



3W STEREO CLASS-D Audio Amplifier and Class AB Headphone Driver (DC VOLUME, UVP and AGC Function)

Description

The PAM8009 is a 3W, Class D audio-power amplifier for driving bridged-tied stereo speakers. Advanced DC volume control minimizes external components and allows BTL (Speaker) volume control and SE(Headphone) volume control, the gain range is from +20dB (Volume=5V) to -60dB (Volume=0V) with 64 steps precise control.

Integrated power-limit technology which suppress the output signal clip automatically due to the over level input signal. This technology also offers low THD+N and protects speaker.

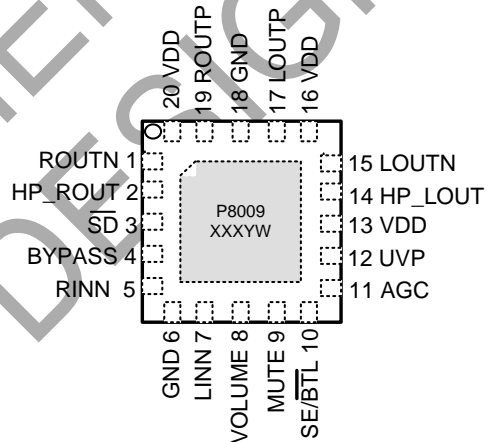
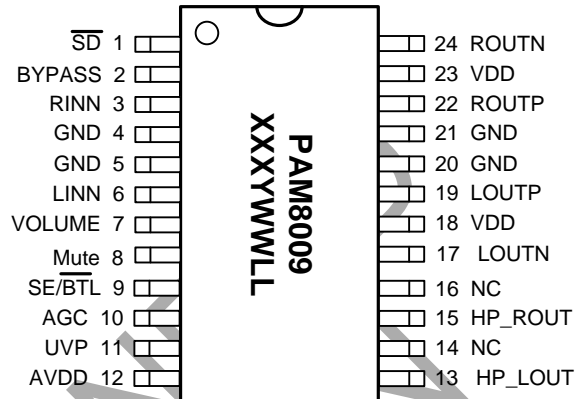
Integrated Undervoltage Protection(UVP) technology, external undervoltage detection can be used to shut down the PAM8009 before an input device can generate a pop.

PAM8009 is available in SO-24 and U-QFN4040-20.

Features

- Operating Voltage: 2.8v ~ 5.5v
- Filter – Free and Low EMI
- Low Quiescent Current
- $I_{DD}=7mA @ V_{DD}= 5V$
- 64 Steps DC Volume Control from -80dB to +20dB by DC Voltage with Hysteresis
- Power Limit Function
 - Disable: $0.45V_{DD} \sim V_{DD}$
 - Max. Power: GND
- UVP Function
 - Disable: Floating
- Output Power @ THD+N=1%
 - BTL Mode
 - $V_{DD}=5V, R_L=4\Omega; P_o=2.4W$
 - $V_{DD}=5V, R_L=8\Omega; P_o=1.4W$
 - SE Mode
 - $V_{DD}=5V, R_L=32\Omega; P_o=60mW$
- Output Power @ THD+N = 10%
 - BTL Mode
 - $V_{DD}=5V, R_L=4\Omega; P_o=3.0W$
 - $V_{DD}=5V, R_L=8\Omega; P_o=1.7W$
- Input Signal and Headphone Output Signal in Phase
- Thermal and Over-Current Protections with Auto-Recovery
- Power Enhance Package SO-24 and U-QFN4040-20
- Lead Free and Green Devices Available (RoHS Compliant)
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green Device (Note 3)**

Pin Assignments

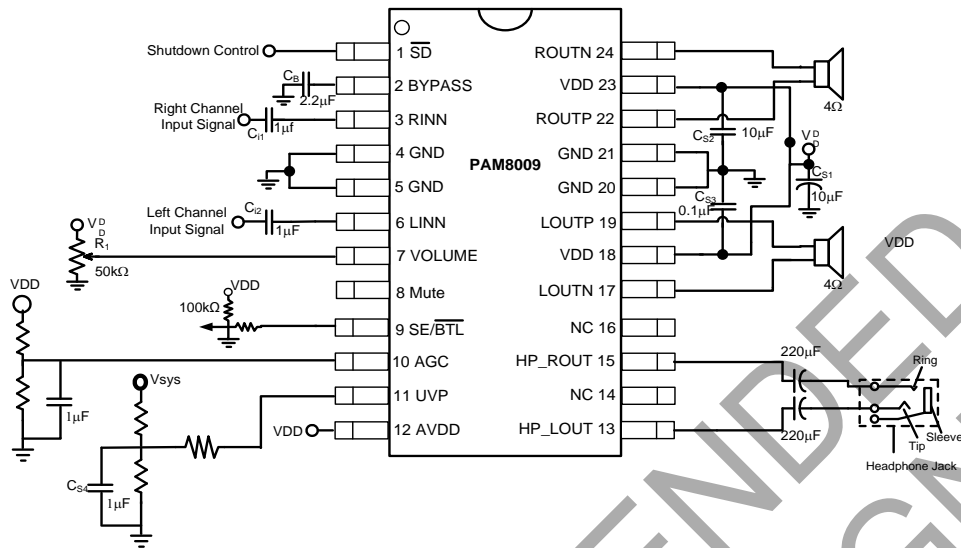


Applications

- LCD Monitor / Projects
- Projects / All-In-One Computers
- Portable Speakers
- Portable DVD Player / Game Machines

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

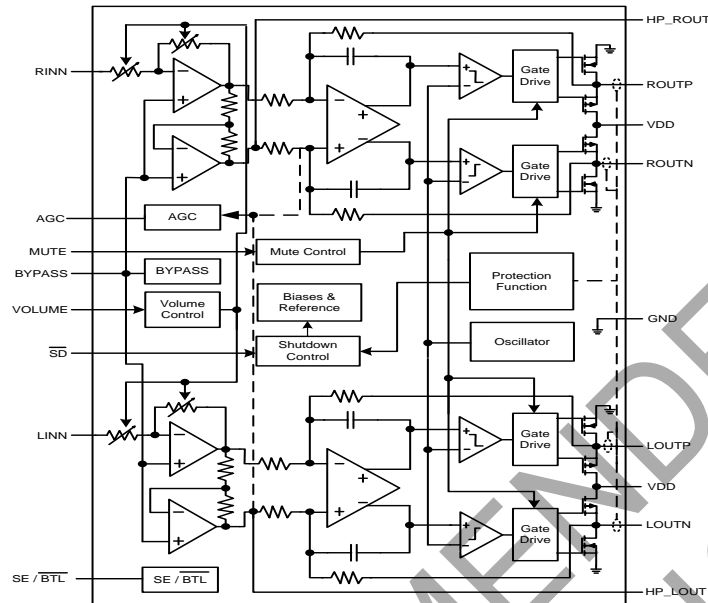
Typical Applications Circuit



Pin Descriptions

| Package Name | | | Function |
|--------------|------------|---------|------------------------------------------------------------------------------|
| SO-24 | QFN-20 | Name | |
| 1 | 3 | /SD | Full Chip Shutdown Control Input (Active Low) |
| 2 | 4 | Bypass | Bias Voltage for Power Amplifier |
| 3 | 5 | RIN | Negative Input of Right Channel Power Amplifier |
| 4, 5, 20, 21 | 6, 18 | GND | Ground Connection |
| 6 | 7 | LIN | Negative Input of Left Channel Power Amplifier |
| 7 | 8 | VOLUME | Internal Gain Setting Input Connect to VDD which Set Max. Gain = +20dB |
| 8 | 9 | MUTE | Mute Control Signal Input (Active High) |
| 9 | 10 | SE/ BTL | Output Mode Control Input High for SE Mode and Low for BTL Mode |
| 10 | 11 | AGC | VDD ~ 0.45 x VDD or Floating, Disable the Function |
| 11 | 12 | UVP | Under Voltage Protection Input Floating or Pull High Disable the Function |
| 12, 18, 23 | 13, 16, 20 | VDD | Power |
| 13 | 14 | HP_LOUT | Headphone Output of Left Channel Power Amplifier |
| 14, 16 | - | N.C | No Connection |
| 15 | 2 | HP_ROUT | Headphone Output of Right Channel Power Amplifier |
| 17 | 15 | LOUTN | Negative Output of Left Channel Power Amplifier |
| 19 | 17 | LOUTP | Positive Output of Left Channel Power Amplifier |
| 22 | 19 | ROUTP | Positive Output of Right Channel Power Amplifier |
| 24 | 1 | ROUTN | Negative Output of Right Channel Power Amplifier |

Functional Block Diagram



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

| Symbol | Parameter | Rating | Unit |
|------------------|------------------------------------------------|-------------------------------|------|
| V _{DD} | Supply Voltage | -0.3 to 6.0 | V |
| V _{DD} | Input Voltage | -0.3 to V _{DD} + 0.3 | |
| T _J | Maximum Junction Temperature | +150 | °C |
| T _{STG} | Storage Temperature Range | - 65 to +150 | |
| T _{SDR} | Maximum Soldering Temperature Range, 5 Seconds | +300 | |

Notes: 4. Stresses greater than the 'Absolute Maximum Ratings' specified above may cause permanent damage to the device. These are stress ratings only; functional operation of the device at these or any other conditions exceeding those indicated in this specification is not implied. Device reliability may be affected by exposure to absolute maximum rating conditions for extended periods of time.

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

| Symbol | Parameter | Max | Unit |
|------------------|-------------------------------------|-------------------------|-----------------------------------------|
| V _{DD} | Supply Voltage Range | 2.8 ~ 5.5 | V |
| V _{IH} | High Level Threshold Voltage | SD, MUTE | 2 ~ V _{DD} |
| | | SE, BTL | 0.8 x V _{DD} ~ V _{DD} |
| V _{IL} | Low Level Threshold Voltage | SD, MUTE | 0 ~ 0.8 |
| | | SE, BTL | 0 ~ 1.0 |
| V _{ICM} | Common Mode Input Voltage | 1 ~ V _{DD} - 1 | V |
| T _A | Ambient Operation Temperature Range | -40 ~ + 85 | °C |
| T _J | Junction Temperature Range | -40 + 125 | |

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

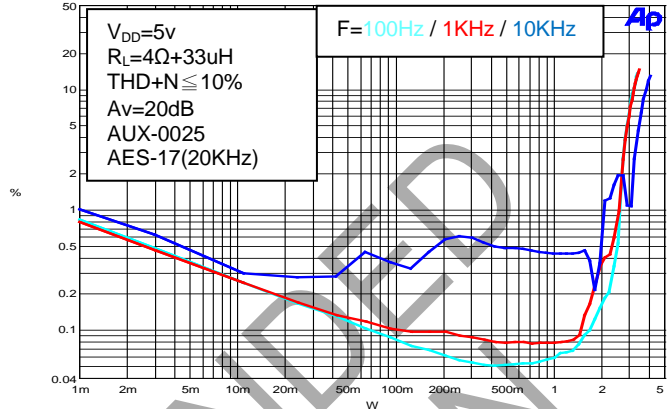
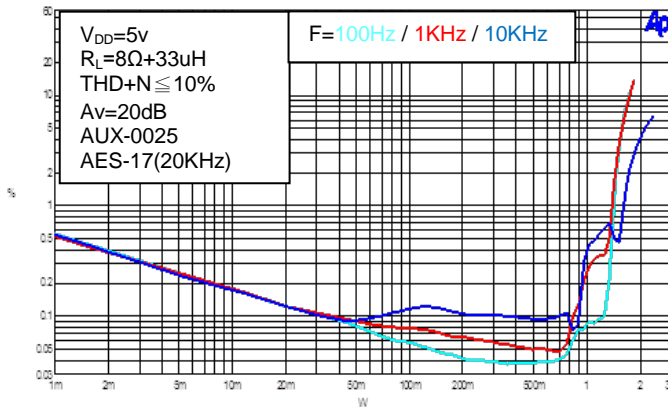
| Symbol | Parameter | Typical Value | Unit |
|-----------------|------------------------------------------|---------------|------|
| θ _{JA} | Thermal Resistance – Junction to Ambient | SO-24 | +96 |
| | | QFN4040-20 | +45 |
| θ _{JC} | Ambient Operation Temperature Range | SO-24 | +18 |
| | | QFN4040-20 | +7 |

Electrical Characteristics (@ $T_A = +25^\circ\text{C}$, $V_{DD} = 5\text{V}$, Gain = Max., $R_L = 8\Omega$, unless otherwise specified.)

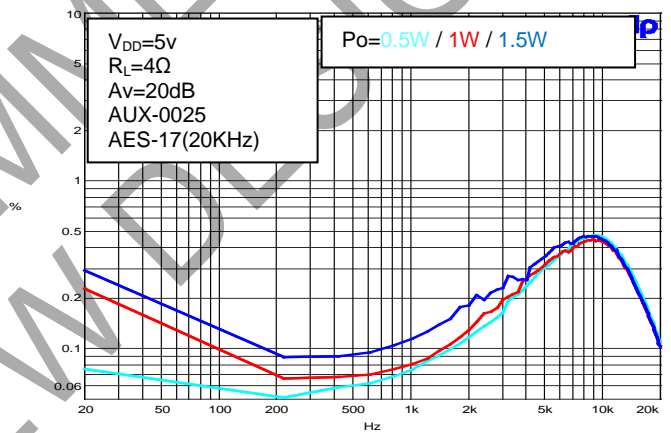
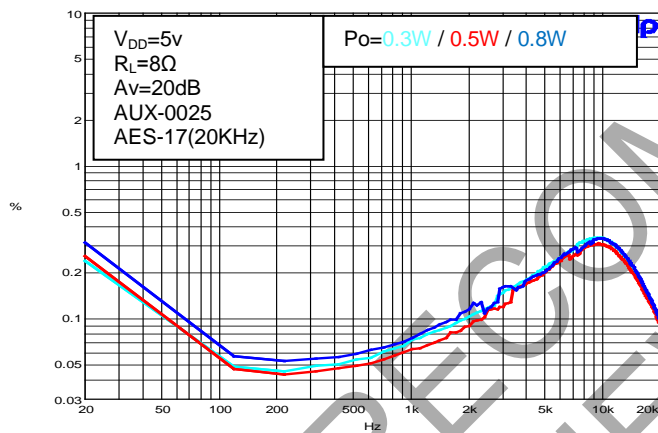
| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|------------------------|--------------------------------------|-------------------------------------------------------|-----|------|-----|------------------|
| BTL Mode | | | | | | |
| VDD | Supply Voltage Range | - | 2.8 | - | 5.5 | V |
| I_Q | Quiescent Current (BTL) | $V_{MUTE}=0$, $V_{SD}=5\text{V}$, No Load | - | 7 | - | mA |
| I_Q | Quiescent Current (SE) | $V_{MUTE}=0$, $V_{SD}=5\text{V}$, No Load | - | 4 | - | mA |
| I_{MUTE} | Mute Current (BTL) | $V_{MUTE}=0$, $V_{SD}=5\text{V}$, No Load | - | 3 | - | mA |
| I_{MUTE} | Mute Current (SE) | $V_{MUTE}=0$, $V_{SD}=5\text{V}$, No Load | - | 4 | - | mA |
| I_{SD} | Shutdown Current | $V_{MUTE}=0$, $V_{SD}=0\text{V}$, No Load | - | - | 1 | μA |
| F_{OSC} | Oscillator Frequency | - | 200 | 250 | 300 | KHz |
| R_i | Input Resistance (BTL) | Gain=20dB | - | - | 33 | $\text{K}\Omega$ |
| R_i | Input Resistance (SE) | Gain=3.5dB | - | - | 56 | $\text{K}\Omega$ |
| V_{OS} | Output Offset Voltage | No load | - | 10 | - | mV |
| $R_{DS(on)}$ | Drain – Source on-State Resistance | VDD=5.5V, $I_{ds}=0.8\text{A}$ P MOSFET | - | 0.26 | - | Ω |
| | | VDD=5.5V, $I_{ds}=0.8\text{A}$ N MOSFET | - | 0.19 | - | |
| | | VDD=4.5V, $I_{ds}=0.6\text{A}$ P MOSFET | - | 0.28 | - | |
| | | VDD=4.5V, $I_{ds}=0.6\text{A}$ N MOSFET | - | 0.21 | - | |
| | | VDD=3.6V, $I_{ds}=0.4\text{A}$ P MOSFET | - | 0.29 | - | |
| | | VDD=3.6V, $I_{ds}=0.4\text{A}$ N MOSFET | - | 0.21 | - | |
| $T_{STARTUP}$ | Startup time from Shutdown | Bypass Capacitor, $C_b=2.2\mu\text{F}$ | - | 1.72 | - | S |
| P_o | Output Power | THD+N=10%, $f=1\text{KHz}$, $R_L=8\Omega$ | 1.5 | 1.7 | - | W |
| | | THD+N=10%, $f=1\text{KHz}$, $R_L=4\Omega$ | 2.8 | 3.0 | - | |
| THD+N | Total Harmonic Distortion Plus Noise | $R_L=8\Omega$, $P_o=0.8\text{W}$, $f=1\text{KHz}$ | - | 0.08 | - | % |
| | | $R_L=4\Omega$, $P_o=1.6\text{W}$, $f=1\text{KHz}$ | - | 0.08 | - | |
| PSRR | Power Supply Ripple Rejection | Input AC-GND, $f=1\text{KHz}$, $V_{pp}=200\text{mV}$ | - | -61 | - | dB |
| CS | Channel Separation | $P_o=1\text{W}$, $f=1\text{KHz}$ | - | -82 | - | dB |
| η | Efficiency | $P_o=1.7\text{W}$, $f=1\text{KHz}$, $R_L=8\Omega$ | 85 | 90 | - | % |
| | | $P_o=3\text{W}$, $f=1\text{KHz}$, $R_L=4\Omega$ | 80 | 88 | - | |
| V_N | Noise | Input AC-GND, A-weighting | - | 180 | - | μV |
| | | Non A-weighting | - | 270 | - | |
| SNR | Signal Noise Ratio | $F=20 \sim 20\text{KHz}$, THD=1% | - | 83 | - | dB |
| SE Mode | | | | | | |
| V_{OS} | Output Offset Voltage | No load | - | 2.5 | - | V |
| P_o | Output Power | THD+N=1%, $R_L=32\Omega$, $f=1\text{KHz}$ | - | 60 | - | mW |
| THD+N | Total Harmonic Distortion Plus Noise | $R_L=32\Omega$, $P_o=50\text{mW}$, $f=1\text{KHz}$ | - | 0.02 | - | % |
| PSRR | Power Supply Ripple Rejection | Input AC-GND, $F=1\text{KHz}$, $V_{pp}=200\text{mV}$ | - | 75 | - | dB |
| CS | Channel Separation | $P_o=1\text{W}$, $f=1\text{KHz}$ | - | -87 | - | dB |
| V_n | Noise | Input AC-GND, A-weighting | - | 74 | - | μV |
| | | Non A-weighting | - | 58 | - | |
| SNR | Signal Noise Ratio | $F=20 \sim 20\text{KHz}$, THD=1% | - | 89 | - | dB |
| Control Section | | | | | | |
| V_{IH} | /SD Input High | - | 1.4 | - | - | V |
| V_{IL} | /SD Input Low | - | - | - | 0.6 | V |
| V_{MH} | Mute Input High | - | 1.4 | - | - | V |
| V_{ML} | Mute Input Low | - | - | - | 0.6 | V |
| OTP | Over Temperature Protection | - | - | 150 | - | $^\circ\text{C}$ |
| OTH | Over Temperature Hysteresis | - | - | 108 | - | $^\circ\text{C}$ |

Typical Performance Characteristics

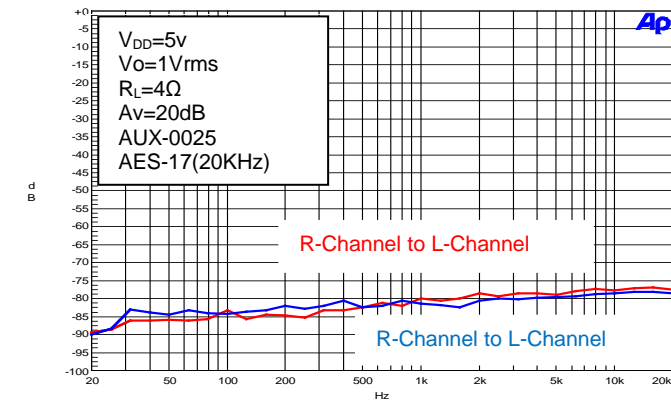
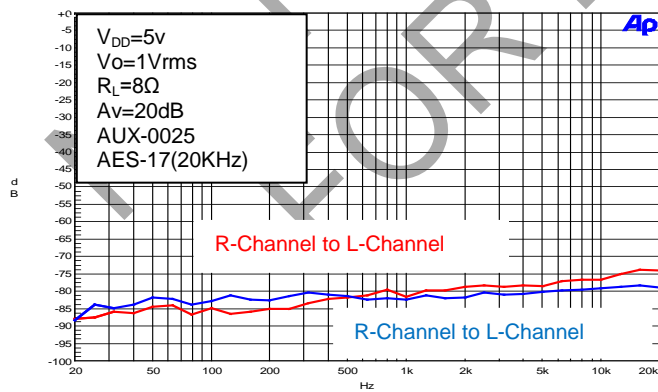
THD+N vs. Output Power



THD+N vs. Frequency

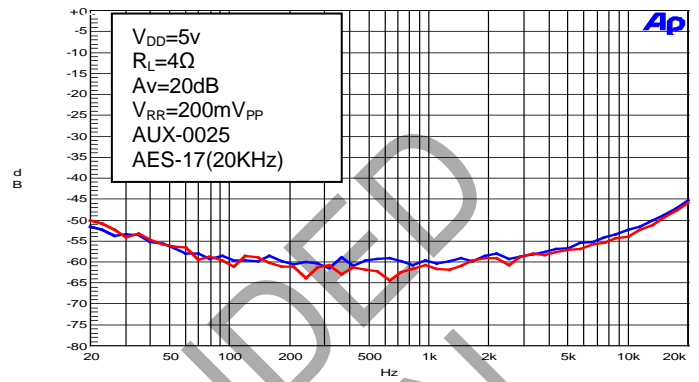
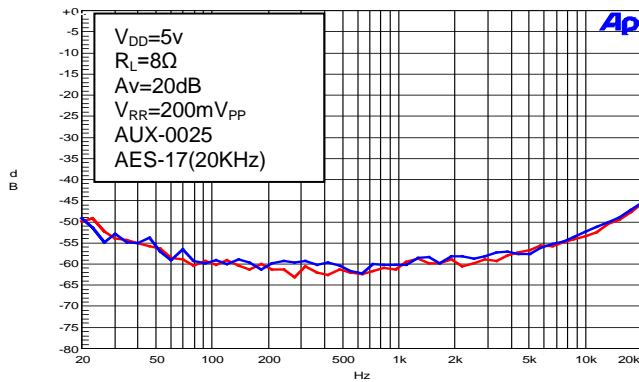


Crosstalk vs. Frequency

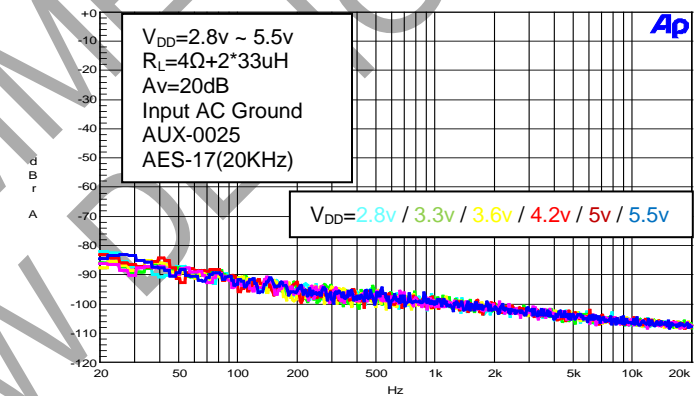
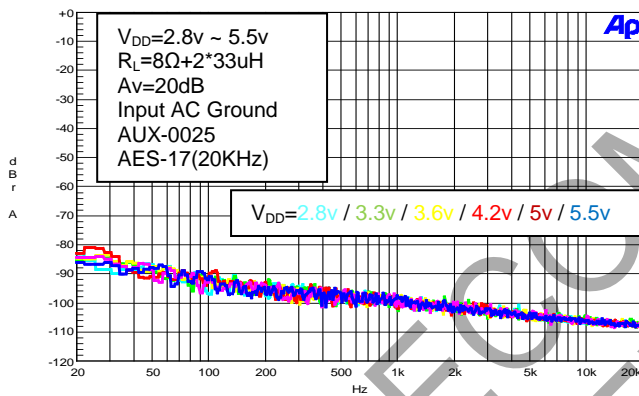


Typical Performance Characteristics (Cont.)

PSRR vs. Frequency



Output Noise vs. Frequency



NOT RECOMMENDED FOR NEW DESIGN

Typical Performance Characteristics (Cont.)

Table 1 DC Volume Control

| STEP | BTL Gain(dB) | SE Gain(dB) | DC Volume (v) | STEP | BTL Gain(dB) | SE Gain(dB) | DC Volume (v) |
|------|--------------|-------------|---------------|------|--------------|-------------|---------------|
| 1 | 20 | 3.51 | 4.708 ~ Max. | 33 | 6.70 | -7.11 | 2.389 ~ 2.461 |
| 2 | 19.6 | 3.22 | 4.637 ~ 4.708 | 34 | 6.40 | -7.43 | 2.315 ~ 2.389 |
| 3 | 19.2 | 2.94 | 4.565 ~ 4.637 | 35 | 6.00 | -7.76 | 2.243 ~ 2.315 |
| 4 | 18.8 | 2.66 | 4.493 ~ 4.565 | 36 | 5.70 | -8.09 | 2.169 ~ 2.243 |
| 5 | 18.4 | 2.39 | 4.421 ~ 4.493 | 37 | 5.30 | -8.42 | 2.097 ~ 2.169 |
| 6 | 18.0 | 2.12 | 4.347 ~ 4.421 | 38 | 4.90 | -8.76 | 2.025 ~ 2.097 |
| 7 | 17.6 | 1.85 | 4.273 ~ 4.347 | 39 | 4.60 | -9.09 | 1.951 ~ 2.025 |
| 8 | 17.1 | 1.46 | 4.195 ~ 4.273 | 40 | 4.20 | -9.43 | 1.879 ~ 1.951 |
| 9 | 16.6 | 1.07 | 4.116 ~ 4.195 | 41 | 3.80 | -9.77 | 1.807 ~ 1.879 |
| 10 | 16.1 | 0.69 | 4.045 ~ 4.116 | 42 | 3.50 | -10.10 | 1.733 ~ 1.807 |
| 11 | 15.6 | 0.32 | 3.979 ~ 4.045 | 43 | 3.10 | -10.46 | 1.661 ~ 1.733 |
| 12 | 15.1 | -0.05 | 3.909 ~ 3.979 | 44 | 2.70 | -10.81 | 1.589 ~ 1.661 |
| 13 | 14.6 | -0.41 | 3.839 ~ 3.909 | 45 | 2.30 | -11.16 | 1.517 ~ 1.589 |
| 14 | 14.2 | -0.77 | 3.767 ~ 3.839 | 46 | 2.00 | -11.52 | 1.443 ~ 1.517 |
| 15 | 13.7 | -1.12 | 3.695 ~ 3.767 | 47 | 1.60 | -11.88 | 1.371 ~ 1.443 |
| 16 | 13.3 | -1.47 | 3.621 ~ 3.695 | 48 | 1.20 | -12.24 | 1.297 ~ 1.371 |
| 17 | 12.9 | -1.82 | 3.551 ~ 3.621 | 49 | 0.80 | -12.62 | 1.225 ~ 1.297 |
| 18 | 12.5 | -2.16 | 3.476 ~ 3.551 | 50 | 0.40 | -12.99 | 1.153 ~ 1.225 |
| 19 | 12.0 | -2.50 | 3.403 ~ 3.476 | 51 | 0.00 | -13.38 | 1.079 ~ 1.153 |
| 20 | 11.6 | -2.84 | 3.332 ~ 3.403 | 52 | -1.00 | -14.37 | 1.005 ~ 1.079 |
| 21 | 11.2 | -3.18 | 3.259 ~ 3.332 | 53 | -2.10 | -15.42 | 0.929 ~ 1.005 |
| 22 | 10.8 | -3.51 | 3.186 ~ 3.259 | 54 | -3.00 | -16.30 | 0.849 ~ 0.929 |
| 23 | 10.5 | -3.84 | 3.114 ~ 3.186 | 55 | -5.00 | -18.23 | 0.771 ~ 0.849 |
| 24 | 10.1 | -4.17 | 3.043 ~ 3.114 | 56 | -7.00 | -20.16 | 0.701 ~ 0.771 |
| 25 | 9.7 | -4.50 | 2.969 ~ 3.043 | 57 | -9.00 | -22.08 | 0.633 ~ 0.701 |
| 26 | 9.3 | -4.82 | 2.897 ~ 2.969 | 58 | -10.9 | -23.96 | 0.563 ~ 0.633 |
| 27 | 8.9 | -5.16 | 2.823 ~ 2.897 | 59 | -17.0 | -30.01 | 0.491 ~ 0.563 |
| 28 | 8.6 | -5.48 | 2.751 ~ 2.823 | 60 | -22.8 | -35.83 | 0.419 ~ 0.491 |
| 29 | 8.2 | -5.80 | 2.678 ~ 2.751 | 61 | -29.0 | -41.98 | 0.347 ~ 0.419 |
| 30 | 7.8 | -6.13 | 2.605 ~ 2.678 | 62 | -33.5 | -46.46 | 0.275 ~ 0.347 |
| 31 | 7.5 | -6.45 | 2.533 ~ 2.605 | 63 | -39.5 | -52.58 | 0.201 ~ 0.275 |
| 32 | 7.1 | -6.78 | 2.461 ~ 2.533 | 64 | -60.0 | -92.95 | 0 ~ 0.201 |

Application Information

AGC Function

When output reaches the maximum power-setting value, the Internal Programmable Gain Amplifier will decrease the gain to prevent the output waveform from clipping. This feature prevents speaker damage from occurring using the AGC pin to set the AGC function, limiting the output power.

Table 1: AGC Setting Threshold vs. Output

| AGC Function | Output Power |
|-------------------------------|----------------------------------------------------------------------------|
| VDD ~ 0.45VDD or AGC Floating | AGC function Disable |
| 0.45VDD ~ 0.27VDD | $P_o = \left[\frac{8(1/2V_{DD} - V_{AGC})^2}{R_l} \right] \times 0.95$ |
| 0.27VDD ~ GND | $P_o = 2.3W$ (Max. output power 4Ω) $P_o = 1.2W$ (Max. output power 8Ω) |

Mute Operation

The MUTE pin is an input for controlling the Class-D output state of the PAM8009. A logic low on this pin enables the outputs, and a logic high on this pin disables the outputs. This pin may be used to quickly disable or enable 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-down.

Shutdown Operation

In order to reduce power consumption while not in use, the PAM8009 contains shutdown circuit to turn off the amplifier's bias circuit. The amplifier is turned off when logic low is placed on the /SD pin. When switching the /SD pin to low level, the amplifier enters a low-consumption current status. The /SD pin can be left floating due to the internal pull-up.

Undervoltage Protection

External undervoltage detection can be used to shut down the PAM8009 before an input device can generate a pop. The shutdown threshold at the UVP pin is 1.2V. The user selects a resistor divider to obtain the shutdown threshold and hysteresis for the specific application.

The threshold can be determined as below:

With the condition: $R_3 \gg R_1/R_2$

$$V_{UVP} = [1.2 - (6\mu A \times R_3)] \times (R_1 + R_2) / R_2$$

$$\text{Hysteresis} = 5\mu A \times R_3 \times (R_1 + R_2) / R_2$$

Power Supply Decoupling

The PAM8009 is a high performance CMOS audio-amplifier that requires adequate power supply decoupling to ensure the outputs of THD and PSRR are as low as possible. Power supply decoupling also prevents oscillation caused by long lead between the amplifier and the speaker. The 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 0.1μF is recommend, placing it as close as possible to the device's V_{DD} lead. For filtering lower-frequency noise signals, a large capacitor of 10μF or greater placed near the audio amplifier is recommended.

Application Information (Cont.)

Input Capacitor (Ci)

Large input capacitors are both expensive and space hungry for portable designs. Clearly, a certain sized capacitor is needed to couple in low frequency 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 (Ci) and Input Resistance (Ri) of the amplifier form a high-pass filter with the corner frequency determined equation below:

$$F_c = 1 / 2\pi R_i \times C_i$$

In addition to system cost and size, click and pop performance is affected by the size of the input coupling capacitor, Ci. A larger in/out coupling capacitor requires more charge to reach its quiescent DC voltage (Normally 1/2 V_{DD}). This charge comes from the internal circuit via the feedback and is apt to create pops upon device enabling. Thus, by minimizing the capacitor size based on necessary low frequency response, turn on pop can be minimized.

Bypass Capacitor (C_{BYP})

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 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 0.47uF to 1.0uF 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.

Ordering Information

PAM8009 x x x

Package Type

D: SOP
K: QFN4x4

Number of Pins

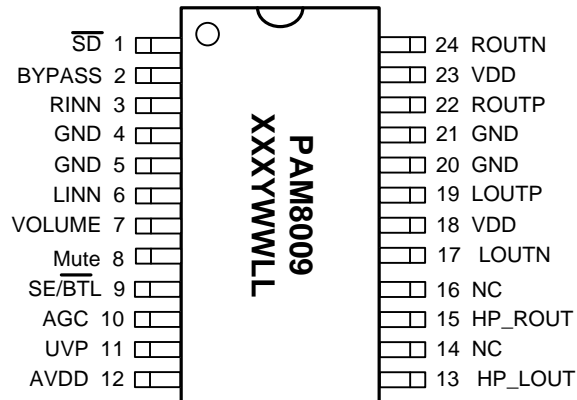
H: 24
G: 20

Shipping Package

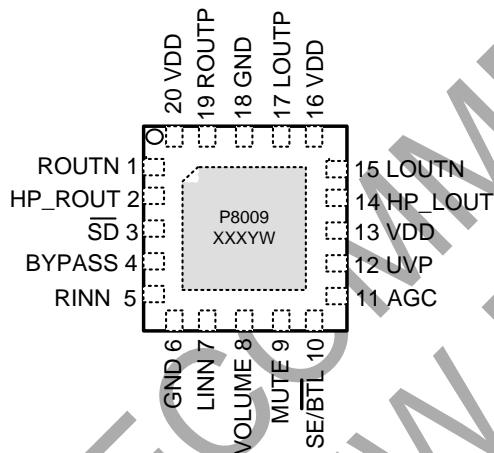
R: Tape & Reel

| Part Number | Package Type | Standard Package |
|-------------|--------------|---------------------|
| PAM8009DHR | SOP-24 | 1000 Unit/Tape&Reel |
| PAM8009KGR | U-QFN4040 | 3000 Unit/Tape&Reel |

Marking Information



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



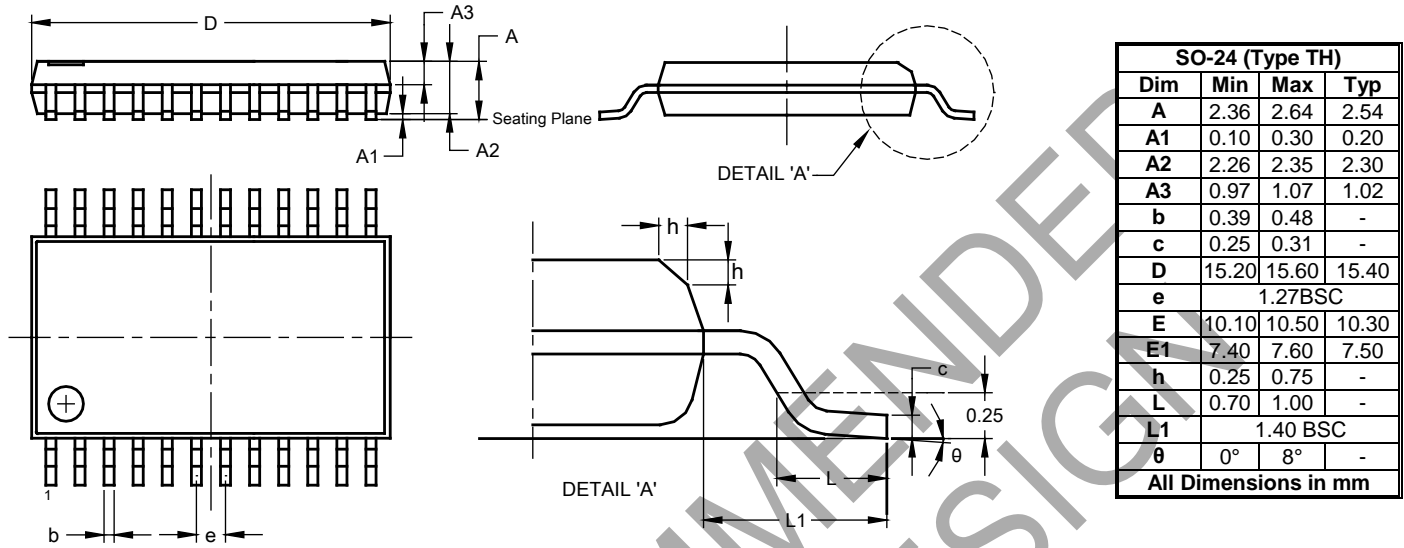
X: Internal Code
Y: Year
W: Week

NOT RECOMMENDED FOR NEW DESIGN

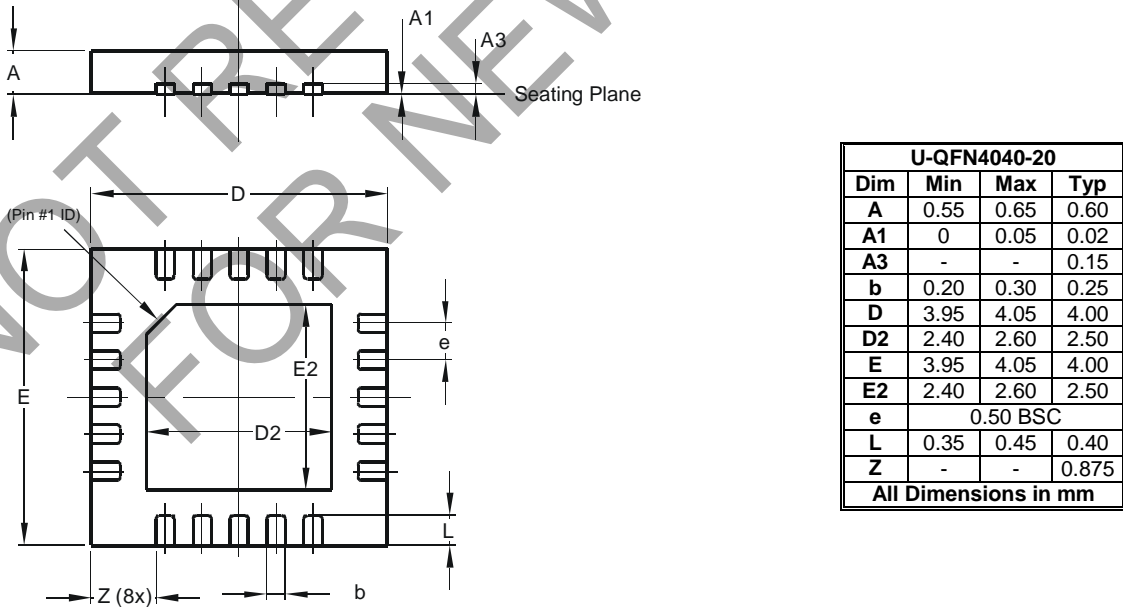
Package Outline Dimensions (All dimensions in mm.)

Please see AP02002 at <http://www.diodes.com/datasheets/ap02002.pdf> for the latest version.

SO-24 (Type TH)



U-QFN4040-20



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