LM4675 Boomer® Audio Power Amplifier Series Ultra-Low EMI, Filterless, 2.65W, Mono, Class D Audio Power Amplifier with Spread Spectrum

Check for Samples: LM4675, LM4675SDBD, LM4675TLBD

FEATURES

- **Spread Spectrum Architecture Reduces EMI**
- **Mono Class D Operation**
- **No Output Filter Required for Inductive Loads**
- **Externally Configurable Gain**
- **Very Fast Turn On Time: 17µs (typ)**
- **Minimum External Components**
- **"Click and Pop" Suppression Circuitry**
- **Micro-Power Shutdown Mode**
- **Available in Space-Saving 0.5mm Pitch DSBGA and WSON Packages**

APPLICATIONS

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

KEY SPECIFICATIONS

- **Efficiency at 3.6V, 400mW into 8Ω Speaker: 89% (typ)**
- **Efficiency at 3.6V, 100mW into 8Ω Speaker: 80% (typ)**
- **Efficiency at 5V, 1W into 8Ω Speaker: 89% (typ)**
- **Quiescent Current, 3.6V Supply: 2.2mA (typ)**
- **Total Shutdown Power Supply Current: 0.01µA (typ)**
- **Single Supply Range: 2.4V to 5.5V**
- **PSRR, f = 217Hz: 82dB**

DESCRIPTION

The LM4675 is a single supply, high efficiency, 2.65W, mono, Class D audio amplifier. A spread spectrum, filterless PWM architecture reduces EMI and eliminates the output filter, reducing external component count, board area consumption, system cost, and simplifying design.

The LM4675 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 2.2W with less than 1% THD+N. Its flexible power supply requirements allow operation from 2.4V to 5.5V. The wide band spread spectrum architecture of the LM4675 reduces EMI-radiated emissions due to the modulator frequency.

The LM4675 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 80%, reaching 89% at 400mW output power.

The LM4675 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 LM4675 is externally configurable which allows independent gain control from multiple sources by summing the signals. Output short circuit and thermal overload protection prevent the device from damage during fault conditions.
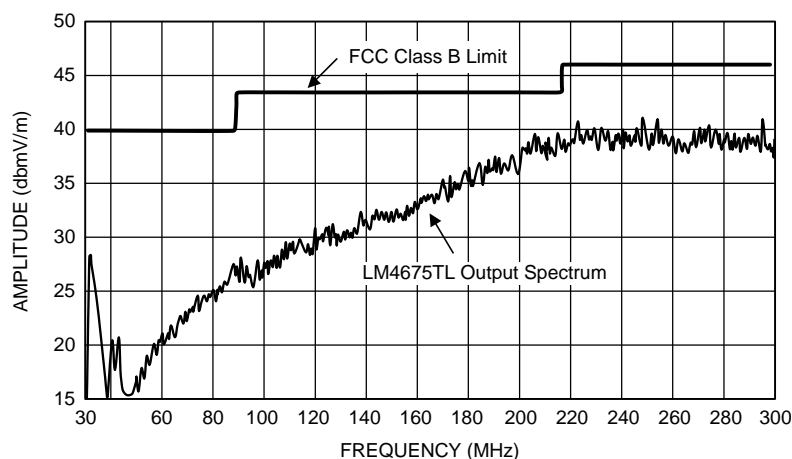
Figure 1. LM4675 Rf Emissions — 6in cable
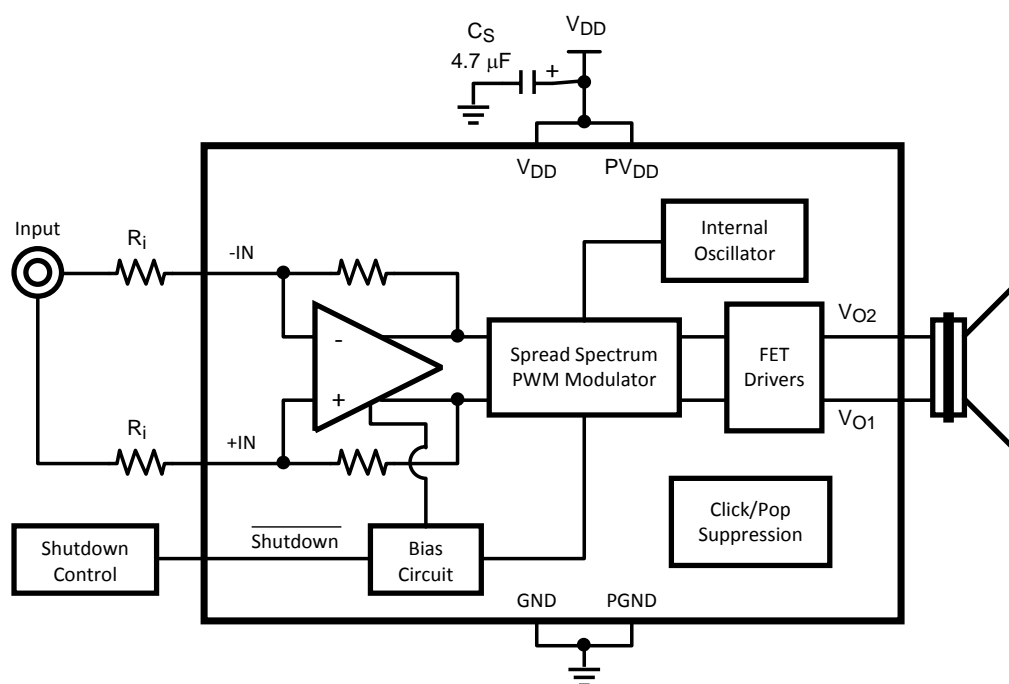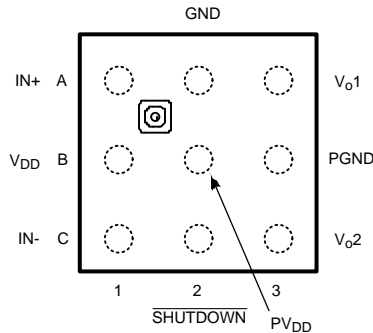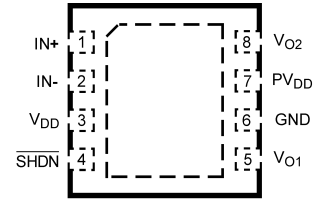
Typical Application

Figure 2. Typical Audio Amplifier Application Circuit

Connection Diagrams

Figure 3. 9-Bump DSBGA - Top View
See YZR0009 Package

Figure 4. 8-Pin WSON - Top View
See NGQ0008A 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
Voltage at Any Input Pin		$V_{DD} + 0.3V ≥ V ≥ GND - 0.3V$
Power Dissipation[(4)]		Internally Limited
ESD Susceptibility, all other pins[(5)]		2.0kV
ESD Susceptibility[(6)]		200V
Junction Temperature (T_{JMAX})		150°C
Thermal Resistance	$θ_{JA}$ (DSBGA)	220°C/W
	$θ_{JA}$ (WSON)	73°C/W
Soldering Information		See ([SNVA009](#)) "microSMD 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) 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 $P_{DMAX} = (T_{JMAX}−T_A)/θ_{JA}$ or the number given in Absolute Maximum Ratings, whichever is lower. For the LM4675, T_{JMAX} = 150°C. The typical $θ_{JA}$ is 99.1°C/W for the DSBGA package.
(5) Human body model, 100pF discharged through a 1.5kΩ resistor.
(6) Machine Model, 220pF – 240pF discharged through all pins.

Operating Ratings[(1)(2)]

Temperature Range $T_{MIN} ≤ T_A ≤ T_{MAX}$	−40°C ≤ T_A ≤ 85°C
Supply Voltage	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.

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		LM4675 Typical[(3)]	LM4675 Limit[(4)(5)]	Units (Limits)
$|V_{OS}|$	Differential Output Offset Voltage	V_I = 0V, A_V = 2V/V, V_{DD} = 2.4V to 5.0V		3		mV
$|I_{IH}|$	Logic High Input Current	V_{DD} = 5.0V, V_I = 5.5V		17	100	µA (max)
$|I_{IL}|$	Logic Low Input Current	V_{DD} = 5.0V, V_I = −0.3V		0.9	5	µA (max)
I_{DD}	Quiescent Power Supply Current	V_{IN} = 0V, No Load, V_{DD} = 5.0V		2.8	3.9	mA (max)
		V_{IN} = 0V, No Load, V_{DD} = 3.6V		2.2	2.9	mA
		V_{IN} = 0V, No Load, V_{DD} = 2.4V		1.6	2.3	mA (max)
		V_{IN} = 0V, R_L = 8Ω, V_{DD} = 5.0V		2.8		
		V_{IN} = 0V, R_L = 8Ω, V_{DD} = 3.6V		2.2		
		V_{IN} = 0V, R_L = 8Ω, V_{DD} = 2.4V		1.6		
I_{SD}	Shutdown Current[(6)]	$V_{SHUTDOWN}$ = 0V V_{DD} = 2.4V to 5.0V		0.01	1.0	µA (max)
V_{SDIH}	Shutdown voltage input high				1.4	V (min)
V_{SDIL}	Shutdown voltage input low				0.4	V (max)
R_{OSD}	Output Impedance	$V_{SHUTDOWN}$ = 0.4V		100		kΩ
A_V	Gain			300kΩ/R_I		V/V (min) V/V (max)
R_{SD}	Resistance from Shutdown Pin to GND			300		kΩ
f_{SW}	Switching Frequency			300±30%		kHz
P_O	Output Power	R_L = 15µH + 4Ω + 15µH THD = 10% (max) f = 1kHz, 22kHz BW	V_{DD} = 5V	2.7		W
			V_{DD} = 3.6V	1.3		W
			V_{DD} = 2.5V	560		mW
		R_L = 15µH + 4Ω + 15µH THD = 1% (max) f = 1kHz, 22kHz BW	V_{DD} = 5V	2.2		W
			V_{DD} = 3.6V	1.08		W
			V_{DD} = 2.5V	450		mW
		R_L = 15µH + 8Ω + 15µH THD = 10% (max) f = 1kHz, 22kHz BW	V_{DD} = 5V	1.6		W
			V_{DD} = 3.6V	820		mW
			V_{DD} = 2.5V	350		mW
		R_L = 15µH + 8Ω + 15µH THD = 1% (max) f = 1kHz, 22kHz BW	V_{DD} = 5V	1.3		W
			V_{DD} = 3.6V	650	600	mW
			V_{DD} = 2.5V	290		mW
THD+N	Total Harmonic Distortion + Noise	V_{DD} = 5V, P_O = 0.1W, f = 1kHz		0.03		%
		V_{DD} = 3.6V, P_O = 0.1W, f = 1kHz		0.02		%
		V_{DD} = 2.5V, P_O = 0.1W, f = 1kHz		0.04		%

(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 TI's 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 and to V_{DD} for the best THD performance in PLAY mode. See the Application Information section under SHUTDOWN FUNCTION for more information.

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	LM4675		Units (Limits)
			Typical[(3)]	Limit[(4)(5)]	
PSRR	Power Supply Rejection Ratio (Input Referred)	V_{Ripple} = 200mV_{PP} Sine, f_{Ripple} = 217Hz, V_{DD} = 3.6, 5V Inputs to AC GND, C_I = 2µF	82		dB
		V_{Ripple} = 200mV_{PP} Sine, f_{Ripple} = 1kHz, V_{DD} = 3.6, 5V Inputs to AC GND, C_I = 2µF	80		dB
SNR	Signal to Noise Ratio	V_{DD} = 5V, P_O = 1W_{RMS}	97		dB
ε_{OUT}	Output Noise (Input Referred)	V_{DD} = 3.6V, f = 20Hz – 20kHz Inputs to AC GND, C_I = 2µF No Weighting	28		µV_{RMS}
		V_{DD} = 3.6V, Inputs to AC GND C_I = 2µF, A Weighted	22		µV_{RMS}
CMRR	Common Mode Rejection Ratio (Input Referred)	V_{DD} = 3.6V, V_{Ripple} = 1V_{PP} Sine f_{Ripple} = 217Hz	80		dB
T_{WU}	Wake-up Time	V_{DD} = 3.6V	17		µs
T_{SD}	Shutdown Time		140		µs
η	Efficiency	V_{DD} = 3.6V, P_{OUT} = 400mW R_L = 8Ω	89		%
		V_{DD} = 5V, P_{OUT} = 1W R_L = 8Ω	89		%

External Components Description

([Figure 2])

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.

Typical Performance Characteristics

The performance graphs were taken using the Audio Precision AUX-0025 Switching Amplifier measurement Filter in series with the LC filter on the demo board.
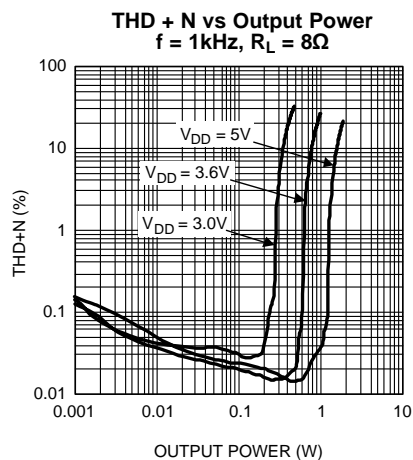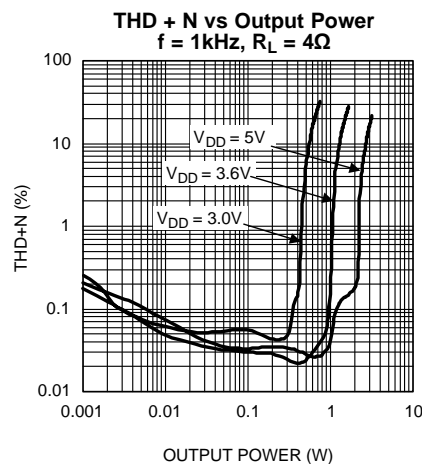
THD + N vs Output Power
f = 1kHz, R_L = 8Ω

Figure 5.

THD + N vs Output Power
f = 1kHz, R_L = 4Ω

Figure 6.

THD + N vs Frequency
V_{DD} = 2.5V, P_{OUT} = 100mW, R_L = 8Ω

Figure 7.

THD + N vs Frequency
V_{DD} = 3.6V, P_{OUT} = 150mW, R_L = 8Ω

Figure 8.

THD + N vs Frequency
V_{DD} = 5V, P_{OUT} = 200mW, R_L = 8Ω

Figure 9.

THD + N vs Frequency
V_{DD} = 2.5V, P_{OUT} = 100mW, R_L = 4Ω

Figure 10.

Product Folder Links: *LM4675 LM4675SDBD LM4675TLBD*

Typical Performance Characteristics (continued)

The performance graphs were taken using the Audio Precision AUX-0025 Switching Amplifier measurement Filter in series with the LC filter on the demo board.
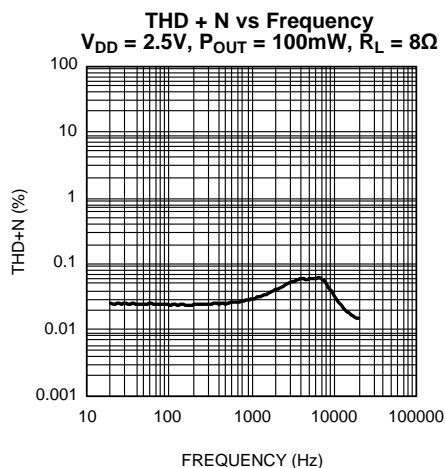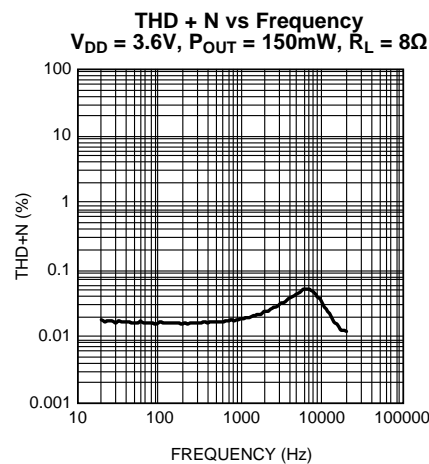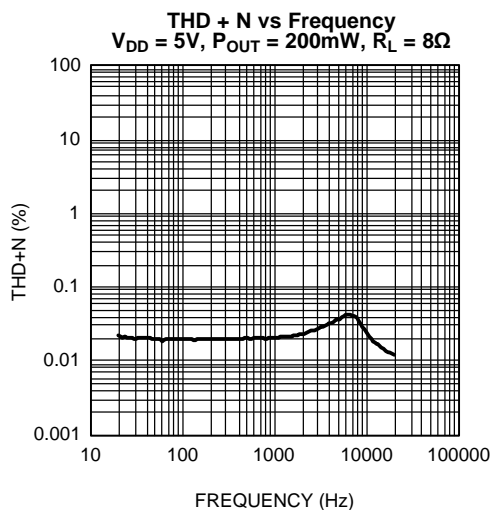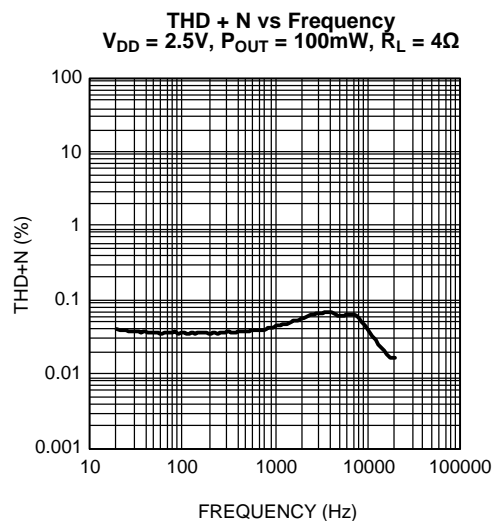
THD + N vs Frequency
$V_{DD} = 3.6V$, $P_{OUT} = 100mW$, $R_L = 4\Omega$

Figure 11.

THD + N vs Frequency
$V_{DD} = 5V$, $P_{OUT} = 150mW$, $R_L = 4\Omega$

Figure 12.

Efficiency vs. Output Power
$R_L = 4\Omega$, $f = 1kHz$

Figure 13.

Efficiency vs. Output Power
$R_L = 8\Omega$, $f = 1kHz$

Figure 14.

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

Figure 15.

Power Dissipation vs. Output Power
$R_L = 8\Omega$, $f = 1kHz$
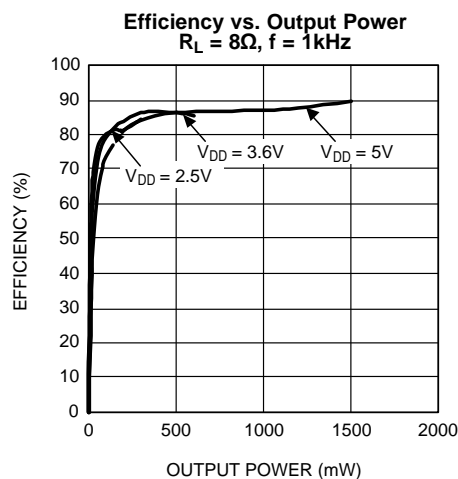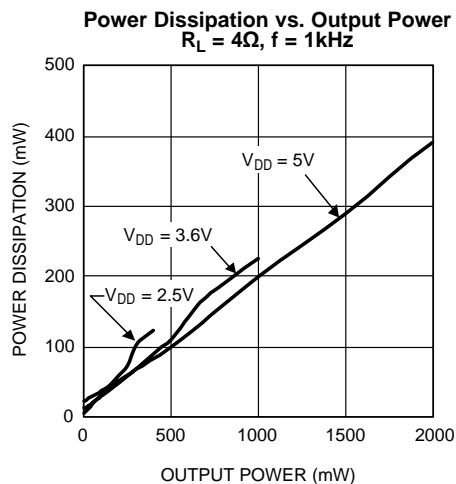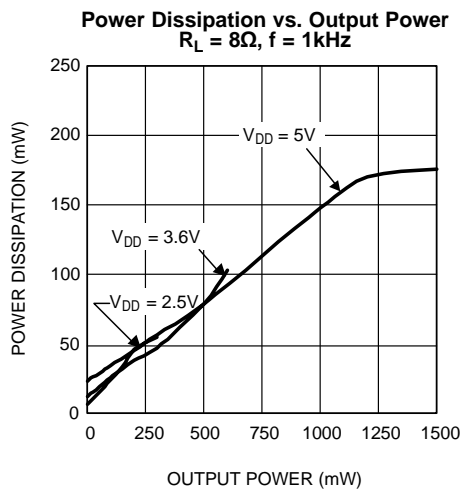
Figure 16.

Typical Performance Characteristics (continued)

The performance graphs were taken using the Audio Precision AUX-0025 Switching Amplifier measurement Filter in series with the LC filter on the demo board.
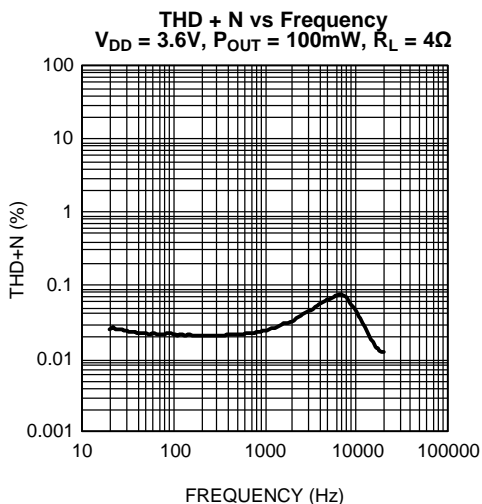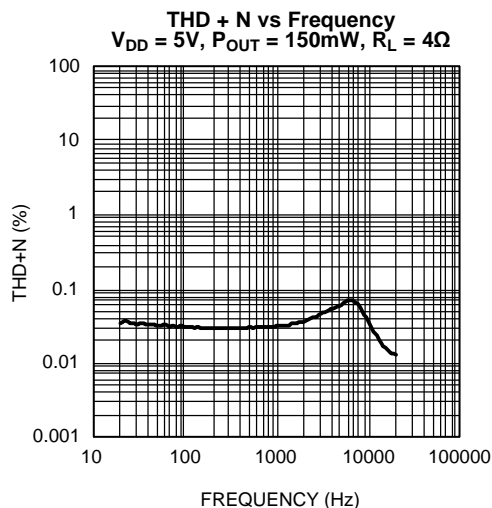
Output Power vs. Supply Voltage
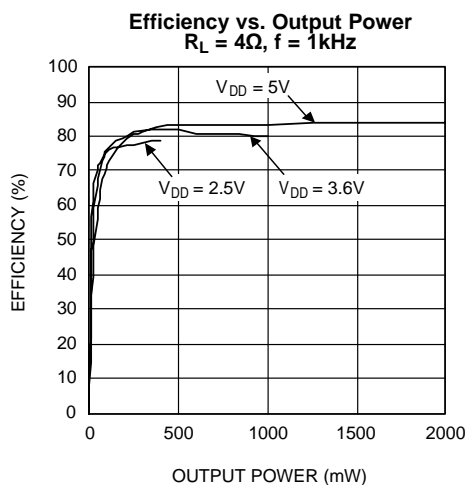$R_L = 4\Omega$, f = 1kHz

THD+N = 10%

THD+N = 1%

Figure 17.

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

THD+N = 10%

THD+N = 1%

Figure 18.

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

Figure 19.

CMRR vs. Frequency
$V_{DD} = 3.6V$, $V_{CM} = 1V_{P-P}$, $R_L = 8\Omega$

Figure 20.

Supply Current vs. Supply Voltage
No Load

Figure 21.

Shutdown Supply Current vs. Supply Voltage
No Load

Figure 22.

Product Folder Links: *LM4675 LM4675SDBD LM4675TLBD*

Typical Performance Characteristics (continued)

The performance graphs were taken using the Audio Precision AUX-0025 Switching Amplifier measurement Filter in series with the LC filter on the demo board.

Fixed Frequency FFT
$V_{DD} = 3.6V$
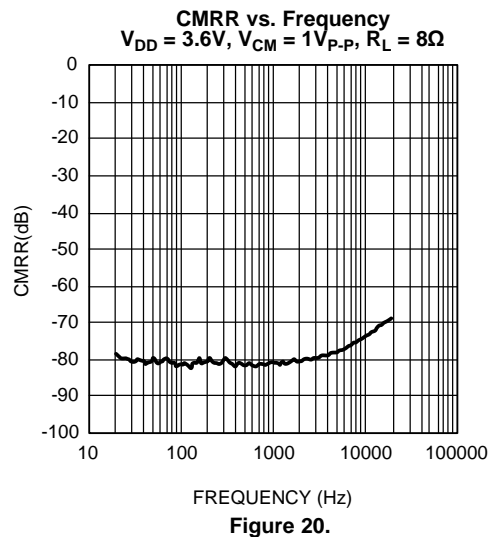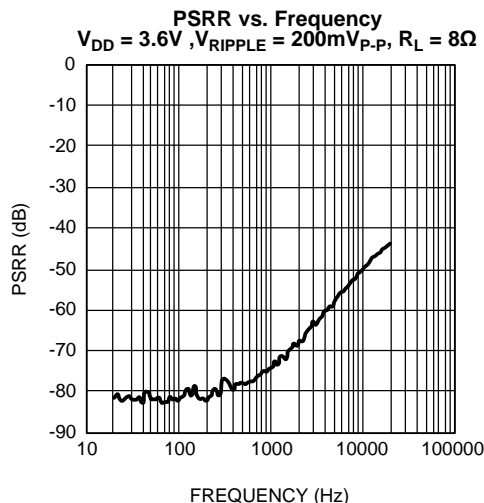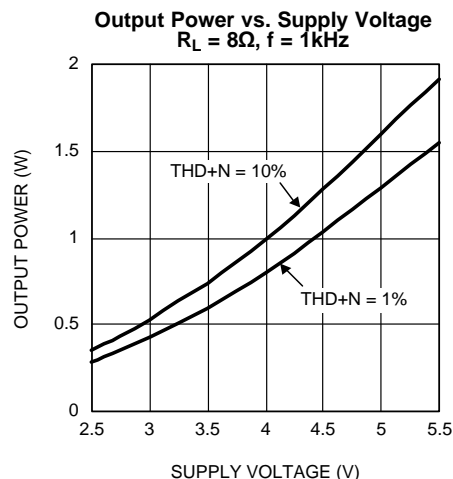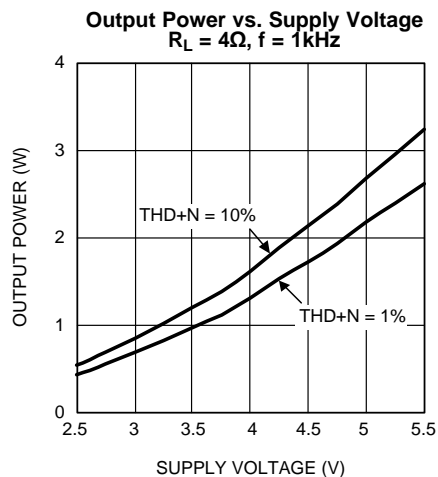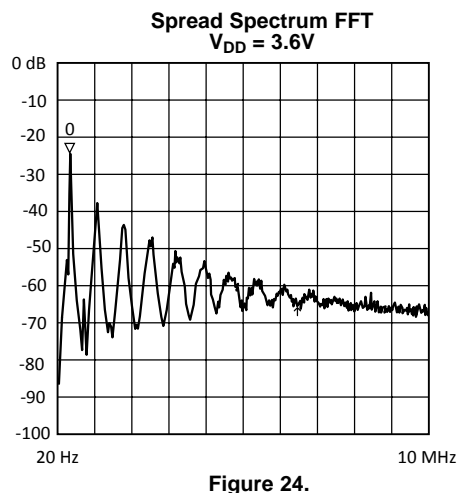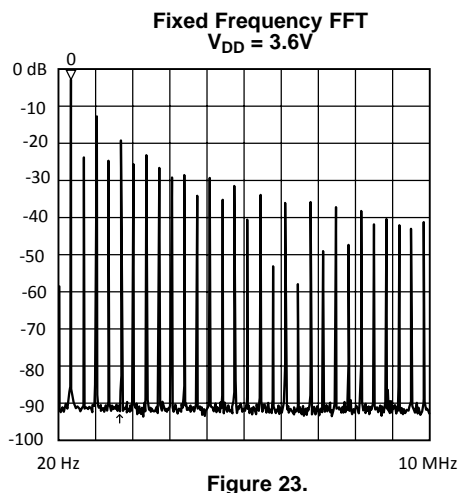
Figure 23.

Spread Spectrum FFT
$V_{DD} = 3.6V$

Figure 24.
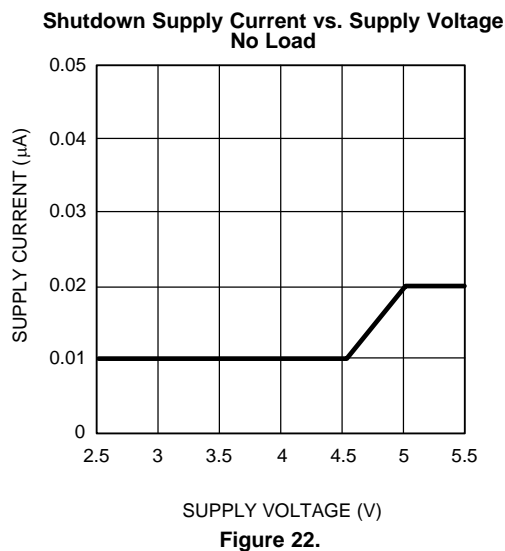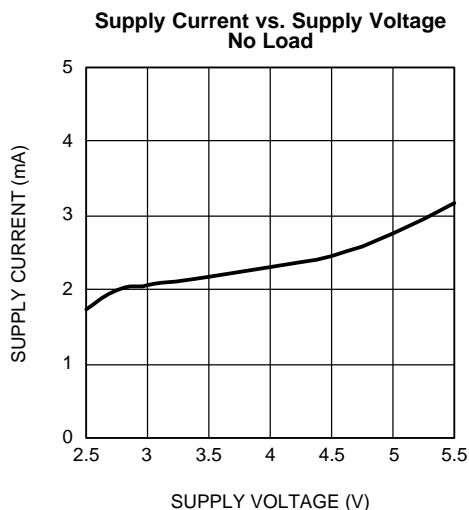
Product Folder Links: *LM4675 LM4675SDBD LM4675TLBD*

APPLICATION INFORMATION

GENERAL AMPLIFIER FUNCTION

The LM4675 features a filterless modulation scheme. The differential outputs of the device switch at 300kHz from V_{DD} to GND. When there is no input signal applied, the two outputs (V_O1 and V_O2) switch with a 50% duty cycle, with both outputs in phase. Because the outputs of the LM4675 are differential, the two signals cancel each other. This results in no net voltage across the speaker, thus there is no load current during an idle state, conserving power.

With an input signal applied, the duty cycle (pulse width) of the LM4675 outputs changes. For increasing output voltages, the duty cycle of V_O1 increases, while the duty cycle of V_O2 decreases. For decreasing output voltages, the converse occurs, the duty cycle of V_O2 increases while the duty cycle of V_O1 decreases. The difference between the two pulse widths yields the differential output voltage.

SPREAD SPECTRUM MODULATION

The LM4675 features a fitlerless spread spectrum modulation scheme that eliminates the need for output filters, ferrite beads or chokes. The switching frequency varies by ±30% about a 300kHz center frequency, reducing the wideband spectral contend, improving EMI emissions radiated by the speaker and associated cables and traces. Where a fixed frequency class D exhibits large amounts of spectral energy at multiples of the switching frequency, the spread spectrum architecture of the LM4675 spreads that energy over a larger bandwidth. The cycle-to-cycle variation of the switching period does not affect the audio reproduction of efficiency.

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 LM4675 and in the transducer load. The amount of power dissipation in the LM4675 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 LM4675 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 LM4675 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 LM4675 also offers the possibility of DC input coupling which eliminates the two external AC coupling, DC blocking capacitors. The LM4675 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 LM4675 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 LM4675 and the load results is lower output power and decreased efficiency. Higher trace resistance between the supply and the LM4675 has the same effect as a poorly regulated supply, increased 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.

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 LM4675 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 LM4675 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 LM4675. 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 LM4675. A 4.7μF tantalum capacitor is recommended.

SHUTDOWN FUNCTION

In order to reduce power consumption while not in use, the LM4675 contains shutdown circuitry that reduces current draw to less than 0.01μA. The trigger point for shutdown is shown as a typical value in the Electrical Characteristics Tables and in the Shutdown Hysteresis Voltage graphs found in the Typical Performance Characteristics section. It is best to switch between ground and supply for minimum current usage while in the shutdown state. While the LM4675 may be disabled with shutdown voltages in between ground and supply, the idle current will be greater than the typical 0.01μA value.

The LM4675 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 LM4675 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 below.

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

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 LM4675 is set by the external resistors, Ri in Figure 2, The Gain is given by Equation 2 below. Best THD+N performance is achieved with a gain of 2V/V (6dB).

$$A_V = 2 * 150 \text{ k}\Omega / R_i \quad (V/V) \tag{2}$$

It is recommended that resistors with 1% tolerance or better be used to set the gain of the LM4675. The Ri resistors should be placed close to the input pins of the LM4675. 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 LM4675. Noise coupled onto input traces which are physically close to each other will be common mode and easily rejected by the LM4675.

Input capacitors may be needed for some applications or when the source is single-ended (see Figure 26, Figure 28). Input capacitors are needed to block any DC voltage at the source so that the DC voltage seen between the input terminals of the LM4675 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 below.

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

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 LM4675 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 28 – Figure 30). 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 LM4675 can be used in many different circuit configurations. The simplest and best performing is the DC coupled, differential input configuration shown in Figure 25. 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 26. 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 LM4675 can be used to amplify more than one audio source. Figure 27 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.

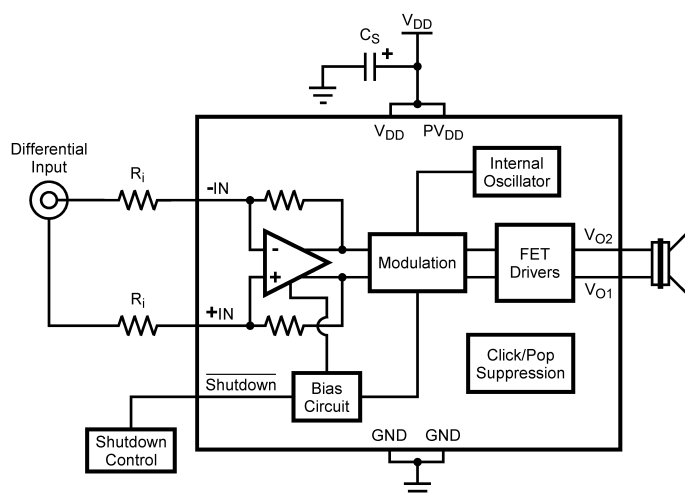## SINGLE-ENDED CIRCUIT CONFIGURATIONS

The LM4675 can also be used with single-ended sources but input capacitors will be needed to block any DC at the input terminals. Figure 28 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 28.

When using more than one single-ended source as shown in Figure 29, 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.

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

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

The LM4675 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 30. Using the principle of superposition, the external component values can be determined with the above equations corresponding to the configuration.

Figure 25. Differential Input Configuration

Product Folder Links: *LM4675 LM4675SDBD LM4675TLBD*
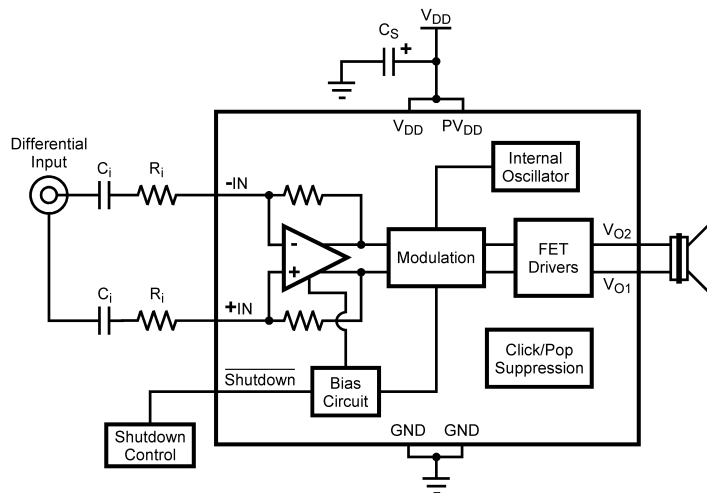
Figure 26. Differential Input Configuration with Input Capacitors
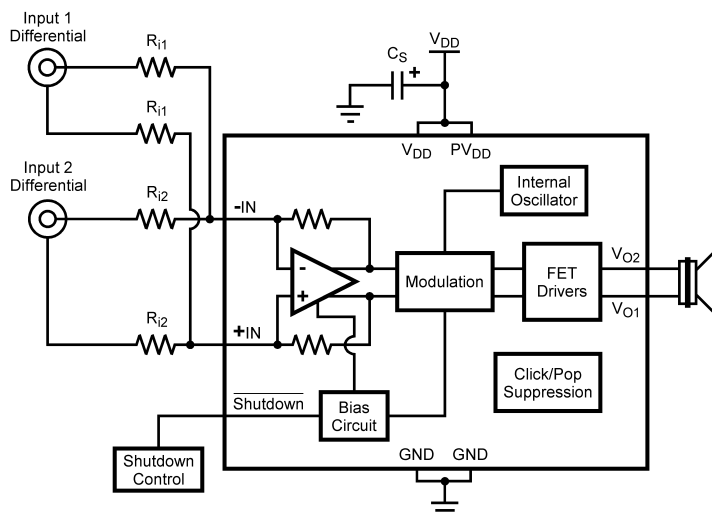
Figure 27. Dual Differential Input Configuration
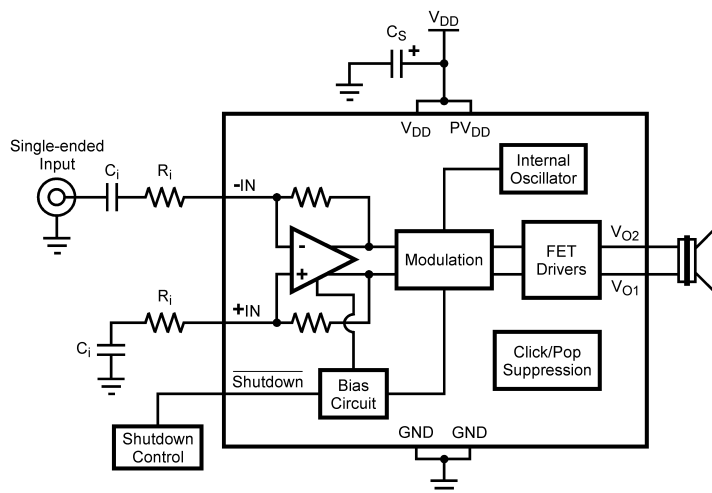
Figure 28. Single-Ended Input Configuration

Figure 29. Dual Single-Ended Input Configuration

Figure 30. Dual Input with a Single-Ended Input and a Differential Input

Product Folder Links: LM4675 LM4675SDBD LM4675TLBD

REFERENCE DESIGN BOARD SCHEMATIC

In addition to the minimal parts required for the application circuit, a measurement filter is provided on the evaluation circuit 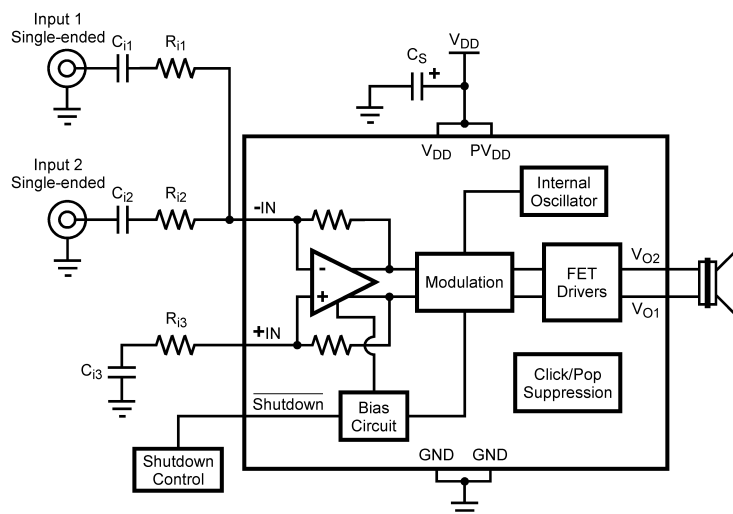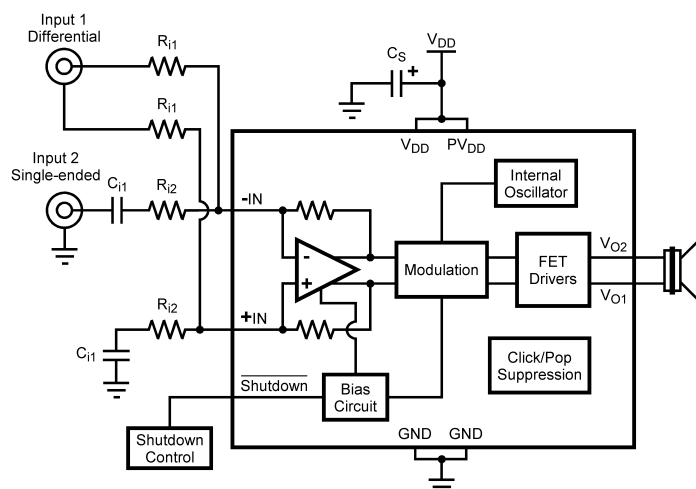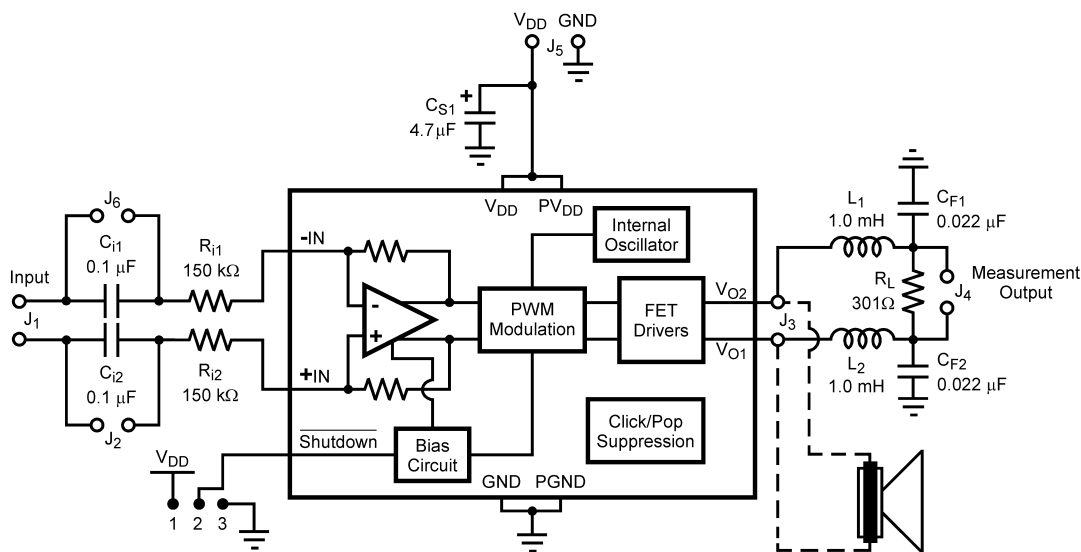board so that conventional audio measurements can be conveniently made without additional equipment. This is a balanced input, grounded differential output low pass filter with a 3dB frequency of approximately 35kHz and an on board termination resistor of 300Ω (see schematic). Note that the capacitive 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 high frequency signals 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.

REVISION HISTORY

Rev	Date	Description
1.0	08/16/06	Initial release.
1.1	09/01/06	Added the DSBGA (YZR009) package.
1.2	10/12/06	Text edit (X-axis label) on Rf Emissions on page 1.
1.3	07/02/08	Text edits.

Changes from Revision B (May 2013) to Revision C   **Page**

- Changed layout of National Data Sheet to TI format 15

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
LM4675SD/NOPB	Active	Production	WSON (NGQ) | 8	1000 | SMALL T&R	Yes	SN	Level-1-260C-UNLIM	-	L4675
LM4675SD/NOPB.A	Active	Production	WSON (NGQ) | 8	1000 | SMALL T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 85	L4675
LM4675SD/NOPB.B	Active	Production	WSON (NGQ) | 8	1000 | SMALL T&R	-	Call TI	Call TI	-40 to 85	
LM4675SDX/NOPB	Active	Production	WSON (NGQ) | 8	4500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-	L4675
LM4675SDX/NOPB.A	Active	Production	WSON (NGQ) | 8	4500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 85	L4675
LM4675SDX/NOPB.B	Active	Production	WSON (NGQ) | 8	4500 | LARGE T&R	-	Call TI	Call TI	-40 to 85	
LM4675TL/NOPB	Active	Production	DSBGA (YZR) | 9	250 | SMALL T&R	Yes	SNAGCU	Level-1-260C-UNLIM	-40 to 85	G H8
LM4675TL/NOPB.A	Active	Production	DSBGA (YZR) | 9	250 | SMALL T&R	Yes	SNAGCU	Level-1-260C-UNLIM	-40 to 85	G H8
LM4675TLX/NOPB	Active	Production	DSBGA (YZR) | 9	3000 | LARGE T&R	Yes	SNAGCU	Level-1-260C-UNLIM	-40 to 85	G H8
LM4675TLX/NOPB.A	Active	Production	DSBGA (YZR) | 9	3000 | LARGE T&R	Yes	SNAGCU	Level-1-260C-UNLIM	-40 to 85	G H8

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts 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.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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PACKAGE MATERIALS INFORMATION

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

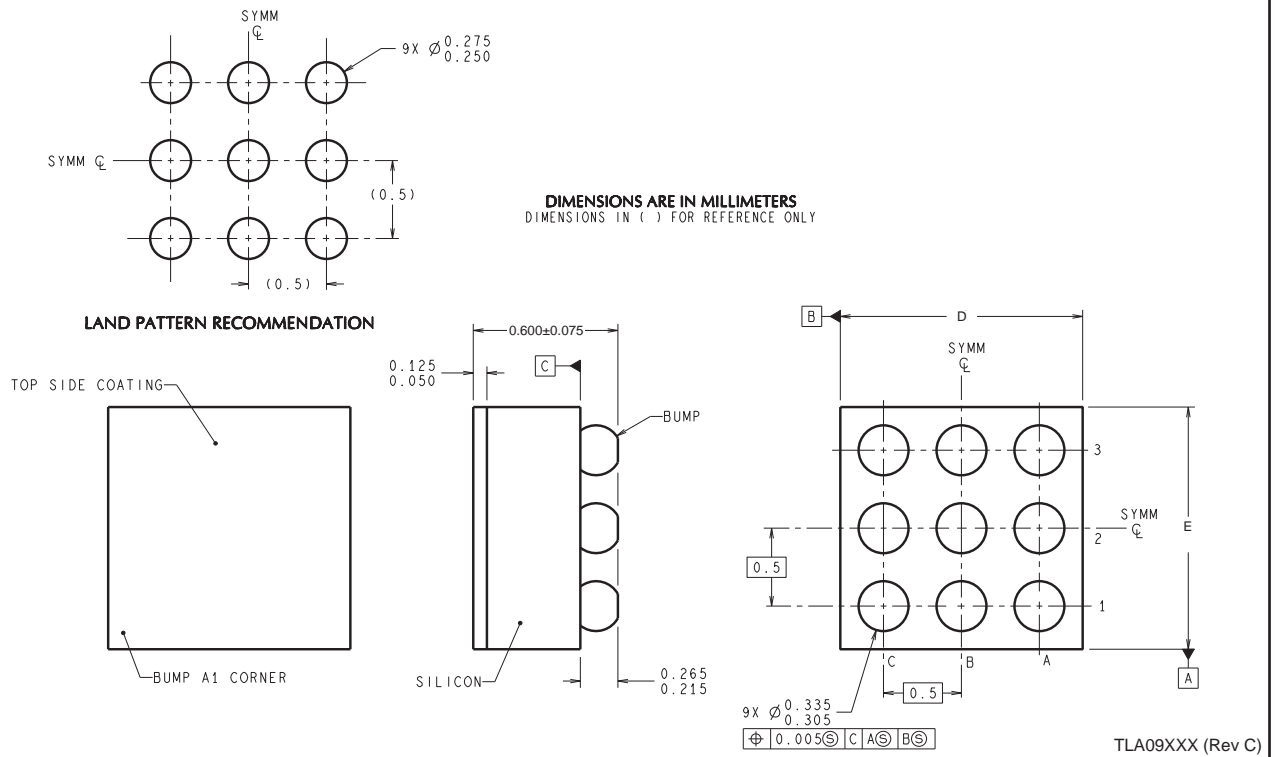| Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM4675SD/NOPB	WSON	NGQ	8	1000	177.8	12.4	3.3	3.3	1.0	8.0	12.0	Q1
LM4675SDX/NOPB	WSON	NGQ	8	4500	330.0	12.4	3.3	3.3	1.0	8.0	12.0	Q1
LM4675TL/NOPB	DSBGA	YZR	9	250	178.0	8.4	1.7	1.7	0.76	4.0	8.0	Q1
LM4675TLX/NOPB	DSBGA	YZR	9	3000	178.0	8.4	1.7	1.7	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)
LM4675SD/NOPB	WSON	NGQ	8	1000	208.0	191.0	35.0
LM4675SDX/NOPB	WSON	NGQ	8	4500	367.0	367.0	35.0
LM4675TL/NOPB	DSBGA	YZR	9	250	208.0	191.0	35.0
LM4675TLX/NOPB	DSBGA	YZR	9	3000	208.0	191.0	35.0

YZR0009

LAND PATTERN RECOMMENDATION

DIMENSIONS ARE IN MILLIMETERS
DIMENSIONS IN ( ) FOR REFERENCE ONLY

TOP SIDE COATING

BUMP A1 CORNER
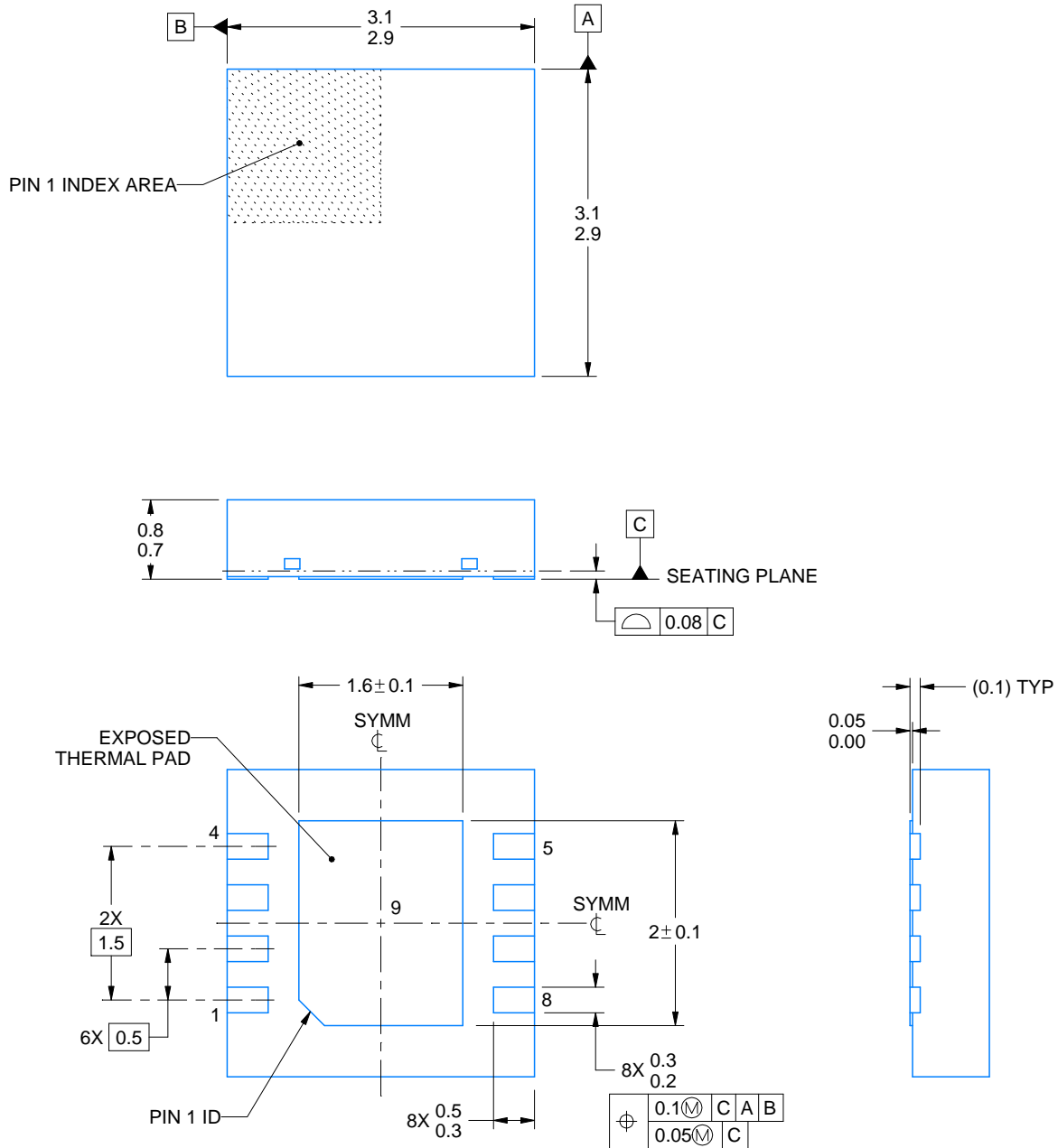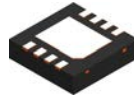
SILICON

BUMP

TLA09XXX (Rev C)

D: Max = 1.562 mm, Min =1.502 mm

E: Max = 1.562 mm, Min =1.502 mm

4215046/A   12/12

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.

TEXAS
INSTRUMENTS
www.ti.com

B | 3.1 / 2.9 | A

PIN 1 INDEX AREA

3.1 / 2.9

0.8 / 0.7

C

SEATING PLANE

⌒ | 0.08 | C

1.6 ± 0.1

SYMM ℄

EXPOSED THERMAL PAD

4

5

2X 1.5

9

SYMM ℄

2 ± 0.1

1

8

6X 0.5

8X 0.3 / 0.2

8X 0.5 / 0.3

PIN 1 ID

⊕ | 0.1 Ⓜ | C | A | B

| 0.05 Ⓜ | C

(0.1) TYP
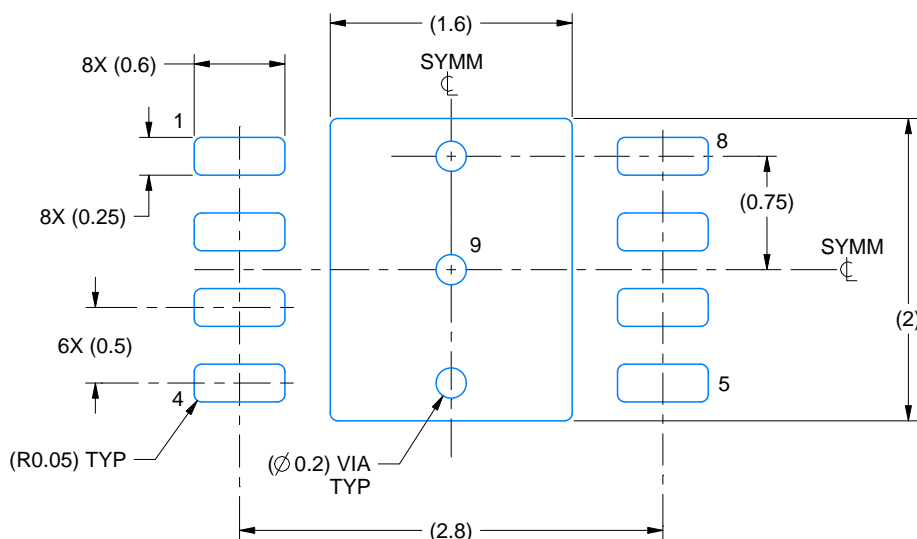
0.05 / 0.00

4214922/A   03/2018

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.
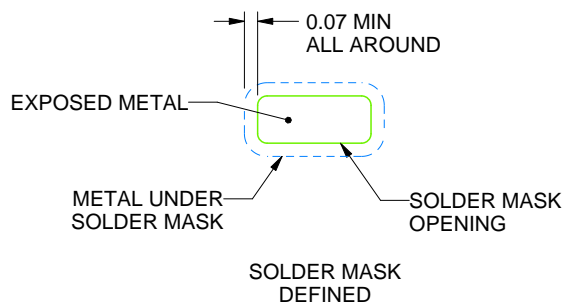
8X (0.6)

(1.6)

SYMM
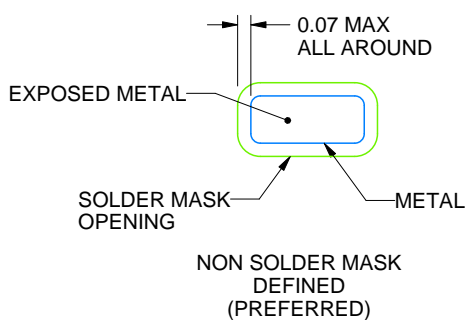
1

8X (0.25)

9

8

(0.75)

SYMM

6X (0.5)

(2)

4

5

(R0.05) TYP

(⌀ 0.2) VIA
TYP

(2.8)

LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:20X

0.07 MAX
ALL AROUND

EXPOSED METAL

SOLDER MASK
OPENING

METAL

NON SOLDER MASK
DEFINED
(PREFERRED)

0.07 MIN
ALL AROUND

EXPOSED METAL

METAL UNDER
SOLDER MASK

SOLDER MASK
OPENING

SOLDER MASK
DEFINED

SOLDER MASK DETAILS

4214922/A   03/2018

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.

8X (0.6)

SYMM

METAL
TYP

9

1

8

8X (0.25)

SYMM

(1.79)

6X (0.5)

4

5

(R0.05) TYP

(1.47)

(2.8)
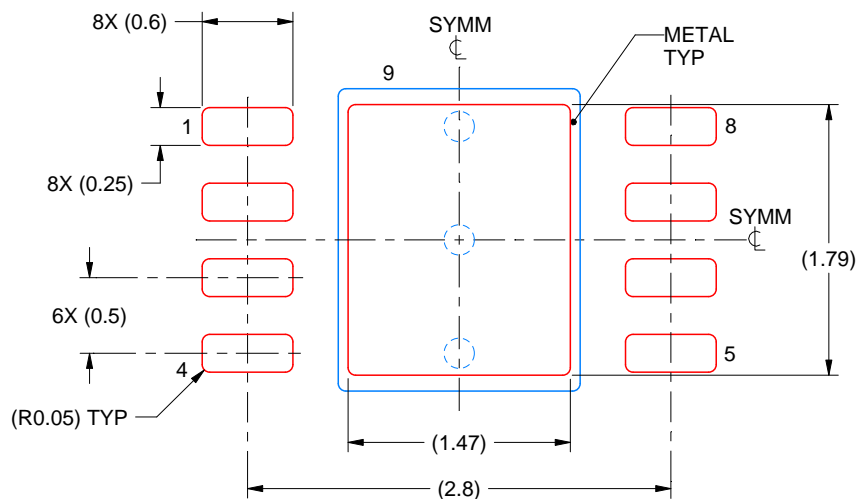
SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL

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

4214922/A   03/2018

NOTES: (continued)

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

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