**General Description**

The MD2203 is a dual bridge-connected audio power amplifier which, when connected to a 5V supply, will deliver 2.2W to a 4Ω load (Note1) or 2.5W to a 3Ω load (Note2) with less than 1.0% THD+N. In addition, the headphone input pin allows the amplifiers to operate in single-ended mode when driving stereo headphones.

Boomer audio power amplifiers were designed specifically to provide high quality output power from a surface mount package while requiring few external components. To simplify audio system design, the MD2203 combines dual bridge speaker amplifiers and stereo headphone amplifiers on one chip.

The MD2203 features an externally controlled, low-power consumption shutdown mode, a stereo headphone amplifier mode, and thermal shutdown protection. It also utilizes cir-mode, and thermal shutdown protection. It also utilizes cir-cuity to reduce “clicks and pops” during device turn-on.

Note1: An MD2203MTE or MD2203LQ that has been properly mounted to a circuit board will deliver 2.2W into 4Ω. The other package options for the MD2203 will deliver 1.1 into 8Ω. See the Application Information sections for further information concerning the MD2203MTE and MD2203LQ.

Note2: An MD2203MTE or MD2203LQ that has been properly mounted to a circuit board and forced-air cooled will deliver 2.5W into 3Ω.

**Key Specifications**

- $P_o$ at 1% THD+N
- MD2203LQ, 3Ω, 4Ω loads 2.5W(typ), 2.2W(typ)
- MD2203MTE, 3Ω, 4Ω loads 2.5W(typ), 2.2W(typ)
- MD2203MTE, 8Ω loads 1.1W(typ)
- MD2203, 8Ω 1.1W(typ)
- Single-ended mode THD+N at 75mW into 32Ω 0.5% (max)
- Shutdown current 0.7μA (typ)
- Supply voltage range 2.0V to 5.5V

**Features**

- Stereo headphone amplifier mode
- “Click and pop” suppression circuit
- Unity-gain stable
- Thermal shutdown protection circuitry
- SOIC, TSSOP, exposed-DAP TSSOP, and LLP packages
- Not recommended for new designs. Contact MD Audio Marketing.

**Applications**

- Multimedia monitors
- Portable and desktop computers
- Portable televisions

---

![Typical Application Diagram](image)
MD2203 Audio Power Amplifier Series
Dual 2.2W Audio Amplifier Plus Stereo Headphone Function

Connection Diagrams

Top View
Order Number MD2203M
See MD Package Number M16B for SO

Top View
Order Number MD2203MT
See MD Package Number MTC20 for TSSOP

Top View
Order Number MD2203MTE
See MD Package Number MXA20A for Exposed-DAP TSSOP

Top View
Order Number MD2203LQ
See MD Package Number LQA24A for Exposed-DAP LLP

*Not recommended for new designs. Contact ID CHIP Audio Marketing.*
**Absolute Maximum Ratings** (Note3)  
If Military/Aerospace specified devices are required, please contact the IDCHIP Sales Office/Distributors for availability and specifications.  

- Supply Voltage: 6.0V  
- Storage Temperature: -65°C to +150°C  
- Input Voltage: (-0.3V to V_DD +0.3V)  
- Power Dissipation: Internally limited  
- ESD Susceptibility Note: 2000V  
- Junction Temperature: 150°C  

Solder Information  
- Small Outline Package  
  - Vapor Phase (60sec.): 215°C  
  - Infrared (15sec.): 220°C  

*Not recommended for new designs. Contact IDCHIP Audio marketing.*

**Operating Ratings**  
- Temperature Range: T_MIN ≤ T_A ≤ T_MAX = -40°C to +85°C  
- Supply Voltage: 2.0V ≤ V_DD ≤ 5.5V

### Electrical Characteristics for Entire IC (Notes3,11)  
The following specifications apply for V_DD = 5V unless otherwise noted. Limit apply for T_A = 25°C.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>MD2203 Typical (Note12)</th>
<th>MD2203 Limit (Note13)</th>
<th>Units (Limits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_DD</td>
<td>Supply Voltage</td>
<td></td>
<td></td>
<td></td>
<td>2 V (min)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.5 V (max)</td>
</tr>
<tr>
<td>I_DD</td>
<td>Quiescent Power Supply Current</td>
<td>V_IN=0V, I_O=0A (Note14), HP-IN=0V</td>
<td>11.5 mA (max)</td>
<td>20 mA (max)</td>
<td>mA (max)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V_IN=0V, I_O=0A (Note14), HP-IN=4V</td>
<td>5.8 mA (min)</td>
<td>6 mA (min)</td>
<td>mA</td>
</tr>
<tr>
<td>I_SD</td>
<td>Shutdown Current</td>
<td>V_DD applied to the SHUTDOWN pin</td>
<td>0.7 μA (max)</td>
<td>2 μA (max)</td>
<td>μA</td>
</tr>
<tr>
<td>V_H</td>
<td>Headphone High Input Voltage</td>
<td></td>
<td>4 V (min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V_L</td>
<td>Headphone Low Input Voltage</td>
<td></td>
<td>0.8 V (max)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Electrical Characteristics for Bridged-Mode Operation (Notes3,11)  
The following specifications apply for V_DD = 5V unless otherwise specified. Limits apply for T_A = 25°C.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>MD2203 Typical (Note12)</th>
<th>MD2203 Limit (Note13)</th>
<th>Units (Limits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_OS</td>
<td>Output Offset Voltage</td>
<td>V_IN=0V</td>
<td>5 mV (max)</td>
<td>50 mV (max)</td>
<td>mV (max)</td>
</tr>
<tr>
<td>P_O</td>
<td>Output Power (Note15)</td>
<td>THD+N=1%, f=1kHz (Note16)</td>
<td>MD2203MTM, R_L=3Ω</td>
<td>2.5 W</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MD2203MTL, R_L=3Ω</td>
<td>2.5 W</td>
<td>W</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MD2203MTM, R_L=4Ω</td>
<td>2.2 W</td>
<td>W</td>
<td></td>
</tr>
</tbody>
</table>
MD2203 Audio Power Amplifier Series
Dual 2.2W Audio Amplifier Plus Stereo Headphone Function

<table>
<thead>
<tr>
<th></th>
<th>MD2203LQ, R_L=4Ω</th>
<th>MD2203, R_L=8Ω</th>
<th>THD+N=10%, f=1kHz (Note 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD2203MTE, R_L=3Ω</td>
<td>3.2 W</td>
<td>3.2 W</td>
<td></td>
</tr>
<tr>
<td>MD2203LQ, R_L=4Ω</td>
<td>2.7 W</td>
<td>2.7 W</td>
<td></td>
</tr>
</tbody>
</table>

Typical Performance Characteristics

MTESpecific Characteristics

![Graph of THD+N vs Output Power for MD2203MTE with VDD=5V, RL=3Ω and BW<80kHz](image1)

![Graph of THD+N vs Frequency for MD2203MTE with VDD=5V, RL=3Ω, PO=2.2W and BW<80kHz](image2)

![Graph of THD+N vs Output Power for MD2203MTE with VDD=5V, RL=4Ω and BW<80kHz](image3)

![Graph of THD+N vs Frequency for MD2203MTE with VDD=5V, RL=4Ω, PO=2.0W and BW<80kHz](image4)
MD2203 Audio Power Amplifier Series
Dual 2.2W Audio Amplifier Plus Stereo Headphone Function

MD2203MTE
Power Dissipation vs Power Output

- $V_{DD} = 5V$
- $3\Omega$
- $4\Omega$

Power Dissipation (W)

Power Out (W)

MD2203MTE
Power Derating Curve

With 2.5 in$^2$
Heatsink Plane

Power Dissipation (W)

Ambient Temperature ($^\circ$C)

Typical Performance Characteristics
MTE Specific Characteristics (Continued)

MD2203MTE (Note 17)
Power Derating Curve

Note 17: This curve shows the MD2203MTE thermal dissipation ability at different ambient temperatures given these conditions:

- 500LFP: The part is soldered to a 1x10 exposed DAP TSSOP test board with 1 centimeter of forced-air flow across it.
- Board Information: Dimensions: 2.74 x 3.24 x 3.7 millimeters, copper content: 10%, copper coverage: 100% (backside layers) and 12% (topside layers), 1% under the exposed-DAP.
- 500LFP: The part is soldered to a 2.5 in$^2$, 1 oz. copper plating with 500 linear feet per minute of forced-air flow across it.
- 2.5 in$^2$: The part is soldered to a 2.5 in$^2$, 1 oz. copper plating.
- Not Attached: The part is not soldered down and is not forced-air cooled.
MD2203 Audio Power Amplifier Series
Dual 2.2W Audio Amplifier Plus Stereo Headphone Function

Non-MTE Specific Characteristics

External Components Description
(Refer to Figure 1.)

<table>
<thead>
<tr>
<th>Components</th>
<th>Functional Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ( R_i )</td>
<td>The inverting input resistance, along with ( R_o ), set the closed-loop gain. ( R_i ) along with ( C_i ) form a high-pass filter with ( f_c = 1/(2\pi R_i C_i) )</td>
</tr>
<tr>
<td>2. ( C_i )</td>
<td>The input coupling capacitor blocks DC voltage at the amplifier's input terminals. ( C_i ) along with ( R_i ) create a high-pass filter with ( f_c = 1/(2\pi R_i C_i) ). Refer to the section, SELECTING PROPER EXTERNAL COMPONENTS, for an explanation of determining the value of ( C_i )</td>
</tr>
<tr>
<td>3. ( R_f )</td>
<td>The feedback resistance, along with ( R_o ), set the closed-loop gain.</td>
</tr>
<tr>
<td>4. ( C_s )</td>
<td>The supply bypass capacitor. Refer to the POWER SUPPLY BYPASSING section for information about properly placing and selecting the value of this capacitor.</td>
</tr>
<tr>
<td>5. ( C_B )</td>
<td>The capacitor, ( C_B ), filters the half-supply voltage present on the BYPASS pin. Refer to the SELECTING PROPER EXTERNAL COMPONENTS section for information concerning proper placement and selecting's value.</td>
</tr>
</tbody>
</table>
Application Information

EXPOSED-DAP PACKAGE PCB MOUNTING CONSIDERATIONS

The MD2203’s exposed-DAP (die attach paddle) package (MTE and LQ) provide a low thermal resistance between the die and the PCB to which the part is mounted and soldered. This allows rapid heat transfer from the die to the surrounding PCB copper traces, ground plane and, finally, surrounding air. The result is a low voltage audio power amplifier that produces 2.2W at ≤1% THD with a 4Ω load. This high power is achieved through careful consideration of necessary thermal design. Failing to optimize thermal design may compromise the MD2203’s high power performance and activate unwanted, though necessary, thermal shutdown protection. The MTE and LQ packages must have their DAPs soldered to a copper pad on the PCB. The DAP’s PCB copper pad is connected to a large plane of continuous unbroken copper. This plane forms a thermal mass and heat sink and radiation area. Place the heat sink area on either outer plane in the case of a two-sided PCB, or on an inner layer of a board with more than two layers. Connect the DAP copper pad to the inner layer or backside copper heat sink area with 32(4x8) (MTE) or 6(3x2) (LQ) vias. The via diameter should be 0.012in-0.013in with a 1.27mm pitch. Ensure efficient thermal conductivity by plating-through and solder-filling the vias. Best thermal performance is achieved with the largest practical copper heat sink area. If the heatsink and amplifier share the same PCB layer, a nominal 2.5in²(min) area is necessary for 5V operation with a 4Ω load. Heatsink areas not placed on the same PCB layer as the MD2203 should be 5in² (min) for the same supply voltage and load resistance. The last two area recommendations apply for 25℃ ambient temperature. Increase the area to compensate for ambient temperatures above 25℃. In systems using cooling fans, the MD2203MTE can take advantage of forced air cooling. With an air flow rate of 450 linear-feet per minute and a 2.5in² exposed copper or 5.0in² inner layer copper plane heatsink, the MD2203MTE can continuously drive a 3Ω load to full power. The MD2203LQ achieves the same output power level without forced air cooling. In all circumstances and conditions, the junction temperature must be held below 150℃ to prevent activating the MD2203’s thermal shutdown protection. The MD2203’s power de-rating curve in the Typical Performance Characteristics shows the maximum power dissipation versus temperature. Example PCB layouts for the exposed-DAP TSSOP and LLP packages are shown in the Demonstration Board Layout section. Further detailed and specific information concerning PCB layout, fabrication, and mounting an LLP package is available from National Semiconductor’s package engineering Group. When contacting them, ask for “Preliminary Application Note for the Assembly of the LLP Package on a Printed Circuit Board, Revision A dated 7/14/00.”

PCB LAYOUT AND SUPPLY REGULATION CONSIDERATIONS FOR DRIVING 3Ω AND 4Ω LOADS

Power dissipated by a load is a function of the voltage swing across the load and the load’s impedance. As load impedance decreases, load dissipation becomes increasingly dependent on the interconnect (PCB trace and wire) resistance between the amplifier output pins and the load’s connections. Residual trace resistance causes a voltage drop, which results in power dissipated in the trace and not in the load as desired. For example, 0.1Ω trace resistance reduces the output power dissipated by a 4Ω load from 2.1W to 2.0W. This problem of decreased load dissipation is exacerbated as load impedance decreases. Therefore, to maintain the highest load dissipation and widest output voltages, PCB traces that connect the output pins to a load must be as wide as possible. Poor power supply regulation adversely affects maximum output power. A poorly regulated supply’s output voltage decreases with increasing load current. Reduced supply voltage causes decreased headroom, output signal clipping, and reduced output power. Even with tightly regulated supplies, trace resistance creates the same effects as poor supply regulation. Therefore, making the power supply traces as wide as possible helps maintain full output voltage swing.
BRIDGE CONFIGURATION EXPLANATION

As shown in Figure 1, the MD2203 consists of two pairs of operational amplifiers, forming a two-channel (channel A and channel B) stereo amplifier. (Though the following discusses channel A, it applies equally to channel B.) External resistors $R_f$ and $R_i$ set the closed-loop gain of Amp1A, whereas two internal 20kΩ resistors set Amp2A’s gain at -1. The MD2203 drives a load, such as a speaker, connected between the two amplifier outputs, -OUTA and +OUTA. Figure 1 shows that Amp1A’s output serves as Amp2A’s input. This results in both amplifiers producing signals identical in magnitude, but 180° out of phase. Taking advantage of this phase difference, a load is placed between -OUTA and +OUTA and driven differentially (commonly referred to as "bridge mode"). This results in a differential gain of

$$A_{VD}=2 \times \left( \frac{R_f}{R_i} \right)$$  \hspace{1cm} (1)

Bridge mode amplifiers are different from single-ended amplifiers that drive loads connected between a single amplifier’s output and ground. For a given supply voltage, bridge mode has a distinct advantage over the single-ended configuration: its differential output doubles the voltage swing across the load. This produces four times the output power when compared to a single-ended amplifier under the same conditions. This increase in attainable output power assumes that the amplifier is not current limited or that channel A’s and channel B’s outputs at half-supply. This eliminates the coupling capacitor that single supply, single-ended amplifiers require. Eliminating an output coupling capacitor in a single-ended configuration forces a single-supply amplifier’s half-supply bias voltage across the load. This increases internal IC power dissipation and may permanently damage loads such as speakers.

POWER DISSIPATION

Power dissipation is a major concern when designing a successful single-ended or bridged amplifier. Equation (2) states the maximum power dissipation point for a single-ended amplifier operating at a given supply voltage and driving a specified output load

$$P_{DMAX}=(V_{DD})^2/(2\pi^2 R_L) \text{ Single-Ended} \hspace{1cm} (2)$$

However, a direct consequence of the increased power delivered to the load by a bridge amplifier is higher internal power dissipation for the same conditions. The MD2203 has two operational amplifiers per channel. The maximum internal power dissipation per channel operating in the bridge mode is four times that of a single-ended amplifier. From Equation (3), assuming a 5V power supply and an 4Ω load, the maximum single channel power dissipation is 1.27W or 2.54W for stereo...
the output signal is not clipped. To ensure minimum output signal clipping when choosing an amplifier’s closed-loop gain, refer to the Audio Power Amplifier Design section.

Another advantage of the differential bridge output is no net DC voltage across the load. This is accomplished by biasing operation.

\[
P_{\text{Dmax}} = 4x(V_{\text{DD}})/(2\pi R \text{L}_{\text{Bridge Mode}})
\]

**Application Information (Continued)**

sents a tradeoff: as the size of \( C_{\text{B}} \) increases, the turn-on time increases. There is a linear relationship between the size of \( C_{\text{B}} \) and the turn-on time. Here are some typical turn-on times for various values of \( C_{\text{B}} \):

<table>
<thead>
<tr>
<th>( C_{\text{B}} )</th>
<th>( T_{\text{ON}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01μF</td>
<td>20ms</td>
</tr>
<tr>
<td>0.1μF</td>
<td>200ms</td>
</tr>
<tr>
<td>0.22μF</td>
<td>440ms</td>
</tr>
<tr>
<td>0.47μF</td>
<td>940ms</td>
</tr>
<tr>
<td>1.0μF</td>
<td>2sec</td>
</tr>
</tbody>
</table>

In order to eliminate "clicks and pops", all capacitors must be discharged before turn-on. Rapidly switching \( V_{\text{DD}} \) may not allow the capacitors to fully discharge, which may cause "clicks and pops". In a single-ended configuration, the output is coupled to the load by \( C_{\text{OUT}} \). This capacitor usually has a high value. \( C_{\text{OUT}} \), discharges through a small resistor \( R \). Depending on the size of \( C_{\text{OUT}} \), the discharge time constant can be relatively large. To reduce transients in single-ended mode, an external \( 1k \Omega \) - \( 5k \Omega \) resistor can be placed in parallel with the internal \( 20k \Omega \) resistor. The tradeoff for using this resistor is increased quiescent current.

**NO LOAD STABILITY**

The MD2203 may exhibit low level oscillation when the load resistance is greater than \( 10k \Omega \). This oscillation only occurs as the output signal swings near the supply voltages. Prevent this oscillation by connecting a \( 5k \Omega \) between the output pins and ground.

**AUDIO POWER AMPLIFIER DESIGN**

**Audio Amplifier Design: Driving 1W into an 8 Load**

The following are the desired operational parameters:

- **Power Output**: 1W
- **Load Impedance**: 8Ω
- **Input Level**: 1Vrms

The desired output voltage easily met by the commonly used 5V supply voltage. The additional voltage creates the benefit of headroom, allowing the MD2203 to produce peak output power in excess of 1W without clipping or other audible distortion. The choice of supply voltage must also not create a situation that violates maximum power dissipation as explained above in the Power Dissipation section. After satisfying the MD2203’s power dissipation requirements, the minimum differential gain is found using Equation (10).

\[
AVD \geq \sqrt{\left(P_{\text{Omax}}/R_{\text{L}}\right)/\left(V_{\text{IN}}\right)} = V_{\text{rms}}/V_{\text{in}} \quad (10)
\]

Thus, a minimum gain of 2.83 allows the MD2203’s to reach full output swing and maintain low noise and THD+N performance. For this example, let \( A_{\text{VD}} = 3 \).

The amplifier’s overall gain is set using the input (\( R_{i} \)) and feedback (\( R_{f} \)) resistors. With the desired input impedance set at \( 20k \Omega \), the feedback resistor is found using Equation (11).

\[
R_{f}/R_{i} = A_{\text{VD}}/2 \quad (11)
\]

The value of \( R_{f} \) is \( 30k \Omega \).

The last step in this design example is setting the amplifier’s -3dB frequency bandwidth. To achieve the desired ±0.25dB pass band magnitude variation limit, the low frequency response must extend to at least one-fifth the lower bandwidth limit and the high frequency response must extend to at least five times the upper bandwidth limit. The gain variation for both response limits is 0.17dB, well within the ±0.25dB desired limit. The results are an

\[
f_{L} = 100Hz/5 = 20Hz \quad (12)
\]

and an

\[
FH = 20kHz \times 5 = 100kHz \quad (13)
\]

As mentioned in the External Components section, \( R_{i} \) and \( C_{i} \) create a highpass filter that sets the amplifier’s lower bandpass frequency limit. Find the coupling capacitor’s value using Equation (12).

\[
C_{i} \geq \frac{1}{2\pi R_{i} f_{L}}
\]

The result is
The design begins by specifying the minimum supply voltage necessary to obtain the specified output power. One way to find the minimum supply voltage is to use the Output Power vs Supply Voltage curve in the Typical Performance Characteristics section. Another way, using Equation (4), is to calculate the peak output voltage necessary to achieve the desired output power for a given load impedance. To account for the amplifier’s dropout voltage, two additional voltages, based on the Dropout Voltage vs Supply Voltage in the Typical Performance Characteristics curves, must be added to the result obtained by Equation (8). The result in Equation (9).

\[
V_{\text{peak}} = \sqrt{2 R_{L} P_{O}} \quad (8)
\]

\[
V_{DD} \geq (V_{\text{OUTPEAK}} + (V_{\text{ODTOP}} + V_{\text{ODBOT}})) \quad (9)
\]

The Output Power vs Supply Voltage graph for an 8Ω load indicates a minimum supply voltage of 4.6V. This is 1/(2π*20kΩ*20Hz)=0.398μF (4)

Use a 0.39μF capacitor, the closest standard value

The product of the desired high frequency cutoff (100kHz in this example) and the differential gain, $A_{\text{vin}}=3$ and $f_{\text{H}}=100$KHZ, the closed-loop gain bandwidth product (GBWP) is 3.5MHz. With this margin, the amplifier can be used in designs that require more differential gain while avoiding performance-restricting bandwidth limitations.

RECOMMENDED PRINTED CIRCUIT BOARD LAYOUT

Figures 3 through 6 show the recommended two-layer PC board layout that is optimized for the 20-pin MTE-packaged MD2203 and associated external components. Figures 7 through 11 show the recommended four-layer PC board layout that is optimized for the 24-pin LQ-packaged MD2203 and associated external components. These circuits are designed for use with an external 5V supply and 4Ω speakers. These circuit boards are easy to use. Apply 5V and ground to the board’s VDD and GND pads, respectively. Connect 4Ω speakers between the board’s –OUTA and +OUTA and OUTB and +OUTB pads.
MD2203 Audio Power Amplifier Series
Dual 2.2W Audio Amplifier Plus Stereo Headphone Function

Physical Dimensions inches (millimeters) unless otherwise noted

LAND PATTERN RECOMMENDATION

DIMENSIONS ARE IN MILLIMETERS

20-Lead Molded PKG, TSSOP, JEDEC, 4.4mm BODY WIDTH
Order Number MD2203 MT
MD Package Number MTC20