



PAM8403

Filterless 3W Class-D Stereo Audio Amplifier

Key Features

- 3W Output at 10% THD with a 4Ω Load and 5V Power Supply
- Filterless, Low Quiescent Current and Low EMI
- Low THD+N
- Superior Low Noise
- Efficiency up to 90%
- 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
- Cellular Phones/Speaker Phones

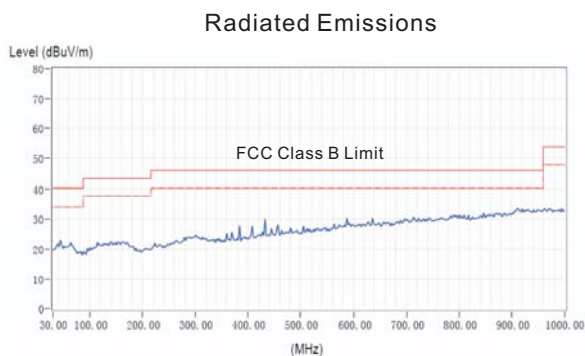
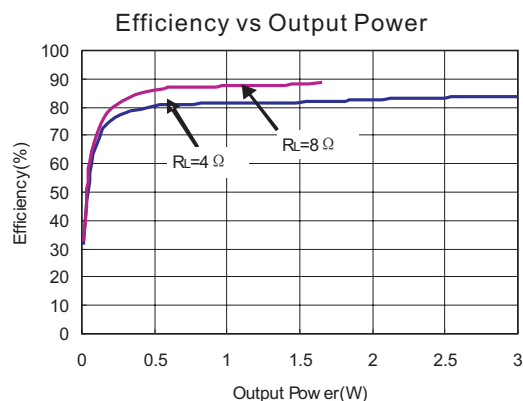
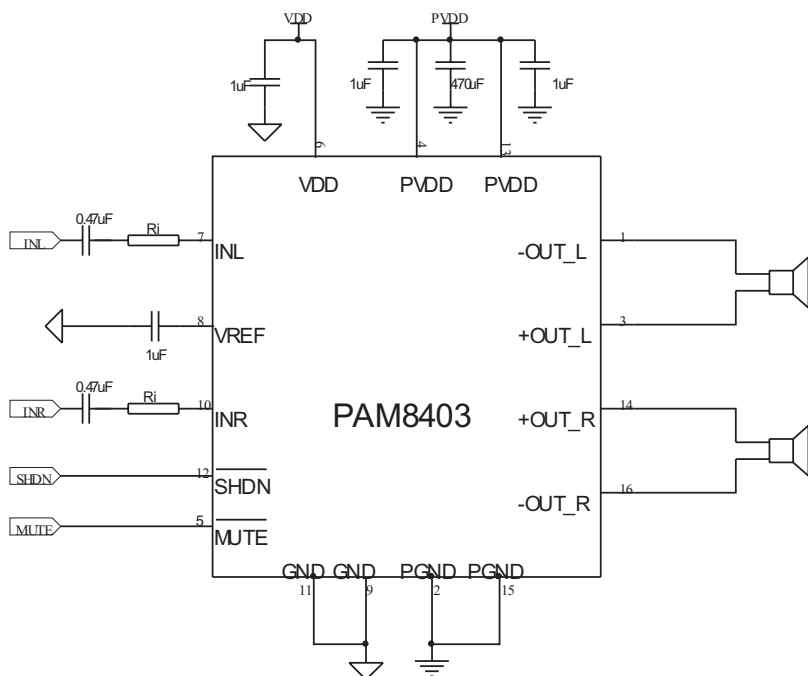
General Description

The PAM8403 is a 3W, class-D audio amplifier. It offers low THD+N, allowing it to produce high-quality sound reproduction. The new filterless architecture allows the device to drive the speaker directly, without needing low-pass output filters, which will save the system cost and PCB area.

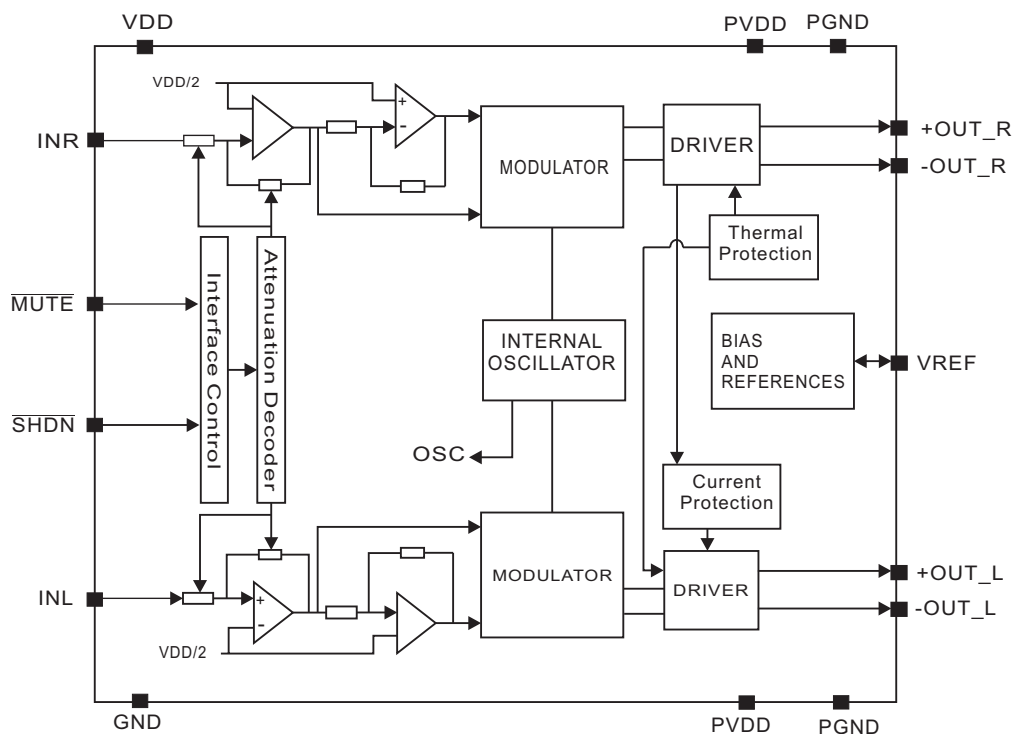
With the same numbers of external components, the efficiency of the PAM8403 is much better than class-AB cousins. It can extend the battery life, ideal for portable applications.

The PAM8403 is available in a DIP-16 and SOP-16 packages.

Typical Application

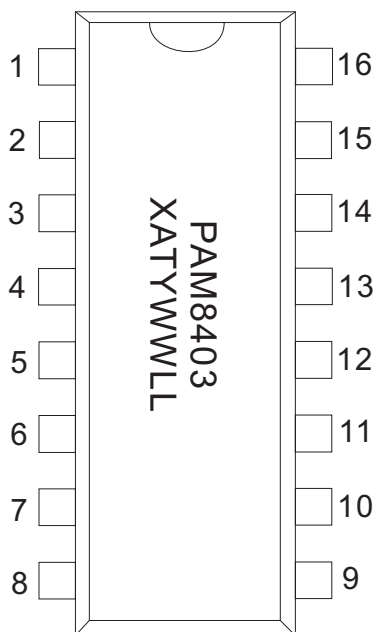


Block Diagram

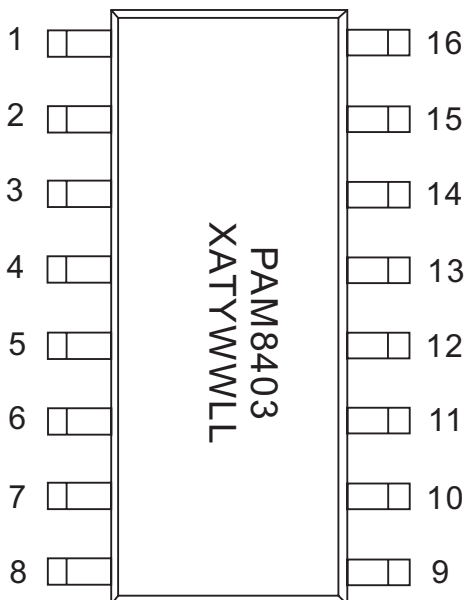


Pin Configuration & Marking Information

Top View
DIP-16



Top View
SOP-16



X: Internal Code
A: Assembly Code
T: Testing Code
Y: Year
WW: Weekly
LL: Internal Code



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Pin Descriptions

Pin Number	Pin Name	Description
1	-OUT_L	Left Channel Negative Output
2	PGND	Power GND
3	+OUT_L	Left Channel Positive Output
4	PVDD	Power VDD
5	$\overline{\text{MUTE}}$	Mute Control Input (active low)
6	VDD	Analog VDD
7	INL	Left Channel Input
8	VREF	Internal analog reference, connect a bypass capacitor from VREF to GND
9	GND	Analog GND
10	INR	Right Channel Input
11	GND	Analog GND
12	$\overline{\text{SHDN}}$	Shutdown Control Input(active low)
13	PVDD	Power VDD
14	+OUT_R	Right Channel Positive Output
15	PGND	Power GND
16	-OUT_R	Right Channel Negative Output

Absolute Maximum Ratings

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.

Supply Voltage	5.5V	Operation Junction Temperature.....	-40°C to 125°C
Operation Temperature Range.....	-40°C to 85°C	Storage Temperature.....	-65°C to 150°C
Maximum Junction Temperature.....	150°C	Soldering Temperature.....	300°C, 5sec

Recommended Operating Conditions

Supply voltage Range.....	2.5V to 5V	Junction Temperature Range.....	-40°C to 125°C
Operation Temperature Range.....	-40°C to 85°C		

Thermal Information

Parameter	Symbol	Package	Maximum	Unit
Thermal Resistance (Junction to Ambient)	θ_{JA}	DIP-16	90	°C/W
		SOP-16	110	



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Electrical Characteristic

$V_{DD}=5V$, Gain = 18.5dB, $R_L=8\Omega$ (Note 1), $T_A=25^\circ C$, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Voltage Range	V_{DD}		2.5		5	V
Quiescent Current	I_Q	No Load		10	15	mA
		$R_L=8\Omega$		11		
		$R_L=4\Omega$		12		
Mute Current	I_{MUTE}	$V_{MUTE}=0V$		1.5	3	mA
Shutdown Current	I_{SHDN}	$V_{SHDN}=0V$		45	100	μA
\overline{SHDN} Input High	V_{SH}		1.2			V
\overline{SHDN} Input Low	V_{SL}	Note 2			0.5	
\overline{MUTE} Input High	V_{MH}		1.2			V
\overline{MUTE} Input Low	V_{ML}	Note 3			0.5	
Output Offset Voltage	V_{OS}	No Load		10	30	mV
Drain-Source On-State Resistance	$R_{DS(ON)}$	$I_{DS}=0.5A$	P MOSFET	0.3	0.40	Ω
			N MOSFET	0.22	0.35	
Output Power	P_O	THD+N=10%, 1kHz	$R_L=8\Omega$	1.55	1.7	W
			$R_L=4\Omega$	2.85	3.0	
Total Harmonic Distortion Plus Noise	THD+N	$R_L=8\Omega$, $P_O=0.25W$		0.08		%
		$R_L=8\Omega$, $P_O=1.1W$		0.27	1.0	
		$R_L=4\Omega$, $P_O=0.35W$		0.08		
		$R_L=4\Omega$, $P_O=2.0W$		0.3	1.0	
Power Supply Ripple Rejection	PSRR	No input, $f=1KHz$, $V_{pp}=200mV$	45	55		dB
Channel Separation	CS	$P_O=1W$, $R_L=4\Omega$	60	80		dB
Oscillator Frequency	f_{OSC}	$P_O=1W$, $R_L=8\Omega$	250	350	450	kHz
Efficiency	η	$P_O=1.7W$, $f=1kHz$, $R_L=8\Omega$	85	89		%
		$P_O=3.0W$, $f=1kHz$, $R_L=4\Omega$	80	83		%
Signal Noise Ratio	SNR	$f=20$ to $20KHz$	$R_L=4\Omega$	65	80	dB
			$R_L=8\Omega$	65	80	dB
Over Temperature Protection	OTP			120		$^\circ C$
Over Temperature Hysteresis	OTH			40		$^\circ C$

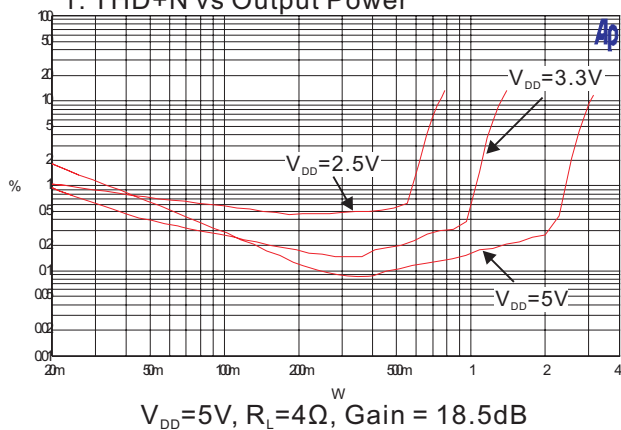
Note 1: All the loads here are delicate to use for speaker.

Note 2: Grounded or $<0.9V$ to Shutdown

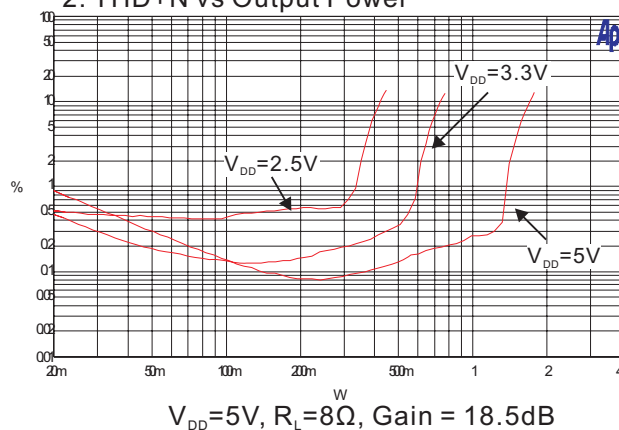
Note 3: Grounded or $<0.9V$ to Mute

Typical Operating Characteristics ($T_A=25^\circ\text{C}$)

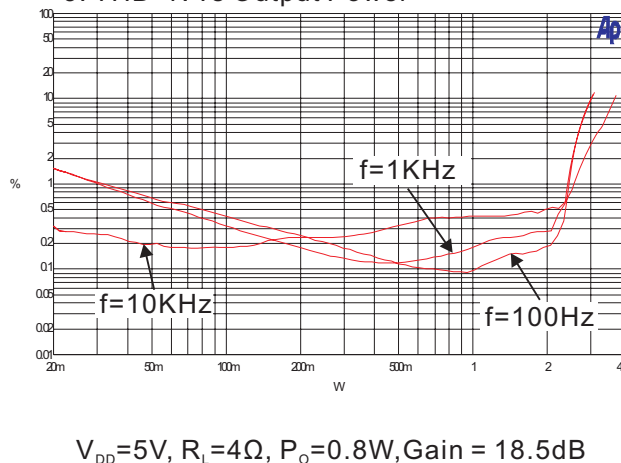
1. THD+N vs Output Power



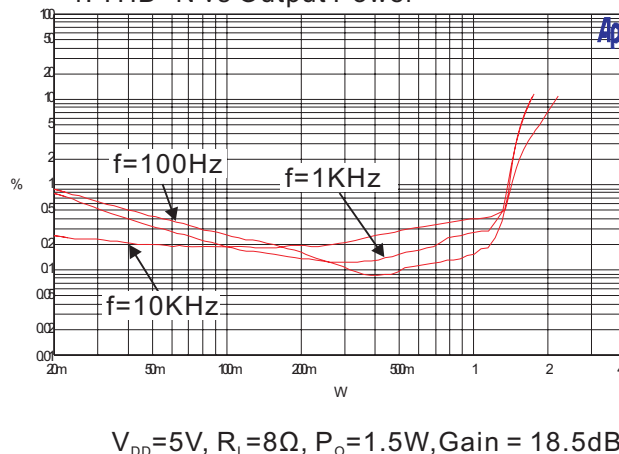
2. THD+N vs Output Power



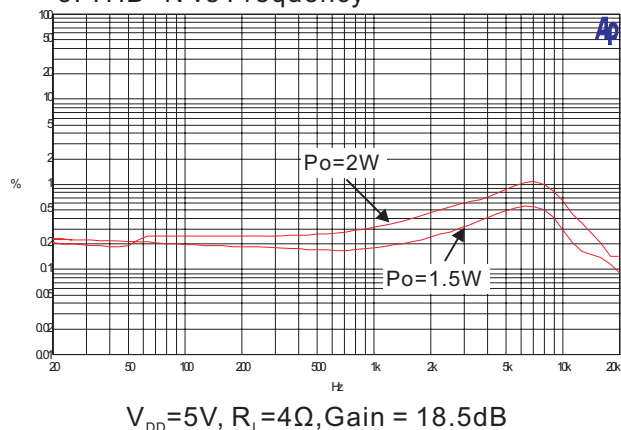
3. THD+N vs Output Power



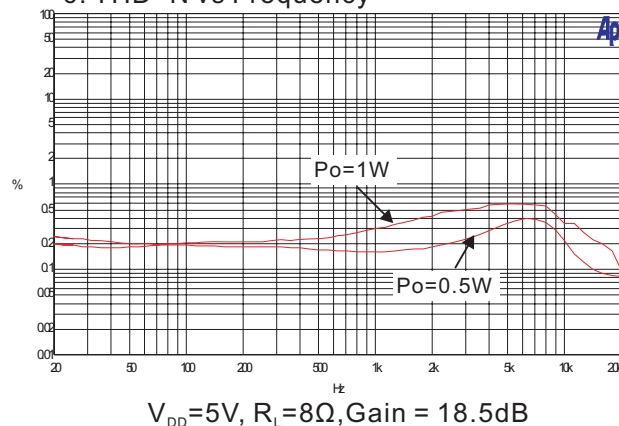
4. THD+N vs Output Power



5. THD+N vs Frequency

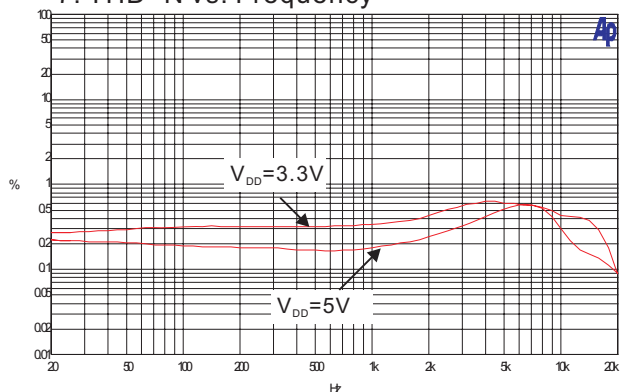


6. THD+N vs Frequency



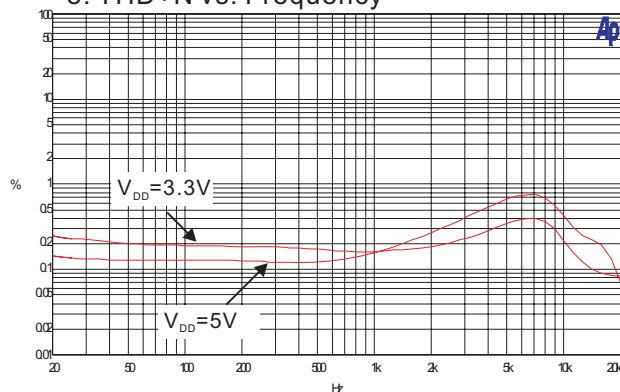
Typical Operating Characteristics(continued)

7. THD+N vs. Frequency



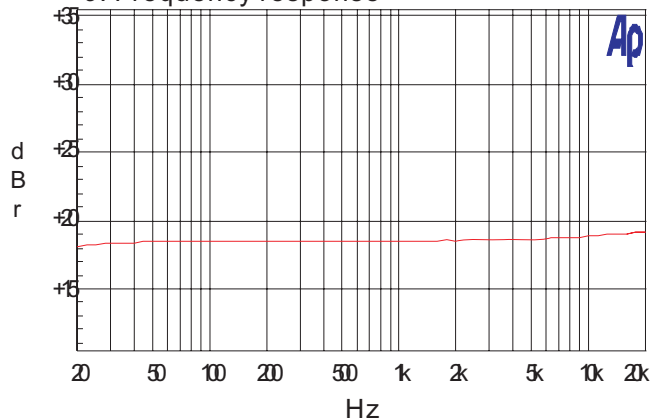
$P_o=0.8W, R_L=4\Omega, \text{Gain}=18.5\text{dB}$

8. THD+N vs. Frequency



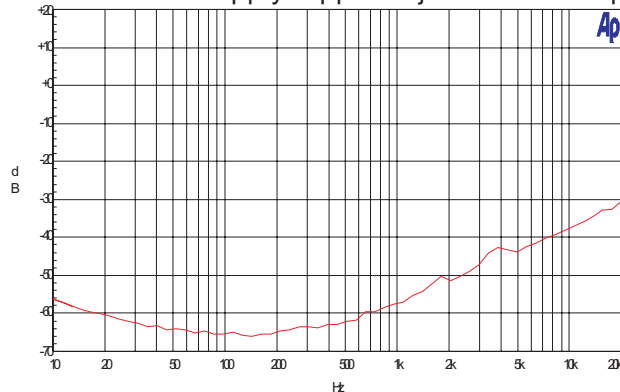
$P_o=0.1W, R_L=8\Omega, \text{Gain}=18.5\text{dB}$

9. Frequency response



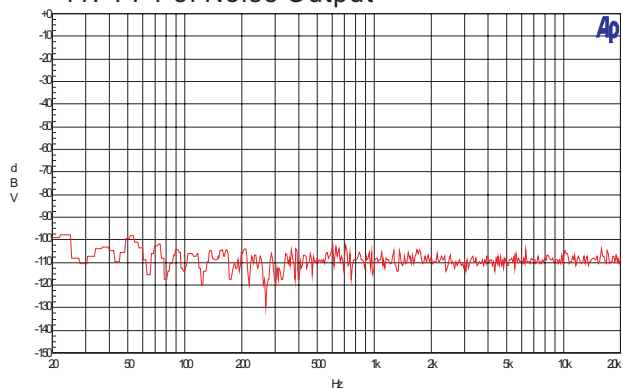
$V_{DD}=5V, \text{Gain}=18.5\text{dB}$

10. Power Supply Ripple Rejection VS Frequency



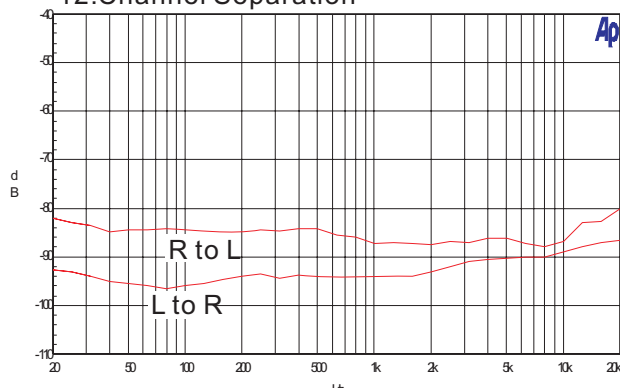
$V_{DD}=5V$ with 200mVpp Ripple

11. FFT of Noise Output



$V_{DD}=5V, \text{Gain}=18.5\text{dB}$

12. Channel Separation



$V_{DD}=5V, R_L=4\Omega, P_o=1.0W, \text{Gain}=18.5\text{dB}$

Application Notice

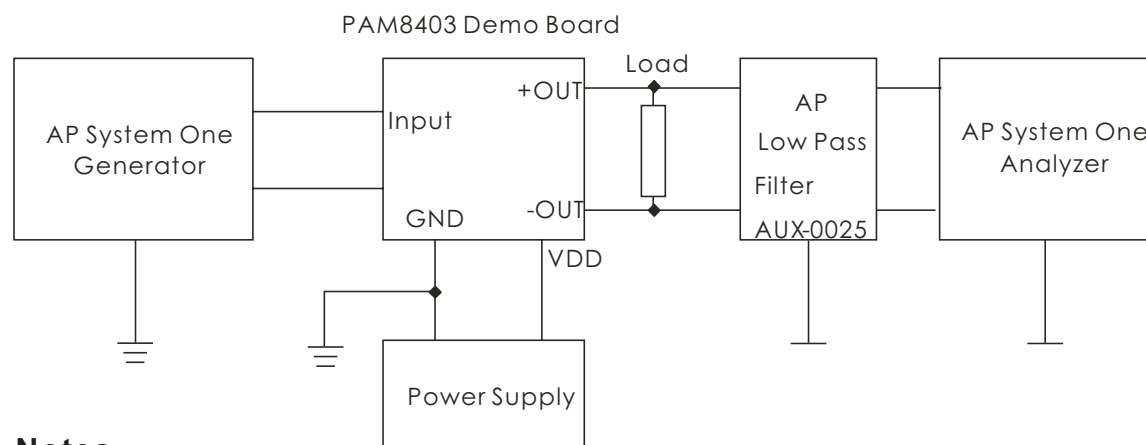
1. When the PAM8403 works with LC filters, it should be connected with the speaker before it's powered on, otherwise it will be damaged easily.
2. When the PAM8403 works without LC filters, it's better to add a ferrite chip bead at the outgoing line of speaker for suppressing the possible electromagnetic interference.
3. The absolute maximum rating of the PAM8403 operation voltage is 5.5V. When the PAM8403 is powered with 4 battery cells, it's worth noting that the voltage of 4 new dry or alkaline batteries is over 6V, higher than its maximum operation voltage, which will probably

make the device damaged. Therefore, it's recommended to use either 4 Ni-MH (Nickel Metal Hydride) rechargeable batteries or 3 dry or alkaline batteries.

4. It should not make the input signal too high, which will cause the clipping of output signal when increasing the volume. Because the digital volume control of the PAM8403 has big gain, it will make the device damaged.

5. When testing the PAM8403 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 of using speaker as load.

Test Setup for Performance Testing



Notes

1. The AP AUX-0025 low pass filter is necessary for every class-D amplifier measurement done by AP analyzer.
2. Two 22uH inductors are used in series with load resistor to emulate the small speaker for efficiency measurement.



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Application Information

Maximum Gain

As shown in block diagram (page 2), the PAM8403 has two internal amplifiers stage. The first stage's gain is externally configurable, while the second stage's is internally fixed in a fixed-gain, inverting configuration. The closed-loop gain of the first stage is set by selecting the ratio of R_f to R_i , while the second stage's gain is fixed at 1.4x. The output of amplifier one serves as the input to amplifier two which results in both amplifiers producing signals identical in magnitude, but out of phase by 180°. Consequently, the differential gain for the IC is

$$A_{VD} = 20 \cdot \log [2 \cdot (R_f/R_i) \cdot 1.4]$$

The PAM8403 sets maximum $R_f = 85K\Omega$, minimum $R_i = 15K\Omega$, so the maximum closed-gain is 24dB.

Mute Operation

The \overline{MUTE} pin is an input for controlling the output state of the PAM8403. 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 characteristic table. The \overline{MUTE} pin can be left floating due to the pull-up internal.

Shutdown operation

In order to reduce power consumption while not in use, the PAM8403 contains shutdown circuitry that is used to turn off the amplifier's bias circuitry. This shutdown feature turns the amplifier off when logic low is placed on the \overline{SHDN} pin. By switching the \overline{SHDN} pin connected to GND, the PAM8403 supply current draw will be minimized in idle mode. The \overline{SHDN} pin can be left floating due to the pull-up internal.

Power supply decoupling

The PAM8403 is a high performance CMOS audio amplifier that requires adequate power supply decoupling to ensure the output THD and PSRR are as low as possible. Power supply decoupling is affecting low frequency response. Optimum decoupling is achieved by using two capacitors of different types that target different types of noise on the power supply leads. For higher frequency transients, spikes, or digital

hash on the line, a good low equivalent-series-resistance (ESR) ceramic capacitor, typically 1.0 μ F, placed as close as possible to the device V_{DD} terminal works best. For filtering lower-frequency noise signals, a larger capacitor of 20 μ F (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 certain sized capacitor is needed to couple in low frequencies without severe attenuation. But in many cases the speakers used in portable systems, whether internal or external, have little ability to reproduce signals below 100Hz to 150Hz. Thus, using a large input capacitor may not increase actual system performance. In this case, input 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 input coupling capacitor requires more charge to reach its quiescent DC voltage (nominally 1/2 V_{DD}). This charge comes from the internal circuit via the feedback and is apt to create pops upon device enable. Thus, by minimizing the capacitor size based on necessary low frequency response, turn-on pops can be minimized.

Analog Reference Bypass Capacitor (C_{BYP})

The Analog Reference Bypass Capacitor (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 drive signal. This noise is from the internal analog reference to the amplifier, which appears as degraded PSRR and THD+N.

Bypass capacitor (C_{BYP}) values of 0.47 μ F to 1.0 μ F ceramic is recommended for the best THD and noise performance. Increasing the bypass capacitor reduces clicking and popping noise

Application Information(continued)

from power on/off and entering and leaving shutdown.

Power On/Off Pop noise Reducing

Power on pop noise reducing: The PAM8403 contains circuitry to minimize turn-on pop noise. In this case, turn-on refers to either power supply turn-on or device coming out shutdown mode. When the device is turning on, the amplifiers are internally muted. An internal current source ramps up the voltage of VREF pin. The device will remain in mute mode until the VREF pin has reached its half supply voltage, $1/2 V_{DD}$. As soon as the VREF node is stable, the device will become fully operational.

Power off pop noise reducing: for the best power-off pop performance, the amplifier should be placed in the mute /shutdown mode prior to removing the power supply voltage. An external circuit shows in figure 2 also can minimize the power off pop noise: the V_{TH} is set around $1.3V @ V_{DD}=5V$ which is a little higher than the mute/shutdown threshold voltage, R1 reduce the internal resistor temperature coefficient and capacitor C speeds up the response. Note that this circuit can only work in between $V_{DD}=4.5V$ to $5.5V$, otherwise the PAM8403 can not work, other than the ratio of the resistor divider needs to be changed.

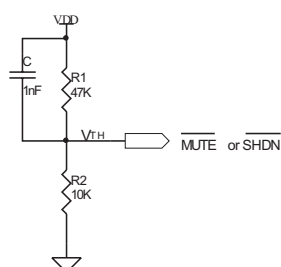


Figure 2: External Circuit to reduce power off pop noise

Under Voltage Lock-out (UVLO)

The PAM8403 incorporates circuitry designed to detect when the supply voltage is low. When the supply voltage drops to 2.0V or below, the PAM8403 outputs are disable, and the device comes out of this state and starts to normal functional until $V_{DD} \geq 2.2V$.

Short Circuit Protection (SCP)

The PAM8403 has short circuit protection circuitry on the outputs that prevents damage to the device during output-to-output and output-to-GND short. When a short circuit is detected on the outputs, the outputs are disable immediately. If the short was removed, the device activates again.

Over Temperature Protection

Thermal protection on the PAM8403 prevents damage to the device when the internal die temperature exceeds $120^{\circ}C$. 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 $40^{\circ}C$. This large hysteresis will prevent motor boating sound well and the device begins normal operation at this point with no external system interaction.

How to Reduce EMI (Electro Magnetic Interference)

A simple solution is to put an additional capacitor 1000uF 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 which shows at Figure 3. The ferrite filter reduces EMI around 1 MHz and higher. When selecting a ferrite bead, choose one with high impedance at high frequencies, but low impedance at low frequencies.

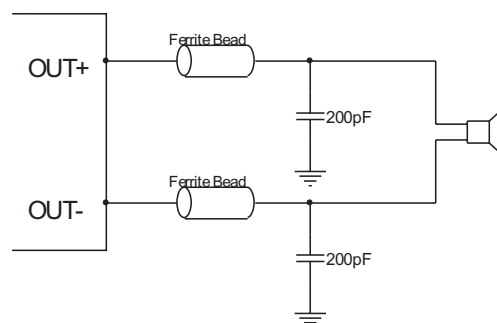


Figure 3: Ferrite Bead Filter to reduce EMI

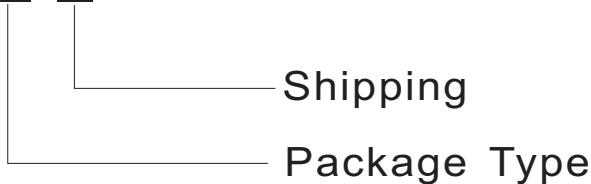


PAM8403

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Ordering Information

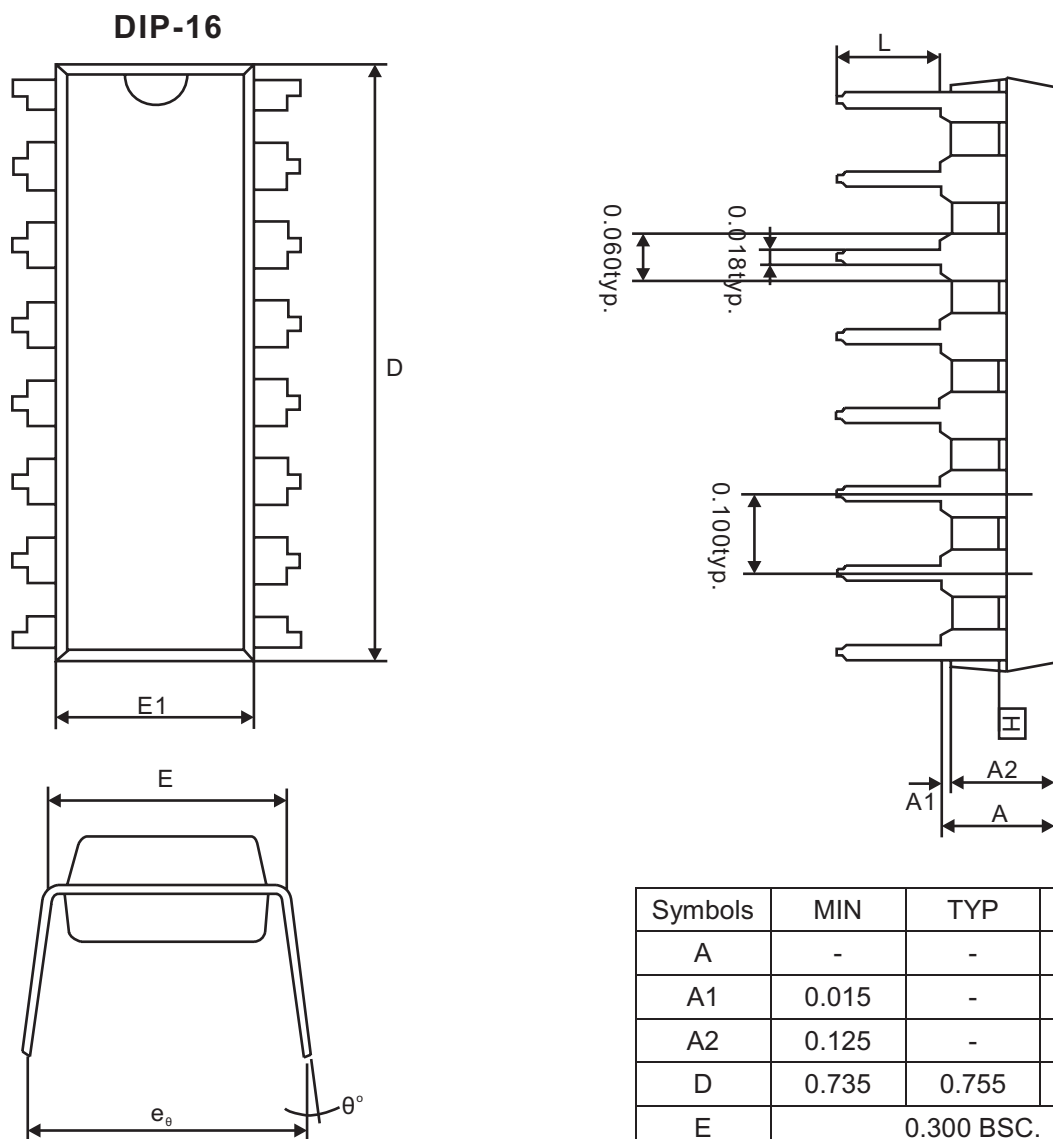
PAM8403 X X



Part Number	Marking	Package Type	Standard Package
PAM8403QT	PAM8403 XATYWWLL	DIP-16	30 Units/Tube
PAM8403DT	PAM8403 XATYWWLL	SOP-16	50 Units/Tube
PAM8403DR	PAM8403 XATYWWLL	SOP-16	2,500 Units/Tape&Reel

Please consult PAM sales office or authorized Rep. /Distributor for detailed ordering information.

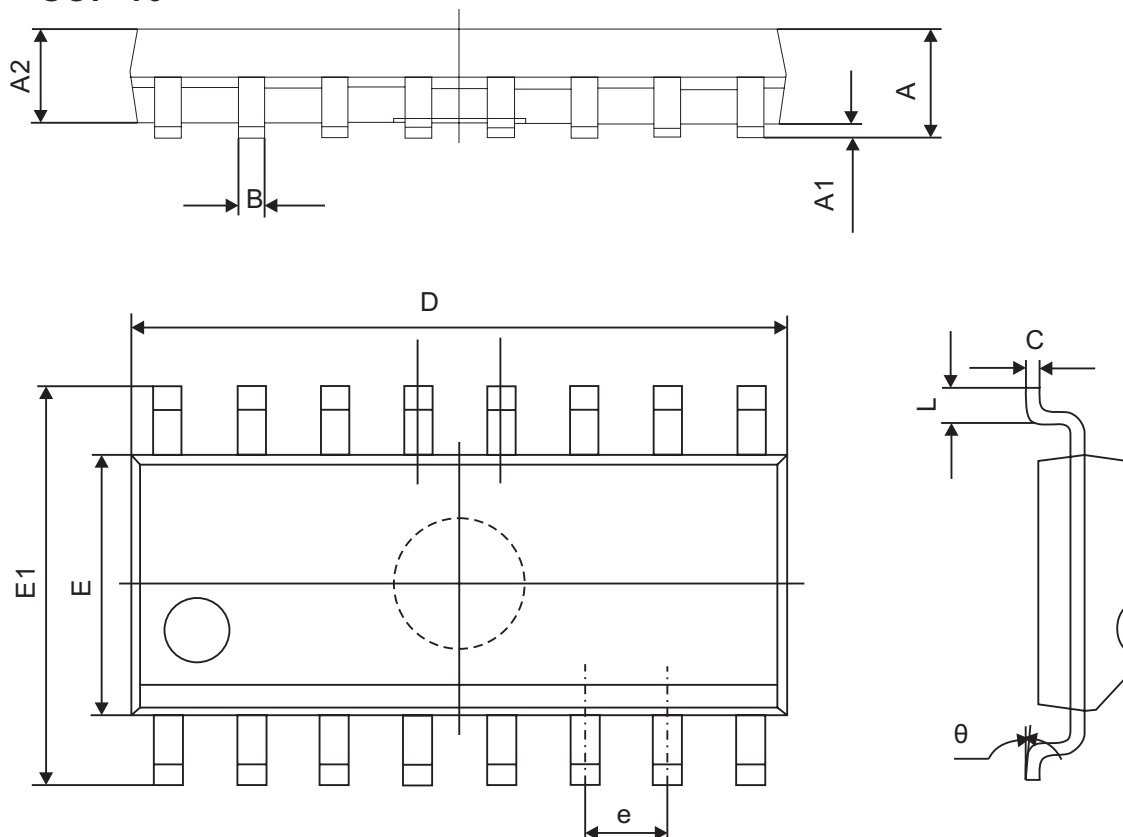
Outline Dimension



Unit: Inch

Outline Dimension

SOP-16



Symbol	Dimensions Millimeters	
	Min	Max
A	1.350	1.750
A1	0.100	0.250
A2	1.350	1.550
B	0.330	0.510
C	0.190	0.250
D	9.800	10.000
E	3.800	4.000
E1	5.800	6.300
e	1.270(TYP)	
L	0.400	1.270
θ	0°	8°

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