

LM4674A Boomer® Audio Power Amplifier Series Filterless 2.5W Stereo Class D Audio Power Amplifier

Check for Samples: [LM4674A](#)

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 DSBGA Package

APPLICATIONS

- Mobile Phones
- PDAs
- Laptops

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 $V_{DD} = 5V$, $R_L = 4\Omega$, THD $\leq 10\%$ 2.5W (typ)
- Power Output at $V_{DD} = 5V$, $R_L = 8\Omega$, THD $\leq 10\%$ 1.5W (typ)
- Shutdown Current 0.1μA (typ)

DESCRIPTION

The LM4674A 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 LM4674A 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 LM4674A 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 $P_O = 500mW$. Four gain options are pin selectable through the GAIN0 and GAIN1 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 controls maximizes power savings in mixed mono/stereo applications.



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Typical Application

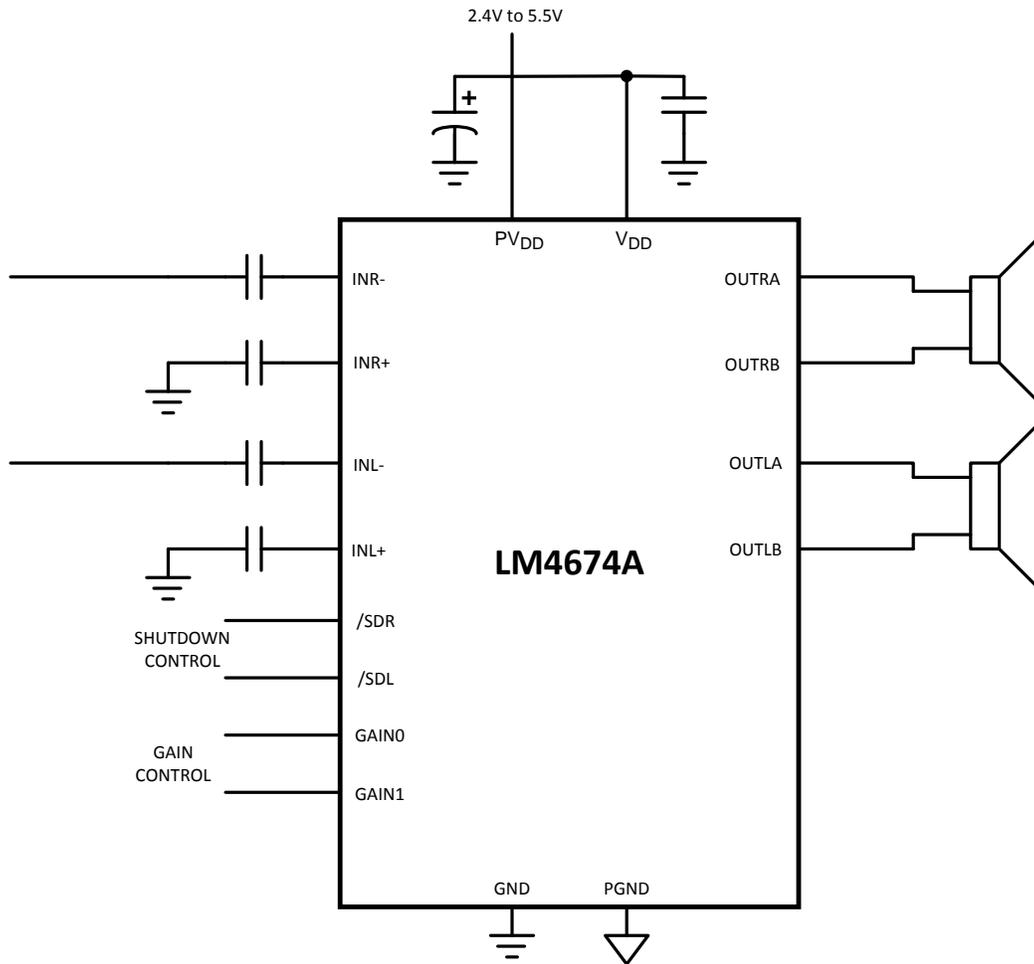


Figure 1. Typical Audio Amplifier Application Circuit

Connection Diagram

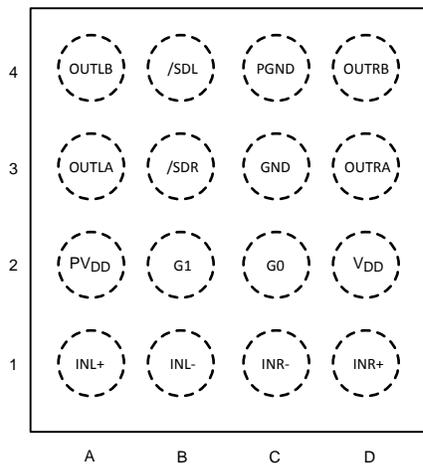


Figure 2. DSBGA - Top View
See YZR0016 Package



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 ⁽¹⁾ | | 6.0V |
| Storage Temperature | | –65°C to +150°C |
| Input Voltage | | –0.3V to $V_{DD} + 0.3V$ |
| Power Dissipation ⁽⁴⁾ | | Internally Limited |
| ESD Susceptibility, all other pins ⁽⁵⁾ | | 2000V |
| ESD Susceptibility ⁽⁶⁾ | | 200V |
| Junction Temperature (T_{JMAX}) | | 150°C |
| Thermal Resistance | θ_{JA} | 45.7°C/W |

- (1) All voltages are measured with respect to the ground 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 TI Sales Office/ Distributors for availability and specifications.
- (4) 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 LM4674A see [power derating](#) currents for more information.
- (5) Human body model, 100pF discharged through a 1.5k Ω resistor.
- (6) Machine Model, 220pF–240pF discharged through all pins.

Operating Ratings⁽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 |

- (1) All voltages are measured with respect to the ground 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.

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

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 | LM4674A | | Units (Limits) |
|------------|------------------------------------|--|------------------------|----------------------|----------------|
| | | | Typical ⁽³⁾ | Limit ⁽⁴⁾ | |
| 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 | $V_{SD1} = V_{SD2} = GND$ | 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 | $V_{SHUTDOWN} = 0.4V$ | 4.2 | | ms |
| A_V | Gain | $GAIN_0, GAIN_1 = GND$ | 6 | 6 ± 0.5 | dB |
| | | $GAIN_0 = V_{DD}, GAIN_1 = GND$ | 12 | 12 ± 0.5 | dB |
| | | $GAIN_0 = GND, GAIN_1 = V_{DD}$ | 18 | 18 ± 0.5 | dB |
| | | $GAIN_0, GAIN_1 = V_{DD}$ | 24 | 24 ± 0.5 | dB |
| R_{IN} | Input Resistance | $A_V = 6dB$ | 28 | | k Ω |
| | | $A_V = 12dB$ | 18.75 | | k Ω |
| | | $A_V = 18dB$ | 11.25 | | k Ω |
| | | $A_V = 24dB$ | 6.25 | | k Ω |
| P_O | Output Power | $R_L = 15\mu H + 4\Omega + 15\mu H$, 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 |
| | | $R_L = 15\mu H + 8\Omega + 15\mu H$, 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 |
| | | $R_L = 15\mu H + 4\Omega + 15\mu H$, 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 |
| | | $R_L = 15\mu H + 8\Omega + 15\mu H$, 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 | $P_O = 500mW$, $f = 1kHz$, $R_L = 8\Omega$ | 0.07 | | % |
| | | $P_O = 300mW$, $f = 1kHz$, $R_L = 8\Omega$ | 0.05 | | % |

(1) All voltages are measured with respect to the ground 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) Typicals are measured at $25^\circ C$ and represent the parametric norm.

(4) Limits are specified to TI's AOQL (Average Outgoing Quality Level).

Electrical Characteristics $V_{DD} = 3.6V^{(1)(2)}$ (continued)

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 | LM4674A | | Units (Limits) |
|-----------------|------------------------------|--|------------------------|----------------------|----------------|
| | | | Typical ⁽³⁾ | Limit ⁽⁴⁾ | |
| PSRR | Power Supply Rejection Ratio | $V_{RIPPLE} = 200mV_{P-P}$ Sine, $f_{RIPPLE} = 217Hz$, Inputs AC GND, $C_I = 1\mu F$, input referred | 75 | | dB |
| | | $V_{RIPPLE} = 1V_{P-P}$ Sine, $f_{RIPPLE} = 1kHz$, Inputs AC GND, $C_I = 1\mu F$, input referred | 75 | | dB |
| CMRR | Common Mode Rejection Ratio | $V_{RIPPLE} = 1V_{P-P}$ $f_{RIPPLE} = 217Hz$ | 67 | | dB |
| η | Efficiency | $P_O = 1W$, $f = 1kHz$, $R_L = 8\Omega$, $V_{DD} = 5V$ | 85 | | % |
| | 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 |

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. |

Block Diagrams

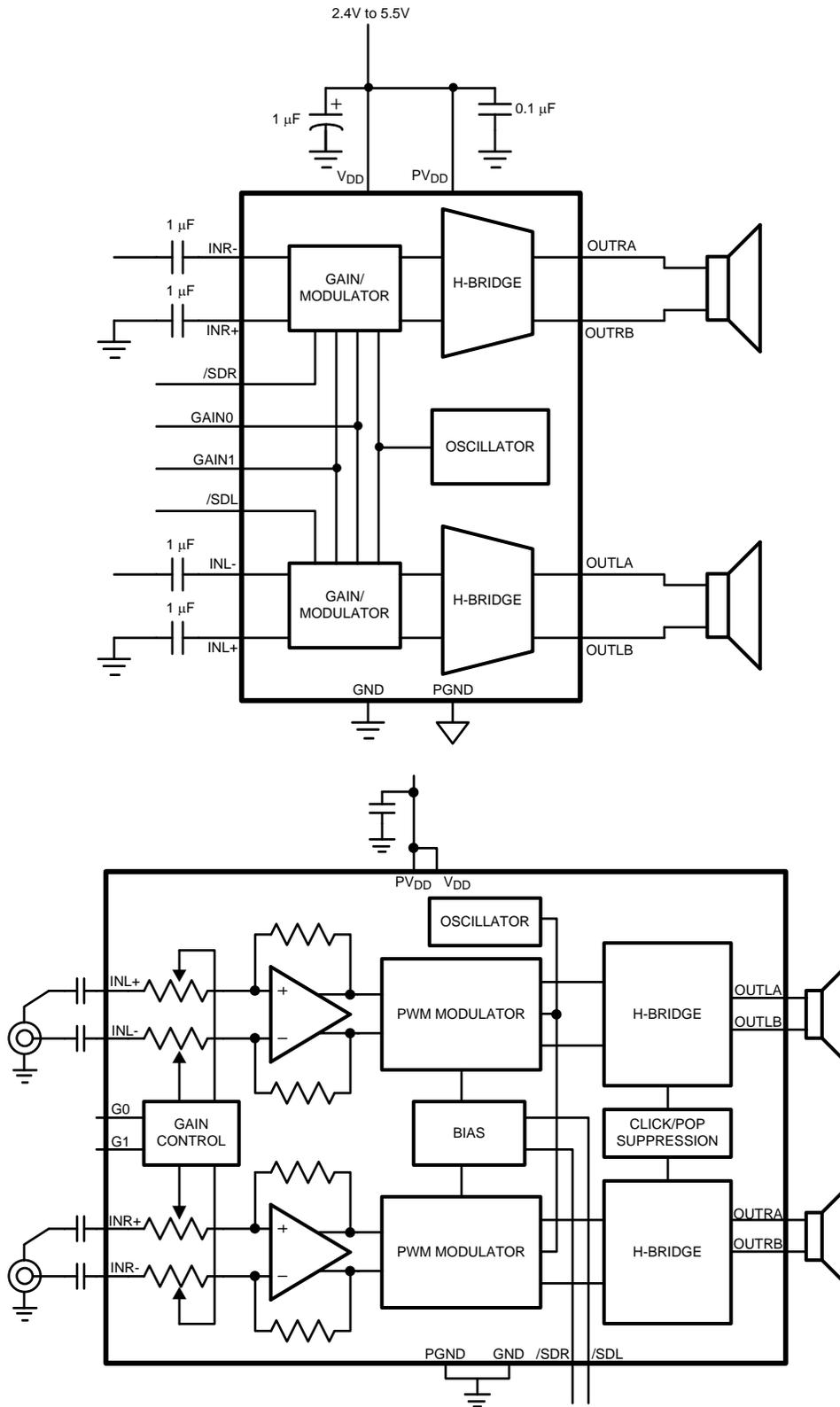


Figure 3. Differential Input Configuration

Typical Performance Characteristics

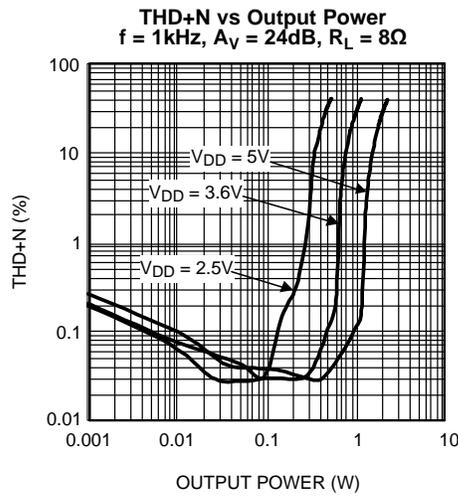


Figure 4.

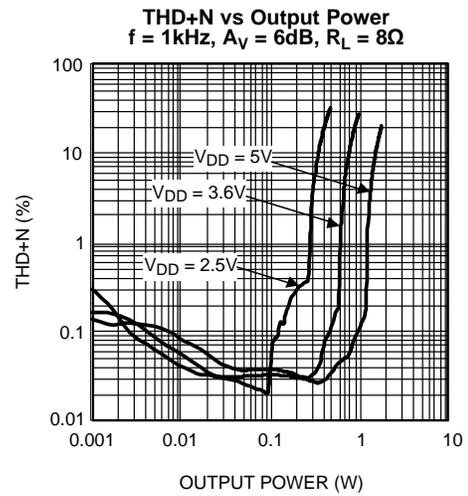


Figure 5.

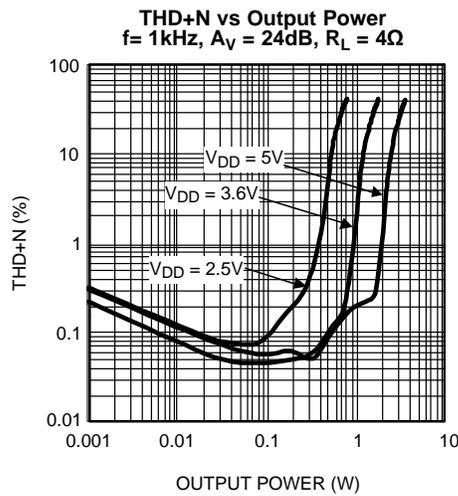


Figure 6.

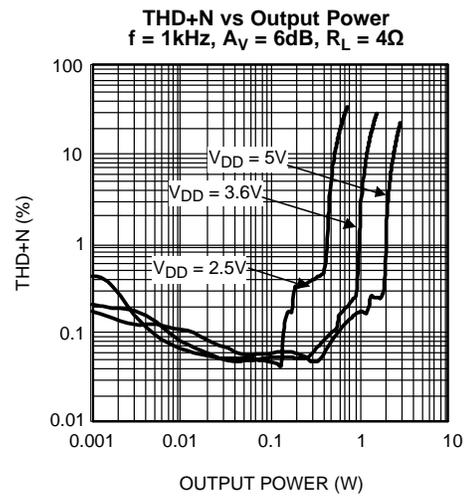


Figure 7.

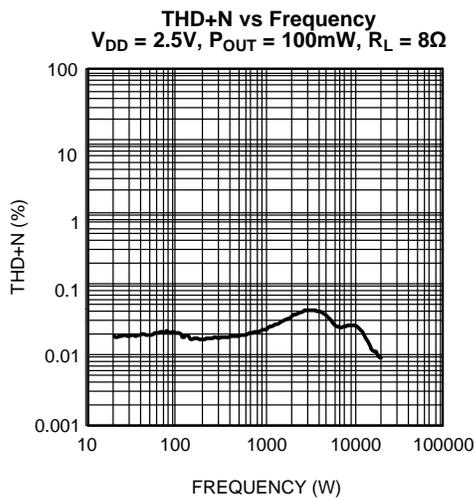


Figure 8.

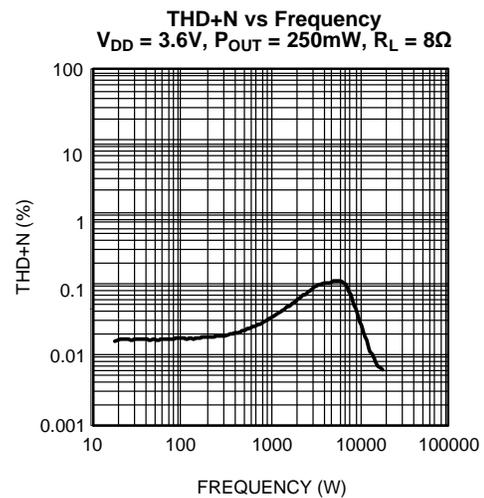


Figure 9.

Typical Performance Characteristics (continued)

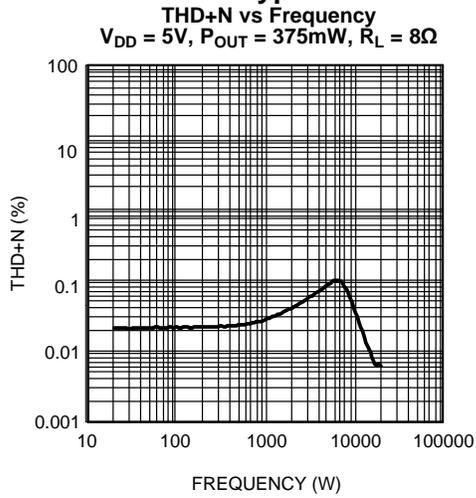


Figure 10.

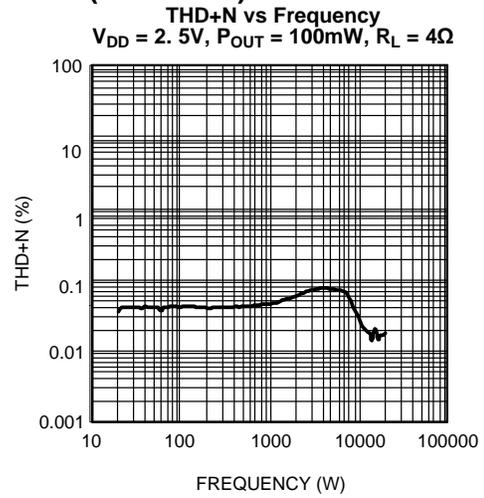


Figure 11.

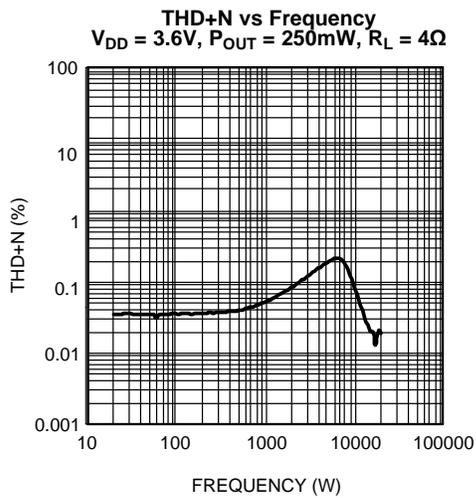


Figure 12.

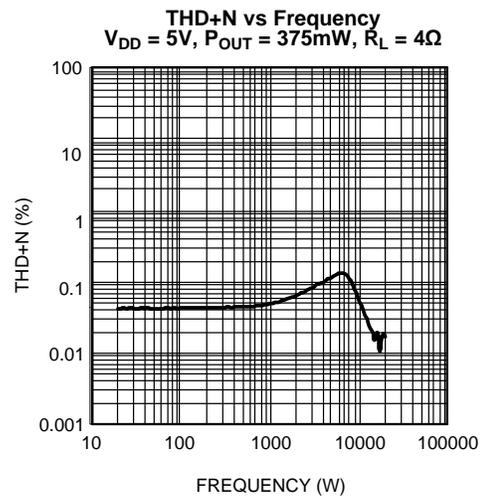


Figure 13.

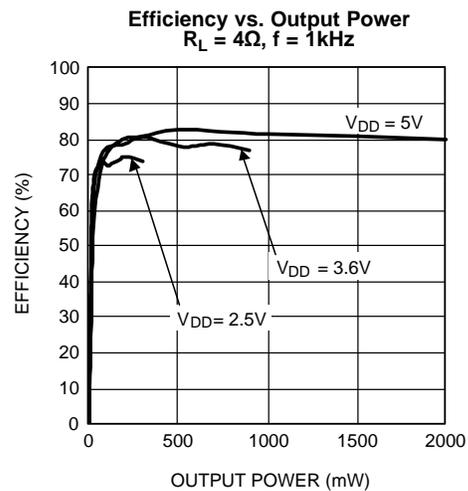


Figure 14.

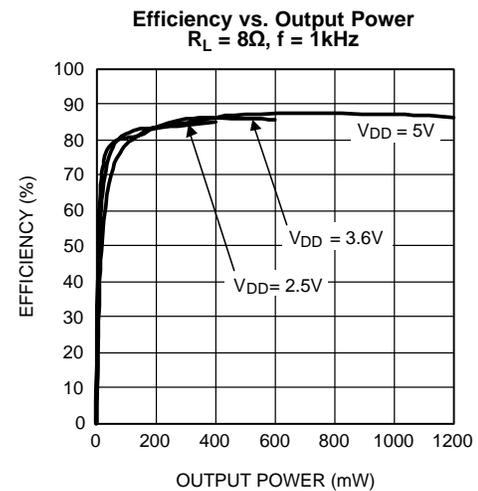


Figure 15.

Typical Performance Characteristics (continued)

Power Dissipation vs. Output Power
 $R_L = 4\Omega, f = 1\text{kHz}$

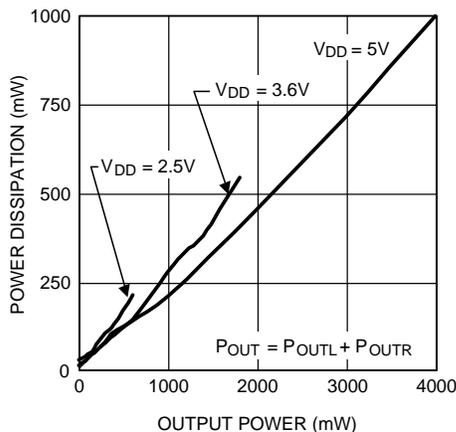


Figure 16.

Power Dissipation vs. Output Power
 $R_L = 8\Omega, f = 1\text{kHz}$

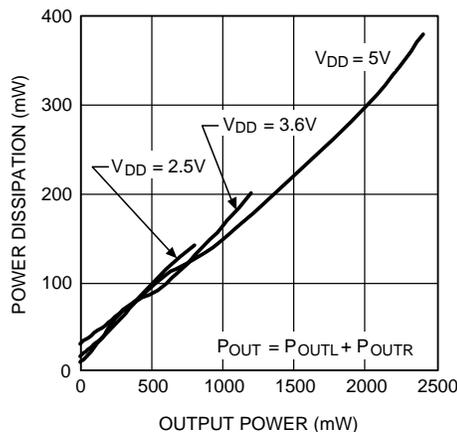


Figure 17.

Output Power vs. Supply Voltage
 $R_L = 4\Omega, f = 1\text{kHz}$

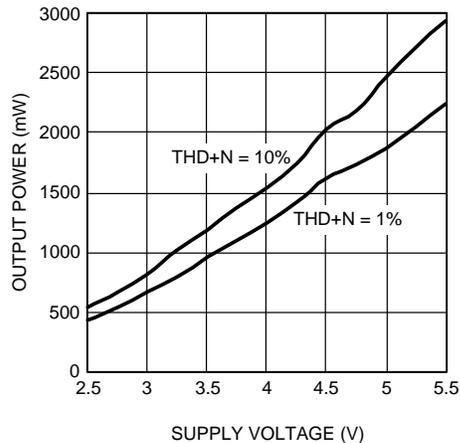


Figure 18.

Output Power vs. Supply Voltage
 $R_L = 8\Omega, f = 1\text{kHz}$

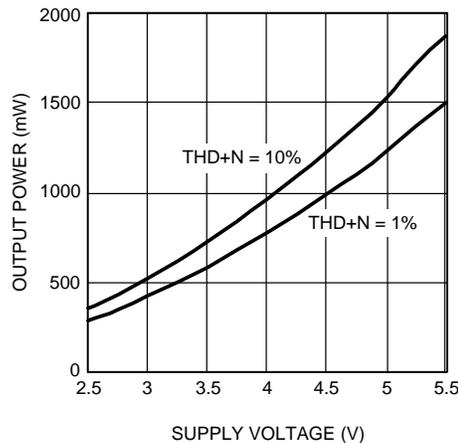


Figure 19.

PSRR vs. Frequency
 $V_{DD} = 3.6\text{V}, V_{RIPPLE} = 200\text{mV}_{P-P}, R_L = 8\Omega$

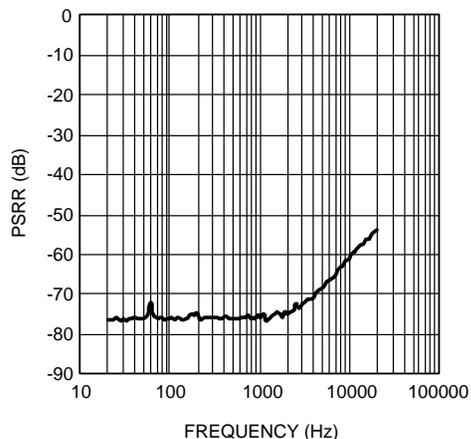


Figure 20.

Crosstalk vs. Frequency
 $V_{DD} = 3.6\text{V}, V_{RIPPLE} = 1\text{V}_{P-P}, R_L = 8\Omega$

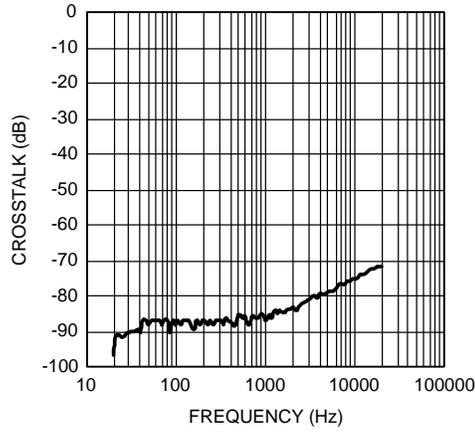


Figure 21.

Typical Performance Characteristics (continued)

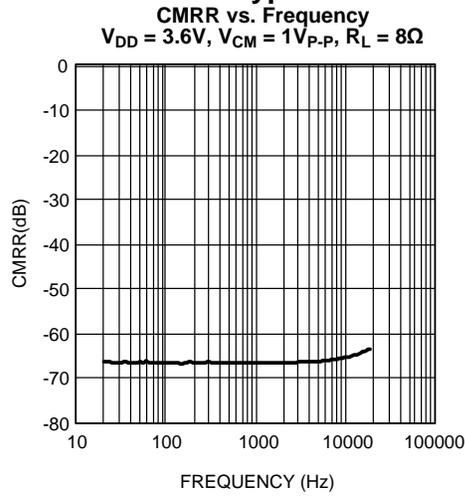


Figure 22.

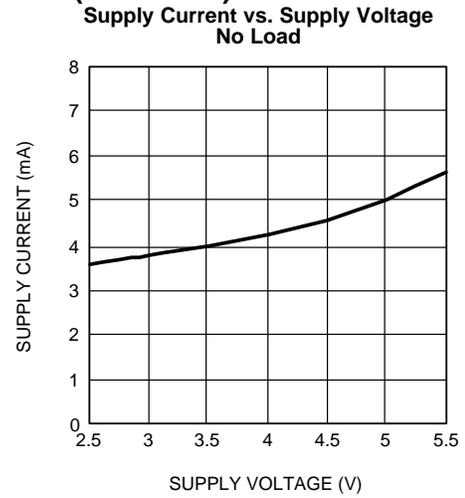


Figure 23.

APPLICATION INFORMATION

GENERAL AMPLIFIER FUNCTION

The LM4674A 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 (OUT_A and OUT_B) 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 LM4674A outputs changes. For increasing output voltage, the duty cycle of OUT_A increases, while the duty cycle of OUT_B decreases. 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 LM4674A 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 LM4674A 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. The efficiency of the LM4674A 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, along with switching losses due to gate charge.

SHUTDOWN FUNCTION

The LM4674A features independent left and right channel shutdown controls, allowing each channel to be disabled independently. /SDR controls the right channel, while /SDL controls the left channel. Driving either low disables the corresponding channel, reducing supply current to 0.03 μ A.

It is best to switch between ground and V_{DD} for minimum current consumption while in shutdown. The LM4674A 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. Increased THD+N may also be observed when a voltage of less than V_{DD} is applied to /SD_ for logic levels between GND and V_{DD} . Bypass /SD_ with a 0.1 μ F capacitor.

The LM4674A shutdown inputs have internal pulldown resistors. The purpose of these resistors is to eliminate any unwanted state changes when /SD_ is floating. To minimize shutdown current, /SD_ should be driven to GND or left floating. If /SD_ is not driven to GND or floating, an increase in shutdown supply current will be noticed.

SINGLE-ENDED AUDIO AMPLIFIER CONFIGURATION

The LM4674A is compatible with single-ended sources. When configured for single-ended inputs, input capacitors must be used to block and DC component at the input of the device. [Figure 25](#) 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 LM4674A 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 LM4674A. The input capacitors create a high-pass filter with the input resistors R_I . The -3dB point of the high pass filter is found using [Equation 1](#) below.

$$f = 1 / 2\pi R_{IN} C_{IN} \quad (1)$$

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 LM4674A 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, 217Hz 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 LM4674A features four internally configured gain settings. The device gain is selected through the two logic inputs, G_0 and G_1 . The gain settings are as shown in the following table.

| G1 | G0 | GAIN | |
|----|----|------|----|
| | | 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 LM4674A and the load results in lower output power and decreased efficiency. Higher trace resistance between the supply and the LM4674A 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 of 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 LM4674A 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 LM4674A outputs may be needed to reduce EMI radiation.

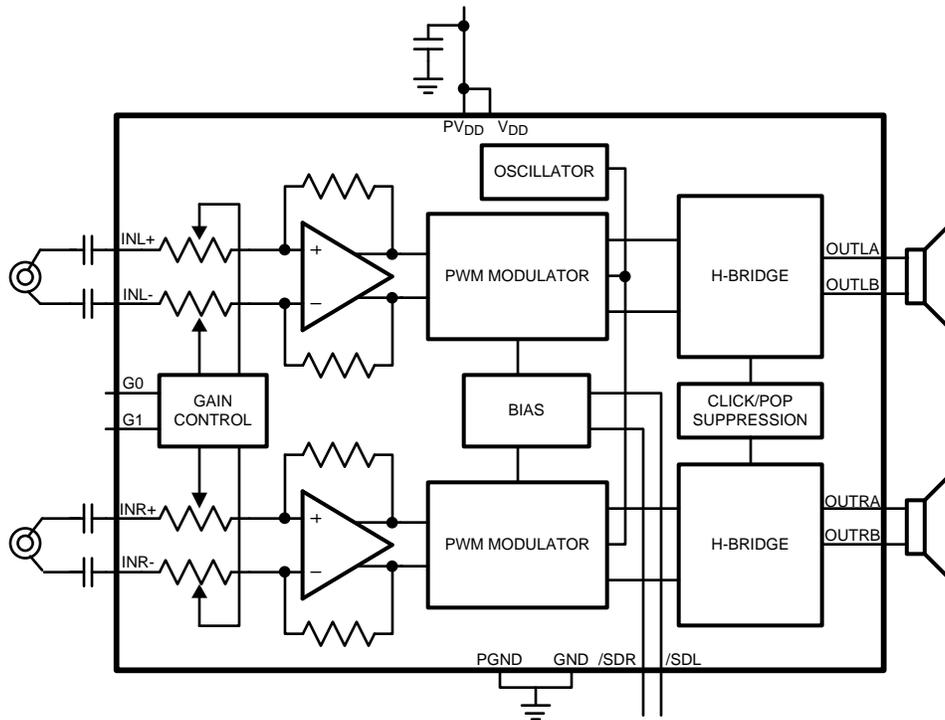


Figure 24. Differential Input Configuration

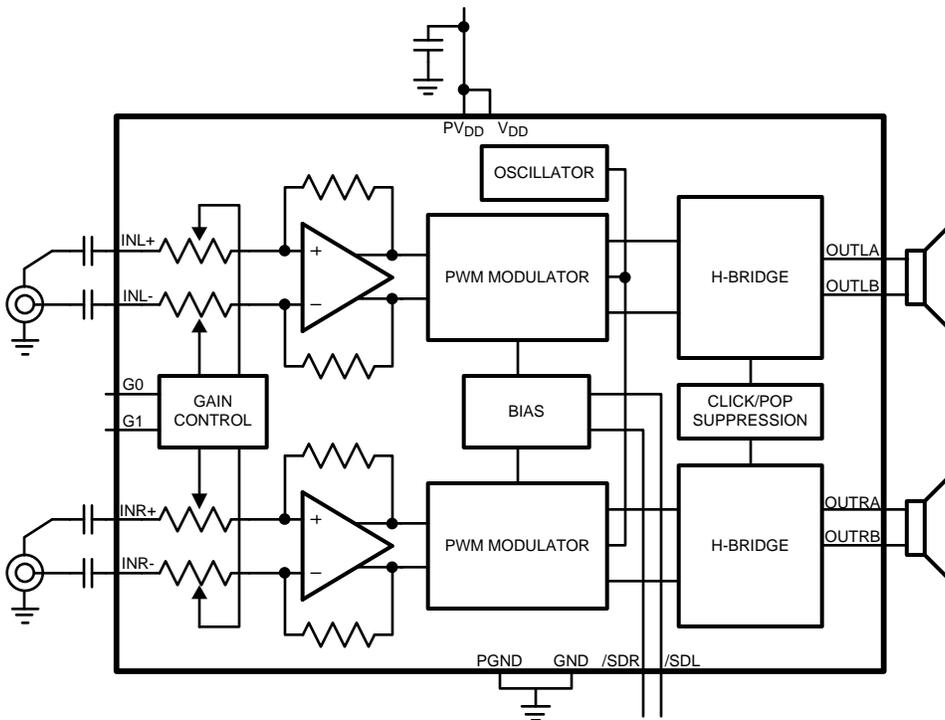


Figure 25. Single-Ended Input Configuration

REVISION HISTORY

| Rev | Date | Description |
|-----|---------|----------------------|
| 1.0 | 9/13/06 | Initial WEB release. |

Changes from Original (May 2013) to Revision A **Page**

- Changed layout of National Data Sheet to TI format [13](#)

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|--------------------|------|----------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|----------------|
| LM4674ATL/NOPB | ACTIVE | DSBGA | YZR | 16 | 250 | RoHS & Green | SNAGCU | Level-1-260C-UNLIM | -40 to 85 | GI2 | Samples |
| LM4674ATLX/NOPB | ACTIVE | DSBGA | YZR | 16 | 3000 | RoHS & Green | SNAGCU | Level-1-260C-UNLIM | -40 to 85 | GI2 | Samples |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

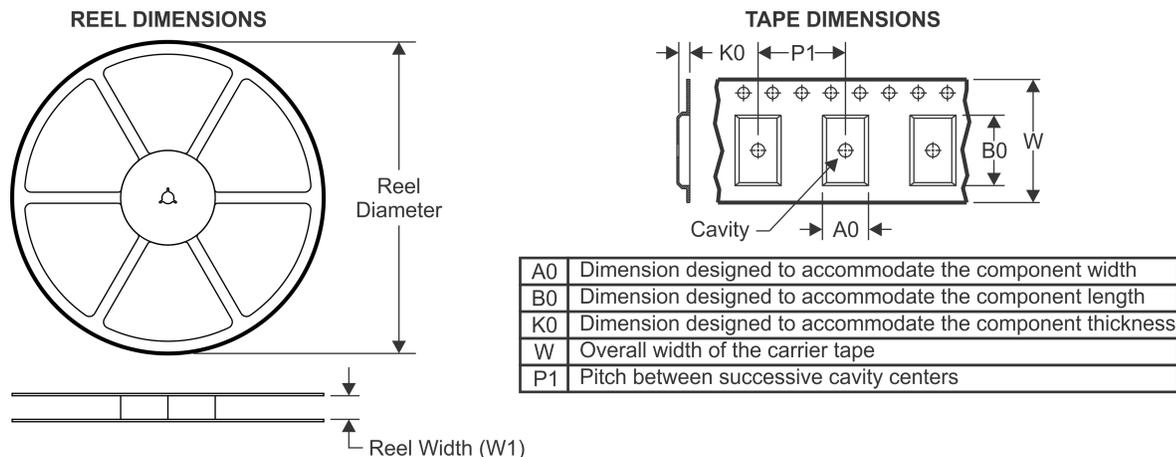
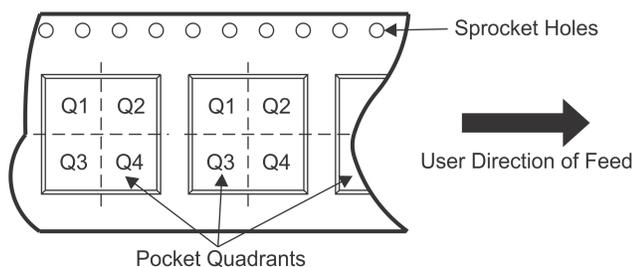
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

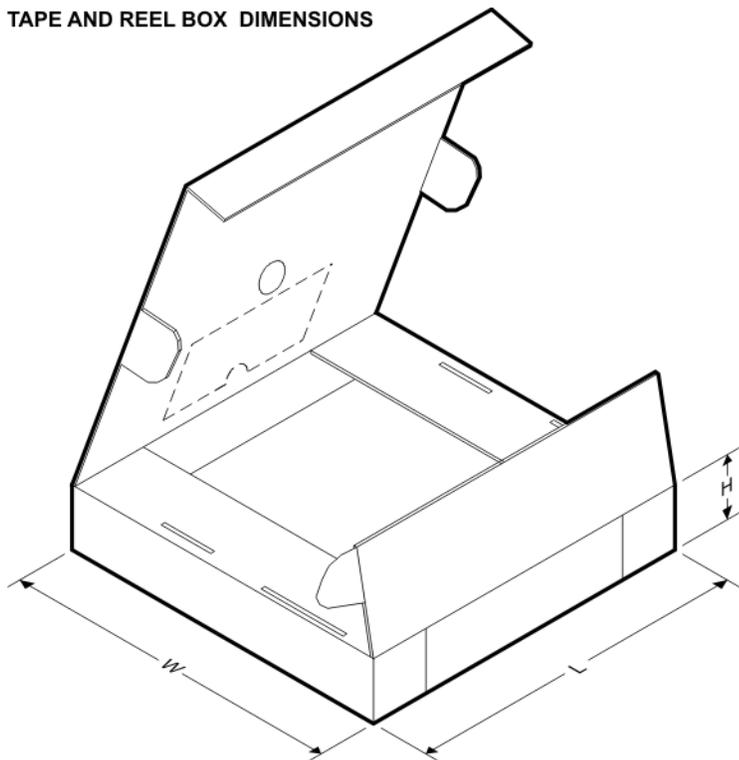
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TAPE AND REEL INFORMATION

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE


*All dimensions are nominal

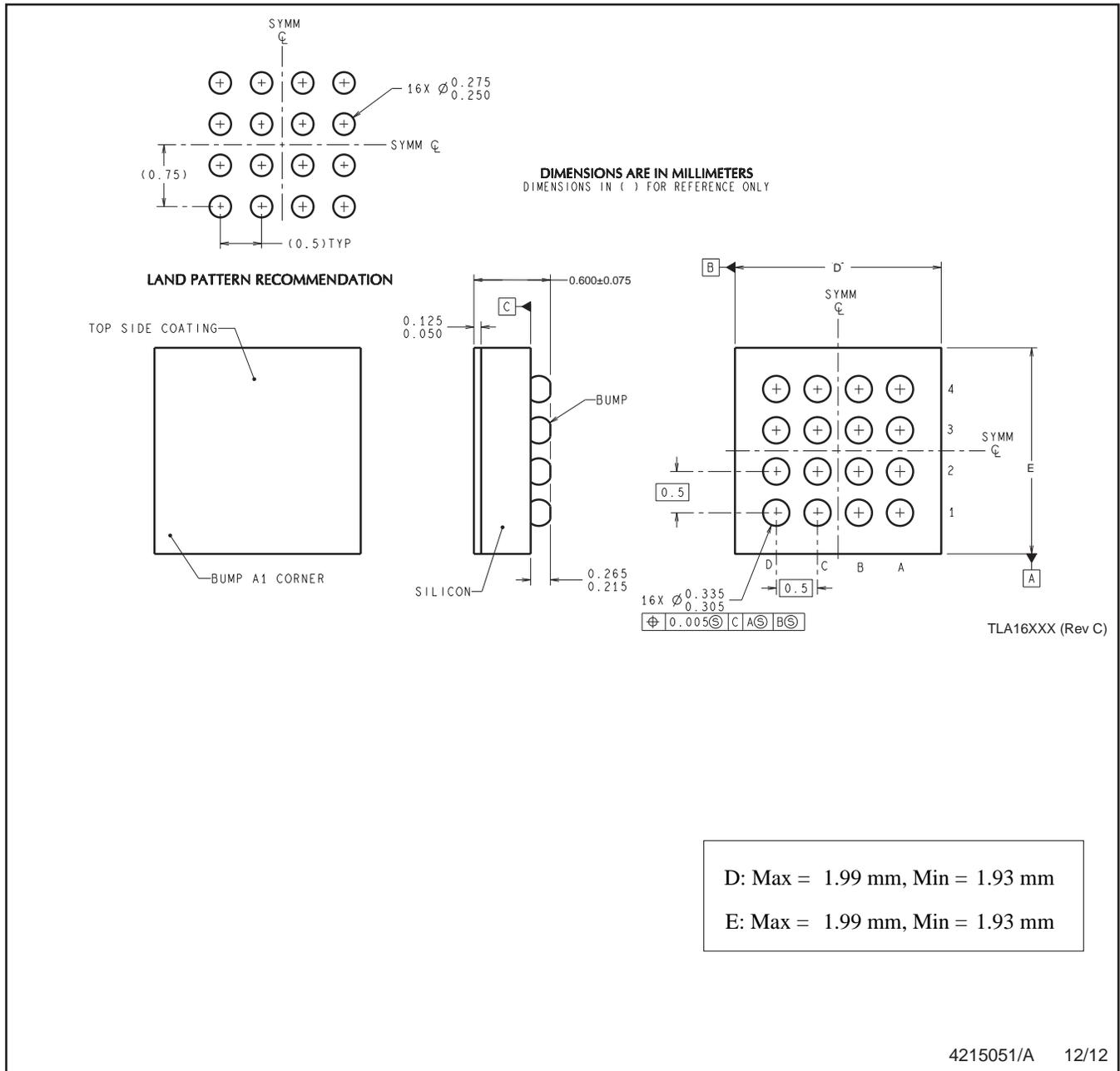
| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LM4674ATL/NOPB | DSBGA | YZR | 16 | 250 | 178.0 | 8.4 | 2.08 | 2.08 | 0.76 | 4.0 | 8.0 | Q1 |
| LM4674ATLX/NOPB | DSBGA | YZR | 16 | 3000 | 178.0 | 8.4 | 2.08 | 2.08 | 0.76 | 4.0 | 8.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|-----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LM4674ATL/NOPB | DSBGA | YZR | 16 | 250 | 208.0 | 191.0 | 35.0 |
| LM4674ATLX/NOPB | DSBGA | YZR | 16 | 3000 | 208.0 | 191.0 | 35.0 |

YZR0016



NOTES: A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
 B. This drawing is subject to change without notice.

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