PAM8007

FILTERLESS 3W CLASS-D STEREO AUDIO AMPLIFIER with DC VOLUME CONTROL and HEADPHONE OUTPUT

Description

The PAM8007 is a 3W, Class-D audio amplifier with headphone amplifier. Advanced 64-Step DC volume control minimizes external components and allows speaker volume control and headphone volume control. It offers low THD+N, to produce high-quality sound reproduction. The new filterless architecture allows the device to drive the speaker directly, without low-pass output filters which will save 30% system cost and 75% PCB area.

With the same numbers of external components, the efficiency of the PAM8007 is much better than class-AB cousins. It can extend the battery life thus be ideal for portable applications.

The PAM8007 is available in a SSOP-24 and SOP-24 package.

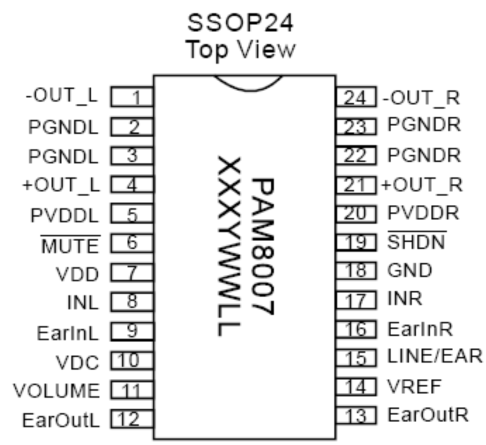
Features

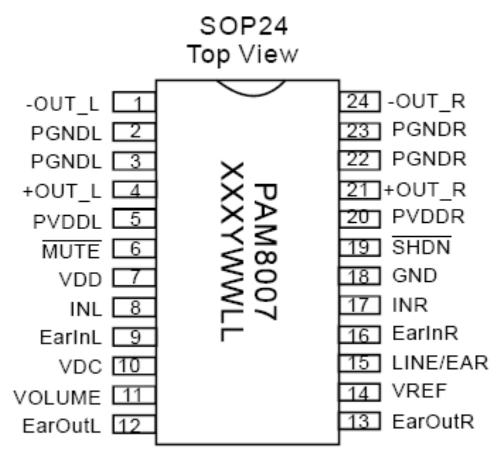
- 3W Output at 10% THD with a 4Ω Load and 5V Power Supply
- Filterless, Low Quiescent Current and Low EMI
- Low THD+N
- 64-Step DC Volume Control
- Headphone Output Function
- Superior Low Noise
- Low Pop Noise
- Efficiency Up to 92%
- Short Circuit Protection
- Thermal Shutdown
- Few External Components to Save the Space and Cost
- Pb-Free Package

Applications

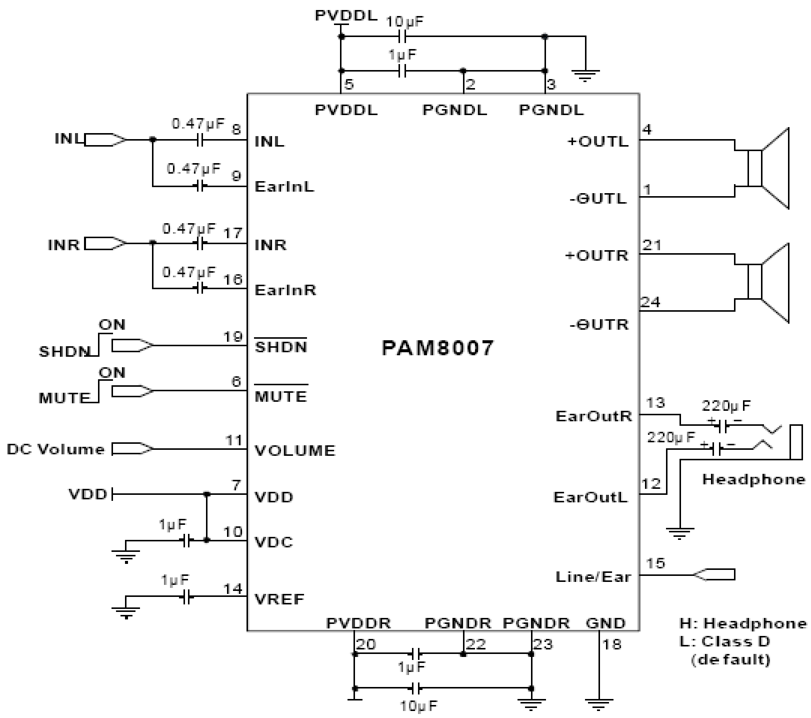
- LCD Monitors / TV Projectors
- Notebook Computers
- Portable Speakers
- Portable DVD Players, Game Machines
- VoIP/Speaker Phones

Pin Assignments





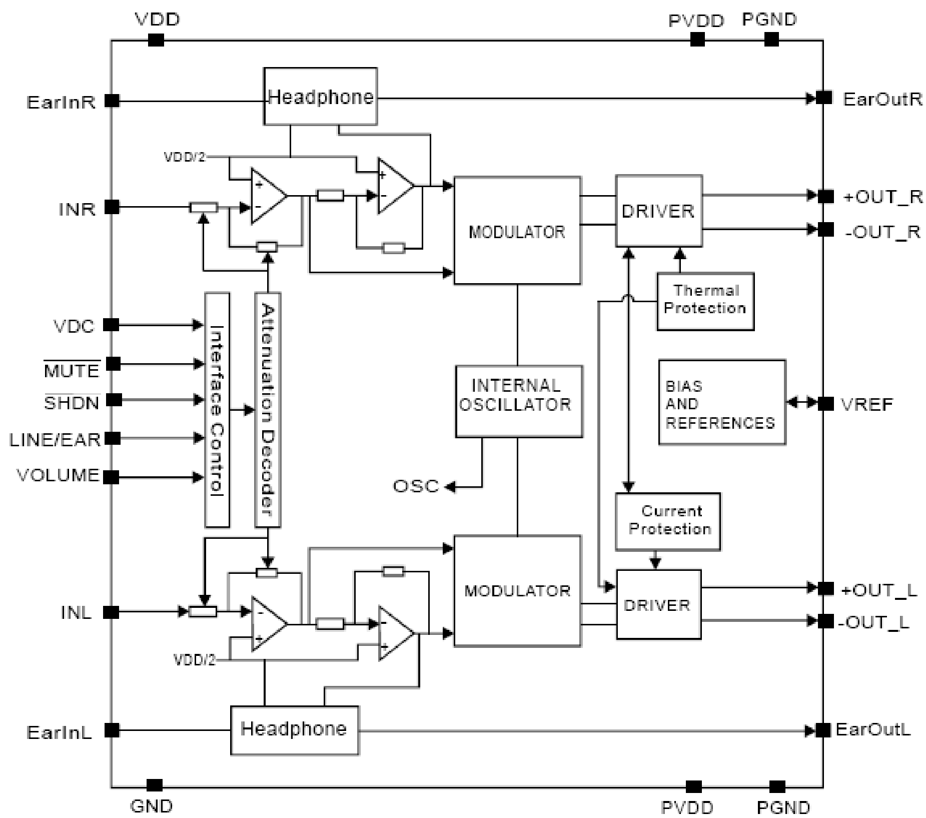
Typical Applications Circuit



Pin Descriptions

Pin Number	Pin Name	Function
1	-OUT_L	Left Channel Negative Output
2	PGNDL	Left Channel Power GND
3	PGNDL	Left Channel Power GND
4	+OUT_L	Left Channel Positive Output
5	PVDDL	Left Channel Power Supply
6	MUTE	Mute Control Input (active low)
7	VDD	Analog VDD
8	INL	Left Channel Input
9	EAR INL	Left Earphone Input
10	VDC	Analog Reference for Gain Control Section
11	VOLUME	DC Volume Control to Set the Gain of Class-D
12	EAR OUT L	Left Earphone Output(Non-Inverting)
13	EAR OUT R	Right Earphone Output(Non-Inverting)
14	VREF	Internal Analog Reference, connect a bypass capacitor from VREF to GND
15	LINE/EAR	Line / Earphone Switch. Speaker Output (active low), Earphone Output (active high)
16	EAR LN R	Right Earphone Input
17	INR	Right Channel Input
18	GND	Analog GND
19	SHDN	Shutdown Control Input (active low)
20	PVDDR	Right Channel Power Supply
21	+OUT_R	Right Channel Positive Output
22	PGNDR	Right Channel Power GND
23	PGNDR	Right Channel Power GND
24	-OUT_R	Right Channel Negative Output

Functional Block Diagram



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

These are stress ratings only and functional operation is not implied. Exposure to absolute maximum ratings for prolonged time periods may affect device reliability. All voltages are with respect to ground.

Parameter	Rating	Unit
Supply Voltage	6.0	V
Input Voltage	-0.3 to V_{DD} +0.3	
Maximum Junction Temperature	150	°C
Storage Temperature	-65 to +150	
Soldering Temperature	300, 5sec	

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

Parameter	Rating	Unit
Supply Voltage Range	2.5 to 5.5	V
Ambient Operation Temperature Range	-20 to +85	°C
Junction Temperature Range	-20 to +125	°C

Thermal Information

Parameter	Package	Symbol	Max	Unit
Thermal Resistance (Junction to Ambient)	SSOP-24	θ_{JA}	90	°C/W
	SOP-24		79.2	
Thermal Resistance (Junction to Case)	SSOP-24	θ_{JC}	32	
	SOP-24		27	

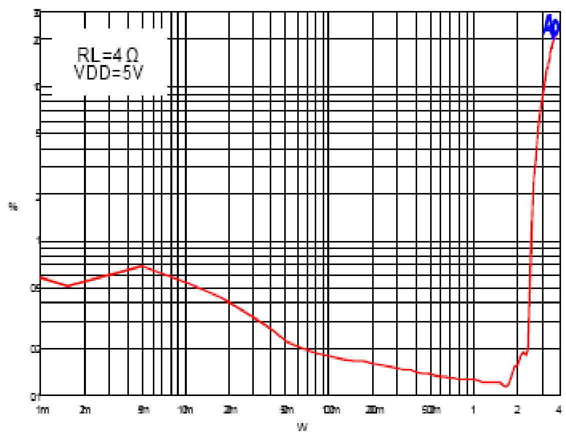
Electrical Characteristics (@T_A = +25°C, V_{DD} = 5V, Gain = 24dB, R_L = 8Ω, unless otherwise specified.)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Class D Stage						
Supply Voltage Range	V_{DD}		2.5		5.5	V
Quiescent Current	I_Q	No Load		12	16	mA
Output Offset Voltage	V_{OS}	No Load		10	50	mV
Drain-Source On-State Resistance	$R_{DS(ON)}$	I_{DS} = 0.5A, P MOSFET		0.23		Ω
		I_{DS} = 0.5A, N MOSFET		0.17		
Output Power	P_O	THD+N = 10%, f = 1kHz, R_L = 8Ω	1.55	1.75		W
		THD+N = 10%, f = 1kHz, R_L = 4Ω	2.85	3.1		
Total Harmonic Distortion Plus Noise	THD+N	R_L = 8Ω, P_O = 1W, f = 1KHz		0.12		%
		R_L = 4Ω, P_O = 2W, f = 1KHz		0.15		
Power Supply Ripple Rejection	PSRR	Input AC-GND, f = 1KHz, V_{PP} = 200mV		63		dB
Channel Separation	CS	V_O = 1V_{RMS}, f = 1KHz		-88		dB
Oscillator Frequency	f_{OSC}		200	250	300	kHz
Efficiency	η	P_O = 1.75W, f =1 kHz, R_L = 8Ω	85	92		%
		P_O = 3.0W, f =1 kHz, R_L = 4Ω	80	88		%
Noise	V_N	Input AC-GND, Gain = 12dB, A-Weighting		65		µV
		Input AC-GND, Gain = 12dB, No A-Weighting		90		
Signal Noise Ratio	SNR	f = 20 – 20kHz, THD = 1%		84		dB
Earphone Stage						
Output Power	P_O	THD+N = 1%, R_L = 32Ω, f = 1kHz		69		mW
Total Harmonic Distortion Plus Noise	THD+N	R_L = 32Ω, P_O = 10mW, f = 1kHz		0.04		%
Power Supply Ripple Rejection	PSRR	Input AC-GND, f = 1kHz, V_{PP} = 200mV		73		dB
Channel Separation	CS	V_O = 1V_{RMS}, f = 1kHz		95		dB
Noise	V_N	Input AC-GND, A-Weighting		19		µV
		Input AC-GND, No A-Weighting		25		
Signal Noise Ratio	SNR	f = 20 – 20kHz, THD = 1%		97		dB
Control Section						
Mute Current	I_{MUTE}	V_{MUTE} = 0V		8	12	mA
Shutdown Current	I_{SHDN}	V_{SHDN} = 0V			20	µA
$\overline{SHDN}$ Input High	V_{SH}		1.5			V
$\overline{SHDN}$ Input Low	V_{SL}				0.4	
$\overline{MUTE}$ Input High	V_{MH}		1.5			V
$\overline{MUTE}$ Input Low	V_{ML}				0.4	
Line/Ear Input High	V_{DH}		2.5			V
Line/Ear Input Low	V_{DL}				0.4	
Over Temperature Protection	OTP			150		°C
Over Temperature Hysteresis	OTH			30		°C

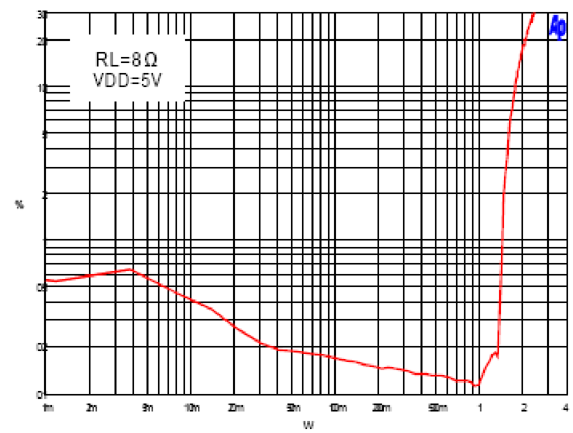
Typical Performance Characteristics (@T_A = +25°C, unless otherwise specified.)

Speaker

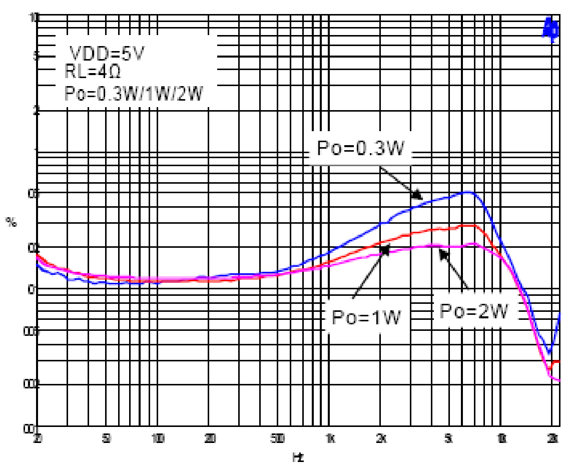
1. THD+N vs Output Power



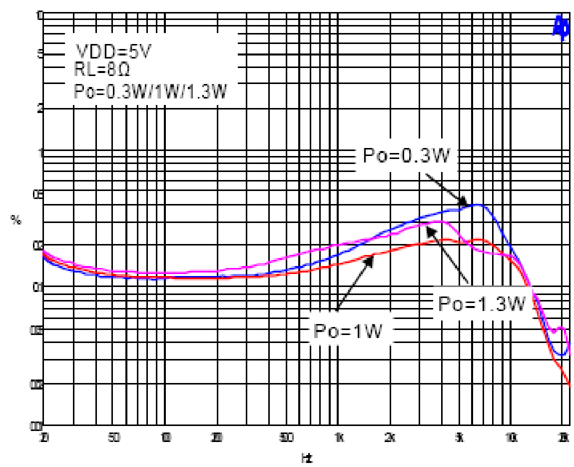
2. THD+N vs Output Power



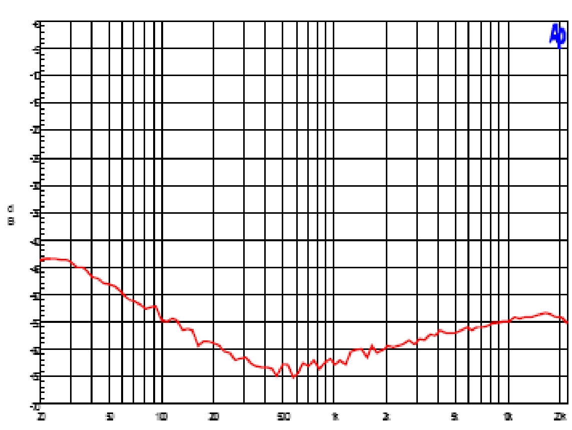
3. THD+N vs Frequency



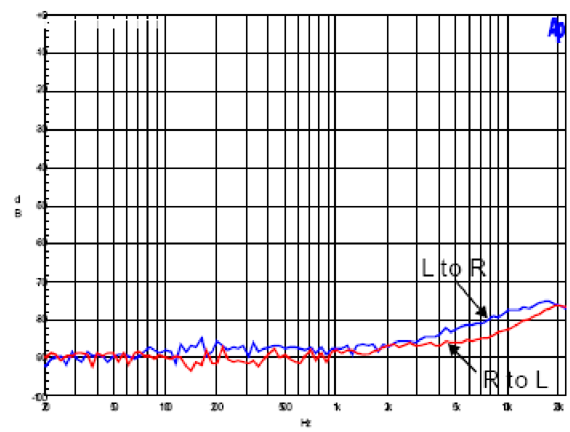
4. THD+N vs Frequency



5. PSRR vs Frequency



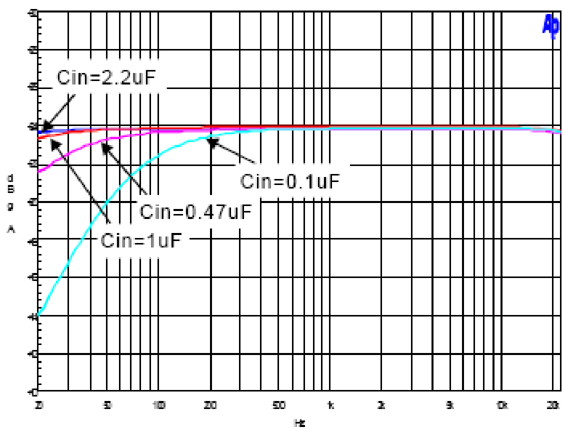
6. Crosstalk vs Frequency



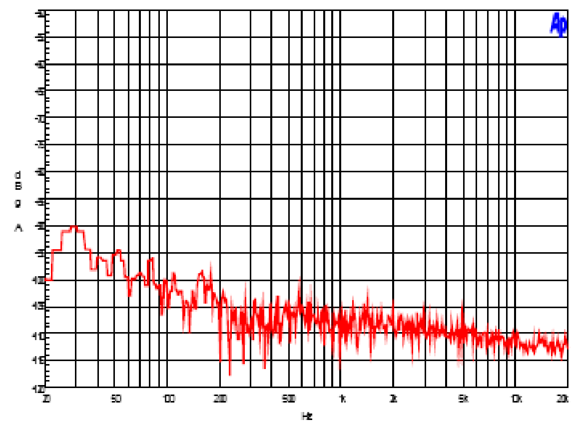
Typical Performance Characteristics (cont.) (@T_A = +25°C, unless otherwise specified.)

Speaker

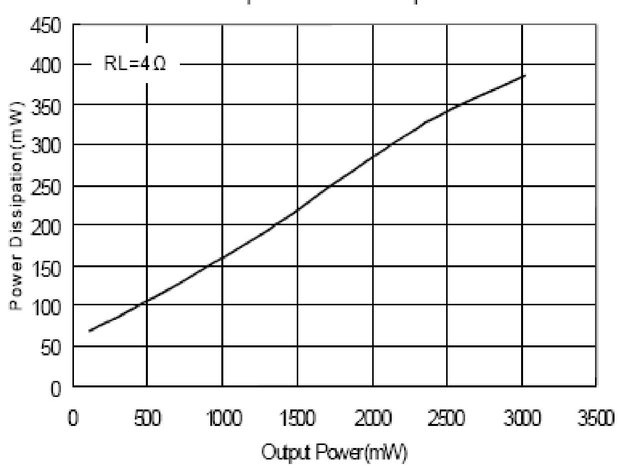
7. Frequency Response



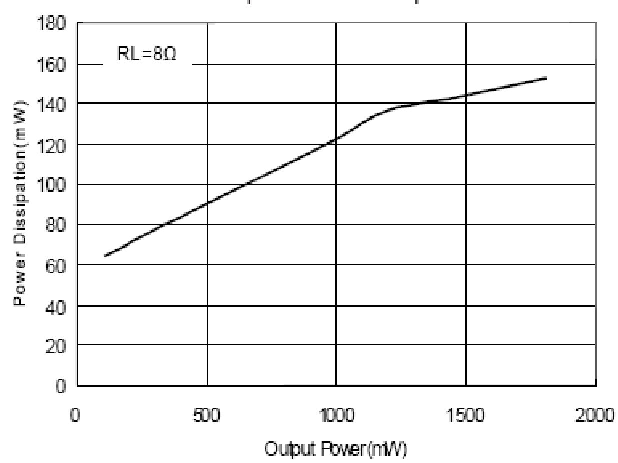
8. Noise Floor



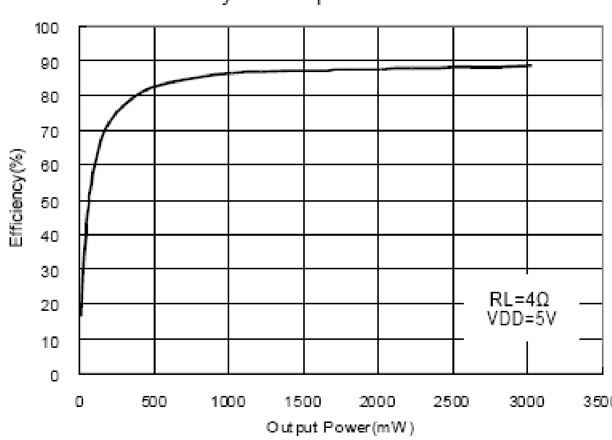
9. Power Dissipation vs Output Power



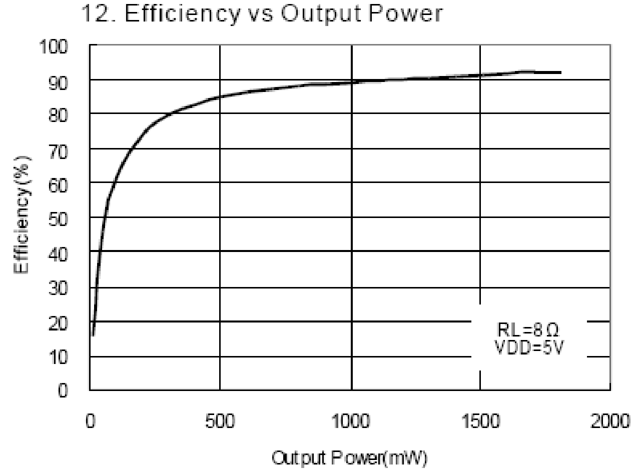
10. Power Dissipation vs Output Power



11. Efficiency vs Output Power



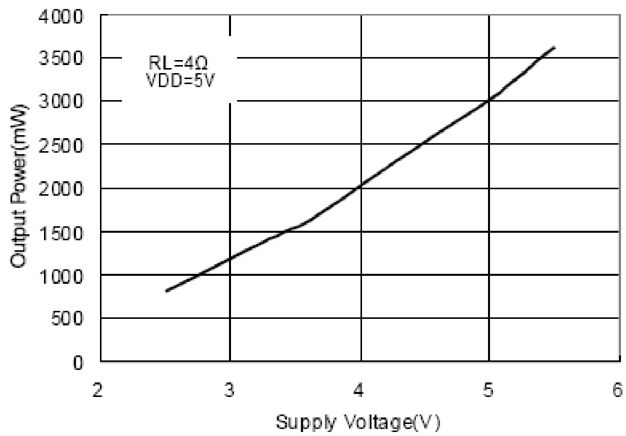
12. Efficiency vs Output Power



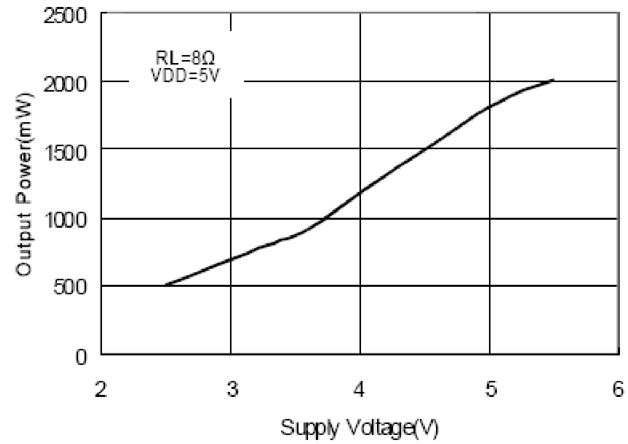
Typical Performance Characteristics (cont.) (@T_A = +25°C, unless otherwise specified.)

Speaker

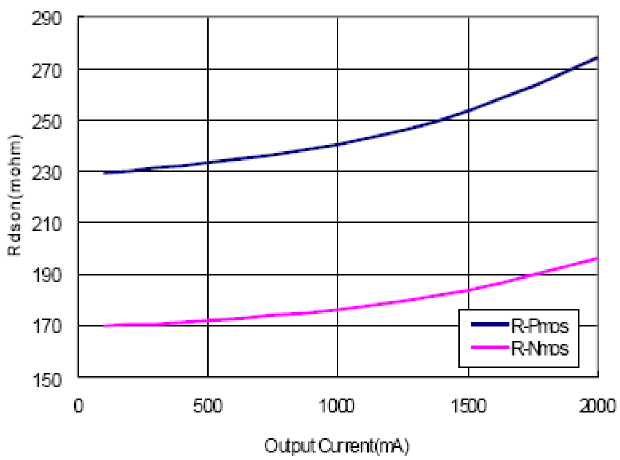
13. Output Power VS Supply Voltage



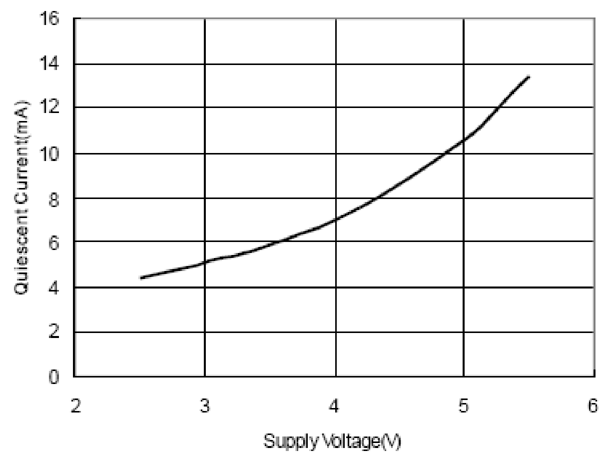
14. Output Power VS Supply Voltage



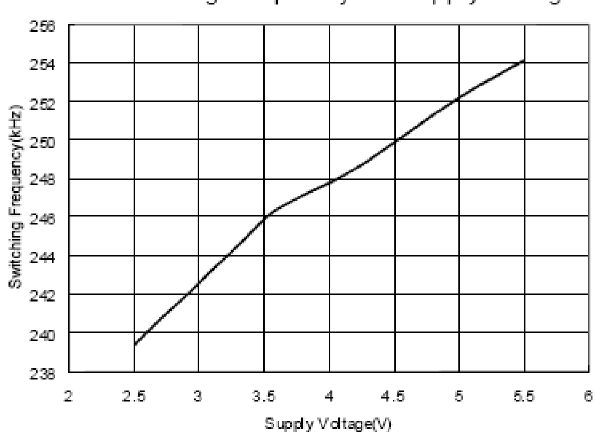
15. Rdson VS Output Current



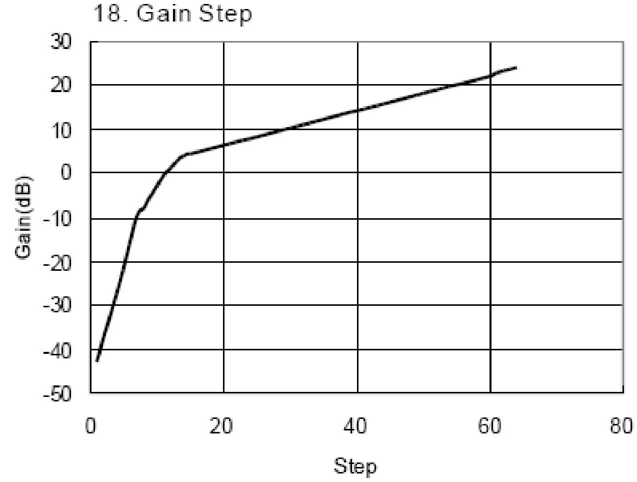
16. Quiescent Current



17. Switching Frequency VS Supply Voltage



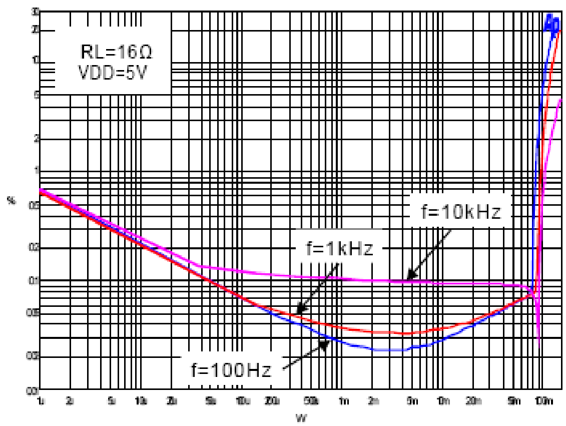
18. Gain Step



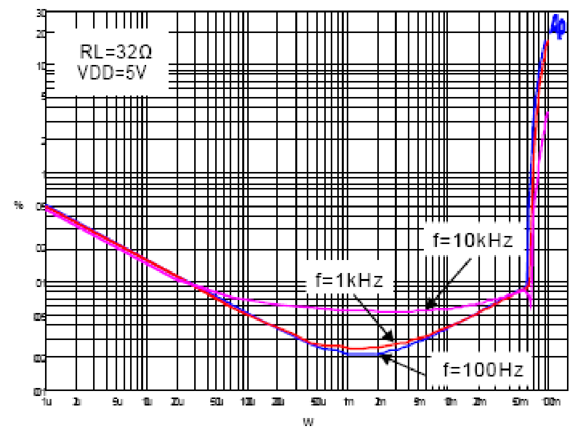
Typical Performance Characteristics (cont.) (@T_A = +25°C, unless otherwise specified.)

Earphone Output

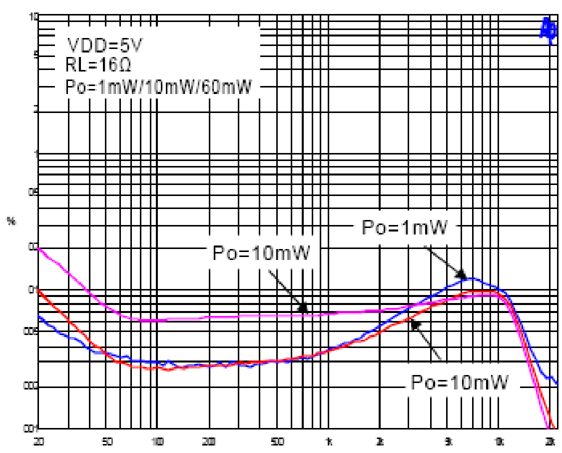
1. THD+N vs Output Power



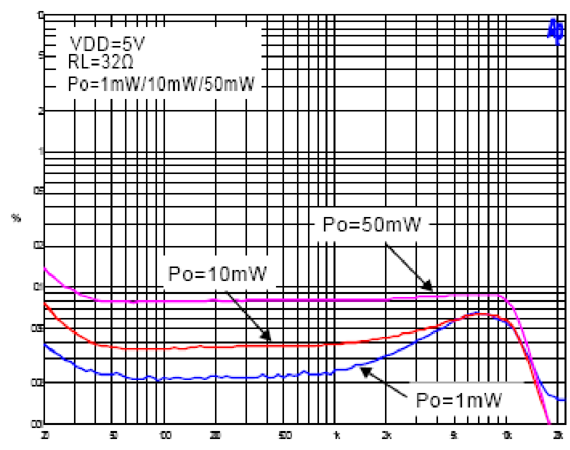
2. THD+N vs Output Power



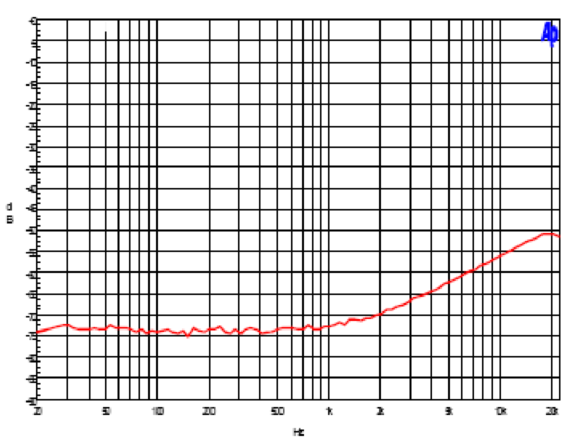
3. THD+N vs Frequency



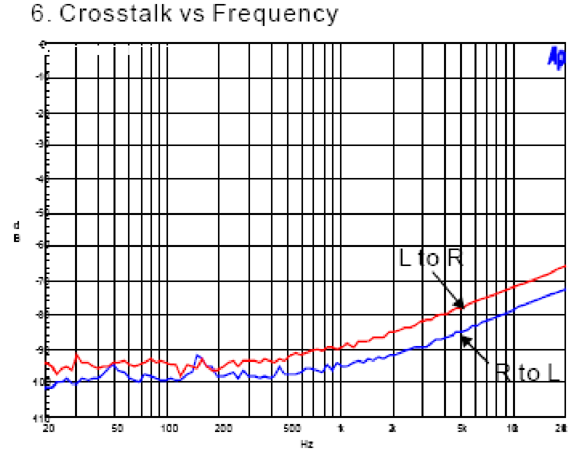
4. THD+N vs Frequency



5. PSRR vs Frequency

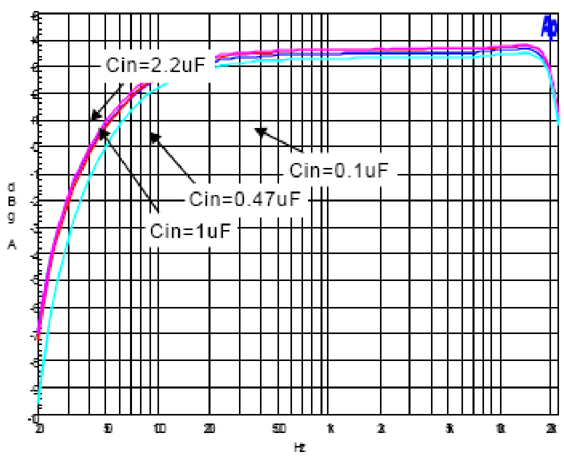


6. Crosstalk vs Frequency

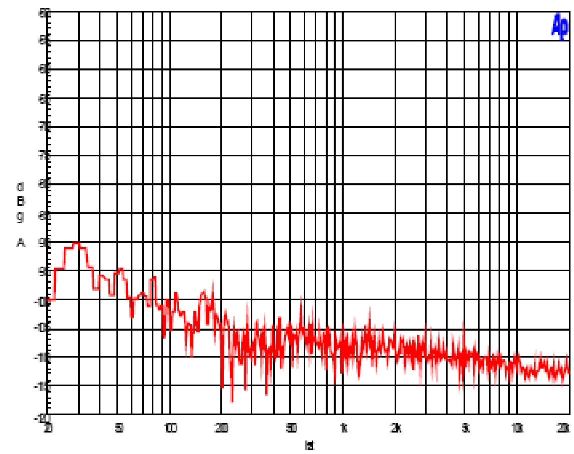


Typical Performance Characteristics (cont.) (@T_A = +25°C, unless otherwise specified.)

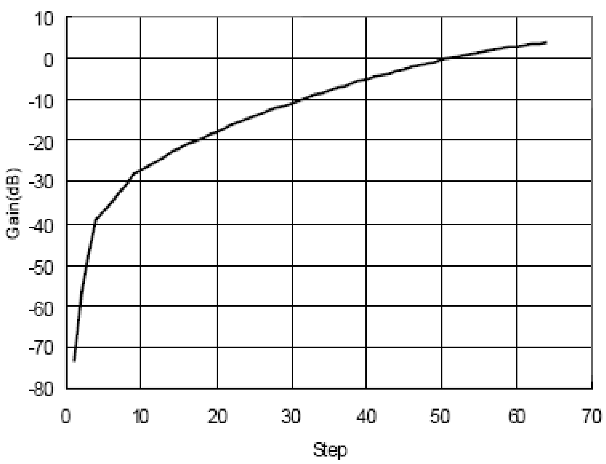
7. Frequency Response



8. Noise Floor



9.Gain Step



Typical Performance Characteristics (cont.) (@T_A = +25°C, unless otherwise specified.)

Table 1. DC Volume Control

STEP	Gain (dB) Class D	Gain (dB) Earphone		STEP	Gain (dB) Class D	Gain (dB) Earphone
1	-80	-80		33	11.6	-9.2
2	-40	-60		34	12.0	-8.6
3	-34	-50		35	12.4	-8.0
4	-28	-40		36	12.8	-7.4
5	-22	-37.7		37	13.2	-6.8
6	-16	-35.4		38	13.6	-6.2
7	-10	-33.1		39	14.0	-5.7
8	-7.5	-30.8		40	14.4	-5.2
9	-5	-28.5		41	14.8	-4.7
10	-2.5	-27.5		42	15.2	-4.2
11	0	-26.4		43	15.6	-3.7
12	1.5	-25.3		44	16.0	-3.2
13	3.0	-24.2		45	16.4	-2.7
14	4.0	-23.1		46	16.8	-2.2
15	4.4	-22.2		47	17.2	-1.8
16	4.8	-21.4		48	17.6	-1.4
17	5.2	-20.6		49	18.0	-1.0
18	5.6	-19.8		50	18.4	-0.6
19	6.0	-19.0		51	18.8	-0.2
20	6.4	-18.2		52	19.2	0.2
21	6.8	-17.4		53	19.6	0.6
22	7.2	-16.6		54	20.0	0.9
23	7.6	-15.9		55	20.4	1.2
24	8.0	-15.2		56	20.8	1.5
25	8.4	-14.5		57	21.2	1.8
26	8.8	-13.8		58	21.6	2.1
27	9.2	-13.1		59	22.0	2.4
28	9.6	-12.4		60	22.4	2.7
29	10.0	-11.7		61	22.8	2.9
30	10.4	-11.0		62	23.2	3.1
31	10.8	-10.4		63	23.6	3.3
32	11.2	-9.8		64	24.0	3.5

Application Information

Mute Operation

The $\overline{MUTE}$ pin is an input for controlling the output state of the PAM8007. A logic low on this pin disables the outputs, and a logic high on this pin enables the outputs. This pin may be used as a quick disable or enable of the outputs without a volume fade. Quiescent current is listed in the electrical characteristics table. The $\overline{MUTE}$ pin can be left floating due to the internal pull-up.

For the best power on/off pop performance, the amplifier should be placed in the MUTE mode prior to turning on/off the power supply.

Shutdown Operation

In order to reduce power consumption while not in use, the PAM8007 contains shutdown circuitry to turn off the amplifier's bias circuitry. The amplifier is turned off when logic low is placed on the $\overline{SHDN}$ pin. By switching the $\overline{SHDN}$ pin connected to GND, the PAM8007 supply current draw will be minimized in idle mode. The $\overline{SHDN}$ pin can be left floating due to the internal pull-up.

Line/Ear Operation

In order to control the speaker/headphone switch, the PAM8007 contains detect circuitry. When line/ear logic low, speaker actice; when logic high, earphone active.

Power Supply Decoupling

The PAM8007 is a high performance CMOS audio amplifier that requires an adequate power supply decoupling to ensure the output THD and PSRR are as low as possile. Power supply decoupling affects low frequency on the power supply leads for higher frey response. Optimum decoupling is achieved by using two capacitors of different types that target different types of noise frequency tranisients, spike, or digital hash on the line, a good low equivalent-series-resistance (ESR) ceramic capacitor, typically 1.0μF, placed as close as possible to the device V_{DD} terminal works best. For filtering lower-frequency noise signals, a large capacitor of 10μF (ceramic) or greater placed near the audio power amplifier is recommended.

Input Capacitor (C_I)

Large input capacitors are both expensive and space hungry for portable designs. Clearly, a certai sized capacitor is needed to couple in low frequencies without severe attenuation. But in many cases the speakers used in portable systems, whether internal or external, have little ability to reproduce signals below 100Hz to 150Hz. Thus, using a large input capacitor may not increase actual system performance. In this case, inout capacitor (C_I) and input resistance (R_I) of the amplifier form a high-pass filter with the corner frequency determined equation below;

$$f_C = \frac{1}{2\Pi R_I C_I}$$

In addition to system cost and size, click and pop performance is affected by the size of the input coupling capacitor, C_I. A larger inout coupling capacitor requires more charge to reach its quiescent DC voltage (nominally ½ V_{DD}). This charge comes from the internal circuit via the feedback and is apt to create pops upon device enable. Thus, by minmizing the capacitor size based on necessary low frequency response, turn-on pops can be minimized.

Analog Reference Bypass Capacitor (C_{BYP})

Analog Reference Bypass Capacitior (C_{BYP}) is the most critical capacitor and serves several important functions. During start-up or recovery from shutdown mode, C_{BYP} determines the rate at which the amplifier starts up. The second function is to reduce noise produced by the power supply caused by coupling into the output device signal. The noise is from the internal analog reference to the amplifier, which appears as degraded PSRR and THD+N.

A ceramic bypass capacitor (C_{BYP}) of 0.47μF to 1.0μF is recommended for the best THD and noise performance. Increasing the bypass capacitor reduces clicking and popping noise from power on/off and entering and leaving shutdown.

Short Circuit Protection (SCP)

The PAM8007 has short circuit protection circuitry on the outputs that prevents the device from damage when output-to-output and output-to GND short. When a short circuit is detected on the outputs, the outputs are disabled immediately. If the short was removed, the device activates again.

Application Information (cont.)

Over Temperature Protection

Thermal protection on the PAM8007 prevents the device from damage when the internal die temperature exceeds +150°C. There is a 15 degree tolerance on this trip point from device to device. Once the die temperature exceeds the thermal set point, the device outputs are disabled. This is not a latched fault. The thermal fault is cleared once the temperature of the die is reduced by +30°C. This large hysteresis will prevent motor boating sound well. The device begins normal operation at this point without external system interaction.

How to Reduce EMI (Elect ro Magnetic Interference)

A simple solution is to put an additional capacitor 1000μF at power supply terminal for power line coupling if the traces from amplifier to speakers are short (<20CM).

Most applications require a ferrite bead filter as shown at Figure 1. The ferrite filter reduces EMI around 1MHz and higher. When selecting a ferrite bead, choose one with high impedance at high frequencies, and low impedance at low frequencies (MH2012HM221-T).

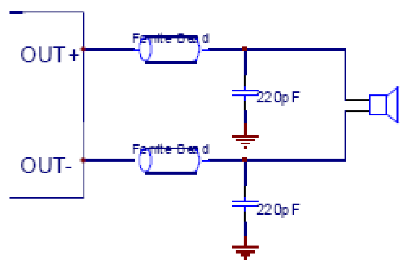


Figure 1. Ferrite Bead Filter to Reduce EMI

PCB Layout Guidelines Grounding

At this stage it is paramount to notice the necessity of separate grounds. Noise currents in the output power stage need to be returned to output noise ground and nowhere else. Were these currents to circulate elsewhere, they may get into the power supply, the signal ground, etc, worse yet, they may form a loop and radiate noise. Any of these cases results in degraded amplifier performance. The logical returns for the output noise currents associated with Class D switching are the respective PGND pins for each channel. The switch state diagram illustrates that PGND is instrumental in nearly every switch state. This is the perfect point to which the output noise ground trace should return. Also note that output noise ground is channel specific. A two channel amplifier has two seperate channels and consequently must have two seperate output noise ground traces. The layout of the PAM8007 offers separate PGND connections for each channel and in some cases each side of the bridge. Output noise grounds must be tied to system ground at the power in exclusively. Signal currents for the inputs, reference, etc need to be returned to quite ground. This ground is only tied to the signal components and the GND pin, and GND then tied to system ground.

PCB Layout Example

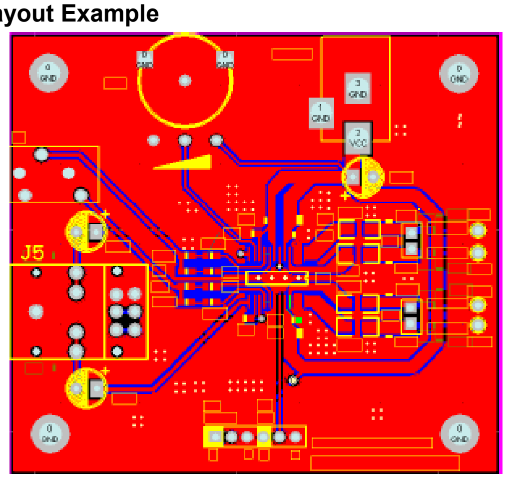


Figure 2. Top Layer

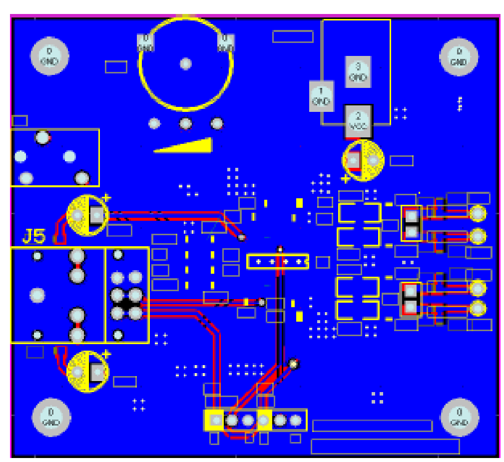
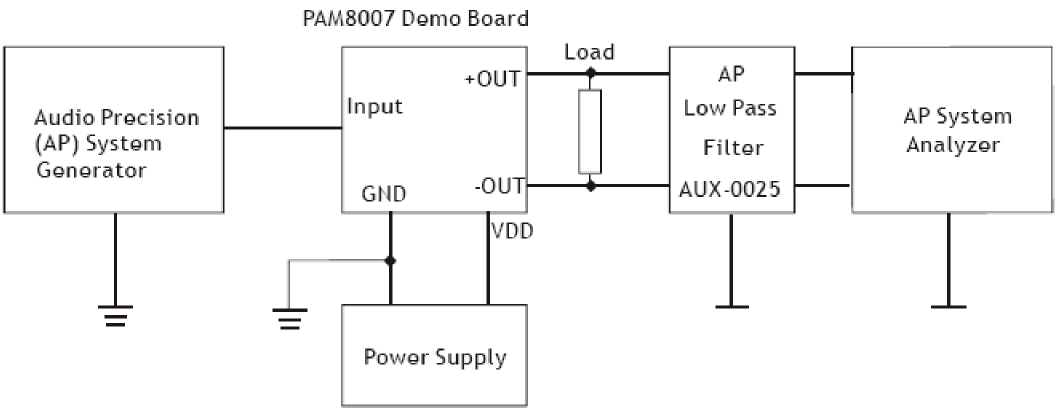


Figure 3. Bottom Layer

Application Information (cont.)

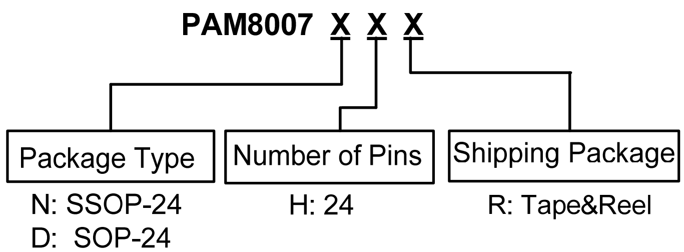
Test Setup for Performance Testing (Class D)

1. When the PAM8007 works with LC filters, it should be connected with the speaker before it's powered on, otherwise it will be damaged easily.
2. When the PAM8007 works without LC filters, it's better to add a ferrite chip bead at the outgoing line of speaker for suppressing the possible electromagnetic interference.
3. The absolute maximum rating of the PAM8007 operation voltage is 6.0V. When the PAM8007 is powered with four battery cells, it should be noted that the voltage of four new dry or alkaline batteries is over 6V, higher than its maximum operation voltage, which probably make the device damaged. Therefore, it's recommended to use either four Ni-MH (Nickel Metal Hydride) rechargeable batteries or three dry or alkaline batteries.
4. The input signal should not be too high, if too high, it will cause the clipping of output signal when increasing the volume. Because the DC volume control of the PAM8007 has big gain, it will make the device damaged.
5. When testing the PAM8007 without LC filters by using resistor instead of speaker as the output load, the test results, e.g. THD or efficiency, will be worse than those using speaker as load.



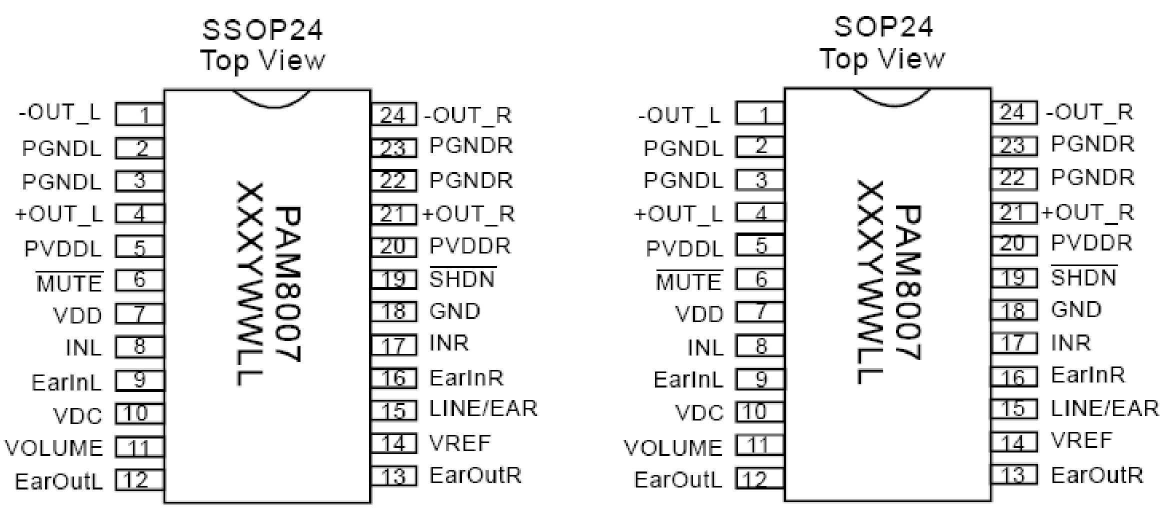
Notes: 1. The Audio Precision (AP) AUX-0025 low pass filter is necessary for class-D amplifier measurement with AP analyzer.
2. Two 22μH inductors are used in series with load resistor to emulate the small speaker for efficiency measurement.

Ordering Information



Part Number	Package Type	Standard Package
PAM8007NHR	SSOP-24	2500 Units/Tape&Reel
PAM8007DHR	SOP24	1000 Units/Tape&Reel

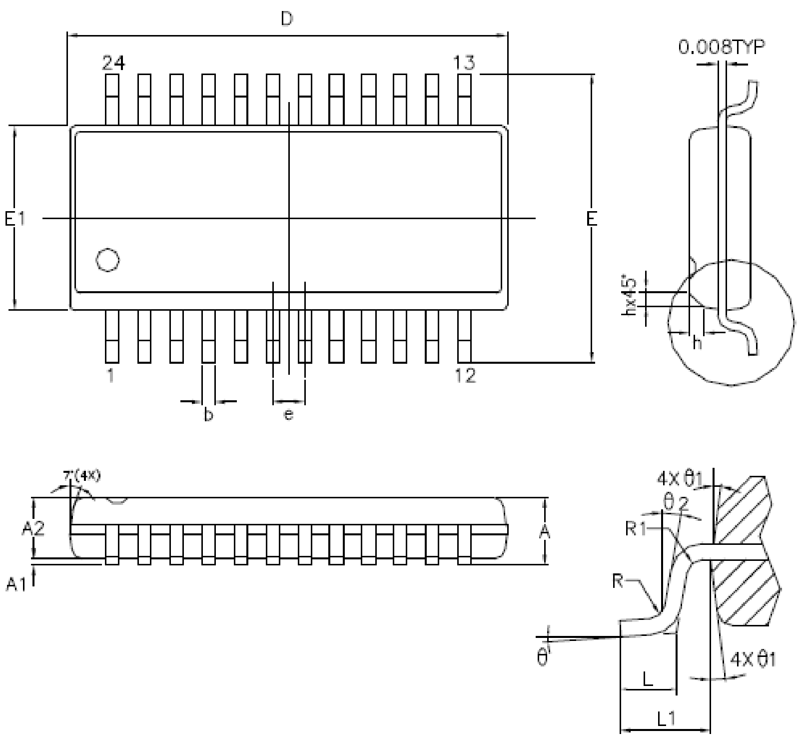
Marking Information



X: Internal Code
Y: Year
WW: Week
LL: Internal Code

Package Outline Dimensions (All dimensions in mm.)

SSOP-24

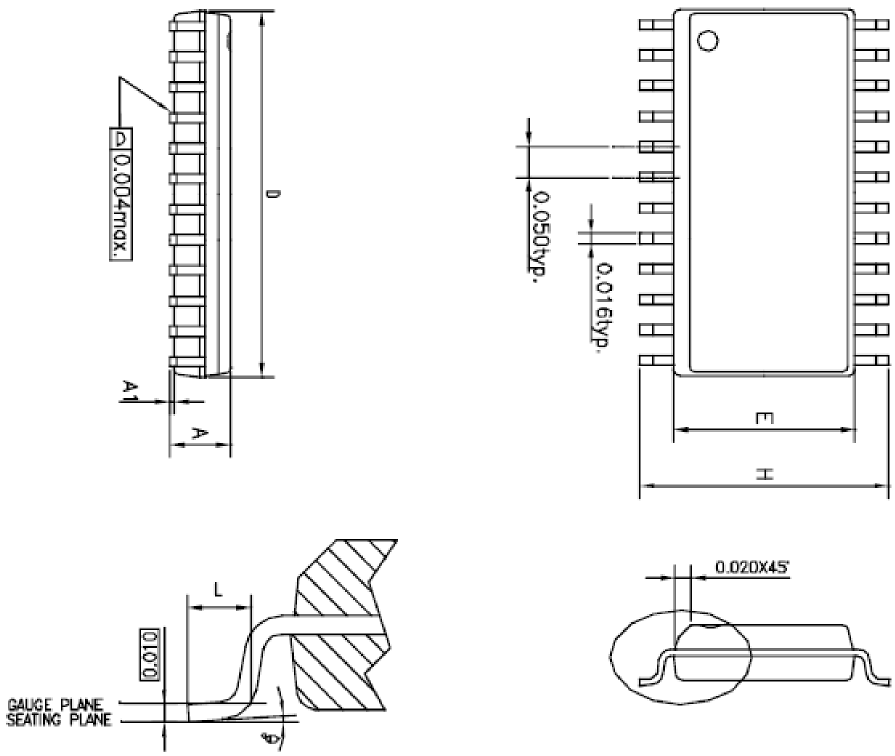


SYMBOLS	MIN.	NOM.	MAX.
A	0.053	0.061	0.069
A1	0.004	–	0.010
A2	0.049	0.057	0.065
b	0.008	0.010	0.012
D	0.335	0.341	0.347
E	0.228	0.236	0.244
E1	0.150	0.154	0.158
e	–	0.025	–
L	0.016	0.033	0.050
L1		0.041 REF	
R	0.003	–	–
R1	0.003	–	–
h	0.010	0.015	0.020
θ	0°	4°	8°
θ1	5°	10°	15°
θ2	0°	–	–

UNIT : INCH

Package Outline Dimensions (cont.) (All dimensions in mm.)

SOP-24



SYMBOLS	MIN.	NOM	MAX.
A	0.093	0.099	0.104
A1	0.004	–	0.012
D	0.599	0.600	0.614
E	0.291	0.295	0.299
H	0.394	0.406	0.419
L	0.016	0.035	0.050
θ°	0	–	8

UNIT : INCH

NOTES:

1.JEDEC OUTLINE : MS-013 AD

2.DIMENSIONS "D" DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.MOLD FLASH, PROTRUSIONS AND GATE BURRS SHALL NOT EXCEED .15mm (.006in) PER SIDE.

3.DIMENSIONS "E" DOES NOT INCLUDE INTER-LEAD FLASH, OR PROTRUSIONS. INTER-LEAD FLASH AND PROTRUSIONS SHALL NOT EXCEED .25mm (.010in) PER SIDE.

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