MAXIM

80mW, DirectDrive Stereo Headphone Driver with Shutdown

MAX4410

General Description

The MAX4410 stereo headphone driver is designed for portable equipment where board space is at a premium. The MAX4410 uses a unique, patented, DirectDrive architecture to produce a ground-referenced output from a single supply, eliminating the need for large DC-blocking capacitors, saving cost, board space, and component height.

The MAX4410 delivers up to 80mW per channel into a 16Ω load and has low 0.005% THD + N. A high power-supply rejection ratio (90dB at 1kHz) allows this device to operate from noisy digital supplies without an additional linear regulator, and includes ±8kV ESD protection. Comprehensive click-and-pop circuitry suppresses audible clicks and pops on startup and shutdown. Independent left/right, low-power shutdown controls make it possible to optimize power savings in mixed mode, mono/stereo applications.

The MAX4410 operates from a single 1.8V to 3.6V supply, consumes only 7mA of supply current, has short-circuit and thermal overload protection, and is specified over the extended -40°C to +85°C temperature range. The MAX4410 is available in a tiny (2mm x 2mm), 16-bump ultra chip-scale package (UCSP™) and a 14-pin TSSOP package.

Applications

|	
Notebooks	MP3 Players
Cellular Phones	Web Pads
PDAs	Portable Audio Equipment

Features

♦ **No Bulky DC-Blocking Capacitors Required**

♦ **Ground-Referenced Outputs Eliminate DC-Bias Voltages on Headphone Ground Pin**

♦ **No Degradation of Low-Frequency Response Due to Output Capacitors**

♦ **80mW Per Channel into 16Ω**

♦ **Low 0.005% THD + N**

♦ **High PSRR (90dB at 1kHz)**

♦ **Integrated Click-and-Pop Suppression**

♦ **1.8V to 3.6V Single-Supply Operation**

♦ **Low Quiescent Current**

♦ **Independent Left/Right, Low-Power Shutdown Controls**

♦ **Short-Circuit and Thermal Overload Protection**

♦ **±8kV ESD-Protected Amplifier Outputs**

♦ **Available in Space-Saving Packages**
   16-Bump UCSP (2mm x 2mm)
   14-Pin TSSOP

Ordering Information

PART	TEMP RANGE	PIN/BUMP-PACKAGE
MAX4410EBE-T*	-40°C to +85°C	16 UCSP-16
MAX4410EUD	-40°C to +85°C	14 TSSOP

*Future product—contact factory for availability.

Pin Configurations

UCSP (B16-2)

TSSOP
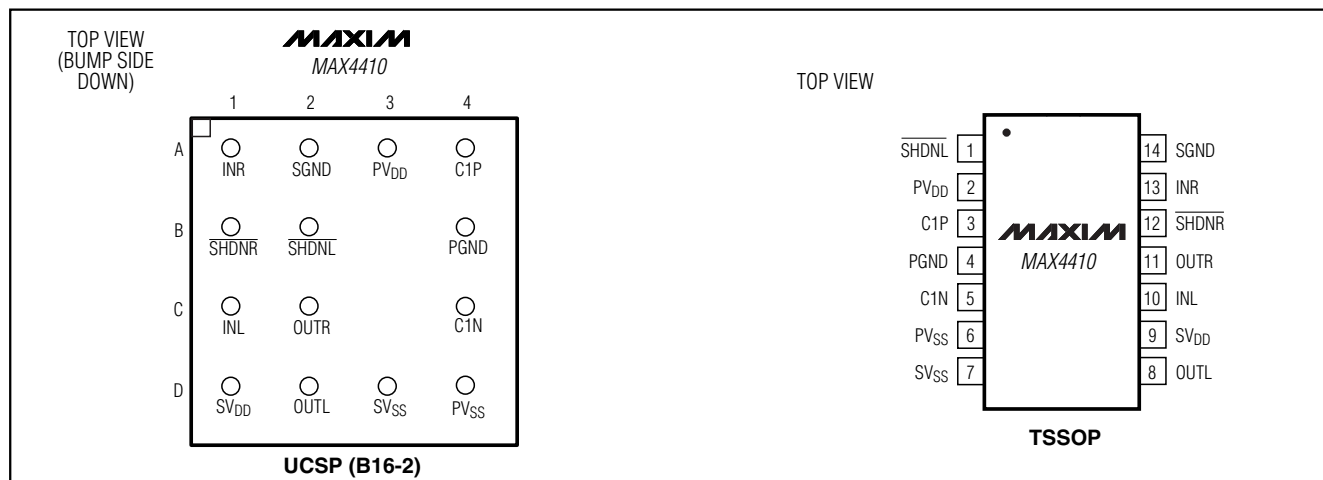
UCSP is a trademark of Maxim Integrated Products, Inc.

Functional Diagram/Typical Application Circuit appears at end of data sheet.

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80mW, DirectDrive Stereo Headphone Driver with Shutdown

ABSOLUTE MAXIMUM RATINGS

PGND to SGND ....-0.3V to +0.3V
PV_{DD} to SV_{DD} ....-0.3V to +0.3V
PV_{SS} to SV_{SS} ....-0.3V to +0.3V
PV_{DD} and SV_{DD} to PGND or SGND ....-0.3V to +4V
PV_{SS} and SV_{SS} to PGND or SGND ....-4V to +0.3V
IN_ to SGND ....-0.3V to +0.3V
$\overline{SHDN}$_ to SGND.......................(SGND - 0.3V) to (SV_{DD} + 0.3V)
OUT_ to SGND ....(SV_{SS} - 0.3V) to (SV_{DD} +0.3V)
C1P to PGND............................(PGND - 0.3V) to (PV_{DD} + 0.3V)
C1N to PGND ....(PV_{SS} - 0.3V) to (PGND + 0.3V)
Output Short Circuit to GND or V_{DD}..........................Continuous

Continuous Power Dissipation (T_A = +70°C)
    16-Bump UCSP (derate 15.2mW/°C above +70°C) ..1212mW
    14-Pin TSSOP (derate 9.1mW/°C above +70°C) 727mW
Junction Temperature...+150°C
Operating Temperature Range ....-40°C to +85°C
Storage Temperature Range ....-65°C to +150°C
Bump Temperature (soldering) (Note 1)
    Infrared (15s) ....+220°C
    Vapor Phase (60s) ....+215°C
Lead Temperature (soldering, 10s) ....+300°C

Note 1: This device is constructed using a unique set of packaging techniques that impose a limit on the thermal profile the device can be exposed to during board-level solder attach and rework. This limit permits only the use of the solder profiles recommended in the industry-standard specification, JEDEC 020A, paragraph 7.6, Table 3 for IR/VPR and convection reflow. Preheating is required. Hand or wave soldering is not allowed.

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
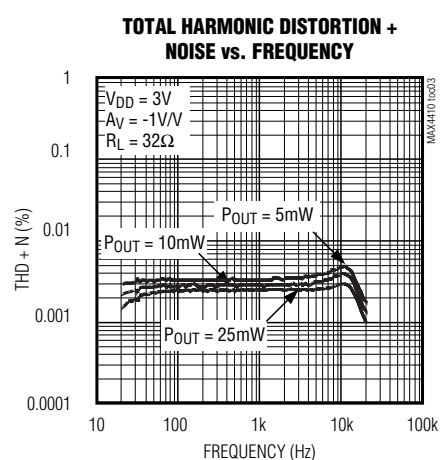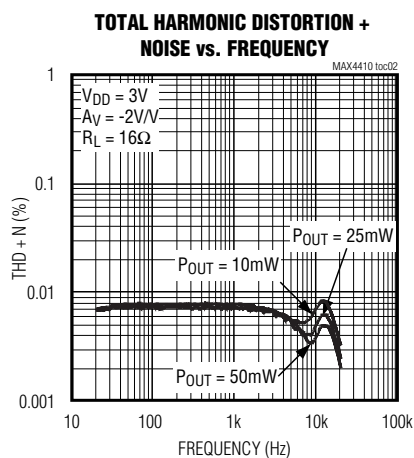
(PV_{DD} = SV_{DD} = 3V, PGND = SGND = 0, $\overline{SHDNL}$ = $\overline{SHDNR}$ = SV_{DD}, C1 = C2 = 2.2µF, R_{IN} = R_F = 10kΩ, R_L = ∞, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 2)

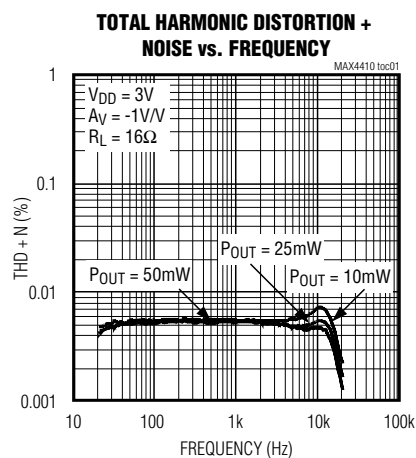| PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Supply Voltage Range	V_{DD}	Guaranteed by PSRR test		1.8		3.6	V
Quiescent Supply Current	I_{DD}	One channel enabled			4		mA
		Two channels enabled			7	11.5	
Shutdown Supply Current	$I_{\overline{SHDN}}$	$\overline{SHDNL}$ = $\overline{SHDNR}$ = GND			6	10	µA
$\overline{SHDN}$_ Thresholds		V_{IH}		0.7 x SV_{DD}			V
		V_{IL}				0.3 x SV_{DD}	
$\overline{SHDN}$_ Input Leakage Current				-1		+1	µA
$\overline{SHDN}$_ to Full Operation	t_{SON}				175		µs
CHARGE PUMP							
Oscillator Frequency	f_{OSC}			272	320	368	kHz
AMPLIFIERS							
Input Offset Voltage	V_{OS}	Input AC-coupled, R_L = 32Ω			0.5	2.4	mV
Input Bias Current	I_{BIAS}			-100		+100	nA
Power-Supply Rejection Ratio	PSRR	1.8 ≤ V_{DD} ≤ 3.6V	DC	75	90		dB
		200mV$_{P-P}$ ripple	f_{RIPPLE} = 1kHz		90		
			f_{RIPPLE} = 20kHz		55		
Output Power	P_{OUT}	THD + N = 1%	R_L = 32Ω		65		mW
			R_L = 16Ω	40	80		

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ELECTRICAL CHARACTERISTICS (continued)

(PV$_{DD}$ = SV$_{DD}$ = 3V, PGND = SGND = 0, $\overline{SHDNL}$ = $\overline{SHDNR}$ = SV$_{DD}$, C1 = C2 = 2.2µF, R$_{IN}$ = R$_F$ = 10kΩ, R$_L$ = ∞, T$_A$ = T$_{MIN}$ to T$_{MAX}$, unless otherwise noted. Typical values are at T$_A$ = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Total Harmonic Distortion Plus Noise	THD + N	f$_{IN}$ = 1kHz	R$_L$ = 32Ω, P$_{OUT}$ = 25mW		0.003		%
			R$_L$ = 16Ω, P$_{OUT}$ = 50mW		0.005		
Signal-to-Noise Ratio	SNR	R$_L$ = 32Ω, P$_{OUT}$ = 20mW, f$_{IN}$ = 1kHz			95		dB
Slew Rate	SR				0.8		V/µs
Maximum Capacitive Load	C$_L$	No sustained oscillations			300		pF
Crosstalk		R$_L$ = 16Ω, P$_{OUT}$ = 1.6mW, f$_{IN}$ = 10kHz			67		dB
Thermal Shutdown Threshold					140		°C
Thermal Shutdown Hysteresis					15		°C
ESD Protection		Human body model (OUTR, OUTL)			±8		kV

Note 2: All specifications are 100% tested at T$_A$ = +25°C; temperature limits are guaranteed by design.
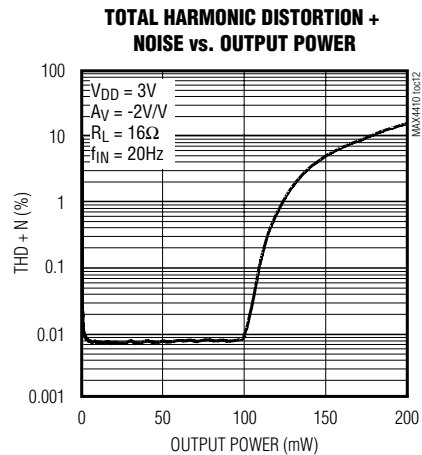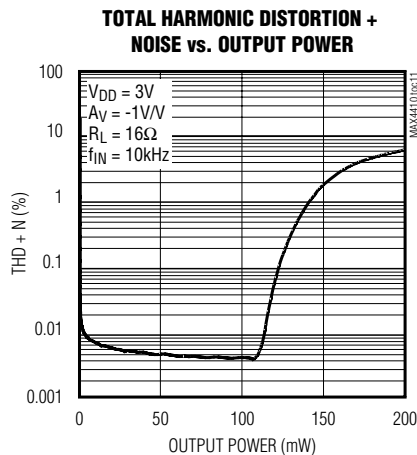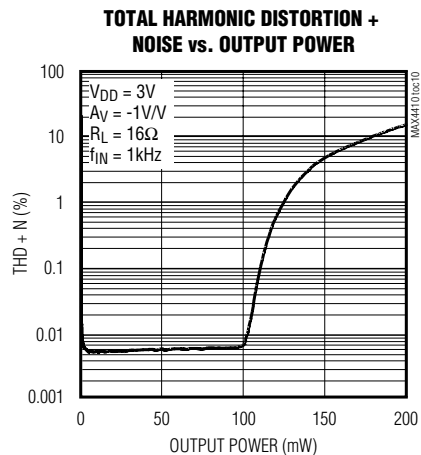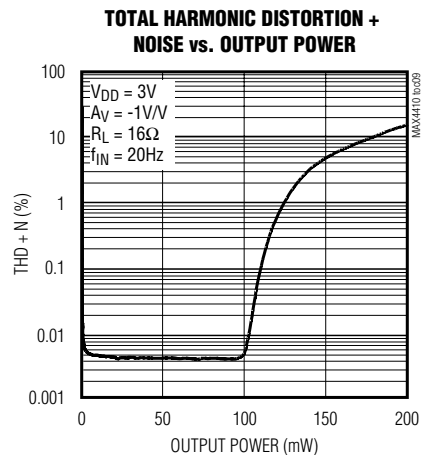
Typical Operating Characteristics

(C1 = C2 = 2.2µF, THD + N measurement bandwidth = 22Hz to 22kHz, single-channel driven, T$_A$ = +25°C, unless otherwise noted.)

TOTAL HARMONIC DISTORTION + NOISE vs. FREQUENCY

TOTAL HARMONIC DISTORTION + NOISE vs. FREQUENCY

TOTAL HARMONIC DISTORTION + NOISE vs. FREQUENCY

80mW, DirectDrive Stereo Headphone Driver with Shutdown
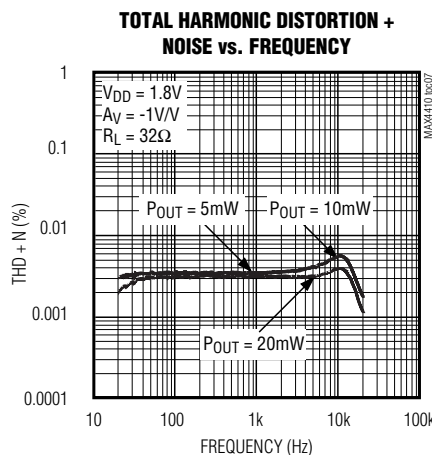
Typical Operating Characteristics (continued)
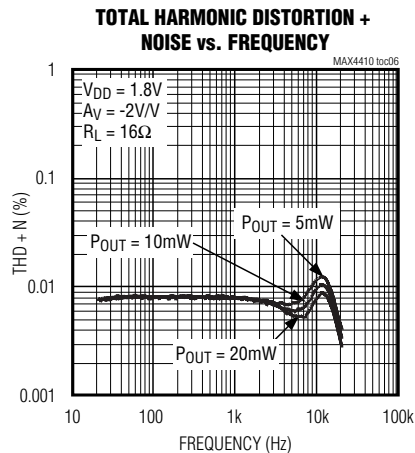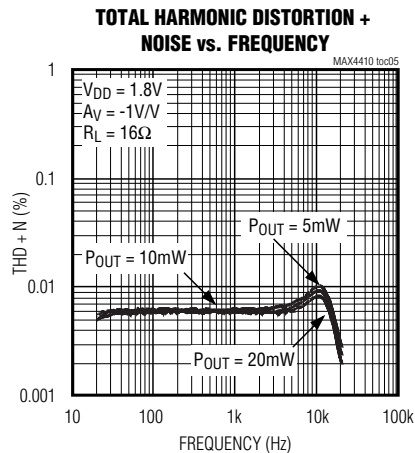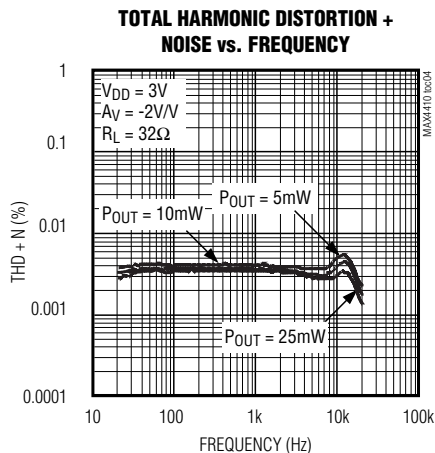
(C1 = C2 = 2.2µF, THD + N measurement bandwidth = 22Hz to 22kHz, single-channel driven, T_A = +25°C, unless otherwise noted.)

TOTAL HARMONIC DISTORTION + NOISE vs. FREQUENCY

V_{DD} = 3V
A_V = -2V/V
R_L = 32Ω

P_{OUT} = 10mW
P_{OUT} = 5mW
P_{OUT} = 25mW

TOTAL HARMONIC DISTORTION + NOISE vs. FREQUENCY

V_{DD} = 1.8V
A_V = -1V/V
R_L = 16Ω

P_{OUT} = 5mW
P_{OUT} = 10mW
P_{OUT} = 20mW

TOTAL HARMONIC DISTORTION + NOISE vs. FREQUENCY

V_{DD} = 1.8V
A_V = -2V/V
R_L = 16Ω

P_{OUT} = 5mW
P_{OUT} = 10mW
P_{OUT} = 20mW

TOTAL HARMONIC DISTORTION + NOISE vs. FREQUENCY

V_{DD} = 1.8V
A_V = -1V/V
R_L = 32Ω

P_{OUT} = 5mW
P_{OUT} = 10mW
P_{OUT} = 20mW

TOTAL HARMONIC DISTORTION + NOISE vs. FREQUENCY

V_{DD} = 1.8V
A_V = -2V/V
R_L = 32Ω

P_{OUT} = 5mW
P_{OUT} = 10mW
P_{OUT} = 20mW

TOTAL HARMONIC DISTORTION + NOISE vs. OUTPUT POWER

V_{DD} = 3V
A_V = -1V/V
R_L = 16Ω
f_{IN} = 20Hz

TOTAL HARMONIC DISTORTION + NOISE vs. OUTPUT POWER

V_{DD} = 3V
A_V = -1V/V
R_L = 16Ω
f_{IN} = 1kHz

TOTAL HARMONIC DISTORTION + NOISE vs. OUTPUT POWER

V_{DD} = 3V
A_V = -1V/V
R_L = 16Ω
f_{IN} = 10kHz

TOTAL HARMONIC DISTORTION + NOISE vs. OUTPUT POWER

V_{DD} = 3V
A_V = -2V/V
R_L = 16Ω
f_{IN} = 20Hz

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_____Typical Operating Characteristics (continued)

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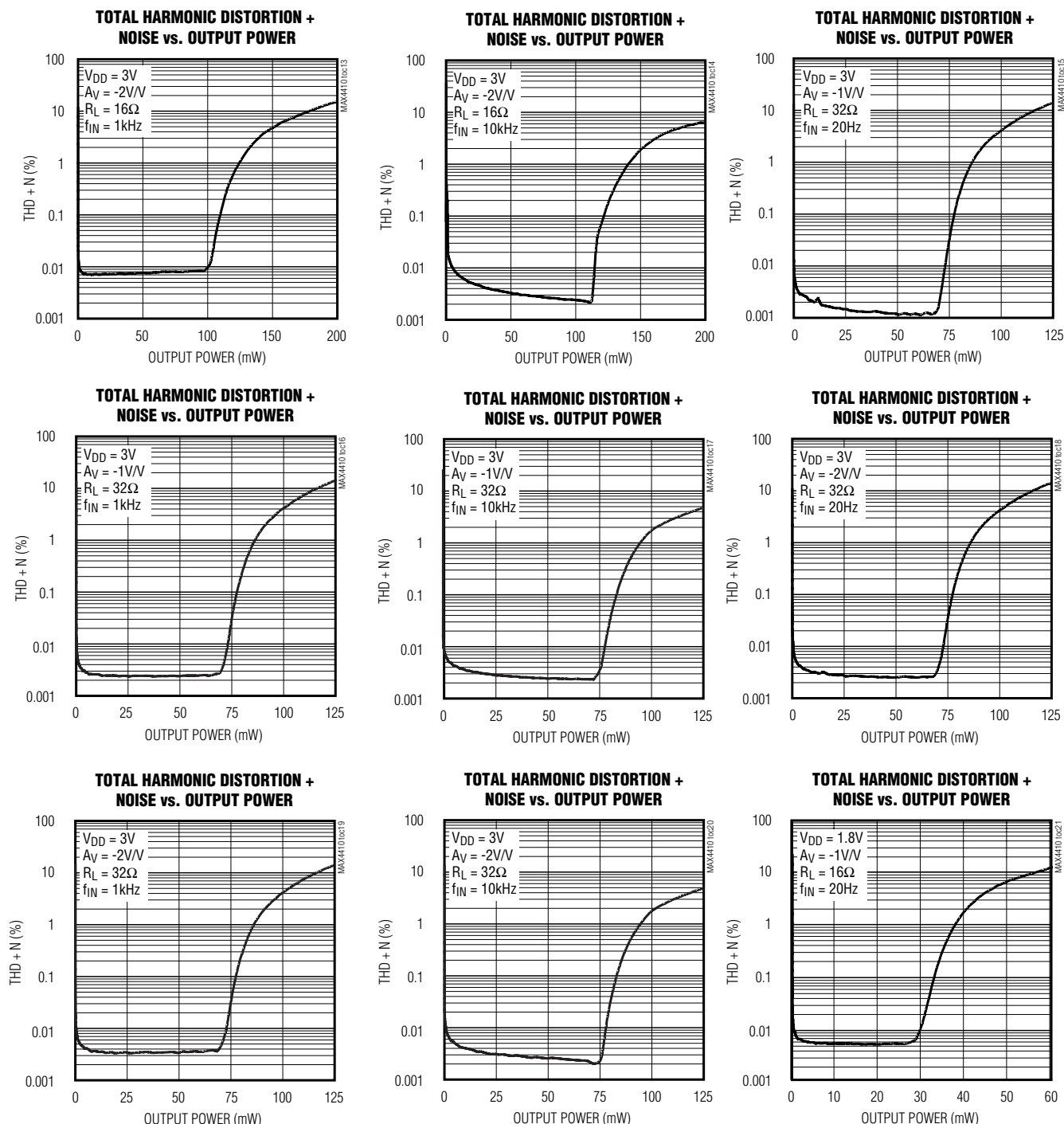
TOTAL HARMONIC DISTORTION + NOISE vs. OUTPUT POWER

V_{DD} = 3V
A_V = -2V/V
R_L = 16Ω
f_{IN} = 1kHz

MAX4410 toc13

THD + N (%)

OUTPUT POWER (mW)

TOTAL HARMONIC DISTORTION + NOISE vs. OUTPUT POWER

V_{DD} = 3V
A_V = -2V/V
R_L = 16Ω
f_{IN} = 10kHz

MAX4410 toc14

THD + N (%)

OUTPUT POWER (mW)

TOTAL HARMONIC DISTORTION + NOISE vs. OUTPUT POWER

V_{DD} = 3V
A_V = -1V/V
R_L = 32Ω
f_{IN} = 20Hz

MAX4410 toc15

THD + N (%)

OUTPUT POWER (mW)

TOTAL HARMONIC DISTORTION + NOISE vs. OUTPUT POWER

V_{DD} = 3V
A_V = -1V/V
R_L = 32Ω
f_{IN} = 1kHz

MAX4410 toc16

THD + N (%)

OUTPUT POWER (mW)

TOTAL HARMONIC DISTORTION + NOISE vs. OUTPUT POWER

V_{DD} = 3V
A_V = -1V/V
R_L = 32Ω
f_{IN} = 10kHz

MAX4410 toc17

THD + N (%)

OUTPUT POWER (mW)

TOTAL HARMONIC DISTORTION + NOISE vs. OUTPUT POWER

V_{DD} = 3V
A_V = -2V/V
R_L = 32Ω
f_{IN} = 20Hz

MAX4410 toc18

THD + N (%)

OUTPUT POWER (mW)

TOTAL HARMONIC DISTORTION + NOISE vs. OUTPUT POWER

V_{DD} = 3V
A_V = -2V/V
R_L = 32Ω
f_{IN} = 1kHz

MAX4410 toc19

THD + N (%)

OUTPUT POWER (mW)

TOTAL HARMONIC DISTORTION + NOISE vs. OUTPUT POWER

V_{DD} = 3V
A_V = -2V/V
R_L = 32Ω
f_{IN} = 10kHz

MAX4410 toc20

THD + N (%)

OUTPUT POWER (mW)

TOTAL HARMONIC DISTORTION + NOISE vs. OUTPUT POWER

V_{DD} = 1.8V
A_V = -1V/V
R_L = 16Ω
f_{IN} = 20Hz

MAX4410 toc21

THD + N (%)

OUTPUT POWER (mW)

80mW, DirectDrive Stereo Headphone Driver with Shutdown

_____ **_Typical Operating Characteristics (continued)_**
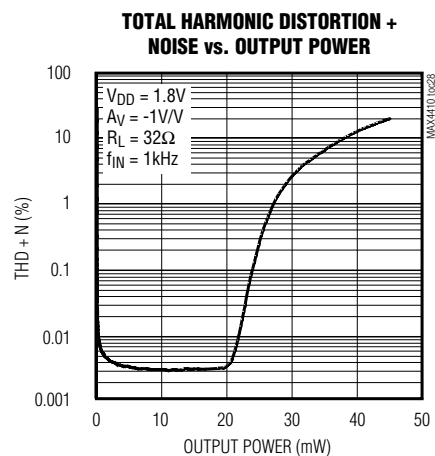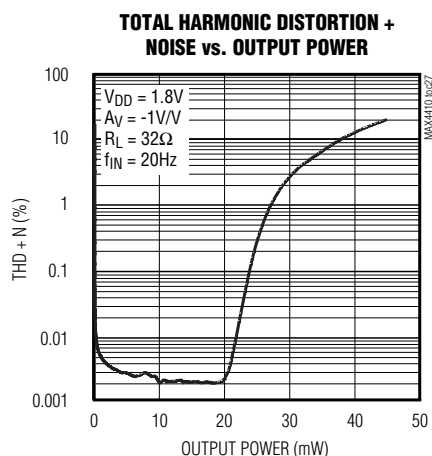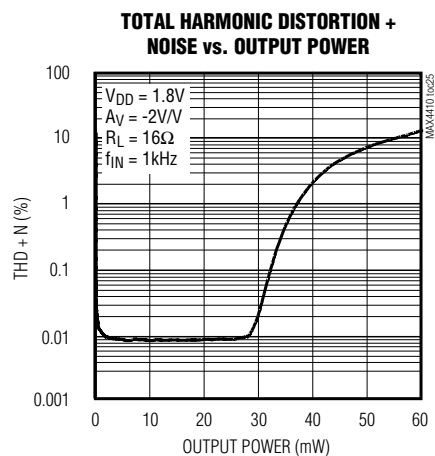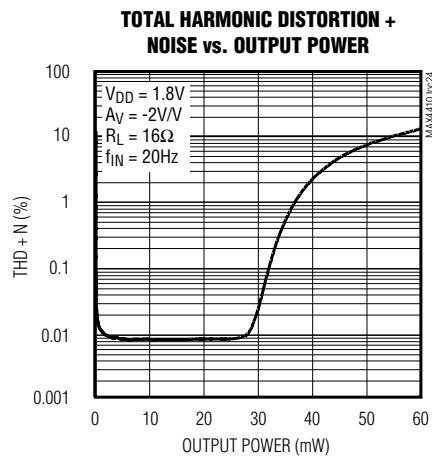
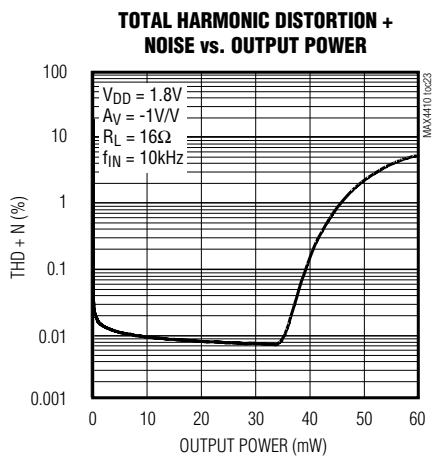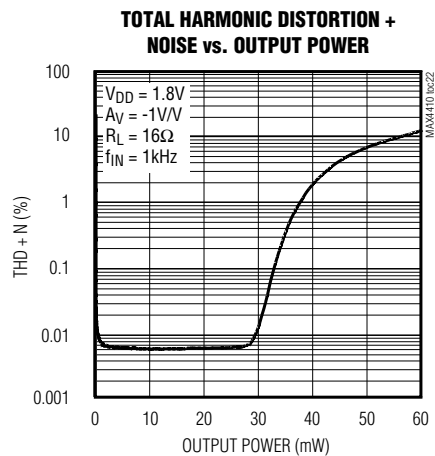(C1 = C2 = 2.2µF, THD + N measurement bandwidth = 22Hz to 22kHz, single-channel driven, T_A = +25°C, unless otherwise noted.)
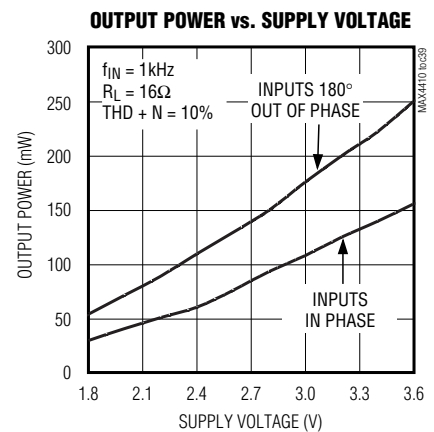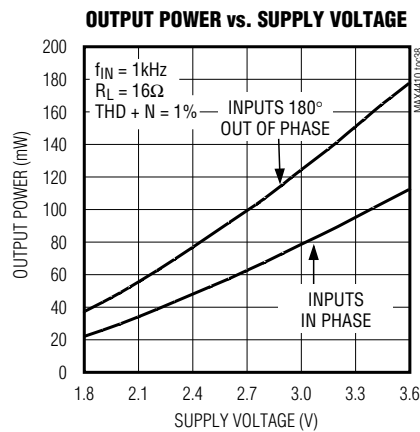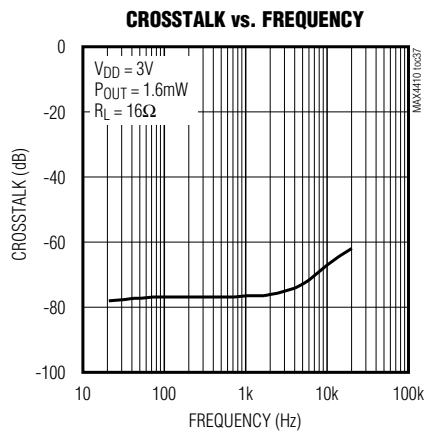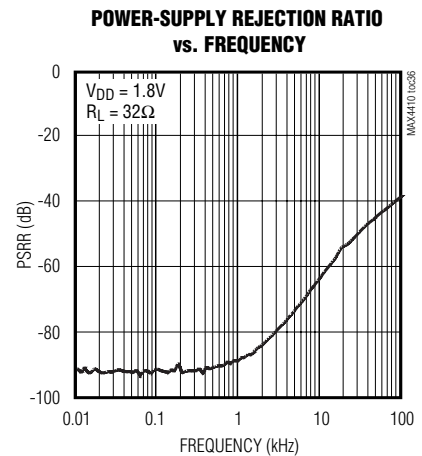
**TOTAL HARMONIC DISTORTION +
NOISE vs. OUTPUT POWER**

V_{DD} = 1.8V
A_V = -1V/V
R_L = 16Ω
f_{IN} = 1kHz

**TOTAL HARMONIC DISTORTION +
NOISE vs. OUTPUT POWER**

V_{DD} = 1.8V
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f_{IN} = 10kHz

**TOTAL HARMONIC DISTORTION +
NOISE vs. OUTPUT POWER**

V_{DD} = 1.8V
A_V = -2V/V
R_L = 16Ω
f_{IN} = 20Hz

**TOTAL HARMONIC DISTORTION +
NOISE vs. OUTPUT POWER**

V_{DD} = 1.8V
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R_L = 16Ω
f_{IN} = 1kHz

**TOTAL HARMONIC DISTORTION +
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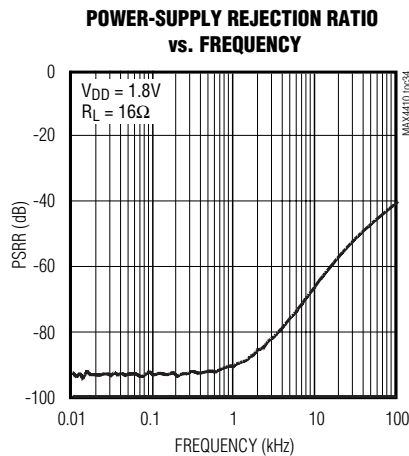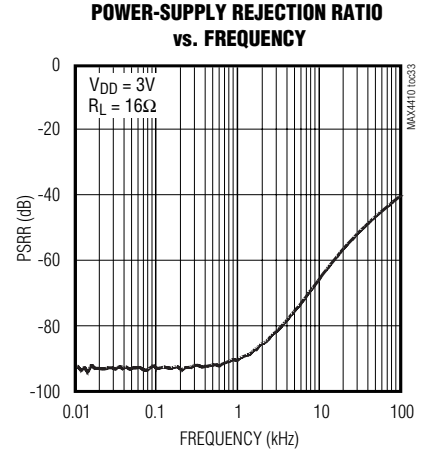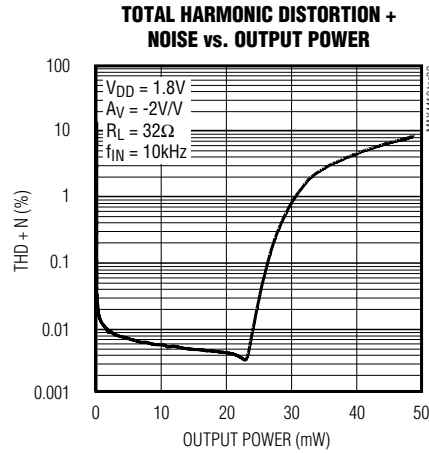
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(C1 = C2 = 2.2µF, THD + N measurement bandwidth = 22Hz to 22kHz, single-channel driven, T_A = +25°C, unless otherwise noted.)

TOTAL HARMONIC DISTORTION + NOISE vs. OUTPUT POWER

MAX4410 toc31

V_{DD} = 1.8V
A_V = -2V/V
R_L = 32Ω
f_{IN} = 1kHz

TOTAL HARMONIC DISTORTION + NOISE vs. OUTPUT POWER

MAX4410 toc32

V_{DD} = 1.8V
A_V = -2V/V
R_L = 32Ω
f_{IN} = 10kHz

POWER-SUPPLY REJECTION RATIO vs. FREQUENCY

MAX4410 toc33

V_{DD} = 3V
R_L = 16Ω

POWER-SUPPLY REJECTION RATIO vs. FREQUENCY

MAX4410 toc34

V_{DD} = 1.8V
R_L = 16Ω

POWER-SUPPLY REJECTION RATIO vs. FREQUENCY

MAX4410 toc35

V_{DD} = 3V
R_L = 32Ω

POWER-SUPPLY REJECTION RATIO vs. FREQUENCY

MAX4410 toc36

V_{DD} = 1.8V
R_L = 32Ω

CROSSTALK vs. FREQUENCY

MAX4410 toc37

V_{DD} = 3V
P_{OUT} = 1.6mW
R_L = 16Ω

OUTPUT POWER vs. SUPPLY VOLTAGE

MAX4410 toc38

f_{IN} = 1kHz
R_L = 16Ω
THD + N = 1%

INPUTS 180° OUT OF PHASE

INPUTS IN PHASE

OUTPUT POWER vs. SUPPLY VOLTAGE

MAX4410 toc39

f_{IN} = 1kHz
R_L = 16Ω
THD + N = 10%

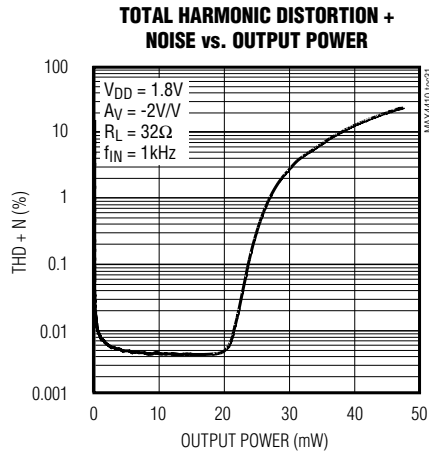INPUTS 180° OUT OF PHASE

INPUTS IN PHASE

MAXIM _____ 7

80mW, DirectDrive Stereo Headphone Driver with Shutdown
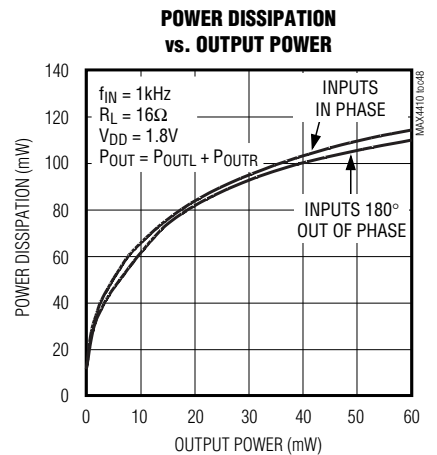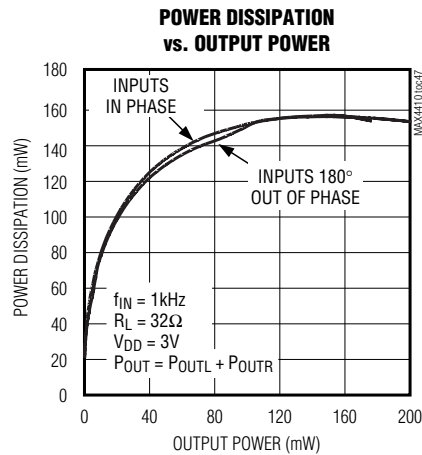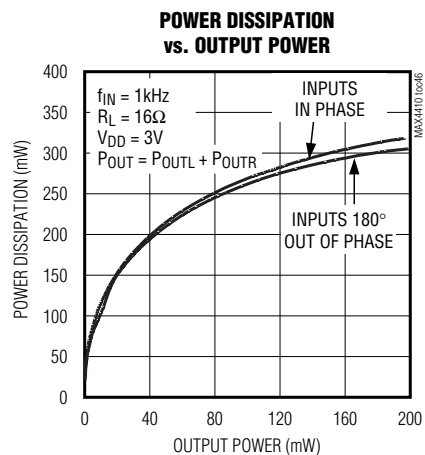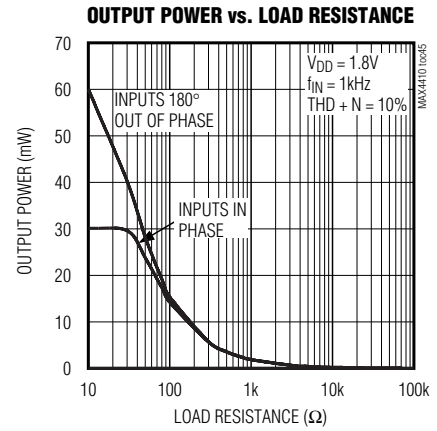
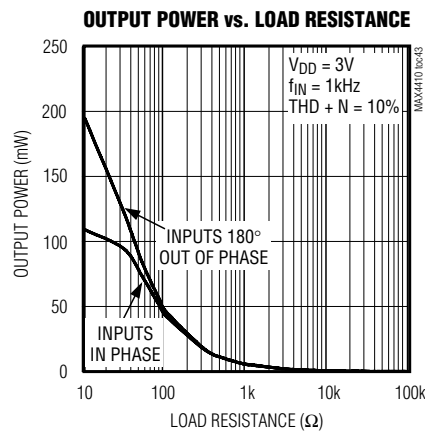_____Typical Operating Characteristics (continued)

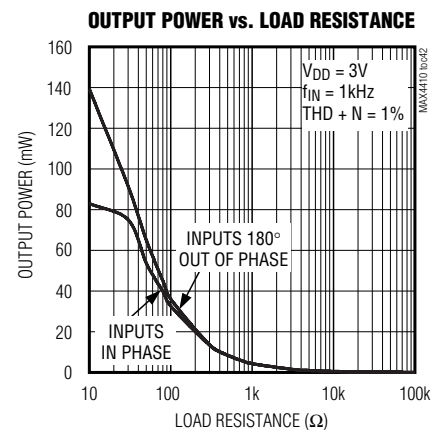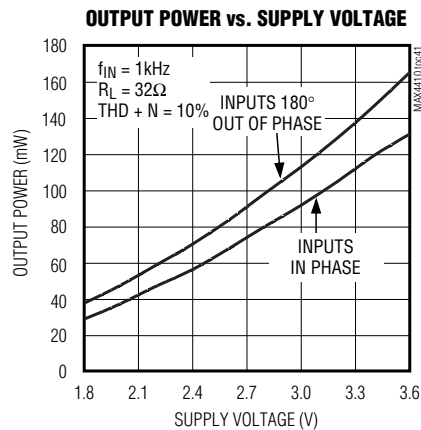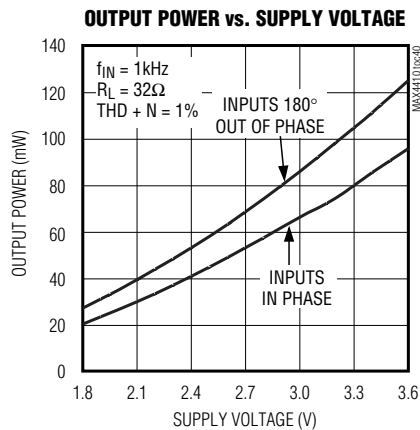(C1 = C2 = 2.2µF, THD + N measurement bandwidth = 22Hz to 22kHz, single-channel driven, T$_A$ = +25°C, unless otherwise noted.)

OUTPUT POWER vs. SUPPLY VOLTAGE

f$_{IN}$ = 1kHz
R$_L$ = 32Ω
THD + N = 1%

INPUTS 180° OUT OF PHASE

INPUTS IN PHASE

OUTPUT POWER vs. SUPPLY VOLTAGE

f$_{IN}$ = 1kHz
R$_L$ = 32Ω
THD + N = 10%

INPUTS 180° OUT OF PHASE

INPUTS IN PHASE

OUTPUT POWER vs. LOAD RESISTANCE

V$_{DD}$ = 3V
f$_{IN}$ = 1kHz
THD + N = 1%

INPUTS 180° OUT OF PHASE

INPUTS IN PHASE

OUTPUT POWER vs. LOAD RESISTANCE

V$_{DD}$ = 3V
f$_{IN}$ = 1kHz
THD + N = 10%

INPUTS 180° OUT OF PHASE

INPUTS IN PHASE

OUTPUT POWER vs. LOAD RESISTANCE

V$_{DD}$ = 1.8V
f$_{IN}$ = 1kHz
THD + N = 1%

INPUTS 180° OUT OF PHASE

INPUTS IN PHASE

OUTPUT POWER vs. LOAD RESISTANCE

V$_{DD}$ = 1.8V
f$_{IN}$ = 1kHz
THD + N = 10%

INPUTS 180° OUT OF PHASE

INPUTS IN PHASE

POWER DISSIPATION vs. OUTPUT POWER

f$_{IN}$ = 1kHz
R$_L$ = 16Ω
V$_{DD}$ = 3V
P$_{OUT}$ = P$_{OUTL}$ + P$_{OUTR}$

INPUTS IN PHASE

INPUTS 180° OUT OF PHASE

POWER DISSIPATION vs. OUTPUT POWER

INPUTS IN PHASE

INPUTS 180° OUT OF PHASE

f$_{IN}$ = 1kHz
R$_L$ = 32Ω
V$_{DD}$ = 3V
P$_{OUT}$ = P$_{OUTL}$ + P$_{OUTR}$

POWER DISSIPATION vs. OUTPUT POWER

f$_{IN}$ = 1kHz
R$_L$ = 16Ω
V$_{DD}$ = 1.8V
P$_{OUT}$ = P$_{OUTL}$ + P$_{OUTR}$

INPUTS IN PHASE

INPUTS 180° OUT OF PHASE

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MAX4410

Typical Operating Characteristics (continued)

(C1 = C2 = 2.2µF, THD + N measurement bandwidth = 22Hz to 22kHz, single-channel driven, T_A = +25°C, unless otherwise noted.)
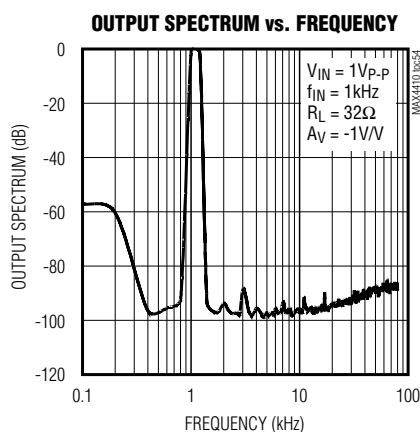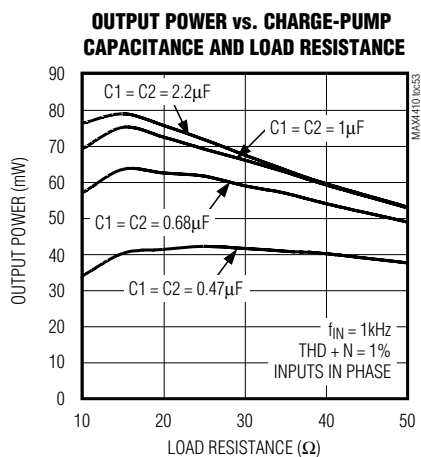
POWER DISSIPATION vs. OUTPUT POWER

INPUTS IN PHASE

INPUTS 180° OUT OF PHASE

f_{IN} = 1kHz
R_L = 32Ω
V_{DD} = 1.8V
P_{OUT} = P_{OUTL} + P_{OUTR}

GAIN AND PHASE vs. FREQUENCY

V_{DD} = 3V
A_V = 1000V/V
R_L = 16Ω

GAIN FLATNESS vs. FREQUENCY

V_{DD} = 3V
A_V = -1V/V
R_L = 16Ω

CHARGE-PUMP OUTPUT RESISTANCE vs. SUPPLY VOLTAGE

$V_{IN\_}$ = GND
I_{PVSS} = 10mA
NO LOAD

OUTPUT POWER vs. CHARGE-PUMP CAPACITANCE AND LOAD RESISTANCE

C1 = C2 = 2.2µF
C1 = C2 = 1µF
C1 = C2 = 0.68µF
C1 = C2 = 0.47µF

f_{IN} = 1kHz
THD + N = 1%
INPUTS IN PHASE

OUTPUT SPECTRUM vs. FREQUENCY

V_{IN} = 1V_{P-P}
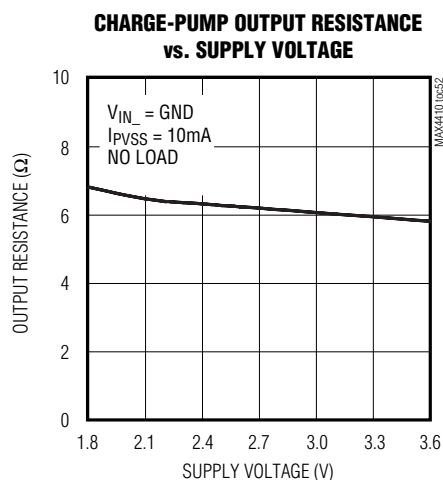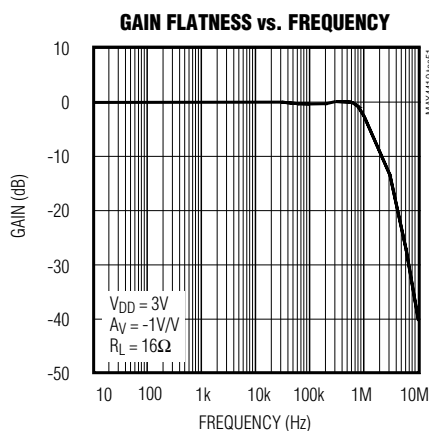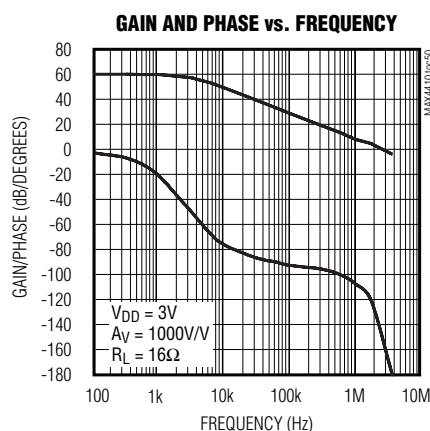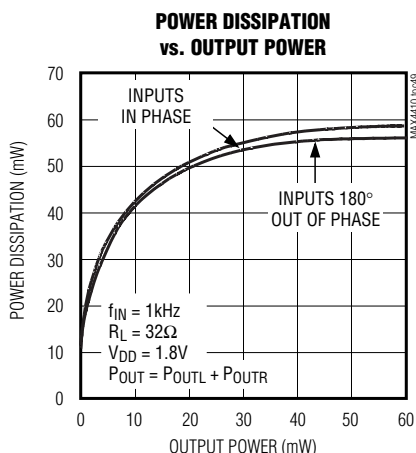f_{IN} = 1kHz
R_L = 32Ω
A_V = -1V/V

80mW, DirectDrive Stereo Headphone Driver with Shutdown

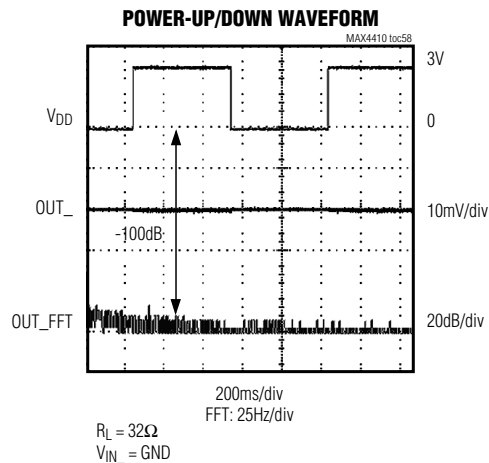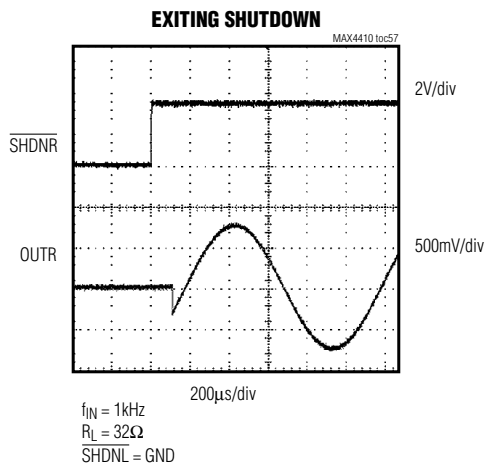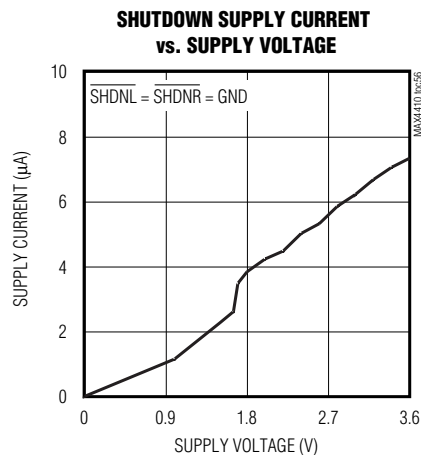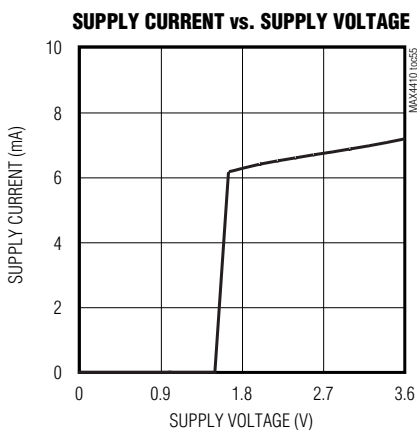## _____Typical Operating Characteristics (continued)

(C1 = C2 = 2.2µF, THD + N measurement bandwidth = 22Hz to 22kHz, single-channel driven, T_A = +25°C, unless otherwise noted.)

SUPPLY CURRENT vs. SUPPLY VOLTAGE

MAX4410 toc55

SHUTDOWN SUPPLY CURRENT vs. SUPPLY VOLTAGE

MAX4410 toc56

$\overline{SHDNL}$ = $\overline{SHDNR}$ = GND

EXITING SHUTDOWN

MAX4410 toc57

$\overline{SHDNR}$ 2V/div

OUTR   500mV/div

f_{IN} = 1kHz
R_L = 32Ω
$\overline{SHDNL}$ = GND

200µs/div

POWER-UP/DOWN WAVEFORM

MAX4410 toc58

V_{DD} 3V
                0

OUT_   10mV/div

-100dB

OUT_FFT   20dB/div

R_L = 32Ω
$V_{IN\_}$ = GND

200ms/div
FFT: 25Hz/div

80mW, DirectDrive Stereo Headphone Driver with Shutdown

Pin Description

PIN	BUMP	NAME	FUNCTION
TSSOP	UCSP		
1	B2	$\overline{\text{SHDNL}}$	Active-Low, Left-Channel Shutdown. Connect to V_{DD} for normal operation.
2	A3	PV_{DD}	Charge-Pump Power Supply. Powers charge-pump inverter, charge-pump logic, and oscillator.
3	A4	C1P	Flying Capacitor Positive Terminal
4	B4	PGND	Power Ground. Connect to SGND.
5	C4	C1N	Flying Capacitor Negative Terminal
6	D4	PV_{SS}	Charge-Pump Output
7	D3	SV_{SS}	Amplifier Negative Power Supply. Connect to PV_{SS}.
8	D2	OUTL	Left-Channel Output
9	D1	SV_{DD}	Amplifier Positive Power Supply. Connect to PV_{DD}.
10	C1	INL	Left-Channel Audio Input
11	C2	OUTR	Right-Channel Output
12	B1	$\overline{\text{SHDNR}}$	Active-Low, Right-Channel Shutdown. Connect to V_{DD} for normal operation.
13	A1	INR	Right-Channel Audio Input
14	A2	SGND	Signal Ground. Connect to PGND.

80mW, DirectDrive Stereo Headphone Driver with Shutdown

Detailed Description

The MAX4410 stereo headphone driver features Maxim's patented DirectDrive architecture, eliminating the large output-coupling capacitors required by traditional single-supply headphone drivers. The device consists of two 80mW Class AB headphone drivers, undervoltage lockout (UVLO)/shutdown control, charge-pump, and comprehensive click-and-pop suppression circuitry (see the *Functional Diagram/Typical Application Circuit*). The charge pump inverts the positive supply (PV$_{DD}$), creating a negative supply (PV$_{SS}$). The headphone drivers operate from these bipolar supplies with their outputs biased about GND (Figure 1). The drivers have almost twice the supply range compared to other 3V single-supply drivers, increasing the available output power. The benefit of this GND bias is that the driver outputs do not have a DC component typically V$_{DD}$/2. Thus, the large DC-blocking capacitors are unnecessary, improving frequency response while conserving board space and system cost.

Each channel has independent left/right, active-low shutdown controls, making it possible to optimize power savings in mixed-mode, mono/stereo operation. The device features an undervoltage lockout that prevents operation from an insufficient power supply and click-and-pop suppression that eliminates audible transients on startup and shutdown. Additionally, the MAX4410 features thermal overload and short-circuit protection and can withstand ±8kV ESD strikes on the output pins.

DirectDrive

Traditional single-supply headphone drivers have their outputs biased about a nominal DC voltage (typically half the supply) for maximum dynamic range. Large coupling capacitors are needed to block this DC bias from the headphone. Without these capacitors, a significant amount of DC current flows to the headphone, resulting in unnecessary power dissipation and possible damage to both headphone and headphone driver.

Maxim's patented DirectDrive architecture uses a charge pump to create a negative supply voltage. This allows the outputs of the MAX4410 to be biased about GND, almost doubling dynamic range while operating from a single supply. With no DC component, there is no need for the large DC-blocking capacitors. Instead of two large (220µF, typ) tantalum capacitors, the MAX4410 charge pump requires two small ceramic capacitors, conserving board space, reducing cost, and improving the frequency response of the headphone driver. See the Output Power vs. Charge-Pump Capacitance and Load Resistance graph in the *Typical*
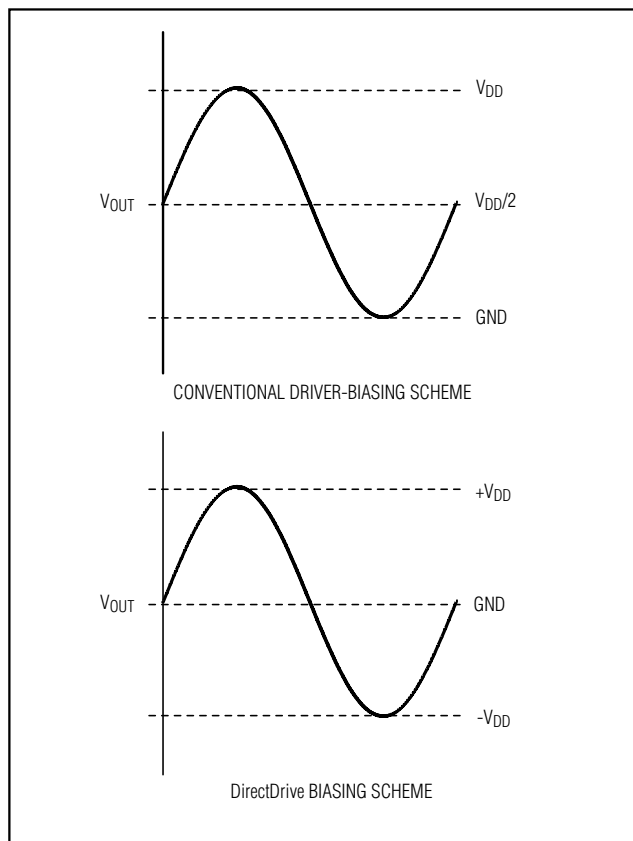

Figure 1. Traditional Driver Output Waveform vs. MAX4410 Output Waveform

Operating Characteristics for details of the possible capacitor sizes. There is a low DC voltage on the driver outputs due to amplifier offset. However, the offset of the MAX4410 is typically 0.5mV, which, when combined with a 32Ω load, results in less than 16µA of DC current flow to the headphones.

Previous attempts to eliminate the output-coupling capacitors involved biasing the headphone return (sleeve) to the DC-bias voltage of the headphone amplifiers. This method raises some issues:

1) The sleeve is typically grounded to the chassis. Using this biasing approach, the sleeve must be isolated from system ground, complicating product design.

2) During an ESD strike, the driver's ESD structures are the only path to system ground. Thus, the driver must be able to withstand the full ESD strike.

3) When using the headphone jack as a line out to other

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equipment, the bias voltage on the sleeve may conflict with the ground potential from other equipment, resulting in possible damage to the drivers.

Charge Pump

The MAX4410 features a low-noise charge pump. The 320kHz switching frequency is well beyond the audio range, and thus does not interfere with the audio signals. The switch drivers feature a controlled switching speed that minimizes noise generated by turn-on and turn-off transients. By limiting the switching speed of the switches, the di/dt noise caused by the parasitic bond wire and trace inductance is minimized. Although not typically required, additional high-frequency noise attenuation can be achieved by increasing the size of C2 (see the *Functional Diagram/Typical Application Circuit*).

Shutdown

The MAX4410 features two shutdown controls allowing either channel to be shut down or muted independently. $\overline{SHDNL}$ controls the left channel while $\overline{SHDNR}$ controls the right channel. Driving either $\overline{SHDN\_}$ low disables the respective channel, sets the driver output impedance to 1kΩ, and reduces the supply current. When both $\overline{SHDN\_}$ inputs are driven low, the charge pump is also disabled, further reducing supply current draw to 6µA. The charge pump is enabled once either $\overline{SHDN\_}$ input is driven high.

Click-and-Pop Suppression

In traditional single-supply audio drivers, the output-coupling capacitor is a major contributor of audible clicks and pops. Upon startup, the driver charges the coupling capacitor to its bias voltage, typically half the supply. Likewise, on shutdown the capacitor is discharged to GND. This results in a DC shift across the capacitor, which in turn, appears as an audible transient at the speaker. Since the MAX4410 does not require output-coupling capacitors, this does not arise.

Additionally, the MAX4410 features extensive click-and-pop suppression that eliminates any audible transient sources internal to the device. The Power-Up/Down Waveform in the *Typical Operating Characteristics* shows that there are minimal spectral components in the audible range at the output upon startup or shutdown.

In most applications, the output of the preamplifier driving the MAX4410 has a DC bias of typically half the supply. At startup, the input-coupling capacitor is charged to the preamplifier's DC-bias voltage through the R_F of the MAX4410, resulting in a DC shift across the capacitor and an audible click/pop. Delaying the rise of the MAX4410's $\overline{SHDN\_}$ signals 4 to 5 time constants (200ms to 300ms) relative to that of the preamplifier's eliminates this click/pop.

Applications Information

Power Dissipation

Under normal operating conditions, linear power amplifiers can dissipate a significant amount of power. The maximum power dissipation for each package is given in the *Absolute Maximum Ratings* section under Continuous Power Dissipation or can be calculated by the following equation:

$$P_{DISSPKG(MAX)} = \frac{T_{J(MAX)} - T_A}{\theta_{JA}}$$

where $T_{J(MAX)}$ is +150°C, T_A is the ambient temperature, and θ_{JA} is the reciprocal of the derating factor in °C/W as specified in the *Absolute Maximum Ratings* section. For example, θ_{JA} of the TSSOP package is +109.9°C/W.

The MAX4410 has two sources of power dissipation, the charge pump and the two drivers. If the power dissipation for a given application exceeds the maximum allowed for a given package, either reduce V_{DD}, increase load impedance, decrease the ambient temperature, or add heat sinking to the device. Large output, supply, and ground traces improve the maximum power dissipation in the package.

Thermal overload protection limits total power dissipation in the MAX4410. When the junction temperature exceeds +140°C, the thermal protection circuitry disables the amplifier output stage. The amplifiers are enabled once the junction temperature cools by 15°C. This results in a pulsing output under continuous thermal overload conditions.

Output Power

The device has been specified for the worst-case scenario— when both inputs are in phase. Under this condition, the drivers simultaneously draw current from the charge pump, leading to a slight loss in headroom of V_{SS}. In typical stereo audio applications, the left and right signals have differences in both magnitude and phase, subsequently leading to an increase in the maximum attainable output power. Figure 2 shows the two extreme cases for in and out of phase. In reality, the available power lies between these extremes.

MAX4410

Table 1. Suggested Capacitor Manufacturers

SUPPLIER	PHONE	FAX	WEBSITE
Taiyo Yuden	800-348-2496	847-925-0899	www.t-yuden.com
TDK	847-803-6100	847-390-4405	www.component.tdk.com

Note: *Please indicate you are using the MAX4410 when contacting these component suppliers.*
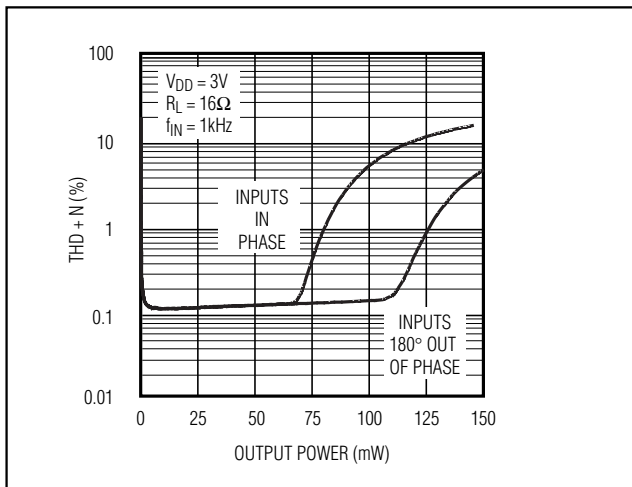

Figure 2. Output Power vs. Supply Voltage with Inputs In/Out of Phase

Component Selection

Gain-Setting Resistors

External feedback components set the gain of the MAX4410. Resistors R_F and R_{IN} (see the *Functional Diagram/Typical Application Circuit*) set the gain of each amplifier as follows:

$$A_V = -\left(\frac{R_F}{R_{IN}}\right)$$

To minimize V_{OS}, set R_F equal to 10kΩ. Values other than 10kΩ increase V_{OS} due to the input bias current, which in turn increases the amount of DC current flow to the speaker.

Compensation Capacitor

The stability of the MAX4410 is affected by the value of the feedback resistor (R_F). The combination of R_F and the input and parasitic trace capacitance introduces an additional pole. Adding a capacitor in parallel with R_F compensates for this pole. Under typical conditions with proper layout, the device is stable without the additional capacitor.

Input Filtering

The input capacitor (C_{IN}), in conjunction with R_{IN}, forms a highpass filter that removes the DC bias from an incoming signal (see the *Functional Diagram/Typical Application Circuit*). The AC-coupling capacitor allows the amplifier to bias the signal to an optimum DC level. Assuming zero-source impedance, the -3dB point of the highpass filter is given by:

$$f_{-3dB} = \frac{1}{2\pi R_{IN} C_{IN}}$$

Choose R_{IN} according to the *Gain-Setting Resistors* section. Choose the C_{IN} such that f_{-3dB} is well below the lowest frequency of interest. Setting f_{-3dB} too high affects the low-frequency response of the amplifier. Use capacitors whose dielectrics have low-voltage coefficients, such as tantalum or aluminum electrolytic. Capacitors with high-voltage coefficients, such as ceramics, may result in increased distortion at low frequencies.

Other considerations when designing the input filter include the constraints of the overall system and the actual frequency band of interest. Although high-fidelity audio calls for a flat-gain response between 20Hz and 20kHz, portable voice-reproduction devices such as cellular phones and two-way radios need only concentrate on the frequency range of the spoken human voice (typically 300Hz to 3.5kHz). In addition, speakers used in portable devices typically have a poor response below 150Hz. Taking these two factors into consideration, the input filter may not need to be designed for a 20Hz to 20kHz response, saving both board space and cost due to the use of smaller capacitors.

Charge-Pump Capacitor Selection

Use capacitors with an ESR less than 100mΩ for optimum performance. Low-ESR ceramic capacitors minimize the output resistance of the charge pump. For best performance over the extended temperature range, select capacitors with an X7R dielectric. Table 1 lists suggested manufacturers.

Flying Capacitor (C1)

The value of the flying capacitor (C1) affects the load regulation and output resistance of the charge pump. A C1 value that is too small degrades the device's ability to provide sufficient current drive, which leads to a loss
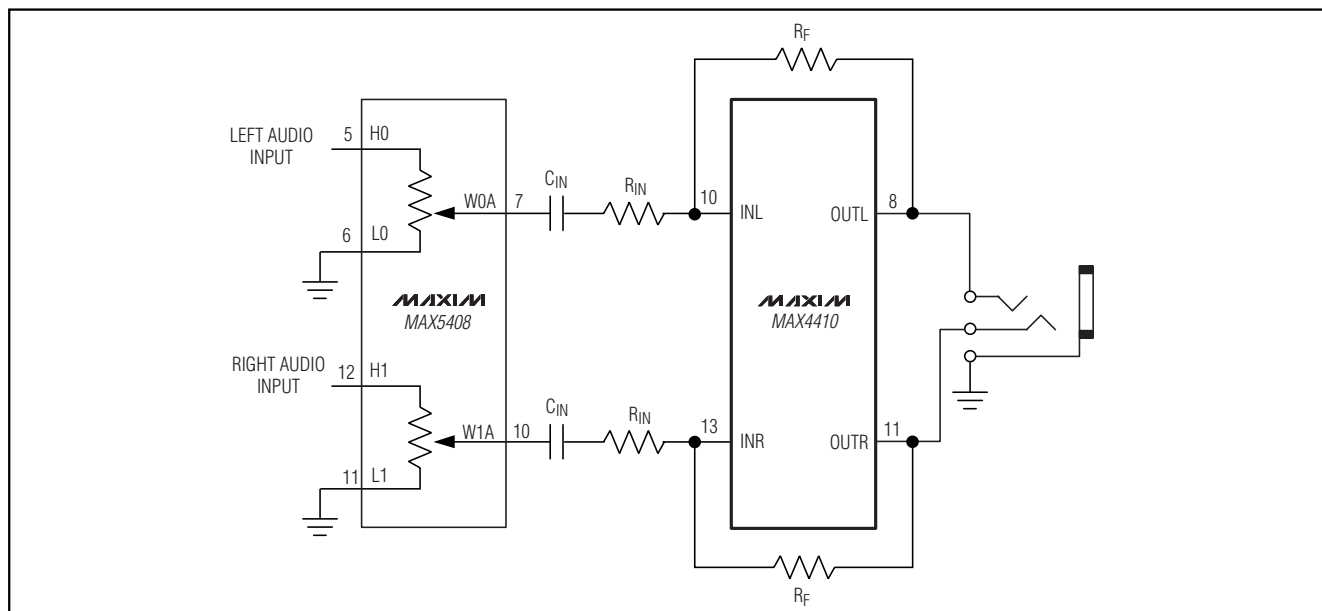
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Figure 3. MAX4410 and MAX5408 Volume Control Circuit

of output voltage. Increasing the value of C1 improves load regulation and reduces the charge-pump output resistance to an extent. See the Output Power vs. Charge-Pump Capacitance and Load Resistance graph in the *Typical Operating Characteristics*. Above 2.2µF, the on-resistance of the switches and the ESR of C1 and C2 dominate.

Output Capacitor (C2)
The output capacitor value and ESR directly affect the ripple at PV_{SS}. Increasing the value of C2 reduces output ripple. Likewise, decreasing the ESR of C2 reduces both ripple and output resistance. Lower capacitance values can be used in systems with low maximum output power levels. See the Output Power vs. Charge-Pump Capacitance and Load Resistance graph in the *Typical Operating Characteristics.*

Power-Supply Bypass Capacitor
The power-supply bypass capacitor (C3) lowers the output impedance of the power supply, and reduces the impact of the MAX4410's charge-pump switching transients. Bypass PV_{DD} with C3, the same value as C1, and place it physically close to the PV_{DD} and PGND pins (refer to the MAX4410 EV kit for a suggested layout).

Adding Volume Control
The addition of a digital potentiometer provides simple volume control. Figure 3 shows the MAX4410 with the MAX5408 dual log taper digital potentiometer used as an input attenuator. Connect the high terminal of the

MAX5408 to the audio input, the low terminal to ground and the wiper to C_{IN}. Setting the wiper to the top position passes the audio signal unattenuated. Setting the wiper to the lowest position fully attenuates the input.

Layout and Grounding
Proper layout and grounding are essential for optimum performance. Connect PGND and SGND together at a single point on the PC board. Connect all components associated with the charge pump (C2 and C3) to the PGND plane. Connect PV_{DD} and SV_{DD} together at the device. Connect PV_{SS} and SV_{SS} together at the device. Bypassing of both supplies is accomplished by charge-pump capacitors C2 and C3 (see *Functional Diagram/Typical Application Circuit*). Place capacitors C2 and C3 as close to the device as possible. Route PGND and all traces that carry switching transients away from SGND and the traces and components in the audio signal path. Refer to the layout example in the MAX4410 EV kit data sheet.

When using the MAX4410 in a UCSP package, make sure the traces to OUTR (bump C2) are wide enough to handle the maximum expected current flow. Multiple traces may be necessary.

UCSP Considerations
For general UCSP information and PC layout considerations, refer to the Maxim Application Note: *Wafer-Level Ultra Chip-Scale Package*.

80mW, DirectDrive Stereo Headphone Driver with Shutdown

_____*Functional Diagram/Typical Application Circuit*

( ) DENOTE BUMPS FOR UCSP.
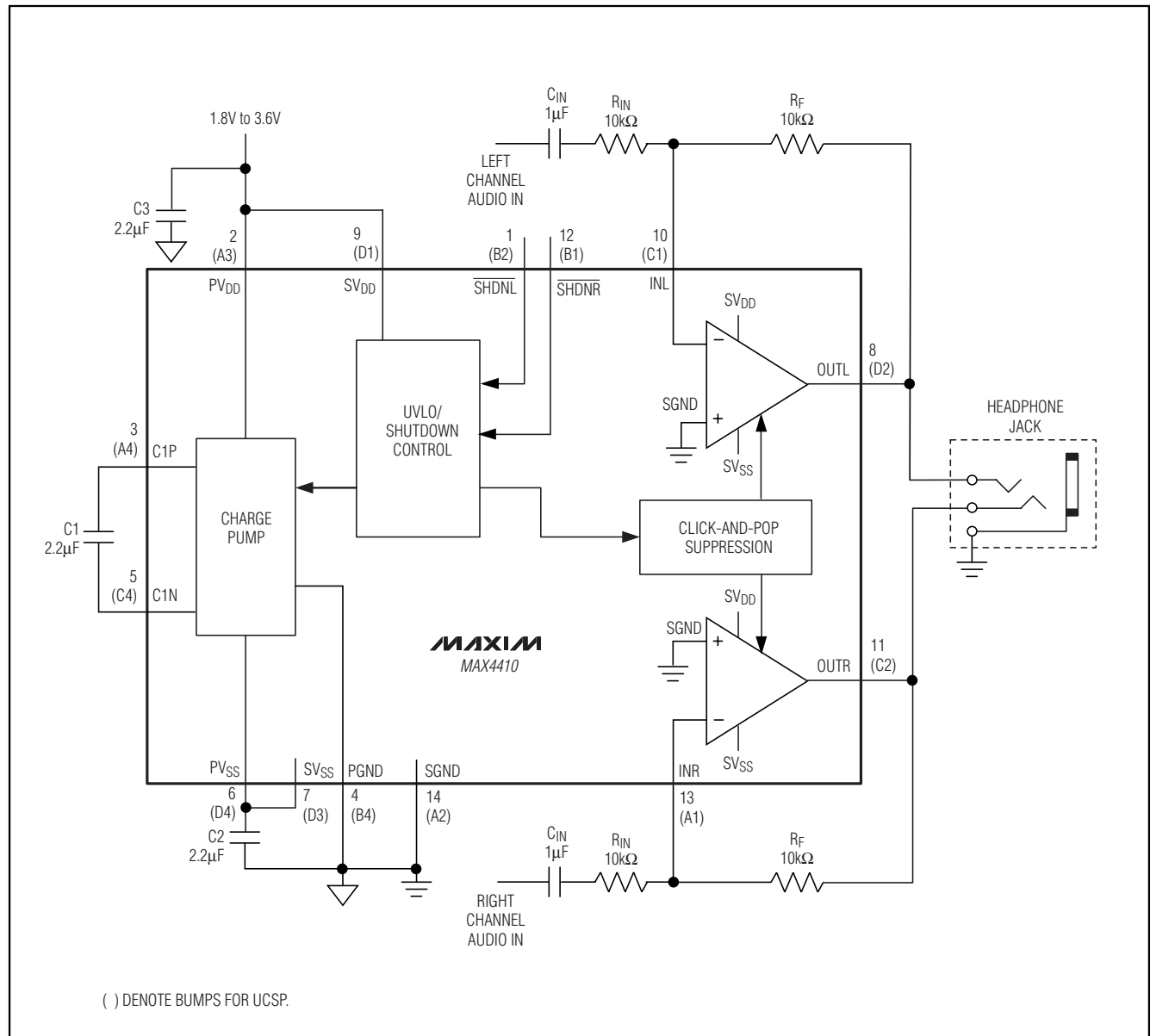
_____*Chip Information*

TRANSISTOR COUNT: 4337
PROCESS: BiCMOS

80mW, DirectDrive Stereo Headphone Driver with Shutdown

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)
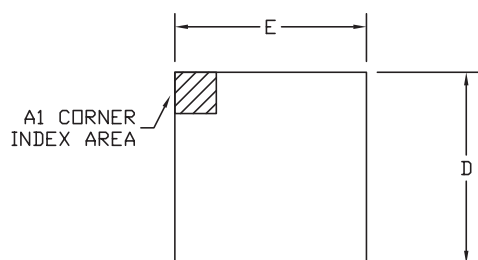

SYMBOL	DIMENSIONS
A	0.60±0.05
D	2.02±0.05
E	2.02±0.05
e	0.50 BASIC
b	∅ 0.35 BASIC
A1	0.27±0.04
A2	0.33 Ref.
hd	0.26 Ref.
he	0.26 Ref.

SOLDER BALL DEPOPULATION	
PKG. CODE	DEPOPULATED BALL
B16-1	NONE
B16-2	B3, C3

TOP VIEW

NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. MEETS JEDEC M0195.

BOTTOM VIEW
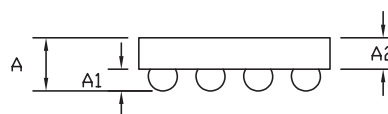
SIDE VIEW

PROPRIETARY INFORMATION

TITLE:
PACKAGE OUTLINE, 4×4 UCSP

APPROVAL	DOCUMENT CONTROL NO.	REV.	1/1
	21-0101	C	

4x4 UCSP.EPS

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MAX4410

Package Information (continued)

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)
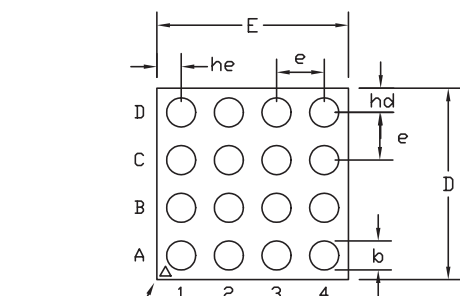

TSSOP,NO PADS.EPS

TOP VIEW

BOTTOM VIEW

SIDE VIEW

END VIEW

SEE DETAIL A

DETAIL A

LEAD TIP DETAIL

WITH PLATING

BASE METAL

SEATING PLANE

PARTING LINE

SYMBOL	COMMON DIMENSIONS			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	—	1.10		.043
A1	0.05	0.15	.002	.006
A2	0.85	0.95	.033	.037
b	0.19	0.30	.007	.012
b1	0.19	0.25	.007	.010
c	0.090	0.20	.0035	.008
c1	0.090	0.135	.0035	.0053
D	SEE VARIATIONS		SEE VARIATIONS	
E	4.30	4.50	.169	.177
e	0.65 BSC		.026 BSC	
H	6.25	6.50	.246	.256
L	0.50	0.70	.020	.028
N	SEE VARIATIONS		SEE VARIATIONS	
α	0°	8°	0°	8°

JEDEC		VARIATIONS			
MO-153	N	MILLIMETERS		INCHES	
		MIN.	MAX.	MIN.	MAX.
AB-1	14 D	4.90	5.10	.193	.201
AB	16 D	4.90	5.10	.193	.201
AC	20 D	6.40	6.60	.252	.260
AD	24 D	7.70	7.90	.303	.311
AE	28 D	9.60	9.80	.378	.386

NOTES:
1. DIMENSIONS D AND E DO NOT INCLUDE FLASH
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED 0.15mm PER SIDE
3. CONTROLLING DIMENSION: MILLIMETER
4. MEETS JEDEC OUTLINE MO-153. SEE JEDEC VARIATIONS TABLE.
5. "N" REFERS TO NUMBER OF LEADS
6. THE LEAD TIPS MUST LIE WITHIN A SPECIFIED ZONE. THIS TOLERANCE ZONE IS DEFINED BY TWO PARALLEL PLANES. ONE PLANE IS THE SEATING PLANE, DATUM [-C-]; THE OTHER PLANE IS AT THE SPECIFIED DISTANCE FROM [-C-] IN THE DIRECTION INDICATED.

MAXIM

PROPRIETARY INFORMATION

TITLE:
PACKAGE OUTLINE, TSSOP, 4.40 MM BODY

APPROVAL	DOCUMENT CONTROL NO.	REV	
	21-0066	E	1/1