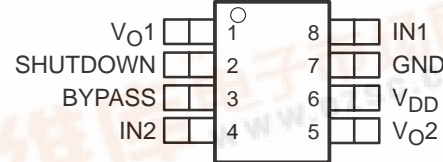


# 300-mW STEREO AUDIO POWER AMPLIFIER

SLOS174B – JANUARY 1997 – REVISE MARCH 2000

- 300-mW Stereo Output
- PC Power Supply Compatibility 5-V and 3.3-V Specified Operation
- Shutdown Control
- Internal Mid-Rail Generation
- Thermal and Short-Circuit Protection
- Surface-Mount Packaging
- Functional Equivalent of the LM4880

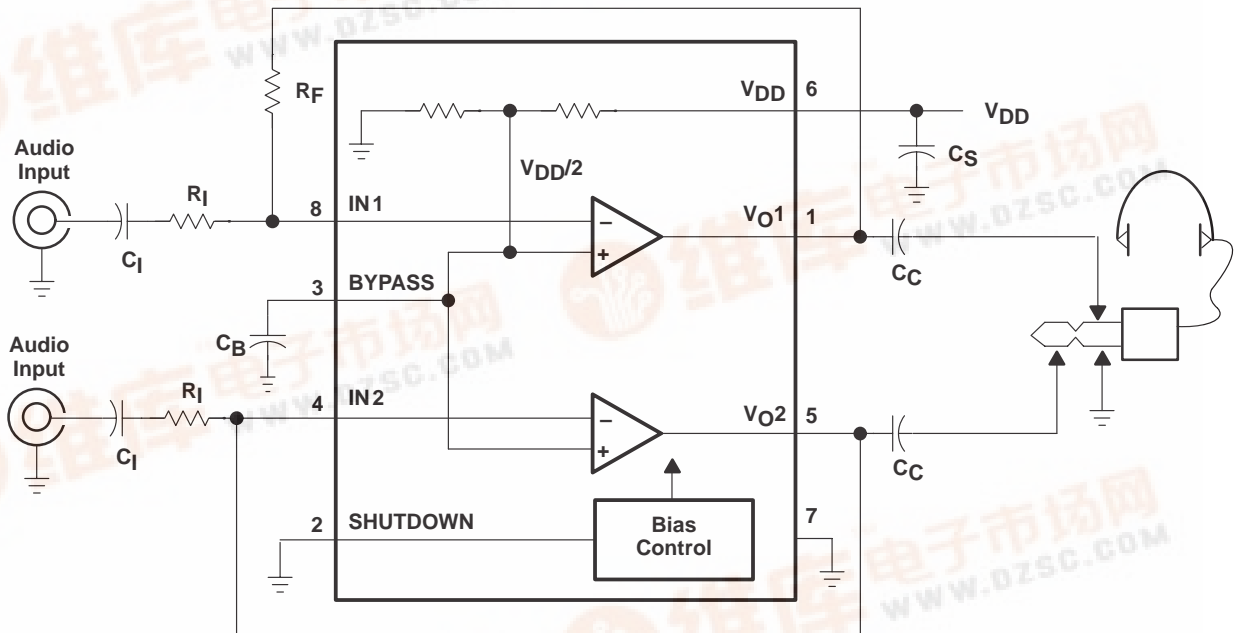
D PACKAGE  
(TOP VIEW)



## description

The TPA302 is a stereo audio power amplifier capable of delivering 250 mW of continuous average power into an 8-Ω load at less than 0.06% THD+N from a 5-V power supply or up to 300 mW at 1% THD+N. The TPA302 has high current outputs for driving small unpowered speakers at 8 Ω or headphones at 32 Ω. For headphone applications driving 32-Ω loads, the TPA302 delivers 60 mW of continuous average power at less than 0.06% THD+N. The amplifier features a shutdown function for power-sensitive applications as well as internal thermal and short-circuit protection. The amplifier is available in an 8-pin SOIC (D) package that reduces board space and facilitates automated assembly.

## 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.

# TPA302

## 300-mW STEREO AUDIO POWER AMPLIFIER

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### AVAILABLE OPTIONS

T <sub>A</sub>	PACKAGED DEVICES
	SMALL OUTLINE† (D)
–40°C to 85°C	TPA302D

† The D packages are available taped and reeled. To order a taped and reeled part, add the suffix R (e.g., TPA302DR)

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

Supply voltage, V <sub>DD</sub>	6 V
Input voltage, V <sub>I</sub>	–0.3 V to V <sub>DD</sub> + 0.3 V
Continuous total power dissipation	Internally Limited (See Dissipation Rating Table)
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	731 mW	5.8 mW/°C	460 mW	380 mW

### recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V <sub>DD</sub>	2.7	5.5	V
Operating free-air temperature, T <sub>A</sub>	–40	85	°C

### dc electrical characteristics at specified free-air temperature, V<sub>DD</sub> = 3.3 V (unless otherwise noted)

PARAMETER	TEST CONDITION	MIN	TYP	MAX	UNIT
I <sub>DD</sub> Supply current			2.25	5	mA
V <sub>IO</sub> Input offset voltage			5	20	mV
PSRR Power supply rejection ratio	V <sub>DD</sub> = 3.2 V to 3.4 V		55		dB
I <sub>DD(SD)</sub> Quiescent current in shutdown			0.6	20	μA

### ac operating characteristics, V<sub>DD</sub> = 3.3 V, T<sub>A</sub> = 25°C, R<sub>L</sub> = 8 Ω (unless otherwise noted)

PARAMETER	TEST CONDITION	MIN	TYP	MAX	UNIT
P <sub>O</sub> Output power	Gain = –1, f = 1 kHz	THD < 0.08%	100		mW
		THD < 1%	125		
		THD < 0.08%, R <sub>L</sub> = 32 Ω	25		
		THD < 1%, R <sub>L</sub> = 32 Ω	35		
B <sub>OM</sub> Maximum output power bandwidth	Gain = 10, 1% THD		20		kHz
B <sub>1</sub> Unity gain bandwidth	Open loop		1.5		MHz
Channel separation	f = 1 kHz		75		dB
Supply ripple rejection ratio	f = 1 kHz		45		dB
V <sub>n</sub> Noise output voltage	Gain = –1		10		μVrms

# TPA302

## 300-mW STEREO AUDIO POWER AMPLIFIER

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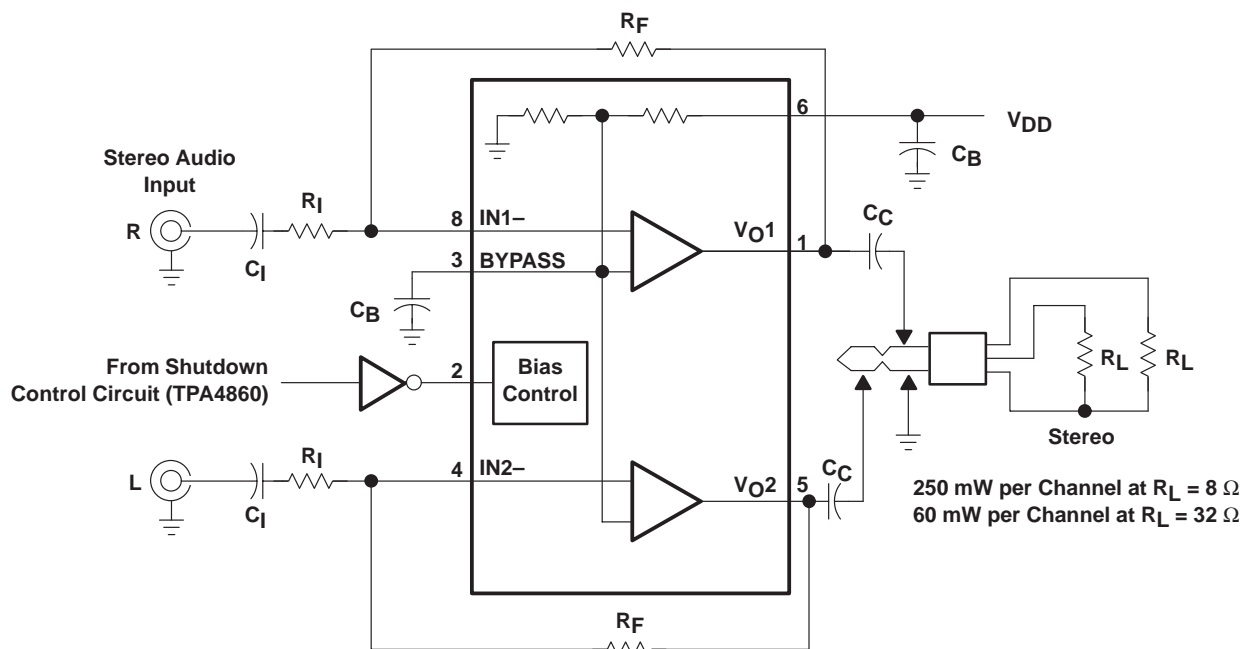
**dc electrical characteristics at specified free-air temperature,  $V_{DD} = 5\text{ V}$  (unless otherwise noted)**

PARAMETER		TEST CONDITION	MIN	TYP	MAX	UNIT
$I_{DD}$	Supply current			4	10	mA
$V_{OO}$	Output offset voltage	See Note 1		5	20	mV
PSRR	Power supply rejection ratio	$V_{DD} = 4.9\text{ V to } 5.1\text{ V}$		65		dB
$I_{DD(SD)}$	Quiescent current in shutdown			0.6		$\mu\text{A}$

**ac operating characteristics,  $V_{DD} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_L = 8\ \Omega$  (unless otherwise noted)**

PARAMETER		TEST CONDITION	MIN	TYP	MAX	UNIT
$P_O$	Output power	Gain = $-1$ , $f = 1\text{ kHz}$				mW
		THD < 0.06%		250		
		THD < 1%		300		
		THD < 0.06%, $R_L = 32\ \Omega$		60		
$B_{OM}$	Maximum output power bandwidth	Gain = 10, 1% THD		20		kHz
$B_1$	Unity gain bandwidth	Open loop		1.5		MHz
	Channel separation	$f = 1\text{ kHz}$		75		dB
	Supply ripple rejection ratio	$f = 1\text{ kHz}$		45		dB
$V_n$	Noise output voltage	Gain = $-1$		10		$\mu\text{Vrms}$

### typical application



TPA302

300-mW STEREO AUDIO POWER AMPLIFIER

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TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
THD+N	Total harmonic distortion plus noise	vs Frequency	1–3, 7–9, 13–15, 19–21
		vs Output power	4–6, 10–12 16–18, 22–24
I <sub>DD</sub>	Supply current	vs Supply voltage vs Free-air temperature	25 26
V <sub>n</sub>	Output noise voltage	vs Frequency	27, 28
	Maximum package power dissipation	vs Free-air temperature	29
	Power dissipation	vs Output power	30, 31
P <sub>Omax</sub>	Maximum output power	vs Free-air temperature	32, 33
P <sub>O</sub>	Output power	vs Load resistance	34
		vs Supply voltage	35
	Open loop response		36
	Closed loop response		37
	Crosstalk	vs Frequency	38, 39
	Supply ripple rejection ratio	vs Frequency	40, 41

TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
FREQUENCY

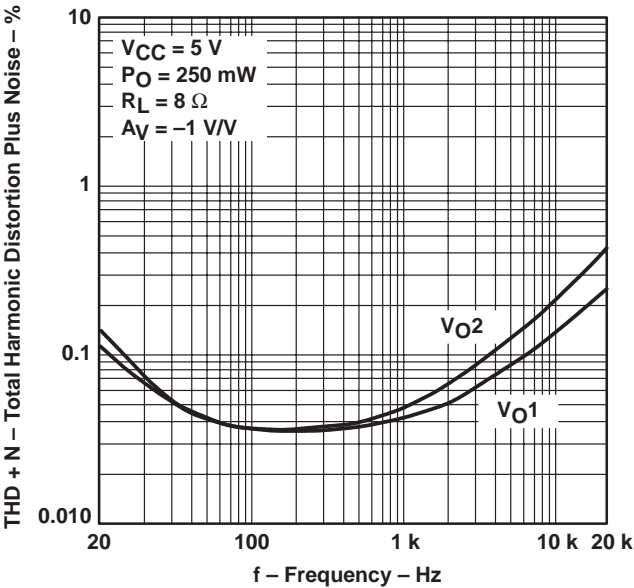


Figure 1

TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
FREQUENCY

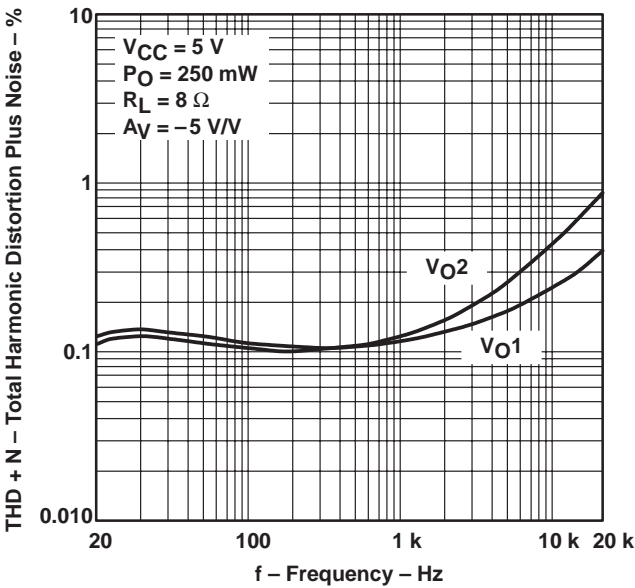


Figure 2

# TPA302 300-mW STEREO AUDIO POWER AMPLIFIER

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## TYPICAL CHARACTERISTICS

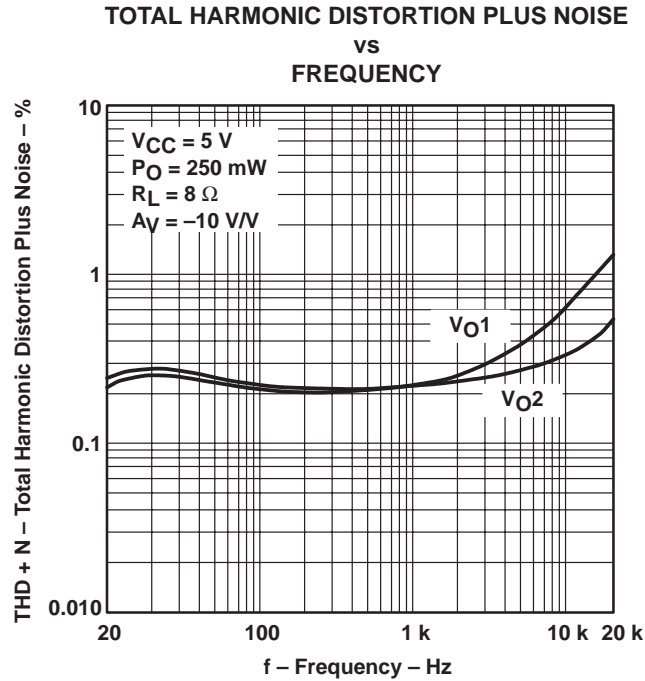


Figure 3

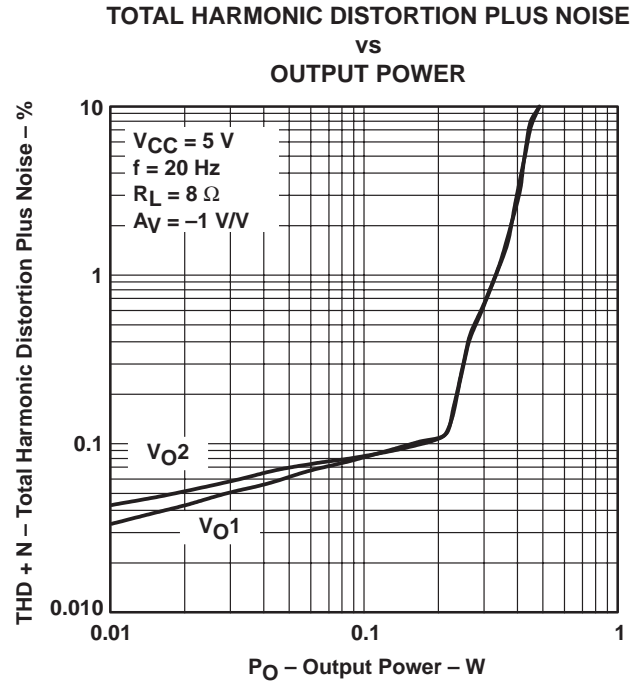


Figure 4

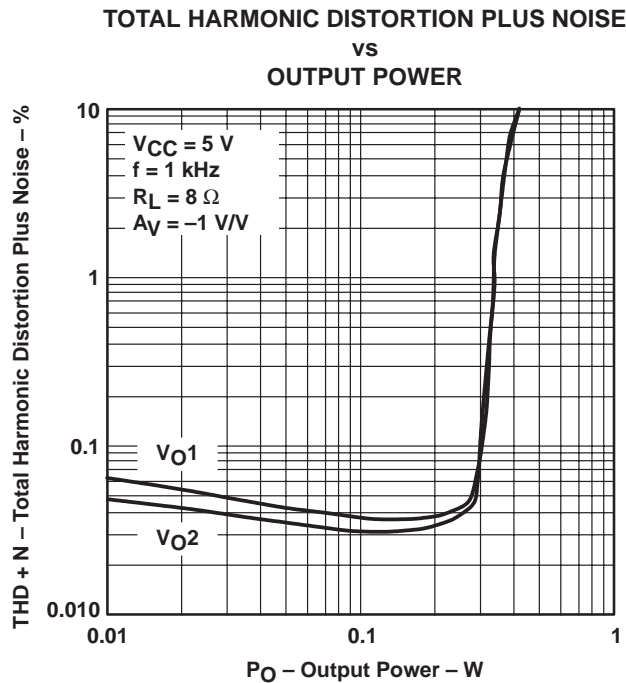


Figure 5

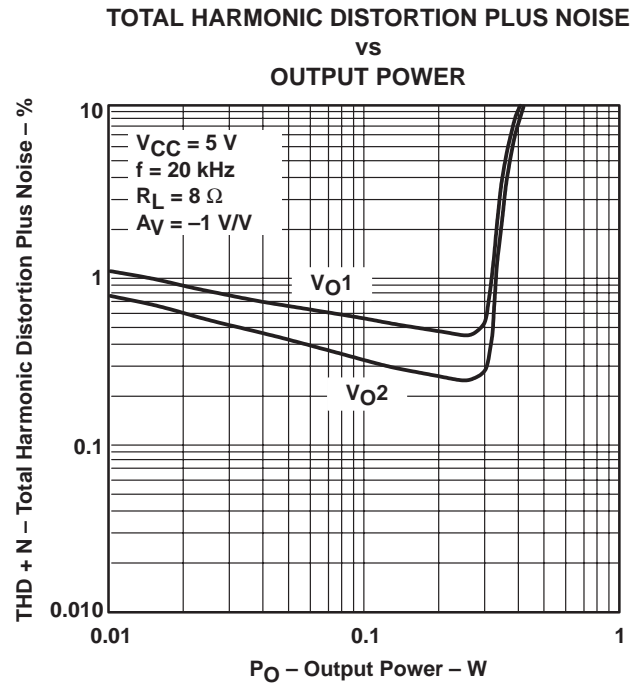


Figure 6

# TPA302

## 300-mW STEREO AUDIO POWER AMPLIFIER

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### TYPICAL CHARACTERISTICS

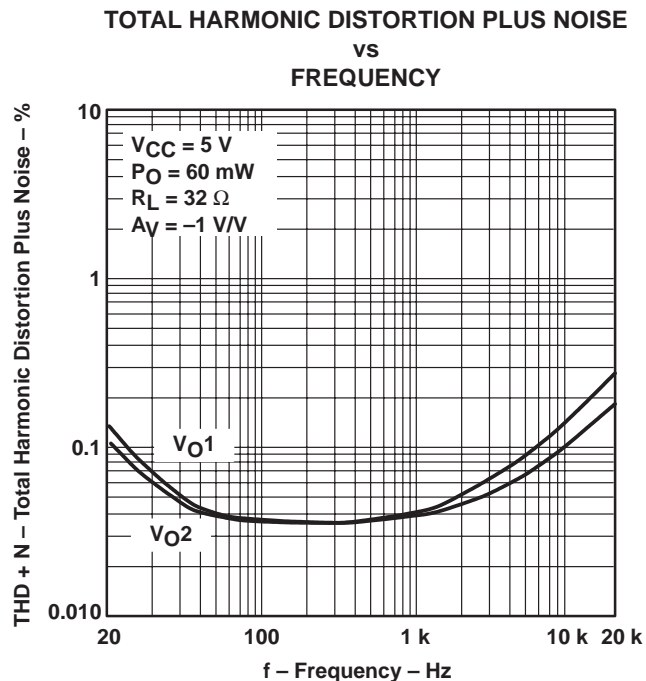


Figure 7

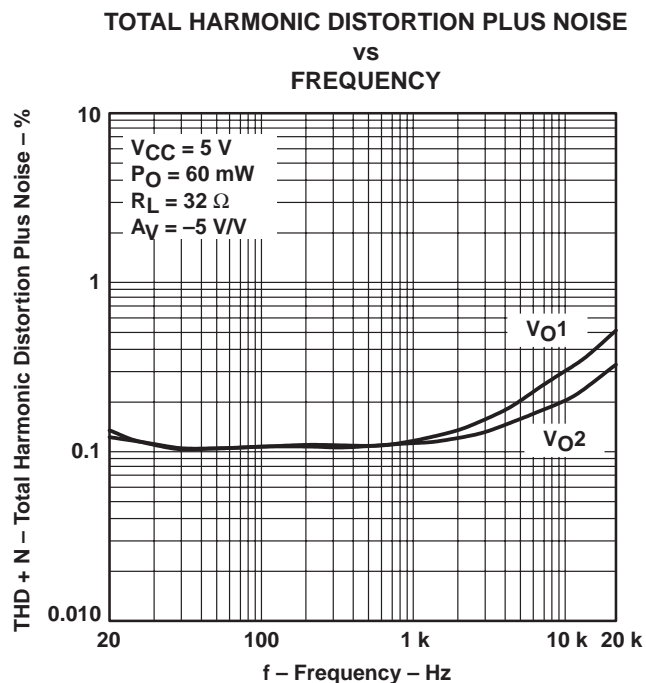


Figure 8

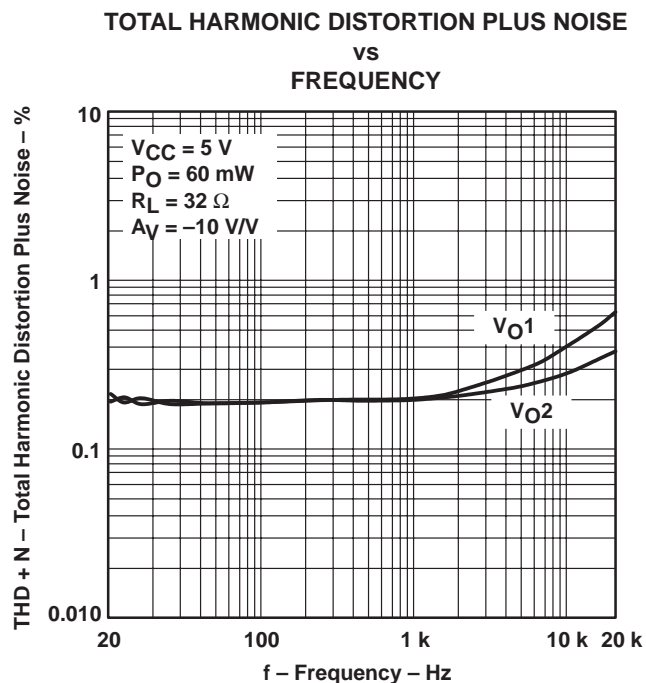


Figure 9

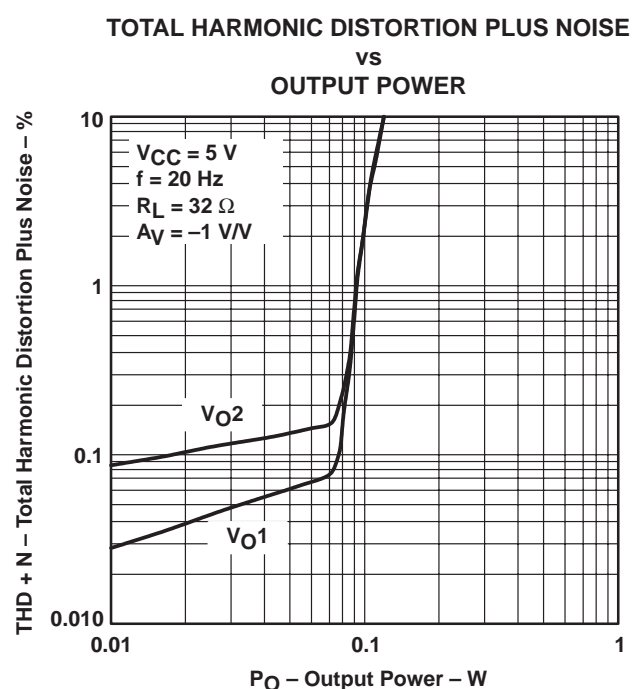


Figure 10

# TPA302 300-mW STEREO AUDIO POWER AMPLIFIER

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## TYPICAL CHARACTERISTICS

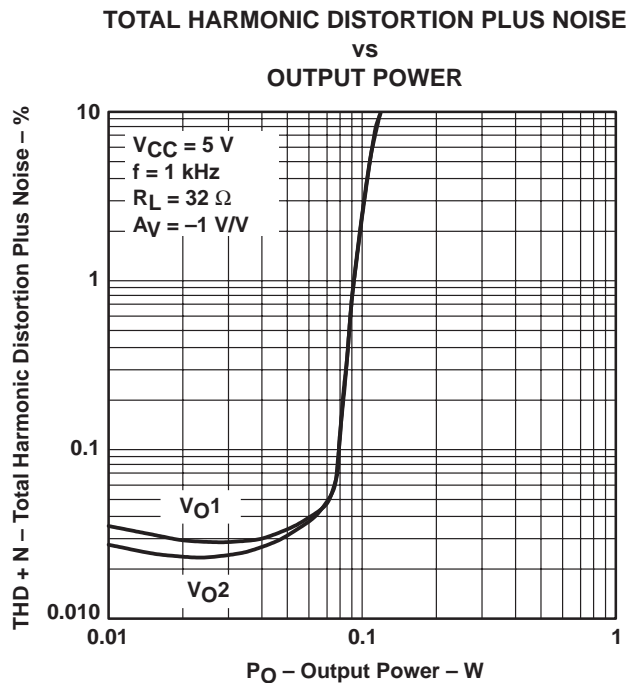


Figure 11

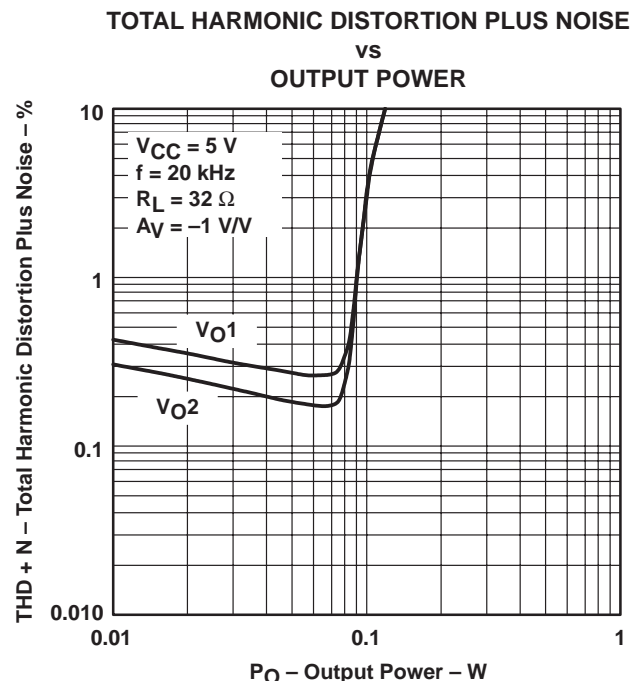


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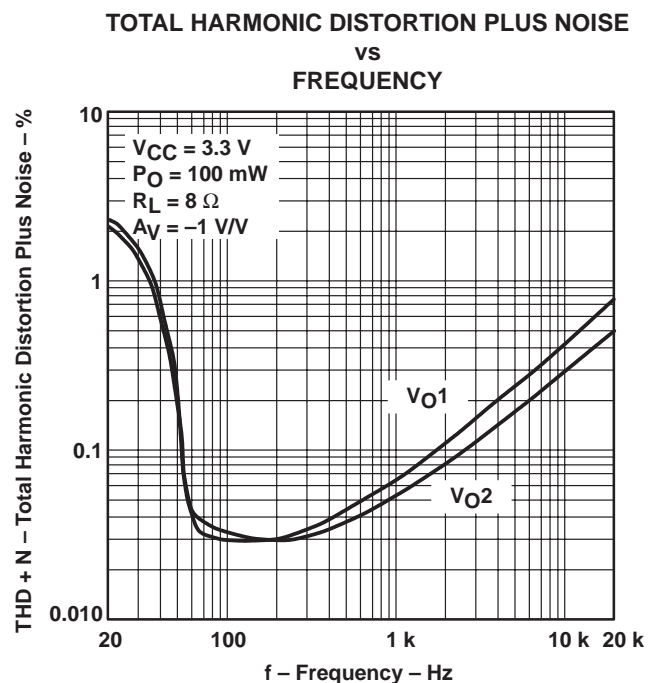


Figure 13

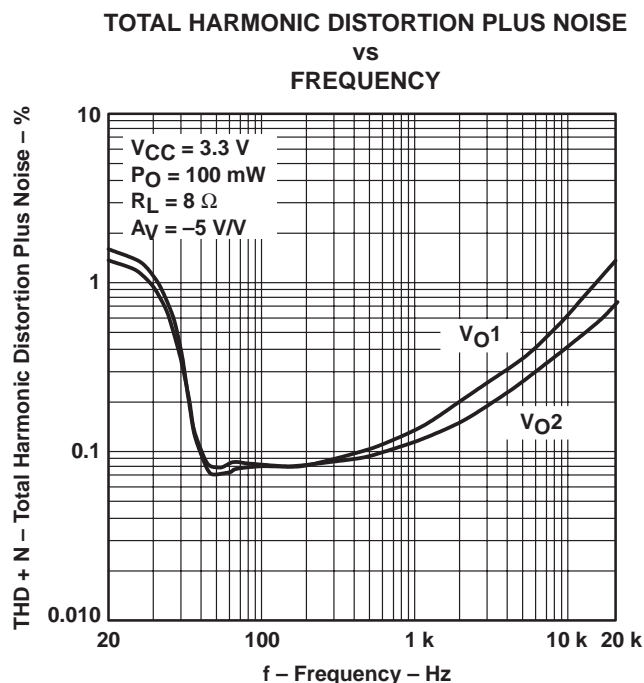


Figure 14

# TPA302

## 300-mW STEREO AUDIO POWER AMPLIFIER

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### TYPICAL CHARACTERISTICS

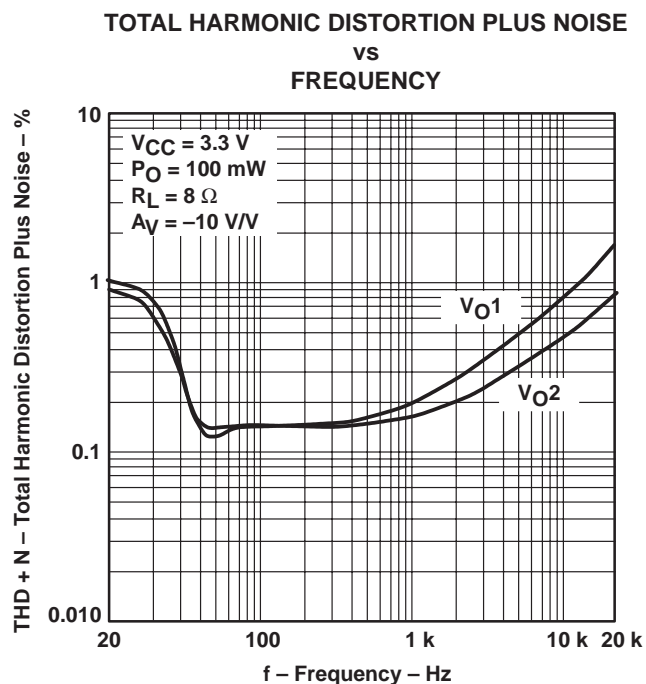


Figure 15

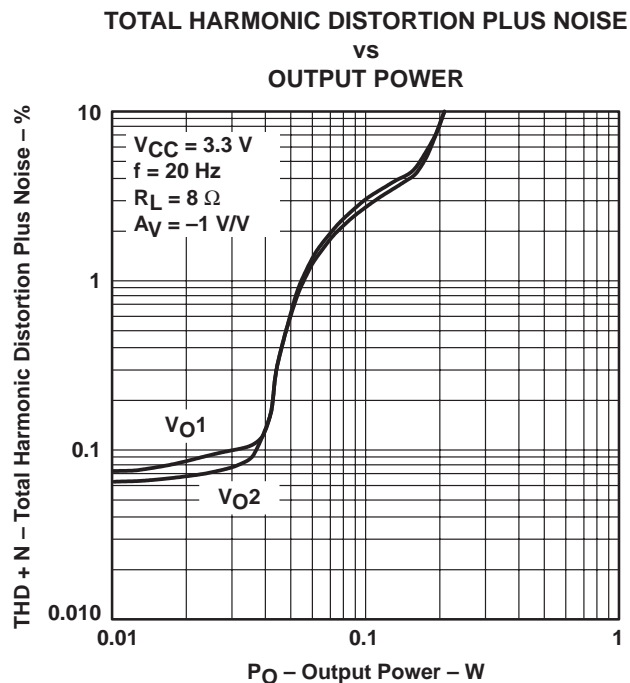


Figure 16

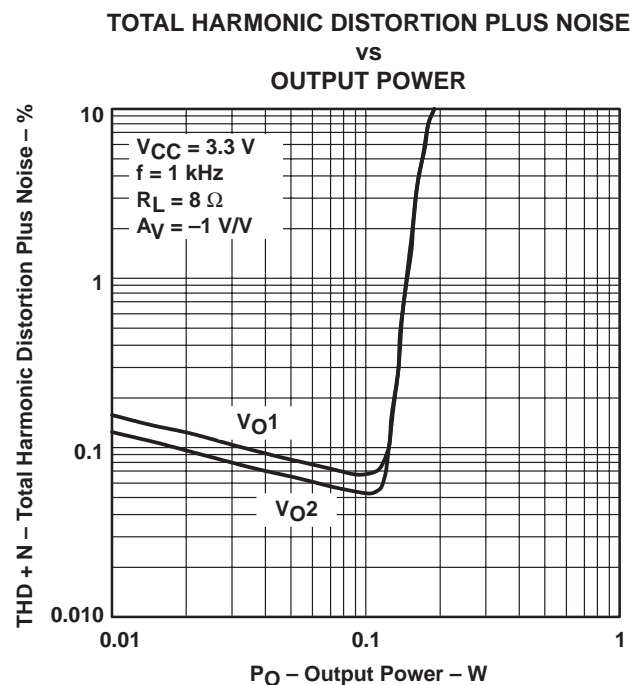


Figure 17

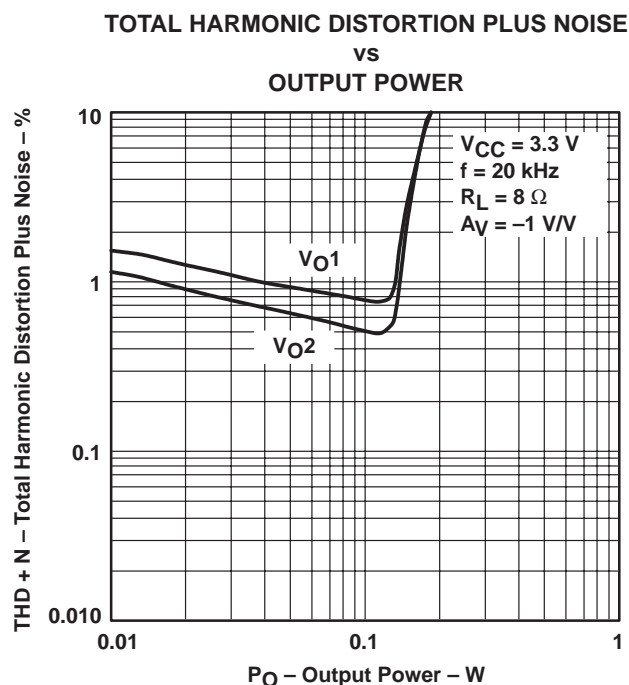


Figure 18



# TYPICAL CHARACTERISTICS

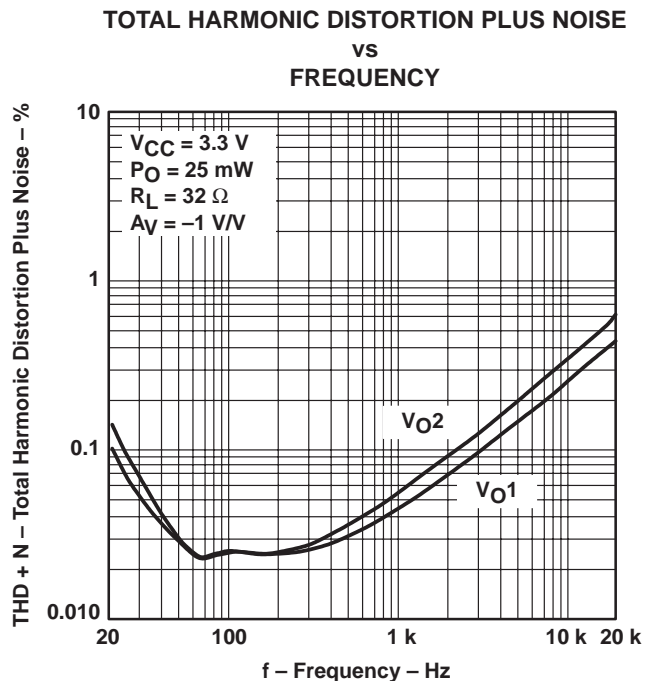


Figure 19

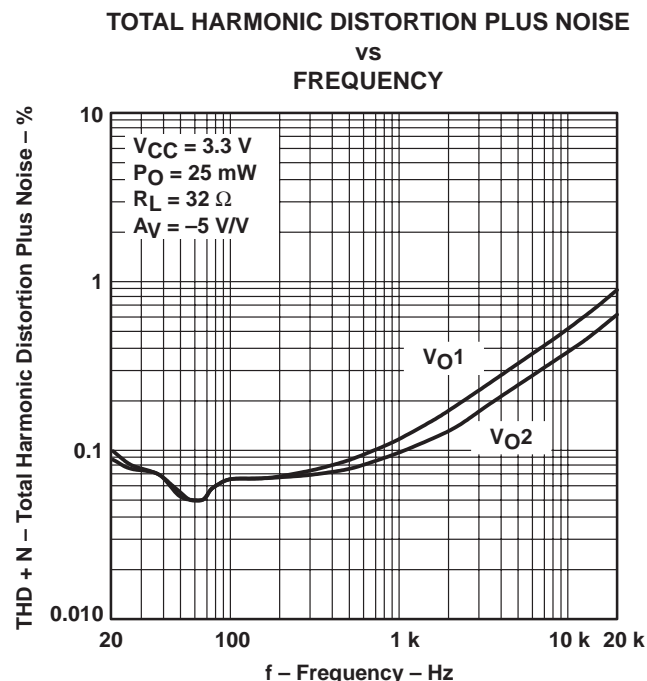


Figure 20

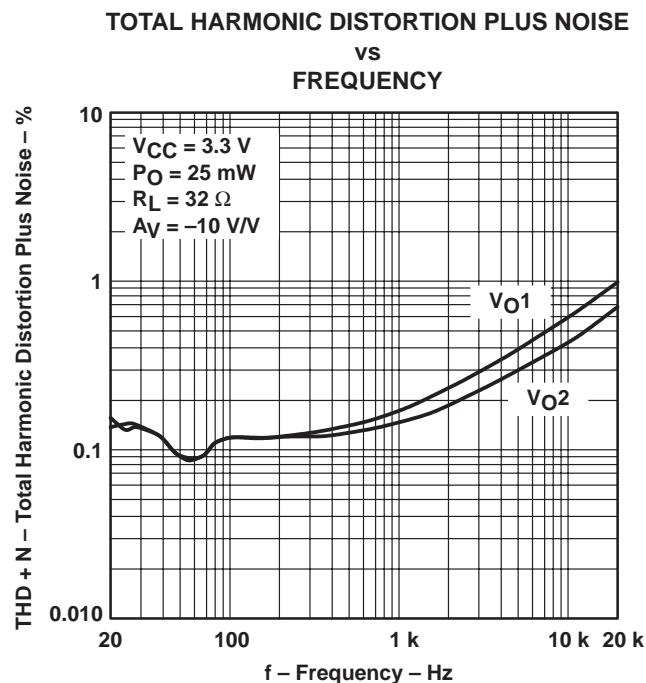


Figure 21

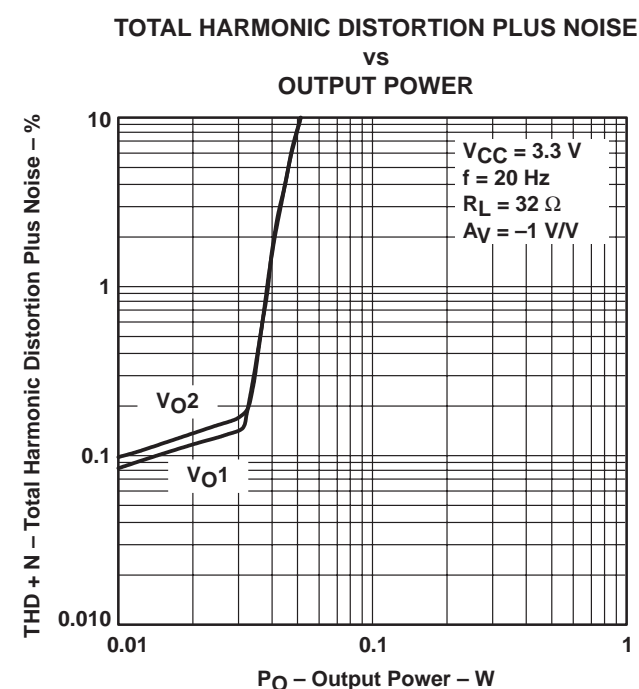


Figure 22

TPA302  
300-mW STEREO AUDIO POWER AMPLIFIER

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TYPICAL CHARACTERISTICS

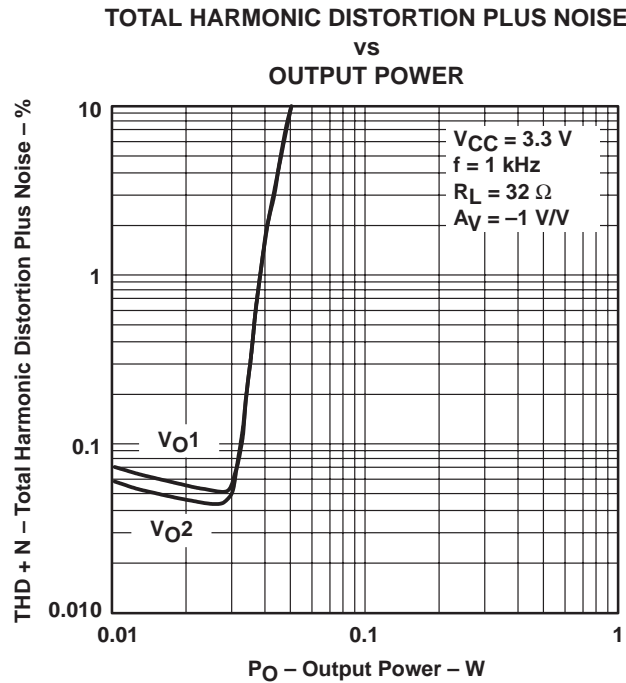


Figure 23

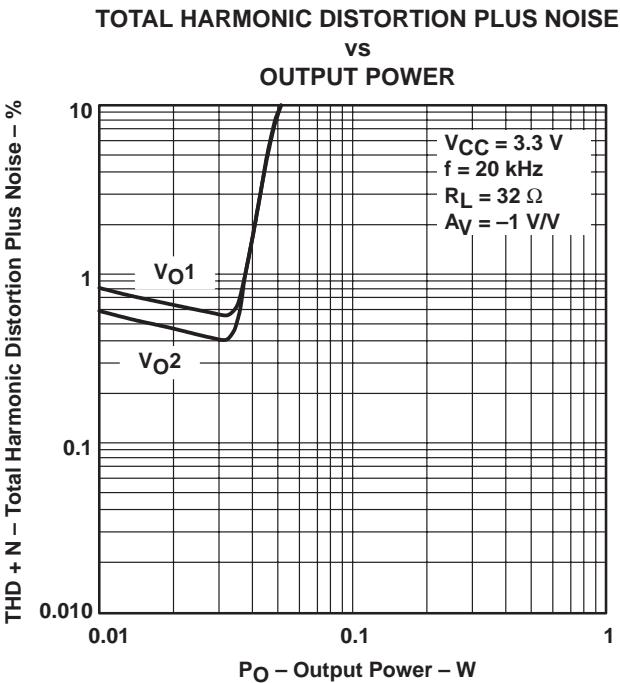


Figure 24

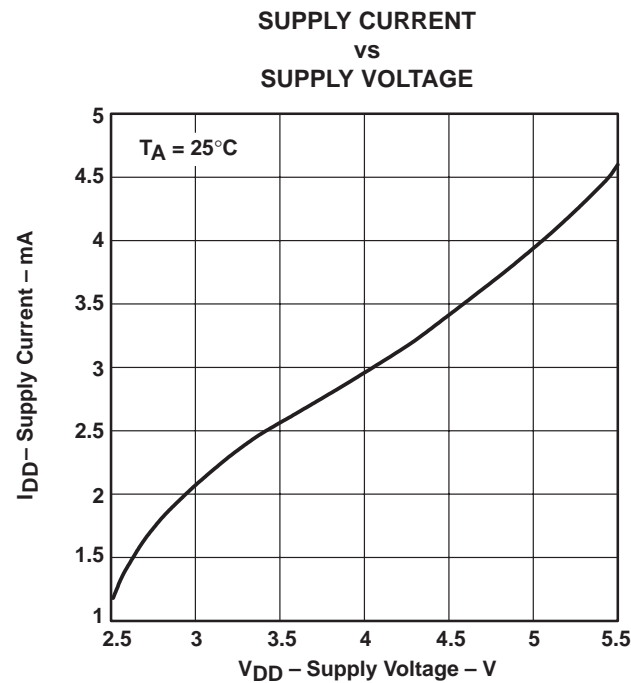


Figure 25

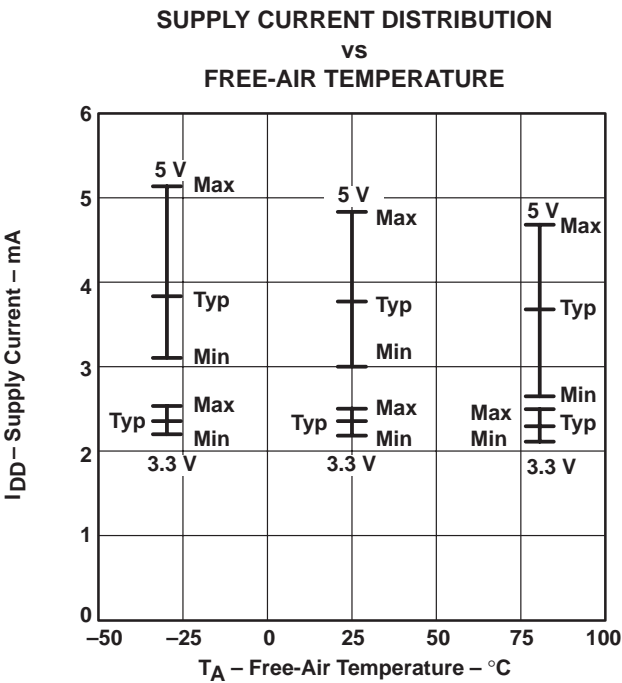


Figure 26

# TPA302 300-mW STEREO AUDIO POWER AMPLIFIER

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## TYPICAL CHARACTERISTICS

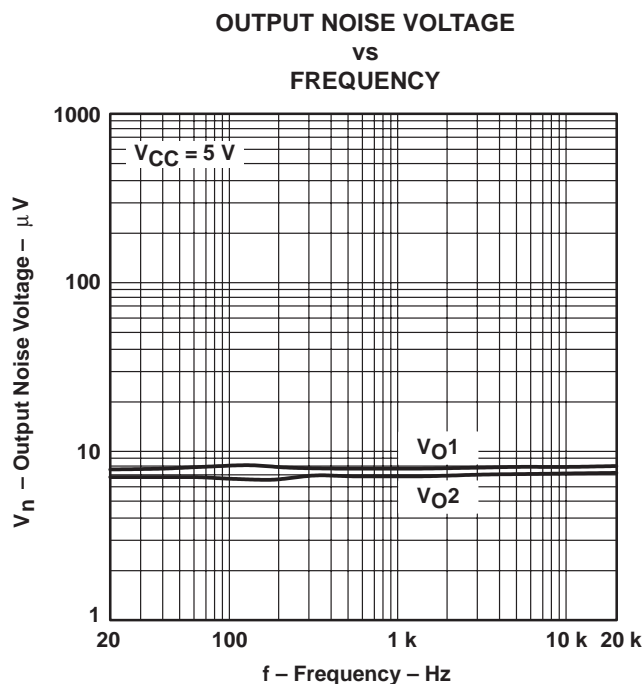


Figure 27

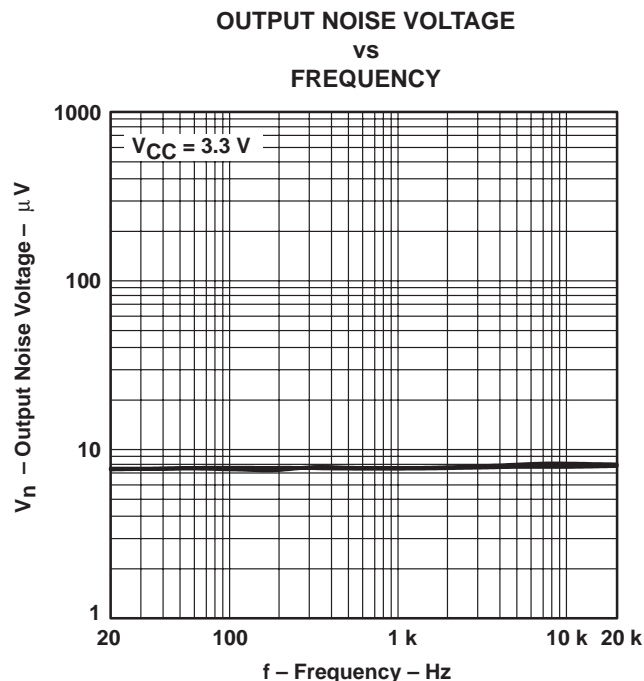


Figure 28

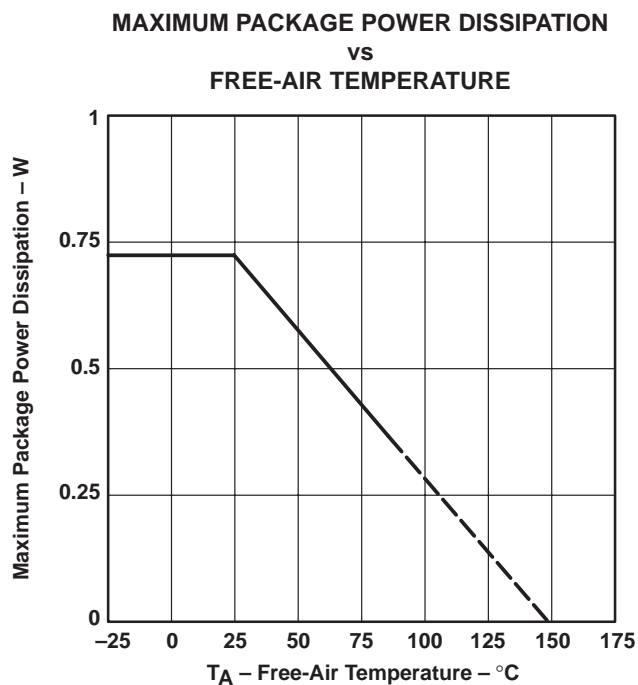


Figure 29

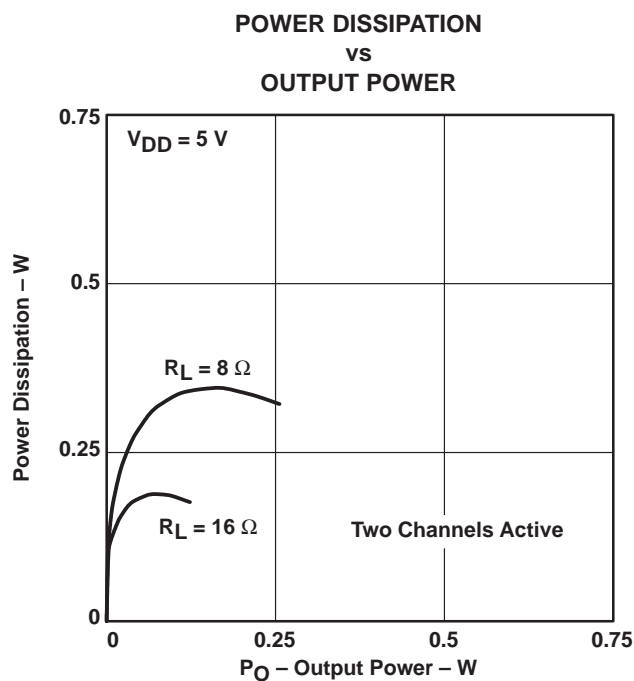


Figure 30

TPA302  
300-mW STEREO AUDIO POWER AMPLIFIER

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TYPICAL CHARACTERISTICS

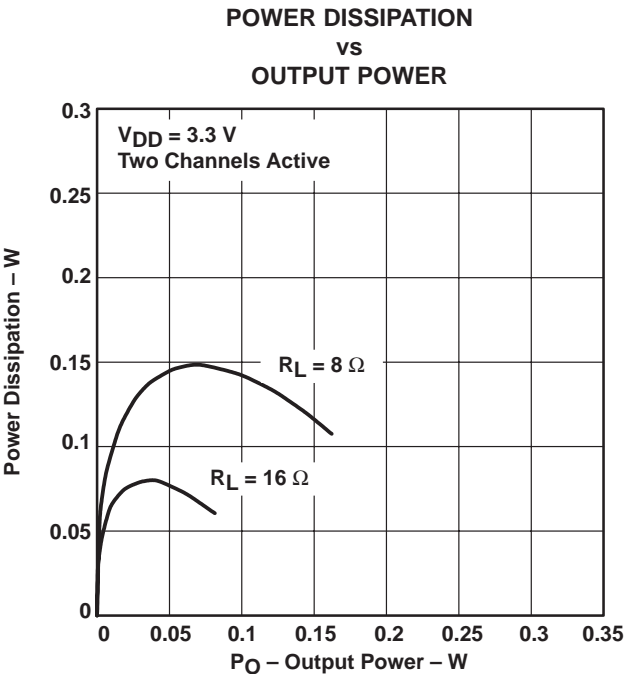


Figure 31

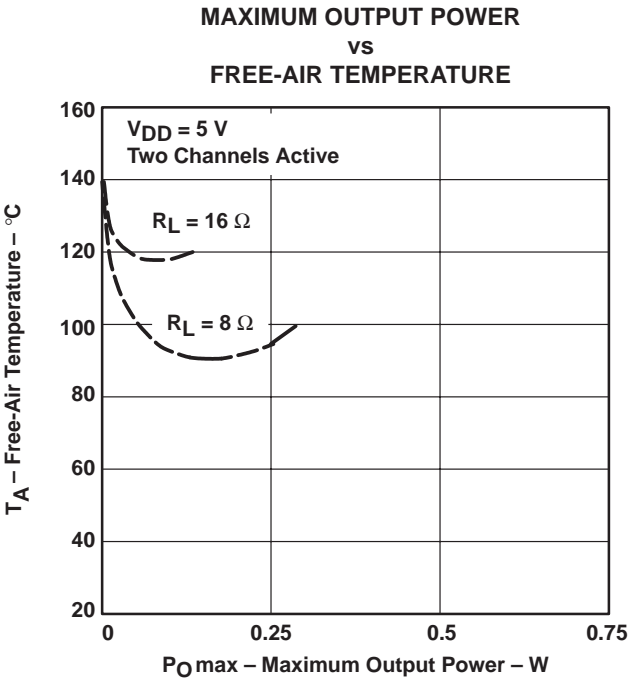


Figure 32

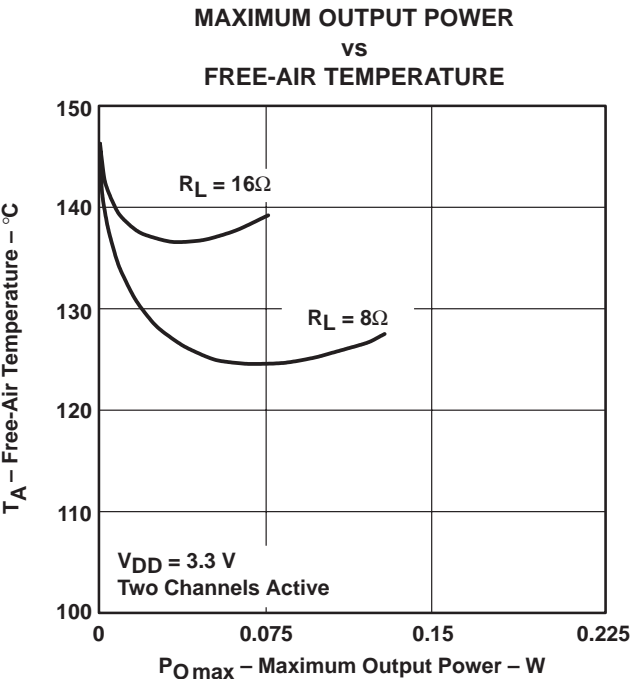


Figure 33

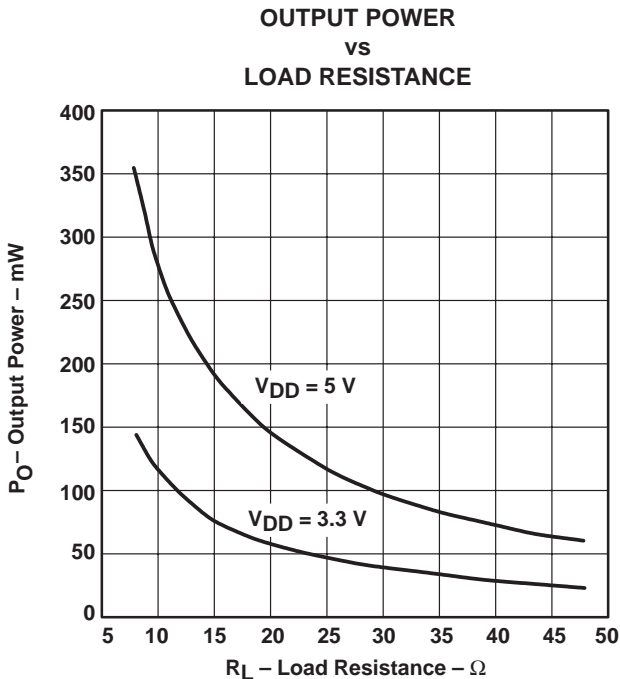


Figure 34

# TPA302 300-mW STEREO AUDIO POWER AMPLIFIER

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## TYPICAL CHARACTERISTICS

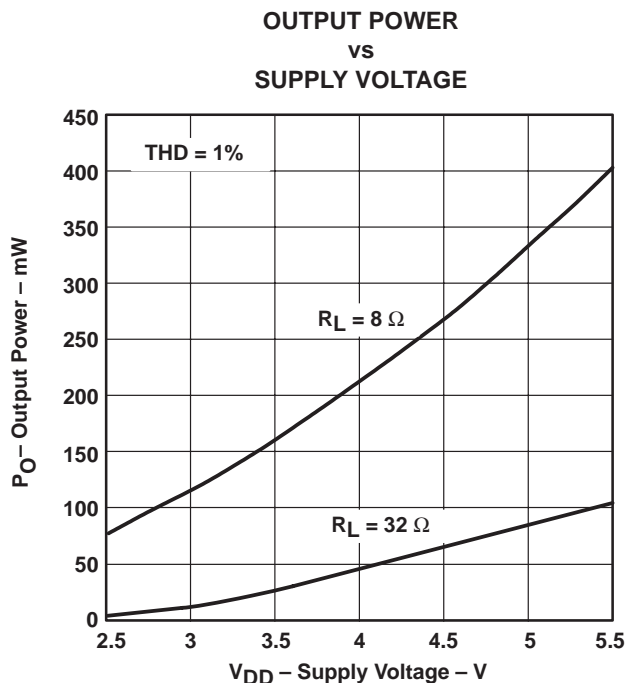


Figure 35

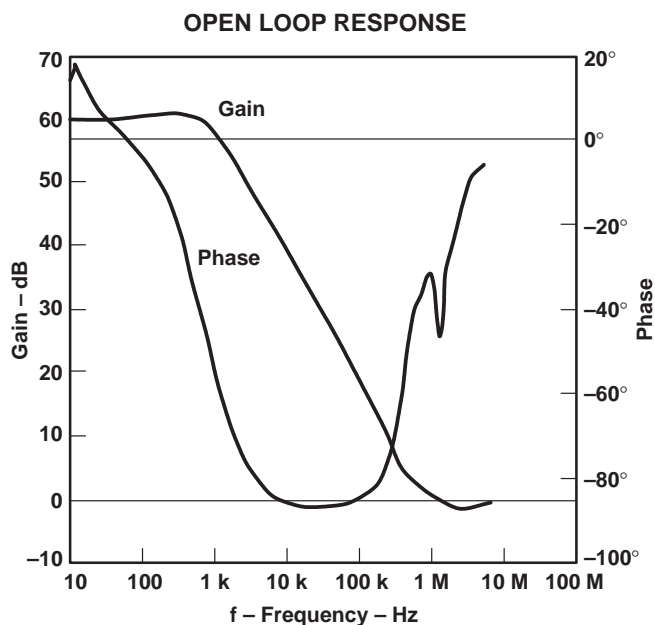


Figure 36

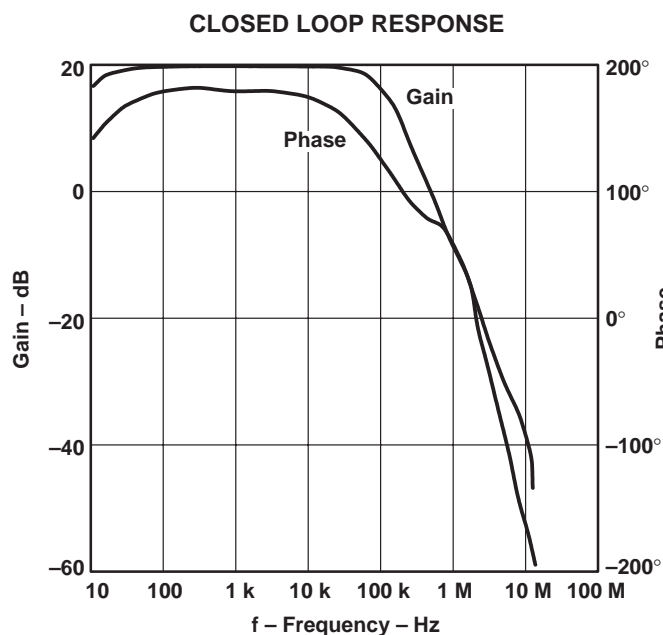


Figure 37

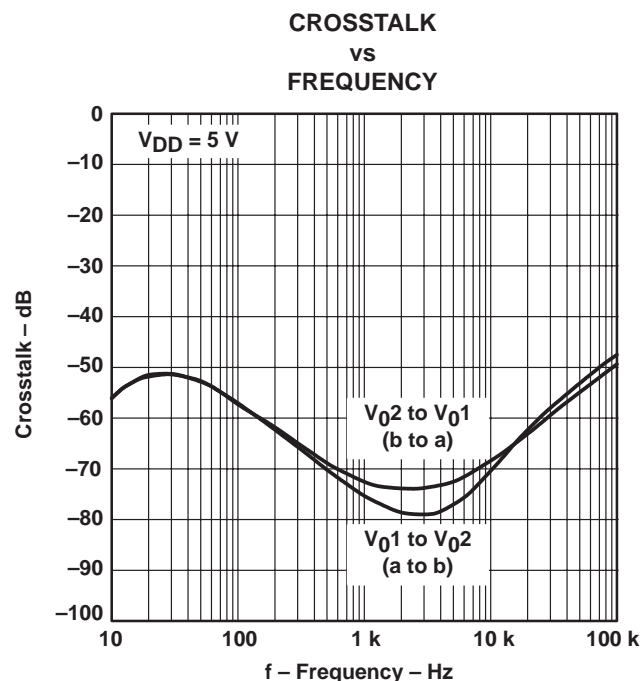


Figure 38

TPA302  
300-mW STEREO AUDIO POWER AMPLIFIER

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TYPICAL CHARACTERISTICS

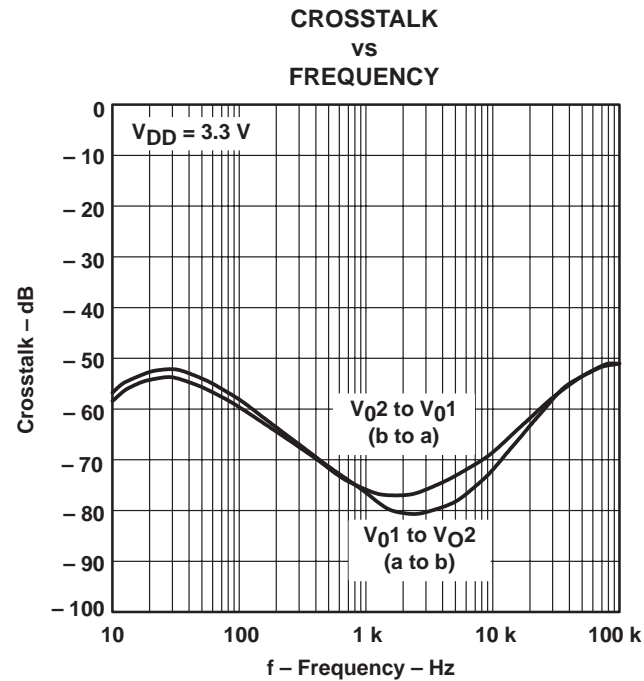


Figure 39

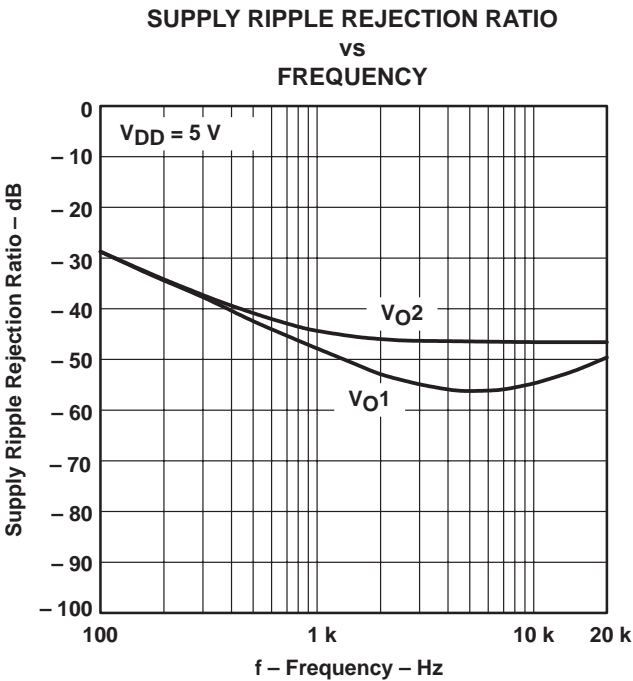


Figure 40

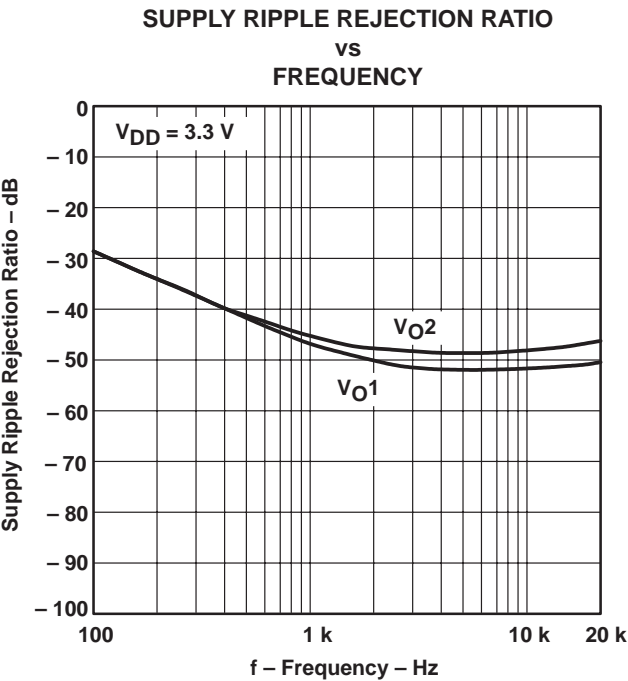


Figure 41

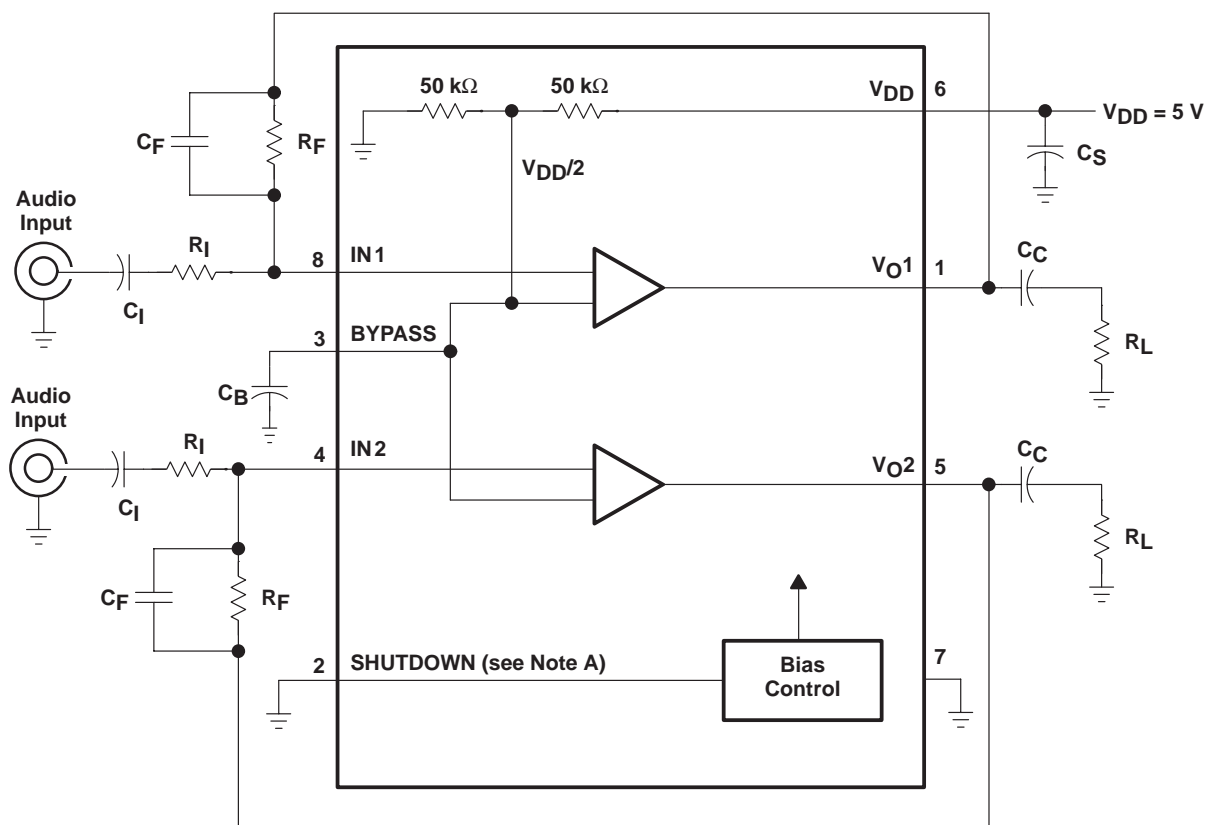
# TPA302 300-mW STEREO AUDIO POWER AMPLIFIER

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## APPLICATION INFORMATION

### selection of components

Figure 42 is a schematic diagram of a typical application circuit.



NOTE A: SHUTDOWN must be held low for normal operation and asserted high for shutdown mode.

Figure 42. TPA302 Typical Notebook Computer Application Circuit

# TPA302

## 300-mW STEREO AUDIO POWER AMPLIFIER

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### APPLICATION INFORMATION

#### gain setting resistors, $R_F$ and $R_I$

The gain for the TPA302 is set by resistors  $R_F$  and  $R_I$  according to equation 1.

$$\text{Gain} = - \left( \frac{R_F}{R_I} \right) \quad (1)$$

Given that the TPA302 is a MOS amplifier, the input impedance is very high, consequently input leakage currents are not generally a concern although noise in the circuit increases as the value of  $R_F$  increases. In addition, a certain range of  $R_F$  values is required for proper start-up operation of the amplifier. Taken together it is recommended that the effective impedance seen by the inverting node of the amplifier be set between 5 k $\Omega$  and 20 k $\Omega$ . The effective impedance is calculated in equation 2.

$$\text{Effective Impedance} = \frac{R_F R_I}{R_F + R_I} \quad (2)$$

As an example, consider an input resistance of 10 k $\Omega$  and a feedback resistor of 50 k $\Omega$ . The gain of the amplifier would be  $-5$  and the effective impedance at the inverting terminal would be 8.3 k $\Omega$ , which is within the recommended range.

For high performance applications metal film resistors are recommended because they tend to have lower noise levels than carbon resistors. For values of  $R_F$  above 50 k $\Omega$  the amplifier tends to become unstable due to a pole formed from  $R_F$  and the inherent input capacitance of the MOS input structure. For this reason, a small compensation capacitor of approximately 5 pF should be placed in parallel with  $R_F$ . This, in effect, creates a low-pass filter network with the cutoff frequency defined in equation 3.

$$f_{c(\text{lowpass})} = \frac{1}{2\pi R_F C_F} \quad (3)$$

For example if  $R_F$  is 100 k $\Omega$  and  $C_F$  is 5 pF then  $f_{c(\text{lowpass})}$  is 318 kHz, which is well outside of the audio range.

#### 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 4.

$$f_{c(\text{highpass})} = \frac{1}{2\pi R_I C_I} \quad (4)$$

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 k $\Omega$  and the specification calls for a flat bass response down to 40 Hz. Equation 4 is reconfigured as equation 5.

$$C_I = \frac{1}{2\pi R_I f_{c(\text{highpass})}} \quad (5)$$

In this example,  $C_I$  is 0.40  $\mu\text{F}$  so one would likely choose a value in the range of 0.47  $\mu\text{F}$  to 1  $\mu\text{F}$ . 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, especially in high-gain applications ( $>10$ ). 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. Please note that it is important to confirm the capacitor polarity in the application.



## APPLICATION INFORMATION

### power supply decoupling, $C_S$

The TPA302 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  $\mu\text{F}$ , 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  $\mu\text{F}$  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 startup or recovery from shutdown mode,  $C_B$  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 25-k $\Omega$  source inside the amplifier. To keep the start-up pop as low as possible, the relationship shown in equation 6 should be maintained.

$$\frac{1}{(C_B \times 25 \text{ k}\Omega)} \leq \frac{1}{(C_I R_I)} \quad (6)$$

As an example, consider a circuit where  $C_B$  is 0.1  $\mu\text{F}$ ,  $C_I$  is 0.22  $\mu\text{F}$  and  $R_I$  is 10 k $\Omega$ . Inserting these values into the equation 9 results in:  $400 \leq 454$  which satisfies the rule. Bypass capacitor,  $C_B$ , values of 0.1  $\mu\text{F}$  to 1  $\mu\text{F}$  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 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 7.

$$f_c = \frac{1}{2\pi R_L C_C} \quad (7)$$

The main disadvantage, from a performance standpoint, is that the load impedances are typically small, which drives 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 8  $\Omega$ , 32  $\Omega$ , and 47 k $\Omega$ . Table 1 summarizes the frequency response characteristics of each configuration.

# TPA302

## 300-mW STEREO AUDIO POWER AMPLIFIER

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

R <sub>L</sub>	C <sub>C</sub>	LOWEST FREQUENCY
8 Ω	68 μF	293 Hz
32 Ω	68 μF	73 Hz
47,000 Ω	68 μF	0.05 Hz

As Table 1 indicates, most of the bass response is attenuated into 8-Ω loads while 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. The rules described earlier still hold with the addition of the following relationship:

$$\frac{1}{(C_B \times 25 \text{ k}\Omega)} \leq \frac{1}{(C_I R_I)} \ll \frac{1}{R_L C_C} \quad (8)$$

#### shutdown mode

The TPA302 employs a shutdown mode of operation designed to reduce quiescent supply current,  $I_{DD(q)}$ , to the absolute minimum level during periods of nonuse for battery-power conservation. For example, during device sleep modes or when other audio-drive currents are used (i.e., headphone mode), the speaker drive is not required. The SHUTDOWN input terminal should be held low during normal operation when the amplifier is in use. Pulling SHUTDOWN high causes the outputs to mute and the amplifier to enter a low-current state,  $I_{DD} < 1 \mu\text{A}$ . SHUTDOWN should never be left unconnected because amplifier operation would be unpredictable.

#### using low-ESR capacitors

Low-ESR capacitors are recommended throughout this applications section. 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.

## APPLICATION INFORMATION

### thermal considerations

A prime consideration when designing an audio amplifier circuit is internal power dissipation in the device. The curve in Figure 43 provides an easy way to determine what output power can be expected out of the TPA302 for a given system ambient temperature in designs using 5-V supplies. This curve assumes no forced airflow or additional heat sinking.

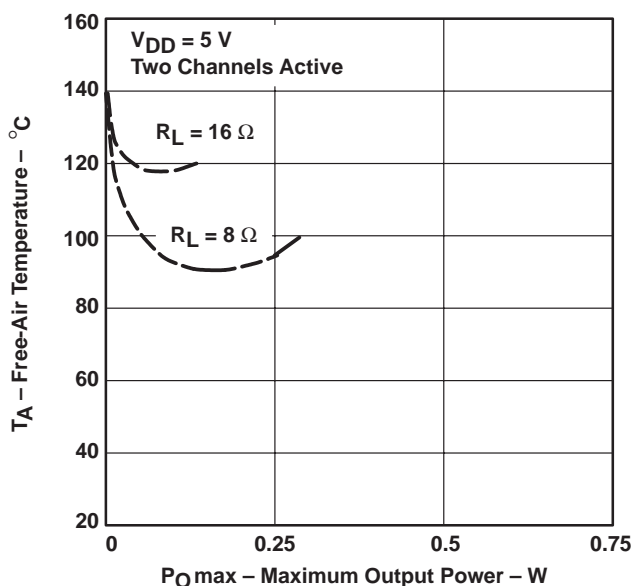


Figure 43. Free-Air Temperature Versus Maximum Output Power

### 5-V versus 3.3-V operation

The TPA302 was designed for operation over a supply range of 2.7 V to 5.5 V. This data sheet provides full specifications for 5-V and 3.3-V operation since are considered to be the two most common standard voltages. There are no special considerations for 3.3-V versus 5-V operation as far as supply bypassing, gain setting, or stability. Supply current is slightly reduced from 3.5 mA (typical) to 2.5 mA (typical). The most important consideration is that of output power. Each amplifier in the TPA302 can produce a maximum voltage swing of  $V_{DD} - 1$  V. This means, for 3.3-V operation, clipping starts to occur when  $V_{O(PP)} = 2.3$  V as opposed when  $V_{O(PP)} = 4$  V while operating at 5 V. The reduced voltage swing subsequently reduces maximum output power into the load before distortion begins to become significant.

# TPA302

## 300-mW STEREO AUDIO POWER AMPLIFIER

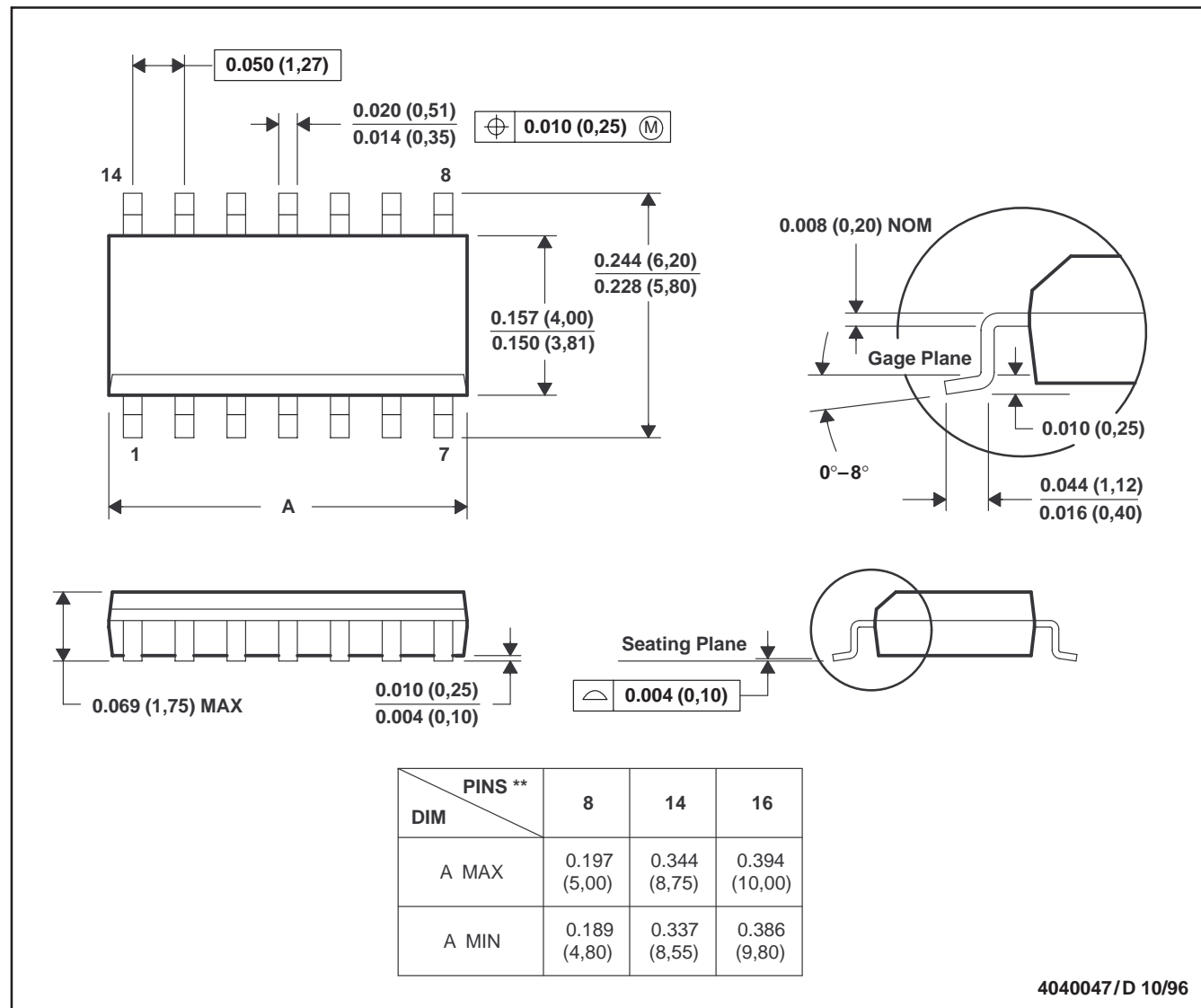
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### MECHANICAL INFORMATION

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

PLASTIC SMALL-OUTLINE PACKAGE

14 PINS SHOWN



- NOTES:
- B. All linear dimensions are in inches (millimeters).
  - C. This drawing is subject to change without notice.
  - D. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
  - E. Falls within JEDEC MS-012

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