National Semiconductor

February 2000

LM4808 Boomer® Audio Power Amplifier Series
Dual 105 mW Headphone Amplifier

General Description

The LM4808 is a dual audio power amplifier capable of delivering 105 mW 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 using surface mount packaging. Since the LM4808 does not require bootstrap capacitors or snubber networks, it is optimally suited for low-power portable systems.

The unity-gain stable LM4808 can be configured by external gain-setting resistors.

Key Specifications

- THD+N at 1 kHz at 105 mW continuous average output power into 16Ω — 0.1% (max)
- THD+N at 1 kHz at 70 mW continuous average output power into 32Ω — 0.1% (typ)
- Output power at 0.1% THD+N at 1 kHz into 32Ω — 70 mW (typ)

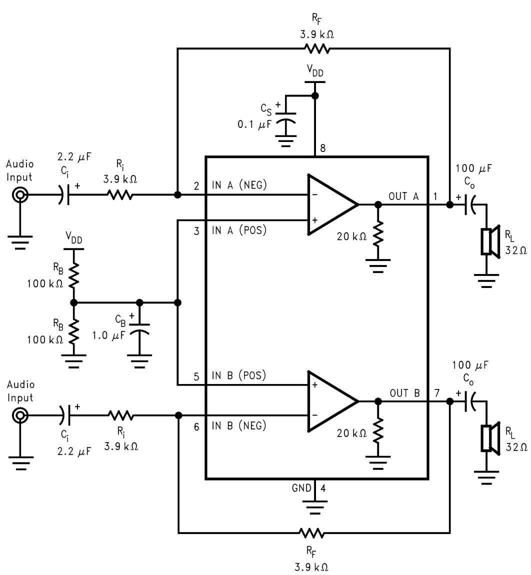
Features

- SOP and MSOP surface mount packaging
- Switch on/off click suppression
- Excellent power supply ripple rejection
- Unity-gain stable
- Minimum external components

Applications

- Headphone Amplifier
- Personal Computers
- Microphone Preamplifier

Typical Application

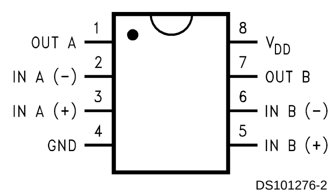


*Refer to the **Application Information** Section for information concerning proper selection of the input and output coupling capacitors.

FIGURE 1. Typical Audio Amplifier Application Circuit

Connection Diagram

SOP & MSOP Package



Top View
Order Number LM4808M, LM4808MM
See NS Package Number M08A, MUA08A

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 DS101276

Absolute Maximum Ratings (Note 3)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage	6.0V
Storage Temperature	−65˚C to +150˚C
Input Voltage	−0.3V to V_{DD} + 0.3V
Power Dissipation (Note 4)	Internally limited
ESD Susceptibility (Note 5)	3500V
ESD Susceptibility (Note 6)	250V
Junction Temperature	150˚C
Soldering Information (Note 1)	
Small Outline Package	
Vapor Phase (60 seconds)	215˚C
Infrared (15 seconds)	220˚C
Thermal Resistance	
θ_{JC} (MSOP)	56˚C/W
θ_{JA} (MSOP)	210˚C/W
θ_{JC} (SOP)	35˚C/W
θ_{JA} (SOP)	170˚C/W

Operating Ratings

Temperature Range	
$T_{MIN} \leq T_A \leq T_{MAX}$	−40˚C ≤ T_A ≤ 85˚C
Supply Voltage	2.0V ≤ V_{DD} ≤ 5.5V

Note 1: See AN-450 "Surface Mounting and their Effects on Product Reliability" for other methods of soldering surface mount devices.

Electrical Characteristics (Notes 2, 3)

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

Symbol	Parameter	Conditions	LM4808		Units (Limits)
			Typ (Note 7)	**Limit** (Note 8)	
V_{DD}	Supply Voltage			2.0	V (min)
				5.5	V (max)
I_{DD}	Supply Current	V_{IN} = 0V, I_O = 0A	1.2	3.0	mA (max)
P_{tot}	Total Power Dissipation	V_{IN} = 0V, I_O = 0A	6	16.5	mW (max)
V_{OS}	Input Offset Voltage	V_{IN} = 0V	10	50	mV (max)
Ibias	Input Bias Current		10		pA
V_{CM}	Common Mode Voltage		0		V
			4.3		V
G_V	Open-Loop Voltage Gain	R_L = 5kΩ	67		dB
Io	Max Output Current	THD+N < 0.1 %	70		mA
R_O	Output Resistance		0.1		Ω
V_O	Output Swing	R_L = 32Ω, 0.1% THD+N, Min	.3		V
		R_L = 32Ω, 0.1% THD+N, Max	4.7		
PSRR	Power Supply Rejection Ratio	Cb = 1.0µF, Vripple = 100mV_{PP}, f = 100Hz	89		dB
Crosstalk	Channel Separation	R_L = 32Ω	75		dB
THD+N	Total Harmonic Distortion + Noise	f = 1 kHz			
		R_L = 16Ω, V_O =3.5V_{PP} (at 0 dB)	0.05		%
			66		dB
		R_L = 32Ω, V_O =3.5V_{PP} (at 0 dB)	0.05		%
			66		dB
SNR	Signal-to-Noise Ratio	V_O = 3.5V_{pp} (at 0 dB)	105		dB
f_G	Unity Gain Frequency	Open Loop, R_L = 5kΩ	5.5		MHz
P_o	Output Power	THD+N = 0.1%, f = 1 kHz			
		R_L = 16Ω	105		mW
		R_L = 32Ω	70	60	mW
		THD+N = 10%, f = 1 kHz			
		R_L = 16Ω	150		mW
		R_L = 32Ω	90		mW
C_I	Input Capacitance		3		pF
C_L	Load Capacitance			200	pF
SR	Slew Rate	Unity Gain Inverting	3		V/µs

Electrical Characteristics (Notes 2, 3)

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

Symbol	Parameter	Conditions	Conditions		Units (Limits)
			Typ (Note 7)	**Limit** (Note 8)	
I_{DD}	Supply Current	V_{IN} = 0V, I_O = 0A	1.0		mA (max)
V_{OS}	Input Offset Voltage	V_{IN} = 0V	7		mV (max)
P_o	Output Power	THD+N = 0.1%, f = 1 kHz			
		R_L = 16Ω	40		mW
		R_L = 32Ω	28		mW
		THD+N = 10%, f = 1 kHz			
		R_L = 16Ω	56		mW
		R_L = 32Ω	38		mW

Electrical Characteristics (Notes 2, 3)

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

Symbol	Parameter	Conditions	Conditions		Units (Limits)
			Typ (Note 7)	**Limit** (Note 8)	
I_{DD}	Supply Current	V_{IN} = 0V, I_O = 0A	0.9		mA (max)
V_{OS}	Input Offset Voltage	V_{IN} = 0V	5		mV (max)
P_o	Output Power	THD+N = 0.1%, f = 1 kHz			
		R_L = 16Ω	20		mW
		R_L = 32Ω	16		mW
		THD+N = 10%, f = 1 kHz			
		R_L = 16Ω	31		mW
		R_L = 32Ω	22		mW

Note 2: All voltages are measured with respect to the ground pin, unless otherwise specified.

Note 3: *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 guarantee specific performance limits. *Electrical Characteristics* state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

Note 4: The maximum power dissipation must be derated at elevated temperatures and is dictated by T_{JMAX}, θ_{JA}, and the ambient temperature T_A. The maximum allowable power dissipation is $P_{DMAX} = (T_{JMAX} - T_A) / \theta_{JA}$. For the LM4808, T_{JMAX} = 150˚C, and the typical junction-to-ambient thermal resistance, when board mounted, is 210˚C/W for the MSOP Package and 107˚C/W for package N08E.

Note 5: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Note 6: Machine Model, 220 pF–240 pF discharged through all pins.

Note 7: Typicals are measured at 25˚C and represent the parametric norm.

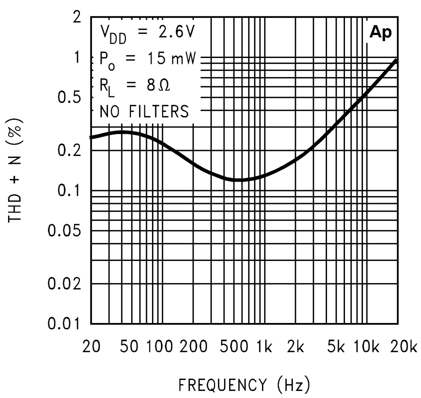
Note 8: Limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

External Components Description (*Figure 1*)

Compo-nents	Functional Description
1. R_i	Inverting input resistance which sets the closed-loop gain in conjuction 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 amplifier's input terminals. Also creates a highpass filter with R_i at $f_c = 1 / (2\pi R_i C_i)$. Refer to the section, **Proper Selection of External Components,** for and explanation of how to determine the value of C_i.
3. R_f	Feedback resistance which sets closed-loop gain in conjuction with R_i.
4. C_S	Supply bypass capacitor which provides power supply filtering. Refer to the **Application Information** section for proper placement and selection of the supply bypass capacitor.
5. C_B	Bypass pin capacitor which provides half-supply filtering. Refer to the section, **Proper Selection of External Components,** for information concerning proper placement and selection of C_B.
6. C_O	Output coupling capacitor which blocks the DC voltage at the amplifier's output. Forms a high pass filter with R_L at $f_O = 1/(2\pi R_L C_O)$
7. R_B	Resistor which forms a voltage divider that provides a half-supply DC voltage to the non-inverting input of the amplifier.

Typical Performance Characteristics

THD+N vs Frequency



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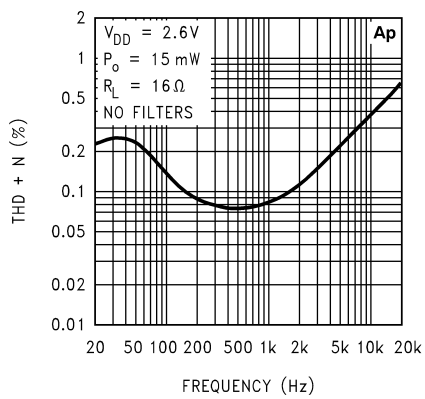
THD+N vs Frequency



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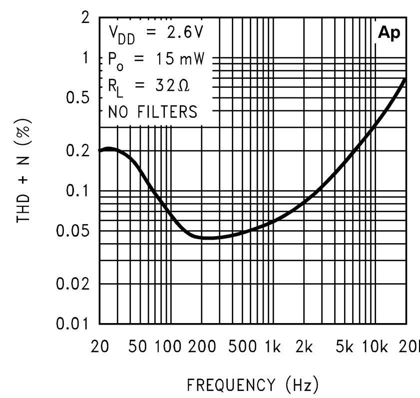
THD+N vs Frequency



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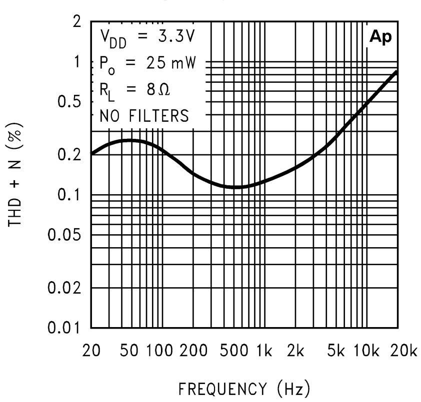
THD+N vs Frequency



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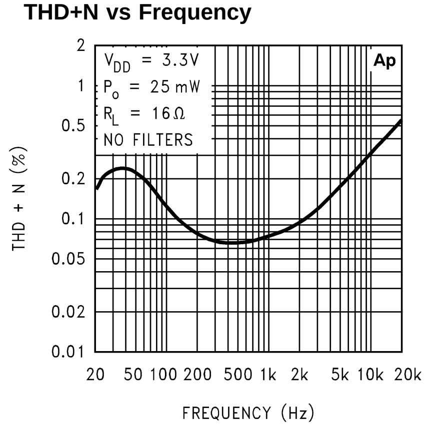
THD+N vs Frequency



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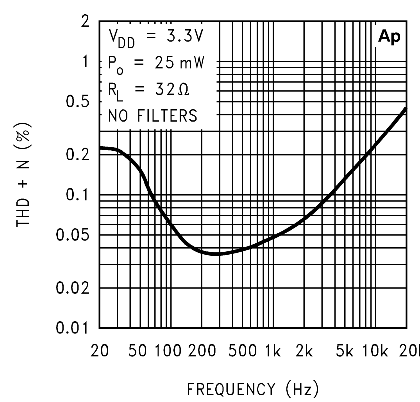
THD+N vs Frequency



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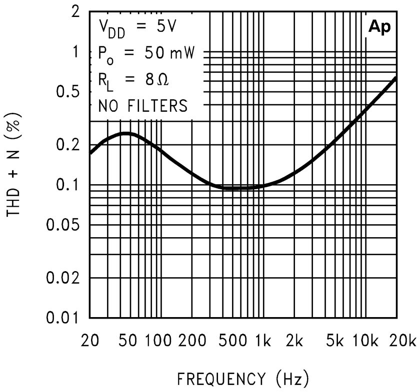
Typical Performance Characteristics (Continued)

THD+N vs Frequency



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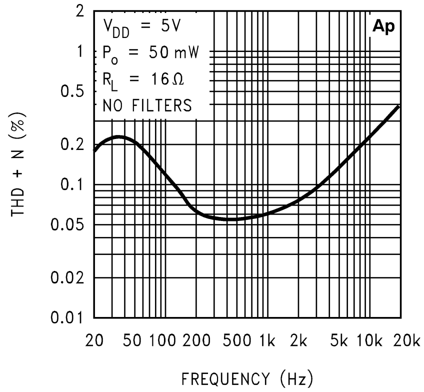
THD+N vs Frequency



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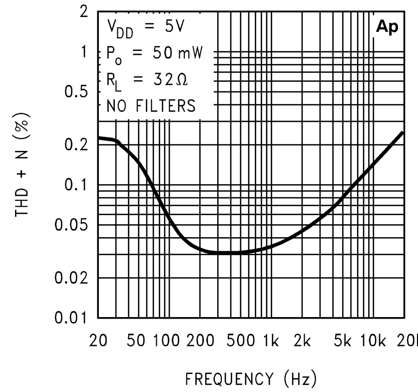
THD+N vs Frequency



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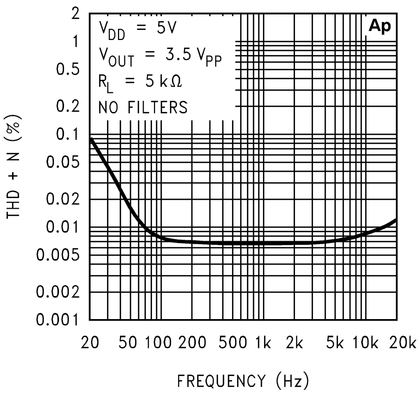
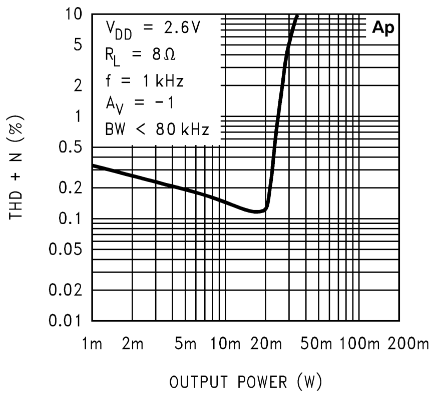
THD+N vs Frequency



DS101276-12

THD+N vs Output Power



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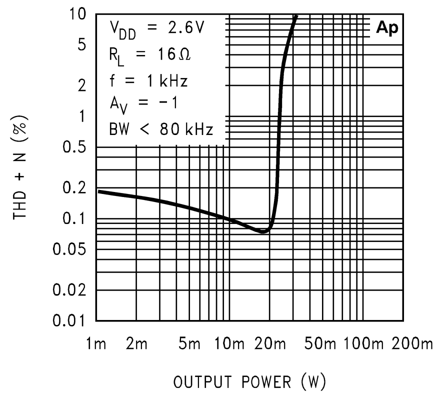
THD+N vs Output Power



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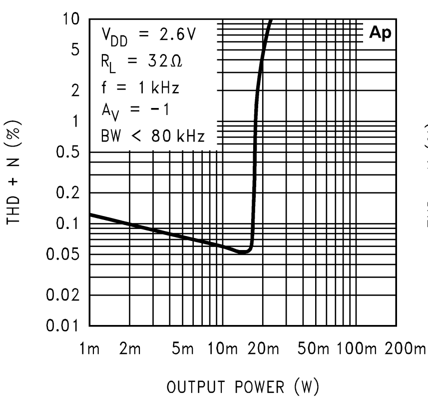
THD+N vs Output Power



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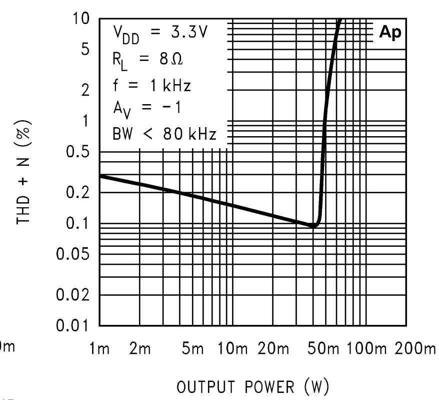
THD+N vs Output Power



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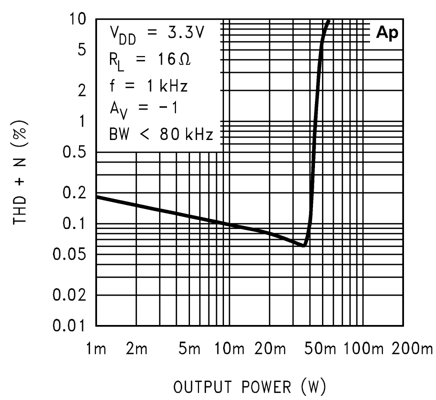
THD+N vs Output Power



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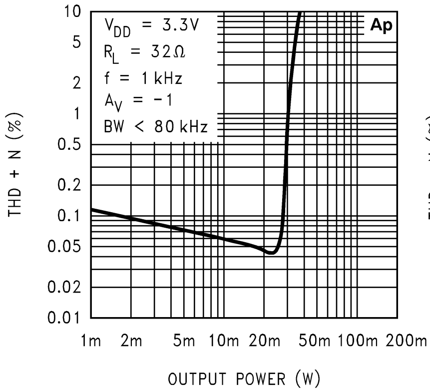
Typical Performance Characteristics (Continued)

THD+N vs Output Power



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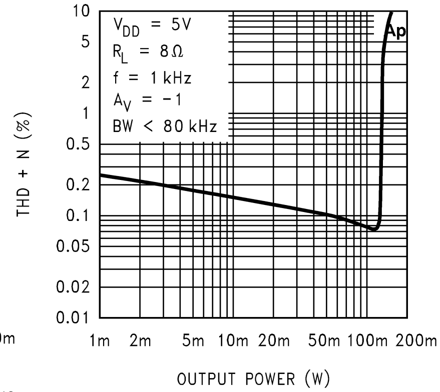
THD+N vs Output Power



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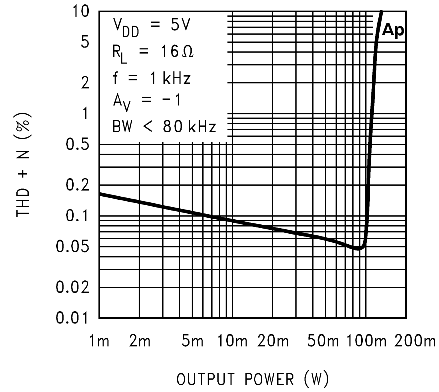
THD+N vs Output Power



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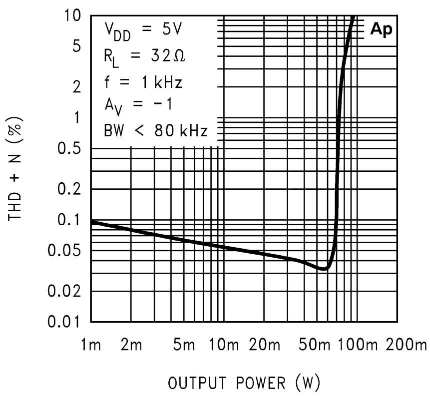
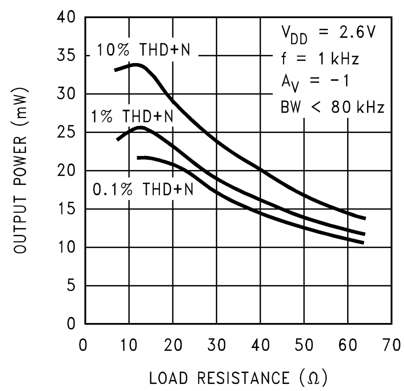
THD+N vs Output Power



DS101276-21

Output Power vs Load Resistance



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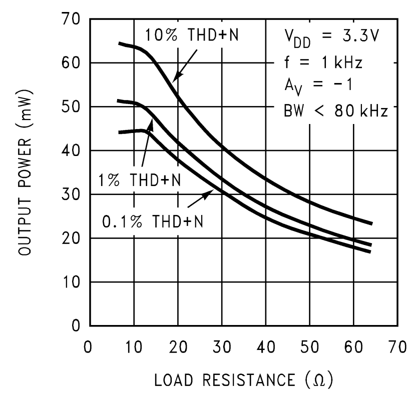
Output Power vs Load Resistance



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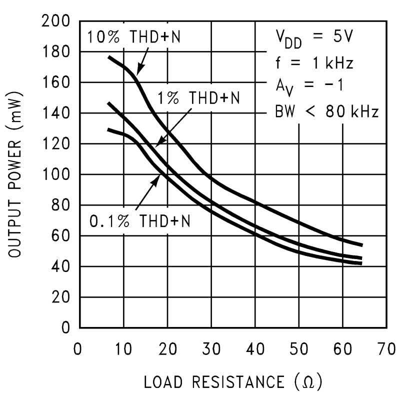
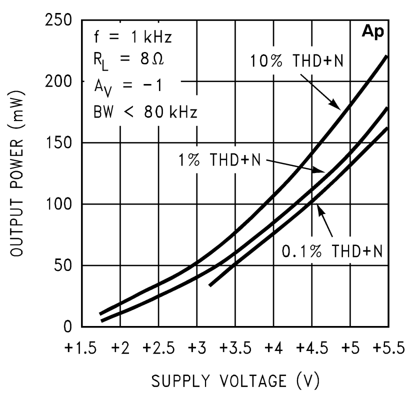
Output Power vs Load Resistance



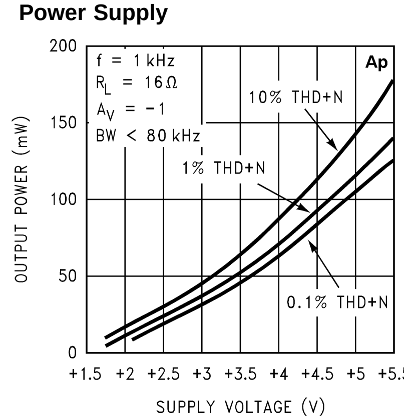
DS101276-24

Output Power vs Supply Voltage



DS101276-25

Output Power vs Power Supply



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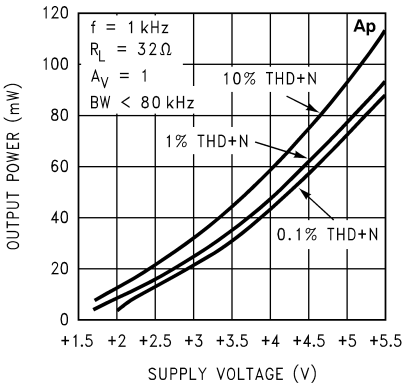
Typical Performance Characteristics (Continued)

Output Power vs Power Supply



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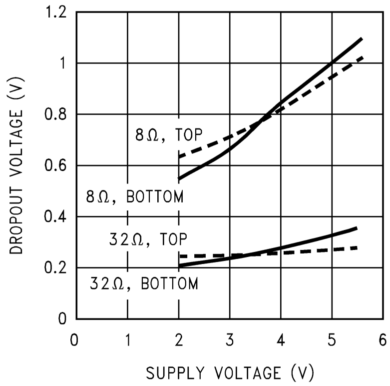
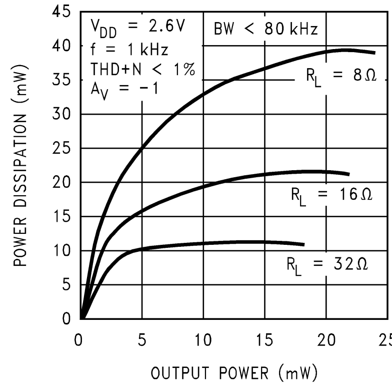
Clipping Voltage vs Supply Voltage



DS101276-28

Power Dissipation vs Output Power



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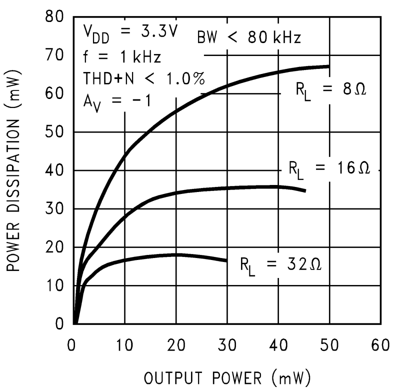
Power Dissipation vs Output Power



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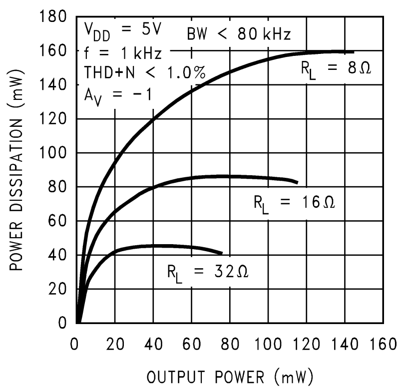
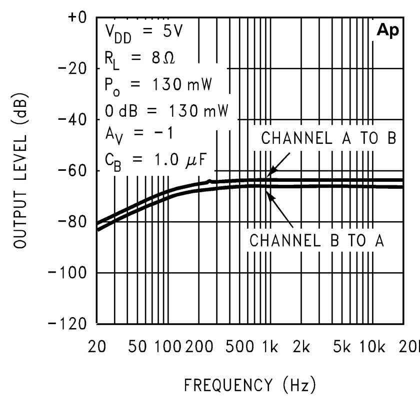
Power Dissipation vs Output Power



DS101276-31

Channel Separation



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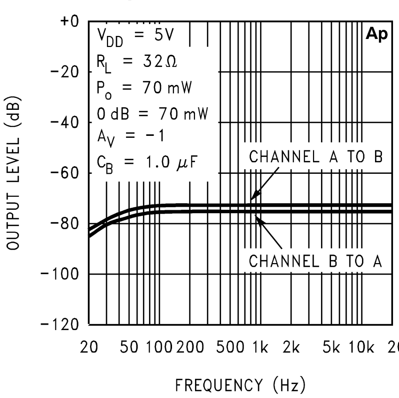
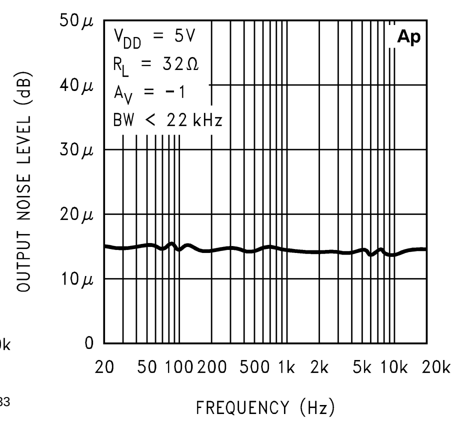
Channel Separation



DS101276-33

Noise Floor



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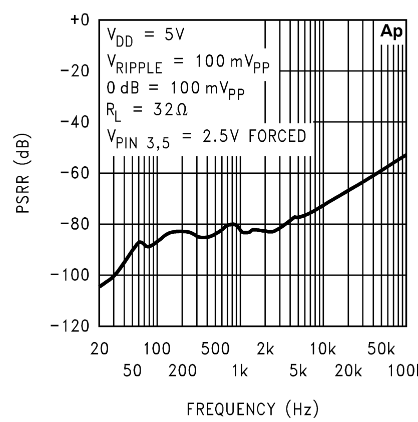
Power Supply Rejection Ratio



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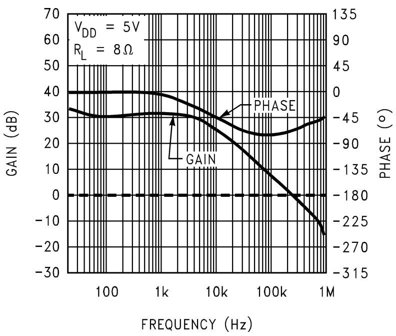
Typical Performance Characteristics (Continued)

Open Loop Frequency Response



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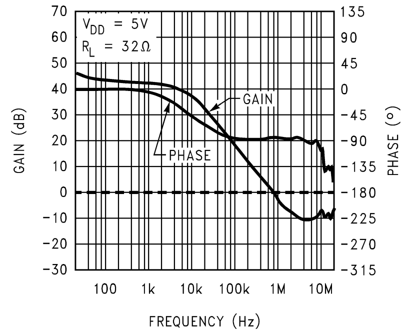
Open Loop Frequency Response



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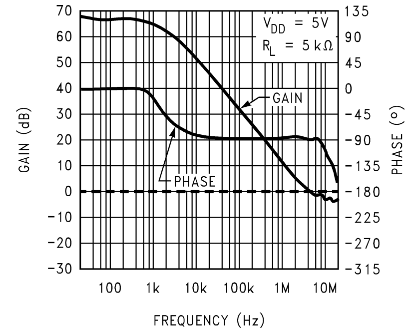
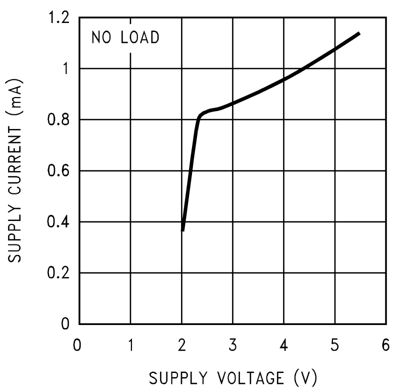
Open Loop Frequency Response



DS101276-38

Supply Current vs Supply Voltage



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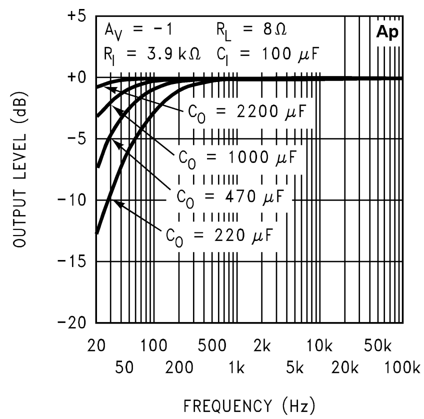
Frequency Response vs Output Capacitor Size



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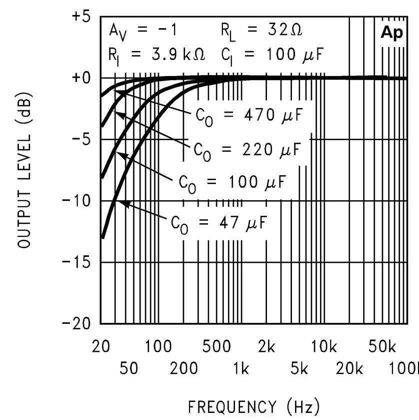
Frequency Response vs Output Capacitor Size



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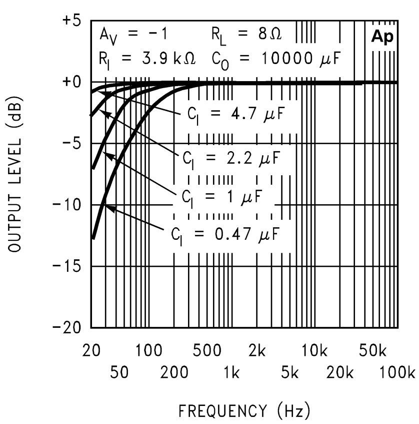
Frequency Response vs Output Capacitor Size



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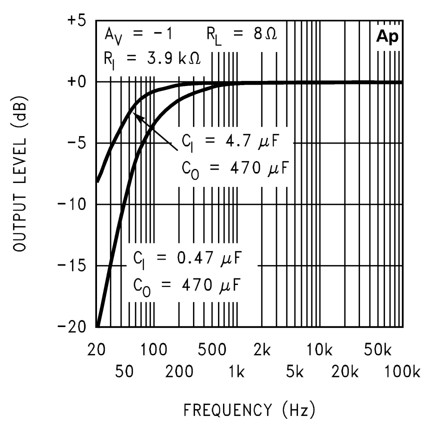
Typical Application Frequency Response



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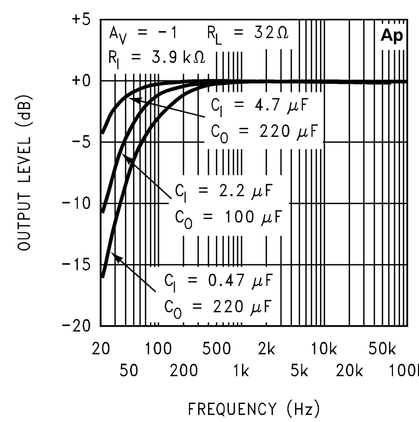
Typical Application Frequency Response



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Application Information

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.

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

Since the LM4808 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 LM4808 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 40 mW per amplifier. Thus the maximum package dissipation point is 80 mW. The maximum power dissipation point obtained must not be greater than the power dissipation that results from Equation 2:

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

For package MUA08A, θ_{JA} = 210˚C/W, and for package M08A, θ_{JA} = 170˚C/W. T_{JMAX} = 150˚C for the LM4808. 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 32Ω load, the maximum ambient temperature possible without violating the maximum junction temperature is approximately 131.6˚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 amplifer, 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. As displayed in the **Typical Performance Characteristics** section, the effect of a larger half supply bypass capacitor is improved low frequency PSRR due to increased half-supply stability. Typical applications employ a 5V regulator with 10 µF and a 0.1 µF bypass capacitors which aid in supply stability, but do not eliminate the need for bypassing the supply nodes of the LM4808. The selection of bypass capacitors, especially C_B, is thus dependent upon desired low frequency PSRR, click and pop performance as explained in the section, **Proper Selection of External Components** section, system cost, and size constraints.

PROPER SELECTION OF EXTERNAL COMPONENTS

Selection of external components when using integrated power amplifiers is critical to optimize device and system performance. While the LM4808 is tolerant of external component combinations, consideration to component values must be used to maximize overall system quality.

The LM4808 is unity gain stable and this gives a designer maximum system flexibility. The LM4808 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 Vrms 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 dicated by the choice of external components shown in *Figure 1*. Both the input coupling capacitor, C_i, and the output coupling capacitor, C_o, form first order high pass filters which limit low frequency response. These values should be chosen based on needed frequency response for a few distinct reasons.

Selection of Input and Output Capacitor Size

Large value input and output capacitors are both expensive and space consuming 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 150 Hz. Thus using large input and output capacitors may not increase system performance.

In addition to system cost and size, click and pop performance is affected 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 and output capacitor sizes, 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 LM4808 turns on. The slower the LM4808's outputs ramp to their quiescent DC voltage (nominally 1/2 V_{DD}), the smaller the turn on pop. While the device will function properly, (no oscillations or motorboating), with C_B equal to 1 µF, the device will be much more susceptible to turn on clicks and pops. Thus, a value of C_B equal to 1 µF or larger is recommended in all but the most cost sensitive designs.

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	20 kΩ
Bandwidth	100 Hz–20 kHz ± 0.50 dB

A designer must first determine the needed supply rail to obtain the specified output power. Calculating the required supply rail involves knowing two parameters, V_{OPEAK} and also the dropout voltage. The latter is typically 300mV and can be found from the graphs in the **Typical Performance Characteristics.** V_{OPEAK} can be determined from Equation 3.

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

Application Information (Continued)

For 70 mW of output power into a 32Ω load, the required $V_{O\text{-}PEAK}$ is 2.12 volts. A minimum supply rail of 2.42V results from adding V_{OPEAK} and V_{OD}. Since 5V is a standard supply voltage in most applications, it is chosen for the supply rail. Extra supply voltage creates headroom that allows the LM4808 to reproduce peaks in excess of 70 mW without clipping the signal. 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. 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 4.

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

$$A_V = R_f/R_i \quad (5)$$

From Equation 4, the minimum gain is: $A_V = 1.26$

Since the desired input impedance was 20kΩ, and with a gain of 1.26, a value of 27kΩ is designated for R_f, assuming 5% tolerance resistors. This combination results in a nominal gain of 1.35. 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 −3dB point is 0.17dB down from passband response assuming a single pole roll-off. As stated in the **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 frequency low response of 100Hz within ±0.5dB, 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.

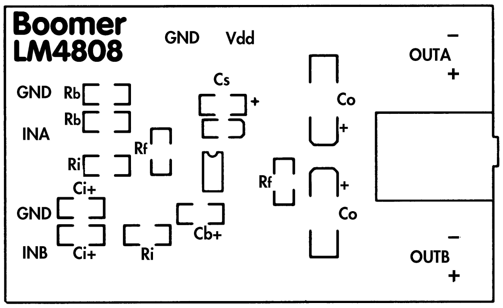
$$C_i \geq 1 / (2\pi * 20\ k\Omega * 20\ Hz) = 0.397\mu F;\ \text{use } 0.39\mu F.$$

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

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 1.35 and f_H = 100kHz, the resulting GBWP = 135kHz which is much smaller than the LM4808 GBWP of 900kHz. This figure displays that if a designer has a need to design an amplifier with a higher gain, the LM4808 can still be used without running into bandwidth limitations.

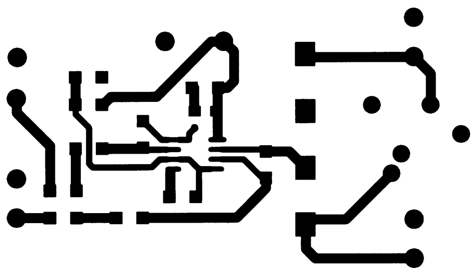
Application Information (Continued)

Silk Screen



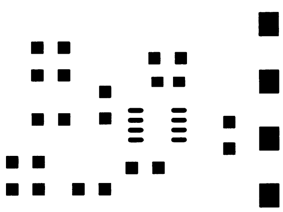
DS101276-39

Top Layer



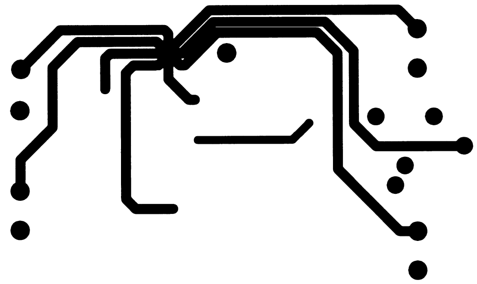
DS101276-40

Solder Mask



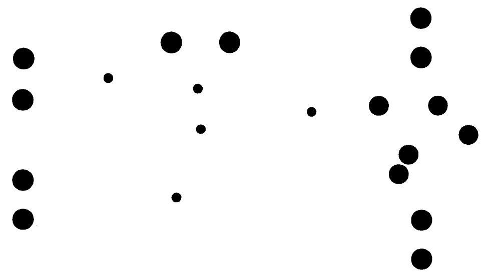
DS101276-41

Bottom Layer



DS101276-42

Drill Drawing



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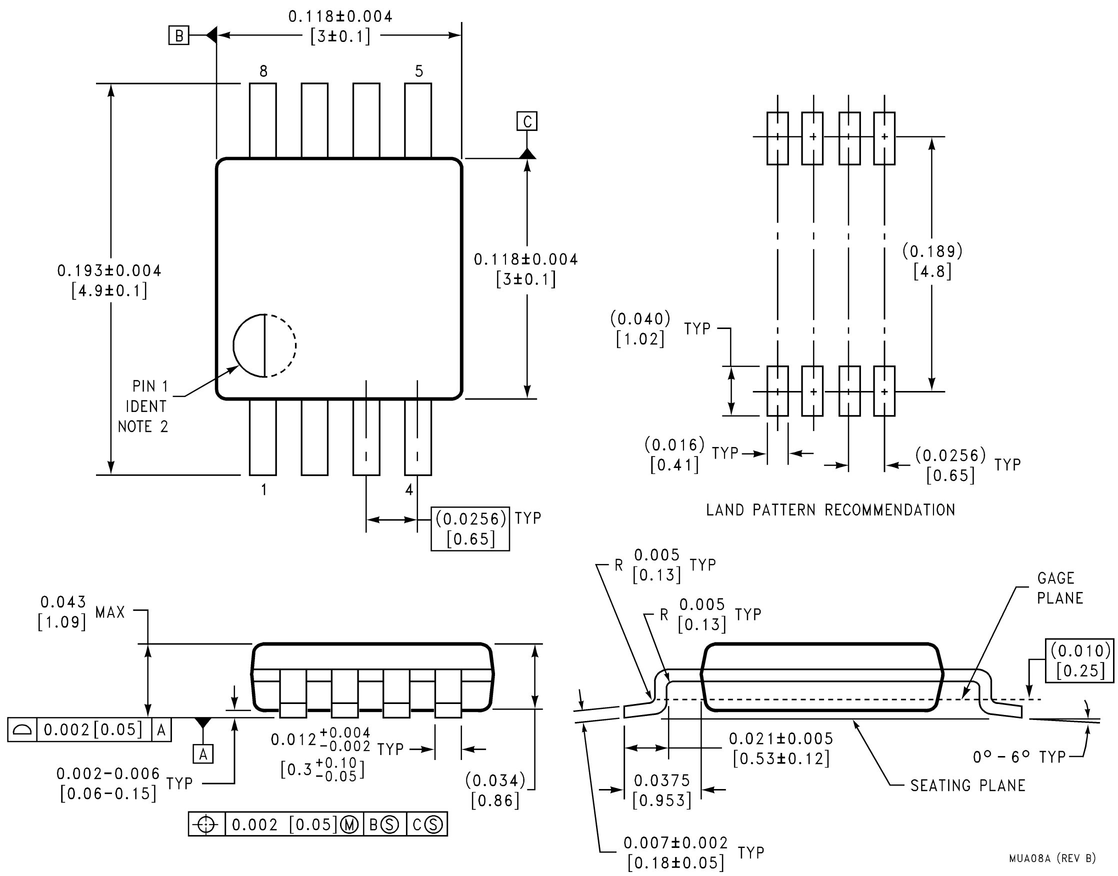
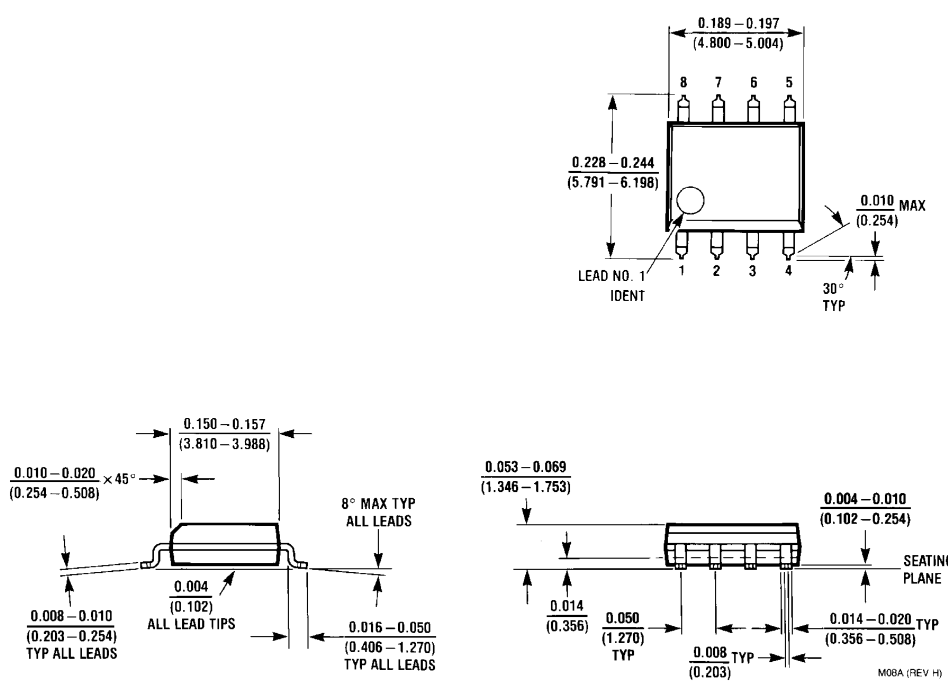
Physical Dimensions inches (millimeters) unless otherwise noted



Order Number LM4808MM
NS Package Number MUA08A



Order Number LM4808M
NS Package Number M08A

Notes

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