National Semiconductor

October 17, 2008

LM48860 Boomer® Audio Power Amplifier Series
Ground-Referenced, Ultra Low Noise, Fixed Gain Stereo Headphone Amplifier

General Description

The LM48860 is a ground referenced, fixed-gain audio power amplifier capable of delivering 40mW per channel of continuous average power into a 16Ω single-ended load with less than 1% THD+N from a 3V power supply.

The LM48860 features a new circuit technology that utilizes a charge pump to generate a negative reference voltage. This allows the outputs to be biased about ground, thereby eliminating output-coupling capacitors typically used with normal single-ended loads.

Boomer audio power amplifiers were designed specifically to provide high quality output power with a minimal amount of external components. The LM48860 does not require output coupling capacitors or bootstrap capacitors, and therefore is ideally suited for mobile phone and other low voltage applications where minimal power consumption is a primary requirement.

The LM48860 features a low-power consumption shutdown mode selectable for either channel separately. This is accomplished by driving either the $\overline{\text{SD\_RC}}$ (Shutdown Right Channel) or $\overline{\text{SD\_LC}}$ (Shutdown Left Channel) (or both) pins with logic low, depending on which channel is desired shutdown. Additionally, the LM48860 features an internal thermal shutdown protection mechanism.

The LM48860 contains advanced pop & click circuitry that eliminates noises which would otherwise occur during turn-on and turn-off transitions.

The LM48860 has an internal fixed gain of 1.5V/V.

Key Specifications

■ PSRR at 217Hz (V_{DD} = 3.0V)	80dB (typ)
■ Stereo Power Output at V_{DD} = 3V R_L = 16Ω, THD+N = 1%	40mW (typ)
■ Shutdown Current	0.1μA (typ)
■ Internal Fixed Gain	1.5V/V (typ)
■ Operating Voltage	2.0V to 5.5V

Features

- Fixed logic levels with supply voltage
- Ground referenced outputs
- High PSRR
- Available in space-saving micro SMD package
- Ultra low current shutdown mode
- Improved pop & click circuitry eliminates noises during turn-on and turn-off transitions
- No output coupling capacitors, snubber networks, bootstrap capacitors, or gain-setting resistors required
- Shutdown either channel independently

Applications

- Mobile Phones
- MP3 Players
- PDAs
- Portable electronic devices
- Notebook PCs

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Typical Application

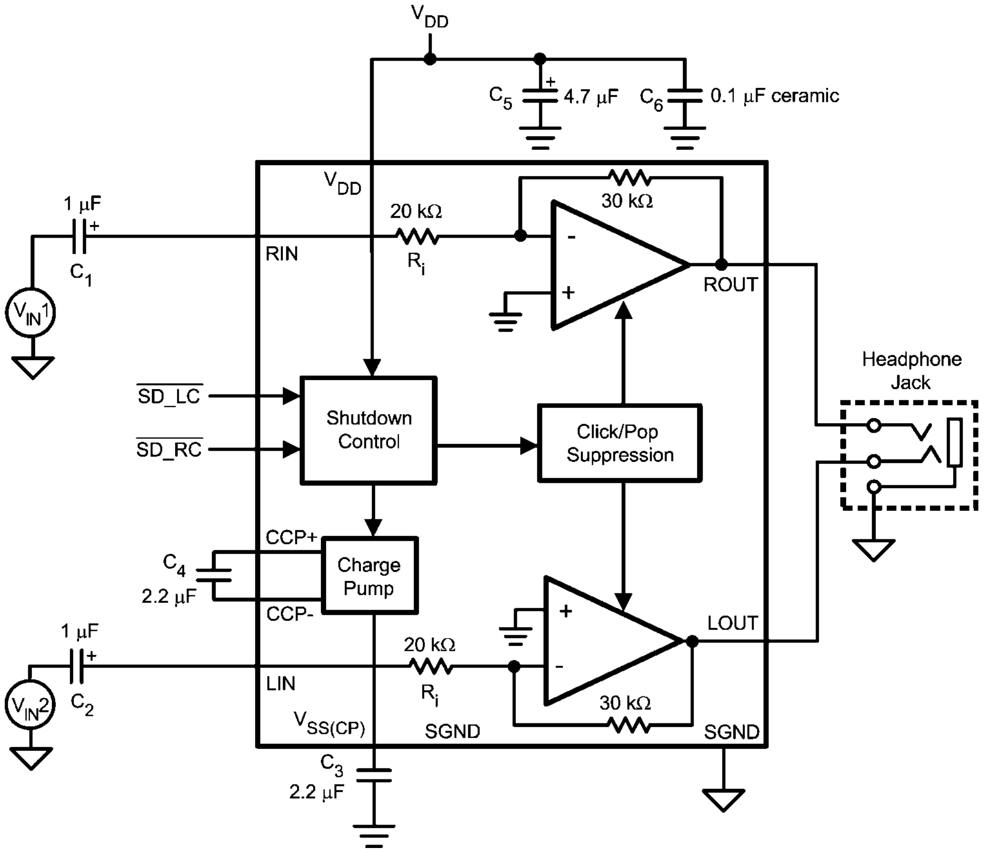
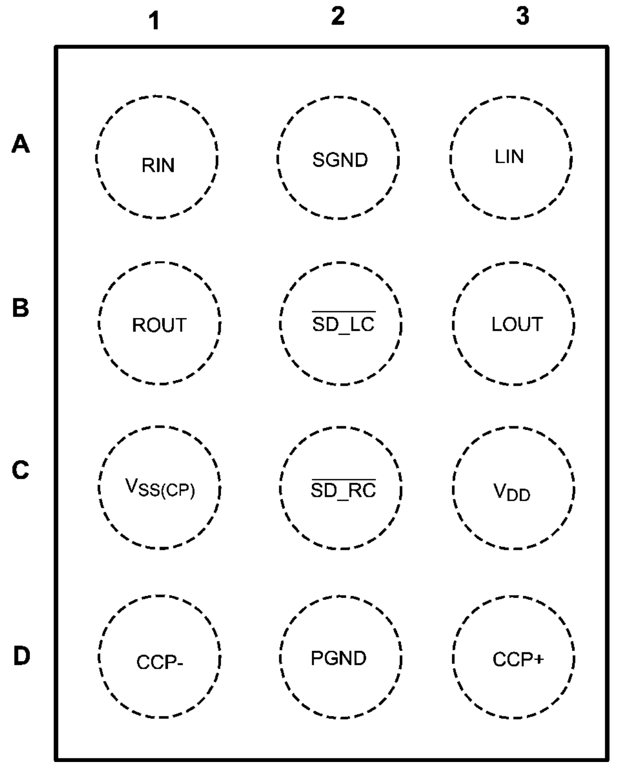


FIGURE 1. Typical Audio Amplifier Application Circuit

Connection Diagram

LM48860TL Pinout
(BUMP DOWN VIEW)



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Top View
Order Number LM48860TL
See NS Package Number TLA12XXX

Pin Descriptions

Pin	Name	Function
A1	RIN	Right Channel Input
A2	SGND	Signal Ground
A3	LIN	Left Channel Input
B1	ROUT	Right Channel Output
B2	$\overline{\text{SD\_LC}}$	Active Low Shutdown, Left Channel
B3	LOUT	Left Channel Output
C1	$V_{SS(CP)}$	Charge Pump Voltage Output
C2	$\overline{\text{SD\_RC}}$	Active-Low Shutdown, Right Channel
C3	V_{DD}	Supply Voltage
D1	CCP-	Negative Terminal - Charge Pump Flying Capacitor
D2	PGND	Power Ground
D3	CCP+	Positive Terminal - Charge Pump Flying Capacitor

Absolute Maximum Ratings (Notes 2, 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor 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}
Power Dissipation (Note 3)	Internally Limited
ESD Rating(Note 4)	2000V
ESD Rating (Note 5)	200V
Junction Temperature	150°C
Thermal Resistance	
θ_{JA} (typ) TLA12XXX	59.3°C/W

Operating Ratings

Temperature Range	
$T_{MIN} \le T_A \le T_{MAX}$	$-40°C \le T_A \le 85°C$
Supply Voltage (V_{DD})	$2.0V \le V_{DD} \le 5.5V$

Electrical Characteristics V_{DD} = 3V (Notes 1, 2)

The following specifications apply for V_{DD} = 3V and 16Ω load unless otherwise specified. Limits apply to T_A = 25°C.

Symbol	Parameter	Conditions	LM48860		Units (Limits)
			Typical (Note 6)	**Limit** (Note 7)	
I_{DD}	Quiescent Power Supply Current Full Power Mode	V_{DD} = 3.0V, V_{IN} = 0V, inputs terminated both channels enabled	4	5.5	mA (max)
		V_{DD} = 5.0V, V_{IN} = 0V, inputs terminated both channels enabled	4.2		mA
I_{SD}	Shutdown Current	SD_LC = SD_RC= GND	0.1	1	μA (max)
		SD_LC = SD_RC= GND, V_{DD} = 5.0V	0.1	1	μA (max)
V_{OS}	Output Offset Voltage	R_L = 32Ω, V_{IN} = 0V	0.7	5.5	mV (max)
A_V	Voltage Gain		–1.5		V/V
ΔA_V	Channel-to-channel Gain Matching		1		%
R_{IN}	Input Resistance		20	15 25	kΩ (min) kΩ (max)
P_O	Output Power	THD+N = 1% (max); f = 1kHz, R_L = 16Ω, (two channels in phase)	40	35	mW (min)
		THD+N = 1% (max); f = 1kHz, R_L = 32Ω, (two channels in phase)	50	40	mW (min)
THD+N	Total Harmonic Distortion + Noise	P_O = 20mW, f = 1kHz, R_L = 16Ω (two channels in phase)	0.025		%
		P_O = 25mW, f = 1kHz, R_L = 32Ω (two channels in phase)	0.014		%
PSRR	Power Supply Rejection Ratio Full Power Mode	V_{RIPPLE} = 200mV_{PP}, Input Referred			
		f = 217Hz	80	73	dB (min)
		f = 1kHz	75		dB
		f = 20kHz	60		dB
SNR	Signal-to-Noise Ratio	R_L = 32Ω, P_{OUT} = 50mW, f = 1kHz, BW = 20Hz to 22kHz, A-weighted	105		dB
V_{IH}	Shutdown Input Voltage High	V_{DD} = 2.0V to 5.5V		1.2	V (min)
V_{IL}	Shutdown Input Voltage Low	V_{DD} = 2.0V to 5.5V		0.45	V (max)
X_{TALK}	Crosstalk	R_L = 16Ω, P_O = 1.6mW, f = 1kHz	75		dB
ϵ_{OS}	Output Noise	A-weighted filter, V_{IN} = 0V	8		μV

Symbol	Parameter	Conditions	LM48860		Units (Limits)
			Typical (Note 6)	Limit (Note 7)	
Z_{OUT}	Output Impedance	V_{SD} = GND Input Terminated Input not terminated	30	20	kΩ (min)
		SD_LC = SD_RC = GND	30		kΩ
I_L	Input Leakage		±0.1		nA

Note 1: "*Absolute Maximum Ratings*" indicate limits beyond which damage to the device may occur, including inoperability and degradation of device reliability and/or performance. Functional operation of the device and/or non-degradation at the *Absolute Maximum Ratings* or other conditions beyond those indicated in the *Recommended Operating Conditions* is not implied. The *Recommended Operating Conditions* indicate conditions at which the device is functional and the device should not be operated beyond such conditions. All voltages are measured with respect to the ground pin, unless otherwise specified.

Note 2: The *Electrical Characteristics* tables list guaranteed specifications under the listed *Recommended Operating Conditions* except as otherwise modified or specified by the *Electrical Characteristics Conditions* and/or Notes. Typical specifications are estimations only and are not guaranteed.

Note 3: The maximum power dissipation must be derated at elevated temperatures and is dictated by T_{JMAX}, θ_{JA}, and the ambient temperature, T_A. The maximum allowable power dissipation is $P_{DMAX} = (T_{JMAX} - T_A) / \theta_{JA}$ or the number given in *Absolute Maximum Ratings*, whichever is lower. For the LM48860, see power derating curves for additional information.

Note 4: Human body model, applicable std. JESD22-A114C.

Note 5: Machine model, applicable std. JESD22-A115-A.

Note 6: Typical values represent most likely parametric norms at T_A = +25ºC, and at the Recommended Operation Conditions at the time of product characterization and are not guaranteed.

Note 7: Datasheet min/max specification limits are guaranteed by test or statistical analysis.

Note 8: θ_{JA} value is measured with the device mounted on a PCB with a 1.5" x 1.375", 1oz copper heatsink.

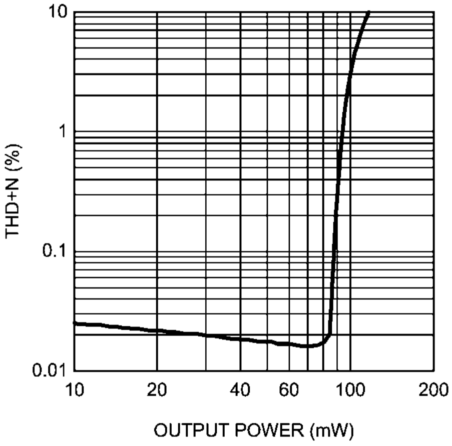
External Components Description

(*Figure 1*)

Components		Functional Description
1.	C_1	Input coupling capacitor which blocks the DC voltage at the amplifier's input terminals. Also creates a high pass-pass filter with R_i at $f_C = 1/(2R_iC_1)$. Refer to the section **Proper Selection of External Components**, for an explanation of how to determine the value of C_1.
2.	C_2	Input coupling capacitor which blocks the DC voltage at the amplifier's input terminals. Also creates a high pass-pass filter with R_i at $f_C = 1/(2R_iC_2)$. Refer to the **Power Supply Bypassing** section for an explanation of how to determine the value of C_2.
3.	C_3	Output capacitor. Low ESR ceramic capacitor (≤100mΩ)
4.	C_4	Flying capacitor. Low ESR ceramic capacitor (≤100mΩ)
5.	C_5	Tantalum capacitor. Supply bypass capacitor which provides power supply filtering. Refer to the Power Supply Bypassing section for information concerning proper placement and selection of the supply bypass capacitor.
6.	C_6	Ceramic capacitor. Supply bypass capacitor which provides power supply filtering. Refer to the Power Supply Bypassing section for information concerning proper placement and selection of the supply bypass capacitor.

Typical Performance Characteristics

THD+N vs Output Power
V_{DD} = 3V, R_L = 16Ω
f = 1kHz, 22kHz BW, one channel enabled



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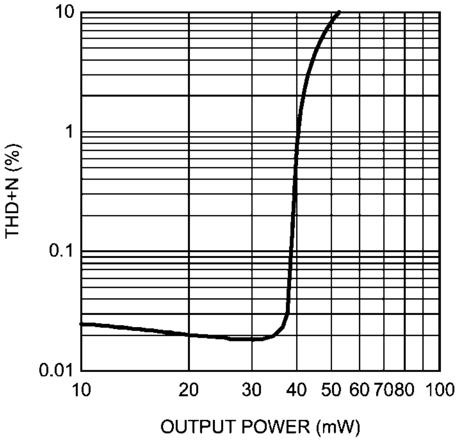
THD+N vs Output Power
V_{DD} = 3V, R_L = 16Ω, f = 1kHz
22kHz BW, two channels in phase



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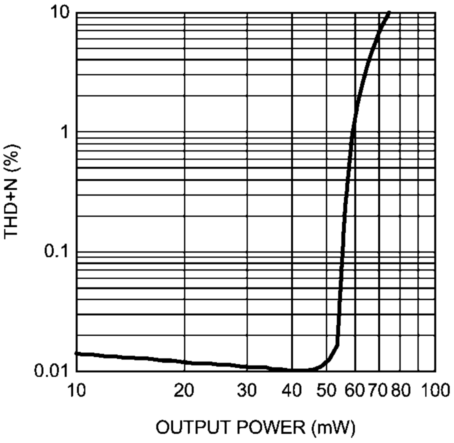
THD+N vs Output Power
V_{DD} = 3V, R_L = 32Ω
f = 1kHz, 22kHz BW, one channel enabled



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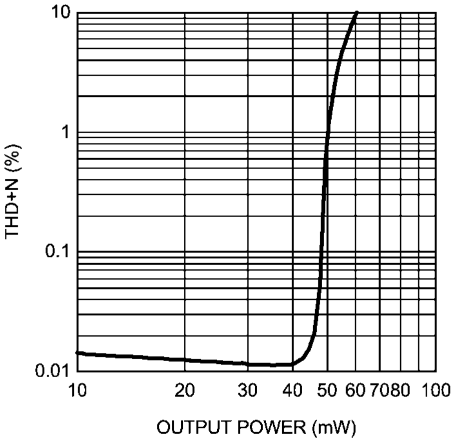
THD+N vs Output Power
V_{DD} = 3V, R_L = 32Ω, f = 1kHz
22kHz BW, two channels in phase



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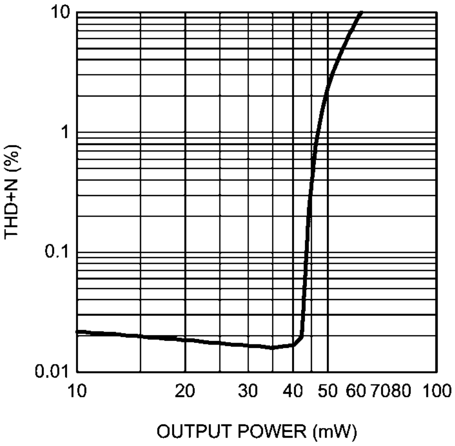
THD+N vs Output Power
V_{DD} = 3.6V, R_L = 16Ω
f = 1kHz, 22kHz BW, one channel enabled



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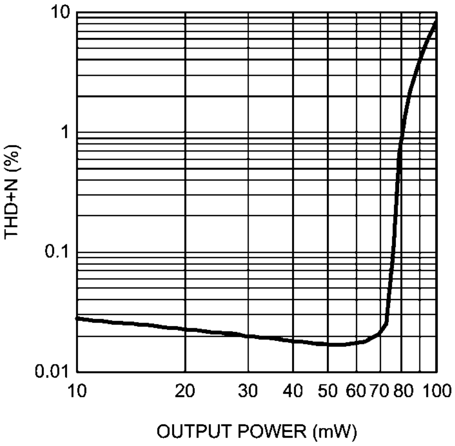
THD+N vs Output Power
V_{DD} = 3.6V, R_L = 16Ω, f = 1kHz
22kHz BW, two channels in phase



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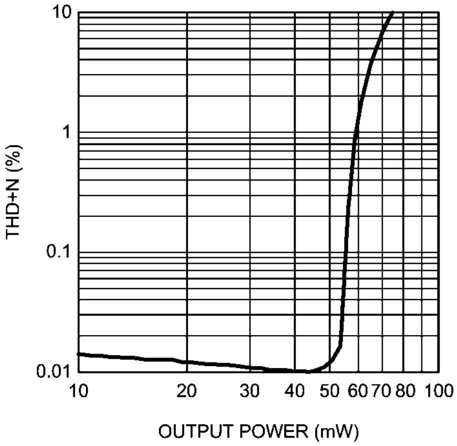
THD+N vs Output Power
V_{DD} = 3.6V, R_L = 32Ω
f = 1kHz, 22kHz BW, one channel enabled



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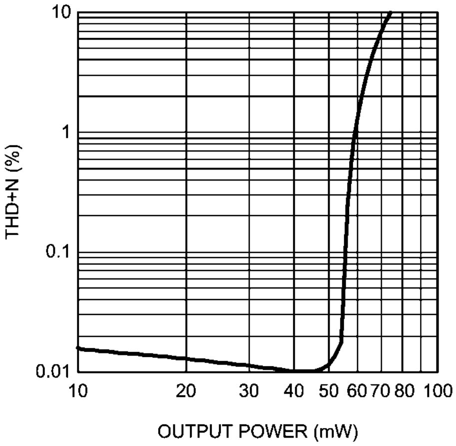
THD+N vs Output Power
V_{DD} = 3.6V, R_L = 32Ω, f = 1kHz
22kHz BW, two channels in phase



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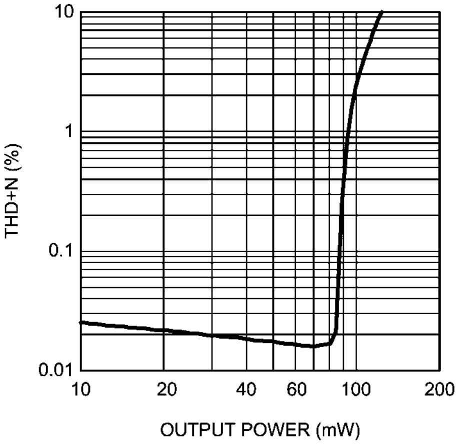
THD+N vs Output Power
V_{DD} = 4.2V, R_L = 16Ω
f = 1kHz, 22kHz BW, one channel enabled



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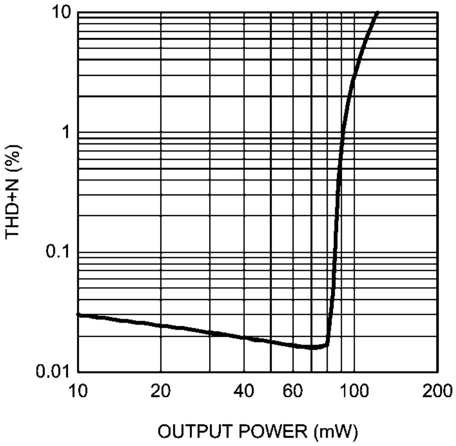
THD+N vs Output Power
V_{DD} = 4.2V, R_L = 16Ω, f = 1kHz
22kHz BW, two channels in phase



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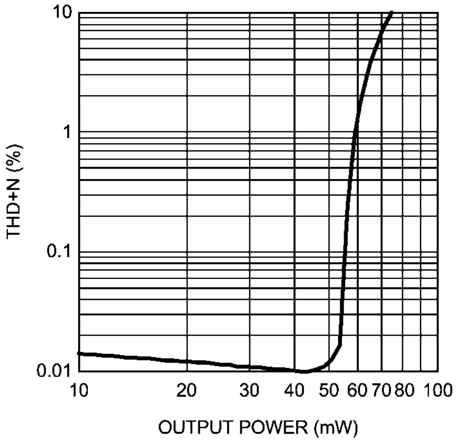
THD+N vs Output Power
V_{DD} = 4.2V, R_L = 32Ω
f = 1kHz, 22kHz BW, one channel enabled



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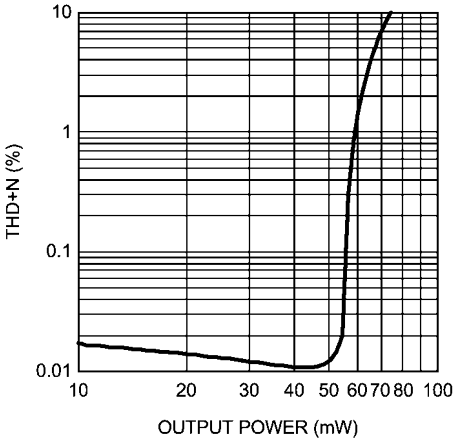
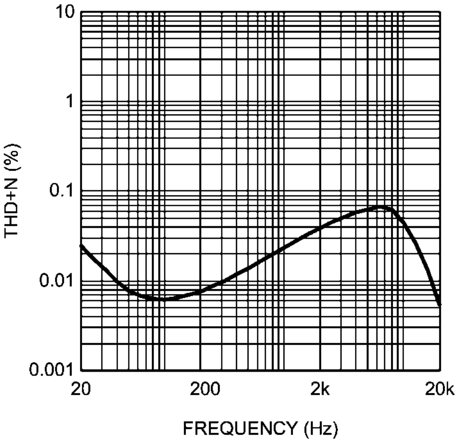
THD+N vs Output Power
V_{DD} = 4.2V, R_L = 32Ω, f = 1kHz
22kHz BW, two channels in phase



300068d7

THD+N vs Frequency
$V_{DD} = 3V$, $R_L = 16\Omega$
$P_O = 20mW$, 22kHz BW



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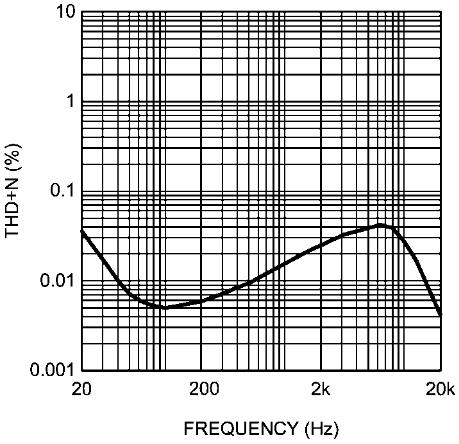
THD+N vs Frequency
$V_{DD} = 3V$, $R_L = 32\Omega$
$P_O = 20mW$, 22kHz BW



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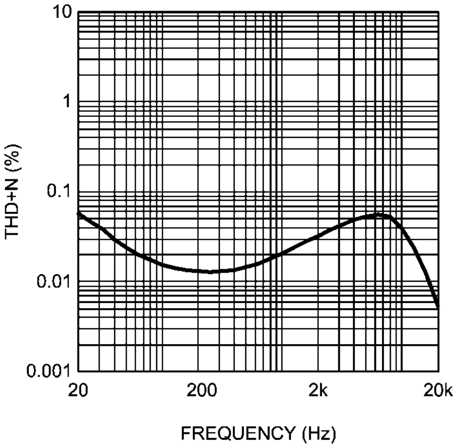
THD+N vs Frequency
$V_{DD} = 3.6V$, $R_L = 16\Omega$
$P_O = 30mW$, 22kHz BW



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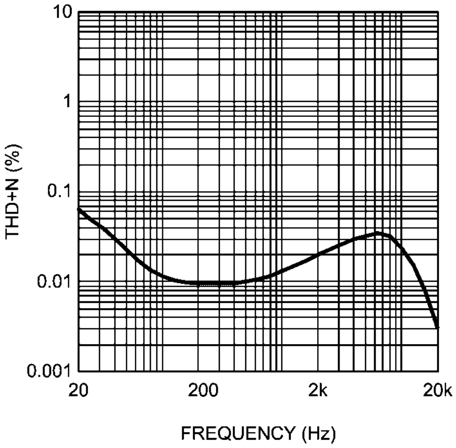
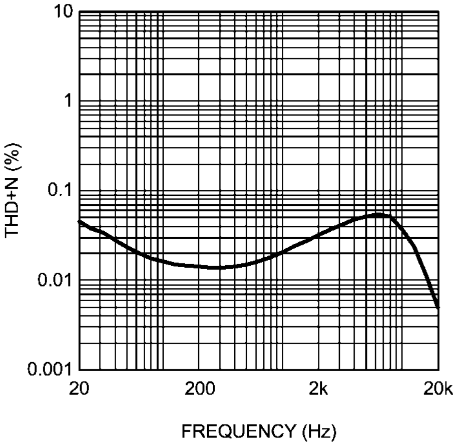
THD+N vs Frequency
$V_{DD} = 3.6V$, $R_L = 32\Omega$
$P_O = 30mW$, 22kHz BW



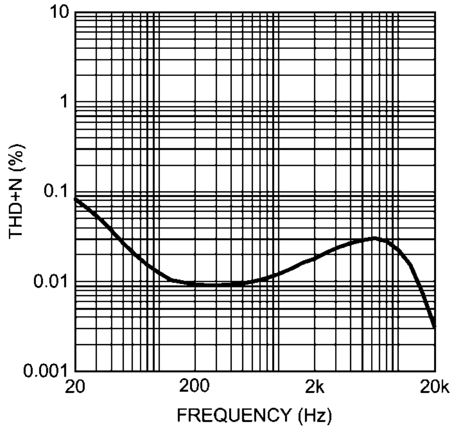
300068c5

THD+N vs Frequency
$V_{DD} = 4.2V$, $R_L = 16\Omega$
$P_O = 30mW$, 22kHz BW



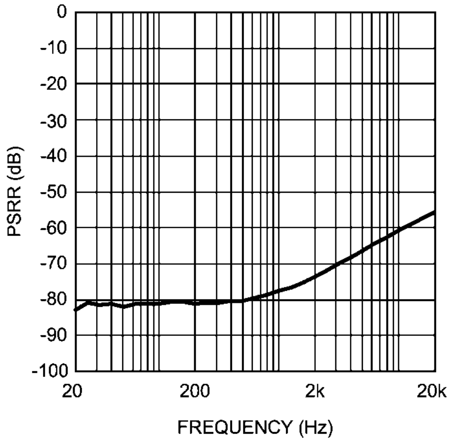
300068c6

THD+N vs Frequency
$V_{DD} = 4.2V$, $R_L = 32\Omega$
$P_O = 30mW$, 22kHz BW



300068c7

PSRR vs Frequency
V_{DD} = 3V, R_L = 16Ω
V_{RIPPLE} = 200mV_{PP}



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PSRR vs Frequency
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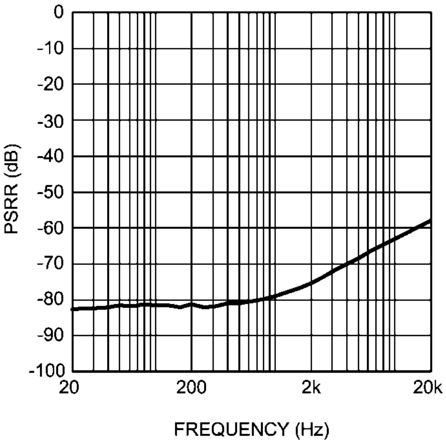
V_{RIPPLE} = 200mV_{PP}



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PSRR vs Frequency
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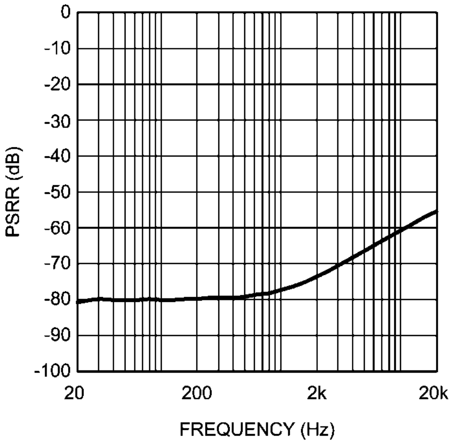
V_{RIPPLE} = 200mV_{PP}



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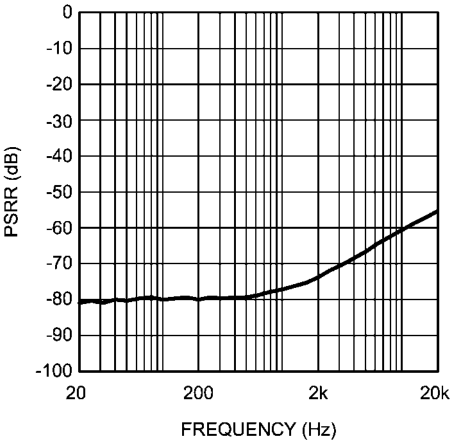
PSRR vs Frequency
V_{DD} = 3.6V, R_L = 32Ω
V_{RIPPLE} = 200mV_{PP}



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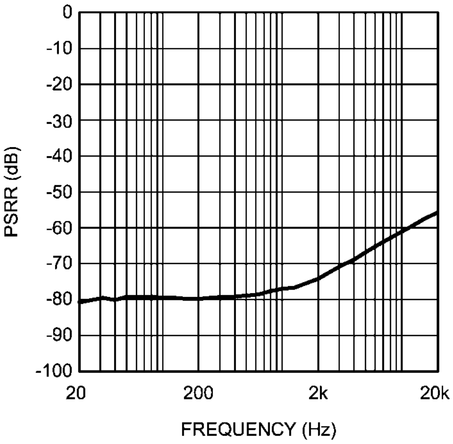
PSRR vs Frequency
V_{DD} = 4.2V, R_L = 16Ω
V_{RIPPLE} = 200mV_{PP}



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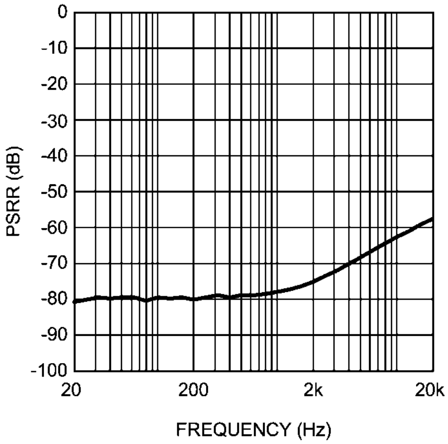
PSRR vs Frequency
V_{DD} = 4.2V, R_L = 32Ω
V_{RIPPLE} = 200mV_{PP}



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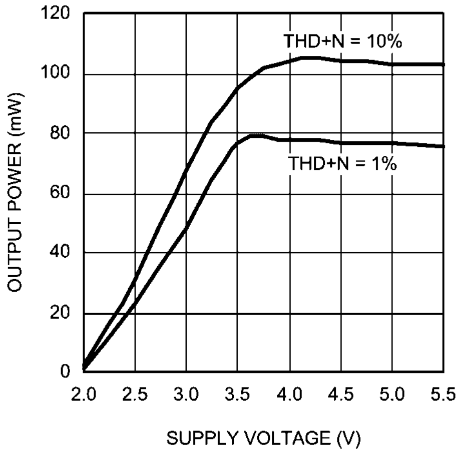
Output Power vs Supply Voltage
R_L = 16Ω, f = 1kHz, 22kHz BW



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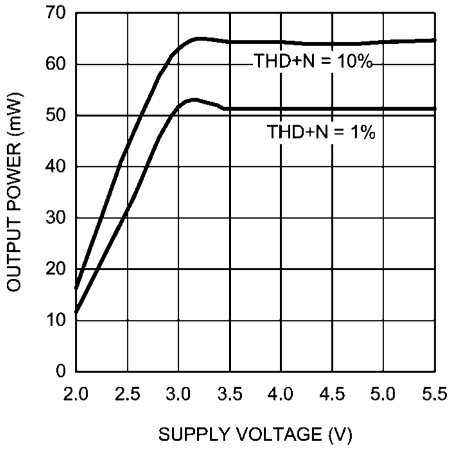
Output Power vs Supply Voltage
R_L = 32Ω, f = 1kHz, 22kHz BW



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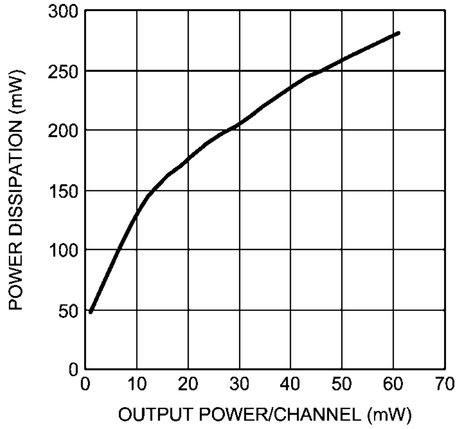
Power Dissipation vs Output Power
V_{DD} = 3V, R_L = 16Ω, f = 1kHz



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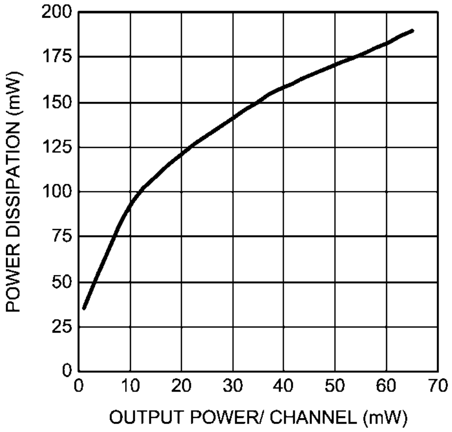
Power Dissipation vs Output Power
V_{DD} = 3V, R_L = 32Ω, f = 1kHz



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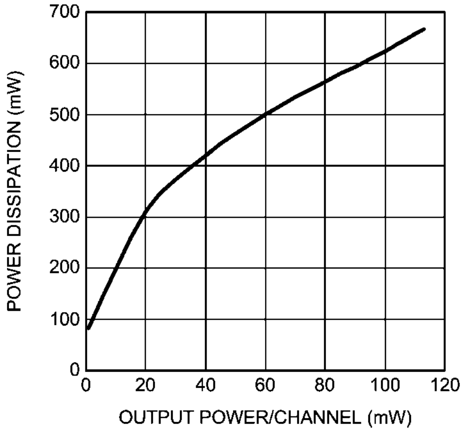
Power Dissipation vs Output Power
V_{DD} = 5V, R_L = 16Ω, f = 1kHz



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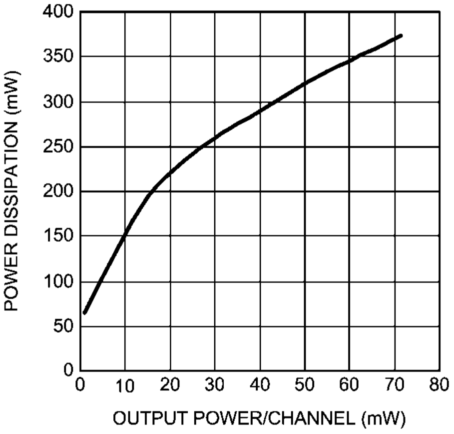
Power Dissipation vs Output Power
V_{DD} = 5V, R_L = 32Ω, f = 1kHz



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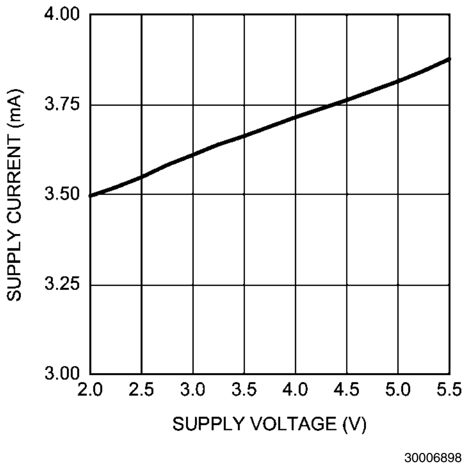
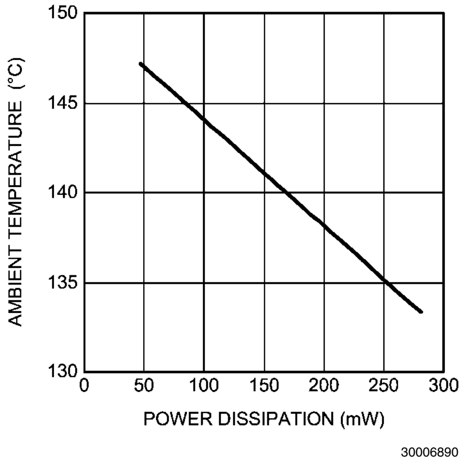
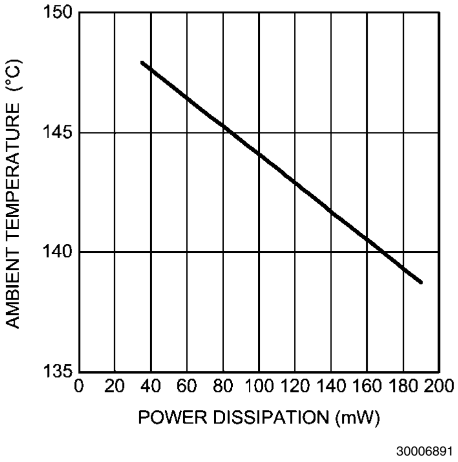
Supply Current vs Supply Voltage
V_{IN} = GND, No Load



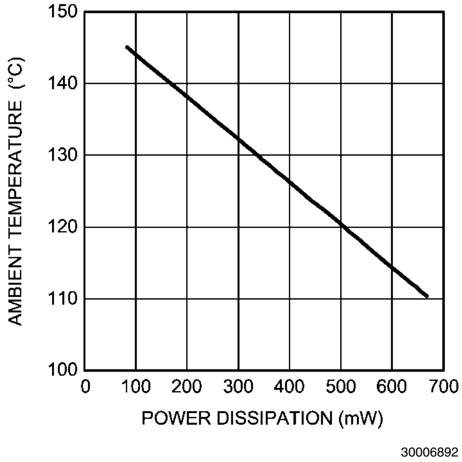
Power Derating Curve
V_{DD} = 3V, R_L = 16Ω



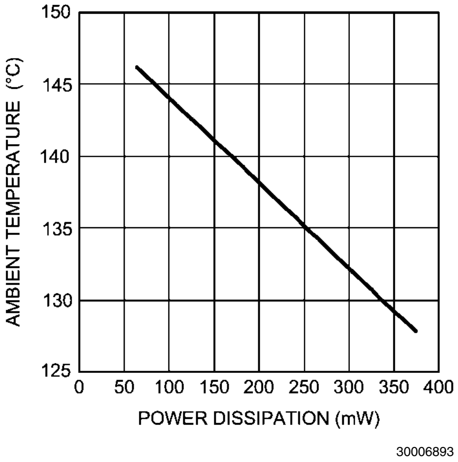
Power Derating Curve
V_{DD} = 3V, R_L = 32Ω



Power Derating Curve
V_{DD} = 5V, R_L = 16Ω



Power Derating Curve
V_{DD} = 5V, R_L = 32Ω



Application Information

SUPPLY VOLTAGE SEQUENCING

It is a good general practice to first apply the supply voltage to a CMOS device before any other signal or supply on other pins. This is also true for the LM48860 audio amplifier which is a CMOS device.

Before applying any signal to the inputs or shutdown pins of the LM48860, it is important to apply a supply voltage to the V_{DD} pins. After the device has been powered, signals may be applied to the shutdown pins (see MICRO POWER SHUTDOWN) and input pins.

ELIMINATING THE OUTPUT COUPLING CAPACITOR

The LM48860 features a low noise inverting charge pump that generates an internal negative supply voltage. This allows the outputs of the LM48860 to be biased about GND instead of a nominal DC voltage, like traditional headphone amplifiers. Because there is no DC component, the large DC blocking capacitors (typically 220µF) are not necessary. The coupling capacitors are replaced by two, small ceramic charge pump capacitors, saving board space and cost.

Eliminating the output coupling capacitors also improves low frequency response. In traditional headphone amplifiers, the headphone impedance and the output capacitor form a high pass filter that not only blocks the DC component of the output, but also attenuates low frequencies, impacting the bass response. Because the LM48860 does not require the output coupling capacitors, the low frequency response of the device is not degraded by external components.

In addition to eliminating the output coupling capacitors, the ground referenced output nearly doubles the available dynamic range of the LM48860 when compared to a traditional headphone amplifier operating from the same supply voltage.

OUTPUT TRANSIENT ('CLICK AND POPS') ELIMINATED

The LM48860 contains advanced circuitry that virtually eliminates output transients ('clicks and pops'). This circuitry prevents all traces of transients when the supply voltage is first applied or when the part resumes operation after coming out of shutdown mode.

AMPLIFIER CONFIGURATION EXPLANATION

As shown in Figure 2, the LM48860 has two internal operational amplifiers. The two amplifiers have internally configured gain.

Since this is an output ground-referenced amplifier, the LM48860 does not require output coupling capacitors.

POWER DISSIPATION

From the graph (THD+N vs Output Power , V_{DD} = 3V, R_L = 16Ω, f = 1kHz, 22kH BW, two channels in phase, page 6) assuming a 3V power supply and a 16Ω load, the maximum power dissipation point and thus the maximum package dissipation point is 281mW. The maximum power dissipation point obtained must not be greater than the power dissipation that results from Equation 1.

$$P_{DMAX} = (T_{JMAX} - T_A) / (\theta_{JA}) \quad (1)$$

For the micro SMD package θ_{JA} = 59.3°C/W. T_{JMAX} = 150°C for the LM48860. Depending on the ambient temperature, T_A, of the system surroundings, Equation 1 can be used to find the maximum internal power dissipation supported by the IC packaging. If the maximum power dissipation from the graph is greater than that of Equation 1, then either the supply voltage must be decreased, the load impedance increased or T_A reduced (see power derating curves). For the application of a 5V power supply, with a 16Ω load, the maximum ambient temperature possible without violating the maximum junction temperature is approximately 110°C provided that device operation is around the maximum power dissipation point. Power dissipation is a function of output power and thus, if typical operation is not around the maximum power dissipation point, the ambient temperature may be increased accordingly.

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 3V power supply typically use a 4.7µF capacitor in parallel with a 0.1µF ceramic filter capacitor to stabilize the power supply's output, reduce noise on the supply line, and improve the supply's transient response. Keep the length of leads and traces that connect capacitors between the LM48860's power supply pin and ground as short as possible.

MICRO POWER SHUTDOWN

The voltage applied to the $\overline{\text{SD\_LC}}$ (shutdown left channel) pin and the $\overline{\text{SD\_RC}}$ (shutdown right channel) pin controls the LM48860’s shutdown function. When active, the LM48860’s micropower shutdown feature turns off the amplifiers’ bias circuitry, reducing the supply current. The trigger point is 0.45V for a logic-low level, and 1.2V for logic-high level. The low 0.01µA (typ) shutdown current is achieved by applying a voltage that is as near as ground a possible to the $\overline{\text{SD\_LC}}$/$\overline{\text{SD\_RC}}$ pins. A voltage that is higher than ground may increase the shutdown current. Do not let SD_LC/SD_RC float, connect either to high or low.

SELECTING PROPER EXTERNAL COMPONENTS

Optimizing the LM48860's performance requires properly selecting external components. Though the LM48860 operates well when using external components with wide tolerances, best performance is achieved by optimizing component values.

Charge Pump Capacitor Selection

Use low ESR (equivalent series resistance) (<100mΩ) ceramic capacitors with an X7R dielectric for best performance. Low ESR capacitors keep the charge pump output impedance to a minimum, extending the headroom on the negative supply. Higher ESR capacitors result in reduced output power from the audio amplifiers.

Charge pump load regulation and output impedance are affected by the value of the flying capacitor (C4). A larger valued C4 (up to 3.3uF) improves load regulation and minimizes charge pump output resistance. Beyond 3.3uF, the switch-on resistance dominates the output impedance.

The output ripple is affected by the value and ESR of the output capacitor (C3). Larger capacitors reduce output ripple on the negative power supply. Lower ESR capacitors minimize the output ripple and reduce the output impedance of the charge pump.

The LM48860 charge pump design is optimized for 2.2uF, low ESR, ceramic, flying and output capacitors.

Input Capacitor Value Selection

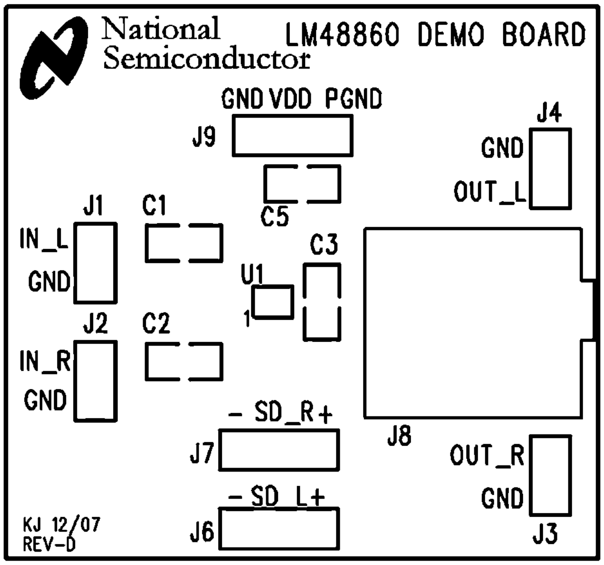
Amplifying the lowest audio frequencies requires high value input coupling capacitors (C1 and C2 in Figure 1). A high value capacitor can be expensive and may compromise space efficiency in portable designs. In many cases, however, the speakers used in portable systems, whether internal or external, have little ability to reproduce signals below 150Hz. Applications using speakers with this limited frequency response reap little improvement by using high value input and output capacitors.

As shown in Figure 1, the internal input resistor, R_i and the input capacitors, C1 and C2, produce a -3dB high-pass filter cutoff frequency that is found using Equation (2).

$$f_{i\text{-}3dB} = 1 / 2\pi R_{IN}C \quad \text{(Hz)} \qquad (2)$$

The value of R_{IN} can be found in the *Electrical Characteristics* tables.

Demonstration Board PCB Layout



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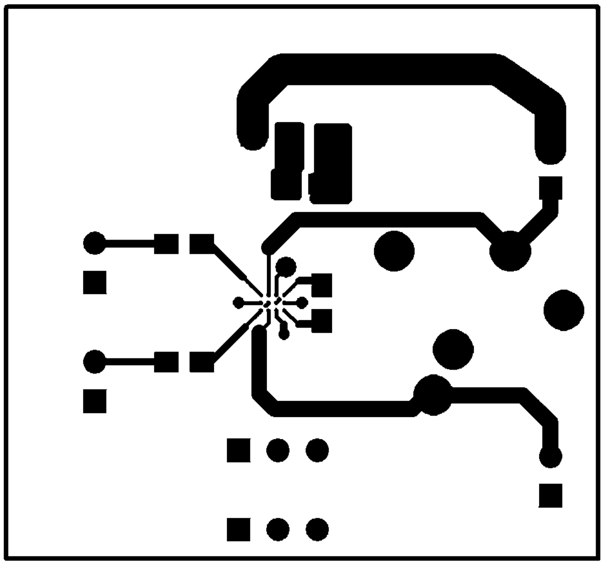
Top Silkscreen



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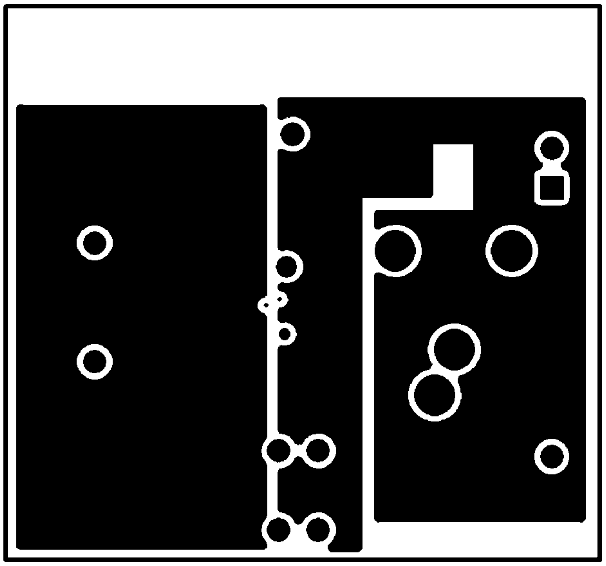
Top Layer



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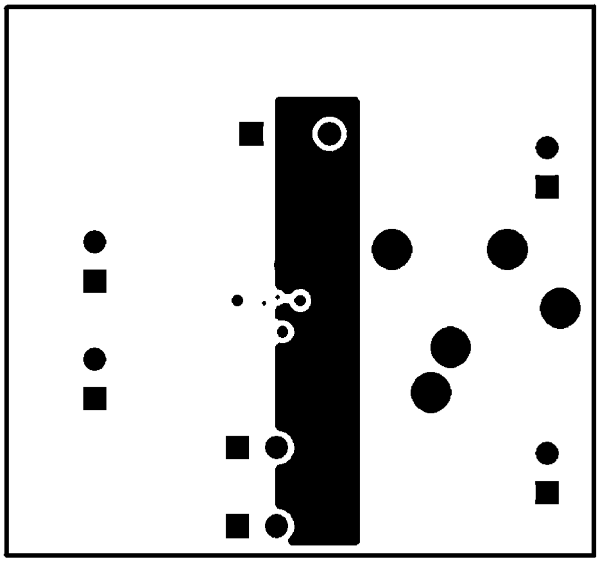
Midlayer 1



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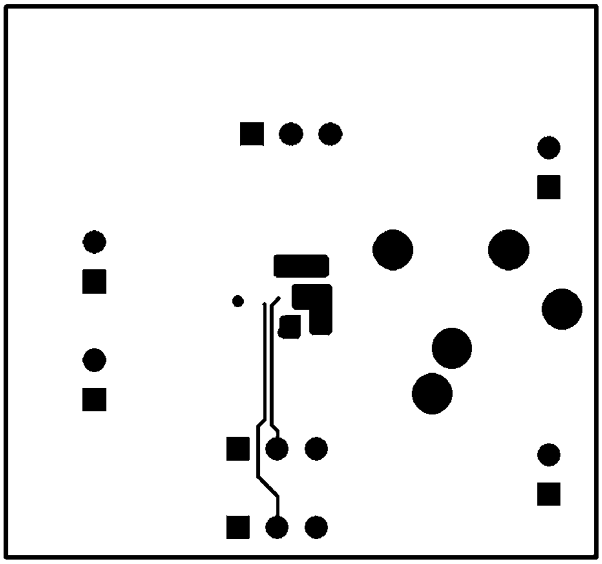
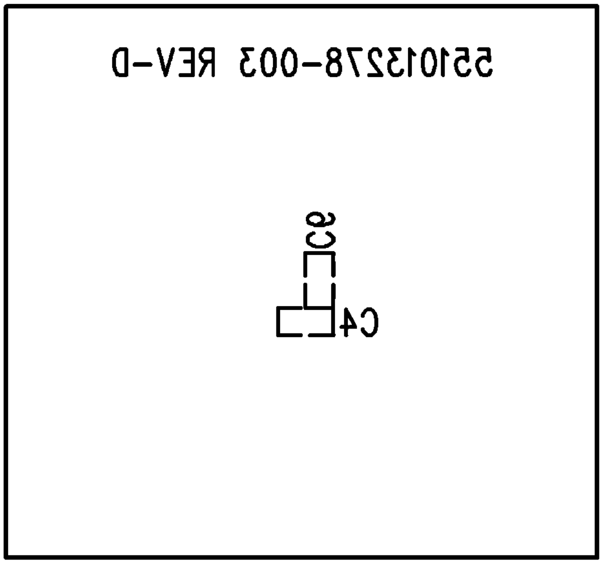
Midlayer 2



Bottom Layer

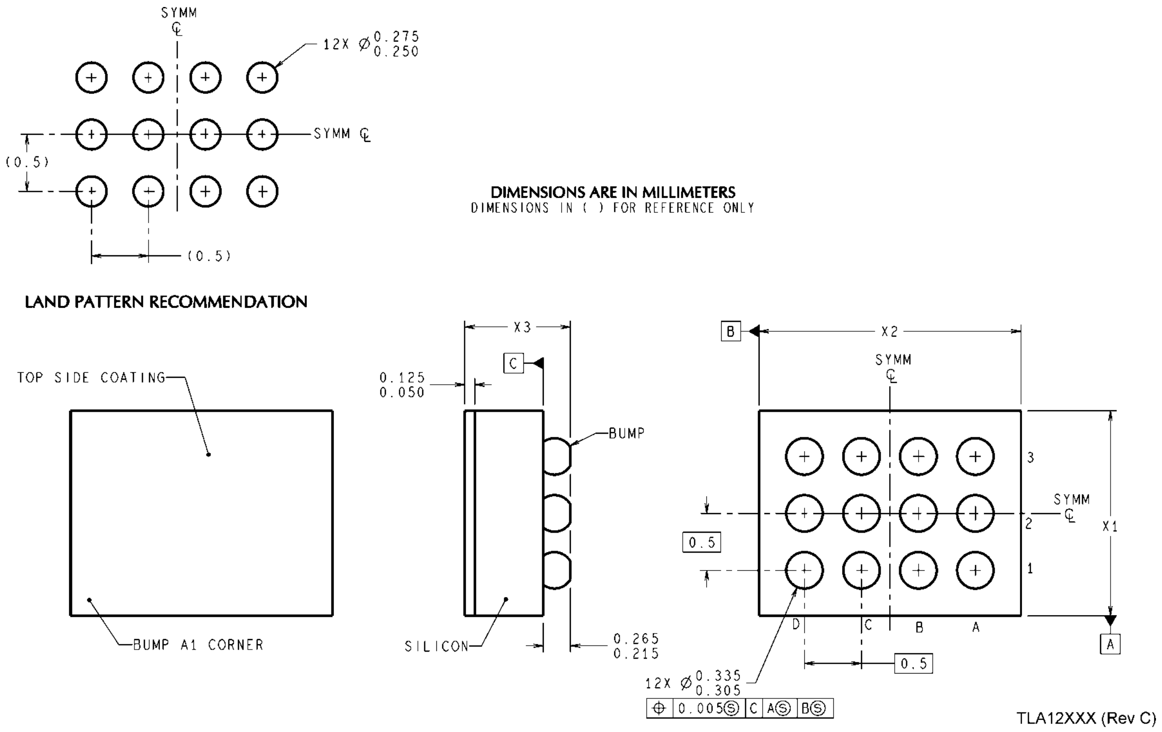


Bottom Silkscreen

Revision History

Rev	Date	Description
1.0	01/16/08	Initial release.
1.01	01/29/08	Text edits.
1.02	02/14/08	Fixed typos (x-axis) on few curves.
1.03	10/17/08	Edited the X1 and X2 limits under the Physical Dimension section.

Physical Dimensions inches (millimeters) unless otherwise noted



12 – Bump micro SMD
Order Number LM48860TL
NS Package Number TLA12XXX
X1 = 1.5±0.03mm, X2 = 2.0±0.03mm, X3 = 0.600±0.075mm,

Notes

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