ALTERNATIVE 5W STEREO AUDIO AMPLIFIER

Description

The PAM8406 is a 5W audio amplifier with an alternative option between Class-D and Class-AB output which makes PAM8406 very ideally for the applications efficiency-EMI compatible.

PAM8406 offers low THD+N, high SNR allowing it to achieve high-quality sound reproduction. The fully differential output wi th new filter less architecture (Class-D Mode) allows the device to drive the speaker directly, requiring no low-pass output filters and DC blocking capacitors, thus to save the system cost and PCB area.

The efficiency of the PAM8406 is up to 90%. It can extend the battery life, ideally for portable applications. The PAM8406 is fully protected against faults with short circuit protection and thermal protection.

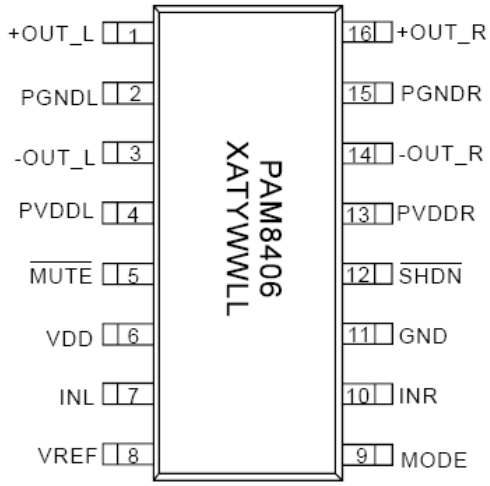
The PAM8406 is available in SOP-16L/SOP-16(EP) package.

Features

- Alternative Output: Class-D or Class-AB
- 5W Output at 10% THD with a 2Ω Load and 5V Power Supply at Class-D Mode
- 3W Output at 10% THD with a 4Ω Load and 5V Power Supply
- Filterless, Low Quiescent Current and No EMI
- Low THD+N at Fully Output Range
- Superior Low Noise
- Efficiency up to 90% with Class-D Mode
- No Pop At Turn-on/off
- Fully Short Circuit Protection With Auto Recovery
- Thermal Shutdown
- Few External Components to Save the Space and Cost
- SOP-16L/SOP-16(EP) Package

Pin Assignments

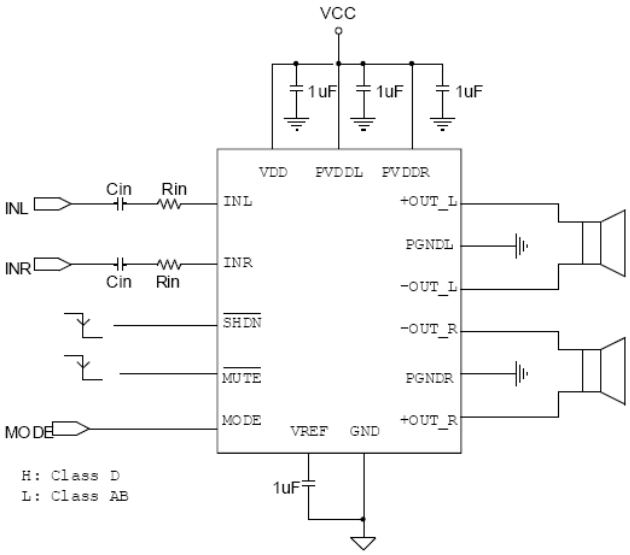
Top View
SOP-16/SOP-16(EP)



Applications

- LCD TVs
- Mutimedia Speakers
- AM/FM System
- DABs

Typical Applications Circuit



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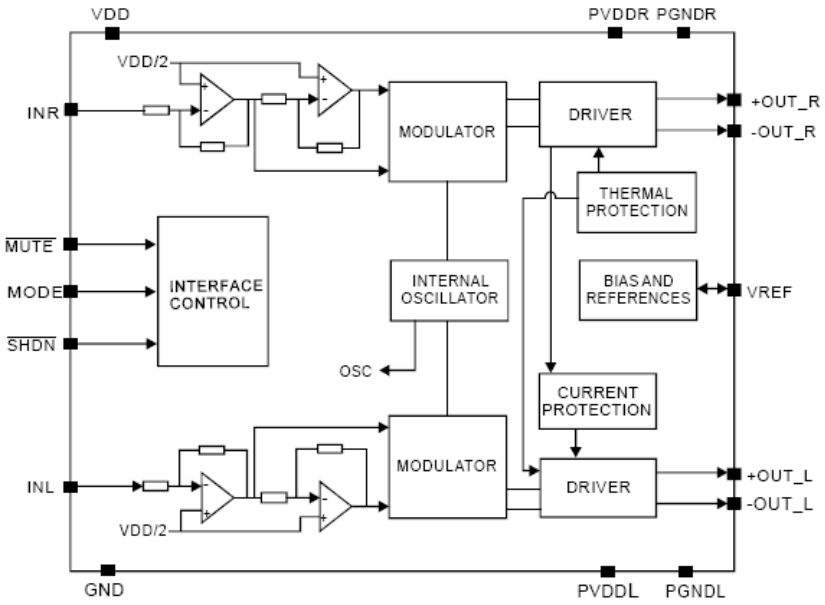
Pin Descriptions

Pin Number	Pin Name	Function
1	+OUT_L	Left Channel Positive Output
2	PGNDL	Power GND
3	-OUT_L	Left Channel Negative Output
4	PVDDL	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	MODE	High: Class-D; Low: Class-AB
10	INR	Right Channel Input
11	GND	Analog GND
12	$\overline{\text{SHND}}$	Shutdown Control Input (active low)
13	PVDDR	Power VDD
14	-OUT_R	Right Channel Negative Output
15	PGNDR	Power GND
16	+OUT_R	Right Channel Positive Output

Functional Block Diagram



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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} +0.3V	
Operation Temperature Range	-40 to +85	°C
Maximum Junction Temperature	150	
Operation Junction Temperature	-40 to +125	
Storage Temperature	-65 to +150	
Soldering Temperature	300, 5 sec	

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

Parameter	Rating	Unit
Supply Voltage Range	2.5 to 5.5	V
Operation Temperature Range	-40 to +85	°C
Junction Temperature Range	-40 to +125	°C

Thermal Information

Parameter	Package	Symbol	Max	Unit
Thermal Resistance (Junction to Ambient)	SOP-16	θ_{JA}	110	°C/W
Thermal Resistance (Junction to Case)	SOP-16	θ_{JC}	23	

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Electrical Characteristics

(@T_A = +25°C, V_{DD} = 5V, Gain = 24dB, R_L = 8Ω, both Class-AB and D mode, unless otherwise specified.)

Symbol	Parameter	Test Conditions		Min	Typ	Max	Units
V_{DD}	Supply Voltage			2.5		5.5	V
P_O	Output Power	THD+N = 10%, f = 1KHz, R_L = 2Ω (Class-D)	V_{DD} = 5.0V		5.0		W
			V_{DD} = 3.6V		2.6		
			V_{DD} = 2.5V		1.3		
		THD+N = 1%, f = 1KHz, R_L = 2Ω (Class-D)	V_{DD} = 5.0V		4.0		W
			V_{DD} = 3.6V		2.0		
			V_{DD} = 2.5V		1.0		
		THD+N = 10%, f = 1KHz, R_L = 4Ω	V_{DD} = 5.0V		3.14		W
			V_{DD} = 3.6V		1.5		
			V_{DD} = 2.5V		0.76		
		THD+N = 1%, f = 1KHz, R_L = 4Ω	V_{DD} = 5.0V		2.55		W
			V_{DD} = 3.6V		1.45		
			V_{DD} = 2.5V		0.63		
		THD+N = 10%, f = 1KHz, R_L = 8Ω	V_{DD} = 5.0V		1.8		W
			V_{DD} = 3.6V		0.92		
			V_{DD} = 2.5V		0.44		
		THD+N = 1%, f = 1KHz, R_L = 8Ω	V_{DD} = 5.0V		1.6		W
			V_{DD} = 3.6V		0.76		
			V_{DD} = 2.5V		0.36		
THD+N	Total Harmonic Distortion Plus Noise	V_{DD} = 5.0V, P_O = 0.1W to 1W , R_L = 8Ω	f = 1kHz		0.15		%
		V_{DD} = 3.6V, P_O = 0.05W to 0.5W, R_L = 8Ω			0.11		
		V_{DD} = 5.0V, P_O = 0.1W to 2W, R_L = 4Ω	f = 1kHz		0.15		%
		V_{DD} = 3.6V, P_O = 0.05W to 2W, R_L = 4Ω			0.11		
		V_{DD} = 5.0V, P_O = 0.1W to 2W, R_L = 2Ω (Class-D)	f = 1kHz		0.15		%
		V_{DD} = 3.6V, P_O = 0.05W to 1W, R_L = 2Ω (Class-D)			0.11		
G_V	Closed Loop Gain	V_{DD} = 3V to 5V					dB
PSRR	Power Supply Ripple Rejection	V_{DD} = 5.0V, Inputs AC-Grounded with C_{IN} = 0.47μF	f = 100Hz		-70		dB
			f = 1kHz		-65		
C_S	Crosstalk	V_{DD} = 5.0V, P_O = 0.5W, R_L = 8Ω, G_V = 24db	f = 1kHz		-95		dB
SNR	Signal-to-Noise Ratio	V_{DD} = 5.0V, THD = 1%, G_V = 24db	f = 1kHz		90		dB
V_N	Output Noise	V_{DD} = 5.0V, Inputs AC-Grounded	A-Weighting		100		μV
			No A-Weighting		150		
η	Efficiency	R_L = 8Ω, THD = 10%	Class D Mode f = 1kHz		90		%
		R_L = 4Ω, THD = 10%			85		
		R_L = 2Ω, THD = 10%			80		
I_Q	Quiescent Current	V_{DD} = 5.0V	No Load		10		mA
		V_{DD} = 3.6V			8		
		V_{DD} = 2.5V			6		
	Quiescent Current	V_{DD} = 5.0V	No Load		25		mA
		V_{DD} = 3.6V			15		
		V_{DD} = 2.5V			10		

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Electrical Characteristics (cont.)

(@T_A = +25°C, V_{DD} = 5V, Gain = 24dB, R_L = 8Ω, both Class-AB and D mode, unless otherwise specified.)

Symbol	Parameter	Test Conditions		Min	Typ	Max	Units
I_{MUTE}	Muting Current	V_{DD} = 5.0V	V_{MUTE} = 0.3V		2.4		mA
I_{SD}	Shutdown Current	V_{DD} = 2.5V to 5.5V	V_{SD} = 0.3V		< 1		μA
$R_{DS(ON)}$	Static Drain-to-Source On-State Resistor	I_{DS} = 500mA, V_{GS} = 5V	PMOS		180		mΩ
			NMOS		140		
f_{SW}	Switching Frequency	V_{DD} = 2.5V to 5.5V	Class-D		250		kHz
V_{OS}	Output Offset Voltage	Input AC-GND, V_{DD} = 5.0V			10		mV
V_{IH}	Enable Input High Voltage	V_{DD} = 5.0V		1.4			V
V_{IL}	Enable Input Low Voltage	V_{DD} = 5.0V				0.4	
V_{IH}	MUTE Input High Voltage	V_{DD} = 5.0V		1.4			V
V_{IL}	MUTE Input Low Voltage	V_{DD} = 5.0V				0.4	
V_{IH}	MODE Input High Voltage	V_{DD} = 5.0V		1.4			V
V_{IL}	MODE Input Low Voltage	V_{DD} = 5.0V				0.4	
OTP	Over Temperature Protection	No Load, Junction Temperature	V_{DD} = 5.0V		150		°C
OTH	Over Temperature Hysterisis				30		

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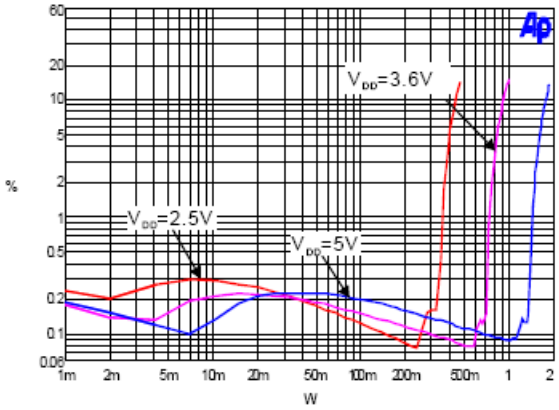
Typical Performance Characteristics

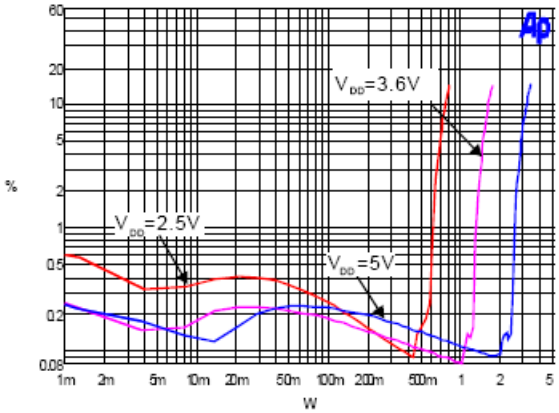
(@T_A = +25°C, V_{DD} = 5V, Gain = 24dB, R_L = 8Ω, both Class-AB and D mode, unless otherwise specified.)

1. THD+N vs Output Power



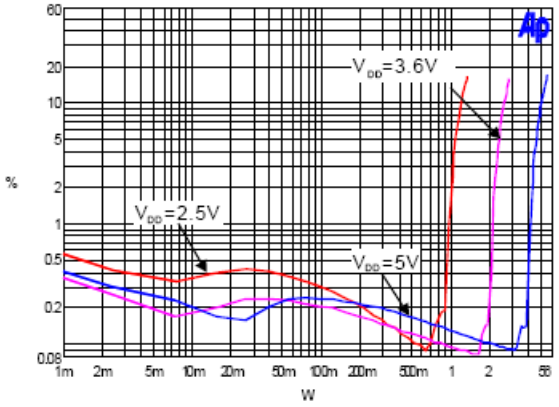
Class D, R_L=8Ω, f=1kHz

2. THD+N vs Output Power



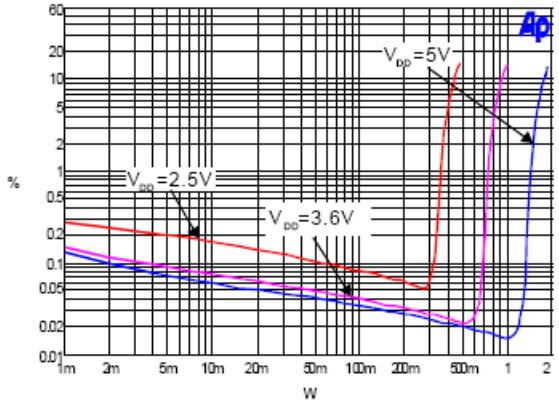
Class D, R_L=4Ω, f=1kHz

3. THD+N vs Output Power



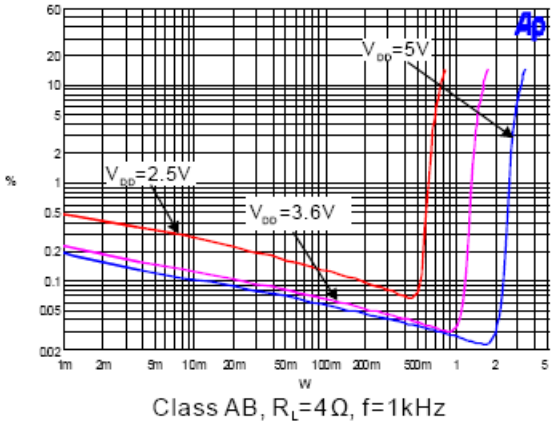
Class D, R_L=2Ω, f=1kHz

4. THD+N vs Output Power



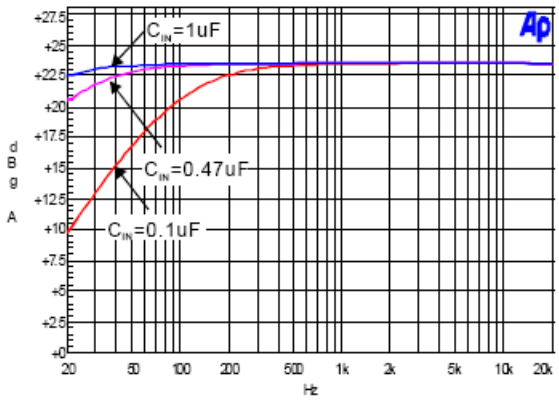
Class AB, R_L=8Ω, f=1kHz

5. THD+N vs Output Power



Class AB, R_L=4Ω, f=1kHz

6. Frequency Response



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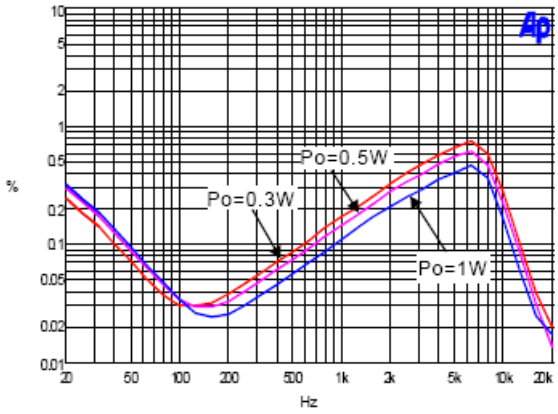
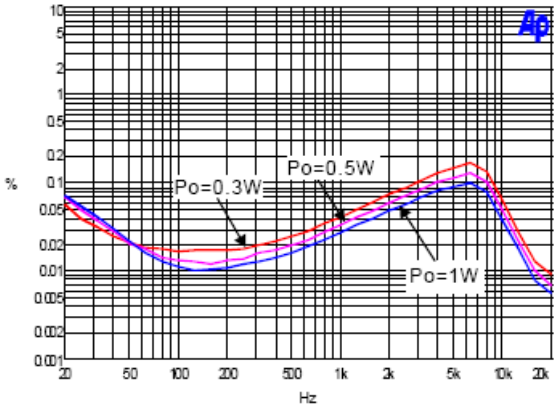
Typical Performance Characteristics (cont.)

(@T_A = +25°C, V_{DD} = 5V, Gain = 24dB, R_L = 8Ω, both Class-AB and D mode, unless otherwise specified.)

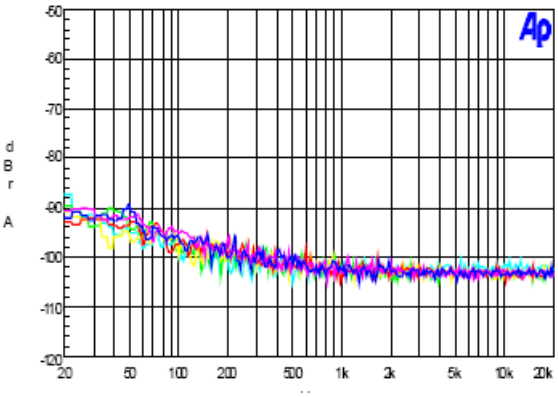
7. THD+N vs Frequency (Class D)



8. THD+N vs Output Power (Class AB)

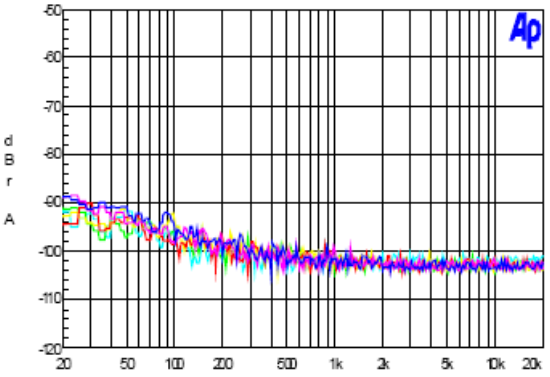


9.Noise Floor (Class D)



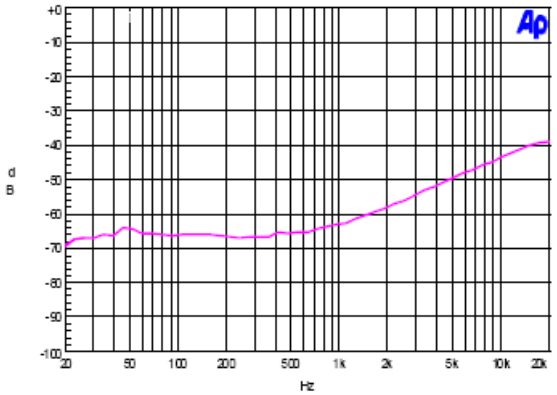
R_L=4Ω,Vin=2.5V/3.3V/3.6V/4.2/5V/5.5V

10. Noise Floor (Class AB)

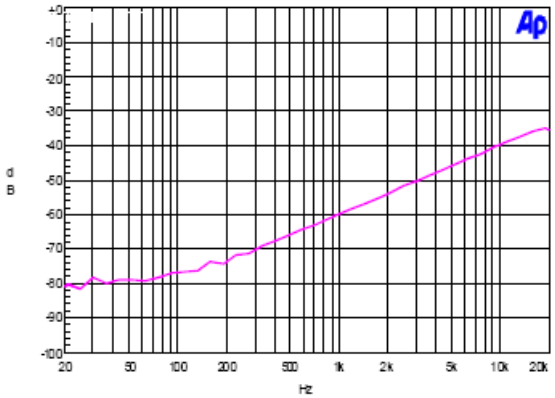


R_L=4Ω,Vin=2.5V/3.3V/3.6V/4.2/5V/5.5V

11. PSRR (Class D)



12. PSRR (Class AB)



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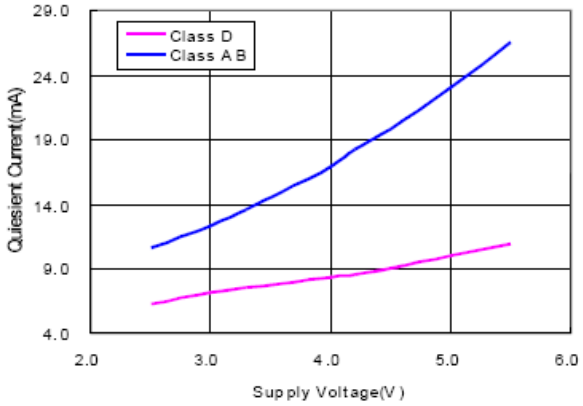
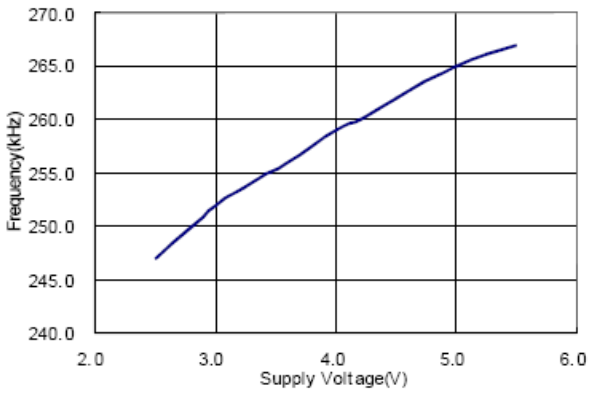
Typical Performance Characteristics (cont.)

(@T_A = +25°C, V_{DD} = 5V, Gain = 24dB, R_L = 8Ω, both Class-AB and D mode, unless otherwise specified.)

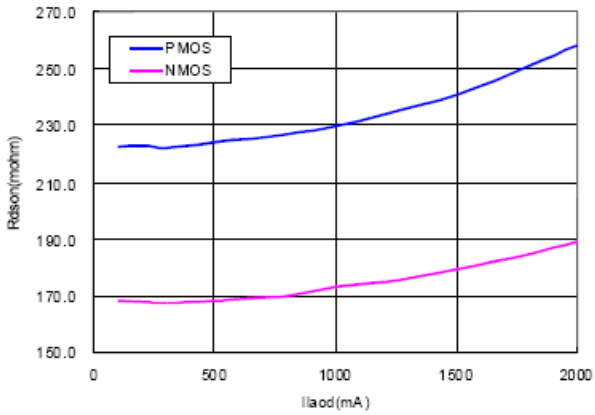
13. Quiescent Current vs Supply Voltage



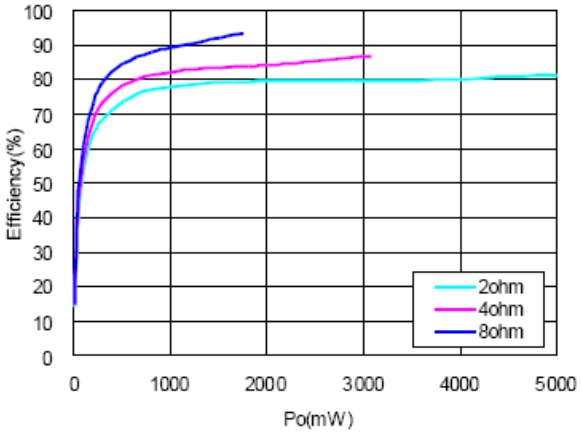
14. Frequency vs Supply Voltage



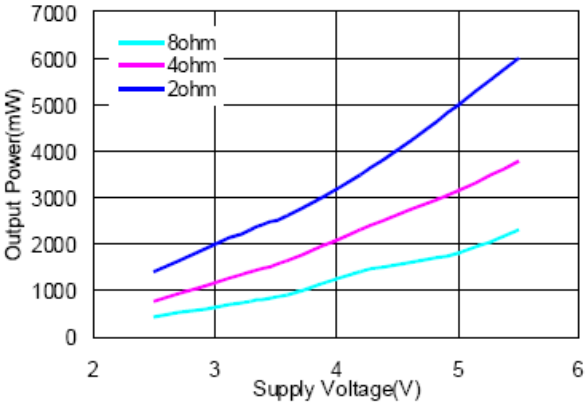
15.Rds(on) vs Iload



16. Efficiency vs Output Power(Class D)



17. Output Power vs Power Supply



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Application Information

Application Note

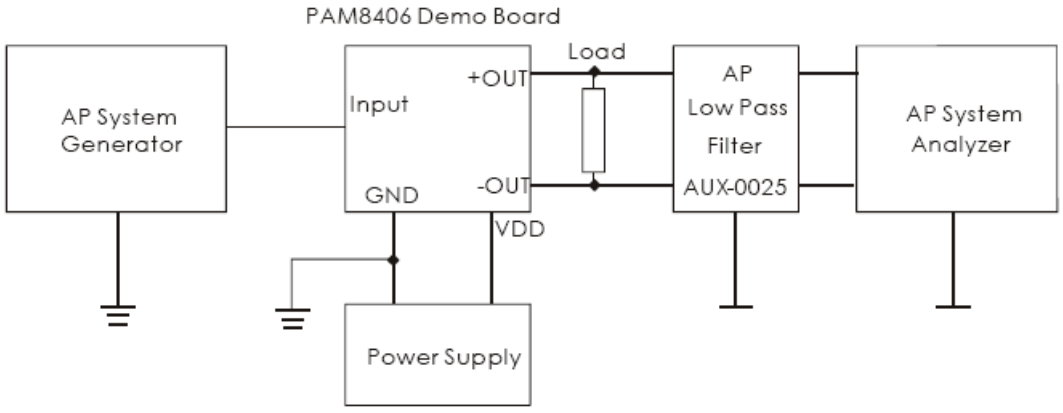
1. When the PAM8406 works in Class-D with LC filters, it should be connected with the speaker before it's powered on, otherwise it will be damaged easily.

2. When the PAM8406 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 recommended operating voltage is 5.5V. When the PAM8406 is powered with four battery cells, it should be noted that the voltage of four new dry or alkaline batteries is over 6.0V, higher than its operation voltage, which will probably damage the device. Therefore, it's recommended to use either four Ni-MH (Nickel Metal Hydride) rechargeable batteries or 3 dry or alkaline batteries.

4. One should not make the input signal too large. Large signal can cause the clipping of output signal when increasing the volume. This will damage the device because of big gain of the PAM8406.

Test Setup for Performance Testing



Notes: 1. The 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.

Maximum Gain

As shown in block diagram (Page 2), the PAM8406 has two internal amplifier stages. The first stage's gain is externally configurable, while the second stage's is internally fixed. 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 2x.The output of amplifier 1 serves as the input to amplifier 2, thus the two amplifiers produce signals identical in magnitude, but different in phase by 180°. Consequently, the differential gain for the IC is

$$A_{VD} = 20*\log [2*(R_F/R_I)]$$

The PAM8406 sets maximum R_F =142kΩ, minimum R_I =18kΩ, so the maximum closed-gain is 24dB.

Mode Selection

When mode pin high, it features Class-D; mode pin low, it's class AB. Mode pin can't be floating.

Mute Operation

The MUTE pin is an input for controlling the output state of the PAM8406. 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 MUTE pin can be left floating due to the internal pull-up.

Shutdown Operation

In order to reduce power consumption while not in use, the PAM8406 contains shutdown circuitry to turn off the amplifier's bias circuitry. This shutdown feature turns the amplifier off when logic low is applied to the SHDN pin. By switching the SHDN pin connected to GND, the PAM8406 supply current draw will be minimized in idle mode. The SHDN pin can be left floating due to the internal pull-up.

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Application Information (cont.)

Power Supply Decoupling

The PAM8406 is a high performance CMOS audio amplifier that requires adequate power supply decoupling to ensure the output THD and PSRR as low as possible. Power supply decoupling affects low frequency response. Optimum decoupling is achieved by using two capacitors of different types targeting to 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 1.0μF, works best, placing it as close as possible to the device V_{DD} terminal. For filtering lower frequency noise signals, a large capacitor of 20μF (ceramic) or greater is recommended, placing it near the audio power amplifier.

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 by 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 caused by the power supply 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.

A ceramic bypass capacitor (C_{BYP}) with values 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.

Under Voltage Lock-Out (UVLO)

The PAM8406 incorporates circuitry designed to detect low supply voltage. When the supply voltage drops to 2.0V or below, the PAM8406 outputs are disabled, and the device comes out of this state and starts to normal function when $V_{DD} \geq 2.2V$.

Short Circuit Protection (SCP)

The PAM8406 has short circuit protection circuitry on the outputs to prevent damage to the device when output-to-output or output-to-GND short occurs. When a short circuit is detected on the outputs, the outputs are disabled immediately. If the short was removed, the device activates again.

Over Temperature Protection

Thermal protection on the PAM8406 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 and the device begins normal operation at this point without external system intervention.

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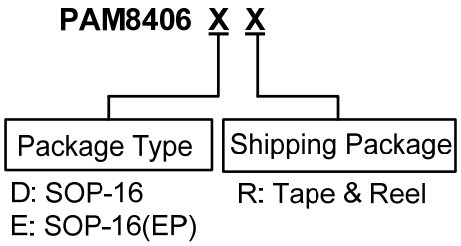
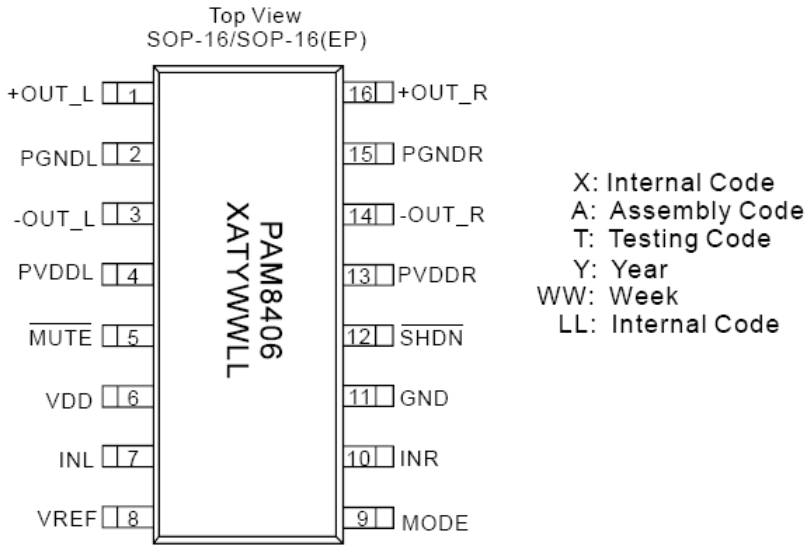
Ordering Information



Part Number	Part Marking	Package Type	Standard Package
PAM8406DR	PAM8406 XATYWWLL	SOP-16	2500 Units/Tape&Reel
PAM8406ER	PAM8406 XATYWWLL	SOP-16(EP)	2500 Units/Tape&Reel

Marking Information



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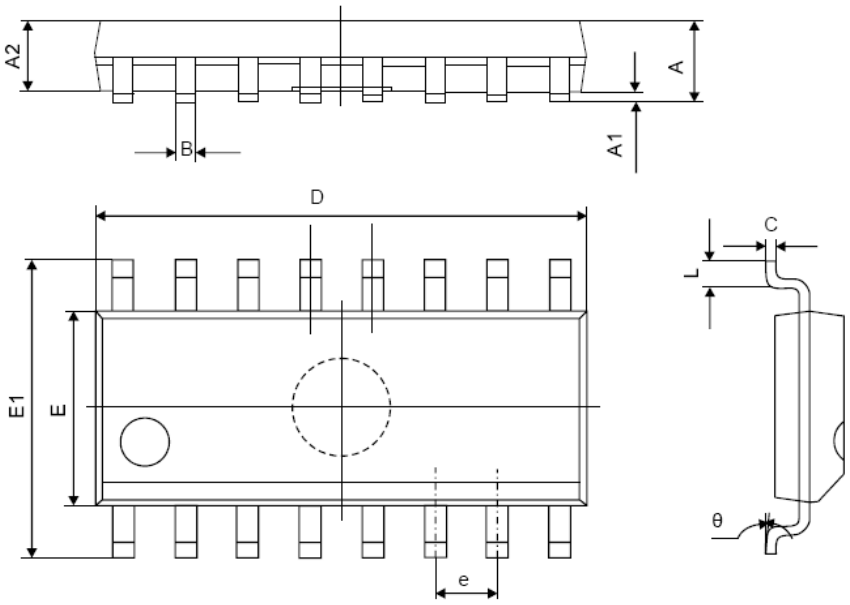
Package Outline Dimensions (All dimensions in mm.)

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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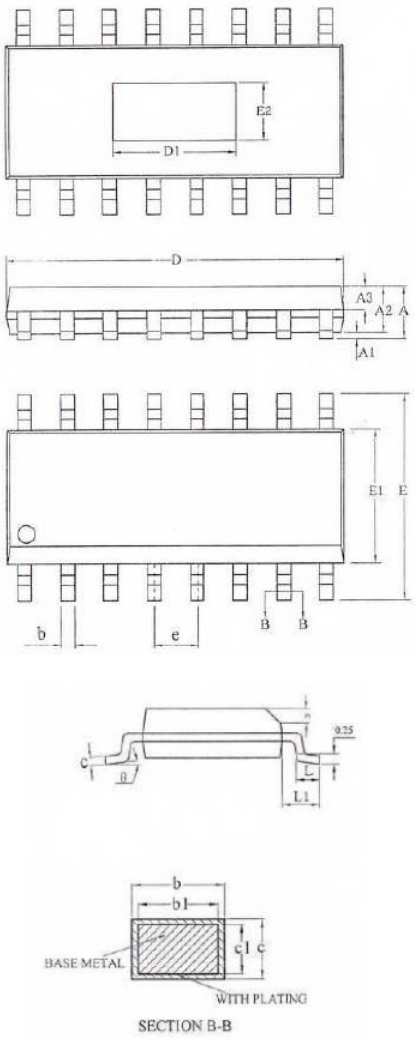
Package Outline Dimensions (All dimensions in mm.)

SOP-16(EP)



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	—	—	1.75
A1	0.05	—	0.225
A2	1.30	1.40	1.50
A3	0.60	0.65	0.70
b	0.39	—	0.48
b1	0.38	0.41	0.43
c	0.21	—	0.26
c1	0.19	0.20	0.21
D	9.70	9.90	10.10
E	5.80	6.00	6.20
E1	3.70	3.90	4.10
e	1.27BSC		
h	0.25	—	0.50
L	0.50	—	0.80
L1	1.05BSC		
θ	0	—	8°
D1	3.86REF		
E2	1.67REF		
编带尺寸 (mil)	95*180		

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2. support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in significant injury to the user.

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