

MAXIN

## Mono 3.2W Class D Amplifier


#### Abstract

General Description The MAX98304 mono 3.2W Class D amplifier provides Class AB audio performance with Class D efficiency. This device offers five selectable gain settings (0dB, $3 \mathrm{~dB}, 6 \mathrm{~dB}, 9 \mathrm{~dB}$, and 12 dB ) set by a single gain-select input (GAIN). Active emissions-limiting, edge-rate, and overshoot control circuitry greatly reduces EMI. A filterless spreadspectrum modulation scheme eliminates the need for output filtering found in traditional Class D devices. These features reduce application component count. The IC's 0.95 mA at $3.7 \mathrm{~V}(1.2 \mathrm{~mA}$ at 5 V ) quiescent current extends battery life in portable applications. The IC is available in a 9-bump ( $1.0 \mathrm{~mm} \times 1.0 \mathrm{~mm}$ ) WLP with 0.3 mm pitch that is specified over the extended $-40^{\circ} \mathrm{C}$ to $+85^{\circ} \mathrm{C}$ temperature range.


| Notebook and Netbook Computers |
| :--- |
| Cellular Phones |
| Tablets |
| MP3 Players |
| Portable Audio Players |
| VoIP Phones |

Typical Application Circuit

Low Quiescent Current: 0.95mA at 3.7V

- Spread Spectrum and Active Emissions Limiting
Five Pin-Selectable Gains
19んVRMS Ultra-Low Noise
90dB PSRR
Click-and-Pop Suppression
Thermal and Overcurrent Protection
Low-Current Shutdown Mode
1.0mm x 1.0mm, 9-Bump WLP (0.3mm Pitch)
Space-Saving Package Space-Saving Package

Ordering Information

| PART | TEMP RANGE | PIN- <br> PACKAGE | TOP <br> MARK |
| :---: | :---: | :--- | :---: |
| MAX98304EWL + | $-40^{\circ} \mathrm{C}$ to $+85^{\circ} \mathrm{C}$ | 9 WLP | AIR |

+Denotes a lead(Pb)-free/RoHS-compliant package.

## Bump Configuration



## Mono 3.2W Class D Amplifier

ABSOLUTE MAXIMUM RATINGS<br>PVDD, IN+, IN-, SHDN, GAIN to PGND..................-0.3V to +6 V All Other Pins to PGND .........................-0.3V to (VPVDD +0.3 V ) Continuous Current Into/Out of PVDD, PGND, OUT_ $\ldots \pm 750 \mathrm{~mA}$ Continuous Input Current (all other pins)........................ $\pm 20 \mathrm{~mA}$ Duration of Short Circuit Between<br>OUT_ and PVDD, PGND ........................................ Continuous<br>OUT+ and OUT- ....................................................Continuous

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS

$\left(V_{P V D D}=\sqrt{S H D N}=5.0 V, V \operatorname{VGND}=0 \mathrm{~V}, \mathrm{AV}=12 \mathrm{~dB}(\mathrm{GAIN}=\mathrm{PGND}), \mathrm{RL}=\infty, \mathrm{RL}\right.$ connected between OUT + to OUT-, AC measurement bandwidth 20 Hz to $22 \mathrm{kHz}, \mathrm{T}_{\mathrm{A}}=\mathrm{T}_{\text {MIN }}$ to $T_{\text {MAX }}$, unless otherwise noted. Typical values are at $\mathrm{T}_{\mathrm{A}}=+25^{\circ} \mathrm{C}$.) (Notes 1, 2)

| PARAMETER | SYMBOL | CONDITIONS |  | MIN | TYP | MAX | UNITS |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Supply Voltage Range | PVDD | Inferred from PSRR test |  | 2.5 |  | 5.5 | V |
| Undervoltage Lockout | UVLO | PVDD falling |  | 1.5 | 1.8 | 2.2 | V |
| Quiescent Supply Current | IDD | $\mathrm{T}_{\mathrm{A}}=+25^{\circ} \mathrm{C}$ |  |  | 1.2 | 1.8 | mA |
|  |  | $\mathrm{V}_{\text {PVDD }}=3.7 \mathrm{~V}$ |  | 0.95 |  |  |  |
| Shutdown Supply Current | ISHDN | $\mathrm{V}_{\text {SHDN }}=0 \mathrm{~V}, \mathrm{~T}_{\mathrm{A}}=+25^{\circ} \mathrm{C}$ |  | < 0.1 |  | 10 | $\mu \mathrm{A}$ |
| Turn-On Time | ton |  |  | 3.4 |  | 10 | ms |
| Bias Voltage | VBIAS |  |  |  | VPVDD $/ 2$ |  | V |
| Input Resistance | RIN | $\mathrm{T}_{\mathrm{A}}=+25^{\circ} \mathrm{C},$ <br> single-ended | $A v=12 d B$ | 45 | 70 |  | k $\Omega$ |
|  |  |  | $A V=9 \mathrm{~dB}$ | 64 | 100 |  |  |
|  |  |  | $A V=6 d B$ | 90 | 140 |  |  |
|  |  |  | $A V=3 d B$ | 128 | 200 |  |  |
|  |  |  | $A \mathrm{~V}=0 \mathrm{~dB}$ | 180 | 280 |  |  |
| Voltage Gain | Av | Connect GAIN to PGND |  | 11.5 | 12 | 12.5 | dB |
|  |  | Connect GAIN to PGND through $100 \mathrm{k} \Omega \pm 5 \%$ |  | 8.5 | 9 | 9.5 |  |
|  |  | Connect GAIN to PVDD |  | 5.5 | 6 | 6.5 |  |
|  |  | Connect GAIN to PVDD through 100k $\Omega \pm 5 \%$ |  | 2.5 | 3 | 3.5 |  |
|  |  | GAIN unconnected |  | -0.5 | 0 | +0.5 |  |
| Output Offset Voltage | Vos | $\mathrm{T}_{\mathrm{A}}=+25^{\circ} \mathrm{C}$ (Note 3) |  |  | $\pm 1$ | $\pm 4.5$ | mV |
| Click and Pop | KCP | Peak voltage, <br> A-weighted, 32 <br> samples per second, $R \mathrm{~L}=8 \Omega \text { (Notes 3, 4) }$ | Into shutdown | -74-60 |  |  | dBV |
|  |  |  | Out of shutdown |  |  |  |  |
| Common-Mode Rejection Ratio | CMRR | $\mathrm{f} / \mathrm{N}=1 \mathrm{kHz}$, input referred |  | 80 |  |  | dB |

## Mono 3.2W Class D Amplifier

## ELECTRICAL CHARACTERISTICS (continued)

$(\mathrm{VPVDD}=\mathrm{V}$ SHDN $=5.0 \mathrm{~V}, \mathrm{~V} \mathrm{PGND}=0 \mathrm{~V}, \mathrm{AV}=12 \mathrm{~dB}(\mathrm{GAIN}=\mathrm{PGND}), \mathrm{RL}=\infty, \mathrm{RL}$ connected between OUT+ to OUT-, AC measurement bandwidth 20 Hz to $22 \mathrm{kHz}, \mathrm{T}_{\mathrm{A}}=\mathrm{T}_{\text {MIN }}$ to $\mathrm{T}_{\mathrm{MAX}}$, unless otherwise noted. Typical values are at $\mathrm{T}_{\mathrm{A}}=+25^{\circ} \mathrm{C}$.) (Notes 1, 2)

| PARAMETER | SYMBOL | CONDITIONS |  | MIN TYP | MAX | UNITS |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Power-Supply Rejection Ratio (Note 3) | PSRR | $\mathrm{V}_{\text {PVDD }}=2.5 \mathrm{~V}$ to $5.5 \mathrm{~V}, \mathrm{~T}_{\mathrm{A}}=+25^{\circ} \mathrm{C}$ |  | 7290 |  | dB |
|  |  | VRIPPLE $=200 \mathrm{mVP-P}$ | $\mathrm{f}=217 \mathrm{~Hz}$ | 80 |  |  |
|  |  |  | $\mathrm{f}=1 \mathrm{kHz}$ | 84 |  |  |
|  |  |  | $\mathrm{f}=20 \mathrm{kHz}$ | 84 |  |  |
| Output Power | Pout | $\begin{aligned} & \mathrm{THD}+\mathrm{N}=10 \%, \\ & \mathrm{f}=1 \mathrm{kHz}, \\ & \mathrm{RL}=4 \Omega+33 \mu \mathrm{H} \end{aligned}$ | VPVDD $=5.0 \mathrm{~V}$ | 3.2 |  | W |
|  |  |  | VPVDD $=4.2 \mathrm{~V}$ | 2.2 |  |  |
|  |  |  | VPVDD $=3.7 \mathrm{~V}$ | 1.7 |  |  |
|  |  | $\begin{aligned} & \mathrm{THD}+\mathrm{N}=1 \%, \\ & \mathrm{f}=1 \mathrm{kHz}, \\ & \mathrm{RL}=4 \Omega+33 \mu \mathrm{H} \end{aligned}$ | VPVDD $=5.0 \mathrm{~V}$ | 2.6 |  |  |
|  |  |  | VPVDD $=4.2 \mathrm{~V}$ | 1.8 |  |  |
|  |  |  | VPVDD $=3.7 \mathrm{~V}$ | 1.4 |  |  |
|  |  | $\begin{aligned} & \mathrm{THD}+\mathrm{N}=10 \%, \\ & \mathrm{f}=1 \mathrm{kHz}, \\ & \mathrm{RL}=8 \Omega+68 \mu \mathrm{H} \end{aligned}$ | VPVDD $=5.0 \mathrm{~V}$ | 1.8 |  |  |
|  |  |  | VPVDD $=4.2 \mathrm{~V}$ | 1.2 |  |  |
|  |  |  | VPVDD $=3.7 \mathrm{~V}$ | 0.96 |  |  |
|  |  | $\begin{aligned} & \mathrm{THD}+\mathrm{N}=1 \%, \\ & \mathrm{f}=1 \mathrm{kHz}, \\ & \mathrm{RL}=8 \Omega+68 \mu \mathrm{H} \end{aligned}$ | VPVDD $=5.0 \mathrm{~V}$ | 1.4 |  |  |
|  |  |  | VPVDD $=4.2 \mathrm{~V}$ | 1 |  |  |
|  |  |  | VPVDD $=3.7 \mathrm{~V}$ | 0.8 |  |  |
| Total Harmonic Distortion Plus Noise | THD+N | $\mathrm{fin}=1 \mathrm{kHz}$ | $\begin{aligned} & \mathrm{RL}=4 \Omega \\ & \text { POUT }=1 \mathrm{~W} \end{aligned}$ | 0.03 | 0.1 | \% |
|  |  |  | $\begin{aligned} & \mathrm{R}_{\mathrm{L}}=8 \Omega \\ & \text { Pout }=0.7 \mathrm{~W} \end{aligned}$ | 0.03 |  |  |
| Oscillator Frequency | fosc |  |  | 300 |  | kHz |
| Spread-Spectrum Bandwidth |  |  |  | $\pm 12.5$ |  | kHz |
| Efficiency | $\eta$ | POUT $=1.75 \mathrm{~W}, \mathrm{RL}=8 \Omega$ |  | 93 |  | \% |
| Noise | $\mathrm{V}_{\mathrm{N}}$ | A-weighted (Note 3) | $\mathrm{A}_{\mathrm{V}}=12 \mathrm{~dB}$ | 31 |  | $\mu V_{\text {RMS }}$ |
|  |  |  | $A V=9 d B$ | 26 |  |  |
|  |  |  | $A V=6 d B$ | 23 |  |  |
|  |  |  | $\mathrm{A} v=3 \mathrm{~dB}$ | 21 |  |  |
|  |  |  | $A \mathrm{~V}=0 \mathrm{~dB}$ | 19 |  |  |
| Output Current Limit | ILIM |  |  | 2.8 |  | A |
| Thermal Shutdown Level |  |  |  | 155 |  | ${ }^{\circ} \mathrm{C}$ |
| Thermal Shutdown Hysteresis |  |  |  | 15 |  | ${ }^{\circ} \mathrm{C}$ |
| DIGITAL INPUT ( $\overline{\text { SHDN }}$ ) |  |  |  |  |  |  |
| Input-Voltage High | VINH | VPVDD $=2.5 \mathrm{~V}$ to 5.5 V |  | 1.4 |  | V |
| Input-Voltage Low | VINL | VPVDD $=2.5 \mathrm{~V}$ to 5.5 V |  |  | 0.4 | V |
| Input Leakage Current |  |  |  |  | $\pm 1$ | $\mu \mathrm{A}$ |

Note 1: This device is $100 \%$ production tested at $+25^{\circ} \mathrm{C}$. All temperature limits are guaranteed by design.
Note 2: Testing performed with a resistive load in series with an inductor to simulate an actual speaker load. For $R \mathrm{~L}=4 \Omega$,
$L=33 \mu \mathrm{H}$. For $R L=8 \Omega, L=68 \mu H$.
Note 3: Amplifier inputs AC-coupled to ground
Note 4: Mode transitions controlled by SHDN.

## Mono 3.2W Class D Amplifier

## Typical Operating Characteristics

$\left(\mathrm{VPVDD}=\mathrm{V}\right.$ SHDN $=5.0 \mathrm{~V}, \mathrm{VPGND}=0 \mathrm{~V}, \mathrm{AV}=6 \mathrm{~dB}, \mathrm{R}_{\mathrm{L}}=\infty, \mathrm{RL}$ connected between OUT + to OUT-, AC measurement bandwidth 20 Hz to $22 \mathrm{kHz}, \mathrm{T}_{\mathrm{A}}=+25^{\circ} \mathrm{C}$, unless otherwise noted.)


## Mono 3.2W Class D Amplifier

## Typical Operating Characteristics (continued)

$\left(V P V D D=V\right.$ SHDN $=5.0 V, V P G N D=0 V, A V=6 d B, R_{L}=\infty, R_{L}$ connected between OUT+ to OUT-, AC measurement bandwidth 20Hz to $22 \mathrm{kHz}, \mathrm{T}_{\mathrm{A}}=+25^{\circ} \mathrm{C}$, unless otherwise noted.)


## Mono 3.2W Class D Amplifier

Typical Operating Characteristics (continued)
$(V P V D D=V S H D N=5.0 V, V P G N D=0 V, A V=6 d B, R L=\infty, R L$ connected between OUT + to OUT-, $A C$ measurement bandwidth $20 H z$ to $22 \mathrm{kHz}, \mathrm{T}_{\mathrm{A}}=+25^{\circ} \mathrm{C}$, unless otherwise noted.)


## Mono 3.2W Class D Amplifier

## Typical Operating Characteristics (continued)

$\left(V \mathrm{VVDD}=\mathrm{V}\right.$ SHDN $=5.0 \mathrm{~V}, \mathrm{VPGND}=0 \mathrm{~V}, \mathrm{AV}=6 \mathrm{~dB}, \mathrm{RL}=\infty, \mathrm{RL}_{\mathrm{L}}$ connected between OUT+ to OUT-, AC measurement bandwidth 20Hz to $22 \mathrm{kHz}, \mathrm{T}_{\mathrm{A}}=+25^{\circ} \mathrm{C}$, unless otherwise noted.)



Bump Description

| BUMP | NAME | FUNCTION |
| :---: | :---: | :--- |
| A1 | OUT- | Negative Speaker Output |
| A2 | OUT+ | Positive Speaker Output |
| A3 | PVDD | Power Supply. Bypass PVDD to PGND with 0.1 $\mu$ F II 10 $\mu F$. |
| B1 | PGND | Ground |
| B2 | N.C. | No Connection. Can be left unconnected, or connected to PGND. |
| B3 | GAIN | Gain Select. See Table 1 for GAIN settings. |
| C1 | $\overline{\text { SHDN }}$ | Active-Low Shutdown Input. Drive $\overline{\text { SHDN }}$ Iow to place the device in shutdown. |
| C2 | IN- | Inverting Audio Input |
| C3 | IN+ | Noninverting Audio Input |

## Mono 3.2W Class D Amplifier

## Detailed Description

The MAX98304 features low quiescent current, a lowpower shutdown mode, comprehensive click-and-pop suppression, and excellent RF immunity.
The device offers Class $A B$ audio performance with Class D efficiency in a minimal board-space solution.
The Class D amplifier features spread-spectrum modulation, edge-rate, and overshoot control circuitry that offers significant improvements to switch-mode amplifier radiated emissions.
The amplifier features click-and-pop suppression that reduces audible transients on startup and shutdown. The amplifier includes thermal overload and short-circuit protection.

## Class D Speaker Amplifier

The filterless Class D amplifier offers much higher efficiency than Class $A B$ amplifiers. The high efficiency of a Class D amplifier is due to the switching operation of the output stage transistors. Any power loss associated with the Class D output stage is mostly due to the I2R loss of the MOSFET on-resistance and quiescent current overhead.

## Ultra-Low EMI Filterless Output Stage

Traditional Class D amplifiers require the use of external LC filters, or shielding, to meet EN55022B electromag-netic-interference (EMI) regulation standards. Maxim's patented active emissions-limiting edge-rate control circuitry and spread-spectrum modulation reduces EMI emissions, while maintaining up to $93 \%$ efficiency.

Maxim's patented spread-spectrum modulation mode flattens wideband spectral components, while proprietary techniques ensure that the cycle-to-cycle variation of the switching period does not degrade audio reproduction or efficiency. The IC's spread-spectrum modulator randomly varies the switching frequency by $\pm 12.5 \mathrm{kHz}$ around the center frequency ( 300 kHz ). Above 10 MHz , the wideband spectrum looks like noise for EMI purposes (Figure 1).

## Speaker Current Limit

If the output current of the speaker amplifier exceeds the current limit (2.8A typ), the IC disables the outputs for approximately $100 \mu \mathrm{~s}$. At the end of $100 \mu \mathrm{~s}$, the outputs are reenabled. If the fault condition still exists, the IC continues to disable and reenable the outputs until the fault condition is removed.

Selectable Gain
The IC offers five programmable gain selections through a single gain input (GAIN).

Table 1. Gain Control Configuration

| GAIN PIN | MAXIMUM GAIN (dB) |
| :--- | :---: |
| Connect to PGND | 12 |
| Connect to PGND through <br> $100 \mathrm{k} \Omega \pm 5 \%$ resistor | 9 |
| Connect to PVDD | 6 |
| Connect to PVDD through <br> $100 k \Omega \pm 5 \%$ resistor | 3 |
| Unconnected | 0 |



Figure 1. EMI with 60 cm of Speaker Cable and No Output Filtering

# Mono 3.2W Class D Amplifier 

Shutdown
The IC features a low-power shutdown mode, drawing less than $0.1 \mu \mathrm{~A}$ (typ) of supply current. Drive SHDN low to put the IC into shutdown.

## Click-and-Pop Suppression

The IC speaker amplifier features Maxim's comprehensive click-and-pop suppression. During startup, the click-and-pop suppression circuitry reduces any audible transient sources internal to the device. When entering shutdown, the differential speaker outputs ramp down to PGND quickly and simultaneously.

## Applications Information

Filterless Class D Operation
Traditional Class D amplifiers require an output filter. The filter adds cost, size, and decreases efficiency and THD +N performance. The IC's filterless modulation scheme does not require an output filter.
Because the switching frequency of the IC is well beyond the bandwidth of most speakers, voice coil movement due to the switching frequency is very small. Use a speaker with a series inductance $>10 \mu \mathrm{H}$. Typical $8 \Omega$ speakers exhibit series inductances in the $20 \mu \mathrm{H}$ to $100 \mu \mathrm{H}$ range.

## Component Selection <br> Power-Supply Input (PVDD)

PVDD powers the speaker amplifier. PVDD ranges from 2.5V to 5.5 V . Bypass PVDD with a $0.1 \mu \mathrm{~F}$ and $10 \mu \mathrm{~F}$ capacitor to PGND. Apply additional bulk capacitance at the device if long input traces between PVDD and the power source are used.

Input Filtering
The input-coupling capacitor (CIN), in conjunction with the amplifier's internal input resistance (RIN), forms a highpass filter that removes the DC bias from the incoming signal. These capacitors allow the amplifier to bias the signal to an optimum DC level.
Assuming zero source impedance CIN is:

$$
\mathrm{C}_{\mathbb{I N}}=\frac{2 \pi \times \mathrm{R}_{\mathbb{N}}\left[\mathrm{f}_{-3 \mathrm{~F}]}\right.}{\mathrm{f}^{2}}
$$

where $f-3 d B$ is the $-3 d B$ corner frequency and RIN is the input resistance shown in the Electrical Characteristics table. Use capacitors with adequately low voltage-coefficient for best low-frequency THD performance.

## Layout and Grounding

Proper layout and grounding are essential for optimum performance. Good grounding improves audio performance and prevents switching noise from coupling into the audio signal.
Use wide, low-resistance output traces. As the load impedance decreases, the current drawn from the device increases. At higher current, the resistance of the output traces decreases the power delivered to the load. For example, if 2 W is delivered from the device output to a $4 \Omega$ load through $100 \mathrm{~m} \Omega$ of total speaker trace, 1.904 W is being delivered to the speaker. If power is delivered through $10 \mathrm{~m} \Omega$ of total speaker trace, 1.99 W is being delivered to the speaker. Wide output, supply, and ground traces also improve the power dissipation of the device.
The IC is inherently designed for excellent RF immunity. For best performance, add ground fills around all signal traces on top or bottom PCB planes.

## WLP Applications Information

For the latest application details on WLP construction, dimensions, tape carrier information, PCB techniques, bump-pad layout, and recommended reflow temperature profile, as well as the latest information on reliability testing results, refer to Application Note 1891: Waferlevel packaging (WLP) and its applications. Figure 2 shows the dimensions of the WLP balls used on the IC.


Figure 2. MAX98304 WLP Ball Dimensions

## Mono 3.2W Class D Amplifier



Chip Information
PROCESS: CMOS

## Mono 3.2W Class D Amplifier

## Package Information

For the latest package outline information and land patterns, go to www.maxim-ic.com/packages. Note that a "+", "\#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

| PACKAGE TYPE | PACKAGE CODE | OUTLINE NO. | LAND PATTERN NO. |
| :---: | :---: | :---: | :---: |
| 9 WLP | W91D1+1 | $\underline{\underline{21-0486}}$ | - |



IOP VIEW


SIDE VIEW

| COMMON DIMENSIONS |  |
| :--- | :--- |
| A | $0.64 \pm 0.05$ |
| A1 | $0.16 \pm 0.03$ |
| A2 | 0.48 REF |
| A3 | 0.025 BASIC |
| A4 | 0.07 BASIC |
| b | $\varnothing 0.21 \pm 0.03$ |
| D1 | 0.60 BASIC |
| E1 | 0.60 BASIC |
| e | 0.30 BASIC |
| SD | 0.00 BASIC |
| SE | 0.00 BASIC |


| PKG. CODE | E |  | D |  | DEPOPULATED |
| :--- | :---: | :---: | :---: | :---: | :--- |
|  | MIN | MAX | MIN | MAX |  |
|  | 0.95 | 0.99 | 0.95 | 0.99 | NONE |


NOTES:

1. Terminal pitch is defined by terminal center to center value.
2. Outer dimension is defined by center lines between scribe lines.
3. All dimensions in millimeters.
4. Marking shown is for package orientation reference only.
5. Tolerance is $\pm 0.02 \mathrm{~mm}$ unless specified otherwise.
6. All dimensions apply to PbFree (+) package codes only.
-DRAWING NOT TO SCALE-


## Mono 3.2W Class D Amplifier

| REVISION <br> NUMBER | REVISION <br> DATE | DESCRIPTION | PAGES <br> CHANGED |
| :---: | :---: | :--- | :---: | :---: |
| 0 | $9 / 10$ | Initial release | - |

