19-3049; Rev 0; 10/03

EVALUATION KIT AVAILABLE

MAXIM

5V, Differential Input, DirectDrive, 130mW Stereo Headphone Amplifiers with Shutdown

General Description

The MAX9722A/MAX9722B stereo headphone amplifiers are designed for portable equipment where board space is at a premium. The MAX9722A/MAX9722B use a unique, patented DirectDrive architecture to produce a ground-referenced output from a single supply, eliminating the need for large DC-blocking capacitors, which saves cost, board space, and component height. Additionally, the gain of the amplifier is set internally (-2V/V, MAX9722B) or adjusted externally (MAX9722A). The MAX9722A/MAX9722B deliver up to 70mW per channel into a 16Ω load or 130mW into a 32Ω load and have low 0.009% THD+N. An 80dB at 217Hz power-supply rejection ratio (PSRR) allows these devices to operate from noisy digital supplies without an additional linear regulator. The MAX9722A/MAX9722B include ±8kV ESD protection on the headphone outputs. Comprehensive anticlick-and-pop circuitry suppresses audible clicks and pops on startup and shutdown. A low-power shutdown mode reduces the supply current to 0.1µA.

The MAX9722A/MAX9722B operate from a single 2.4V to 5.5V supply, consume only 5.5mA of supply current, feature short-circuit and thermal-overload protection, and are specified over the extended -40°C to +85°C temperature range. The devices are available in tiny 16-pin thin QFN (3mm × 3mm × 0.8mm) and 16-pin TSSOP packages.

Applications

Notebook and Desktop PCs
MP3 Players
Flat-Panel Monitors
Cellular Phones
Smart Phones
PDAs
Portable Audio Equipment

Ordering Information

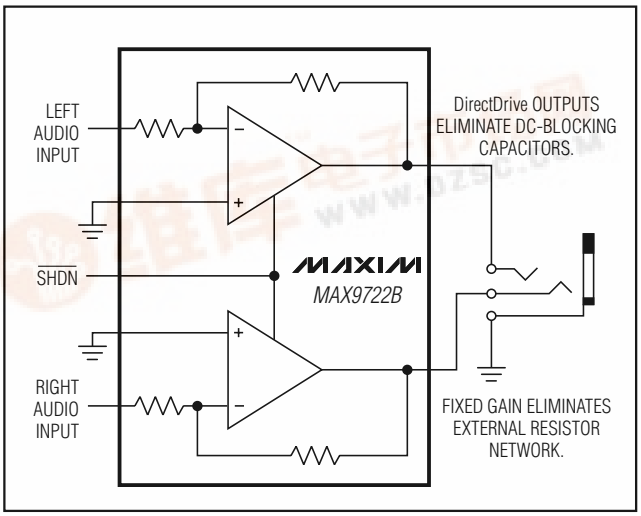
PART	TEMP RANGE	PIN-PACKAGE	TOP MARK
MAX9722AETE	-40°C to +85°C	16 Thin QFN-EP* (3mm × 3mm × 0.8mm)	AAX
MAX9722AEUE	-40°C to +85°C	16 TSSOP	—
MAX9722BETE	-40°C to +85°C	16 Thin QFN-EP* (3mm × 3mm × 0.8mm)	AAY
MAX9722BEUE	-40°C to +85°C	16 TSSOP	—

*EP = Exposed paddle.

Features

- 2.4V to 5.5V Single-Supply Operation
- High PSRR (80dB at 217Hz) Eliminates LDO
- No Bulky DC-Blocking Capacitors Required
- Ground-Referenced Outputs Eliminate DC Bias Voltage on Headphone Ground Pin
- No Degradation of Low-Frequency Response Due to Output Capacitors
- Differential Inputs for Enhanced Noise Cancellation
- Adjustable Gain (MAX9722A) or Fixed -2V/V Gain (MAX9722B)
- 130mW per Channel into 32Ω
- Low 0.009% THD+N
- Integrated Click-and-Pop Suppression
- Low Quiescent Current (5.5mA)
- Short-Circuit and Thermal-Overload Protection
- ±8kV ESD-Protected Amplifier Outputs (Human Body Model)
- Available in a Space-Saving 16-Pin Thin QFN (3mm × 3mm × 0.8mm) Package

Simplified Diagram



Pin Configurations and Typical Operating Circuit appear at end of data sheet.

5V, Differential Input, DirectDrive, 130mW Stereo Headphone Amplifiers with Shutdown

ABSOLUTE MAXIMUM RATINGS

PGND to SGND .....-0.3V to +0.3V
PV_{DD} and SV_{DD} to PGND or SGND .....-0.3V to +6V
PV_{SS} and SV_{SS} to PGND.....+0.3V to -6V
IN_ to SGND .....(SV_{SS} - 0.3V) to (SV_{DD} + 0.3V)
OUT_ to PGND .....-3.0V to +3.0V
$\overline{SHDN}$ to SGND.....(SGND - 0.3V) to (SV_{DD} + 0.3V)
C1P to PGND .....-0.3V to (PV_{DD} + 0.3V)
C1N to PGND.....(SV_{SS} - 0.3V) to +0.3V
PV_{DD} to SV_{DD}.....0V
PV_{SS} to SV_{SS} 0V
Output Short Circuit to GND.....Continuous
Continuous Power Dissipation (T_A = +70°C)
16-Pin Thin QFN (derate 14.7mW/°C above +70°C)....1176mW
16-Pin TSSOP (derate 9.4mW/°C above +70°C) 755mW
Junction Temperature .....+150°C
Operating Temperature Range.....-40°C to +85°C
Storage Temperature Range .....-65°C to +150°C
Lead Temperature (soldering, 10s) .....+300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(PV_{DD} = SV_{DD} = +5V, PGND = SGND = 0V, $\overline{SHDN}$ = SV_{DD}, C1 = C2 = 1µF, R_L = ∞, resistive load referenced to ground, for MAX9722A gain = -1V/V (R_{IN} = R_F = 10kΩ), for MAX9722B gain = -2V/V (internally set), T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C, unless otherwise noted.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
GENERAL						
Supply Voltage Range	V_{DD}	Guaranteed by PSRR test	2.4		5.5	V
Quiescent Supply Current	I_{DD}	R_L = ∞		5.5	13	mA
Shutdown Supply Current	$I_{\overline{SHDN}}$	$\overline{SHDN}$ = SGND		0.1	2	µA
$\overline{SHDN}$ Input Logic High	V_{IH}		2			V
$\overline{SHDN}$ Input Logic Low	V_{IL}				0.8	V
$\overline{SHDN}$ Input Leakage Current			-1	+0.05	+1	µA
$\overline{SHDN}$ to Full Operation Time	t_{SON}			80		µs
AMPLIFIERS						
Voltage Gain	A_V	MAX9722B (Note 2)	-1.98	-2	-2.02	V/V
Gain Matching		MAX9722B, between the right and left channels		±2		%
Input Offset Voltage	V_{IS}	Between IN_+ and IN_-, AC-coupled (MAX9722A)		±0.5	±2.5	mV
		Between IN_+ and IN_-, AC-coupled (MAX9722B)		±1.5	±5	
Input Bias Current	I_{BIAS}	IN_+ and IN_-		50		nA
Input Impedance	R_{IN}	MAX9722B, measured at IN_	10	14.4	20	kΩ
Input Common-Mode Voltage Range	V_{CM}		-0.5		+0.7	V
Common-Mode Rejection Ratio	CMRR	Input referred, MAX9722A, T_A = +25°C	-60	-70		dB
Power-Supply Rejection Ratio (Note 3)	PSRR	DC, V_{DD} = 2.4V to 5.5V, input referred	-80	-90		dB
		f = 217Hz, 100mV_{P-P} ripple, input referred		-80		
		f = 10kHz, 100mV_{P-P} ripple, input referred		-50		
Output Power	P_{OUT}	R_L = 16Ω, THD+N = 1%, T_A = +25°C	60	70		mW
		R_L = 32Ω, THD+N = 1%, T_A = +25°C		130		
Output Voltage	V_{OUT}	R_L = 1kΩ		2		V_{RMS}
Output Impedance in Shutdown				10		kΩ

ELECTRICAL CHARACTERISTICS (continued)

(PV_{DD} = SV_{DD} = +5V, PGND = SGND = 0V, $\overline{SHDN}$ = SV_{DD}, C1 = C2 = 1µF, R_L = ∞, resistive load referenced to ground, for MAX9722A gain = -1V/V (R_{IN} = R_F = 10kΩ), for MAX9722B gain = -2V/V (internally set), T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C, unless otherwise noted.) (Note 1)

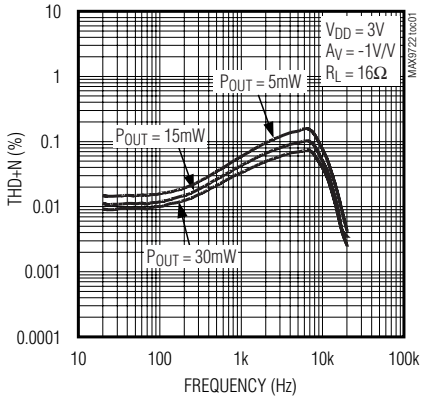
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Total Harmonic Distortion Plus Noise (Note 4)	THD+N	R_L = 16Ω, P_{OUT} = 55mW, f = 1kHz		0.03		%
		R_L = 32Ω, P_{OUT} = 125mW, f = 1kHz		0.009		
Signal-to-Noise Ratio	SNR	R_L = 32Ω, P_{OUT} = 20mW, f = 22Hz to 22kHz		100		dB
Noise	V_n	22Hz to 22kHz bandwidth, input AC grounded		6		$µV_{RMS}$
Slew Rate	SR			0.5		V/µs
Maximum Capacitive Load	C_L	No sustained oscillation		200		pF
Charge-Pump Oscillator Frequency	f_{OSC}		505	600	800	kHz
Crosstalk		R_L = 32Ω, V_{IN} = 200mV_{P-P}, f = 10kHz, A_V = 1		78		dB
ESD Protection		Human Body Model (OUTR and OUTL)		±8		kV
Thermal-Shutdown Threshold				145		°C
Thermal-Shutdown Hysteresis				5		°C

Note 1: All specifications are 100% tested at T_A = +25°C; temperature limits are guaranteed by design.
Note 2: Gain for the MAX9722A is adjustable.
Note 3: The amplifier inputs are AC-coupled to ground through $C_{IN\_}$.
Note 4: Measurement bandwidth is 22Hz to 22kHz.

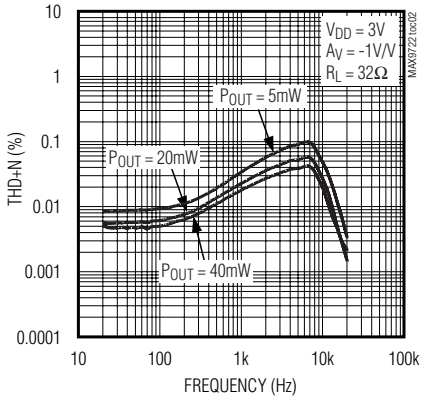
Typical Operating Characteristics

(MAX9722A, PV_{DD} = SV_{DD} = +5V, PGND = SGND = 0V, $\overline{SHDN}$ = SV_{DD}, C1 = C2 = 1µF, R_L = ∞, gain = -1V/V, single-ended input, THD+N measurement bandwidth = 22Hz to 22kHz, T_A = +25°C, unless otherwise noted.)

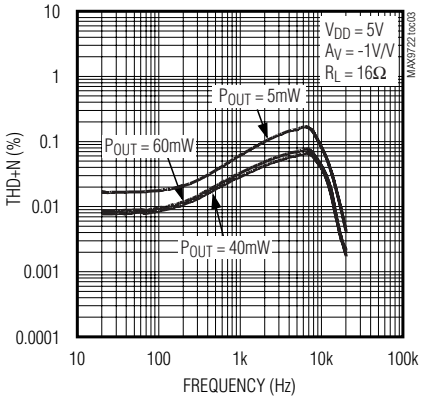
TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY



TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY



TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY

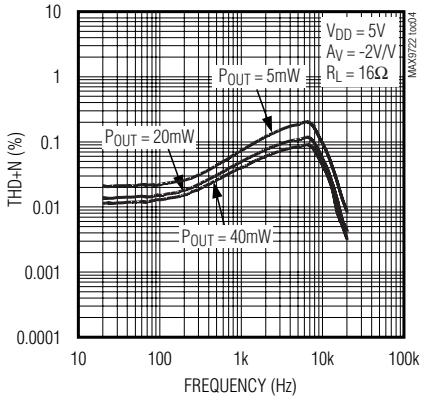


5V, Differential Input, DirectDrive, 130mW Stereo Headphone Amplifiers with Shutdown

Typical Operating Characteristics (continued)

(MAX9722A, PV_{DD} = SV_{DD} = +5V, PGND = SGND = 0V, $\overline{SHDN}$ = SV_{DD}, C1 = C2 = 1µF, R_L = ∞, gain = -1V/V, single-ended input, THD+N measurement bandwidth = 22Hz to 22kHz, T_A = +25°C, unless otherwise noted.)

TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY



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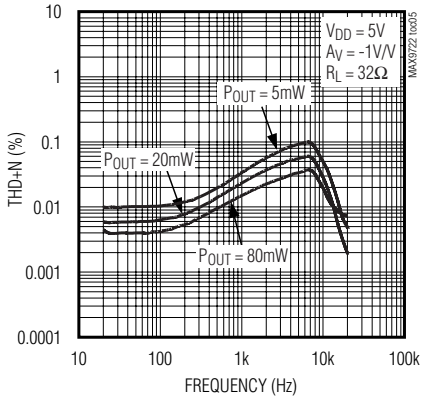

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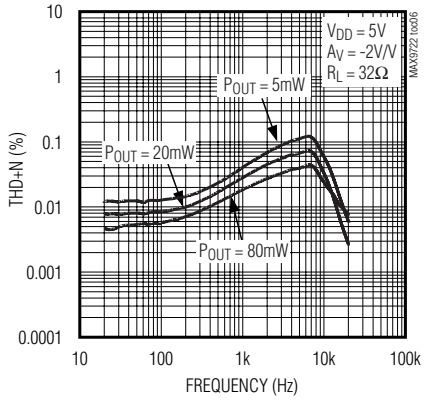
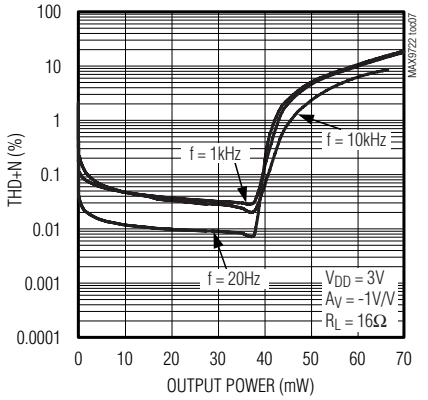


TOTAL HARMONIC DISTORTION PLUS NOISE vs. OUTPUT POWER



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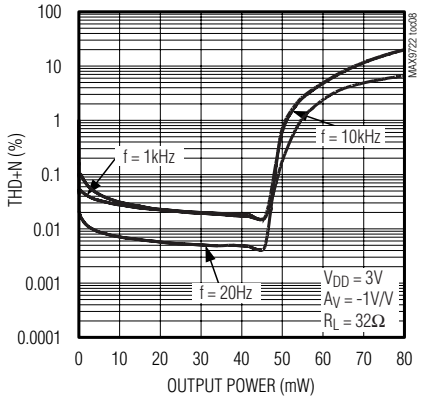

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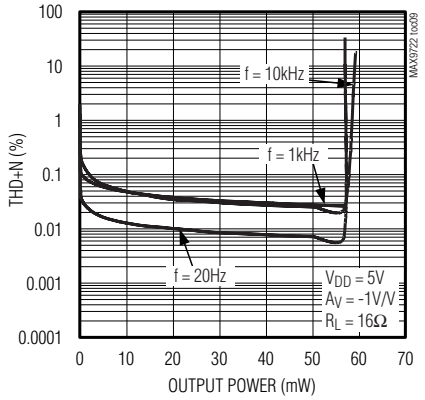

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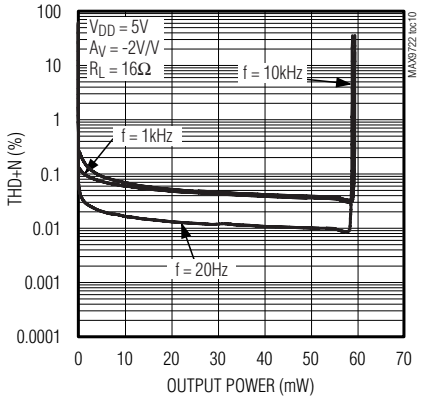

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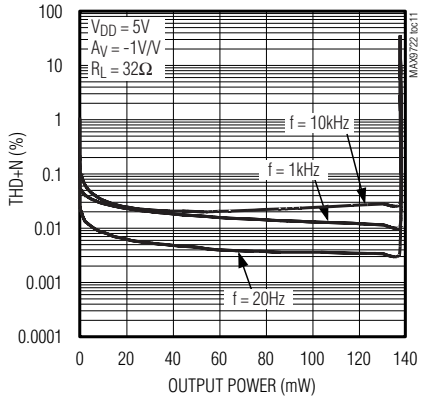

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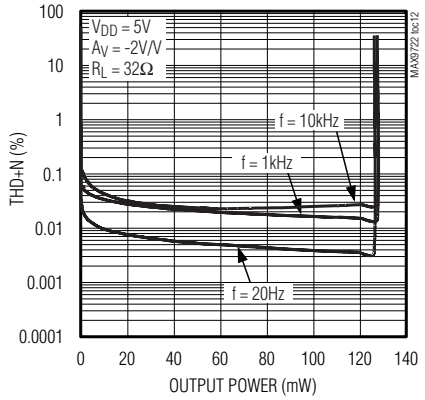
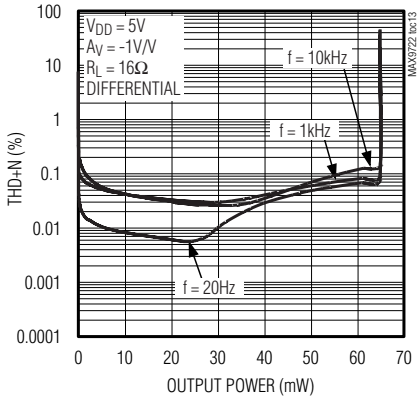


5V, Differential Input, DirectDrive, 130mW Stereo Headphone Amplifiers with Shutdown

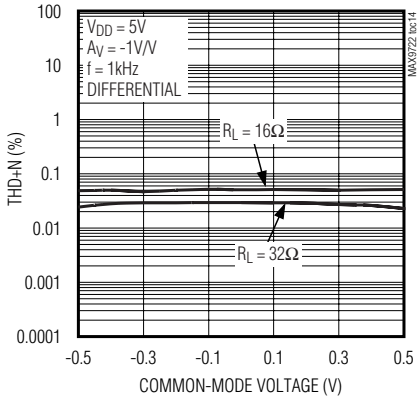
Typical Operating Characteristics (continued)

(MAX9722A, PV_{DD} = SV_{DD} = +5V, PGND = SGND = 0V, $\overline{SHDN}$ = SV_{DD}, C1 = C2 = 1µF, R_L = ∞, gain = -1V/V, single-ended input, THD+N measurement bandwidth = 22Hz to 22kHz, T_A = +25°C, unless otherwise noted.)

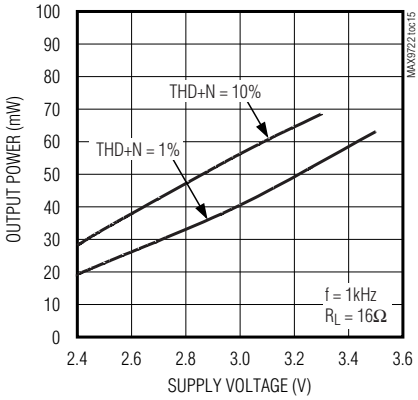
TOTAL HARMONIC DISTORTION PLUS NOISE vs. OUTPUT POWER



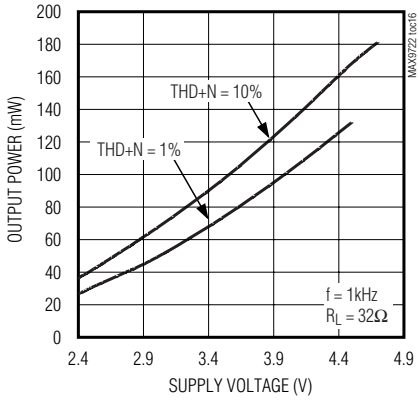
TOTAL HARMONIC DISTORTION PLUS NOISE vs. COMMON-MODE VOLTAGE



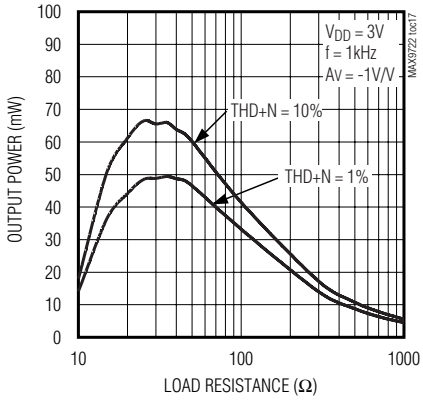
OUTPUT POWER vs. SUPPLY VOLTAGE



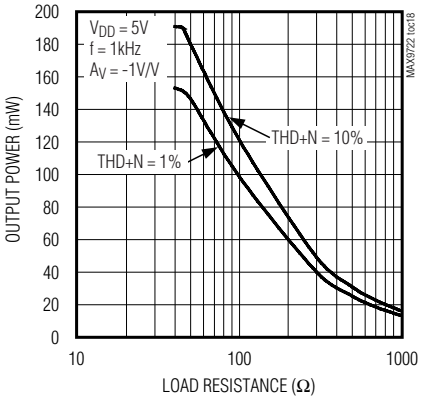
OUTPUT POWER vs. SUPPLY VOLTAGE



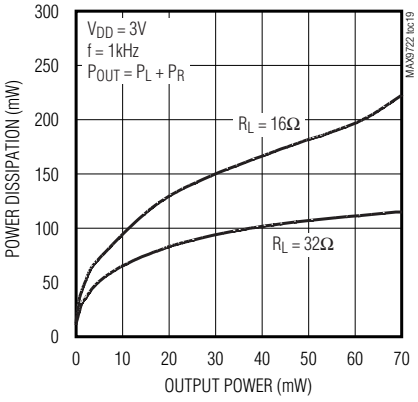
OUTPUT POWER vs. LOAD RESISTANCE



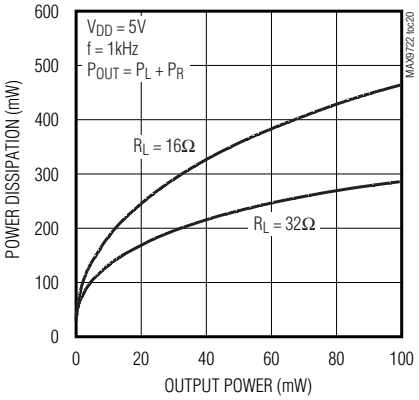
OUTPUT POWER vs. LOAD RESISTANCE



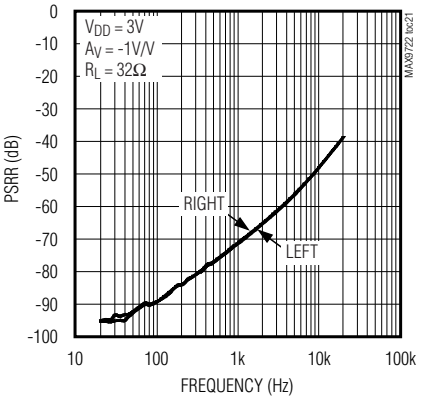
POWER DISSIPATION vs. OUTPUT POWER



POWER DISSIPATION vs. OUTPUT POWER



POWER-SUPPLY REJECTION RATIO vs. FREQUENCY

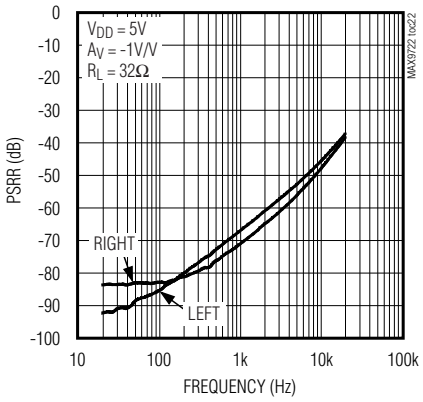


5V, Differential Input, DirectDrive, 130mW Stereo Headphone Amplifiers with Shutdown

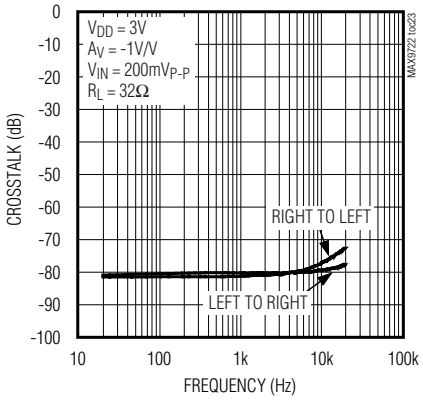
Typical Operating Characteristics (continued)

(MAX9722A, PV_{DD} = SV_{DD} = +5V, PGND = SGND = 0V, $\overline{SHDN}$ = SV_{DD}, C1 = C2 = 1µF, R_L = ∞, gain = -1V/V, single-ended input, THD+N measurement bandwidth = 22Hz to 22kHz, T_A = +25°C, unless otherwise noted.)

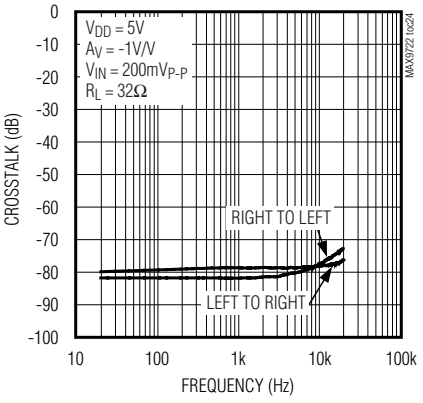
POWER-SUPPLY REJECTION RATIO vs. FREQUENCY



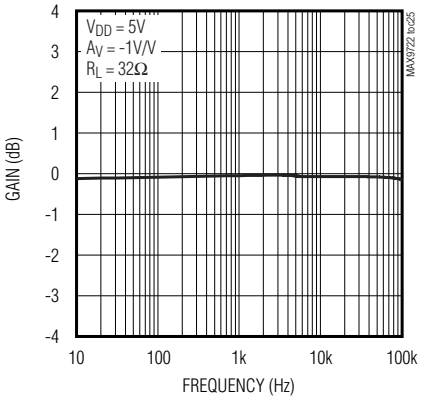
CROSSTALK vs. FREQUENCY



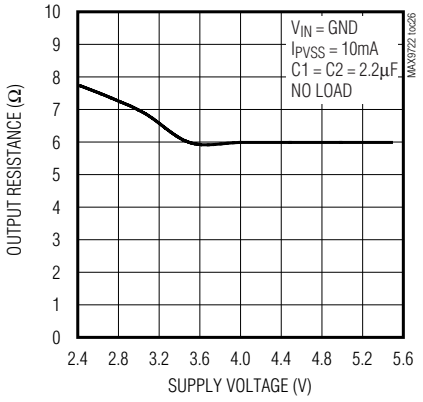
CROSSTALK vs. FREQUENCY



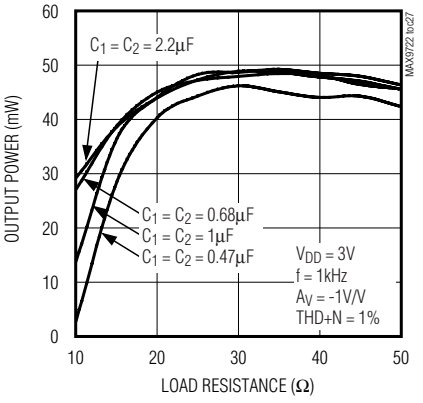
GAIN FLATNESS vs. FREQUENCY



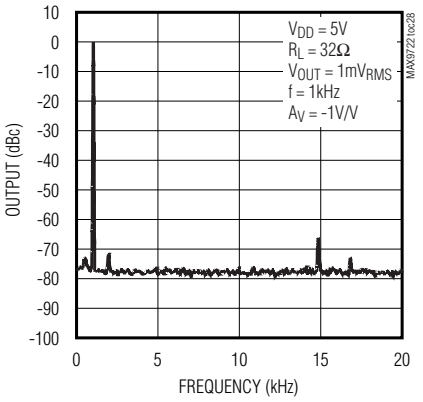
CHARGE-PUMP OUTPUT RESISTANCE vs. SUPPLY VOLTAGE



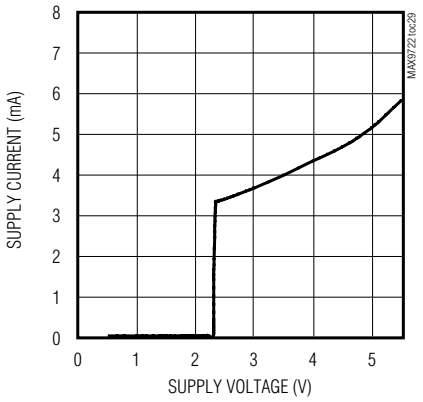
OUTPUT POWER vs. LOAD RESISTANCE



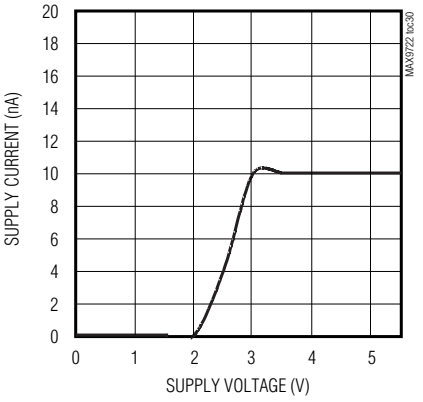
OUTPUT SPECTRUM vs. FREQUENCY



SUPPLY CURRENT vs. SUPPLY VOLTAGE



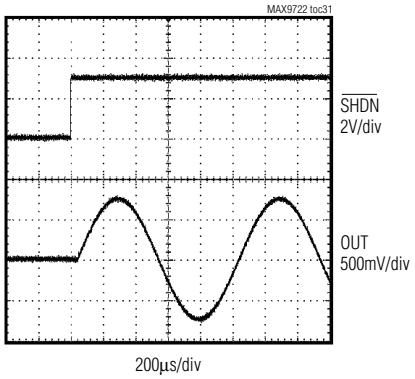
SHUTDOWN SUPPLY CURRENT vs. SUPPLY VOLTAGE



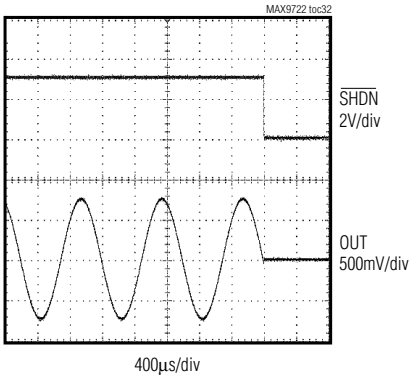
Typical Operating Characteristics (continued)

(MAX9722A, PV_{DD} = SV_{DD} = +5V, PGND = SGND = 0V, $\overline{SHDN}$ = SV_{DD}, C1 = C2 = 1µF, R_L = ∞, gain = -1V/V, single-ended input, THD+N measurement bandwidth = 22Hz to 22kHz, T_A = +25°C, unless otherwise noted.)

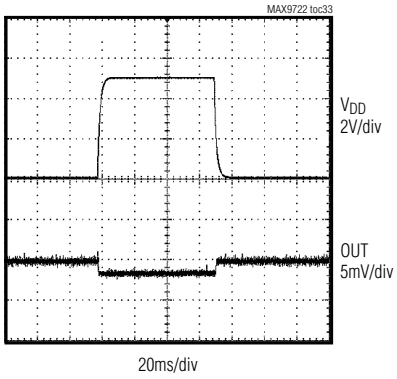
EXIT SHUTDOWN TRANSIENT



SHUTDOWN TRANSIENT



POWER-UP/DOWN TRANSIENT



Pin Description

PIN		NAME	FUNCTION
THIN QFN	TSSOP		
1	3	PV_{DD}	Charge-Pump Power Supply. Powers charge-pump inverter, charge-pump logic, and oscillator. Connect to positive supply (2.4V to 5.5V). Bypass with a 1µF capacitor to PGND as close to the pin as possible.
2	4	C1P	Flying Capacitor Positive Terminal
3	5	PGND	Power Ground. Connect to ground.
4	6	C1N	Flying Capacitor Negative Terminal
5	7	PV_{SS}	Charge-Pump Output. Connect to SV_{SS}.
6	8	SGND	Signal Ground. Connect to ground.
7	9	INR+	Noninverting Right-Channel Audio Input
8	10	INR-	Inverting Right-Channel Audio Input
9, 13	11, 15	SV_{DD}	Amplifier Positive Power Supply. Connect to positive supply (2.4V to 5.5V). Bypass with a 1µF capacitor to SGND as close to the pin as possible.
10	12	OUTR	Right-Channel Output
11	13	SV_{SS}	Amplifier Negative Power Supply. Connect to PV_{SS}.
12	14	OUTL	Left-Channel Output
14	16	INL-	Inverting Left-Channel Audio Input
15	1	INL+	Noninverting Left-Channel Audio Input
16	2	$\overline{SHDN}$	Active-Low Shutdown Input
—	—	EP	Exposed Paddle. Leave this connection unconnected or solder to a piece of electrically isolated copper. **Do not connect to any voltage potential.**

5V, Differential Input, DirectDrive, 130mW Stereo Headphone Amplifiers with Shutdown

Detailed Description

The MAX9722A/MAX9722B stereo headphone amplifiers feature Maxim's patented DirectDrive architecture, eliminating the large output-coupling capacitors required by conventional single-supply headphone amplifiers. The devices consist of two class AB headphone amplifiers, undervoltage lockout (UVLO)/shutdown control, charge pump, and comprehensive click-and-pop suppression circuitry (see *Typical Application Circuit*). The charge pump inverts the positive supply (PV_{DD}), creating a negative supply (PV_{SS}). The headphone amplifiers operate from these bipolar supplies with their outputs biased about GND (Figure 1). The benefit of this GND bias is that the amplifier outputs do not have a DC component, typically $V_{DD}/2$. The large DC-blocking capacitors required with conventional headphone amplifiers are unnecessary, thus conserving board space, reducing system cost, and improving frequency response. The device features an undervoltage lockout that prevents operation from an insufficient power supply and click-and-pop suppression that eliminates audible transients on startup and shutdown. Additionally, the MAX9722A/MAX9722B feature thermal-overload and short-circuit protection and can withstand ±8kV ESD strikes at the output pins.

Differential Input

The MAX9722 can be configured as a differential input amplifier (Figure 2), making it compatible with many CODECs. A differential input offers improved noise immunity over a single-ended input. In devices such as cellular phones, high-frequency signals from the RF transmitter can couple into the amplifier's input traces. The signals appear at the amplifier's inputs as common-mode noise. A differential input amplifier amplifies the difference of the two inputs, and signals common to both inputs are cancelled. Configured differentially, the gain of the MAX9722 is set by:

$$A_V = R_{F1}/R_{IN1}$$

R_{IN1} must be equal to R_{IN2}, and R_{F1} must be equal to R_{F2}.

The common-mode rejection ratio (CMRR) is limited by the external resistor matching. For example, the worst-case variation of 1% tolerant resistors results in 40dB CMRR, while 0.1% resistors result in 60dB CMRR. For best matching, use resistor arrays.

The R_{IN1} and R_{F1} of the MAX9722B are internal, set R_{IN2} = 15kΩ and R_{F2} = 30kΩ. However, for best results, use the MAX9722A.

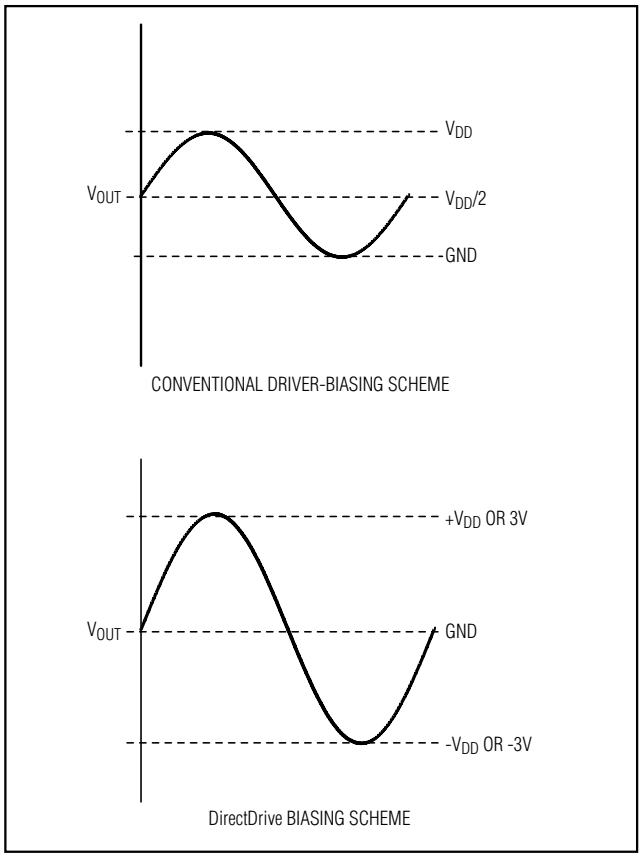


Figure 1. Conventional Driver Output Waveform vs. MAX9722A/MAX9722B Output Waveform

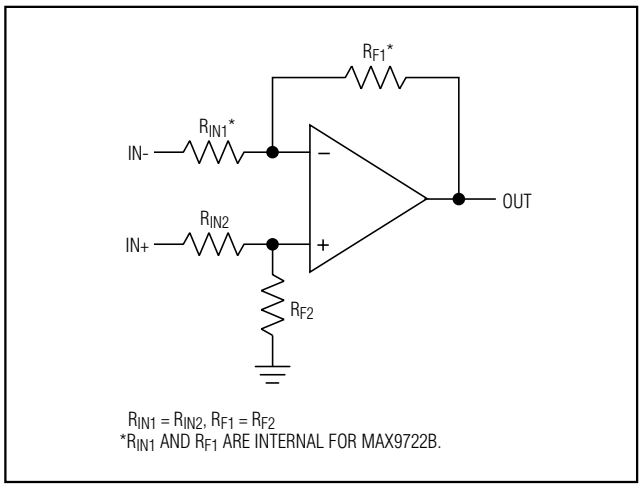


Figure 2. Differential Input Configuration

5V, Differential Input, DirectDrive, 130mW Stereo Headphone Amplifiers with Shutdown

DirectDrive

Conventional single-supply headphone amplifiers have their outputs biased about a nominal DC voltage (typically half the supply) for maximum dynamic range. Large coupling capacitors are needed to block this DC bias from the headphone. Without these capacitors, a significant amount of DC current flows to the headphone, resulting in unnecessary power dissipation and possible damage to both the headphone and the headphone amplifier.

Maxim's patented DirectDrive architecture uses a charge pump to create an internal negative supply voltage, allowing the MAX9722A/MAX9722B outputs to be biased about GND. With no DC component, there is no need for the large DC-blocking capacitors. Instead of two large (220µF, typ) tantalum capacitors, the MAX9722A/MAX9722B charge pump requires two small ceramic capacitors, conserving board space, reducing cost, and improving the frequency response of the headphone amplifier. See the Output Power vs. Charge-Pump Capacitance and Load Resistance graph in the *Typical Operating Characteristics* for details of the possible capacitor sizes. There is a low DC voltage on the amplifier outputs due to amplifier offset. However, the offset of the MAX9722A is typically 0.5mV, which, when combined with a 32Ω load, results in less than 15.6µA of DC current flow to the headphones. Previous attempts to eliminate the output-coupling capacitors involved biasing the headphone return (sleeve) to the DC-bias voltage of the headphone amplifiers. This method raises some issues:

- The sleeve is typically grounded to the chassis. Using this biasing approach, the sleeve must be isolated from system ground, complicating product design.
- During an ESD strike, the amplifier's ESD structures are the only path to system ground. Thus, the amplifier must be able to withstand the full ESD strike.
- When using the headphone jack as a line out to other equipment, the bias voltage on the sleeve may conflict with the ground potential from other equipment, resulting in possible damage to the amplifiers.
- When using a combination microphone and speaker headset, the microphone typically requires a GND reference. The amplifier DC bias on the sleeve conflicts with the microphone requirements (Figure 3).

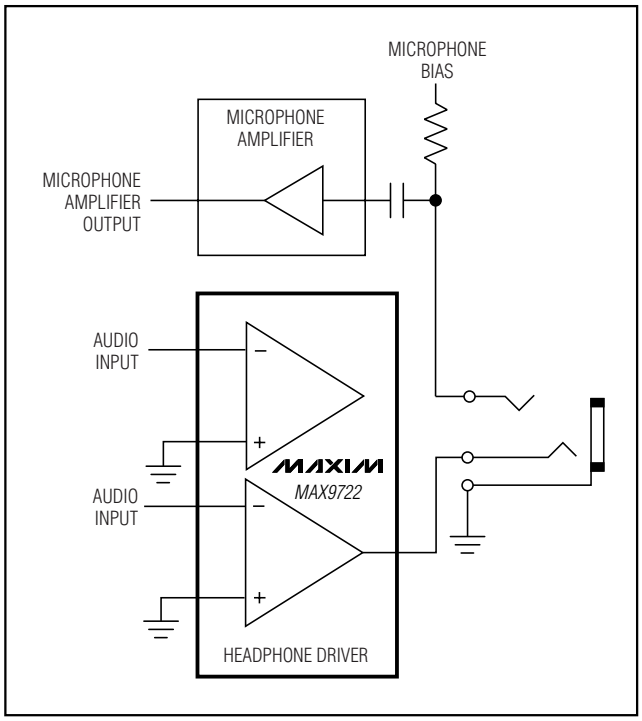


Figure 3. Earbud Speaker/Microphone Combination Headset Configuration

Low-Frequency Response

In addition to the cost and size disadvantages of the DC-blocking capacitors required by conventional headphone amplifiers, these capacitors limit the amplifier's low-frequency response and can distort the audio signal:

1) The impedance of the headphone load and the DC-blocking capacitor form a highpass filter with the -3dB point set by:

$$f_{-3dB} = \frac{1}{2\pi R_L C_{OUT}}$$

where R_L is the impedance of the headphone and C_{OUT} is the value of the DC-blocking capacitor.

The highpass filter is required by conventional single-ended, single power-supply headphone amplifiers to block the midrail DC-bias component of the audio signal from the headphones. The drawback to the filter is that it can attenuate low-frequency signals. Larger values of C_{OUT} reduce this effect but result in physically larger, more expensive capacitors. Figure 4 shows the relationship between the size of C_{OUT} and the resulting low-frequency attenuation. Note that the -3dB point for a 16Ω headphone with a 100µF blocking capacitor is 100Hz, well within the normal audio band, resulting in low-frequency attenuation of the reproduced signal.

5V, Differential Input, DirectDrive, 130mW Stereo Headphone Amplifiers with Shutdown

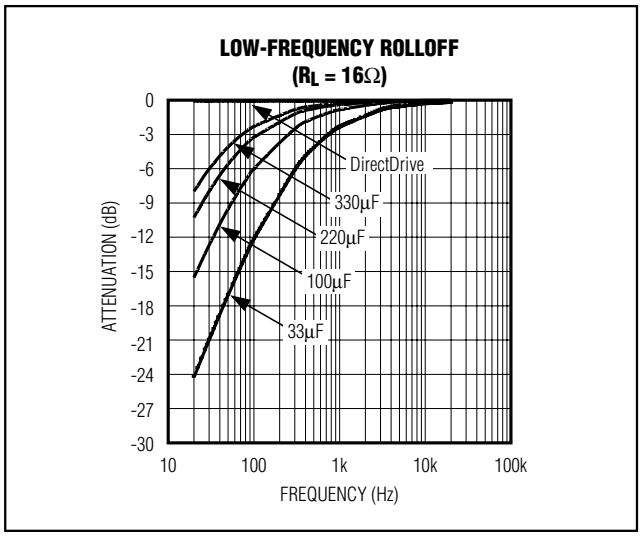


Figure 4. Low-Frequency Attenuation for Common DC-Blocking Capacitor Values

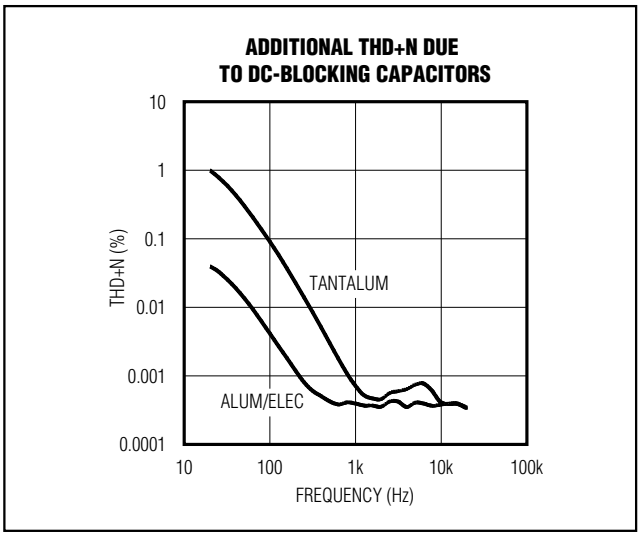


Figure 5. Distortion Contributed by DC-Blocking Capacitors

2) The voltage coefficient of the DC-blocking capacitor contributes distortion to the reproduced audio signal as the capacitance value varies and the function of the voltage across the capacitor changes. The reactance of the capacitor dominates at frequencies below the -3dB point and the voltage coefficient appears as frequency-dependent distortion. Figure 5 shows the THD+N introduced by two different capacitor dielectric types. Note that below 100Hz, THD+N increases rapidly. The combination of low-frequency attenuation and frequency-dependent distortion compromises audio reproduction in portable audio equipment that emphasizes low-frequency effects such as in multimedia laptops, MP3, CD, and DVD players. By eliminating the DC-blocking capacitors through DirectDrive technology, these capacitor-related deficiencies are eliminated.

Charge Pump

The MAX9722A/MAX9722B feature a low-noise charge pump. The 600kHz switching frequency is well beyond the audio range and, thus, does not interfere with the audio signals. Also, the 600kHz switching frequency does not interfere with the 450kHz AM transceivers. The switch drivers feature a controlled switching speed that minimizes noise generated by turn-on and turn-off transients. By limiting the switching speed of the charge pump, the di/dt noise caused by the parasitic bond wire and trace inductance is minimized. Although not typically required, additional high-frequency noise attenuation can be achieved by increasing the value of C2 (see *Typical Application Circuit*).

Click-and-Pop Suppression

In conventional single-supply audio amplifiers, the output-coupling capacitor is a major contributor of audible clicks and pops. Upon startup, the amplifier charges the coupling capacitor to its bias voltage, typically half the supply. Likewise, on shutdown, the capacitor is discharged to GND. This results in a DC shift across the capacitor, which, in turn, appears as an audible transient at the speaker. Since the MAX9722A/MAX9722B do not require output-coupling capacitors, this problem does not arise.

Additionally, the MAX9722A/MAX9722B feature extensive click-and-pop suppression that eliminates any audible transient sources internal to the device. The Power-Up/Down Waveform in the *Typical Operating Characteristic*s shows that there is minimal DC shift and no spurious transients at the output upon startup or shutdown.

In most applications, the output of the preamplifier driving the MAX9722A/MAX9722B has a DC bias of typically half the supply. At startup, the input-coupling capacitor is charged to the preamplifier's DC-bias voltage through the feedback resistor of the MAX9722A/MAX9722B, resulting in a DC shift across the capacitor and an audible click/pop. Delaying the rise of $\overline{SHDN}$ 4 to 5 time constants (80ms to 100ms) based on R_{IN} and C_{IN}, relative to the startup of the preamplifier, eliminates this click/pop caused by the input filter.

5V, Differential Input, DirectDrive, 130mW Stereo Headphone Amplifiers with Shutdown

Shutdown

The MAX9722A/MAX9722B feature shutdown control allowing audio signals to be shut down or muted. Driving $\overline{SHDN}$ low disables the amplifiers and the charge pump, sets the amplifier output impedance to 10kΩ, and reduces the supply current. In shutdown mode, the supply current is reduced to 0.1µA. The charge pump is enabled once $\overline{SHDN}$ is driven high.

Applications Information

Power Dissipation

Under normal operating conditions, linear power amplifiers can dissipate a significant amount of power. The maximum power dissipation for each package is given in the *Absolute Maximum Ratings* section under Continuous Power Dissipation or can be calculated by the following equation:

$$P_{DISSPKG(MAX)} = \frac{T_{J(MAX)} - T_A}{\theta_{JA}}$$

where $T_{J(MAX)}$ is +145°C, T_A is the ambient temperature, and θ_{JA} is the reciprocal of the derating factor in °C/W as specified in the *Absolute Maximum Ratings* section. For example, θ_{JA} of the thin QFN package is +63.8°C/W, and 99.3°C/W for the TSSOP package.

The MAX9722A/MAX9722B have two power dissipation sources: the charge pump and two amplifiers. If power dissipation for a given application exceeds the maximum allowed for a particular package, either reduce SV_{DD}, increase load impedance, decrease the ambient temperature, or add heatsinking to the device. Large output, supply, and ground traces improve the maximum power dissipation in the package.

Thermal-overload protection limits total power dissipation in the MAX9722A/MAX9722B. When the junction temperature exceeds +145°C, the thermal-protection circuitry disables the amplifier output stage. The amplifiers are enabled once the junction temperature cools by 5°C. This results in a pulsing output under continuous thermal-overload conditions.

Output Power

The device has been specified for the worst-case scenario—when both inputs are in-phase. Under this condition, the amplifiers simultaneously draw current from the charge pump, leading to a slight loss in SV_{SS} headroom. In typical stereo audio applications, the left and right signals have differences in both magnitude and phase, subsequently leading to an increase in the maximum attainable output power. Figure 6 shows the two extreme cases for in- and out-of-phase. In reality, the available power lies between these extremes.

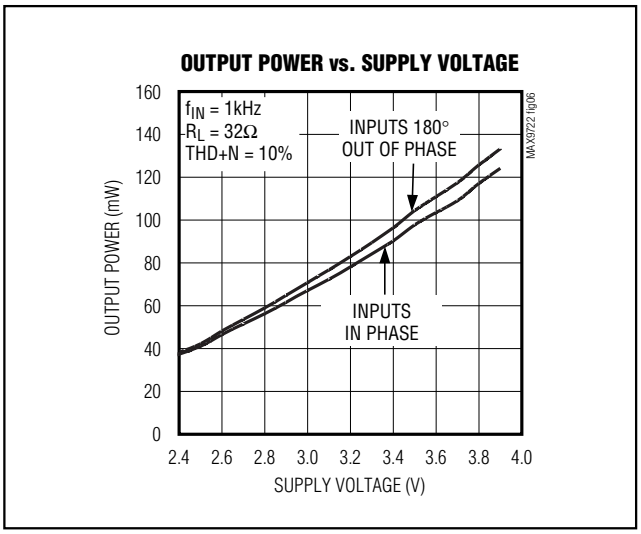


Figure 6. Distortion Contributed by DC-Blocking Capacitors

Powering Other Circuits from a Negative Supply

An additional benefit of the MAX9722A/MAX9722B is the internally generated, negative supply voltage (PV_{SS}). This voltage provides the ground-referenced output level. PV_{SS} can, however, be used to power other devices within a design limit current drawn from PV_{SS} to 5mA; exceeding this affects the headphone amplifier operation. A typical application is a negative supply to adjust the contrast of LCD modules.

PV_{SS} is roughly proportional to PV_{DD} and is not a regulated voltage. The charge-pump output impedance must be taken into account when powering other devices from PV_{SS}. The charge-pump output impedance plot appears in the *Typical Operating Characteristics*. For best results, use 1µF charge-pump capacitors.

UVLO

The MAX9722A/MAX9722B feature an UVLO function that prevents the device from operating if the supply voltage is less than 2.2V (typ). This feature ensures proper operation during brownout conditions and prevents deep battery discharge. Once the supply voltage reaches the UVLO threshold, the MAX9722A/MAX9722B charge pump is turned on and the amplifiers are powered.

5V, Differential Input, DirectDrive, 130mW Stereo Headphone Amplifiers with Shutdown

Component Selection

Input Filtering

The input capacitor (C_{IN}), in conjunction with the input resistor (R_{IN}), forms a highpass filter that removes the DC bias from an incoming signal (see the *Typical Application Circuit*). The AC-coupling capacitor allows the device to bias the signal to an optimum DC level. Assuming zero source impedance, the -3dB point of the highpass filter is given by:

$$f_{-3dB} = \frac{1}{2\pi R_{IN} C_{IN}}$$

Choose C_{IN} so f_{-3dB} is well below the lowest frequency of interest. For the MAX9722B, use the value of R_{IN} as given in the *DC Electrical Characteristics* table. Setting f_{-3dB} too high affects the device's low-frequency response. Use capacitors whose dielectrics have low-voltage coefficients, such as tantalum or aluminum electrolytic. Capacitors with high-voltage coefficients, such as ceramics, can result in increased distortion at low frequencies.

Charge-Pump Capacitor Selection

Use capacitors with an ESR less than 100mΩ for optimum performance. Low-ESR ceramic capacitors minimize the output resistance of the charge pump. For best performance over the extended temperature range, select capacitors with an X7R dielectric. Table 1 lists suggested manufacturers.

Flying Capacitor (C1)

The value of the flying capacitor (C1) affects the charge pump's load regulation and output resistance. A C1 value that is too small degrades the device's ability to provide sufficient current drive, which leads to a loss of output voltage. Increasing the value of C1 improves load regulation and reduces the charge-pump output resistance to an extent. See the Output Power vs. Charge-Pump Capacitance and Load Resistance graph in the *Typical Operating Characteristics*. Above 1µF, the on-resistance of the switches and the ESR of C1 and C2 dominate.

Hold Capacitor (C2)

The hold capacitor value and ESR directly affect the ripple at PV_{SS}. Increasing the value of C2 reduces output ripple. Likewise, decreasing the ESR of C2 reduces both ripple and output resistance. Lower capacitance values can be used in systems with low maximum output power levels. See the Output Power vs. Charge-Pump Capacitance and Load Resistance graph in the *Typical Operating Characteristics*.

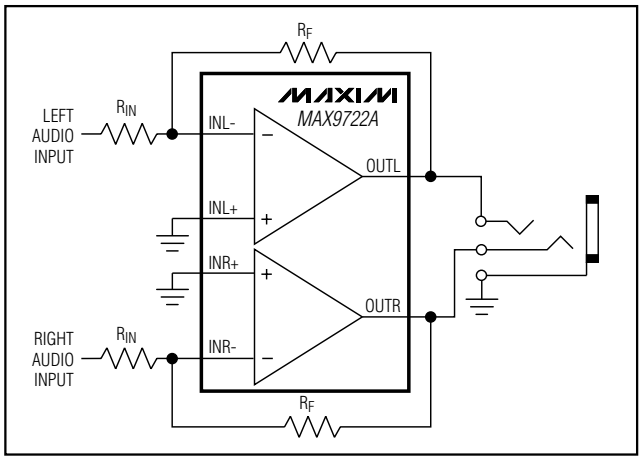


Figure 7. Gain Setting for the MAX9722A

Power-Supply Bypass Capacitor

The power-supply bypass capacitor (C3) lowers the output impedance of the power supply and reduces the impact of the MAX9722A/MAX9722Bs' charge-pump switching transients. Bypass PV_{DD} with C3, the same value as C1, and place it physically close to the PV_{DD} and PGND pins.

Amplifier Gain

The gain of the MAX9722B is internally set at -2V/V. All gain-setting resistors are integrated into the device, reducing external component count. The internally set gain, in combination with DirectDrive, results in a headphone amplifier that requires only five tiny 1µF capacitors to complete the amplifier circuit: two for the charge pump, two for audio input coupling, and one for power-supply bypassing (see the *Typical Application Circuit*).

The gain of the MAX9722A amplifier is set externally as shown in Figure 7, the gain is:

$$A_V = -R_F/R_{IN}$$

Choose feedback resistor values of 10kΩ. Values other than 10kΩ increase output offset voltage due to the input bias current, which, in turn, increases the amount of DC current flow to the load.

Table 1. Suggested Capacitor Manufacturers

SUPPLIER	PHONE	FAX	WEBSITE
Murata	770-436-1300	770-436-3030	www.murata.com
Taiyo Yuden	800-348-2496	847-925-0899	www.t-yuden.com
TDK	847-803-6100	847-390-4405	www.component.tdk.com

5V, Differential Input, DirectDrive, 130mW Stereo Headphone Amplifiers with Shutdown

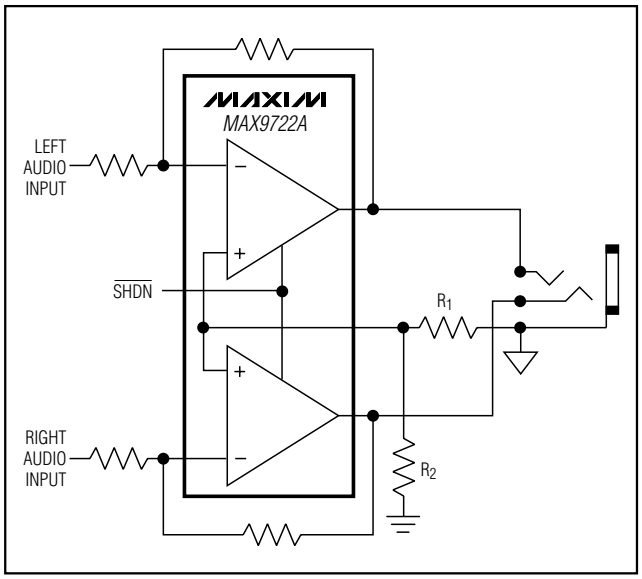


Figure 8. Common-Mode Sense Input Eliminates Ground-Loop Noise

Common-Mode Sense

When the headphone jack is used as a line out to interface between other equipment (notebooks, desktops, and stereo receivers), potential differences between the equipment grounds can create ground loops and excessive ground-current flow. The MAX9722A's INR+ and INL+ inputs are connected together to form a common-mode input that senses and corrects for the difference between the headphone return and device ground (see Figure 8). Connect INR+ and INL+ through a resistive voltage-divider between the headphone jack return and SGND of the device. For optimum common-mode rejection, use the same value resistors for R_1 and R_{IN}, and R_2 and R_F. For the MAX9722B, R_{IN} = 15kΩ and R_F = 30kΩ. Improve DC CMRR by adding a capacitor between SGND and R_2 (see the *Typical Application Circuit*). If ground sensing is not required, connect INR+ and INL+ directly to SGND.

Common-Mode Noise Rejection

Figure 9 shows a theoretical connection between two devices, for example, a notebook computer (transmitter, on the left) and an amplifier (receiver, on the right),

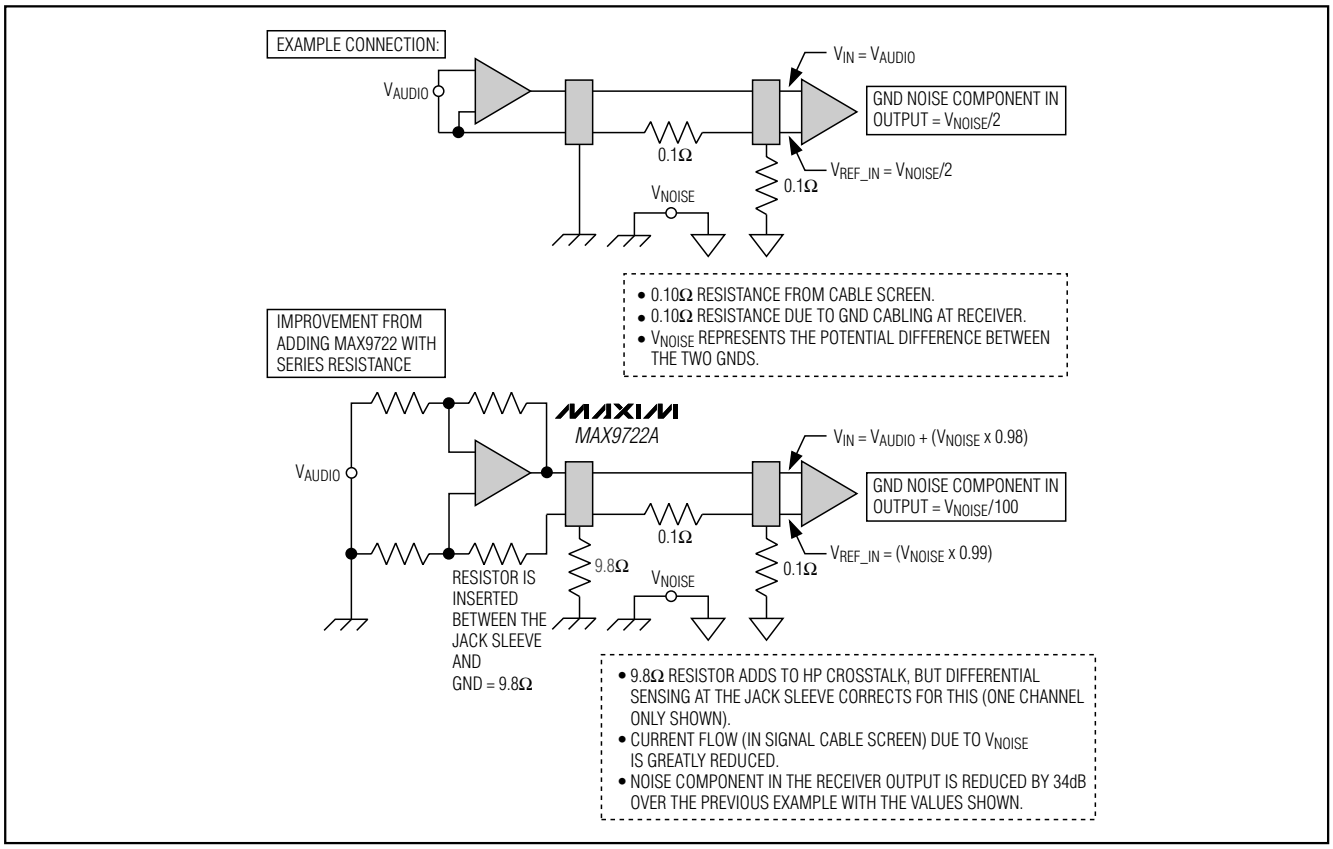


Figure 9. Common-Mode Noise Rejection

5V, Differential Input, DirectDrive, 130mW Stereo Headphone Amplifiers with Shutdown

such as the headphone socket used as a line output to a home hi-fi system. In the upper diagram, any difference between the two GND references (represented by V_{NOISE}) causes current to flow through the screen of cable between the two devices. This can cause noise pickup at the receiver due to the potential divider action of the audio screen cable impedance and the GND wiring of the amplifier.

Introducing impedance between the jack socket and GND of the notebook helps (as shown in the lower diagram). This has the following effect:

Current flow (from GND potential differences) in the cable screen is reduced, which is a safety issue.

It allows the MAX9722A/MAX9722B differential sensing to reduce the GND noise seen by the receiver (amplifier).

The other side effect is that the differential headphone jack sensing corrects the headphone crosstalk (from introducing the resistance on the jack GND return). Only one channel is depicted in Figure 9.

Figure 9 has some example numbers for resistance, but the audio designer has control over only one series resistance applied to the headphone jack return. Note that this resistance can be bypassed for ESD purposes at frequencies much higher than audio if required. The upper limit for this added resistance is the amount of output swing the headphone amplifier tolerates when driving low-impedance loads. Any headphone return current appears as a voltage across this resistor.

Piezoelectric Speaker Amplifier

Low-profile piezoelectric speakers can provide quality sound for portable electronics. However, piezoelectric speakers typically require large voltage swings (>8V_{P-P}) across the speaker element to produce usable sound pressure levels. Power sources in portable devices are usually low voltage in nature. Operating from batteries, conventional amplifiers cannot provide sufficient voltage swing to drive a piezoelectric speaker. However, the MAX9722's DirectDrive architecture can be configured to drive a piezoelectric speaker with up to 12V_{P-P} while operating from a single 5V supply.

The stereo MAX9722 features an inverting charge pump that takes the positive 5V supply and creates a negative -5V supply. Each output of the MAX9722 can swing 6V_{P-P}. This may be sufficient to drive a piezoelectric speaker. If a higher output voltage is desired, configuring the MAX9722A as a bridge-tied load (BTL) amplifier (Figure 10) doubles the maximum output swing as seen by the load to 12V_{P-P}. In a BTL configuration, the right channel of the MAX9722 serves as the master amplifier, setting the gain of the device, driving one side of the speaker, and providing signal to the left channel. The left channel is configured as a unity-gain follower, inverting the output of the right channel and driving the other leg of the speaker. Use precision resistors to set the gain of the left channel to ensure low distortion and good matching.

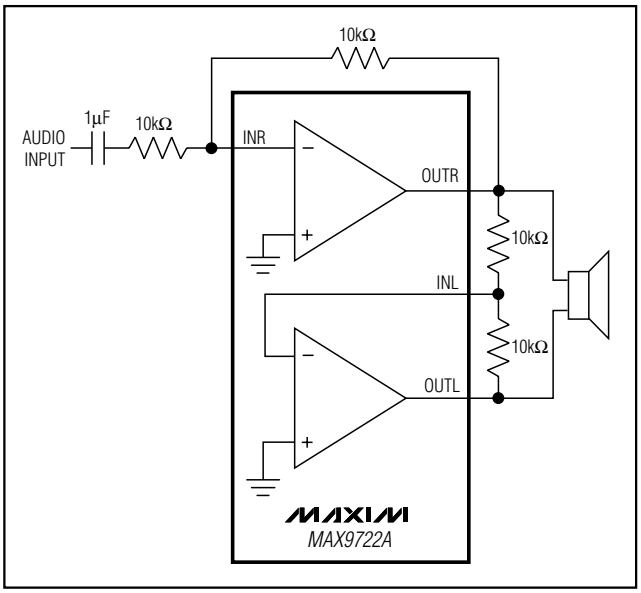


Figure 10. MAX9722 BTL Configuration

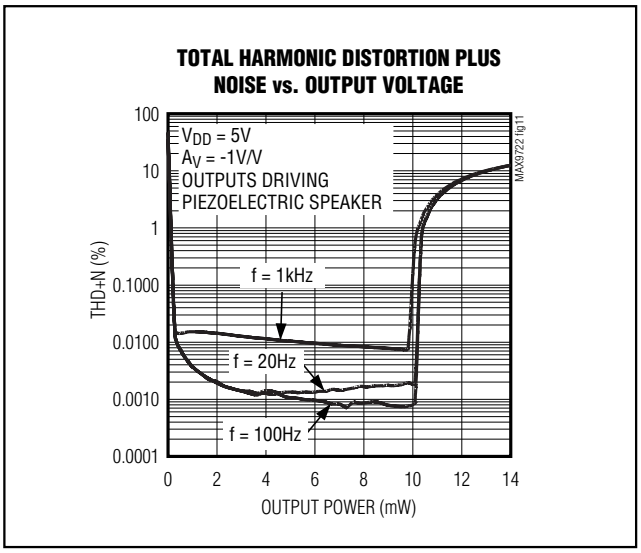


Figure 11. MAX9722 THD+N vs. Output Voltage

The MAX9722 was tested with a Panasonic WM-R57A piezoelectric speaker, and the resulting THD+N curves are shown (Figures 11 and 12). Note in both graphs, as frequency increases, the THD+N increases. This is due

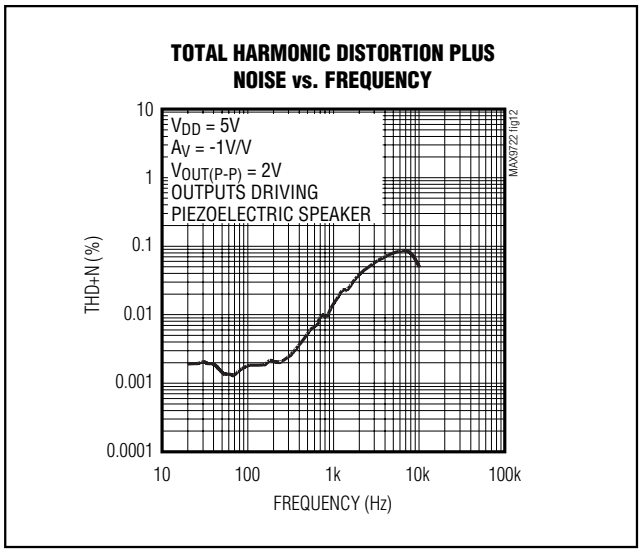


Figure 12. MAX9722 THD+N vs. Frequency

to the capacitive nature of the piezoelectric speaker, as frequency increases, the speaker impedance decreases, resulting in a larger current draw from the amplifier.

Furthermore, the capacitive nature of the speaker can cause the MAX9722 to become unstable. In these tests, the MAX9722 exhibited instabilities when driving the WM-R57A. A simple inductor/resistor network in series with the speaker isolates the speaker's capacitance from the amplifier, and ensures the device output sees a resistive load of about 10Ω at high frequency maintaining stability. Although the MAX9722 was not stable with the WM-R57A, a different speaker with different characteristics may result in stable operation, and elimination of the isolation components.

Layout and Grounding

Proper layout and grounding are essential for optimum performance. Connect PGND and SGND together at a single point on the PC board. Connect all components associated with the charge pump (C2 and C3) to the PGND plane. Connect PV_{DD} and SV_{DD} together at the device. Connect PV_{SS} and SV_{SS} together at the device. Bypassing of both supplies is accomplished by charge-pump capacitors C2 and C3 (see the *Typical Application Circuit*). Place capacitors C2 and C3 as close to the device as possible. Route PGND and all traces that carry switching transients away from SGND and the traces and components in the audio signal path. Refer to the MAX9722 evaluation kit for layout guidelines.

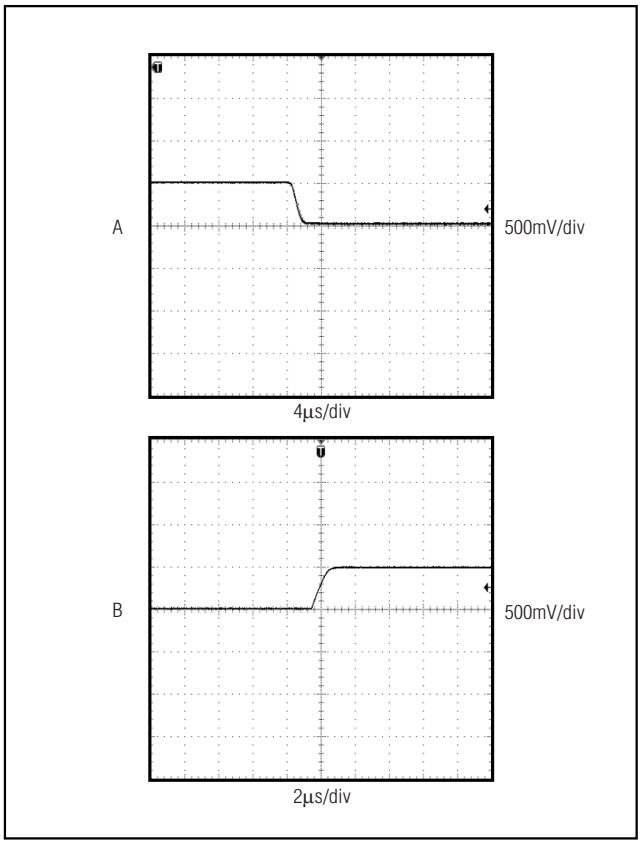


Figure 13. MAX9722 Capacitive-Load Stability Waveform: (a) Falling Edge, (b) Rising Edge

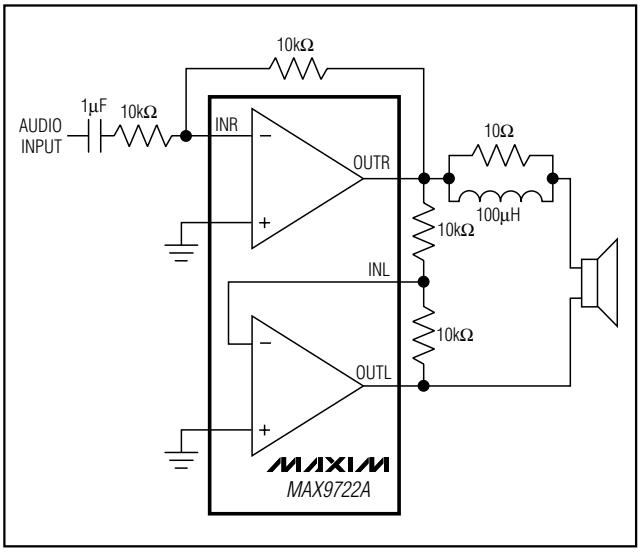


Figure 14. Isolation Network Improves Stability

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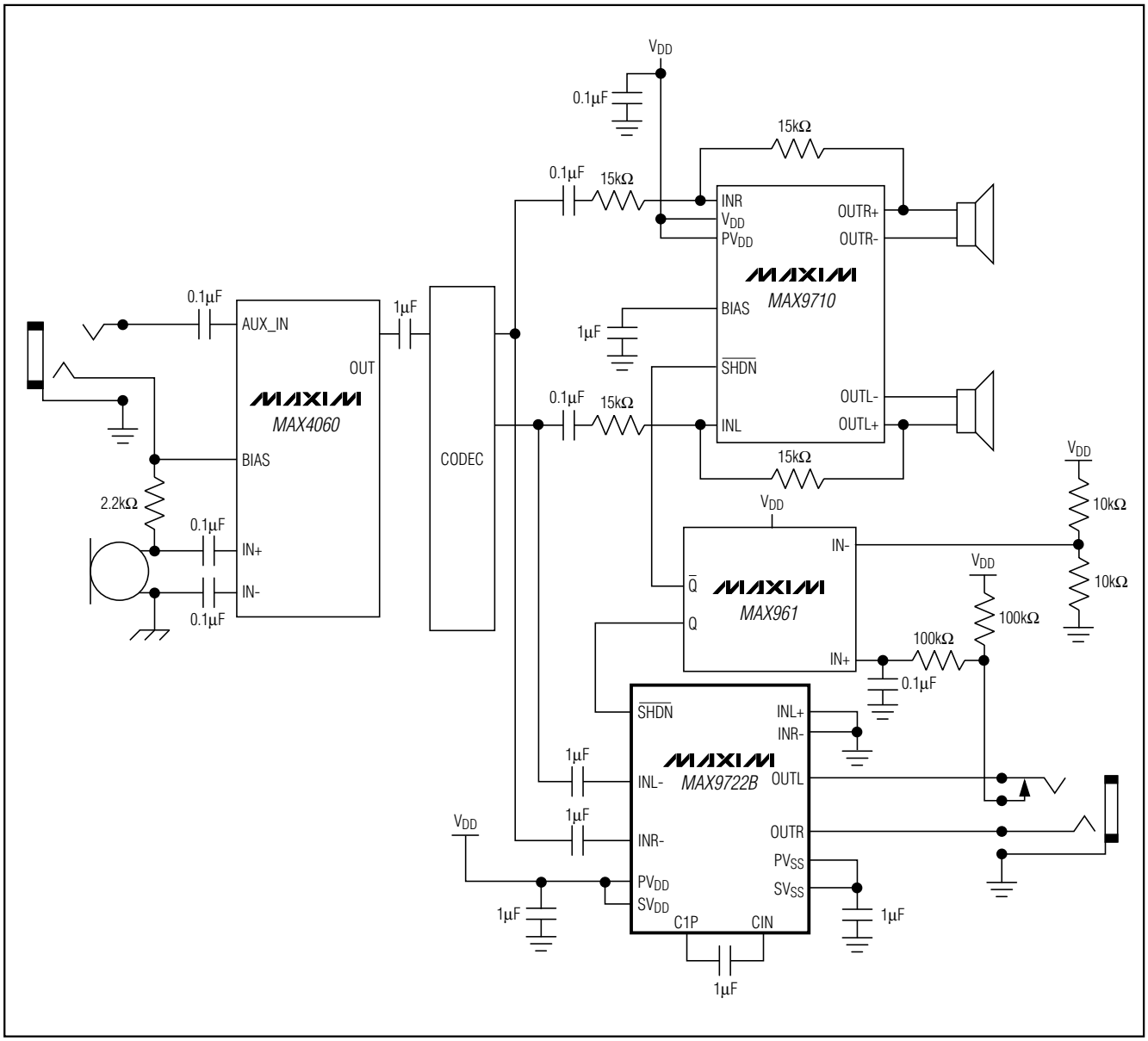
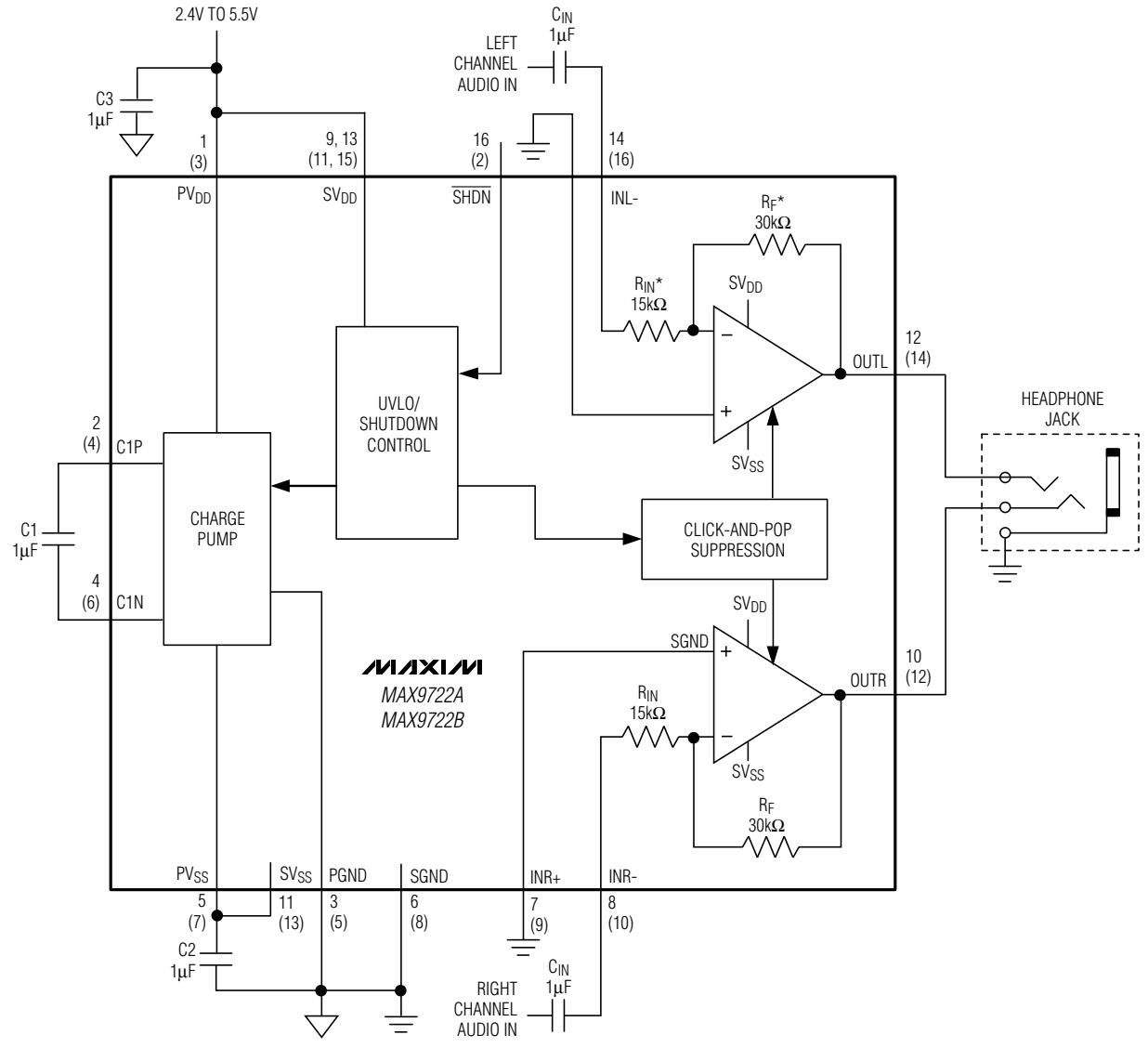
System Diagram



The thin QFN package features an exposed paddle that improves thermal efficiency of the package. The MAX9722A/MAX9722B do not require additional heatsinking. Ensure the exposed paddle is isolated from GND or SV_{DD}. Do not connect the exposed paddle to GND or SV_{DD}.

5V, Differential Input, DirectDrive, 130mW Stereo Headphone Amplifiers with Shutdown

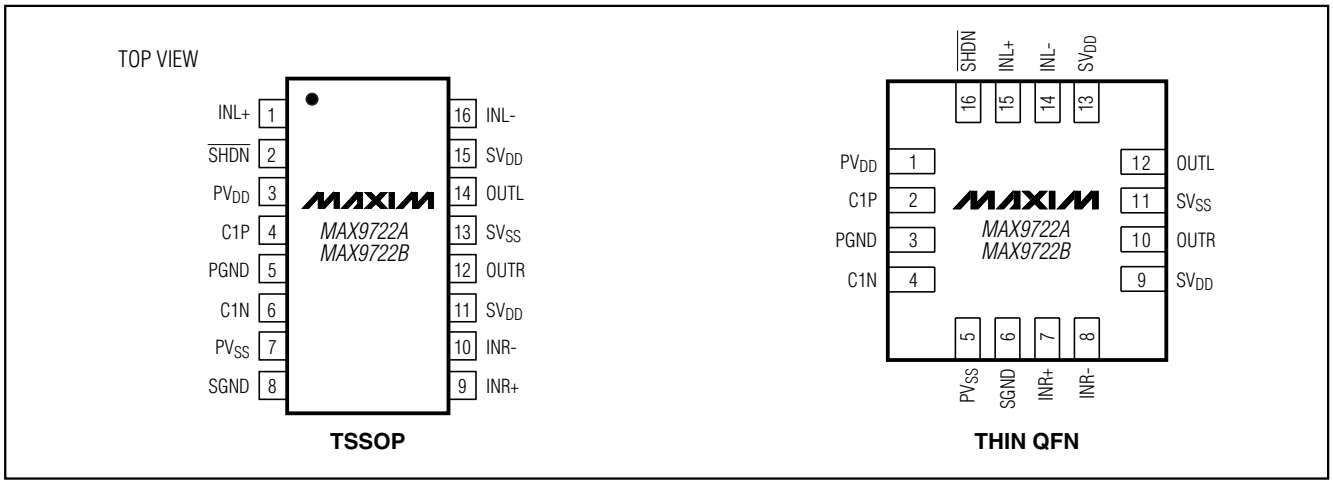
Typical Application Circuit



*FOR MAX9722A, R_{IN} AND R_F ARE EXTERNAL TO THE DEVICE.
( ) FOR TSSOP PACKAGE.

5V, Differential Input, DirectDrive, 130mW Stereo Headphone Amplifiers with Shutdown

Pin Configurations



Chip Information

TRANSISTOR COUNT: 1100

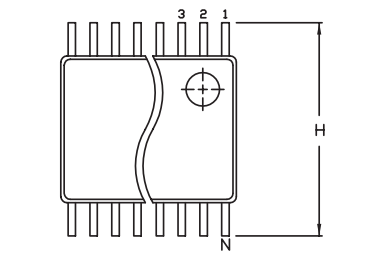
PROCESS: BiCMOS

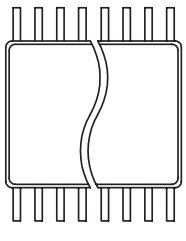
5V, Differential Input, DirectDrive, 130mW Stereo Headphone Amplifiers with Shutdown

Package Information

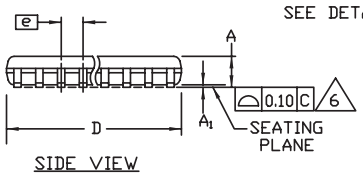
(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)

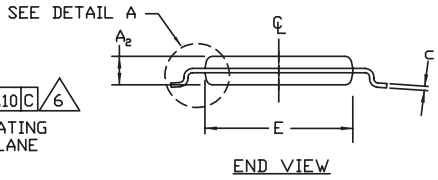
TSSOP4.40mm.EPS



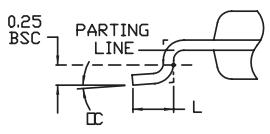


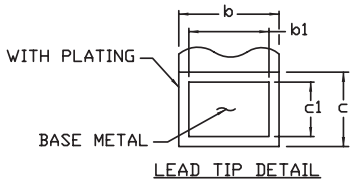
SYMBOL	COMMON DIMENSIONS			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	——	1.10		.043
A_1	0.05	0.15	.002	.006
A_2	0.85	0.95	.033	.037
b	0.19	0.30	.007	.012
b_1	0.19	0.25	.007	.010
c	0.09	0.20	.004	.008
c_1	0.09	0.14	.004	.006
D	SEE VARIATIONS		SEE VARIATIONS	
E	4.30	4.50	.169	.177
e	0.65 BSC		.026 BSC	
H	6.25	6.55	.246	.258
L	0.50	0.70	.020	.028
N	SEE VARIATIONS		SEE VARIATIONS	
α	0°	8°	0°	8°





JEDEC			VARIATIONS			
MO-153	N		MILLIMETERS		INCHES	
			MIN.	MAX.	MIN.	MAX.
AB-1	14	D	4.90	5.10	.193	.201
AB	16	D	4.90	5.10	.193	.201
AC	20	D	6.40	6.60	.252	.260
AD	24	D	7.70	7.90	.303	.311
AE	28	D	9.60	9.80	.378	.386





NOTES:
1. DIMENSIONS D AND E DO NOT INCLUDE FLASH
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED 0.15mm PER SIDE
3. CONTROLLING DIMENSION: MILLIMETER
4. MEETS JEDEC OUTLINE MO-153. SEE JEDEC VARIATIONS TABLE
5. "N" REFERS TO NUMBER OF LEADS
6. THE LEAD TIPS MUST LIE WITHIN A SPECIFIED ZONE. THIS TOLERANCE ZONE IS DEFINED BY TWO PARALLEL PLANES. ONE PLANE IS THE SEATING PLANE, DATUM [-C-]; THE OTHER PLANE IS AT THE SPECIFIED DISTANCE FROM [-C-] IN THE DIRECTION INDICATED

DALLAS SEMICONDUCTOR MAXIM

PROPRIETARY INFORMATION

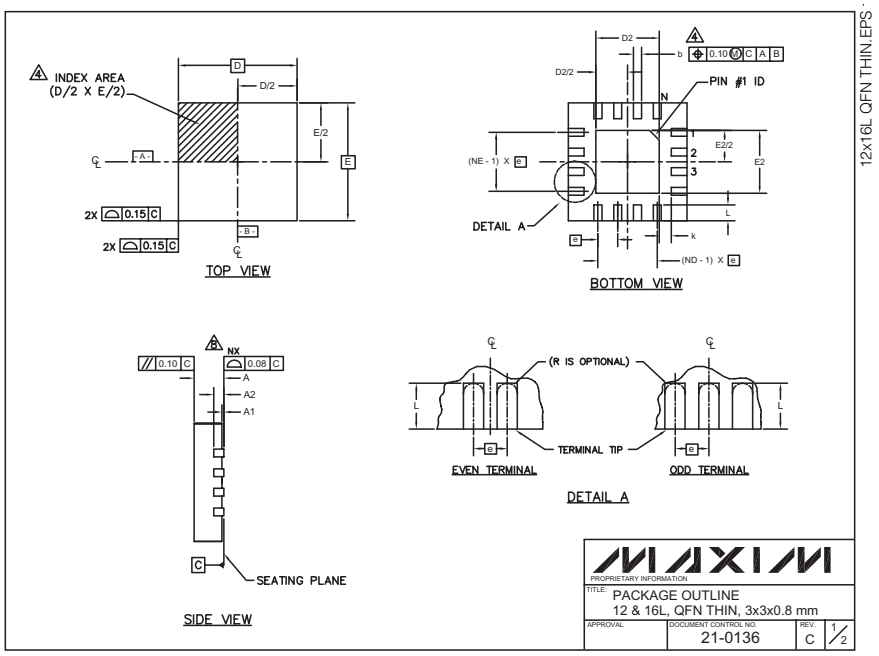
TITLE: PACKAGE OUTLINE, TSSOP 4.40mm BODY

APPROVAL	DOCUMENT CONTROL NO.	REV.	
	21-0066	F	1/1

5V, Differential Input, DirectDrive, 130mW Stereo Headphone Amplifiers with Shutdown

Package Information (continued)

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)



PKG	12L 3x3			16L 3x3		
REF.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.70	0.75	0.80	0.70	0.75	0.80
b	0.20	0.25	0.30	0.20	0.25	0.30
D	2.90	3.00	3.10	2.90	3.00	3.10
E	2.90	3.00	3.10	2.90	3.00	3.10
e	0.50 BSC.			0.50 BSC.		
L	0.45	0.55	0.65	0.30	0.40	0.50
N	12			16		
ND	3			4		
NE	3			4		
A1	0	0.02	0.05	0	0.02	0.05
A2	0.20 REF			0.20 REF		
k	0.25	-	-	0.25	-	-

EXPOSED PAD VARIATIONS								
PKG. CODES	D2			E2			PIN ID	JEDEC
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.		
T1233-1	0.95	1.10	1.25	0.95	1.10	1.25	0.35 x 45°	WEED-1
T1633-1	0.95	1.10	1.25	0.95	1.10	1.25	0.35 x 45°	WEED-2
T1633F-3	0.65	0.80	0.95	0.65	0.80	0.95	0.225 x 45°	-

NOTES:

1. DIMENSIONING & TOLERANCING CONFORM TO ASME Y14.5M-1994.
2. ALL DIMENSIONS ARE IN MILLIMETERS. ANGLES ARE IN DEGREES.
3. N IS THE TOTAL NUMBER OF TERMINALS.
4. THE TERMINAL #1 IDENTIFIER AND TERMINAL NUMBERING CONVENTION SHALL CONFORM TO JESD 95-1 SPP-012. DETAILS OF TERMINAL #1 IDENTIFIER ARE OPTIONAL, BUT MUST BE LOCATED WITHIN THE ZONE INDICATED. THE TERMINAL #1 IDENTIFIER MAY BE EITHER A MOLD OR MARKED FEATURE.
5. DIMENSION b APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.20 mm AND 0.25 mm FROM TERMINAL TIP.
6. ND AND NE REFER TO THE NUMBER OF TERMINALS ON EACH D AND E SIDE RESPECTIVELY.
7. DEPOPULATION IS POSSIBLE IN A SYMMETRICAL FASHION.
8. COPLANARITY APPLIES TO THE EXPOSED HEAT SINK SLUG AS WELL AS THE TERMINALS.
9. DRAWING CONFORMS TO JEDEC MO220 REVISION C.

PROPRIETARY INFORMATION
TITLE: PACKAGE OUTLINE 12 & 16L, QFN THIN, 3x3x0.8 mm
APPROVAL
DOCUMENT CONTROL NO. 21-0136
REV. C
2/2

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