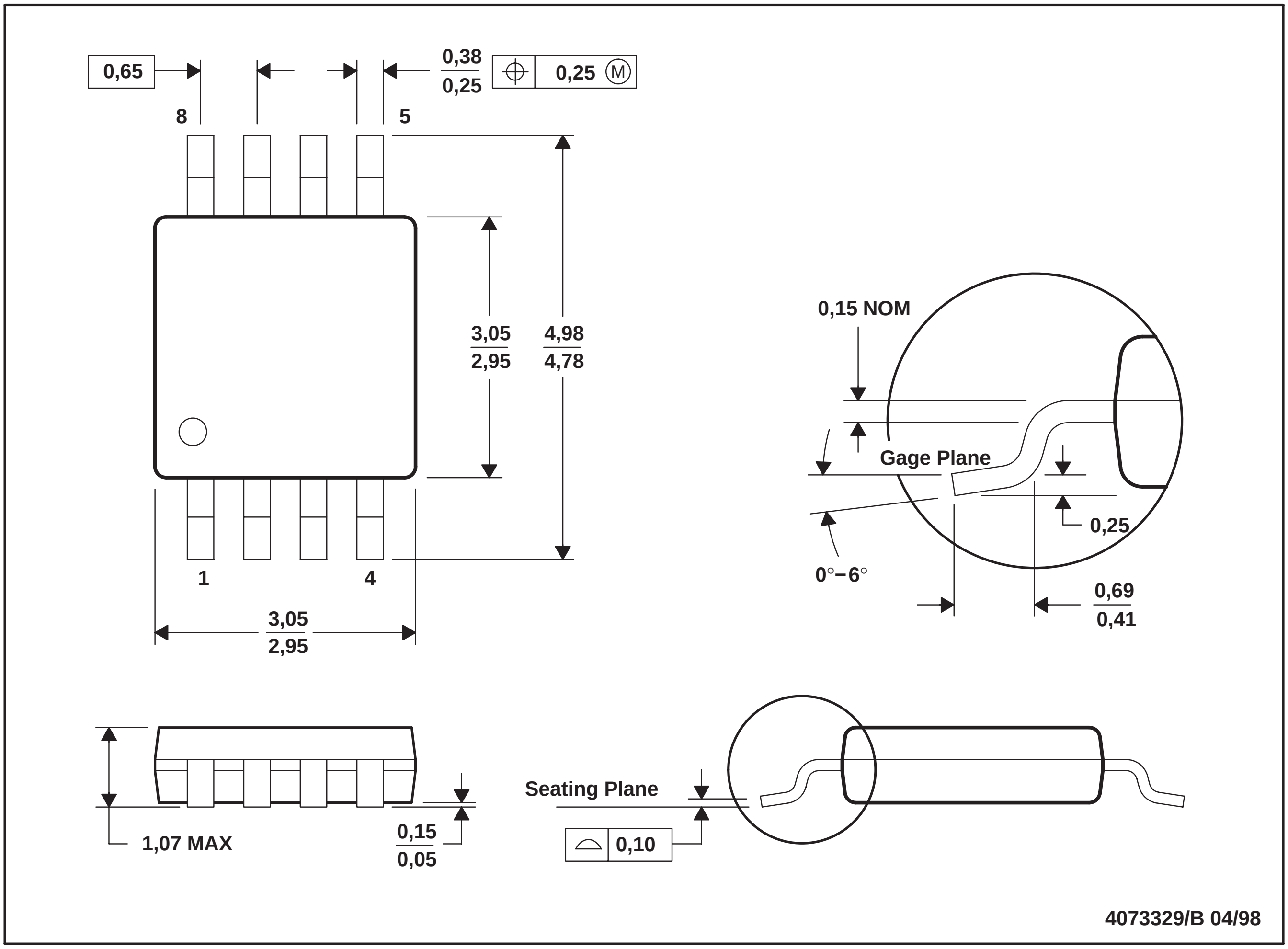
DIM \ PINS **	8	14	16
A MAX	0.197 (5,00)	0.344 (8,75)	0.394 (10,00)
A MIN	0.189 (4,80)	0.337 (8,55)	0.386 (9,80)

4040047 / D 10/96

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).

MECHANICAL INFORMATION

DGK (R-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

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