60mW TRUE CAP FREE STEREO HEADPHONE AMPLIFIER

Description

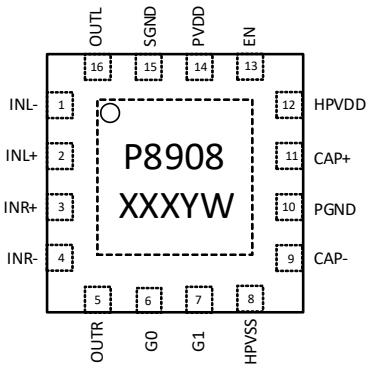
The PAM8908 stereo headphone driver is designed for portable equipment where board space is at a premium. The PAM8908 uses a unique, patent pending architecture to produce a ground-referenced output from a single supply, eliminating the need for large DC-blocking capacitors, saving cost, board space, and component height.

The PAM8908 delivers up to 60mW per channel into a 32Ω load and has low 0.03% THD+N. A high power-supply rejection ratio (80dB at 1kHz) allows this device to operate from noisy digital supplies without an additional linear regulator.

The PAM8908 operates from a single supply from 2.5V to 5.5V and has short-circuit and overtemperature protections. Shutdown mode reduces supply current to less than 1µA.

Pin Assignments

U-QFN3030-16 Standard



Top View

Features

- Patent Pending 3 Phase Power Line Shift Charge Pump Eliminates Need for DC-Blocking Capacitors
- True Cap Free Architecture, Output Biased at 0V (System Ground)
- Excellent Low Frequency Fidelity
- 80dB PSRR at 1kHz
- Less than 1µA Shutdown Current
- Support Both Fully Differential and Single-Ended Inputs
- Short-Circuit and Overtemperature Protections
- Selectable Gain Settings: -6dB, 0dB, 3dB and 6dB
- Available in Space-Saving Package: U-QFN3030-16 Standard
- Lead-Free and Green Devices Available (RoHS Compliant)
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- **For automotive applications requiring specific change control (i.e. parts qualified to AEC-Q100/101/104/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please contact us or your local Diodes representative. https://www.diodes.com/quality/product-definitions/**

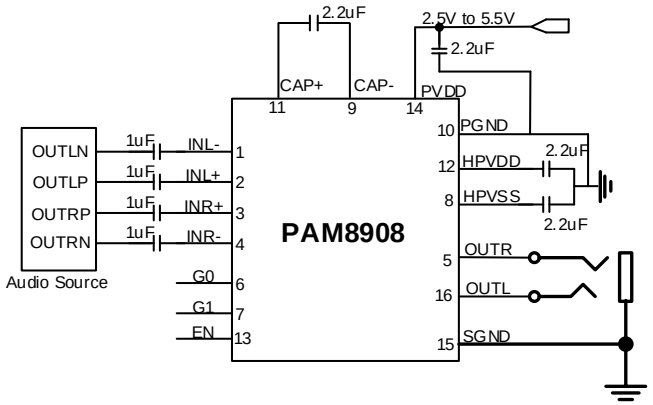
Applications

- Smart phones/cellular phones
- Notebook computers
- Portable DVD players
- Personal digital assistants (PDAs)
- Electronic dictionaries
- Digital still cameras
- Portable gaming

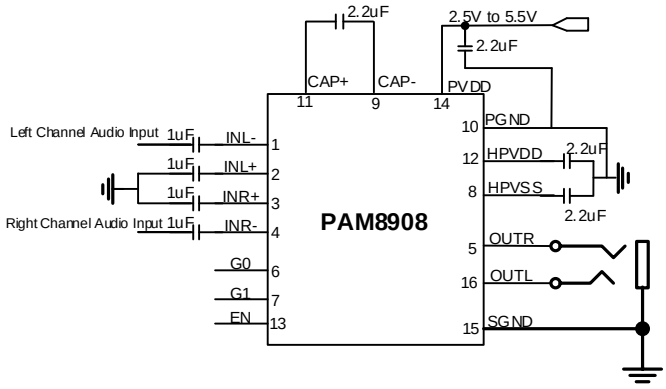
Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
2. See https://www.diodes.com/quality/lead-free/ for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

Typical Applications Circuit

Typical Application Configuration with Differential Input Signals



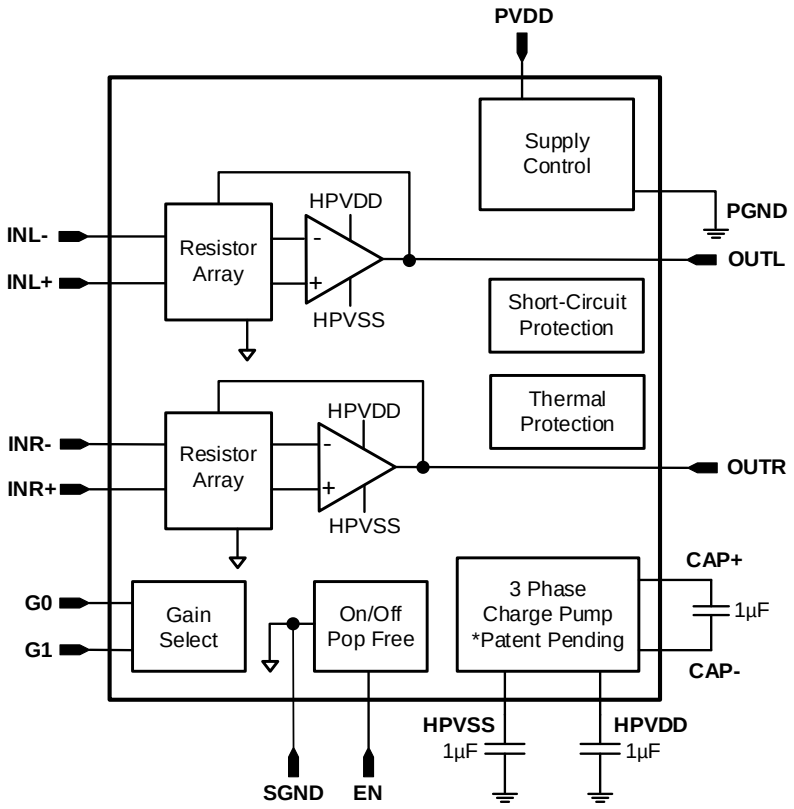
Typical Application Configuration with Single-Ended Input Signal



Pin Descriptions

Pin Number	Pin Name	I/O/P	Function
1	INL-	I	Inverting left input for differential signals.
2	INL+	I	Non-inverting left input for differential signals.
3	INR+	I	Inverting right input for differential signals.
4	INR-	I	Non-inverting right input for differential signals.
5	OUTR	O	Right headphone amplifier output. Connect to right terminal of headphone jack.
6	G0	I	Gain select bit 0.
7	G1	I	Gain select bit 1.
8	HPVSS	P	Charge pump output and negative power supply for output amplifiers; connect 1µF capacitor to GND.
9	CAP-	O	Charge pump negative flying cap.
10	PGND	P	Power Ground.
11	CAP+	O	Charge pump positive flying cap.
12	HPVDD	O	Positive power supply for headphone amplifiers. Charge pump positive half V_{DD} output.
13	EN	I	Amplifier enabled. Connect to logic low to shut down; connect to logic high to activate.
14	PVDD	P	Power V_{DD}.
15	SGND	I	Amplifier reference voltage.
16	OUTL	O	Left headphone amplifier output. Connect to left terminal of headphone jack.

Functional Block Diagram



Absolute Maximum Ratings (@T_A = +25°C, unless otherwise specified.) (Note 4)

All voltages are with respect to ground.

Parameter	Rating	Unit
Supply Voltage (PV_{DD})	6.0	V
Input Voltage (INR+, INR-, INL+, INL-)	HPV_{SS} -0.3 to HPV_{DD} +0.3	V
Control Interface Voltage (G0, G1, EN)	-0.3 to PV_{DD} +0.3	V
Storage Temperature	-65 to +150	°C
Maximum Junction Temperature	+150	
Soldering Temperature	+250, 10sec	

Note: 4. Stresses greater than those listed under *Absolute Maximum Ratings* can 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 under *Recommended Operating Conditions* is not implied. Exposure to *Absolute Maximum Ratings* for extended periods can affect device reliability.

Recommended Operating Conditions (@T_A = +25°C, unless otherwise specified.)

Symbol	Parameter	Rating	Unit
V_{DD}	Supply Voltage Range	2.5 to 5.5	V
T_A	Ambient Temperature Range	-40 to +85	°C
T_J	Junction Temperature Range	-40 to +125	

Thermal Information (@T_A = +25°C, unless otherwise specified.)

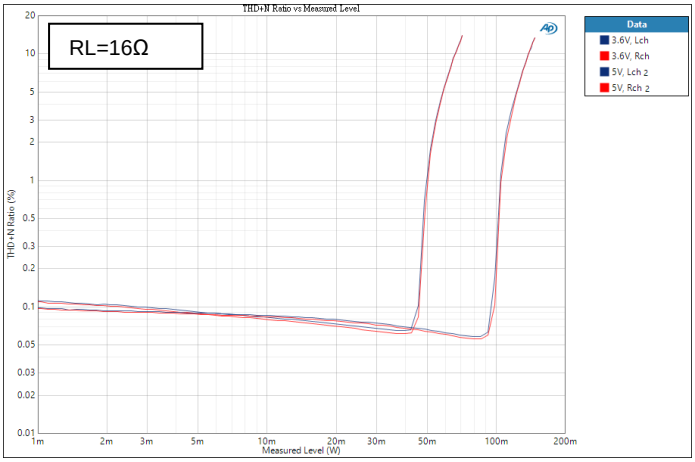
Symbol	Parameter	Package	Max	Unit
θ_{JA}	Thermal Resistance (Junction to Ambient)	U-QFN3030-16 Standard	35	°C/W
θ_{JC}	Thermal Resistance (Junction to Case)	U-QFN3030-16 Standard	14	°C/W

Electrical Characteristics (@T_A = +25°C, PV_{DD} = 3.6V, R_L = 16Ω, unless otherwise specified.)

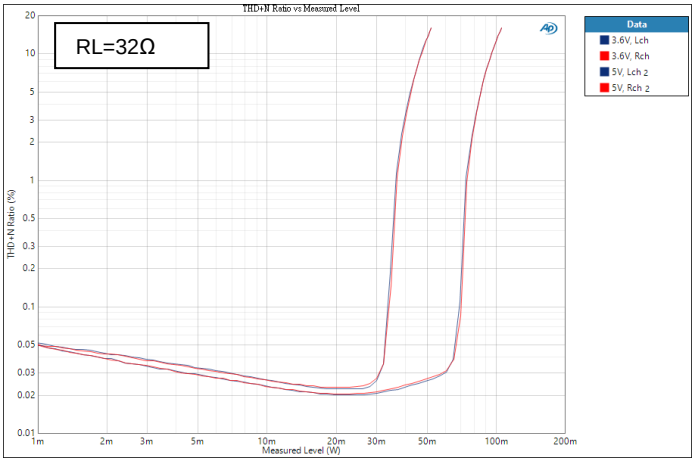
Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
PV_{DD}	Supply Voltage	—	2.5	—	5.5	V
I_Q	Quiescent Current	EN = PV_{DD}, No Load	—	4	—	mA
P_O	Output Power per Channel PV_{DD} = 3.6V	THD = 1%, f = 1kHz, R_L = 16Ω, In Phase	—	36.5	—	mW
		THD = 1%, f = 1kHz, R_L = 32Ω, In Phase	—	30	—	mW
		THD = 1%, f = 1kHz, R_L = 16Ω, Out Phase	—	49	—	mW
		THD = 1%, f = 1kHz, R_L = 32Ω, Out Phase	—	35.5	—	mW
	Output Power per Channel PV_{DD} = 5.0V	THD = 1%, f = 1kHz, R_L = 16Ω, In Phase	—	77	—	mW
		THD = 1%, f = 1kHz, R_L = 32Ω, In Phase	—	61	—	mW
		THD = 1%, f = 1kHz, R_L = 16Ω, Out Phase	—	103.5	—	mW
		THD = 1%, f = 1kHz, R_L = 32Ω, Out Phase	—	73.5	—	mW
I_{SD}	Shutdown Current	EN = 0V, PV_{DD} = 2.5V to 5.5V	—	0.1	1	μA
V_{IH}	EN High-Level Input Voltage	—	1.4	—	—	V
V_{IL}	EN Low-Level Voltage	—	—	—	0.6	V
V_{GH}	G0, G1 High-Level Input Voltage	—	1.4	—	—	V
V_{GL}	G0, G1 Low-Level Voltage	—	—	—	0.6	V
V_{OS}	Output Offset Voltage	—	—	1	5	mV
AV	Closed-Loop Voltage Gain	G0 = 0V, G1 = 0V	—	-6	—	dB
		G0 = PV_{DD}, G1 = 0V	—	0	—	dB
		G0 = 0V, G1 = PV_{DD}	—	3	—	dB
		G0 = PV_{DD}, G1 = PV_{DD}	—	6	—	dB
PSRR	Power Supply Rejection Ratio	Input A C-GND, f + 1kHz, V_{PP} = 200mV	—	75	—	dB
THD+N	Total Harmonic Distortion Plus Noise	P_O = 20mW, f = 1kHz	—	0.03	—	%
SNR	Signal to Noise Ratio	P_O = 20mW, into 16Ω	—	100	—	dB
EN	Noise Output Voltage	A-Weighted	—	10	—	μV_{RMS}
CS	Crosstalk	P_O = 15mW, f = 1kHz	—	80	—	dB
f_{OSC}	Charge Pump Switching Frequency	—	1.2	1.5	1.8	MHz
t_{ON}	Startup Time	EN from low to high	—	0.4	—	ms
OTP	Thermal Shutdown	Threshold	—	+150	—	°C
OTPH	Thermal Shutdown Hysteresis	Hysteresis	—	+20	—	°C

Typical Performance Characteristics (@T_A = +25°C, PV_{DD} = 3.6V, f = 1kHz, Gain = 6dB, unless otherwise specified.)

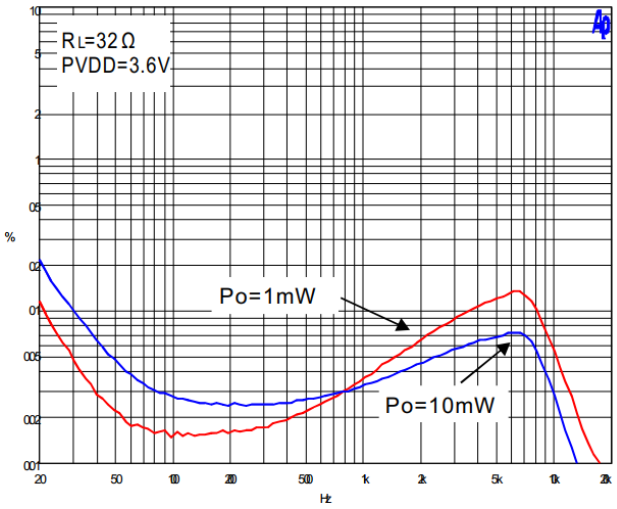
1. THD+N vs Output Power



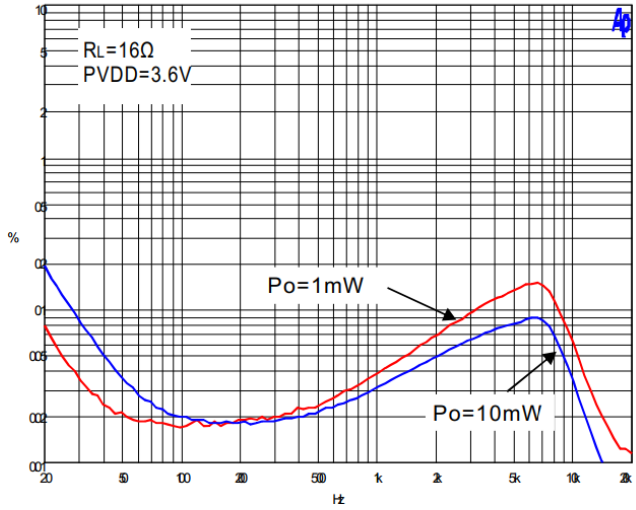
2. THD+N vs Output Power



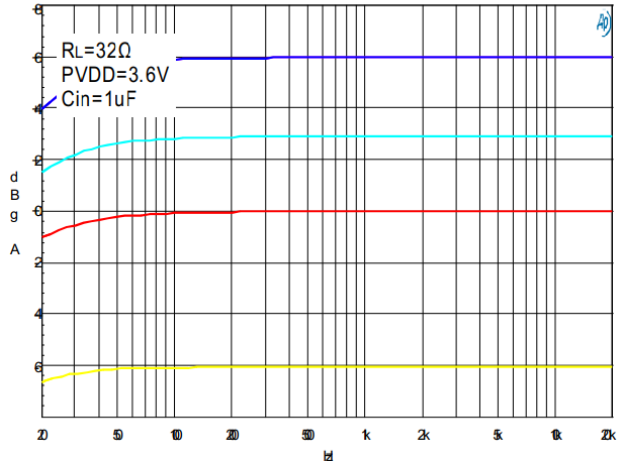
3. THD+N vs Frequency



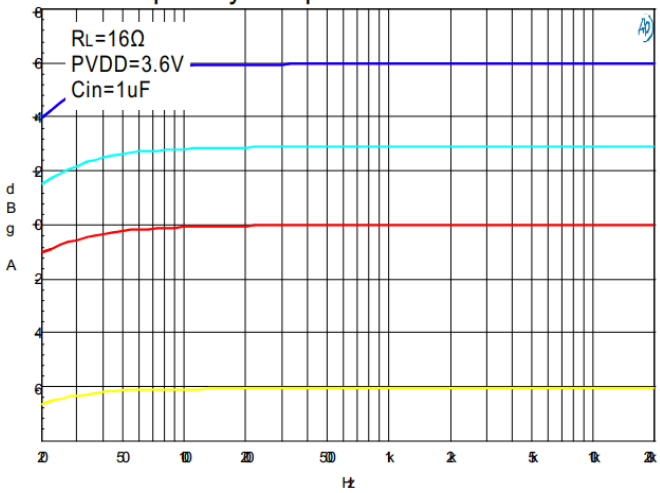
4. THD+N vs Frequency



5. Frequency Response

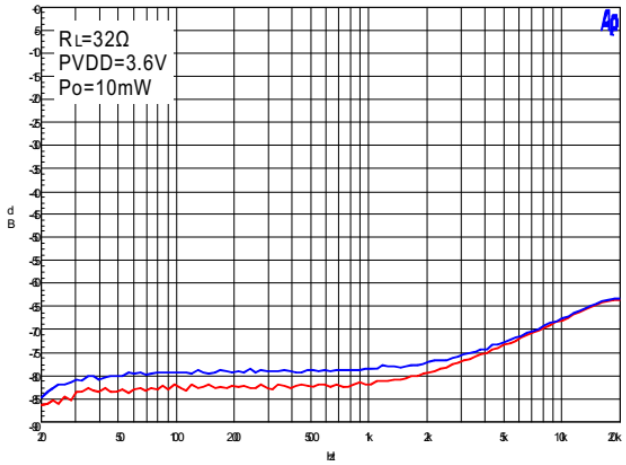


6. Frequency Response

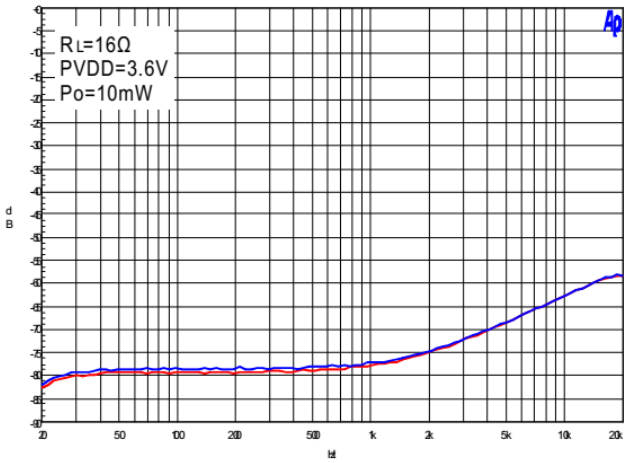


Typical Performance Characteristics (continued) (@T_A = +25°C, PV_{DD} = 3.6V, f = 1kHz, Gain = 6dB, unless otherwise specified.)

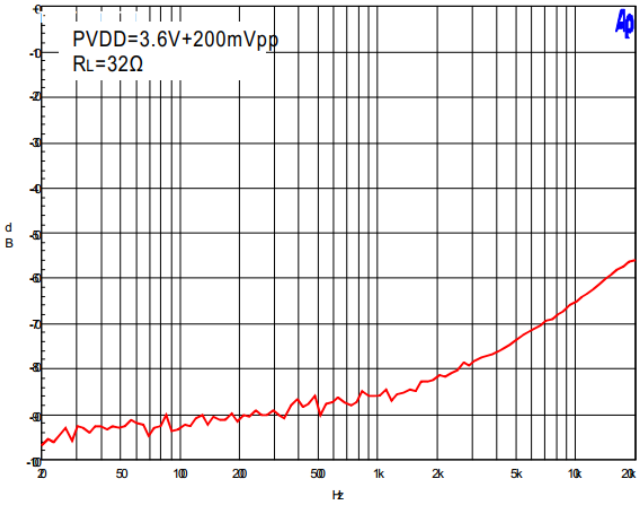
7. Crosstalk



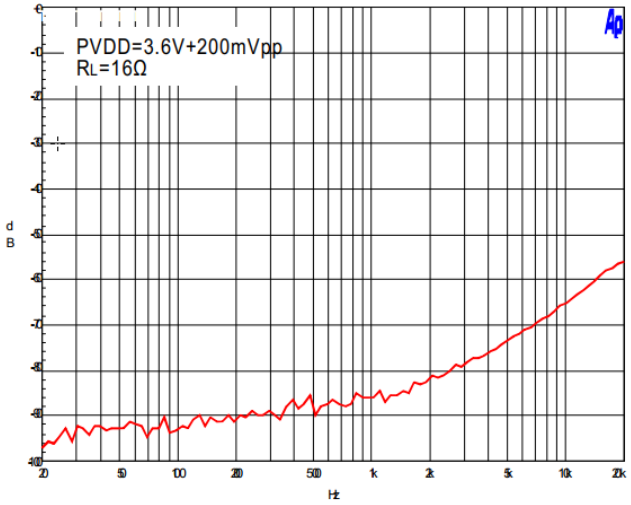
8. Crosstalk



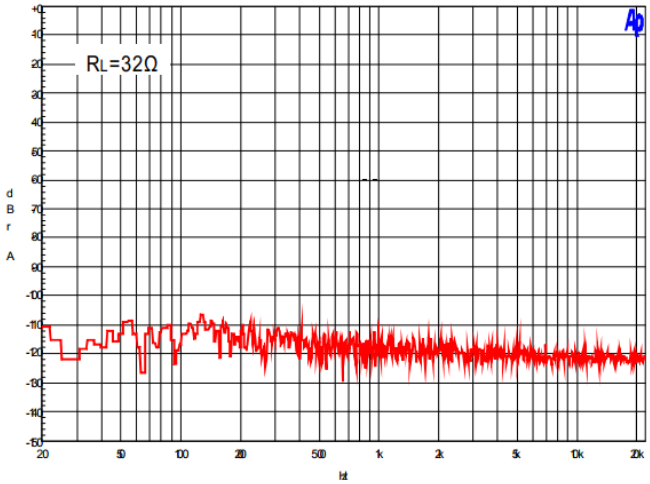
9. PSRR



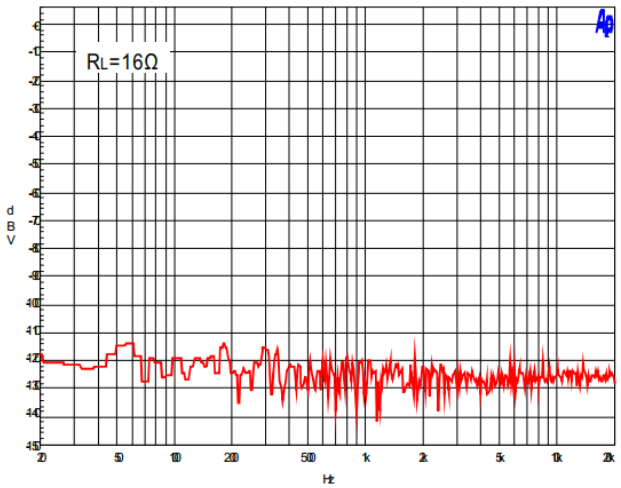
10. PSRR



11. FFT Noise

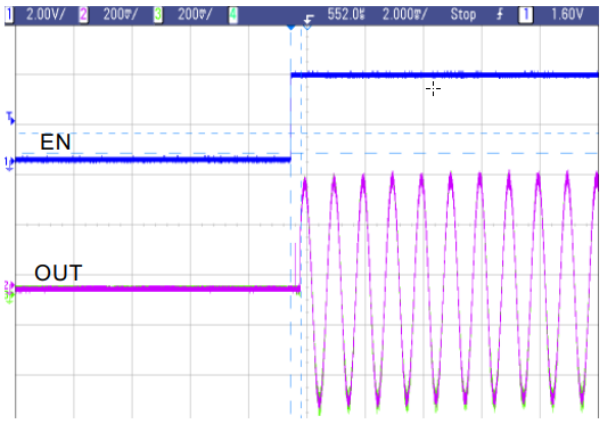


12. FFT Noise

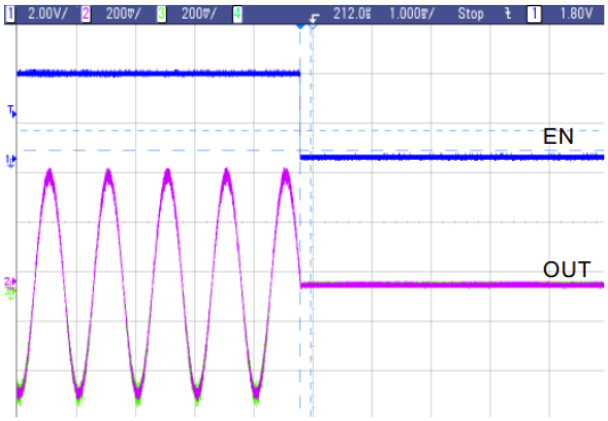


Typical Performance Characteristics (continued) (@T_A = +25°C, C_{IN} = 10µF, C_O = 10µF, L = 4.7µH, unless otherwise specified.)

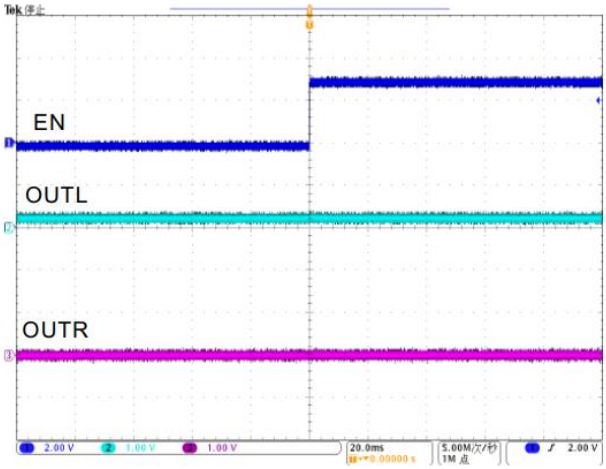
13. Start up with signal



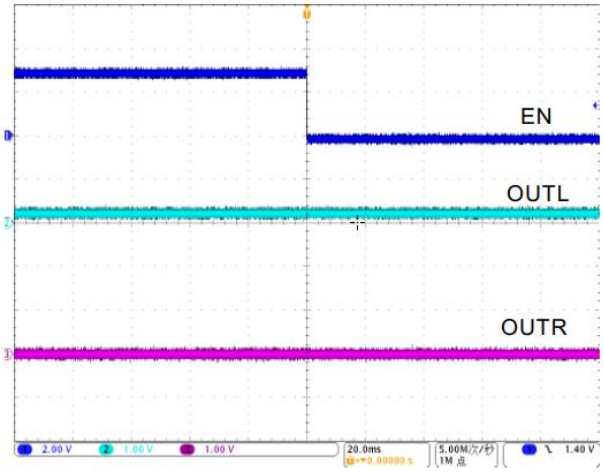
14. Shutdown with signal



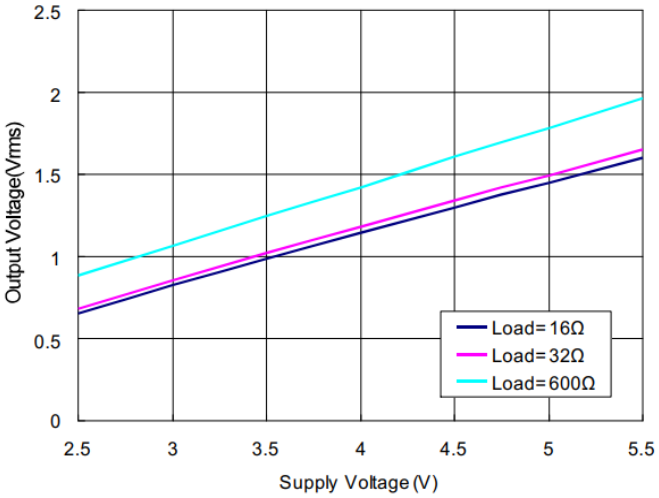
15. Start up without signal



16. Shutdown without signal



17. Output Voltage vs Supply Voltage



Application Information

The basic PAM8908 application circuit is shown on page 2.

Gain Control

The PAM8908 has four gain settings which are controlled with pins G0 and G1. The following table gives an overview of the gain function.

G0 Voltage	G1 Voltage	Amplifier Gain
≤ 0.6V	≤ 0.6V	-6dB
≥ 1.4V	≤ 0.6V	0dB
≤ 0.6V	≥ 1.4V	3dB
≥ 1.4V	≥ 1.4V	6dB

Input Coupling Capacitors

Input coupling capacitors block any DC bias from the audio source and ensure maximum dynamic range. Input coupling capacitors also minimize PAM8908 turn-on pop to an inaudible level. The input capacitors are in series with PAM8908 internal input resistors, creating a high-pass filter. The following equation calculates the high-pass filter corner frequency.

$$f_C = \frac{1}{2\pi R_{IN} C_{IN}}$$

The input impedance, R_{IN}, is dependent on device gain. Larger input capacitors decrease the corner frequency. See the following table for input impedance values.

G0 Voltage	G1 Voltage	R_{IN}
≤ 0.6V	≤ 0.6V	26.4kΩ
≥ 1.4V	≤ 0.6V	19.8kΩ
≤ 0.6V	≥ 1.4V	16.5kΩ
≥ 1.4V	≥ 1.4V	13.2kΩ

For a given high-pass cutoff frequency, the minimum input coupling capacitor is found as:

$$C_{IN} = \frac{1}{2\pi f_C R_{IN}}$$

Example: Design for a 20Hz corner frequency with a PAM8908 gain of +6dB. The input impedance table gives R_{IN} as 13.2kΩ. The C_{IN} equation shows the input coupling capacitors must be at least 0.6µF to achieve a 20Hz high-pass corner frequency. Choose a 0.68µF standard value capacitor for each PAM8908 input (X5R material or better is required for best performance).

Charge Pump Flying Capacitor, HPVDD Capacitor and HPVSS Capacitor

The PAM8908 uses a built-in charge pump to generate a positive and negative voltage supply for the headphone amplifiers. The charge pump flying capacitor connects between CAP+ and CAP-. It transfers charge to generate the positive and negative supply voltage. The HPVDD capacitor or HPVSS capacitor must be at least equal to or larger than value to the flying capacitor to allow maximum charge transfer. Use low equivalent-series-resistance (ESR) ceramic capacitors (X5R material or better is required for best performance) to maximize charge pump efficiency. Typical value is 1µF for the HPVDD, HPVSS and flying capacitors.

Power Supply Decoupling Capacitors

The PAM8908 True Cap Free headphone amplifier requires adequate power supply decoupling to ensure that output noise and total harmonic distortion (THD) remain low. Use good low equivalent-series-resistance (ESR) ceramic capacitors (X5R material or better is required for best performance). Place a 2.2µF capacitor within 5mm of the PVDD pin. Reducing the distance between the decoupling capacitor and PVDD minimizes parasitic inductance and resistance, improving PAM8908 supply rejection performance. Use 0402 or smaller size capacitors if possible.

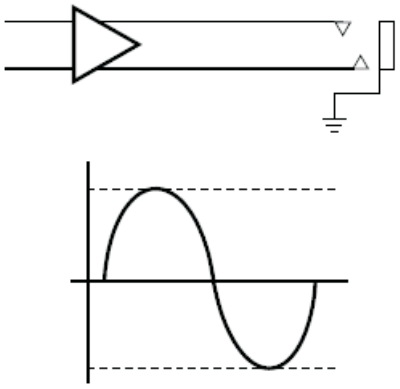
Application Information (continued)

Power Supply Sequencing

Use input coupling capacitors to ensure inaudible turn-on pop. Activate the PAM8908 after all audio sources have been activated and their output voltages have settled. On power-down, deactivate the PAM8908 before deactivating the audio input source. The EN pin controls device shutdown: set to 0.6V or lower to deactivate the PAM8908; set to 1.4V or higher to activate it.

True Cap Free Headphone Amplifiers

The True Cap Free amplifier architecture operates from a single supply voltage and uses two internal charge pumps to generate a positive supply and a rail for the headphone amplifier. The output voltages are centered around 0V and are capable of positive and negative voltage swings as shown in the following drawing.



True Cap Free amplifiers require no output DC-blocking capacitors. The headphone connector shield pin connects to ground and will interface with headphones and non-headphone accessories. The PAM8908 is a True Cap Free amplifier.

LAYOUT RECOMMENDATIONS

Exposed Pad on PAM8908

Solder the exposed metal pad on the PAM8908 U-QFN3030-16 Standard package to the landing pad on the PCB. Connect the landing pad to ground or leave it electrically unconnected (floating). Do not connect the landing pad to PVDD or to any other power supply voltage. If the pad is grounded, it must be connected to the same ground as the PGND. Soldering the thermal pad is required for mechanical reliability and enhances thermal conductivity of the package.

GND Connections

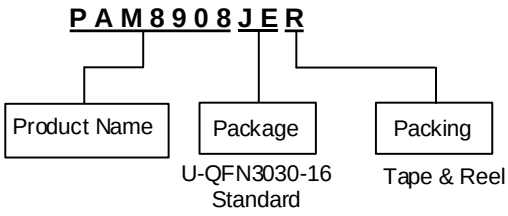
The SGND pin is an input reference and must be connected to the headphone ground connector pin. This ensures no turn-on pop and minimizes output offset voltage. Do not connect more than ±0.3V to SGND.

PGND is a power ground. Connect supply decoupling capacitors for PVDD, HPVDD, and HPVSS to PGND.

Power Supply Connections

Connect the supply voltage to the PVDD pin and decouple it with an X5R or better capacitor. Place both PVDD capacitors within 5mm of PVDD pin on the PAM8908. Ensure that the ground connection of PVDD capacitor has a minimum length return path to the device. Failure to properly decouple the PAM8908 may degrade audio or EMC performance.

Ordering Information



Orderable Part Number	Package	Packing	
		Qty.	Carrier
PAM8908JER	U-QFN3030-16 Standard	3000 Units	Tape & Reel

Marking Information

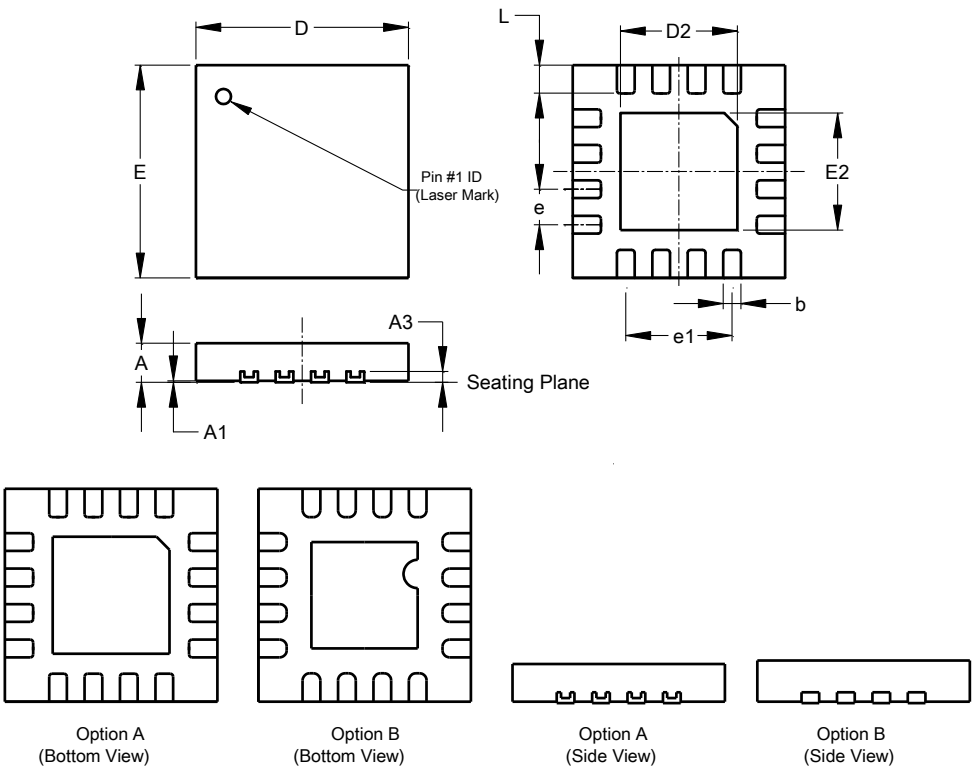
(Top View)

P8908: Marking ID
XXX: Internal Code
Y: Year (ex: 4 = 2024)
W: Week (A to Z: Week 1 to 26, a to z: week 27 to 52,
z represents week 52 and 53)

Package Outline Dimensions

Please see http://www.diodes.com/package-outlines.html for the latest version.

U-QFN3030-16 Standard

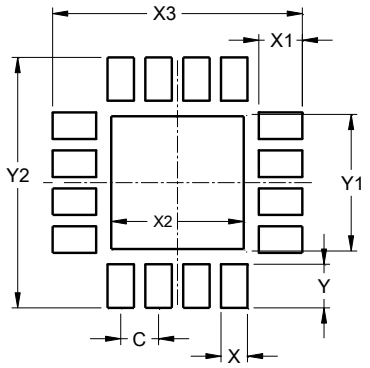


U-QFN3030-16 Standard			
Dim	**Min**	**Max**	**Typ**
A	0.50	0.65	0.60
A1	0.00	0.05	0.02
A3	--	--	0.15
b	0.18	0.30	0.25
D	2.95	3.05	3.00
D2 (Option A)	1.60	1.70	1.65
D2 (Option B)	1.40	1.60	1.50
E	2.95	3.05	3.00
E2 (Option A)	1.60	1.70	1.65
E2 (Option B)	1.40	1.60	1.50
e	0.500 BSC		
e1	1.500 REF		
L	0.35	0.45	0.40
All Dimensions in mm			

Suggested Pad Layout

Please see http://www.diodes.com/package-outlines.html for the latest version.

U-QFN3030-16 Standard



Dimensions	Value (in mm)
C	0.500
X	0.350
X1	0.570
X2	1.800
X3	3.300
Y	0.570
Y1	1.800
Y2	3.300

Mechanical Data

- Moisture Sensitivity: Level 1 per J-STD-020
- Terminals: Finish – NiPdAu, Solderable per J-STD-002, Test B1 (e4)
- Weight: 15.85mg (Approximate)

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