LM4668 Boomer® Audio Power Amplifier Series 10W High-Efficiency Mono BTL Audio Power Amplifier

Check for Samples: LM4668

FEATURES

- **Soft-Start Circuitry Eliminates Noise During Turn-On Transition**
- **Low Current Shutdown Mode**
- **Low Quiescent Current**
- **6W BTL Output, R_L = 8Ω**
- **Short Circuit Protection**
- **Fixed, Internally Set Gain of 30dB**

APPLICATIONS

- **Flat Panel Monitors**
- **Flat Panel TVs**
- **Computer Sound Cards**

KEY SPECIFICATIONS

- **Power Output BTL (V_{DD} = 14V, f_{IN} = 1kHz, THD+N = 10%, R_L = 8Ω): 10W (typ)**
- **Quiescent Power Supply Current: 30mA (typ)**
- **Efficiency (V_{DD} = 12V, f_{IN} = 1kHz, R_L = 8Ω, P_{OUT}= 6W): 79% (typ)**
- **Shutdown Current: 0.15mA (typ)**
- **Fixed Gain: 30dB (typ)**

DESCRIPTION

The LM4668 is a high efficiency switching audio power amplifier primarily designed for demanding applications in flat panel monitors and TV's. It is capable of delivering 6W to an 8Ω mono BTL load with less than 1% distortion (THD+N) from a $12V_{DC}$ power supply.

Boomer audio power amplifiers were designed specifically to provide high quality output power with a minimal amount of external components. The LM4668 features a micro-power, active-low shutdown mode, an internal thermal shutdown protection mechanism, and short circuit protection.

The LM4668 contains advanced transient ("pop and click") suppression circuitry that eliminates noises that would otherwise occur during turn-on and turn-off transitions.

Connection Diagrams

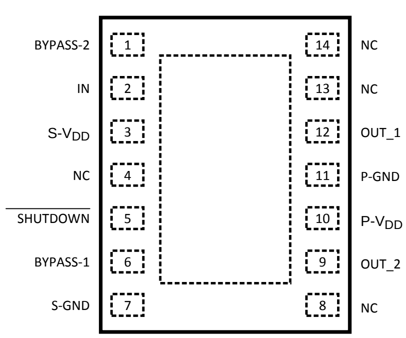

Figure 1. Top View
14-Pin VSON
See NHH0014A Package

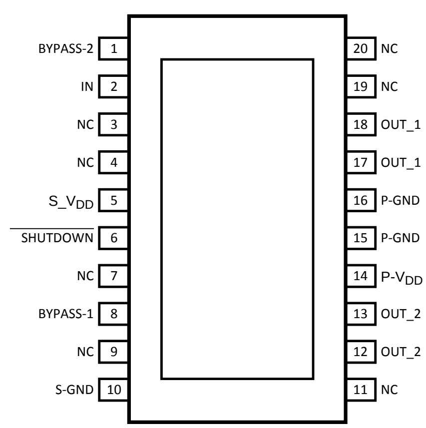

Figure 2. Top View
20-Pin TSSOP
See PWP Package

Typical Application

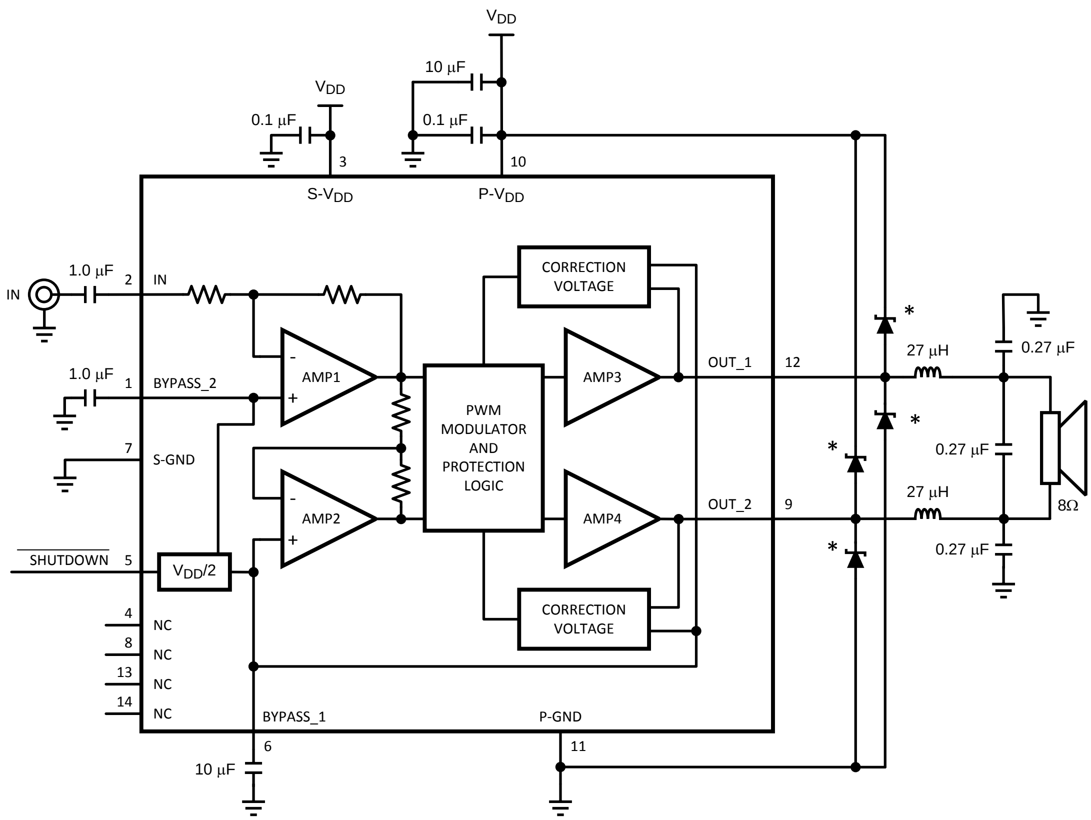

Figure 3. Typical Audio Amplifier Application Circuit (* Zetex ZHCS506)

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

Absolute Maximum Ratings[1][2][3]

Supply Voltage	16V
Storage Temperature	−65°C to +150°C
Input Voltage	−0.3V to V_{DD} +0.3V
Power Dissipation[4]	Internally limited
ESD Susceptibility[5]	2000V
ESD Susceptibility[6]	200V
Junction Temperature (VSSON and TSSOP)	150°C
Thermal Resistance	
θ_{JC}	2°C/W
θ_{JA}	40°C/W

(1) All voltages are measured with respect to the GND pin unless otherwise specified.
(2) 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 ensure specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which ensure specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not ensured for parameters where no limit is given, however, the typical value is a good indication of device performance.
(3) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.
(4) The maximum power dissipation must be de-rated 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 LM4668 typical application (shown in Figure 1) with V_{DD} = 12V, R_L = 8Ω stereo operation, the total power dissipation is 900mW. θ_{JA} = 40°C/W
(5) Human body model, 100pF discharged through a 1.5kΩ resistor.
(6) Machine model, 220pF – 240pF discharged through all pins.

Operating Ratings

Temperature Range	
$T_{MIN} \le T_A \le T_{MAX}$	−40°C ≤ T_A ≤ 85°C
Supply Voltage[1]	9V ≤ V_{DD} ≤ 14.0V

(1) Please refer to Under Voltage Protection under General Features.

Electrical Characteristics for the LM4668 (1)

The following specifications apply for the circuit shown in Figure 1 operating with V_{DD} = 12V, R_L = 8Ω, and f_{IN} = 1kHz, unless otherwise specified. Limits apply for T_A = 25°C.

Symbol	Parameter	Conditions	LM4668		Units (Limits)
			Typical (2)	Limit (3) (4)	
I_{DD}	Quiescent Power Supply Current	V_{IN} = 0V, I_O = 0A, R_L = 8Ω	30	65	mA (max)
I_{SD}	Shutdown Current	$V_{SHUTDOWN}$ = GND (5)	0.15		mA
A_V	Amplifier Gain	BTL output voltage with respect to input voltage, V_{IN} = 100mV_{p-p}	30	32 28	dB (max) dB (min)
P_O	Output Power	THD+N = 1% (max) THD+N = 10%, V_{DD} = 14V	6 10	5	W (min) W
THD+N	Total Harmonic Distortion + Noise	P_{OUT} = 1W_{RMS}	0.2		%
f_{BW}	Frequency Response Bandwith	P_{OUT} = 6W, post filter, -3dB relative to the output amplitude at 1kHz, See Figure 1	20 20000		Hz Hz
η	Efficiency	P_{OUT} = 6W, including output filter	79		%
éN	Output Noise	A-Weighted Filter, V_{IN} = 0V	220		µV
SNR	Signal-to-Noise Ratio	A-Weighted Filter, P_{OUT} = 6W A_V = 30dB	90		dB
PSRR	Power Supply Rejection Ratio	V_{RIPPLE} = 20mV_{p-p}, C_{BYPASS_1} = 10µF, input referred f = 50Hz f = 60Hz f = 100Hz f = 120Hz f = 1kHz	79 82 85 84 75		dB
t_{WU}	Wake-Up time	C_{BYPASS} = 10µF	600		ms
T_{SD}	Thermal Shutdown Temperature		170		°C (min) °C (max)
V_{SDIH}	Shutdown Voltage Input High			4	V (min)
V_{SDIL}	Shutdown Voltage Input Low			1.5	V (max)

(1) All voltages are measured with respect to the GND pin unless otherwise specified.
(2) Typicals are measured at 25°C and represent the parametric norm.
(3) Limits are ensured to AOQL (Average Outgoing Quality Level).
(4) Datasheets min/max specification limits are ensured by design, test, or statistical analysis.
(5) Shutdown current is measured in a normal room environment. The SHUTDOWN pin should be driven as close as possible to GND for minimum shutdown current.

TYPICAL PERFORMANCE CHARACTERISTICS

THD+N vs Frequency
V_{DD} = 9V, R_L = 8Ω, P_O = 1W

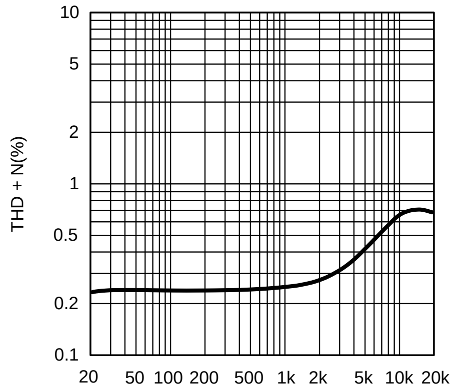

Figure 4.

THD+N vs Frequency
V_{DD} = 12V, R_L = 8Ω, P_O = 1W

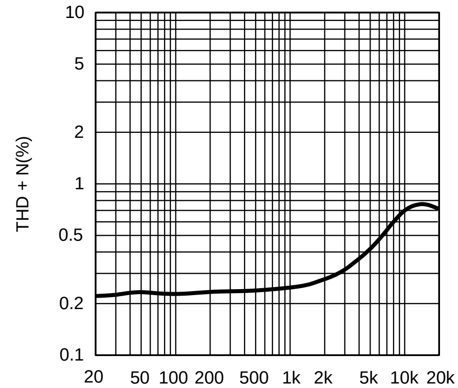

Figure 5.

THD+N vs Frequency
V_{DD} = 14V, R_L = 8Ω, P_O = 1W

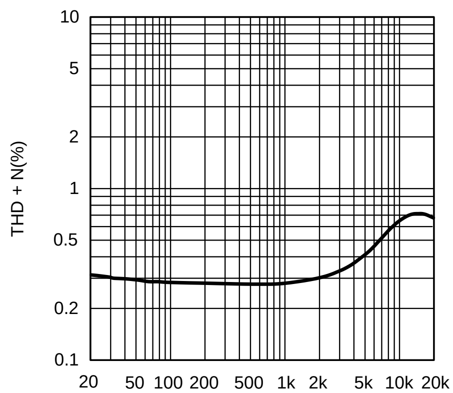

Figure 6.

THD+N vs Output Power
R_L = 8Ω, V_{DD} = 9V, f = 1kHz

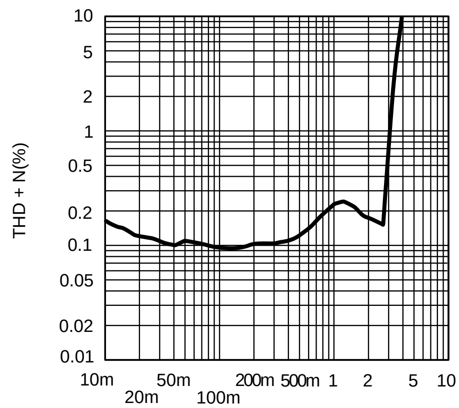

Figure 7.

THD+N vs Output Power
R_L = 8Ω, V_{DD} = 12V, f = 1kHz

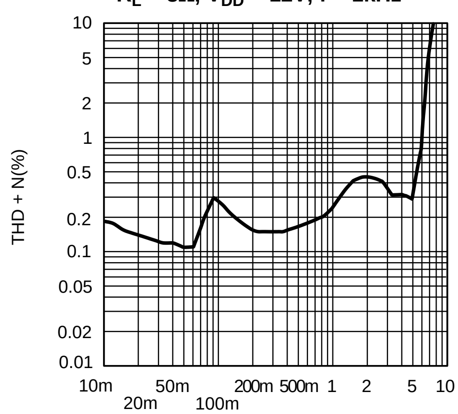

Figure 8.

THD+N vs Output Power
R_L = 8Ω, V_{DD} = 14V, f = 1kHz

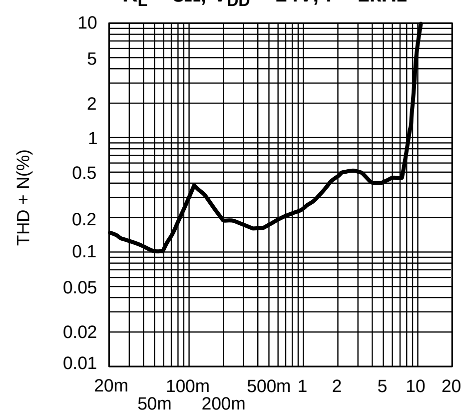

Figure 9.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Amplifier Output Power vs Power Supply Voltage
R_L = 8Ω, f = 1kHz

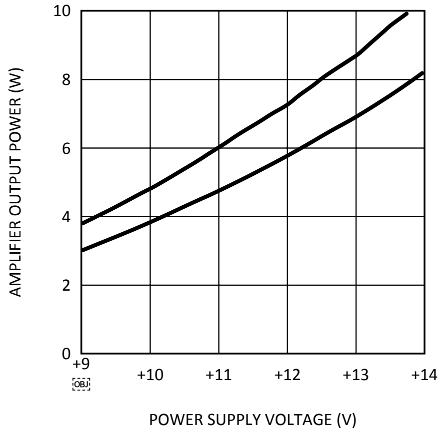

Figure 10.

Amplifier Output Magnitude vs Frequency
R_L = 8Ω, V_{DD} = 12V

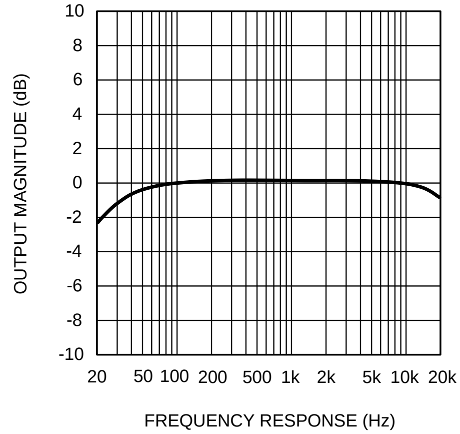

Figure 11.

Power Rejection Ratio vs Frequency
V_{DD} = 9V, R_L = 8Ω, Input Referred

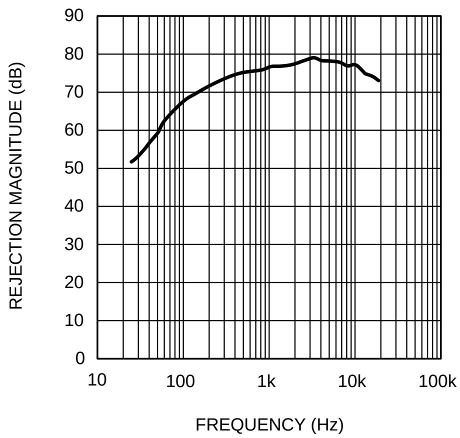

Figure 12.

Power Rejection Ratio vs Frequency
V_{DD} = 12V, R_L = 8Ω, Input Referred

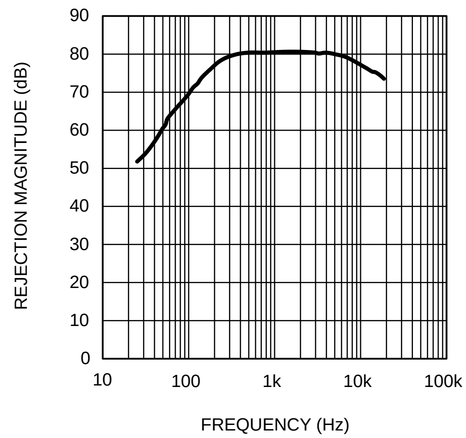

Figure 13.

Power Rejection Ratio vs Frequency
V_{DD} = 14V, R_L = 8Ω, Input Referred

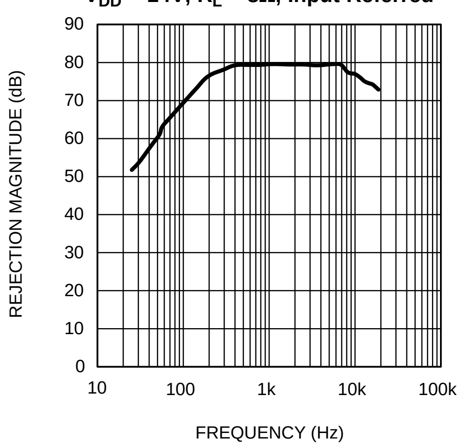

Figure 14.

Amplifier Power Dissipation vs Amplifier Load Dissipation
V_{DD} = 14V, R_L = 8Ω, f = 1kHz

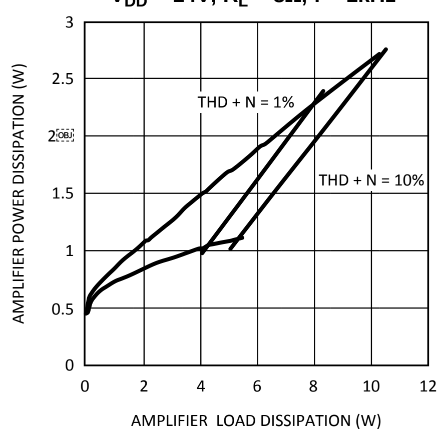

Figure 15.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Amplifier Power Dissipation vs Load Power Dissipation
V_{DD} = 12V, R_L = 8Ω, f = 1kHz

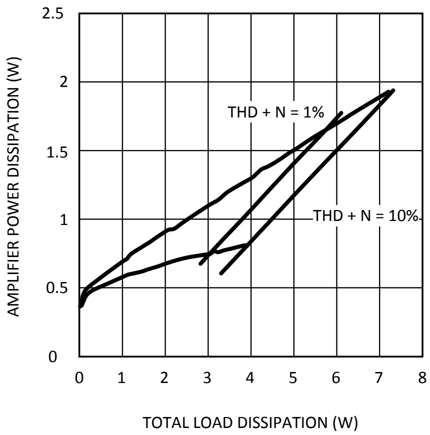

Figure 16.

Amplifier Power Dissipation vs Total Load Power Dissipation
V_{DD} = 9V, R_L = 8Ω, f = 1kHz

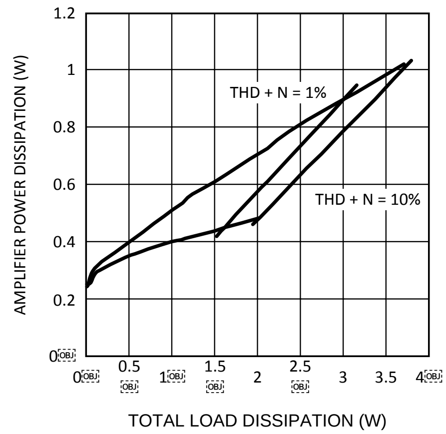

Figure 17.

Output Power vs Load Resistance
V_{DD} = 14V, f = 1kHz

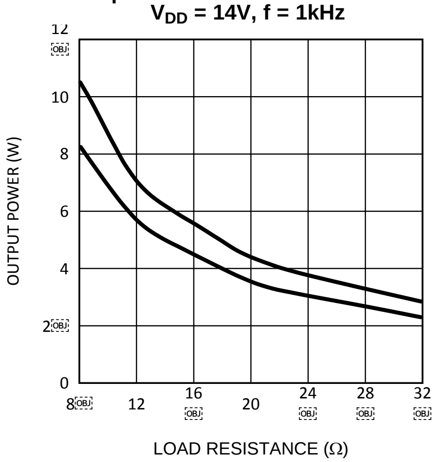

Figure 18.

Output Power vs Load Resistance
V_{DD} = 12V, f = 1kHz

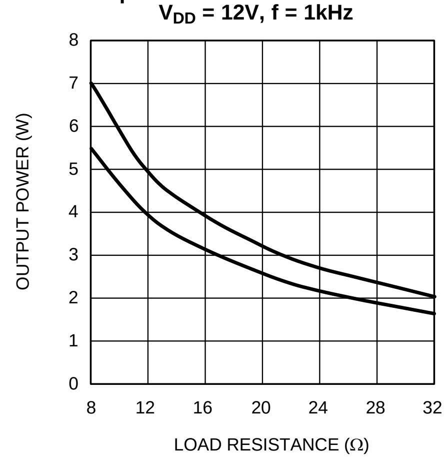

Figure 19.

Output Power vs Load Resistance
V_{DD} = 9V, f = 1kHz

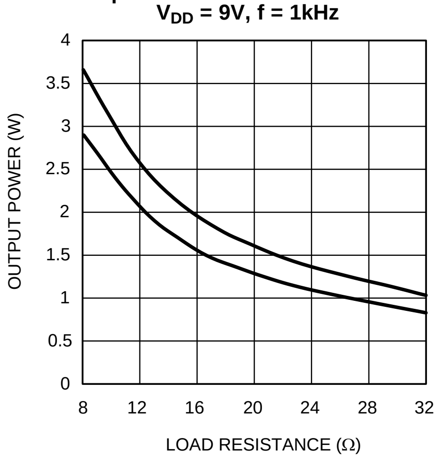

Figure 20.

Power Supply Current vs Power Supply Voltage
V_{IN} = 0V, R_L = 8Ω

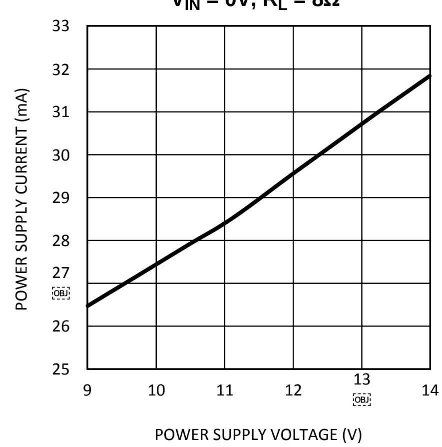

Figure 21.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Power Dissipation vs Ambient Temperature

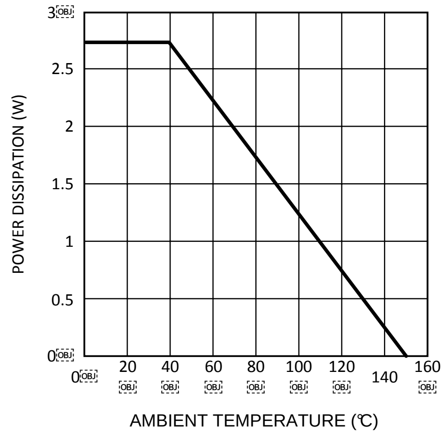

Figure 22.

GENERAL FEATURES

System Functional Information

Modulation Technique

Unlike typical Class D amplifiers that use single-ended comparators to generate a pulse-width modulated switching waveform and RC timing circuits to set the switching frequency, the LM4668 uses a balanced differential floating modulator. Oscillation is a result of injecting complimentary currents onto the respective plates of a floating, on-die capacitor. The value of the floating capacitor and value of the components in the modulator's feedback network and sets the nominal switching frequency at 450kHz. Modulation results from imbalances in the injected currents. The amount of current imbalance is directly proportional to the applied input signal's magnitude and frequency.

Using a balanced, floating modulator produces a Class D amplifier that is immune to common mode noise sources such as substrate noise. This noise occurs because of the high frequency, high current switching in the amplifier's output stage. The LM4668 is immune to this type of noise because the modulator, the components that set its switching frequency, and even the load all float with respect to ground.

The balanced modulator's pulse width modulated output drives the gates of the LM4668's H-bridge configured output power MOSFETs. The pulse-train present at the power MOSFETs' output is applied to an LC low pass filter that removes the 450kHz energy component. The filter's output signal, which is applied to the driven load, is an amplified replica of the audio input signal.

Shutdown Function

The LM4668's active-low shutdown function allows the user to place the amplifier in a shutdown mode while the system power supply remains active. Activating shutdown deactivates the output switching waveform and minimizes the quiescent current. Applying logic 0 (GND) to pin 8 enables the shutdown function. Applying logic 1 ($4V \le V_{LOGIC} \le V_{DD}$) to pin 8 disables the shutdown function and restores full amplifier operation.

Under Voltage Protection

The under voltage protection disables the output driver section of the LM4668 while the supply voltage is below 8V. This condition may occur as power is first applied or during low line conditions, changes in load resistance, or when power supply sag occurs. The under voltage protection ensures that all of the LM4668's power MOSFETs are off. This action eliminates shoot-through current and minimizes output transients during turn-on and turn-off. The under voltage protection gives the digital logic time to stabilize into known states, further minimizing turn output transients.

Turn-On Time

The LM4668 has an internal timer that determines the amplifier's turn-on time. After power is first applied or the part returns from shutdown, the nominal turn-on time is 600ms. This delay allows all externally applied capacitors to charge to a final value of $V_{DD}/2$. Further, during turn-on, the outputs are muted. This minimizes output transients that may occur while the part settles into is quiescent operating mode.

Output Stage Fault Detection And Protection

The output stage MOSFETs are protected against output conditions that could otherwise compromise their operational status. An onboard fault detection circuit continuously monitors the signal on each output MOSFET's gate and compares it against the respective drain voltage. When a condition is detected that violates a MOSFET's Safe Operating Area (SOA), the drive signal is disconnected from the output MOSFETs' gates. The fault detect circuit maintains this protective condition for approximately 600ms, at which time the drive signal is reconnected. If the fault condition is no longer present, normal operation resumes.

If the fault condition remains, however, the drive signal is again disconnected.

Thermal Protection

The LM4668 has thermal shutdown circuitry that monitors the die temperature. Once the LM4668 die temperature reaches 170°C, the LM4668 disables the output switching waveform and remains disabled until the die temperature falls below 140°C (typ).

Over-Modulation Protection

The LM4668's over-modulation protection is a result of the preamplifier's (AMP1 and AMP2, Figure 1) inability to produce signal magnitudes that equal the power supply voltages. Since the preamplifier's output magnitude will always be less than the supply voltage, the duty cycle of the amplifier's switching output will never reach zero. Peak modulation is limited to a nominal 95%.

APPLICATION INFORMATION

Supply Bypassing

Correct power supply bypassing has two important goals. The first is to reduce noise on the power supply lines and minimize deleterious effects that the noise may cause to the amplifier's operation. The second is to help stabilize an unregulated power supply and to improve the supply's transient response under heavy current demands. These two goals require different capacitor value ranges. Therefore, various types and values are recommended for supply bypassing. For noise de-coupling, generally small ceramic capacitors (0.01µF to 0.1µF) are recommended. Larger value (1µF to 10µF) tantalum capacitors are needed for the transient current demands. These two capacitors in parallel will do an adequate job of removing most noise from the supply rails and providing the necessary transient current. These capacitors should be placed as close as possible to each IC's supply pin(s) using leads as short as possible.

The LM4668 has two V_{DD} pins: a power V_{DD} (PV_{DD}) and a signal V_{DD} (SV_{DD}). The parallel combination of the low value ceramic (0.1µF) and high value tantalum (10µF) should be used to bypass the PV_{DD} pin. A small value (0.1µF) ceramic or tantalum can be used to bypass the SV_{DD} pin.

Amplifier Output Filtering

The LM4668 requires a lowpass filter connected between the amplifier's bridge output and the load. The second-order LC output filter shown in Figure 1 creates the lowpass response that is necessary to attenuate signal energy at the amplifier's switching frequency. It also serves to suppress EMI. Together, the output filter's 0.27µF capacitors and the recommended minimum inductor value of 27µH produce a nominal cutoff frequency of 47kHz. This cutoff frequency ensures that the attenuation is much less than 3dB at 20kHz.

The output filter cutoff frequency and topology are also optimized for operational efficiency. A higher cutoff frequency compromises efficiency, whereas a lower cutoff frequency compromises the high frequencies within the audio frequency range. The filter's topology also minimizes high frequency peaking, which can also decrease the amplifier's efficiency.

The output filter inductors must have a current rating that exceeds the amplifier's output current when driving the load to maximum dissipation. Assuming a load dissipation of 10W in an 8Ω load with the amplifier operating on a 14V supply, the RMS current is 1.1A. In this case, the inductors' current rating should be at least $1.2A_{RMS}$ or $1.6A_{PEAK}$.

If a different output filter cutoff frequency (f_C) is desired, the following brief discussion covers the selection of the capacitor and inductor values. In the following equations, R_L is the load resistance and C_L is three times the final value of the three common-mode filter capacitor found between the two output filter inductors (each inductor is L) as shown in Figure 1. When calculating values for L and C_L, R_L should be 8Ω, since the LM4668 is specified for 8Ω loads.

The filter's two inductors are equal to:

$$L = R_L / 2\pi f_C \quad (1)$$

and each of the three capacitors are equal to:

$$C = L / 1.5R^2 \quad (2)$$

Schottky Diode Amplifier Output Overdrive Protection

The Schottky diodes shown in Figure 1 provide protection against an over-voltage condition that may be caused by inductor-induced transients. These diodes are necessary when the nominal supply voltage exceeds 12V, the load impedance falls below 6Ω or the ambient temperature in the operating environment rises above 50°C.

THD+N Measurements and Out of Audio Band Noise

THD+N (Total Harmonic Distortion plus Noise) is a very important parameter by which all audio amplifiers are measured. Often it is shown as a graph where either the output power or frequency is changed over the operating range. A very important variable in the measurement of THD+N is the bandwidth-limiting filter at the input of the test equipment. Class D amplifiers, by design, switch their output power devices at a much higher frequency than the accepted audio range (20Hz - 20kHz). Alternately switching the output voltage between V_{DD} and GND allows the LM4668 to operate at much higher efficiency than that achieved by traditional Class AB amplifiers. Switching the outputs at high frequency also increases the out-of-band noise. Under normal circumstances the output lowpass filter significantly reduces this out-of-band noise. If the low pass filter is not optimized for a given switching frequency, there can be significant increase in out-of-band noise. THD+N measurements can be significantly affected by out-of-band noise, resulting in a higher than expected THD+N measurement. To achieve a more accurate measurement of THD, the test equipment's input bandwidth of the must be limited. Some common upper filter points are 22kHz, 30kHz, and 80kHz. The input filter limits the noise component of the THD+N measurement to a smaller bandwidth resulting in a more real-world THD+N value.

Recommended Printed Circuit Board Layout

Figure 23, Figure 24, and Figure 25 show the recommended two-layer PC board layout that is optimized for the 14-pin PWP packaged LM4668 and associated external components.Figure 26, Figure 27, and Figure 28 show the recommended two-layer PC board layout that is optimized for the 14-pin NHH0014A packaged LM4668 and associated external components. These circuits are designed for use with an external 12V supply and 8Ω speakers (or load resistors). This circuit board is easy to use. Apply 12V and ground to the board's V_{DD} and GND terminals, respectively. Connect speakers (or load resistors) between the board's -OUT and +OUT terminals. Apply the input signal to the input pin labeled -IN.

Demonstration Board Layout

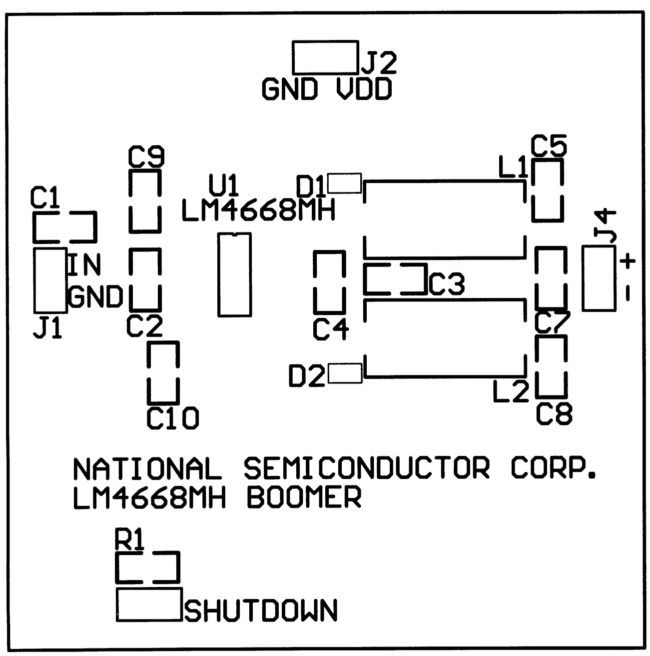

Figure 23. Recommended PWP PCB Layout Top Silkscreen

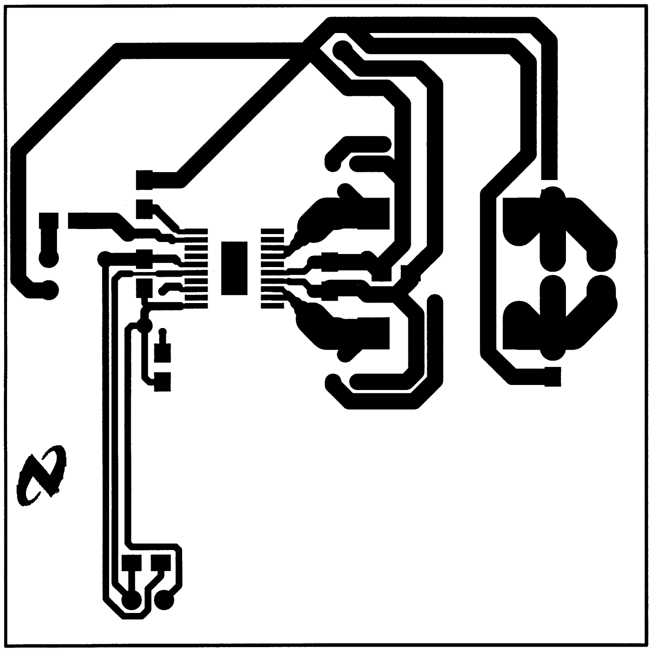

Figure 24. Recommended PWP PCB Layout Top Layer

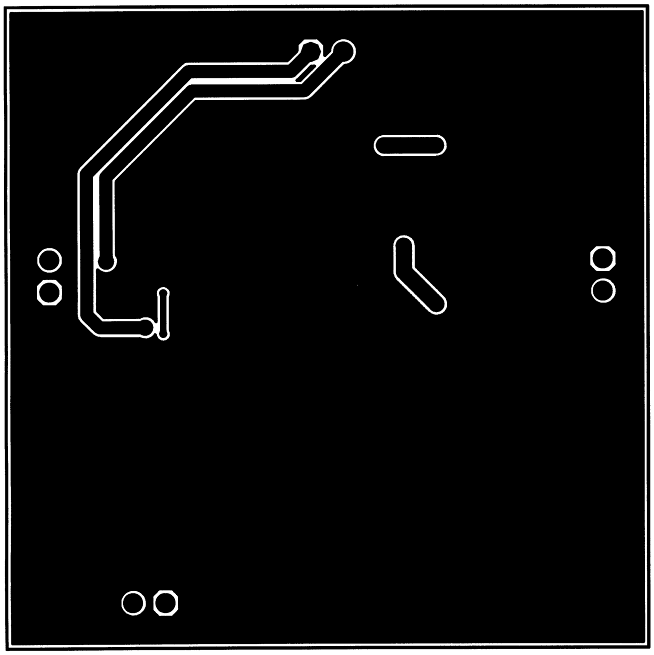

Figure 25. Recommended PWP PCB Layout Bottom Layer

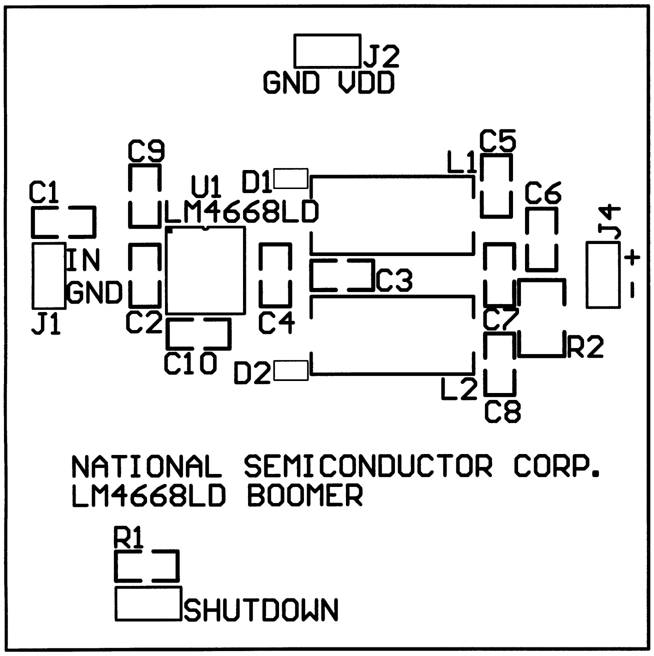

Figure 26. Recommended NHH0014A PCB Layout Top Silkscreen Layer

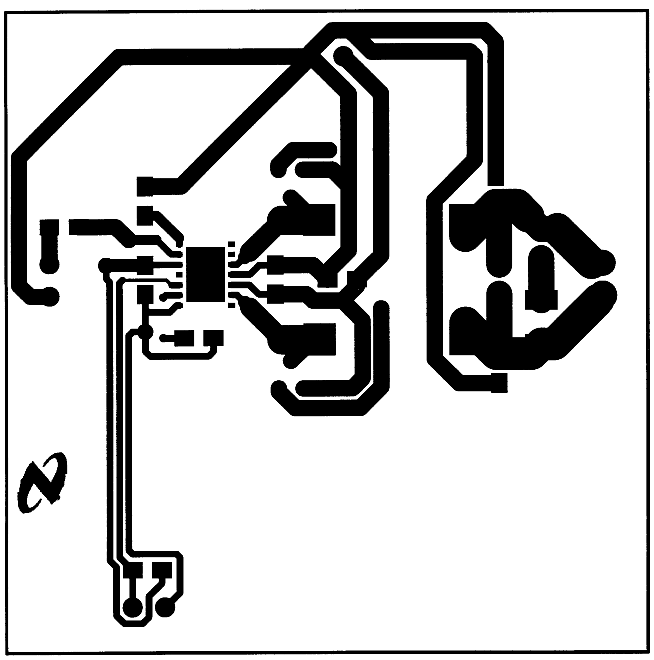

Figure 27. Recommended NHH0014A PCB Layout Top Layer

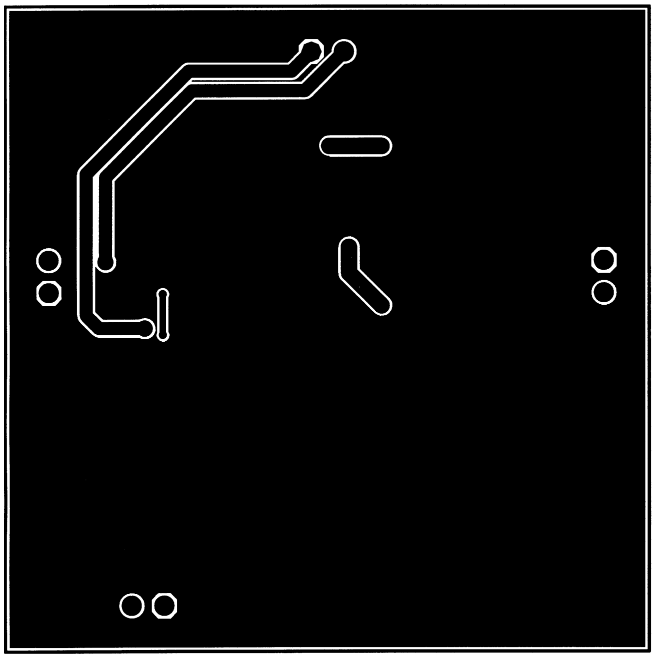

Figure 28. Recommended NHH0014A PCB Layout Bottom Layer

REVISION HISTORY

Changes from Revision C (April 2013) to Revision D	Page
• Changed layout of National Data Sheet to TI format	14

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
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