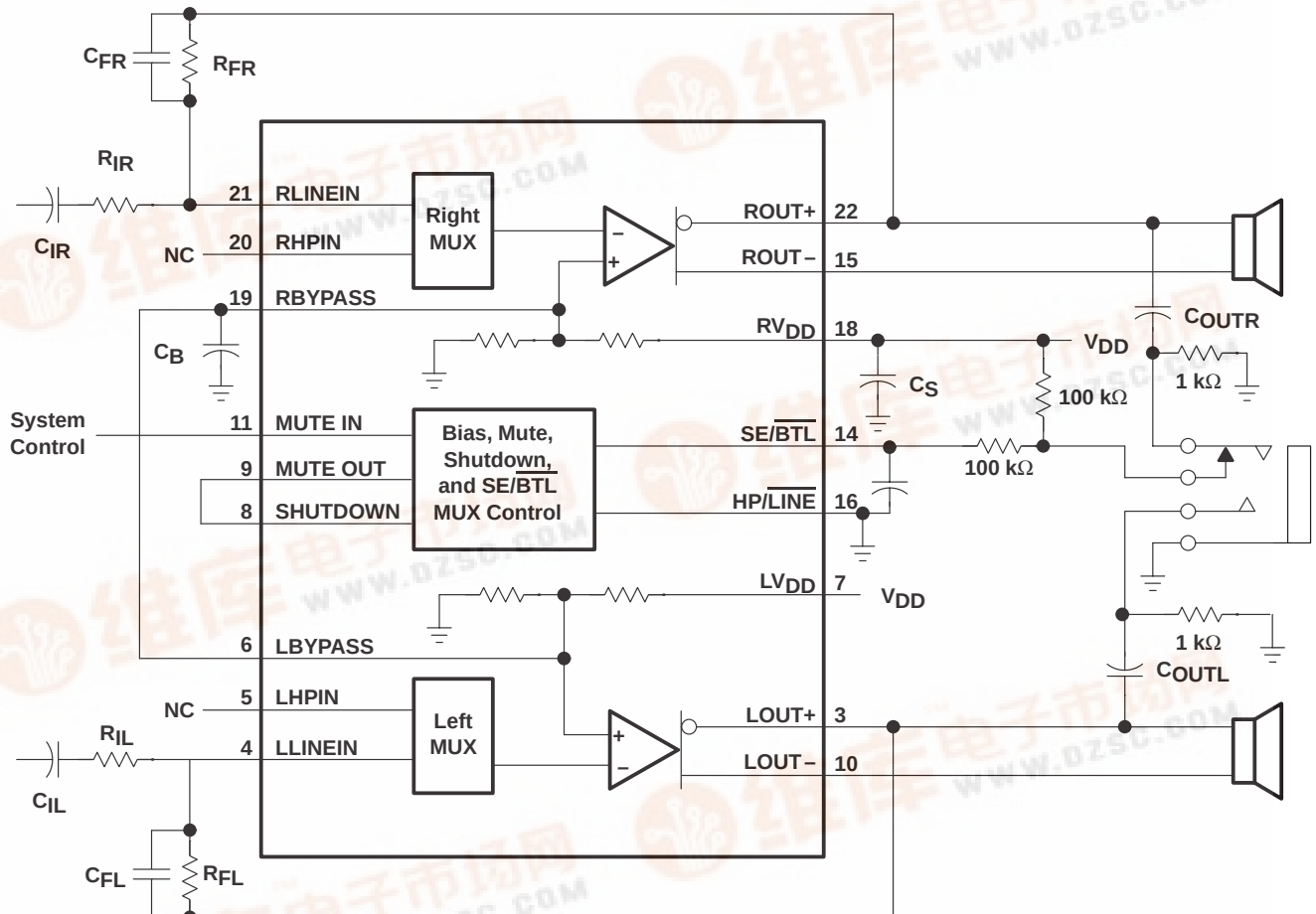
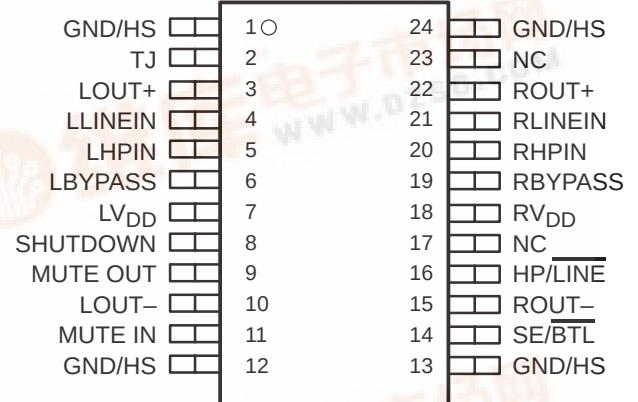


- Integrated Depop Circuitry
- High Power with PC Power Supply
  - 2 W/Ch at 5 V into a 3-Ω Load
  - 800 mW/Ch at 3 V
- Fully Specified for Use With 3-Ω Loads
- Ultra-Low Distortion
  - 0.05% THD+N at 2 W and 3-Ω Load
- Bridge-Tied Load (BTL) or Single-Ended (SE) Modes
- Stereo Input MUX
- Surface-Mount Power Package  
24-Pin TSSOP PowerPAD™
- Shutdown Control . . .  $I_{DD} = 5 \mu A$

PWP PACKAGE  
(TOP VIEW)



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.

PowerPAD is a trademark of Texas Instruments Incorporated.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

# TPA0202

## 2-W STEREO AUDIO POWER AMPLIFIER

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### description

The TPA0202 is a stereo audio power amplifier in a 24-pin TSSOP thermal package capable of delivering greater than 2 W of continuous RMS power per channel into 3-Ω loads. The TPA0202 simplifies design and frees up board space for other features. Full power distortion levels of less than 0.1% THD+N from a 5-V supply are typical. Low-voltage applications are also well served by the TPA0202 providing 800-mW per channel into 3-Ω loads with a 3.3-V supply voltage.

The TPA0202 has integrated depop circuitry that virtually eliminates transients that cause noise in the speakers during power up and when using the mute and shutdown modes.

Amplifier gain is externally configured by means of two resistors per input channel and does not require external compensation for settings of 2 to 20 in BTL mode (1 to 10 in SE mode). An internal input MUX allows two sets of stereo inputs to the amplifier. In notebook applications, where internal speakers are driven as BTL and the line (often headphone drive) outputs are required to be SE, the TPA0202 automatically switches into SE mode when the SE/BTL input is activated. Using the TPA0202 to drive line outputs up to 700 mW/channel into external 3-Ω loads is ideal for small non-powered external speakers in portable multimedia systems. The TPA0202 also features a shutdown function for power sensitive applications, holding the supply current at 5 μA.

The PowerPAD package<sup>†</sup> (PWP) delivers a level of thermal performance that was previously achievable only in TO-220-type packages. Thermal impedances of approximately 35°C/W are readily realized in multilayer PCB applications. This allows the TPA0202 to operate at full power into 3-Ω loads at ambient temperature of up to 85°C with 300 CFM of forced-air cooling. Into 8-Ω loads, the operating ambient temperature increases to 100°C.

AVAILABLE OPTIONS

| T <sub>A</sub> | PACKAGE                     |
|----------------|-----------------------------|
|                | TSSOP <sup>‡</sup><br>(PWP) |
| –40°C to 85°C  | TPA0202PWP                  |

<sup>‡</sup> The PWP packages are available taped and reeled. To order a taped and reeled part, add the suffix R (e.g., TPA0202PWPR).

<sup>†</sup> See Texas Instruments document, *PowerPAD Thermally Enhanced Package Application Report* (Literature Number SLMA002) for more information on the PowerPAD package.

TPA0202  
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### Terminal Functions

| TERMINAL<br>NAME | NO.              | I/O | DESCRIPTION                                                                                                                                                                                                                   |
|------------------|------------------|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| GND/HS           | 1, 12,<br>13, 24 |     | Ground connection for circuitry, directly connected to thermal pad                                                                                                                                                            |
| HP/LINE          | 16               | I   | Input MUX control input, hold high to select LHP IN or RHP IN (5, 20), hold low to select LLINE IN or RLINE IN (4, 21)                                                                                                        |
| LBYPASS          | 6                |     | Tap to voltage divider for left channel internal mid-supply bias                                                                                                                                                              |
| LHP IN           | 5                | I   | Left channel headphone input, selected when HP/LINE terminal (16) is held high                                                                                                                                                |
| LLINE IN         | 4                | I   | Left channel line input, selected when HP/LINE terminal (16) is held low                                                                                                                                                      |
| LOUT+            | 3                | O   | Left channel + output in BTL mode, + output in SE mode                                                                                                                                                                        |
| LOUT–            | 10               | O   | Left channel – output in BTL mode, high-impedance state in SE mode                                                                                                                                                            |
| LVDD             | 7                | I   | Supply voltage input for left channel and for primary bias circuits                                                                                                                                                           |
| MUTE IN          | 11               | I   | Mute all amplifiers, hold low for normal operation, hold high to mute                                                                                                                                                         |
| MUTE OUT         | 9                | O   | Follows MUTE IN terminal (11), provides buffered output                                                                                                                                                                       |
| NC               | 17, 23           |     | No internal connection                                                                                                                                                                                                        |
| RBYPASS          | 19               |     | Tap to voltage divider for right channel internal mid–supply bias                                                                                                                                                             |
| RHPIN            | 20               | I   | Right channel headphone input, selected when HP/LINE terminal (16) is held high                                                                                                                                               |
| RLINEIN          | 21               | I   | Right channel line input, selected when HP/LINE terminal (16) is held low                                                                                                                                                     |
| ROUT+            | 22               | O   | Right channel + output in BTL mode, + output in SE mode                                                                                                                                                                       |
| ROUT–            | 15               | O   | Right channel – output in BTL mode, high impedance state in SE mode                                                                                                                                                           |
| RVDD             | 18               | I   | Supply voltage input for right channel                                                                                                                                                                                        |
| SE/BTL           | 14               | I   | Hold low for BTL mode, hold high for SE mode                                                                                                                                                                                  |
| SHUTDOWN         | 8                | I   | Places entire IC in shutdown mode when held high, $I_{DD} = 5\ \mu\text{A}$                                                                                                                                                   |
| TJ               | 2                | O   | Sources a current proportional to the junction temperature. This terminal should be left unconnected during normal operation. For more information, see the <i>junction temperature measurement</i> section of this document. |

# TPA0202

## 2-W STEREO AUDIO POWER AMPLIFIER

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### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)<sup>†</sup>

|                                                              |                                                   |
|--------------------------------------------------------------|---------------------------------------------------|
| Supply voltage, $V_{DD}$                                     | 6 V                                               |
| Input voltage, $V_I$                                         | –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                                             |

<sup>†</sup> 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          | $T_A \leq 25^\circ\text{C}$ | DERATING FACTOR | $T_A = 70^\circ\text{C}$ | $T_A = 85^\circ\text{C}$ |
|------------------|-----------------------------|-----------------|--------------------------|--------------------------|
| PWP <sup>‡</sup> | 2.7 W                       | 21.8 mW/°C      | 1.7 W                    | 1.4 W                    |

<sup>‡</sup> Please see the Texas Instruments document, *PowerPAD Thermally Enhanced Package Application Report* (literature number 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 the before mentioned document.

### recommended operating conditions

|                                       |                                                                                                                                  | MIN  | NOM | MAX | UNIT |
|---------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|------|-----|-----|------|
| Supply Voltage, $V_{DD}$              |                                                                                                                                  | 3    | 5   | 5.5 | V    |
| Operating free-air temperature, $T_A$ | $V_{DD} = 5$ V,<br>250 mW/ch average power,<br>4-Ω stereo BTL drive,<br>with proper PCB design                                   | –40  |     | 85  | °C   |
|                                       | $V_{DD} = 5$ V,<br>2 W/ch average power,<br>3-Ω stereo BTL drive,<br>with proper PCB design<br>and 300 CFM forced-air<br>cooling | –40  |     | 85  |      |
| Common mode input voltage, $V_{ICM}$  | $V_{DD} = 5$ V                                                                                                                   | 1.25 |     | 4.5 | V    |
|                                       | $V_{DD} = 3.3$ V                                                                                                                 | 1.25 |     | 2.7 |      |

### dc electrical characteristics, $T_A = 25^\circ\text{C}$

| PARAMETER              |                                                 | TEST CONDITIONS                             |            | TYP† | MAX | UNIT |
|------------------------|-------------------------------------------------|---------------------------------------------|------------|------|-----|------|
| I <sub>DD</sub>        | Supply current                                  | V <sub>DD</sub> = 5 V                       | Stereo BTL | 19   | 25  | mA   |
|                        |                                                 |                                             | Stereo SE  | 9    | 15  | mA   |
|                        |                                                 |                                             | Mono BTL   | 9    | 15  | mA   |
|                        |                                                 |                                             | Mono SE    | 3    | 10  | mA   |
|                        |                                                 | V <sub>DD</sub> = 3.3 V                     | Stereo BTL | 13   | 20  | mA   |
|                        |                                                 |                                             | Stereo SE  | 5    | 10  | mA   |
|                        |                                                 |                                             | Mono BTL   | 5    | 10  | mA   |
|                        |                                                 |                                             | Mono SE    | 3    | 6   | mA   |
| V <sub>OO</sub>        | Output offset voltage (measured differentially) | V <sub>DD</sub> = 5 V, Gain = 2, See Note 1 | 5          | 25   | mV  |      |
| I <sub>DD</sub> (MUTE) | Supply current in mute mode                     | V <sub>DD</sub> = 5 V                       | 1.5        |      | mA  |      |
| I <sub>DD</sub> (SD)   | I <sub>DD</sub> in shutdown                     | V <sub>DD</sub> = 5 V                       | 5          | 15   | μA  |      |

NOTE 1: At  $3\text{ V} < V_{DD} < 5\text{ V}$  the dc output voltage is approximately  $V_{DD}/2$ .

# TPA0202

## 2-W STEREO AUDIO POWER AMPLIFIER

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**ac operating characteristics,  $V_{DD} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_L = 3\ \Omega$  (unless otherwise noted)**

| PARAMETER |                                        | TEST CONDITIONS            |                             |                      | TYP | MAX | UNIT               |
|-----------|----------------------------------------|----------------------------|-----------------------------|----------------------|-----|-----|--------------------|
| $P_O$     | Output power (each channel) see Note 2 | THD = 0.2%,                | BTL,                        | See Figure 3         | 2   |     | W                  |
|           |                                        | THD = 1%,                  | BTL,                        | See Figure 3         | 2.2 |     |                    |
| THD+N     | Total harmonic distortion plus noise   | $P_O = 2\text{ W}$ ,       | $f = 20 - 20\text{ kHz}$ ,  | See Figure 5         | 200 |     | m%                 |
|           |                                        | $V_I = 1\text{ V}$ ,       | $R_L = 10\text{ k}\Omega$ , | $A_V = 1\text{ V/V}$ | 100 |     | m%                 |
| $B_{OM}$  | Maximum output power bandwidth         | $A_V = 10\text{ V/V}$      | THD < 1 %,                  | See Figure 5         | >20 |     | kHz                |
|           | Phase margin                           | $R_L = 4\ \Omega$ ,        | Open Loop,                  | See Figure 43        | 85° |     |                    |
|           | Supply ripple rejection ratio          | $f = 1\text{ kHz}$ ,       | See Figure 37               |                      | 80  |     | dB                 |
|           |                                        | $f = 20 - 20\text{ kHz}$ , | See Figure 37               |                      | 60  |     |                    |
|           | Mute attenuation                       |                            |                             |                      | 85  |     | dB                 |
|           | Channel-to-channel output separation   | $f = 1\text{ kHz}$ ,       | See Figure 39               |                      | 85  |     | dB                 |
|           | Line/HP input separation               |                            |                             |                      | 100 |     | dB                 |
|           | BTL attenuation in SE mode             |                            |                             |                      | 100 |     | dB                 |
| $Z_I$     | Input impedance                        |                            |                             |                      | 2   |     | M $\Omega$         |
|           | Signal-to-noise ratio                  | $P_O = 500\text{ mW}$ ,    | BTL                         |                      | 95  |     | dB                 |
| $V_n$     | Output noise voltage                   | See Figure 35              |                             |                      | 21  |     | $\mu\text{V(rms)}$ |

NOTE 2: Output power is measured at the output terminals of the IC at 1 kHz.

**ac operating characteristics,  $V_{DD} = 3.3\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_L = 3\ \Omega$**

| PARAMETER |                                        | TEST CONDITIONS            |                             |                      | TYP | MAX | UNIT               |
|-----------|----------------------------------------|----------------------------|-----------------------------|----------------------|-----|-----|--------------------|
| $P_O$     | Output power (each channel) see Note 2 | THD = 0.2%,                | BTL,                        | See Figure 10        | 800 |     | mW                 |
|           |                                        | THD = 1%,                  | BTL,                        | See Figure 10        | 900 |     |                    |
| THD+N     | Total harmonic distortion plus noise   | $P_O = 800\text{ mW}$ ,    | $f = 20 - 20\text{ kHz}$ ,  | See Figure 11        | 350 |     | m%                 |
|           |                                        | $V_I = 1\text{ V}$ ,       | $R_L = 10\text{ k}\Omega$ , | $A_V = 1\text{ V/V}$ | 200 |     | m%                 |
| $B_{OM}$  | Maximum output power bandwidth         | $A_V = 10\text{ V/V}$      | THD < 1 %,                  | See Figure 11        | >20 |     | kHz                |
|           | Phase margin                           | $R_L = 4\ \Omega$ ,        | Open Loop,                  | See Figure 44        | 85° |     |                    |
|           | Supply ripple rejection ratio          | $f = 1\text{ kHz}$ ,       | See Figure 37               |                      | 70  |     | dB                 |
|           |                                        | $f = 20 - 20\text{ kHz}$ , | See Figure 37               |                      | 55  |     |                    |
|           | Mute attenuation                       |                            |                             |                      | 85  |     | dB                 |
|           | Channel-to-channel output separation   | $f = 1\text{ kHz}$ ,       | See Figure 40               |                      | 85  |     | dB                 |
|           | Line/HP input separation               |                            |                             |                      | 100 |     | dB                 |
|           | BTL attenuation in SE mode             |                            |                             |                      | 100 |     | dB                 |
| $Z_I$     | Input impedance                        |                            |                             |                      | 2   |     | M $\Omega$         |
|           | Signal-to-noise ratio                  | $P_O = 500\text{ mW}$ ,    | BTL                         |                      | 95  |     | dB                 |
| $V_n$     | Output noise voltage                   | See Figure 37              |                             |                      | 21  |     | $\mu\text{V(rms)}$ |

NOTE 2: Output power is measured at the output terminals of the IC at 1 kHz.

# TPA0202

## 2-W STEREO AUDIO POWER AMPLIFIER

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### PARAMETER MEASUREMENT INFORMATION

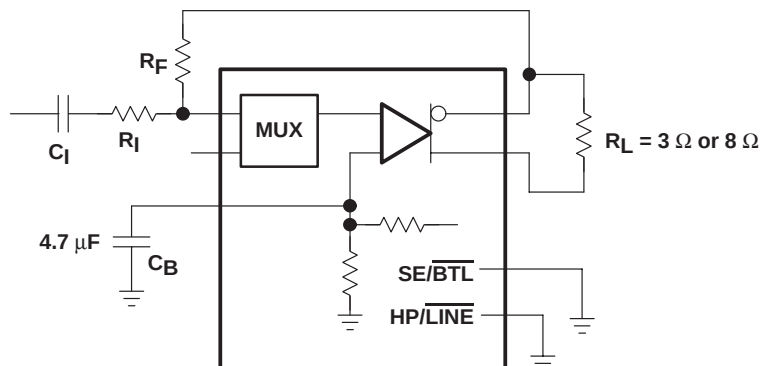


Figure 1. BTL Test Circuit

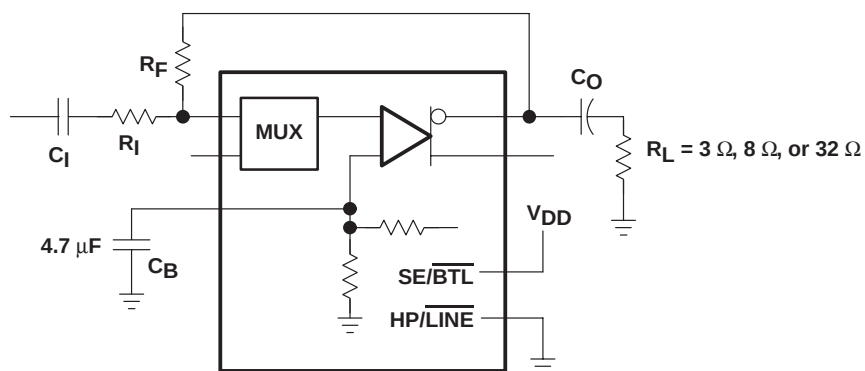


Figure 2. SE Test Circuit

# TPA0202

## 2-W STEREO AUDIO POWER AMPLIFIER

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### TYPICAL CHARACTERISTICS

Table of Graphs

|                                                 |                                         | FIGURE                                                                    |
|-------------------------------------------------|-----------------------------------------|---------------------------------------------------------------------------|
| THD + N    Total harmonic distortion plus noise | vs Frequency                            | 4, 5, 7, 8, 11, 12, 14, 15, 17, 18, 20, 21, 23, 24, 26, 27, 29, 30 32, 33 |
|                                                 | vs Output power                         | 3, 6, 9, 10, 13, 16, 19, 22, 25, 28, 31, 34                               |
| $V_N$ Output noise voltage                      | vs Frequency                            | 35,36                                                                     |
| Supply ripple rejection ratio                   | vs Frequency                            | 37,38                                                                     |
| Crosstalk                                       | vs Frequency                            | 39 – 42                                                                   |
| Open loop response                              | vs Frequency                            | 43,44                                                                     |
| Closed loop response                            | vs Frequency                            | 45, 48                                                                    |
| $I_{DD}$ Supply current                         | vs Supply voltage                       | 49                                                                        |
| $P_O$ Output power                              | vs Supply voltage<br>vs Load resistance | 50, 51<br>52, 53                                                          |
| $P_D$ Power dissipation                         | vs Output power                         | 54 – 57                                                                   |

TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
OUTPUT POWER

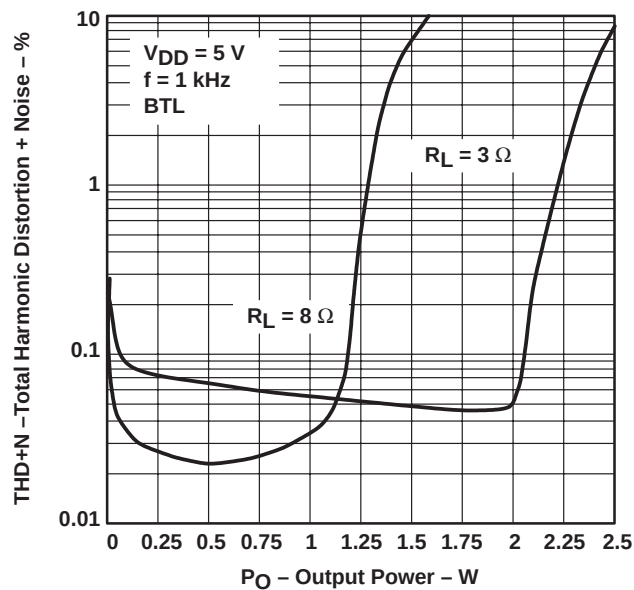


Figure 3

TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
FREQUENCY

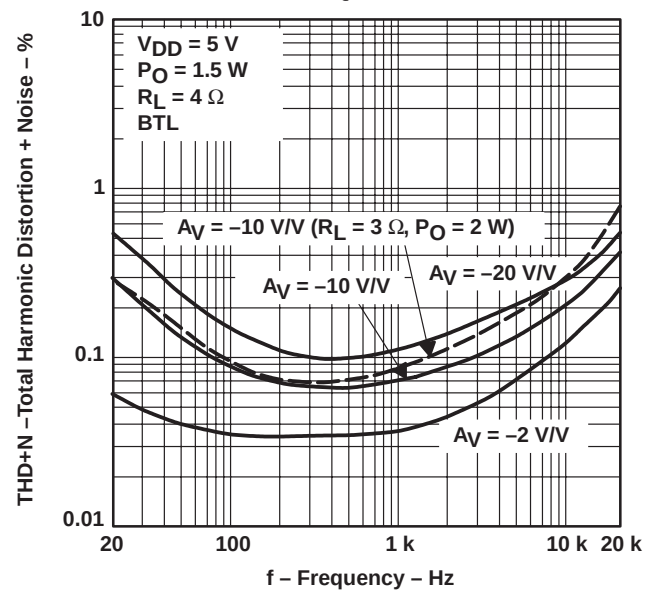


Figure 4

# TPA0202

## 2-W STEREO AUDIO POWER AMPLIFIER

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### TYPICAL CHARACTERISTICS

TOTAL HARMONIC DISTORTION PLUS NOISE  
VS  
FREQUENCY

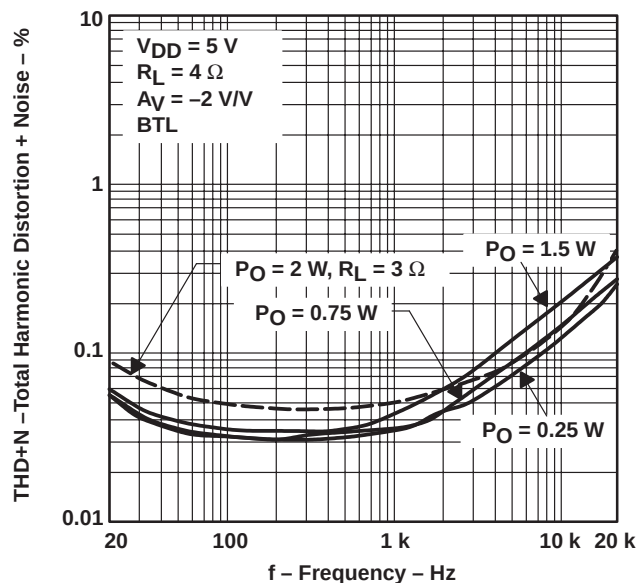


Figure 5

TOTAL HARMONIC DISTORTION PLUS NOISE  
VS  
OUTPUT POWER

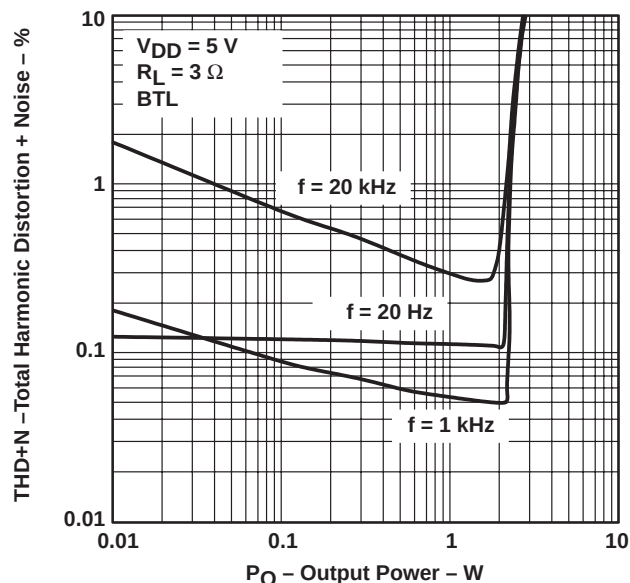


Figure 6

TOTAL HARMONIC DISTORTION PLUS NOISE  
VS  
FREQUENCY

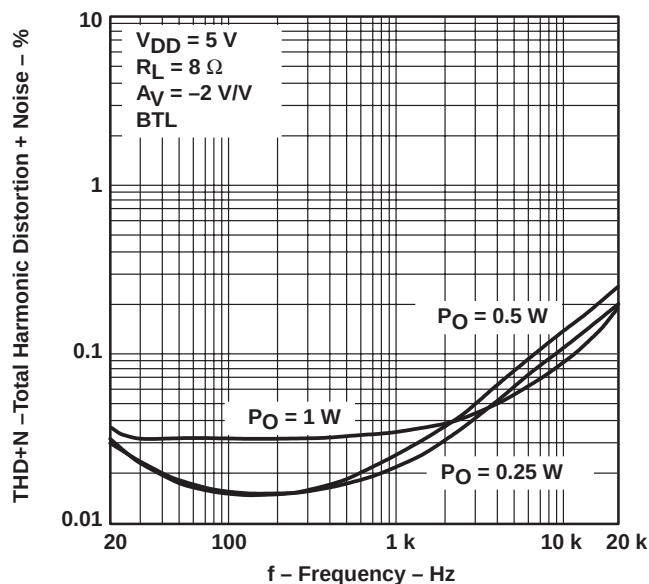


Figure 7

TOTAL HARMONIC DISTORTION PLUS NOISE  
VS  
FREQUENCY

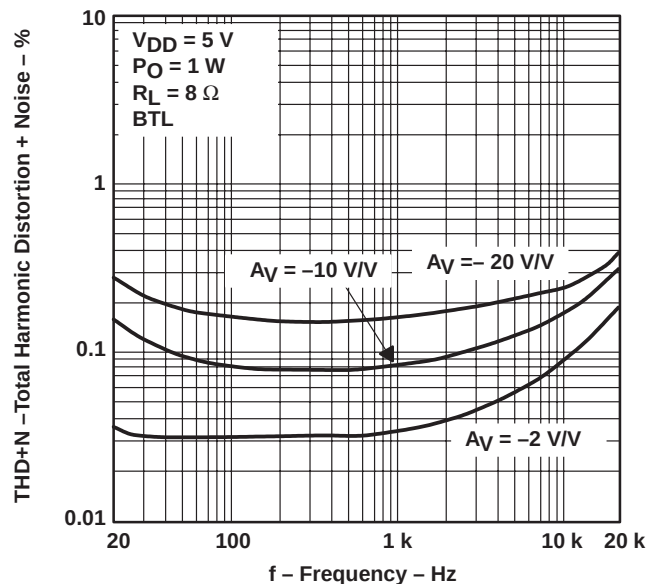


Figure 8



# TYPICAL CHARACTERISTICS

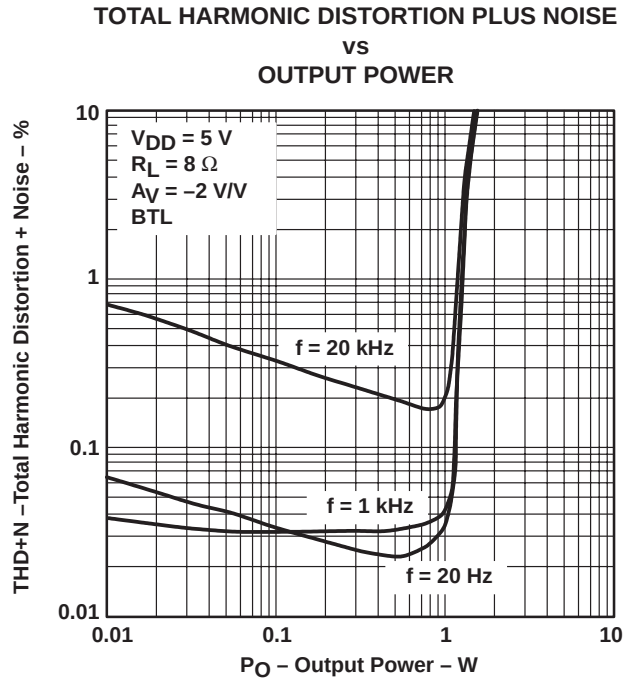


Figure 9

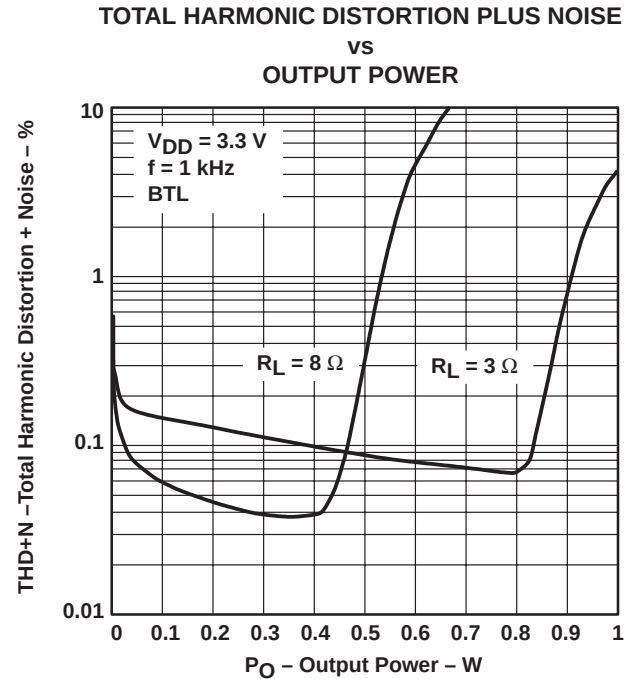


Figure 10

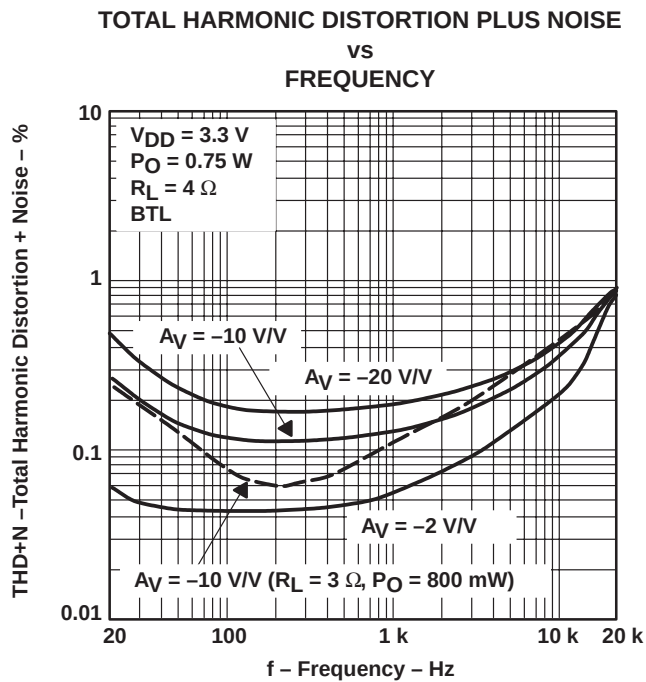


Figure 11

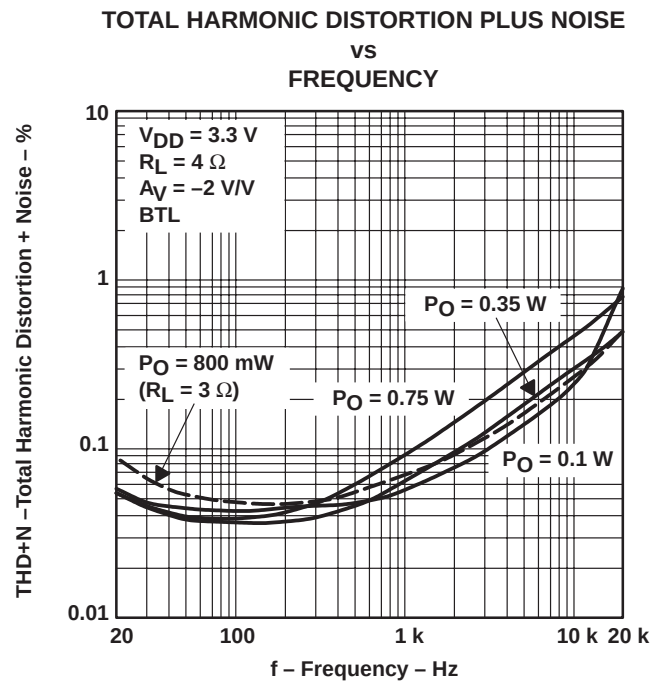


Figure 12

# TPA0202

## 2-W STEREO AUDIO POWER AMPLIFIER

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### TYPICAL CHARACTERISTICS

TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
OUTPUT POWER

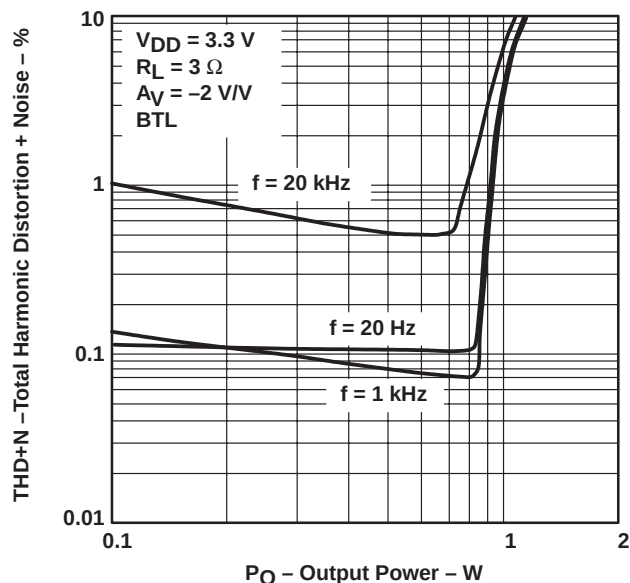


Figure 13

TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
FREQUENCY

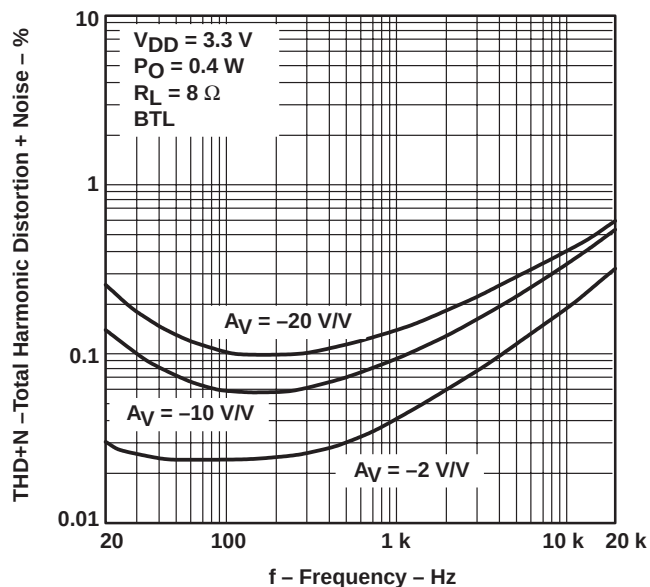


Figure 14

TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
FREQUENCY

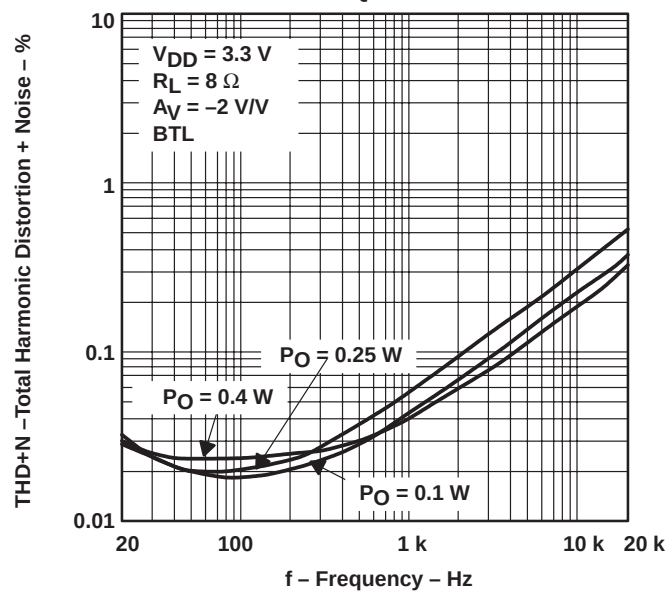


Figure 15

TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
OUTPUT POWER

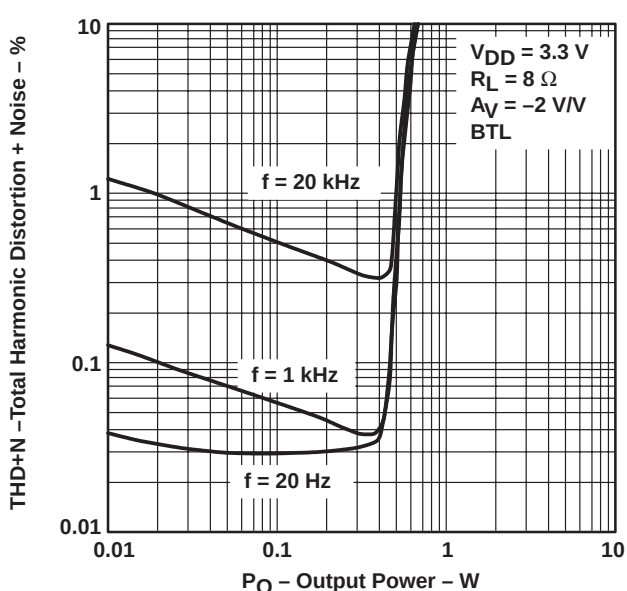


Figure 16

# TPA0202 2-W STEREO AUDIO POWER AMPLIFIER

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## TYPICAL CHARACTERISTICS

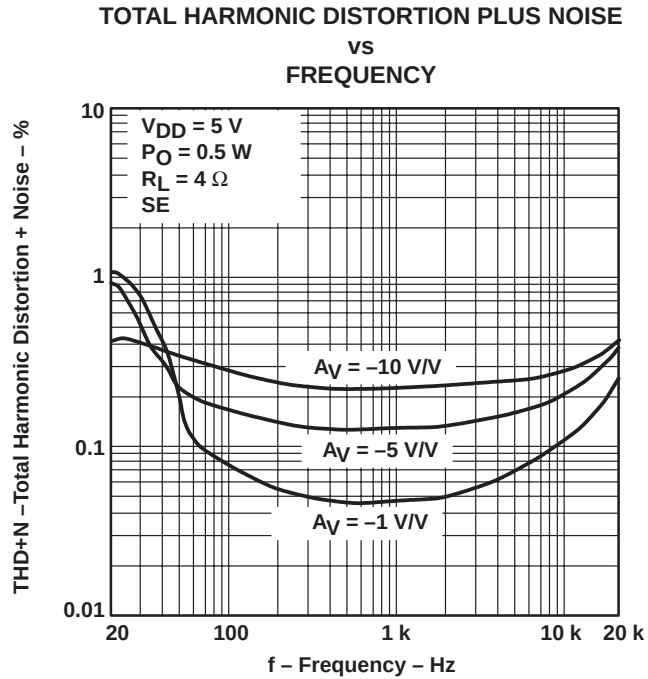


Figure 17

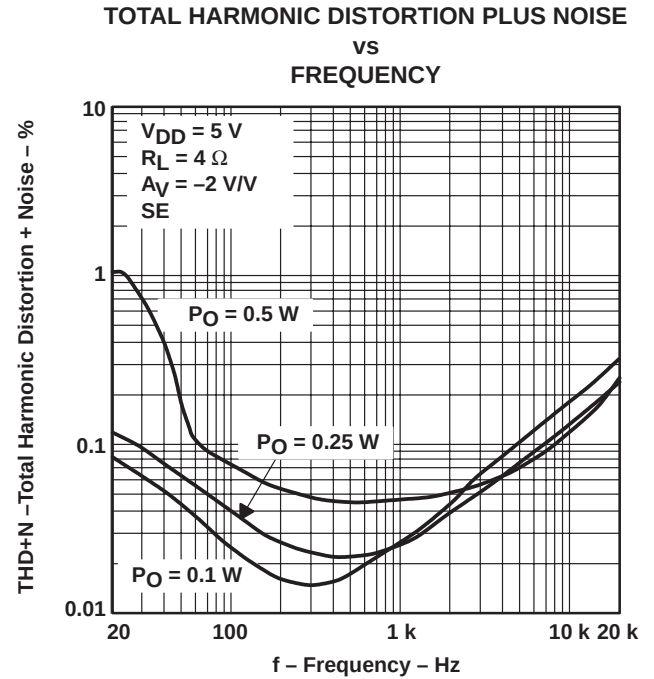


Figure 18

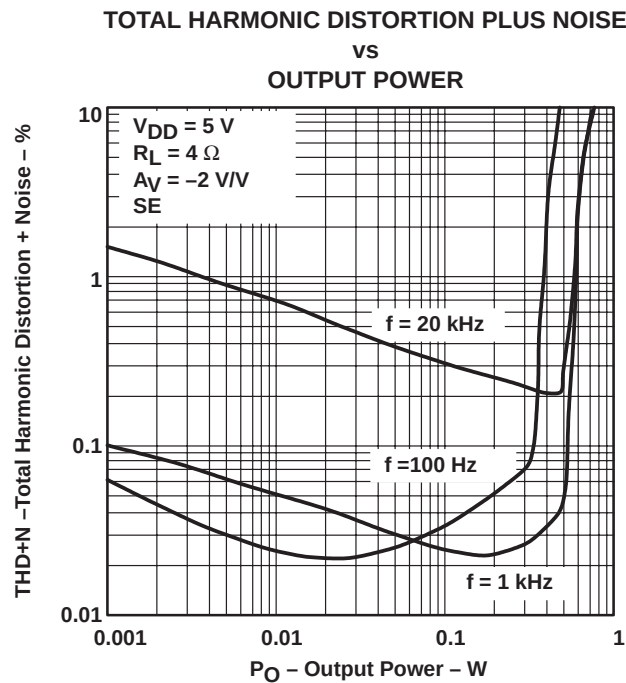


Figure 19

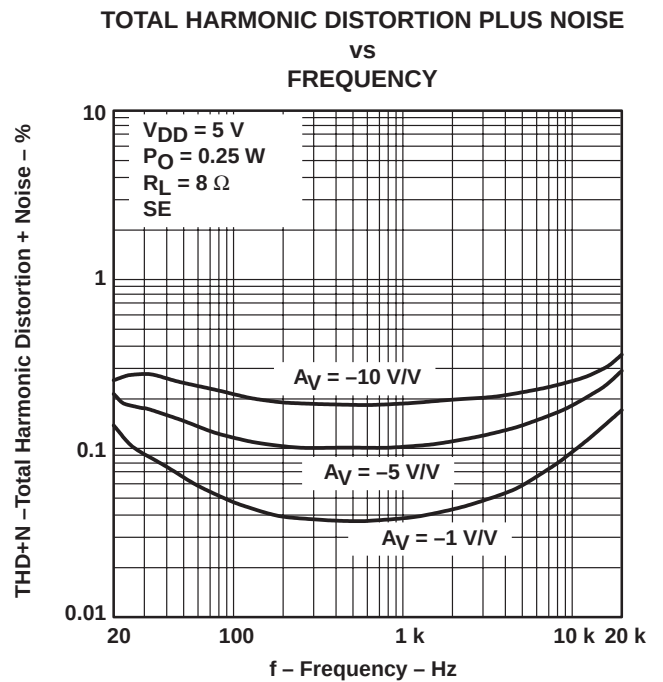


Figure 20

# TPA0202

## 2-W STEREO AUDIO POWER AMPLIFIER

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### TYPICAL CHARACTERISTICS

TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
FREQUENCY

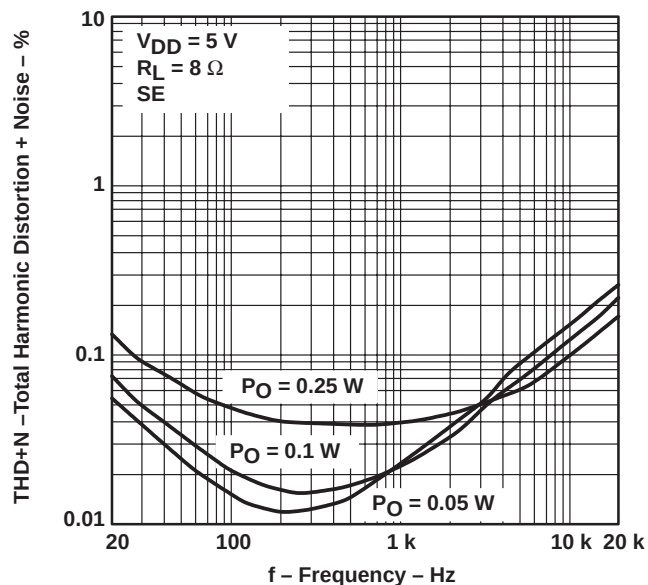


Figure 21

TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
OUTPUT POWER

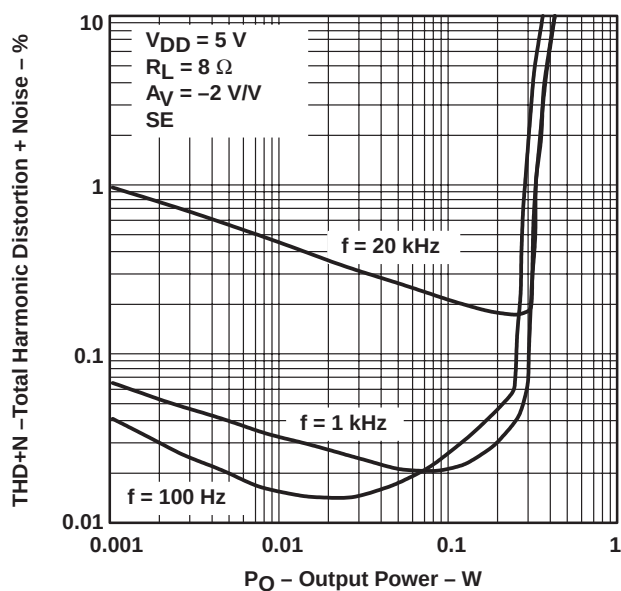


Figure 22

TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
FREQUENCY

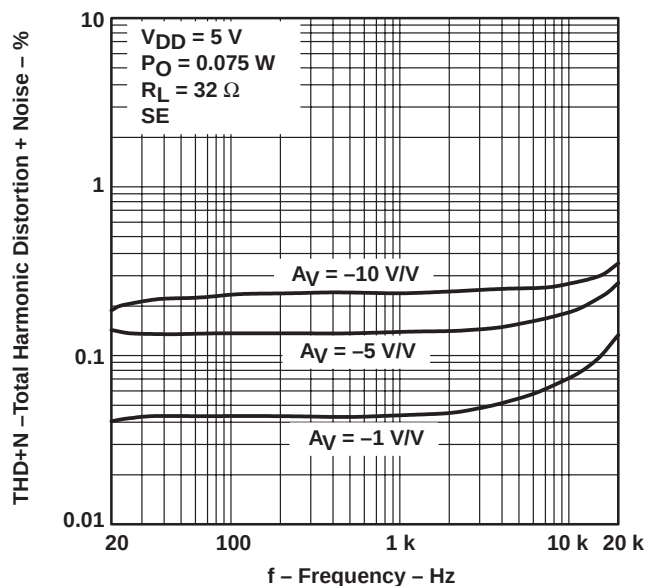


Figure 23

TOTAL HARMONIC DISTORTION PLUS NOISE  
vs  
FREQUENCY

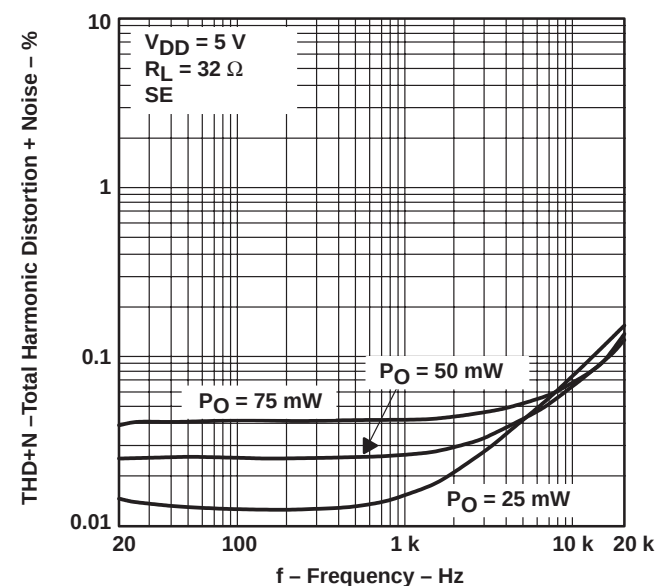


Figure 24

# TPA0202 2-W STEREO AUDIO POWER AMPLIFIER

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## TYPICAL CHARACTERISTICS

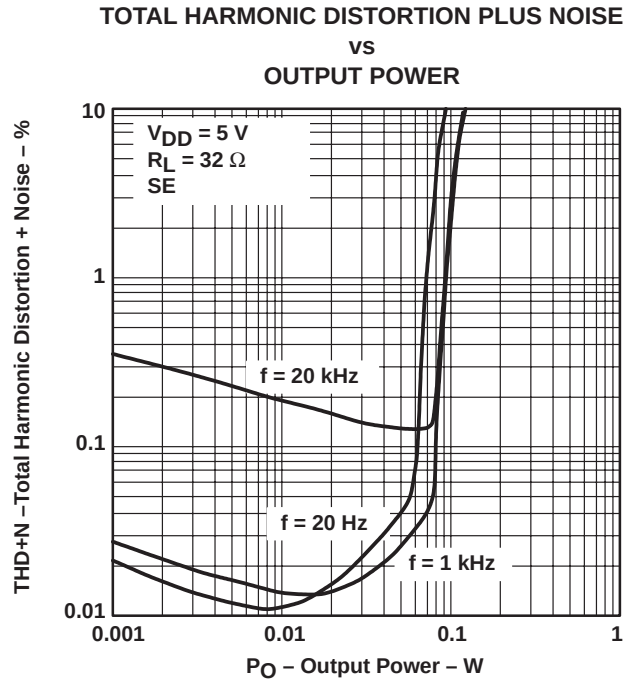


Figure 25

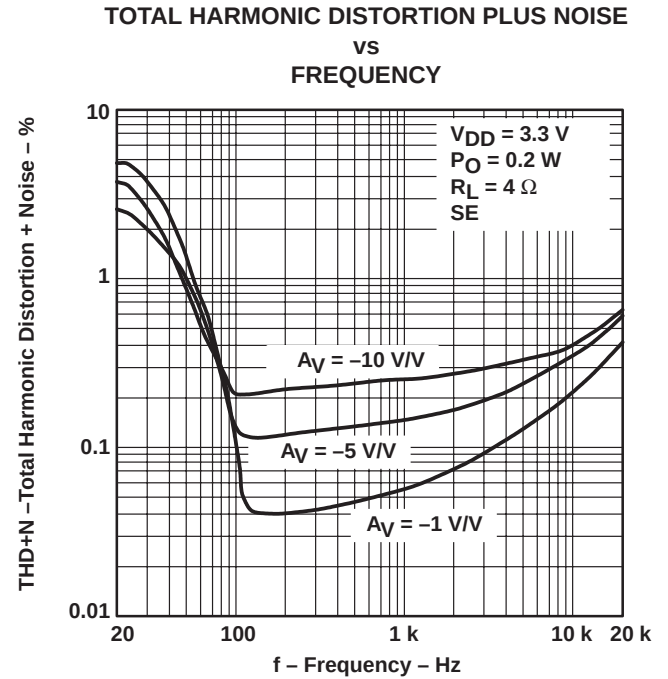


Figure 26

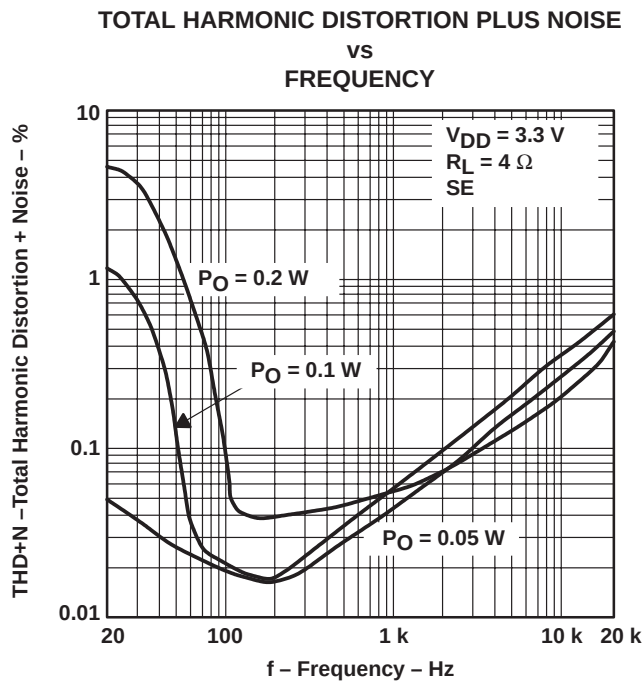


Figure 27

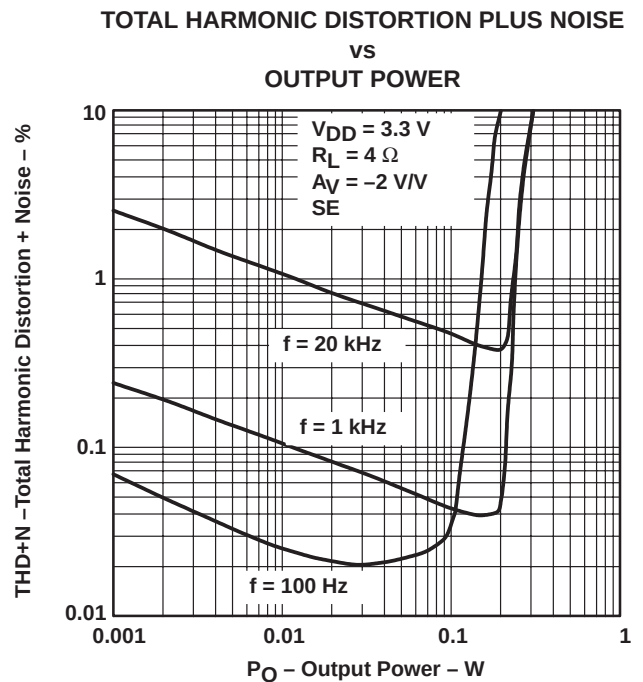


Figure 28

# TPA0202

## 2-W STEREO AUDIO POWER AMPLIFIER

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### TYPICAL CHARACTERISTICS

TOTAL HARMONIC DISTORTION PLUS NOISE  
VS  
FREQUENCY

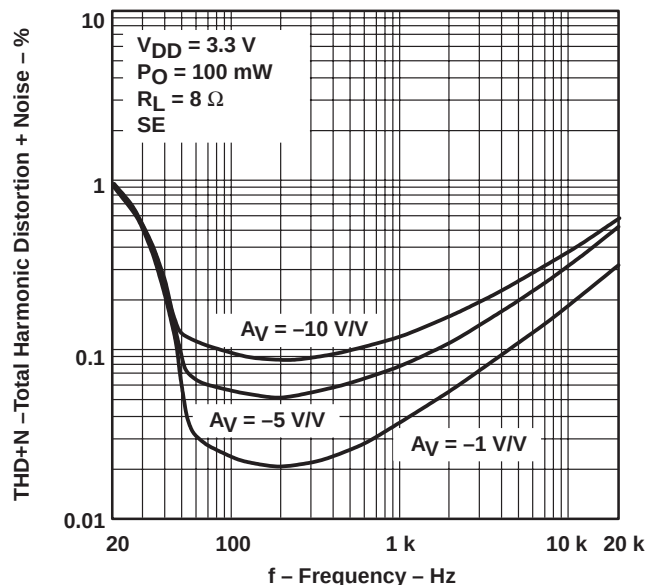


Figure 29

TOTAL HARMONIC DISTORTION PLUS NOISE  
VS  
FREQUENCY

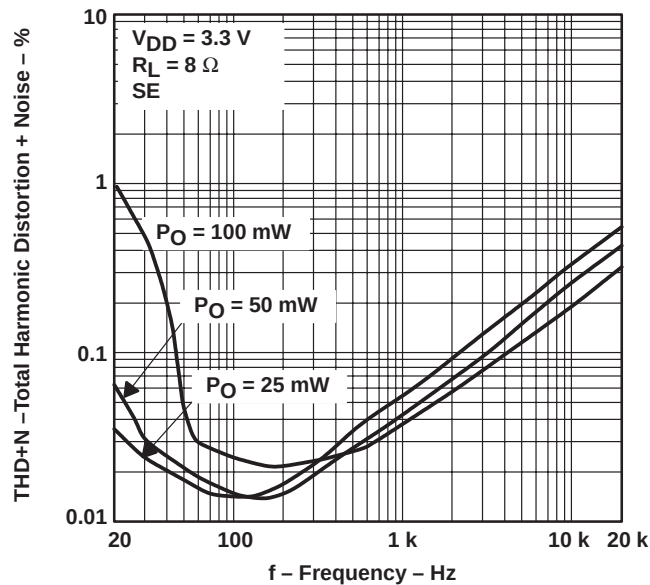


Figure 30

TOTAL HARMONIC DISTORTION PLUS NOISE  
VS  
OUTPUT POWER

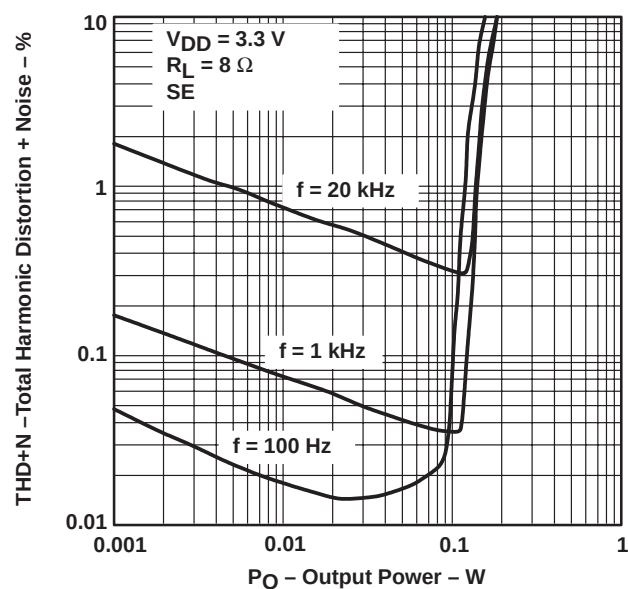


Figure 31

TOTAL HARMONIC DISTORTION PLUS NOISE  
VS  
FREQUENCY

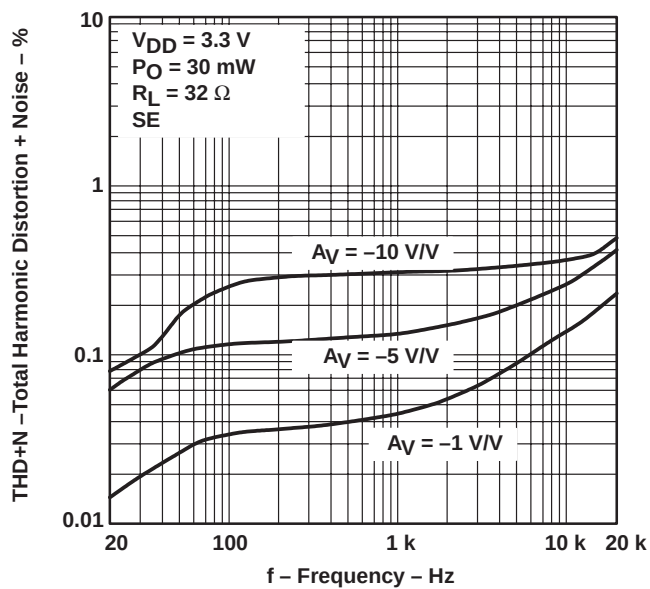


Figure 32

# TPA0202 2-W STEREO AUDIO POWER AMPLIFIER

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## TYPICAL CHARACTERISTICS

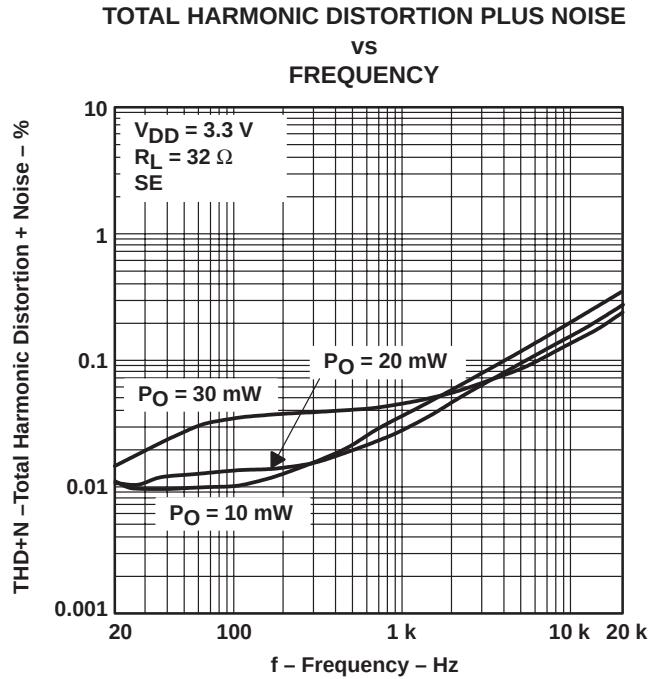


Figure 33

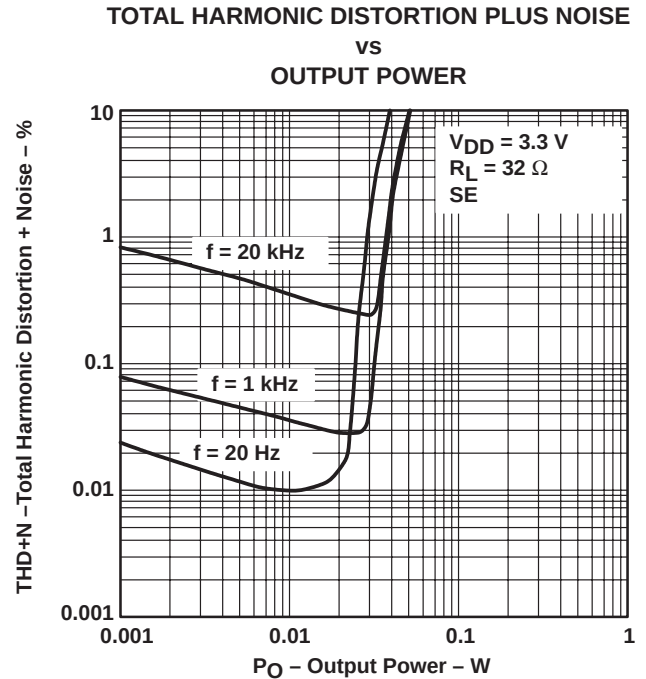


Figure 34

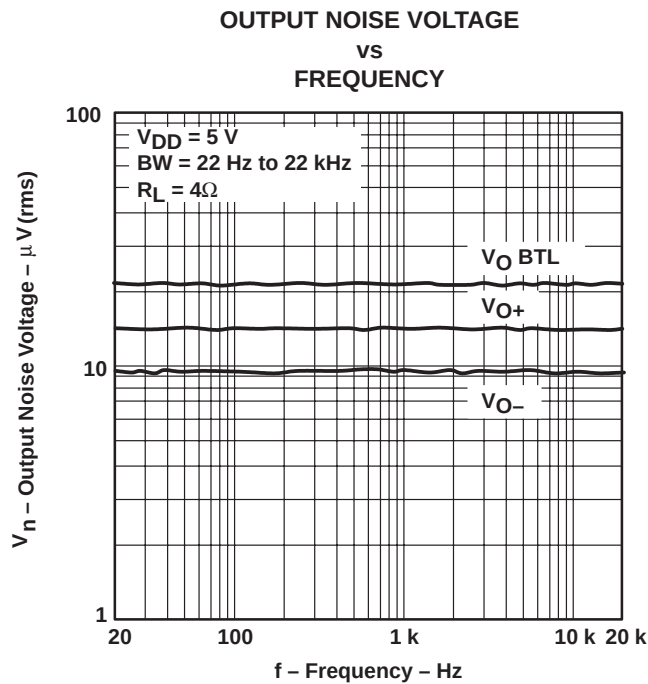


Figure 35

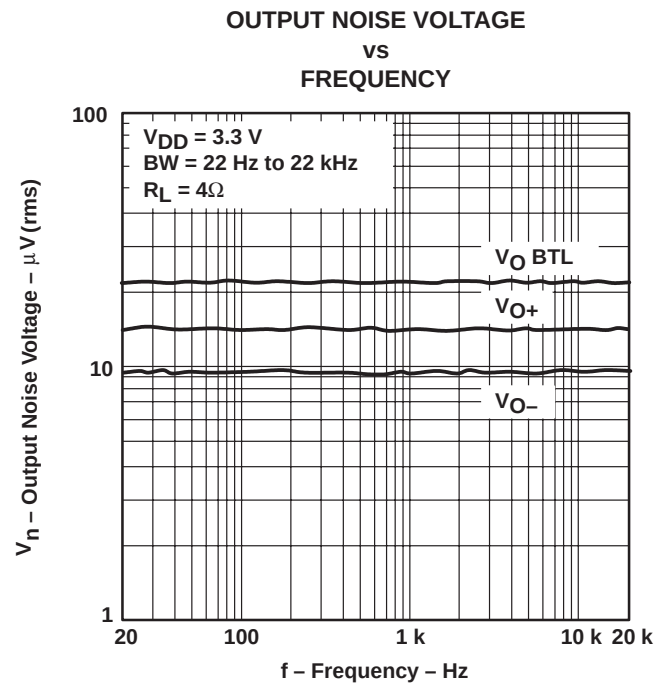


Figure 36

# TPA0202

## 2-W STEREO AUDIO POWER AMPLIFIER

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### TYPICAL CHARACTERISTICS

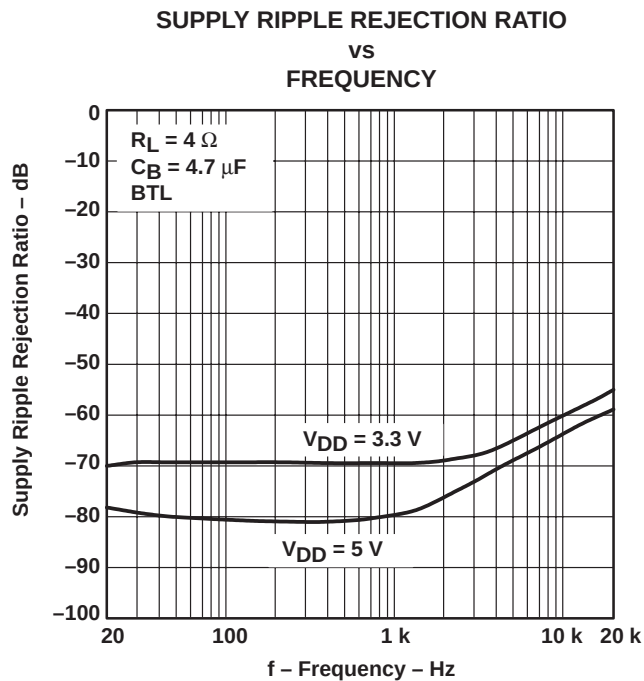


Figure 37

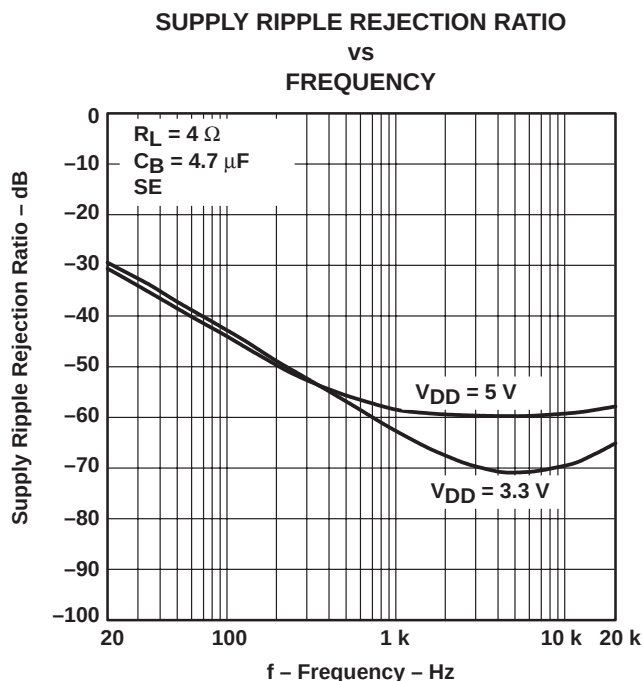


Figure 38

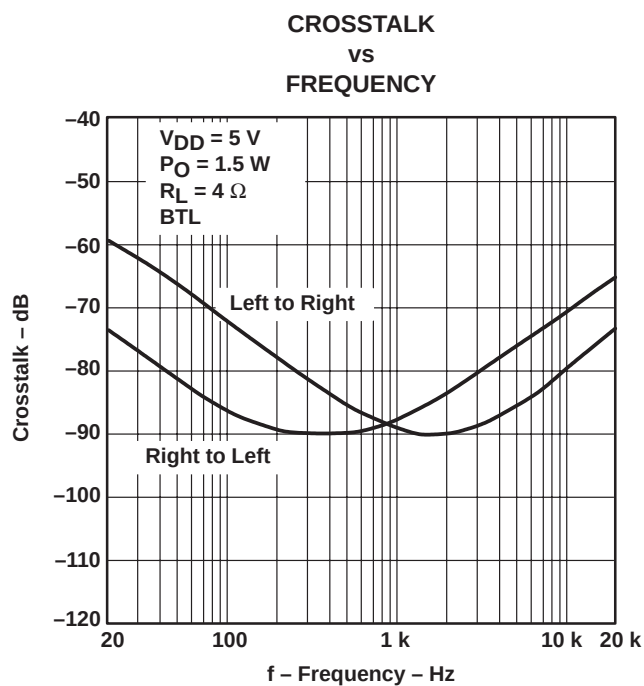


Figure 39

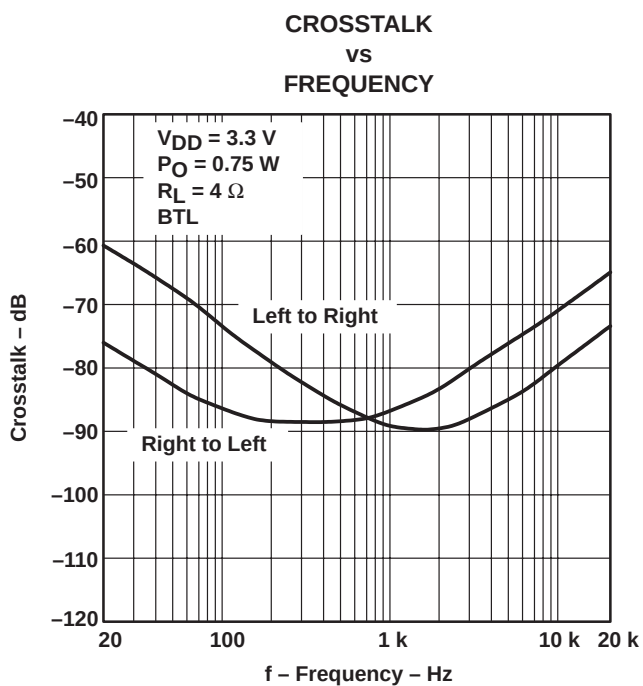


Figure 40



TYPICAL CHARACTERISTICS

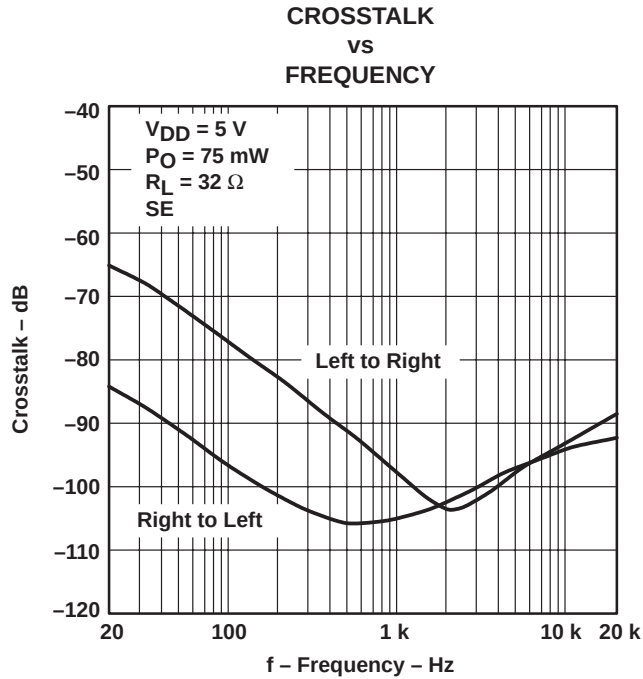


Figure 41

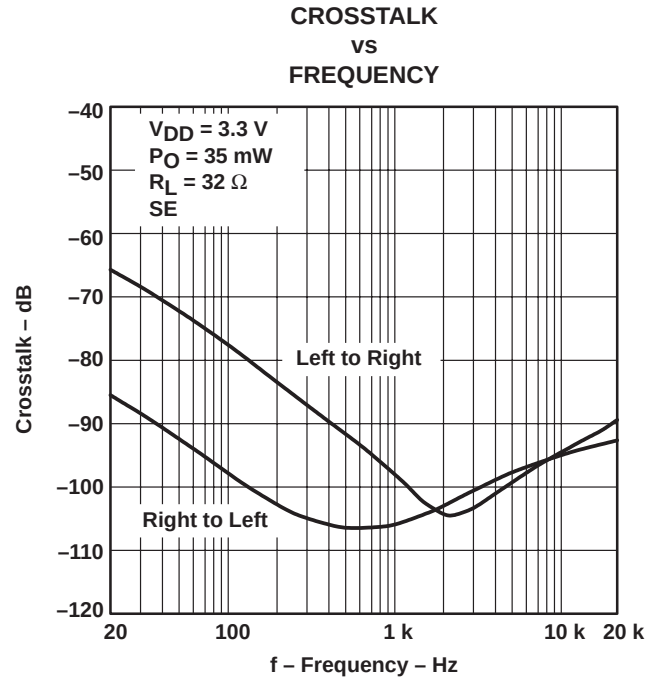


Figure 42

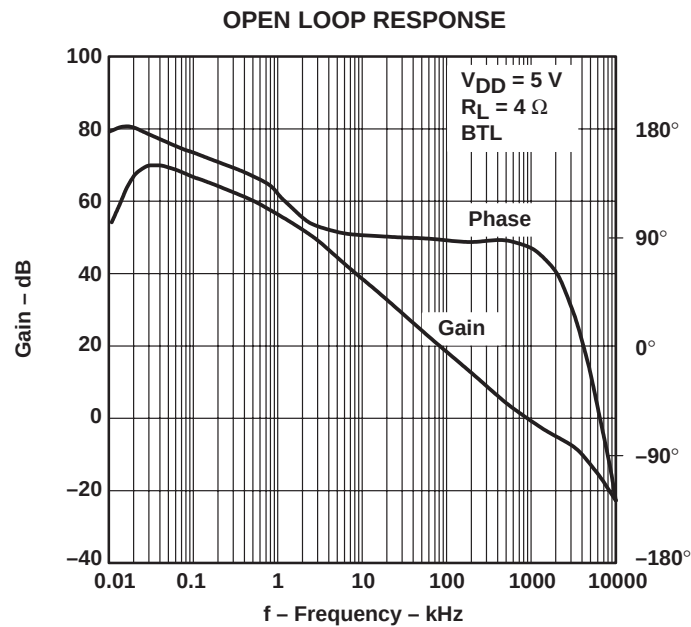


Figure 43

# TPA0202

## 2-W STEREO AUDIO POWER AMPLIFIER

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### TYPICAL CHARACTERISTICS

#### OPEN LOOP RESPONSE

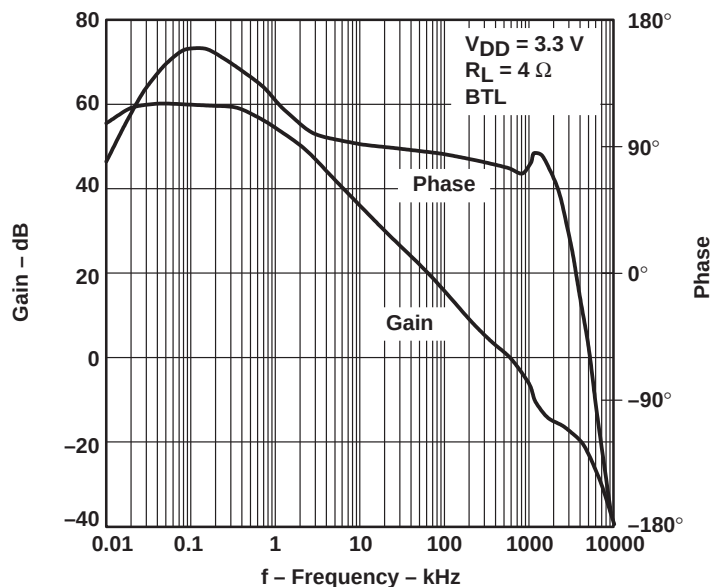


Figure 44

#### CLOSED LOOP RESPONSE

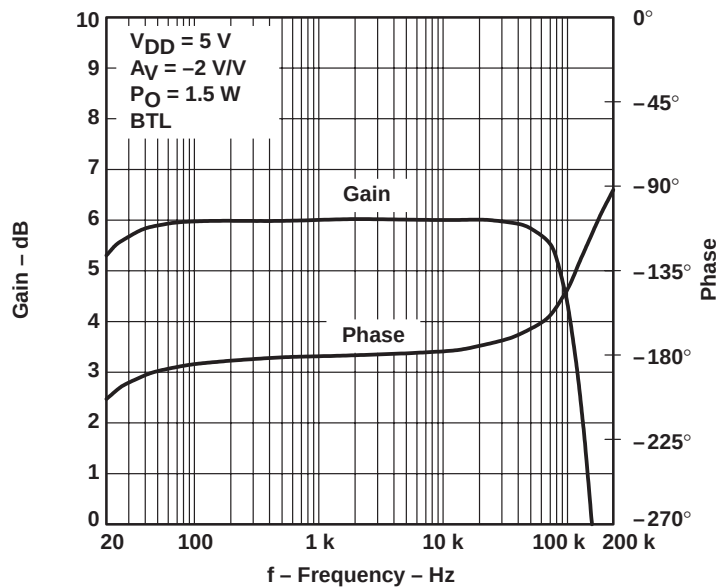


Figure 45

## TYPICAL CHARACTERISTICS

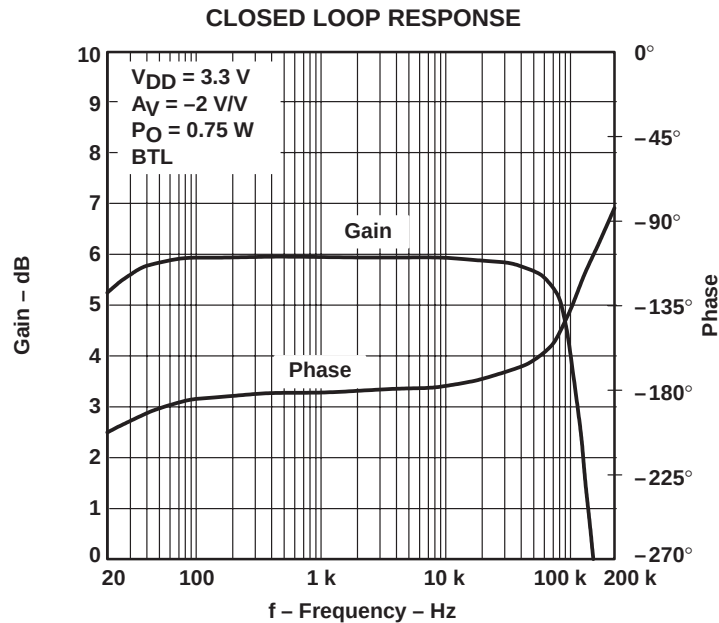


Figure 46

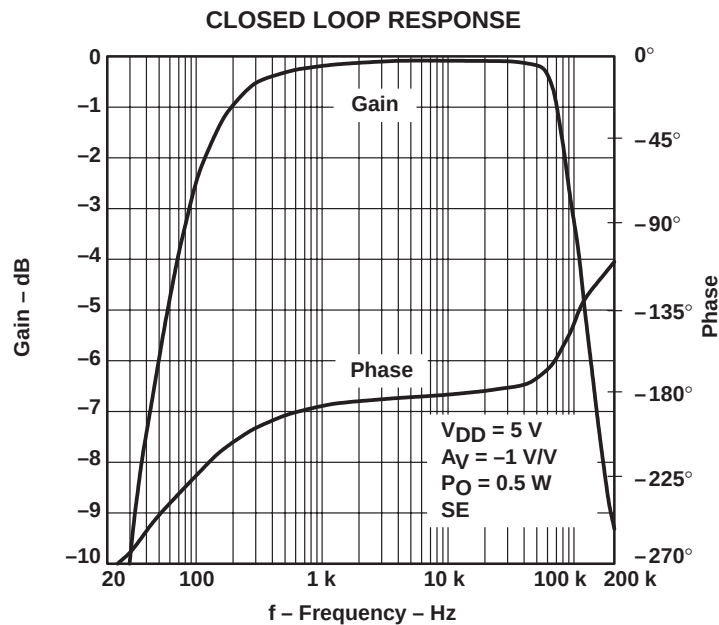


Figure 47

TPA0202  
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TYPICAL CHARACTERISTICS

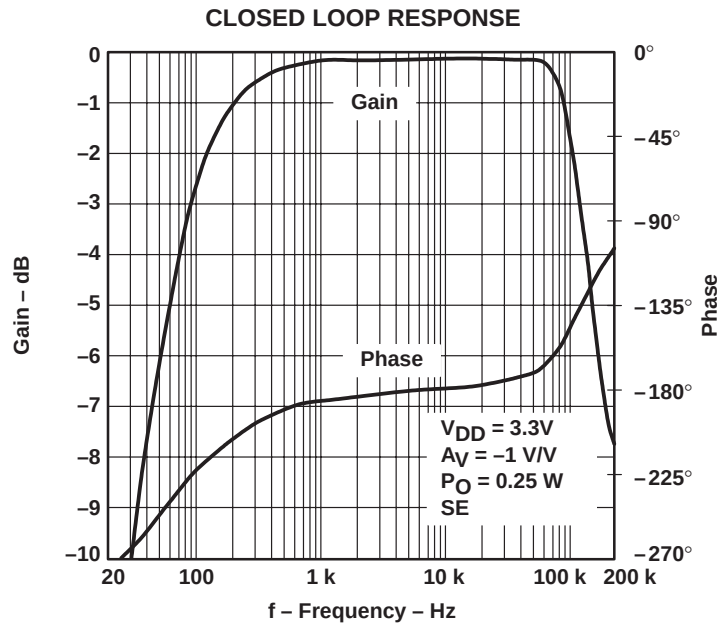


Figure 48

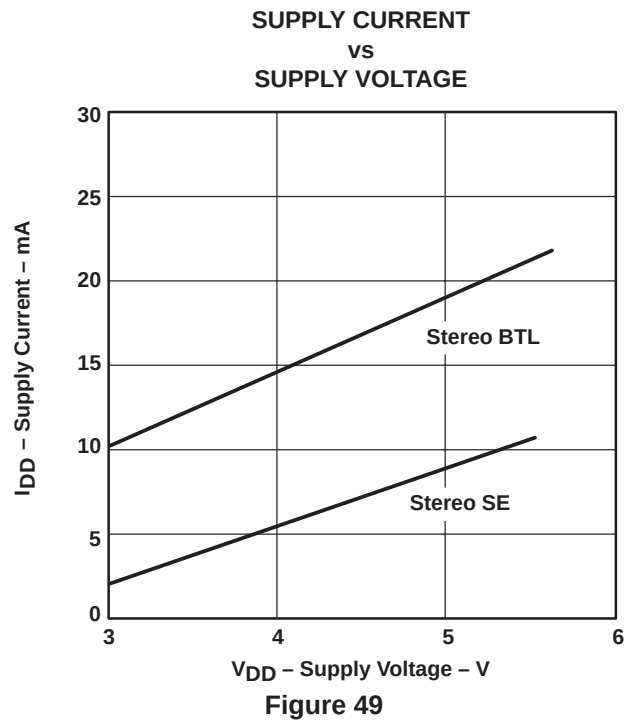


Figure 49

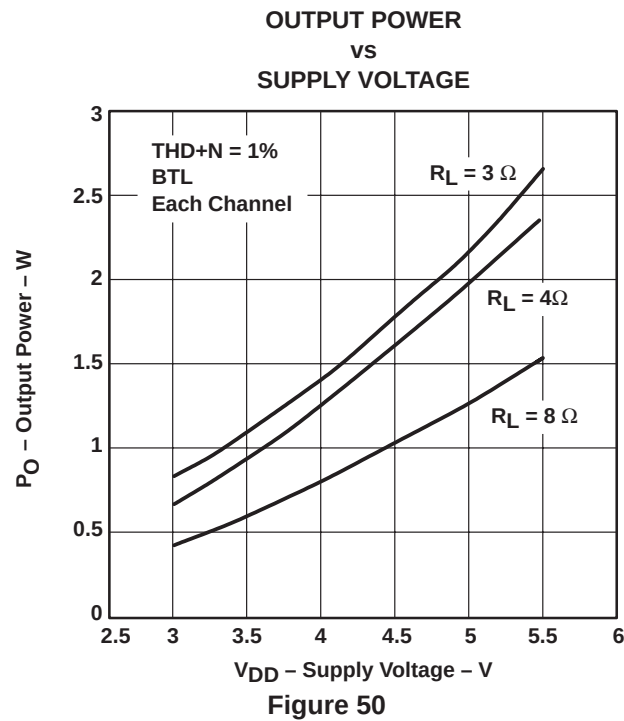


Figure 50

# TPA0202 2-W STEREO AUDIO POWER AMPLIFIER

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## TYPICAL CHARACTERISTICS

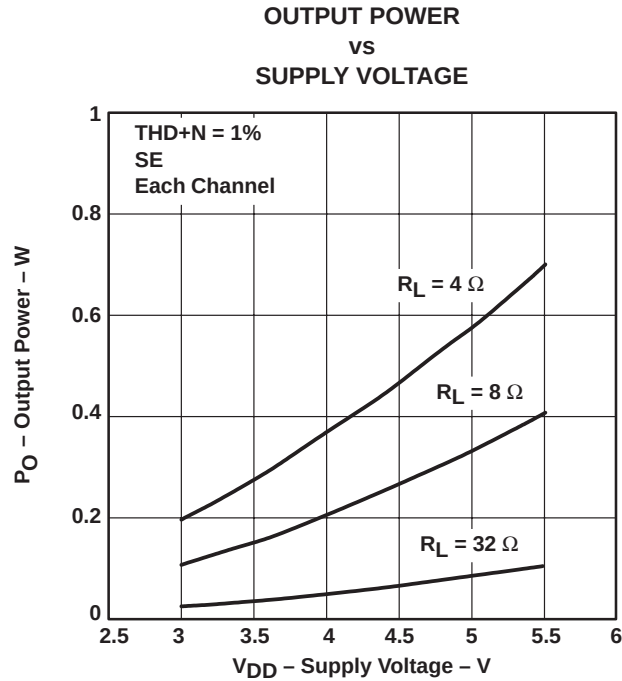


Figure 51

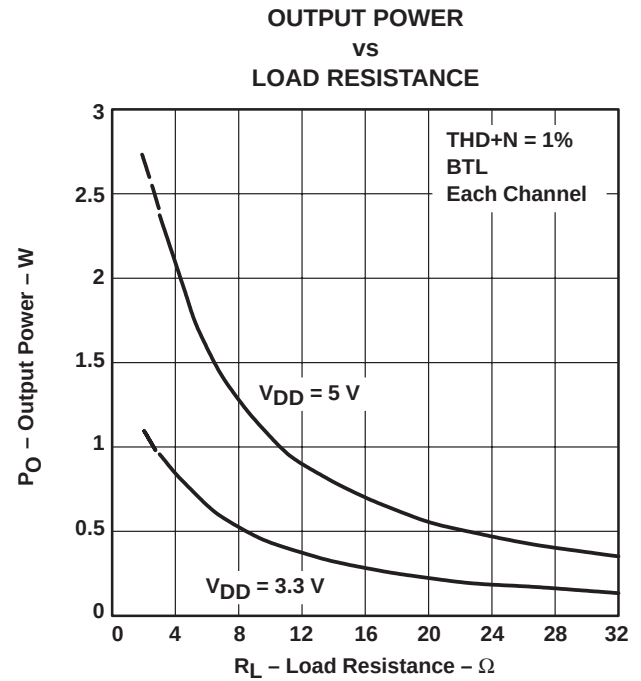


Figure 52

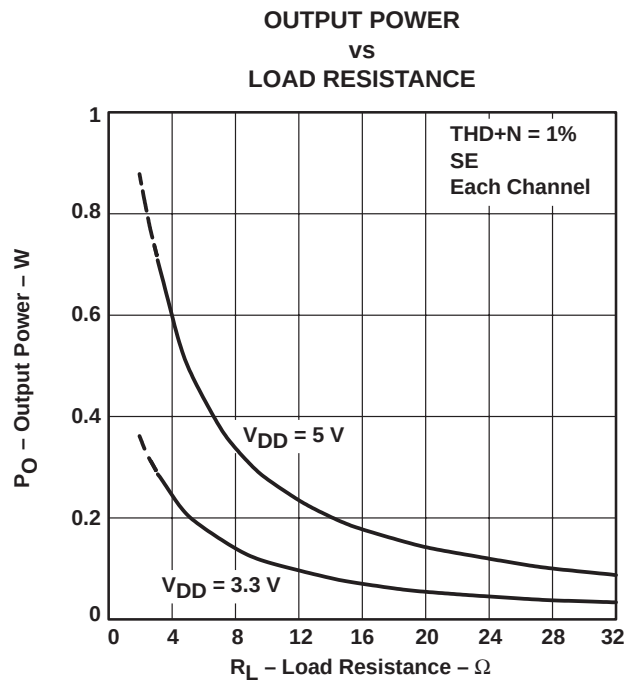


Figure 53

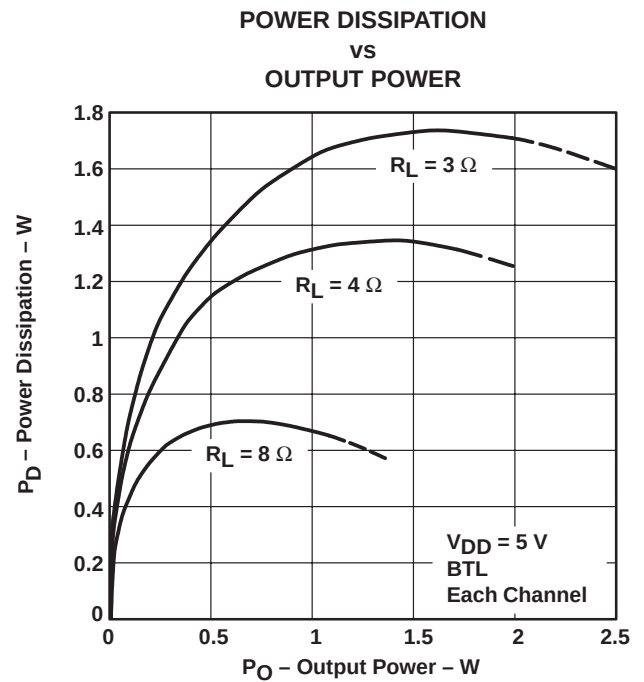


Figure 54

TPA0202  
2-W STEREO AUDIO POWER AMPLIFIER

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TYPICAL CHARACTERISTICS

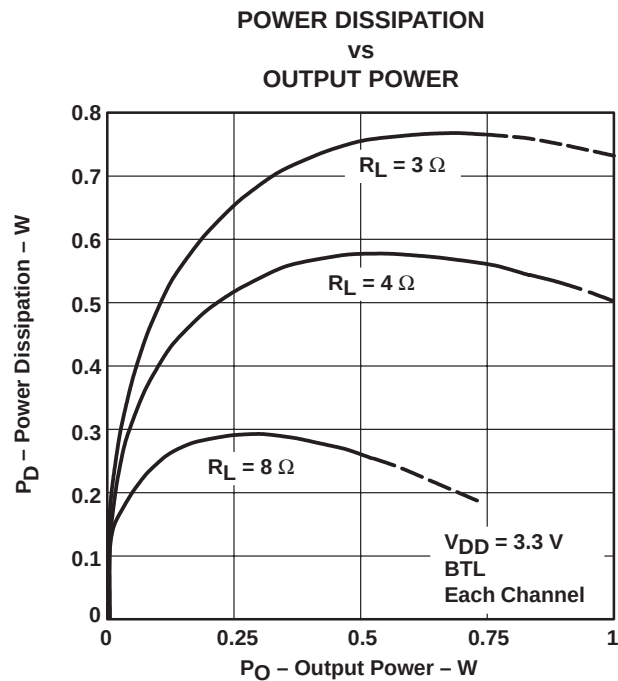


Figure 55

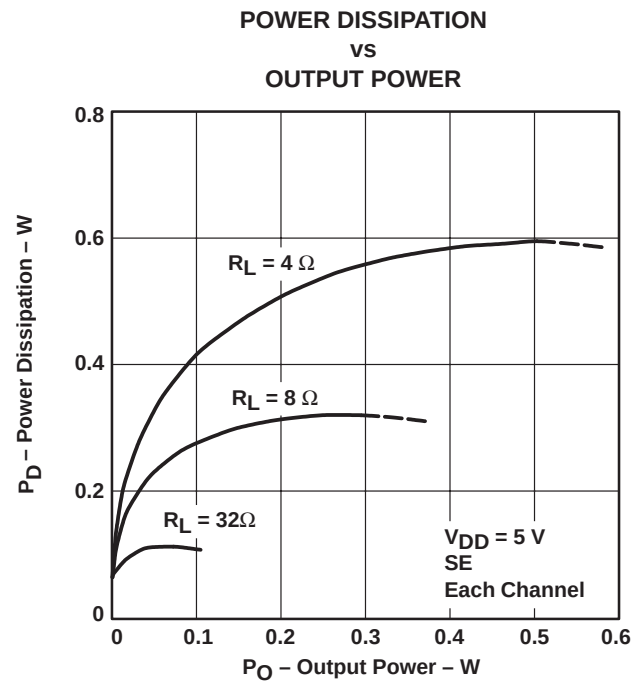


Figure 56

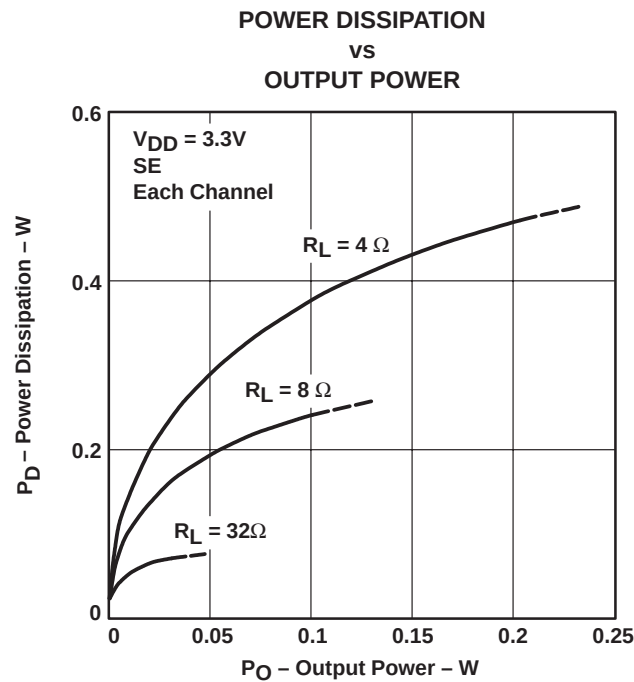


Figure 57

## THERMAL INFORMATION

The thermally enhanced PWP package is based on the 24-pin TSSOP, but includes a thermal pad (see Figure 58) to provide an effective thermal contact between the IC and the PWB.

Traditionally, surface-mount and power have been mutually exclusive terms. A variety of scaled-down TO-220-type packages have leads formed as gull wings to make them applicable for surface-mount applications. These packages, however, have only two shortcomings: they do not address the very low profile requirements ( $<2$  mm) of many of today's advanced systems, and they do not offer a terminal-count high enough to accommodate increasing integration. On the other hand, traditional low-power surface-mount packages require power-dissipation derating that severely limits the usable range of many high-performance analog circuits.

The PowerPAD package (thermally enhanced TSSOP) combines fine-pitch surface-mount technology with thermal performance comparable to much larger power packages.

The PowerPAD package is designed to optimize the heat transfer to the PWB. Because of the very small size and limited mass of a TSSOP package, thermal enhancement is achieved by improving the thermal conduction paths that remove heat from the component. The thermal pad is formed using a patented lead-frame design and manufacturing technique to provide a direct connection to the heat-generating IC. When this pad is soldered or otherwise thermally coupled to an external heat dissipator, high power dissipation in the ultra-thin, fine-pitch, surface-mount package can be reliably achieved.

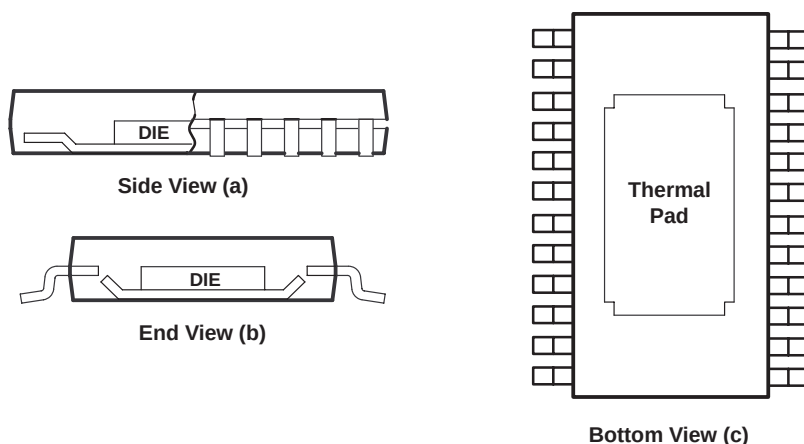


Figure 58. Views of Thermally Enhanced PWP Package

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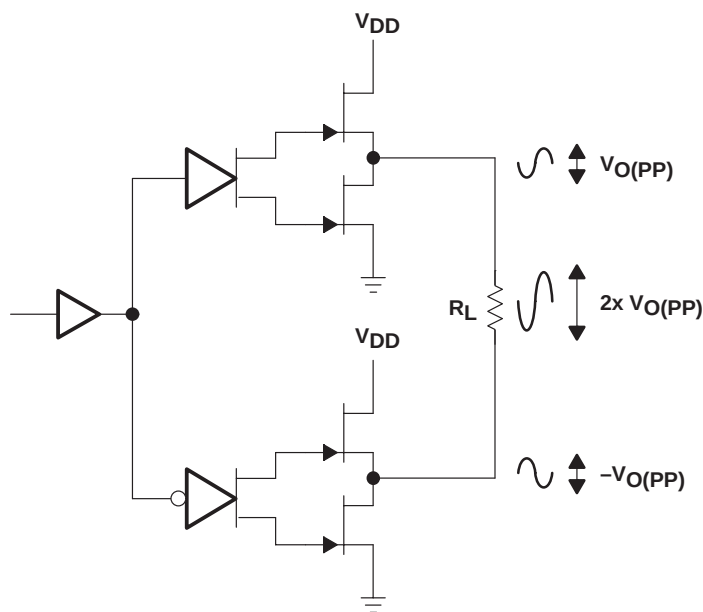
### APPLICATION INFORMATION

#### bridged-tied load versus single-ended mode

Figure 59 shows a linear audio power amplifier (APA) in a BTL configuration. The TPA0202 BTL amplifier consists of two linear 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  $4 \times$  the output power from the same supply rail and load impedance (see equation 1).

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

$$\text{Power} = \frac{V_{(rms)}^2}{R_L} \quad (1)$$



**Figure 59. 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 single-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 60. 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 2.

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



## APPLICATION INFORMATION

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

For example, a 68- $\mu\text{F}$  capacitor with an 8- $\Omega$  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.

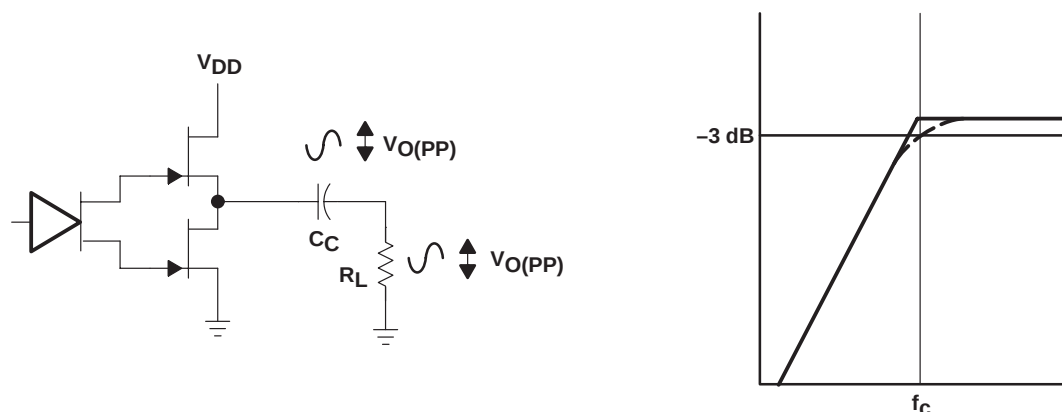


Figure 60. Single-Ended Configuration and Frequency Response

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 $\times$  the output power of the SE configuration. Internal dissipation versus output power is discussed further in the *thermal considerations* section.

### BTL amplifier efficiency

Linear amplifiers are notoriously inefficient. The primary cause of these inefficiencies is 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,  $I_{DD\text{rms}}$ , 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 values of power in the load and in the amplifier, the current and voltage waveform shapes must first be understood (see Figure 61).

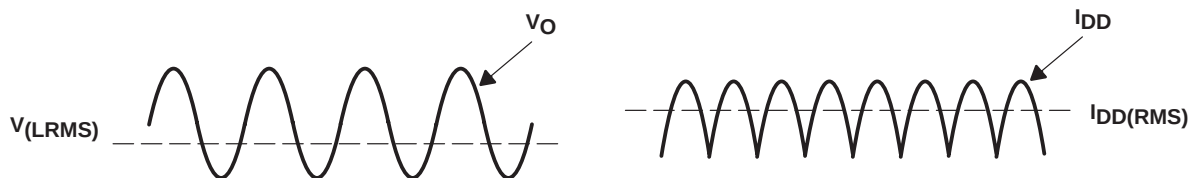


Figure 61. Voltage and Current Waveforms for BTL Amplifiers

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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.

$$\text{Efficiency} = \frac{P_L}{P_{\text{SUP}}} \quad (3)$$

Where:

$$P_L = \frac{V_{L\text{rms}}^2}{R_L} = \frac{V_P^2}{2R_L}$$

$$V_{L\text{rms}} = \frac{V_P}{\sqrt{2}}$$

$$P_{\text{SUP}} = V_{DD} I_{DD\text{rms}} = \frac{V_{DD} 2V_P}{\pi R_L}$$

$$I_{DD\text{rms}} = \frac{2V_P}{\pi R_L}$$

$$\text{Efficiency of a BTL Configuration} = \frac{\pi V_P}{2V_{DD}} = \frac{\pi \left( \frac{P_L R_L}{2} \right)^{1/2}}{2V_{DD}} \quad (4)$$

Table 1 employs equation 4 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. For a stereo 1-W audio system with 8-Ω loads and a 5-V supply, the maximum draw on the power supply is almost 3.25 W.

**Table 1. Efficiency Vs Output Power in 5-V 8-Ω BTL Systems**

| OUTPUT POWER (W) | EFFICIENCY (%) | PEAK-TO-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 <sup>†</sup>        | 0.53                     |

<sup>†</sup> High peak voltages cause the THD to increase.

A final point to remember about linear amplifiers (either SE or BTL) is how to manipulate the terms in the efficiency equation to utmost advantage when possible. Note that in equation 4,  $V_{DD}$  is in the denominator. This indicates that as  $V_{DD}$  goes down, efficiency goes up.

# TPA0202

## 2-W STEREO AUDIO POWER AMPLIFIER

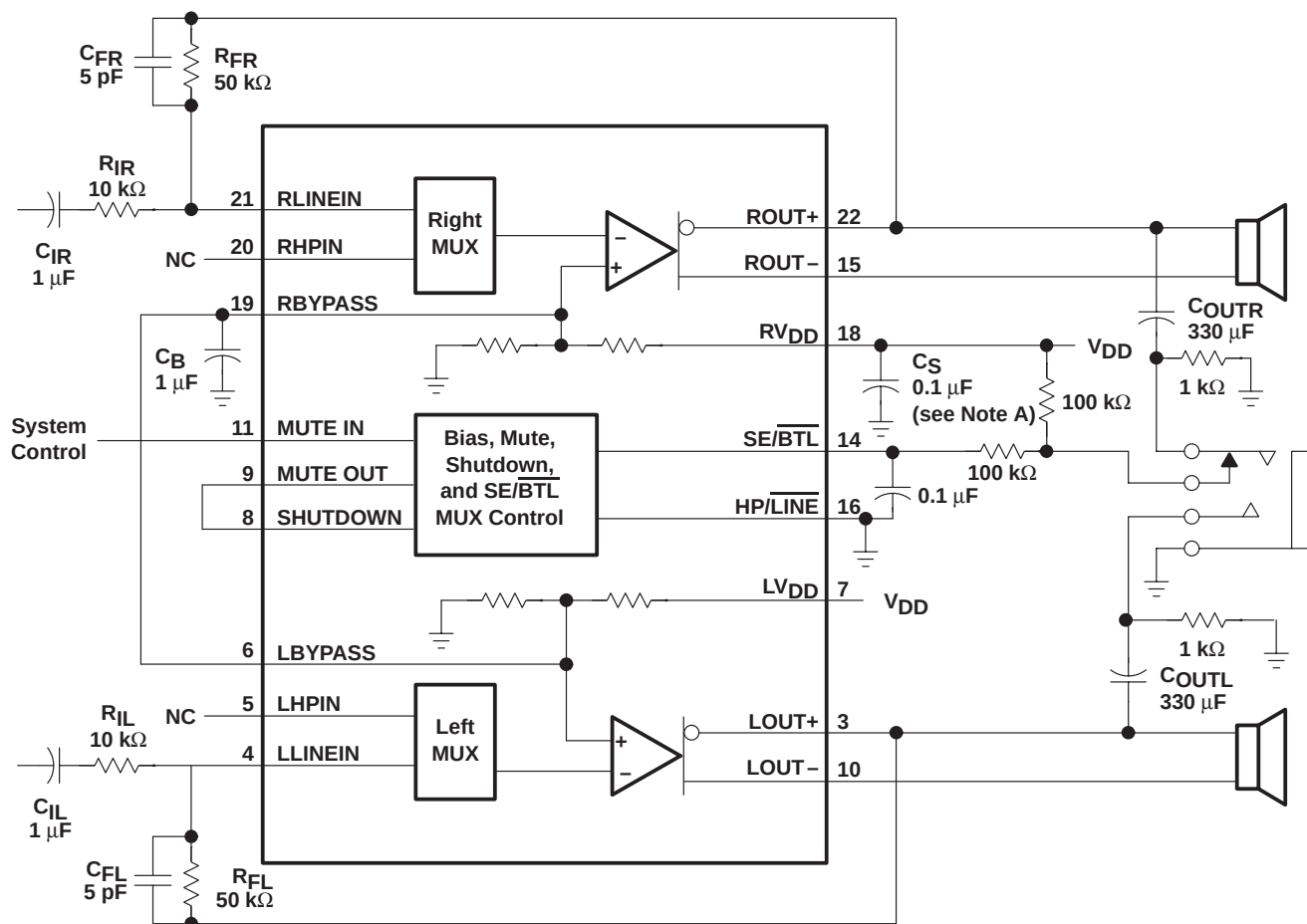
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For example, if the 5-V supply is replaced with a 3.3-V supply (TPA0202 has a maximum recommended  $V_{DD}$  of 5.5 V) in the calculations of Table 1, then efficiency at 0.5 W would rise from 44% to 67% and internal power dissipation would fall from 0.62 W to 0.25 W at 5 V. Then for a stereo 0.5-W system from a 3.3-V supply, the maximum draw would only be 1.5 W as compared to 2.24 W from 5 V. In other words, use the efficiency analysis to choose the correct supply voltage and speaker impedance for the application.

### selection of components

Figure 62 and Figure 63 are a schematic diagrams of a typical notebook computer application circuits.



NOTE A: A 0.1  $\mu\text{F}$  ceramic capacitor should be placed as close as possible to the IC. For filtering lower-frequency noise signals, a larger aluminum electrolytic capacitor of 10  $\mu\text{F}$  or greater should be placed near the audio power amplifier.

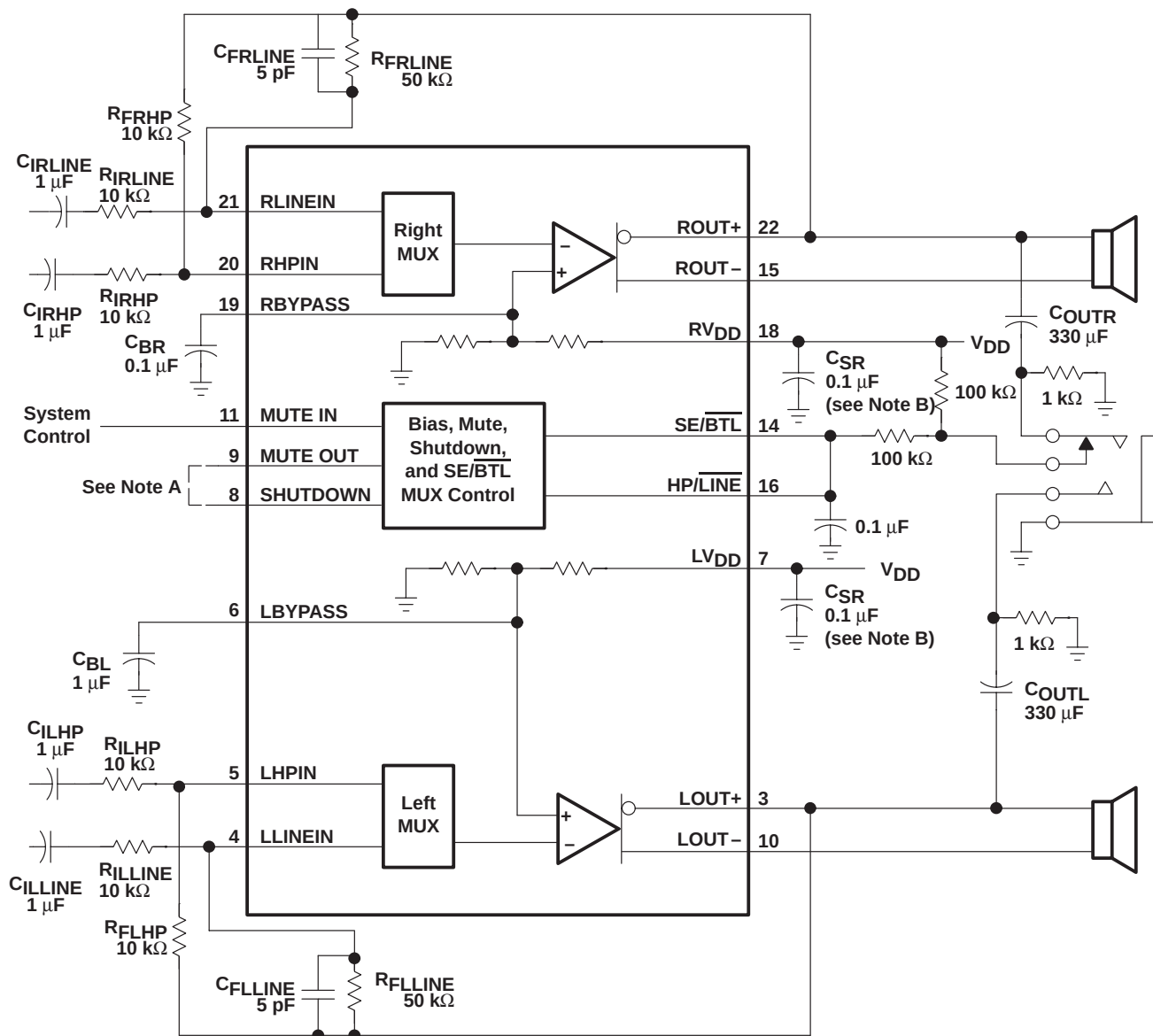
Figure 62. TPA0202 Minimum Configuration Application Circuit

# TPA0202

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### APPLICATION INFORMATION



- NOTES: A. This connection is for ultra-low current in shutdown mode.  
 B. A 0.1  $\mu\text{F}$  ceramic capacitor should be placed as close as possible to the IC. For filtering lower-frequency noise signals, a larger aluminum electrolytic capacitor of 10  $\mu\text{F}$  or greater should be placed near the audio power amplifier.

Figure 63. TPA0202 Full Configuration Application Circuit

## APPLICATION INFORMATION

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

The gain for each audio input of the TPA0202 is set by resistors  $R_F$  and  $R_I$  according to equation 5 for BTL mode.

$$\text{BTL Gain} = -2 \left( \frac{R_F}{R_I} \right) \quad (5)$$

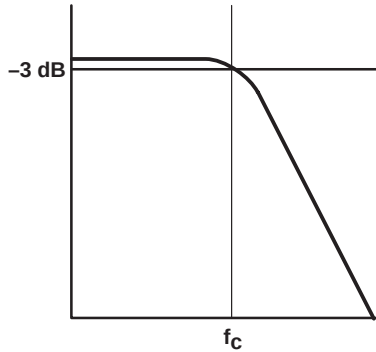
BTL mode operation brings about the factor 2 in the gain equation due to the inverting amplifier mirroring the voltage swing across the load. Given that the TPA0202 is a MOS amplifier, the input impedance is very high, consequently input leakage currents are not generally a concern although noise in 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 6.

$$\text{Effective Impedance} = \frac{R_F R_I}{R_F + R_I} \quad (6)$$

As an example consider an input resistance of 10 k $\Omega$  and a feedback resistor of 50 k $\Omega$ . The BTL gain of the amplifier would be  $-10$  and the effective impedance at the inverting terminal would be 8.3 k $\Omega$ , which is well 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  $R_F$  when  $R_F$  is greater than 50 k $\Omega$ . This, in effect, creates a low pass filter network with the cutoff frequency defined in equation 7.

$$f_{c(\text{lowpass})} = \frac{1}{2\pi R_F C_F} \quad (7)$$



For example, if  $R_F$  is 100 k $\Omega$  and  $C_F$  is 5 pF then  $f_c$  is 318 kHz, which is well outside of the audio range.

## TPA0202

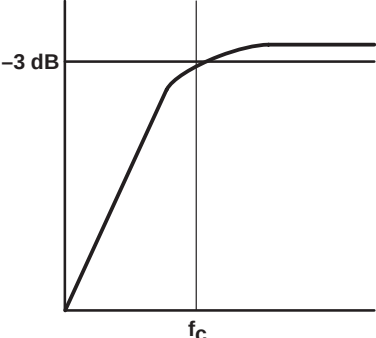
### 2-W STEREO AUDIO POWER AMPLIFIER

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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 8.

$$f_{c(\text{highpass})} = \frac{1}{2\pi R_I C_I} \quad (8)$$


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 8 is reconfigured as equation 9.

$$C_I = \frac{1}{2\pi R_I f_c} \quad (9)$$

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. 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.

##### power supply decoupling, $C_S$

The TPA0202 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  $\mu\text{F}$  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 audio power amplifier is recommended.

## APPLICATION INFORMATION

### midrail bypass capacitor, $C_B$

The midrail bypass capacitor,  $C_B$ , is the most critical capacitor and serves several important functions. During startup or recovery from shutdown mode,  $C_B$  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. The capacitor is fed from a 100-k $\Omega$  source inside the amplifier. To keep the start-up pop as low as possible, the relationship shown in equation 10 should be maintained.

$$\frac{1}{(C_B \times 100 \text{ k}\Omega)} \leq \frac{1}{C_I(R_I + R_F)} \quad (10)$$

As an example, consider a circuit where  $C_B$  is 1  $\mu$ F,  $C_I$  is 0.22  $\mu$ F,  $R_F$  is 50 k $\Omega$ , and  $R_I$  is 10 k $\Omega$ . Inserting these values into the equation 10 we get  $10 \leq 75$ , which satisfies the rule. Bypass capacitor,  $C_B$ , values of 0.1  $\mu$ F to 1  $\mu$ F ceramic or tantalum low-ESR capacitors are recommended for the best THD and noise performance.

In Figure 63, the full feature configuration, two bypass capacitors are used. This provides the maximum separation between right and left drive circuits. When absolute minimum cost and/or component space is required, one bypass capacitor can be used as shown in Figure 62. It is critical that terminals 6 and 19 be tied together in this configuration.

### load considerations

Extremely low impedance loads (below 4  $\Omega$ ) coupled with certain external component selections, board layouts, and cabling can cause oscillations in the system. Using a single air-cored inductor in series with the load eliminates any spurious oscillations that might occur. An inductance of approximately 1  $\mu$ H has been shown to eliminate such oscillations. There are no special considerations when using 4  $\Omega$  and above loads with this amplifier.

### optimizing depop operation

Circuitry has been included in the TPA0202 to minimize the amount of popping heard at power-up and when coming out of shutdown mode. Popping occurs whenever a voltage step is applied to the speaker. If high impedances are used for the feedback and input resistors, it is possible for the input capacitor to drift downwards from mid-rail during mute and shutdown. A high gain amplifier intensifies the problem as the small delta in voltage is multiplied by the gain. So it is advantageous to use low-gain configurations, and to limit the size of the gain-setting resistors. The time constant of the input coupling capacitor ( $C_I$ ) and the gain-setting resistors ( $R_I$  and  $R_F$ ) needs to be shorter than the time constant formed by the bypass capacitor ( $C_B$ ) and the output impedance of the mid-rail generator, which is nominally 100 k $\Omega$  (see equation 10).

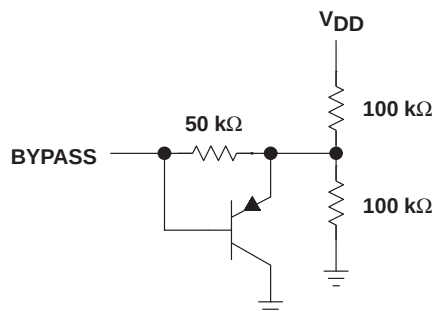
The effective output impedance of the mid-rail generator is actually greater than 100 k $\Omega$  due to a PNP transistor clamping the input node (see Figure 64).

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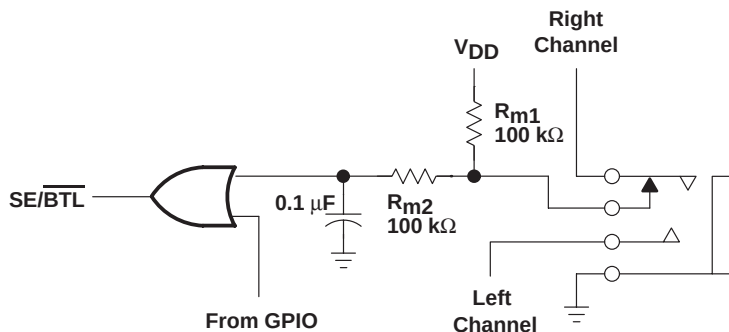
**Figure 64. PNP Transistor Clamping of BYPASS Terminal**

The PNP transistor limits the voltage drop across the 50 kΩ resistor by slewing the internal node slowly when power is applied. At start-up, the xBYPASS capacitor is at 0. The PNP is pulling the mid-point of the bias circuit down, so the capacitor sees a lower effective voltage, and thus charges slower. This appears as a linear ramp (while the PNP transistor is conducting), followed by the expected exponential ramp of an R-C circuit.

If the expression in equation 10 cannot be fulfilled or the small amount of pop is still unacceptable for the application, then external circuitry must be added that can eliminate the pop heard during power up and while transitioning out of mute or shutdown modes.

By holding the device in SE mode when the pop normally occurs, no pop can be heard through the BTL-connected speakers (as the negative output is in a high impedance state when the amplifier is in SE mode).

From a hardware point of view, the easiest way to implement this is to drive the SE/BTL terminal from the general-purpose input-output (GPIO) in the system. If the SE/BTL terminal is normally connected to a headphone socket (as shown in Figure 65), then the GPIO signal must either be taken through an OR gate (see Figure 65) or isolated with a diode (see Figure 66).



**Figure 65. Implementation with an OR Gate**



## APPLICATION INFORMATION

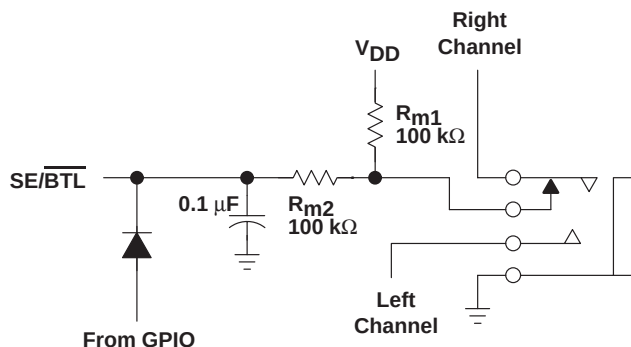


Figure 66. Implementation with a Diode

The OR gate and diode isolate the GPIO terminal from the headphone switch. In these implementations, the headphone switch has priority.

When the amplifier is in mute mode, the output stage continues to be biased. This causes the transition out of mute mode to be very fast with only a short delay (from 100 ms to 500 ms). During power up or the transition out of shutdown mode, a longer delay (from 1 s to 2 s) is required. The exact delay time required is dependent on the values of the external components used with the amplifier (see Figure 67).

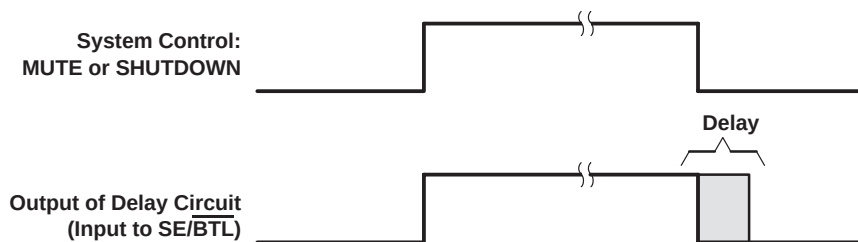


Figure 67. Transition Delay Timing

### single-ended operation

In SE mode (see Figure 59 and Figure 60), the load is driven from the primary amplifier output for each channel (OUT+, terminals 22 and 3).

In SE mode the gain is set by the  $R_F$  and  $R_I$  resistors and is shown in equation 11. Since the inverting amplifier is not used to mirror the voltage swing on the load, the factor of 2, from equation 5, is not included.

$$\text{SE Gain} = - \left( \frac{R_F}{R_I} \right) \quad (11)$$

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 (see equation 12):

$$\frac{1}{(C_B \times 25 \text{ k}\Omega)} \leq \frac{1}{(C_I R_I)} \ll \frac{1}{R_L C_C} \quad (12)$$

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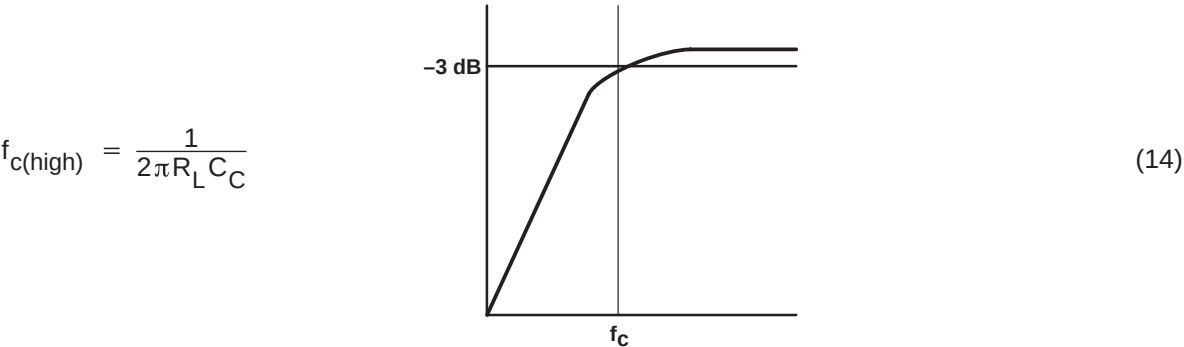
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output coupling capacitor, C<sub>C</sub>

In the typical single-supply SE configuration, an output coupling capacitor (C<sub>C</sub>) 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 14.



The main disadvantage, from a performance standpoint, is the load impedances are typically small, which drives the low-frequency corner higher degrading the bass response. Large values of C<sub>C</sub> are required to pass low frequencies into the load. Consider the example where a C<sub>C</sub> of 330 μF is chosen and loads vary from 3 Ω, 4 Ω, 8 Ω, 32 Ω, 10 kΩ, to 47 kΩ. Table 2 summarizes the frequency response characteristics of each configuration.

Table 2. Common Load Impedances Vs Low Frequency Output Characteristics in SE Mode

| R <sub>L</sub> | C <sub>C</sub> | 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 2 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.

## APPLICATION INFORMATION

### SE/BTL operation

The ability of the TPA0202 to easily switch between BTL and SE modes is one of its most important cost saving features. This feature eliminates the requirement for an additional headphone amplifier in applications where internal stereo speakers are driven in BTL mode but external headphone or speakers must be accommodated. Internal to the TPA0202, two separate amplifiers drive OUT+ and OUT–. The SE/BTL input (terminal 14) controls the operation of the follower amplifier that drives LOUT– and ROUT– (terminals 10 and 15). When SE/BTL is held low, the amplifier is on and the TPA0202 is in the BTL mode. When SE/BTL is held high, the OUT– amplifiers are in a high output impedance state, which configures the TPA0202 as an SE driver from LOUT+ and ROUT+ (terminals 3 and 22).  $I_{DD}$  is reduced by approximately one-half in SE mode. Control of the SE/BTL input can be from a logic-level CMOS source or, more typically, from a resistor divider network as shown in Figure 68.

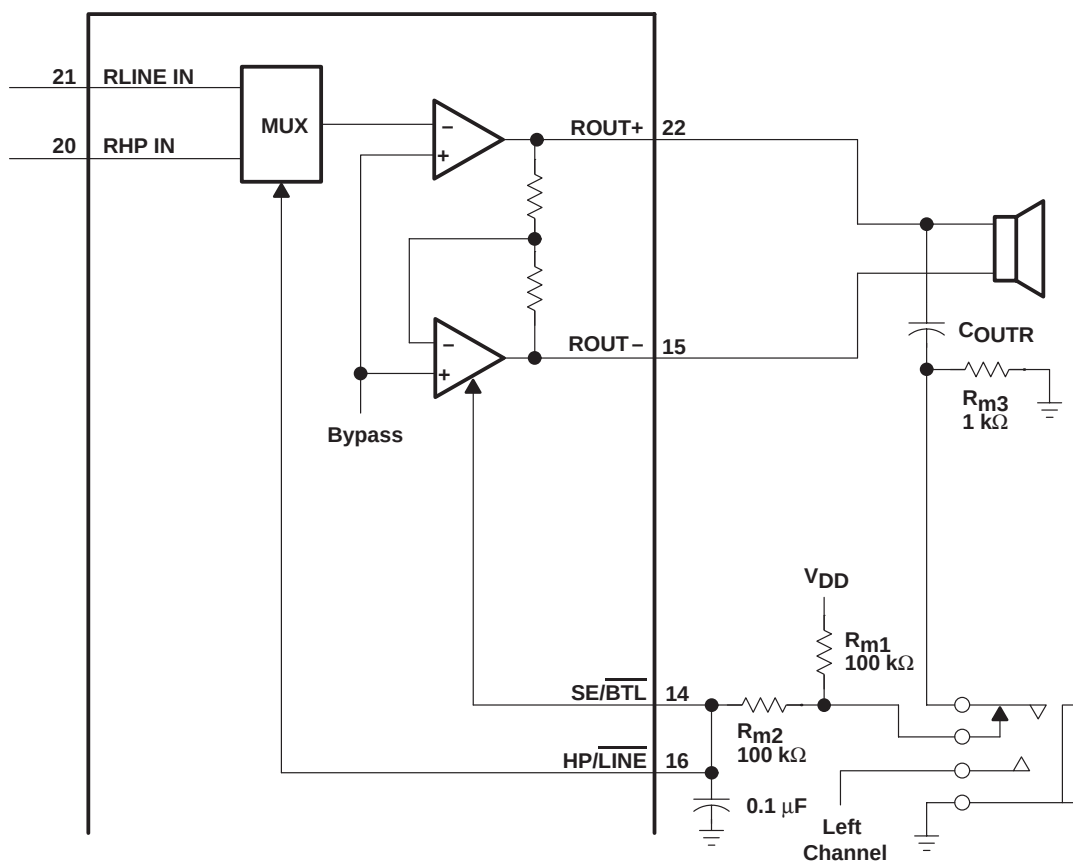


Figure 68. TPA0202 Resistor Divider Network Circuit

Using a readily available 1/8-in. (3.5 mm) stereo headphone jack, the control switch is closed when no plug is inserted. When closed the 100-kΩ/1-kΩ divider pulls the SE/BTL input low. When a plug is inserted, the 1-kΩ resistor is disconnected and the SE/BTL input is pulled high. When the input goes high, the OUT– amplifier is shutdown causing the speaker to mute (virtually open-circuits the speaker). The OUT+ amplifier then drives through the output capacitor ( $C_O$ ) into the headphone jack.

As shown in the full feature application (Figure 63), the input MUX control can be tied to the SE/BTL input. The benefits of doing this are described in the following input MUX operation section.

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#### Input MUX operation

Working in concert with the SE/BTL feature, the HP/LINE MUX feature gives the audio designer the flexibility of a multichip design in a single IC (see Figure 69). The primary function of the MUX is to allow different gain settings for BTL versus SE mode. Speakers typically require approximately a factor of 10 more gain for similar volume listening levels as compared to headphones. To achieve headphone and speaker listening parity, the resistor values would need to be set as follows:

$$\text{SE Gain}_{(\text{HP})} = - \left( \frac{R_{F(\text{HP})}}{R_{I(\text{HP})}} \right) \quad (15)$$

If, for example  $R_{I(\text{HP})} = 10 \text{ k}\Omega$  and  $R_{F(\text{HP})} = 10 \text{ k}\Omega$  then  $\text{SE Gain}_{(\text{HP})} = -1$

$$\text{BTL Gain}_{(\text{LINE})} = -2 \left( \frac{R_{F(\text{LINE})}}{R_{I(\text{LINE})}} \right) \quad (16)$$

If, for example  $R_{I(\text{LINE})} = 10 \text{ k}\Omega$  and  $R_{F(\text{LINE})} = 50 \text{ k}\Omega$  then  $\text{BTL Gain}_{(\text{LINE})} = -10$

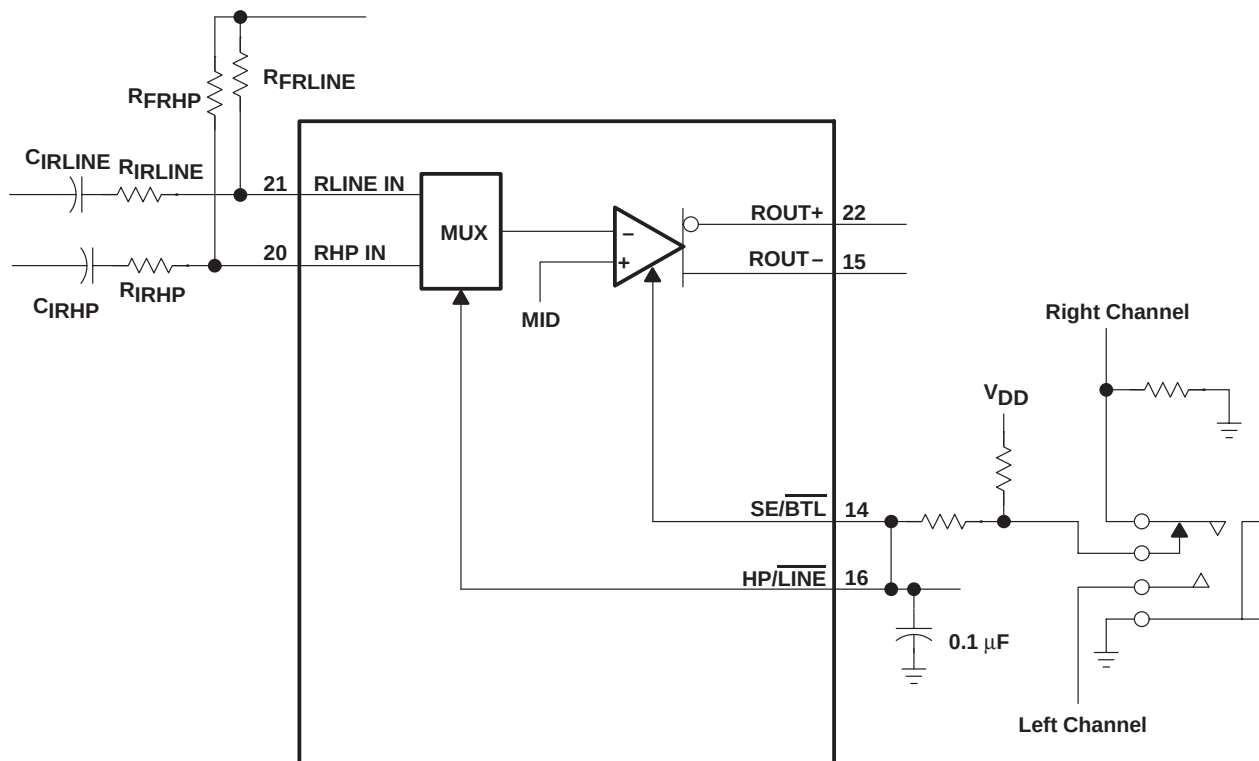


Figure 69. TPA0202 Example Input MUX Circuit

Another advantage of using the MUX feature is setting the gain of the headphone channel to  $-1$ . This provides the optimum distortion performance into the headphones where clear sound is more important. Refer to the SE/BTL operation section for a description of the headphone jack control circuit.

## APPLICATION INFORMATION

### mute and shutdown modes

The TPA0202 employs both a mute and a shutdown mode of operation designed to reduce supply current,  $I_{DD}$ , to the absolute minimum level during periods of nonuse for battery-power conservation. 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,  $I_{DD} = 5 \mu\text{A}$ . SHUTDOWN or MUTE IN should never be left unconnected because amplifier operation would be unpredictable. Mute mode alone reduces  $I_{DD}$  to 1.5 mA.

**Table 3. Shutdown and Mute Mode Functions**

| INPUTS <sup>†</sup> |         |         |          | OUTPUT   | AMPLIFIER STATE |        |
|---------------------|---------|---------|----------|----------|-----------------|--------|
| SE/BTL              | HP/LINE | MUTE IN | SHUTDOWN | MUTE OUT | INPUT           | OUTPUT |
| Low                 | Low     | Low     | Low      | Low      | L/R Line        | BTL    |
| X                   | X       | —       | High     | —        | X               | Mute   |
| X                   | X       | High    | —        | High     | X               | Mute   |
| Low                 | High    | Low     | Low      | Low      | L/R HP          | BTL    |
| High                | Low     | Low     | Low      | Low      | L/R Line        | SE     |
| High                | High    | Low     | Low      | Low      | L/R HP          | SE     |

<sup>†</sup> Inputs should never be left unconnected.

X = do not care

### 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.

### 5-V versus 3.3-V operation

The TPA0202 operates over a supply range of 3 V to 5.5 V. This data sheet provides full specifications for 5-V and 3.3-V operation, as these 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 goes. For 3.3-V operation, supply current is reduced from 19 mA (typical) to 13 mA (typical). The most important consideration is that of output power. Each amplifier in TPA0202 can produce a maximum voltage swing of  $V_{DD} - 1 \text{ V}$ . This means, for 3.3-V operation, clipping starts to occur when  $V_{O(PP)} = 2.3 \text{ V}$  as opposed to  $V_{O(PP)} = 4 \text{ V}$  at 5 V. The reduced voltage swing subsequently reduces maximum output power into an 8- $\Omega$  load before distortion becomes significant.

Operation from 3.3-V supplies, as can be shown from the efficiency formula in equation 4, consumes approximately two-thirds the supply power for a given output-power level than operation from 5-V supplies. When the application demands less than 500 mW, 3.3-V operation should be strongly considered, especially in battery-powered applications to improve the efficiency.

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#### APPLICATION INFORMATION

##### headroom and thermal considerations

Linear 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 headroom to pass the loudest portions without distortion as compared with the average power output. From the TPA0202 data sheet, one can see that when the TPA0202 is operating from a 5-V supply into a 3-Ω speaker that 2 W peaks are available. Converting watts to dB:

$$\begin{aligned} P_{\text{dB}} &= 10 \text{Log} \left( \frac{P_W}{P_{\text{ref}}} \right) \\ &= 10 \text{Log} \left( \frac{2}{1} \right) \\ &= 3.0 \text{ dB} \end{aligned} \tag{17}$$

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

$$\begin{aligned} 3.0 \text{ dB} - 15 \text{ dB} &= -12 \text{ dB} \text{ (15 dB headroom)} \\ 3.0 \text{ dB} - 12 \text{ dB} &= -9 \text{ dB} \text{ (12 dB headroom)} \\ 3.0 \text{ dB} - 9 \text{ dB} &= -6 \text{ dB} \text{ (9 dB headroom)} \\ 3.0 \text{ dB} - 6 \text{ dB} &= -3 \text{ dB} \text{ (6 dB headroom)} \\ 3.0 \text{ dB} - 3 \text{ dB} &= 0 \text{ dB} \text{ (3 dB headroom)} \end{aligned}$$

Converting dB back into watts:

$$\begin{aligned} P_W &= 10^{P_{\text{dB}}/10} \times P_{\text{ref}} \\ &= 63 \text{ mW} \text{ (15 dB headroom)} \\ &= 120 \text{ mW} \text{ (12 dB headroom)} \\ &= 250 \text{ mW} \text{ (9 dB headroom)} \\ &= 500 \text{ mW} \text{ (6 dB headroom)} \\ &= 1000 \text{ mW} \text{ (3 dB headroom)} \end{aligned} \tag{18}$$

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 0 dB of headroom, against 12 dB and 15 dB applications drastically affects maximum ambient temperature ratings for the system. Using the power dissipation curves for a 5-V, 3-Ω system, the internal dissipation in the TPA0202 and maximum ambient temperatures is shown in Table 4.

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#### headroom and thermal considerations (continued)

Table 4. TPA0202 Power Rating, 5-V, 3-Ω, Stereo

| PEAK OUTPUT POWER (W) | AVERAGE OUTPUT POWER | POWER DISSIPATION (W/Channel) | MAXIMUM AMBIENT TEMPERATURE |
|-----------------------|----------------------|-------------------------------|-----------------------------|
| 2                     | 2 W                  | 1.7                           | –3°C                        |
| 2                     | 1000 mW (3 dB)       | 1.6                           | 6°C                         |
| 2                     | 500 mW (6 dB)        | 1.4                           | 24°C                        |
| 2                     | 250 mW (9 dB)        | 1.1                           | 51°C                        |
| 2                     | 120 mW (12 dB)       | 0.8                           | 78°C                        |
| 2                     | 63 mW (15 dB)        | 0.6                           | 96°C                        |

DISSIPATION RATING TABLE

| PACKAGE | T <sub>A</sub> ≤ 25°C | DERATING FACTOR | T <sub>A</sub> = 70°C | T <sub>A</sub> = 85°C |
|---------|-----------------------|-----------------|-----------------------|-----------------------|
| PWP†    | 2.7 W                 | 21.8 mW/°C      | 1.7 W                 | 1.4 W                 |
| PWP‡    | 2.8 W                 | 22.1 mW/°C      | 1.8 W                 | 1.4 W                 |

† This parameter is measured with the recommended copper heat sink pattern on a 1-layer PCB, 4 in<sup>2</sup> 5-in × 5-in PCB, 1 oz. copper, 2-in × 2-in coverage.

‡ This parameter is measured with the recommended copper heat sink pattern on an 8-layer PCB, 6.9 in<sup>2</sup> 1.5-in × 2-in PCB, 1 oz. copper with layers 1, 2, 4, 5, 7, and 8 at 5% coverage (0.9 in<sup>2</sup>) and layers 3 and 6 at 100% coverage (6 in<sup>2</sup>).

The maximum ambient temperature depends on the heatsinking ability of the PCB system. Using the 0 CFM and 300 CFM data from the dissipation rating table, the derating factor for the PWP package with 6.9 in<sup>2</sup> of copper area on a multilayer PCB is 22 mW/°C and 54 mW/°C respectively. Converting this to Θ<sub>JA</sub>:

$$\Theta_{JA} = \frac{1}{\text{Derating}} \quad (19)$$

For 0 CFM :

$$\begin{aligned}
 &= \frac{1}{0.022} \\
 &= 45^\circ\text{C/W}
 \end{aligned}$$

To calculate maximum ambient temperatures, first consider that the numbers from the dissipation graphs are per channel so the dissipated heat needs to be doubled for two channel operation. Given Θ<sub>JA</sub>, 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 TPA0202 is 150 °C. The internal dissipation figures are taken from the Power Dissipation vs Output Power graphs.

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#### headroom and thermal considerations (continued)

$$\begin{aligned} T_{A \text{ Max}} &= T_{J \text{ Max}} - \Theta_{JA} P_D \\ &= 150 - 45(0.6 \times 2) = 96^\circ\text{C} \text{ (15 dB headroom, 0 CFM)} \end{aligned} \quad (20)$$

#### NOTE:

Internal dissipation of 0.6 W is estimated for a 2-W system with 15 dB headroom per channel.

Table 4 shows that for some applications no airflow is required to keep junction temperatures in the specified range. The TPA0202 is designed with thermal protection that turns the device off when the junction temperature surpasses 150°C to prevent damage to the IC. Table 4 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.

#### junction temperature measurement

Characterizing a PCB layout with respect to thermal impedance is very difficult, as it is usually impossible to know the junction temperature of the IC in question. The TPA0202 terminal 2 (TJ) sources a current proportional to the junction temperature. The circuit internal to TJ is shown in Figure 70.

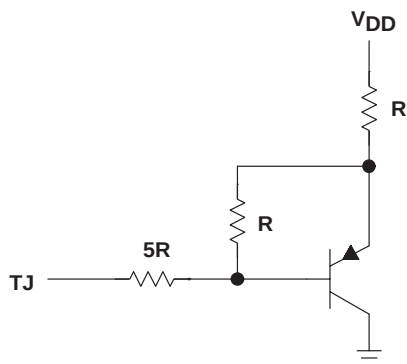


Figure 70. TJ Terminal Internal Circuit

Connect an ammeter between TJ and ground to measure the current. As the resistors have a tolerance of  $\pm 20\%$ , this measurement must be calibrated on each device. The intent of this function is in characterization of the PCB and end equipment and not a real-time measurement of temperature. Typically a 25°C reading is  $-120 \mu\text{A}$  for a 3.3-V supply and  $-135 \mu\text{A}$  for a 5-V supply. The slope is approximately  $0.25 \mu\text{A}/^\circ\text{C}$  for both  $V_{DD} = 3.3 \text{ V}$  and  $V_{DD} = 5 \text{ V}$ . To reduce quiescent current, do not ground TJ in normal operation. It can be connected to  $V_{DD}$  or left floating as it has a resistor connected across the base-emitter junction.



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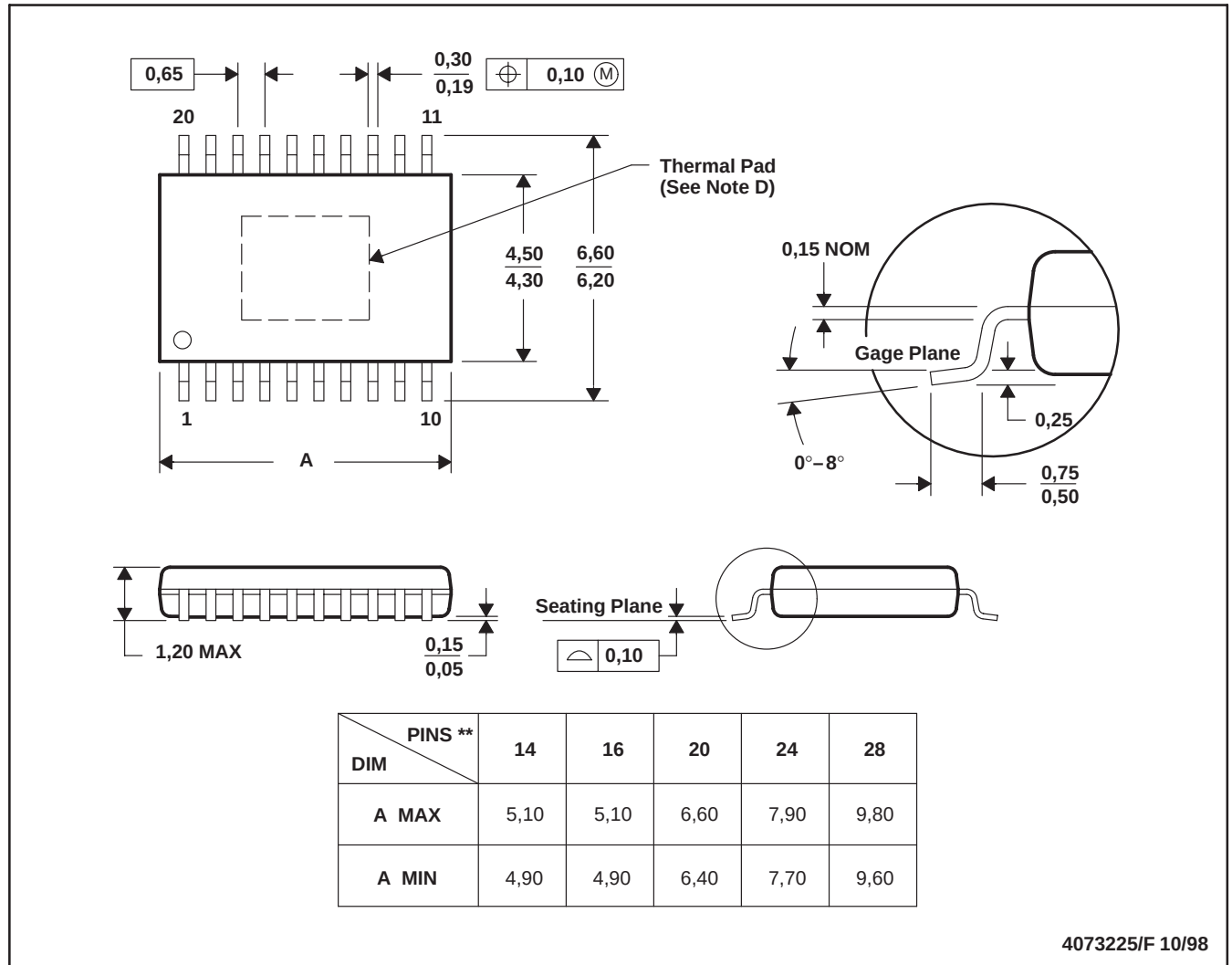
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### MECHANICAL INFORMATION

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

PowerPAD™ PLASTIC SMALL-OUTLINE

20 PINS SHOWN



- 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 protrusions.
  - D. The package thermal performance may be enhanced by bonding the thermal pad to an external thermal plane. This pad is electrically and thermally connected to the backside of the die and possibly selected leads.
  - E. Falls within JEDEC MO-153

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