

## **LM4809 Boomer® Audio Power Amplifier Series Dual 105mW Headphone Amplifier with Active-Low Shutdown Mode**

Check for Samples: [LM4809](#), [LM4809LQBD](#)

### **FEATURES**

- **Active-Low Shutdown Mode**
- **"Click and Pop" Reduction Circuitry**
- **Low Shutdown Current**
- **WSOP, MSOP, and SOIC Surface Mount Packaging**
- **No Bootstrap Capacitors Required**
- **Unity-Gain Stable**

### **APPLICATIONS**

- **Headphone Amplifier**
- **Personal Computers**
- **Microphone Preamplifier**
- **PDA's**

### **KEY SPECIFICATIONS**

- **THD+N at 1kHz at 105mW Continuous Average Power into 16Ω 0.1% (typ)**
- **THD+N at 1kHz at 70mW Continuous Average Power into 32Ω 0.1% (typ)**
- **Shutdown Current 0.4μA (typ)**

### **DESCRIPTION**

The LM4809 is a dual audio power amplifier capable of delivering 105mW per channel of continuous average power into a 16Ω load with 0.1% (THD+N) from a 5V power supply.

Boomer audio power amplifiers were designed specifically to provide high quality output power with a minimal amount of external components. Since the LM4809 does not require bootstrap capacitors or snubber networks, it is optimally suited for low-power portable systems.

The unity-gain stable LM4809 can be configured by external gain-setting resistors.

The LM4809 features an externally controlled, active-low, micropower consumption shutdown mode, as well as an internal thermal shutdown protection mechanism.



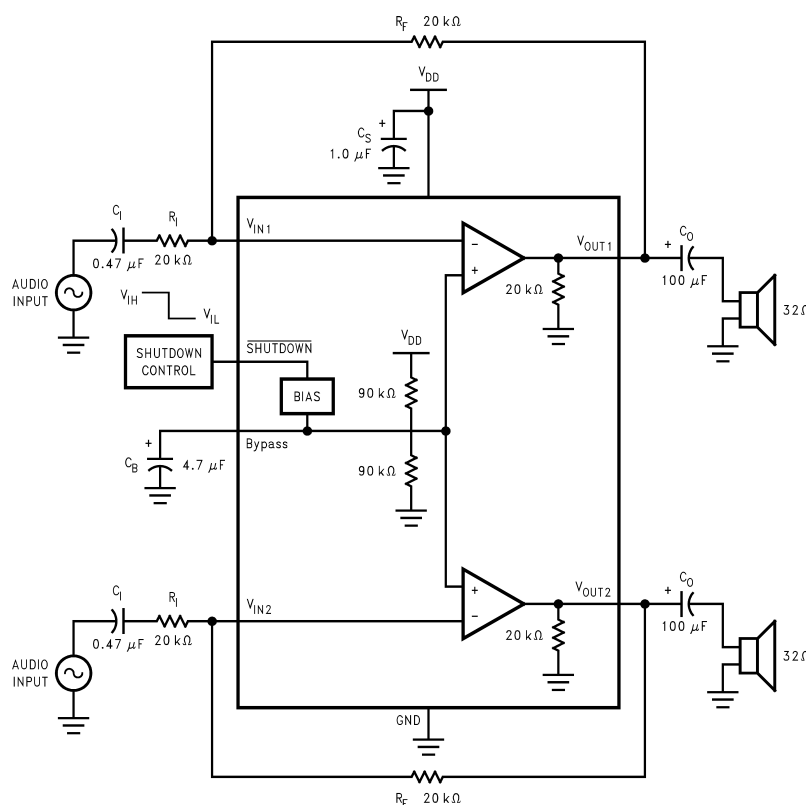
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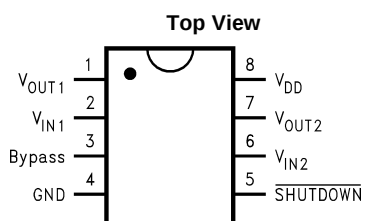
## Typical Application



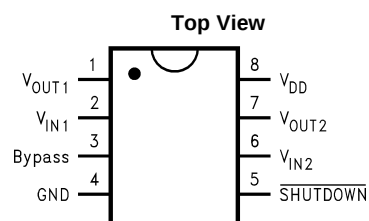
\*Refer to [Application Information](#) for information concerning proper selection of the input and output coupling capacitors.

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

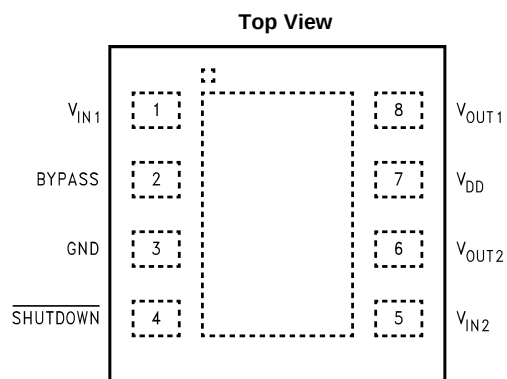
## Connection Diagrams



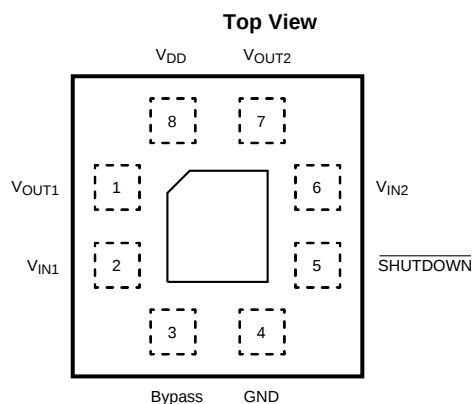
**Figure 2. VSSOP Package**  
See Package Number DGK0008A



**Figure 3. SOIC Package**  
See Package Number D0008A



**Figure 4. WSON Package**  
See Package Number NGL0008B



**Figure 5. WSON Package**  
See Package Number NGP0008A



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        |
| ESD Susceptibility <sup>(3)</sup>      |              |                        | 3.5kV                  |
| ESD Machine model <sup>(4)</sup>       |              |                        | 250V                   |
| Junction Temperature (T <sub>J</sub> ) |              |                        | 150°C                  |
| Soldering Information                  | SOIC Package | Vapor Phase (60 sec.)  | 215°C                  |
|                                        |              | Infrared (15 sec.)     | 220°C                  |
| Thermal Resistance                     |              | θ <sub>JA</sub> (SOIC) | 170°C/W                |
|                                        |              | θ <sub>JC</sub> (SOIC) | 35°C/W                 |
|                                        |              | θ <sub>JA</sub> (MSOP) | 210°C/W                |
|                                        |              | θ <sub>JC</sub> (MSOP) | 56°C/W                 |
|                                        |              | θ <sub>JA</sub> (WSON) | 117°C/W <sup>(5)</sup> |
|                                        |              | θ <sub>JA</sub> (WSON) | 150°C/W <sup>(6)</sup> |
|                                        |              | θ <sub>JC</sub> (WSON) | 15°C/W                 |

- (1) *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur.
- (2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.
- (3) Human body model, 100pF discharged through a 1.5kΩ resistor.
- (4) Machine Model ESD test is covered by specification EIAJ IC-121-1981. A 200pF cap is charged to the specified voltage, then discharged directly into the IC with no external series resistor (resistance of discharge path must be under 50Ω).
- (5) The given θ<sub>JA</sub> is for an LM4809 packaged in an NGL0008B with the Exposed-Dap soldered to a printed circuit board copper pad with an area equivalent to that of the Exposed-Dap itself.
- (6) The given θ<sub>JA</sub> is for an LM4809 packaged in an NGL0008B with the Exposed-Dap not soldered to any printed circuit board copper.

## 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 (V <sub>CC</sub> ) |                                                      | 2.0V ≤ V <sub>CC</sub> ≤ 5.5V |

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

The following specifications apply for V<sub>DD</sub> = 5V unless otherwise specified, limits apply to T<sub>A</sub> = 25°C.

| Parameter       |                              | Test Conditions                                                                                            | LM4809             |                      | Units<br>(Limits) |
|-----------------|------------------------------|------------------------------------------------------------------------------------------------------------|--------------------|----------------------|-------------------|
|                 |                              |                                                                                                            | Typ <sup>(3)</sup> | Limit <sup>(4)</sup> |                   |
| V <sub>DD</sub> | Supply Voltage               |                                                                                                            |                    | 2.0                  | V (min)           |
|                 |                              |                                                                                                            |                    | 5.5                  | V (max)           |
| I <sub>DD</sub> | Supply Current               | V <sub>IN</sub> = 0V, I <sub>O</sub> = 0A                                                                  | 1.4                | 3                    | mA (max)          |
| I <sub>SD</sub> | Shutdown Current             | V <sub>IN</sub> = 0V, V <sub>SHUTDOWN</sub> = GND                                                          | 0.4                | 2                    | μA(max)           |
| V <sub>OS</sub> | Output Offset Voltage        | V <sub>IN</sub> = 0V                                                                                       | 4.0                | 50                   | mV(max)           |
| P <sub>O</sub>  | Output Power                 | THD+N = 0.1%, f = 1kHz                                                                                     |                    |                      |                   |
|                 |                              | R <sub>L</sub> = 16Ω                                                                                       | 105                |                      | mW                |
|                 |                              | R <sub>L</sub> = 32Ω                                                                                       | 70                 | 65                   | mW (min)          |
| THD+N           | Total Harmonic Distortion    | P <sub>O</sub> = 50mW, R <sub>L</sub> = 32Ω<br>f = 20Hz to 20kHz                                           | 0.3                |                      | %                 |
| Crosstalk       | Channel Separation           | R <sub>L</sub> = 32Ω; P <sub>O</sub> = 70mW                                                                | 70                 |                      | dB                |
| PSRR            | Power Supply Rejection Ratio | C <sub>B</sub> = 1.0μF; V <sub>RIPPLE</sub> = 200mV <sub>PP</sub> ,<br>f = 1kHz; Input terminated into 50Ω | 70                 |                      | dB                |

- (1) *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur.
- (2) All voltages are measured with respect to the ground pin, unless otherwise specified.
- (3) Typical specifications are specified at +25°C and represent the most likely parametric norm.
- (4) Datasheet min/max specification limits are ensured by design, test, or statistical analysis.

### Electrical Characteristics $V_{DD} = 5V$ <sup>(1)(2)</sup> (continued)

The following specifications apply for  $V_{DD} = 5V$  unless otherwise specified, limits apply to  $T_A = 25^\circ C$ .

| Parameter  |                             | Test Conditions | LM4809             |                      | Units (Limits) |
|------------|-----------------------------|-----------------|--------------------|----------------------|----------------|
|            |                             |                 | Typ <sup>(3)</sup> | Limit <sup>(4)</sup> |                |
| $V_{SDIH}$ | Shutdown Voltage Input High |                 |                    | $0.8 \times V_{DD}$  | V (min)        |
| $V_{SDIL}$ | Shutdown Voltage Input Low  |                 |                    | $0.2 \times V_{DD}$  | V (max)        |

### Electrical Characteristics $V_{DD} = 3.3V$ <sup>(1)(2)</sup>

The following specifications apply for  $V_{DD} = 3.3V$  unless otherwise specified, limits apply to  $T_A = 25^\circ C$ .

| Parameter  |                              | Test Conditions                                                                              | LM4809             |                      | Units (Limits) |
|------------|------------------------------|----------------------------------------------------------------------------------------------|--------------------|----------------------|----------------|
|            |                              |                                                                                              | Typ <sup>(3)</sup> | Limit <sup>(4)</sup> |                |
| $I_{DD}$   | Supply Current               | $V_{IN} = 0V, I_O = 0A$                                                                      | 1.1                |                      | mA             |
| $I_{SD}$   | Shutdown Current             | $V_{IN} = 0V, V_{SHUTDOWN} = GND$                                                            | 0.4                |                      | $\mu A$        |
| $V_{OS}$   | Output Offset Voltage        | $V_{IN} = 0V$                                                                                | 4.0                |                      | mV             |
| $P_O$      | Output Power                 | THD+N = 0.1%, $f = 1kHz$                                                                     |                    |                      |                |
|            |                              | $R_L = 16\Omega$                                                                             | 40                 |                      | mW             |
|            |                              | $R_L = 32\Omega$                                                                             | 28                 |                      | mW             |
| THD+N      | Total Harmonic Distortion    | $P_O = 25mW, R_L = 32\Omega$<br>$f = 20Hz$ to $20kHz$                                        | 0.4                |                      | %              |
| Crosstalk  | Channel Separation           | $R_L = 32\Omega; P_O = 25mW$                                                                 | 70                 |                      | dB             |
| PSRR       | Power Supply Rejection Ratio | $C_B = 1.0\mu F; V_{RIPPLE} = 200mV_{PP}$ ,<br>$f = 1kHz$ ; Input terminated into $50\Omega$ | 70                 |                      | dB             |
| $V_{SDIH}$ | Shutdown Voltage Input High  |                                                                                              |                    | $0.8 \times V_{DD}$  | V (min)        |
| $V_{SDIL}$ | Shutdown Voltage Input Low   |                                                                                              |                    | $0.2 \times V_{DD}$  | V (max)        |

- (1) *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur.
- (2) All voltages are measured with respect to the ground pin, unless otherwise specified.
- (3) Typical specifications are specified at  $+25^\circ C$  and represent the most likely parametric norm.
- (4) Datasheet min/max specification limits are ensured by design, test, or statistical analysis.

### Electrical Characteristics $V_{DD} = 2.6V$ <sup>(1)(2)</sup>

The following specifications apply for  $V_{DD} = 2.6V$  unless otherwise specified, limits apply to  $T_A = 25^\circ C$ .

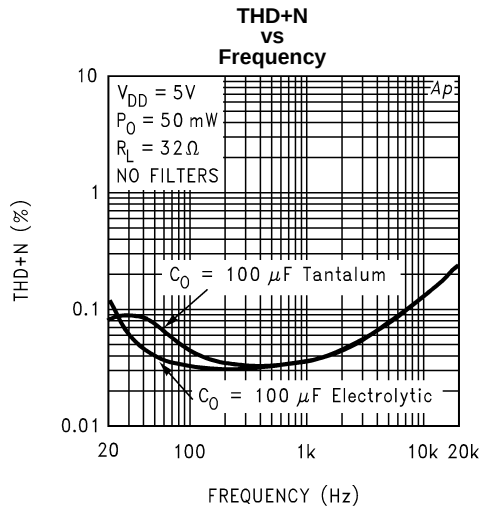
| Parameter  |                              | Test Conditions                                                                              | LM4809             |                      | Units (Limits) |
|------------|------------------------------|----------------------------------------------------------------------------------------------|--------------------|----------------------|----------------|
|            |                              |                                                                                              | Typ <sup>(3)</sup> | Limit <sup>(4)</sup> |                |
| $I_{DD}$   | Supply Current               | $V_{IN} = 0V, I_O = 0A$                                                                      | 0.9                |                      | mA             |
| $I_{SD}$   | Shutdown Current             | $V_{IN} = 0V, V_{SHUTDOWN} = GND$                                                            | 0.2                |                      | $\mu A$        |
| $V_{OS}$   | Output Offset Voltage        | $V_{IN} = 0V$                                                                                | 4.0                |                      | mV             |
| $P_O$      | Output Power                 | THD+N = 0.1%, $f = 1kHz$                                                                     |                    |                      |                |
|            |                              | $R_L = 16\Omega$                                                                             | 20                 |                      | mW             |
|            |                              | $R_L = 32\Omega$                                                                             | 16                 |                      | mW             |
| THD+N      | Total Harmonic Distortion    | $P_O = 15mW, R_L = 32\Omega$<br>$f = 20Hz$ to $20kHz$                                        | 0.6                |                      | %              |
| Crosstalk  | Channel Separation           | $R_L = 32\Omega; P_O = 15mW$                                                                 | 70                 |                      | dB             |
| PSRR       | Power Supply Rejection Ratio | $C_B = 1.0\mu F; V_{RIPPLE} = 200mV_{PP}$ ,<br>$f = 1kHz$ ; Input terminated into $50\Omega$ | 70                 |                      | dB             |
| $V_{SDIH}$ | Shutdown Voltage Input High  |                                                                                              |                    | $0.8 \times V_{DD}$  | V (min)        |
| $V_{SDIL}$ | Shutdown Voltage Input Low   |                                                                                              |                    | $0.2 \times V_{DD}$  | V (max)        |

- (1) *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur.
- (2) All voltages are measured with respect to the ground pin, unless otherwise specified.
- (3) Typical specifications are specified at  $+25^\circ C$  and represent the most likely parametric norm.
- (4) Datasheet min/max specification limits are ensured by design, test, or statistical analysis.

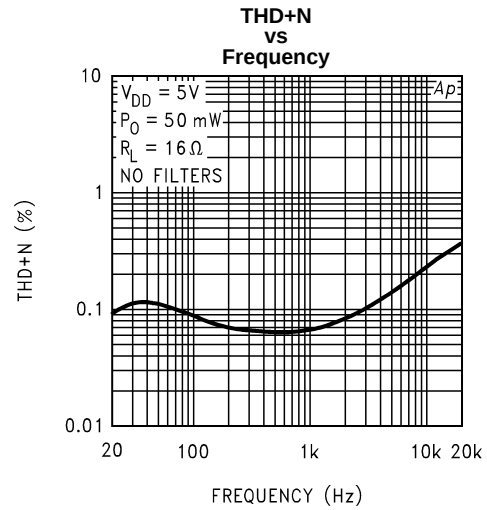
## External Components Description

| Components | Functional Description (See <a href="#">Figure 1</a> )                                                                                                                                                                                                                                                     |
|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. $R_i$   | The inverting input resistance, along with $R_f$ , set the closed-loop gain. $R_i$ , along with $C_i$ , form a high pass filter with $f_c = 1/(2\pi R_i C_i)$ .                                                                                                                                            |
| 2. $C_i$   | The input coupling capacitor blocks DC voltage at the amplifier's input terminals. $C_i$ , along with $R_i$ , create a highpass filter with $f_c = 1/(2\pi R_i C_i)$ . Refer to the section, <a href="#">Selecting Proper External Components</a> , for an explanation of determining the value of $C_i$ . |
| 3. $R_f$   | The feedback resistance, along with $R_i$ , set closed-loop gain.                                                                                                                                                                                                                                          |
| 4. $C_S$   | This is the supply bypass capacitor. It provides power supply filtering. Refer to the <a href="#">Application Information</a> section for proper placement and selection of the supply bypass capacitor.                                                                                                   |
| 5. $C_B$   | This is the BYPASS pin capacitor. It provides half-supply filtering. Refer to the section, <a href="#">Selecting Proper External Components</a> , for information concerning proper placement and selection of $C_B$ .                                                                                     |
| 6. $C_O$   | This is the output coupling capacitor. It blocks the DC voltage at the amplifier's output and forms a high pass filter with $R_L$ at $f_o = 1/(2\pi R_L C_O)$                                                                                                                                              |

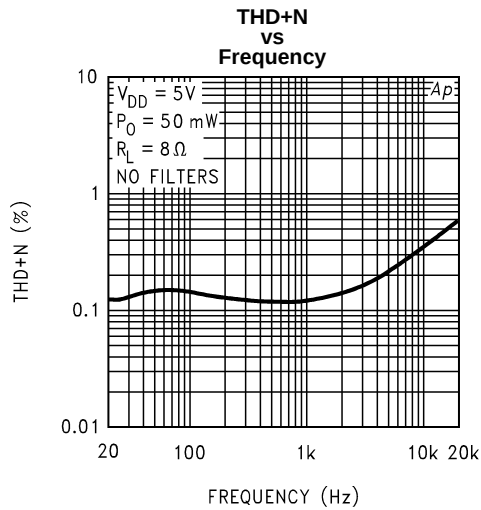
## Typical Performance Characteristics



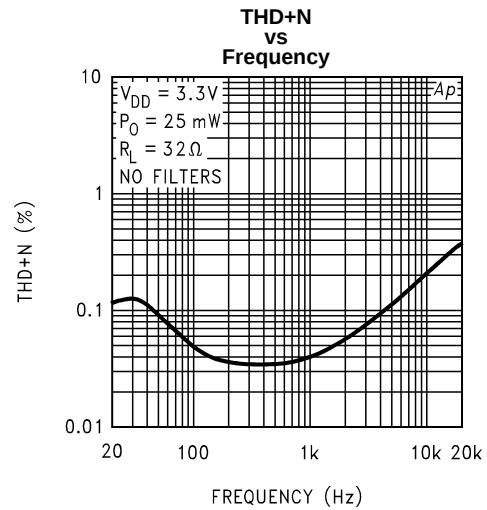
**Figure 6.**



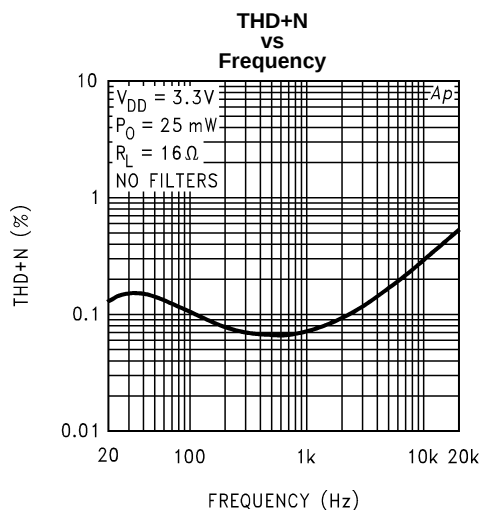
**Figure 7.**



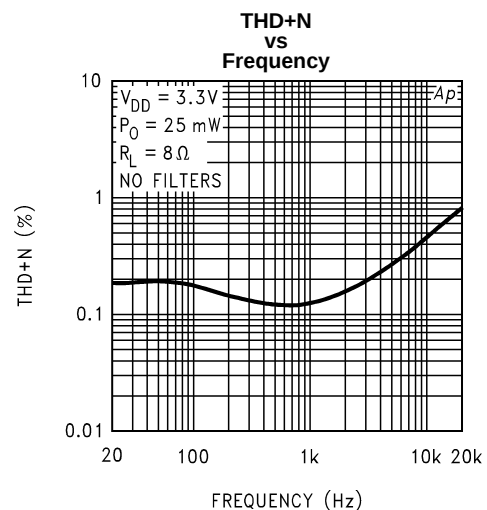
**Figure 8.**



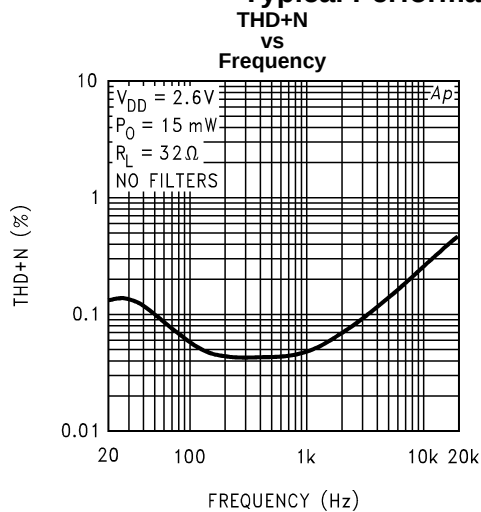
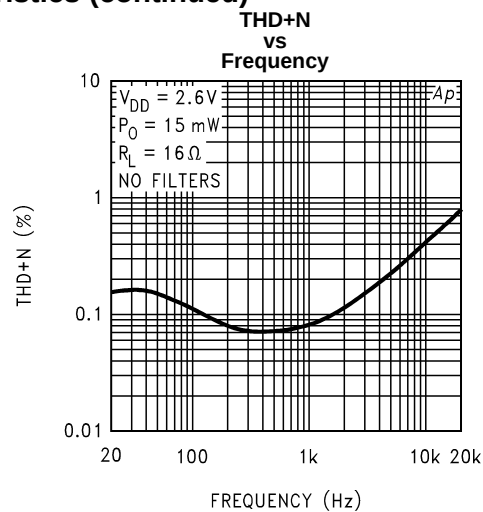
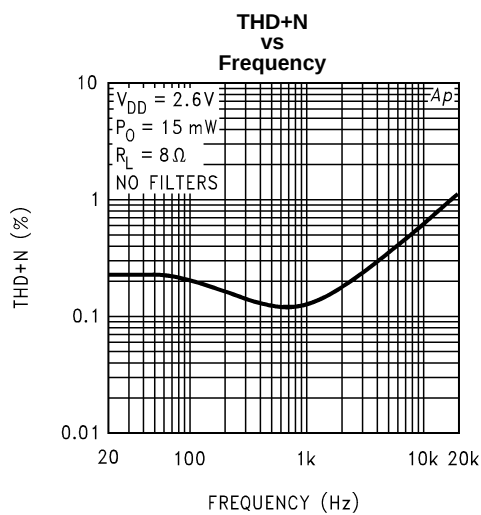
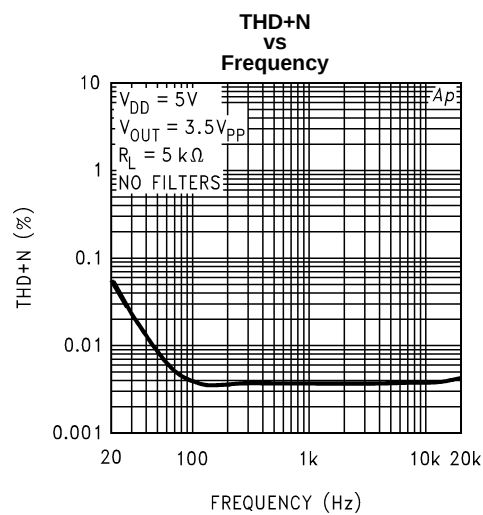
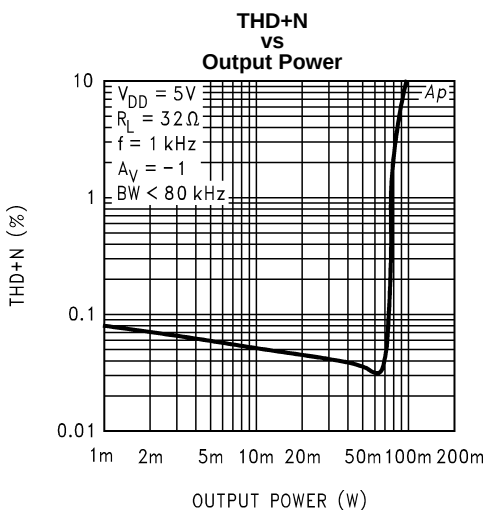
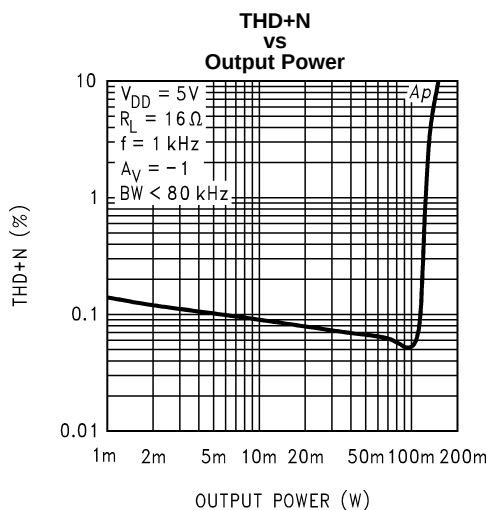
**Figure 9.**



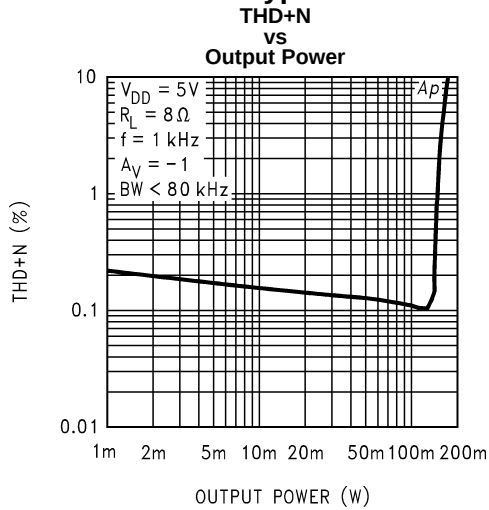
**Figure 10.**



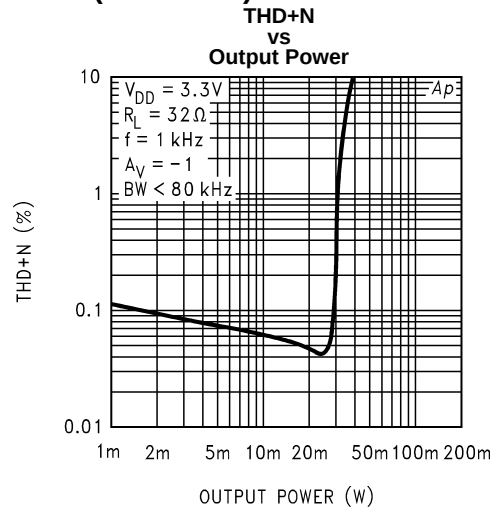
**Figure 11.**

**Typical Performance Characteristics (continued)****Figure 12.****Figure 13.****Figure 14.****Figure 15.****Figure 16.****Figure 17.**

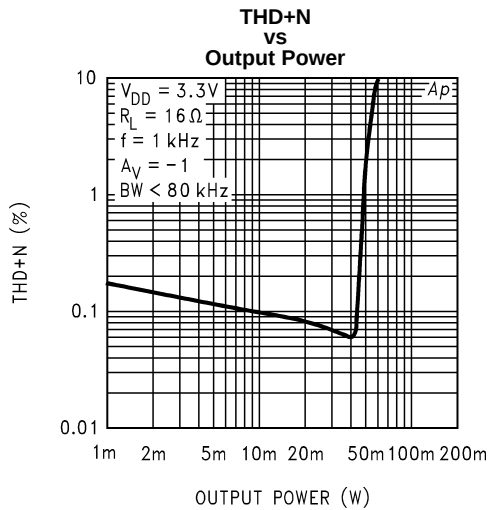
## Typical Performance Characteristics (continued)



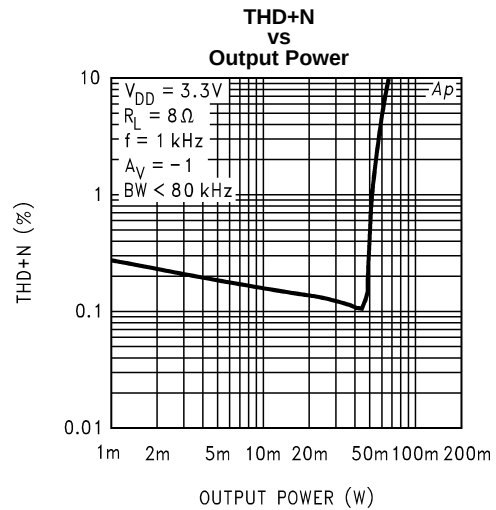
**Figure 18.**



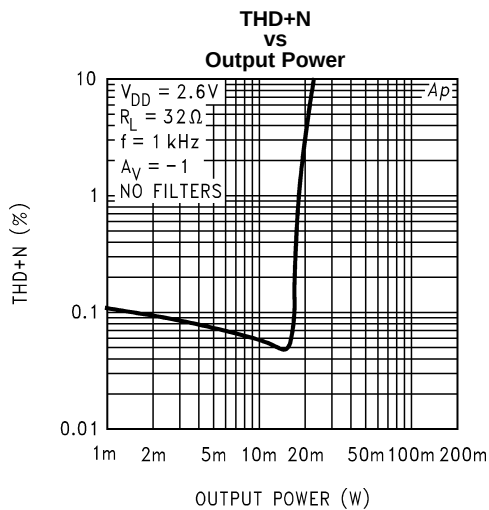
**Figure 19.**



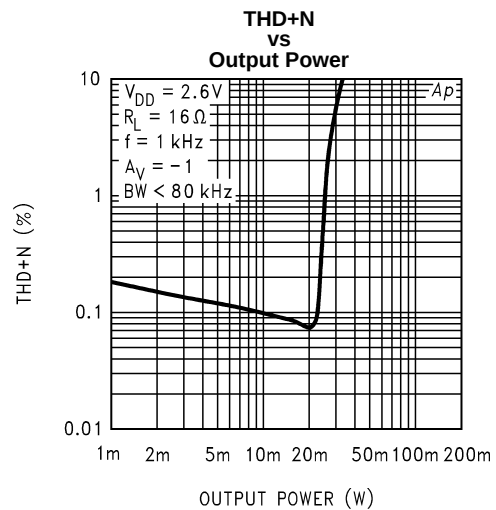
**Figure 20.**



**Figure 21.**



**Figure 22.**



**Figure 23.**

# Typical Performance Characteristics (continued)

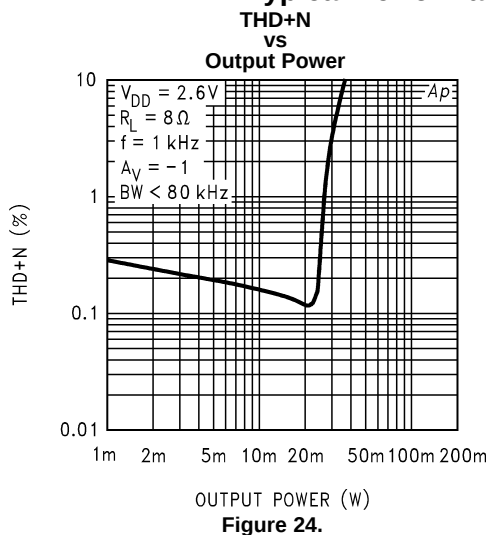


Figure 24.

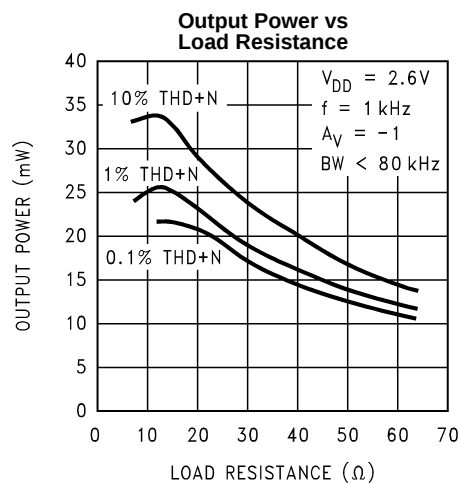


Figure 25.

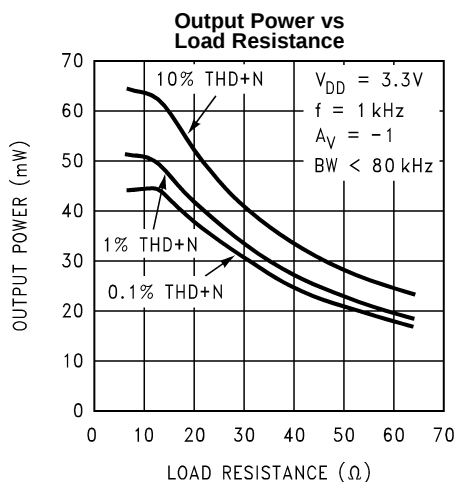


Figure 26.

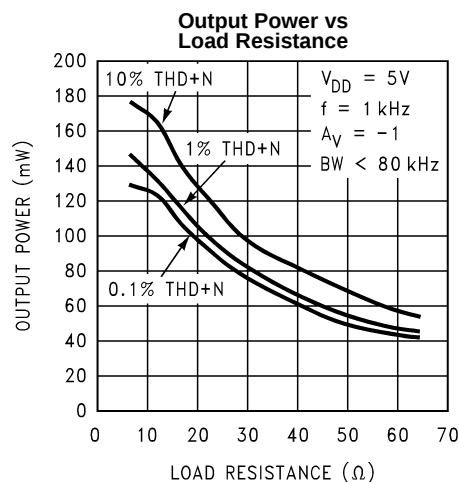


Figure 27.

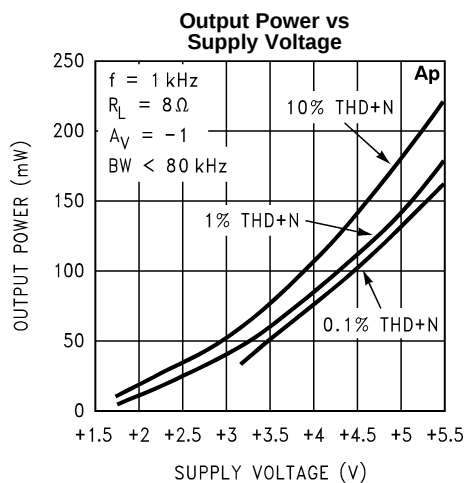


Figure 28.

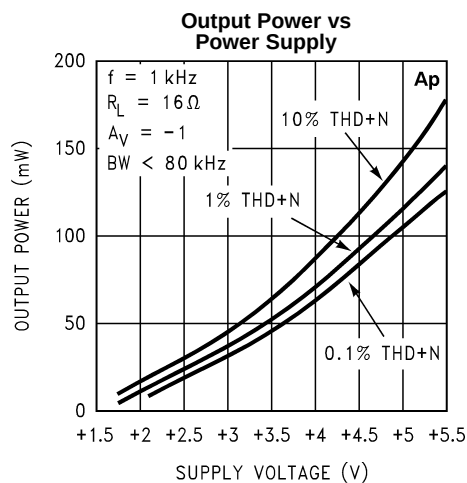
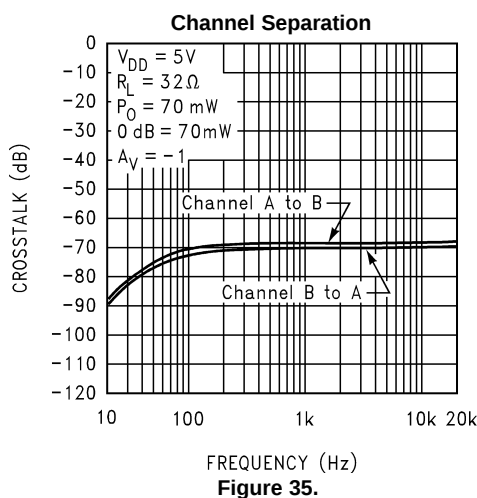
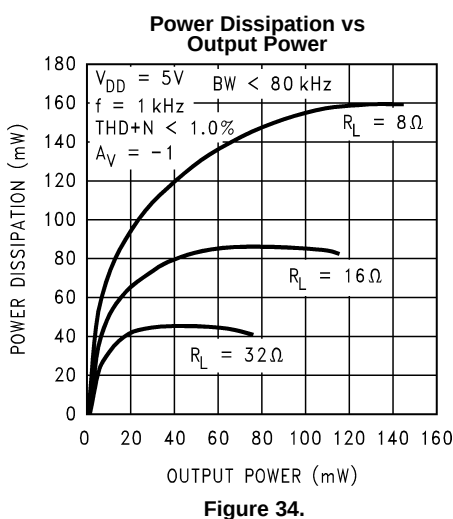
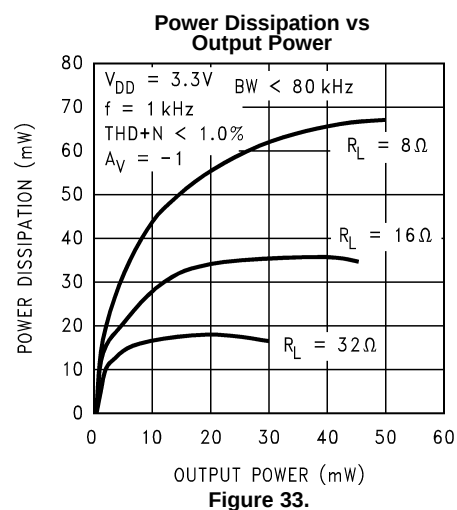
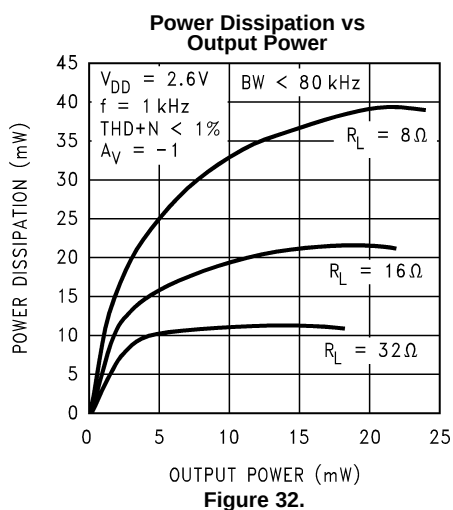
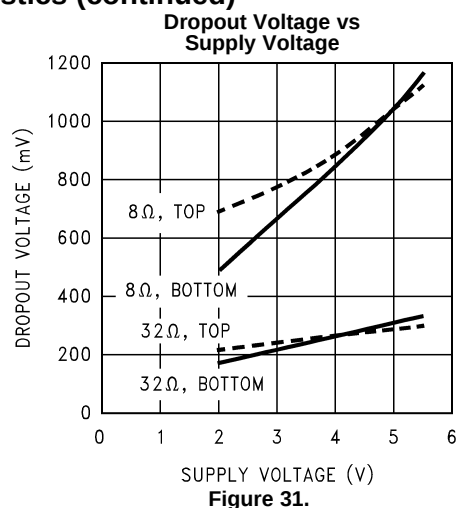
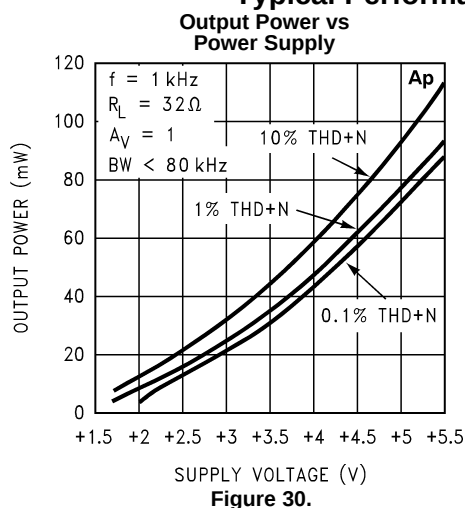


Figure 29.

## Typical Performance Characteristics (continued)



## Typical Performance Characteristics (continued)

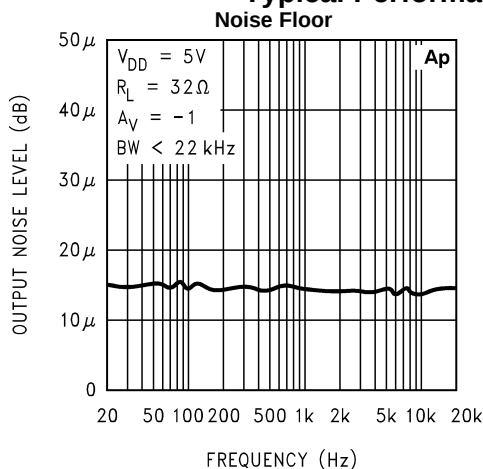


Figure 36.

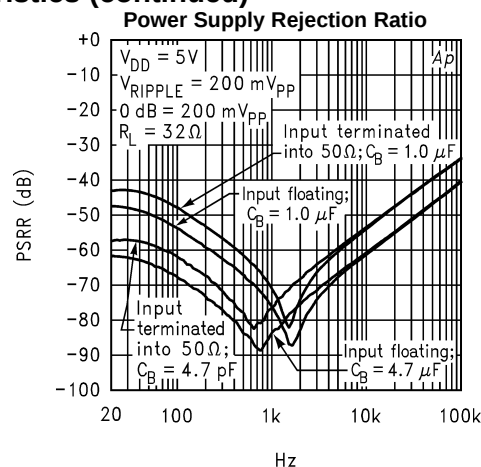


Figure 37.

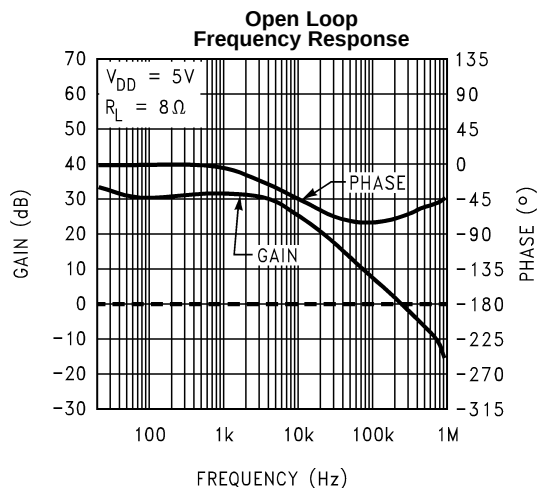


Figure 38.

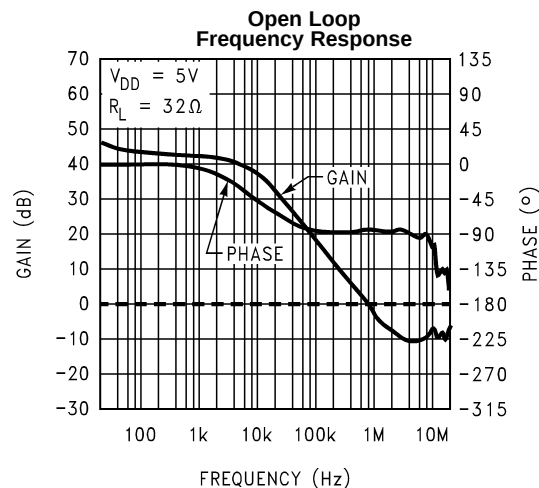


Figure 39.

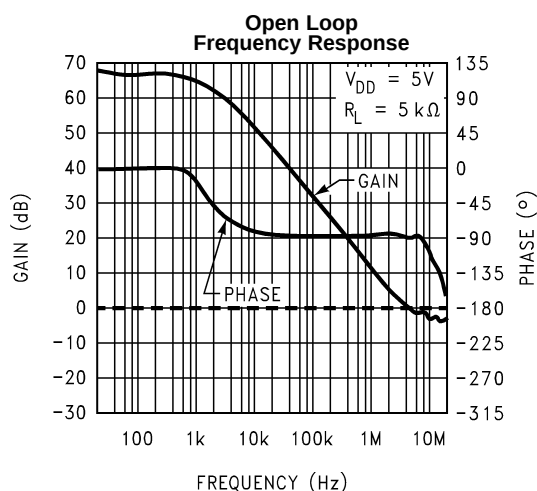


Figure 40.

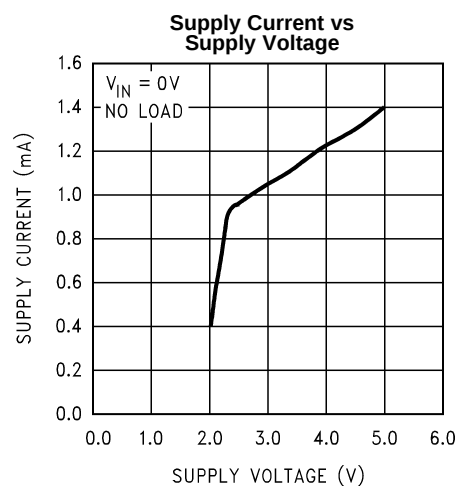


Figure 41.

## APPLICATION INFORMATION

### MICRO-POWER SHUTDOWN

The voltage applied to the SHUTDOWN pin controls the LM4809's shutdown function. Activate micro-power shutdown by applying a logic low voltage to the SHUTDOWN pin. The logic threshold is typically  $V_{DD}/2$ . When active, the LM4809's micro-power shutdown feature turns off the amplifier's bias circuitry, reducing the supply current. The low 0.4μA typical shutdown current is achieved by applying a voltage that is as near as GND as possible to the SHUTDOWN pin. A voltage that is above GND may increase the shutdown current.

There are a few ways to control the micro-power shutdown. These include using a single-pole, single-throw switch, a microprocessor, or a microcontroller. When using a switch, connect an external 100kΩ pull-down resistor between the SHUTDOWN pin and GND. Connect the switch between the SHUTDOWN pin and  $V_{DD}$ . Select normal amplifier operation by closing the switch. Opening the switch connects the SHUTDOWN pin to GND through the pull-down resistor, activating micro-power shutdown. The switch and resistor ensure that the SHUTDOWN pin will not float. This prevents unwanted state changes. In a system with a microprocessor or a microcontroller, use a digital output to apply the control voltage to the SHUTDOWN pin. Driving the SHUTDOWN pin with active circuitry eliminates the pull-down resistor.

### EXPOSED-DAP PACKAGE PCB MOUNTING CONSIDERATION

The LM4809's exposed-Dap (die attach paddle) package (LD or LQ) provides a low thermal resistance between the die and the PCB to which the part is mounted and soldered. This allows rapid heat transfer from the die to the surrounding PCB copper traces, ground plane, and surrounding air.

The LD or LQ package should have its DAP soldered to a copper pad on the PCB. The DAP's PCB copper pad may be connected to a large plane of continuous unbroken copper. This plane forms a thermal mass, heat sink, and radiation area.

However, since the LM4809 is designed for headphone applications, connecting a copper plane to the DAP's PCB copper pad is not required. [Figure 34](#) in [Typical Performance Characteristics](#) shows that the maximum power dissipated is just 45mW per amplifier with a 5V power supply and a 32Ω load.

Further detailed and specific information concerning PCB layout, fabrication, and mounting an NGL0008B or NGP0008A package is available from Texas Instruments' Package Engineering Group under application note AN1187.

### POWER DISSIPATION

Power dissipation is a major concern when using any power amplifier and must be thoroughly understood to ensure a successful design. [Equation 1](#) states the maximum power dissipation point for a single-ended amplifier operating at a given supply voltage and driving a specified output load.

$$P_{DMAX} = (V_{DD})^2 / (2\pi^2 R_L) \quad (1)$$

Since the LM4809 has two operational amplifiers in one package, the maximum internal power dissipation point is twice that of the number which results from [Equation 1](#). Even with the large internal power dissipation, the LM4809 does not require heat sinking over a large range of ambient temperature. From [Equation 1](#), assuming a 5V power supply and a 32Ω load, the maximum power dissipation point is 40mW per amplifier. Thus the maximum package dissipation point is 80mW. The maximum power dissipation point obtained must not be greater than the power dissipation that results from [Equation 2](#):

$$P_{DMAX} = (T_{JMAX} - T_A) / \theta_{JA} \quad (2)$$

For package MUA08A,  $\theta_{JA} = 210^{\circ}\text{C/W}$ .  $T_{JMAX} = 150^{\circ}\text{C}$  for the LM4809. Depending on the ambient temperature,  $T_A$ , of the system surroundings, [Equation 2](#) can be used to find the maximum internal power dissipation supported by the IC packaging. If the result of [Equation 1](#) is greater than that of [Equation 2](#), then either the supply voltage must be decreased, the load impedance increased or  $T_A$  reduced. For the typical application of a 5V power supply, with a  $32\Omega$  load, the maximum ambient temperature possible without violating the maximum junction temperature is approximately  $133.2^{\circ}\text{C}$  provided that device operation is around the maximum power dissipation point. Power dissipation is a function of output power and thus, if typical operation is not around the maximum power dissipation point, the ambient temperature may be increased accordingly. Refer to the [Typical Performance Characteristics](#) curves for power dissipation information for lower output powers.

## POWER SUPPLY BYPASSING

As with any power amplifier, proper supply bypassing is critical for low noise performance and high power supply rejection. Applications that employ a 5V regulator typically use a  $10\mu\text{F}$  in parallel with a  $0.1\mu\text{F}$  filter capacitors to stabilize the regulator's output, reduce noise on the supply line, and improve the supply's transient response. However, their presence does not eliminate the need for a local  $1.0\mu\text{F}$  tantalum bypass capacitance connected between the LM4809's supply pins and ground. Keep the length of leads and traces that connect capacitors between the LM4809's power supply pin and ground as short as possible. Connecting a  $4.7\mu\text{F}$  capacitor,  $C_B$ , between the BYPASS pin and ground improves the internal bias voltage's stability and improves the amplifier's PSRR. The PSRR improvements increase as the bypass pin capacitor value increases. Too large, however, increases the amplifier's turn-on time. The selection of bypass capacitor values, especially  $C_B$ , depends on desired PSRR requirements, click and pop performance (as explained in the section, [Selecting Proper External Components](#)), system cost, and size constraints.

## SELECTING PROPER EXTERNAL COMPONENTS

Optimizing the LM4809's performance requires properly selecting external components. Though the LM4809 operates well when using external components with wide tolerances, best performance is achieved by optimizing component values.

The LM4809 is unity-gain stable, giving a designer maximum design flexibility. The gain should be set to no more than a given application requires. This allows the amplifier to achieve minimum THD+N and maximum signal-to-noise ratio. These parameters are compromised as the closed-loop gain increases. However, low gain demands input signals with greater voltage swings to achieve maximum output power. Fortunately, many signal sources such as audio CODECs have outputs of  $1V_{RMS}$  ( $2.83V_{P-P}$ ). Please refer to the [Audio Power Amplifier Design](#) section for more information on selecting the proper gain.

### Input and Output Capacitor Value Selection

Amplifying the lowest audio frequencies requires high value input and output coupling capacitors ( $C_I$  and  $C_O$  in [Figure 1](#)). A high value capacitor can be expensive and may compromise space efficiency in portable designs. In many cases, however, the speakers used in portable systems, whether internal or external, have little ability to reproduce signals below 150Hz. Applications using speakers with this limited frequency response reap little improvement by using high value input and output capacitors.

Besides affecting system cost and size,  $C_I$  has an effect on the LM4809's click and pop performance. The magnitude of the pop is directly proportional to the input capacitor's size. Thus, pops can be minimized by selecting an input capacitor value that is no higher than necessary to meet the desired  $-3\text{dB}$  frequency. Please refer to the [Optimizing Click and Pop Reduction Performance](#) section for a more detailed discussion on click and pop performance.

As shown in [Figure 1](#), the input resistor,  $R_I$  and the input capacitor,  $C_I$ , produce a  $-3\text{dB}$  high pass filter cutoff frequency that is found using [Equation 3](#). In addition, the output load  $R_L$ , and the output capacitor  $C_O$ , produce a  $-3\text{dB}$  high pass filter cutoff frequency defined by [Equation 4](#).

$$f_{I-3db} = 1/2\pi R_I C_I \quad (3)$$

$$f_{O-3db} = 1/2\pi R_L C_O \quad (4)$$

Also, careful consideration must be taken in selecting a certain type of capacitor to be used in the system. Different types of capacitors (tantalum, electrolytic, ceramic) have unique performance characteristics and may affect overall system performance.

### Bypass Capacitor Value Selection

Besides minimizing the input capacitor size, careful consideration should be paid to the value of  $C_B$ , the capacitor connected to the BYPASS pin. Since  $C_B$  determines how fast the LM4809 settles to quiescent operation, its value is critical when minimizing turn-on pops. The slower the LM4809's outputs ramp to their quiescent DC voltage (nominally  $1/2 V_{DD}$ ), the smaller the turn-on pop. Choosing  $C_B$  equal to  $4.7\mu\text{F}$  along with a small value of  $C_i$  (in the range of  $0.1\mu\text{F}$  to  $0.47\mu\text{F}$ ), produces a click-less and pop-less shutdown function. As discussed above, choosing  $C_i$  no larger than necessary for the desired bandwidth helps minimize clicks and pops.

### OPTIMIZING CLICK AND POP REDUCTION PERFORMANCE

The LM4809 contains circuitry that minimizes turn-on and shutdown transients or “clicks and pop”. For this discussion, turn-on refers to either applying the power supply voltage or when the shutdown mode is deactivated. During turn-on, the LM4809's internal amplifiers are configured as unity gain buffers. An internal current source charges up the capacitor on the BYPASS pin in a controlled, linear manner. The gain of the internal amplifiers remains unity until the voltage on the BYPASS pin reaches  $1/2 V_{DD}$ . As soon as the voltage on the BYPASS pin is stable, the device becomes fully operational. During device turn-on, a transient (pop) is created from a voltage difference between the input and output of the amplifier as the voltage on the BYPASS pin reaches  $1/2 V_{DD}$ . For this discussion, the input of the amplifier refers to the node between  $R_i$  and  $C_i$ . Ideally, the input and output track the voltage applied to the BYPASS pin. During turn-on, the buffer-configured amplifier output charges the input capacitor,  $C_i$ , through the input resistor,  $R_i$ . This input resistor delays the charging time of  $C_i$  thereby causing the voltage difference between the input and output that results in a transient (pop). Higher value capacitors need more time to reach a quiescent DC voltage (usually  $1/2 V_{DD}$ ) when charged with a fixed current. Decreasing the value of  $C_i$  and  $R_i$  will minimize turn-on pops at the expense of the desired -3dB frequency.

Although the BYPASS pin current cannot be modified, changing the size of  $C_B$  alters the device's turn-on time and the magnitude of “clicks and pops”. Increasing the value of  $C_B$  reduces the magnitude of turn-on pops. However, this presents a tradeoff: as the size of  $C_B$  increases, the turn-on time increases. There is a linear relationship between the size of  $C_B$  and the turn-on time. Here are some typical turn-on times for various values of  $C_B$ :

| $C_B$             | $T_{ON}$ |
|-------------------|----------|
| $0.1\mu\text{F}$  | 80ms     |
| $0.22\mu\text{F}$ | 170ms    |
| $0.33\mu\text{F}$ | 270ms    |
| $0.47\mu\text{F}$ | 370ms    |
| $0.68\mu\text{F}$ | 490ms    |
| $1.0\mu\text{F}$  | 920ms    |
| $2.2\mu\text{F}$  | 1.8sec   |
| $3.3\mu\text{F}$  | 2.8sec   |
| $4.7\mu\text{F}$  | 3.4sec   |
| $10\mu\text{F}$   | 7.7sec   |

In order eliminate “clicks and pops”, all capacitors must be discharged before turn-on. Rapidly switching  $V_{DD}$  may not allow the capacitors to fully discharge, which may cause “clicks and pops”. In a single-ended configuration, the output is coupled to the load by  $C_O$ . This capacitor usually has a high value.  $C_O$  discharges through internal  $20\text{k}\Omega$  resistors. Depending on the size of  $C_O$ , the discharge time constant can be relatively large. To reduce transients in single-ended mode, an external  $1\text{k}\Omega$ – $5\text{k}\Omega$  resistor can be placed in parallel with the internal  $20\text{k}\Omega$  resistor. The tradeoff for using this resistor is increased quiescent current.

## AUDIO POWER AMPLIFIER DESIGN

### Design a Dual 70mW/32Ω Audio Amplifier

|                 |                        |
|-----------------|------------------------|
| Given:          |                        |
| Power Output    | 70 mW                  |
| Load Impedance  | 32Ω                    |
| Input Level     | 1 Vrms (max)           |
| Input Impedance | 20kΩ                   |
| Bandwidth       | 100 Hz–20 kHz ± 0.50dB |

The design begins by specifying the minimum supply voltage necessary to obtain the specified output power. One way to find the minimum supply voltage is to use [Figure 28](#) in the [Typical Performance Characteristics](#) section. Another way, using [Equation 5](#), is to calculate the peak output voltage necessary to achieve the desired output power for a given load impedance. To account for the amplifier's dropout voltage, two additional voltages, based on [Figure 31](#) in [Typical Performance Characteristics](#), must be added to the result obtained by [Equation 5](#). For a single-ended application, the result is [Equation 6](#).

$$V_{\text{opeak}} = \sqrt{2R_L P_O} \quad (5)$$

$$V_{DD} \geq (2V_{\text{OPEAK}} + (V_{\text{ODTOP}} + V_{\text{ODBOT}})) \quad (6)$$

[Figure 28](#) for a 32Ω load indicates a minimum supply voltage of 4.8V. This is easily met by the commonly used 5V supply voltage. The additional voltage creates the benefit of headroom, allowing the LM4809 to produce peak output power in excess of 70mW without clipping or other audible distortion. The choice of supply voltage must also not create a situation that violates maximum power dissipation as explained above in the [Power Dissipation](#) section. Remember that the maximum power dissipation point from [Equation 1](#) must be multiplied by two since there are two independent amplifiers inside the package. Once the power dissipation equations have been addressed, the required gain can be determined from [Equation 7](#).

$$A_V \geq \sqrt{P_O R_L} / (V_{IN}) = V_{\text{orms}} / V_{\text{inrms}} \quad (7)$$

Thus, a minimum gain of 1.497 allows the LM4809 to reach full output swing and maintain low noise and THD+N performance. For this example, let  $A_V = 1.5$ .

The amplifiers overall gain is set using the input ( $R_i$ ) and feedback ( $R_f$ ) resistors. With the desired input impedance set at 20kΩ, the feedback resistor is found using [Equation 8](#).

$$A_V = R_f / R_i \quad (8)$$

The value of  $R_f$  is 30kΩ.

The last step in this design is setting the amplifier's –3db frequency bandwidth. To achieve the desired  $\pm 0.25\text{dB}$  pass band magnitude variation limit, the low frequency response must extend to at least one-fifth the lower bandwidth limit and the high frequency response must extend to at least five times the upper bandwidth limit. The gain variation for both response limits is 0.17dB, well within the  $\pm 0.25\text{dB}$  desired limit. The results are an

$$f_L = 100\text{Hz}/5 = 20\text{Hz} \quad (9)$$

and a

$$f_H = 20\text{kHz} \times 5 = 100\text{kHz} \quad (10)$$

As stated in the [Selecting Proper External Components](#) section, both  $R_i$  in conjunction with  $C_i$ , and  $C_o$  with  $R_L$ , create first order highpass filters. Thus to obtain the desired low frequency response of 100Hz within  $\pm 0.5\text{dB}$ , both poles must be taken into consideration. The combination of two single order filters at the same frequency forms a second order response. This results in a signal which is down 0.34dB at five times away from the single order filter –3dB point. Thus, a frequency of 20Hz is used in the following equations to ensure that the response is better than 0.5dB down at 100Hz.

$$C_i \geq 1 / (2\pi * 20\text{k}\Omega * 20\text{Hz}) = 0.397\mu\text{F}; \text{ use } 0.39\mu\text{F}. \quad (11)$$

$$C_o \geq 1 / (2\pi * 32\Omega * 20\text{Hz}) = 249\mu\text{F}; \text{ use } 330\mu\text{F}. \quad (12)$$

The high frequency pole is determined by the product of the desired high frequency pole,  $f_H$ , and the closed-loop gain,  $A_v$ . With a closed-loop gain of 1.5 and  $f_H = 100\text{kHz}$ , the resulting GBWP = 150kHz which is much smaller than the LM4809's GBWP of 900kHz. This figure displays that if a designer has a need to design an amplifier with a higher gain, the LM4809 can still be used without running into bandwidth limitations.

## Demonstration Board Schematic

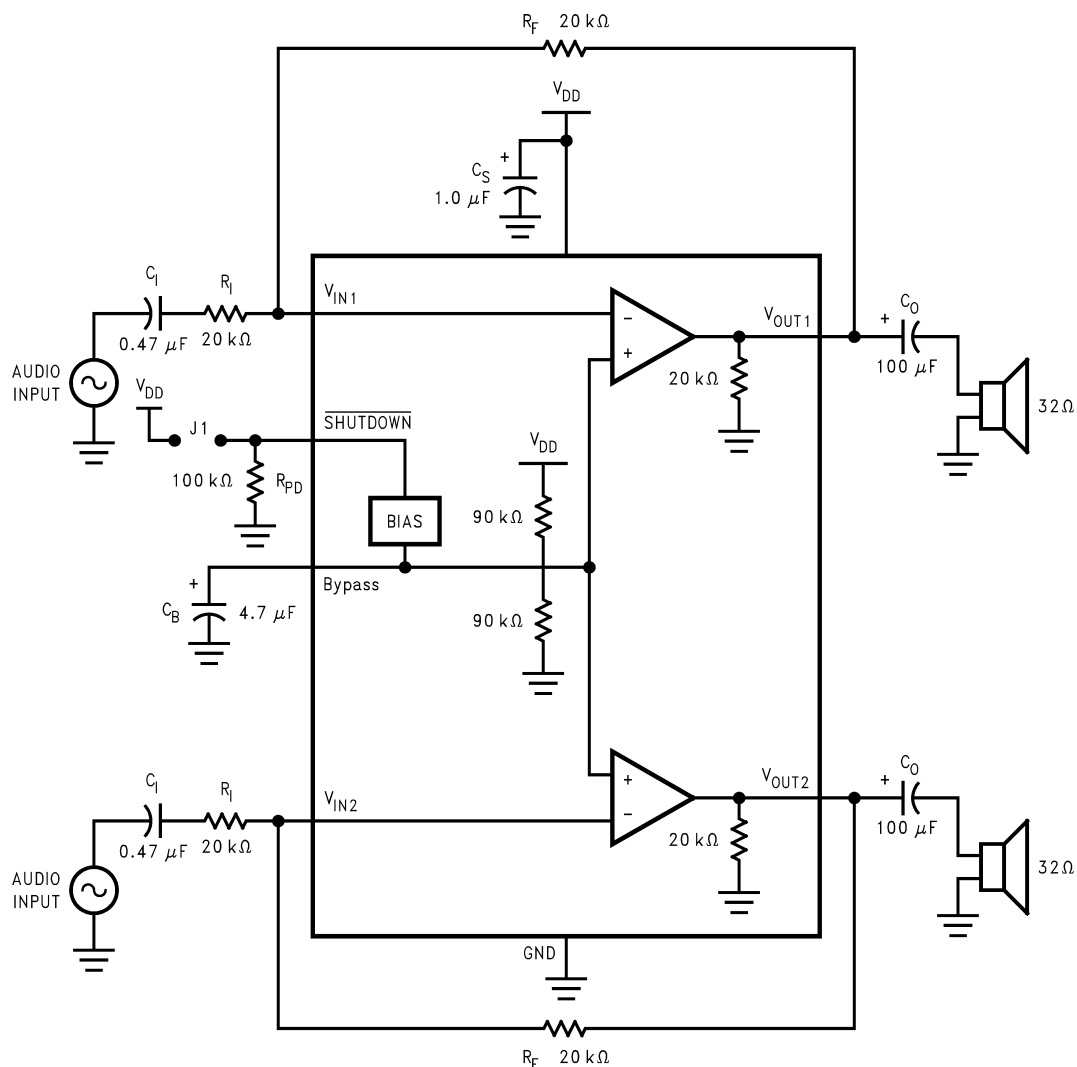


Figure 42. LM4809 Demonstration Board Schematic

## Demonstration Board Layout

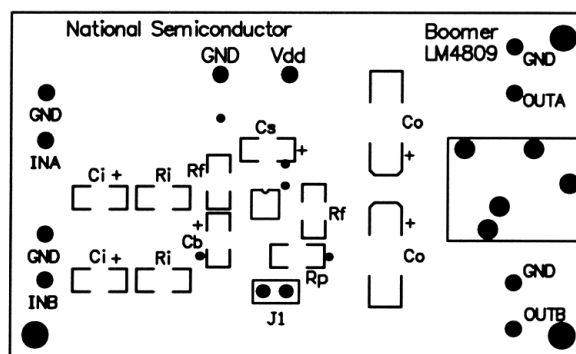


Figure 43. Recommended DGK0008A PC Board Layout  
Component-Side Silkscreen

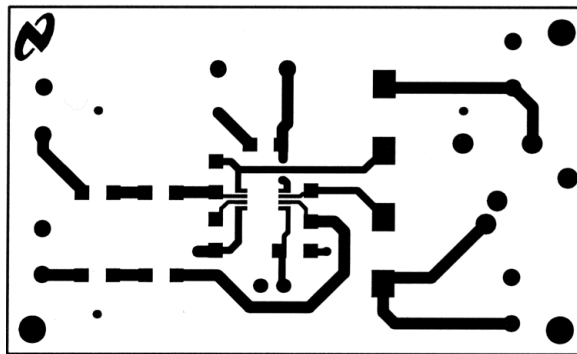


Figure 44. Recommended DGK0008A PC Board Layout  
Component-Side Layout

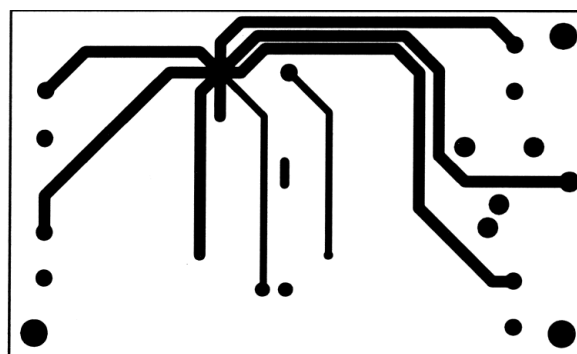


Figure 45. Recommended DGK0008A PC Board Layout  
Bottom-Side Layout

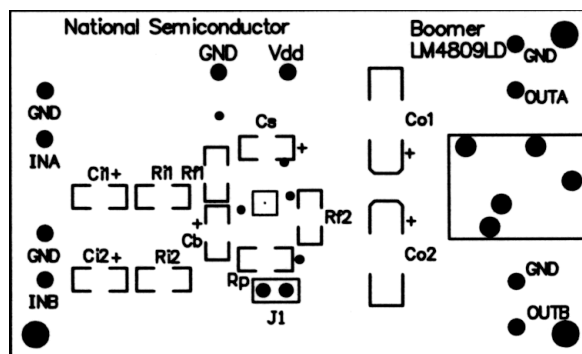


Figure 46. Recommended NGL0008B PC Board Layout  
Component-Side Silkscreen

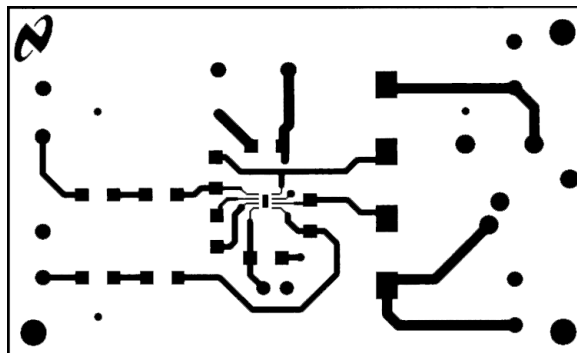


Figure 47. Recommended NGL0008B PC Board Layout  
Component-Side Layout

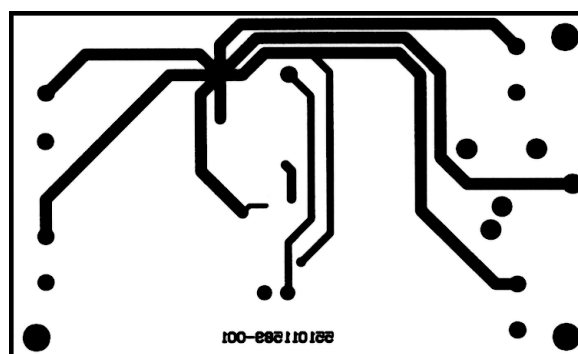


Figure 48. Recommended NGL0008B PC Board Layout  
Bottom-Side Layout

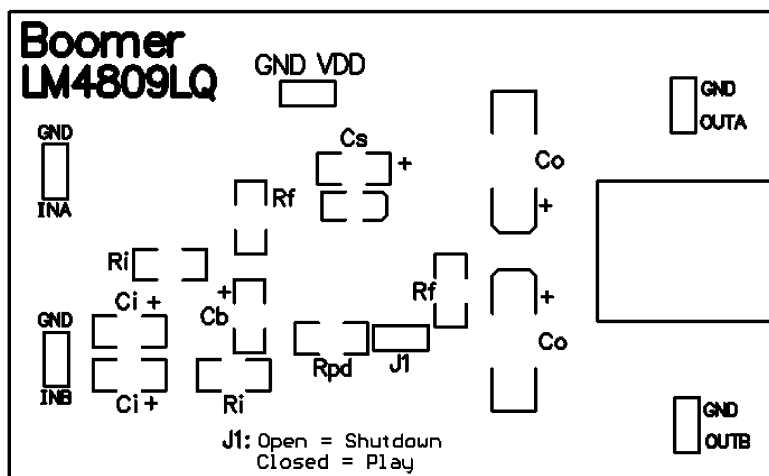
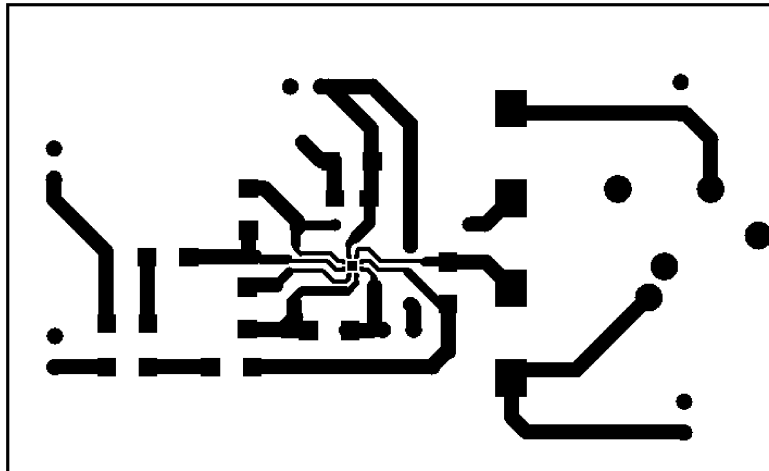
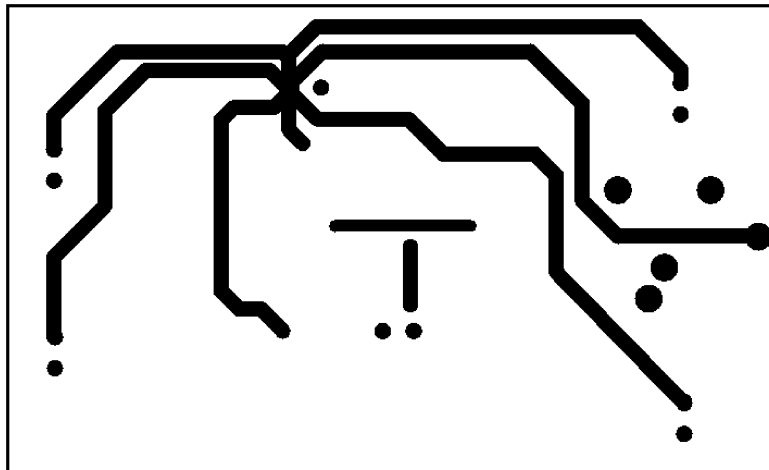


Figure 49. Recommended NGP0008A PC Board Layout  
Component-Side Silkscreen



**Figure 50. Recommended NGP0008A PC Board Layout  
Component-Side Layout**



**Figure 51. Recommended NGP0008A PC Board Layout  
Bottom-Side Layout**

## REVISION HISTORY

### Changes from Revision E (April 2013) to Revision F

### Page

- Changed layout of National Data Sheet to TI format ..... [21](#)

## PACKAGING INFORMATION

| Orderable part number          | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|--------------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">LM4809LDX/NOPB</a> | Active        | Production           | WSOP (NGL)   8  | 4500   LARGE T&R      | Yes         | SN                                   | Level-3-260C-168 HR               | -40 to 85    | G09                 |
| LM4809LDX/NOPB.A               | Active        | Production           | WSOP (NGL)   8  | 4500   LARGE T&R      | Yes         | SN                                   | Level-3-260C-168 HR               | -40 to 85    | G09                 |
| LM4809LDX/NOPB.B               | Active        | Production           | WSOP (NGL)   8  | 4500   LARGE T&R      | -           | Call TI                              | Call TI                           | -40 to 85    |                     |
| <a href="#">LM4809MM/NOPB</a>  | Active        | Production           | VSSOP (DGK)   8 | 1000   SMALL T&R      | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 85    | G09                 |
| LM4809MM/NOPB.A                | Active        | Production           | VSSOP (DGK)   8 | 1000   SMALL T&R      | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 85    | G09                 |
| <a href="#">LM4809MMX/NOPB</a> | Active        | Production           | VSSOP (DGK)   8 | 3500   LARGE T&R      | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 85    | G09                 |
| LM4809MMX/NOPB.A               | Active        | Production           | VSSOP (DGK)   8 | 3500   LARGE T&R      | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 85    | G09                 |

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts 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.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

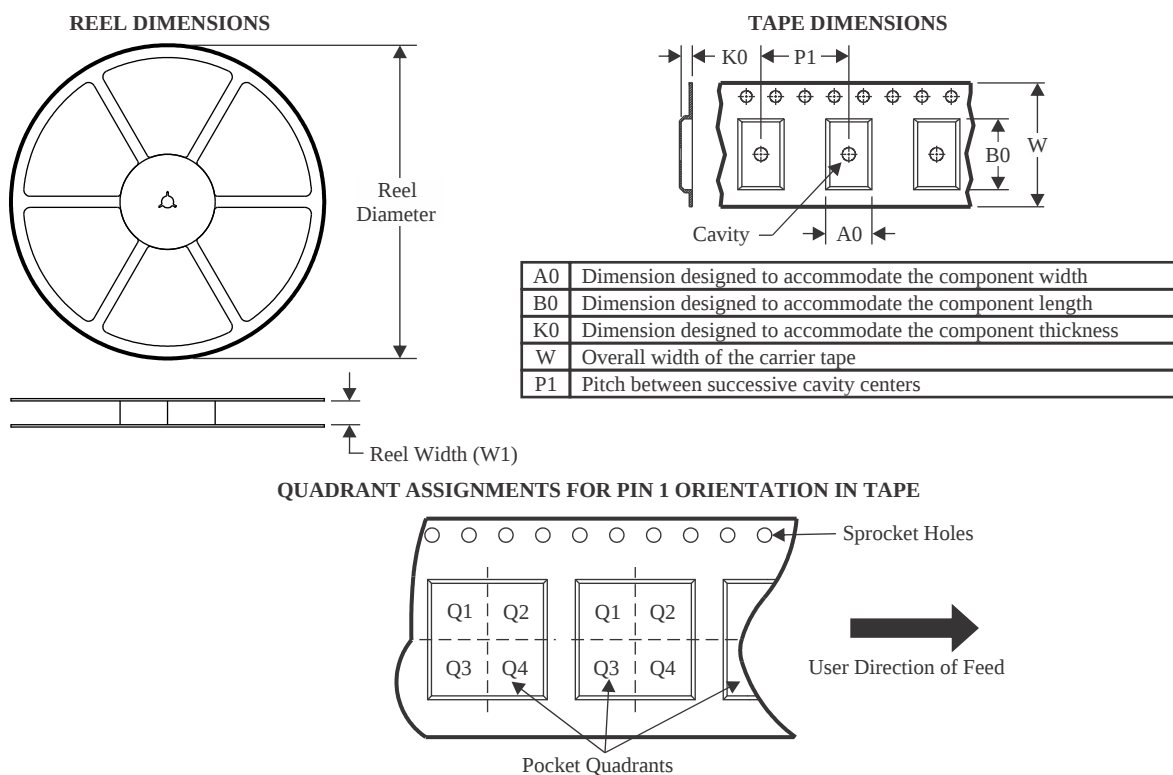
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "-" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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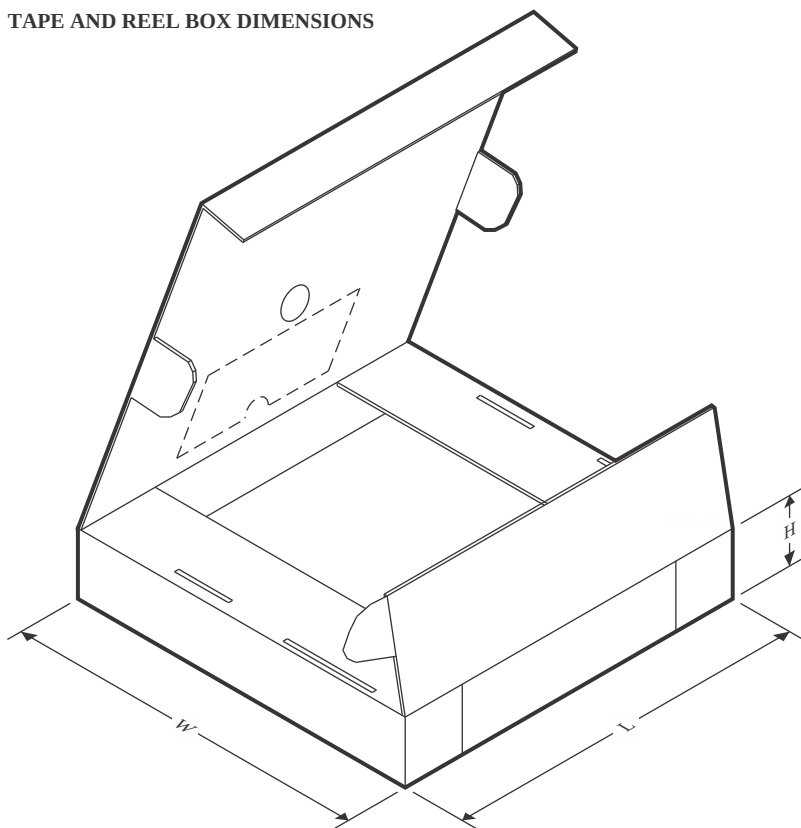
## TAPE AND REEL INFORMATION



\*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 |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LM4809LDX/NOPB | WSOP         | NGL             | 8    | 4500 | 330.0              | 12.4               | 2.8     | 2.8     | 1.0     | 8.0     | 12.0   | Q1            |
| LM4809MM/NOPB  | VSSOP        | DGK             | 8    | 1000 | 177.8              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| LM4809MMX/NOPB | VSSOP        | DGK             | 8    | 3500 | 330.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |

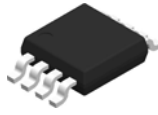
## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device         | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LM4809LDX/NOPB | WSON         | NGL             | 8    | 4500 | 356.0       | 356.0      | 36.0        |
| LM4809MM/NOPB  | VSSOP        | DGK             | 8    | 1000 | 208.0       | 191.0      | 35.0        |
| LM4809MMX/NOPB | VSSOP        | DGK             | 8    | 3500 | 367.0       | 367.0      | 35.0        |

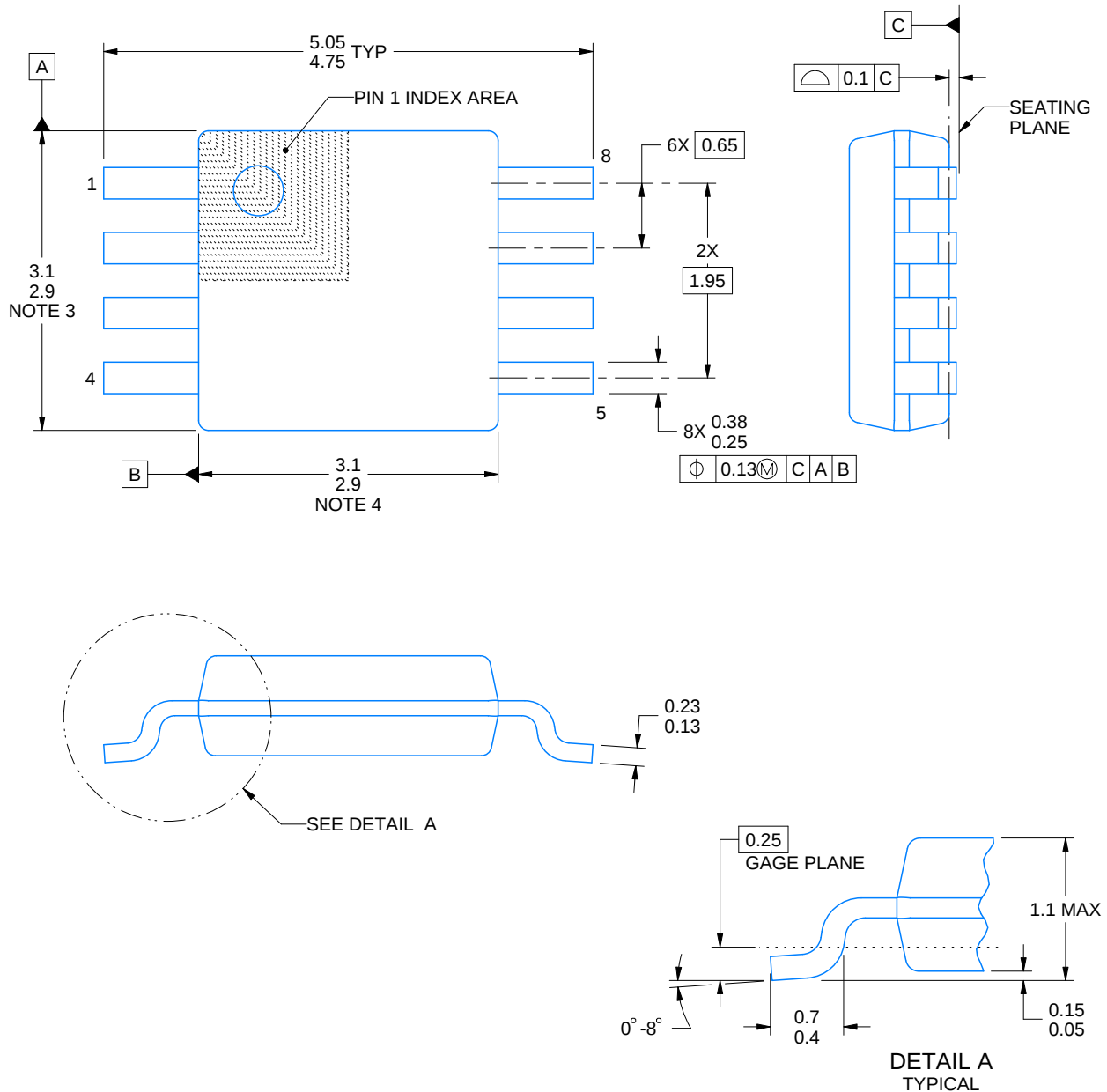
DGK0008A



# PACKAGE OUTLINE

VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



4214862/A 04/2023

## NOTES:

PowerPAD is a trademark of Texas Instruments.

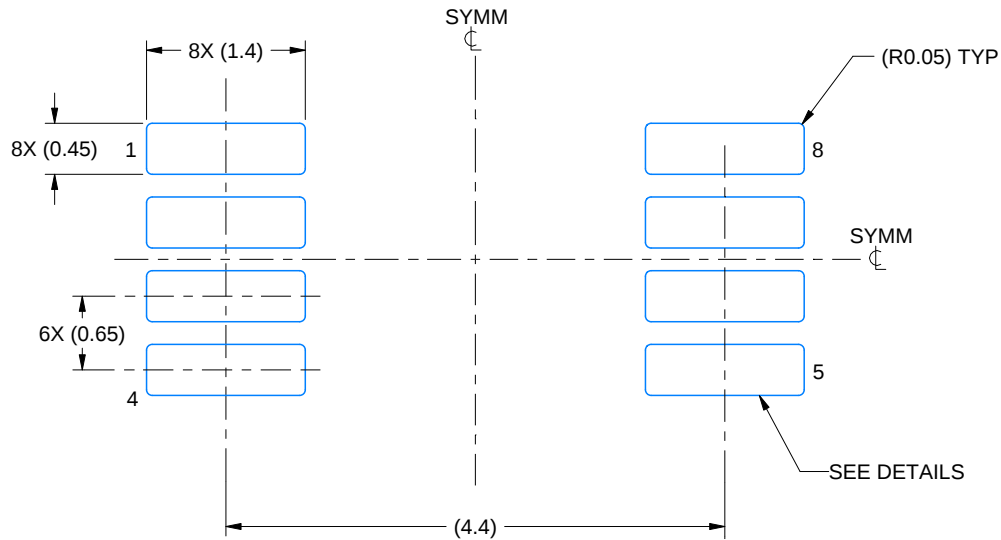
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-187.

# EXAMPLE BOARD LAYOUT

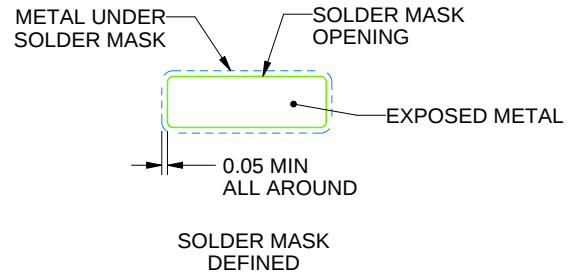
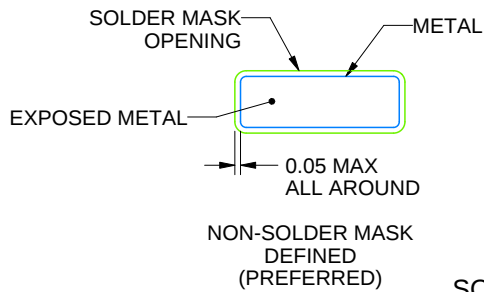
DGK0008A

<sup>TM</sup> VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 15X



SOLDER MASK DETAILS

4214862/A 04/2023

NOTES: (continued)

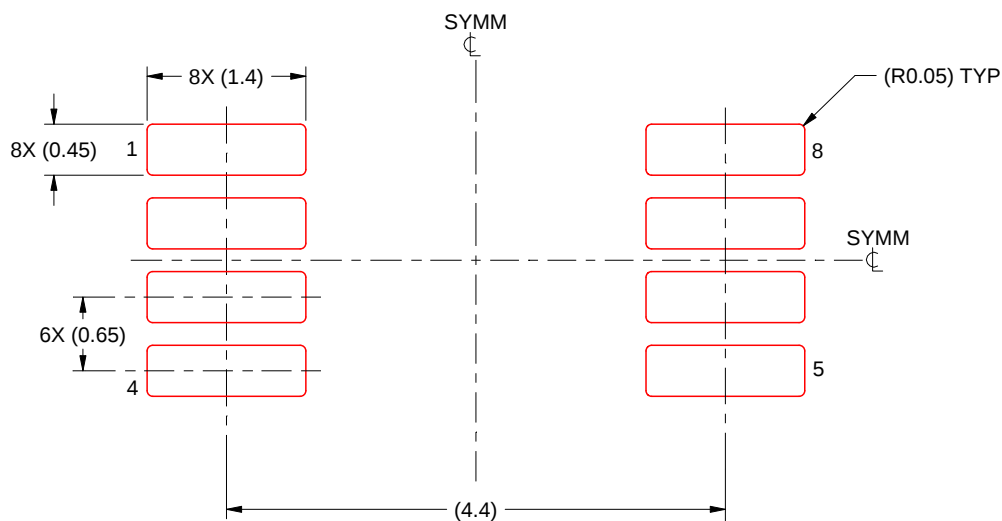
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.
9. Size of metal pad may vary due to creepage requirement.

## EXAMPLE STENCIL DESIGN

DGK0008A

<sup>TM</sup> VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



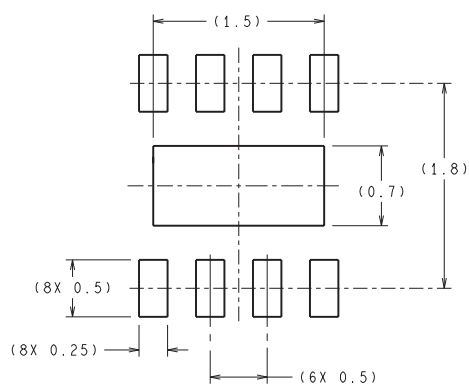
SOLDER PASTE EXAMPLE  
SCALE: 15X

4214862/A 04/2023

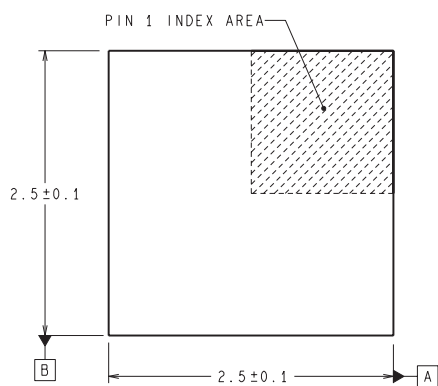
NOTES: (continued)

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

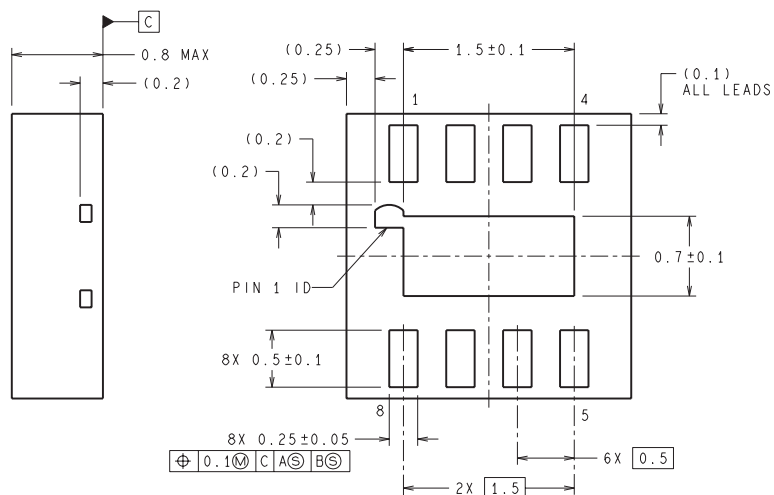
NGL0008B



**RECOMMENDED LAND PATTERN**  
1:1 RATIO WITH PKG SOLDER PADS



**DIMENSIONS ARE IN MILLIMETERS**  
DIMENSIONS IN ( ) FOR REFERENCE ONLY



LDA08B (Rev B)

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