National Semiconductor

November 1996

LM4863 Boomer® Audio Power Amplifier Series
Dual 1.1W Audio Amplifier plus Stereo Headphone Function

General Description

The LM4863 is a dual bridge-connected audio power amplifier capable of delivering 1.1W of continuous average power to an 8Ω load with less than 0.5% (THD) using a 5V power supply. In addition, enabling the headphone input pin allows the amplifiers to be operated in single-ended mode to drive stereo headphones.

Boomer audio power amplifiers were designed specifically to provide high quality output power from a surface mount package while requiring a minimal amount of external components. Since the LM4863 incorporates both dual bridge speaker drive and stereo headphone functionality on chip, it is optimally suited for multimedia environments.

The LM4863 features an externally controlled, low-power consumption shutdown mode, a stereo headphone amplifier mode, and thermal shutdown protection. It also utilizes circuitry to reduce “clicks and pops” during device turn-on.

The closed loop response of the unity-gain stable LM4863, can be configured by external gain-setting resistors.

Key Specifications

- Bridged Mode—THD at 1W continuous average output power into 8Ω — 0.5% (max)
- Single-Ended Mode—THD at 75 mW continuous average output power into 32Ω — 0.5% (max)
- Shutdown current — 0.7 μA (typ)
- Output power at 10% THD+N into 8Ω — 1.5W (typ)

Features

- Stereo Headphone Amplifier Mode
- “Click and Pop” Suppression Circuitry
- Minimal Amount of External Components
- Small Outline and Dual-In-Line Packaging Available
- Unity-Gain Stable
- External Gain Configuration Capability
- Thermal Shutdown Protection Circuitry

Applications

- Multimedia Monitors
- Portable and Desktop Computers
- Portable Televisions

Typical Application

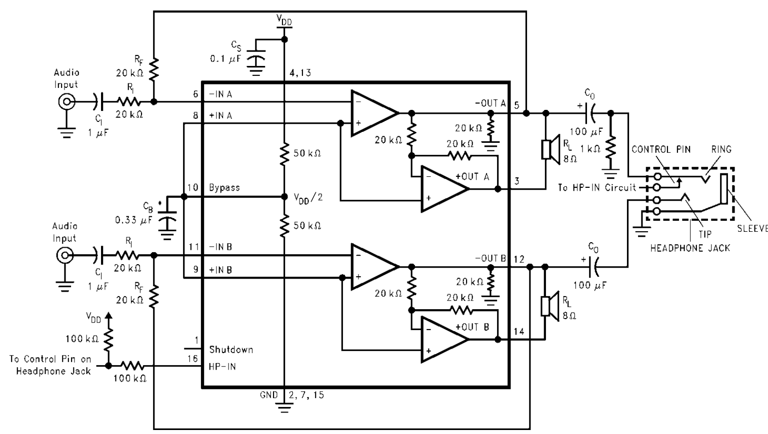

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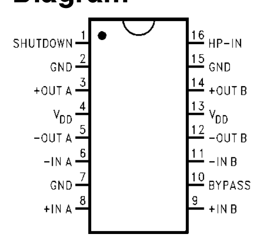
FIGURE 1. Typical Audio Amplifier Application Circuit

* Refer to the section **Proper Selection of External Components**, for a detailed discussion of C_B size.

Connection Diagram



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Top View

Order Number LM4863
See NS Package Number M16B for SO
See NS Package Number N16A for DIP

Absolute Maximum Ratings

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 3)	Internally limited
ESD Susceptibility (Note 4)	2000V
ESD Susceptibility (Note 5)	200V
Junction Temperature	150°C
Solder Information	
Small Outline Package	
Vapor Phase (60 sec.)	215°C
Infrared (15 sec.)	220°C

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

Thermal Resistance	
θ_{JC} (typ)—M16B	20°C/W
θ_{JA} (typ)—M16B	80°C/W
θ_{JC} (typ)—N16A	20°C/W
θ_{JA} (typ)—N16A	63°C/W

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 for Entire IC (Notes 1, 2)

The following specifications apply for V_{DD} = 5V unless otherwise noted. Limits apply for T_A = 25°C.

Symbol	Parameter	Conditions	LM4863		Units (Limits)
			Typical (Note 6)	Limit (Note 7)	
V_{DD}	Supply Voltage			2	V (min)
				5.5	V (max)
I_{DD}	Quiescent Power Supply Current	V_{IN} = 0V, I_O = 0A (Note 8), HP-IN = 0V	11.5	20 6	mA (max) mA (min)
		V_{IN} = 0V, I_O = 0A (Note 8), HP-IN = 4V	5.8		mA
I_{SD}	Shutdown Current	V_{PIN1} = V_{DD}	0.7	2	µA (min)
V_{IH}	Headphone High Input Voltage			4	V (min)
V_{IL}	Headphone Low Input Voltage			0.8	V (max)

Electrical Characteristics for Bridged-Mode Operation (Notes 1, 2)

The following specifications apply for V_{DD} = 5V unless otherwise specified. Limits apply for T_A = 25°C.

Symbol	Parameter	Conditions	LM4863		Units (Limits)
			Typical (Note 6)	Limit (Note 7)	
V_{OS}	Output Offset Voltage	V_{IN} = 0V	5	50	mV (max)
P_O	Output Power	THD = 0.5% (max), f = 1 kHz, R_L = 8Ω	1.1	1.0	W (min)
		THD+N = 1%, f = 1 kHz, R_L = 32Ω	0.34		W
		THD+N = 10%, f = 1 kHz, R_L = 8Ω	1.5		W
THD+N	Total Harmonic Distortion+Noise	P_O = 1W, 20 Hz ≤ f ≤ 20 kHz, A_{VD} = 2	0.3		%
PSRR	Power Supply Rejection Ratio	V_{DD} = 5V, V_{RIPPLE} = 200 mV_{RMS}, R_L = 8Ω, C_B = 1.0 µF	67		dB
X_{TALK}	Channel Separation	f = 1 kHz, C_B = 1.0 µF	90		dB

Electrical Characteristics for Single-Ended Operation (Notes 1, 2)

The following specifications apply for V_{DD} = 5V unless otherwise specified. Limits apply for T_A = 25°C.

Symbol	Parameter	Conditions	LM4863		Units (Limits)
			Typical (Note 6)	Limit (Note 7)	
V_{OS}	Output Offset Voltage	V_{IN} = 0V	5	50	mV (max)
P_O	Output Power	THD = 0.5%, f = 1 kHz, R_L = 32Ω THD+N = 1%, f = 1 kHz, R_L = 8Ω THD+N = 10%, f = 1 kHz, R_L = 8Ω	85 340 440	75	mW (min) mW mW
THD+N	Total Harmonic Distortion+Noise	A_V = −1, P_O = 75 mW, 20 Hz ≤ f ≤ 20 kHz, R_L = 32Ω	0.2		%
PSRR	Power Supply Rejection Ratio	C_B = 1.0 µF, V_{RIPPLE} = 200 mV_{RMS}, f = 1 kHz	52		dB
X_{TALK}	Channel Separation	f = 1 kHz, C_B = 1.0 µF	60		dB

Note 1: All voltages are measured with respect to the ground pins, 2, 7, and 15, unless otherwise specified.

Note 2: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not 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 3: 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 LM4863, T_{JMAX} = 150°C, and the typical junction-to-ambient thermal resistance, when board mounted, is 80°C/W assuming the M16B package.

Note 4: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Note 5: Machine model, 220 pF–240 pF discharged through all pins.

Note 6: Typicals are measured at 25°C and represent the parametric norm.

Note 7: Limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

Note 8: The quiescent power supply current depends on the offset voltage when a practical load is connected to the amplifier.

Truth Table for Logic Inputs

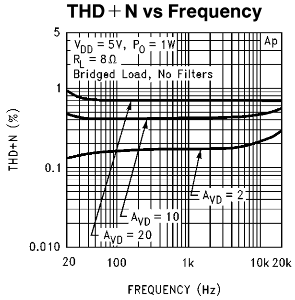
SHUTDOWN	HP-IN	LM4863 MODE
Low	Low	Bridged
Low	High	Single-Ended
High	Low	LM4863 Shutdown
High	High	LM4863 Shutdown

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, **Proper Selection of External Components**, for an explanation of how to determine the value of C_i.
3.	R_f	Feedback resistance which sets the closed-loop gain in conjunction with R_i.
4.	C_S	Supply bypass capacitor which provides power supply filtering. Refer to the **Power Supply Bypassing** section for information concerning proper placement and selection of the supply bypass capacitor.
5.	C_B	Bypass pin capacitor which provides half-supply filtering. Refer to the section, **Proper Selection of External Components**, for information concerning proper placement and selection of C_B.

Typical Performance Characteristics

THD + N vs Frequency



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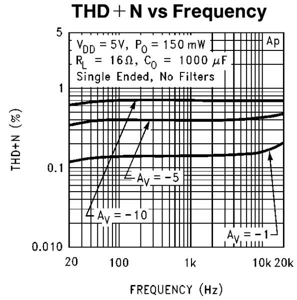
THD + N vs Frequency



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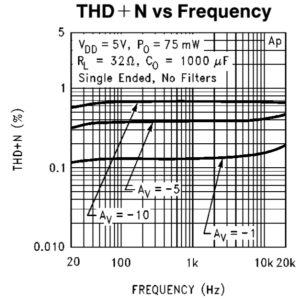
THD + N vs Frequency



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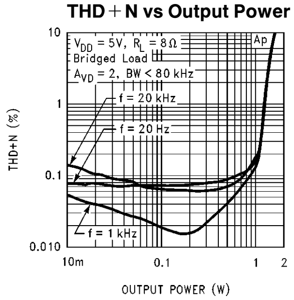
THD + N vs Output Power



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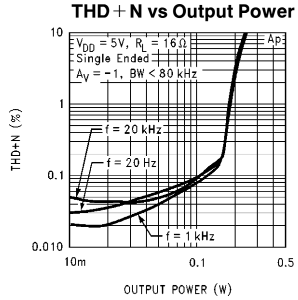
THD + N vs Output Power



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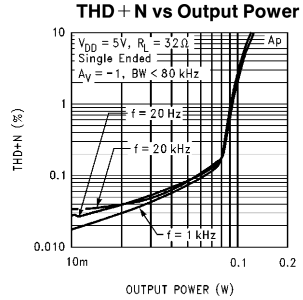
THD + N vs Output Power



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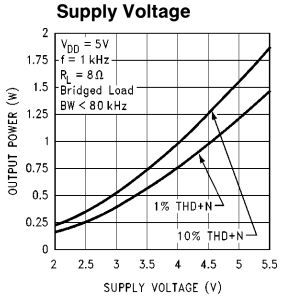
Output Power vs Supply Voltage



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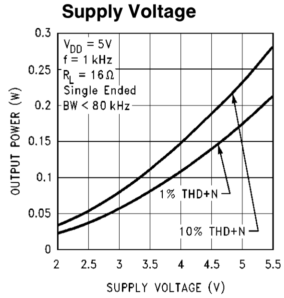
Output Power vs Supply Voltage



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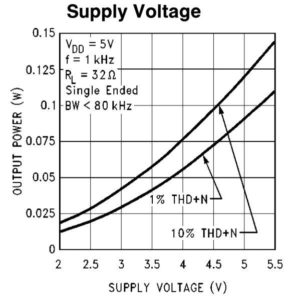
Output Power vs Supply Voltage



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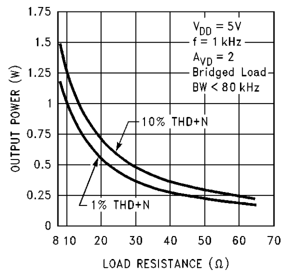
Typical Performance Characteristics (Continued)

Output Power vs Load Resistance



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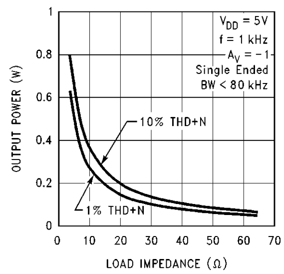
Output Power vs Load Resistance



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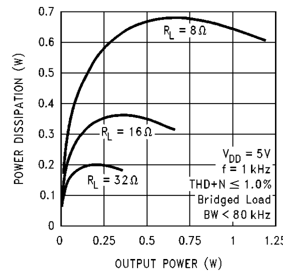
Power Dissipation vs Output Power



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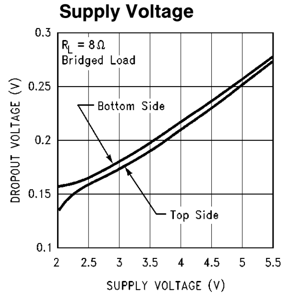
Dropout Voltage vs Supply Voltage



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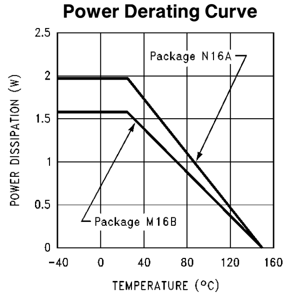
Power Derating Curve



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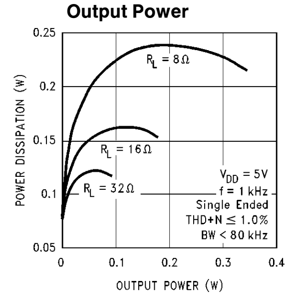
Power Dissipation vs Output Power



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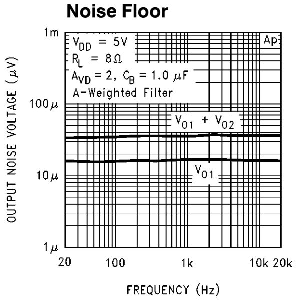
Noise Floor



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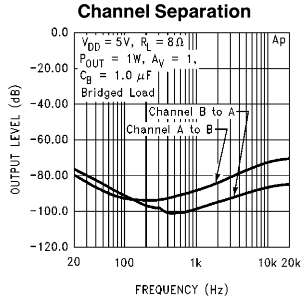
Channel Separation



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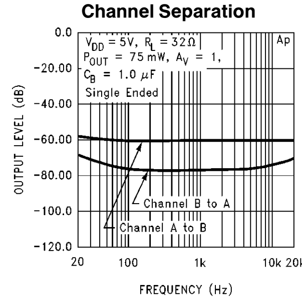
Channel Separation



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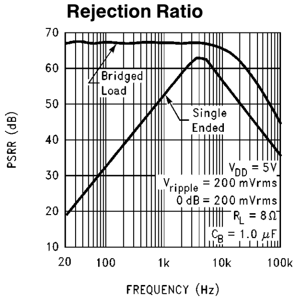
Power Supply Rejection Ratio



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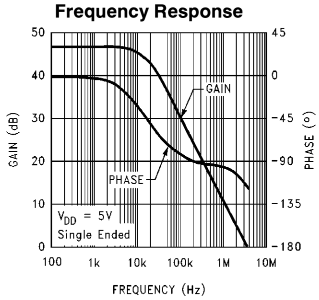
Open Loop Frequency Response



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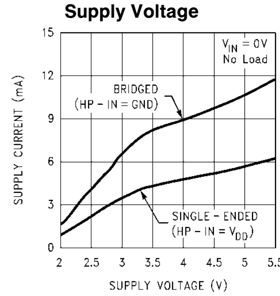
Supply Current vs Supply Voltage



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Application Information

BRIDGE CONFIGURATION EXPLANATION

As shown in *Figure 1,* the LM4863 has two pairs of operational amplifiers internally, allowing for a few different amplifier configurations. The first amplifier's gain is externally configurable, while the second amplifier is internally fixed in a unity-gain, inverting configuration. The closed-loop gain of the first amplifier is set by selecting the ratio of R_f to R_i while the second amplifier's gain is fixed by the two internal 20 kΩ resistors. *Figure 1* shows that the output of amplifier one serves as the input to amplifier two which results in both amplifiers producing signals identical in magnitude, but out of phase 180°. Consequently, the differential gain for each channel of the IC is

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

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

A bridge amplifier design has a few distinct advantages over the single-ended configuration, as it provides differential drive to the load, thus doubling the output swing for a specified supply voltage. Four times the output power is possible as compared to a single-ended amplifier under the same conditions. This increase in attainable output power assumes that the amplifier is not current limited or clipped. In order to choose an amplifier's closed-loop gain without causing excessive clipping, please refer to the **Audio Power Amplifier Design** section.

A bridge configuration, such as the one used in LM4863, also creates a second advantage over single-ended amplifiers. Since the differential outputs, +OutA, −OutA, +OutB, and −OutB, are biased at half-supply, no net DC voltage exists across the load. This eliminates the need for an output coupling capacitor which is required in a single supply, single-ended amplifier configuration. If an output coupling capacitor is not used in a single-ended configuration, the half-supply bias across the load would result in both increased internal IC power dissipation as well as permanent loudspeaker damage.

POWER DISSIPATION

Power dissipation is a major concern when designing a successful amplifier, whether the amplifier is bridged or single-ended. Equation 1 states the maximum power dissipation point for a single-ended amplifier operating at a given supply voltage and driving a specified load.

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

However, a direct consequence of the increased power delivered to the load by a bridge amplifier is an increase in internal power dissipation. Equation 2 states the maximum power dissipation point for a bridge amplifier operating at the same given conditions.

$$P_{DMAX} = 4 * (V_{DD})^2/(2\pi^2 R_L) \qquad \text{Bridge Mode (2)}$$

Since the LM4863 is a dual channel power amplifier, the maximum internal power dissipation is 2 times that of Equation 1 or Equation 2 depending on the mode of operation. Even with this substantial increase in power dissipation, the LM4863 does not require heatsinking. The power dissipation from Equation 2, assuming a 5V power supply and an 8Ω load, must not be greater than the power dissipation that results from Equation 3:

$$P_{DMAX} = (T_{JMAX} - T_A)/\theta_{JA} \qquad (3)$$

For package M16A, θ_{JA} = 80°C/W, and for package N16A, θ_{JA} = 63°C/W. T_{JMAX} = 150°C for the LM4863. Depending on the ambient temperature, T_A, of the system surroundings, Equation 3 can be used to find the maximum internal power dissipation supported by the IC packaging. If the result of Equation 2 is greater than that of Equation 3, then either the supply voltage must be decreased, the load impedance increased, or the ambient temperature reduced. For the typical application of a 5V power supply, with an 8Ω bridged load, the maximum ambient temperature possible without violating the maximum junction temperature is approximately 48°C provided that device operation is around the maximum power dissipation point and assuming surface mount packaging. Internal power dissipation is a function of output power. If typical operation is not around the maximum power dissipation point, the ambient temperature can be increased. Refer to the **Typical Performance Characteristics** curves for power dissipation information for different 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. The effect of a larger half supply bypass capacitor is improved 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 filtering. This does not eliminate the need for bypassing the supply nodes of the LM4863. The selection of bypass capacitors, especially C_B, is thus dependent upon desired PSRR requirements, click and pop performance as explained in the section, **Proper Selection of External Components**, system cost, and size constraints.

SHUTDOWN FUNCTION

In order to reduce power consumption while not in use, the LM4863 contains a shutdown pin to externally turn off the amplifier's bias circuitry. This shutdown feature turns the amplifier off when a logic high is placed on the shutdown pin. The trigger point between a logic low and logic high level is typically half supply. It is best to switch between ground and the supply V_{DD} to provide maximum device performance. By switching the shutdown pin to V_{DD}, the LM4863 supply current draw will be minimized in idle mode. While the device will be disabled with shutdown pin voltages less than V_{DD}, the idle current may be greater than the typical value of 0.7 µA. In either case, the shutdown pin should be tied to a definite voltage to avoid unwanted state changes.

Application Information (Continued)

In many applications, a microcontroller or microprocessor output is used to control the shutdown circuitry which provides a quick, smooth transition into shutdown. Another solution is to use a single-pole, single-throw switch in conjunction with an external pull-up resistor. When the switch is closed, the shutdown pin is connected to ground and enables the amplifier. If the switch is open, then the external pull-up resistor will disable the LM4863. This scheme guarantees that the shutdown pin will not float, thus preventing unwanted state changes.

HP-IN FUNCTION

The LM4863 possesses a headphone control pin that turns off the amplifiers which drive +OutA and +OutB so that single-ended operation can occur and a bridged connected load is muted. Quiescent current consumption is reduced when the IC is in this single-ended mode.

Figure 2 shows the implementation of the LM4863's headphone control function using a single-supply headphone amplifier. The voltage divider of R1 and R2 sets the voltage at the HP-IN pin (pin 16) to be approximately 50 mV when there are no headphones plugged into the system. This logic-low voltage at the HP-IN pin enables the LM4863 and places it in bridged mode operation. Resistor R4 limits the amount of current flowing out of the HP-IN pin when the voltage at that pin goes below ground resulting from the music coming from the headphone amplifier. The output coupling capacitors protect the headphones by blocking the amplifier's half supply DC voltage.

When there are no headphones plugged into the system and the IC is in bridged mode configuration, both loads are essentially at a 0V DC potential. Since the HP-IN threshold is set at 4V, even in an ideal situation, the output swing cannot cause a false single-ended trigger.

When a set of headphones are plugged into the system, the contact pin of the headphone jack is disconnected from the signal pin, interrupting the voltage divider set up by resistors R1 and R2. Resistor R1 then pulls up the HP-IN pin, enabling the headphone function. This disables the second side of the amplifier thus muting the bridged speakers. The amplifier then drives the headphones, whose impedance is in parallel with resistors R2 and R3. Resistors R2 and R3 have negligible effect on output drive capability since the typical impedance of headphones are 32Ω. Also shown in *Figure 2* are the electrical connections for the headphone jack and plug. A 3-wire plug consists of a Tip, Ring and Sleave, where the Tip and Ring are signal carrying conductors and the Sleave is the common ground return. One control pin contact for each headphone jack is sufficient to indicate to control inputs that the user has inserted a plug into a jack and that another mode of operation is desired.

The LM4863 can be used to drive both a pair of bridged 8Ω speakers and a pair of 32Ω headphones without using the HP-IN pin. In this case the HP-IN would not be connected to the headphone jack but to a microprocessor or a switch. By enabling the HP-IN pin, the 8Ω speakers can be muted.

PROPER SELECTION OF EXTERNAL COMPONENTS

Proper selection of external components in applications using integrated power amplifiers is critical to optimize device and system performance. While the LM4863 is tolerant to a variety of external component combinations, consideration to component values must be used to maximize overall system quality.

The LM4863 is unity-gain stable, giving the designer maximum system performance. The LM4863 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.

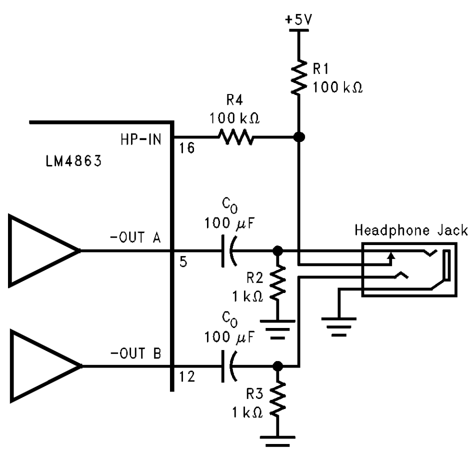

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FIGURE 2. Headphone Input Circuit

Application Information (Continued)

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

CLICK AND POP CIRCUITRY

The LM4863 contains circuitry to minimize turn-on transients or "clicks and pops". In this case, turn-on refers to either power supply turn-on or the device coming out of shutdown mode. When the device is turning on, the amplifiers are internally configured as unity gain buffers. An internal current source ramps up the voltage of the bypass pin. Both the inputs and outputs ideally track the voltage at the bypass pin. The device will remain in buffer mode until the bypass pin has reached its half supply voltage, 1/2 V_{DD}. As soon as the bypass node is stable, the device will become fully operational, where the gain is set by the external resistors.

Although the bypass pin current source cannot be modified, the size of C_B can be changed to alter the device turn-on time and the amount of "clicks and pops". By increasing amount of turn-on pop can be reduced. However, the tradeoff for using a larger bypass capacitor is an increase in turn-on time for this device. There is a linear relationship between the size of C_B and the turn-on time. Here are some typical turn-on times for a given C_B:

C_B	T_{ON}
0.01 µF	20 ms
0.1 µF	200 ms
0.22 µF	420 ms
0.47 µF	840 ms
1.0 µF	2 Sec

In order eliminate "clicks and pops", all capacitors must be discharged before turn-on. Rapid on/off switching of the device or the shutdown function may cause the "click and pop" circuitry to not operate fully, resulting in increased "click and pop" noise. In a single-ended configuration, the output coupling capacitor, C_O, is of particular concern. This capacitor discharges through the internal 20 kΩ resistors. Depending on the size of C_O, the time constant can be relatively large. To reduce transients in single-ended mode, an external 1 kΩ−5 kΩ resistor can be placed in parallel with the internal 20 kΩ resistor. The tradeoff for using this resistor is an increase in quiescent current.

The value of C_I will also reflect turn-on pops. Clearly, a certain size for C_I is needed to couple in low frequencies without excessive attenuation. But in many cases, the speakers used in portable systems, whether integral or external, have little ability to reproduce signals below 100 Hz to 150 Hz. In this case, using a large input and output capacitor may not increase system performance. In most cases, choosing a small value of C_I in the range of 0.1 µF to 0.33 µF), along with C_B equal to 1.0 µF should produce a virtually clickless and popless turn-on. In cases where C_I is larger than 0.33 µF, it may be advantageous to increase the value of C_B. Again, it should be understood that increasing the value of C_B will reduce the "clicks and pops" at the expense of a longer device turn-on time.

AUDIO POWER AMPLIFIER DESIGN

Design a 1W/8Ω Bridged Audio Amplifier

Given:

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

A designer must first determine the minimum supply rail to obtain the specified output power. By extrapolating from the Output Power vs Supply Voltage graphs in the **Typical Performance Characteristics** section, the supply rail can be easily found. A second way to determine the minimum supply rail is to calculate the required V_{opeak} using Equation 3 and add the dropout voltage. Using this method, the minimum supply voltage would be (V_{opeak} + (2 * V_{od})), where V_{od} is extrapolated from the Dropout Voltage vs Supply Voltage curve in the **Typical Performance Characteristics** section.

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

Using the Output Power vs Supply Voltage graph for an 8Ω load, the minimum supply rail is 3.9V. But 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 LM4863 to reproduce peaks in excess of 1W without producing audible distortion. At this time, the designer must make sure that the power supply choice along with the output impedance does not violate the conditions explained in the **Power Dissipation** section.

Once the power dissipation equations have been addressed, the required differential gain can be determined from Equation 4.

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

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

From equation 4, the minimum A_{VD} is 2.83; use $A_{VD} = 3$

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

$$f_L = 100\text{ Hz}/5 = 20\text{ Hz}$$

$$f_H = 20\text{ kHz} \times 5 = 100\text{ kHz}$$

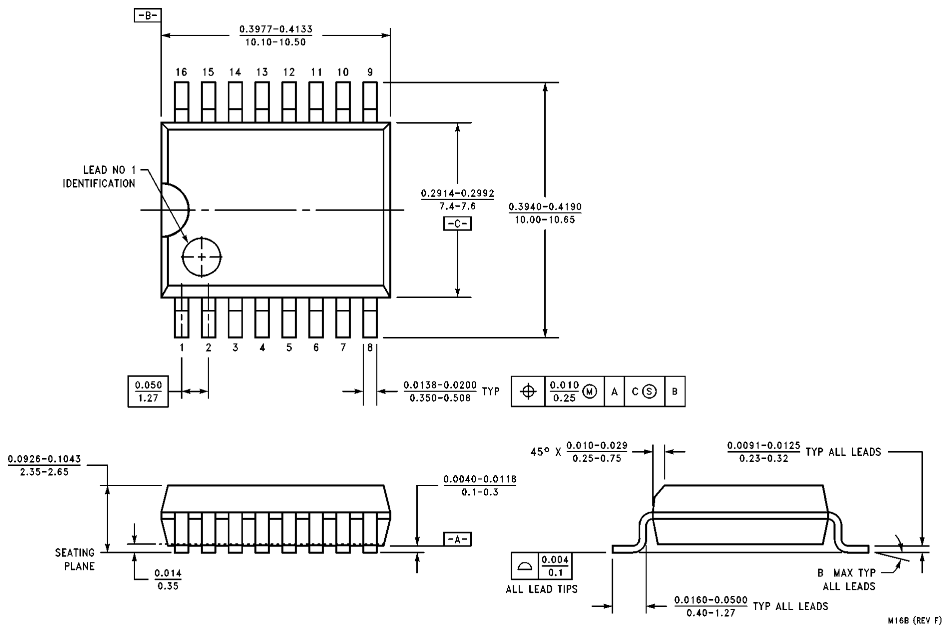
As stated in the **External Components** section, R_i in conjunction with C_i create a highpass filter.

$$C_i \geq \frac{1}{2\pi R_i f_c}$$

$$C_i \geq 1/(2\pi * 20\text{ k}\Omega * 20\text{ Hz}) = 0.397\ \mu F; \quad \text{use } 0.33\ \mu F$$

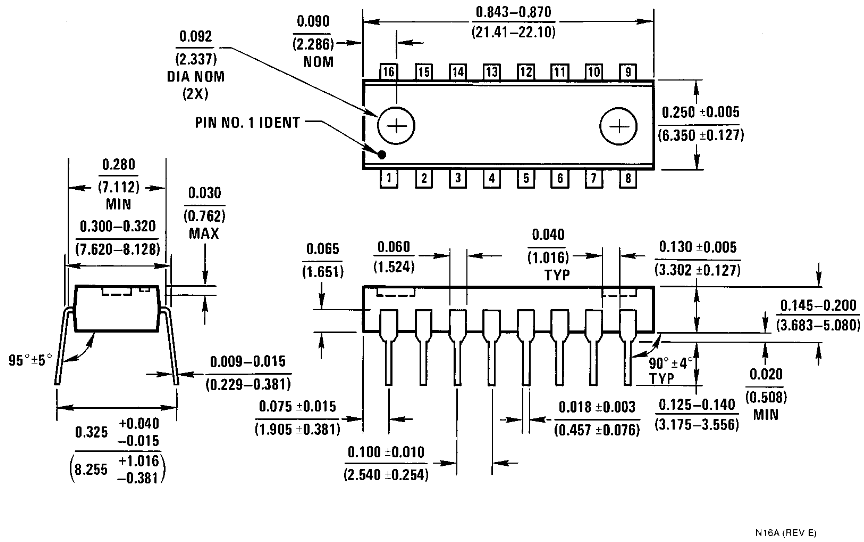
The high frequency pole is determined by the product of the desired high frequency pole, f_H, and the differential gain, A_{VD}. With a A_{VD} = 3 and f_H = 100 kHz, the resulting GBWP = 150 kHz which is much smaller than the LM4863 GBWP of 3.5 MHz. This figure displays that if a designer has a need to design an amplifier with a higher differential gain, the LM4863 can still be used without running into bandwidth problems.

Physical Dimensions inches (millimeters) unless otherwise noted



16-Lead (0.300″ Wide) Molded Small Outline Package, JEDEC
Order Number LM4863
NS Package Number M16B

Physical Dimensions inches (millimeters) unless otherwise noted (Continued) — Lit. # 108157-001



16-Lead (0.300″ Wide) Molded Dual-In-Line Package
Order Number LM4863
NS Package Number N16A

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