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# Stereo 2.4W Audio Power Amplifier with DC Volume Control and Headphone

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## GENERAL DESCRIPTION

The EMA2203 is a monolithic integrated circuit that provides DC volume control, and stereo bridged audio power amplifiers capable of producing 2W into 4Ω or 2.4W into 3Ω with less than 1.0% THD+N.

The EMA2203 incorporates a DC volume control, stereo bridged audio power amplifiers making it optimally suited for multimedia monitors, portable radios, desktop, and portable computer applications. The EMA2203 features an low-power consumption shutdown mode, and both power amplifier and headphone..

Advanced pop & click circuitry is built in to eliminate noises that would otherwise occur during turn-on and turn-off transitions.

## KEY SPECIFICATION

- BTL mode P<sub>o</sub> at 5V, f=1kHz, 1% THD+N
  - 2.4W (typ) into 3Ω
  - 2.0W (typ) into 4Ω

- 1.1W (typ) into 8Ω
- BTL mode P<sub>o</sub> at 5V, f=1kHz, 10% THD+N
  - 3W (typ) into 3Ω
- Single-ended mode P<sub>o</sub> at 5V, f=1kHz, 1% THD+N
  - 85mW (typ) into 32Ω
- Shutdown current 0.1μA (typ)

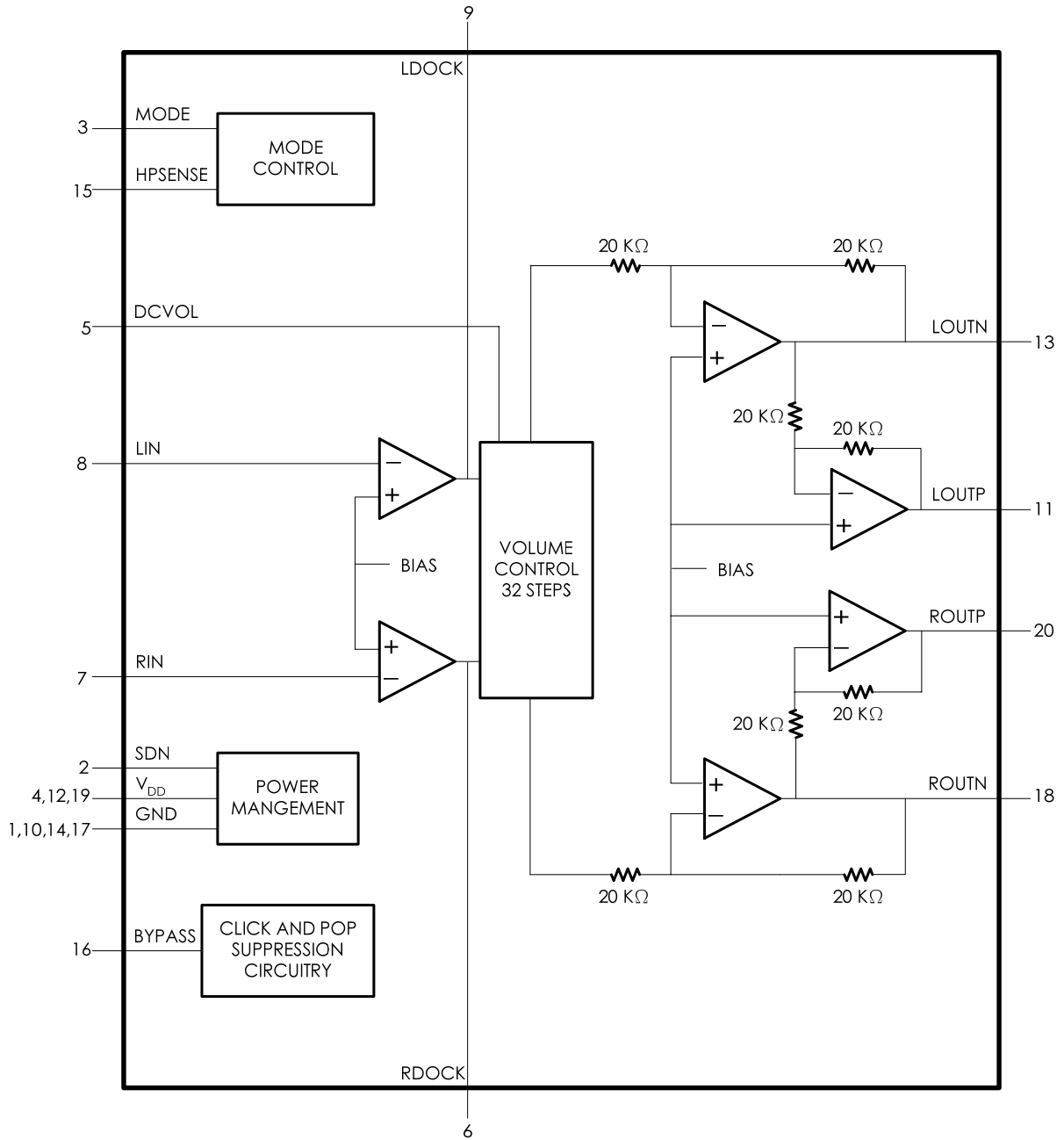
## FEATURES

- 32 steps DC Volume Control
- Stereo switchable bridged/single-ended power amplifiers
- "Click and pop" suppression circuitry
- Thermal shutdown protection circuitry

## APPLICATIONS

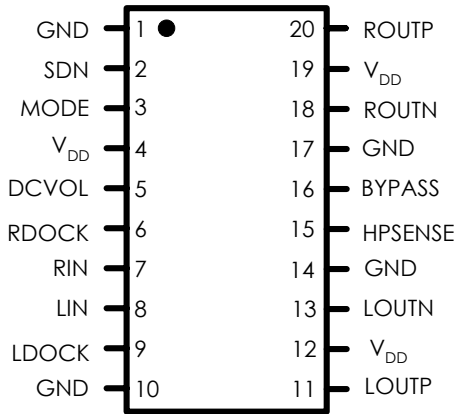
- Portable and Desktop Computers
- Multimedia Monitors
- Portable Radios, PDAs, and Portable TVs

## FUNCTION BLOCK DIAGRAM



## CONNECTION DIAGRAM

TSSOP-20FD Package



## ORDER INFORMATION

EMA2203-50QE20GRR/NRR

- |      |                                  |
|------|----------------------------------|
| 50   | 5.0V Operation                   |
| QE20 | TSSOP-20FD Package               |
| GRR  | RoHS (Pb Free)                   |
|      | Rating: -40 to 85°C              |
|      | Package in Tape & Reel           |
| NRR  | RoHS & Halogen free (By Request) |
|      | Rating: -40 to 85°C              |
|      | Package in Tape & Reel           |

## Order, Mark & Packing Information

Package	Product ID	Marking	Packing
TSSOP-20FD	EMA2203-50QE20NRR		2.5K units Tape & Reel

## TERMINAL FUNCTIONS

TERMINAL		I/O	Function DESCRIPTION
NAME	NO.		
GND	1,10,14,17	I	Ground
SDN	2	I	High Level Shutdown
MODE	3	I	32-Steps Volume Control Enable/Disable
V <sub>DD</sub>	4,12,19	I	Power Supply
DCVOL	5	I	DC Level Input for Volume Adjustment
RDOCK	6	O	Right Channel Audio Output as Pre-amplifier for Dock
LDOCK	9	O	Left Channel Audio Output as Pre-amplifier for Dock
RIN	7	I	Right Channel Audio Input
LIN	8	I	Left Channel Audio Input
LOUTP	11	O	Left Channel Positive (Relative to LIN) Output
LOUTN	13	O	Left Channel Negative (Relative to LIN) Output
HPSENSE	15	I	Headphone Enable/Disable
BYPASS	16	-	Mid-supply voltage, Adding a Bypass Capacitor to Improve PSRR and Noise Immunity / Turn-on Time Define
ROUTN	18	O	Right Channel (Relative to RIN) Negative Output
ROUTP	20	O	Right Channel (Relative to RIN) Positive Output

## TYPICAL APPLICATION CIRCUIT

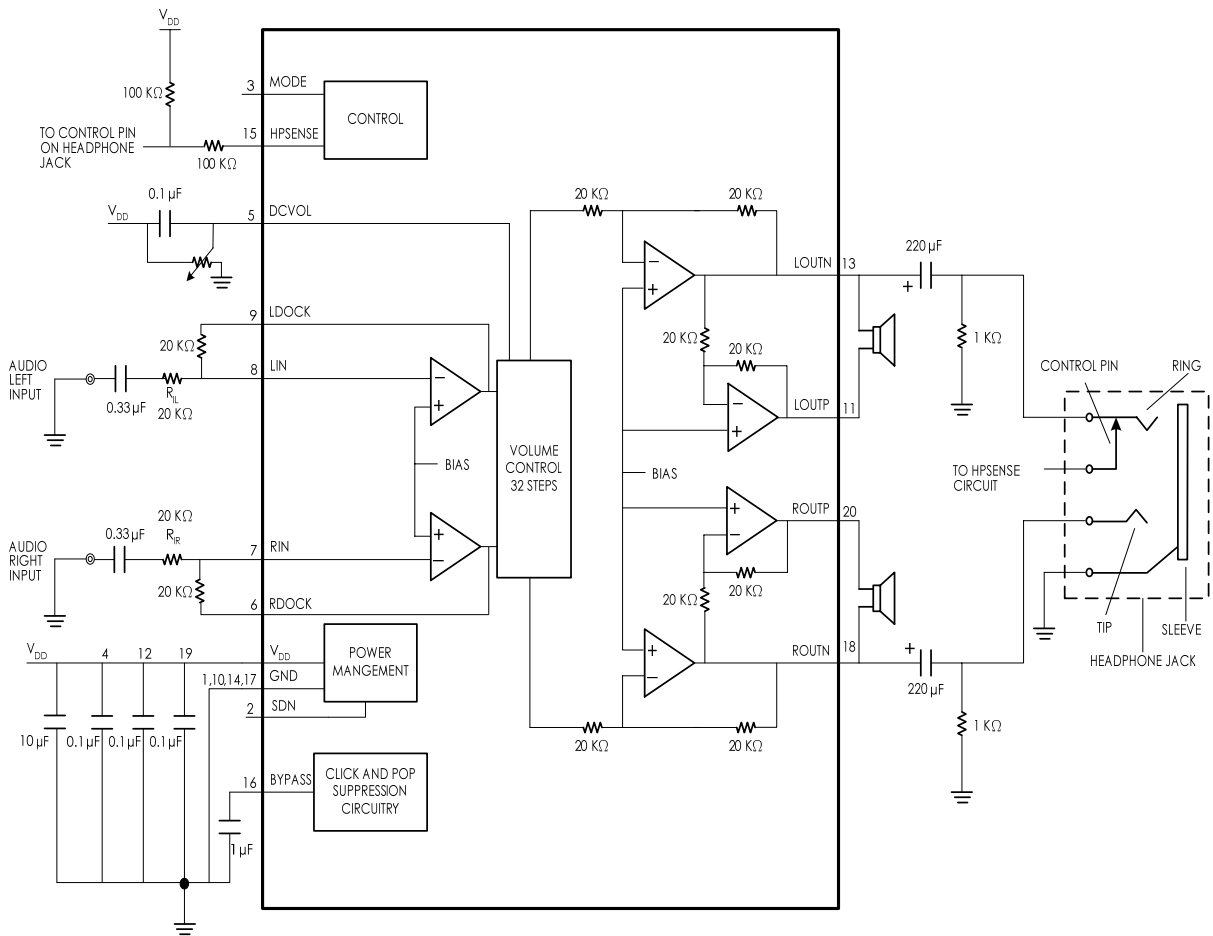


Figure1. Typical Audio Power Amplifier Application Circuit

## Absolute Maximum Ratings (Note 1)

Supply Voltage	6.0V	Thermal Resistance	
Storage Temperature	-65°C to +150°C	$\theta_{JA}$ (TSSOP-20FD)	80°C/W
Input Voltage	-0.3V to $V_{DD} + 0.3V$	Operating Ratings	
Power Dissipation	Internally Limited	Temperature Range	$-40^{\circ}C \leq T_A \leq 85^{\circ}C$
ESD Susceptibility	(Note 2) HBM 2kV (Note 3) MM 200V	Supply Voltage	$2.7V \leq V_{DD} \leq 5.5V$
Junction Temperature	150°C		

## ELECTRICAL CHARACTERISTICS FOR ENTIRE IC

The following specifications apply for  $V_{DD} = 5V$  unless otherwise specified. Limits apply for  $T_A = 25^{\circ}C$ .

Symbol	Parameter	Conditions	Conditions		Units (Limits)
			Typical	Limit	
$V_{DD}$	Supply Voltage			2.7	V(min)
				5.5	V(max)
$I_{DD}$	Quiescent Power Supply Current	Input AC to GND, No Load	10	20	mA (max)
$I_{SD}$	Shutdown Current	$V_{SDN} = 5V$	0.1	1.0	$\mu A$ (max)
$V_{IH}$	HPSENSE High Level			4.0	V (min)
	SDN High Level			1.2	
$V_{IL}$	HPSENSE Low Level			0.8	V (max)
	SDN Low Level			0.4	

## Electrical Characteristics for Volume Attenuators

The following specifications apply for  $V_{DD} = 5V$ ,  $A_v = 2$  unless otherwise specified. Limits apply for  $T_A = 25^{\circ}C$ .

Symbol	Parameter	Conditions	Conditions		Units (Limits)
			Typical	Limit	
$C_{RANGE}$	Attenuator Range	$V_{DCVOL} = 5V$	6		dB(max)
		$V_{DCVOL} = 0V$	-88	-80	dB(min)

## Electrical Characteristics for Single-Ended Mode Operation

The following specifications apply for  $V_{DD} = 5V$  unless otherwise specified. Limits apply for  $T_A = 25^{\circ}C$ .

Symbol	Parameter	Conditions	Conditions		Units (Limits)
			Typical	Limit	
$P_O$	Output Power	THD+N=1%, f=1kHz, 32 $\Omega$	85		mW
		THD+N=10%, f=1kHz, 32 $\Omega$	95		mW
THD+N	Total Harmonic Distortion + Noise	$V_{OUT} = 1 V_{RMS}$ , f=1kHz, 10k $\Omega$ $A_v = 1$	0.05		%

## Electrical Characteristics for Single-Ended Mode Operation

The following specifications apply for  $V_{DD} = 5V$  unless otherwise specified. Limits apply for  $T_A = 25^\circ C$ .

Symbol	Parameter	Conditions	Conditions		Units (Limits)
			Typical	Limit	
PSRR	Power Supply Rejection Ratio	$C_{Bypass} = 1\mu F$ , $f = 120Hz$ , $V_{RIPPLE} = 200mV_{RMS}$	58		dB
SNR	Signal to Noise Ratio	$P_{OUT} = 75mW$ , $32\Omega$ , A-Wtd filter	102		dB
$X_{TALK}$	Channel Separation	$C_{Bypass} = 1\mu F$ , $f = 1kHz$ ,	65		dB

## Electrical Characteristics for Bridged Mode Operation

The following specifications apply for  $V_{DD} = 5V$  unless otherwise specified. Limits apply for  $T_A = 25^\circ C$ .

Symbol	Parameter	Conditions	Conditions		Units (Limits)
			Typical	Limit	
$V_{OS}$	Output Offset Voltage		5	50	mV (max)
$P_O$	Output Power	THD+N = 1% ; $f = 1kHz$ , $3\Omega$	2.4		W
		THD+N = 1% ; $f = 1kHz$ , $4\Omega$	2		W
		THD+N = 1% ; $f = 1kHz$ , $8\Omega$	1.1	1.0	W(min)
		THD+N = 10% ; $f = 1kHz$ , $8\Omega$	1.5		W
$T_{WU}$	Wake-up time	$C_{Bypass} = 1\mu F$	300	600	ms (max)
$T_{SD}$	Thermal Shutdown Temperature		160		$^\circ C$
THD+N	Total Harmonic Distortion + Noise	$P_O = 1W$ ; $20Hz < f < 20kHz$ , $8\Omega$ , $A_v = 2$	0.3		%
		$P_O = 340mW$ , $32\Omega$	1.0		%
PSRR	Power Supply Rejection Ratio	$C_{Bypass} = 1\mu F$ , $f = 120Hz$ , $4\Omega$ $V_{RIPPLE} = 200mV_{RMS}$	60		dB (min)
SNR	Signal to Noise Ratio	$P_O = 1.1W$ , $8\Omega$ , A-Wtd filter	93		dB
$X_{TALK}$	Channel Separation	$C_{Bypass} = 1\mu F$ , $f = 1kHz$ ,	80		dB
$T_{SD}$	Shut Down Time		0.1		ms (max)

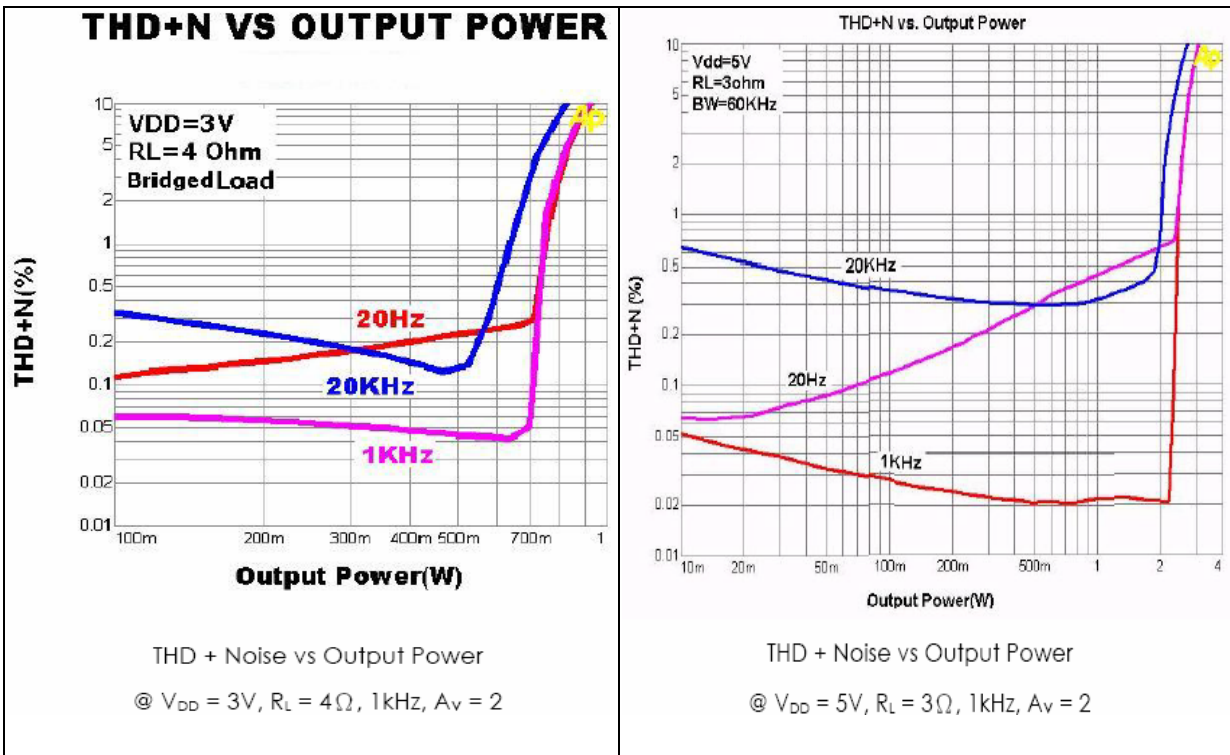
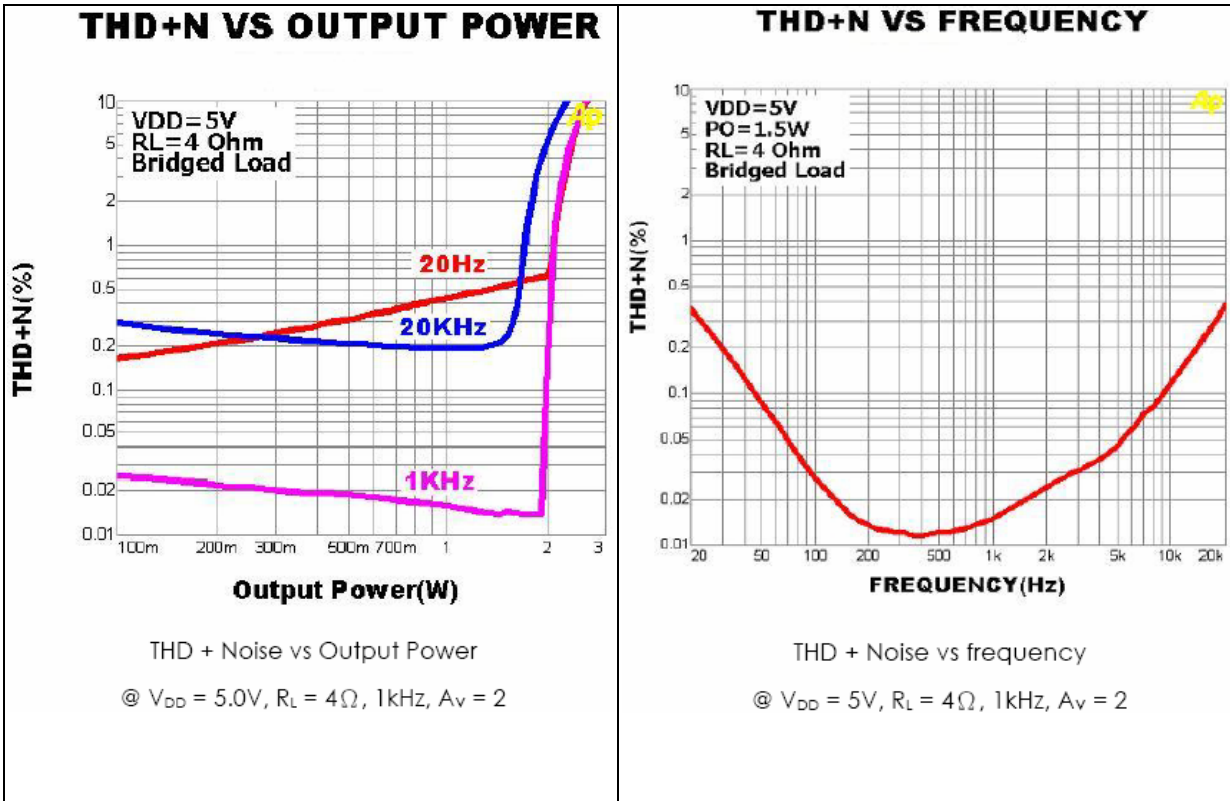
**Note 1:** *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur. *Operating Ratings* indicate conditions for which the device is functional, but do not guarantee specific performance limits. *Electrical Characteristics* state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

**Note 2:** Human body model, 100pF discharged through a 1.5k $\Omega$  resistor.

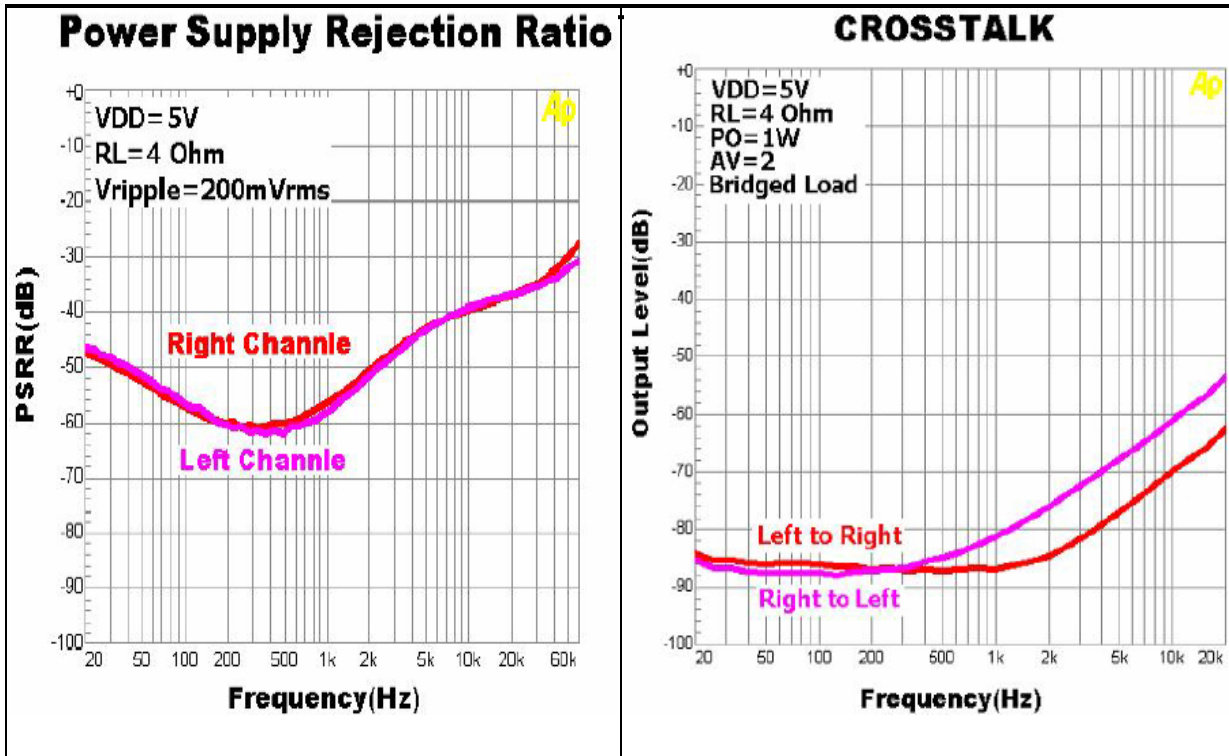
**Note 3:** Machine Model, 220pF–240pF discharged through all pins.

**Note 4:** All voltages are measured with respect to the ground pins, unless otherwise specified. All specifications are tested using the typical application as shown in *Figure 1*.

## TYPICAL PERFORMANCE CHARACTERISTICS







## TRUTH TABLE FOR LOGIC INPUTS

SDN	MODE	HPSENSE	DC Vol. Control	Bridged Output	Single-Ended Output
0	0	0	Fixed Level	Vol. Fixed	-
0	0	1	Fixed Level	-	Vol. Fixed
0	1	0	Adjustable	Vol. Changes	-
0	1	1	Adjustable	-	Vol. Changes
1	X	X	-	-	-

## POWER SUPPLY BYPASSING

As with any power amplifier, proper supply bypassing is critical for low noise performance and high power supply rejection. Applications that employ a 5V regulator typically use a 10 $\mu$ F in parallel with a 0.1 $\mu$ F filter capacitors to stabilize the regulator's output, reduce noise on the supply line, and improve the supply's transient response. However, their presence does not eliminate the need for a local 1.0 $\mu$ F tantalum bypass capacitance connected between the EMA2203's supply pins and ground. Do not substitute a ceramic capacitor for the tantalum. Doing so may cause oscillation. Keep the length of leads and traces that connect capacitors between the EMA2203's power supply pin and ground as short as possible. Connecting a 1 $\mu$ F capacitor,  $C_{\text{Bypass}}$ , between the BYPASS pin and ground improves the internal bias voltage's stability and improves the amplifier's PSRR. The PSRR improvements increase as the bypass pin capacitor value increases. Too large, however, increases turn-on time and can compromise amplifier's click and pop performance. The selection of bypass capacitor values, especially  $C_{\text{Bypass}}$ , depends on desired PSRR requirements, click and pop performance, system cost, and size constraints.

## SELECTING PROPER EXTERNAL COMPONENTS

Optimizing the EMA2203's performance requires properly selecting external components. Though the EMA2203 operates well when using external components with wide tolerances, best performance is achieved by optimizing component values. The EMA2203 is unity-gain stable, giving a designer maximum design flexibility. The gain should be set to no more than a given application requires. This allows the amplifier to achieve minimum THD+N and maximum signal-to-noise ratio. These parameters are compromised as the closed-loop gain increases. However, low gain demands input signals with greater voltage swings to achieve maximum output power. Fortunately, many signal sources such as audio CODECs have outputs of 1V<sub>RMS</sub> (2.83V<sub>P-P</sub>).

## INPUT CAPACITOR VALUE SELECTION

Amplifying the lowest audio frequencies requires high value input coupling capacitor (0.33 $\mu$ F in *Figure 1*). A high value capacitor can be expensive and may compromise space efficiency in portable designs. In many cases, however, the speakers used in portable systems, whether internal or external, have little ability to reproduce signals below 150 Hz. Applications using speakers with this limited frequency response reap little improvement by using large input capacitor.

Besides effecting system cost and size, the input coupling capacitor has an affect on the EMA2203's click and pop performance. When the supply voltage is first applied, a transient (pop) is created as the charge on the input capacitor changes from zero to a quiescent state. The magnitude of the pop is directly proportional to the input

capacitor's size. Higher value capacitors need more time to reach a quiescent DC voltage (usually  $V_{DD}/2$ ) when charged with a fixed current. The amplifier's output charges the input capacitor through the feedback resistor,  $R_f$ . Thus, pops can be minimized by selecting an input capacitor value that is no higher than necessary to meet the desired -3dB frequency.

As shown in *Figure 1*, the input resistor (20k $\Omega$ ) and the input capacitor produce a -3dB high pass filter cutoff frequency that is found using Equation (1).

$$f_{-3dB} = \frac{1}{2\pi R_{IN} C_1} \quad (1)$$

As an example when using a speaker with a low frequency limit of 150Hz, the input coupling capacitor, using Equation (1), is 0.063 $\mu$ F. The 0.33 $\mu$ F input coupling capacitor shown in *Figure 1* allows the EMA2203 to drive high efficiency, full range speaker whose response extends below 30Hz.

### OPTIMIZING CLICK AND POP REDUCTION PERFORMANCE

The EMA2203 contains circuitry that minimizes turn-on and shutdown transients or "clicks and pop". For this discussion, turn-on refers to either applying the power supply voltage or when the shutdown mode is deactivated. While the power supply is ramping to its final value, the EMA2203's internal amplifiers are configured as unity gain buffers. An internal current source changes the voltage of the BYPASS pin in a controlled, linear manner. Ideally, the input and outputs track the voltage applied to the BYPASS pin. The gain of the internal amplifiers remains unity until the voltage on the bypass pin reaches  $1/2 V_{DD}$ . As soon as the voltage on the bypass pin is stable, the device becomes fully operational. Although the BYPASS pin current cannot be modified, changing the size of  $C_{Bypass}$  alters the device's turn-on time and the magnitude of "clicks and pops". Increasing the value of  $C_{Bypass}$  reduces the magnitude of turn-on pops. However, this presents a tradeoff: as the size of  $C_{Bypass}$  increases, the turn-on time increases. There is a linear relationship between the size of  $C_{Bypass}$  and the turn-on time. Here are some typical turn-on times for various values of  $C_{Bypass}$ :

$C_B$	$T_{ON}$
0.1 $\mu$ F	30 ms
0.22 $\mu$ F	60 ms
0.47 $\mu$ F	150 ms
1.0 $\mu$ F	300 ms

In order to eliminate "clicks and pops", all capacitors must be discharged before turn-on. Rapidly switching  $V_{DD}$  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  $C_{OUT}$ . This capacitor usually has a high value.  $C_{OUT}$  discharges through internal switch. Depending on the size of  $C_{OUT}$ , the discharge time constant can be relatively large. To reduce transients in single-ended mode, an external 1k $\Omega$ -5k $\Omega$  resistor  $R_{PULL}$  can be placed in parallel with the load resistor. For EMA2203 operating in single-ended mode, turn-on time is typically 800ms with 1.0  $\mu$ F BYPASS capacitor to reach good "clicks and pops" elimination performance.

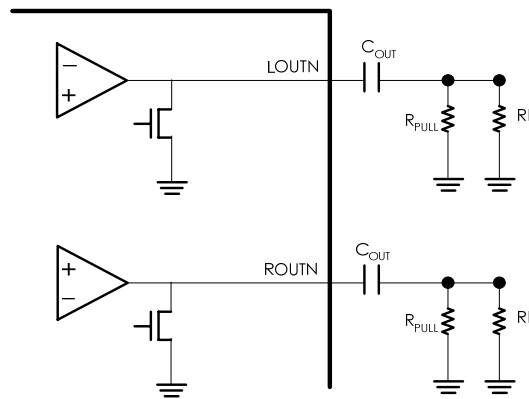


Figure2. Single-ended Output Configuration

### DOCKING STATION INTERFACE

Applications such as notebook computers can take advantage of a docking station to connect to external devices such as monitors or audio/visual equipment that sends or receives line level signals. The EMA2203 has two outputs, Pin 6 and Pin 9, which connect to outputs of the internal input amplifiers that drive the volume control inputs. These input amplifiers can drive loads of >1kΩ (such as powered speakers) with a rail-to-rail signal. Since the output signal present on the RDOCK and LDOCK pins is biased to  $V_{DD}/2$ , coupling capacitors should be connected in series with the load. Typical values for the coupling capacitors are 0.33μF to 1.0μF. If polarized coupling capacitors are used, connect their "+" terminals to the respective output pin.

Since the DOCK outputs precede the internal volume control, the signal amplitude will be equal to the input signal's magnitude and cannot be adjusted. However, the input amplifier's closed-loop gain can be adjusted using external resistors. These resistors are shown in *Figure 1* as 20kΩ devices that set each input amplifier's gain to -1. Use Equation 2 to determine the input and feedback resistor values for a desired gain.

$$-A_V = \frac{R_F}{R_I} \tag{2}$$

Adjusting the input amplifier's gain sets the minimum gain for that channel. The DOCK outputs adds circuit and functional flexibility because their use supercedes using the inverting outputs of each bridged output amplifier as line-level outputs.

### MICRO-POWER SHUTDOWN

The voltage applied to the SDN pin controls the EMA2203's shutdown function. Activate micro-power shutdown by applying  $V_{DD}$  to the SDN pin. When active, the EMA2203's micro-power shutdown feature turns off the amplifier's bias circuitry, reducing the supply current. The logic threshold is typically  $V_{DD}/2$ . The low 0.1μA typical shutdown current is achieved by applying a voltage that is as near as  $V_{DD}$  as possible to the SDN pin. A voltage that is less than  $V_{DD}$  may increase the shutdown current. *Table 1* shows the logic signal levels that activate and deactivate micro-power shutdown and headphone amplifier operation.

There are a few ways to control the micro-power shutdown. These include using a single-pole, single-throw switch, a microprocessor, or a microcontroller. When using a switch, connecting an external 10kΩ pull-up resistor between the SDN pin and V<sub>DD</sub>. Connect the switch between the SDN pin and ground. Select normal amplifier operation by closing the switch. Opening the switch connects the SDN pin to V<sub>DD</sub> through the pull-up resistor, activating micro-power shutdown. The switch and resistor guarantee that the SDN pin will not float. This prevents unwanted state changes. In a system with a microprocessor or a microcontroller, use a digital output to apply the control voltage to the SDN pin. Driving the SDN pin with active circuitry eliminates the pull up resistor.

**TABLE 1. Truth Table for SDN and HPSENSE Operation**

SDN PIN	HPSENSE PIN	OPERATIONAL MODE (MUX INPUT CHANNEL #)
Logic Low	Logic Low	Bridged Amplifiers
Logic Low	Logic High	Single-Ended Amplifiers
Logic High	-	Micro-Power Shutdown

### MODE FUNCTION

The EMA2203's MODE function has two states controlled by the voltage applied to the MODE pin (pin 3). Mode 0, selected by applying 0V to the MODE pin, forces the EMA2203 to effectively function as a "line-out," unity-gain amplifier. Mode 1, which uses the internal DC controlled volume control, is selected by applying V<sub>DD</sub> to the MODE pin. This mode sets the amplifier's gain according to the DC voltage applied to the DCVOL pin. Prevent unanticipated gain behavior by connecting the MODE pin to V<sub>DD</sub> or ground. Do not let pin 3 float.

### HPSENSE FUNCTION

Applying a voltage between 4V and V<sub>DD</sub> to the EMA2203's HPSENSE headphone control pin turns off inverting amplifier of each channel, muting a bridged-connected load. Quiescent current consumption is reduced when the IC is in this single-ended mode.

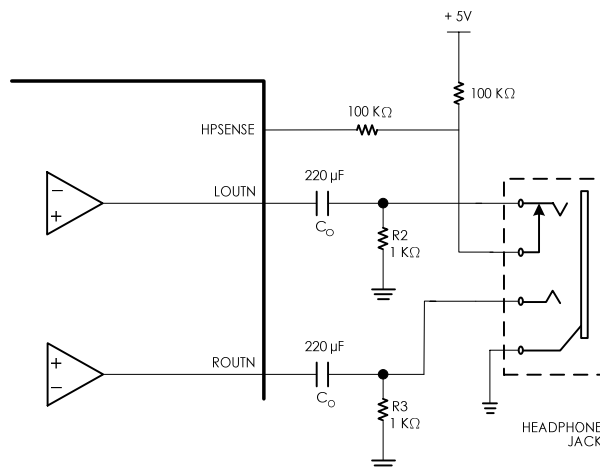
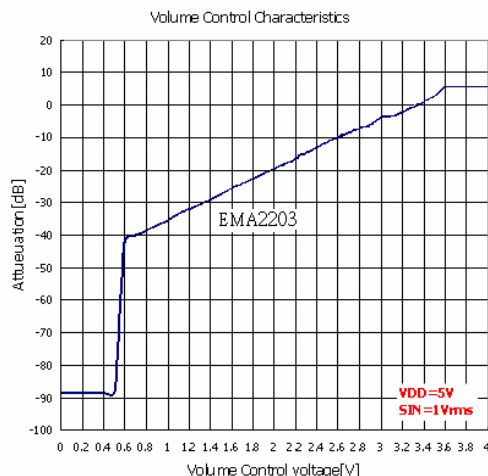


Figure3. Headphone Sensing Circuit

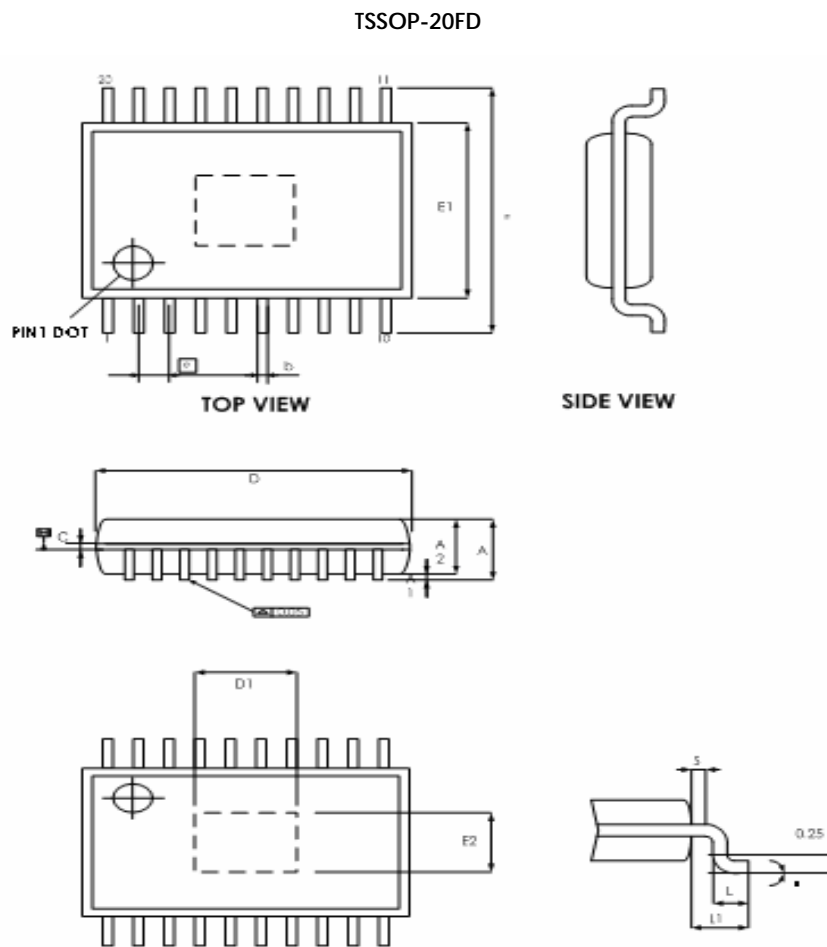
## DC VOLUME CONTROL

The EMA2203 has an internal stereo volume control whose setting is a function of the DC voltage applied to the DCVOL pin. The volume control's voltage input range is 0V to  $V_{DD}$ . The volume range is from 6dB (DC control voltage = 80%  $V_{DD}$ ) to -88dB (DC control voltage = 0V). The volume remains at 6dB for DC control voltages greater than 80%  $V_{DD}$ . When the MODE input is 0V, the EMA2203 operates at unity gain, bypassing the volume control. A graph showing a typical volume response versus DC control voltage is shown below.



Like all volume controls, the EMA2203's internal volume control is set while listening to an amplified signal that is applied to an external speaker. The actual voltage applied to the DCVOL pin is a result of the volume a listener desires. As such, the volume control is designed for use in a feedback system that includes human ears and preferences. This feedback system operates quite well without the need for accurate gain. The user simply sets the volume to the desired level as determined by their ear, without regard to the actual DC voltage that produces the volume. Therefore, the accuracy of the volume control is not critical, as long as the volume changes monotonically, matches well between stereo channels, and the step size is small enough to reach a desired volume that is not too loud or too soft. Since gain accuracy is not critical, there will be volume variation from part-to-part even with the same applied DC control voltage. The gain of a given EMA2203 can be set with a fixed external voltage, but another EMA2203 may require a different control voltage to achieve the same gain. The typical part-to-part variation can be as large as 8dB for the same control voltage.

## Physical Dimensions (TSSOP-20FD Package)



SYMBOLS	MIN	NOM	MAX
A	-	-	1.20
A1	0.05	-	0.15
a2	0.80	0.90	1.05
b	0.19	-	0.30
C	0.09	-	0.20
D	6.40	6.50	6.60
E1	4.30	4.40	4.50
E	6.40 BSC		
e	0.65 BSC		
L1	1.00 BSC		
L	0.50	0.60	0.75
S	0.20	-	-
$\theta$	0°	-	8°

Unit: mm

## Revision History

Revision	Date	Description
2.0	2009.06.05	EMP transferred from version 1.0



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