

## LM4808 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.

### Features

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

### 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)

### Applications

- Headphone Amplifier
- Personal Computers
- Microphone Preamplifier

### ORDERING INFORMATION

DEVICE	Package Type	MARKING	Packing	Packing Qty
LM4808M/TR	SOP-8L	LM4808	REEL	2500pcs/reel
LM4808MM/TR	MSOP-8L	4808	REEL	3000pcs/reel

### Typical Application

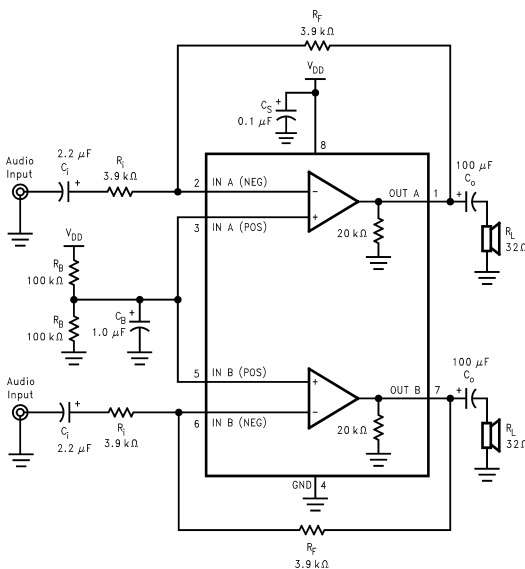
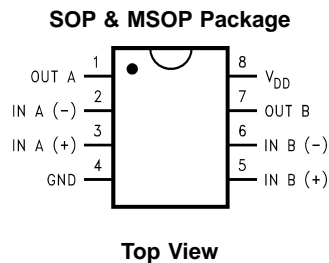


FIGURE 1. Typical Audio Amplifier Application Circuit

### Connection Diagram



## Absolute Maximum Ratings

Supply Voltage	6.0V	Infrared (15 seconds)	220°C
Storage Temperature	-65°C to +150°C	Thermal Resistance	
Input Voltage	-0.3V to $V_{DD} + 0.3V$	$\theta_{JC}$ (MSOP)	56°C/W
Power Dissipation (Note 4)	Internally limited	$\theta_{JA}$ (MSOP)	210°C/W
ESD Susceptibility (Note 5)	3500V	$\theta_{JC}$ (SOP)	35°C/W
ESD Susceptibility (Note 6)	250V	$\theta_{JA}$ (SOP)	170°C/W
Junction Temperature	150°C		
Soldering Information (Note 1)			
Small Outline Package		Temperature Range	
Vapor Phase (60 seconds)	215°C	$T_{MIN} \leq T_A \leq T_{MAX}$	-40°C $\leq T_A \leq$ 85°C
		Supply Voltage	2.0V $\leq V_{DD} \leq$ 5.5V

## Operating Ratings

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

## Electrical Characteristics (Notes 2, 3)

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

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)
$I_{bias}$	Input Bias Current		10		pA
$V_{CM}$	Common Mode Voltage		0		V
			4.3		V
$G_V$	Open-Loop Voltage Gain	$R_L = 5k\Omega$	67		dB
$I_O$	Max Output Current	THD+N < 0.1 %	70		mA
$R_O$	Output Resistance		0.1		$\Omega$
$V_O$	Output Swing	$R_L = 32\Omega, 0.1\% \text{ THD+N, Min}$	.3		V
		$R_L = 32\Omega, 0.1\% \text{ THD+N, Max}$	4.7		
PSRR	Power Supply Rejection Ratio	$C_b = 1.0\mu F, V_{ripple} = 100mV_{PP}, f = 100Hz$	89		dB
Crosstalk	Channel Separation	$R_L = 32\Omega$	75		dB
THD+N	Total Harmonic Distortion + Noise	$f = 1 \text{ kHz}$			
		$R_L = 16\Omega, V_O = 3.5V_{PP} \text{ (at 0 dB)}$	0.05		%
			66		dB
		$R_L = 32\Omega, V_O = 3.5V_{PP} \text{ (at 0 dB)}$	0.05		%
			66		dB
SNR	Signal-to-Noise Ratio	$V_O = 3.5V_{PP} \text{ (at 0 dB)}$	105		dB
$f_G$	Unity Gain Frequency	Open Loop, $R_L = 5k\Omega$	5.5		MHz
$P_O$	Output Power	THD+N = 0.1%, $f = 1 \text{ kHz}$			
		$R_L = 16\Omega$	105		mW
		$R_L = 32\Omega$	70	60	mW
		THD+N = 10%, $f = 1 \text{ kHz}$			
		$R_L = 16\Omega$	150		mW
		$R_L = 32\Omega$	90		mW
$C_I$	Input Capacitance		3		pF
$C_L$	Load Capacitance			200	pF
SR	Slew Rate	Unity Gain Inverting	3		V/ $\mu s$

### Electrical Characteristics (Notes 2, 3)

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

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			
		$R_L = 16\Omega$	40		mW
		$R_L = 32\Omega$	28		mW
		THD+N = 10%, f = 1 kHz			
		$R_L = 16\Omega$	56		mW
		$R_L = 32\Omega$	38		mW

### Electrical Characteristics (Notes 2, 3)

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

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			
		$R_L = 16\Omega$	20		mW
		$R_L = 32\Omega$	16		mW
		THD+N = 10%, f = 1 kHz			
		$R_L = 16\Omega$	31		mW
		$R_L = 32\Omega$	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  $T_{JMAX}$ ,  $\theta_{JA}$ , and the ambient temperature  $T_A$ . The maximum allowable power dissipation is  $P_{DMAX} = (T_{JMAX} - T_A) / \theta_{JA}$ . For the LM4808,  $T_{JMAX} = 150^\circ C$ , and the typical junction-to-ambient thermal resistance, when board mounted, is  $210^\circ C/W$  for the MSOP Package and  $107^\circ C/W$  for package N08E.

**Note 5:** Human body model, 100 pF discharged through a 1.5 k $\Omega$  resistor.

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

**Note 7:** Typicals are measured at  $25^\circ C$  and represent the parametric norm.

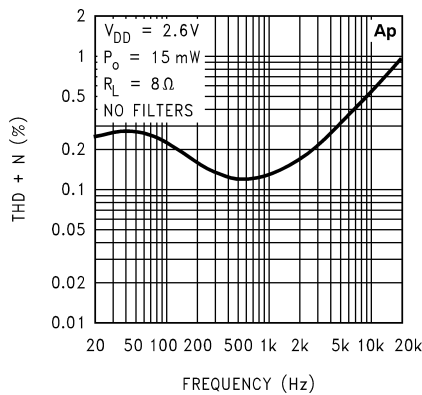
**Note 8:** Limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

## External Components Description (Figure 1)

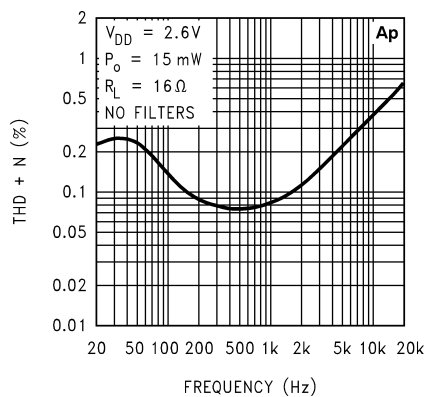
Components	Functional Description
1. $R_i$	Inverting input resistance which sets the closed-loop gain in conjunction with $R_f$ . This resistor also forms a high pass filter with $C_i$ at $f_c = 1 / (2\pi R_i C_i)$ .
2. $C_i$	Input coupling capacitor which blocks the DC voltage at the amplifier's input terminals. Also creates a highpass filter with $R_i$ at $f_c = 1 / (2\pi R_i C_i)$ . Refer to the section, <b>Proper Selection of External Components</b> , for and explanation of how to determine the value of $C_i$ .
3. $R_f$	Feedback resistance which sets closed-loop gain in conjunction with $R_i$ .
4. $C_S$	Supply bypass capacitor which provides power supply filtering. Refer to the <b>Application Information</b> 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, <b>Proper Selection of External Components</b> , 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

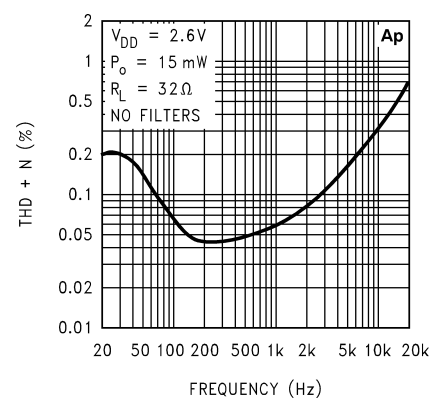
THD+N vs Frequency



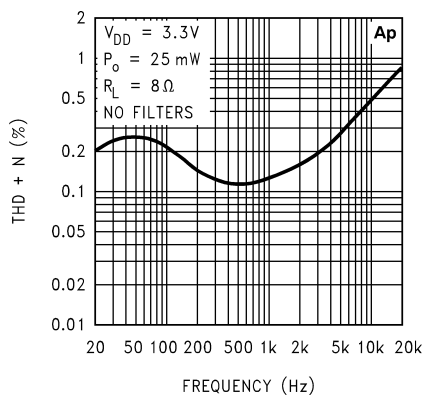
THD+N vs Frequency



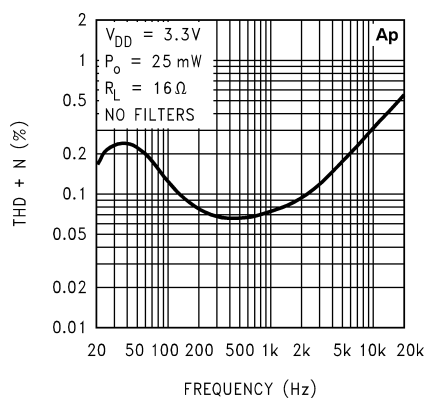
THD+N vs Frequency



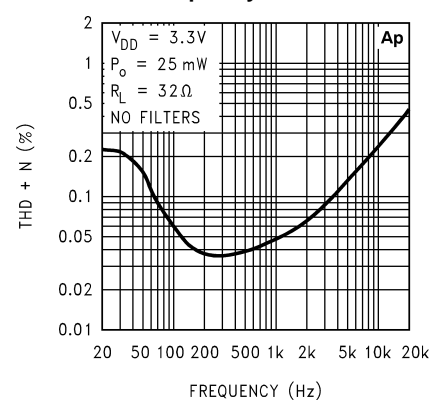
THD+N vs Frequency



THD+N vs Frequency

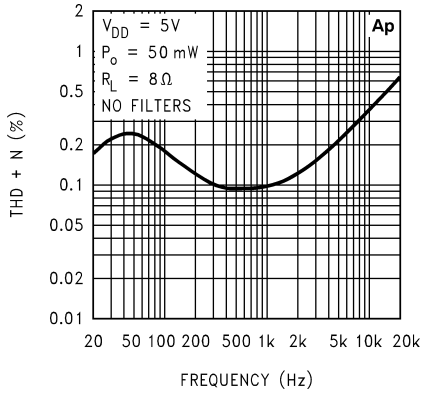


THD+N vs Frequency

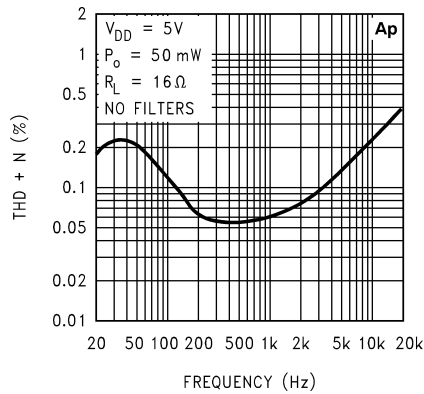


Typical Performance Characteristics (Continued)

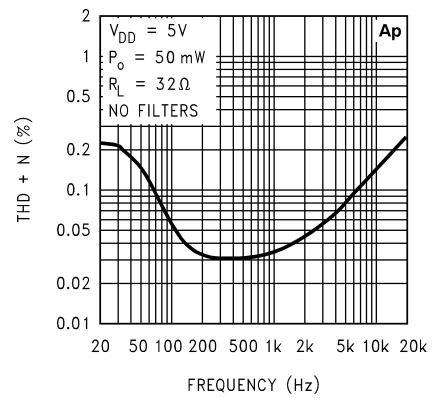
THD+N vs Frequency



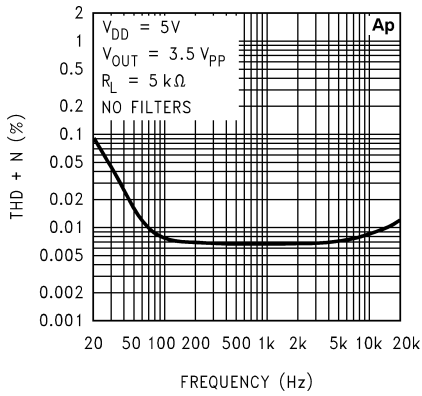
THD+N vs Frequency



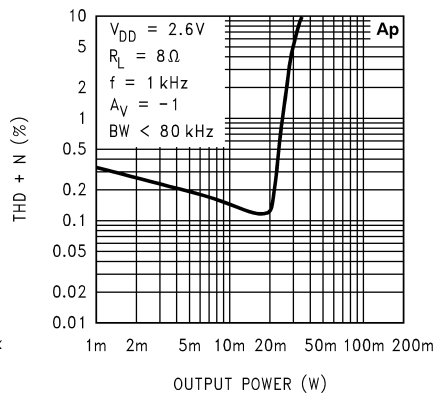
THD+N vs Frequency



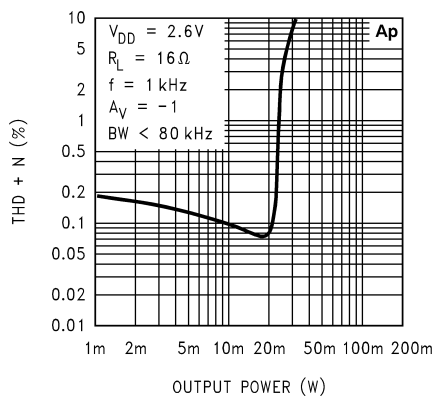
THD+N vs Frequency



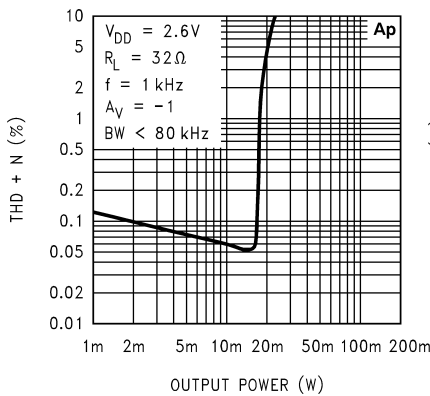
THD+N vs Output Power



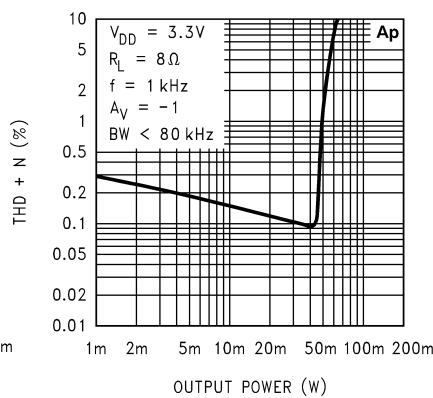
THD+N vs Output Power



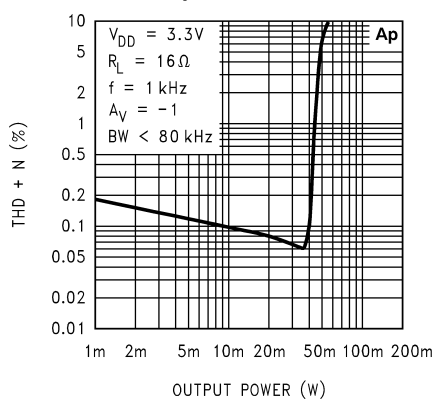
THD+N vs Output Power



THD+N vs Output Power

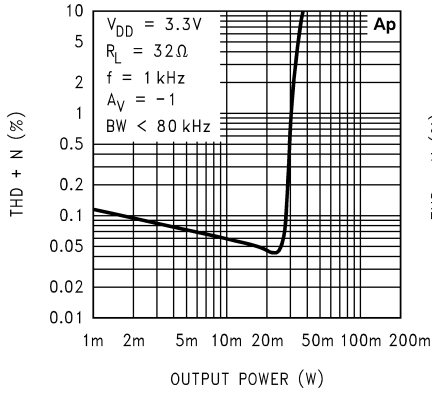


THD+N vs Output Power

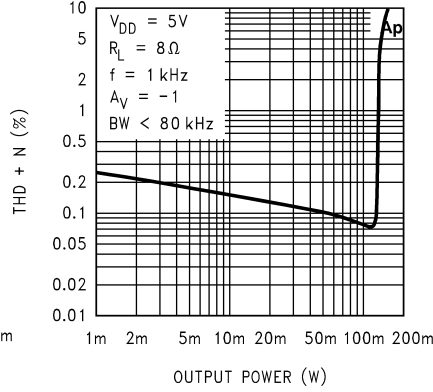


**Typical Performance Characteristics** (Continued)

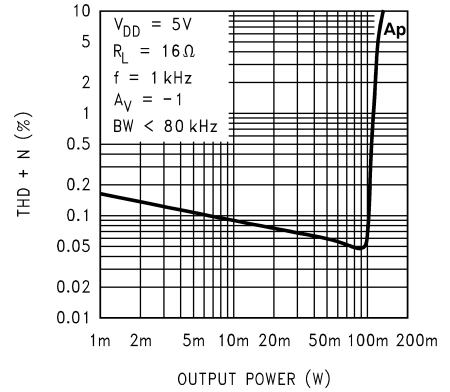
**THD+N vs Output Power**



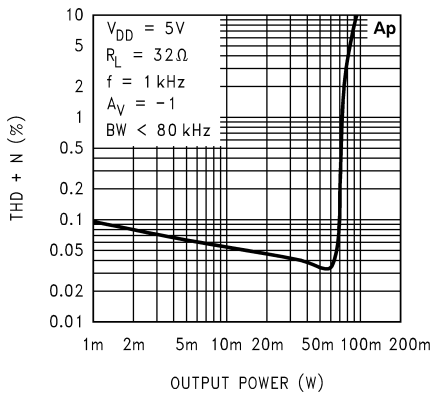
**THD+N vs Output Power**



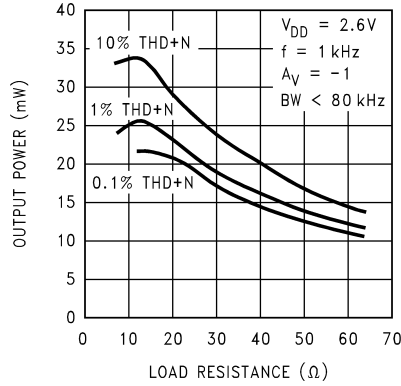
**THD+N vs Output Power**



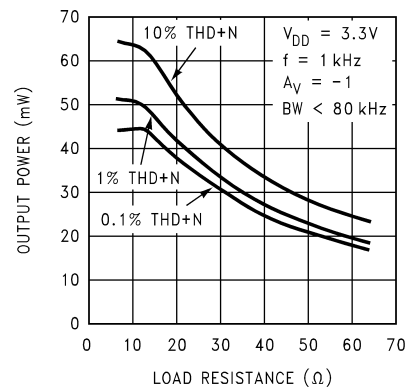
**THD+N vs Output Power**



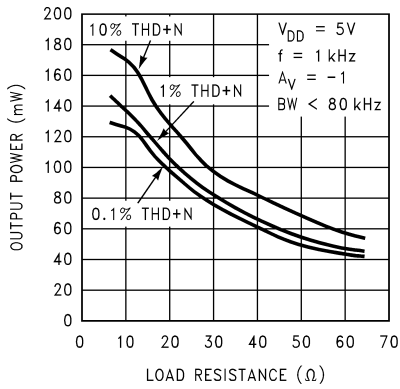
**Output Power vs Load Resistance**



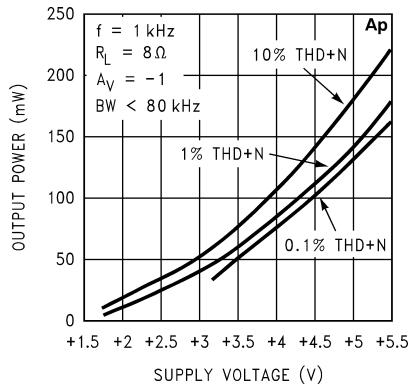
**Output Power vs Load Resistance**



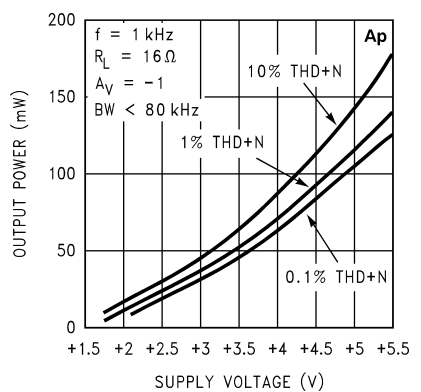
**Output Power vs Load Resistance**



**Output Power vs Supply Voltage**

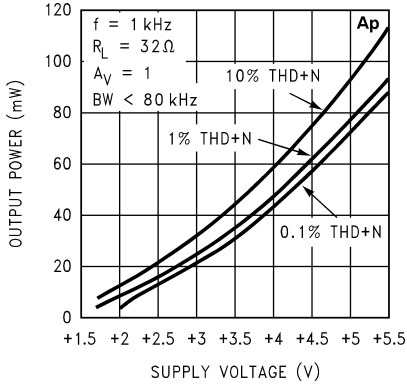


**Output Power vs Power Supply**

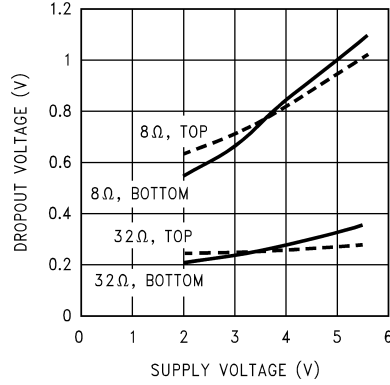


**Typical Performance Characteristics (Continued)**

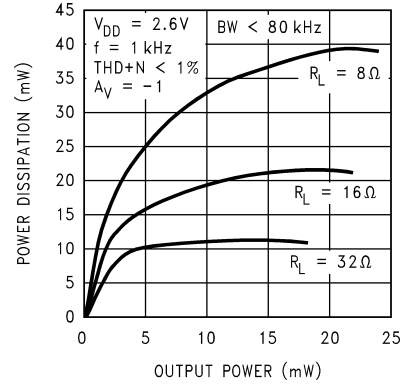
**Output Power vs Power Supply**



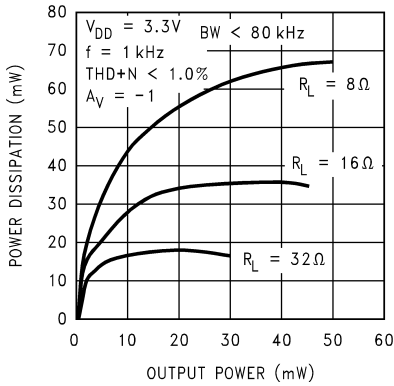
**Clipping Voltage vs Supply Voltage**



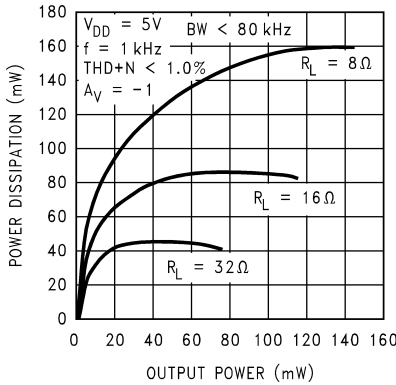
**Power Dissipation vs Output Power**



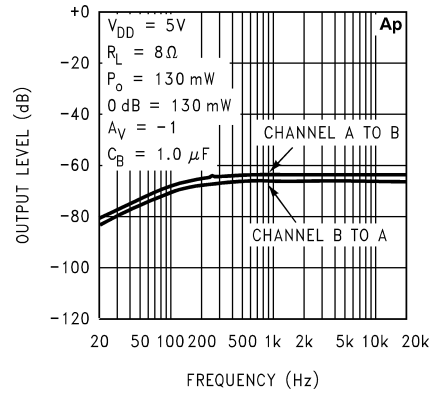
**Power Dissipation vs Output Power**



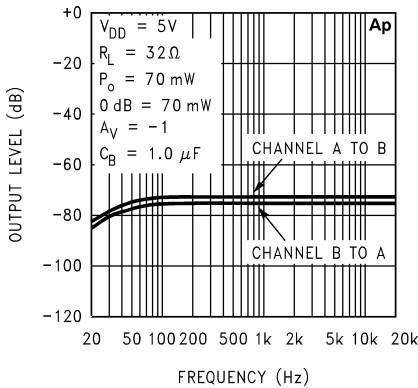
**Power Dissipation vs Output Power**



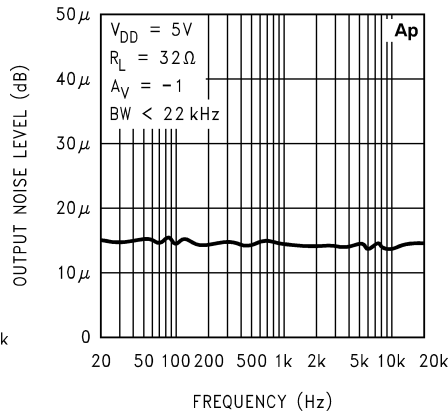
**Channel Separation**



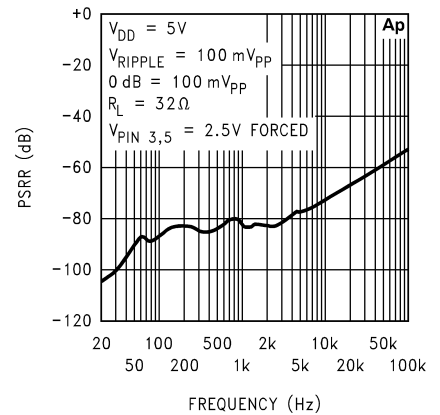
**Channel Separation**



**Noise Floor**

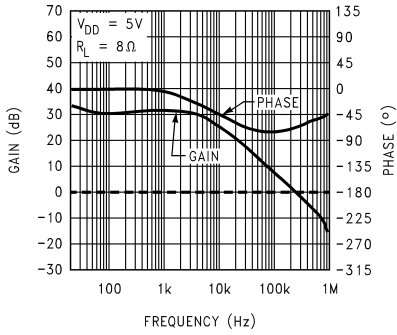


**Power Supply Rejection Ratio**

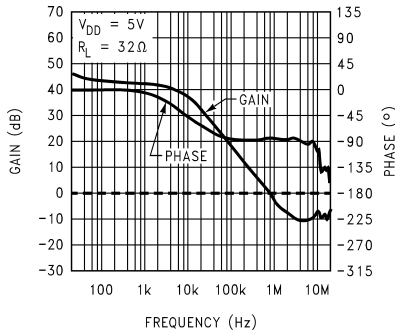


**Typical Performance Characteristics** (Continued)

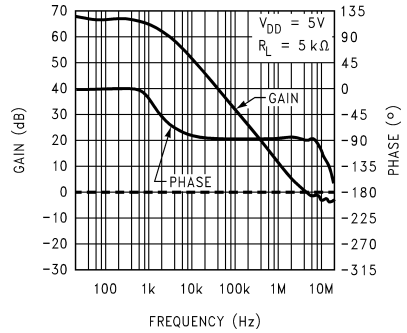
**Open Loop Frequency Response**



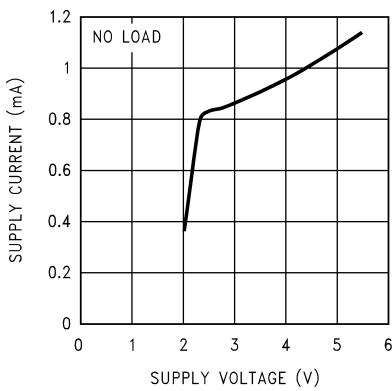
**Open Loop Frequency Response**



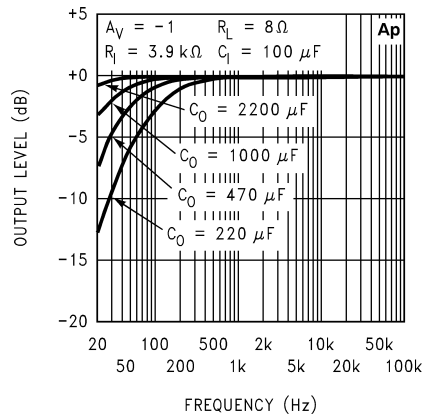
**Open Loop Frequency Response**



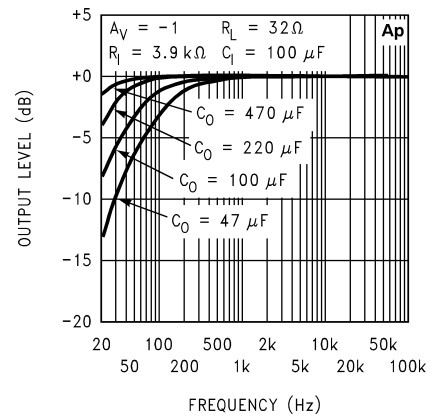
**Supply Current vs Supply Voltage**



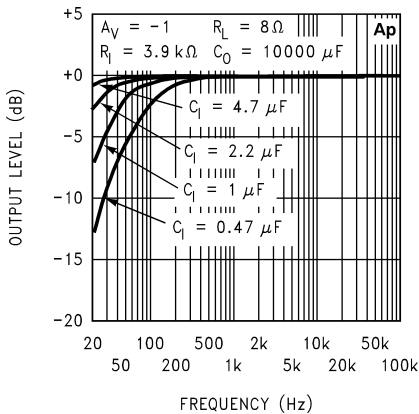
**Frequency Response vs Output Capacitor Size**



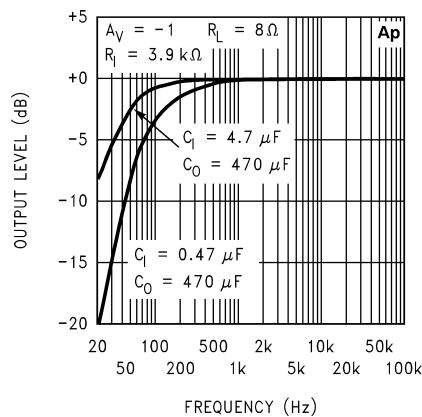
**Frequency Response vs Output Capacitor Size**



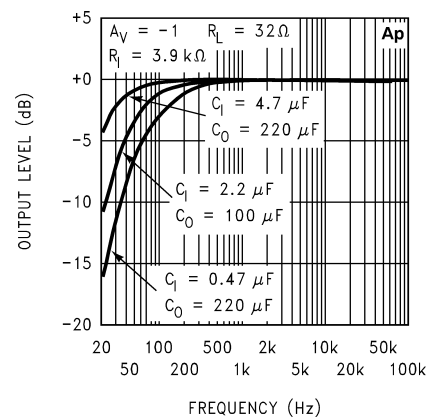
**Frequency Response vs Output Capacitor Size**



**Typical Application Frequency Response**



**Typical Application Frequency Response**





## 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.

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

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:

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

For package MUA08A,  $\theta_{\text{JA}} = 210^\circ\text{C/W}$ , and for package M08A,  $\theta_{\text{JA}} = 170^\circ\text{C/W}$ .  $T_{\text{JMAX}} = 150^\circ\text{C}$  for the LM4808. Depending on the ambient temperature,  $T_{\text{A}}$ , 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  $T_{\text{A}}$  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 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. 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  $C_{\text{B}}$ , 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 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*. Both the input coupling capacitor,  $C_{\text{i}}$ , and the output coupling capacitor,  $C_{\text{o}}$ , 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,  $C_{\text{i}}$ . A larger input coupling capacitor requires more charge to reach its quiescent DC voltage (nominally 1/2  $V_{\text{DD}}$ ). 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  $C_{\text{B}}$  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  $V_{\text{DD}}$ ), the smaller the turn on pop. While the device will function properly, (no oscillations or motorboating), with  $C_{\text{B}}$  equal to 1 μF, the device will be much more susceptible to turn on clicks and pops. Thus, a value of  $C_{\text{B}}$  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 V <sub>rms</sub> (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.

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

For 70 mW of output power into a 32Ω load, the required  $V_{OPEAK}$  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.

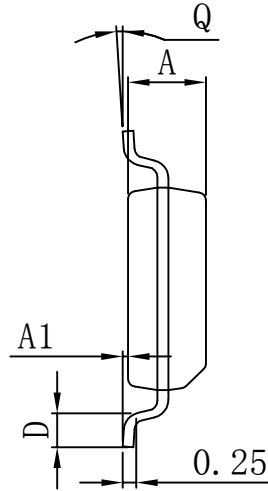
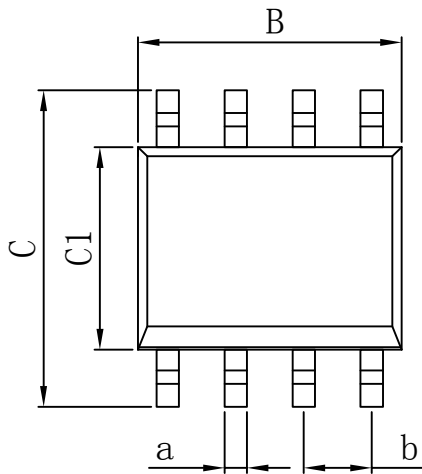
$$C_i \geq 1 / (2\pi * 20 \text{ k}\Omega * 20 \text{ Hz}) = 0.397\mu\text{F}; \text{ use } 0.39\mu\text{F}.$$

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

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  $f_H = 100\text{kHz}$ , 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.

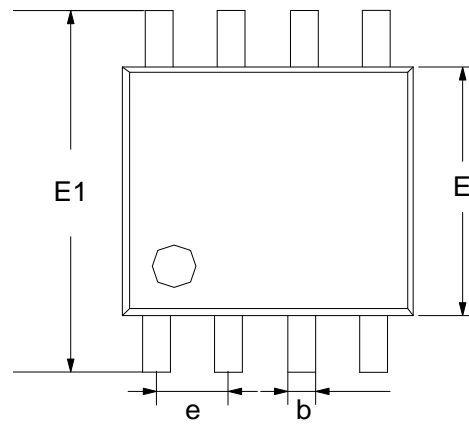
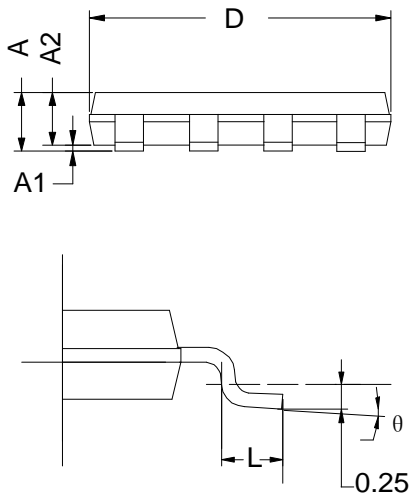
**Package Information**

SOP8



Dimensions In Millimeters					
Symbol :	Min :	Max :	Symbol :	Min :	Max :
A	1.225	1.570	D	0.400	0.950
A1	0.100	0.250	Q	0°	8°
B	4.800	5.100	a	0.420 TYP	
C	5.800	6.250	b	1.270 TYP	
C1	3.800	4.000			

MSOP8



Dimensions In Millimeters					
Symbol :	Min :	Max :	Symbol :	Min :	Max :
A	0.800	1.200	E1	4.700	5.100
A1	0	0.200	L	0.410	0.650
A2	0.760	0.970	θ	0°	6°
D	2.900	3.100	b	0.300 TYP	
E	2.900	3.100	e	0.650 TYP	

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