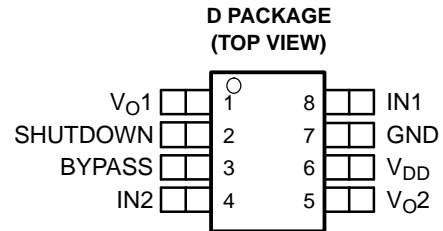




300-mW STEREO AUDIO POWER AMPLIFIER

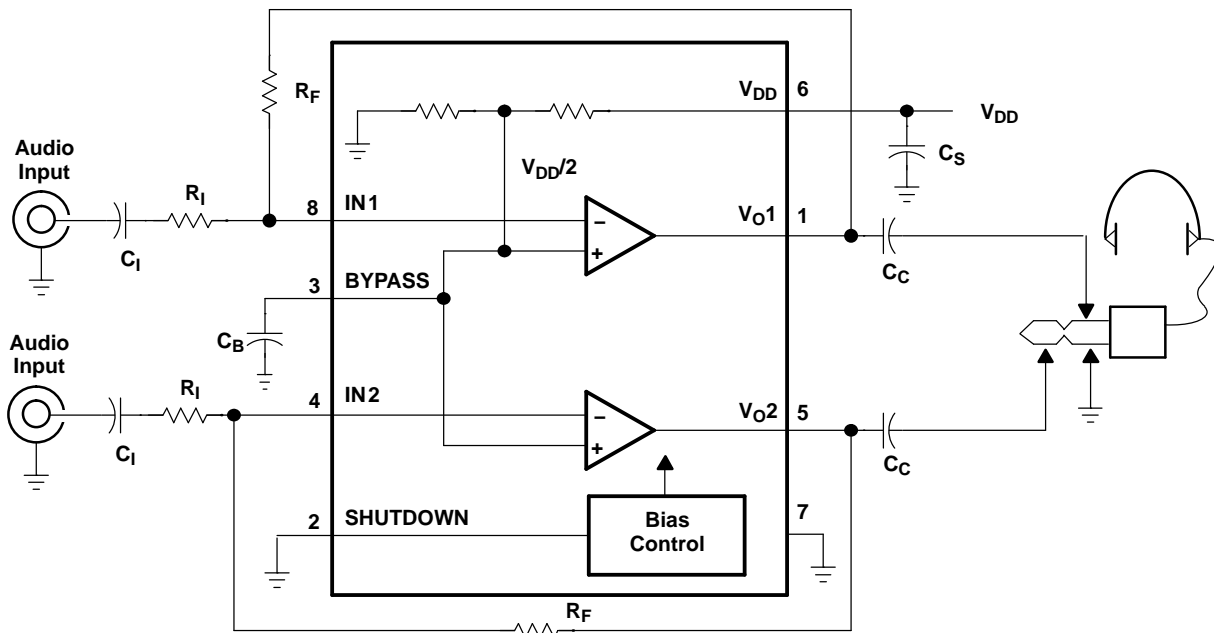
- 300-mW Stereo Output
- PC Power Supply Compatibility 5-V and 3.3-V Specified Operation
- Shutdown Control
- Internal Midrail Generation
- Thermal and Short-Circuit Protection
- Surface-Mount Packaging
- Functional Equivalent of the LM4880



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.



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

AVAILABLE OPTIONS

| | |
|---------------|--|
| T_A | PACKAGED DEVICES |
| | SMALL OUTLINE⁽¹⁾ (D) |
| –40°C to 85°C | TPA302D |

(1) 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)⁽¹⁾

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

(1) 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 | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING |
|----------------|--|--|---|---|
| D | 731 mW | 5.8 mW/°C | 460 mW | 380 mW |

RECOMMENDED OPERATING CONDITIONS

| | MIN | MAX | UNIT |
|--------------------------------------|------------|------------|-------------|
| V_{DD} Supply voltage | 2.7 | 5.5 | V |
| T_A Operating free-air temperature | –40 | 85 | °C |

DC ELECTRICAL CHARACTERISTICS

at specified free-air temperature, $V_{DD} = 3.3$ V (unless otherwise noted)

| PARAMETER | TEST CONDITION | MIN | TYP | MAX | UNIT |
|--|---------------------------|------------|------------|------------|-------------|
| I_{DD} Supply current | | | 2.25 | 5 | mA |
| V_{IO} Input offset voltage | | | 5 | 20 | mV |
| PSRR Power supply rejection ratio | $V_{DD} = 3.2$ V to 3.4 V | | 55 | | dB |
| $I_{DD(SD)}$ Quiescent current in shutdown | | | 0.6 | 20 | µA |

AC OPERATING CHARACTERISTICS
 $V_{DD} = 3.3\text{ V}$, $T_A = 25^\circ\text{C}$, $R_L = 8\ \Omega$ (unless otherwise noted)

| PARAMETER | | TEST CONDITION | | MIN | TYP | MAX | UNIT |
|-----------|--------------------------------|-------------------------|---------------------------------|-----|-----|-----|------------------|
| P_O | Output power | Gain = -1, f = 1 kHz | THD < 0.08% | | 100 | | mW |
| | | | THD < 1% | | 125 | | |
| | | | THD < 0.08%, $R_L = 32\ \Omega$ | | 25 | | |
| | | | THD < 1%, $R_L = 32\ \Omega$ | | 35 | | |
| 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 kHz | | | 75 | | dB |
| | Supply ripple rejection ratio | f = 1 kHz | | | 45 | | dB |
| V_n | Noise output voltage | Gain = -1 | | | 10 | | μVrms |

DC ELECTRICAL CHARACTERISTICS

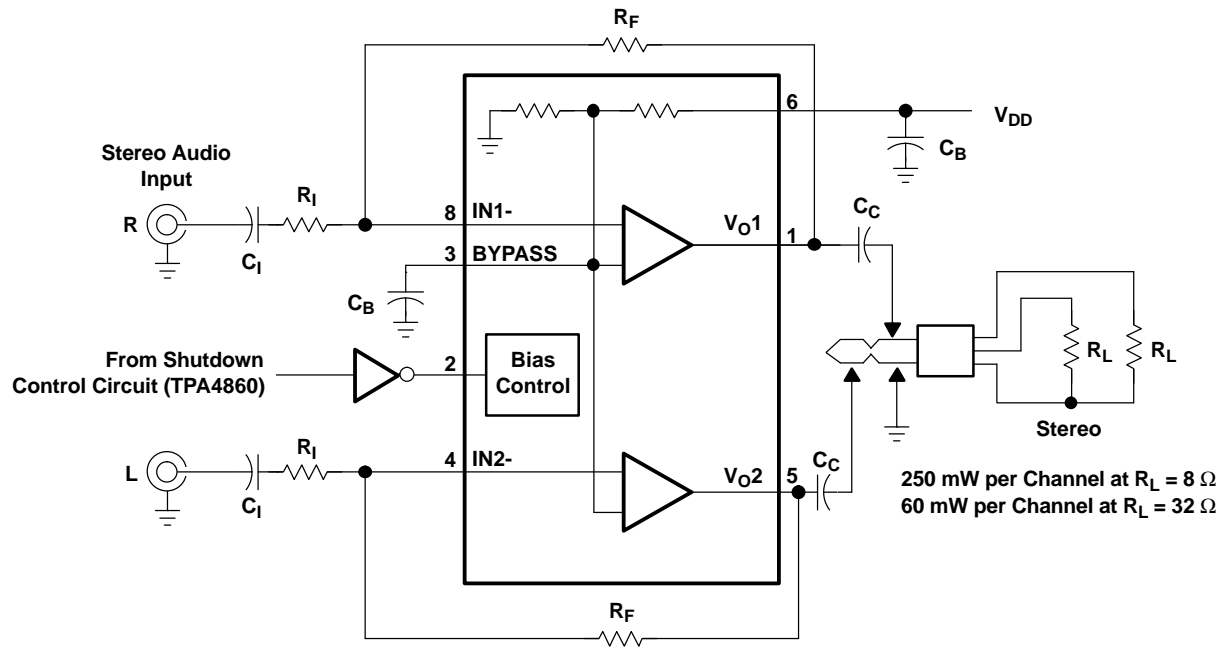
at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITION | MIN | TYP | MAX | UNIT |
|--------------|-------------------------------|--|-----|-----|-----|---------------|
| I_{DD} | Supply current | | | 4 | 10 | mA |
| V_{OO} | Output offset voltage | | | 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 | | μA |

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 kHz | THD < 0.06% | | 250 | | mW |
| | | | THD < 1% | | 300 | | |
| | | | THD < 0.06%, $R_L = 32\ \Omega$ | | 60 | | |
| | | | THD < 1%, $R_L = 32\ \Omega$ | | 80 | | |
| 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 kHz | | | 75 | | dB |
| | Supply ripple rejection ratio | f = 1 kHz | | | 45 | | dB |
| V_n | Noise output voltage | Gain = -1 | | | 10 | | μVrms |

TYPICAL APPLICATION



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 _{DD} | Supply current | vs Supply voltage | 25 |
| | | vs Free-air temperature | 26 |
| V _n | Output noise voltage | vs Frequency | 27, 28 |
| | | Maximum package power dissipation | vs Free-air temperature |
| | Power dissipation | vs Output power | 30, 31 |
| P _{Omax} | Maximum output power | vs Free-air temperature | 32, 33 |
| P _O | 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 + NOISE
vs
FREQUENCY**

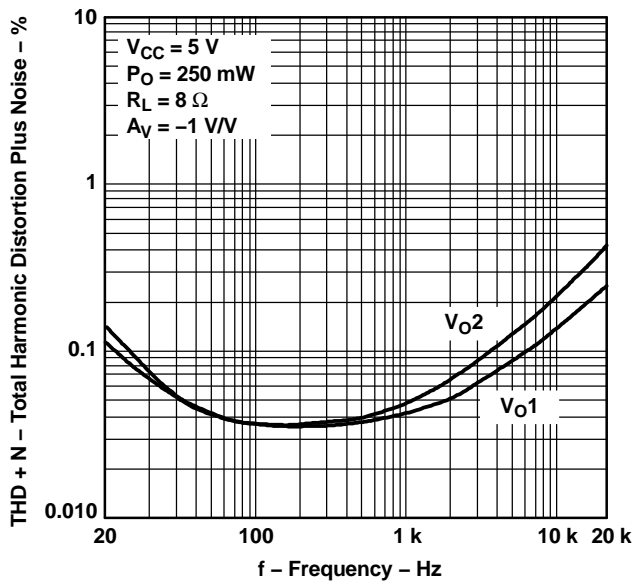


Figure 1.

**TOTAL HARMONIC DISTORTION + NOISE
vs
FREQUENCY**

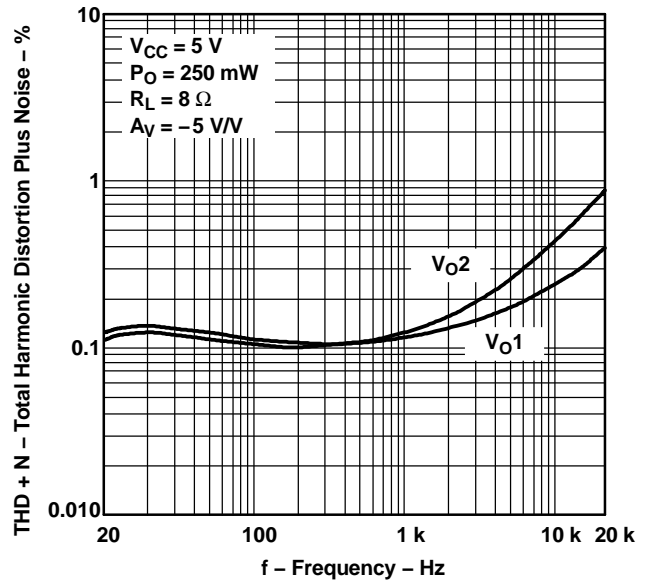


Figure 2.

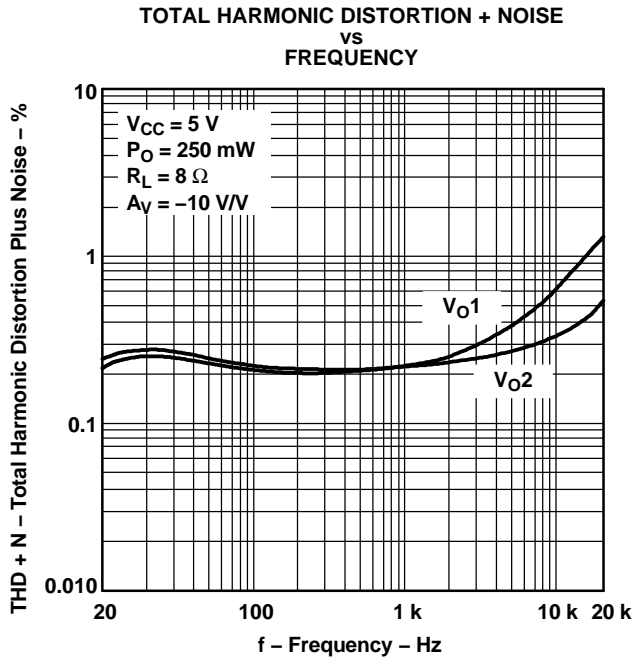


Figure 3.

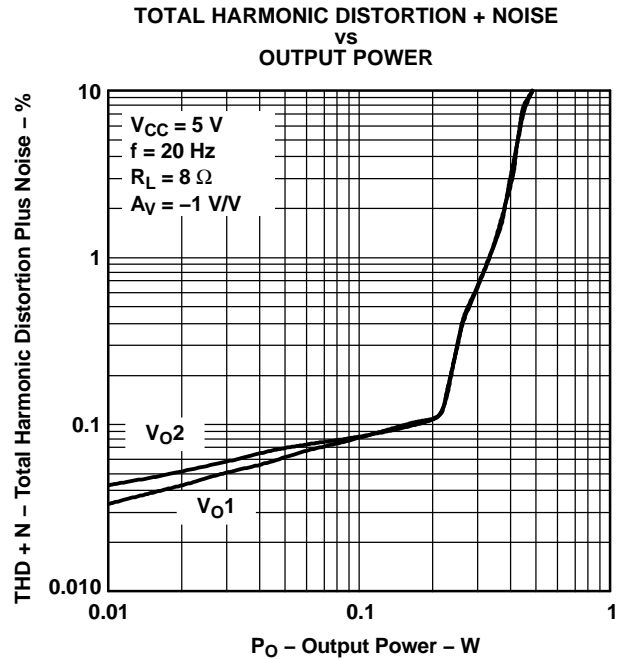


Figure 4.

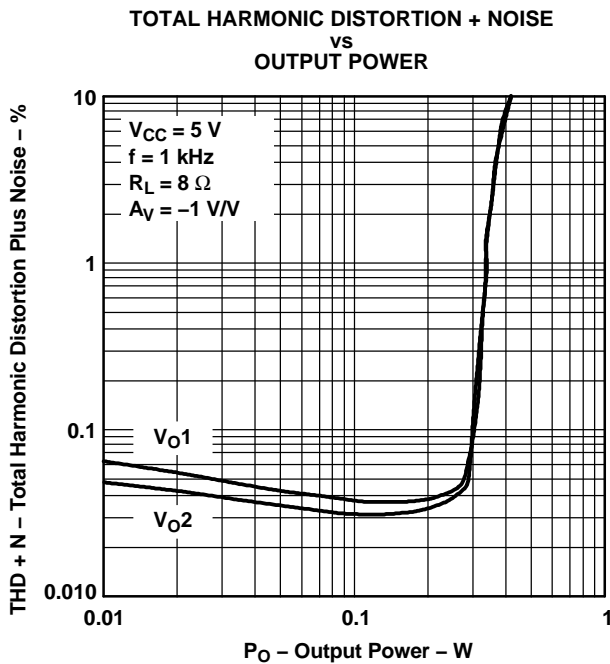


Figure 5.

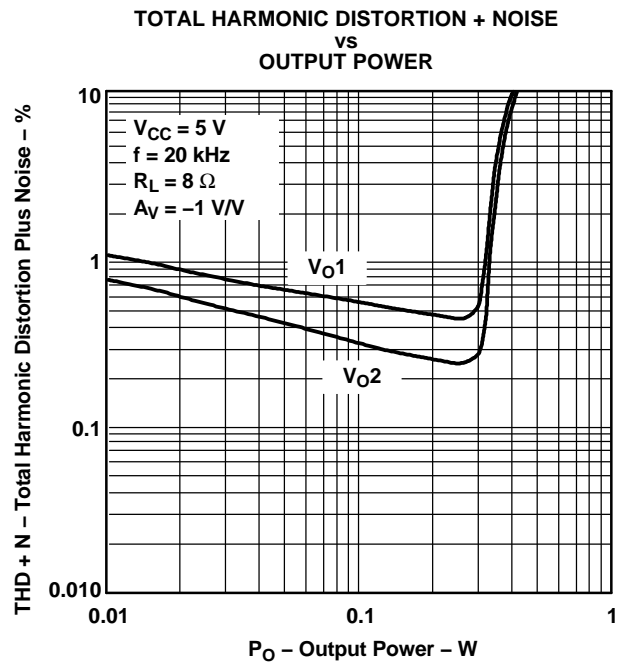


Figure 6.

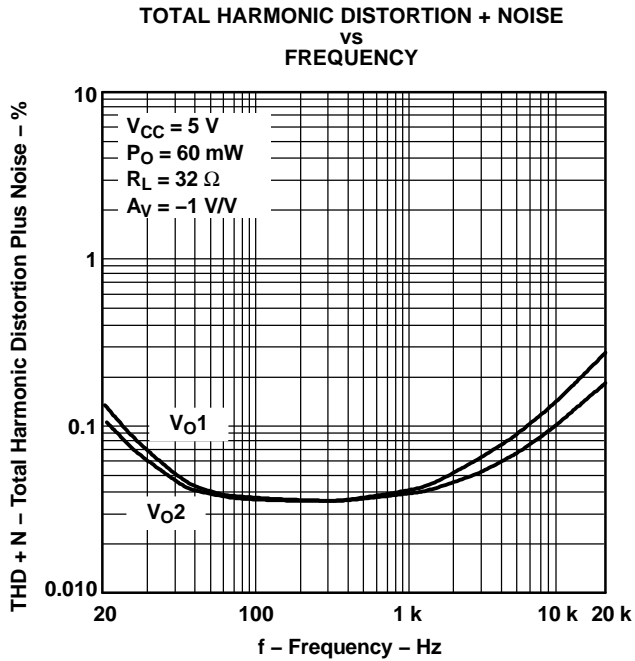


Figure 7.

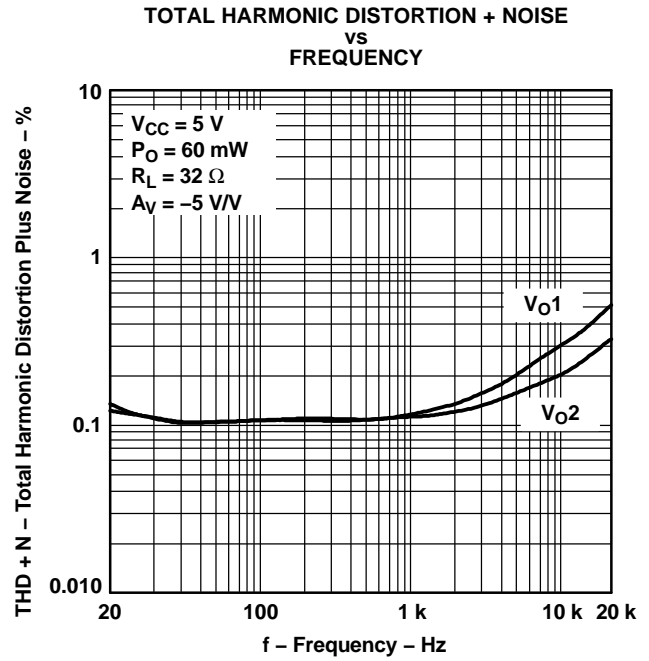


Figure 8.

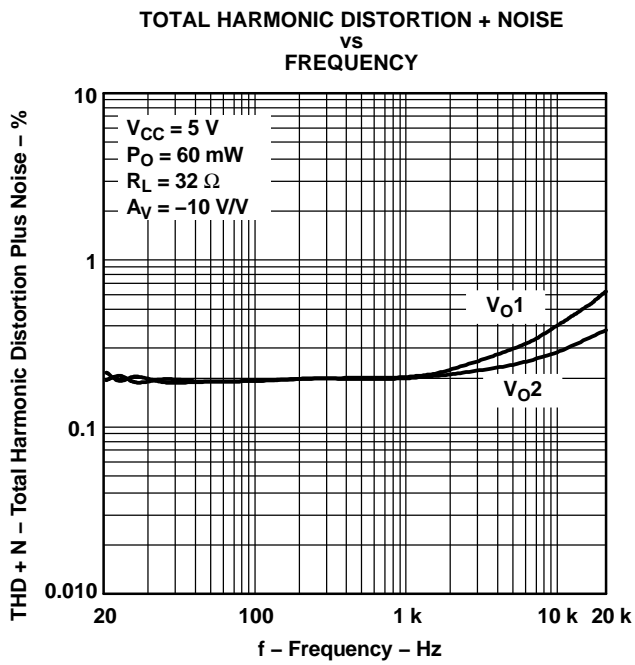


Figure 9.

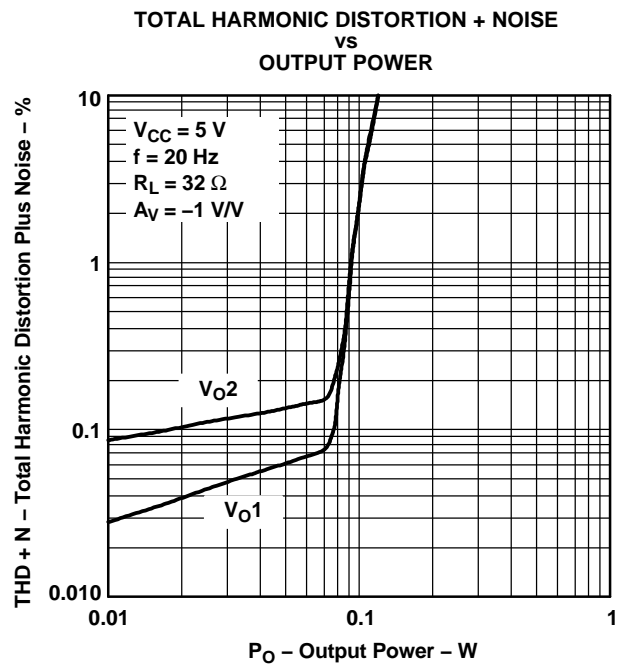


Figure 10.

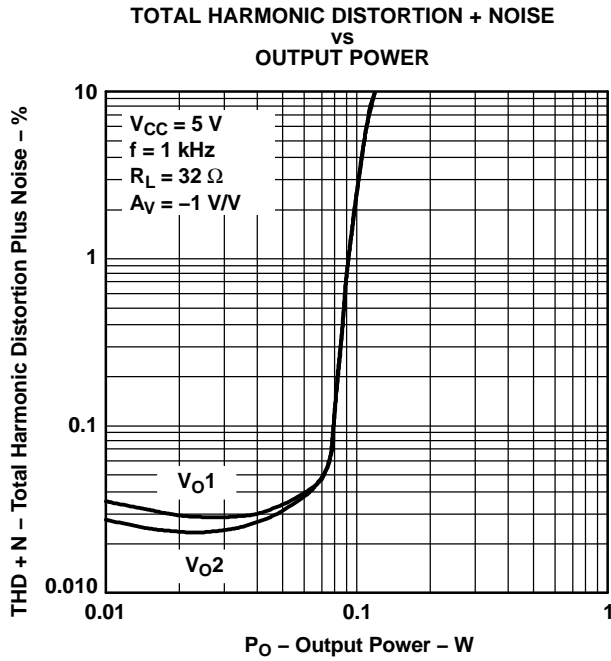


Figure 11.

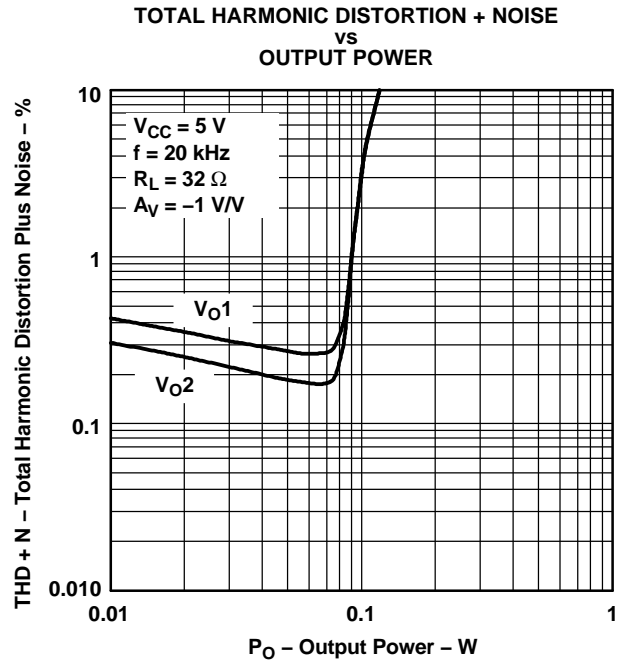


Figure 12.

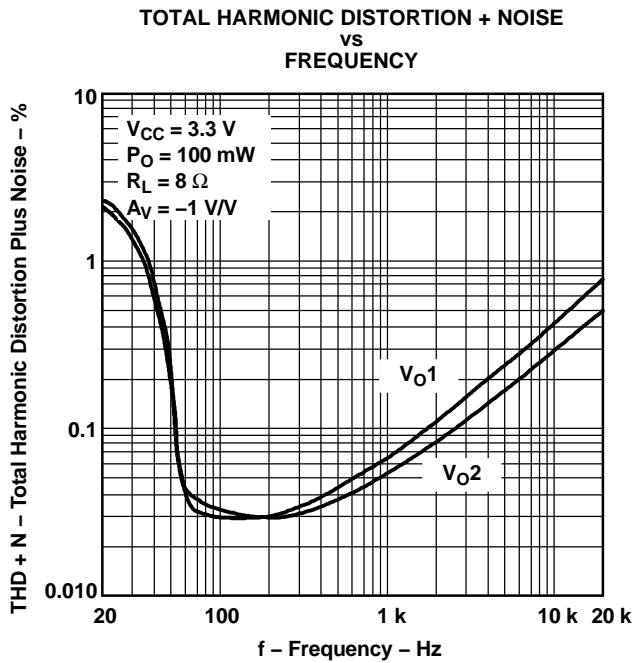


Figure 13.

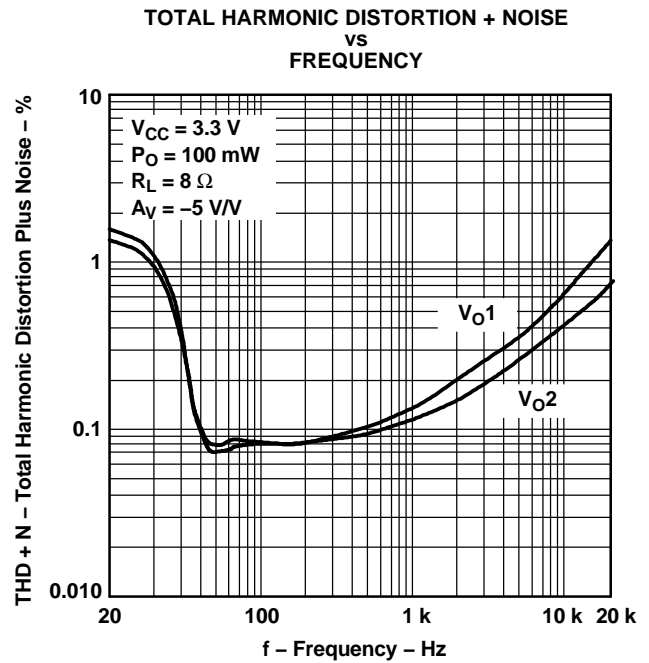


Figure 14.

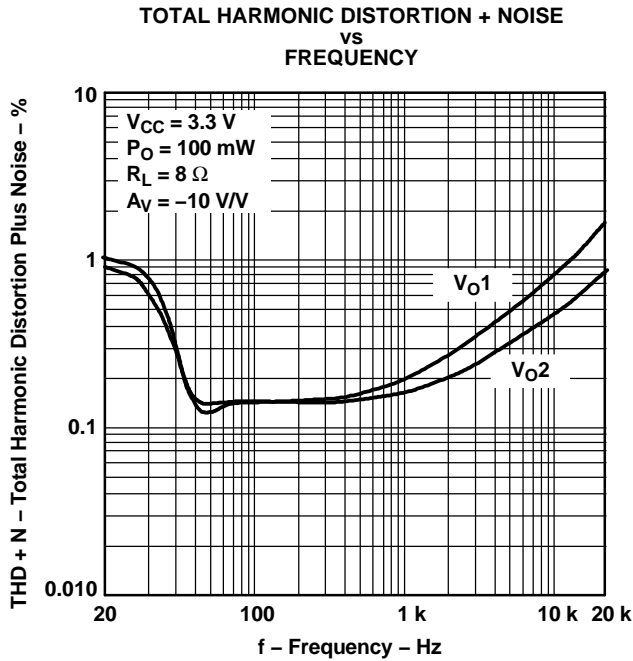


Figure 15.

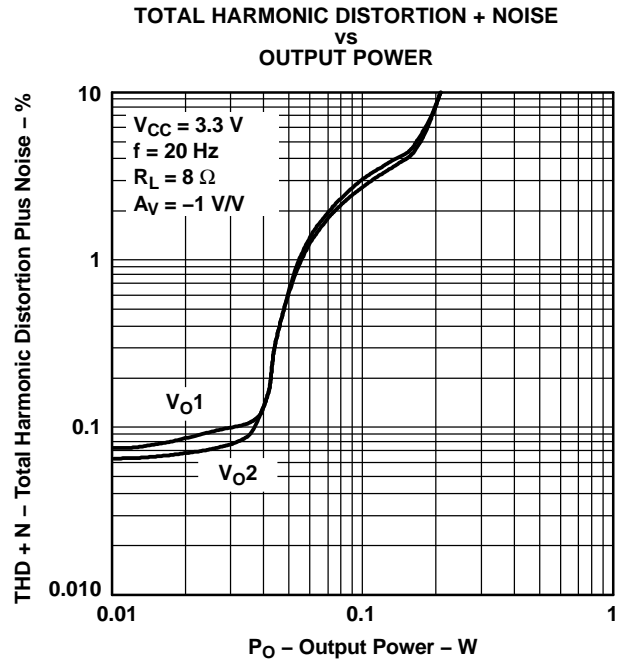


Figure 16.

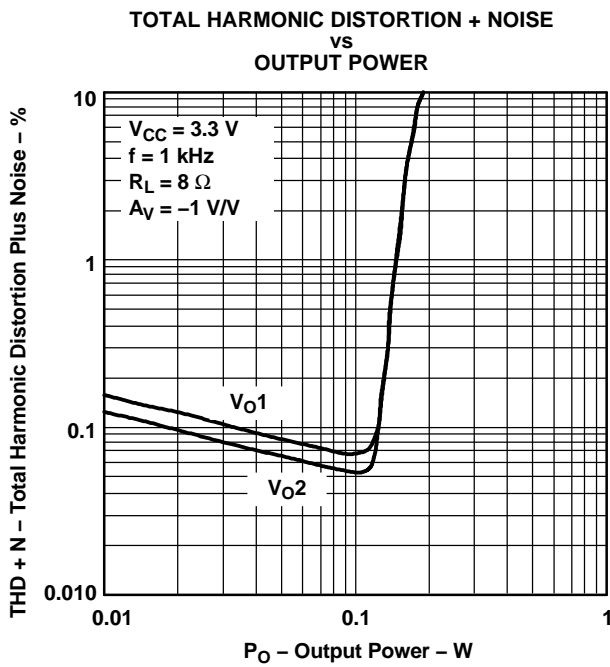


Figure 17.

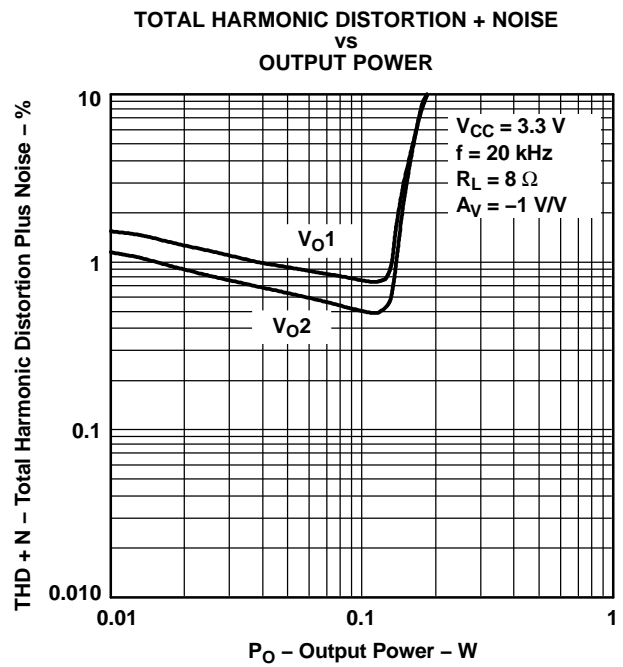


Figure 18.

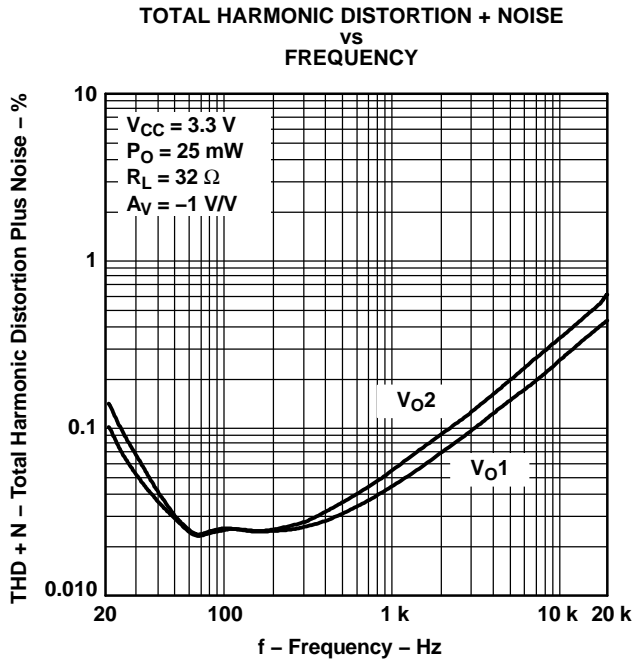


Figure 19.

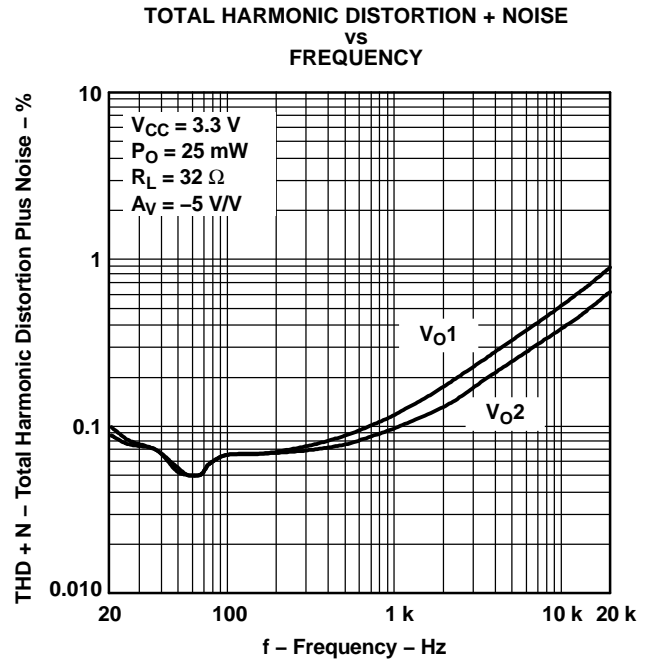


Figure 20.

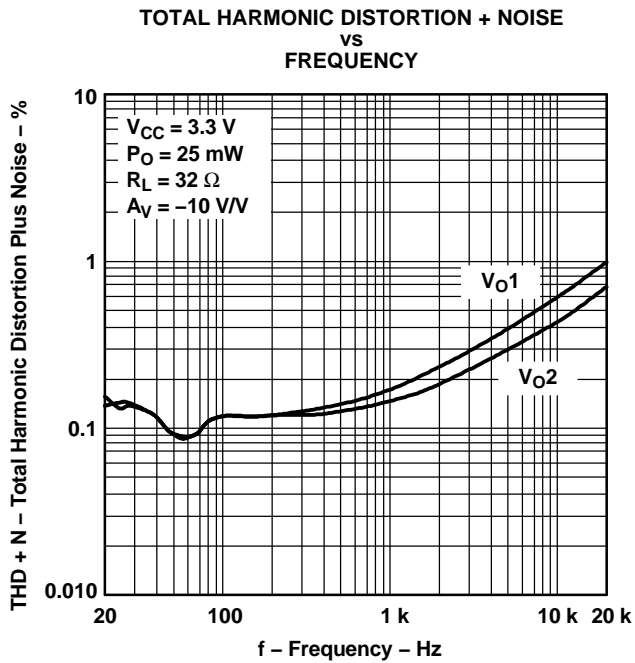


Figure 21.

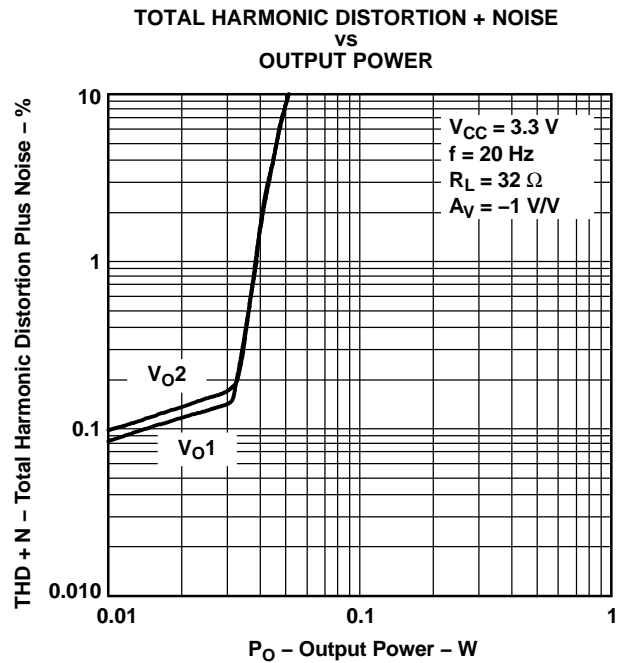


Figure 22.

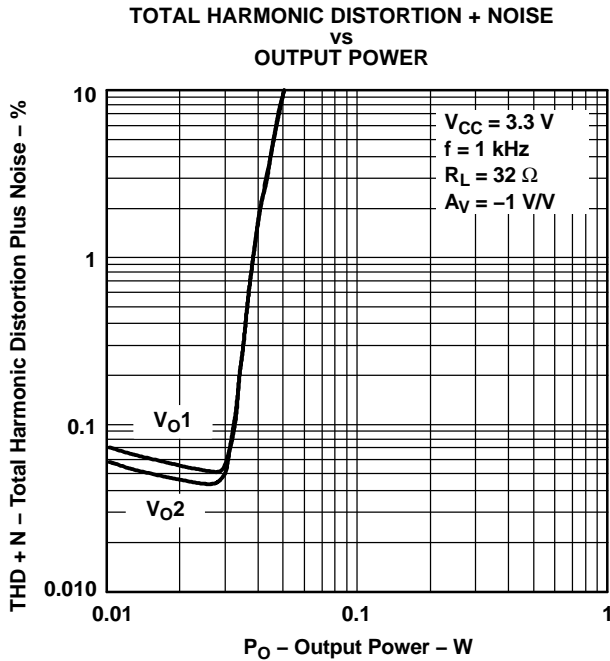


Figure 23.

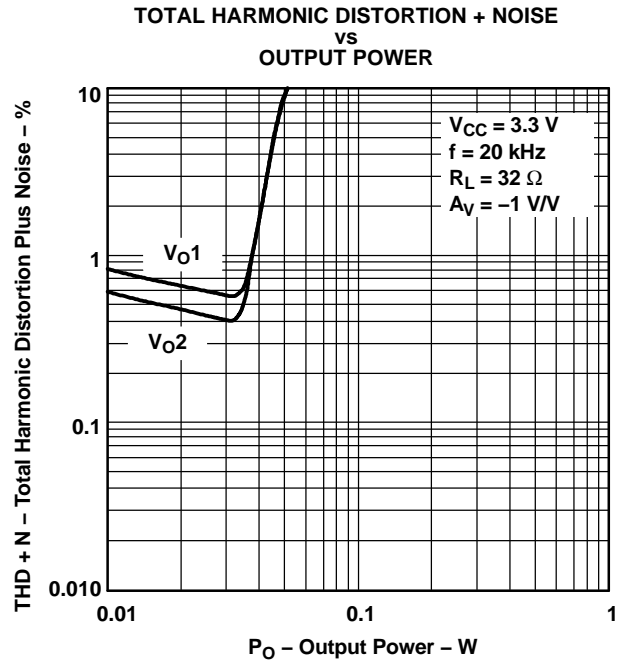


Figure 24.

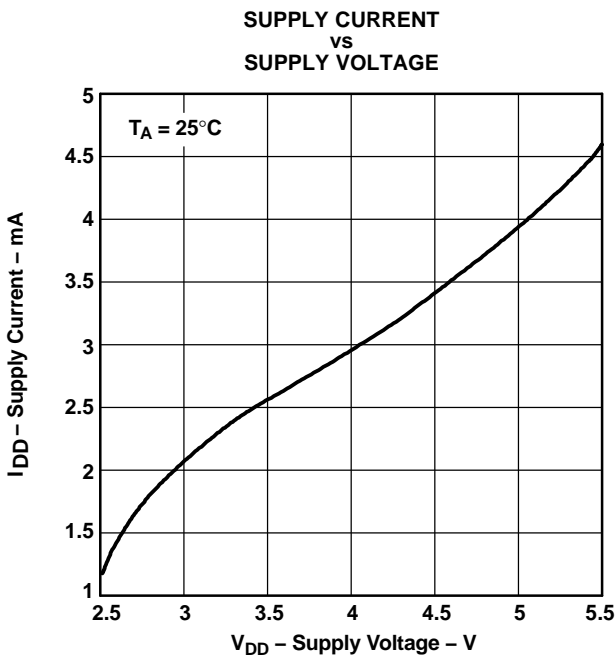


Figure 25.

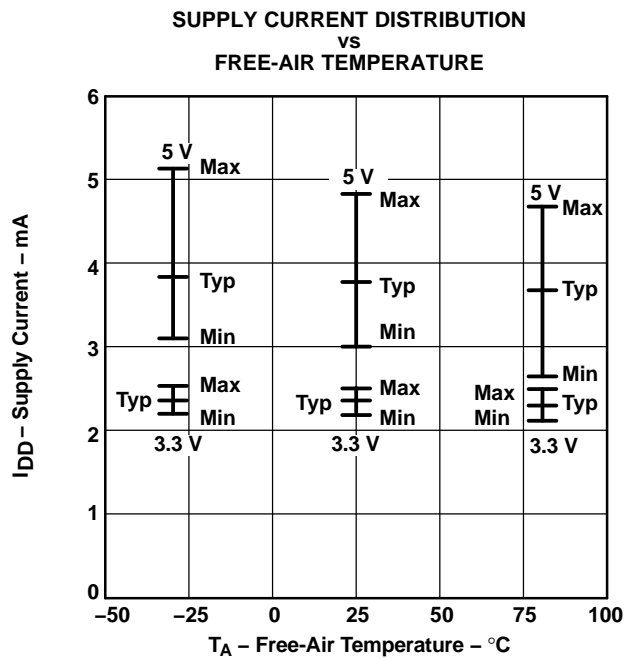


Figure 26.

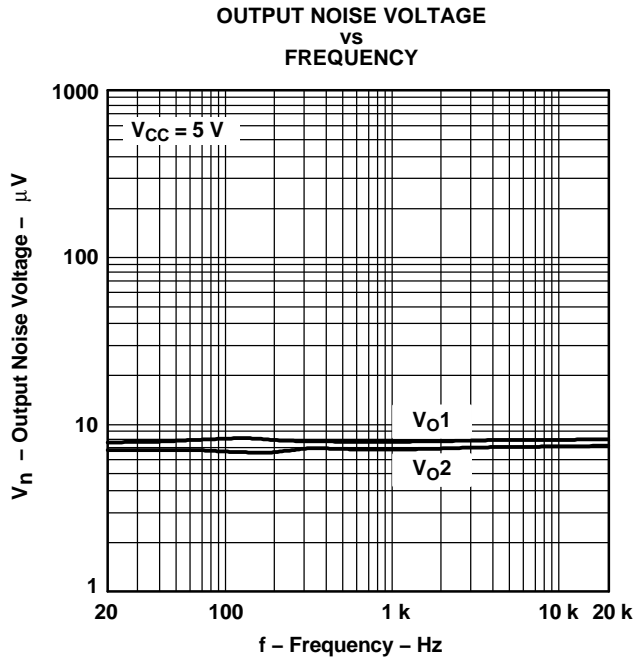


Figure 27.

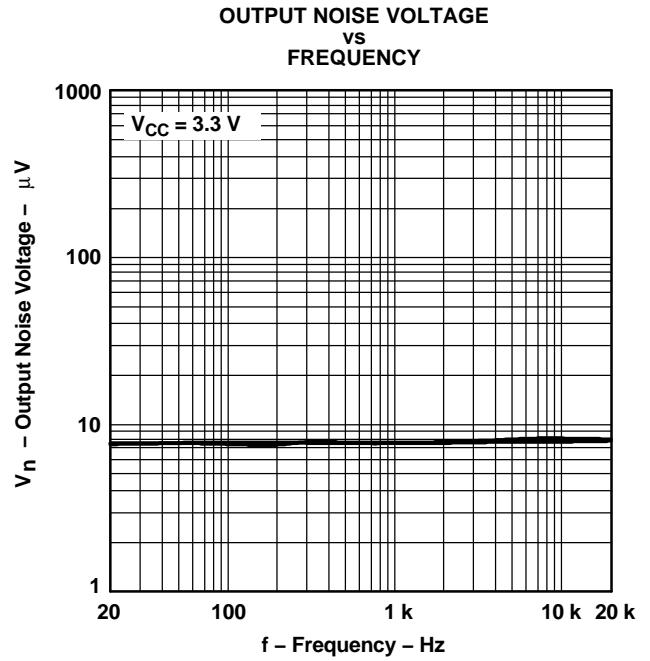


Figure 28.

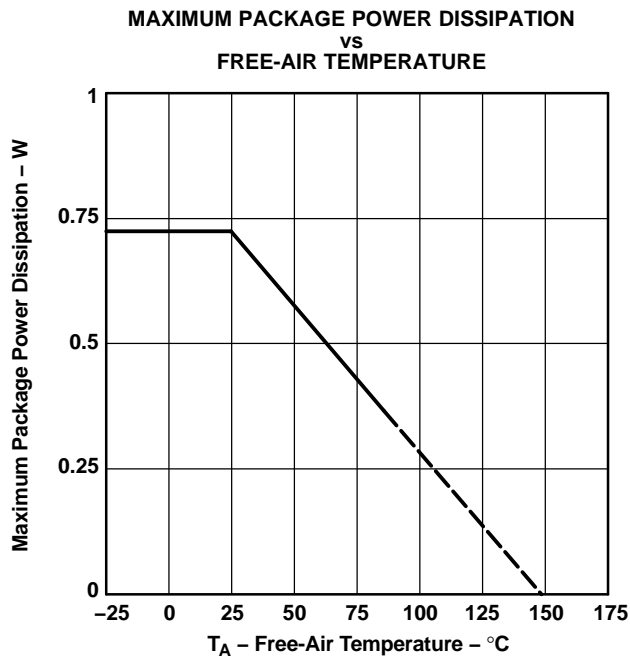


Figure 29.

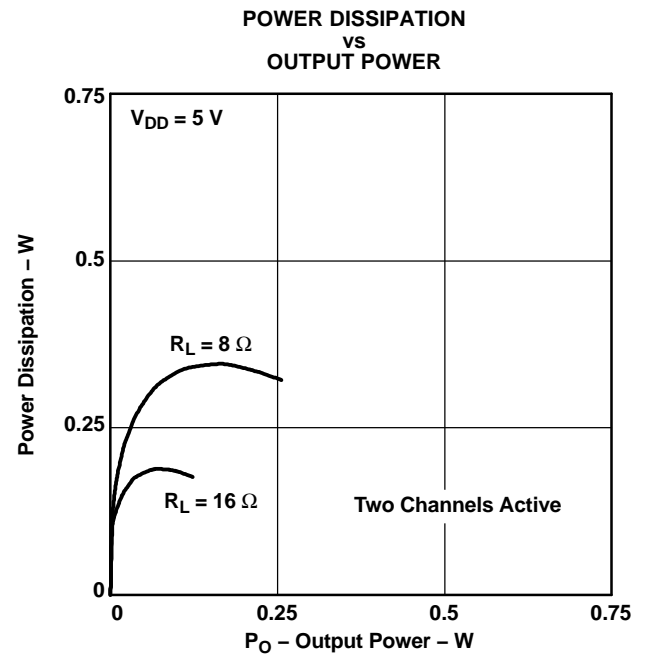


Figure 30.

POWER DISSIPATION
vs
OUTPUT POWER

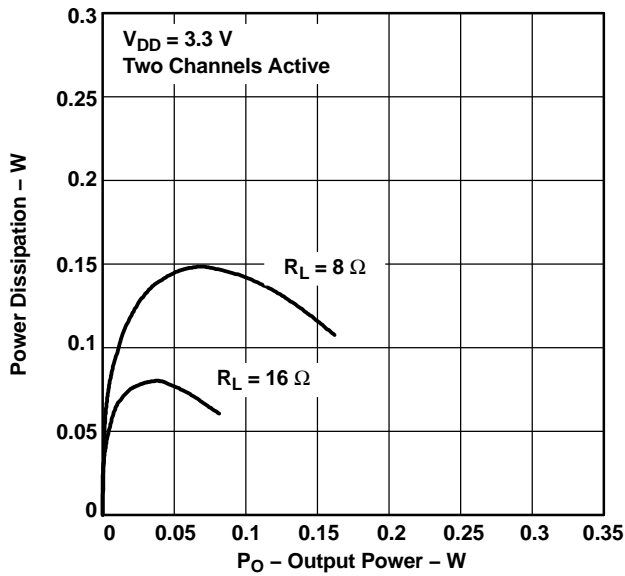


Figure 31.

MAXIMUM OUTPUT POWER
vs
FREE-AIR TEMPERATURE

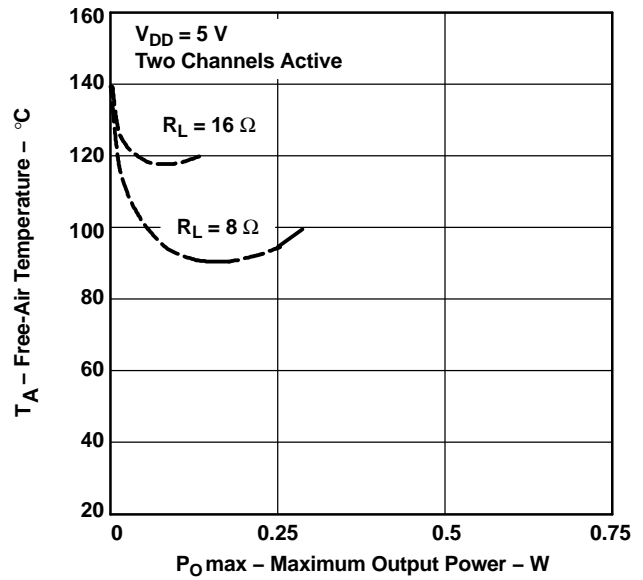


Figure 32.

MAXIMUM OUTPUT POWER
vs
FREE-AIR TEMPERATURE

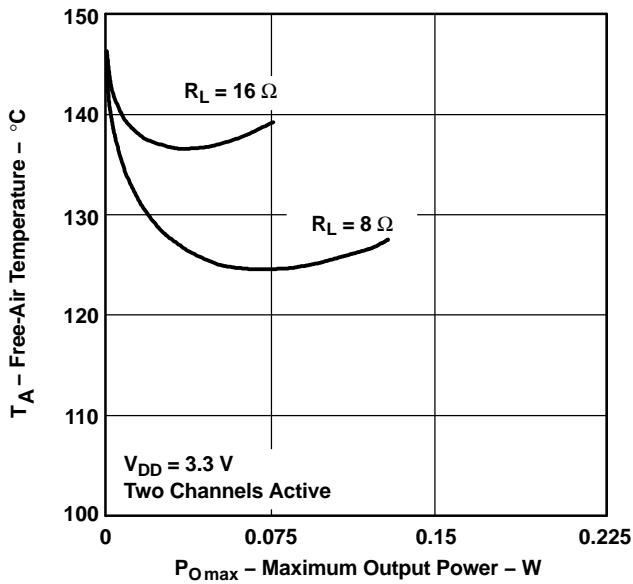


Figure 33.

OUTPUT POWER
vs
LOAD RESISTANCE

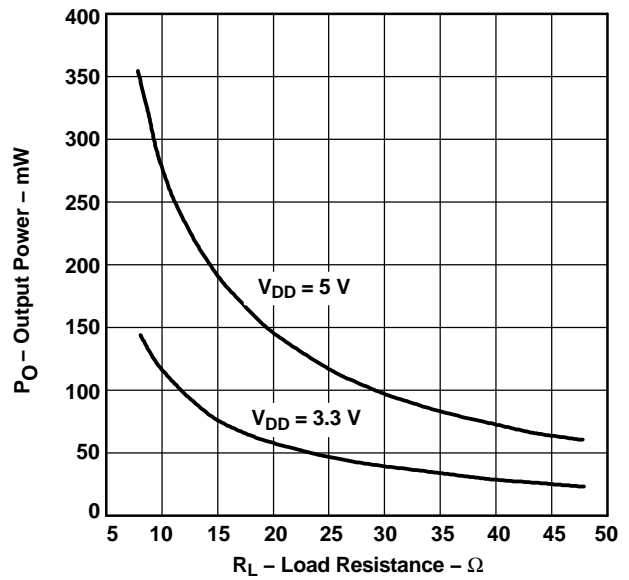


Figure 34.

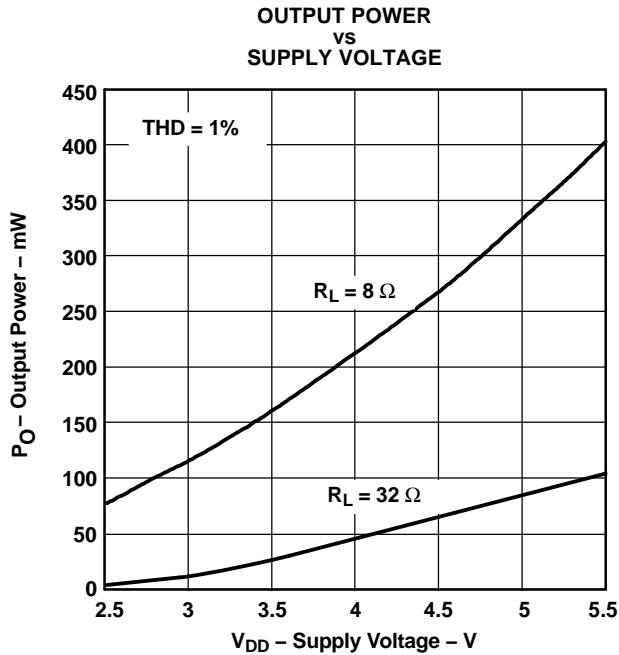


Figure 35.

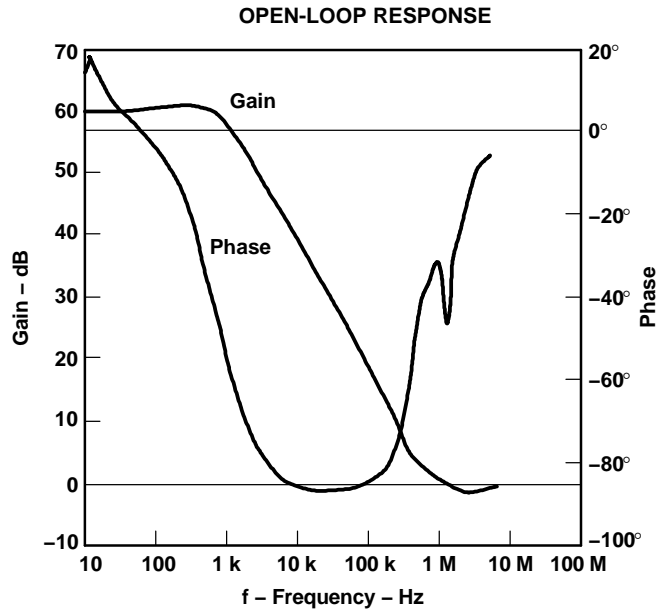


Figure 36.

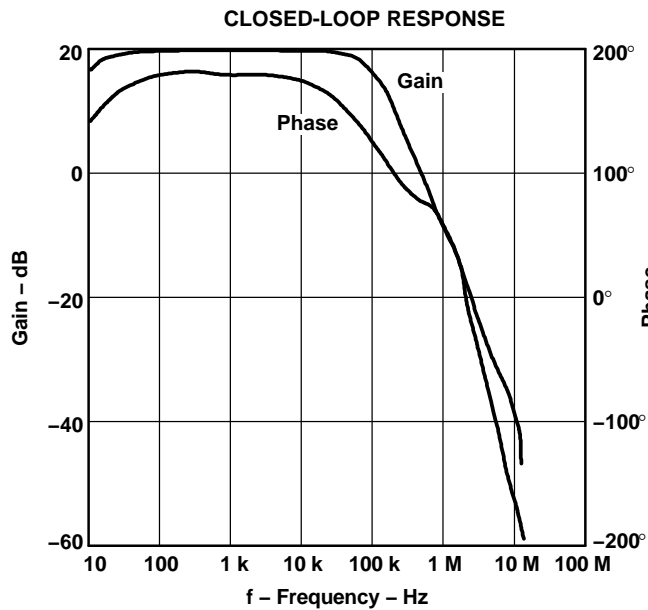


Figure 37.

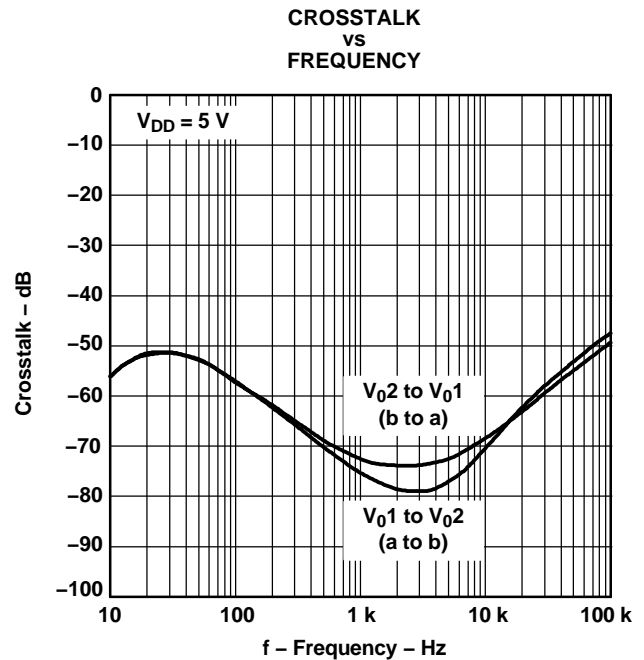


Figure 38.

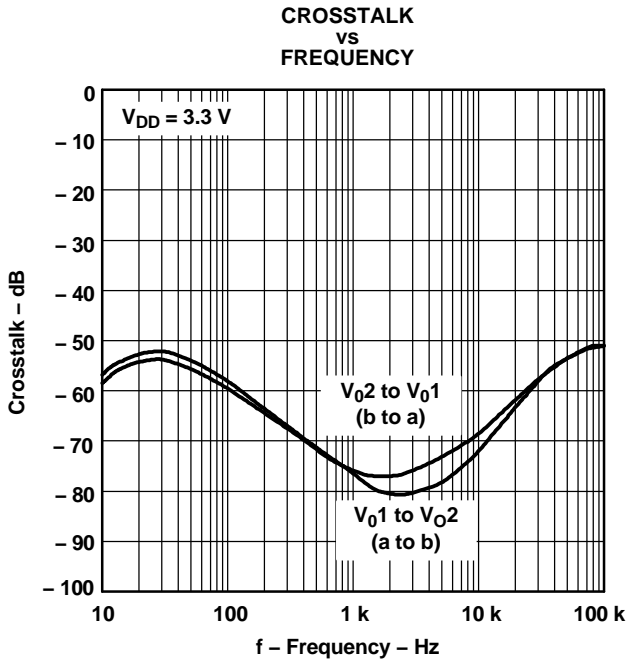


Figure 39.

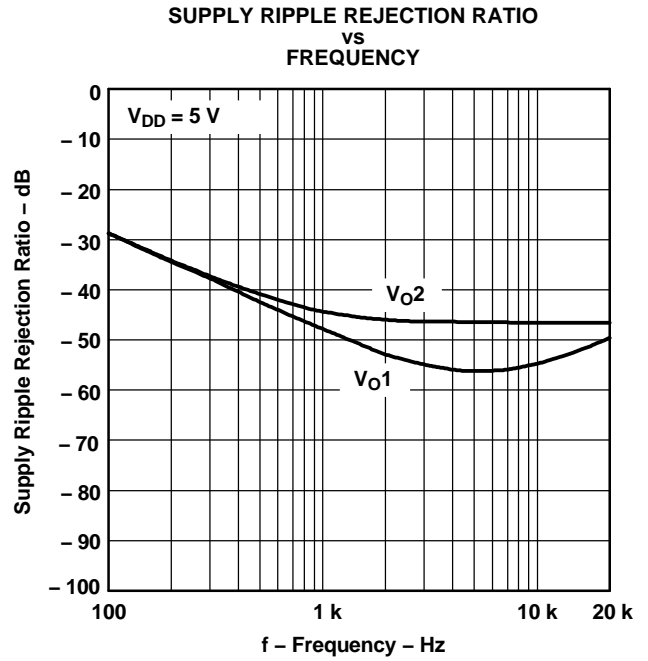


Figure 40.

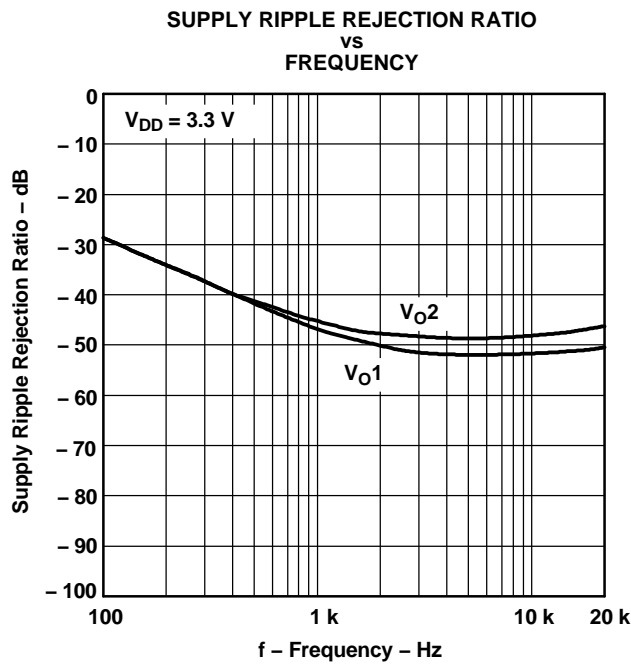
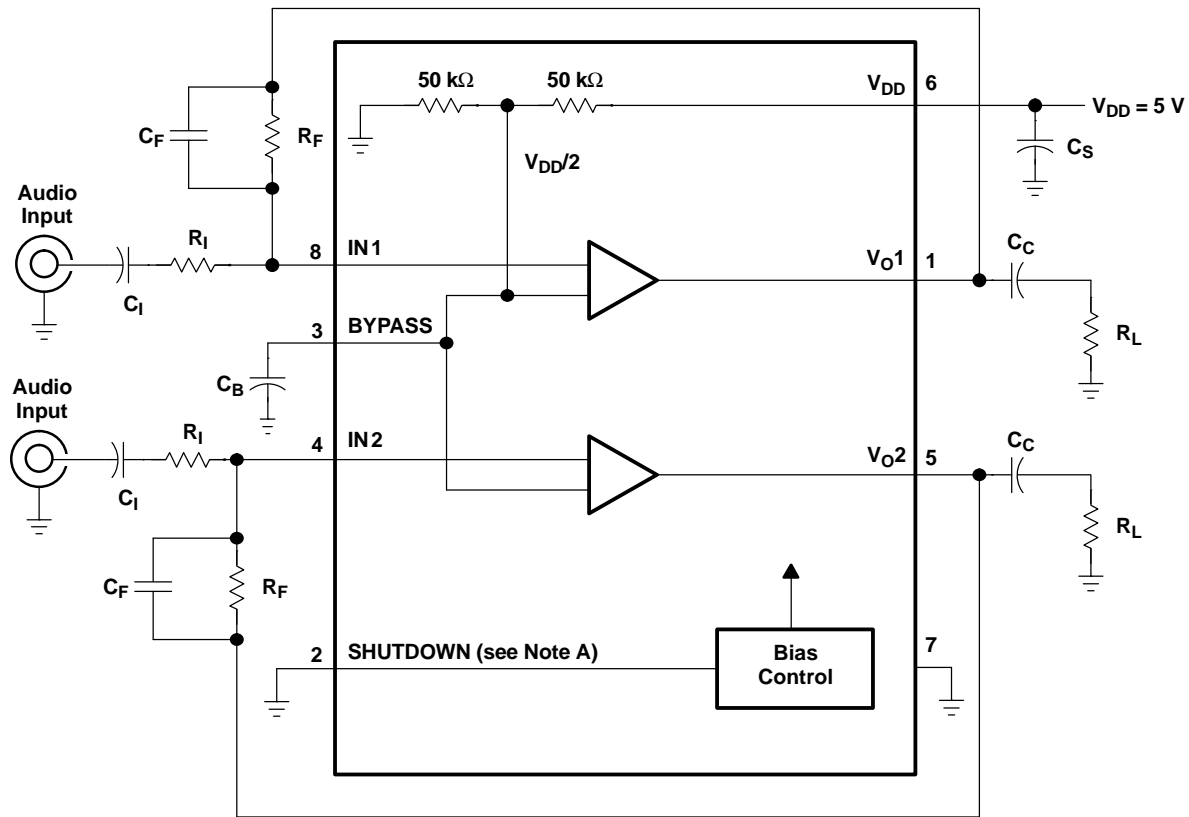


Figure 41.

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

Gain Setting Resistors, RF and R1

The gain for the TPA302 is set by resistors RF and R1 according to Equation 1.

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

Given that the TPA302 is an MOS amplifier, the input impedance is high; consequently, input leakage currents are not generally a concern, although noise in the circuit increases as the value of RF increases. In addition, a certain range of RF 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 kΩ and 20 kΩ. The effective impedance is calculated in Equation 2.

$$\text{Effective Impedance} = \frac{R_F R_I}{R_F + R_I} \tag{2}$$

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

APPLICATION INFORMATION (continued)

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 Ω , 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 . In effect, this 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 Ω 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, 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 Ω 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 0.4 μF ; so, one would likely choose a value in the range of 0.47 μF to 1 μF . A further consideration for this capacitor is the leakage path from the input source through the input network (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. Note that it is important to confirm the capacitor polarity in the application.

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 μF , placed as close as possible to the device V_{DD} lead, works best. For filtering lower frequency noise signals, a larger aluminum electrolytic capacitor of 10 μF or greater placed near the power amplifier is recommended.

Midrail Bypass Capacitor, C_B

The midrail bypass capacitor, C_B , serves several important functions. During 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 cannot 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 Ω 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 μF , C_I is 0.22 μF and R_I is 10 k Ω . Inserting these values into Equation 6 results in: $400 \leq 454$ which satisfies the rule. Recommended values for bypass capacitor C_B are 0.1- μF to 1- μF , ceramic or tantalum low-ESR, for the best THD and noise performance.

APPLICATION INFORMATION (continued)**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 μF is chosen and loads vary from 8 Ω , 32 Ω , and 47 k Ω . Table 1 summarizes the frequency response characteristics of each configuration.

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

| R_L | C_C | LOWEST FREQUENCY |
|-----------------|------------------|------------------|
| 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 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 previously 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, $I_{DD} \sim 0.6 \mu\text{A}$. 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.

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.

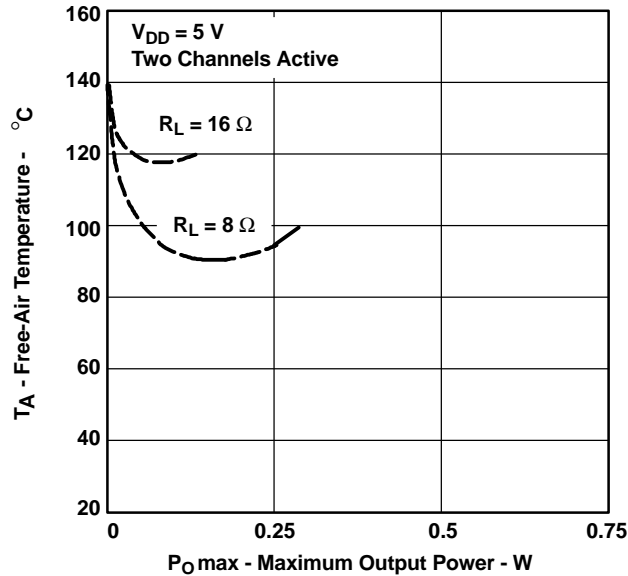


Figure 43. Free-Air Temperature Versus Maximum Output Power

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 because they 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 4 mA (typical) to 2.25 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.

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) | Op Temp (°C) | Top-Side Markings (4) | Samples |
|------------------|---------------|--------------|-----------------|------|-------------|-------------------------|------------------|----------------------|--------------|--------------------------|-------------------------|
| TPA302D | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | | TPA302 | Samples |
| TPA302DG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | | TPA302 | Samples |
| TPA302DR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | | TPA302 | Samples |
| TPA302DRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | | TPA302 | Samples |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

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

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

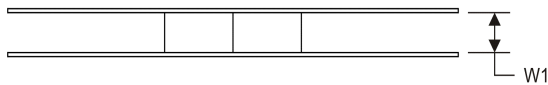
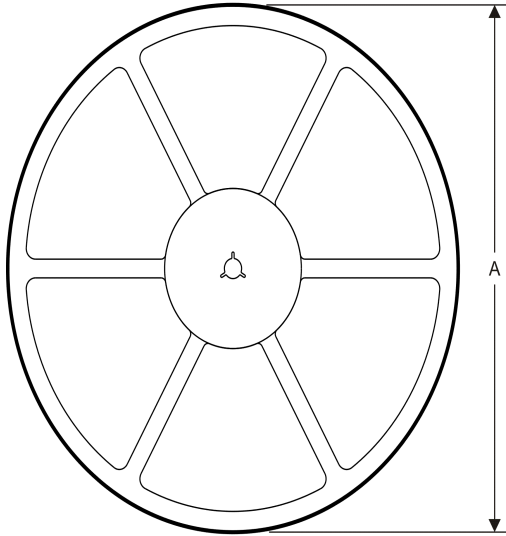
(4) Only one of markings shown within the brackets will appear on the physical device.

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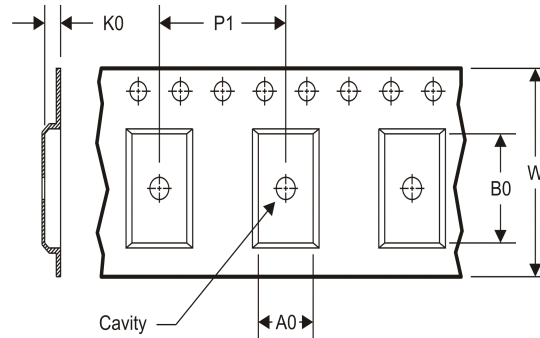
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TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



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

TAPE AND REEL INFORMATION

*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|----------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPA302DR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS

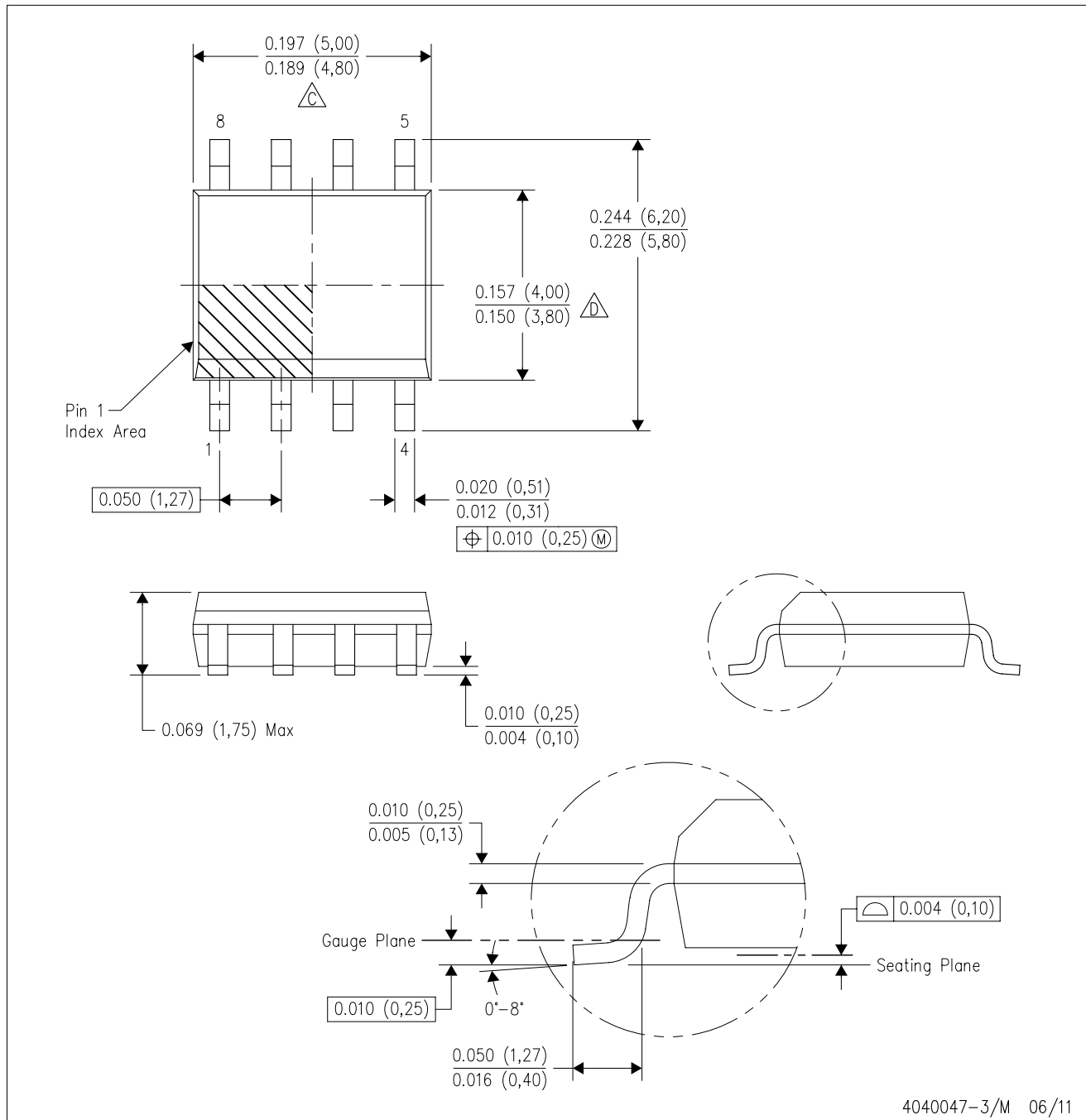


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|----------|--------------|-----------------|------|------|-------------|------------|-------------|
| TPA302DR | SOIC | D | 8 | 2500 | 367.0 | 367.0 | 35.0 |

D (R-PDSO-G8)

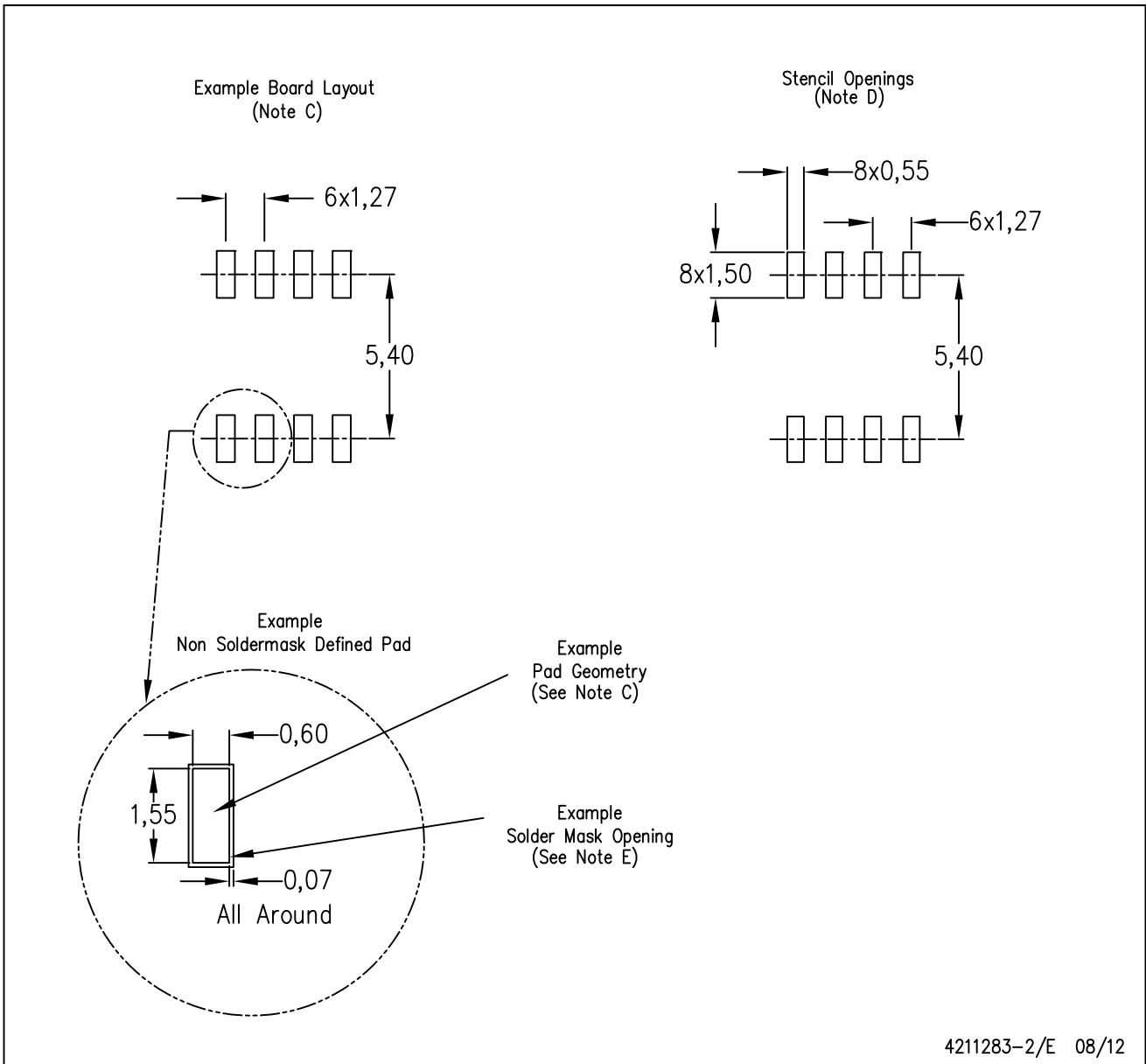
PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
 - D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
 - E. Reference JEDEC MS-012 variation AA.

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



4211283-2/E 08/12

- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Publication IPC-7351 is recommended for alternate designs.
 - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
 - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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