LM4866 Boomer® Audio Power Amplifier Series
2.2W Stereo Audio Amplifier

Check for Samples: LM4866

FEATURES

- **Stereo BTL Amplifier Mode**
- **"Click and Pop" Suppression Circuitry**
- **Unity-Gain Stable**
- **Thermal Shutdown Protection Circuitry**
- **TSSOP and Exposed-DAP WQFN Packages**

KEY SPECIFICATIONS

- **PO at 1% THD+N**
  - **LM4866LQ, 3Ω load: 2.5W(typ)**
  - **LM4866LQ, 4Ω load: 2.2W(typ)**
  - **LM4866MTE, 3Ω load: 2.5W(typ)**
  - **LM4866MTE, 4Ω load: 2.2W(typ)**
  - **LM4866MTE, 8Ω load: 1.1W(typ)**
  - **LM4866MT, 8Ω load: 1.1W(typ)**
- **Shutdown current: 0.7µA(typ)**
- **Supply voltage range: 2.0V to 5.5V**

APPLICATIONS

- **Multimedia Monitors**
- **Portable and Desktop Computers**
- **Portable Televisions**

DESCRIPTION

The LM4866 is a bridge-connected (BTL) stereo audio power amplifier which, when connected to a 5V supply, delivers 2.2W to a 4Ω load or 2.5W to a 3Ω load with less than 1.0% THD+N (see Notes below).

With the LM4866 packaged in the WQFN, the customer benefits include low thermal impedance, low profile, and small size. This package minimizes PCB area and maximizes output power.

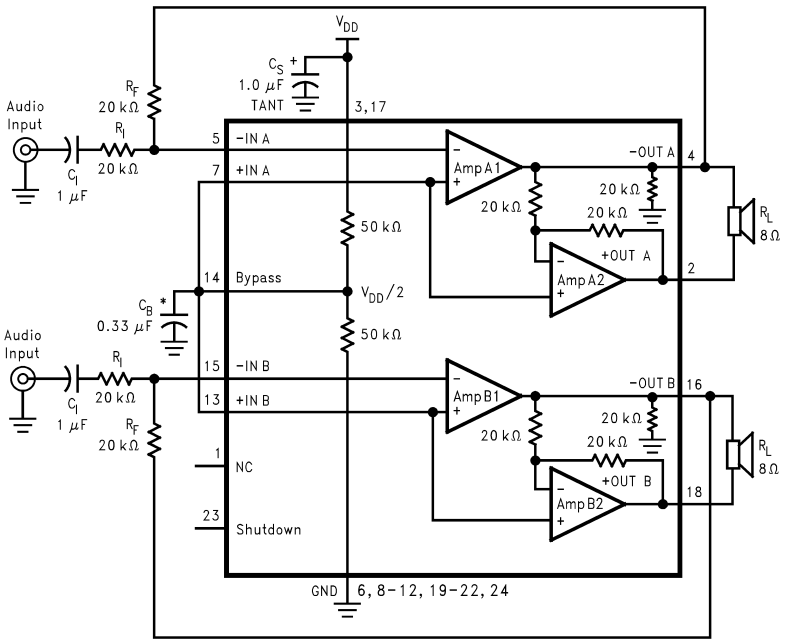
The LM4866 features an externally controlled, low-power consumption shutdown mode, and thermal shutdown protection. It also utilizes circuitry to reduce "clicks and pops" during device turn-on.

Boomer audio power amplifiers are designed specifically to use few external components and provide high quality output power in a surface mount package.

Note: An LM4866PWP or LM4866NHW that has been properly mounted to a circuit board will deliver 2.2W into 4Ω. The other package options for the LM4866 will deliver 1.1W into 8Ω. See the Application Information sections for further information concerning the LM4866PWP and LM4866NHW.

Note: An LM4866PWP or LM4866NHW that has been properly mounted to a circuit board will deliver 2.5W into 3Ω.

Typical Application



Note: Pin out shown for WQFN package. Refer to the Connection Diagrams for the pinout of the TSSOP package.

Connection Diagrams

Top View

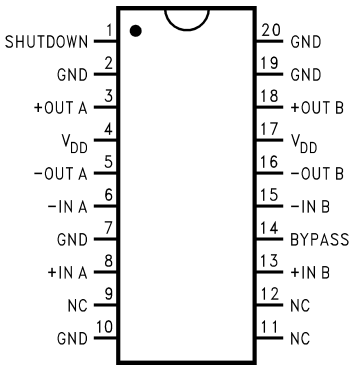


Figure 1. TSSOP Package
See Package Number PW0020A

Top View

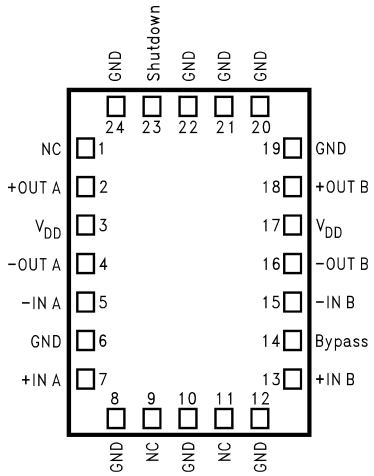


Figure 2. Exposed-DAP WQFN Package
See Package Number NHW0024A

Top View

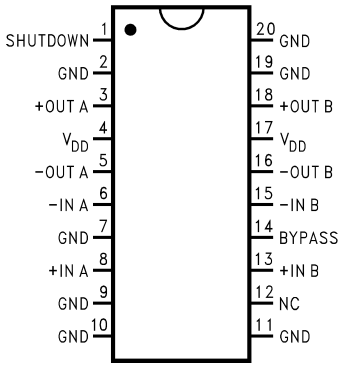


Figure 3. Exposed-DAP TSSOP Package
See Package Number PWP0020A

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]

Supply Voltage			6.0V
Storage Temperature			−65°C to +150°C
Input Voltage			−0.3V to V_{DD} +0.3V
Power Dissipation[3]			Internally limited
ESD Susceptibility[4]			2000V
ESD Susceptibility[5]			200V
Junction Temperature			150°C
Solder Information	Small Outline Package	Vapor Phase (60 sec.)	215°C
		Infrared (15 sec.)	220°C
Thermal Resistance	θ_{JC} (typ)—PW0020A		20°C/W
	θ_{JA} (typ)—PW0020A		80°C/W
	θ_{JC} (typ)—NHW0024A		3.0°C/W
	θ_{JA} (typ)—NHW0024A		42°C/W[6]
	θ_{JC} (typ)—PWP0020A		2°C/W
	θ_{JA} (typ)—PWP0020A		41°C/W[7]
	θ_{JA} (typ)—PWP0020A		51°C/W[8]
	θ_{JA} (typ)—PWP0020A		90°C/W[9]

(1) 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.
(2) If Military/Aerospace specified devices are required, please contact the TI Sales Office/ Distributors for availability and specifications.
(3) The maximum power dissipation is dictated by T_{JMAX}, θ_{JA}, and the ambient temperature T_A and must be derated at elevated temperatures. The maximum allowable power dissipation is $P_{DMAX} = (T_{JMAX} - T_A)/\theta_{JA}$. For the LM4866, T_{JMAX} = 150°C. For the θ_{JA}s for different packages, please see the Application Information section or the Absolute Maximum Ratings section.
(4) Human body model, 100pF discharged through a 1.5kΩ resistor.
(5) Machine model, 220pF–240pF discharged through all pins.
(6) The given θ_{JA} is for an LM4866 packaged in an NHW0024A with the exposed−DAP soldered to an exposed $2in^2$ area of 1oz printed circuit board copper.
(7) The given θ_{JA} is for an LM4866 packaged in an PWP0020A with the exposed−DAP soldered to an exposed $2in^2$ area of 1oz printed circuit board copper.
(8) The given θ_{JA} is for an LM4866 packaged in an PWP0020A with the exposed−DAP soldered to an exposed $1in^2$ area of 1oz printed circuit board copper.
(9) The given θ_{JA} is for an LM4866 packaged in an PWP0020A with the exposed−DAP not soldered to prinbted circuit board copper.

Operating Ratings

Temperature Range $T_{MIN} \le T_A \le T_{MAX}$	−40°C ≤ T_A ≤ 85°C
Supply Voltage	2.0V ≤ V_{DD} ≤ 5.5V

Electrical Characteristics for Entire IC[1][2]

The following specifications apply for V_{DD}= 5V unless otherwise noted. Limits apply for T_A= 25°C.

Parameter		Test Conditions	LM4866		Units (Limits)
			Typical[3]	Limit[4]	
V_{DD}	Supply Voltage			2	V (min)
				5.5	V (max)
I_{DD}	Quiescent Power Supply Current	V_{IN} = 0V, I_O = 0A[5]	11.5	20 6	mA (max) mA (min)
I_{SD}	Shutdown Current	V_{DD} applied to the SHUTDOWN pin	0.7	2	µA (max)

(1) 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.
(2) All voltages are measured with respect to the ground (GND) pins unless otherwise specified.
(3) Typicals are measured at 25°C and represent the parametric norm.
(4) Datasheet min/max specification limits are specified by design, test, or statistical analysis.
(5) The quiescent power supply current depends on the offset voltage when a practical load is connected to the amplifier.

Electrical Characteristics for Bridged-Mode Operation[1][2]

The following specifications apply for V_{DD}= 5V unless otherwise specified. Limits apply for T_A= 25°C.

Parameter		Test Conditions	LM4866		Units (Limits)
			Typical[3]	Limit[4]	
V_{OS}	Output Offset Voltage	V_{IN} = 0V	5	50	mV (max)
P_O	Output Power[5]	THD+N = 1%, f = 1kHz[6]			
		LM4866PWP, R_L = 3Ω	2.5		W
		LM4866NHW, R_L = 3Ω	2.5		W
		LM4866PWP, R_L = 4Ω	2.2		W
		LM4866NHW, R_L = 4Ω	2.2		W
		LM4866PW, R_L = 8Ω	1.1	1.0	W (min)
		THD+N = 10%, f = 1kHz			
		LM4866PWP, R_L = 3Ω	3.2		W
		LM4866NHW, R_L = 3Ω	3.2		W
		LM4866PWP, R_L = 4Ω	2.7		W
		LM4866NHW, R_L = 4Ω	2.7		W
		LM4866PW, R_L = 8Ω	1.5		W
THD+N	Total Harmonic Distortion+Noise	20Hz ≤ f ≤ 20kHz, A_{VD} = 2 LM4866PWP, R_L = 4Ω, P_O = 2W LM4866NHW, R_L = 4Ω, P_O = 2W LM4866PW, R_L = 4Ω, P_O = 1W	0.3 0.3 0.3		
		LM4866PW, R_L = 8Ω, P_O = 1W	0.3		%
PSRR	Power Supply Rejection Ratio	V_{DD} = 5V, V_{RIPPLE} = 200mV_{RMS}, R_L = 8Ω, C_B = 1.0µF	67		dB
X_{TALK}	Channel Separation	f = 1kHz, C_B = 1.0µF	90		dB
SNR	Signal To Noise Ratio	V_{DD} = 5V, P_O = 1.1W, R_L = 8Ω	98		dB

(1) 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.
(2) All voltages are measured with respect to the ground (GND) pins unless otherwise specified.
(3) Typicals are measured at 25°C and represent the parametric norm.
(4) Datasheet min/max specification limits are specified by design, test, or statistical analysis.
(5) Output power is measured at the device terminals.
(6) When driving 3Ω or 4Ω loads and operating on a 5V supply, the LM4866NHW and LM4866PWP must be mounted to a circuit board that has a minimum of 2.5in^2 of exposed, uninterrupted copper area connected to the package's exposed DAP.

Typical Performance Characteristics
NHW Specific Characteristics

LM4866NHW
THD+N vs Output Power

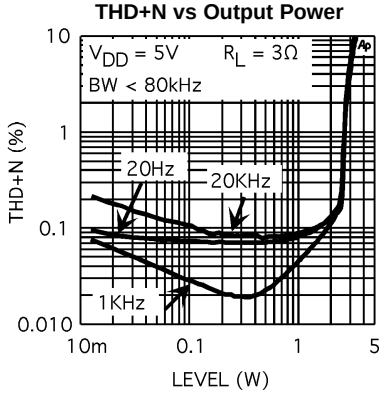


Figure 4.

LM4866NHW
THD+N vs Frequency

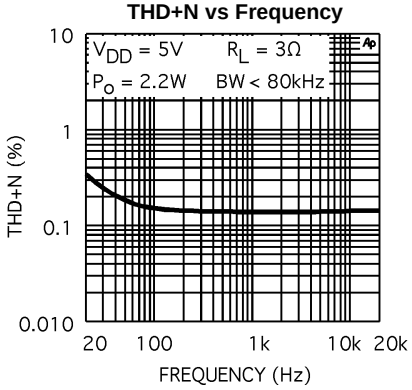


Figure 5.

LM4866NHW
THD+N vs Output Power

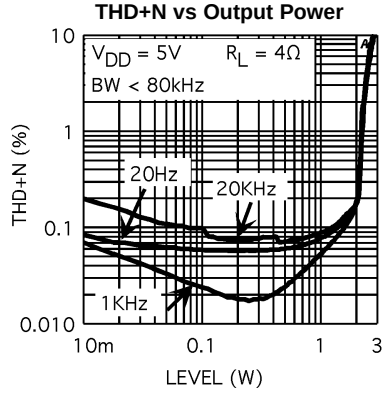


Figure 6.

LM4866NHW
THD+N vs Frequency

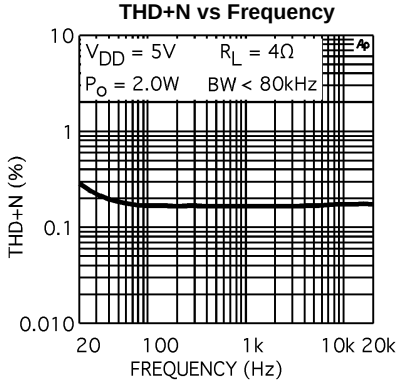


Figure 7.

LM4866NHW
Power Dissipation vs Power Output

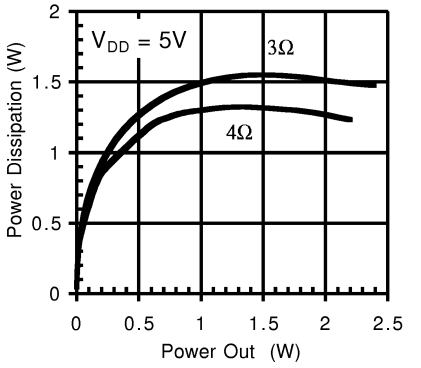
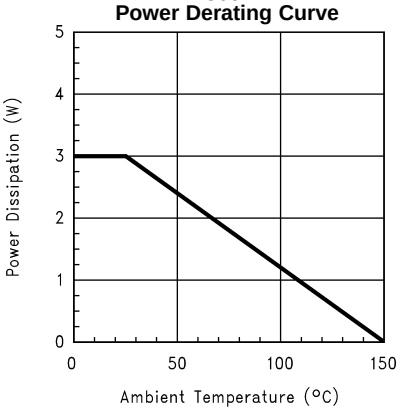


Figure 8.

LM4866NHW
Power Derating Curve



This curve shows the LM4866NHW's thermal dissipation ability at different ambient temperatures given this condition:
The WQFN package's DAP is soldered to a 2.5in^2, 1oz. copper plane.

Figure 9.

Typical Performance Characteristics
PWP Specific Characteristics

LM4866PWP
THD+N vs Output Power

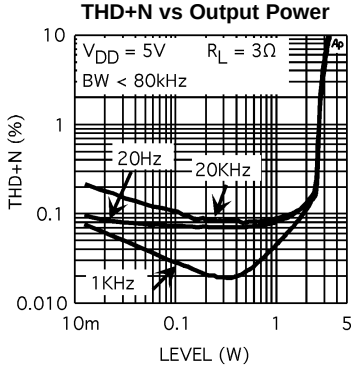


Figure 10.

LM4866PWP
THD+N vs Frequency

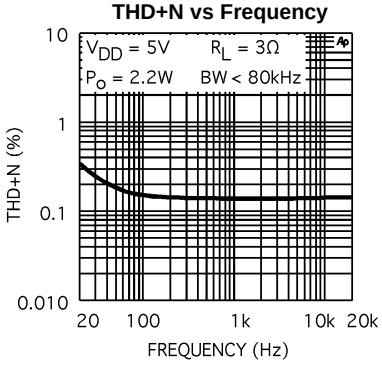


Figure 11.

LM4866PWP
THD+N vs Output Power

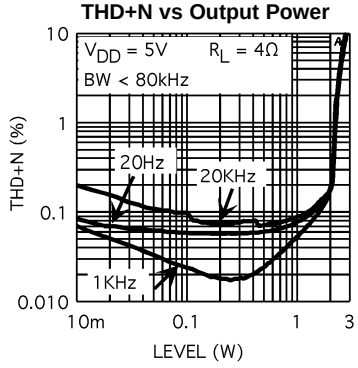


Figure 12.

LM4866PWP
THD+N vs Frequency

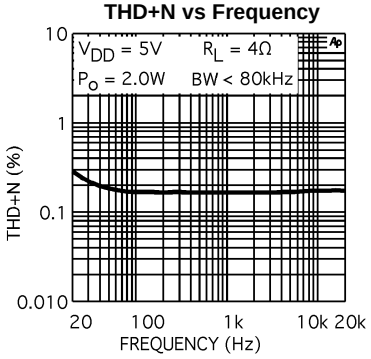


Figure 13.

LM4866PWP
Power Dissipation vs Power Output

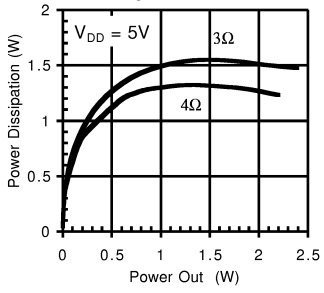
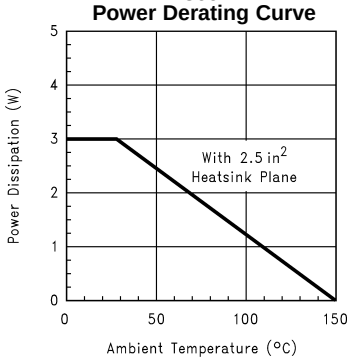


Figure 14.

LM4866PWP
Power Derating Curve



This curve shows the LM4866PWP's thermal dissipation ability at different ambient temperatures given these conditions:

500LFPM + JEDEC board: The part is soldered to a 1S2P 20-lead exposed-DAP TSSOP test board with 500 linear feet per minute of forced-air flow across it.

Board information - copper dimensions: 74x74mm, copper coverage: 100% (buried layer) and 12% (top/bottom layers), 16 vias under the exposed-DAP.

500LFPM + 2.5in^2: The part is soldered to a 2.5in^2, 1 oz. copper plane with 500 linear feet per minute of forced-air flow across it.

2.5in^2: The part is soldered to a 2.5in^2, 1oz. copper plane.

ot Attached: The part is not soldered down and is not forced-air cooled.

Figure 15.

Typical Performance Characteristics

THD+N vs Frequency

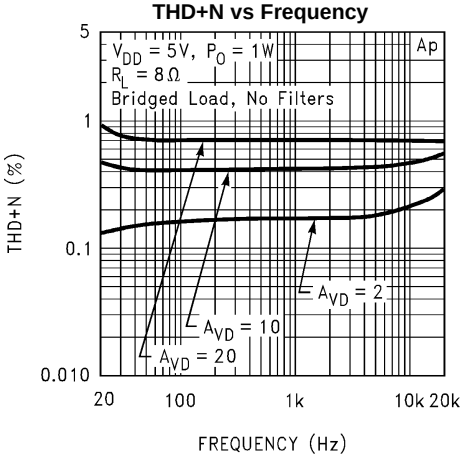


Figure 16.

THD+N vs Output Power

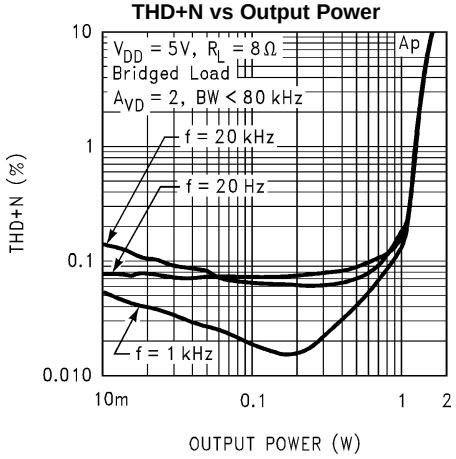


Figure 17.

THD+N vs Output Power

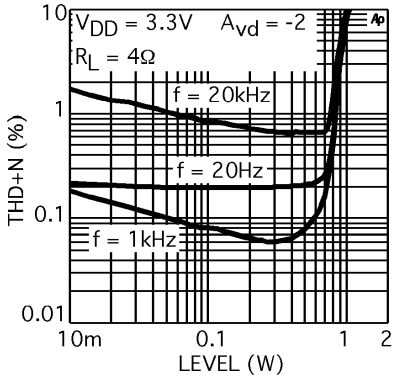


Figure 18.

THD+N vs Frequency

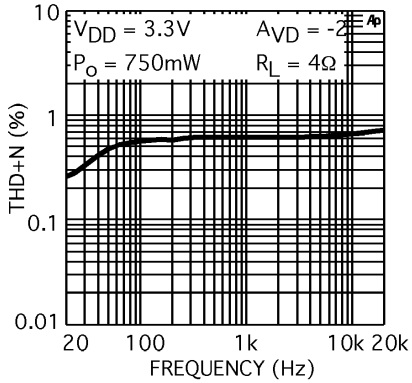


Figure 19.

THD+N vs Output Power

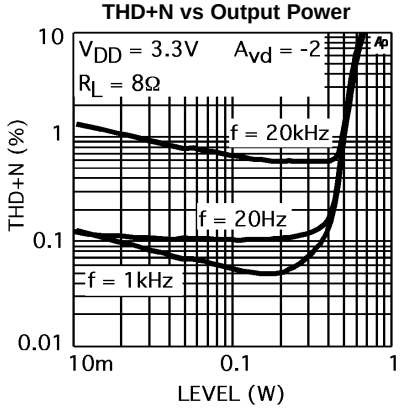


Figure 20.

THD+N vs Frequency

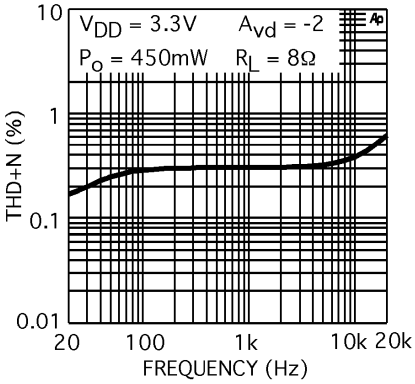


Figure 21.

Typical Performance Characteristics (continued)

Output Power vs Supply Voltage

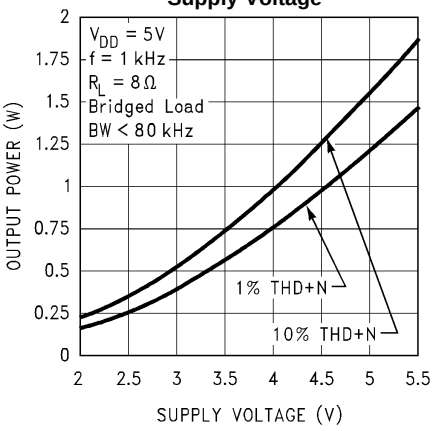


Figure 22.

Output Power vs Load Resistance

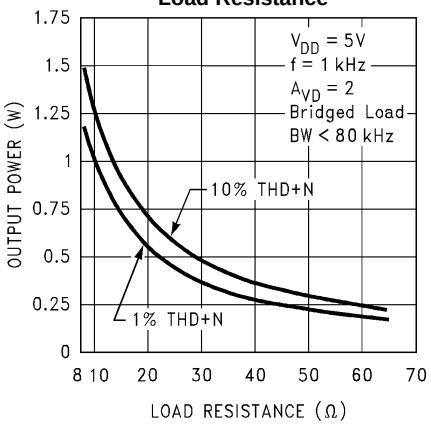


Figure 23.

Power Dissipation vs Output Power

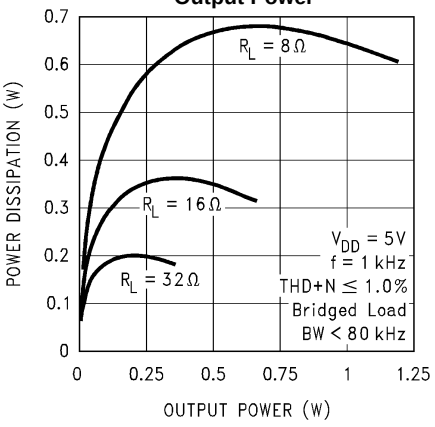


Figure 24.

Dropout Voltage vs Supply Voltage

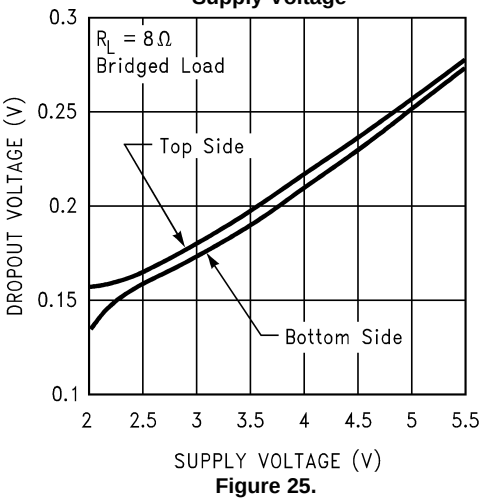


Figure 25.

Power Derating Curve

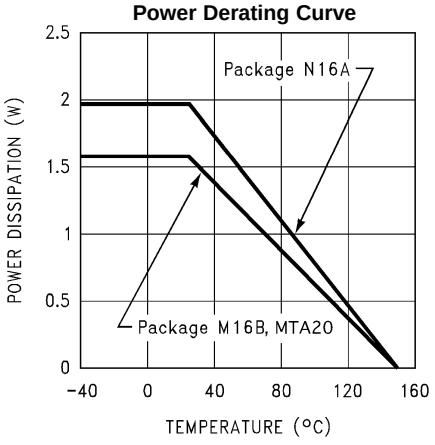


Figure 26.

Noise Floor

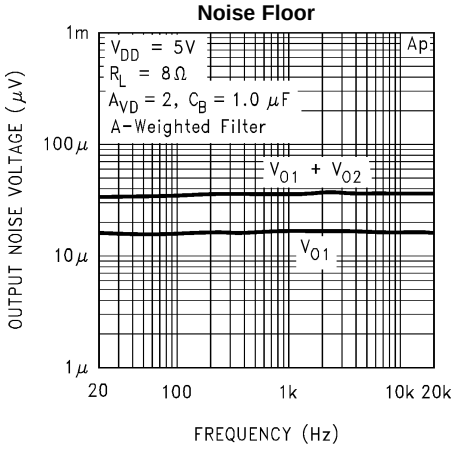


Figure 27.

Typical Performance Characteristics (continued)

Channel Separation

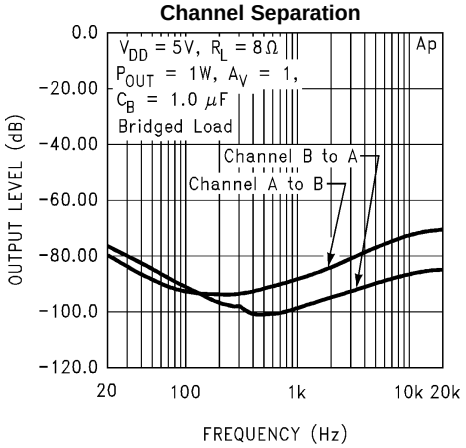


Figure 28.

Power Supply Rejection Ratio

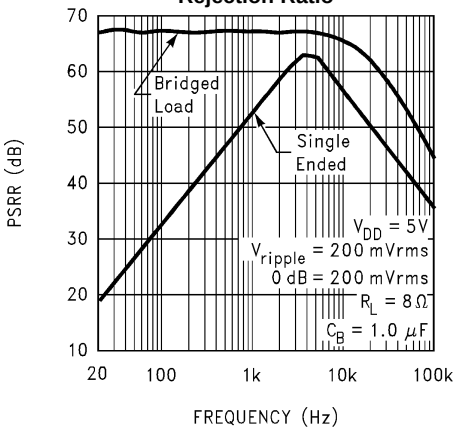


Figure 29.

Open Loop Frequency Response

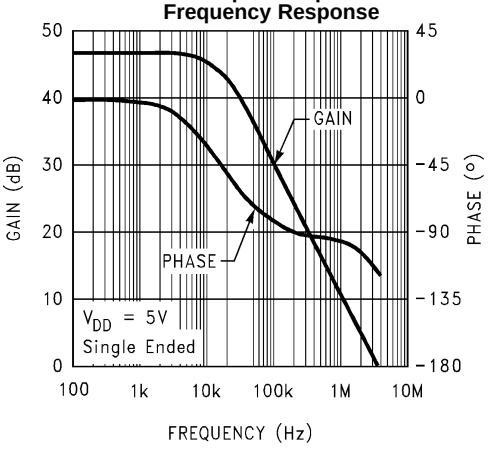


Figure 30.

Supply Current vs Supply Voltage

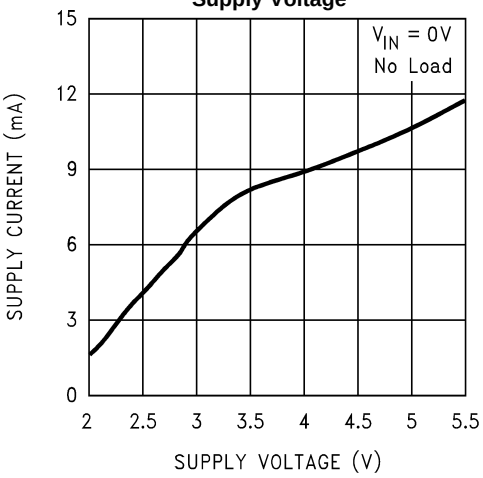


Figure 31.

External Components Description snas1371209

(Refer to Typical Application)

Components		Functional Description
1.	R_i	The Inverting input resistance, along with R_f, set the closed-loop gain. R_i, along with C_i, form a high pass filter with $f_c = 1/(2\pi R_i C_i)$.
2.	C_i	The input coupling capacitor blocks DC voltage at the amplifier's input terminals. C_i, along with R_i, create a highpass filter with $f_c = 1/(2\pi R_i C_i)$. Refer to the section, SELECTING PROPER EXTERNAL COMPONENTS, for an explanation of determining the value of C_i.
3.	R_f	The feedback resistance, along with R_i, set the closed-loop gain.
4.	C_S	The supply bypass capacitor. Refer to the POWER SUPPLY BYPASSING section for information about properly placing, and selecting the value of, this capacitor.
5.	C_B	The capacitor, C_B, filters the half-supply voltage present on the BYPASS pin. Refer to the SELECTING PROPER EXTERNAL COMPONENTS section for information concerning proper placement and selecting C_B's value.

APPLICATION INFORMATION

EXPOSED-DAP PACKAGE (WQFN) PCB MOUNTING CONSIDERATIONS

The LM4866's exposed-DAP (die attach paddle) packages (PWP and NHW) provide a low thermal resistance between the die and the PCB to which the part is mounted and soldered. This allows rapid heat transfer from the die to the surrounding PCB copper traces, ground plane and, finally, surrounding air. The result is a low voltage audio power amplifier that produces 2.2W at ≤ 1% THD with a 4Ω load. This high power is achieved through careful consideration of necessary thermal design. Failing to optimize thermal design may compromise the LM4866's high power performance and activate unwanted, though necessary, thermal shutdown protection.

The PWP and NHW packages must have their DAPs soldered to a copper pad on the PCB. The DAP's PCB copper pad is connected to a large plane of continuous unbroken copper. This plane forms a thermal mass and heat sink and radiation area. Place the heat sink area on either outside plane in the case of a two-sided PCB, or on an inner layer of a board with more than two layers. Connect the DAP copper pad to the inner layer or backside copper heat sink area with 32(4x8) (PWP) or 6(3x2) (NHW) vias. The via diameter should be 0.012in - 0.013in with a 1.27mm pitch. Ensure efficient thermal conductivity by plating-through and solder-filling the vias.

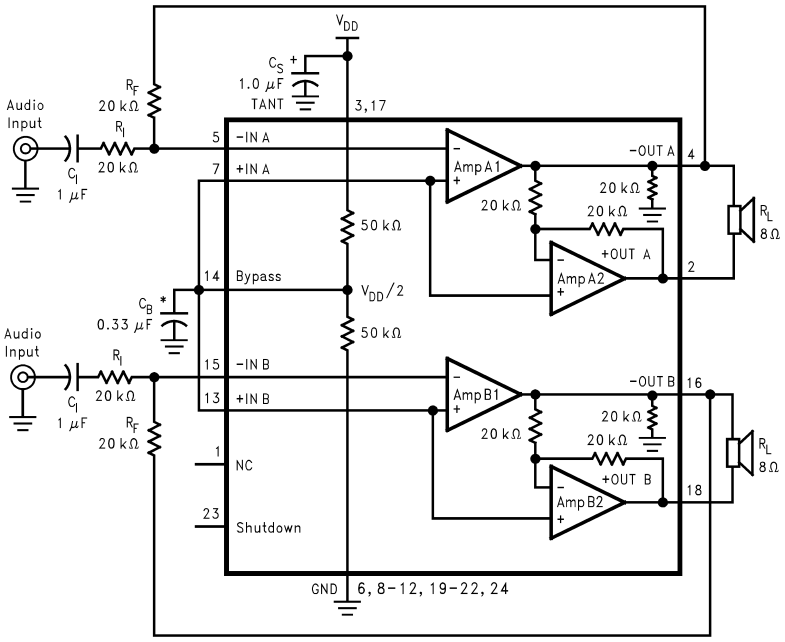
Best thermal performance is achieved with the largest practical copper heat sink area. If the heatsink and amplifier share the same PCB layer, a nominal 2.5in^2 (min) area is necessary for 5V operation with a 4Ω load. Heatsink areas not placed on the same PCB layer as the LM4866 should be 5in^2 (min) for the same supply voltage and load resistance. The last two area recommendations apply for 25°c ambient temperature. Increase the area to compensate for ambient temperatures above 25°c. In systems using cooling fans, the LM4866PWP can take advantage of forced air cooling. With an air flow rate of 450 linear-feet per minute and a 2.5in^2 exposed copper or 5.0in^2 inner layer copper plane heatsink, the LM4866PWP can continuously drive a 3Ω load to full power. The LM4866NHW achieves the same output power level without forced air cooling. In all circumstances and conditions, the junction temperature must be held below 150°C to prevent activating the LM4866's thermal shutdown protection. The LM4866's power de-rating curve in the Typical Performance Characteristics shows the maximum power dissipation versus temperature. Example PCB layouts for the exposed-DAP TSSOP and WQFN packages are shown in the RECOMMENDED PRINTED CIRCUIT BOARD LAYOUT section.

Further detailed and specific information concerning PCB layout, fabrication, and mounting an WQFN package is available from TI's AN-1187 (Literature Number SNOA401).

PCB LAYOUT AND SUPPLY REGULATION CONSIDERATIONS FOR DRIVING 3Ω AND 4Ω LOADS

Power dissipated by a load is a function of the voltage swing across the load and the load's impedance. As load impedance decreases, load dissipation becomes increasingly dependent on the interconnect (PCB trace and wire) resistance between the amplifier output pins and the load's connections. Residual trace resistance causes a voltage drop, which results in power dissipated in the trace and not in the load as desired. For example, 0.1Ω trace resistance reduces the output power dissipated by a 4Ω load from 2.1W to 2.0W. This problem of decreased load dissipation is exacerbated as load impedance decreases. Therefore, to maintain the highest load dissipation and widest output voltage swing, PCB traces that connect the output pins to a load must be as wide as possible.

Poor power supply regulation adversely affects maximum output power. A poorly regulated supply's output voltage decreases with increasing load current. Reduced supply voltage causes decreased headroom, output signal clipping, and reduced output power. Even with tightly regulated supplies, trace resistance creates the same effects as poor supply regulation. Therefore, making the power supply traces as wide as possible helps maintain full output voltage swing.



* Refer to the section SELECTING PROPER EXTERNAL COMPONENTS, for a detailed discussion of C_B size.
Pin out shown for the WQFN package. Refer to the Connection Diagrams for the pinout of the TSSOP package.

Figure 32. Typical Audio Amplifier Application Circuit

BRIDGE CONFIGURATION EXPLANATION

As shown in Figure 32, the LM4866 consists of two pairs of operational amplifiers, forming a two-channel (channel A and channel B) stereo amplifier. (Though the following discusses channel A, it applies equally to channel B.) External resistors R_f and R_i set the closed-loop gain of AmpA1, whereas two internal 20kΩ resistors set AmpA2's gain at -1. The LM4866 drives a load, such as a speaker, connected between the two amplifier outputs, -OUTA and +OUTA.

Figure 32 shows that AmpA1's output serves as AmpA2's input. This results in both amplifiers producing signals identical in magnitude, but 180° out of phase. Taking advantage of this phase difference, a load is placed between -OUTA and +OUTA and driven differentially (commonly referred to as "bridge mode"). This results in a differential gain of

$$A_{VD} = 2 \times (R_f / R_i) \quad (1)$$

Bridge mode amplifiers are different from single-ended amplifiers that drive loads connected between a single amplifier's output and ground. For a given supply voltage, bridge mode has a distinct advantage over the single-ended configuration: its differential output doubles the voltage swing across the load. This produces four times the output power when compared to a single-ended amplifier under the same conditions. This increase in attainable output power assumes that the amplifier is not current limited or that the output signal is not clipped. To ensure minimum output signal clipping when choosing an amplifier's closed-loop gain, refer to the Audio Power Amplifier Design section.

Another advantage of the differential bridge output is no net DC voltage across the load. This is accomplished by biasing channel A's and channel B's outputs at half-supply. This eliminates the coupling capacitor that single supply, single-ended amplifiers require. Eliminating an output coupling capacitor in a single-ended configuration forces a single-supply amplifier's half-supply bias voltage across the load. This increases internal IC power dissipation and may permanently damage loads such as speakers.

POWER DISSIPATION

Power dissipation is a major concern when designing a successful single-ended or bridged amplifier. Equation 2 states the maximum power dissipation point for a single-ended amplifier operating at a given supply voltage and driving a specified output load

$$P_{DMAX} = (V_{DD})^2 / (2\pi^2 R_L) \text{ Single-Ended} \quad (2)$$

However, a direct consequence of the increased power delivered to the load by a bridge amplifier is higher internal power dissipation for the same conditions.

The LM4866 has two operational amplifiers per channel. The maximum internal power dissipation per channel operating in the bridge mode is four times that of a single-ended amplifier. From Equation 3, assuming a 5V power supply and an 4Ω load, the maximum single channel power dissipation is 1.27W or 2.54W for stereo operation.

$$P_{DMAX} = 4 \times (V_{DD})^2 / (2\pi^2 R_L) \text{ Bridge Mode} \quad (3)$$

The LM4973's power dissipation is twice that given by Equation 2 or Equation 3 when operating in the single-ended mode or bridge mode, respectively. Twice the maximum power dissipation point given by Equation 3 must not exceed the power dissipation given by Equation 4:

$$P_{DMAX}' = (T_{JMAX} - T_A) / \theta_{JA} \quad (4)$$

The LM4866's T_{JMAX} = 150°C. In the NHW (WQFN) package soldered to a DAP pad that expands to a copper area of 5in^2 on a PCB, the LM4866's θ_{JA} is 20°C/W. In the PWP package soldered to a DAP pad that expands to a copper area of 2in^2 on a PCB , the LM4866's θ_{JA} is 41°C/W. At any given ambient temperature $T_{J\A}$, use Equation 4 to find the maximum internal power dissipation supported by the IC packaging. Rearranging Equation 4 and substituting PDMAX for PDMAX' results in Equation 5. This equation gives the maximum ambient temperature that still allows maximum stereo power dissipation without violating the LM4866's maximum junction temperature.

$$T_A = T_{JMAX} - 2 \times P_{DMAX} \theta_{JA} \quad (5)$$

For a typical application with a 5V power supply and an 4Ω load, the maximum ambient temperature that allows maximum stereo power dissipation without exceeding the maximum junction temperature is approximately 99°C for the WQFN package and 45°C for the PWP package.

$$T_{JMAX} = P_{DMAX} \theta_{JA} + T_A \quad (6)$$

Equation 6 gives the maximum junction temperature T_{JMAX}. If the result violates the LM4866's 150°C, reduce the maximum junction temperature by reducing the power supply voltage or increasing the load resistance. Further allowance should be made for increased ambient temperatures.

The above examples assume that a device is a surface mount part operating around the maximum power dissipation point. Since internal power dissipation is a function of output power, higher ambient temperatures are allowed as output power or duty cycle decreases.

If the result of Equation 2 is greater than that of Equation 3, then decrease the supply voltage, increase the load impedance, or reduce the ambient temperature. If these measures are insufficient, a heat sink can be added to reduce θ_{JA}. The heat sink can be created using additional copper area around the package, with connections to the ground pin(s), supply pin and amplifier output pins. External, solder attached SMT heatsinks such as the Thermalloy 7106D can also improve power dissipation. When adding a heat sink, the θ_{JA} is the sum of θ_{JC}, θ_{CS}, and θ_{SA}. (θ_{JC} is the junction−to−case thermal impedance, $_{CS}$ is the case−to−sink thermal impedance, and $\theta_{SA}$is the sink−to−ambient thermal impedance.) Refer to the Typical Performance Characteristics curves for power dissipation information at lower output power levels.

POWER SUPPLY BYPASSING

As with any power amplifier, proper supply bypassing is critical for low noise performance and high power supply rejection. Applications that employ a 5V regulator typically use a 10µF in parallel with a 0.1µF filter capacitors to stabilize the regulator's output, reduce noise on the supply line, and improve the supply's transient response. However, their presence does not eliminate the need for a local 1.0µF tantalum bypass capacitance connected between the LM4866's supply pins and ground. Do not substitute a ceramic capacitor for the tantalum. Doing so may cause oscillation in the output signal. Keep the length of leads and traces that connect capacitors between the LM4866's power supply pin and ground as short as possible. Connecting a 1µF capacitor, C_B, between the

BYPASS pin and ground improves the internal bias voltage's stability and improves the amplifier's PSRR. The PSRR improvements increase as the bypass pin capacitor value increases. Too large, however, increases turn-on time and can compromise amplifier's click and pop performance. The selection of bypass capacitor values, especially C_B, depends on desired PSRR requirements, click and pop performance (as explained in the section, SELECTING PROPER EXTERNAL COMPONENTS), system cost, and size constraints.

MICRO-POWER SHUTDOWN

The voltage applied to the SHUTDOWN pin controls the LM4866's shutdown function. Activate micro-power shutdown by applying V_{DD} to the SHUTDOWN pin. When active, the LM4866's micro-power shutdown feature turns off the amplifier's bias circuitry, reducing the supply current. The logic threshold is typically $V_{DD}/2$. The low 0.7µA typical shutdown current is achieved by applying a voltage that is as near as V_{DD} as possible to the SHUTDOWN pin. A voltage thrat is less than V_{DD} may increase the shutdown current.

There are a few ways to control the micro-power shutdown. These include using a single-pole, single-throw switch, a microprocessor, or a microcontroller. When using a switch, connect an external 10kΩ pull-up resistor between the SHUTDOWN pin and V_{DD}. Connect the switch between the SHUTDOWN pin and ground. Select normal amplifier operation by closing the switch. Opening the switch connects the SHUTDOWN pin to V_{DD} through the pull-up resistor, activating micro-power shutdown. The switch and resistor ensure that the SHUTDOWN pin will not float. This prevents unwanted state changes. In a system with a microprocessor or a microcontroller, use a digital output to apply the control voltage to the SHUTDOWN pin. Driving the SHUTDOWN pin with active circuitry eliminates the pull up resistor.

Table 1. LOGIC LEVEL TRUTH TABLE FOR SHUTDOWN OPERATION

SHUTDOWN	OPERATIONAL MODE
Low	Full power, stereo BTL amplifiers
High	Micro-power Shutdown

SELECTING PROPER EXTERNAL COMPONENTS

Optimizing the LM4866's performance requires properly selecting external components. Though the LM4866 operates well when using external components with wide tolerances, best performance is achieved by optimizing component values.

The LM4866 is unity-gain stable, giving a designer maximum design flexibility. The gain should be set to no more than a given application requires. This allows the amplifier to achieve minimum THD+N and maximum signal-to-noise ratio. These parameters are compromised as the closed-loop gain increases. However, low gain demands input signals with greater voltage swings to achieve maximum output power. Fortunately, many signal sources such as audio CODECs have outputs of $1V_{RMS}$ ($2.83V_{P-P}$). Please refer to the Audio Power Amplifier Design section for more information on selecting the proper gain.

Input Capacitor Value Selection

Amplifying the lowest audio frequencies requires high value input coupling capacitor (C_i in Figure 32). A high value capacitor can be expensive and may compromise space efficiency in portable designs. In many cases, however, the speakers used in portable systems, whether internal or external, have little ability to reproduce signals below 150Hz. Applications using speakers with this limited frequency response reap little improvement by using large input capacitor.

Besides effecting system cost and size, C_i has an affect on the LM4866's click and pop performance. When the supply voltage is first applied, a transient (pop) is created as the charge on the input capacitor changes from zero to a quiescent state. The magnitude of the pop is directly proportional to the input capacitor's size. Higher value capacitors need more time to reach a quiescent DC voltage (usually $V_{DD}/2$) when charged with a fixed current. The amplifier's output charges the input capacitor through the feedback resistor, R_f. Thus, pops can be minimized by selecting an input capacitor value that is no higher than necessary to meet the desired -3dB frequency.

A shown in Figure 32, the input resistor (R_I) and the input capacitor, C_I produce a −3dB high pass filter cutoff frequency that is found using Equation 7.

$$f_{-3\,dB} = \frac{1}{2\pi R_{IN} C_1} \quad (7)$$

As an example when using a speaker with a low frequency limit of 150Hz, C_I, using Equation 4, is 0.063µF. The 1.0µF C_I shown in Figure 32 allows the LM4866 to drive high efficiency, full range speaker whose response extends below 30Hz.

Bypass Capacitor Value Selection

Besides minimizing the input capacitor size, careful consideration should be paid to value of C_B, the capacitor connected to the BYPASS pin. Since C_B determines how fast the LM4866 settles to quiescent operation, its value is critical when minimizing turn−on pops. The slower the LM4866's outputs ramp to their quiescent DC voltage (nominally 1/2 V_{DD}), the smaller the turn−on pop. Choosing C_B equal to 1.0µF along with a small value of C_i (in the range of 0.1µF to 0.39µF), produces a click-less and pop-less shutdown function. As discussed above, choosing C_i no larger than necessary for the desired bandwidth helps minimize clicks and pops.

OPTIMIZING CLICK AND POP REDUCTION PERFORMANCE

The LM4866 contains circuitry to minimize turn-on and shutdown transients or "clicks and pop". For this discussion, turn-on refers to either applying the power supply voltage or when the shutdown mode is deactivated. While the power supply is ramping to its final value, the LM4866's internal amplifiers are configured as unity gain buffers. An internal current source changes the voltage of the BYPASS pin in a controlled, linear manner. Ideally, the input and outputs track the voltage applied to the BYPASS pin. The gain of the internal amplifiers remains unity until the voltage on the bypass pin reaches 1/2 V_{DD}. As soon as the voltage on the BYPASS pin is stable, the device becomes fully operational. Although the bypass pin current cannot be modified, changing the size of C_B alters the device's turn-on time and the magnitude of "clicks and pops". Increasing the value of C_B reduces the magnitude of turn-on pops. However, this presents a tradeoff: as the size of C_B increases, the turn-on time increases. There is a linear relationship between the size of C_B and the turn-on time. Here are some typical turn-on times for various values of C_B:

C_B	T_{ON}
0.01µF	20 ms
0.1µF	200 ms
0.22µF	440 ms
0.47µF	940 ms
1.0µF	2 Sec

In order eliminate "clicks and pops", all capacitors must be discharged before turn-on. Rapidly switching V_{DD} may not allow the capacitors to fully discharge, which may cause "clicks and pops".

NO LOAD STABILITY

The LM4866 may exhibit low level oscillation when the load resistance is greater than 10kΩ. This oscillation only occurs as the output signal swings near the supply voltages. Prevent this oscillation by connecting a 5kΩ between the output pins and ground.

AUDIO POWER AMPLIFIER DESIGN

Audio Amplifier Design: Driving 1W into an 8Ω Load

The following are the desired operational parameters:

Power Output:	$1W_{RMS}$
Load Impedance:	8Ω
Input Level:	$1V_{RMS}$
Input Impedance:	20kΩ
Bandwidth:	100Hz−20 kHz ± 0.25 dB

The design begins by specifying the minimum supply voltage necessary to obtain the specified output power. One way to find the minimum supply voltage is to use the Output Power vs Supply Voltage curve in the Typical Performance Characteristics section. Another way, using Equation 4, is to calculate the peak output voltage necessary to achieve the desired output power for a given load impedance. To account for the amplifier's dropout voltage, two additional voltages, based on the Dropout Voltage vs Supply Voltage in the Typical Performance Characteristics curves, must be added to the result obtained by Equation 8. The result in Equation 9.

$$V_{opeak} = \sqrt{(2R_L P_O)} \quad (8)$$

$$V_{DD} \geq (V_{OUTPEAK} + (V_{ODTOP} + V_{ODBOT})) \quad (9)$$

The Output Power vs Supply Voltage graph for an 8Ω load indicates a minimum supply voltage of 4.6V. This is easily met by the commonly used 5V supply voltage. The additional voltage creates the benefit of headroom, allowing the LM4866 to produce peak output power in excess of 1W without clipping or other audible distortion. The choice of supply voltage must also not create a situation that violates maximum power dissipation as explained above in the Power Dissipation section.

After satisfying the LM4866's power dissipation requirements, the minimum differential gain is found using Equation 10.

$$A_{VD} \geq \sqrt{(P_O R_L)}/(V_{IN}) = V_{orms}/V_{inrms} \quad (10)$$

Thus, a minimum gain of 2.83 allows the LM4866's to reach full output swing and maintain low noise and THD+N performance. For this example, let $A_{VD} = 3$.

The amplifier's overall gain is set using the input (R_i) and feedback (R_f) resistors. With the desired input impedance set at 20kΩ, the feedback resistor is found using Equation 11.

$$R_f/R_i = A_{VD}/2 \quad (11)$$

The value of R_f is 30kΩ.

The last step in this design example is setting the amplifier's −3dB frequency bandwidth. To achieve the desired ±0.25dB pass band magnitude variation limit, the low frequency response must extend to at least one−fifth the lower bandwidth limit and the high frequency response must extend to at least five times the upper bandwidth limit. The gain variation for both response limits is 0.17dB, well within the ±0.25dB desired limit. The results are an

and an

$$f_L = 100Hz/5 = 20Hz \quad (12)$$

$$F_H = 20kHz \times 5 = 100kHz \quad (13)$$

As mentioned in the External Components Description snas1371209 section, R_i and C_i create a highpass filter that sets the amplifier's lower bandpass frequency limit. Find the coupling capacitor's value using Equation 14.

$$C_i \geq \frac{1}{2\pi R_i f_c} \quad (14)$$

the result is

$$1/(2\pi * 20k\Omega * 20Hz) = 0.398\mu F \quad (15)$$

Use a 0.39µF capacitor, the closest standard value.

The product of the desired high frequency cutoff (100kHz in this example) and the differential gain, A_{VD}, determines the upper passband response limit. With $A_{VD} = 3$ and $f_H = 100kHz$, the closed-loop gain bandwidth product (GBWP) is 300kHz. This is less than the LM4866's 3.5MHz GBWP. With this margin, the amplifier can be used in designs that require more differential gain while avoiding performance-lrestricting bandwidth limitations.

RECOMMENDED PRINTED CIRCUIT BOARD LAYOUT

Figure 33 through Figure 38 show the recommended four-layer PC board layout that is optimized for the 24-pin NHW-packaged LM4866 and associated external components. Figure 38 through Figure 42 show the recommended four-layer PC board layout that is optimized for the 20-pin PWP-packaged LM4866 and associated components. Figure 39 through Figure 45 show the recommended two-layer PC board layout that is optimized for the 20-pin PW-packaged LM4866 and associated components. These circuits are designed for use with an external 5V supply and 3Ω (or greater) speakers for the NHW- and PWP-packaged LM4866 and 4Ω (or greater) speakers for the PW-packaged LM4866.

This circuit board is easy to use. Apply 5V and ground to the board's V_{DD} and GND pads, respectively. Connect speakers between the board's -OUTA and +OUTA and OUTB and +OUTB pads. Apply the stereo input signal to the input pins labeled "-INA" and "-INB." The stereo input signal's ground references are connected to the respective input channel's "GND" pin, adjacent to the input pins.

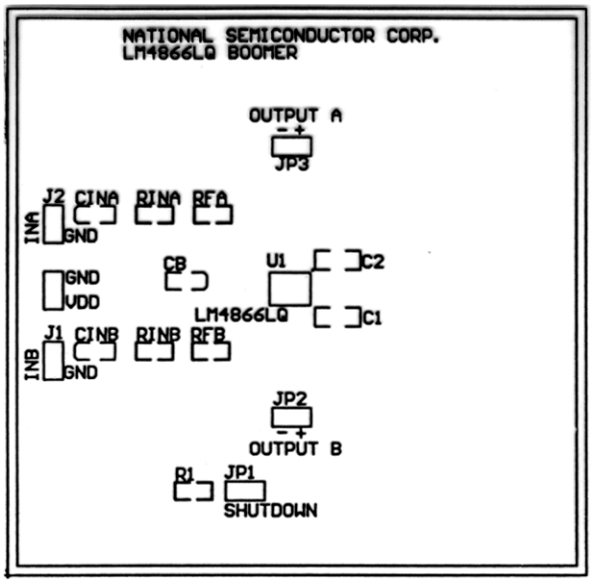


Figure 33. Recommended NHW PC Board Layout: Component-Side Silkscreen

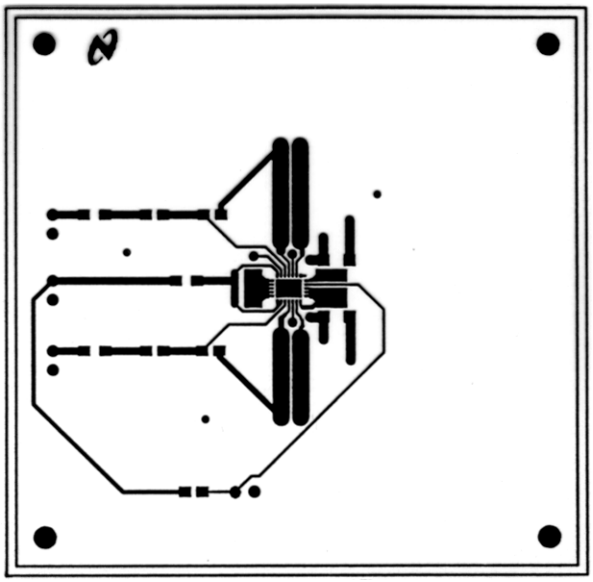


Figure 34. Recommended NHW PC Board Layout: Component-Side Layout

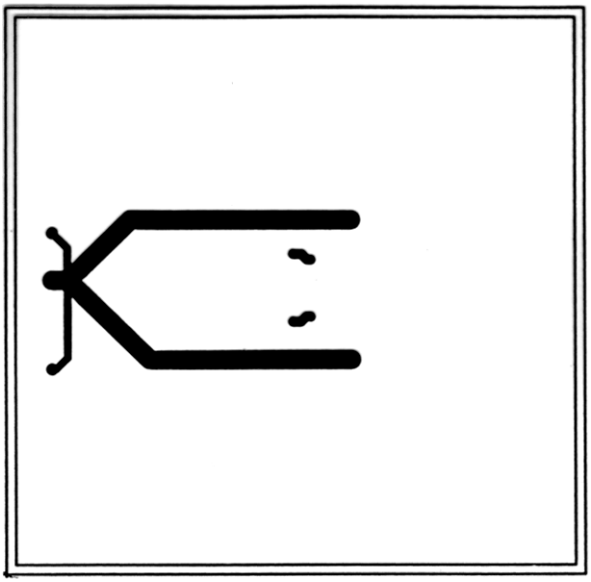


Figure 35. Recommended NHW PC Board Layout: Upper Inner-Layer Layout

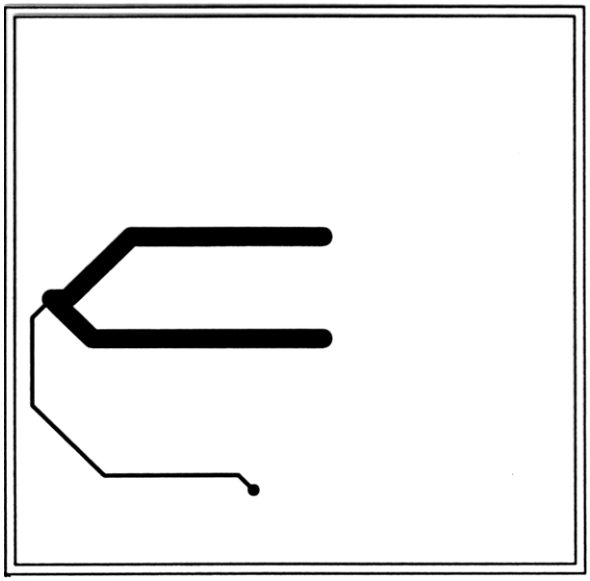


Figure 36. Recommended NHW PC Board Layout: Lower Inner-Layer Layout

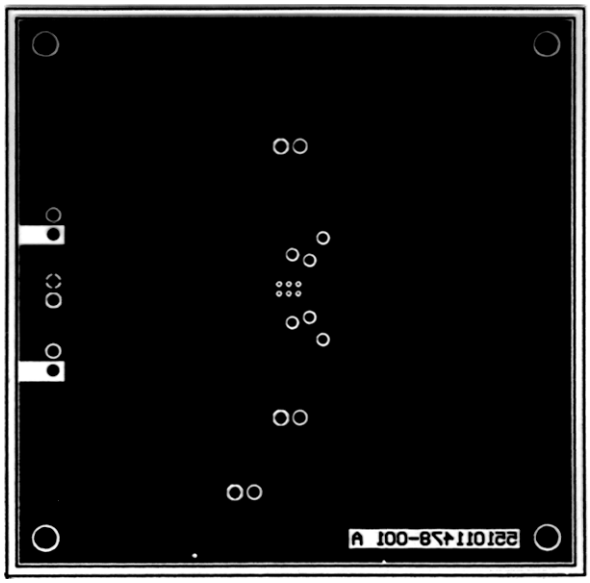


Figure 37. Recommended NHW PC Board Layout: Bottom-Side Layout

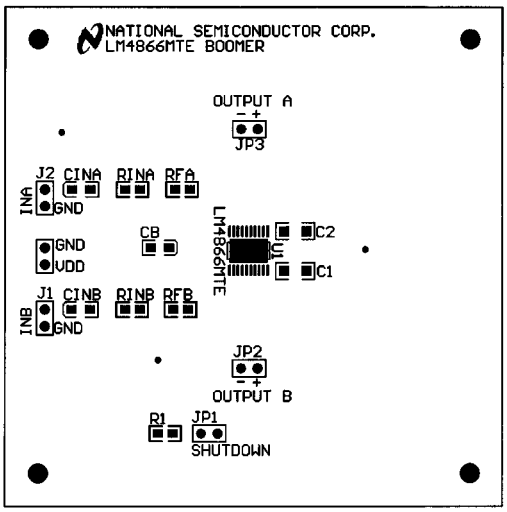


Figure 38. Recommended PWP Board Layout: Component-Side Silkscreen

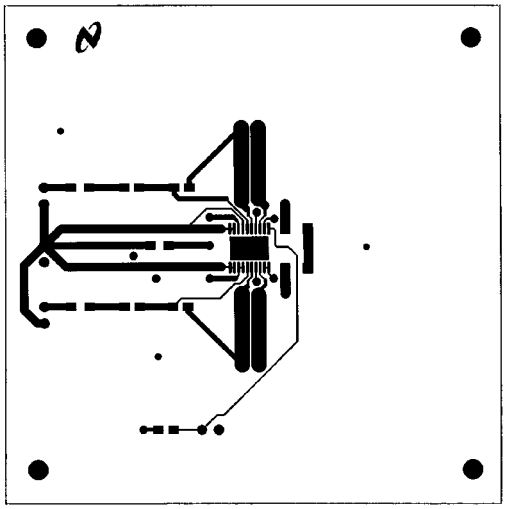


Figure 39. Recommended PWP PC Board Layout: Component-Side Layout

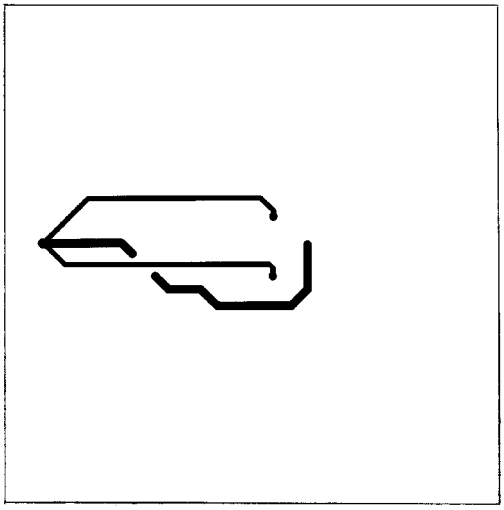


Figure 40. Recommended PWP Board Layout: Upper Inner-Layer Layout

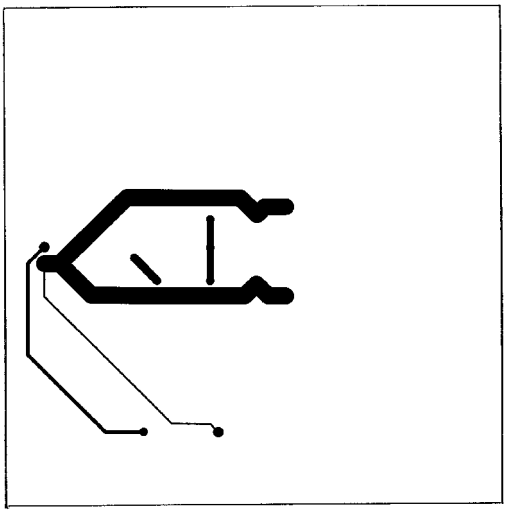


Figure 41. Recommended PWP PC Board Layout: Lower Inner-Layer Layout

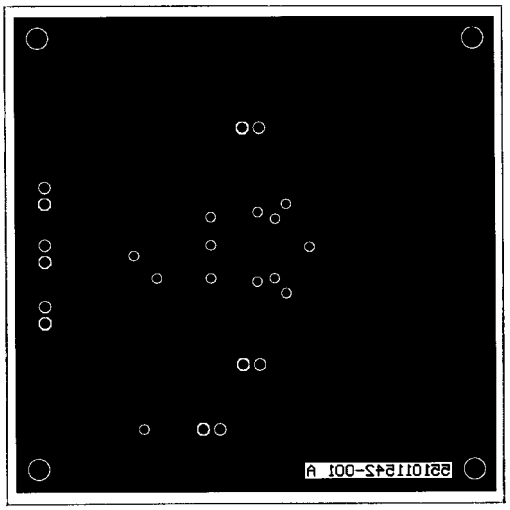


Figure 42. Recommended PWP Board Layout: Bottom-Side Layout

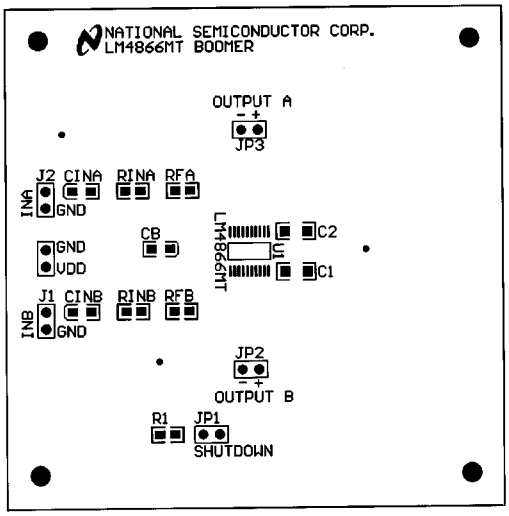


Figure 43. Recommended PW PC Board Layout: Component-Side Silkscreen

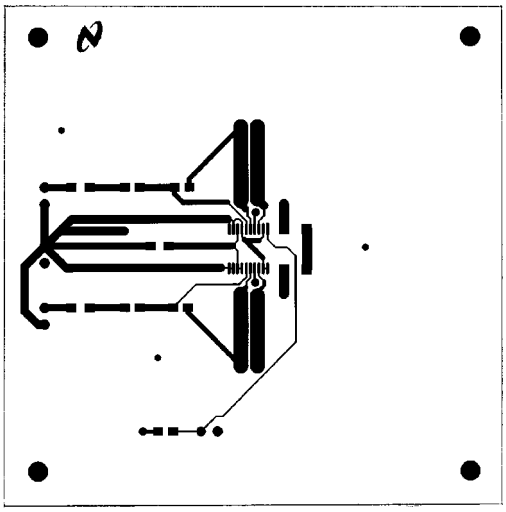


Figure 44. Recommended PW Board Layout: Component-Side Layout

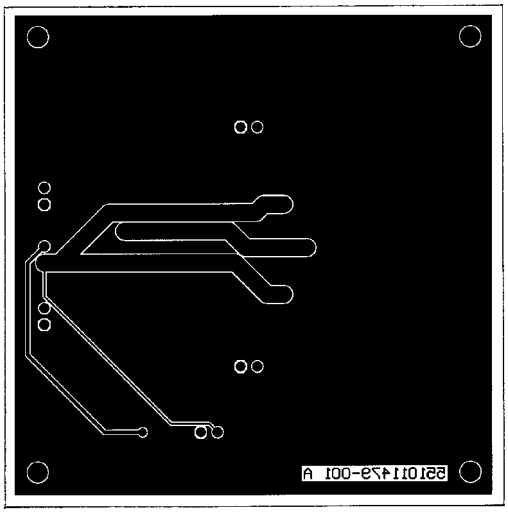


Figure 45. Recommended PW PC Board Layout: Bottom-Side Layout

REVISION HISTORY

Rev	Date	Description
1.1	04/28/05	Changed (min) to (max) for I_{SD} units
E	03/21/2013	Changed layout of National Data Sheet to TI format

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
LM4866MTE/NOPB	ACTIVE	HTSSOP	PWP	20	73	RoHS & Green	SN	Level-1-260C-UNLIM		LM4866 MTE	Samples
LM4866MTEX/NOPB	ACTIVE	HTSSOP	PWP	20	2500	RoHS & Green	SN	Level-1-260C-UNLIM	-40 to 85	LM4866 MTE	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.

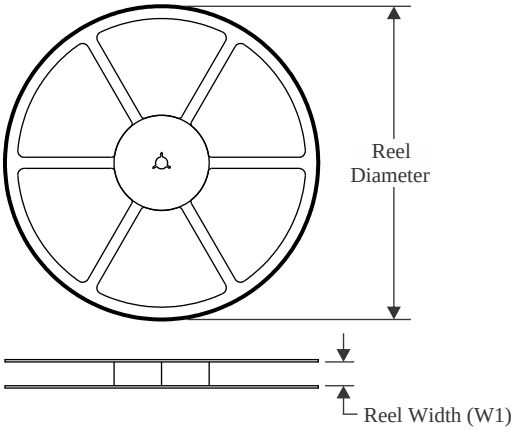
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(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.

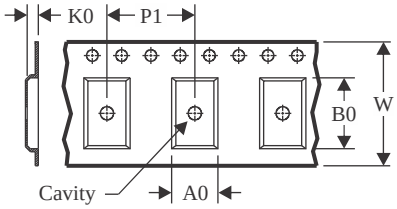
(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

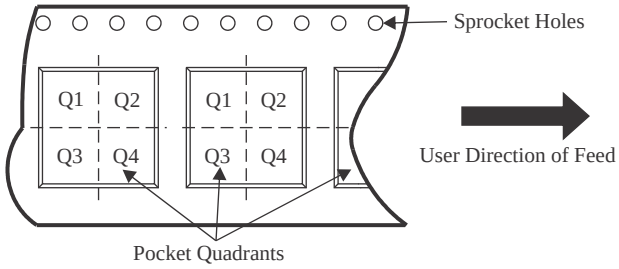


TAPE DIMENSIONS



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

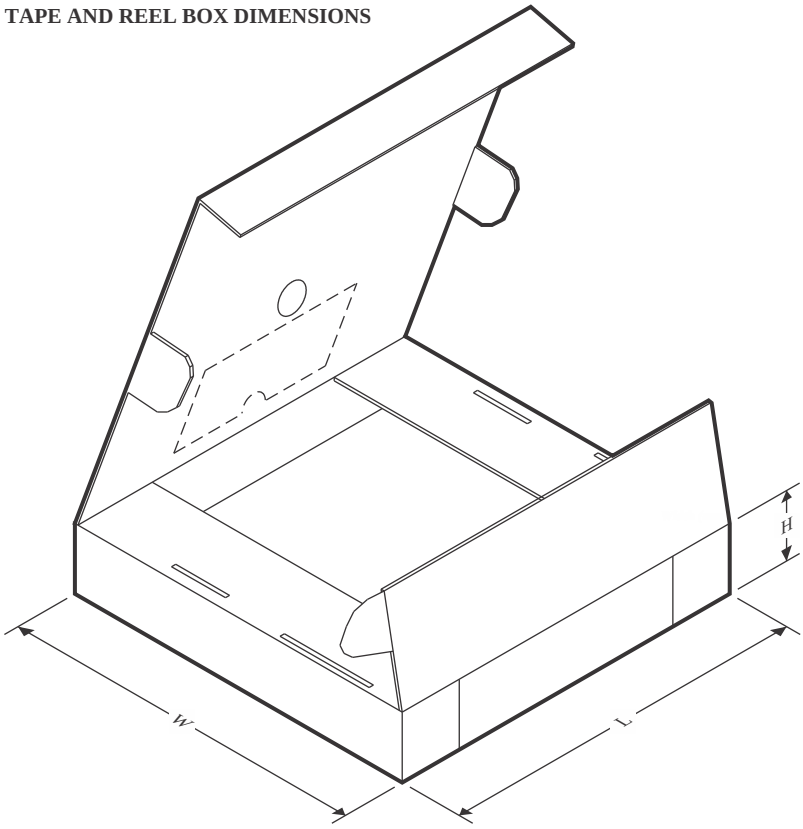
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
LM4866MTEX/NOPB	HTSSOP	PWP	20	2500	330.0	16.4	6.95	7.0	1.4	8.0	16.0	Q1

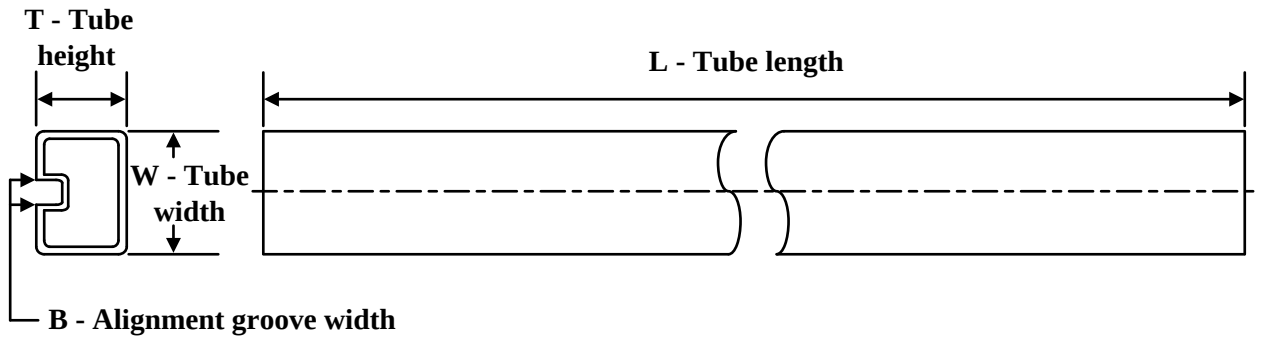
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM4866MTEX/NOPB	HTSSOP	PWP	20	2500	356.0	356.0	35.0

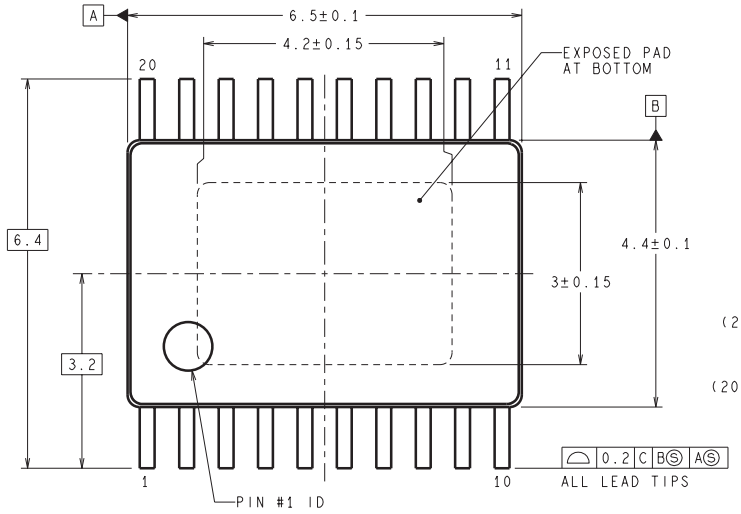
TUBE

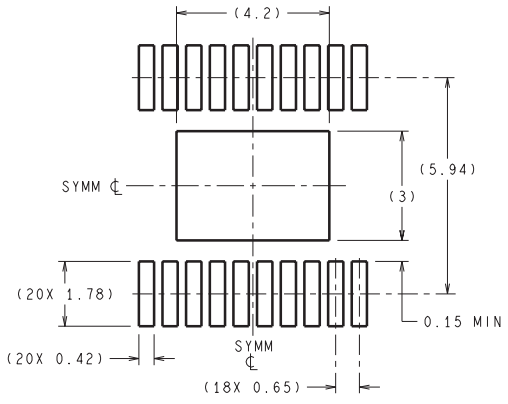


*All dimensions are nominal

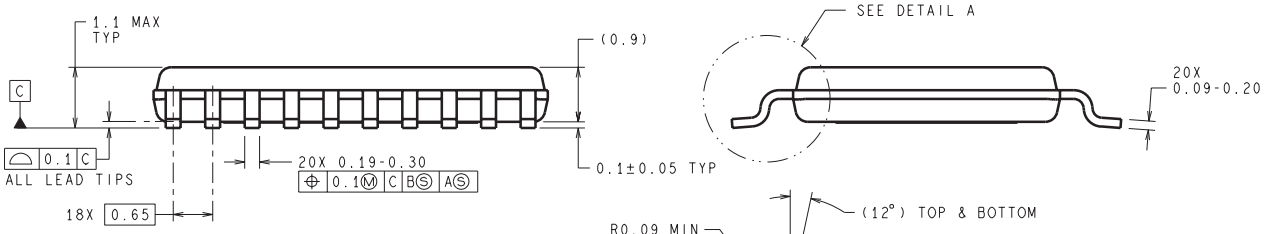
Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
LM4866MTE/NOPB	PWP	HTSSOP	20	73	495	8	2514.6	4.06

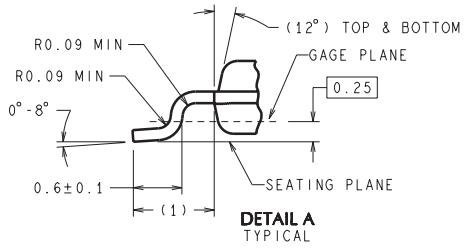
PWP0020A





RECOMMENDED LAND PATTERN





DETAIL A
TYPICAL

DIMENSIONS ARE IN MILLIMETERS
DIMENSIONS IN ( ) FOR REFERENCE ONLY

MXA20A (Rev C)

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