# PAM8602E

## FILTERLESS 2W CLASS-D STEREO AUDIO AMPLIFIER WITH DC VOLUME CONTROL AND HEADPHONE OUTPUT

## Description

The PAM8602E is a 2.0W, 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 PAM8602E is much better than Class-AB cousins. It can extend the battery life thus be ideal for portable applications.

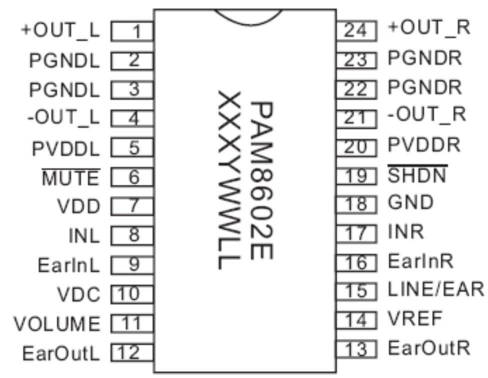
The PAM8602E is available in a SSOP-24 and SOP-24 package.

## Features

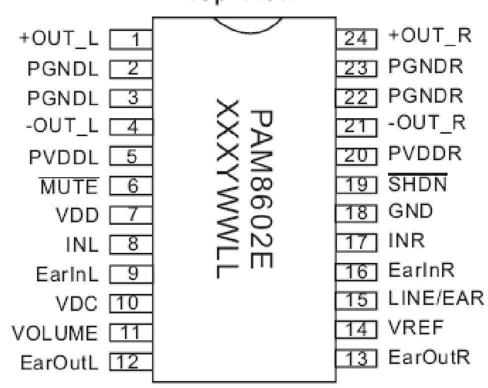
- 2W Output with a 4Ω Load and 5V Power Supply
- Filterless, Low Quiescent Current and Low EMI
- Low THD+N
- 64-Step DC Volume Control
- Headphone Output Function
- Superior Low Noise
- Low Pop Noise
- Efficiency up to 88%
- Short Circuit Protection
- Thermal Shutdown
- Few External Components to Save the Space and Cost
- Pb-Free Package

## Pin Assignments

SSOP24
Top View



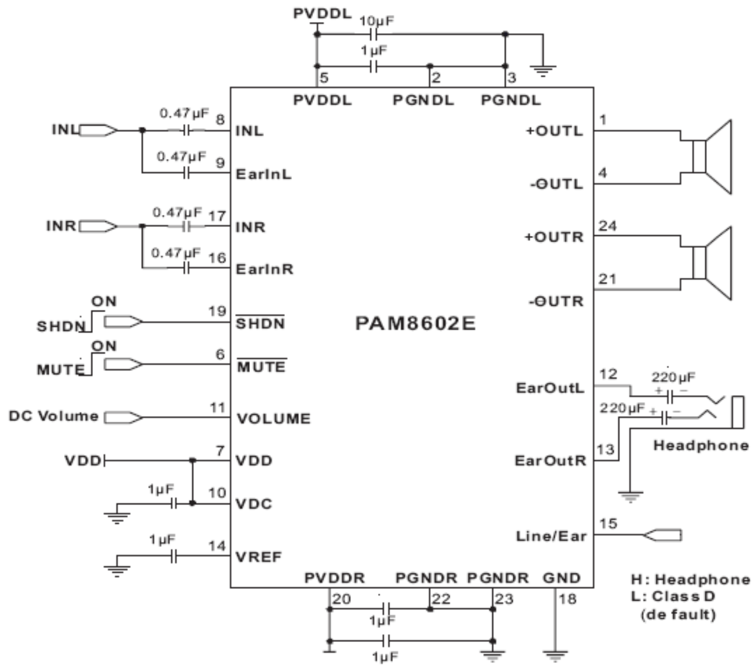

SOP24
Top View




## Applications

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

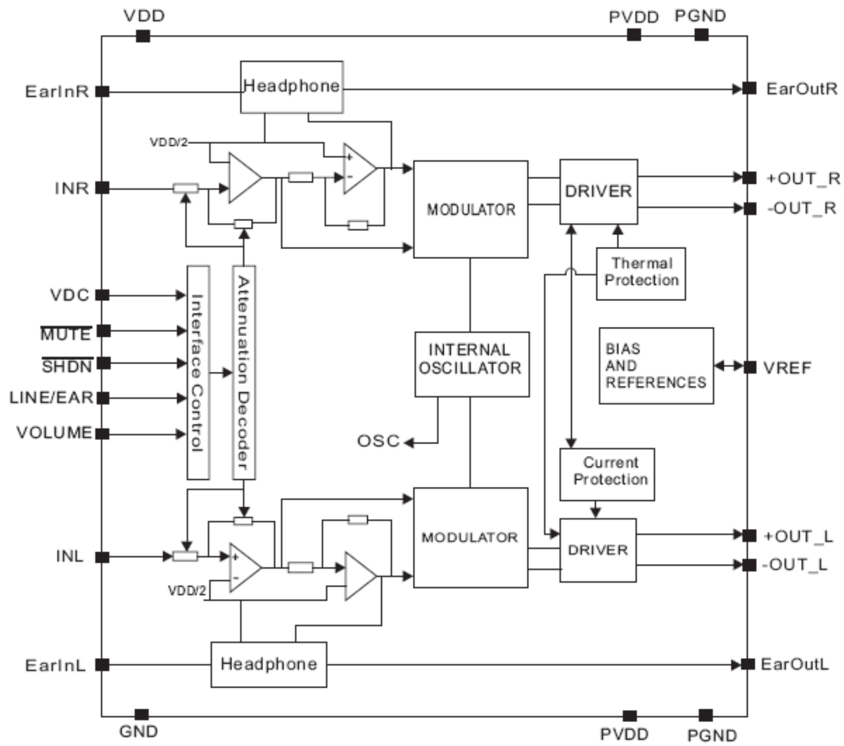
## Typical Applications Circuit




## Pin Descriptions

| Pin Number | Pin Name | Function |
|---|---|---|
| 1 | +OUT_L | Left Channel Positive Output |
| 2 | PGNDL | Left Channel Power GND |
| 3 | PGNDL | Left Channel Positive GND |
| 4 | -OUT_L | Left Channel Negative Output |
| 5 | PVDDL | Left Channel Power Supply |
| 6 | $\overline{\text{MUTE}}$ | Mute Control Input (active low) |
| 7 | VDD | Analog VDD |
| 8 | IN L | Left Channel Input |
| 9 | EAR IN L | Left Earphone Input |
| 10 | VDC | Analog Reference for Gain Control Section |
| 11 | VOLUME | DC Voltage Control to Set the Gain of Class-D |
| 12 | EAR OUT L | Left Earphone Output |
| 13 | EAR OUT R | Right Earphone Output |
| 14 | VREF | Internal Analog Reference, Connect a Bypass Capacitor from VREF to GND |
| 15 | LINE/EAR | Line/ Ear Detect |
| 16 | EAR IN R | Right Earphone Input |
| 17 | INR | Right Channel Input |
| 18 | GND | Analog GND |
| 19 | $\overline{\text{SHDN}}$ | Shutdown Control Input (active low) |
| 20 | PVDDR | Right Channel Power Supply |
| 21 | -OUT_R | Right Channel Negaitive Output |
| 22 | PGNDR | Right Channel Power GND |
| 23 | PGNDR | Right Channel Power GND |
| 24 | +OUT_R | Right Channel Positive 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 | |
| Operation Junction Temperature | -40 to +125 | °C |
| 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 |
| 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 | $\theta_{JA}$ | 96 | °C/W |
| Thermal Resistance (Junction to Ambient) | SOP-24 | $\theta_{JA}$ | 79.2 | °C/W |

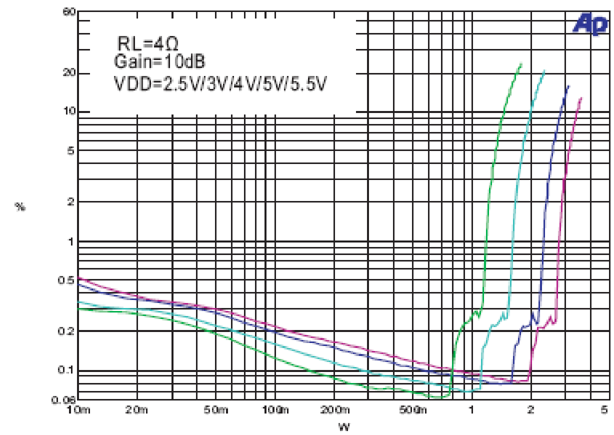
## Electrical Characteristics (@$T_A$ = +25°C, $V_{DD}$ = 5V, Gain = Maximum, $R_L$ = 8Ω, unless otherwise specified.)

| 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 | | | 10 | 15 | 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 | | 0.35 | | Ω |
| | | | N MOSFET | | 0.25 | | |
| Output Power | $P_O$ | THD+N = 10%, f = 1kHz | | 1.55 | 1.70 | | W |
| Total Harmonic Distortion Plus Noise | THD+N | $P_O$ = 0.85W, f = 1KHz | | | 0.08 | | % |
| Power Supply Ripple Rejection | PSRR | Input AC-GND, f = 1KHz, $V_{PP}$ = 200mV | | | 70 | | dB |
| Channel Separation | CS | $P_O$ = 1W, f = 1KHz | | | -95 | | dB |
| Oscillator Frequency | $f_{OSC}$ | | | 200 | 250 | 300 | kHz |
| Efficiency | η | $P_O$ = 1.7W, f =1 kHz | | 85 | 89 | | % |
| Noise | $V_N$ | Input AC-GND | A-Weighting | | 220 | | μV |
| | | | No A-Weighting | | 350 | | |
| Signal Noise Ratio | SNR | f = 20 – 20kHz, THD = 1% | | | 85 | | dB |
| **Earphone Stage** | | | | | | | |
| Quiescent Current | $I_Q$ | No Load | | | 4.5 | 7.5 | mA |
| Output Offset Voltage | $V_{OS}$ | No Load | | | 2.5 | | V |
| Output Power | $P_O$ | THD+N = 1%, $R_L$ = 32Ω, f = 1KHz | | | 60 | | mW |
| Total Harmonic Distortion Plus Noise | THD+N | $R_L$ = 32Ω, $P_O$ = 10mW, f = 1kHz | | | 0.02 | | % |
| Power Supply Ripple Rejection | PSRR | Input AC-GND, f = 1kHz, $V_{PP}$ = 200mV | | | 75 | | dB |
| Channel Separation | CS | $P_O$ = 1W, f = 1kHz | | | -85 | | dB |
| Noise | $V_N$ | Input AC-GND | A-Weighting | | 70 | | μV |
| | | | No A-Weighting | | 40 | | |
| Signal Noise Ratio | SNR | f = 20 - 20kHz, THD = 1% | | | 75 | | dB |
| **Control Section** | | | | | | | |
| Under Voltage Lock-Out | UVLO | | | | 2 | | |
| Mute Current | $I_{MUTE}$ | $V_{MUTE}$ = 0V | | | 1 | 3 | mA |
| Shutdown Current | $I_{SHDN}$ | $V_{SHDN}$ = 0V | | | | 1 | μA |
| $\overline{SHDN}$ Input High | $V_{SH}$ | | | 1.2 | | | |
| $\overline{SHDN}$ Input High | $V_{SL}$ | | | | | 0.5 | |
| $\overline{MUTE}$ Input High | $V_{MH}$ | | | 1.2 | | | |
| $\overline{MUTE}$ Input High | $V_{ML}$ | | | | | 0.5 | |
| Over Temperature Protection | OTP | | | | 140 | | °C |
| Over Temperature Hysteresis | OTH | | | | 30 | | °C |

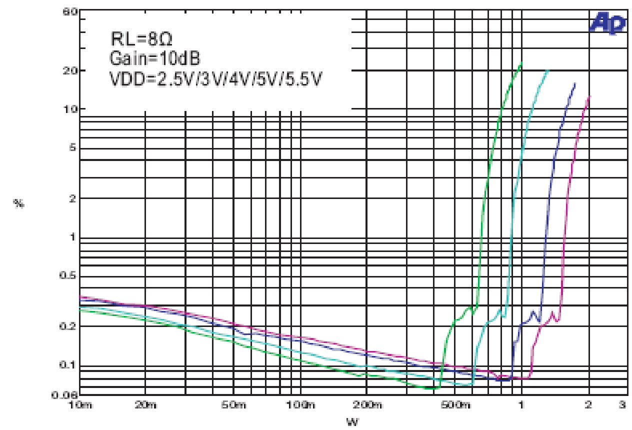
## Typical Performance Characteristics (@$T_A$ = +25°C, unless otherwise specified.)

**Class-D Output**

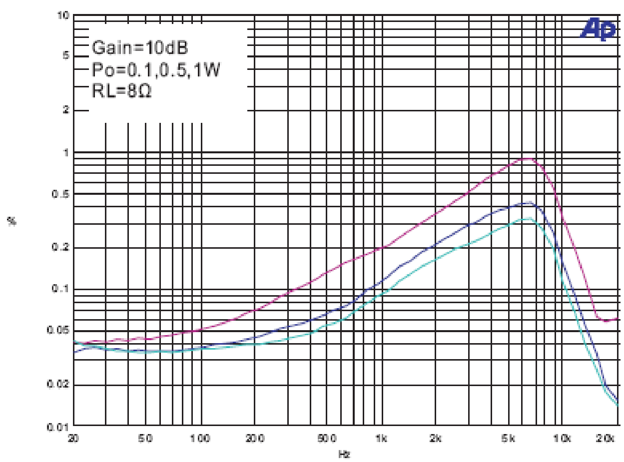
1. THD+N vs Output Power



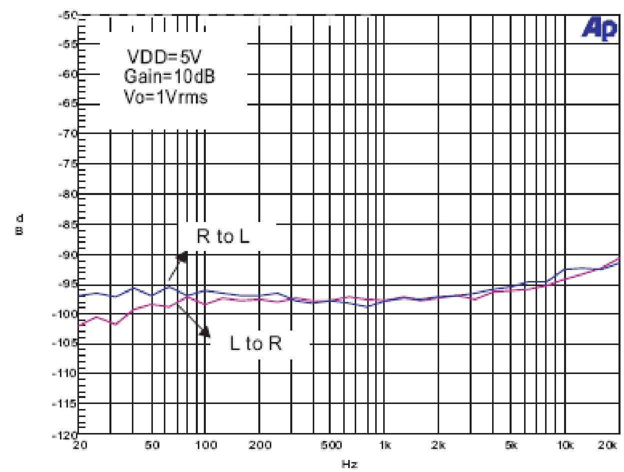

2. THD+N vs Output Power



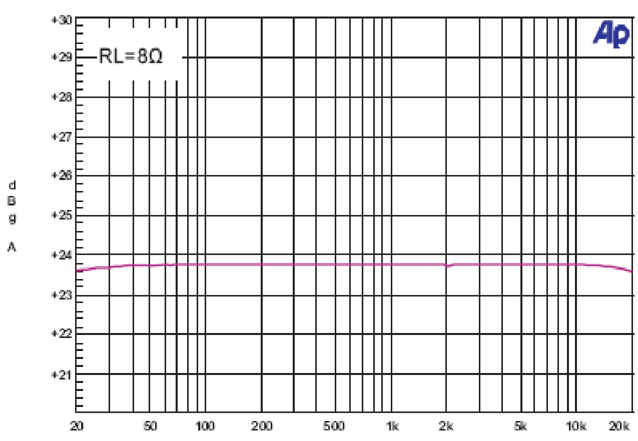

3. THD+N vs Frequency



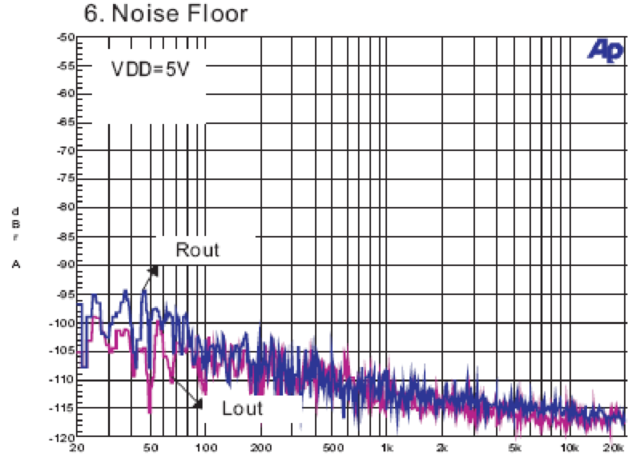

4. Crosstalk vs Frequency




5. Frequency Response



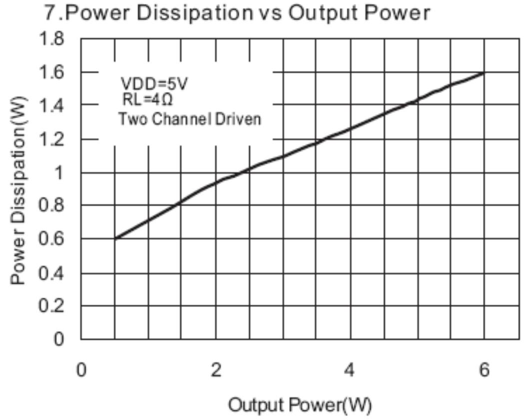

6. Noise Floor



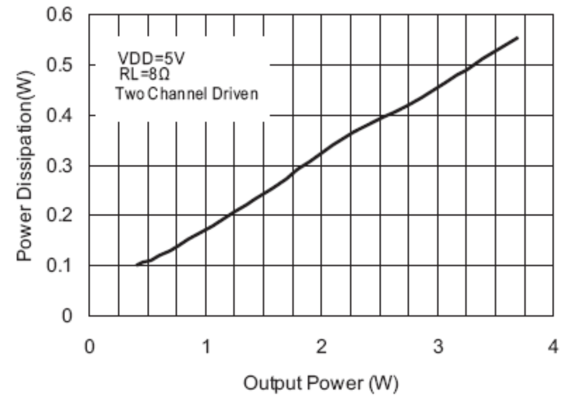
## Typical Performance Characteristics (cont.) (@$T_A$ = +25°C, unless otherwise specified.)

**Class-D Output**

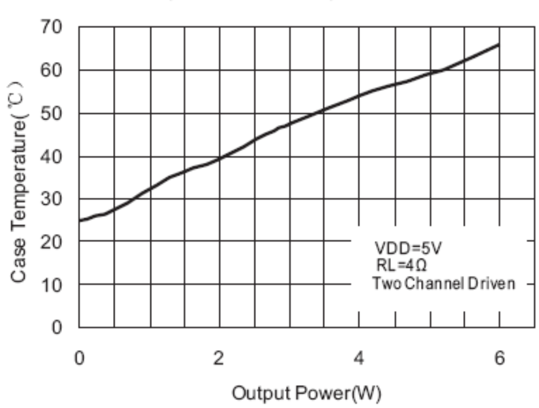
7.Power Dissipation vs Output Power



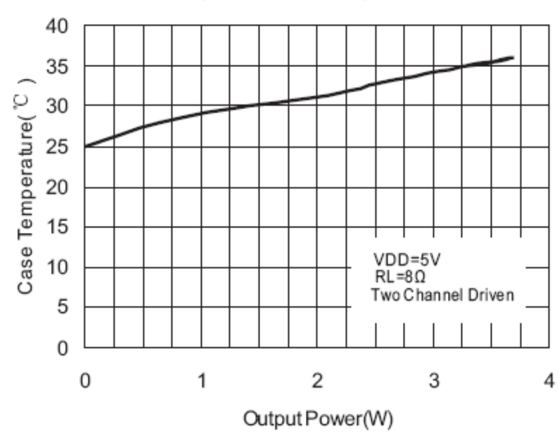

8.Power Dissipation vs Output Power



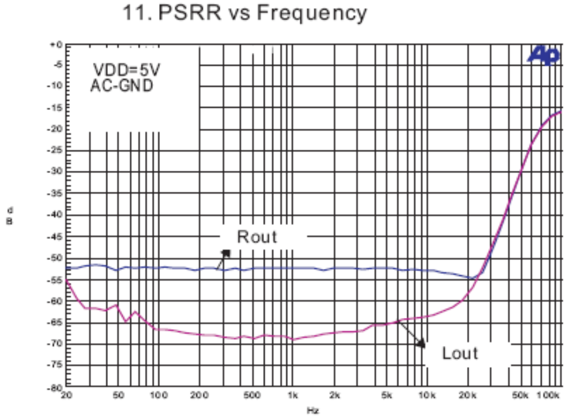

9.Case Temperature vs Output Power




10.Case Temperature vs Output Power



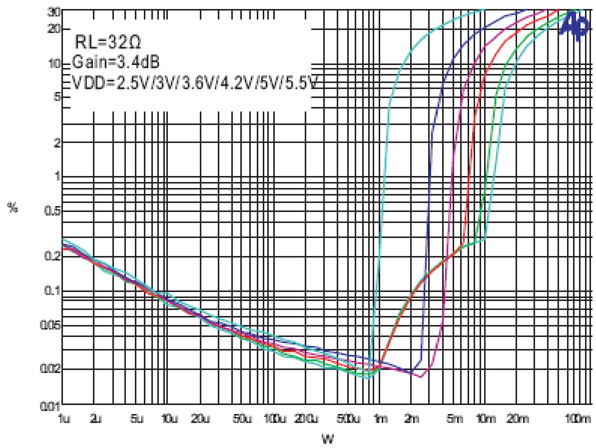

11. PSRR vs Frequency



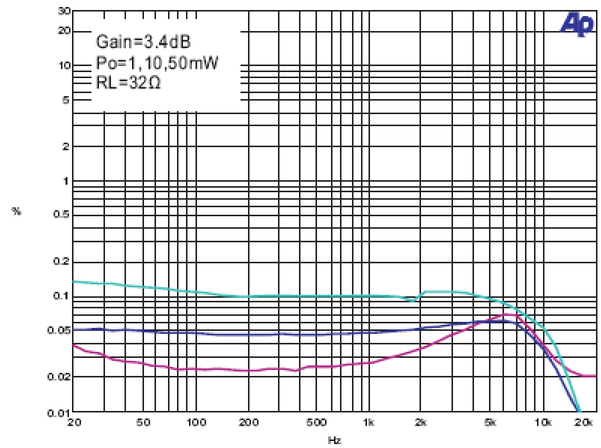
## Typical Performance Characteristics (cont.) (@$T_A$ = +25°C, unless otherwise specified.)

**Earphone Output**

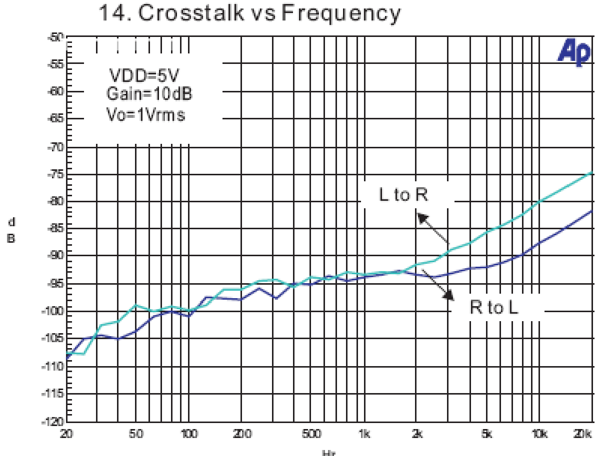
12. THD+N vs Output Power



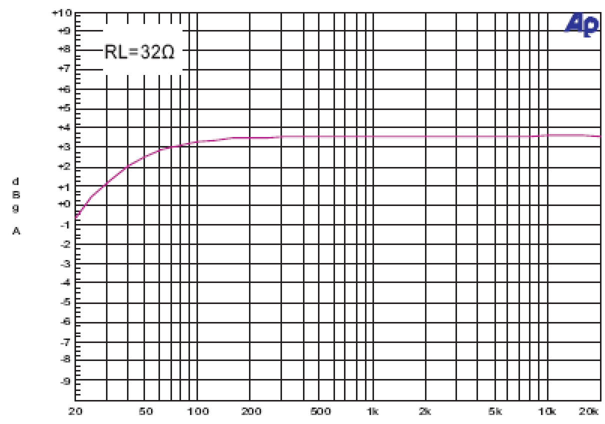

13.THD+N vs Frequency



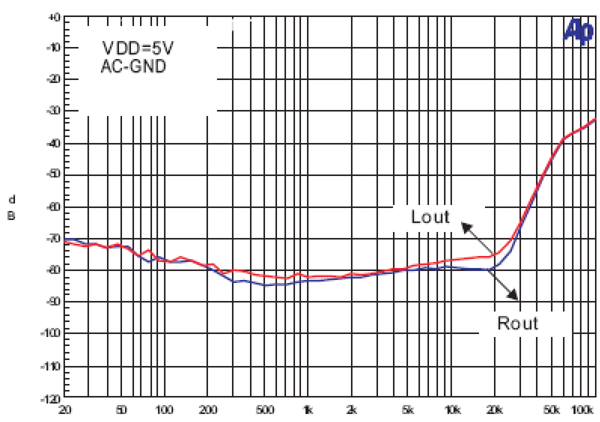

14. Crosstalk vs Frequency



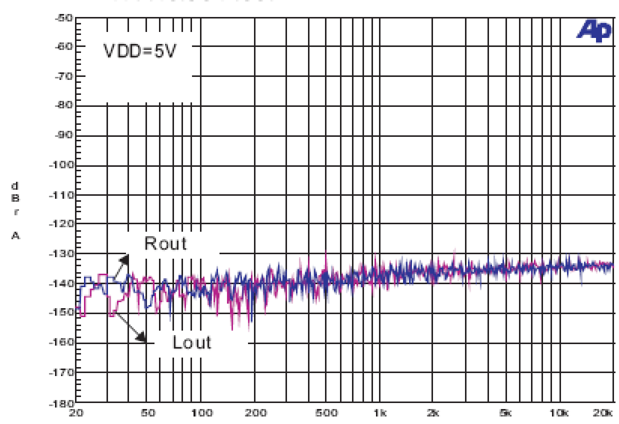

15.Frequency Response




16.PSRR

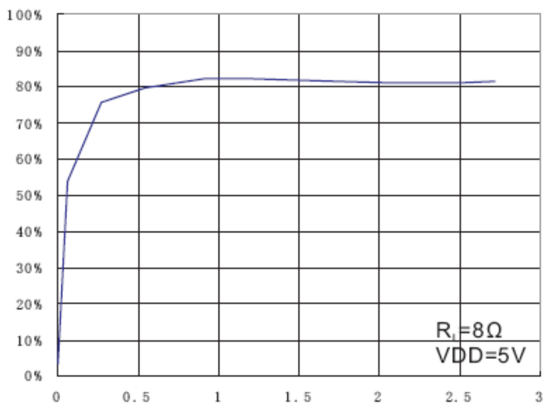



17. Noise Floor

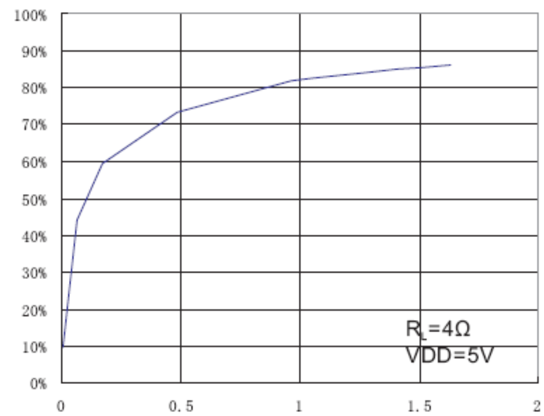


## Typical Performance Characteristics (cont.) (@$T_A$ = +25°C, unless otherwise specified.)

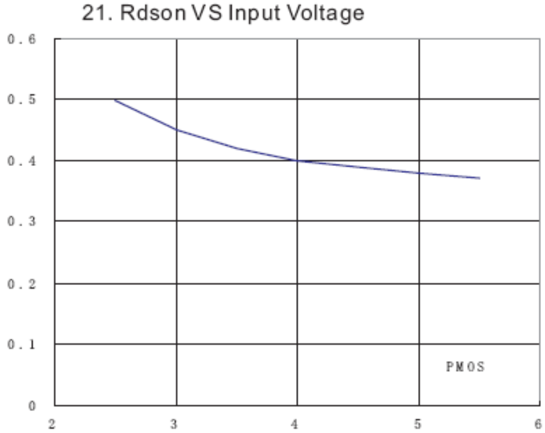
19. Efficiency VS Output Power



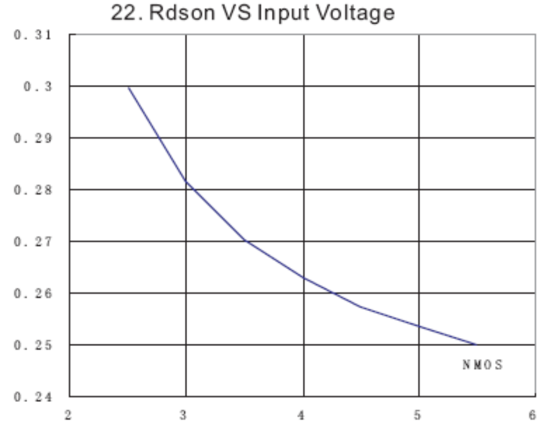

20. Efficiency VS Output Power



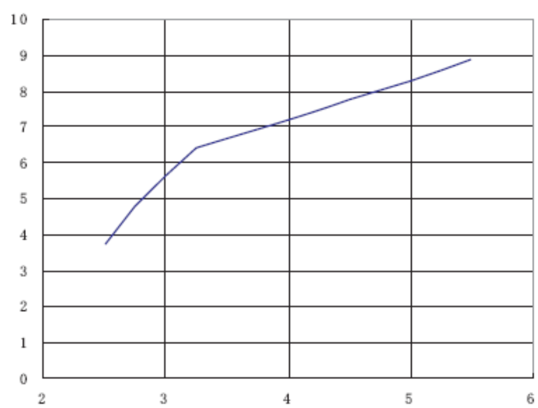

21. Rdson VS Input Voltage



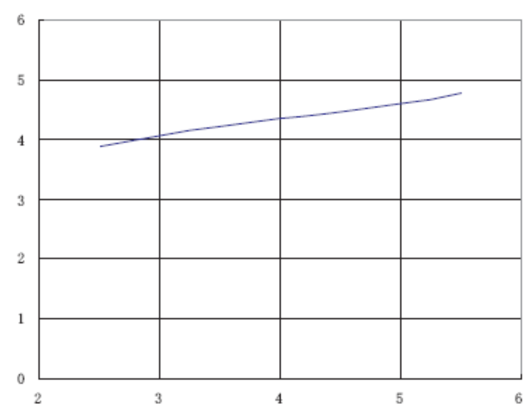

22. Rdson VS Input Voltage



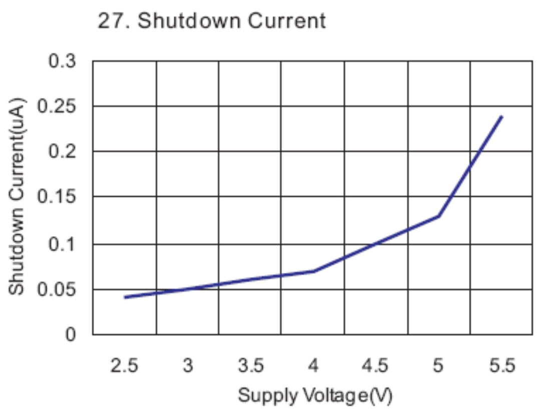

23. Quiescent Current VS VDD(Class D)

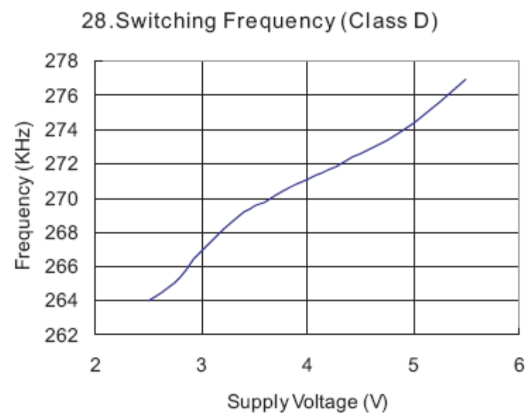


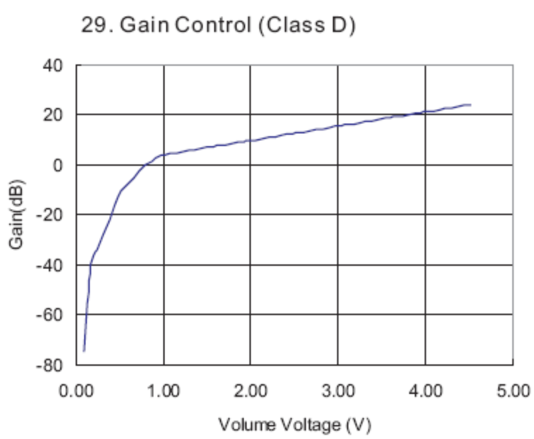

24. Quiescent Current VS VDD(Earphone)

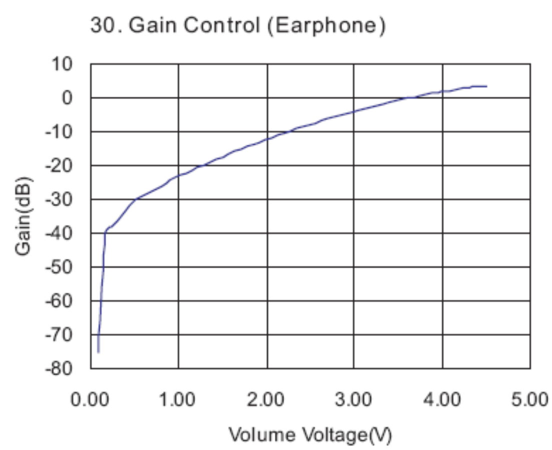


## Typical Performance Characteristics (cont.) (@$T_A$ = +25°C, unless otherwise specified.)



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

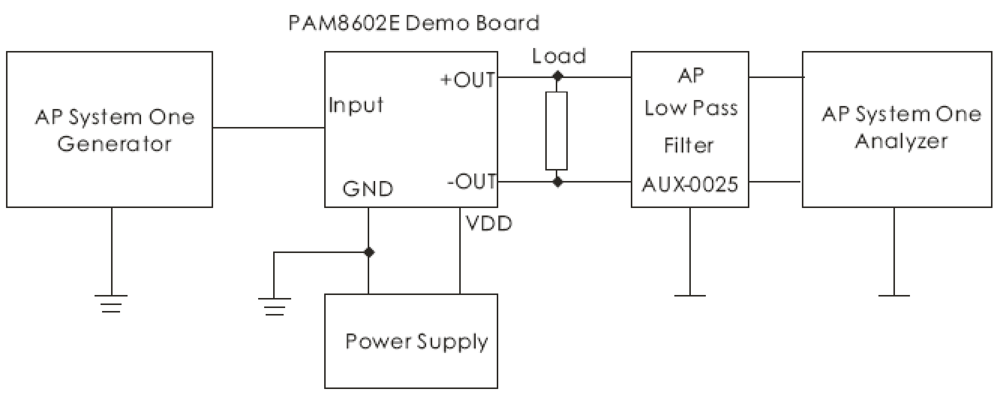
**Table 1. DC Volume Control**

| STEP | Gain (dB) Class D | Gain (dB) Earphone | | STEP | Gain (dB) Class D | Gain (dB) Earphone |
|---|---|---|---|---|---|---|
| 0 | -75 | -75 | | 32 | 11.6 | -9.2 |
| 1 | -40 | -40 | | 33 | 12.0 | -8.6 |
| 2 | -34 | -38 | | 34 | 12.4 | -8.0 |
| 3 | -28 | -36 | | 35 | 12.8 | -7.4 |
| 4 | -22 | -34 | | 36 | 13.2 | -6.8 |
| 5 | -16 | -32 | | 37 | 13.6 | -6.2 |
| 6 | -10 | -30 | | 38 | 14.0 | -5.7 |
| 7 | -7.5 | -29 | | 39 | 14.4 | -5.2 |
| 8 | -5.0 | -28 | | 40 | 14.8 | -4.7 |
| 9 | -2.5 | -27 | | 41 | 15.2 | -4.2 |
| 10 | 0 | -26 | | 42 | 15.6 | -3.7 |
| 11 | 1.5 | -25 | | 43 | 16.0 | -3.2 |
| 12 | 3.0 | -24 | | 44 | 16.4 | -2.7 |
| 13 | 4.0 | -23 | | 45 | 16.8 | -2.2 |
| 14 | 4.4 | -22.2 | | 46 | 17.2 | -1.8 |
| 15 | 4.8 | -21.4 | | 47 | 17.6 | -1.4 |
| 16 | 5.2 | -20.6 | | 48 | 18.0 | -1.0 |
| 17 | 5.6 | -19.8 | | 49 | 18.4 | -0.6 |
| 18 | 6.0 | -19.0 | | 50 | 18.8 | -0.2 |
| 19 | 6.4 | -18.2 | | 51 | 19.2 | 0.2 |
| 20 | 6.8 | -17.4 | | 52 | 19.6 | 0.6 |
| 21 | 7.2 | -16.6 | | 53 | 20.0 | 0.9 |
| 22 | 7.6 | -15.9 | | 54 | 20.4 | 1.2 |
| 23 | 8.0 | -15.2 | | 55 | 20.8 | 1.5 |
| 24 | 8.4 | -14.5 | | 56 | 21.2 | 1.8 |
| 25 | 8.8 | -13.8 | | 57 | 21.6 | 2.1 |
| 26 | 9.2 | -13.1 | | 58 | 22.0 | 2.4 |
| 27 | 9.6 | -12.4 | | 59 | 22.4 | 2.7 |
| 28 | 10.0 | -11.7 | | 60 | 22.8 | 2.9 |
| 29 | 10.4 | -11.0 | | 61 | 23.2 | 3.1 |
| 30 | 10.8 | -10.4 | | 62 | 23.6 | 3.3 |
| 31 | 11.2 | -9.8 | | 63 | 24.0 | 3.5 |

## Application Information

### Test Setup for Performance Testing (Class D)

1. When the PAM8602E 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 PAM8602E 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 PAM8602E operation voltage is 6V. When the PAM8602E 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 PAM8602E has big gain, it will make the device damaged.
5. When testing the PAM8602E 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.

### Mute Operation

The $\overline{MUTE}$ pin is an input for controlling the output state of the PAM8602E. A logic low on this pin disables the outputs, and a logic high 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 internal pull-up.

### Shutdown Operation

In order to reduce power consumption while not in use, the PAM8602E 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 PAM8602E supply current draw will be minimized in idle mode. The $\overline{SHDN}$ pin can be left floating due to the 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.**

### Power Supply Decoupling

The PAM8602E 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 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 transients, spike, or digital hash on the line, a good low equivalent-series-resisitance (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.

## Application Information

### Input Capacitor ($C_I$)

Large input capacitors are both expensive and space hungry for portable designs. Clearly, a certain sized capacitor is needed to 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 resisitance ($R_I$) 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 perfomance 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 ½ $V_{DD}$). This charge comes from the internal circuit via the feedback and is apt to creat pops upon device enable. Thus, by minimizing the capacitor size based on necessary low frequency response, turn-on pops can be minimized.

### Analog Refernce Bypass Capacitor ($C_{BYP}$)

Analog Refernce 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.

A ceramic bypass capacitior ($C_{BYP}$) 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.

### Under Voltage Lock-Out (UVLO)

The PAM8602E incorporates circuitry designed to detect when the supply voltage is low. When the supply voltage drops to 1.8V or below, the PAM8602E outputs are disable, are the device comes out of this state and states to normal functional once $V_{DD} \geq 2.0V$.

### Short Circuit Protection (SCP)

The PAM8602E 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.

### Over Temperature Protection

Thermal protection on the PAM8602E prevents the device from damage when the internal die temperature exceeds +135°C. There is a 15 degree tolerance on this 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 (Electro 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).

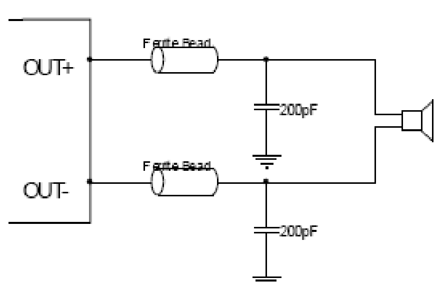


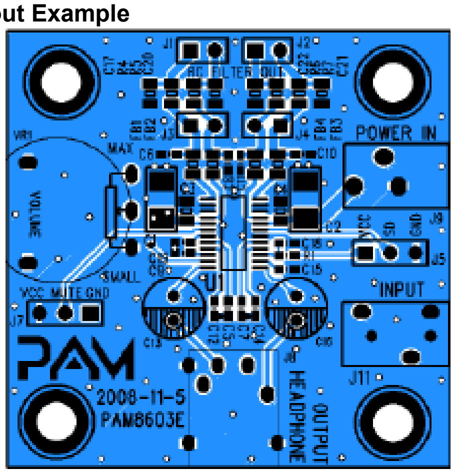

**Figure 1. Ferrite Bead Filter to Reduce EMI**

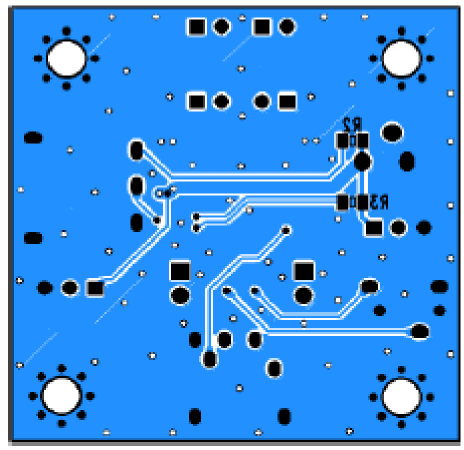
## Application Information (cont.)

### 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 PAM8602E 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



## Ordering Information

PAM8602E X X X

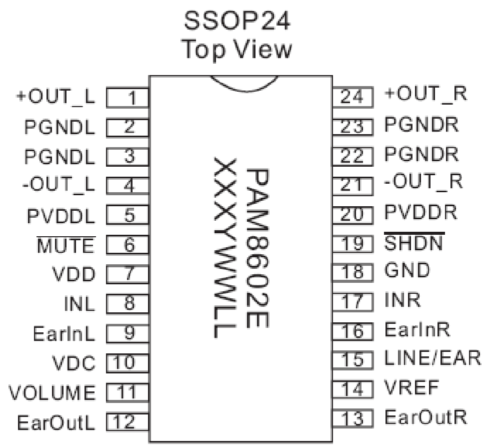
Package Type
N: SSOP-24
D: SOP-24

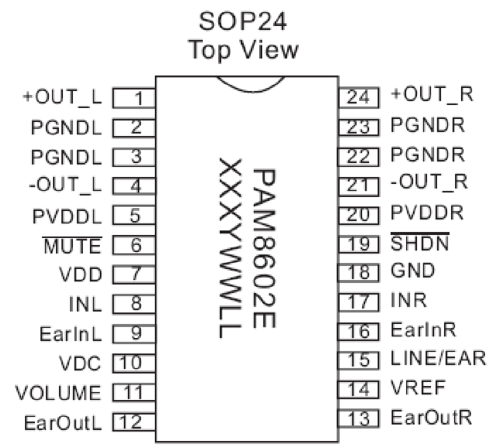
Number of Pins
H: 24 Pins

Shipping Package
R: Tape & Reel

| Part Number | Package Type | Standard Package |
|---|---|---|
| PAM8602ENHR | SSOP-24 | 2500 Units/Tape&Reel |
| PAM8602EDHR | SOP-24 | 100 Units/Tape&Reel |

## Marking Information

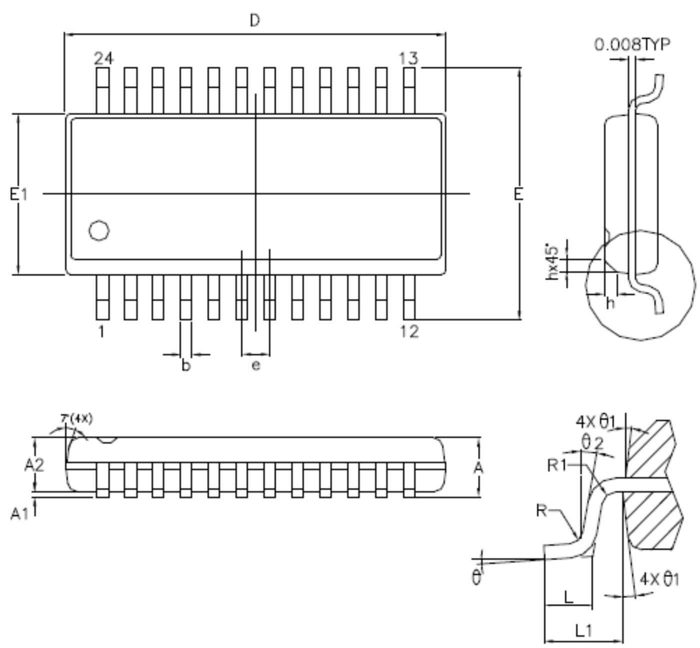



X: Internal Code
Y: Year
WW: Week
LL: Internal Code

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

**SSOP-24**

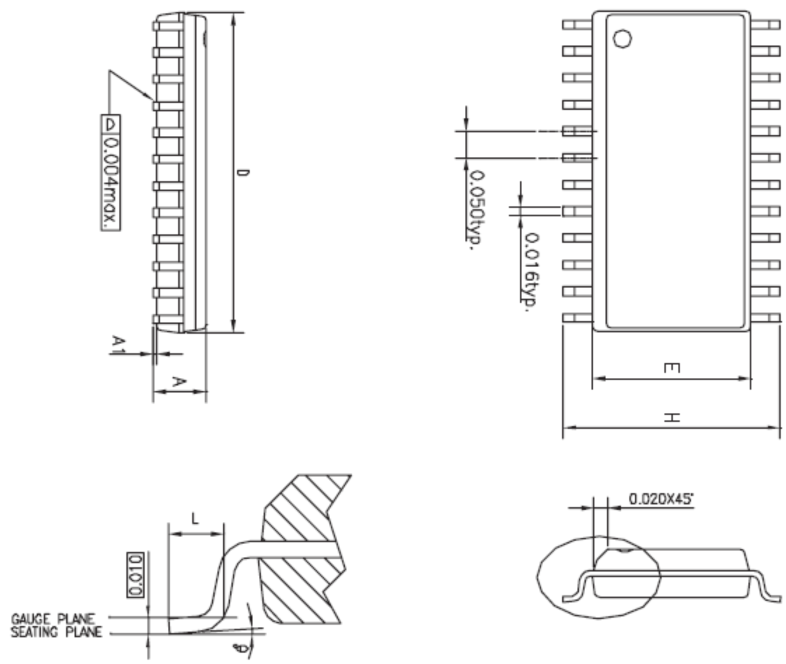



| SYMBOLS | MIN. | NOM. | MAX. |
|---|---|---|---|
| A | 0.053 | 0.061 | 0.069 |
| A1 | 0.004 | – | 0.010 |
| A2 | 0.049 | 0.057 | 0.065 |
| b | 0.008 | 0.010 | 0.012 |
| D | 0.335 | 0.341 | 0.347 |
| E | 0.228 | 0.236 | 0.244 |
| E1 | 0.150 | 0.154 | 0.158 |
| e | – | 0.025 | – |
| L | 0.016 | 0.033 | 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.

**IMPORTANT NOTICE**

DIODES INCORPORATED MAKES NO WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, WITH REGARDS TO THIS DOCUMENT, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION).

Diodes Incorporated and its subsidiaries reserve the right to make modifications, enhancements, improvements, corrections or other changes without further notice to this document and any product described herein. Diodes Incorporated does not assume any liability arising out of the application or use of this document or any product described herein; neither does Diodes Incorporated convey any license under its patent or trademark rights, nor the rights of others. Any Customer or user of this document or products described herein in such applications shall assume all risks of such use and will agree to hold Diodes Incorporated and all the companies whose products are represented on Diodes Incorporated website, harmless against all damages.

Diodes Incorporated does not warrant or accept any liability whatsoever in respect of any products purchased through unauthorized sales channel. Should Customers purchase or use Diodes Incorporated products for any unintended or unauthorized application, Customers shall indemnify and hold Diodes Incorporated and its representatives harmless against all claims, damages, expenses, and attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized application.

Products described herein may be covered by one or more United States, international or foreign patents pending. Product names and markings noted herein may also be covered by one or more United States, international or foreign trademarks.

This document is written in English but may be translated into multiple languages for reference. Only the English version of this document is the final and determinative format released by Diodes Incorporated.

**LIFE SUPPORT**

Diodes Incorporated products are specifically not authorized for use as critical components in life support devices or systems without the express written approval of the Chief Executive Officer of Diodes Incorporated. As used herein:

A. Life support devices or systems are devices or systems which:

1. are intended to implant into the body, or

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.

B. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or to affect its safety or effectiveness.

Customers represent that they have all necessary expertise in the safety and regulatory ramifications of their life support devices or systems, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of Diodes Incorporated products in such safety-critical, life support devices or systems, notwithstanding any devices- or systems-related information or support that may be provided by Diodes Incorporated. Further, Customers must fully indemnify Diodes Incorporated and its representatives against any damages arising out of the use of Diodes Incorporated products in such safety-critical, life support devices or systems.



**www.diodes.com**