

**LM4889 Boomer® Audio Power Amplifier Series 1 Watt Audio Power Amplifier**Check for Samples: [LM4889](#)**FEATURES**

- Available in Space-Saving VSSOP, SOIC, WSON, and DSBGA Packages
- Ultra Low Current Shutdown Mode (3.3 to 2.6V - 0.01 $\mu$ A)
- Can Drive Capacitive Loads up to 500 pF
- Improved Pop & Click Circuitry Eliminates Noises During Turn-On and Turn-Off Transitions
- 2.2 - 5.5V Operation
- No Output Coupling Capacitors, Snubber Networks or Bootstrap Capacitors Required
- Unity-Gain Stable
- External Gain Configuration Capability

**APPLICATIONS**

- Mobile Phones
- PDAs
- Portable Electronic Devices

**KEY SPECIFICATIONS**

- Improved PSRR at 217Hz, 5 - 3.3V 75dB
- Power Output at 5.0V & 2% THD 1.0W(typ.)
- Power Output at 3.3V & 1% THD 400mW(typ.)
- Shutdown Current at 3.3 & 2.6V 0.01 $\mu$ A(typ.)

**DESCRIPTION**

The LM4889 is an audio power amplifier primarily designed for demanding applications in mobile phones and other portable communication device applications. It is capable of delivering 1 watt of continuous average power to an 8 $\Omega$  BTL load with less than 2% distortion (THD+N) from a 5V<sub>DC</sub> power supply.

Boomer™ audio power amplifiers were designed specifically to provide high quality output power with a minimal amount of external components. The LM4889 does not require output coupling capacitors or bootstrap capacitors, and therefore is ideally suited for mobile phone and other low voltage applications where minimal power consumption is a primary requirement.

The LM4889 features a low-power consumption shutdown mode, which is achieved by driving the shutdown pin with a logic low. Additionally, the LM4889 features an internal thermal shutdown protection mechanism.

The LM4889 contains advanced pop & click circuitry to eliminate noise which would otherwise occur during turn-on and turn-off transitions.

The LM4889 is unity-gain stable and can be configured by external gain-setting resistors.



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

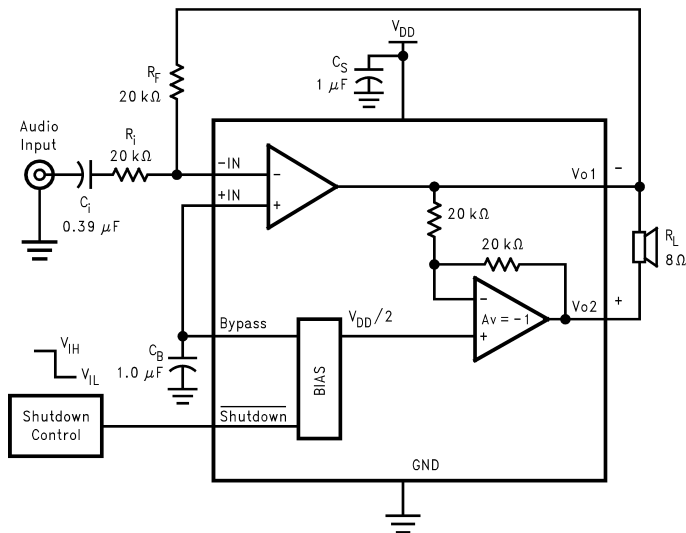
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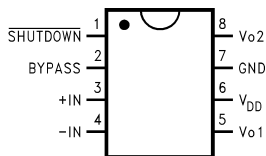
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**Typical Application**

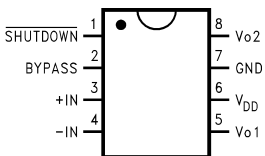


**Figure 1. Typical Audio Amplifier Application Circuit**

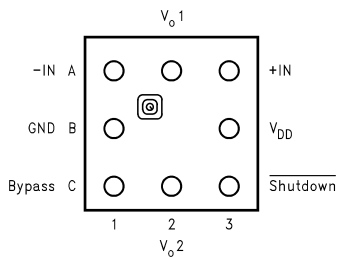
**Connection Diagram**



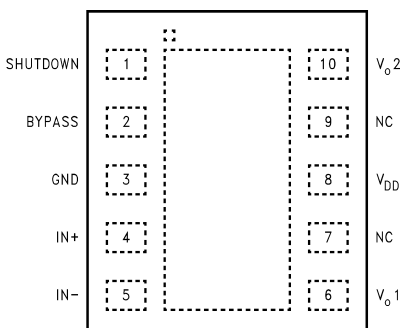
**Figure 2. Small Outline (SOIC) Package - Top View  
See Package Number D**



**Figure 3. Mini Small Outline (VSSOP) Package –  
Top View  
See Package Number DGK**



**Figure 4. 8-Bump DSBGA - Top View  
See Package Number YZR0008**



**Figure 5. WSON Package - Top View  
See Package Number NGZ**



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## Absolute Maximum Ratings<sup>(1)(2)</sup>

|                                   |                                             |                                                      |
|-----------------------------------|---------------------------------------------|------------------------------------------------------|
| Supply Voltage                    |                                             | 6.0V                                                 |
| Storage Temperature               |                                             | –65°C to +150°C                                      |
| Input Voltage                     |                                             | –0.3V to V <sub>DD</sub> +0.3V                       |
| Power Dissipation <sup>(3)</sup>  |                                             | Internally Limited                                   |
| ESD Susceptibility <sup>(4)</sup> |                                             | 2000V                                                |
| ESD Susceptibility <sup>(5)</sup> |                                             | 200V                                                 |
| Junction Temperature              |                                             | 150°C                                                |
| Thermal Resistance                | $\theta_{JC}$ (SOIC)                        | 35°C/W                                               |
|                                   | $\theta_{JA}$ (SOIC)                        | 150°C/W                                              |
|                                   | $\theta_{JA}$ (8 Bump DSBGA) <sup>(6)</sup> | 210°C/W                                              |
|                                   | $\theta_{JC}$ (VSSOP)                       | 56°C/W                                               |
|                                   | $\theta_{JA}$ (VSSOP)                       | 190°C/W                                              |
|                                   | $\theta_{JA}$ (WSON)                        | 220°C/W                                              |
| Soldering Information             |                                             | See the <a href="#">AN-1112 Application Report</a> . |

- (1) *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur. *Operating Ratings* indicate conditions for which the device is functional, but do not ensure specific performance limits. *Electrical Characteristics* state DC and AC electrical specifications under particular test conditions which ensure specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not ensured for parameters where no limit is given, however, the typical value is a good indication of device performance.
- (2) If Military/Aerospace specified devices are required, please contact the TI Sales Office/ Distributors for availability and specifications.
- (3) The maximum power dissipation must be derated at elevated temperatures and is dictated by T<sub>JMAX</sub>,  $\theta_{JA}$ , and the ambient temperature T<sub>A</sub>. The maximum allowable power dissipation is P<sub>DMAX</sub> = (T<sub>JMAX</sub> – T<sub>A</sub>)/ $\theta_{JA}$  or the number given in Absolute Maximum Ratings, whichever is lower. For the LM4889, see [power derating](#) currents for additional information.
- (4) Human body model, 100 pF discharged through a 1.5 k $\Omega$  resistor.
- (5) Machine Model, 220 pF–240 pF discharged through all pins.
- (6) All bumps have the same thermal resistance and contribute equally when used to lower thermal resistance. The LM4889ITL demo board (views featured in the [Application Information](#) section) has two inner layers, one for V<sub>DD</sub> and one for GND. The planes each measure 600mils x 600mils (15.24mm x 15.24mm) and aid in spreading heat due to power dissipation within the IC.

## Operating Ratings

|                                                                        |                               |
|------------------------------------------------------------------------|-------------------------------|
| Temperature Range T <sub>MIN</sub> ≤ T <sub>A</sub> ≤ T <sub>MAX</sub> | –40°C ≤ T <sub>A</sub> ≤ 85°C |
| Supply Voltage                                                         | 2.2V ≤ V <sub>DD</sub> ≤ 5.5V |

## Electrical Characteristics V<sub>DD</sub> = 5V<sup>(1)(2)</sup>

The following specifications apply for V<sub>DD</sub> = 5V, A<sub>V</sub> = 2, and 8 $\Omega$  load unless otherwise specified. Limits apply for T<sub>A</sub> = 25°C.

| Symbol            | Parameter                       | Conditions                                               | LM4889                 |                         | Units<br>(Limits) |
|-------------------|---------------------------------|----------------------------------------------------------|------------------------|-------------------------|-------------------|
|                   |                                 |                                                          | Typical <sup>(3)</sup> | Limit <sup>(4)(5)</sup> |                   |
| I <sub>DD</sub>   | Quiescent Power Supply Current  | V <sub>IN</sub> = 0V, I <sub>O</sub> = 0A, no Load       | 4                      | 8                       | mA (max)          |
|                   |                                 | V <sub>IN</sub> = 0V, I <sub>O</sub> = 0A, with BTL Load | 5                      | 8                       | mA (max)          |
| I <sub>SD</sub>   | Shutdown Current                | V <sub>shutdown</sub> = GND <sup>(6)</sup>               | 0.1                    | 2                       | $\mu$ A (max)     |
| V <sub>SDIH</sub> | Shutdown Voltage Input High     |                                                          |                        | 1.2                     | V (min)           |
| V <sub>SDIL</sub> | Shutdown Voltage Input Low      |                                                          |                        | 0.4                     | V (max)           |
| P <sub>O</sub>    | Output Power                    | THD = 2% (max); f = 1 kHz                                | 1                      |                         | W                 |
| THD+N             | Total Harmonic Distortion+Noise | P <sub>O</sub> = 0.4 Wrms; f = 1kHz                      | 0.1                    |                         | %                 |

- (1) All voltages are measured with respect to the ground pin, unless otherwise specified.
- (2) *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur. *Operating Ratings* indicate conditions for which the device is functional, but do not ensure specific performance limits. *Electrical Characteristics* state DC and AC electrical specifications under particular test conditions which ensure specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not ensured for parameters where no limit is given, however, the typical value is a good indication of device performance.
- (3) Typicals are measured at 25°C and represent the parametric norm.
- (4) Limits are specified to TI's AOQL (Average Outgoing Quality Level).
- (5) Datasheet min/max specification limits are specified by design, test or statistical analysis.
- (6) For DSBGA only, shutdown current is measured in a Normal Room Environment. Exposure to direct sunlight will increase I<sub>SD</sub> by a maximum of 2 $\mu$ A.

## Electrical Characteristics $V_{DD} = 5V^{(1)(2)}$ (continued)

The following specifications apply for  $V_{DD} = 5V$ ,  $A_V = 2$ , and  $8\Omega$  load unless otherwise specified. Limits apply for  $T_A = 25^\circ C$ .

| Symbol | Parameter                    | Conditions                                                                   | LM4889                 |                         | Units<br>(Limits) |
|--------|------------------------------|------------------------------------------------------------------------------|------------------------|-------------------------|-------------------|
|        |                              |                                                                              | Typical <sup>(3)</sup> | Limit <sup>(4)(5)</sup> |                   |
| PSRR   | Power Supply Rejection Ratio | $V_{ripple} = 200mV$ sine p-p<br>$f_{ripple} = 217Hz$<br>$f_{ripple} = 1kHz$ | 62<br>66               |                         | dB<br>dB          |
|        |                              | $V_{ripple} = 200mV$ sine p-p<br>Input Floating                              | 75                     | 68                      | dB                |

## Electrical Characteristics $V_{DD} = 3.3V^{(1)(2)}$

The following specifications apply for  $V_{DD} = 3.3V$ ,  $A_V = 2$ , and  $8\Omega$  load unless otherwise specified. Limits apply for  $T_A = 25^\circ C$ .

| Symbol     | Parameter                       | Conditions                                                                   | LM4889                 |                         | Units<br>(Limits) |
|------------|---------------------------------|------------------------------------------------------------------------------|------------------------|-------------------------|-------------------|
|            |                                 |                                                                              | Typical <sup>(3)</sup> | Limit <sup>(4)(5)</sup> |                   |
| $I_{DD}$   | Quiescent Power Supply Current  | $V_{IN} = 0V$ , $I_O = 0A$ , no Load                                         | 3.5                    | 7                       | mA (max)          |
|            |                                 | $V_{IN} = 0V$ , $I_O = 0A$ , with BTL Load                                   | 4.5                    | 7                       | mA (max)          |
| $I_{SD}$   | Shutdown Current                | $V_{shutdown} = GND^{(6)}$                                                   | 0.01                   | 2                       | $\mu A$ (max)     |
| $V_{SDIH}$ | Shutdown Voltage Input High     |                                                                              |                        | 1.2                     | V (min)           |
| $V_{SDIL}$ | Shutdown Voltage Input Low      |                                                                              |                        | 0.4                     | V (max)           |
| $P_O$      | Output Power                    | THD = 1% (max); $f = 1kHz$                                                   | 0.4                    |                         | W                 |
| THD+N      | Total Harmonic Distortion+Noise | $P_O = 0.25W_{rms}$ ; $f = 1kHz$                                             | 0.1                    |                         | %                 |
| PSRR       | Power Supply Rejection Ratio    | $V_{ripple} = 200mV$ sine p-p<br>$f_{ripple} = 217Hz$<br>$f_{ripple} = 1kHz$ | 60<br>62               |                         | dB<br>dB          |

- (1) All voltages are measured with respect to the ground pin, unless otherwise specified.
- (2) *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur. *Operating Ratings* indicate conditions for which the device is functional, but do not ensure specific performance limits. *Electrical Characteristics* state DC and AC electrical specifications under particular test conditions which ensure specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not ensured for parameters where no limit is given, however, the typical value is a good indication of device performance.
- (3) Typicals are measured at  $25^\circ C$  and represent the parametric norm.
- (4) Limits are specified to TI's AOQL (Average Outgoing Quality Level).
- (5) Datasheet min/max specification limits are specified by design, test or statistical analysis.
- (6) For DSBGA only, shutdown current is measured in a Normal Room Environment. Exposure to direct sunlight will increase  $I_{SD}$  by a maximum of  $2\mu A$ .

## Electrical Characteristics $V_{DD} = 2.6V^{(1)(2)}$

The following specifications apply for  $V_{DD} = 2.6V$ ,  $A_V = 2$ , and  $8\Omega$  load unless otherwise specified. Limits apply for  $T_A = 25^\circ C$ .

| Symbol   | Parameter                       | Conditions                                 | LM4889                 |                         | Units<br>(Limits) |
|----------|---------------------------------|--------------------------------------------|------------------------|-------------------------|-------------------|
|          |                                 |                                            | Typical <sup>(3)</sup> | Limit <sup>(4)(5)</sup> |                   |
| $I_{DD}$ | Quiescent Power Supply Current  | $V_{IN} = 0V$ , $I_O = 0A$ , no Load       | 2.6                    | 6                       | mA (max)          |
|          |                                 | $V_{IN} = 0V$ , $I_O = 0A$ , with BTL Load | 3.0                    | 6                       | mA (max)          |
| $I_{SD}$ | Shutdown Current                | $V_{shutdown} = GND^{(6)}$                 | 0.01                   | 2                       | $\mu A$ (max)     |
| $P_O$    | Output Power ( $8\Omega$ )      | THD = 1% (max); $f = 1 kHz$                | 0.2                    |                         | W                 |
|          | Output Power ( $4\Omega$ )      | THD = 1% (max); $f = 1 kHz$                | 0.22                   |                         | W                 |
| THD+N    | Total Harmonic Distortion+Noise | $P_O = 0.1W_{rms}$ ; $f = 1kHz$            | 0.08                   |                         | %                 |

- (1) All voltages are measured with respect to the ground pin, unless otherwise specified.
- (2) *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur. *Operating Ratings* indicate conditions for which the device is functional, but do not ensure specific performance limits. *Electrical Characteristics* state DC and AC electrical specifications under particular test conditions which ensure specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not ensured for parameters where no limit is given, however, the typical value is a good indication of device performance.
- (3) Typicals are measured at  $25^\circ C$  and represent the parametric norm.
- (4) Limits are specified to TI's AOQL (Average Outgoing Quality Level).
- (5) Datasheet min/max specification limits are specified by design, test or statistical analysis.
- (6) For DSBGA only, shutdown current is measured in a Normal Room Environment. Exposure to direct sunlight will increase  $I_{SD}$  by a maximum of  $2\mu A$ .

## Electrical Characteristics $V_{DD} = 2.6V^{(1)(2)}$ (continued)

The following specifications apply for  $V_{DD} = 2.6V$ ,  $A_V = 2$ , and  $8\Omega$  load unless otherwise specified. Limits apply for  $T_A = 25^\circ C$ .

| Symbol | Parameter                    | Conditions                                                                   | LM4889                 |                         | Units<br>(Limits) |
|--------|------------------------------|------------------------------------------------------------------------------|------------------------|-------------------------|-------------------|
|        |                              |                                                                              | Typical <sup>(3)</sup> | Limit <sup>(4)(5)</sup> |                   |
| PSRR   | Power Supply Rejection Ratio | $V_{ripple} = 200mV$ sine p-p<br>$f_{ripple} = 217Hz$<br>$f_{ripple} = 1kHz$ | 44<br>44               |                         | dB<br>dB          |

## External Components Description

(Figure 1)

| Components |       | Functional Description                                                                                                                                                                                                                                                                                      |
|------------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.         | $R_i$ | Inverting input resistance which sets the closed-loop gain in conjunction with $R_f$ . This resistor also forms a high pass filter with $C_i$ at $f_c = 1/(2\pi R_i C_i)$ .                                                                                                                                 |
| 2.         | $C_i$ | Input coupling capacitor which blocks the DC voltage at the amplifiers input terminals. Also creates a highpass filter with $R_i$ at $f_c = 1/(2\pi R_i C_i)$ . Refer to the section, <a href="#">PROPER SELECTION OF EXTERNAL COMPONENTS</a> , for an explanation of how to determine the value of $C_i$ . |
| 3.         | $R_f$ | Feedback resistance which sets the closed-loop gain in conjunction with $R_i$ . $A_{VD} = 2*(R_f/R_i)$ .                                                                                                                                                                                                    |
| 4.         | $C_S$ | Supply bypass capacitor which provides power supply filtering. Refer to the <a href="#">POWER SUPPLY BYPASSING</a> section for information concerning proper placement and selection of the supply bypass capacitor.                                                                                        |
| 5.         | $C_B$ | Bypass pin capacitor which provides half-supply filtering. Refer to the section, <a href="#">PROPER SELECTION OF EXTERNAL COMPONENTS</a> , for information concerning proper placement and selection of $C_B$ .                                                                                             |

## Typical Performance Characteristics

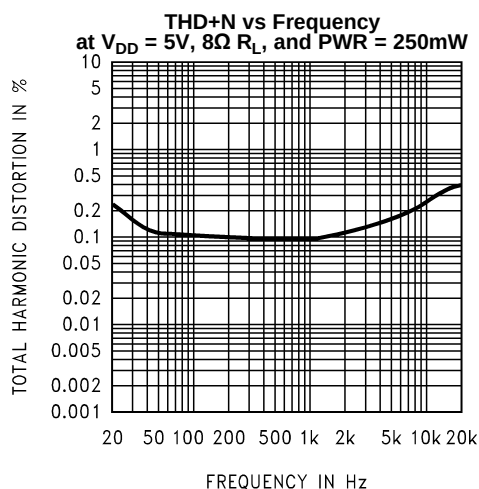


Figure 6.

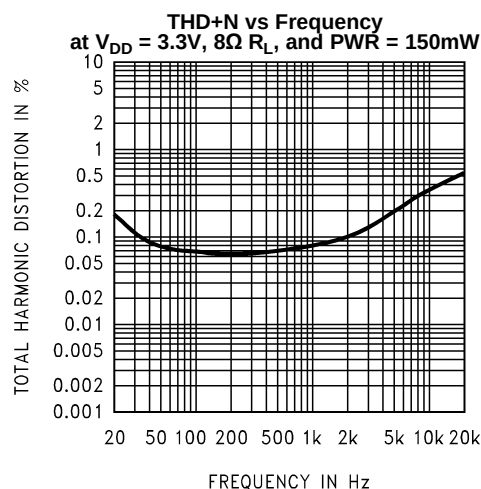


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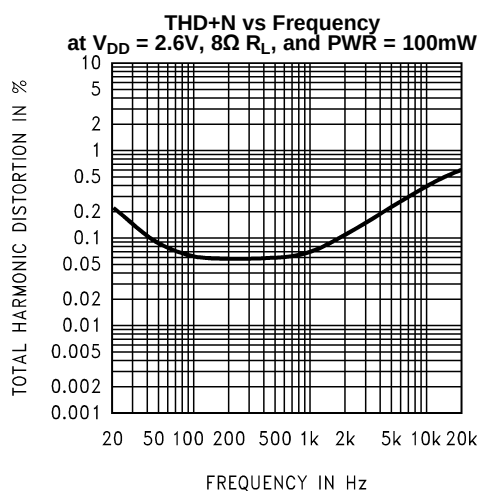


Figure 8.

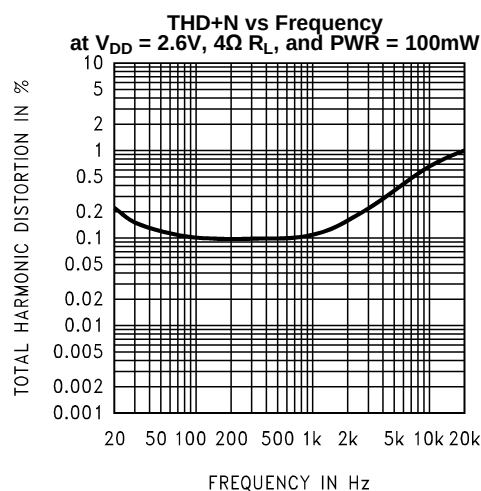


Figure 9.

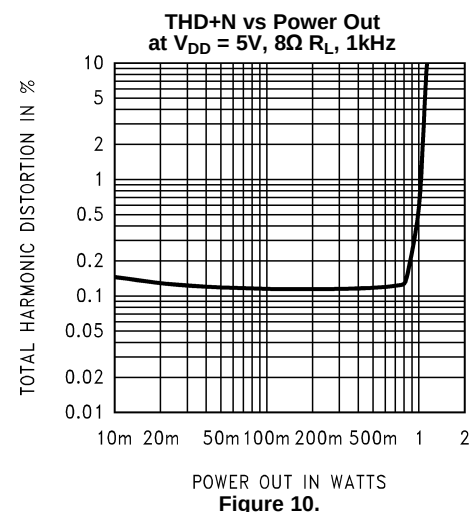


Figure 10.

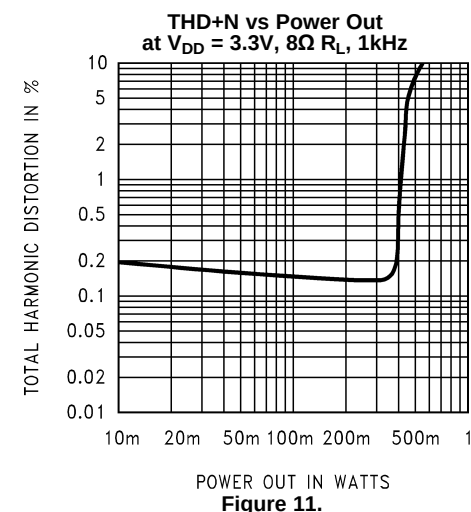
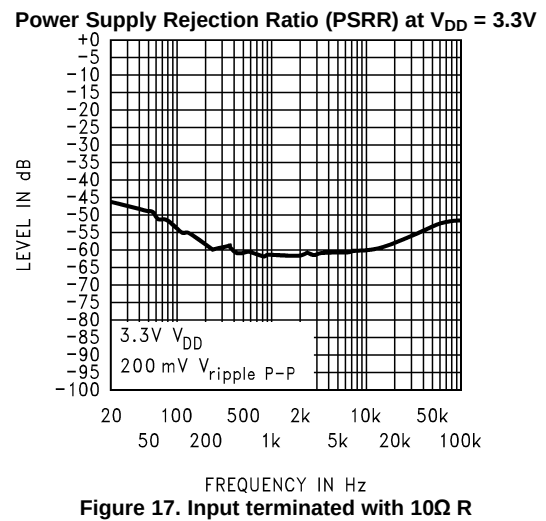
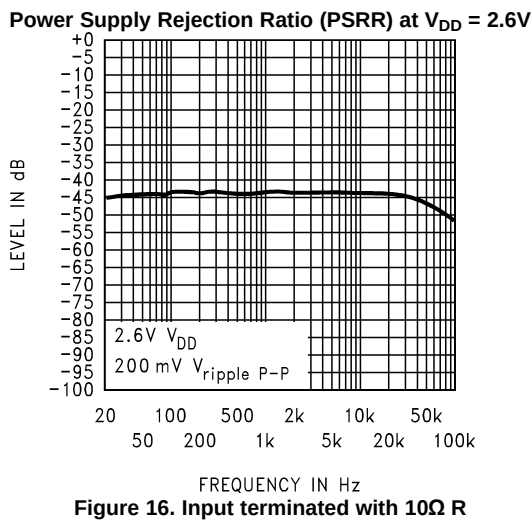
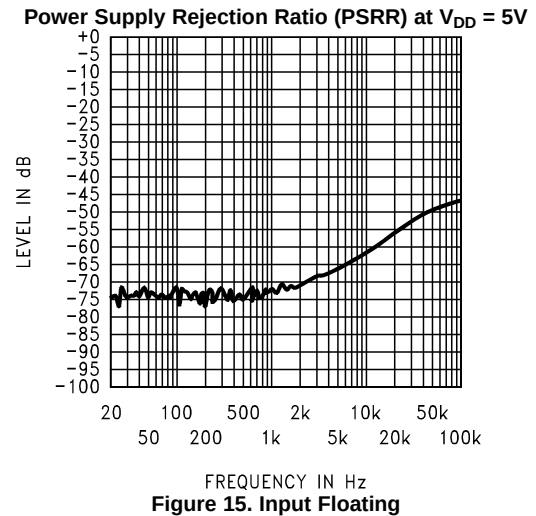
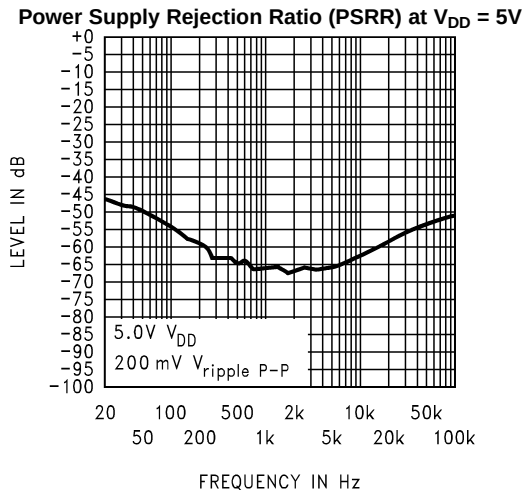
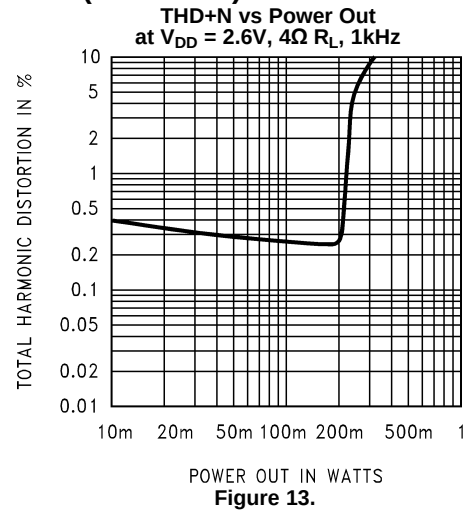
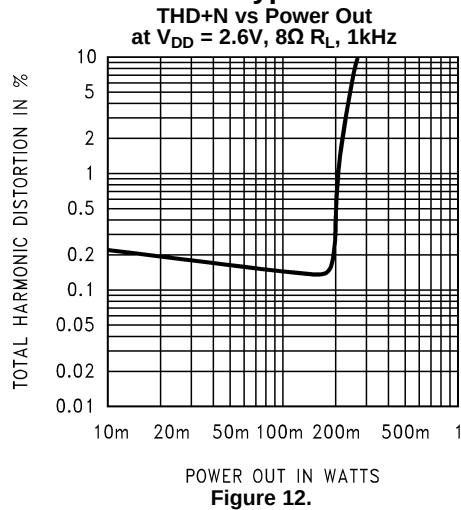


Figure 11.

## Typical Performance Characteristics (continued)



### Typical Performance Characteristics (continued)

**Power Dissipation vs  
Output Power**  
 $V_{DD} = 3.3V$

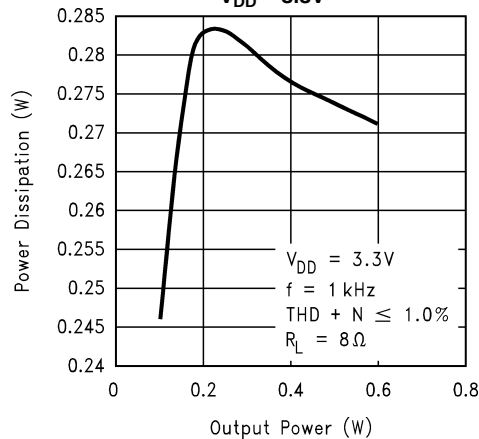


Figure 18.

**Power Dissipation vs  
Output Power**  
 $V_{DD} = 5V$

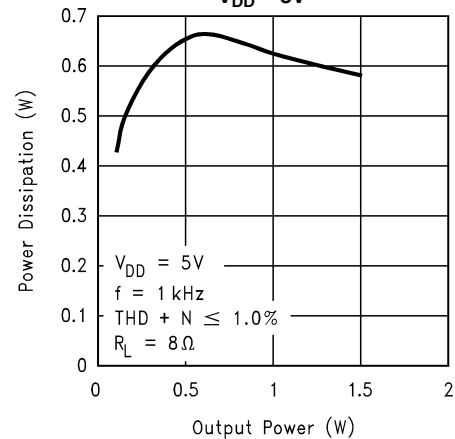


Figure 19.

**Output Power vs  
Load Resistance**

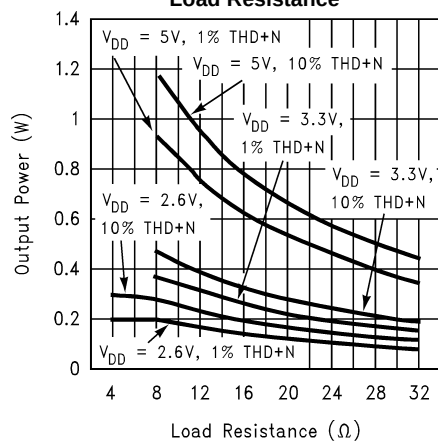


Figure 20.

**Power Dissipation vs  
Output Power**  
 $V_{DD} = 2.6V$

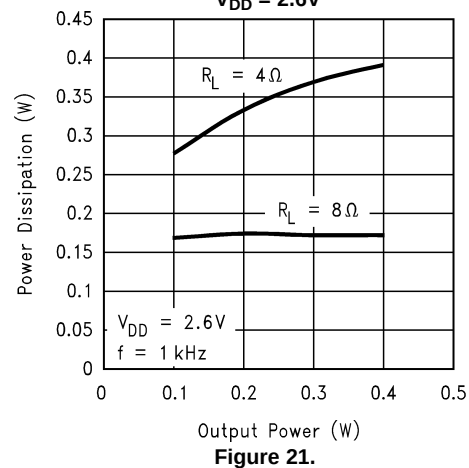


Figure 21.

**Supply Current vs  
Shutdown Voltage**

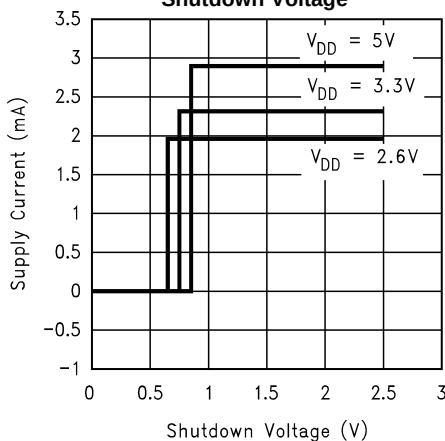


Figure 22.

**Clipping (Dropout) Voltage vs  
Supply Voltage**

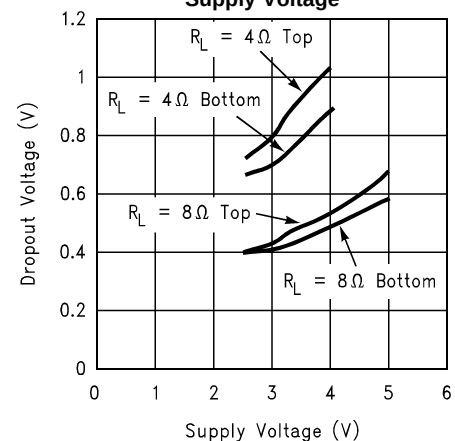


Figure 23.



## Typical Performance Characteristics (continued)

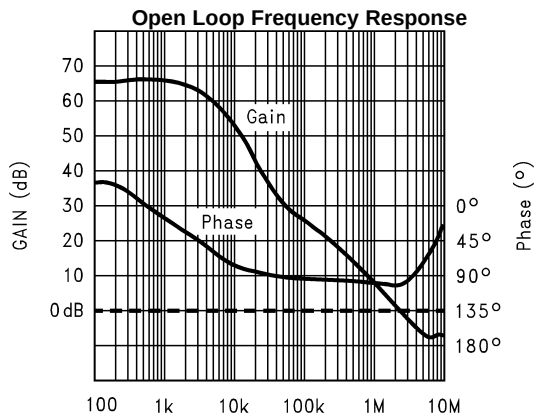


Figure 24.

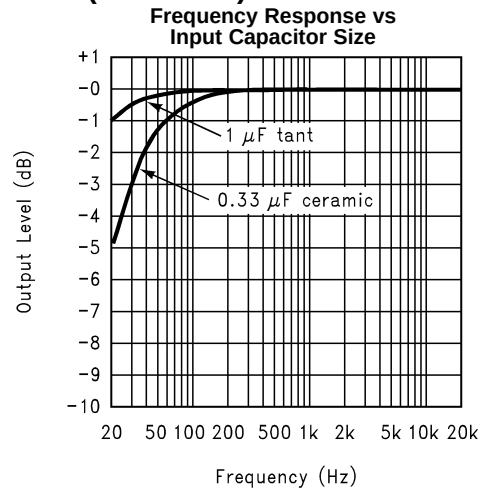


Figure 25.

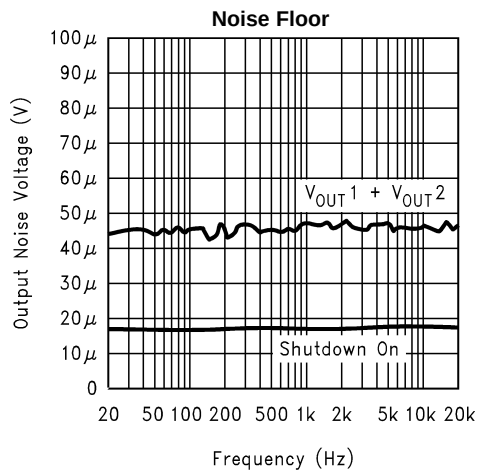


Figure 26.

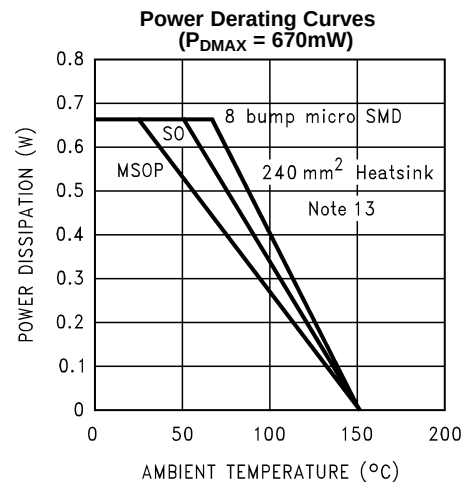


Figure 27.

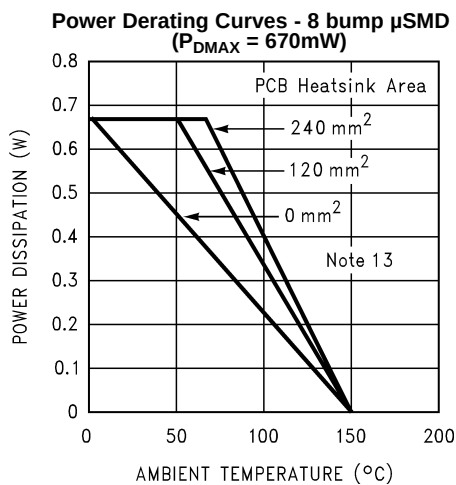


Figure 28.

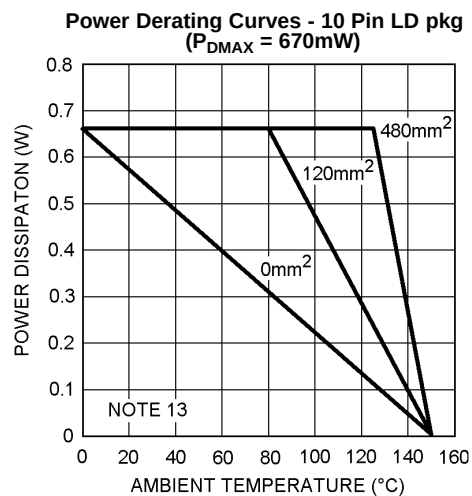


Figure 29.

## Application Information

### BRIDGE CONFIGURATION EXPLANATION

As shown in [Figure 1](#), the LM4889 has two operational amplifiers internally, allowing for a few different amplifier configurations. The first amplifier's gain is externally configurable, while the second amplifier is internally fixed in a unity-gain, inverting configuration. The closed-loop gain of the first amplifier is set by selecting the ratio of  $R_f$  to  $R_i$  while the second amplifier's gain is fixed by the two internal 20kΩ resistors. [Figure 1](#) shows that the output of amplifier one serves as the input to amplifier two which results in both amplifiers producing signals identical in magnitude, but out of phase by 180°. Consequently, the differential gain for the IC is

$$A_{VD} = 2 * (R_f / R_i) \quad (1)$$

By driving the load differentially through outputs Vo1 and Vo2, an amplifier configuration commonly referred to as "bridged mode" is established. Bridged mode operation is different from the classical single-ended amplifier configuration where one side of the load is connected to ground.

A bridge amplifier design has an advantage over the single-ended configuration, as it provides differential drive to the load, thus doubling output swing for a specified supply voltage. Four times the output power is possible as compared to a single-ended amplifier under the same conditions. This increase in attainable output power assumes that the amplifier is not current limited or clipped. In order to choose an amplifier's closed-loop gain without causing excessive clipping, please refer to the [AUDIO POWER AMPLIFIER DESIGN](#) section.

A bridge configuration, such as the one used in LM4889, also creates a second advantage over single-ended amplifiers. Since the differential outputs, Vo1 and Vo2, are biased at half-supply, no net DC voltage exists across the load. This eliminates the need for an output coupling capacitor which is required in a single supply, single-ended amplifier configuration. Without an output coupling capacitor, the half-supply bias across the load would result in both increased internal IC power dissipation and also possible loudspeaker damage.

### POWER DISSIPATION

Power dissipation is a major concern when designing a successful amplifier, whether the amplifier is bridged or single-ended. A direct consequence of the increased power delivered to the load by a bridge amplifier is an increase in internal power dissipation. Since the LM4889 has two operational amplifiers in one package, the maximum internal power dissipation is 4 times that of a single-ended amplifier. The maximum power dissipation for a given application can be derived from the power dissipation graphs or from [Equation 2](#).

$$P_{DMAX} = 4 * (V_{DD})^2 / (2\pi^2 R_L) \quad (2)$$

It is critical that the maximum junction temperature  $T_{JMAX}$  of 150°C is not exceeded.  $T_{JMAX}$  can be determined from the power derating curves by using  $P_{DMAX}$  and the PC board foil area. By adding additional copper foil, the thermal resistance of the application can be reduced from a free air value of 150°C/W, resulting in higher  $P_{DMAX}$ . Additional copper foil can be added to any of the leads connected to the LM4889. It is especially effective when connected to  $V_{DD}$ ,  $G_{ND}$ , and the output pins. Refer to the application information on the LM4889 reference design board for an example of good heat sinking. If  $T_{JMAX}$  still exceeds 150°C, then additional changes must be made. These changes can include reduced supply voltage, higher load impedance, or reduced ambient temperature. Internal power dissipation is a function of output power. Refer to the [Typical Performance Characteristics](#) curves for power dissipation information for different output powers and output loading.

### POWER SUPPLY BYPASSING

As with any amplifier, proper supply bypassing is critical for low noise performance and high power supply rejection. The capacitor location on both the bypass and power supply pins should be as close to the device as possible. Typical applications employ a 5V regulator with 10 μF tantalum or electrolytic capacitor and a ceramic bypass capacitor which aid in supply stability. This does not eliminate the need for bypassing the supply nodes of the LM4889. The selection of a bypass capacitor, especially  $C_B$ , is dependent upon PSRR requirements, click and pop performance (as explained in the section, [PROPER SELECTION OF EXTERNAL COMPONENTS](#)), system cost, and size constraints.

## SHUTDOWN FUNCTION

In order to reduce power consumption while not in use, the LM4889 contains a shutdown pin to externally turn off the amplifier's bias circuitry. This shutdown feature turns the amplifier off when a logic low is placed on the shutdown pin. By switching the shutdown pin to ground, the LM4889 supply current draw will be minimized in idle mode. While the device will be disabled with shutdown pin voltages less than  $0.5V_{DC}$ , the idle current may be greater than the typical value of  $0.1\mu A$ . (Idle current is measured with the shutdown pin grounded).

In many applications, a microcontroller or microprocessor output is used to control the shutdown circuitry to provide a quick, smooth transition into shutdown. Another solution is to use a single-pole, single-throw switch in conjunction with an external pull-up resistor. When the switch is closed, the shutdown pin is connected to ground and disables the amplifier. If the switch is open, then the external pull-up resistor will enable the LM4889. This scheme ensures that the shutdown pin will not float thus preventing unwanted state changes.

## PROPER SELECTION OF EXTERNAL COMPONENTS

Proper selection of external components in applications using integrated power amplifiers is critical to optimize device and system performance. While the LM4889 is tolerant of external component combinations, consideration to component values must be used to maximize overall system quality.

The LM4889 is unity-gain stable which gives the designer maximum system flexibility. The LM4889 should be used in low gain configurations to minimize THD+N values, and maximize the signal to noise ratio. Low gain configurations require large input signals to obtain a given output power. Input signals equal to or greater than 1 V<sub>rms</sub> are available from sources such as audio codecs. Please refer to the section, [AUDIO POWER AMPLIFIER DESIGN](#), for a more complete explanation of proper gain selection.

Besides gain, one of the major considerations is the closed-loop bandwidth of the amplifier. To a large extent, the bandwidth is dictated by the choice of external components shown in [Figure 1](#). The input coupling capacitor,  $C_i$ , forms a first order high pass filter which limits low frequency response. This value should be chosen based on needed frequency response for a few reasons.

## SELECTION OF INPUT CAPACITOR SIZE

Large input capacitors are both expensive and space hungry for portable designs. Clearly, a certain sized capacitor is needed to couple in low frequencies without severe attenuation. But in many cases the speakers used in portable systems, whether internal or external, have little ability to reproduce signals below 100 Hz to 150 Hz. Thus, using a large input capacitor may not increase actual system performance.

In addition to system cost and size, click and pop performance is effected by the size of the input coupling capacitor,  $C_i$ . A larger input coupling capacitor requires more charge to reach its quiescent DC voltage (nominally  $1/2 V_{DD}$ ). This charge comes from the output via the feedback and is apt to create pops upon device enable. Thus, by minimizing the capacitor size based on necessary low frequency response, turn-on pops can be minimized.

Besides minimizing the input capacitor size, careful consideration should be paid to the bypass capacitor value. Bypass capacitor,  $C_B$ , is the most critical component to minimize turn-on pops since it determines how fast the LM4889 turns on. The slower the LM4889's outputs ramp to their quiescent DC voltage (nominally  $1/2 V_{DD}$ ), the smaller the turn-on pop. Choosing  $C_B$  equal to  $1.0 \mu F$  along with a small value of  $C_i$  (in the range of  $0.1 \mu F$  to  $0.39 \mu F$ ), should produce a virtually clickless and popless shutdown function. While the device will function properly, (no oscillations or motorboating), with  $C_B$  equal to  $0.1 \mu F$ , the device will be much more susceptible to turn-on clicks and pops. Thus, a value of  $C_B$  equal to  $1.0 \mu F$  is recommended in all but the most cost sensitive designs.

## AUDIO POWER AMPLIFIER DESIGN

### A 1W/8Ω Audio Amplifier

- Given:
  - Power Output: 1 Wrms
  - Load Impedance: 8Ω
  - Input Level: 1 Vrms
  - Input Impedance: 20 kΩ
  - Bandwidth: 100 Hz–20 kHz ± 0.25 dB

A designer must first determine the minimum supply rail to obtain the specified output power. By extrapolating from the Output Power vs Supply Voltage graphs in the [Typical Performance Characteristics](#) section, the supply rail can be easily found. A second way to determine the minimum supply rail is to calculate the required  $V_{\text{opeak}}$  using [Equation 3](#) and add the output voltage. Using this method, the minimum supply voltage would be  $(V_{\text{opeak}} + (V_{\text{ODTOP}} + V_{\text{ODBOT}}))$ , where  $V_{\text{ODBOT}}$  and  $V_{\text{ODTOP}}$  are extrapolated from the Dropout Voltage vs Supply Voltage curve in the [Typical Performance Characteristics](#) section.

$$V_{\text{opeak}} = \sqrt{(2R_L P_O)} \quad (3)$$

5V is a standard voltage in most applications, it is chosen for the supply rail. Extra supply voltage creates headroom that allows the LM4889 to reproduce peaks in excess of 1W without producing audible distortion. At this time, the designer must make sure that the power supply choice along with the output impedance does not violate the conditions explained in the [POWER DISSIPATION](#) section.

Once the power dissipation equations have been addressed, the required differential gain can be determined from [Equation 4](#).

$$A_{VD} \geq \sqrt{(P_O R_L)} / (V_{IN}) = V_{\text{orms}} / V_{\text{inrms}} \quad (4)$$

$$R_f / R_i = A_{VD} / 2 \quad (5)$$

From [Equation 3](#), the minimum  $A_{VD}$  is 2.83; use  $A_{VD} = 3$ .

Since the desired input impedance was 20 kΩ, and with a  $A_{VD}$  impedance of 2, a ratio of 1.5:1 of  $R_f$  to  $R_i$  results in an allocation of  $R_i = 20$  kΩ and  $R_f = 30$  kΩ. The final design step is to address the bandwidth requirements which must be stated as a pair of –3 dB frequency points. Five times away from a –3 dB point is 0.17 dB down from passband response which is better than the required ±0.25 dB specified.

$$f_L = 100 \text{ Hz} / 5 = 20 \text{ Hz} \quad (6)$$

$$f_H = 20 \text{ kHz} * 5 = 100 \text{ kHz} \quad (7)$$

As stated in the [External Components Description](#) section,  $R_i$  in conjunction with  $C_i$  create a highpass filter.

$$C_i \geq 1 / (2\pi * 20 \text{ k}\Omega * 20 \text{ Hz}) = 0.397 \text{ }\mu\text{F}; \text{ use } 0.39 \text{ }\mu\text{F} \quad (8)$$

The high frequency pole is determined by the product of the desired frequency pole,  $f_H$ , and the differential gain,  $A_{VD}$ . With a  $A_{VD} = 3$  and  $f_H = 100$  kHz, the resulting GBWP = 300kHz which is much smaller than the LM4889 GBWP of 2.5MHz. This calculation shows that if a designer has a need to design an amplifier with a higher differential gain, the LM4889 can still be used without running into bandwidth limitations.

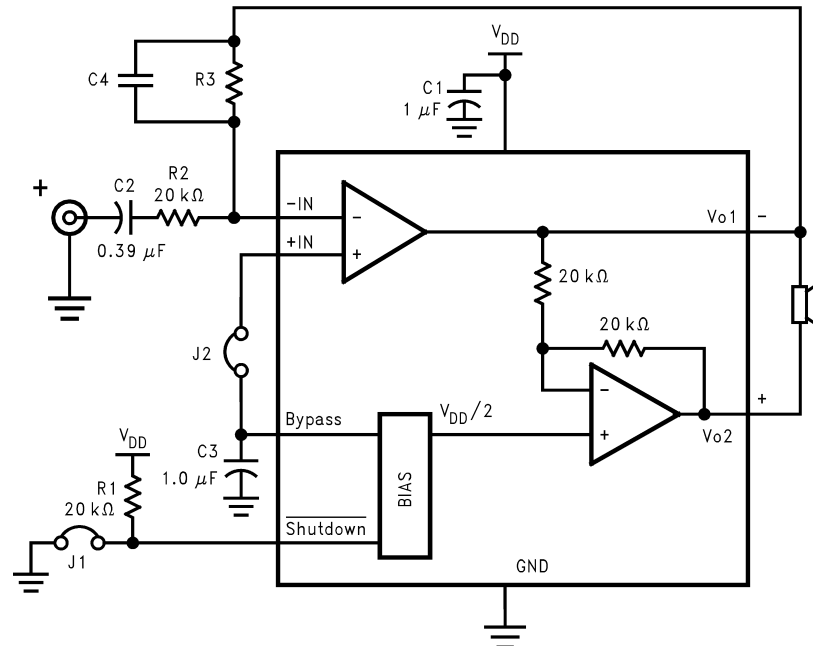


Figure 30. Higher Gain Audio Amplifier

The LM4889 is unity-gain stable and requires no external components besides gain-setting resistors, an input coupling capacitor, and proper supply bypassing in the typical application. However, if a closed-loop differential gain of greater than 10 is required, a feedback capacitor ( $C_4$ ) may be needed as shown in Figure 30 to bandwidth limit the amplifier. This feedback capacitor creates a low pass filter that eliminates possible high frequency oscillations. Care should be taken when calculating the -3dB frequency in that an incorrect combination of  $R_3$  and  $C_4$  will cause rolloff before 20kHz. A typical combination of feedback resistor and capacitor that will not produce audio band high frequency rolloff is  $R_3 = 20k\Omega$  and  $C_4 = 25pF$ . These components result in a -3dB point of approximately 320kHz.

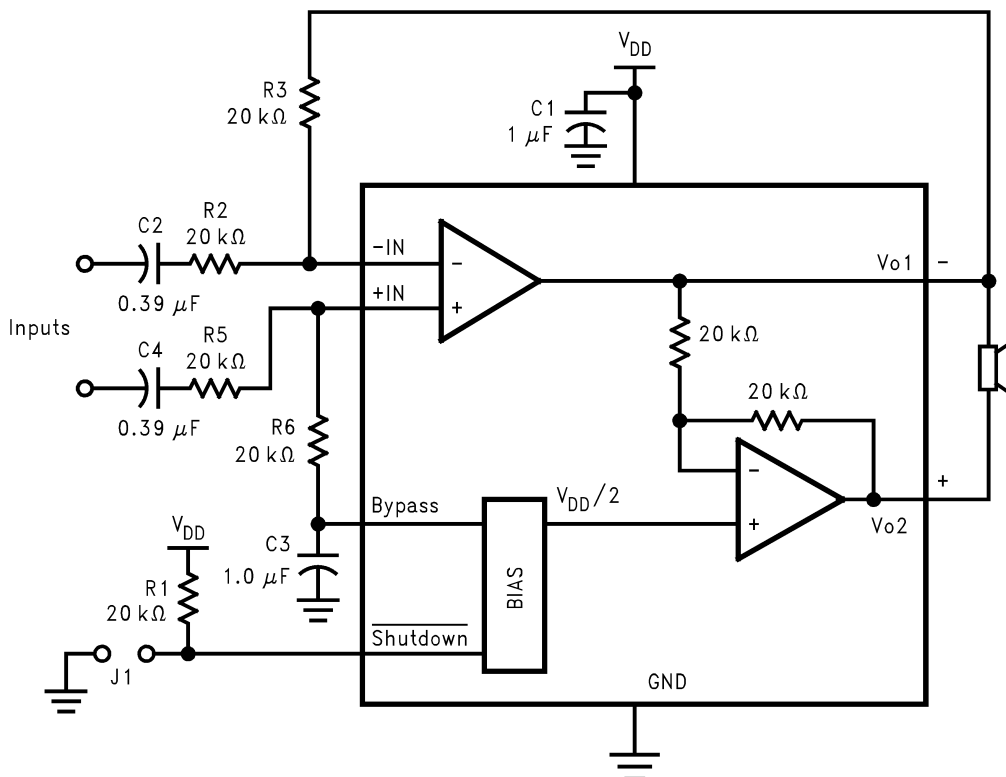


Figure 31. Differential Amplifier Configuration for LM4889

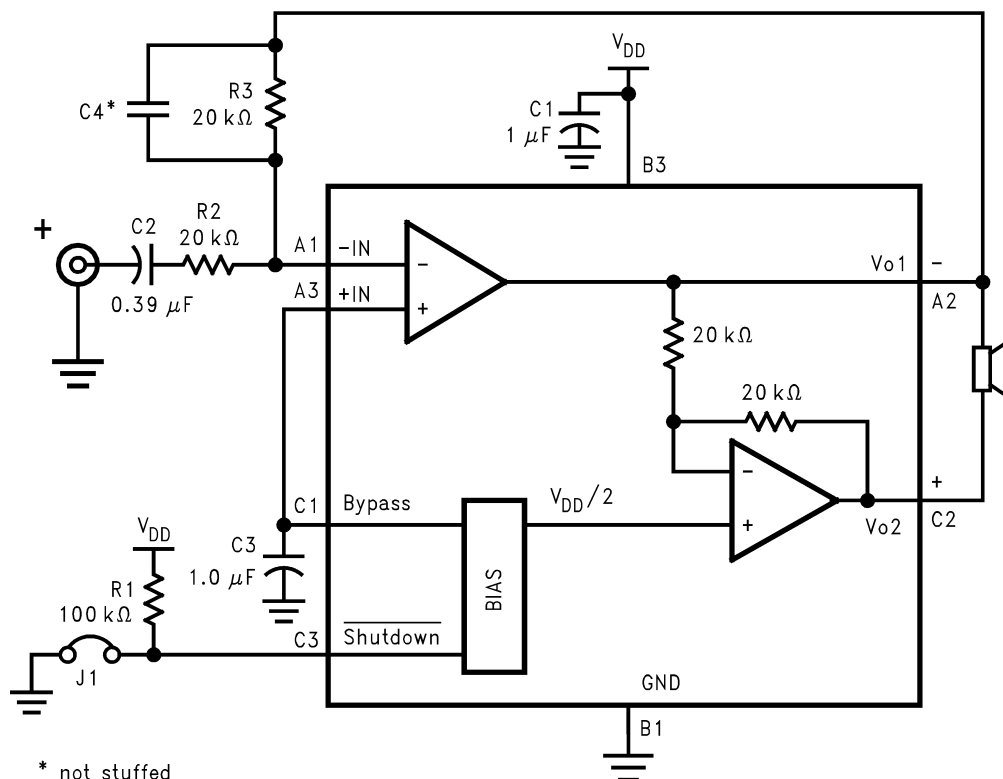
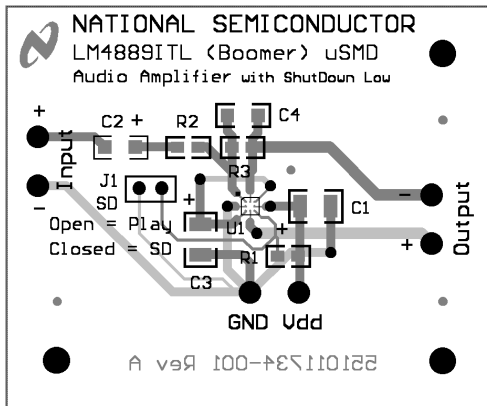


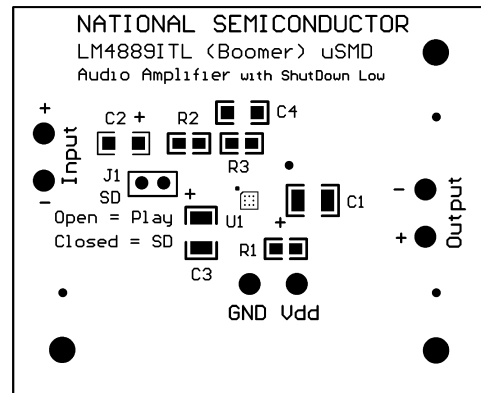
Figure 32. Reference Design Board and Layout - DSBGA

## LM4889 DSBGA DEMO BOARD ARTWORK

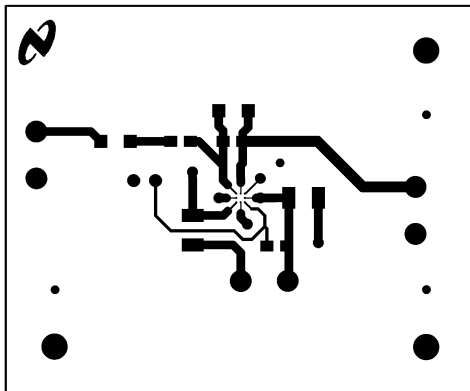
Composite View



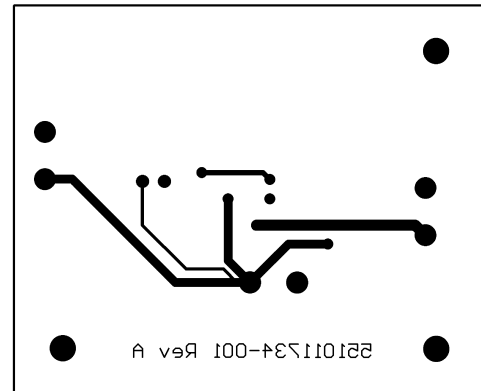
Silk Screen



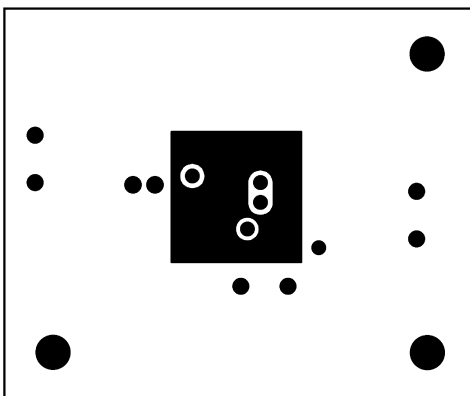
Top Layer



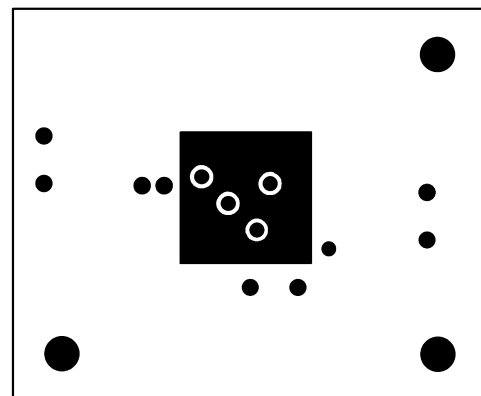
Bottom Layer



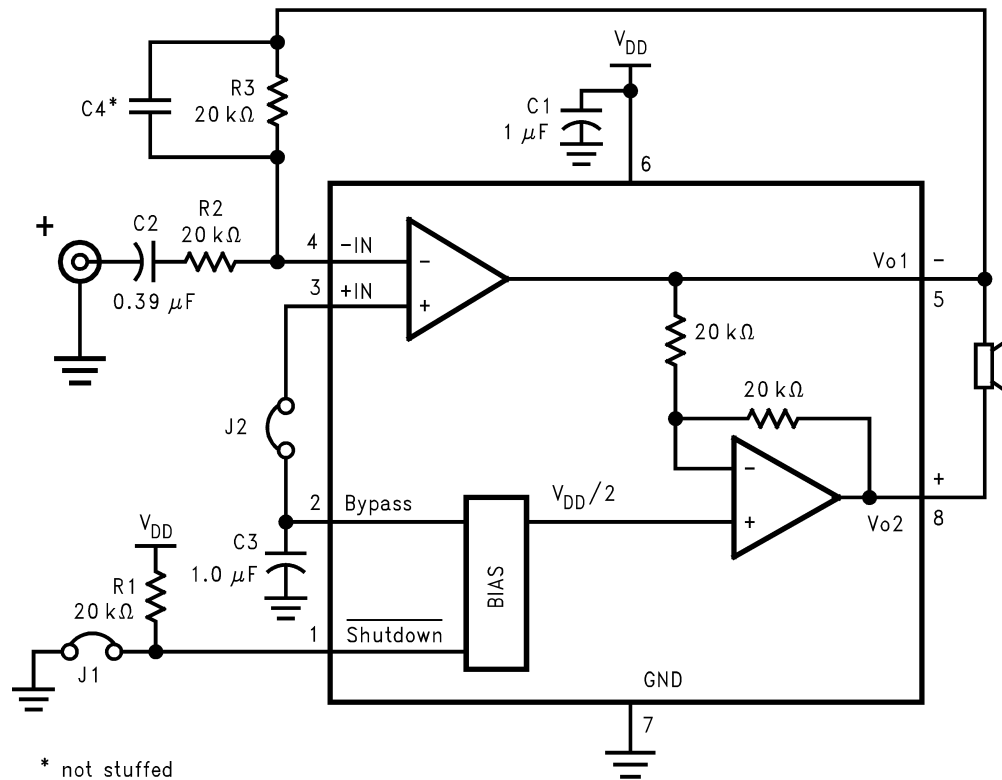
Inner Layer Ground



Inner Layer V<sub>DD</sub>



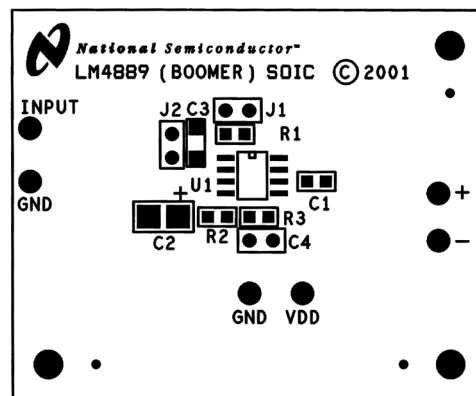
## REFERENCE DESIGN BOARD AND PCB LAYOUT GUIDELINES - VSSOP & SOIC BOARDS



**Figure 33. Reference Design Board**

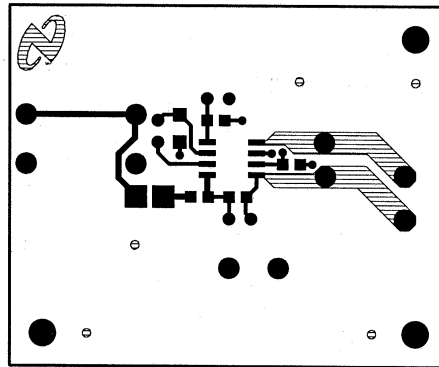
## LM4889 SOIC DEMO BOARD ARTWORK

### Figure 34. Silk Screen

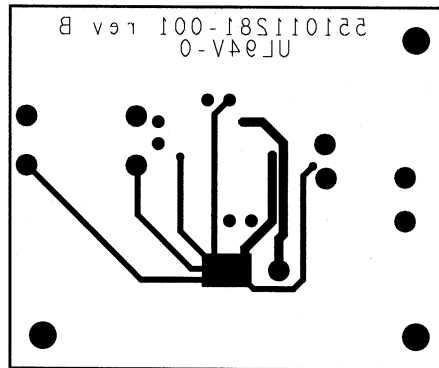




**Figure 35. Top Layer**



**Figure 36. Bottom Layer**



## LM4889 VSSOP DEMO BOARD ARTWORK

**Figure 37. Silk Screen**

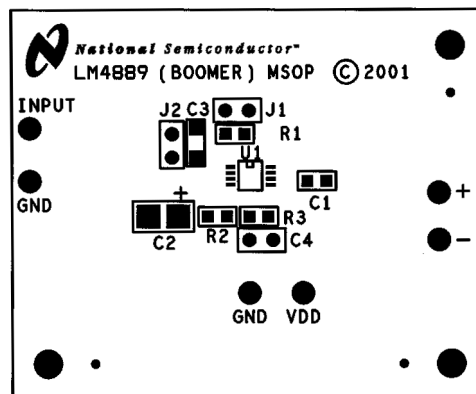


Figure 38. Top Layer

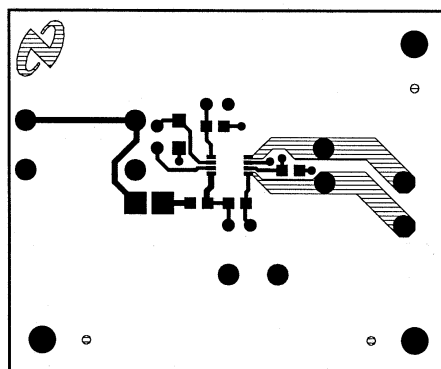
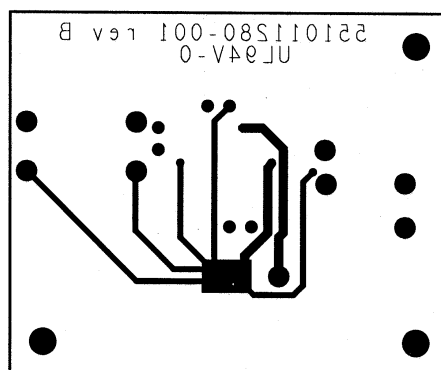


Figure 39. Bottom Layer



## REVISION HISTORY

| Changes from Revision G (May 2013) to Revision H           | Page               |
|------------------------------------------------------------|--------------------|
| • Changed layout of National Data Sheet to TI format ..... | <a href="#">18</a> |

## PACKAGING INFORMATION

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2) | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| LM4889MA/NOPB    | ACTIVE        | SOIC         | D                  | 8    | 95             | RoHS & Green    | SN                                   | Level-1-260C-UNLIM   | -40 to 85    | LM48<br>89MA            | <a href="#">Samples</a> |
| LM4889MAX/NOPB   | ACTIVE        | SOIC         | D                  | 8    | 2500           | RoHS & Green    | SN                                   | Level-1-260C-UNLIM   | -40 to 85    | LM48<br>89MA            | <a href="#">Samples</a> |
| LM4889MM/NOPB    | ACTIVE        | VSSOP        | DGK                | 8    | 1000           | RoHS & Green    | SN                                   | Level-1-260C-UNLIM   | -40 to 85    | GA2                     | <a href="#">Samples</a> |
| LM4889MMX/NOPB   | ACTIVE        | VSSOP        | DGK                | 8    | 3500           | RoHS & Green    | SN                                   | Level-1-260C-UNLIM   | -40 to 85    | GA2                     | <a href="#">Samples</a> |

(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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

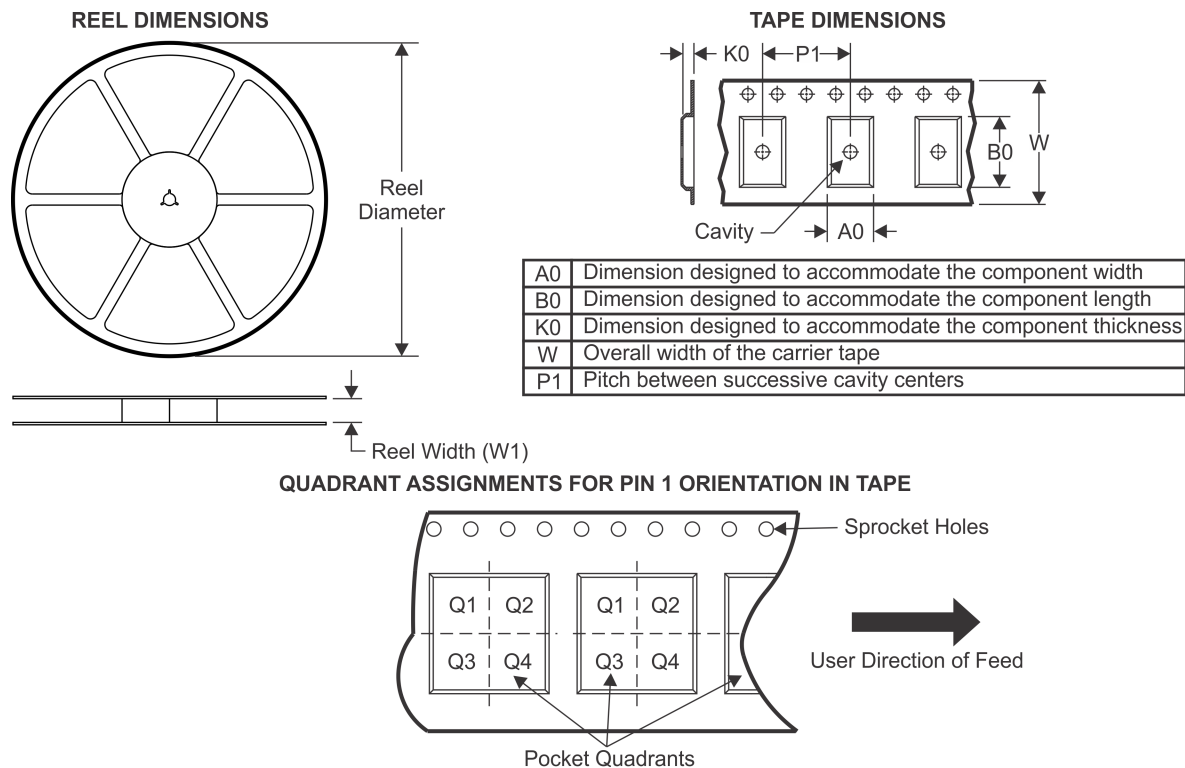
(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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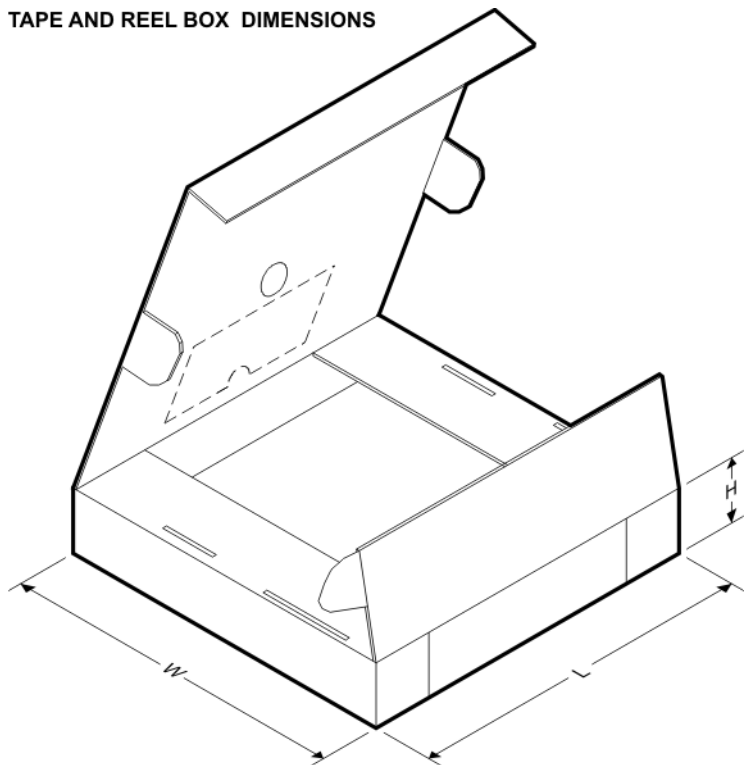
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**TAPE AND REEL INFORMATION**


\*All dimensions are nominal

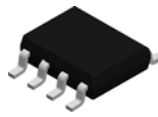
| Device         | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LM4889MAX/NOPB | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.5     | 5.4     | 2.0     | 8.0     | 12.0   | Q1            |
| LM4889MM/NOPB  | VSSOP        | DGK             | 8    | 1000 | 178.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| LM4889MMX/NOPB | VSSOP        | DGK             | 8    | 3500 | 330.0              | 12.4               | 5.3     | 3.4     | 1.4     | 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) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LM4889MAX/NOPB | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| LM4889MM/NOPB  | VSSOP        | DGK             | 8    | 1000 | 210.0       | 185.0      | 35.0        |
| LM4889MMX/NOPB | VSSOP        | DGK             | 8    | 3500 | 367.0       | 367.0      | 35.0        |

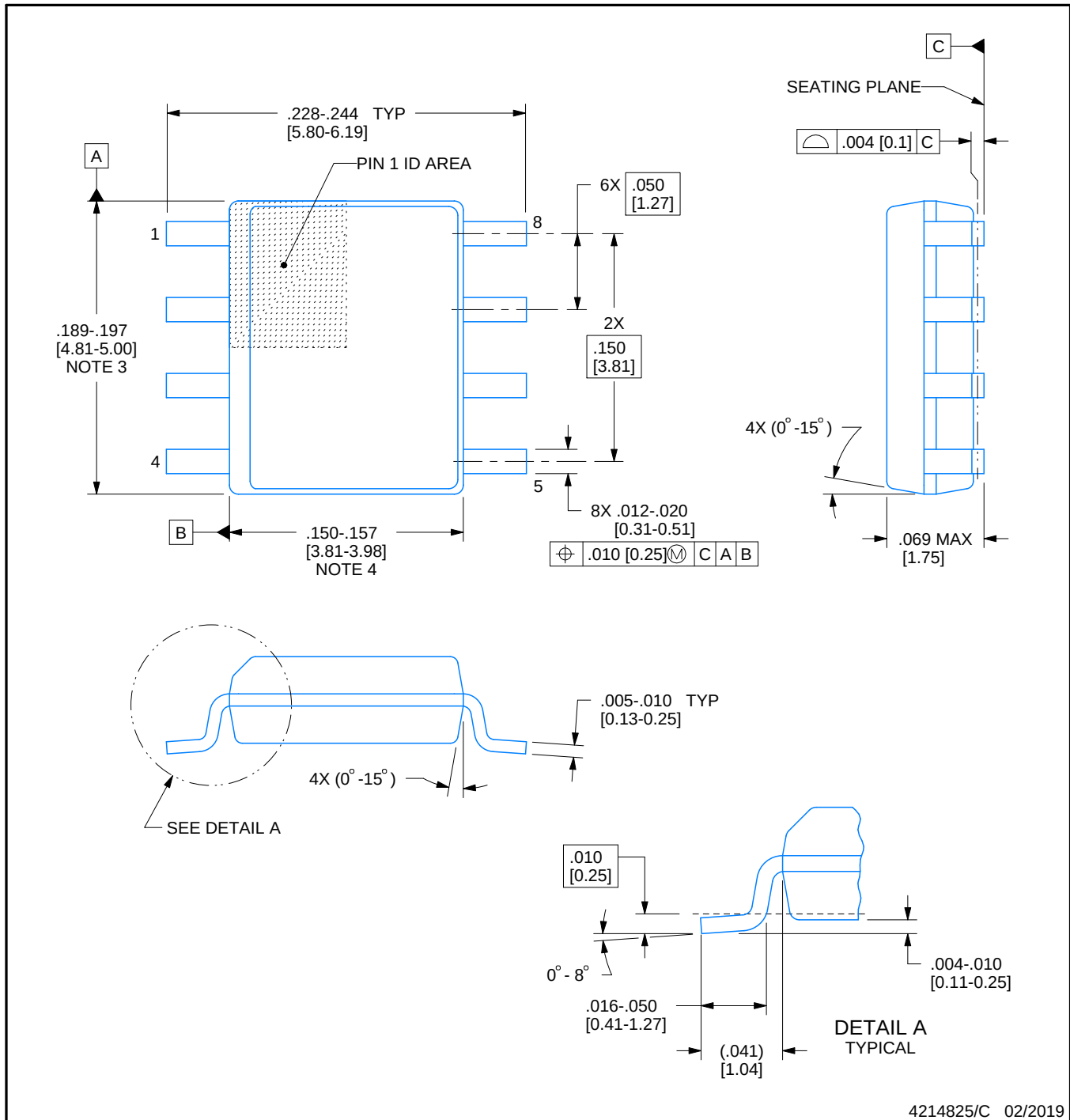


**D0008A**

# PACKAGE OUTLINE

**SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT



4214825/C 02/2019

## NOTES:

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.

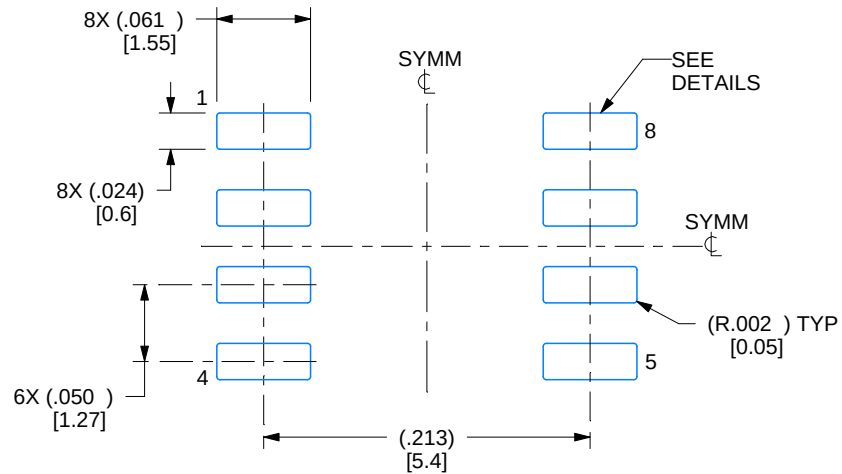


# EXAMPLE BOARD LAYOUT

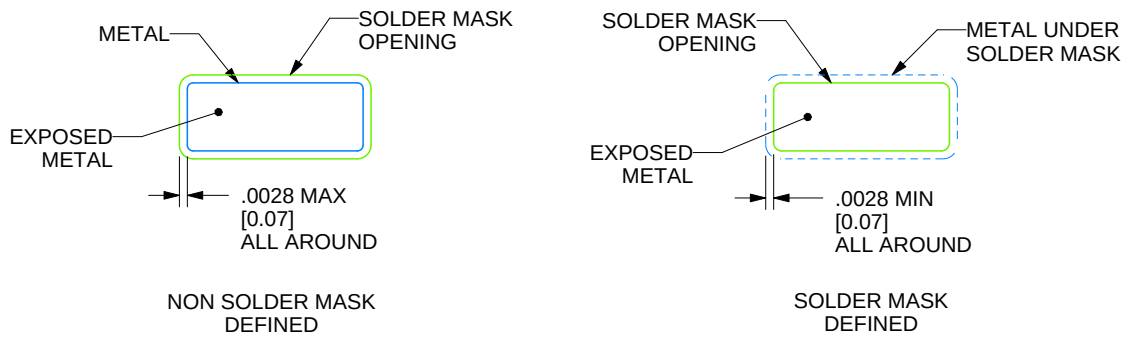
D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

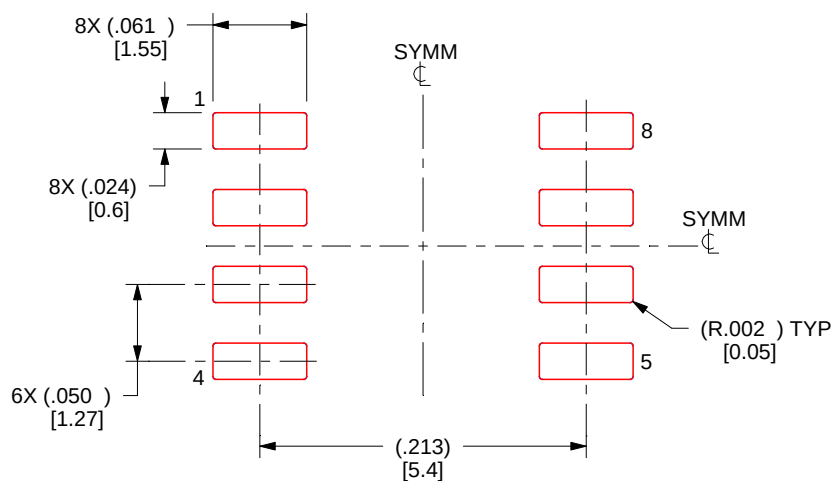
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE  
BASED ON .005 INCH [0.125 MM] THICK STENCIL  
SCALE:8X

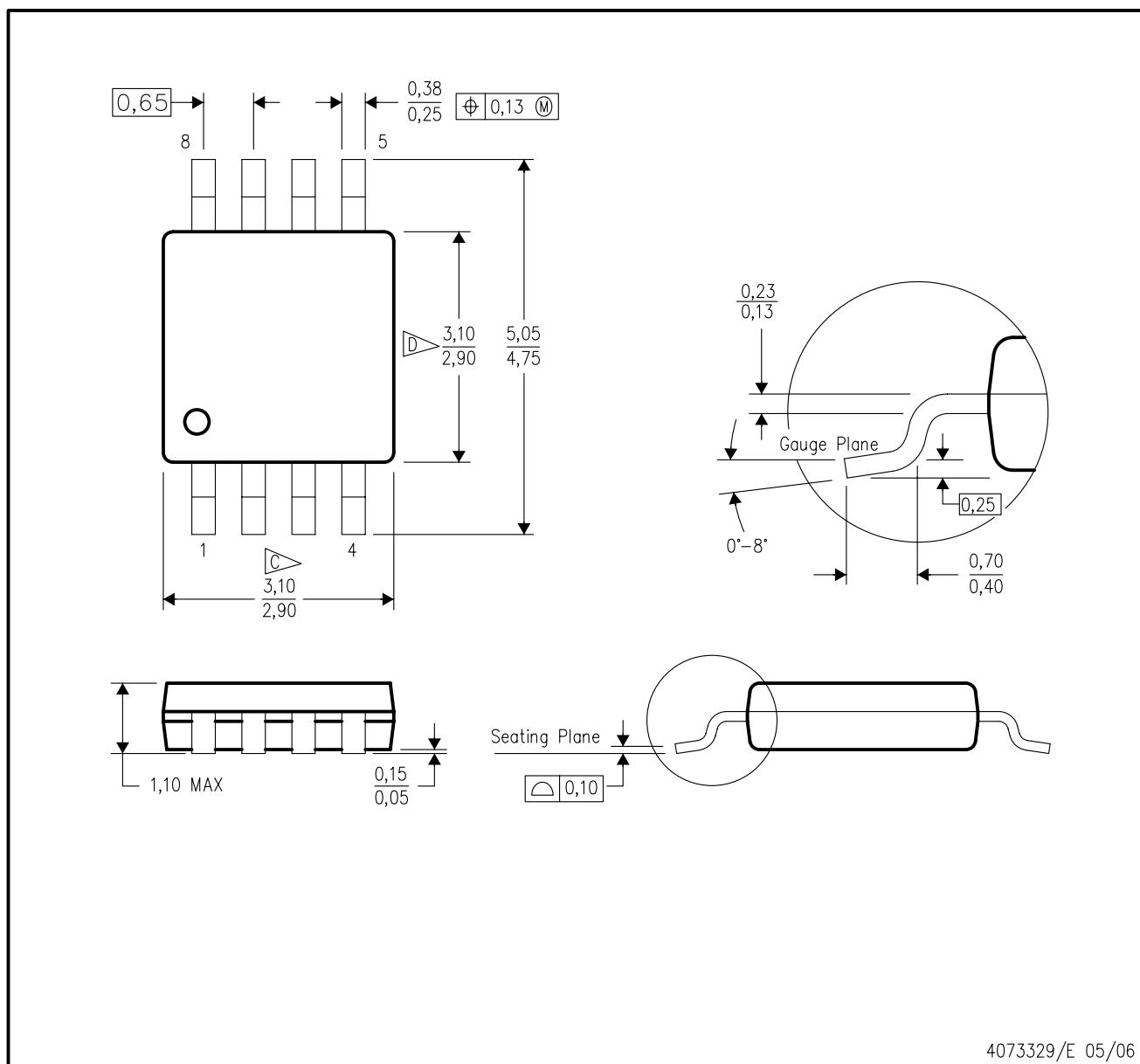
4214825/C 02/2019

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

## DGK (S-PDSO-G8)

## PLASTIC SMALL-OUTLINE PACKAGE

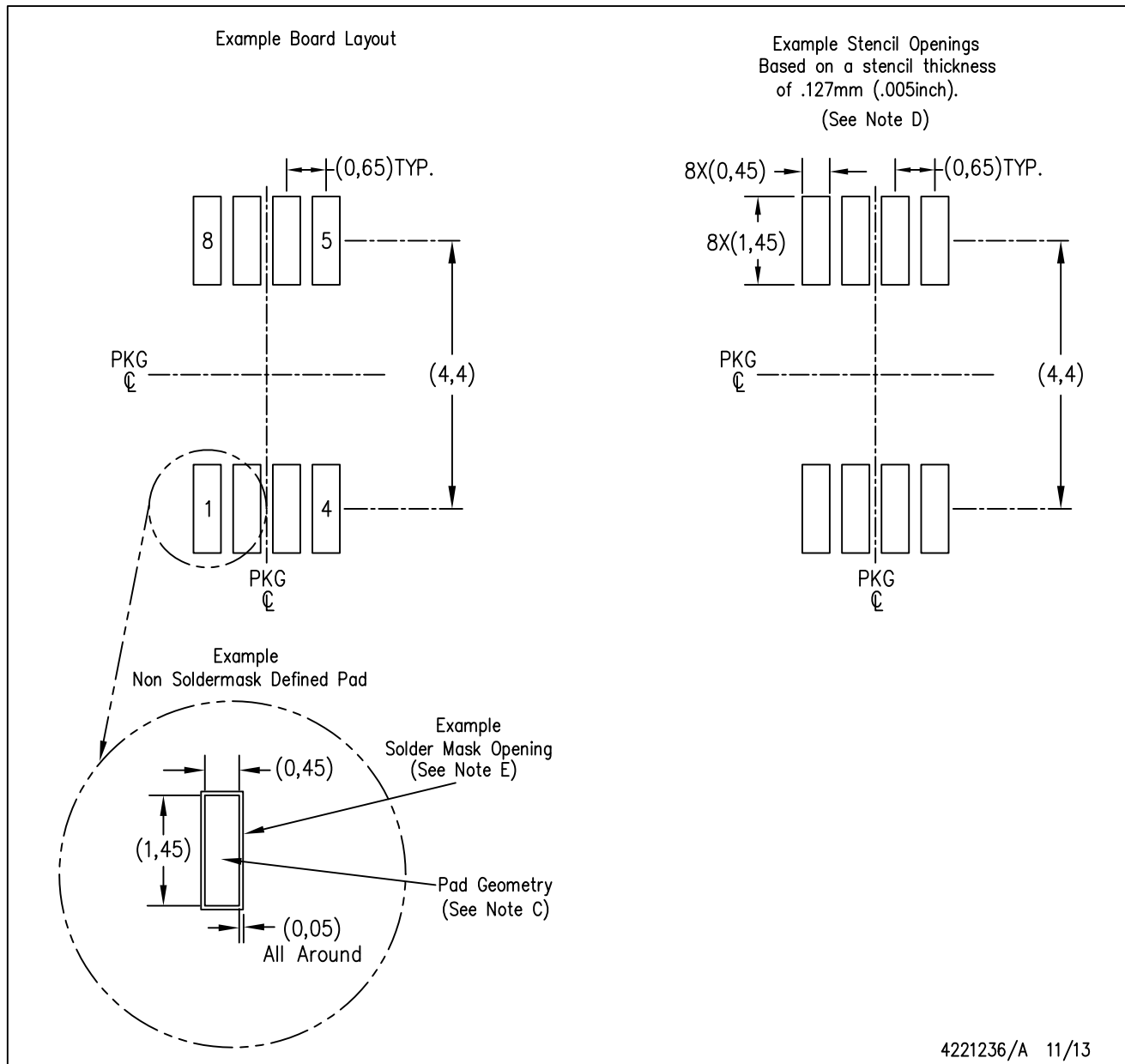


## NOTES:

- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
- D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
- E. Falls within JEDEC MO-187 variation AA, except interlead flash.

DGK (S-PDSO-G8)

PLASTIC SMALL OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. 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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