LM4951 Boomer® Audio Power Amplifier Series Wide Voltage Range 1.8 Watt Audio Amplifier

Check for Samples: LM4951

FEATURES

- **Click and Pop Circuitry Eliminates Noise during Turn-On and Turn-Off Transitions**
- **Low Current, Active-Low Shutdown Mode**
- **Low Quiescent Current**
- **Thermal Shutdown Protection**
- **Unity-Gain Stable**
- **External Gain Configuration Capability**

APPLICATIONS

- **Portable Handheld Devices up to 9V**
- **Cell Phone**
- **PDA**

KEY SPECIFICATIONS

- **Wide Voltage Range: 2.7V to 9 V**
- **Quiescent Power Supply Current (V_{DD} = 7.5V): 2.5mA (typ)**
- **Power Output BTL at 7.5V, 1% THD: 1.8 W (typ)**
- **Shutdown Current: 0.01µA (typ)**
- **Fast Turn on Time: 25ms (typ)**

DESCRIPTION

The LM4951 is an audio power amplifier primarily designed for demanding applications in Portable Handheld devices. It is capable of delivering 1.8W mono BTL to an 8Ω load, continuous average power, with less than 1% distortion (THD+N) from a 7.5V_{DC} power supply.

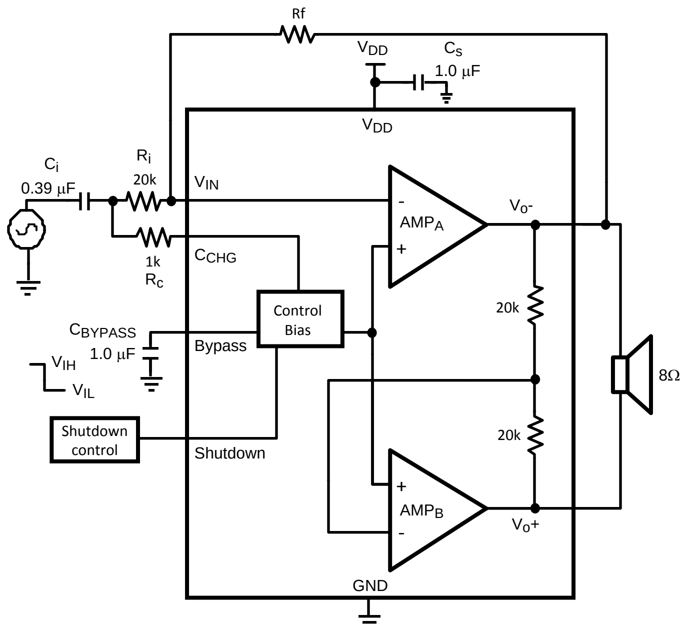
Boomer audio power amplifiers were designed specifically to provide high quality output power with a minimal amount of external components. The LM4951 does not require bootstrap capacitors, or snubber circuits.

The LM4951 features a low-power consumption active-low shutdown mode. Additionally, the LM4951 features an internal thermal shutdown protection mechanism.

The LM4951 contains advanced click and pop circuitry that eliminates noises which would otherwise occur during turn-on and turn-off transitions.

The LM4951 is unity-gain stable and can be configured by external gain-setting resistors.

Typical Application



* R_C is needed for over/under voltage protection. If inputs are less than V_{DD} +0.3V and greater than –0.3V, and if inputs are disabled when in shutdown mode, then R_C may be shorted.

Figure 1. Typical Bridge-Tied-Load (BTL) Audio Amplifier Application Circuit

Connection Diagram

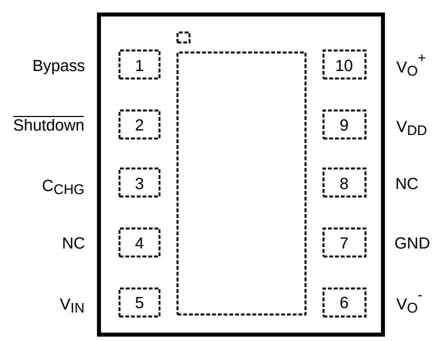
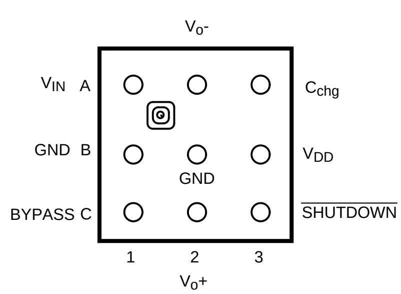


Figure 2. DPR Package (Top View)
See Package Number DPR0010A



A. * DAP can either be soldered to GND or left floating.

Figure 3. 9 Bump DSBGA Package (Top View)
See Package Number YZR0009AAA

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	9.5V
Storage Temperature	−65°C to +150°C
Input Voltage	−0.3V to V_{DD} + 0.3V
Power Dissipation[(4)]	Internally limited
ESD Susceptibility[(5)]	2000V
ESD Susceptibility[(6)]	200V
Junction Temperature	150°C
Thermal Resistance θ_{JA} (WSON)[(4)]	52°C/W
See AN-1187 'Leadless Leadframe Packaging (WSON)' (Literature Number SNOA401)	

(1) All voltages are measured with respect to the GND 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 specified 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 Texas Instruments Sales Office/ Distributors for availability and specifications.
(4) The maximum power dissipation must be derated at elevated temperatures and is dictated by T_{JMAX}, θ_{JA}, and the ambient temperature, T_A. The maximum allowable power dissipation is $P_{DMAX} = (T_{JMAX} - T_A) / \theta_{JA}$ or the given in Absolute Maximum Ratings, whichever is lower. For the LM4951 typical application (shown in Figure 1) with V_{DD} = 7.5V, R_L = 8Ω mono-BTL operation the max power dissipation is 1.42W. θ_{JA} = 73°C/W.
(5) Human body model, 100pF discharged through a 1.5kΩ resistor.
(6) Machine Model, 220pF–240pF discharged through all pins.

Operating Ratings

Temperature Range	$T_{MIN} \leq T_A \leq T_{MAX}$	−40°C ≤ T_A ≤ +85°C
Supply Voltage		2.7V ≤ V_{DD} ≤ 9V

Electrical Characteristics V_{DD} = 7.5V (1)(2)

The following specifications apply for V_{DD} = 7.5V, $A_{V\text{-}BTL}$ = 6dB, R_L = 8Ω unless otherwise specified. Limits apply for T_A = 25°C.

Symbol	Parameter	Conditions	LM4951		Units (Limits)
			Typical (3)	Limit (4)(5)	
I_{DD}	Quiescent Power Supply Current	V_{IN} = 0V, I_O = 0A,RL = 8Ω	2.5	4.5	mA (max)
I_{SD}	Shutdown Current	$V_{SHUTDOWN}$ = GND (6)	0.01	5	µA (max)
V_{OS}	Offset Voltage		5	30	mV (max)
V_{SDIH}	Shutdown Voltage Input High			1.2	V (min)
V_{SDIL}	Shutdown Voltage Input Low			0.4	V (max)
Rpulldown	Pulldown Resistor on S/D		75	45	kΩ (min)
T_{WU}	Wake-up Time	C_B = 1.0µF	25	35	ms
Tsd	Shutdown time	C_B = 1.0µF		10	ms (max)
TSD	Thermal Shutdown Temperature		170	150 190	°C (min) °C (max)
P_O	Output Power	THD = 1% (max); f = 1kHz R_L = 8Ω Mono BTL	1.8	1.5	W (min)
THD+N	Total Harmonic Distortion + Noise	P_O = 600mWrms; f = 1kHz $A_{V\text{-}BTL}$ = 6dB	0.07	0.5	% (max)
THD+N	Total Harmonic Distortion + Noise	P_O = 600mWrms; f = 1kHz $A_{V\text{-}BTL}$ = 26dB	0.35		%
ϵ_{OS}	Output Noise	A-Weighted Filter, R_i = R_f = 20kΩ Input Referred, Note 10	10		µV
PSRR	Power Supply Rejection Ratio	V_{RIPPLE} = 200m$V_{p\text{-}p}$, f = 217Hz, C_B = 1.0µF, Input Referred	66	56	dB (min)

(1) All voltages are measured with respect to the GND 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 specified for parameters where no limit is given, however, the typical value is a good indication of device performance.
(3) Typicals are measured at 25°C and represent the parametric norm.
(4) Limits are specified to AOQL (Average Outgoing Quality Level).
(5) Datasheet min/max specification limits are specified by design, test, or statistical analysis.
(6) Shutdown current is measured in a normal room environment. The Shutdown pin should be driven as close as possible to GND for minimum shutdown current.

Electrical Characteristics V_{DD} = 3.3V (1) (2)

The following specifications apply for V_{DD} = 3.3V, $A_{V\text{-}BTL}$ = 6dB, R_L = 8Ω unless otherwise specified. Limits apply for T_A = 25°C.

Symbol	Parameter	Conditions	LM4951		Units (Limits)
			Typical (3)	Limit (4) (5)	
I_{DD}	Quiescent Power Supply Current	V_{IN} = 0V, I_O = 0A,RL = 8Ω	2.5	4.5	mA (max)
I_{SD}	Shutdown Current	$V_{SHUTDOWN}$ = GND (6)	0.01	2	µA (max)
V_{OS}	Offset Voltage		3	30	mV (max)
V_{SDIH}	Shutdown Voltage Input High			1.2	V (min)
V_{SDIL}	Shutdown Voltage Input Low			0.4	V (max)
T_{WU}	Wake-up Time	C_B = 1.0µF	25		ms (max)
Tsd	Shutdown time	C_B = 1.0µF		10	ms (max)
P_O	Output Power	THD = 1% (max); f = 1kHz R_L = 8Ω Mono BTL	280	230	mW (min)
THD+N	Total Harmonic Distortion + Noise1	P_O = 100mWrms; f = 1kHz $A_{V\text{-}BTL}$ = 6dB	0.07	0.5	% (max)
THD+N	Total Harmonic Distortion + Noise1	P_O = 100mWrms; f = 1kHz $A_{V\text{-}BTL}$ = 26dB	0.35		%
ε_{OS}	Output Noise	A-Weighted Filter, R_i = R_f = 20kΩ Input Referred, Note 10	10		µV
PSRR	Power Supply Rejection Ratio	V_{RIPPLE} = 200m$V_{p\text{-}p}$, f = 217Hz, C_B = 1µF, Input Referred	71	61	dB (min)

(1) All voltages are measured with respect to the GND 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 specified for parameters where no limit is given, however, the typical value is a good indication of device performance.
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Typical Performance Characteristics

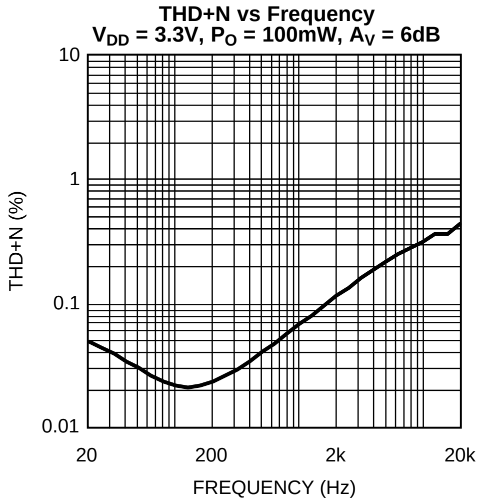

Figure 4.

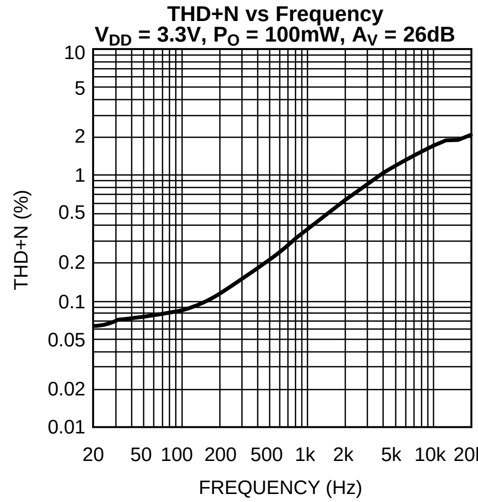

Figure 5.

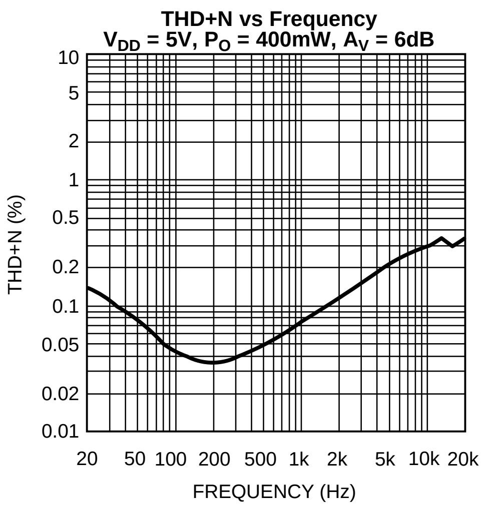

Figure 6.

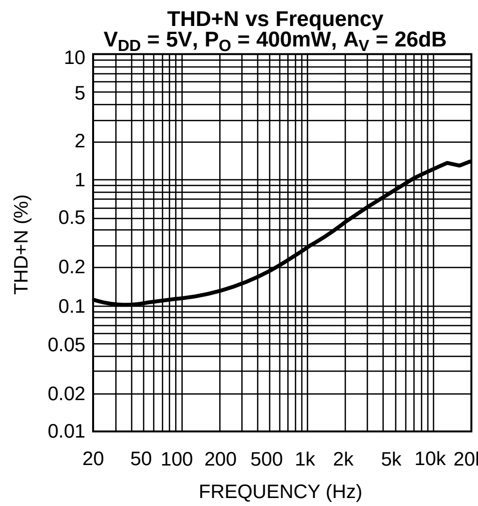

Figure 7.

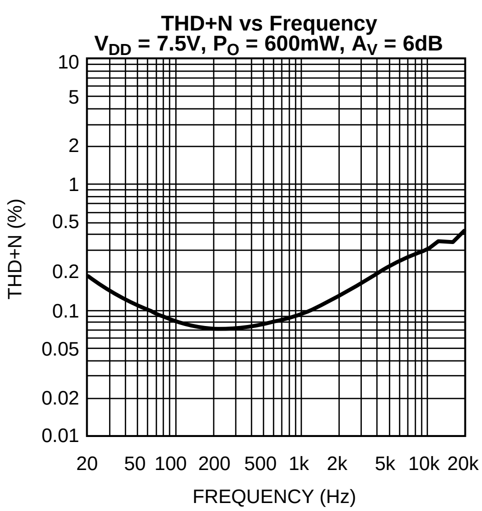

Figure 8.

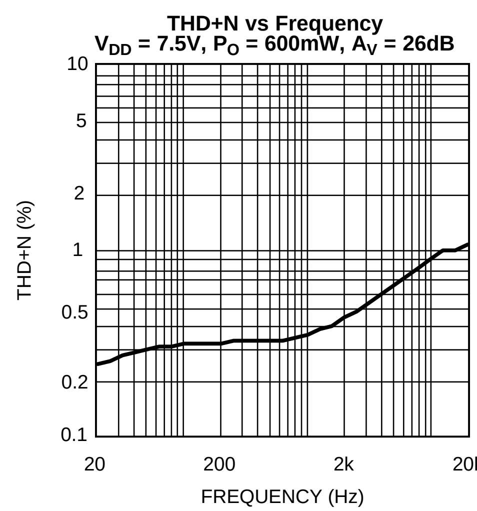

Figure 9.

Typical Performance Characteristics (continued)

THD+N vs Output Power
V_{DD} = 3.3V, f = 1kHz, A_V = 6dB

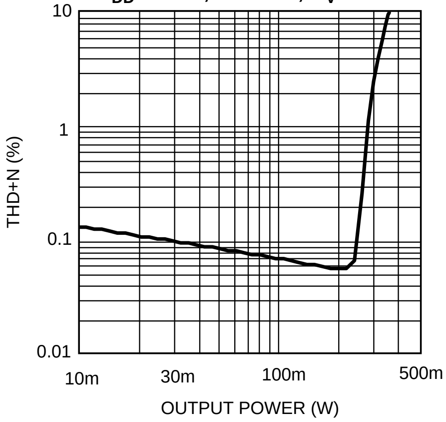

Figure 10.

THD+N vs Output Power
V_{DD} = 3.3V, f = 1kHz, A_V = 26dB

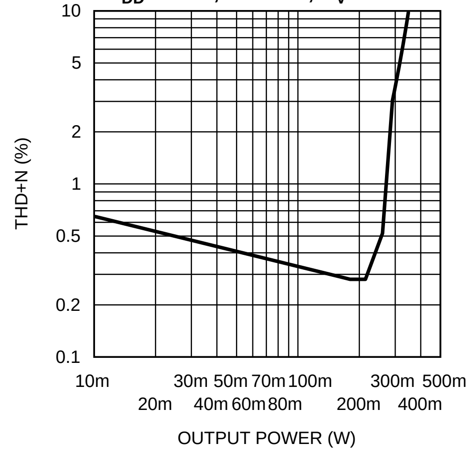

Figure 11.

THD+N vs Output Power
V_{DD} = 5V, f = 1kHz, A_V = 6dB

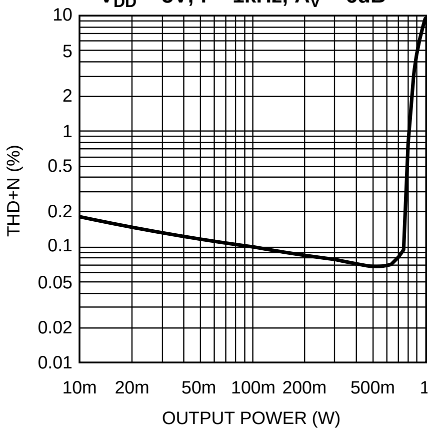

Figure 12.

THD+N vs Output Power
V_{DD} = 5V, f = 1kHz, A_V = 26dB

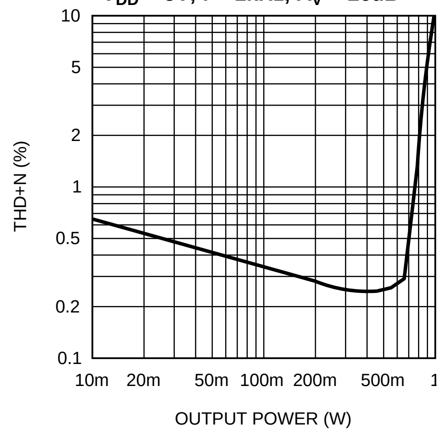

Figure 13.

THD+N vs Output Power
V_{DD} = 7.5V, f = 1kHz, A_V = 6dB

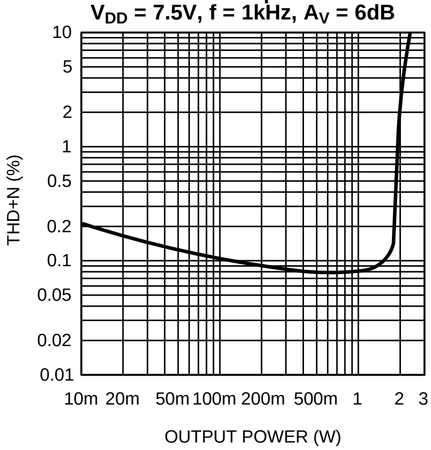

Figure 14.

THD+N vs Output Power
V_{DD} = 7.5V, f = 1kHz, A_V = 26dB

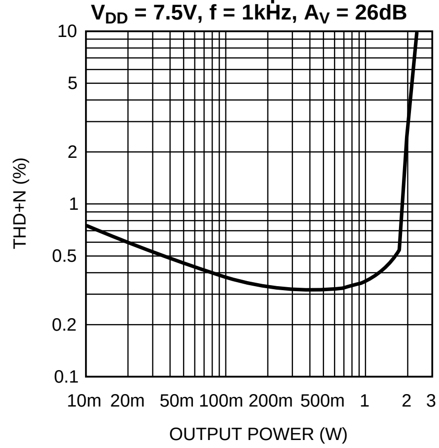

Figure 15.

Typical Performance Characteristics (continued)

Power Supply Rejection vs Frequency
V_{DD} = 3.3V, A_V = 6dB, V_{RIPPLE} = 200mV_{P-P}
Input Terminated into 10Ω

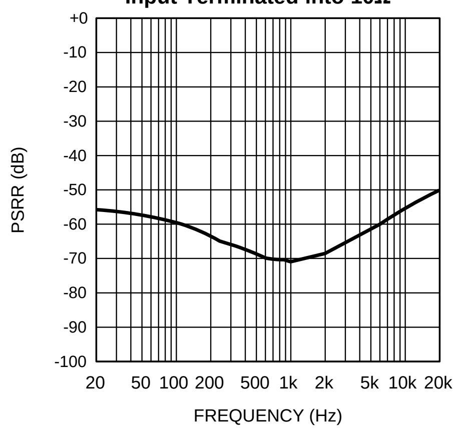

Figure 16.

Power Supply Rejection vs Frequency
V_{DD} = 3.3V, A_V = 26dB, V_{RIPPLE} = 200mV_{P-P}
Input Terminated into 10Ω

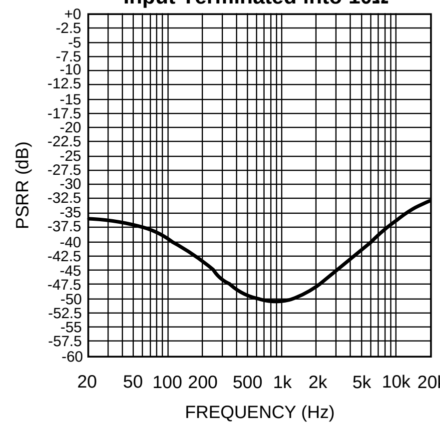

Figure 17.

Power Supply Rejection vs Frequency
V_{DD} = 5V, A_V = 6dB, V_{RIPPLE} = 200mV_{P-P}
Input Terminated into 10Ω

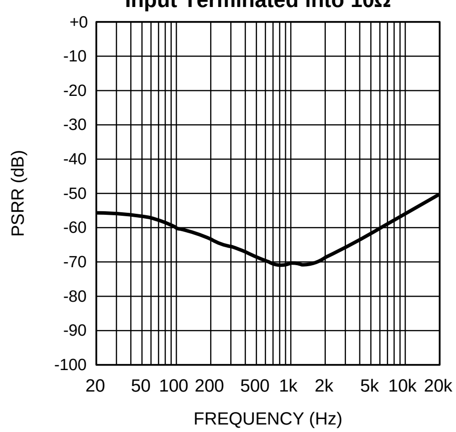

Figure 18.

Power Supply Rejection vs Frequency
V_{DD} = 5V, A_V = 26dB, V_{RIPPLE} = 200mV_{P-P}
Input Terminated into 10Ω

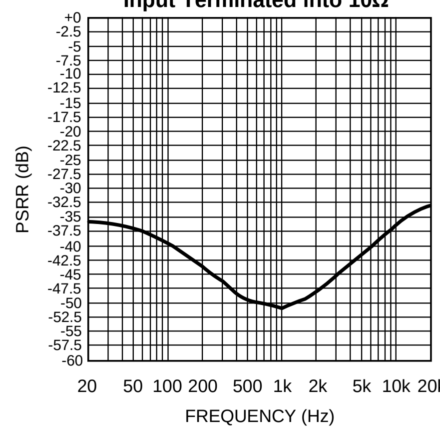

Figure 19.

Power Supply Rejection vs Frequency
V_{DD} = 7.5V, A_V = 6dB, V_{RIPPLE} = 200mV_{P-P}
Input Terminated into 10Ω

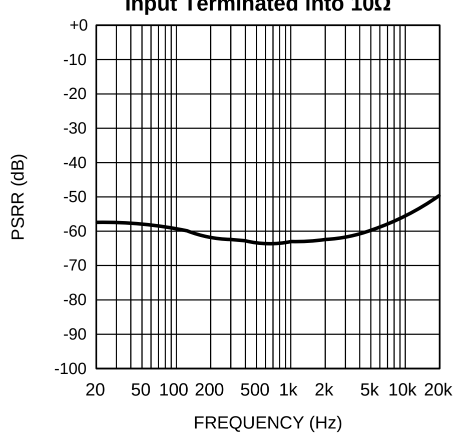

Figure 20.

Power Supply Rejection vs Frequency
V_{DD} = 7.5V, A_V = 26dB, V_{RIPPLE} = 200mV_{P-P}
Input Terminated into 10Ω

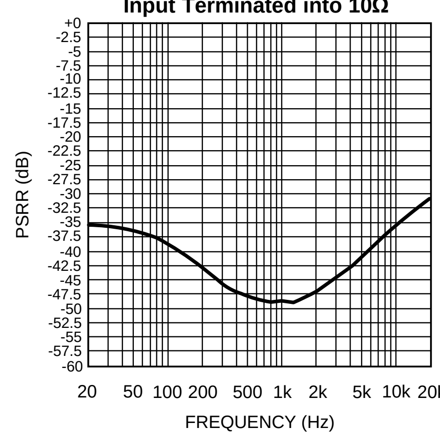

Figure 21.

Typical Performance Characteristics (continued)

Noise Floor
V_{DD} = 3.3V, A_V = 6dB, R_i = R_f = 20kΩ
BW < 80kHz, A-weighted

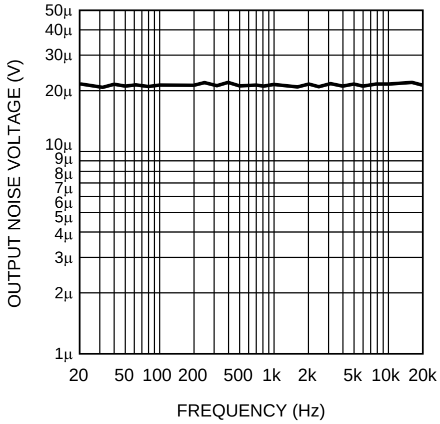

Figure 22.

Noise Floor
V_{DD} = 3V, A_V = 26dB, R_i = 20kΩ, R_f = 200kΩ
BW < 80kHz, A-weighted

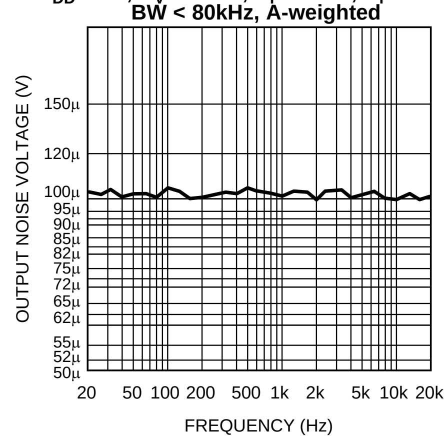

Figure 23.

Noise Floor
V_{DD} = 5V, A_V = 6dB, R_i = R_f = 20kΩ
BW < 80kHz, A-weighted

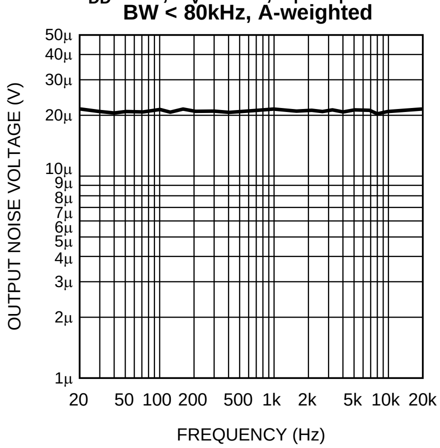

Figure 24.

Noise Floor
V_{DD} = 5V, A_V = 26dB, R_i = 20kΩ, R_f = 200kΩ
BW < 80kHz, A-weighted

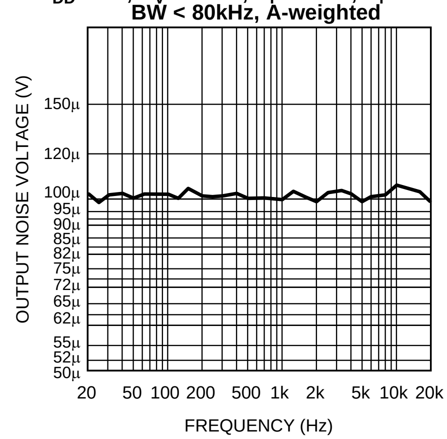

Figure 25.

Noise Floor
V_{DD} = 7.5V, A_V = 6dB, R_i = R_f = 20kΩ
BW < 80kHz, A-weighted

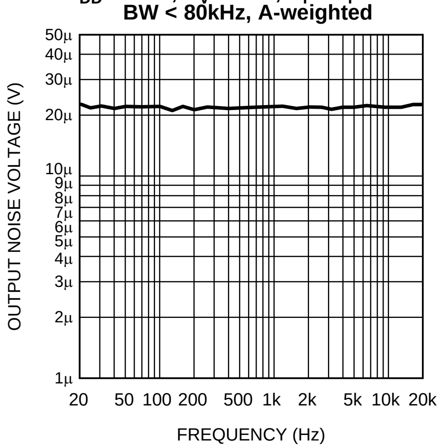

Figure 26.

Noise Floor
V_{DD} = 7.5V, A_V = 26dB, R_i = 20kΩ, R_f = 200kΩ
BW < 80kHz, A-weighted

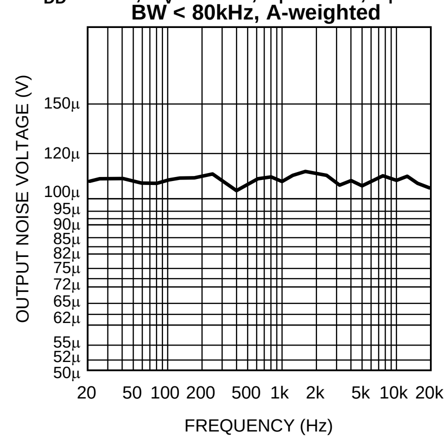

Figure 27.

Typical Performance Characteristics (continued)

Power Dissipation vs Output Power
V_{DD} = 3.3V, R_L = 8Ω, f = 1kHz

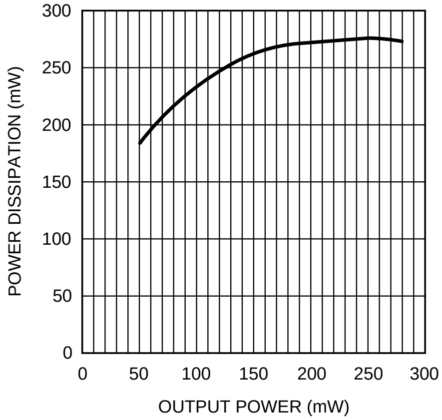

Figure 28.

Power Dissipation vs Output Power
V_{DD} = 7.5V, R_L = 8Ω, f = 1kHz

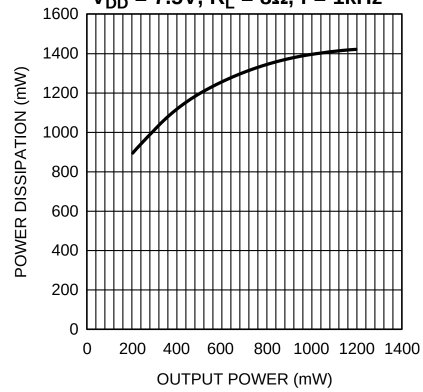

Figure .

Supply Current vs Supply Voltage
R_L = 8Ω, V_{IN} = 0V, R_{source} = 50Ω

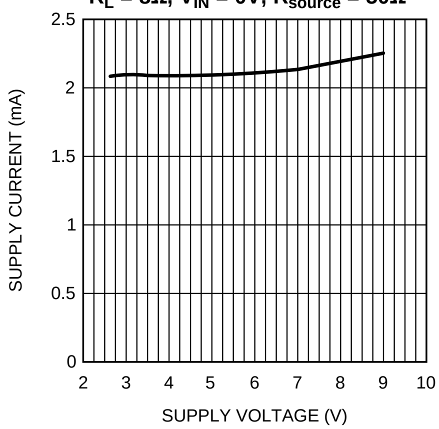

Figure 29.

Clipping Voltage vs Supply Voltage
R_L = 8Ω,
from top to bottom: Negative Voltage Swing; Positive Voltage Swing

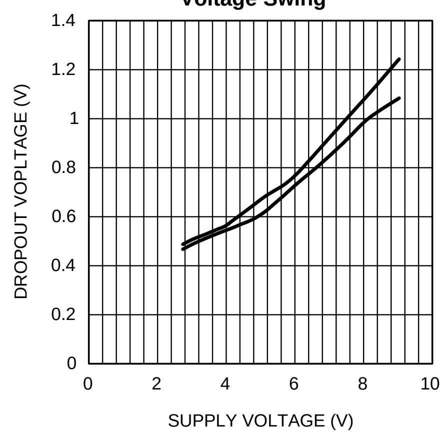

Figure 30.

Output Power vs Supply Voltage
R_L = 8Ω,
from top to bottom: THD+N = 10%, THD+N = 1%

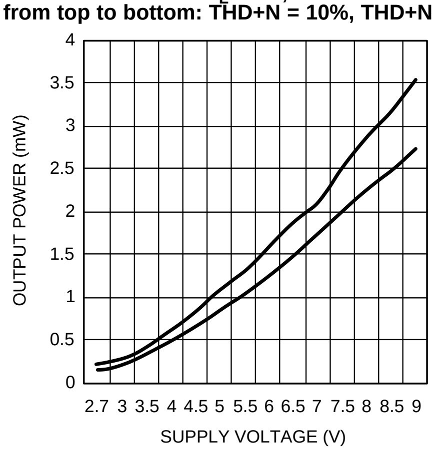

Figure 31.

Output Power vs Load Resistance
V_{DD} = 3.3V, f = 1kHz
from top to bottom: THD+N = 10%, THD+N = 1%

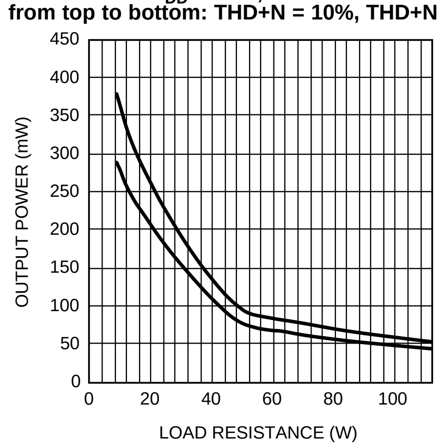

Figure 32.

Typical Performance Characteristics (continued)

Output Power vs Load Resistance
V_{DD} = 7.5V, f = 1kHz
from top to bottom: THD+N = 10%, THD+N = 1%

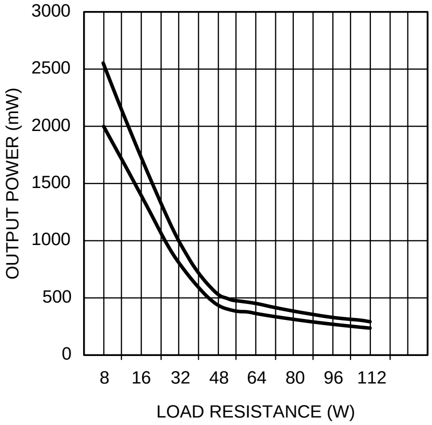

Figure 33.

Frequency Response vs Input Capacitor Size
R_L = 8Ω
from top to bottom: C_i = 1.0µF, C_i = 0.39µF, C_i = 0.039µF

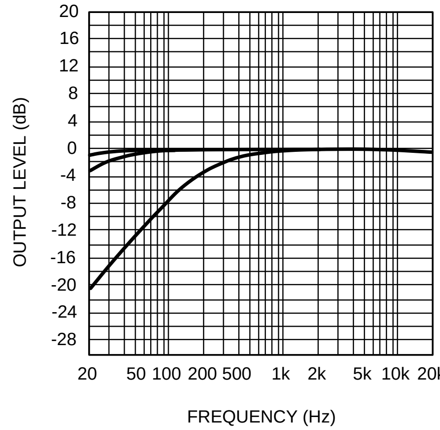

Figure 34.

APPLICATION INFORMATION

HIGH VOLTAGE BOOMER

Unlike previous 5V Boomer amplifiers, the LM4951 is designed to operate over a power supply voltages range of 2.7V to 9V. Operating on a 7.5V power supply, the LM4951 will deliver 1.8W into an 8Ω BTL load with no more than 1% THD+N.

BRIDGE CONFIGURATION EXPLANATION

As shown in Figure 1, the LM4951 consists of two operational amplifiers that drive a speaker connected between their outputs. The value of input and feedback resistors determine the gain of each amplifier. External resistors R_i and R_f set the closed-loop gain of AMP_A, whereas two 20kΩ internal resistors set AMP_B's gain to -1. The LM4951 drives a load, such as a speaker, connected between the two amplifier outputs, V_O+ and V_O -. Figure 1 shows that AMP_A's output serves as AMP_B'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 AMP_A and AMP_B and driven differentially (commonly referred to as "bridge mode"). This results in a differential, or BTL, gain of

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

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. Theoretically, 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 and 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. Under rare conditions, with unique combinations of high power supply voltage and high closed loop gain settings, the LM4951 may exhibit low frequency oscillations.

Another advantage of the differential bridge output is no net DC voltage across the load. This is accomplished by biasing AMP1's and AMP2's outputs at half-supply. This eliminates the coupling capacitor that single supply, single-ended amplifiers require. Eliminating an output coupling capacitor in a typical 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 bridged amplifier.

The LM4951's dissipation when driving a BTL load is given by Equation (2). For a 7.5V supply and a single 8Ω BTL load, the dissipation is 1.42W.

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

The maximum power dissipation point given by Equation (2) must not exceed the power dissipation given by Equation (3):

$$P_{DMAX}' = (T_{JMAX} - T_A) / \theta_{JA} \quad (3)$$

The LM4951's T_{JMAX} = 150°C. In the DPR package, the LM4951's θ_{JA} is 73°C/W when the metal tab is soldered to a copper plane of at least $1in^2$. This plane can be split between the top and bottom layers of a two-sided PCB. Connect the two layers together under the tab with an array of vias. At any given ambient temperature T_A, use Equation (3) to find the maximum internal power dissipation supported by the IC packaging. Rearranging Equation (3) and substituting P_{DMAX} for P_{DMAX}' results in Equation (4). This equation gives the maximum ambient temperature that still allows maximum stereo power dissipation without violating the LM4951's maximum junction temperature.

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

For a typical application with a 7.5V power supply and a BTL 8Ω load, the maximum ambient temperature that allows maximum stereo power dissipation without exceeding the maximum junction temperature is approximately 46°C for the TS package.

$$T_{JMAX} = P_{DMAX\text{-}MONOBTL}\theta_{JA} + T_A \quad (5)$$

Equation (5) gives the maximum junction temperature T_{JMAX}. If the result violates the LM4951'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 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. Further, ensure that speakers rated at a nominal 8Ω do not fall below 6Ω. 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 pins, supply pin and amplifier output pins. Refer to the Typical Performance Characteristics curves for power dissipation information at lower output power levels.

POWER SUPPLY VOLTAGE LIMITS

Continuous proper operation is ensured by never exceeding the voltage applied to any pin, with respect to ground, as listed in the Absolute Maximum Ratings section.

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 voltage 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 LM4951's supply pins and ground. Do not substitute a ceramic capacitor for the tantalum. Doing so may cause oscillation. Keep the length of leads and traces that connect capacitors between the LM4951's power supply pin and ground as short as possible. Connecting a larger capacitor, C_{BYPASS}, 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 the amplifier's click and pop performance. The selection of bypass capacitor values, especially C_{BYPASS}, depends on desired PSRR requirements, click and pop performance (as explained in the section, SELECTING EXTERNAL COMPONENTS), system cost, and size constraints.

MICRO-POWER SHUTDOWN

The LM4951 features an active-low micro-power shutdown mode. When active, the LM4951's micro-power shutdown feature turns off the amplifier's bias circuitry, reducing the supply current. The low 0.01µA typical shutdown current is achieved by applying a voltage to the SHUTDOWN pin that is as near to GND as possible. A voltage that is greater than GND may increase the shutdown current.

There are a few methods to control the micro-power shutdown. These include using a single-pole, single-throw switch (SPST), a microprocessor, or a microcontroller. When using a switch, connect the SPST switch between the shutdown pin and V_{DD}. Select normal amplifier operation by closing the switch. Opening the switch applies GND to the SHUTDOWN pin activating micro-power shutdwon.The switch and internal pull-down resistor ensures 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 active-state voltage to the SHUTDOWN pin.

SELECTING EXTERNAL COMPONENTS

Input Capacitor Value Selection

Two quantities determine the value of the input coupling capacitor: the lowest audio frequency that requires amplification and desired output transient suppression.

As shown in Figure 1, the input resistor (R_i) and the input capacitor (C_i) produce a high pass filter cutoff frequency that is found using Equation 6.

$$f_c = 1/2\pi R_i C_i \quad (6)$$

As an example when using a speaker with a low frequency limit of 50Hz, C_i, using Equation (6) is 0.159µF. The 0.39µF C_{INA} shown in Figure 1 allows the LM4951 to drive high efficiency, full range speaker whose response extends below 30Hz.

Selecting Value For R_C

The LM4951 is designed for very fast turn on time. The Cchg pin allows the input capacitors (CinA and CinB) to charge quickly to improve click/pop performance. Rchg1 and Rchg2 protect the Cchg pins from any over/under voltage conditions caused by excessive input signal or an active input signal when the device is in shutdown. The recommended value for Rchg1 and Rchg2 is 1kΩ. If the input signal is less than V_{DD}+0.3V and greater than -0.3V, and if the input signal is disabled when in shutdown mode, Rchg1 and Rchg2 may be shorted out.

OPTIMIZING CLICK AND POP REDUCTION PERFORMANCE

The LM4951 contains circuitry that eliminates turn-on and shutdown transients ("clicks and pops"). For this discussion, turn-on refers to either applying the power supply voltage or when the micro-power shutdown mode is deactivated.

As the V_{DD}/2 voltage present at the BYPASS pin ramps to its final value, the LM4951's internal amplifiers are configured as unity gain buffers. An internal current source charges the capacitor connected between the BYPASS pin and GND in a controlled 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 V_{DD}/2. As soon as the voltage on the bypass pin is stable, there is a delay to prevent undesirable output transients (“click and pops”). After this delay, the device becomes fully functional.

AUDIO POWER AMPLIFIER DESIGN

Audio Amplifier Design: Driving 1.8W into an 8Ω BTL

The following are the desired operational parameters:	
Power Output	$1.8W_{RMS}$
Load Impedance	8Ω
Input Level	$0.3V_{RMS}$ (max)
Input Impedance	20kΩ
Bandwidth	50Hz–20kHz ± 0.25dB

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 Equation (7) curve in the Typical Performance Characteristics section. Another way, using Equation 7, 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 Figure 30 in the Typical Performance Characteristics curves, must be added to the result obtained by Equation (7). The result is Equation (8).

$$V_{opeak} = \sqrt{(2R_L P_O)} \quad (7)$$

$$V_{DD} = V_{OUTPEAK} + V_{ODTOP} + V_{ODBOT} \quad (8)$$

The commonly used 7.5V supply voltage easily meets this. The additional voltage creates the benefit of headroom, allowing the LM4951 to produce peak output power in excess of 1.8W without clipping or other audible distortion. The choice of supply voltage must also not create a situation that violates of maximum power dissipation as explained above in the POWER DISSIPATION section. After satisfying the LM4951's power dissipation requirements, the minimum differential gain needed to achieve 1.8W dissipation in an 8Ω BTL load is found using Equation (9).

$$A_V \geq \sqrt{(P_O R_L)}/(V_{IN}) = V_{orms}/V_{inrms} \quad (9)$$

Thus, a minimum gain of 12.6 allows the LM4951's to reach full output swing and maintain low noise and THD+N performance. For this example, let $A_{V\text{-}BTL}$ = 13. The amplifier's overall BTL gain is set using the input (R_i) and feedback (R_f) resistors of the first amplifier in the series BTL configuration. Additionaly, $A_{V\text{-}BTL}$ is twice the gain set by the first amplifier's R_i and R_f. With the desired input impedance set at 20kΩ, the feedback resistor is found using Equation (10).

$R_f / R_i = A_{V\text{-}BTL} / 2$ (10)

The value of R_f is 130kΩ (choose 191kΩ, the closest value). The nominal output power is 1.8W.

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

f_L = 50Hz / 5 = 10Hz (11)

and an

f_L = 20kHz x 5 = 100kHz (12)

As mentioned in the SELECTING EXTERNAL COMPONENTS 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 (13).

$C_i = 1 / 2\pi R_i f_L$ (13)

The result is

$1 / (2\pi \times 20k\Omega \times 10Hz) = 0.795\mu F$ (14)

Use a 0.82µF 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} = 7 and f_H = 100kHz, the closed-loop gain bandwidth product (GBWP) is 700kHz. This is less than the LM4951's 3.5MHz GBWP. With this margin, the amplifier can be used in designs that require more differential gain while avoiding performance restricting bandwidth limitations.

RECOMMENDED PRINTED CIRCUIT BOARD LAYOUT

Figures 6-8 show the recommended two-layer PC board layout that is optimized for the DPR0010A. This circuit is designed for use with an external 7.5V supply 8Ω (min) speakers.

These circuit boards are easy to use. Apply 7.5V and ground to the board's V_{DD} and GND pads, respectively. Connect a speaker between the board's OUT_A and OUT_B outputs.

Demonstration Board Layout

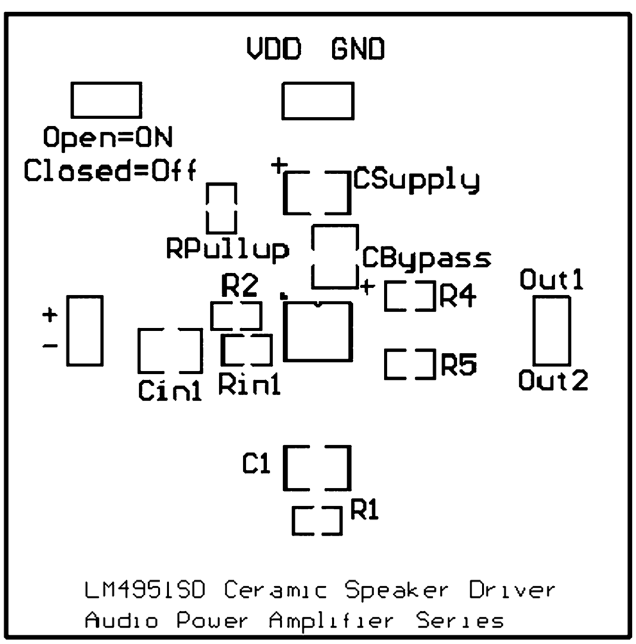

Figure 35. Recommended TS SE PCB Layout: Top Silkscreen

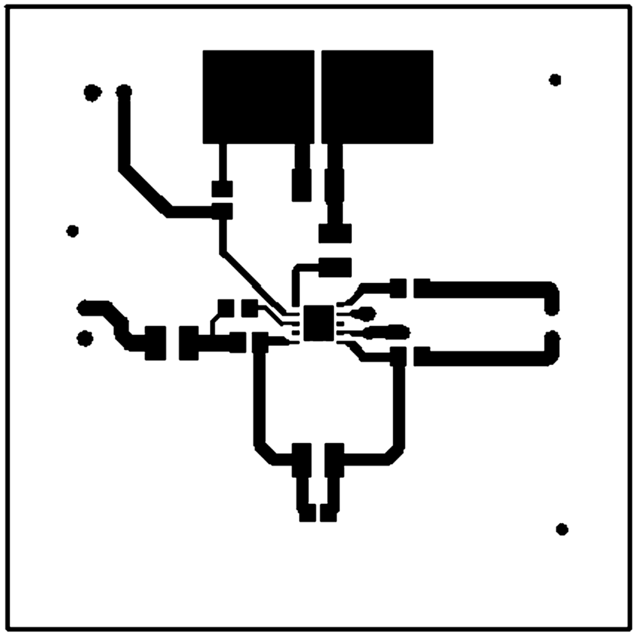

Figure 36. Recommended TS SE PCB Layout: Top Layer

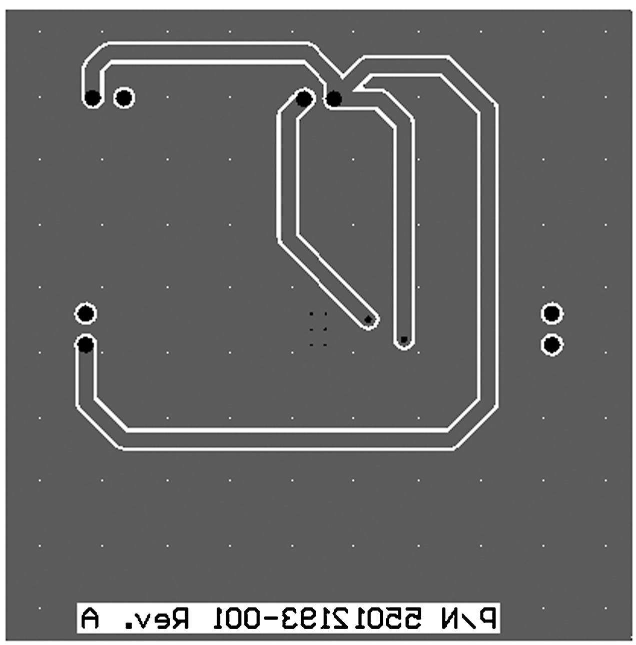

Figure 37. Recommended TS SE PCB Layout: Bottom Layer

Revision History

Rev	Date	Description
1.0	8/25/04	Initial WEB.
1.1	10/19/05	Added the DSBGA pkg, then WEB.

Rev	Date	Description
1.2	08/30/06	Added the Limit value (=35) on the Twu (7.5V Elect Char table), then WEB.
1.3	09/11/06	Added the “Selecting Value For Rc, then WEB.
1.4	05/21/07	Fixed a typo (X3 value = 0.600±0.075) instead of (X3 = 0.600±0.75).
1.5	03/18/09	Text edits.
N	05/03/13	Changed layout of National Data Sheet to TI format.

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)
LM4951SD/NOPB	Active	Production	WSON (DPR) | 10	1000 | SMALL T&R	Yes	SN	Level-1-260C-UNLIM	-	L4951SD
LM4951SD/NOPB.A	Active	Production	WSON (DPR) | 10	1000 | SMALL T&R	Yes	SN	Level-1-260C-UNLIM	See LM4951SD/NOPB	L4951SD
LM4951SDX/NOPB	Active	Production	WSON (DPR) | 10	4500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-	L4951SD
LM4951SDX/NOPB.A	Active	Production	WSON (DPR) | 10	4500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	See LM4951SDX/ NOPB	L4951SD

(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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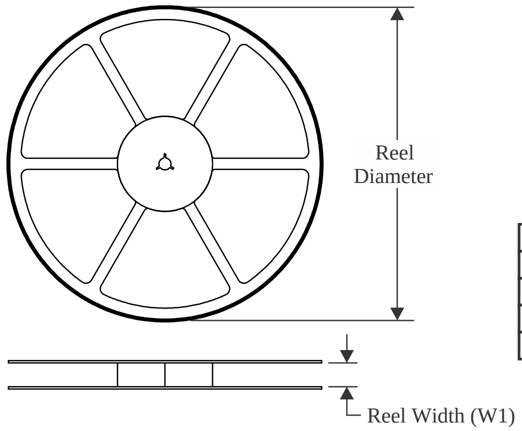
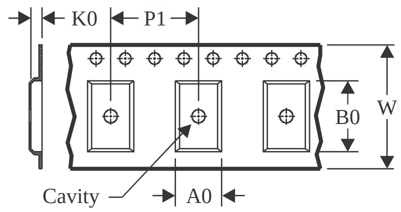
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

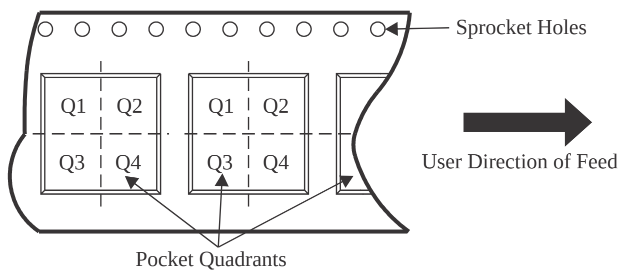


TAPE DIMENSIONS



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

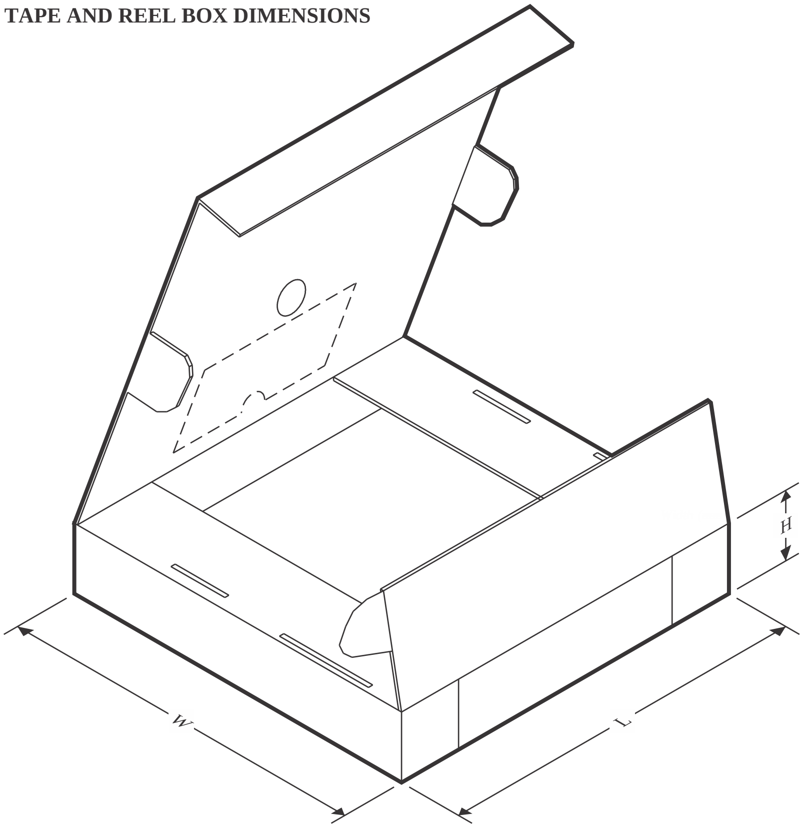
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
LM4951SD/NOPB	WSON	DPR	10	1000	177.8	12.4	4.3	4.3	1.3	8.0	12.0	Q1
LM4951SDX/NOPB	WSON	DPR	10	4500	330.0	12.4	4.3	4.3	1.3	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM4951SD/NOPB	WSON	DPR	10	1000	208.0	191.0	35.0
LM4951SDX/NOPB	WSON	DPR	10	4500	367.0	367.0	35.0

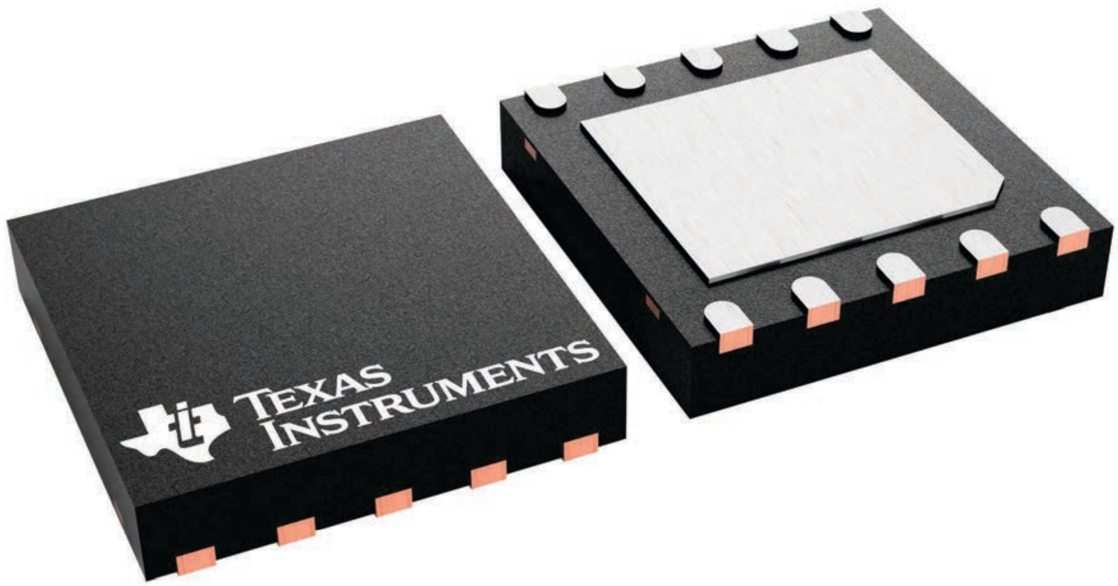
DPR 10

WSON - 0.8 mm max height

4 x 4, 0.8 mm pitch

PLASTIC SMALL OUTLINE - NO LEAD

This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



4232220/A