LM4670 Boomer™ Audio Power Amplifier Series Filterless High Efficiency 3W Switching Audio Amplifier

Check for Samples: LM4670

FEATURES

- **No Output Filter Required for Inductive Loads**
- **Externally Configurable Gain**
- **Very Fast Turn on Time: 1.35ms (Typ)**
- **Minimum External Components**
- **"Click and Pop" Suppression Circuitry**
- **Micro-Power Shutdown Mode**
- **Short Circuit Protection**
- **Available in Space-Saving DSBGA and WSON Packages**

APPLICATIONS

- **Mobile Phones**
- **PDAs**
- **Portable Electronic Devices**

KEY SPECIFICATIONS

- **Efficiency at 3.6V, 100mW into 8Ω Speaker, 77% (Typ)**
- **Efficiency at 3.6V, 600mW into 8Ω Speaker, 88% (Typ)**
- **Efficiency at 5V, 1W into 8Ω Speaker, 87% (Typ)**
- **Quiescent Current, 3.6V Supply, 4.8mA (Typ)**
- **Total Shutdown Power Supply Current, 0.01µA (Typ)**
- **Single Supply Range, 2.4 to 5.5V**

DESCRIPTION

The LM4670 is a fully integrated single-supply high efficiency switching audio amplifier. It features an innovative modulator that eliminates the LC output filter used with typical switching amplifiers. Eliminating the output filter reduces external component count, simplifies circuit design, and reduces board area. The LM4670 processes analog inputs with a delta-sigma modulation technique that lowers output noise and THD when compared to conventional pulse width modulators.

The LM4670 is designed to meet the demands of mobile phones and other portable communication devices. Operating on a single 5V supply, it is capable of driving a 4Ω speaker load at a continuous average output of 2.3W with less than 1% THD+N. Its flexible power supply requirements allow operation from 2.4V to 5.5V.

The LM4670 has high efficiency with speaker loads compared to a typical Class AB amplifier. With a 3.6V supply driving an 8Ω speaker, the IC's efficiency for a 100mW power level is 77%, reaching 88% at 600mW output power.

The LM4670 features a low-power consumption shutdown mode. Shutdown may be enabled by driving the Shutdown pin to a logic low (GND).

The gain of the LM4670 is externally configurable which allows independent gain control from multiple sources by summing the signals.

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Typical Application

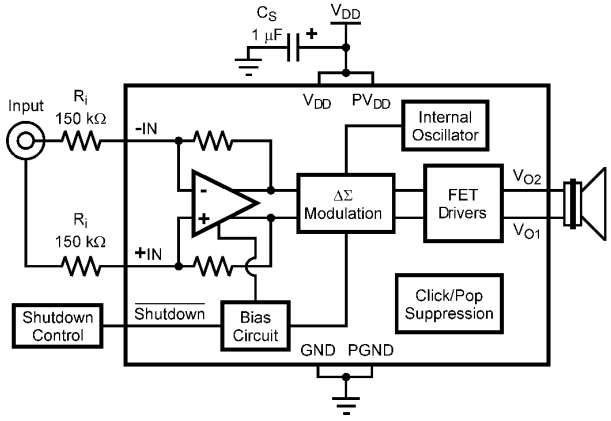

Figure 1. Typical Audio Amplifier Application Circuit

Connection Diagram

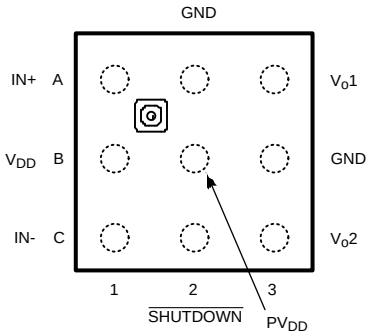

Figure 2. 9 Bump DSBGA Package
Top View
See Package Number YZR0009

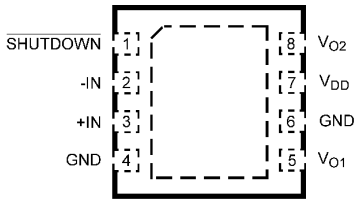

Figure 3. WSON Package
Top View
See Package Number NGQ0008A

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.

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Absolute Maximum Ratings(1)(2)

Supply Voltage(1)		6.0V
Storage Temperature		−65°C to +150°C
Voltage at Any Input Pin		V_{DD} + 0.3V ≥ V ≥ GND - 0.3V
Power Dissipation(3)		Internally Limited
ESD Susceptibility(4)		2.0kV
ESD Susceptibility(5)		200V
Junction Temperature (T_{JMAX})		150°C
Thermal Resistance	θ_{JA} (DSBGA)	220°C/W
	θ_{JA} (WSON)	73°C/W
Soldering Information		
See AN-1112 (SNVA009) "DSBGA Wafers Level Chip Scale Package."		

(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) 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 LM4670, T_{JMAX} = 150°C. The typical θ_{JA} is 220°C/W for the DSBGA package and 64°C/W for the WSON package.
(4) Human body model, 100pF discharged through a 1.5kΩ resistor.
(5) Machine Model, 220pF – 240pF discharged through all pins.

Operating Ratings(1) (2)

Temperature Range	$T_{MIN} \le T_A \le T_{MAX}$	−40°C ≤ T_A ≤ 85°C
	Supply Voltage(3)	2.4V ≤ V_{DD} ≤ 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.
(3) The maximum operating voltage for the LM4670 in the SDA (WSON) package when driving 4Ω loads to greater than 10% THD+N is 5.0V.

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Electrical Characteristics[1][2]

The following specifications apply for A_V = 2V/V (R_I = 150kΩ), R_L = 15µH + 8Ω + 15µH unless otherwise specified. Limits apply for T_A = 25°C.

Symbol	Parameter	Conditions	LM4670		Units (Limits)
			Typical[3]	Limit[4][5]	
$\|V_{OS}\|$	Differential Output Offset Voltage	V_I = 0V, A_V = 2V/V, V_{DD} = 2.4V to 5.0V		25	mV (max)
$PSRR_{GSM}$	GSM Power Supply Rejection Ratio	V_{DD} = 2.4V to 5.0V, Input Referred	64		dB
$CMRR_{GSM}$	GSM Common Mode Rejection Ratio	V_{DD} = 2.4V to 5.0V V_{IC} = V_{DD}/2 to 0.5V, V_{IC} = V_{DD}/2 to V_{DD} – 0.8V, Input Referred	80		dB
$\|I_{IH}\|$	Logic High Input Current	V_{DD} = 5.0V, V_I = 5.8V	20	100	µA (max)
$\|I_{IL}\|$	Logic Low Input Current	V_{DD} = 5.0V, V_I = –0.3V	1	5	µA (max)
I_{DD}	Quiescent Power Supply Current	V_{IN} = 0V, No Load, V_{DD} = 5.0V	7.0	10	mA (max)
		V_{IN} = 0V, No Load, V_{DD} = 3.6V	4.8		mA
		V_{IN} = 0V, No Load, V_{DD} = 2.4V	3.8	5	mA (max)
I_{SD}	Shutdown Current[6]	$V_{SHUTDOWN}$ = 0V V_{DD} = 2.4V to 5.0V	0.01	1	µA (max)
V_{SDIH}	Shutdown voltage input high		1.0	1.4	V (min)
V_{SDIL}	Shutdown voltage input low		0.8	0.4	V (max)
R_{OSD}	Output Impedance	$V_{SHUTDOWN}$ = 0.4V	>100		kΩ
A_V	Gain		300kΩ/R_I	270kΩ/R_I 330kΩ/R_I	V/V (min) V/V (max)
R_{SD}	Resistance from Shutdown Pin to GND		300		kΩ
P_O	Output Power[7][8]	R_L = 15µH + 4Ω + 15µH, THD = 10% (max) f = 1kHz, 22kHz BW V_{DD} = 5V V_{DD} = 3.6V V_{DD} = 2.5V	3.0 1.5 675		W W mW
		R_L = 15µH + 4Ω + 15µH, THD+N = 1% (max) f = 1kHz, 22kHz BW V_{DD} = 5V, V_{DD} = 3.6V, V_{DD} = 2.5V,	2.3 1.2 550		W W mW

(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) Typical specifications are specified at 25°C and represent the parametric norm.
(4) Tested limits are specified to Texas Instruments' AOQL (Average Outgoing Quality Level).
(5) Datasheet min/max specification limits are ensured by design, test, or statistical analysis.
(6) Shutdown current is measured in a normal room environment. Exposure to direct sunlight will increase I_{SD} by a maximum of 2µA. The Shutdown pin should be driven as close as possible to GND for minimal shutdown current. See Application Information under SHUTDOWN FUNCTION for more information.
(7) Typical output power numbers are for the LM4670 in the ITL (DSBGA) package. In the WSON (SDA) package, the output power will be lower due to higher resistance seen from the IC output pad to PCB trace. The difference increases with lower impedance loads.
(8) The maximum operating voltage for the LM4670 in the SDA (WSON) package when driving 4Ω loads to greater than 10% THD+N is 5.0V.

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Electrical Characteristics[1][2] (continued)

The following specifications apply for A_V = 2V/V (R_I = 150kΩ), R_L = 15µH + 8Ω + 15µH unless otherwise specified. Limits apply for T_A = 25°C.

Symbol	Parameter	Conditions	LM4670		Units (Limits)
			Typical[3]	Limit[4][5]	
P_O	Output Power[7]	R_L = 15µH + 8Ω + 15µH, THD = 10% (max) f = 1kHz, 22kHz BW V_{DD} = 5V V_{DD} = 3.6V V_{DD} = 2.5V	 1.65 850 400		 W mW mW
		R_L = 15µH + 8Ω + 15µH, THD+N = 1% (max) f = 1kHz, 22kHz BW V_{DD} = 5V, V_{DD} = 3.6V, V_{DD} = 2.5V,	 1.35 680 325	 600	 W mW (min) mW
THD+N	Total Harmonic Distortion + Noise	V_{DD} = 5V, P_O = 1W_{RMS}, f = 1kHz	0.35		%
		V_{DD} = 3.6V, P_O = 0.5W_{RMS}, f = 1kHz	0.30		%
		V_{DD} = 3.6V, P_O = 0.5W_{RMS}, f = 5kHz	0.30		%
		V_{DD} = 3.6V, P_O = 0.5W_{RMS}, f = 10kHz	0.30		%
PSRR	Power Supply Rejection Ratio	V_{DD} = 3.6V, V_{Ripple} = 200mV_{PP} Sine, f_{Ripple} = 217Hz Inputs to AC GND, C_I = 0.1µ, Input Referred	68		dB
		V_{DD} = 3.6V, V_{Ripple} = 200mV_{PP} Sine, f_{Ripple} = 1kHz Inputs to AC GND, C_I = 0.1µF Input Referred	65		dB
		V_{DD} = 3.6V, V_{Ripple} = 200mV_{PP} Sine, f_{Ripple} = 217Hz f_{IN} = 1kHz, P_O = 10mW_{RMS} Input Referred	62		dB
SNR	Signal to Noise Ratio	V_{DD} = 5V, P_O = 1W_{RMS}	93		dB
ε_{OUT}	Output Noise	V_{DD} = 3.6V, f = 20Hz – 20kHz Inputs to AC GND, C_I = 0.1µF No Weighting, Input Referred	85		µV_{RMS}
		V_{DD} = 3.6V, Inputs to AC GND C_I = 0.1µF, A Weighted Input Referred	65		µV_{RMS}
CMRR	Common Mode Rejection Ratio	V_{DD} = 3.6V, V_{Ripple} = 1V_{PP} Sine f_{Ripple} = 217Hz, Input Referred	80		dB
T_{WU}	Wake-up Time	V_{DD} = 3.6V	1.35		ms
T_{SD}	Shutdown Time	V_{DD} = 3.6V	0.01		ms

External Components Description

See Figure 1

Components		Functional Description
1.	C_S	Supply bypass capacitor which provides power supply filtering. Refer to POWER SUPPLY BYPASSING for information concerning proper placement and selection of the supply bypass capacitor.
2.	R_I	Gain setting resistor. Differential gain is set by the equation A_V = 2 * 150kΩ / R_i(V/V).

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Typical Performance Characteristics(1)

THD+N vs Frequency
V_{DD} = 2.5V, R_L = 15µH + 4Ω + 15µH
P_{OUT} = 375mW, 22kHz BW

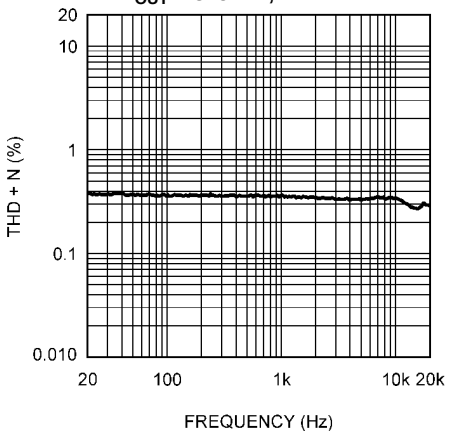

Figure 4.

THD+N vs Frequency
V_{DD} = 3.6V, R_L = 15µH + 4Ω + 15µH
P_{OUT} = 750mW, 22kHz BW

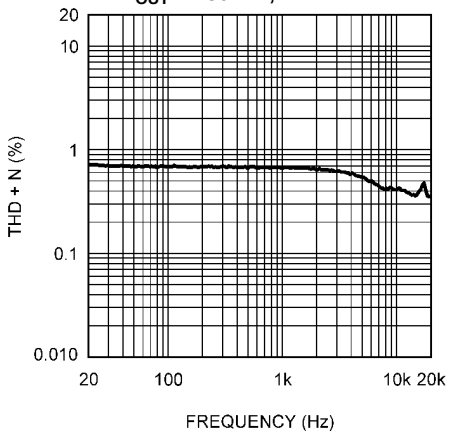

Figure 5.

THD+N vs Frequency
V_{DD} = 5V, R_L = 15µH + 4Ω + 15µH
P_{OUT} = 1.5W, 22kHz BW

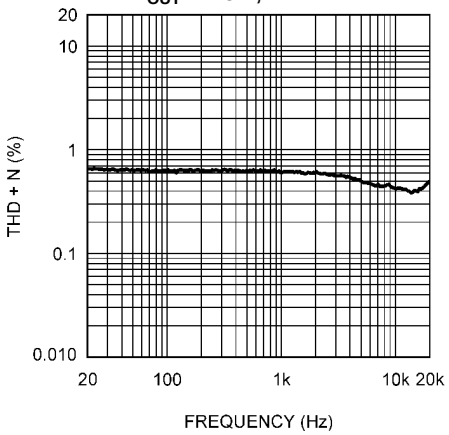

Figure 6.

THD+N vs Frequency
V_{DD} = 2.5V, R_L = 15µH + 8Ω + 15µH
P_{OUT} = 200mW, 22kHz BW

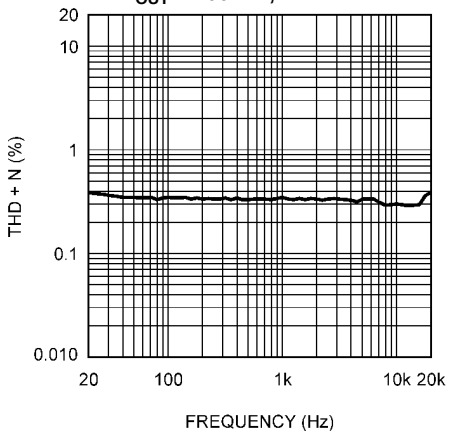

Figure 7.

THD+N vs Frequency
V_{DD} = 3.6V, R_L = 15µH + 8Ω + 15µH
P_{OUT} = 500mW, 22kHz BW

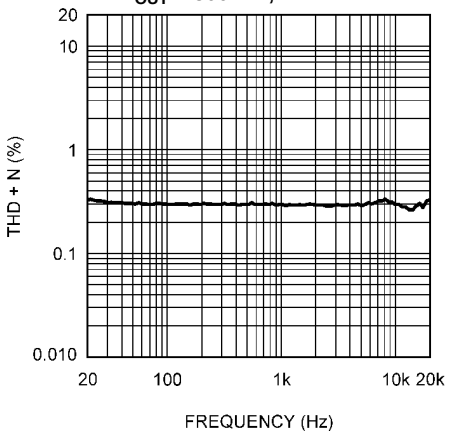

Figure 8.

THD+N vs Frequency
V_{DD} = 5V, R_L = 15µH + 8Ω + 15µH
P_{OUT} = 1W, 22kHz BW

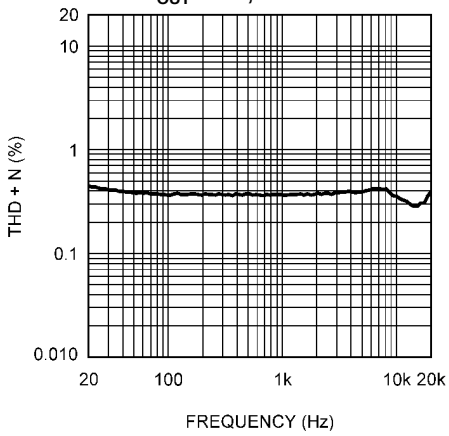

Figure 9.

(1) The performance graphs were taken using the Audio Precision AUX-0025 Switching Amplifier Measurement Filter in series with the LC filter on the board.

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Typical Performance Characteristics[1] (continued)

THD+N vs Output Power
R_L = 15µH + 4Ω + 15µH
f = 1kHz, 22kHz BW

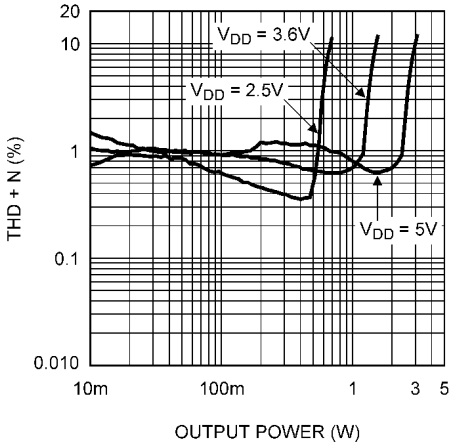

Figure 10.

THD+N vs Output Power
R_L = 15µH + 8Ω + 15µH
f = 1kHz, 22kHz BW

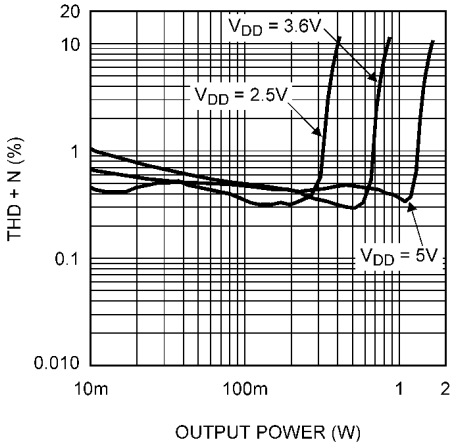

Figure 11.

CMRR vs Frequency
V_{DD} = 3.6V, R_L = 15µH + 8Ω + 15µH
V_{CM} = 1V_{P-P} Sine Wave, 22kHz BW

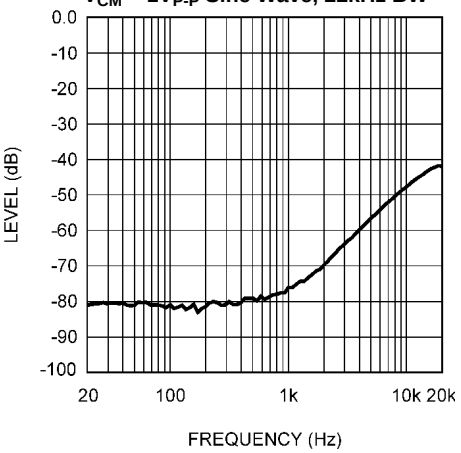

Figure 12.

PSRR vs Frequency
V_{DD} = 3.6V, R_L = 15µH + 8Ω + 15µH
V_{CM} = 200mV_{P-P} Sine Wave, 22kHz BW

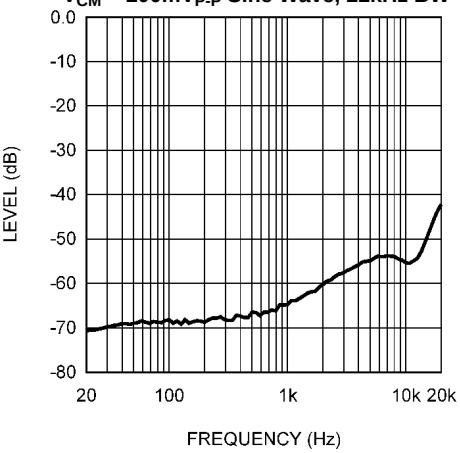

Figure 13.

Efficiency and Power Dissipation
vs Output Power
R_L = 15µH + 4Ω + 15µH, f = 1kHz, THD < 2%

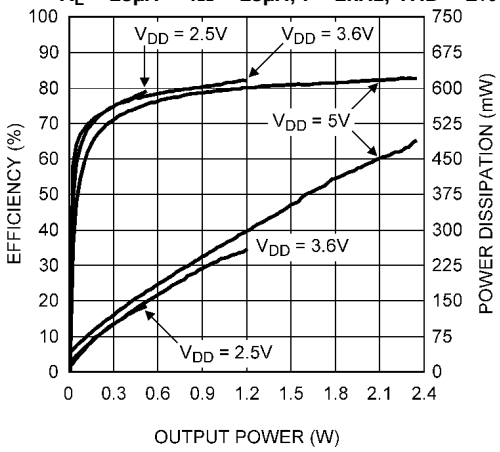

Figure 14.

Efficiency and Power Dissipation
vs Output Power
R_L = 15µH + 8Ω + 15µH, f = 1kHz, THD < 1%

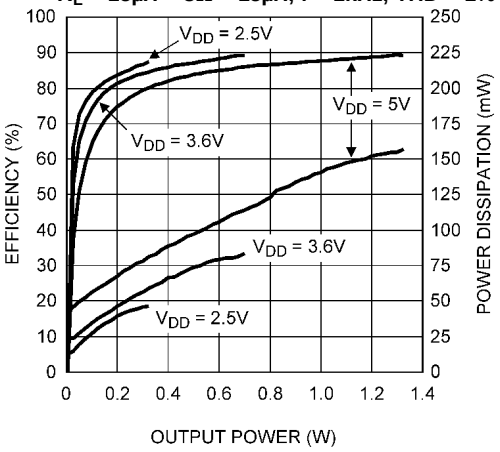

Figure 15.

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Typical Performance Characteristics[1] (continued)

Output Power vs Supply Voltage
R_L = 15µH + 4Ω + 15µH, f = 1kHz, 22kHz BW

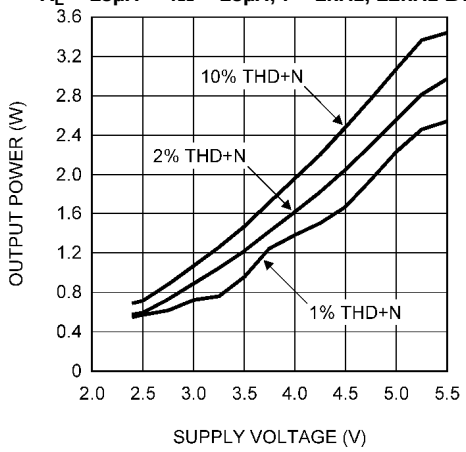

Figure 16.

Output Power vs Supply Voltage
R_L = 15µH + 8Ω + 15µH, f = 1kHz, 22kHz BW

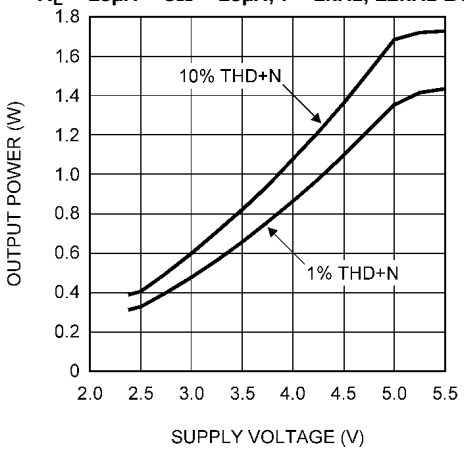

Figure 17.

Supply Current (RMS) vs Output Power
R_L = 15µH + 4Ω + 15µH, f = 1kHz

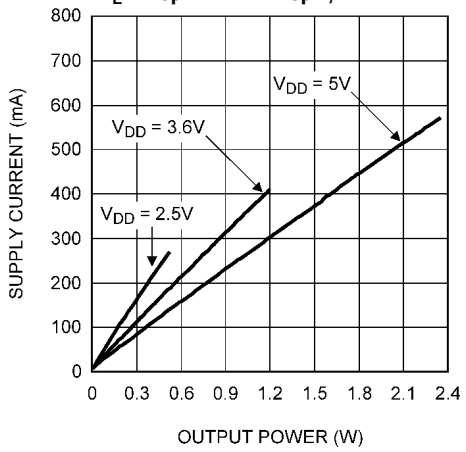

Figure 18.

Supply Current (RMS) vs Output Power
R_L = 15µH + 8Ω + 15µH, f = 1kHz

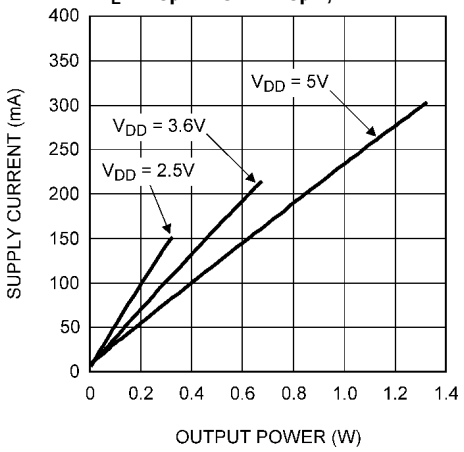

Figure 19.

Shutdown Threshold
R_L = 15µH + 8Ω + 15µH

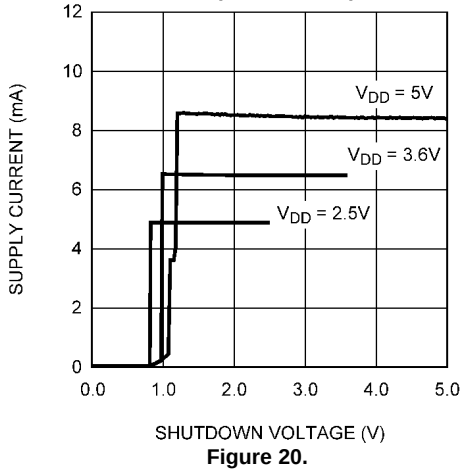

Figure 20.

Shutdwon Threshold vs Supply Voltage
R_L = 15µH + 8Ω + 15µH

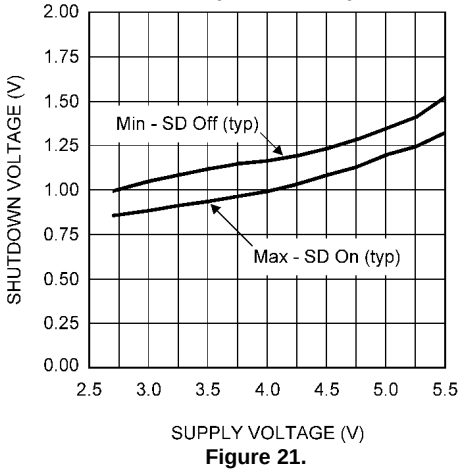

Figure 21.

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Typical Performance Characteristics(1) (continued)

Supply Current vs Shutdown Voltage
R_L = 15µH + 8Ω + 15µH

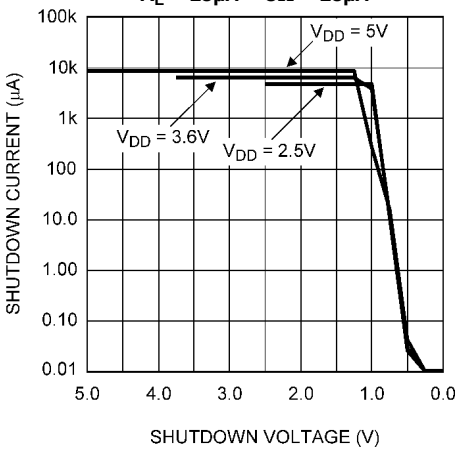

Figure 22.

Supply Current vs Supply Voltage
R_L = 15µH + 8Ω + 15µH

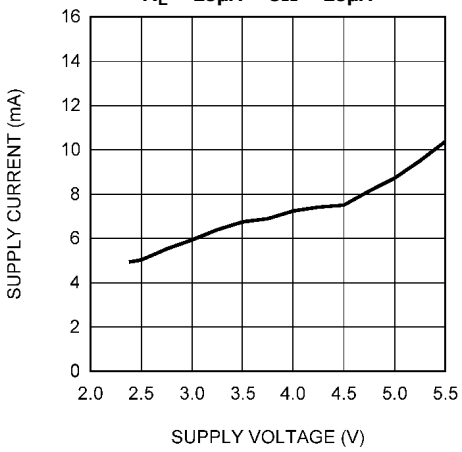

Figure 23.

Supply Current vs Supply Voltage
R_L = Different µH loads

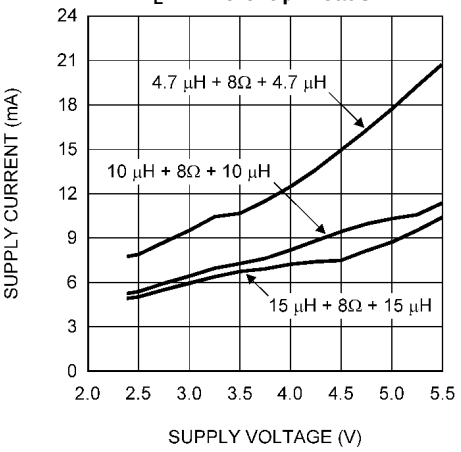

Figure 24.

Differential Gain vs Supply Voltage
R_L = 15µH + 8Ω + 15µH, R_i = 150kΩ, f = 1kHz

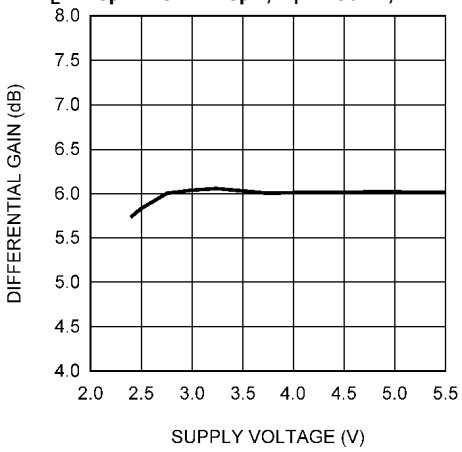

Figure 25.

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APPLICATION INFORMATION

GENERAL AMPLIFIER FUNCTION

The output signals generated by the LM4670 consist of two, BTL connected, output signals that pulse momentarily from near ground potential to V_{DD}. The two outputs can pulse independently with the exception that they both may never pulse simultaneously as this would result in zero volts across the BTL load. The minimum width of each pulse is approximately 350ns. However, pulses on the same output can occur sequentially, in which case they are concatenated and appear as a single wider pulse to achieve an effective 100% duty cycle. This results in maximum audio output power for a given supply voltage and load impedance. The LM4670 can achieve much higher efficiencies than class AB amplifiers while maintaining acceptable THD performance.

The short (350ns) drive pulses emitted at the LM4670 outputs means that good efficiency can be obtained with minimal load inductance. The typical transducer load on an audio amplifier is quite reactive (inductive). For this reason, the load can act as it's own filter, so to speak. This "filter-less" switching amplifier/transducer load combination is much more attractive economically due to savings in board space and external component cost by eliminating the need for a filter.

POWER DISSIPATION AND EFFICIENCY

In general terms, efficiency is considered to be the ratio of useful work output divided by the total energy required to produce it with the difference being the power dissipated, typically, in the IC. The key here is “useful” work. For audio systems, the energy delivered in the audible bands is considered useful including the distortion products of the input signal. Sub-sonic (DC) and super-sonic components (>22kHz) are not useful. The difference between the power flowing from the power supply and the audio band power being transduced is dissipated in the LM4670 and in the transducer load. The amount of power dissipation in the LM4670 is very low. This is because the ON resistance of the switches used to form the output waveforms is typically less than 0.25Ω. This leaves only the transducer load as a potential "sink" for the small excess of input power over audio band output power. The LM4670 dissipates only a fraction of the excess power requiring no additional PCB area or copper plane to act as a heat sink.

DIFFERENTIAL AMPLIFIER EXPLANATION

As logic supply voltages continue to shrink, designers are increasingly turning to differential analog signal handling to preserve signal to noise ratios with restricted voltage swing. The LM4670 is a fully differential amplifier that features differential input and output stages. 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 in signal to noise ratio relative to differential inputs. The LM4670 also offers the possibility of DC input coupling which eliminates the two external AC coupling, DC blocking capacitors. The LM4670 can be used, however, as a single ended input amplifier while still retaining it's fully differential benefits. In fact, completely unrelated signals may be placed on the input pins. The LM4670 simply amplifies the difference between the signals. A major benefit of a differential amplifier is the improved common mode rejection ratio (CMRR) over single input amplifiers. The common-mode rejection characteristic of the differential amplifier reduces sensitivity to ground offset related noise injection, especially important in high noise applications.

PCB LAYOUT CONSIDERATIONS

As output power increases, interconnect resistance (PCB traces and wires) between the amplifier, load and power supply create a voltage drop. The voltage loss on the traces between the LM4670 and the load results is lower output power and decreased efficiency. Higher trace resistance between the supply and the LM4670 has the same effect as a poorly regulated supply, increase ripple on the supply line also reducing the 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. While reducing trace resistance, the use of power planes also creates parasite capacitors that help to filter the power supply line.

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The rising and falling edges are necessarily short in relation to the minimum pulse width (350ns), having approximately 16ns rise and fall times, typical, depending on parasitic output capacitance. 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 V_{DD} 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 LM4670 and the speaker increase, the amount of EMI radiation will increase since the output wires or traces acting as antenna become more efficient with length. What is acceptable EMI is highly application specific. Ferrite chip inductors placed close to the LM4670 may be needed to reduce EMI radiation. The value of the ferrite chip is very application specific.

POWER SUPPLY BYPASSING

As with any power amplifier, proper supply bypassing is critical for low noise performance and high power supply rejection ratio (PSRR). The capacitor (C_S) location should be as close as possible to the LM4670. Typical applications employ a voltage regulator with a 10µF and a 0.1µF bypass capacitors that increase supply stability. These capacitors do not eliminate the need for bypassing on the supply pin of the LM4670. A 1µF tantalum capacitor is recommended.

SHUTDOWN FUNCTION

In order to reduce power consumption while not in use, the LM4670 contains shutdown circuitry that reduces current draw to less than 0.01µA. The trigger point for shutdown is shown as a typical value in Electrical Characteristics and in the Shutdown Hysteresis Voltage graphs found in Typical Performance Characteristics. It is best to switch between ground and supply for minimum current usage while in the shutdown state. While the LM4670 may be disabled with shutdown voltages in between ground and supply, the idle current will be greater than the typical 0.01µA value. Increased THD may also be observed with voltages less than V_{DD} on the Shutdown pin when in PLAY mode.

The LM4670 has an internal resistor connected between GND and Shutdown pins. The purpose of this resistor is to eliminate any unwanted state changes when the Shutdown pin is floating. The LM4670 will enter the shutdown state when the Shutdown pin is left floating or if not floating, when the shutdown voltage has crossed the threshold. To minimize the supply current while in the shutdown state, the Shutdown pin should be driven to GND or left floating. If the Shutdown pin is not driven to GND, the amount of additional resistor current due to the internal shutdown resistor can be found by Equation 1.

$$(V_{SD} - GND) / 300k\Omega \quad (1)$$

With only a 0.5V difference, an additional 1.7µA of current will be drawn while in the shutdown state.

PROPER SELECTION OF EXTERNAL COMPONENTS

The gain of the LM4670 is set by the external resistors, Ri in Figure 1, The Gain is given by Equation 2. Best THD+N performance is achieved with a gain of 2V/V (6dB).

$$A_V = 2 * 150\ k\Omega / R_i\ (V/V) \quad (2)$$

It is recommended that resistors with 1% tolerance or better be used to set the gain of the LM4670. The Ri resistors should be placed close to the input pins of the LM4670. Keeping the input traces close to each other and of the same length in a high noise environment will aid in noise rejection due to the good CMRR of the LM4670. Noise coupled onto input traces which are physically close to each other will be common mode and easily rejected by the LM4670.

Input capacitors may be needed for some applications or when the source is single-ended (see Figure 27 and Figure 29). Input capacitors are needed to block any DC voltage at the source so that the DC voltage seen between the input terminals of the LM4670 is 0V. 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 3.

$$f_C = 1 / (2\pi R_i C_i)\ (Hz) \quad (3)$$

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The input capacitors may also be used to remove low audio frequencies. Small speakers cannot reproduce low bass frequencies so filtering may be desired . When the LM4670 is using a single-ended source, power supply noise on the ground is seen as an input signal by the +IN input pin that is capacitor coupled to ground (see Figure 29 to Figure 31). Setting the high-pass filter point above the power supply noise frequencies, 217Hz in a GSM phone, for example, will filter out this noise so it is not amplified and heard on the output. Capacitors with a tolerance of 10% or better are recommended for impedance matching.

DIFFERENTIAL CIRCUIT CONFIGURATIONS

The LM4670 can be used in many different circuit configurations. The simplest and best performing is the DC coupled, differential input configuration shown in Figure 26. Equation 2 above is used to determine the value of the R_i resistors for a desired gain.

Input capacitors can be used in a differential configuration as shown in Figure 27. Equation 3 above is used to determine the value of the C_i capacitors for a desired frequency response due to the high-pass filter created by C_i and R_i. Equation 2 above is used to determine the value of the R_i resistors for a desired gain

The LM4670 can be used to amplify more than one audio source. Figure 28 shows a dual differential input configuration. The gain for each input can be independently set for maximum design flexibility using the R_i resistors for each input and Equation 2. Input capacitors can be used with one or more sources as well to have different frequency responses depending on the source or if a DC voltage needs to be blocked from a source.

SINGLE-ENDED CIRCUIT CONFIGURATIONS

The LM4670 can also be used with single-ended sources but input capacitors will be needed to block any DC at the input terminals. Figure 29 shows the typical single-ended application configuration. The equations for Gain, Equation 2, and frequency response, Equation 3, hold for the single-ended configuration as shown in Figure 29.

When using more than one single-ended source as shown in Figure 30, the impedance seen from each input terminal should be equal. To find the correct values for C_{i3} and R_{i3} connected to the +IN input pin the equivalent impedance of all the single-ended sources are calculated. The single-ended sources are in parallel to each other. The equivalent capacitor and resistor, C_{i3} and R_{i3}, are found by calculating the parallel combination of all $C_i$values and then all R_i values. Equation 4 and Equation 5 below are for any number of single-ended sources.

$$C_{i3} = C_{i1} + C_{i2} + C_{in} \ldots (F) \quad (4)$$

$$R_{i3} = 1 / (1/R_{i1} + 1/R_{i2} + 1/R_{in} \ldots) (\Omega) \quad (5)$$

The LM4670 may also use a combination of single-ended and differential sources. A typical application with one single-ended source and one differential source is shown in Figure 31. Using the principle of superposition, the external component values can be determined with the above equations corresponding to the configuration.

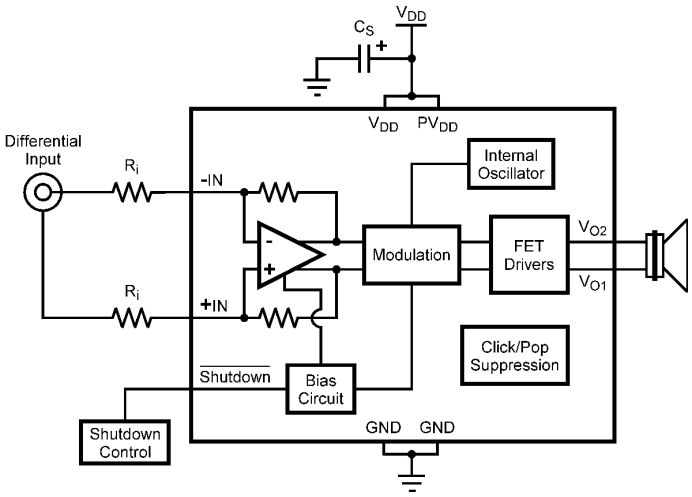

Figure 26. Differential input configuration

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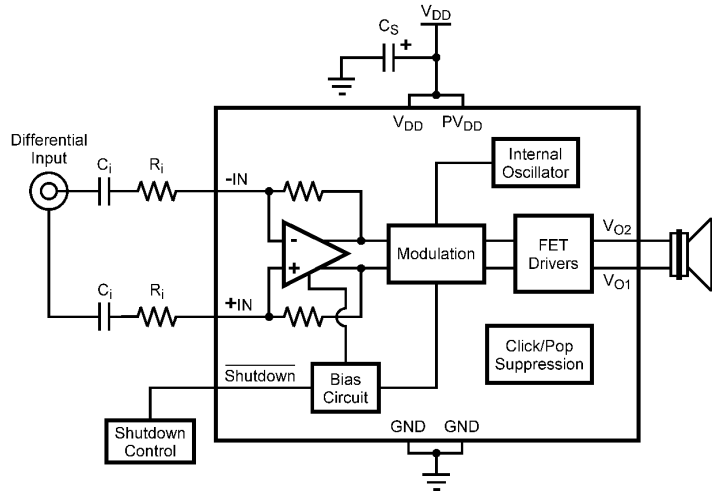

Figure 27. Differential input configuration with input capacitors

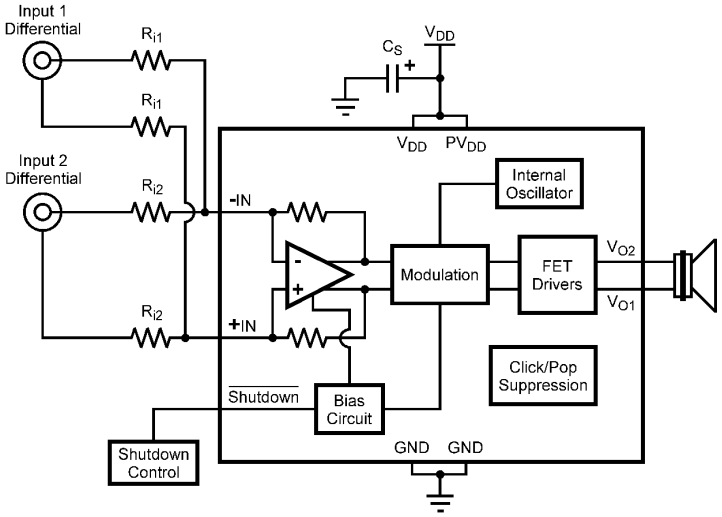

Figure 28. Dual differential input configuration

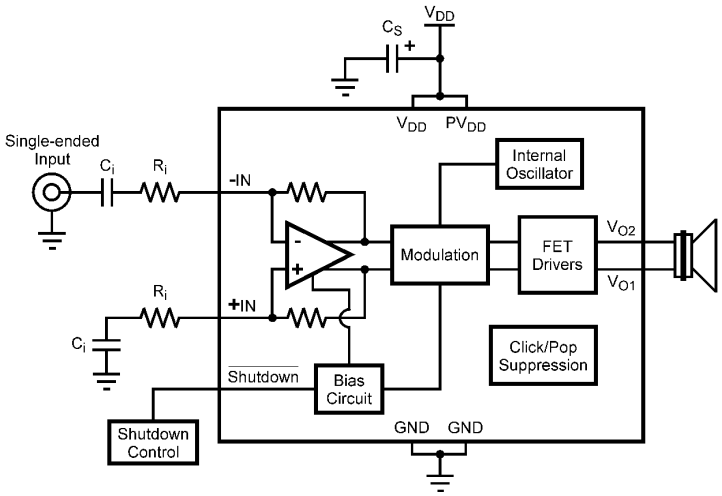

Figure 29. Single-ended input configuration

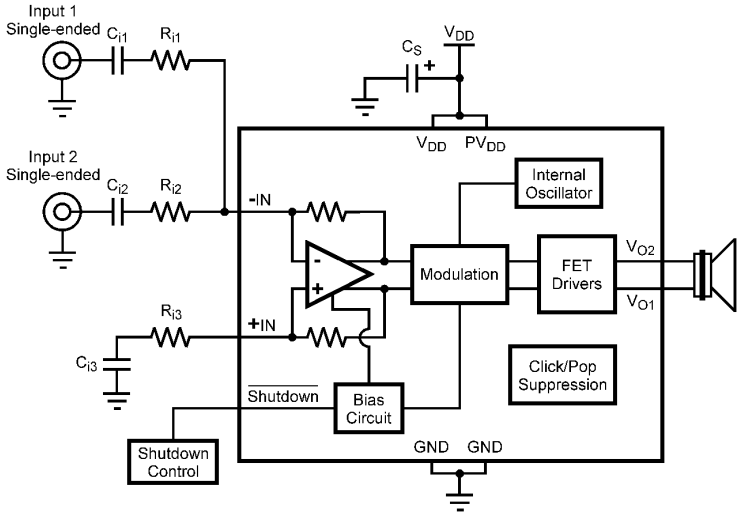

Figure 30. Dual single-ended input configuration

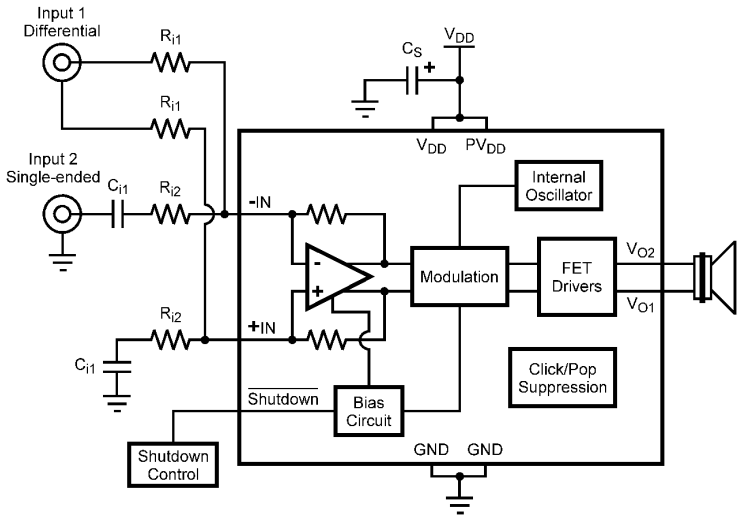

Figure 31. Dual input with a single-ended input and a differential input

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REFERENCE DESIGN BOARD SCHEMATIC

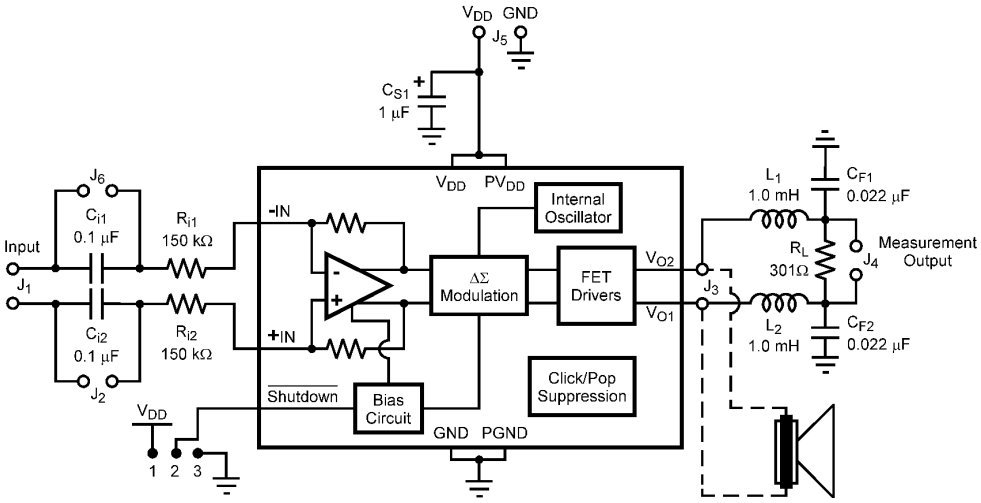

Figure 32. Reference Design Board Schematic

In addition to the minimal parts required for the application circuit, a measurement filter is provided on the evaluation circuit board so that conventional audio measurements can be conveniently made without additional equipment. This is a balanced input, grounded differential output low pass filter with a 3dB frequency of approximately 35kHz and an on board termination resistor of 300Ω (see Figure 32). Note that the capacitive load elements are returned to ground. This is not optimal for common mode rejection purposes, but due to the independent pulse format at each output there is a significant amount of high frequency common mode component on the outputs. The grounded capacitive filter elements attenuate this component at the board to reduce the high frequency CMRR requirement placed on the analysis instruments.

Even with the grounded filter the audio signal is still differential, necessitating a differential input on any analysis instrument connected to it. Most lab instruments that feature BNC connectors on their inputs are **NOT** differential responding because the ring of the BNC is usually grounded.

The commonly used Audio Precision analyzer is differential, but its ability to accurately reject fast pulses of 350ns width is questionable necessitating the on board measurement filter. When in doubt or when the signal needs to be single-ended, use an audio signal transformer to convert the differential output to a single ended output. Depending on the audio transformer's characteristics, there may be some attenuation of the audio signal which needs to be taken into account for correct measurement of performance.

Measurements made at the output of the measurement filter suffer attenuation relative to the primary, unfiltered outputs even at audio frequencies. This is due to the resistance of the inductors interacting with the termination resistor (300Ω) and is typically about -0.25dB (3%). In other words, the voltage levels (and corresponding power levels) indicated through the measurement filter are slightly lower than those that actually occur at the load placed on the unfiltered outputs. This small loss in the filter for measurement gives a lower output power reading than what is really occurring on the unfiltered outputs and its load.

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LM4670 DSBGA BOARD ARTWORK

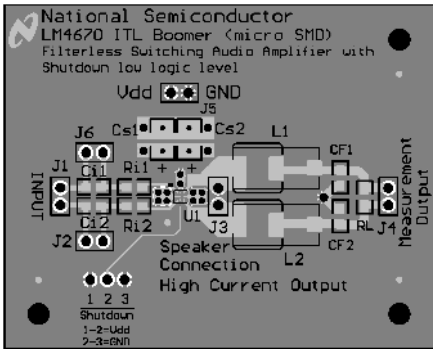

Figure 33. Composite View

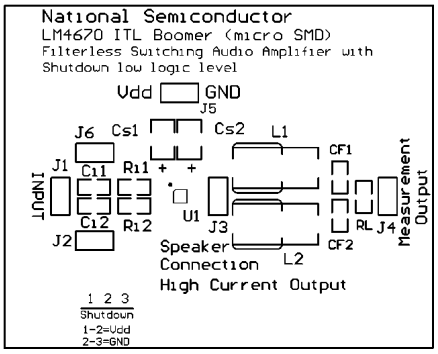

Figure 34. Silk Screen

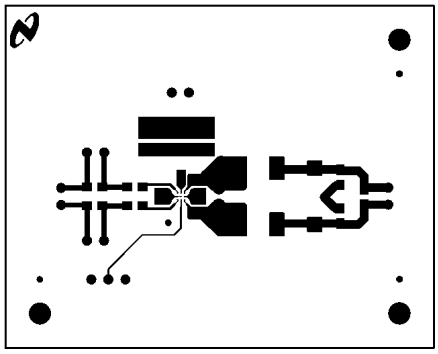

Figure 35. Top Layer

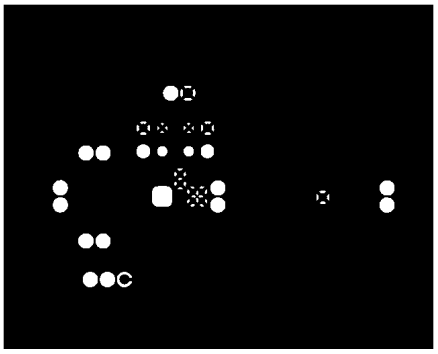

Figure 36. Internal Layer 1, GND

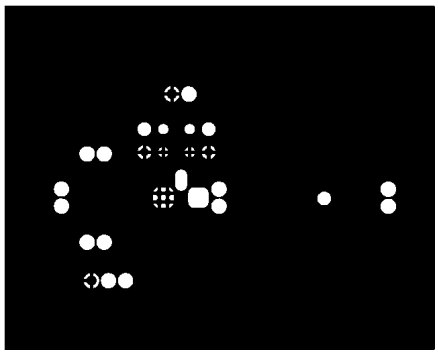

Figure 37. Internal Layer 2, V_{DD}

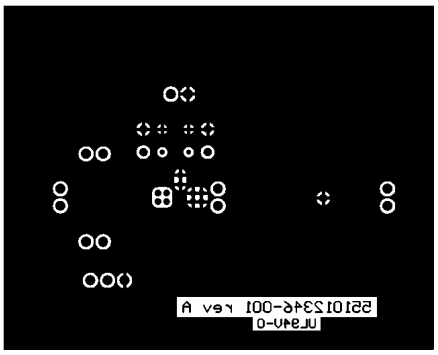

Figure 38. Bottom Layer

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LM4670 WSON BOARD ARTWORK

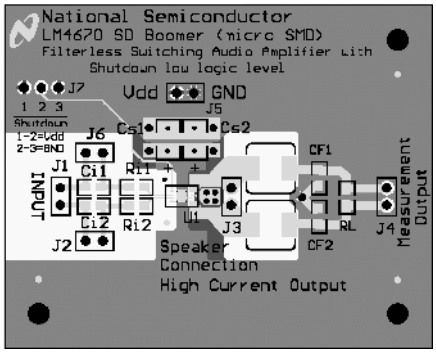

Figure 39. Composite View

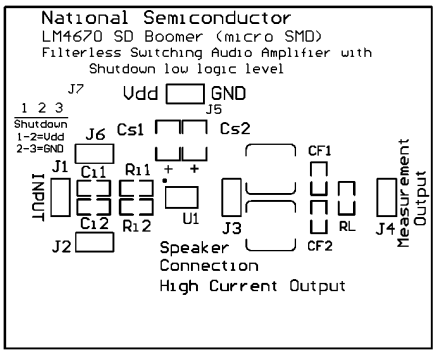

Figure 40. Silk Screen

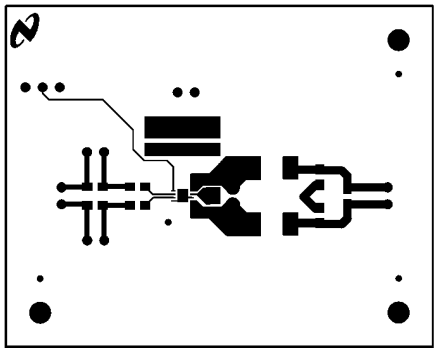

Figure 41. Top Layer

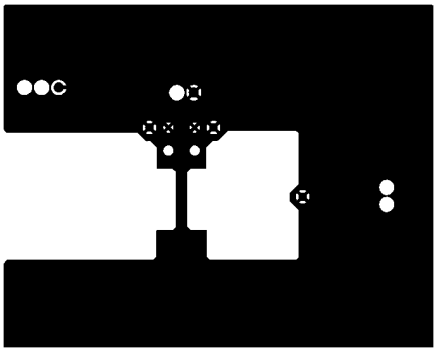

Figure 42. Internal Layer 1, GND

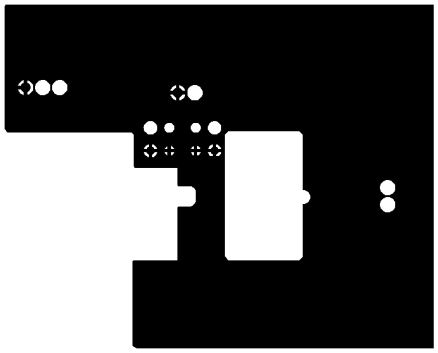

Figure 43. Internal Layer 2, V_{DD}

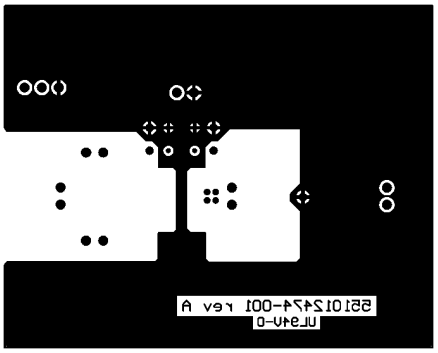

Figure 44. Bottom Layer

Revision History

Rev	Date	Description
1.0	12/15/04	Initial WEB of the D/S (TL pkg).
1.1	7/06/05	Re-released D/S to the WEB (added the SD package).
1.2	7/13/06	Edited Note 9, then re-released D/S to the WEB.
C	5/02/13	Changed layout of National Data Sheet to TI format

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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
LM4670ITL/NOPB	ACTIVE	DSBGA	YZR	9	250	RoHS & Green	SNAGCU	Level-1-260C-UNLIM	-40 to 85	G E6	Samples
LM4670ITLX/NOPB	ACTIVE	DSBGA	YZR	9	3000	RoHS & Green	SNAGCU	Level-1-260C-UNLIM	-40 to 85	G E6	Samples
LM4670SD/NOPB	ACTIVE	WSON	NGQ	8	1000	RoHS & Green	SN	Level-1-260C-UNLIM	-40 to 85	L4670	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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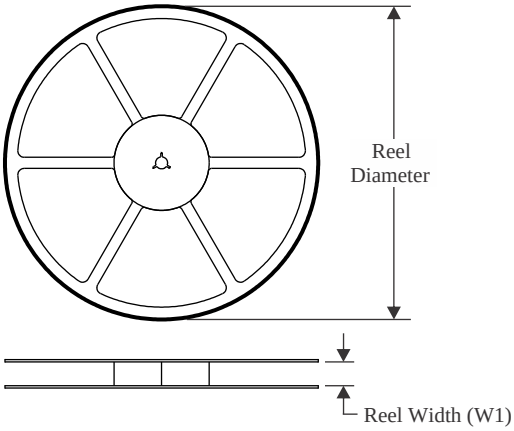
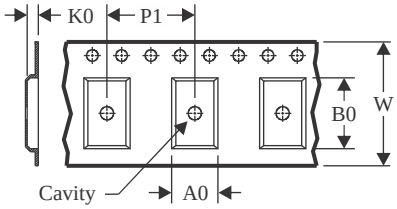
TAPE AND REEL INFORMATION

REEL DIMENSIONS

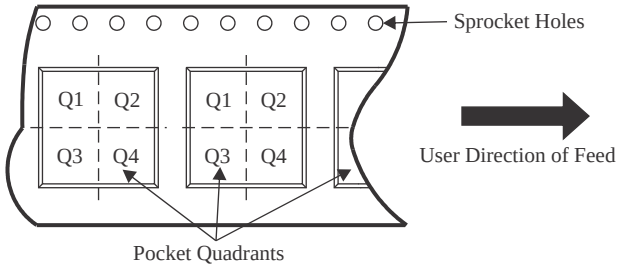


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

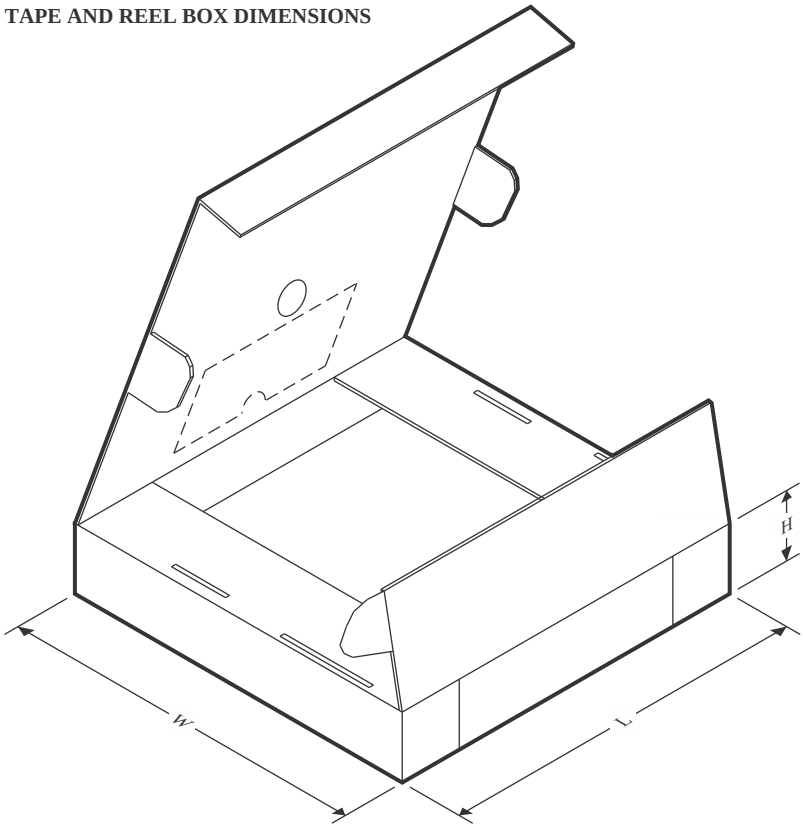
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
LM4670ITL/NOPB	DSBGA	YZR	9	250	178.0	8.4	1.57	1.57	0.76	4.0	8.0	Q1
LM4670ITLX/NOPB	DSBGA	YZR	9	3000	178.0	8.4	1.57	1.57	0.76	4.0	8.0	Q1
LM4670SD/NOPB	WSON	NGQ	8	1000	178.0	12.4	3.3	3.3	1.0	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

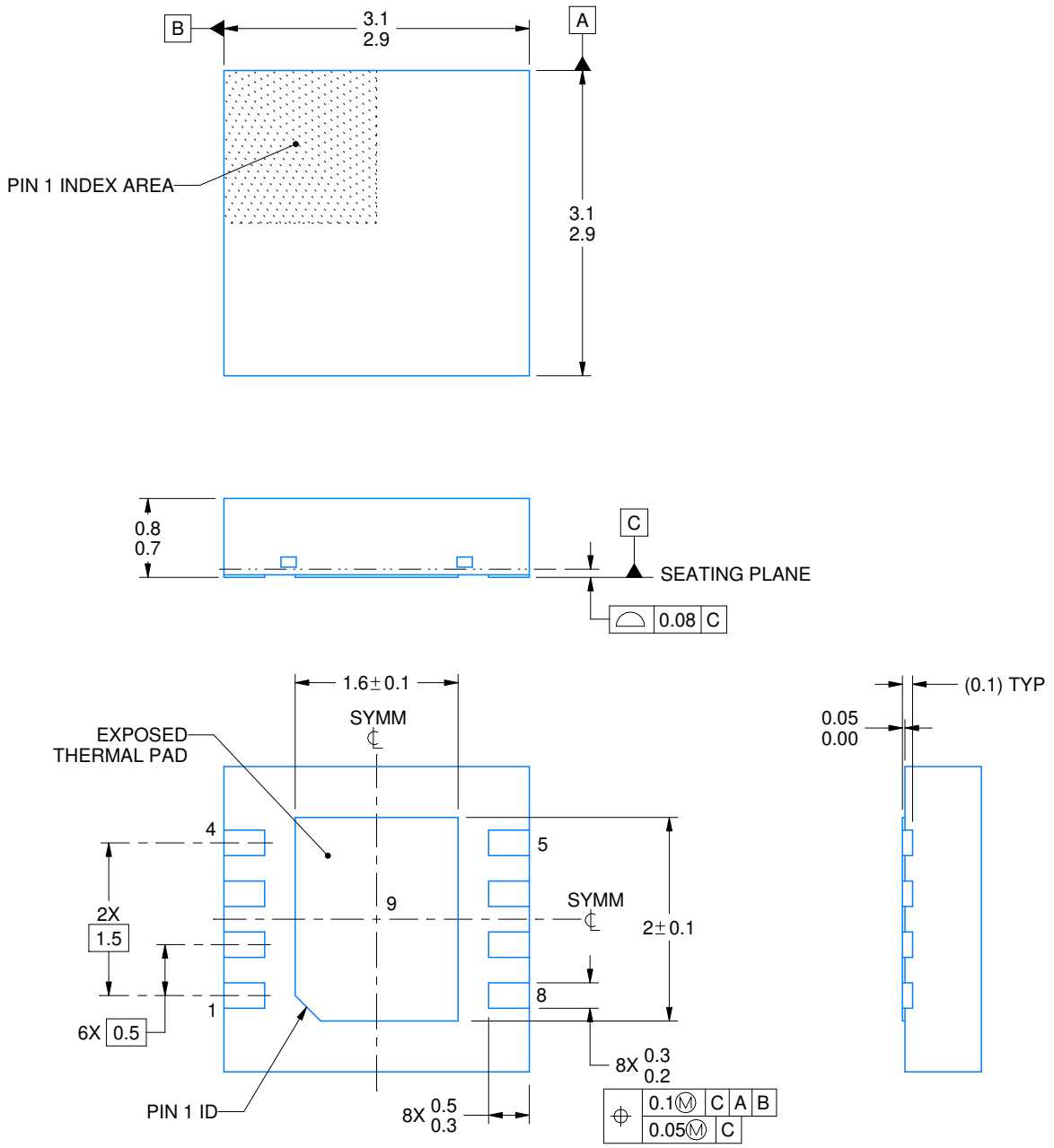
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM4670ITL/NOPB	DSBGA	YZR	9	250	208.0	191.0	35.0
LM4670ITLX/NOPB	DSBGA	YZR	9	3000	208.0	191.0	35.0
LM4670SD/NOPB	WSON	NGQ	8	1000	208.0	191.0	35.0

PACKAGE OUTLINE

NGQ0008A

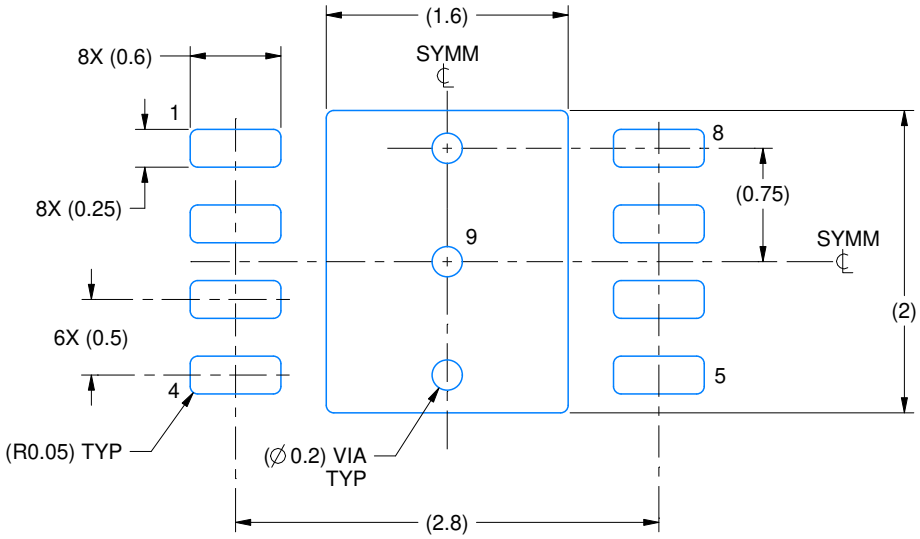
WSON - 0.8 mm max height

PLASTIC SMALL OUTLINE - NO LEAD

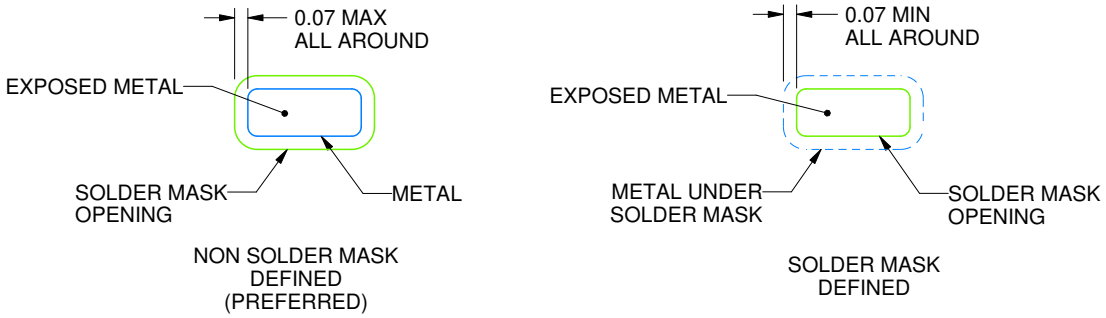


NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:20X



SOLDER MASK DETAILS

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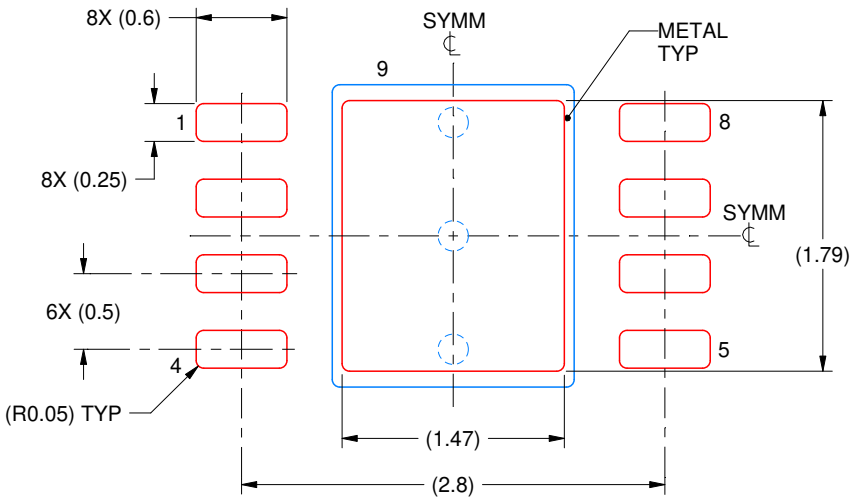
NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.



SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL

EXPOSED PAD 9:
82% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
SCALE:20X

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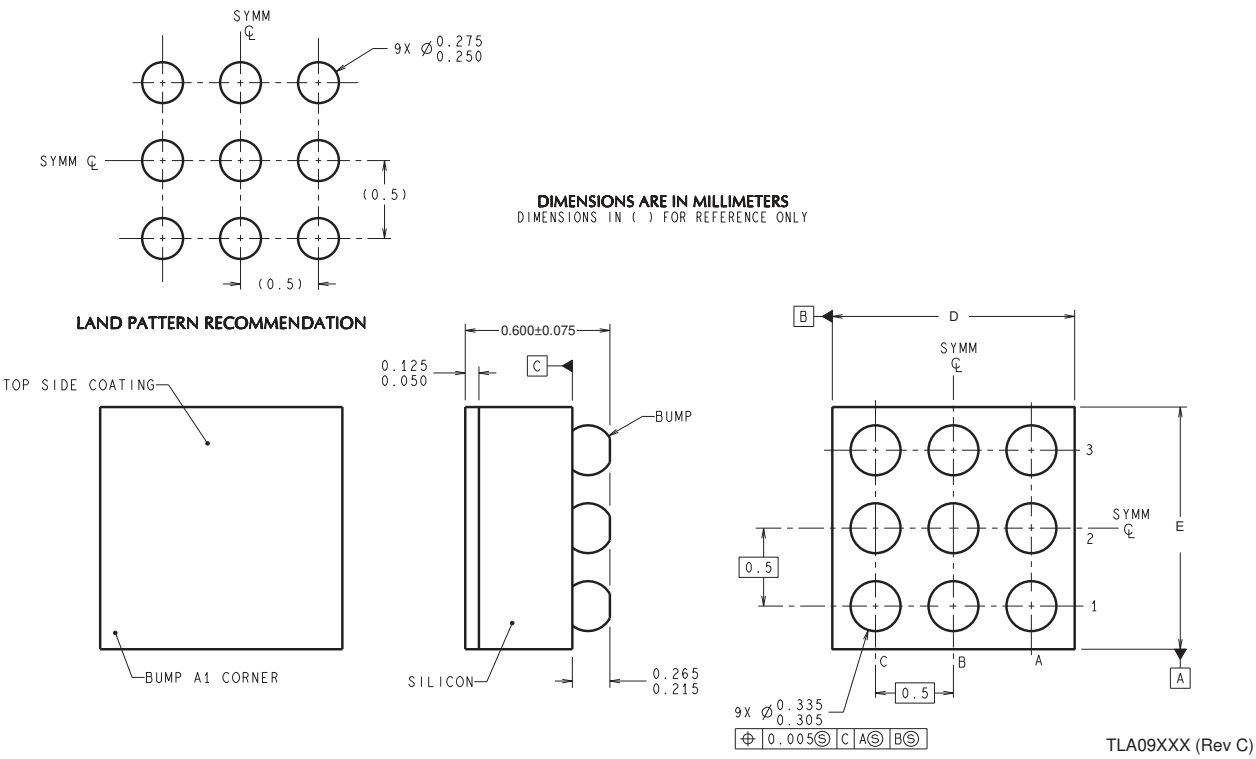
NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

YZR0009



D: Max = 1.514 mm, Min =1.454 mm

E: Max = 1.489 mm, Min =1.428 mm

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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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