**PAM8303C**

# ULTRA LOW EMI, 3W FILTERLESS MONO CLASS-D AUDIO POWER AMPLIFIER

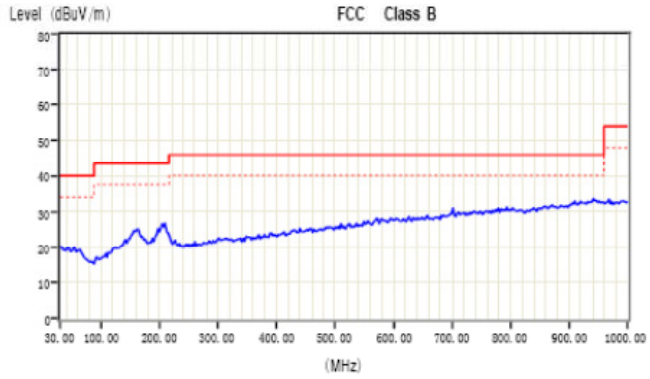
## Description

The PAM8303C is a 3W mono filterless Class-D amplifier with high PSRR and differential input that eliminate noise and RF rectification.

Features like 90% efficiency and small PCB area make the PAM8303C Class-D amplifier ideal for cellular handsets. The filterless architecture requires no external output filter, fewer external components, less PCB area and lower system costs, and simplifies application design.

The PAM8303C features short circuit protection and thermal shutdown.

The PAM8303C is available in 9-ball WCSP, MSOP-8 and DFN 3x3 8-pin packages.




EMI vs Frequency

## Features

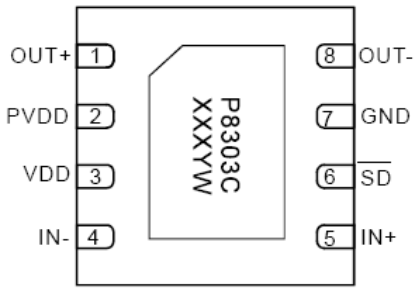
- Ultra Low EMI, -20dB Better Than FCC Class-B @ 300MHz
- High Efficiency up to 90% @1W with an 8Ω Speaker
- Shutdown Current <1μA
- 3W@10% THD Output with a 4Ω Load at 5V Supply
- Demanding Few External Components
- Superior Low Noise without Input
- Supply Voltage from 2.8V to 5.5V
- Short Circuit Protection
- Thermal Shutdown
- Available in Space Saving Packages: 1.45mmx1.45mm WCSP9, MSOP-8, DFN3x3-8
- Pb-Free Package

## Applications

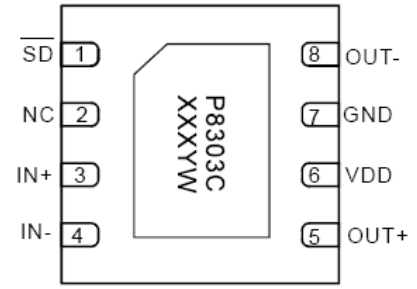
- Cellular Phones/Smart Phones
- MP4/MP3
- GPS
- Digital Photo Frame
- Electronic Dictionary
- Portable Game Machines

## Pin Assignments

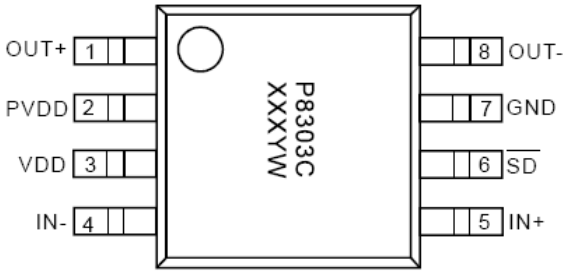
DFN3X3(B)
Top View



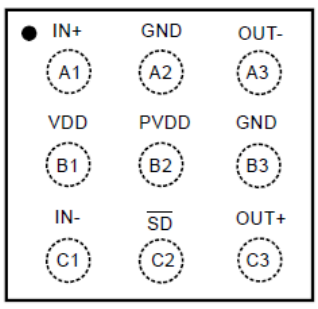

DFN3X3(C)
Top View




MSOP-8(B)
Top View




9 Ball WCSP(A)
Top View





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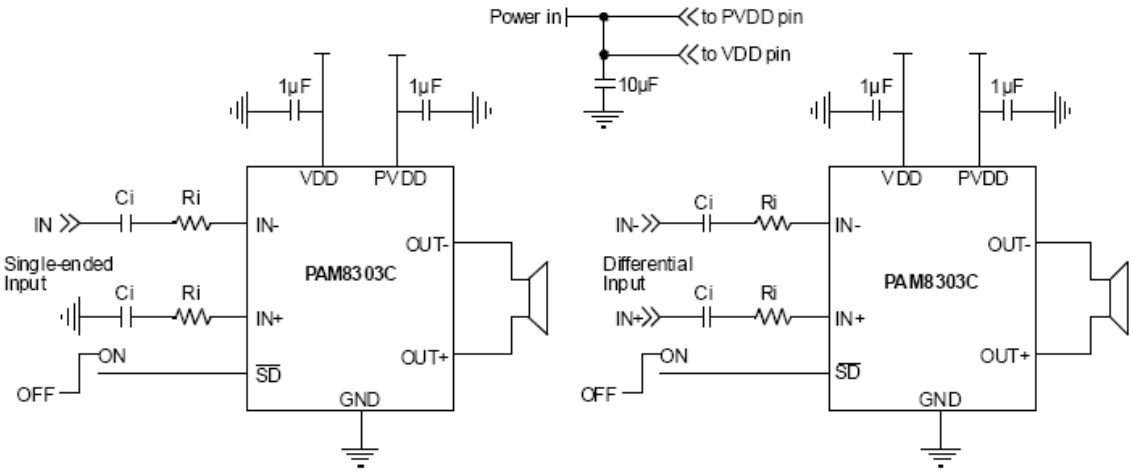
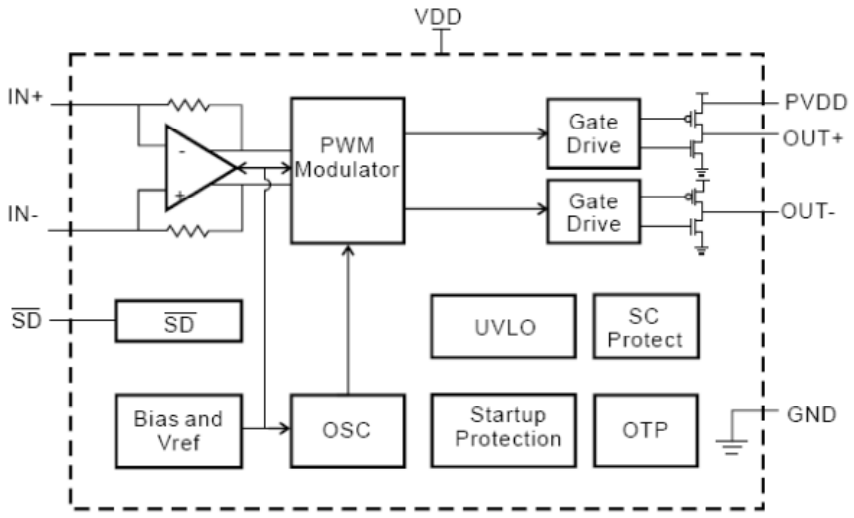
## Typical Applications Circuit




## Pin Descriptions

| Pin Name | Pin Name | | | | Function |
|---|---|---|---|---|---|
| | WCSP(A) | DFN3X3-8 (B) | DFN3X3-8 (C) | MSOP-8 (B) | |
| OUT+ | C3 | 1 | 5 | 1 | Positive BTL Output |
| PVDD | B2 | 2 | — | 2 | Power Supply |
| VDD | B1 | 3 | 6 | 3 | Analog Power Supply |
| IN- | C1 | 4 | 4 | 4 | Negative Differential Input |
| IN+ | A1 | 5 | 3 | 5 | Positive Differential Input |
| SD | C2 | 6 | 1 | 6 | Shutdown Terminal (active low) |
| GND | A2, B3 | 7 | 7 | 7 | Ground |
| OUT- | A3 | 8 | 8 | 8 | Negative BTL Output |
| NC | — | — | 2 | — | |

## 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 $V_{DD}$ +0.3 | |
| Maximum Junction Temperature | 150 | °C |
| Storage Temperature | -65 to +150 | |
| Soldering Temperature | 250, 10 sec | |

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

| Parameter | Rating | Unit |
|---|---|---|
| Supply Voltage Range | 2.8 to 5.5 | V |
| Ambient 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) | WCSP 1.45x1.45 | $\theta_{JA}$ | 90-220 | °C/W |
| | MSOP-8 | | 180 | |
| | DFN3x3-8 | | 47.9 | |
| Thermal Resistance (Junction to Case) | MSOP-8 | $\theta_{JC}$ | 75 | |

**Note**: For the 9-pin CSP package, the thermal resistance is highly dependent on the PCB heat sink area. For example, the $\Theta_{ja}$ can equal to 195°C/W with 50mm$^2$ total area or 135°C/W with 500mm$^2$ area. When using ground and power planes, the value is around 90°C/W.


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## Electrical Characteristics (@$T_A$ = +25°C, $V_{DD}$ = 5V, Gain = 2V/V, $R_L$ = L(33µH) + R + L(33µH), unless otherwise specified.)

| Symbol | Parameter | Test Conditions | | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|---|
| $V_{DD}$ | Supply Voltage | | | 2.8 | | 5.5 | V |
| $P_O$ | Output Power | THD+N = 10%, f = 1KHz, R = 4Ω | $V_{DD}$ = 5.0V | 2.85 | 3.00 | | W |
| | | | $V_{DD}$ = 3.6V | 1.65 | 1.80 | | |
| | | | $V_{DD}$ = 3.2V | 1.20 | 1.35 | | |
| | | THD+N = 1%, f = 1KHz, R = 4Ω | $V_{DD}$ = 5.0V | 2.50 | 2.66 | | W |
| | | | $V_{DD}$ = 3.6V | 1.15 | 1.30 | | |
| | | | $V_{DD}$ = 3.2V | 0.85 | 1.0 | | |
| | | THD+N = 10%, f = 1KHz, R = 8Ω | $V_{DD}$ = 5.0V | 1.65 | 1.8 | | W |
| | | | $V_{DD}$ = 3.6V | 0.75 | 0.9 | | |
| | | | $V_{DD}$ = 3.2V | 0.55 | 0.7 | | |
| | | THD+N = 1%, f = 1KHz, R = 8Ω | $V_{DD}$ = 5.0V | 1.3 | 1.5 | | W |
| | | | $V_{DD}$ = 3.6V | 0.55 | 0.72 | | |
| | | | $V_{DD}$ = 3.2V | 0.40 | 0.55 | | |
| THD+N | Total Harmonic Distortion Plus Noise | $V_{DD}$ = 5.0V, $P_O$ = 1W, R = 8Ω | f = 1kHz | | 0.28 | 0.35 | % |
| | | $V_{DD}$ = 3.6V, $P_O$ = 0.1W, R = 8Ω | | | 0.40 | 0.45 | |
| | | $V_{DD}$ = 3.2V, $P_O$ = 0.1W, R = 8Ω | | | 0.55 | 0.60 | |
| | | $V_{DD}$ = 5.0V, $P_O$ = 0.5W, R = 4Ω | f = 1kHz | | 0.20 | 0.25 | % |
| | | $V_{DD}$ = 3.6V, $P_O$ = 0.2W, R = 4Ω | | | 0.35 | 0.40 | |
| | | $V_{DD}$ = 3.2V, $P_O$ = 0.1W, R = 4Ω | | | 0.5 | 0.55 | |
| PSRR | Power Supply Ripple Rejection | $V_{DD}$ = 3.6V, Inputs AC-Grounded with $C_{IN}$ = 1µF | f = 217Hz | | -63 | -55 | dB |
| | | | f = 1kHz | | -62 | -55 | |
| | | | f = 10kHz | | -52 | -40 | |
| Dyn | Dynamic Range | $V_{DD}$ = 5V, THD = 1%, R = 8Ω | f = 1kHz | 85 | 95 | | |
| $V_N$ | Output Noise | Inputs AC-Grounded | No A-Weighting | | 50 | 100 | µV |
| | | | A-Weighting | | 30 | 60 | |
| CMRR | Common Mode Rejection Ratio | $V_{IC}$ = 100m, $V_{PP}$, f =1kHz | | 40 | 63 | | dB |
| η | Peak Efficiency | $R_L$ = 8Ω, THD = 10% | f = 1kHz | 85 | 90 | | |
| | | $R_L$ = 4Ω, THD = 10% | | 80 | 86 | | % |
| $I_Q$ | Quiescent Current | $V_{DD}$ = 5.0V | R = 8Ω | | 7.5 | 10 | |
| | | $V_{DD}$ = 3.6V | | | 4.6 | 7 | |
| | | $V_{DD}$ = 3.0V | | | 3.6 | 5 | mA |
| $I_{SD}$ | Shutdown Current | $V_{DD}$ = 3.0V to 5.0V | $V_{SD}$ = 0.3V | | 0.5 | 2 | µA |
| $R_{DS(ON)}$ | Static Drain-to-Source On-State Resistor | CSP Package, High Side PMOS plus Low Side NMOS, I = 500mA | $V_{DD}$ = 5.0V | | 280 | 350 | |
| | | | $V_{DD}$ = 3.6V | | 300 | 375 | |
| | | | $V_{DD}$ = 3.0V | | 325 | 400 | |
| | | MSOP/DFN package, High Side PMOS plus Low Side NMOS, I = 500mA | $V_{DD}$ = 5.0V | | 365 | 420 | |
| | | | $V_{DD}$ = 3.6V | | 385 | 450 | |
| | | | $V_{DD}$ = 3.0V | | 410 | 500 | |
| $R_{IN}$ | Input Resistance | | | | 150 | | KΩ |
| $f_{SW}$ | Switching Frequency | $V_{DD}$ = 3V to 5V | | 200 | 250 | 300 | KHz |
| $G_V$ | Closed Loop Gain | $V_{DD}$ = 3V to 5V | | | 300kΩ/$R_I$ | | dB |
| $V_{OS}$ | Output Offset Voltage | Input AC-Ground, $V_{DD}$ = 5V | | | 10 | 50 | mV |
| $V_{IH}$ | Enable Input High Voltage | $V_{DD}$ = 5V | | 1.5 | | | V |
| $V_{IL}$ | Enable Input Low Voltage | $V_{DD}$ = 5V | | | | 0.3 | V |


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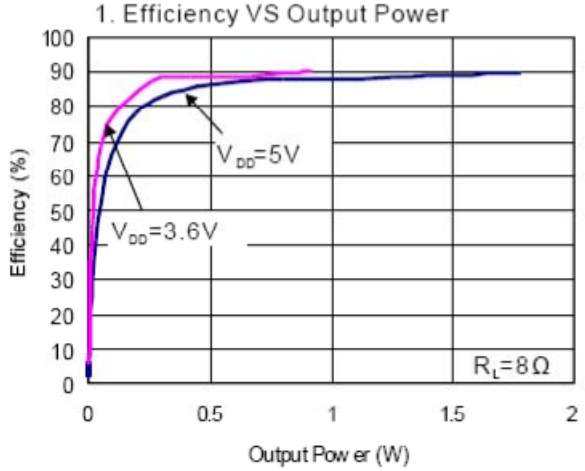
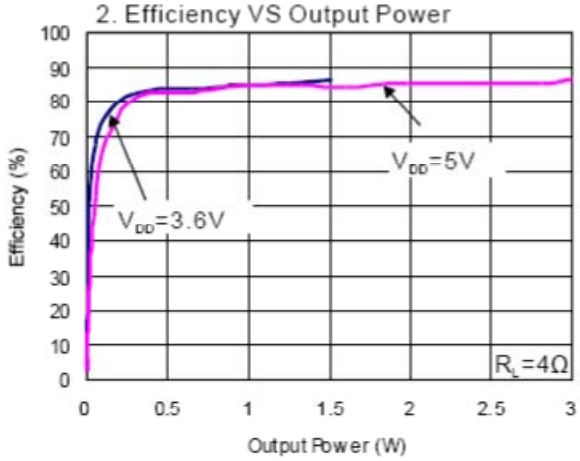
## Typical Performance Characteristics (@$T_A$ = +25°C, $V_{DD}$ = 5V, f = 1kHz, Gain = 2V/V, unless otherwise specified.)

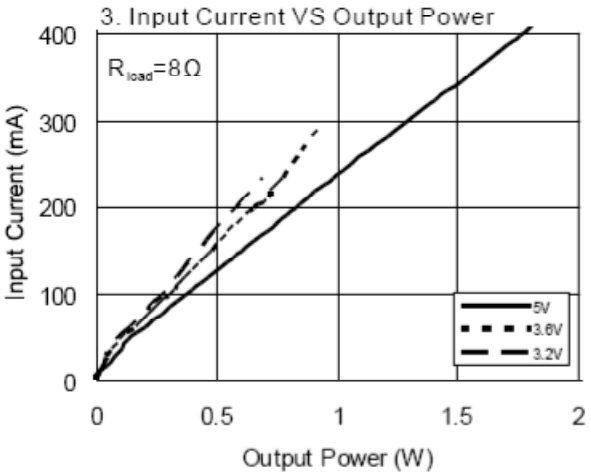
1. Efficiency VS Output Power



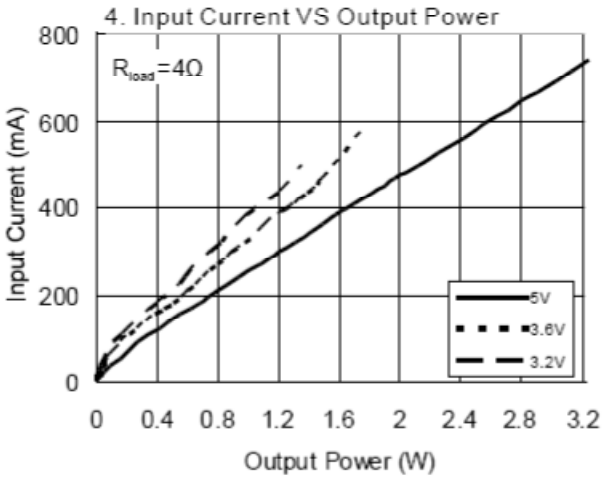

2. Efficiency VS Output Power



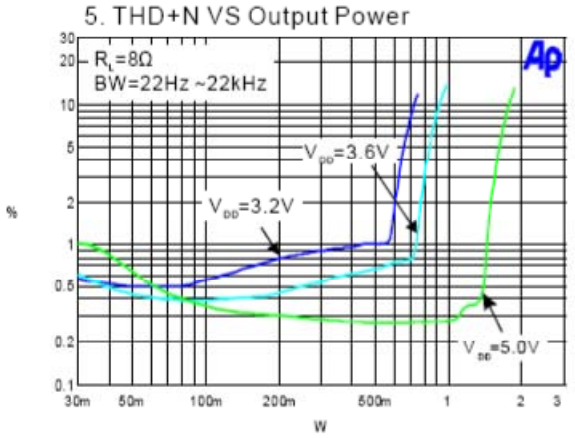

3. Input Current VS Output Power



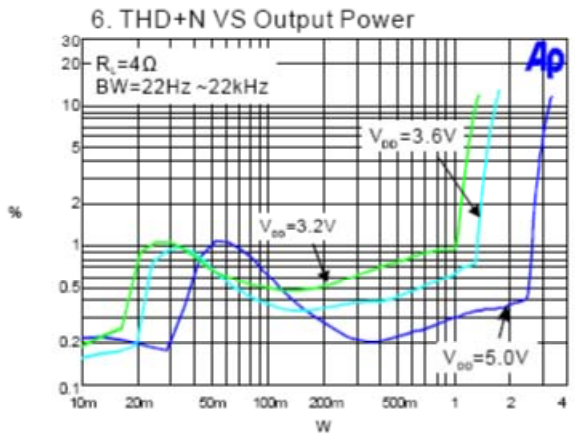

4. Input Current VS Output Power




5. THD+N VS Output Power




6. THD+N VS Output Power





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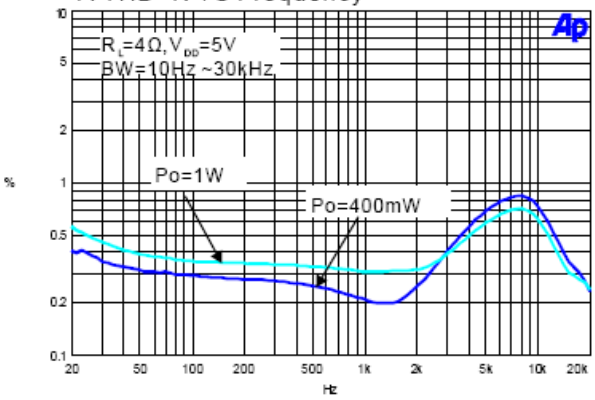
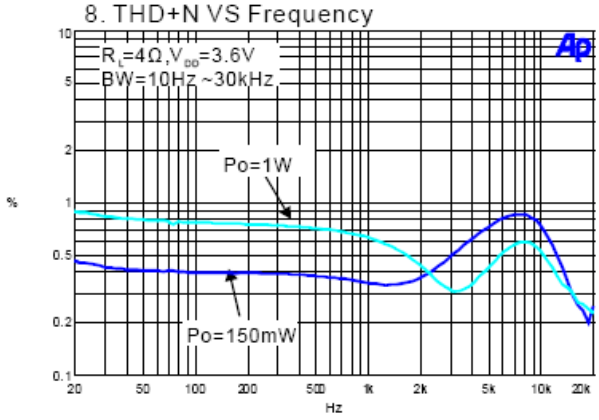
## Typical Performance Characteristics (cont.) (@$T_A$ = +25°C, $V_{DD}$ = 5V, f = 1kHz, Gain = 2V/V, unless otherwise specified.)

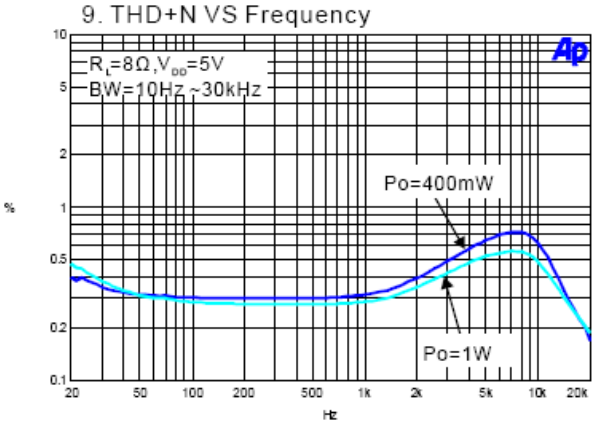
7. THD+N VS Frequency



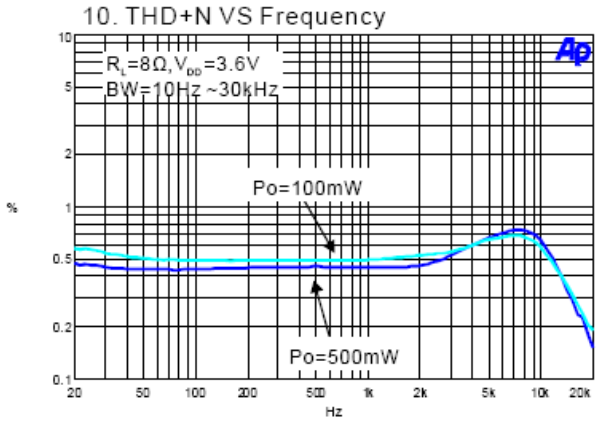

8. THD+N VS Frequency




9. THD+N VS Frequency




10. THD+N VS Frequency





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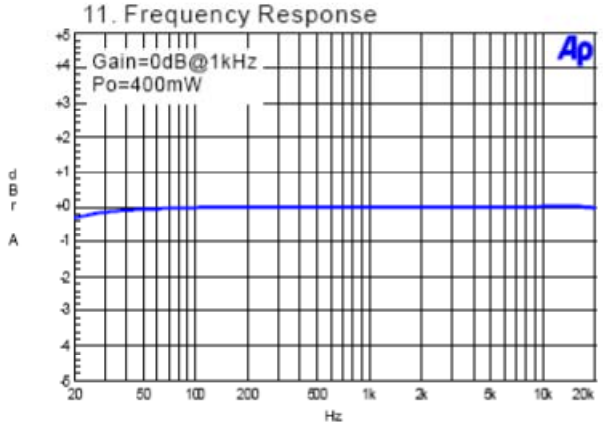
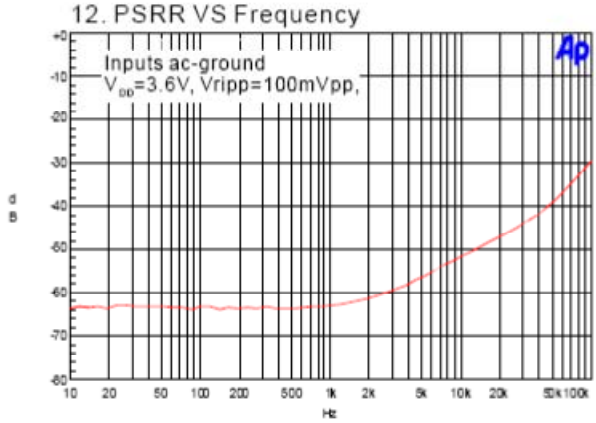
## Typical Performance Characteristics (cont.) (@$T_A$ = +25°C, $V_{DD}$ = 5V, f = 1kHz, Gain = 2V/V, unless otherwise specified.)

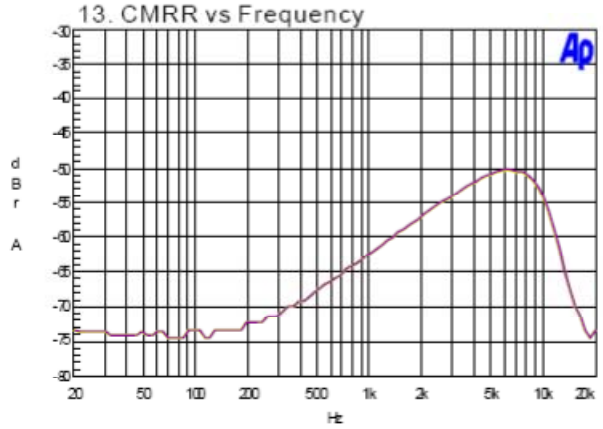
11. Frequency Response



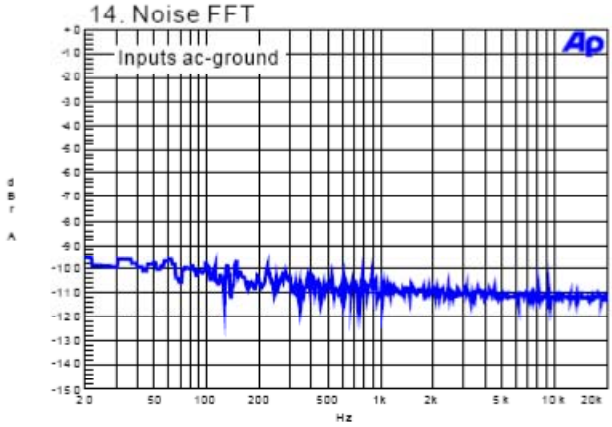

12. PSRR VS Frequency




13. CMRR vs Frequency




14. Noise FFT





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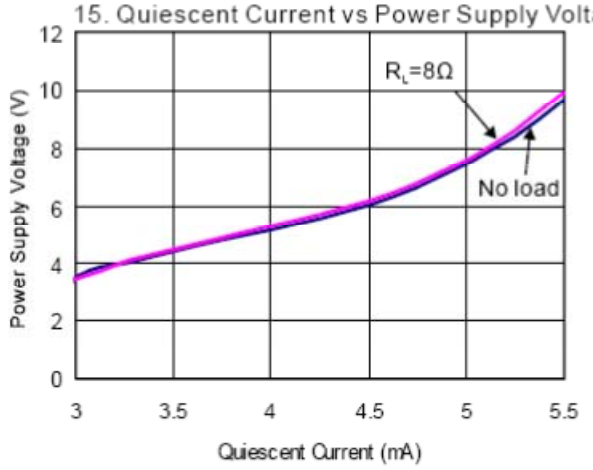
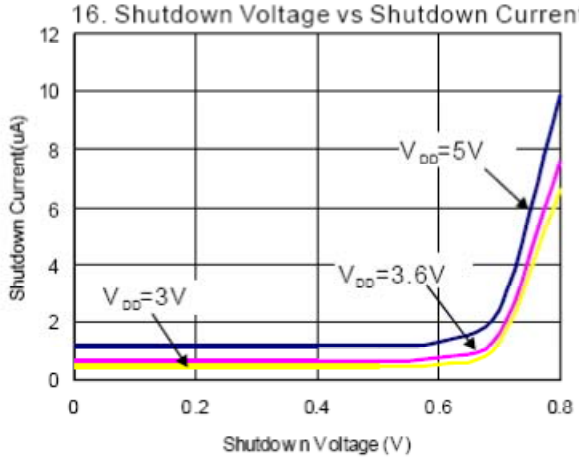
## Typical Performance Characteristics (cont.) (@$T_A$ = +25°C, $V_{DD}$ = 5V, f = 1kHz, Gain = 2V/V, unless otherwise specified.)

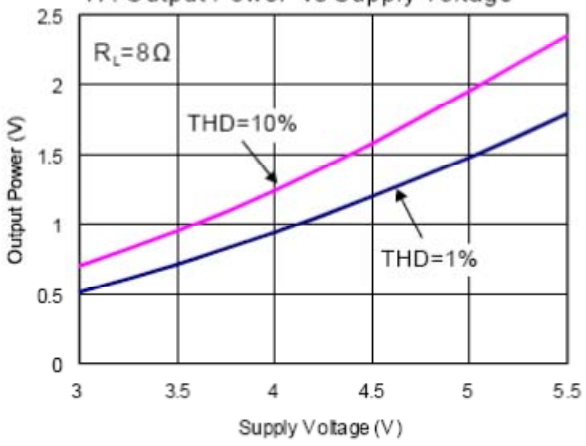
15. Quiescent Current vs Power Supply Voltage



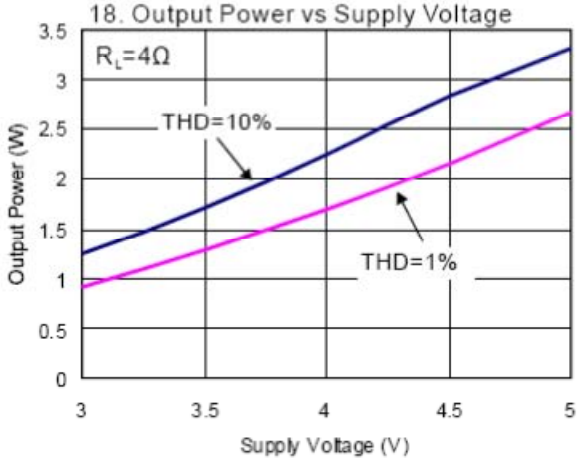

16. Shutdown Voltage vs Shutdown Current




17. Output Power vs Supply Voltage




18. Output Power vs Supply Voltage





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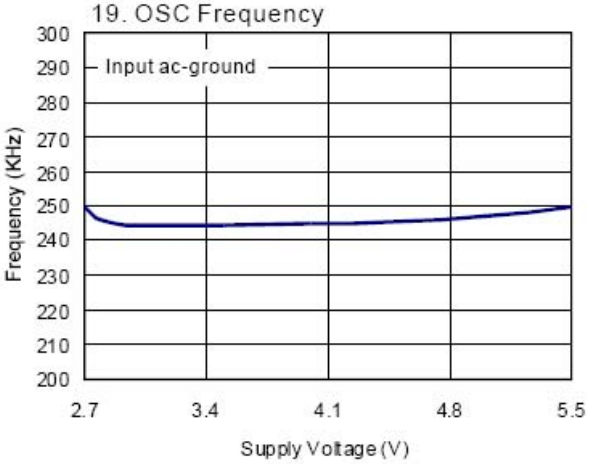
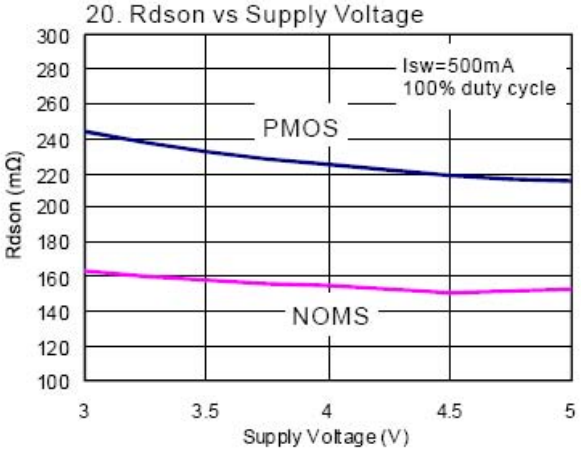
## Typical Performance Characteristics (cont.) (@$T_A$ = +25°C, $V_{DD}$ = 5V, f = 1kHz, Gain = 2V/V, unless otherwise specified.)

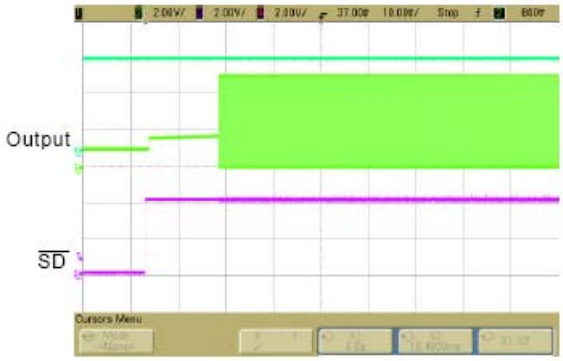
19. OSC Frequency




20. Rdson vs Supply Voltage




21. Start-up from Shutdown





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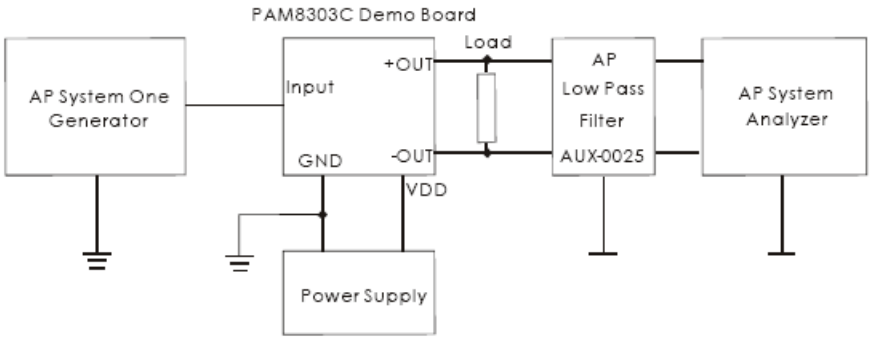
## Application Information

### 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.

### Input Resistance (RI)

The input resistors ($R_I$) set the gain of the amplifier according to Equation 1.

$$\text{Gain} = \frac{2\text{x}150\text{k}\Omega}{R_I}\left(\frac{V}{V}\right)$$

Resistor matching is very important in fully differential amplifiers. The balance of the output on the reference voltage depends on matched ratios of the resistors. CMRR, PSRR, and cancellation of the second harmonic distortion diminish if resistor mismatch occurs. Therefore, it is recommended to use 1% tolerance resistors or better to keep the performance optimized. Matching is more important than overall tolerance. Resistor arrays with 1% matching can be used with a tolerance greater than 1%.

Place the input resistors very close to the PAM8303C to limit noise injection on the high impedance nodes.

For optimal performance the gain should be set to 2X ($R_I$ = 150k) or lower. Lower gain allows the PAM8303C to operate at its best, and keeps a high voltage at the input making the inputs less susceptible to noise. In addition to these features, higher value of $R_I$ minimizes pop noise.

### Input Capacitors ($C_I$)

In the typical application, an input capacitor, $C_i$, is required to allow the amplifier to bias the input signal to the proper DC level for optimum operation. In this case, Ci and the minimum input impedance $R_I$ form is a high-pass filter with the corner frequency determined in the follow equation:

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

It is important to consider the value of $C_i$ as it directly affects the low frequency performance of the circuit. For example, when $R_i$ is 150kΩ and the specification calls for a flat bass response are down to 150Hz. Equation is reconfigured as followed:

$$C_I = \frac{1}{2\Pi R_I F_{CI}}$$

When input resistance variation is considered, the $C_I$ is 7nF, so one would likely choose a value of 10nF. A further consideration for this capacitor is the leakage path from the input source through the input network ($C_I$, $R_I$ + $R_F$) to the load. This leakage current creates a DC offset voltage at the input to the amplifier that reduces useful headroom, especially in high gain applications.

For this reason, a low-leakage tantalum or ceramic capacitor is the best choice. When polarized capacitors are used, the positive side of the capacitor should face the amplifier input in most applications as the DC level is held at $V_{DD}$/2, which is likely higher than the source DC level. Please note that it is important to confirm the capacitor polarity in the application.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## Application Information (cont.)

### Decoupling Capacitor ($C_S$)

The PAM8303C is a high-performance CMOS audio amplifier that requires adequate power supply decoupling to ensure the output total harmonic distortion (THD) as low as possible. Power supply decoupling also prevents the oscillations causing by long lead length between the amplifier and the speaker.

The optimum decoupling is achieved by using two different types of capacitors that target on different types of noise on the power supply leads. For higher frequency transients, spikes, or digital hash on the line, a good low equivalentseries- resistance (ESR) ceramic capacitor, typically 1μF, is placed as close as possible to the device each $V_{DD}$ and $PV_{DD}$ pin for the best operation. For filtering lower frequency noise signals, a large ceramic capacitor of 10μF or greater placed near the audio power amplifier is recommended.

### How to Reduce EMI

Most applications require a ferrite bead filter for EMI elimination 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, but low impedance at low frequencies.

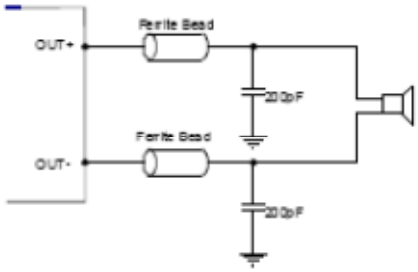


**Figure 1: Ferrite Bead Filter to Reduce EMI**

In order to reduce power consumption while not in use, the PAM8303C 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 $\overline{SD}$ pin. By switching the shutdown pin connected to GND, the PAM8303C supply current draw will be minimized in idle mode.

### Shutdown Operation

In order to reduce power consumption while not in use, the PAM8303C 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 pin. By switching the shutdown pin connected to GND, the PAM8303C supply current draw will be minimized in idle mode.

### Under Voltage Lock-Out (UVLO)

The PAM8303C incorporates circuitry designed to detect low supply voltage. When the supply voltage drops to 2.3V or below, the PAM8303C goes into a state of shutdown, and the device comes out of its shutdown state and restore to normal function only when reset the power supply or $\overline{SD}$ pin.

Thermal protection on the PAM8303C prevents the device from damage when the internal die temperature exceeds +135°C. There is a 15°C tolerance on this trip point from device to device. Once the die temperature exceeds the set point, the device will enter the shutdown state and the outputs are disabled. This is not a latched fault. The thermal fault is cleared once the temperature of the die decreased by 30°C. This large hysteresis will prevent motor boating sound well and the device begins normal operation at this point with no external system interaction.

### POP and Click Circuitry

The PAM8303C contains circuitry to minimize turn-on and turn-off transients or "click and pops", where turn-on refers to either power supply turn-on or device recover from shutdown mode. When the device is turned on, the amplifiers are internally muted. An internal current source ramps up the internal reference voltage. The device will remain in mute mode until the reference voltage reach half supply voltage, 1/2 $V_{DD}$. As soon as the reference voltage is stable, the device will begin full operation. For the best power-off pop performance, the amplifier should be set in shutdown mode prior to removing the power supply voltage.


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## Application Information (cont.)

### PCB Layout Guidelines

#### Grounding

It is recommended to use plain grounding or separate grounds. Do not use one line connecting power GND and analog GND. Noise currents in the output power stage need to be returned to output noise ground and nowhere else. When these currents circulate elsewhere, they may get into the power supply, or the signal ground, etc, even worse, they may form a loop and radiate noise. Any of these instances results in degraded amplifier performance. The output noise ground that the logical returns for the output noise currents associated with Class-D switching must tie to system ground at the power exclusively. Signal currents for the inputs, reference need to be returned to quite ground. This ground only ties to the signal components and the GND pin. GND then ties to system ground.

#### Power Supply Line

As same to the ground, $V_{DD}$ and $PV_{DD}$ need to be separately connected to the system power supply. It is recommended that all the trace could be routed as short and thick as possible. For the power line layout, just imagine water stream, any barricade placed in the trace (shown in Figure 2) could result in the bad performance of the amplifier.

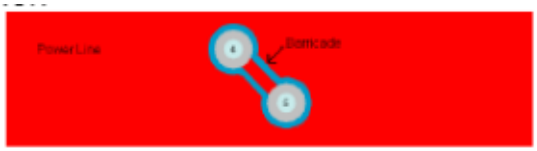


**Figure 2. Power Line**

#### Components Placement

Decoupling capacitors-As previously described, the high-frequency 1µF decoupling capacitors should be placed as close to the power supply terminals ($V_{DD}$ and $PV_{DD}$) as possible. Large bulk power supply decoupling capacitors (10µF or greater) should be placed near the PAM8303C on the $PV_{DD}$ terminal.

Input resistors and capacitors need to be placed very close to input pins.

Output filter - The ferrite EMI filter should be placed as close to the output terminals as possible for the best EMI performance, and the capacitors used in the filters should be grounded to system ground.


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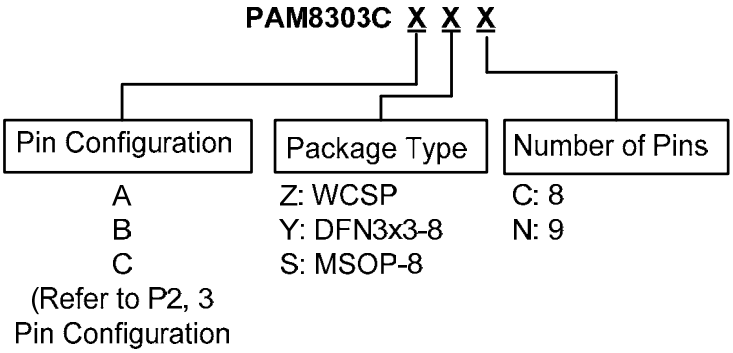
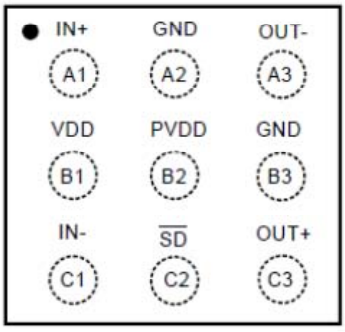
## Ordering Information




| Part Number | Part Marking | Package Type | Standard Package |
|---|---|---|---|
| PAM8303CAZN | BH<br>YW | WCSP 9 | 3000 Units/Tape&Reel |
| PAM8303CBYC | P8303C<br>XXXYW | DFN3x3-8 | 3000 Units/Tape&Reel |
| PAM8303CCYC | P8303C<br>XXXYW | DFN3x3-8 | 3000 Units/Tape&Reel |
| PAM8303CBSC | P8303C<br>XXXYW | MSOP-8 | 2500 Units/Tape&Reel |

## Marking Information

9 Ball WCSP(A)
Top View




**Marking**

BH
YW

BH: Product Code of PAM8303C
Y: Year
W: Week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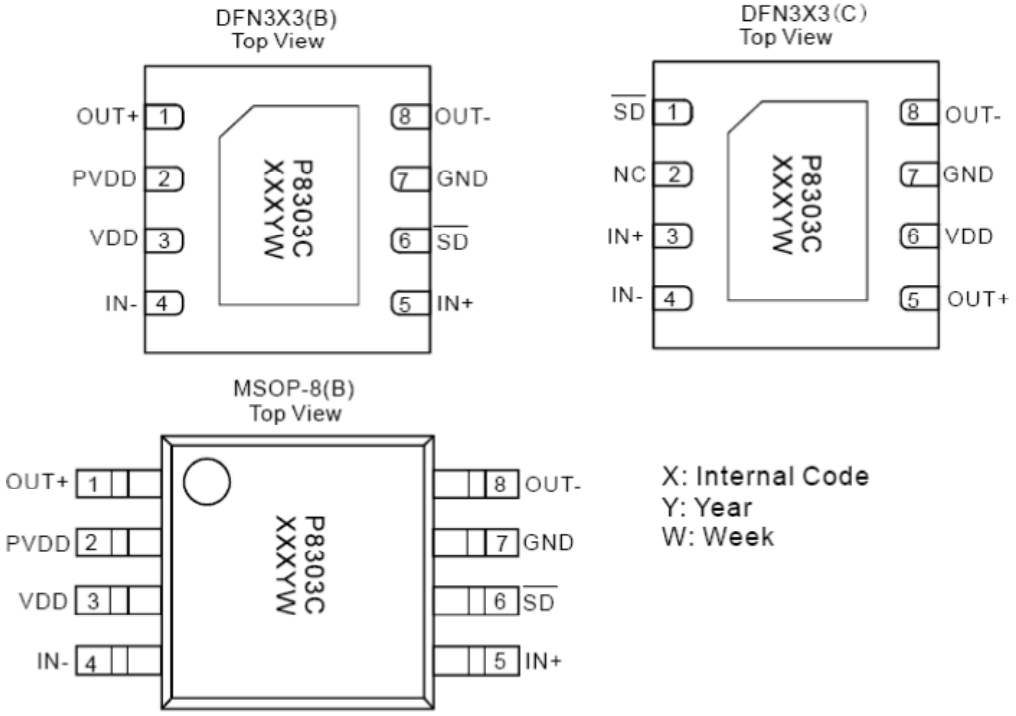
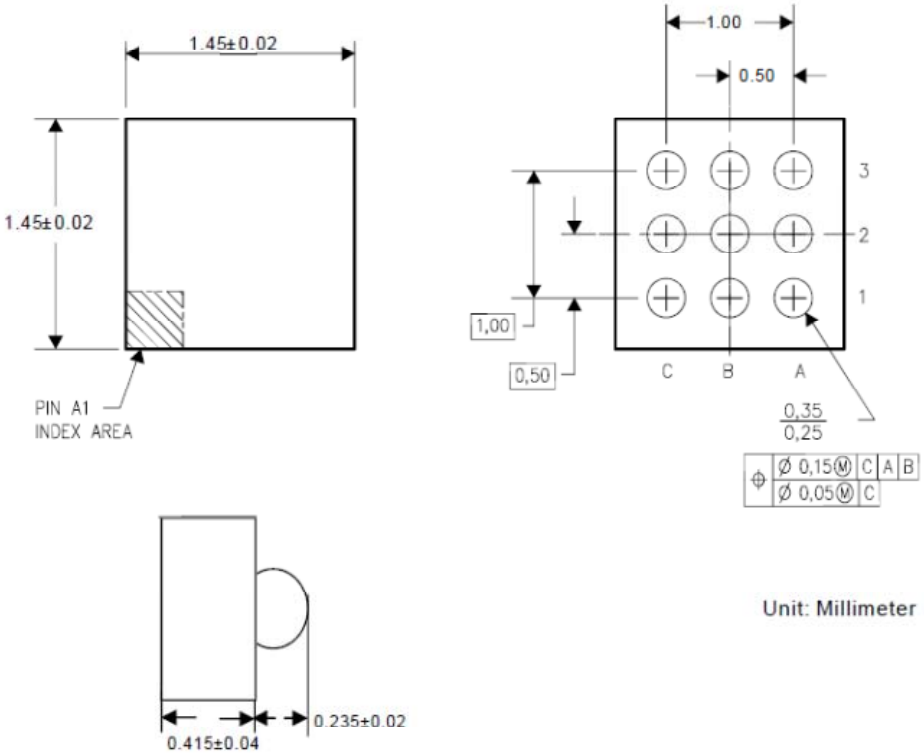
## Marking Information




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

**WCSP**





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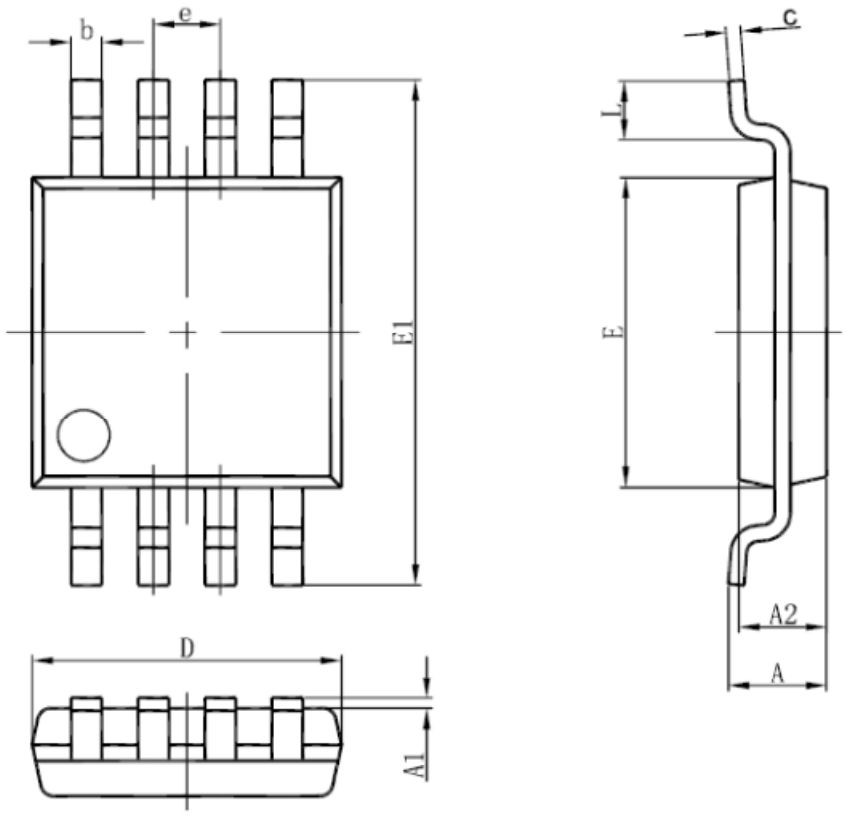
## Package Outline Dimensions (cont.) (All dimensions in mm.)

**MSOP-8**




| REF | Millimeter | |
|---|---|---|
| | Min | Max |
| A | -- | 1.10 |
| A1 | 0.05 | 0.15 |
| A2 | 0.78 | 0.94 |
| b | 0.22 | 0.38 |
| c | 0.08 | 0.23 |
| D | 2.90 | 3.10 |
| E | 2.90 | 3.10 |
| E1 | 4.75 | 5.05 |
| e | 0.65BSC | |
| L | 0.40 | 0.70 |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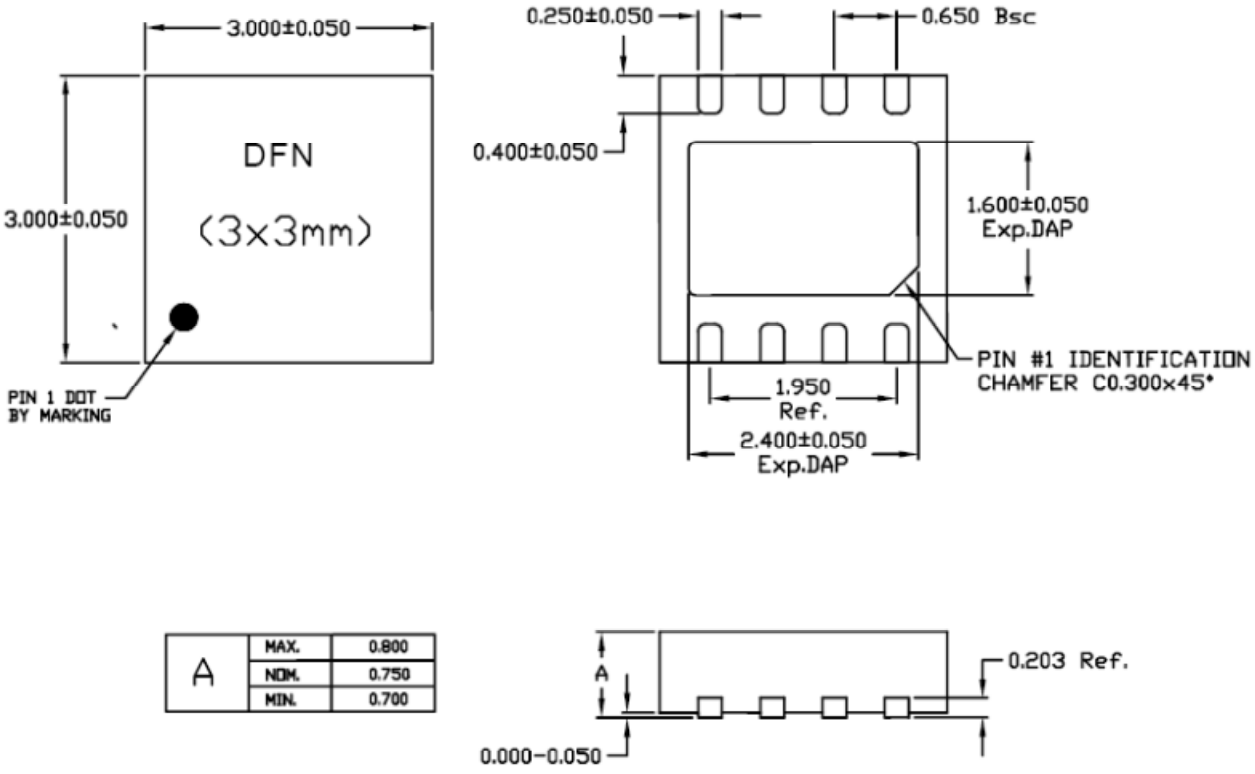
## Package Outline Dimensions (cont.) (All dimensions in mm.)

**DFN3x3-8**




Unit: Millimeter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