

LM4674 Boomer® Audio Power Amplifier Series

Filterless 2.5W Stereo Class D Audio Power Amplifier

General Description

The LM4674 is a single supply, high efficiency, 2.5W/channel, filterless switching audio amplifier. A low noise PWM architecture eliminates the output filter, reducing external component count, board area consumption, system cost, and simplifying design.

The LM4674 is designed to meet the demands of mobile phones and other portable communication devices. Operating from a single 5V supply, the device is capable of delivering 2.5W/channel of continuous output power to a 4Ω load with less than 10% THD+N. Flexible power supply requirements allow operation from 2.4V to 5.5V.

The LM4674 features high efficiency compared to conventional Class AB amplifiers. When driving an 8Ω speaker from a 3.6V supply, the device features 85% efficiency at $P_O = 500\text{mW}$. Four gain options are pin selectable through the G0 and G1 pins.

Output short circuit protection prevents the device from being damaged during fault conditions. Superior click and pop suppression eliminates audible transients on power-up/down and during shutdown. Independent left/right shutdown control maximizes power savings in mixed mono/stereo applications.

Key Specifications

■ Efficiency at 3.6V, 100mW into 8Ω	80% (typ)
■ Efficiency at 3.6V, 500mW into 8Ω	85% (typ)
■ Efficiency at 5V, 1W into 8Ω	85% (typ)
■ Quiescent Power Supply Current at 3.6V supply	4mA
■ Power Output at $V_{DD} = 5\text{V}$, $R_L = 4\Omega$, THD $\leq 10\%$	2.5W (typ)
■ Power Output at $V_{DD} = 5\text{V}$, $R_L = 8\Omega$, THD $\leq 10\%$	1.5W (typ)
■ Shutdown current	0.03μA (typ)

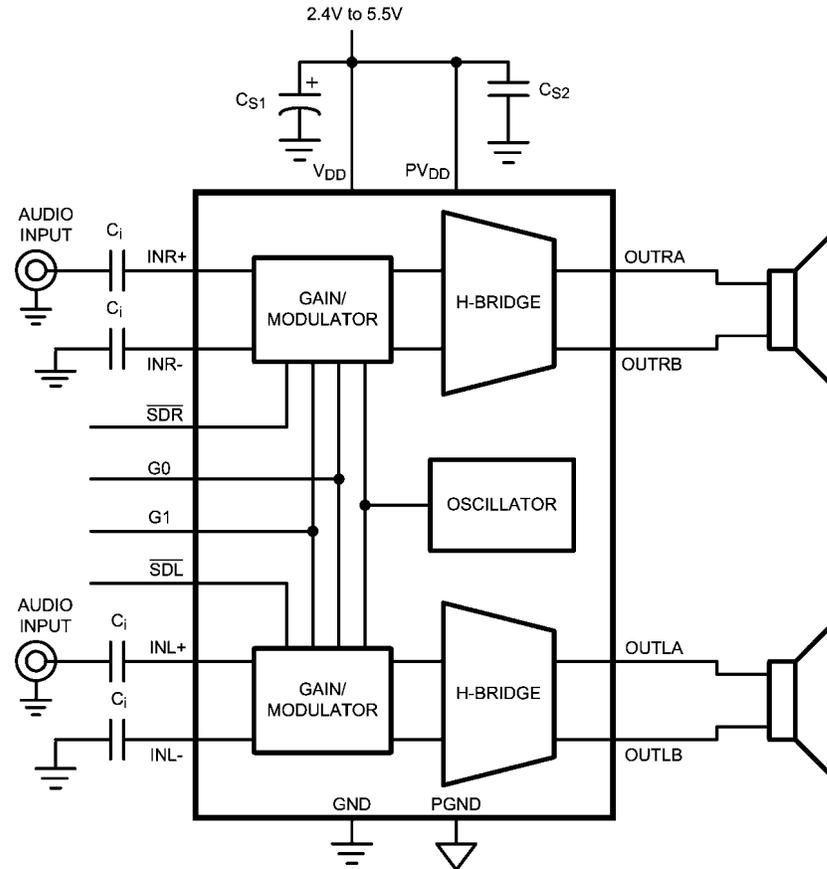
Features

- Output Short Circuit Protection
- Stereo Class D operation
- No output filter required
- Logic selectable gain
- Independent shutdown control
- Minimum external components
- Click and Pop suppression
- Micro-power shutdown
- Available in space-saving 2mm x 2mm x 0.6mm micro SMD, and 4mm x 4mm x 0.8mm LLP packages

Applications

- Mobile phones
- PDAs
- Laptops

Typical Application



20167463

$C_i = 1 \mu\text{F}$
 $C_{S1} = 1 \mu\text{F}$
 $C_{S2} = 0.1 \mu\text{F}$

FIGURE 1. Typical Audio Amplifier Application Circuit

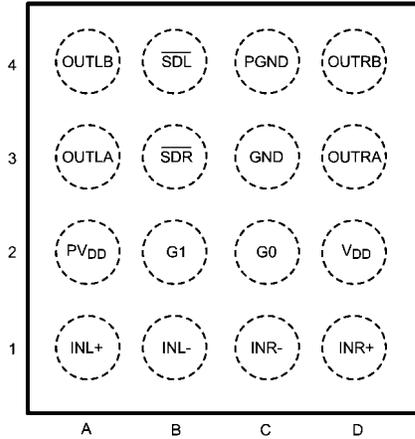
External Components Description

(Figure 1)

Components		Functional Description
1.	C_S	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.
2.	C_i	Input AC coupling capacitor which blocks the DC voltage at the amplifier's input terminals.

Connection Diagrams

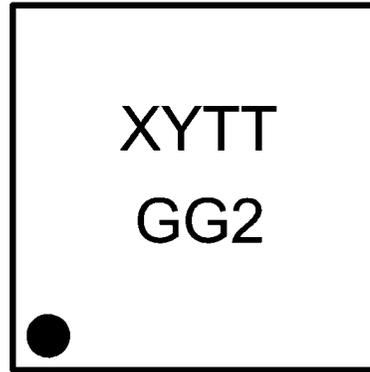
TL Package (2mm x 2mm x 0.6mm)



20167461

Top View
Order Number LM4674TL
See NS Package Number TL1611A

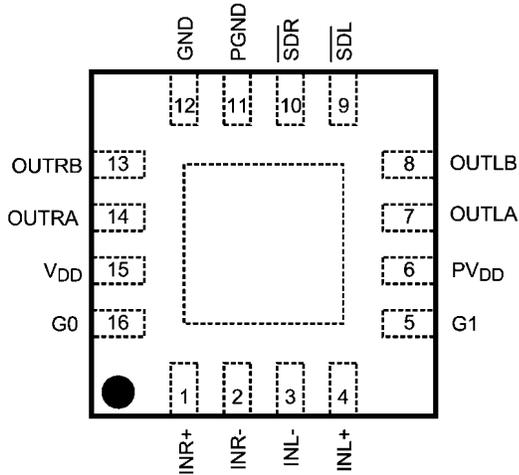
LM4674TL Markings



20167462

Top View
XY = 2 Digit date code
TT = Lot traceability
G = Boomer Family
G2 = LM4674TL

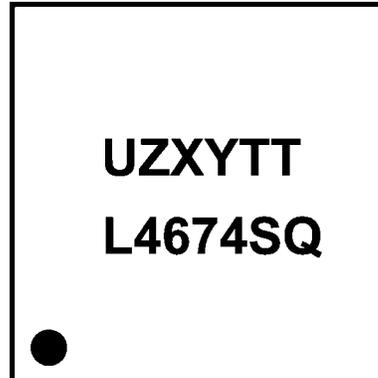
LLP Package (4mm x 4mm x 0.8mm)



20167466

Top View
Order Number LM4674SQ
See NS Package Number SQA16A

LM4674SQ Markings



20167465

Top View
U = Wafer Fab Code
Z = Assembly Plant
XY = 2 Digit date code
TT = Lot traceability
L4674SQ = LM4674SQ

BUMP	PIN	NAME	FUNCTION
A1	4	INL+	Non-inverting left channel input
A2	6	PV _{DD}	Power V _{DD}
A3	7	OUTLA	Left channel output A
A4	8	OUTLB	Left channel output B
B1	3	INL-	Inverting left channel input
B2	5	G1	Gain setting input 1
B3	10	$\overline{\text{SDR}}$	Right channel shutdown input
B4	9	$\overline{\text{SDL}}$	Left channel shutdown input
C1	2	INR-	Inverting right channel input
C2	16	G0	Gain setting input 0
C3	12	GND	Ground
C4	11	PGND	Power Ground
D1	1	INR+	Non-inverting right channel input
D2	15	V _{DD}	Power Supply
D3	14	OUTRA	Right channel output A
D4	13	OUTRB	Right channel output B

Absolute Maximum Ratings (Notes 1, 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage (Note 1)	6.0V
Storage Temperature	-65°C to +150°C
Input Voltage	-0.3V to $V_{DD} + 0.3V$
Power Dissipation (Note 3)	Internally Limited
ESD Susceptibility, all other pins (Note 4)	2000V
ESD Susceptibility (Note 5)	200V

Junction Temperature (T_{JMAX})	150°C
Thermal Resistance	
θ_{JA} (μ SMD)	45.7°C/W
θ_{JA} (LLP)	38.9°C/W

Operating Ratings (Notes 1, 2)

Temperature Range	
$T_{MIN} \leq T_A \leq T_{MAX}$	-40°C $\leq T_A \leq$ 85°C
Supply Voltage	2.4V $\leq V_{DD} \leq$ 5.5V

Electrical Characteristics $V_{DD} = 3.6V$ (Notes 1, 2)

The following specifications apply for $A_V = 6dB$, $R_L = 15\mu H + 8\Omega + 15\mu H$, $f = 1kHz$ unless otherwise specified. Limits apply for $T_A = 25^\circ C$.

Symbol	Parameter	Conditions	LM4674		Units (Limits)
			Typical	Limit	
			(Note 6)	(Notes 7, 8)	
V_{OS}	Differential Output Offset Voltage	$V_{IN} = 0$, $V_{DD} = 2.4V$ to $5.0V$	5		mV
I_{DD}	Quiescent Power Supply Current	$V_{IN} = 0$, $R_L = \infty$, Both channels active, $V_{DD} = 3.6V$	4	6	mA
		$V_{IN} = 0$, $R_L = \infty$, Both channels active, $V_{DD} = 5V$	5	7.5	mA
I_{SD}	Shutdown Current	$V_{SDR} = V_{SDL} = GND$	0.03	1	μA
V_{SDIH}	Shutdown Voltage Input High			1.4	V (min)
V_{SDIL}	Shutdown Voltage Input Low			0.4	V (max)
T_{WU}	Wake Up Time	$V_{SDR/SDL} = 0.4V$	0.5		ms
A_V	Gain	$G0, G1 = GND$ $R_L = \infty$	6	6 ± 0.5	dB
		$G0 = V_{DD}$, $G1 = GND$ $R_L = \infty$	12	12 ± 0.5	dB
		$G0 = GND$, $G1 = V_{DD}$ $R_L = \infty$	18	18 ± 0.5	dB
		$G0, G1 = V_{DD}$ $R_L = \infty$	24	24 ± 0.5	dB
R_{IN}	Input Resistance	$A_V = 6dB$	28		$k\Omega$
		$A_V = 12dB$	18.75		$k\Omega$
		$A_V = 18dB$	11.25		$k\Omega$
		$A_V = 24dB$	6.25		$k\Omega$

Symbol	Parameter	Conditions	LM4674		Units (Limits)
			Typical	Limit	
			(Note 6)	(Notes 7, 8)	
P _O	Output Power	R _L = 15μH + 4Ω + 15μH, THD ≤ 10% f = 1kHz, 22kHz BW			
		V _{DD} = 5V	2.5		W
		V _{DD} = 3.6V	1.2		W
		V _{DD} = 2.5V	0.530		W
		R _L = 15μH + 8Ω + 15μH, THD ≤ 10% f = 1kHz, 22kHz BW			
		V _{DD} = 5V	1.5		W
		V _{DD} = 3.6V	0.78	0.6	W
		V _{DD} = 2.5V	0.350		W
		R _L = 15μH + 4Ω + 15μH, THD ≤ 1% f = 1kHz, 22kHz BW			
		V _{DD} = 5V	1.9		W
		V _{DD} = 3.6V	1		W
		V _{DD} = 2.5V	0.430		W
		R _L = 15μH + 8Ω + 15μH, THD = 1% f = 1kHz, 22kHz BW			
		V _{DD} = 5V	1.25		W
		V _{DD} = 3.6V	0.63		W
		V _{DD} = 2.5V	0.285		W
THD+N	Total Harmonic Distortion	P _O = 500mW, f = 1kHz, R _L = 8Ω	0.07		%
		P _O = 300mW, f = 1kHz, R _L = 8Ω	0.05		%
PSRR	Power Supply Rejection Ratio	V _{RIPPLE} = 200mV _{P-P} Sine, f _{RIPPLE} = 217Hz, Inputs AC GND, C _i = 1μF, input referred	75		dB
		V _{RIPPLE} = 1V _{P-P} Sine, f _{RIPPLE} = 1kHz, Inputs AC GND, C _i = 1μF, input referred	75		dB
CMRR	Common Mode Rejection Ratio	V _{RIPPLE} = 1V _{P-P} f _{RIPPLE} = 217Hz	67		dB
η	Efficiency	P _O = 1W, f = 1kHz, R _L = 8Ω, V _{DD} = 5V	85		%
Xtalk	Crosstalk	P _O = 500mW, f = 1kHz	84		dB
SNR	Signal to Noise Ratio	V _{DD} = 5V, P _O = 1W	96		dB
ε _{OS}	Output Noise	Input referred, A-Weighted Filter	20		μV

Note 1: All voltages are measured with respect to the ground pin, unless otherwise specified.

Note 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 guarantee specific performance limits. *Electrical Characteristics* state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

Note 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 LM4674 see power derating currents for more information.

Note 4: Human body model, 100pF discharged through a 1.5kΩ resistor.

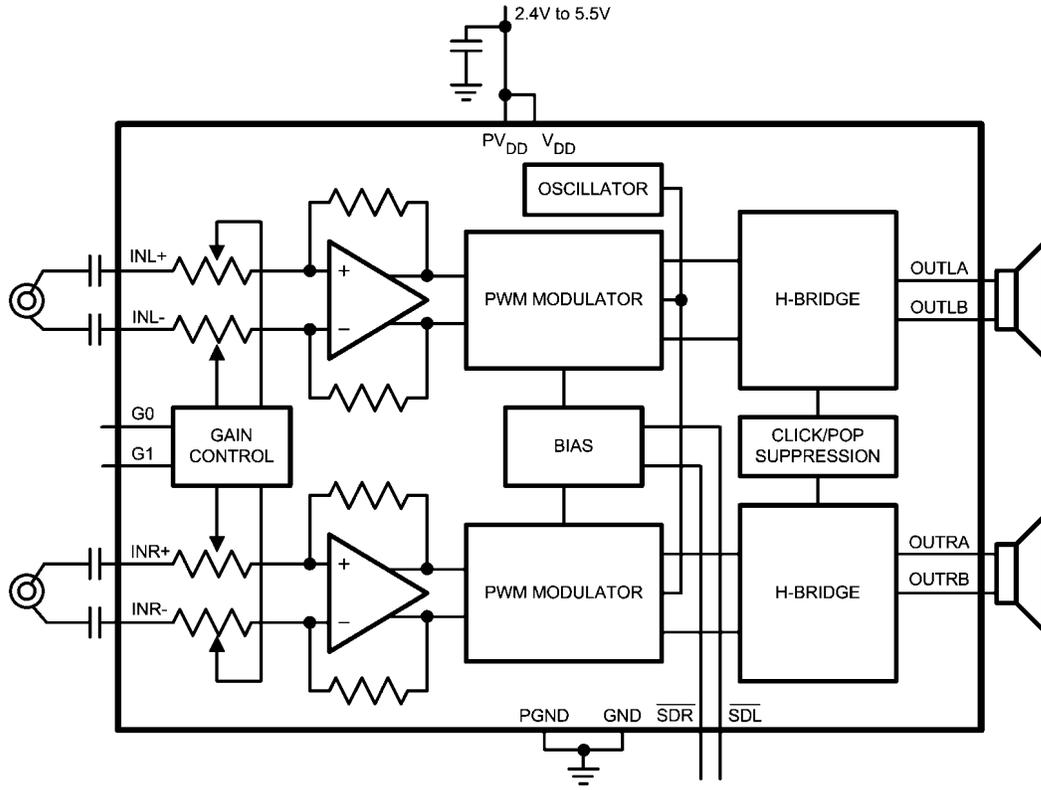
Note 5: Machine Model, 220pF–240pF discharged through all pins.

Note 6: Typicals are measured at 25°C and represent the parametric norm.

Note 7: Limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

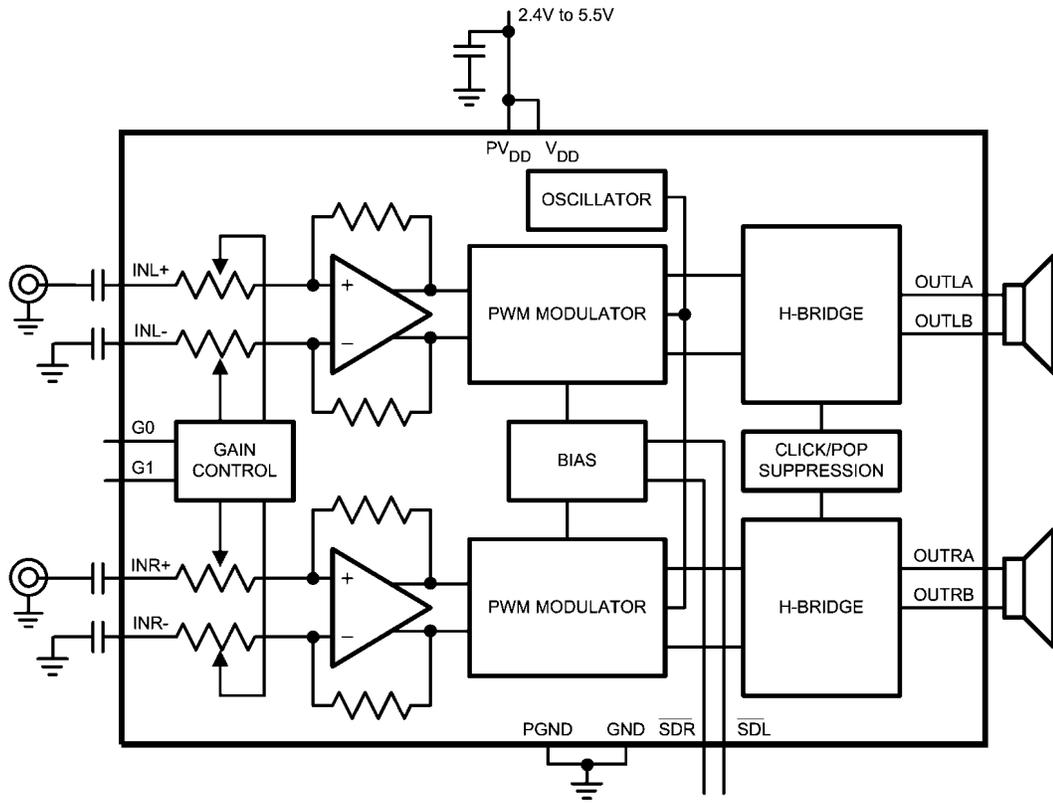
Note 8: Datasheet min/max specification limits are guaranteed by design, test, or statistical analysis.

Block Diagrams



20167426

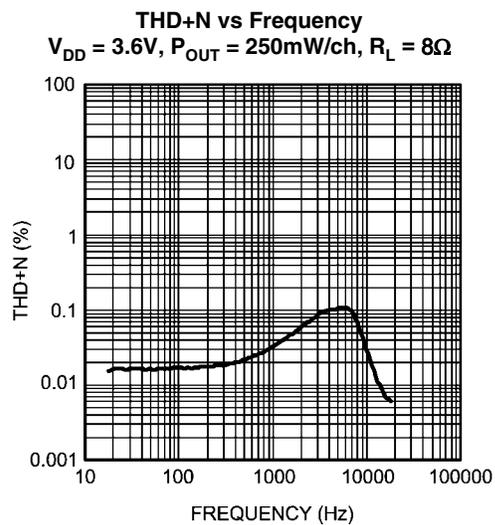
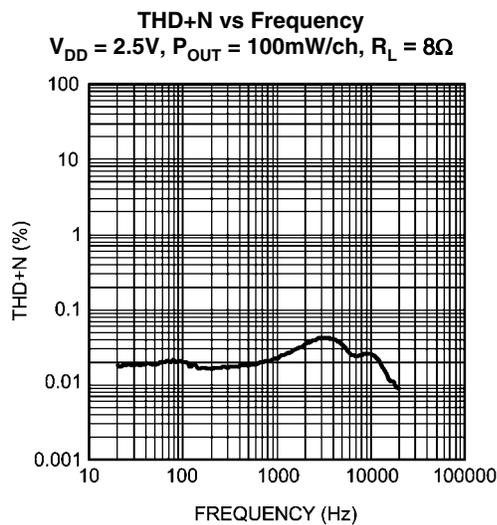
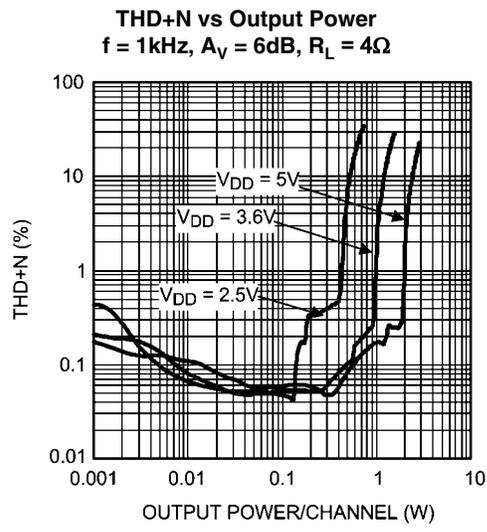
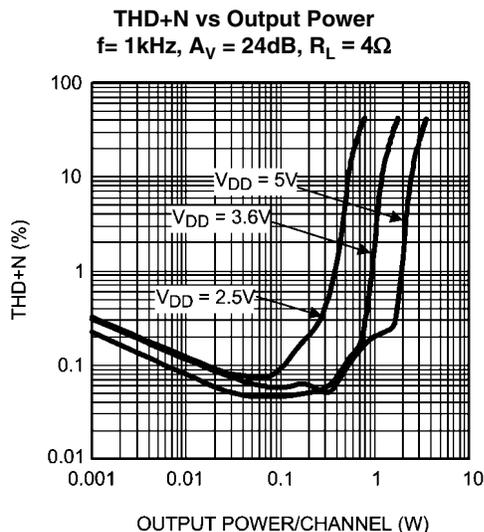
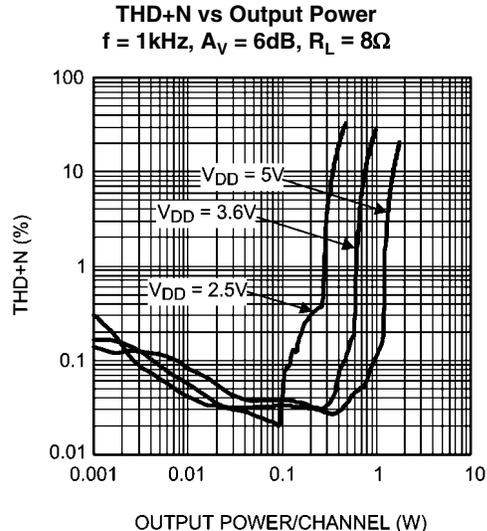
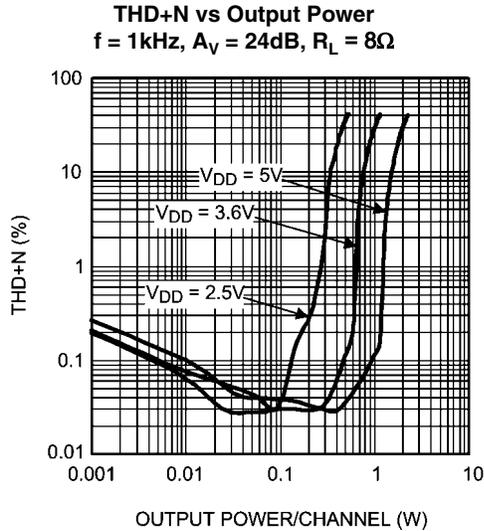
FIGURE 2. Differential Input Configuration

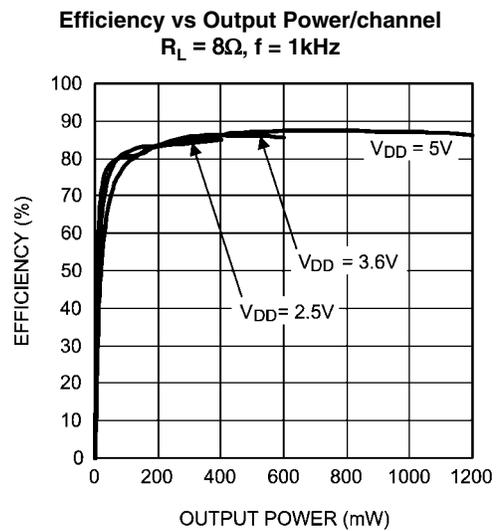
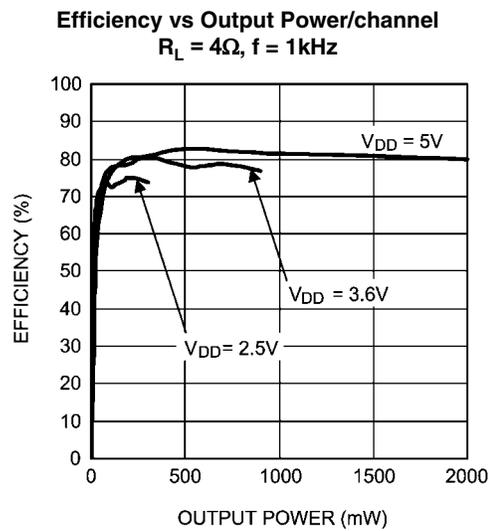
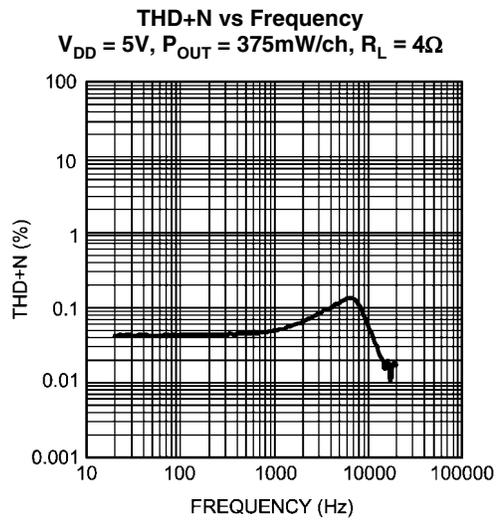
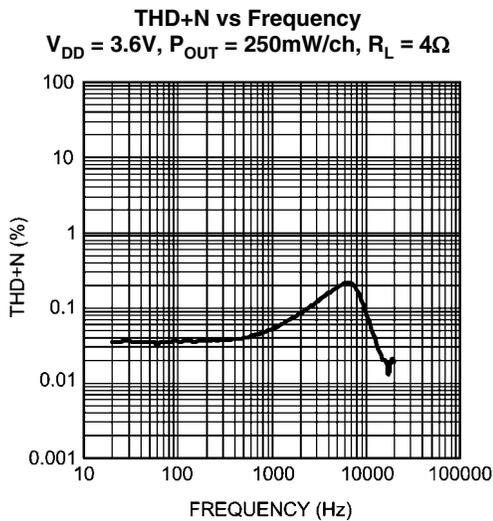
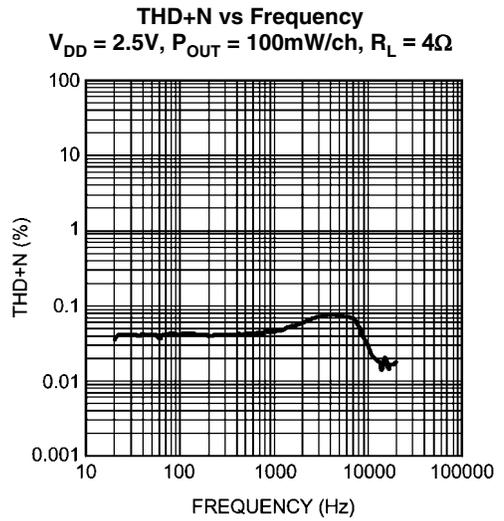
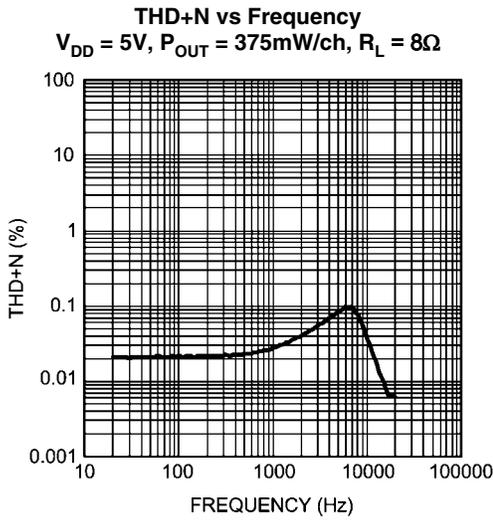


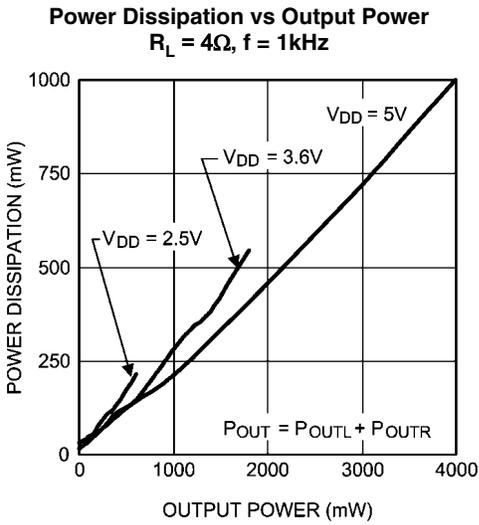
20167464

FIGURE 3. Single-Ended Input Configuration

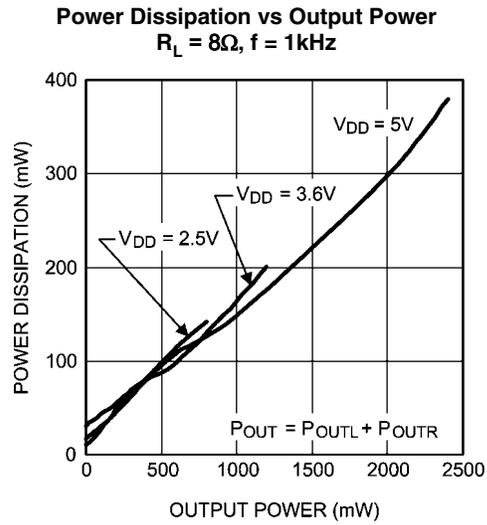
Typical Performance Characteristics



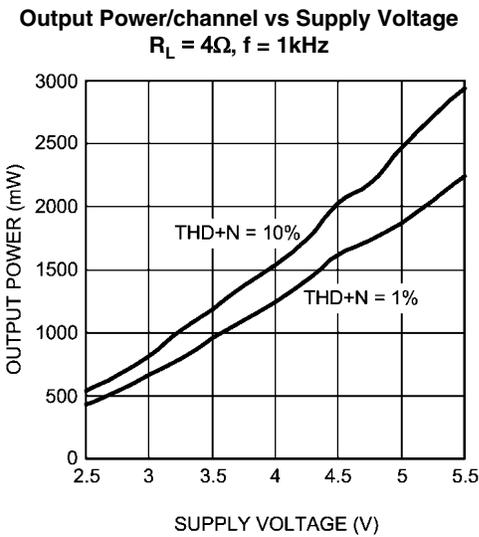




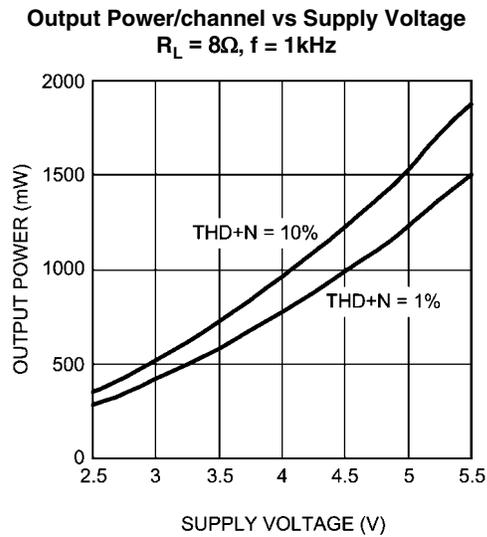
20167451



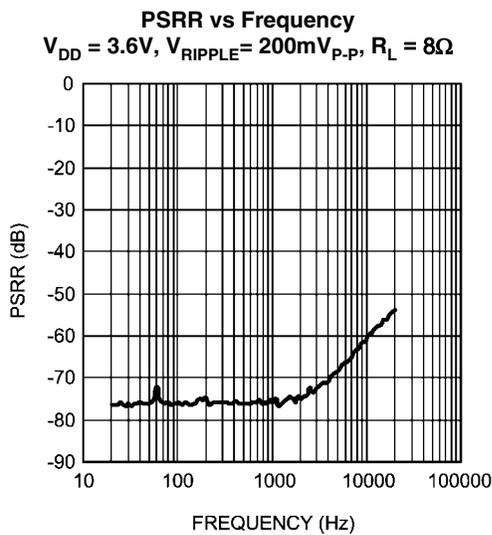
20167452



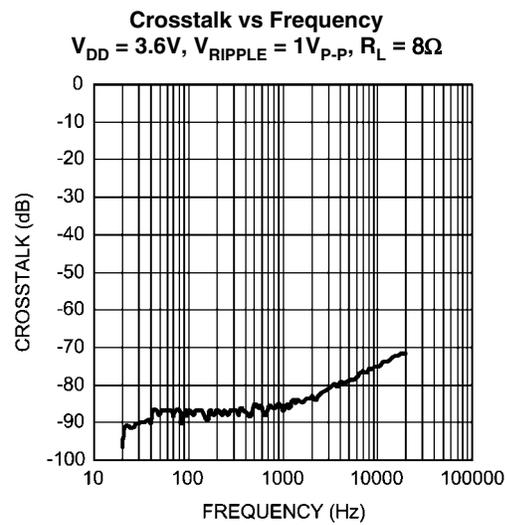
20167453



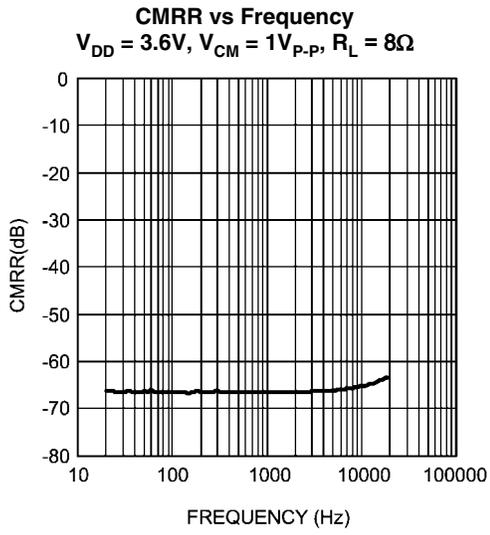
20167454



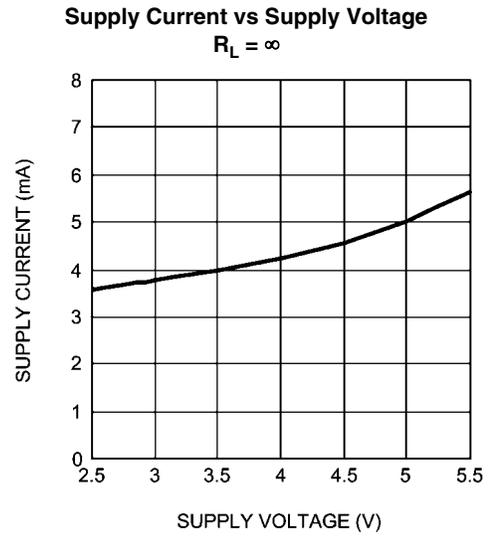
20167455



20167422



20167457



20167458

Application Information

GENERAL AMPLIFIER FUNCTION

The LM4674 stereo Class D audio power amplifier features a filterless modulation scheme that reduces external component count, conserving board space and reducing system cost. The outputs of the device transition from V_{DD} to GND with a 300kHz switching frequency. With no signal applied, the outputs for each channel switch with a 50% duty cycle, in phase, causing the two outputs to cancel. This cancellation results in no net voltage across the speaker, thus there is no current to the load in the idle state.

With the input signal applied, the duty cycle (pulse width) of the LM4674 outputs changes. For increasing output voltage, the duty cycle of the A output increases, while the duty cycle of the B output decreases for each channel. For decreasing output voltages, the converse occurs. The difference between the two pulse widths yields the differential output voltage.

DIFFERENTIAL AMPLIFIER EXPLANATION

As logic supplies continue to shrink, system designers are increasingly turning to differential analog signal handling to preserve signal to noise ratios with restricted voltage signs. The LM4674 features two fully differential amplifiers. A differential amplifier amplifies the difference between the two input signals. Traditional audio power amplifiers have typically offered only single-ended inputs resulting in a 6dB reduction of SNR relative to differential inputs. The LM4674 also offers the possibility of DC input coupling which eliminates the input coupling capacitors. A major benefit of the fully differential amplifier is the improved common mode rejection ratio (CMRR) over single ended input amplifiers. The increased CMRR of the differential amplifier reduces sensitivity to ground offset related noise injection, especially important in noisy systems.

POWER DISSIPATION AND EFFICIENCY

The major benefit of a Class D amplifier is increased efficiency versus a class AB amplifier. The efficiency of the LM4674 is attributed to the region of operation of the transistors in the output stage. The Class D output stage acts as current steering switches, consuming negligible amounts of power compared to their Class AB counterparts. Most of the power loss associated with the output stage is due to the IR loss of the MOSFET on-resistance ($R_{DS(ON)}$), along with switching losses due to gate charge.

SHUTDOWN FUNCTION

The LM4674 features independent left and right channel shutdown controls, allowing each channel to be disabled independently. \overline{SDR} controls the right channel, while \overline{SDL} controls the left channel. Driving either low disables the corresponding channel.

It is best to switch between ground and V_{DD} for minimum current consumption while in shutdown. The LM4674 may be disabled with shutdown voltages in between GND and V_{DD} , the idle current will be greater than the typical 0.03 μ A value. For logic levels between GND and V_{DD} bypass \overline{SD}_- with a 0.1 μ F capacitor.

The LM4674 shutdown inputs have internal pulldown resistors. The purpose of these resistors is to eliminate any un-

wanted state changes when \overline{SD}_- is floating. To minimize shutdown current, \overline{SD}_- should be driven to GND or left floating. If \overline{SD}_- is not driven to GND or floating, an increase in shutdown supply current will be noticed.

SINGLE-ENDED AUDIO AMPLIFIER CONFIGURATION

The LM4674 is compatible with single-ended sources. When configured for single-ended inputs, input capacitors must be used to block any DC component at the input of the device. Figure 3 shows the typical single-ended applications circuit.

AUDIO AMPLIFIER POWER SUPPLY BYPASSING/FILTERING

Proper power supply bypassing is critical for low noise performance and high PSRR. Place the supply bypass capacitor as close to the device as possible. Typical applications employ a voltage regulator with 10 μ F and 0.1 μ F bypass capacitors that increase supply stability. These capacitors do not eliminate the need for bypassing of the LM4674 supply pins. A 1 μ F capacitor is recommended.

AUDIO AMPLIFIER INPUT CAPACITOR SELECTION

Input capacitors may be required for some applications, or when the audio source is single-ended. Input capacitors block the DC component of the audio signal, eliminating any conflict between the DC component of the audio source and the bias voltage of the LM4674. The input capacitors create a high-pass filter with the input resistance R_i . The -3dB point of the high pass filter is found using Equation 1 below.

$$f = 1 / 2\pi R_i C_i \quad (1)$$

The values for R_i can be found in the EC table for each gain setting.

The input capacitors can also be used to remove low frequency content from the audio signal. Small speakers cannot reproduce, and may even be damaged by low frequencies. High pass filtering the audio signal helps protect the speakers. When the LM4674 is using a single-ended source, power supply noise on the ground is seen as an input signal. Setting the high-pass filter point above the power supply noise frequencies, 217 Hz in a GSM phone, for example, filters out the noise such that it is not amplified and heard on the output. Capacitors with a tolerance of 10% or better are recommended for impedance matching and improved CMRR and PSRR.

AUDIO AMPLIFIER GAIN SETTING

The LM4674 features four internally configured gain settings. The device gain is selected through the two logic inputs, G0 and G1. The gain settings are as shown in the following table.

LOGIC INPUT		GAIN	
G1	G0	V/V	dB
0	0	2	6
0	1	4	12
1	0	8	18
1	1	16	24

PCB LAYOUT GUIDELINES

As output power increases, interconnect resistance (PCB traces and wires) between the amplifier, load and power supply create a voltage drop. The voltage loss due to the traces between the LM4674 and the load results in lower output power and decreased efficiency. Higher trace resistance between the supply and the LM4674 has the same effect as a poorly regulated supply, increasing ripple on the supply line, and reducing peak output power. The effects of residual trace resistance increases as output current increases due to higher output power, decreased load impedance or both. To maintain the highest output voltage swing and corresponding peak output power, the PCB traces that connect the output pins to the load and the supply pins to the power supply should be as wide as possible to minimize trace resistance.

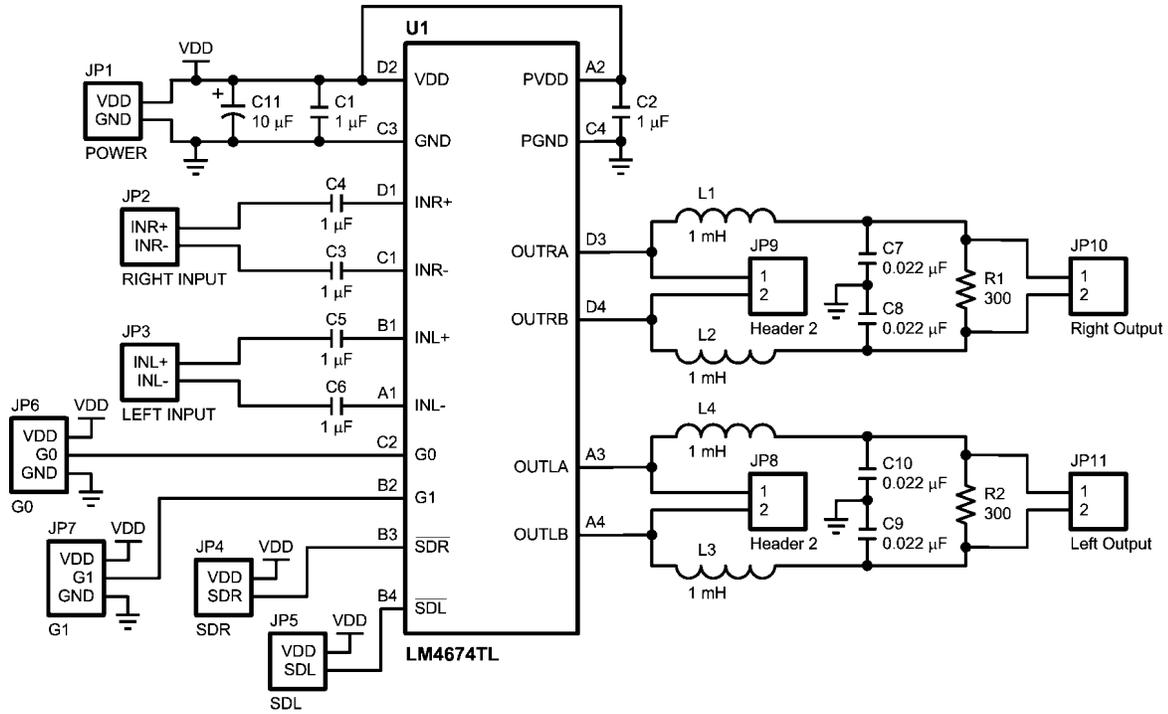
The use of power and ground planes will give the best THD +N performance. In addition to reducing trace resistance, the

use of power planes creates parasitic capacitors that help to filter the power supply line.

The inductive nature of the transducer load can also result in overshoot on one or both edges, clamped by the parasitic diodes to GND and VDD in each case. From an EMI standpoint, this is an aggressive waveform that can radiate or conduct to other components in the system and cause interference. It is essential to keep the power and output traces short and well shielded if possible. Use of ground planes beads and micro-strip layout techniques are all useful in preventing unwanted interference.

As the distance from the LM4674 and the speaker increases, the amount of EMI radiation increases due to the output wires or traces acting as antennas become more efficient with length. Ferrite chip inductors placed close to the LM4674 outputs may be needed to reduce EMI radiation.

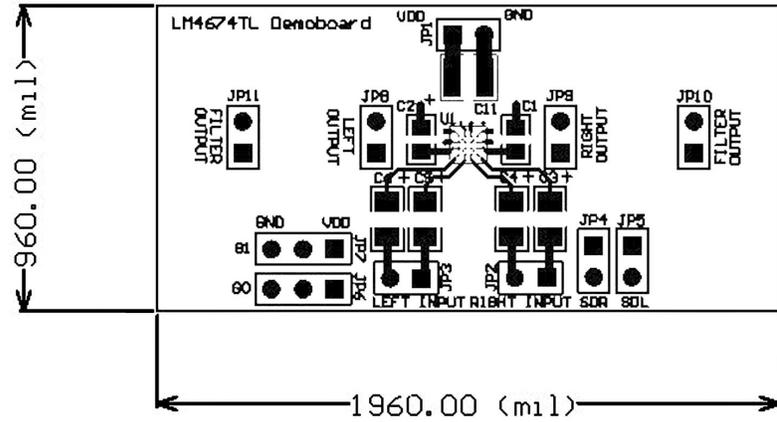
LM4674TL Demo Board Schematic



LM4674TL Demo Board Schematic

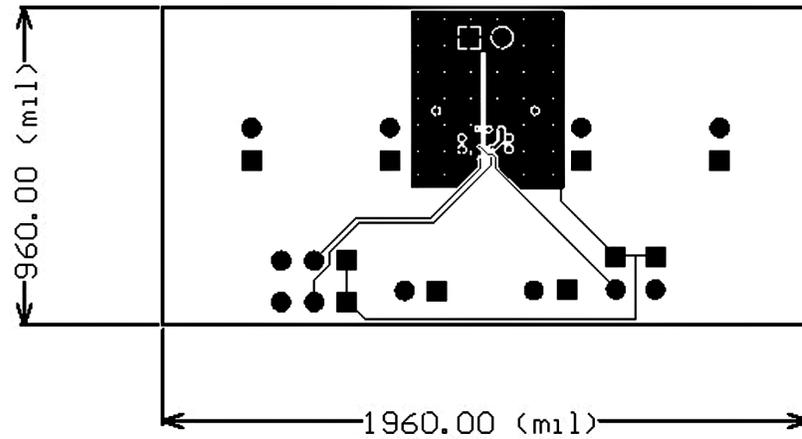
20167474

LM4674TL Demonstration Board Layout



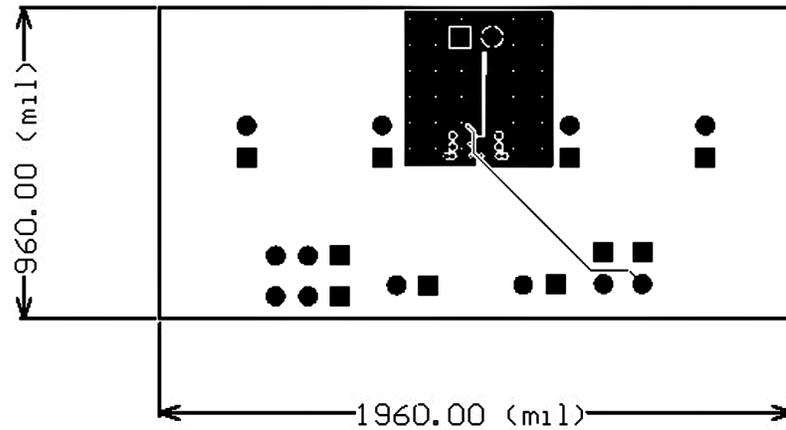
Layer 1

20167476



Layer 2

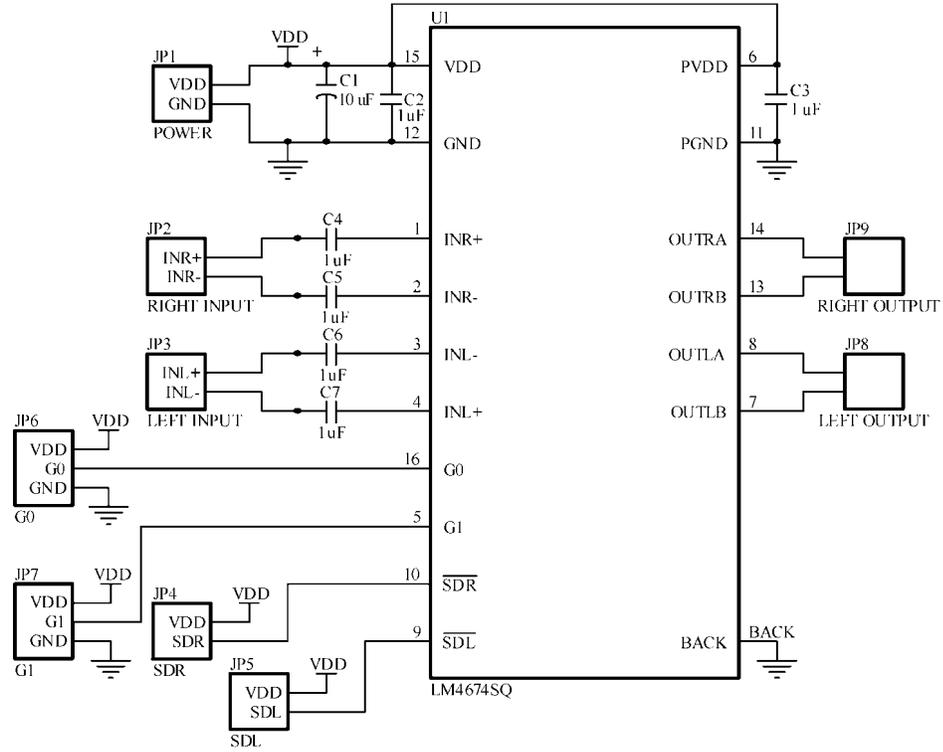
20167477



Layer 3

20167478

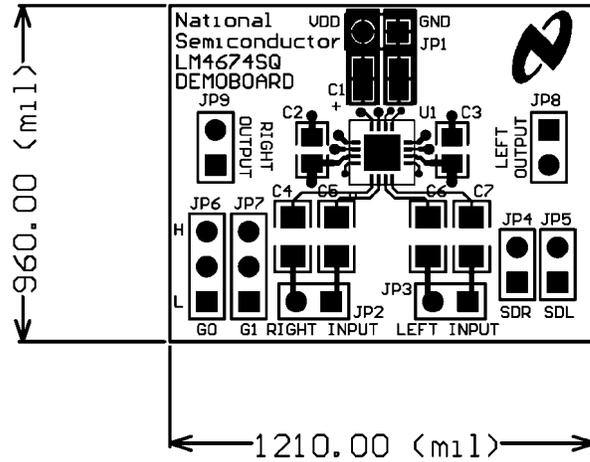
LM4674SQ Demo Board Schematic



LM4674SQ Demo Board Schematic

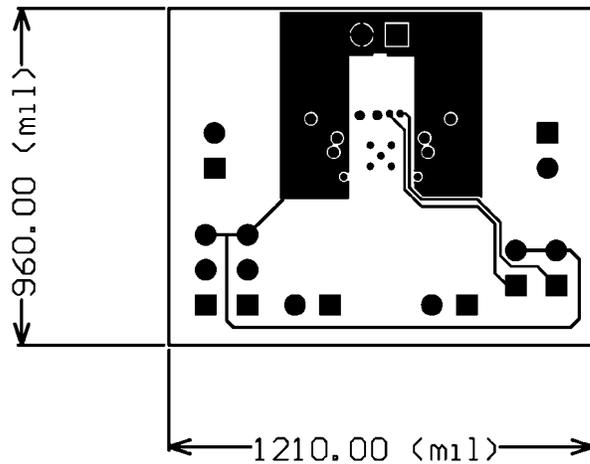
20167481

LM4674SQ Demonstration Board Layout



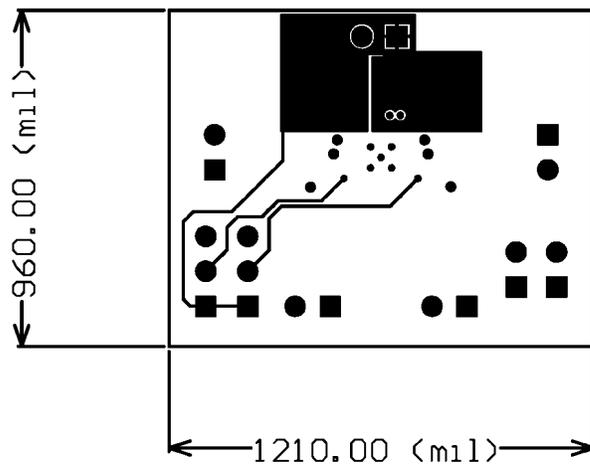
Layer 1

20167485



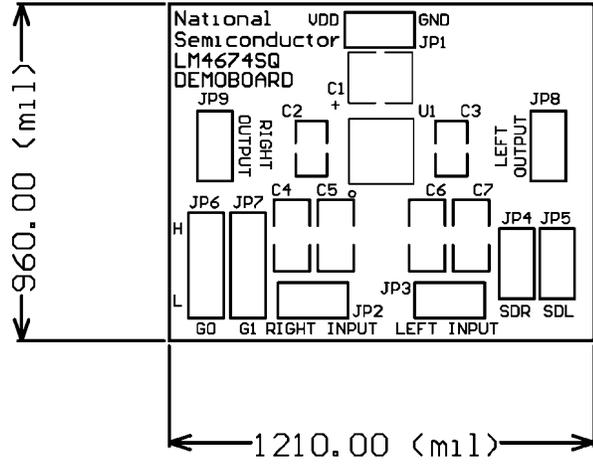
Layer 2

20167483



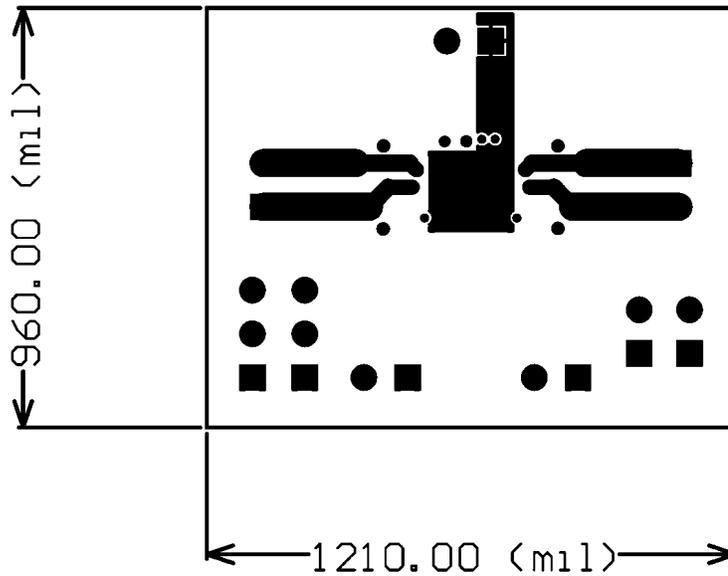
Layer 3

20167484



Top Silkscreen

20167486



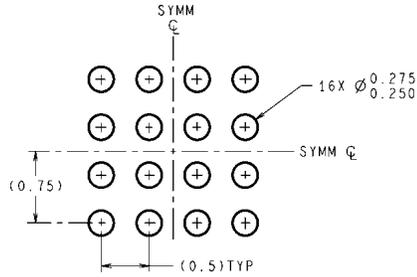
Bottom Layer

20167487

Revision Table

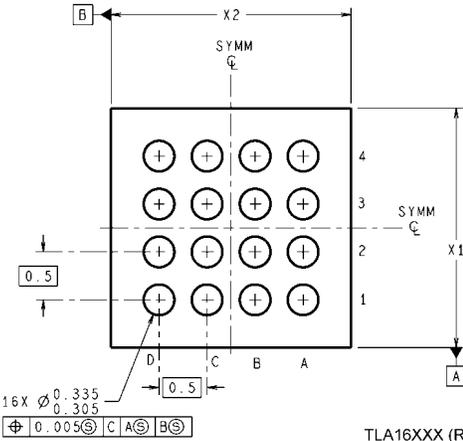
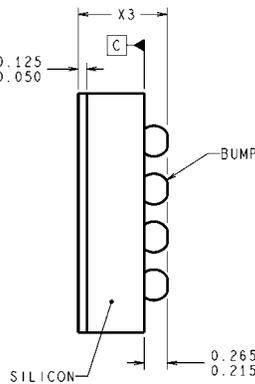
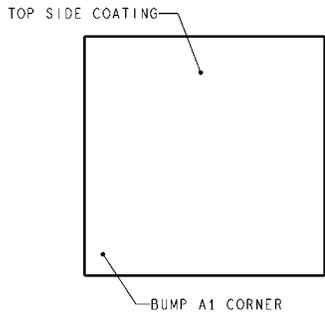
Rev	Date	Description
1.0	12/16/06	Initial release.
1.1	05/17/06	Added the LLP package.
1.2	05/31/06	Added the LLP markings.
1.3	09/05/06	Added "No Load" in the Conditions on Av (3.6V table).
1.4	09/21/06	Edited graphics (26, 38, 60) and input some text edits.
1.5	09/27/06	Edited Figure 1 (page 2), TL and LLP pkg/markings drawings (page 3). Input text edits.
1.6	07/13/07	Added the TL and SQ demo boards and schematics diagrams.
1.7	10/30/07	Updated the SQ schematic diagram and replaced the demo boards.
1.8	07/02/08	Text edits (under SHUTDOWN FUNCTION).

Physical Dimensions inches (millimeters) unless otherwise noted



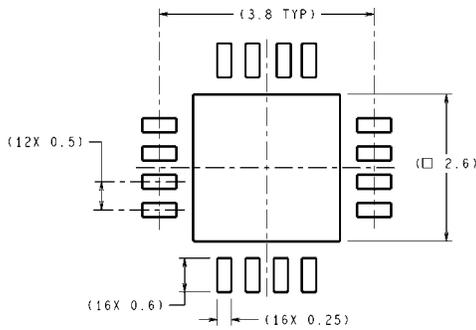
DIMENSIONS ARE IN MILLIMETERS
DIMENSIONS IN () FOR REFERENCE ONLY

LAND PATTERN RECOMMENDATION



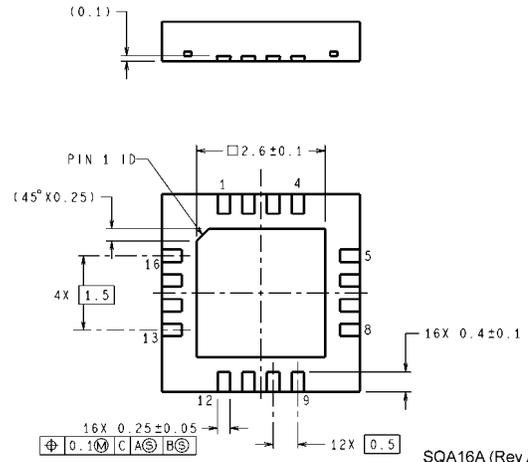
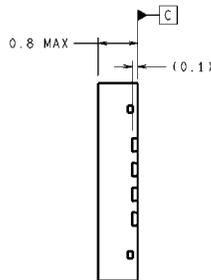
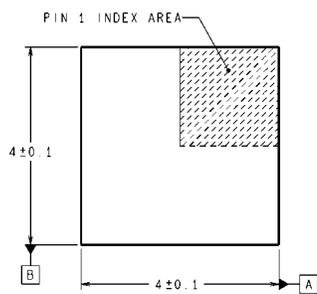
TLA16XXX (Rev C)

16 Bump micro SMD
Order Number LM4674TL
NS Package Number TLA1611A
X1 = 2mm X2 = 2mm X3 = 0.6mm



DIMENSIONS ARE IN MILLIMETERS
DIMENSIONS IN () FOR REFERENCE ONLY

RECOMMENDED LAND PATTERN



SQA16A (Rev A)

LLP Package
Order Number LM4674SQ
NS Package Number SQA16A

Notes

LM4674

Notes

For more National Semiconductor product information and proven design tools, visit the following Web sites at:

Products		Design Support	
Amplifiers	www.national.com/amplifiers	WEBENCH	www.national.com/webench
Audio	www.national.com/audio	Analog University	www.national.com/AU
Clock Conditioners	www.national.com/timing	App Notes	www.national.com/appnotes
Data Converters	www.national.com/adc	Distributors	www.national.com/contacts
Displays	www.national.com/displays	Green Compliance	www.national.com/quality/green
Ethernet	www.national.com/ethernet	Packaging	www.national.com/packaging
Interface	www.national.com/interface	Quality and Reliability	www.national.com/quality
LVDS	www.national.com/lvds	Reference Designs	www.national.com/refdesigns
Power Management	www.national.com/power	Feedback	www.national.com/feedback
Switching Regulators	www.national.com/switchers		
LDOs	www.national.com/lido		
LED Lighting	www.national.com/led		
PowerWise	www.national.com/powerwise		
Serial Digital Interface (SDI)	www.national.com/sdi		
Temperature Sensors	www.national.com/tempsensors		
Wireless (PLL/VCO)	www.national.com/wireless		

THE CONTENTS OF THIS DOCUMENT ARE PROVIDED IN CONNECTION WITH NATIONAL SEMICONDUCTOR CORPORATION ("NATIONAL") PRODUCTS. NATIONAL MAKES NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE ACCURACY OR COMPLETENESS OF THE CONTENTS OF THIS PUBLICATION AND RESERVES THE RIGHT TO MAKE CHANGES TO SPECIFICATIONS AND PRODUCT DESCRIPTIONS AT ANY TIME WITHOUT NOTICE. NO LICENSE, WHETHER EXPRESS, IMPLIED, ARISING BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT.

TESTING AND OTHER QUALITY CONTROLS ARE USED TO THE EXTENT NATIONAL DEEMS NECESSARY TO SUPPORT NATIONAL'S PRODUCT WARRANTY. EXCEPT WHERE MANDATED BY GOVERNMENT REQUIREMENTS, TESTING OF ALL PARAMETERS OF EACH PRODUCT IS NOT NECESSARILY PERFORMED. NATIONAL ASSUMES NO LIABILITY FOR APPLICATIONS ASSISTANCE OR BUYER PRODUCT DESIGN. BUYERS ARE RESPONSIBLE FOR THEIR PRODUCTS AND APPLICATIONS USING NATIONAL COMPONENTS. PRIOR TO USING OR DISTRIBUTING ANY PRODUCTS THAT INCLUDE NATIONAL COMPONENTS, BUYERS SHOULD PROVIDE ADEQUATE DESIGN, TESTING AND OPERATING SAFEGUARDS.

EXCEPT AS PROVIDED IN NATIONAL'S TERMS AND CONDITIONS OF SALE FOR SUCH PRODUCTS, NATIONAL ASSUMES NO LIABILITY WHATSOEVER, AND NATIONAL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY RELATING TO THE SALE AND/OR USE OF NATIONAL PRODUCTS INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS PRIOR WRITTEN APPROVAL OF THE CHIEF EXECUTIVE OFFICER AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

Life support devices or systems are devices which (a) are intended for surgical implant into the body, or (b) support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in a significant injury to the user. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system or to affect its safety or effectiveness.

National Semiconductor and the National Semiconductor logo are registered trademarks of National Semiconductor Corporation. All other brand or product names may be trademarks or registered trademarks of their respective holders.

Copyright© 2008 National Semiconductor Corporation

For the most current product information visit us at www.national.com



National Semiconductor Americas Technical Support Center
 Email: support@nsc.com
 Tel: 1-800-272-9959

National Semiconductor Europe Technical Support Center
 Email: europe.support@nsc.com
 German Tel: +49 (0) 180 5010 771
 English Tel: +44 (0) 870 850 4288

National Semiconductor Asia Pacific Technical Support Center
 Email: ap.support@nsc.com

National Semiconductor Japan Technical Support Center
 Email: jpn.feedback@nsc.com