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National Semiconductor

August 2004

LM4950 Boomer® Audio Power Amplifier Series
7.5W Mono-BTL or 3.1W Stereo Audio Power Amplifier

General Description

The LM4950 is a dual audio power amplifier primarily designed for demanding applications in flat panel monitors and TV's. It is capable of delivering 3.1 watts per channel to a 4Ω single-ended load with less than 1% THD+N or 7.5 watts mono BTL to an 8Ω load, with less than 10% THD+N from a $12V_{DC}$ power supply.

Boomer audio power amplifiers were designed specifically to provide high quality output power with a minimal amount of external components. The LM4950 does not require bootstrap capacitors or snubber circuits. Therefore, it is ideally suited for display applications requiring high power and minimal size.

The LM4950 features a low-power consumption active-low shutdown mode. Additionally, the LM4950 features an internal thermal shutdown protection mechanism along with short circuit protection.

The LM4950 contains advanced pop & click circuitry that eliminates noises which would otherwise occur during turn-on and turn-off transitions.

The LM4950 is a unity-gain stable and can be configured by external gain-setting resistors.

Key Specifications

■ Quiscent Power Supply Current	16mA (typ)
■ P_{OUT} (SE)	
V_{DD} = 12V, R_L = 4Ω, 1% THD+N	3.1W (typ)
■ P_{OUT} (BTL)	
V_{DD} = 12V, R_L = 8Ω, 10% THD+N	7.5W (typ)
■ Shutdown current	40µA (typ)

Features

- Pop & click circuitry eliminates noise during turn-on and turn-off transitions
- Low current, active-low shutdown mode
- Low quiescent current
- Stereo 3.1W output, R_L = 4Ω
- Mono 7.5W BTL output, R_L = 8Ω
- Short circuit protection
- Unity-gain stable
- External gain configuration capability

Applications

- Flat Panel Monitors
- Flat panel TV's
- Computer Sound Cards

Typical Application

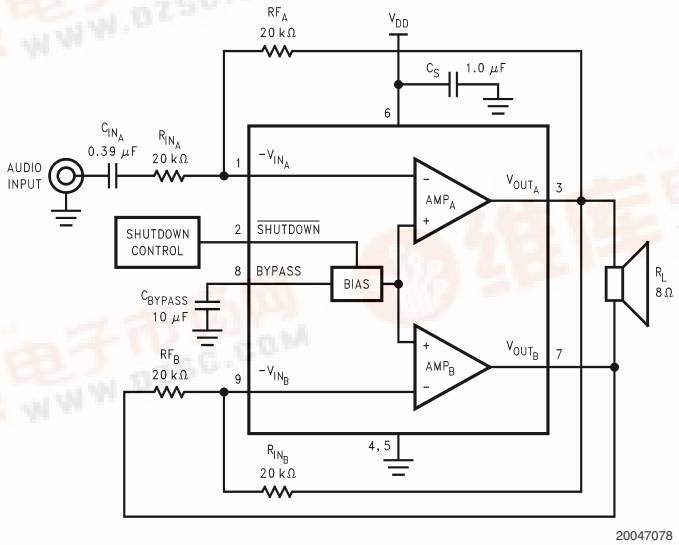

FIGURE 1. Typical Bridge-Tied-Load (BTL) Audio Amplifier Application Circuit

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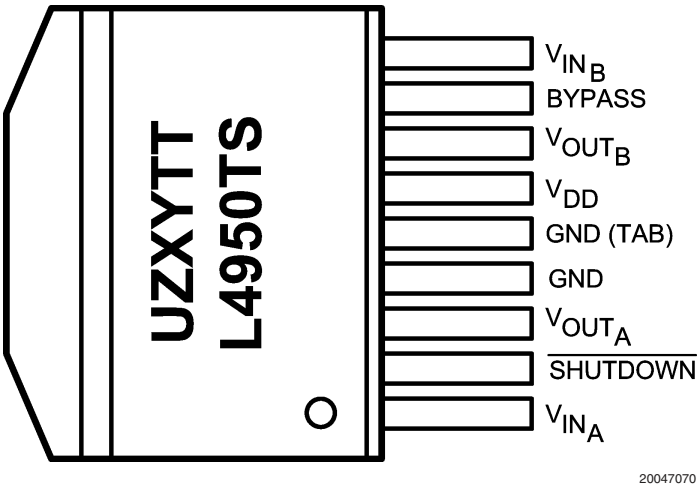
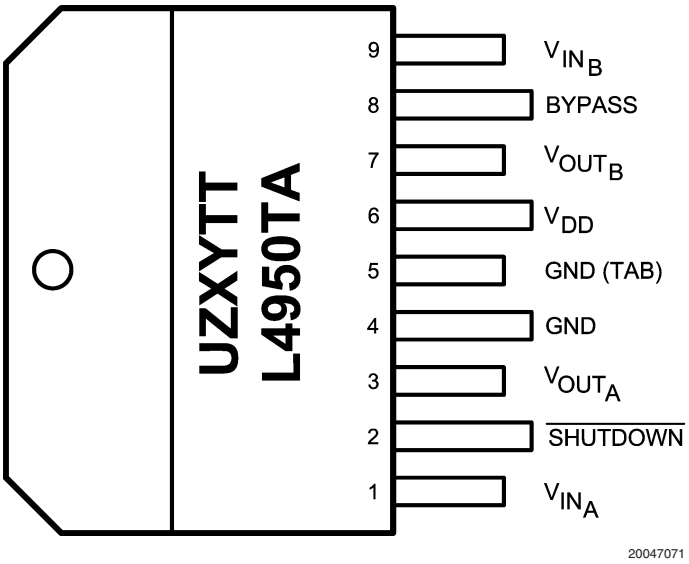
Connection Diagrams

Plastic Package, TO-263



Top View
U = Wafer Fab Code
Z = Assembly Plant Code
XY = Date Code
TT = Die Traceability
Order Number LM4950TS
See NS Package Number TS9A

Plastic Package, TO-220



Top View
U = Wafer Fab Code
Z = Assembly Plant Code
XY = Date Code
TT = Die Traceability
Order Number LM4950TA
See NS Package Number TA09A

Absolute Maximum Ratings (Notes 1, 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage (pin 6, referenced to GND, pins 4 and 5)	18.0V
Storage Temperature	−65˚C to +150˚C
Input Voltage	
pins 3 and 7	−0.3V to V_{DD} + 0.3V
pins 1, 2, 8, and 9	−0.3V to 9.5V
Power Dissipation (Note 3)	Internally limited
ESD Susceptibility (Note 4)	2000V
ESD Susceptibility (Note 5)	200V
Junction Temperature	150˚C
Thermal Resistance	
θ_{JC} (TS)	4˚C/W
θ_{JA} (TS) (Note 3)	20˚C/W
θ_{JC} (TA)	4˚C/W
θ_{JA} (TA) (Note 3)	20˚C/W

Operating Ratings

Temperature Range	
$T_{MIN} \le T_A \le T_{MAX}$	$-40˚C \le T_A \le 85˚C$
Supply Voltage	$9.6V \le V_{DD} \le 16V$

Electrical Characteristics V_{DD} = 12V (Notes 1, 2)

The following specifications apply for V_{DD} = 12V, A_V = 0dB (SE) or 6dB (BTL) unless otherwise specified. Limits apply for T_A = 25˚C.

Symbol	Parameter	Conditions	LM4950		Units (Limits)
			Typical (Note 6)	Limit (Notes 7, 8)	
I_{DD}	Quiescent Power Supply Current	V_{IN} = 0V, I_O = 0A, No Load	16	30	mA (max)
I_{SD}	Shutdown Current	$V_{SHUTDOWN}$ = GND (Note 9)	40	80	µA (max)
V_{OS}	Offset Voltage	V_{IN} = 0V, RL = 8Ω	5	30	mV (max)
V_{SDIH}	Shutdown Voltage Input High			2.0 V_{DD}/2	V (min) V (max)
V_{SDIL}	Shutdown Voltage Input Low			0.4	V (max)
T_{WU}	Wake-up Time	C_B = 10µF	440		ms
TSD	Thermal Shutdown Temperature		170	150 190	˚C (min) ˚C (max)
P_O	Output Power	f = 1kHz R_L = 4Ω SE, Single Channel, THD+N = 1% R_L = 8Ω BTL, THD+N = 10%	 3.1 7.5	3.0	W (min)
THD+N	Total Harmonic Distortion + Noise	P_O = 2.5Wrms; f = 1kHz; R_L = 4Ω SE	0.05		%
		P_O = 2.5Wrms; A_V = 10; f = 1kHz; R_L = 4Ω, SE	0.14		
ϵ_{OS}	Output Noise	A-Weighted Filter, V_{IN} = 0V, Input Referred	10		µV
X_{TALK}	Channel Separation	f_{IN} = 1kHz, P_O = 1W, SE Mode R_L = 8Ω R_L = 4Ω	 76 70		dB
PSRR	Power Supply Rejection Ratio	V_{RIPPLE} = 200mV_{p-p}, f = 1kHz, R_L = 8Ω, BTL	70	56	dB (min)
I_{OL}	Output Current Limit	V_{IN} = 0V, R_L = 500mΩ	5		A

Note 1: All voltages are measured with respect to the GND pin, unless otherwise specified.

Note 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 guarantee specific performance limits. *Electrical Characteristics* state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

Note 3: The maximum power dissipation must be derated at elevated temperatures and is dictated by T_{JMAX}, θ_{JA}, and the ambient temperature, T_A. The maximum allowable power dissipation is $P_{DMAX} = (T_{JMAX} - T_A) / \theta_{JA}$ or the given in Absolute Maximum Ratings, whichever is lower. For the LM4950 typical application (shown in *Figure 1*) with V_{DD} = 12V, R_L = 4Ω stereo operation the total power dissipation is 3.65W. θ_{JA} = 20˚C/W for both TO263 and TO220 packages mounted to 16in^2 heatsink surface area.

Note 4: Human body model, 100pF discharged through a 1.5 kΩ resistor.

Note 5: Machine Model, 220pF–240pF discharged through all pins.

Electrical Characteristics V_{DD} = 12V (Notes 1, 2) (Continued)

Note 6: Typicals are measured at 25˚C and represent the parametric norm.

Note 7: Limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

Note 8: Datasheet min/max specification limits are guaranteed by design, test, or statistical analysis.

Note 9: 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.

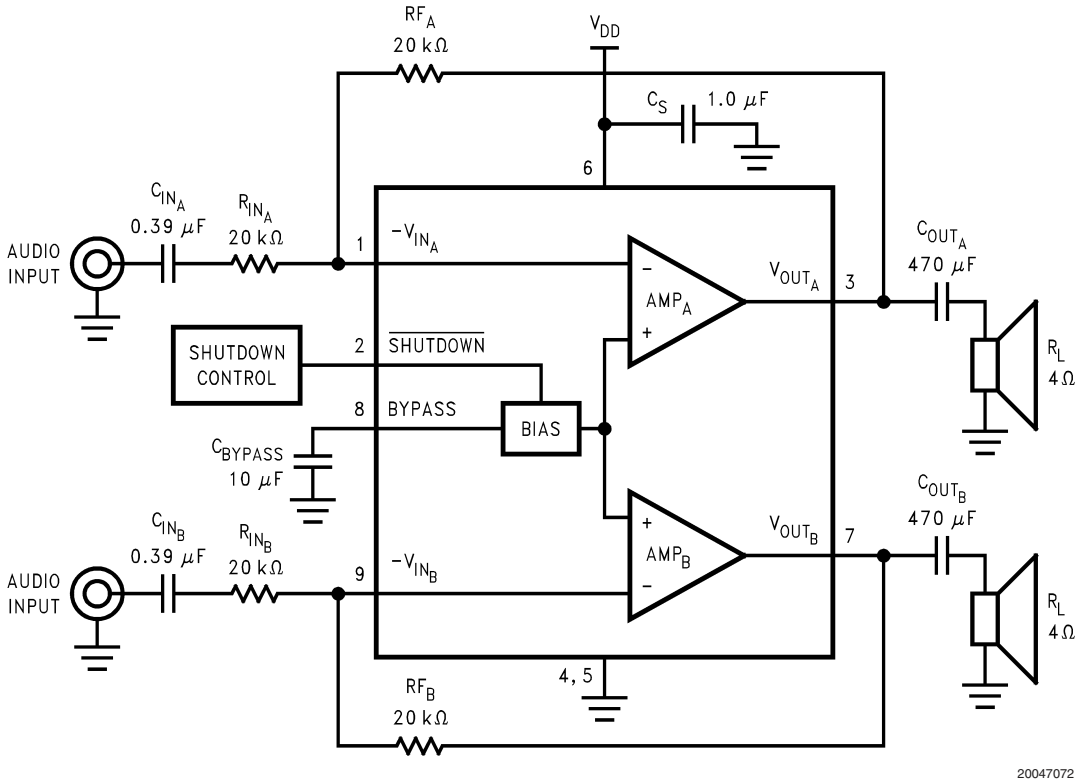


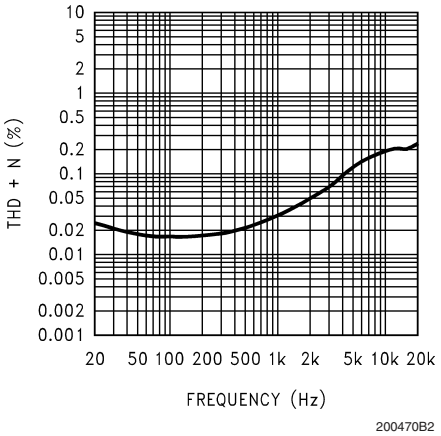
FIGURE 2. Typical Stereo Single-Ended (SE) Audio Amplifier Application Circuit

External Components Description Refer to (*Figure 1.*)

Components	Functional Description
1. R_{IN}	This is the inverting input resistance that, along with R_F, sets the closed-loop gain. Input resistance R_{IN} and input capacitance C_{IN} form a high pass filter. The filter's cutoff frequency is $f_c = 1/(2\pi R_{IN}C_{IN})$.
2. C_{IN}	This is the input coupling capacitor. It blocks DC voltage at the amplifier's inverting input. C_{IN} and R_{IN} create a highpass filter. The filter's cutoff frequency is $f_C = 1/(2\pi R_{IN}C_{IN})$. Refer to the **SELECTING EXTERNAL COMPONENTS**, for an explanation of determining C_{IN}'s value.
3. R_F	This is the feedback resistance that, along with R_i, sets 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_{BYPASS}	This capacitor filters the half-supply voltage present on the BYPASS pin. Refer to the Application section, **SELECTING EXTERNAL COMPONENTS**, for information about properly placing, and selecting the value of, this capacitor.

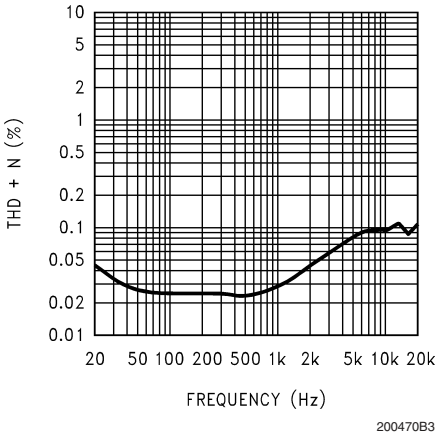
Typical Performance Characteristics

THD+N vs Frequency



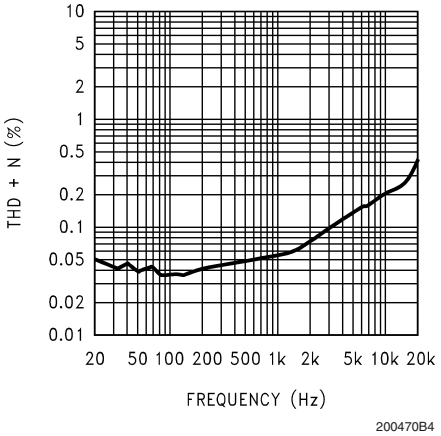
V_{DD} = 12V, R_L = 8Ω,
BTL operation, P_{OUT} = 1W

THD+N vs Frequency



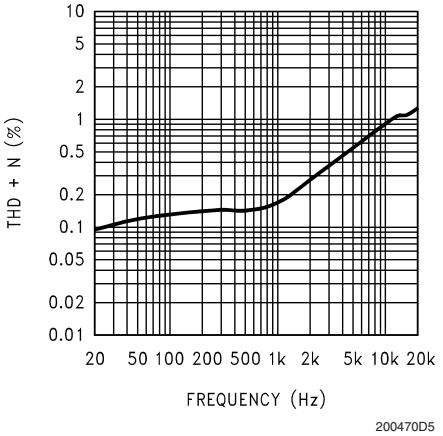
V_{DD} = 12V, R_L = 8Ω,
BTL operation, P_{OUT} = 3W

THD+N vs Frequency



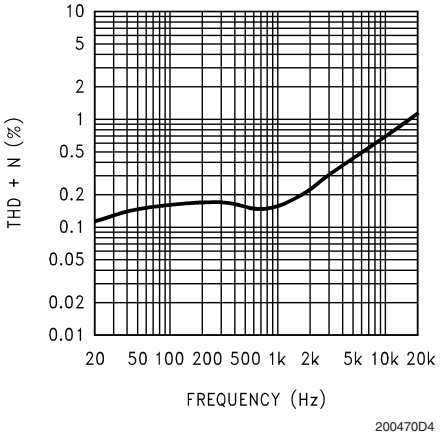
V_{DD} = 12V, R_L = 8Ω,
BTL operation, P_{OUT} = 5W

THD+N vs Frequency



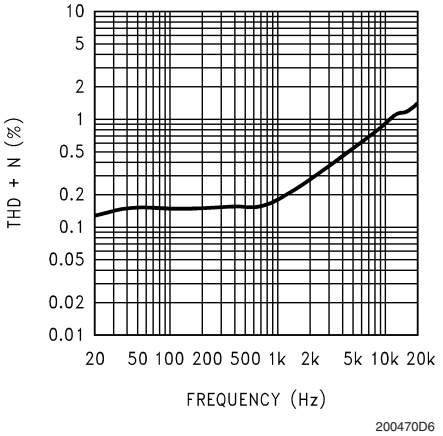
V_{DD} = 12V, R_L = 8Ω,
BTL operation, $BTLA_V$ = 20, P_{OUT} = 1W

THD+N vs Frequency



V_{DD} = 12V, R_L = 8Ω,
BTL operation, $BTLA_V$ = 20, P_{OUT} = 3W

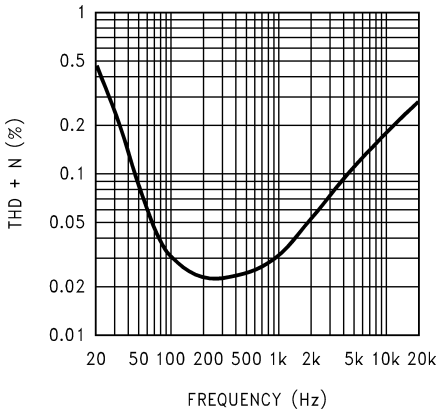
THD+N vs Frequency



V_{DD} = 12V, R_L = 8Ω,
BTL operation, $BTLA_V$ = 20, P_{OUT} = 5W

Typical Performance Characteristics (Continued)

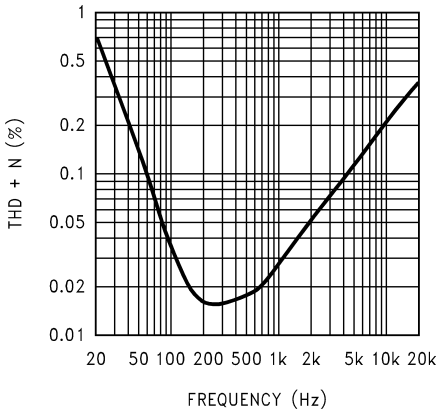
THD+N vs Frequency



20047099

V_{DD} = 12V, R_L = 4Ω, SE operation, both channels driven and loaded (average shown), P_{OUT} = 1W, A_V = 1

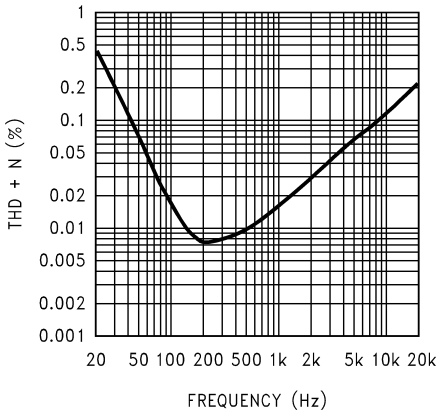
THD+N vs Frequency



200470A0

V_{DD} = 12V, R_L = 4Ω, SE operation, both channels driven and loaded (average shown), P_{OUT} = 2.5W, A_V = 1

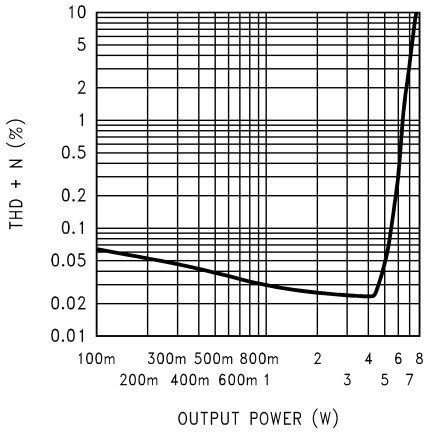
THD+N vs Frequency



200470A1

V_{DD} = 12V, R_L = 8Ω, SE operation, both channels driven and loaded (average shown), P_{OUT} = 1W, A_V = 1

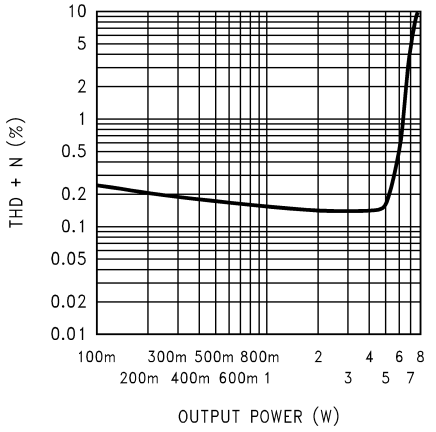
THD+N vs Output Power



200470A9

V_{DD} = 12V, R_L = 8Ω, BTL operation, f_{IN} = 1kHz

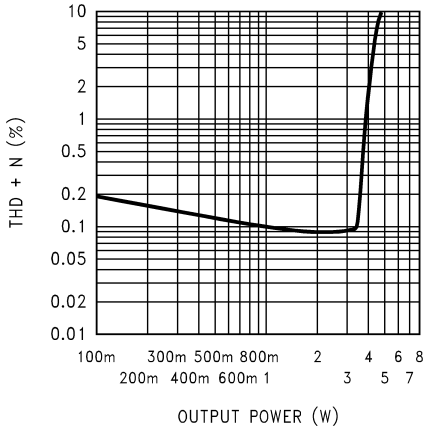
THD+N vs Output Power



200470D0

V_{DD} = 12V, R_L = 8Ω, BTL operation, $BTLA_V$ = 20, f_{IN} = 1kHz

THD+N vs Output Power

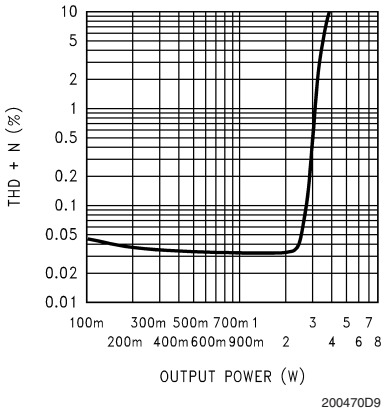


200470D1

V_{DD} = 12V, R_L = 16Ω, BTL operation, $BTLA_V$ = 20, f_{IN} = 1kHz

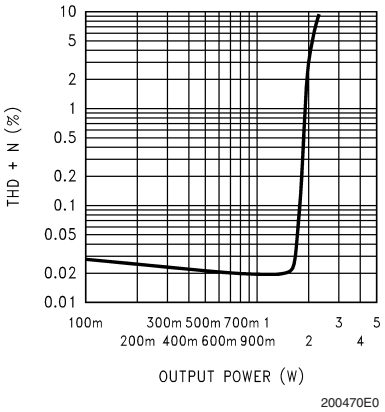
Typical Performance Characteristics (Continued)

THD+N vs Output Power



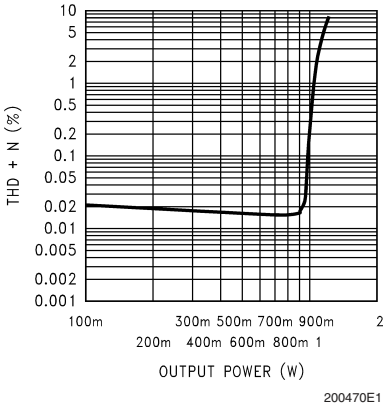
V_{DD} = 12V, R_L = 4Ω, SE operation, both channels driven and loaded (average shown), f_{IN} = 1kHz

THD+N vs Output Power



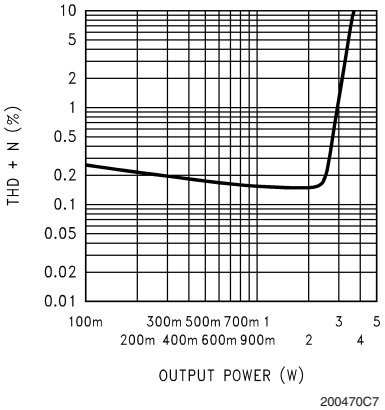
V_{DD} = 12V, R_L = 8Ω, SE operation, both channels driven and loaded (average shown), f_{IN} = 1kHz

THD+N vs Output Power



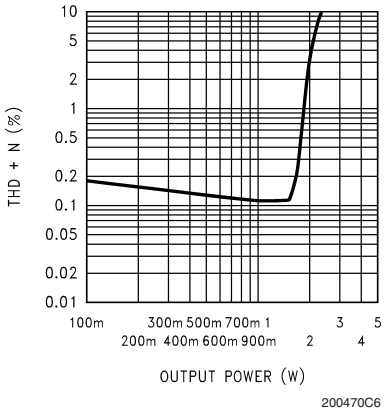
V_{DD} = 12V, R_L = 16Ω, SE operation, both channels driven and loaded (average shown), f_{IN} = 1kHz

THD+N vs Output Power



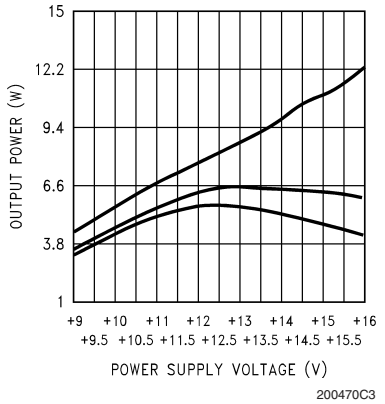
V_{DD} = 12V, R_L = 4Ω, SE operation, A_V = 10 both channels driven and loaded (average shown), f_{IN} = 1kHz

THD+N vs Output Power



V_{DD} = 12V, R_L = 8Ω, SE operation, A_V = 10 both channels driven and loaded (average shown), f_{IN} = 1kHz

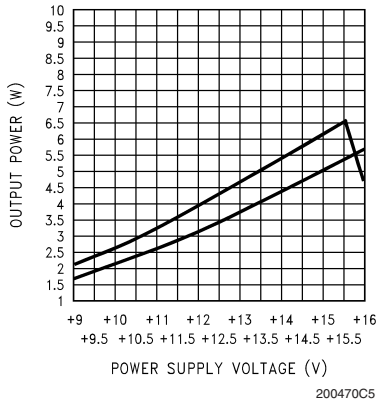
Output Power vs Power Supply Voltage



R_L = 8Ω, BTL, f_{IN} = 1kHz, at (from top to bottom at 12V): THD+N = 10% THD+N = 1%, THD+N = 0.2%

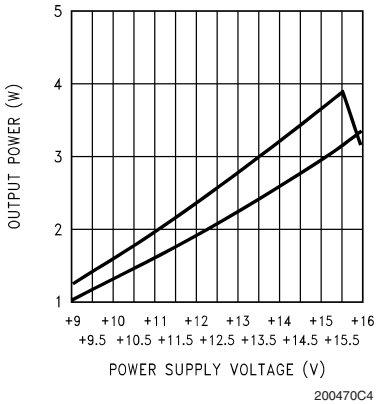
Typical Performance Characteristics (Continued)

Output Power vs Power Supply Voltage



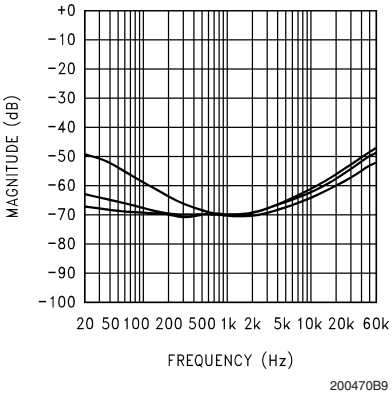
R_L = 4Ω, SE operation, both channels driven and loaded (average shown), at (from top to bottom at 12V): THD+N = 10%, THD+N = 1%

Output Power vs Power Supply Voltage



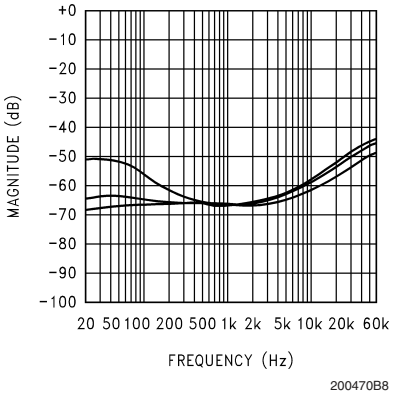
R_L = 8Ω, SE operation, f_{IN} = 1kHz, both channels driven and loaded (average shown), at (from top to bottom at 12V): THD+N = 10%, THD+N = 1%

Power Supply Rejection vs Frequency



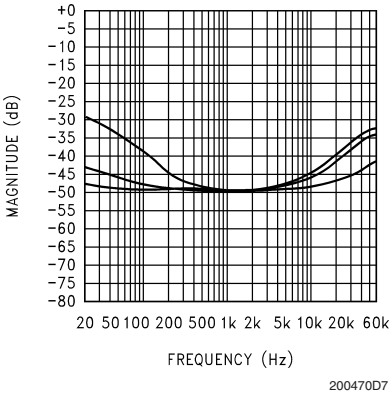
V_{DD} = 12V, R_L = 8Ω, BTL operation, V_{RIPPLE} = 200mV_{p-p}, at (from top to bottom at 60Hz): C_{BYPASS} = 1µF, C_{BYPASS} = 4.7µF, C_{BYPASS} = 10µF,

Power Supply Rejection vs Frequency



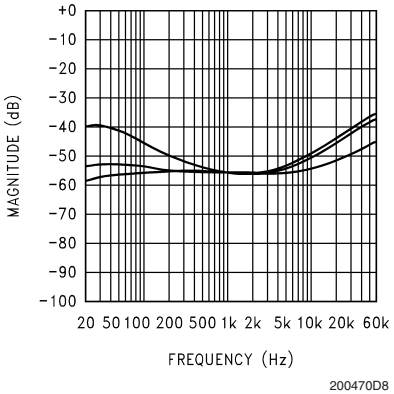
V_{DD} = 12V, R_L = 8Ω, SE operation, V_{RIPPLE} = 200mV_{p-p}, at (from top to bottom at 60Hz): C_{BYPASS} = 1µF, C_{BYPASS} = 4.7µF, C_{BYPASS} = 10µF,

Power Supply Rejection vs Frequency



V_{DD} = 12V, R_L = 8Ω, BTL operation, V_{RIPPLE} = 200mV_{p-p}, A_V = 20, at (from top to bottom at 60Hz): C_{BYPASS} = 1µF, C_{BYPASS} = 4.7µF, C_{BYPASS} = 10µF

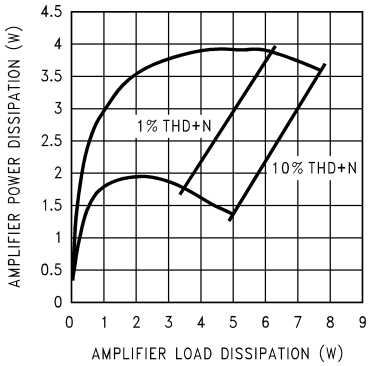
Power Supply Rejection vs Frequency



V_{DD} = 12V, R_L = 8Ω, SE operation, V_{RIPPLE} = 200mV_{p-p}, A_V = 10, at (from top to bottom at 60Hz): C_{BYPASS} = 1µF, C_{BYPASS} = 4.7µF, C_{BYPASS} = 10µF

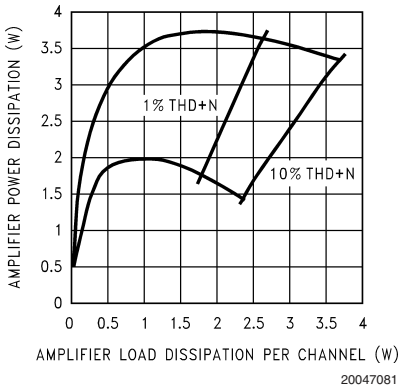
Typical Performance Characteristics (Continued)

Total Power Dissipation vs Load Dissipation



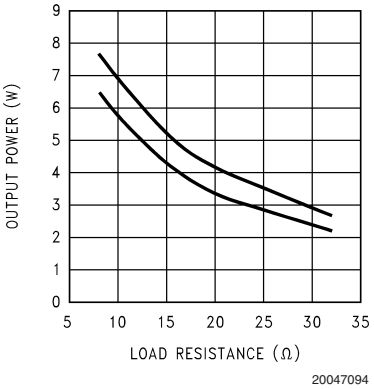
V_{DD} = 12V, BTL operation, f_{IN} = 1kHz, at (from top to bottom at 3W): R_L = 8Ω, R_L = 16Ω

Total Power Dissipation vs Load Dissipation



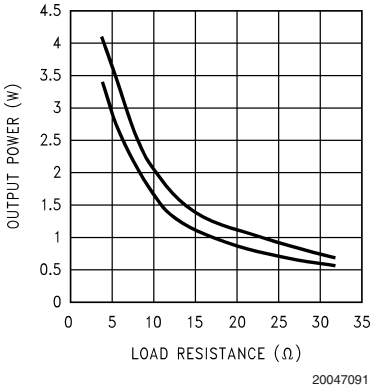
V_{DD} = 12V, SE operation, f_{IN} = 1kHz, at (from top to bottom at 1W): R_L = 4Ω, R_L = 8Ω

Output Power vs Load Resistance



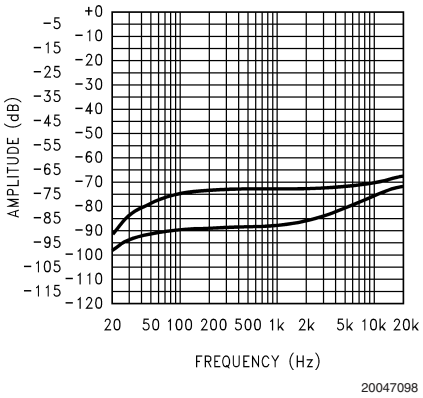
V_{DD} = 12V, BTL operation, f_{IN} = 1kHz, at (from top to bottom at 15Ω): THD+N = 10%, THD+N = 1%

Output Power vs Load Resistance



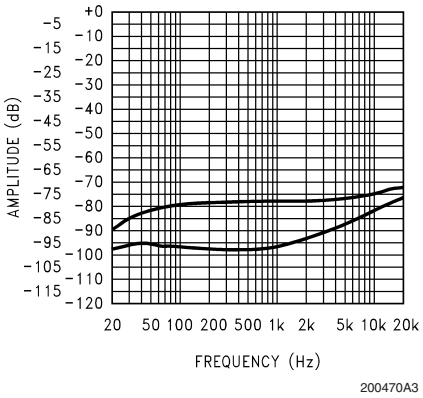
V_{DD} = 12V, SE operation, f_{IN} = 1kHz, both channels driven and loaded, at (from top to bottom at 15Ω): THD+N = 10%, THD+N = 1%

Channel-to-Channel Crosstalk vs Frequency



V_{DD} = 12V, R_L = 4Ω, P_{OUT} = 1W, SE operation, at (from top to bottom at 1kHz): V_{INB} driven, V_{OUTA} measured; V_{INA} driven, V_{OUTB} measured

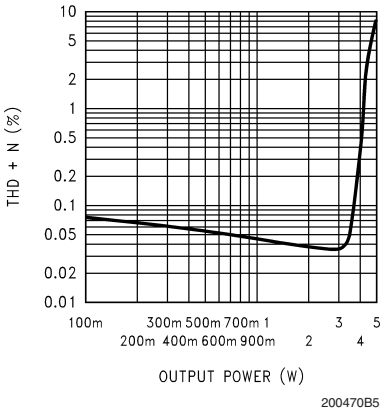
Channel-to-Channel Crosstalk vs Frequency



V_{DD} = 12V, R_L = 8Ω, P_{OUT} = 1W, SE operation, at (from top to bottom at 1kHz): V_{INB} driven, V_{OUTA} measured; V_{INA} driven, V_{OUTB} measured

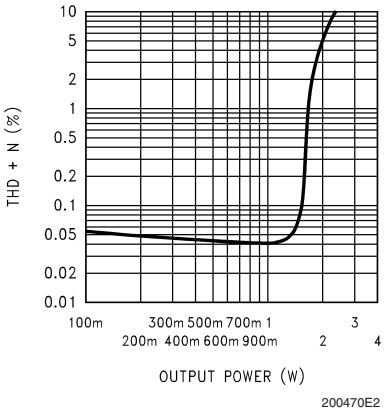
Typical Performance Characteristics (Continued)

THD+N vs Output Power



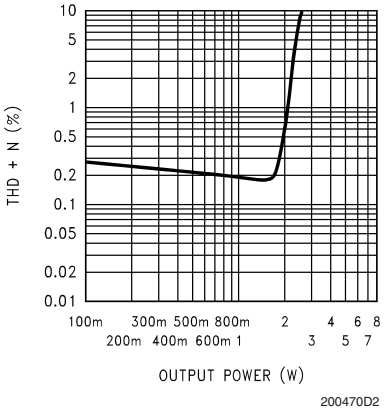
V_{DD} = 9.6V, R_L = 8Ω, BTL operation, f_{IN} = 1kHz

THD+N vs Output Power



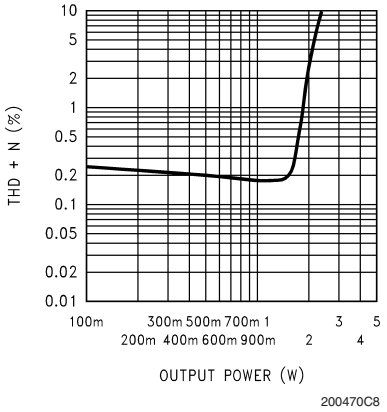
V_{DD} = 9.6V, R_L = 4Ω, SE operation, f_{IN} = 1kHz both channels driven and loaded (average shown)

THD+N vs Output Power



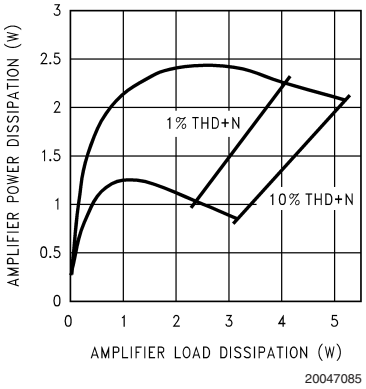
V_{DD} = 9.6V, R_L = 8Ω, BTL operation, $BTLA_V$ = 20, f_{IN} = 1kHz

THD+N vs Output Power



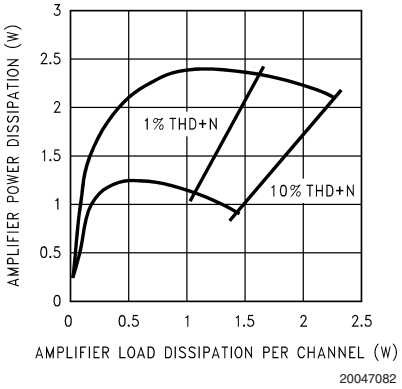
V_{DD} = 9.6V, R_L = 4Ω, SE operation, AV = 10, f_{IN} = 1kHz both channels driven and loaded (average shown)

Total Power Dissipation vs Load Dissipation



V_{DD} = 9.6V, BTL operation, f_{IN} = 1kHz at (from top to bottom at 2W): R_L = 8Ω, R_L = 16Ω

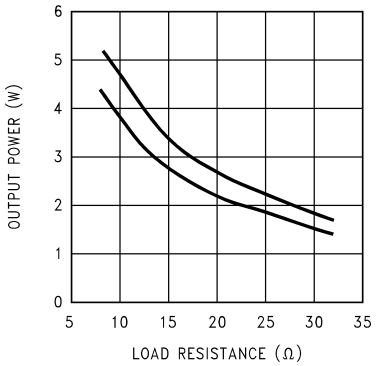
Total Power Dissipation vs Load Dissipation per Channel



V_{DD} = 9.6V, SE operation, f_{IN} = 1kHz, at (from top to bottom at 1W): R_L = 4Ω, R_L = 8Ω

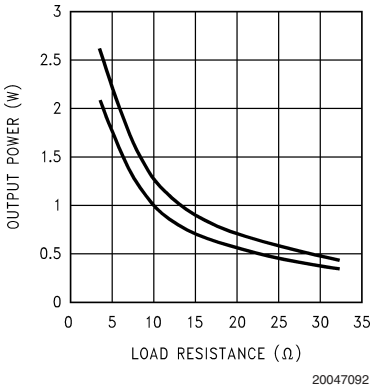
Typical Performance Characteristics (Continued)

Output Power vs Load Resistance



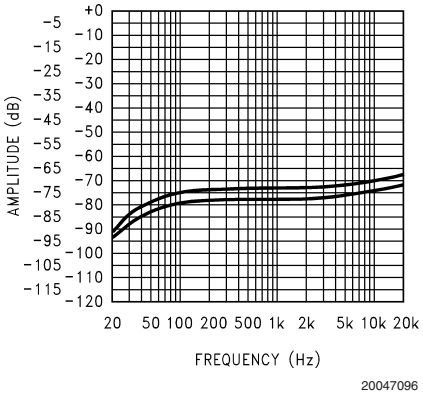
V_{DD} = 9.6V, BTL operation, f_{IN} = 1kHz, at (from top to bottom at 15Ω): THD+N = 10%, THD+N = 1%

Output Power vs Load Resistance



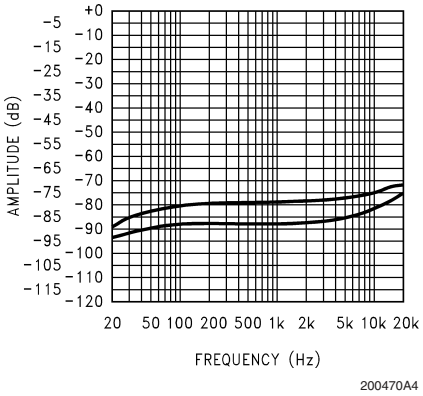
V_{DD} = 9.6V, SE operation, f_{IN} = 1kHz, both channels driven and loaded, at (from top to bottom at 15Ω): THD+N = 10%, THD+N = 1%

Channel-to Channel Crosstalk vs Frequency



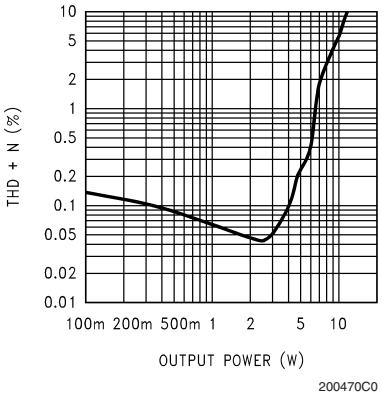
V_{DD} = 9.6V, R_L = 4Ω, P_{OUT} = 1W, SE operation, at (from top to bottom at 1kHz): V_{INB} driven, V_{OUTA} measured; V_{INA} driven, V_{OUTB} measured

Channel-to Channel Crosstalk vs Frequency



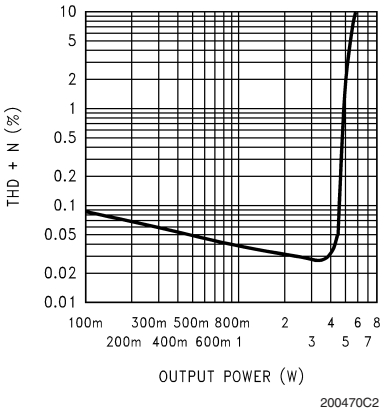
V_{DD} = 9.6V, R_L = 8Ω, P_{OUT} = 1W, SE operation, at (from top to bottom at 1kHz): V_{INB} driven, V_{OUTA} measured; V_{INA} driven, V_{OUTB} measured

THD+N vs Output Power



V_{DD} = 15V, R_L = 8Ω, BTL operation, f_{IN} = 1kHz

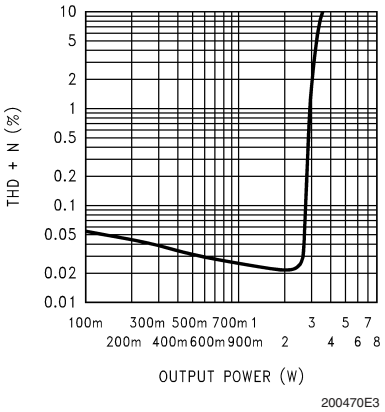
THD+N vs Output Power



V_{DD} = 15V, R_L = 4Ω, SE operation, f_{IN} = 1kHz both channels driven and loaded (average shown)

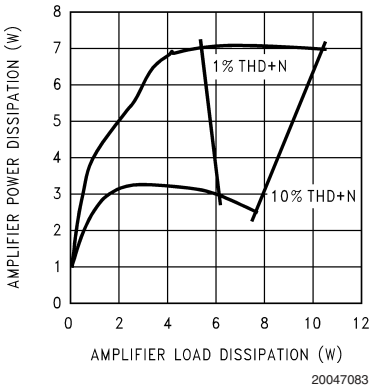
Typical Performance Characteristics (Continued)

THD+N vs Output Power



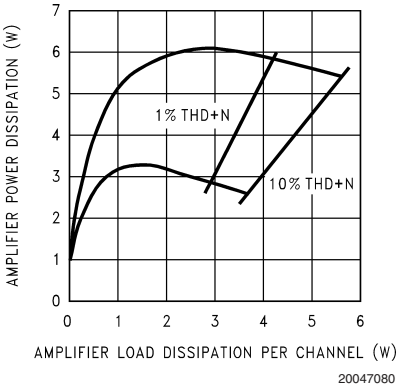
V_{DD} = 15V, R_L = 8Ω,
SE operation, f_{IN} = 1kHz
both channels driven and loaded (average shown)

Total Power Dissipation vs Load Dissipation



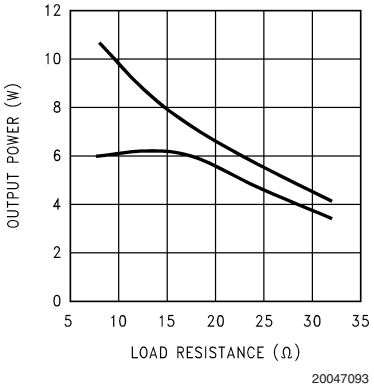
V_{DD} = 15V, BTL operation, f_{IN} = 1kHz,
at (from top to bottom at 4W): R_L = 8Ω, R_L = 16Ω

Total Power Dissipation vs Load Dissipation per Channel



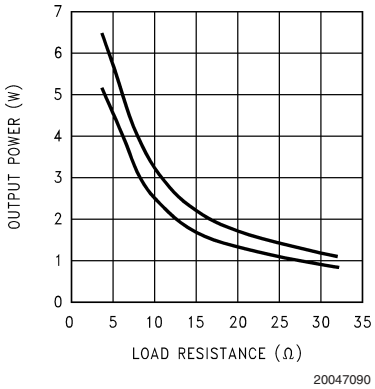
V_{DD} = 15V, SE operation, f_{IN} = 1kHz,
at (from top to bottom at 2W): R_L = 4Ω, R_L = 8Ω

Output Power vs Load Resistance



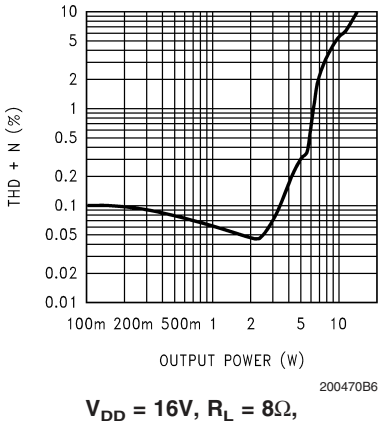
V_{DD} = 15V, BTL operation, f_{IN} = 1kHz,
at (from top to bottom at 15Ω):
THD+N = 10%, THD+N = 1%

Output Power vs Load Resistance



V_{DD} = 15V, SE operation, f_{IN} = 1kHz,
both channels driven and loaded,
at (from top to bottom at 15Ω): THD+N = 10%, THD+N = 1%

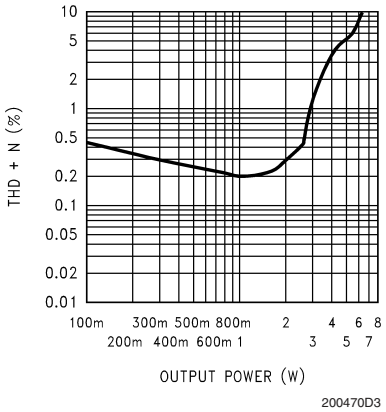
THD+N vs Output Power



V_{DD} = 16V, R_L = 8Ω,
BTL operation, f_{IN} = 1kHz

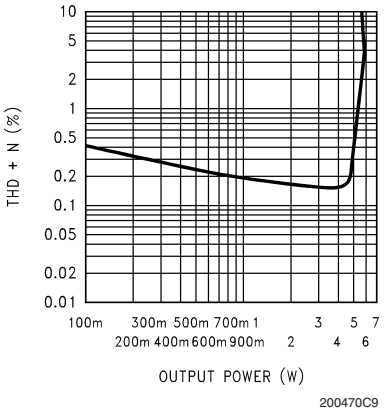
Typical Performance Characteristics (Continued)

THD+N vs Output Power



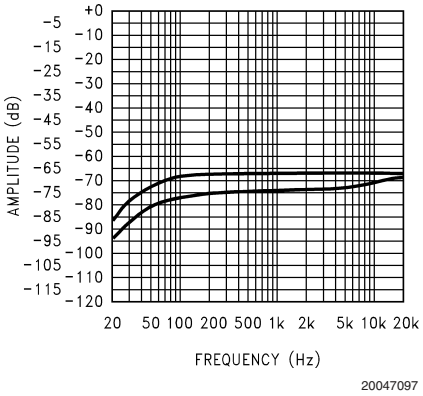
V_{DD} = 16V, R_L = 8Ω,
BTL operation, f_{IN} = 1kHz, $BTLA_V$ = 20

THD+N vs Output Power



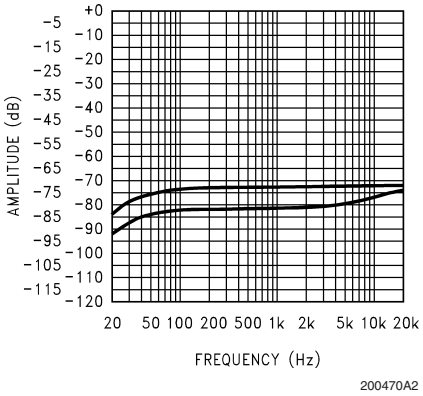
V_{DD} = 16V, R_L = 4Ω, A_V = 10
SE operation, f_{IN} = 1kHz,
both channels driven and loaded (average shown)

Channel-to-Channel Crosstalk vs Frequency



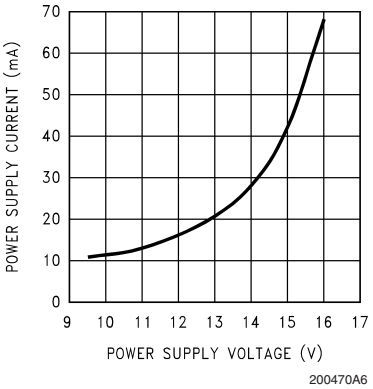
V_{DD} = 16V, R_L = 4Ω, P_{OUT} = 1W, SE operation
at (from top to bottom at 1kHz): V_{INB} driven, V_{OUTA} measured;
V_{INA} driven, V_{OUTB} measured

Channel-to-Channel Crosstalk vs Frequency



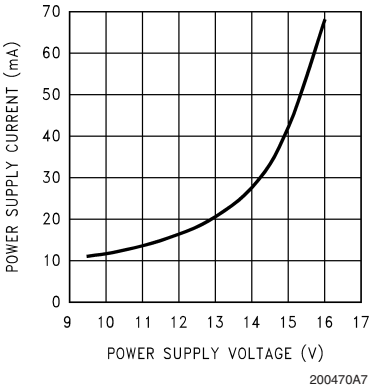
V_{DD} = 16V, R_L = 8Ω, P_{OUT} = 1W, SE operation
at (from top to bottom at 1kHz): V_{INB} driven, V_{OUTA} measured;
V_{INA} driven, V_{OUTB} measured

Power Supply Current vs Power Supply Voltage



R_L = 8Ω, BTL operation
V_{IN} = 0V, R_{SOURCE} = 50Ω

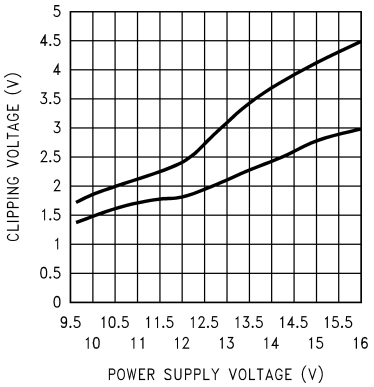
Power Supply Current vs Power Supply Voltage



R_L = 4Ω, SE operation
V_{IN} = 0V, R_{SOURCE} = 50Ω

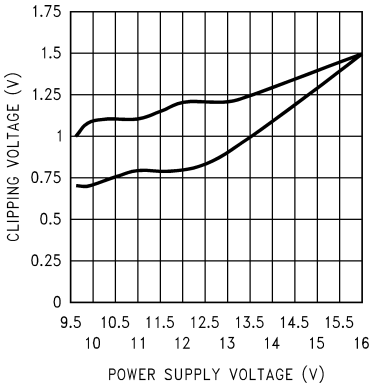
Typical Performance Characteristics (Continued)

Clipping Voltage vs Power Supply Voltage



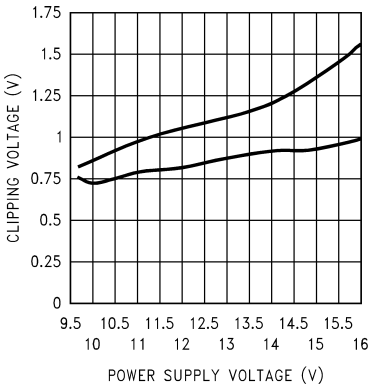
R_L = 8Ω, BTL operation, f_{IN} = 1kHz at (from top to bottom at 12V): positive signal swing, negative signal swing

Clipping Voltage vs Power Supply Voltage



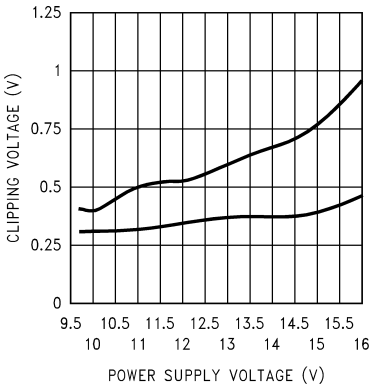
R_L = 16Ω, BTL operation, f_{IN} = 1kHz at (from to bottom at 12V): positive signal swing, negative signal swing

Clipping Voltage vs Power Supply Voltage



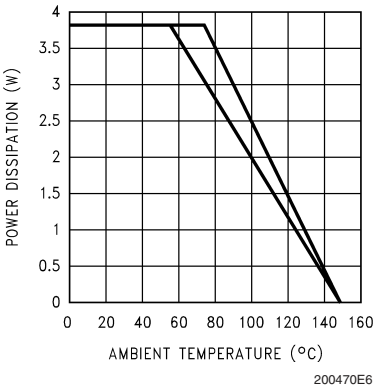
R_L = 4Ω, SE operation, f_{IN} = 1kHz both channels driven and loaded, at (from top to bottom at 13V): negative signal swing, positive signal swing

Clipping Voltage vs Power Supply Voltage



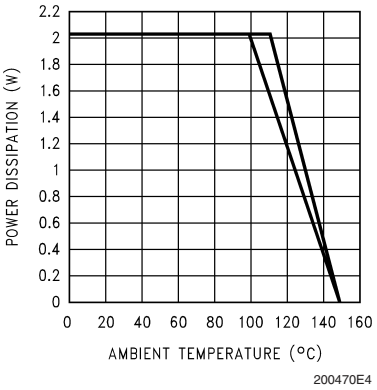
R_L = 8Ω, SE operation, f_{IN} = 1kHz both channels driven and loaded, at (from to bottom at 13V): negative signal swing, positive signal swing

Power Dissipation vs Ambient Temperature



V_{DD} = 12V, R_L = 8Ω (BTL), f_{IN} = 1kHz, (from to bottom at 80˚C): 16in^2 copper plane heatsink area, 8in^2 copper plane heatsink area

Power Dissipation vs Ambient Temperature



V_{DD} = 12V, R_L = 8Ω (SE), f_{IN} = 1kHz, (from to bottom at 120˚C): 16in^2 copper plane heatsink area, 8in^2 copper plane heatsink area

Application Information

HIGH VOLTAGE BOOMER WITH INCREASED OUTPUT POWER

Unlike previous 5V Boomer® amplifiers, the LM4950 is designed to operate over a power supply voltages range of 9.6V to 16V. Operating on a 12V power supply, the LM4950 will deliver 7.5W into an 8Ω BTL load with no more than 10% THD+N.

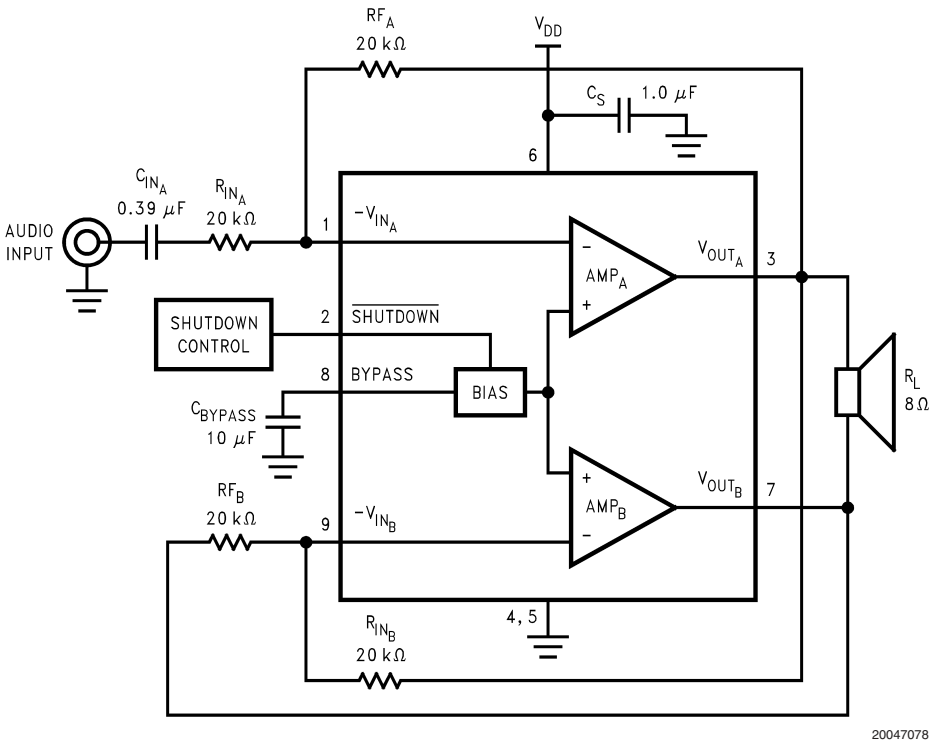


FIGURE 3. Typical LM4950 BTL Application Circuit

BRIDGE CONFIGURATION EXPLANATION

As shown in *Figure 3*, the LM4950 consists of two operational amplifiers that drive a speaker connected between their outputs. The value of external input and feedback resistors determine the gain of each amplifier. Resistors RIN_A and RF_A set the closed-loop gain of AMP_A, whereas two 20kΩ resistors set AMP_B's gain to -1. The LM4950 drives a load, such as a speaker, connected between the two amplifier outputs, $VOUT_A$ and $VOUT_B$. *Figure 3* 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.

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 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.

Application Information (Continued)

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

The LM4950's dissipation is twice the value given by Equation (2) when driving two SE loads. For a 12V supply and two 8Ω SE loads, the LM4950's dissipation is 1.82W.

The LM4950's dissipation when driving a BTL load is given by Equation (3). For a 12V supply and a single 8Ω BTL load, the dissipation is 3.65W.

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

The maximum power dissipation point given by Equation (3) must not exceed the power dissipation given by Equation (4):

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

The LM4950's T_{JMAX} = 150˚C. In the TS package, the LM4950's θ_{JA} is 20˚C/W when the metal tab is soldered to a copper plane of at least 16in^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 a 5x5 array of vias. For the TA package, use an external heatsink with a thermal impedance that is less than 20˚C/W. At any given ambient temperature T_A, use Equation (4) to find the maximum internal power dissipation supported by the IC packaging. Rearranging Equation (4) and substituting P_{DMAX} for P_{DMAX}' results in Equation (5). This equation gives the maximum ambient temperature that still allows maximum stereo power dissipation without violating the LM4950's maximum junction temperature.

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

For a typical application with a 12V 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 77˚C for the TS package.

$$T_{JMAX} = P_{DMAX\text{-}MONOBTL}\theta_{JA} + T_A \qquad (6)$$

Equation (6) gives the maximum junction temperature T_{JMAX}. If the result violates the LM4950'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 (3) is greater than that of Equation (4), then decrease the supply voltage, increase the load impedance, or reduce the ambient temperature. Further, ensure that speakers rated at a nominal 4Ω (SE operation) or 8Ω (BTL operation) do not fall below 3Ω or 6Ω, respectively. 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 LM4950'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 LM4950's power supply pin and ground as short as possible. Connecting a 10µF 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 LM4950 features an active-low micro-power shutdown mode. When active, the LM4950's micro-power shutdown feature turns off the amplifier's bias circuitry, reducing the supply current. The low 40µA 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 a 100kΩ pull-up resistor between the SHUTDOWN pin and V_{DD} and a second 100kΩ resistor in parallel with the SPST switch connected between the SHUTDOWN pin and GND. The two resistors form a voltage divider that ensures that the voltage applied to the SHUTDOWN pin does not exceed $V_{DD}/2$. Select normal amplifier operation by opening the switch. Closing the switch applies GND to the SHUTDOWN pin, activating micro-power shutdown. The switch and resistor guarantee 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. Again, ensure that the microcontroller or microprocessor logic-high signal does not exceed the LM4950's $V_{DD}/2$ SHUTDOWN signal limit.

Application Information (Continued)

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 3, the input resistor (R_{IN}) and the input capacitor (C_{IN}) produce a high pass filter cutoff frequency that is found using Equation (7).

$$f_c = 1/2\pi R_i C_i \quad (7)$$

As an example when using a speaker with a low frequency limit of 50Hz, C_i, using Equation (7) is 0.159µF. The 0.39µF C_{INA} shown in *Figure 3* allows the LM4950 to drive high efficiency, full range speaker whose response extends below 30Hz.

Bypass Capacitor Value

Besides minimizing the input capacitor size, careful consideration should be paid to value of C_{BYPASS}, the capacitor connected to the BYPASS pin. Since C_{BYPASS} determines how fast the LM4950 settles to quiescent operation, its value is critical when minimizing turn-on pops. The slower the LM4950's outputs ramp to their quiescent DC voltage (nominally $V_{DD}/2$), the smaller the turn-on pop. Choosing C_{BYPASS} equal to 10µF along with a small value of C_{IN} (in the range of 0.1µF to 0.39µF), produces a click-less and pop-less shutdown function. As discussed above, choosing C_{IN} no larger than necessary for the desired bandwidth helps minimize clicks and pops.

OPTIMIZING CLICK AND POP REDUCTION PERFORMANCE

The LM4950 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 LM4950's internal amplifiers are configured as unity gain buffers and are disconnected from the AMP_A and AMP_B pins. 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 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, the device becomes fully operational and the amplifier outputs are reconnected to their respective output pins. Although the BYPASS pin current cannot be modified, changing the size of C_{BYPASS} alters the device's turn-on time. Here are some typical turn-on times for various values of C_{BYPASS}:

C_B (µF)	T_{ON} (ms)
1.0	120
2.2	120
4.7	200
10	440

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".

There is a relationship between the value of C_{IN} and C_{BYPASS} that ensures minimum output transient when power is applied or the shutdown mode is deactivated. Best performance is achieved by setting the time constant created by C_{IN} and $R_i + R_f$ to a value less than the turn-on time for a given value of C_{BYPASS} as shown in the table above.

DRIVING PIEZO-ELECTRIC SPEAKER TRANSDUCERS

The LM4950 is able to drive capacitive piezo-electric transducer loads that are less than equal to 200nF. Stable operation is assured by placing 33pF capacitors in parallel with the 20kΩ feedback resistors. The additional capacitors are shown in *Figure 4*.

When driving piezo-electric tranducers, sound quality and accoustic power is entirely dependent upon a transducer's frequency response and efficiency. In this application, power dissipated by the LM4950 is very low, typically less than 250mW when driving a 200nF piezo-electric transduce (V_{DD} = 12V).

Application Information (Continued)

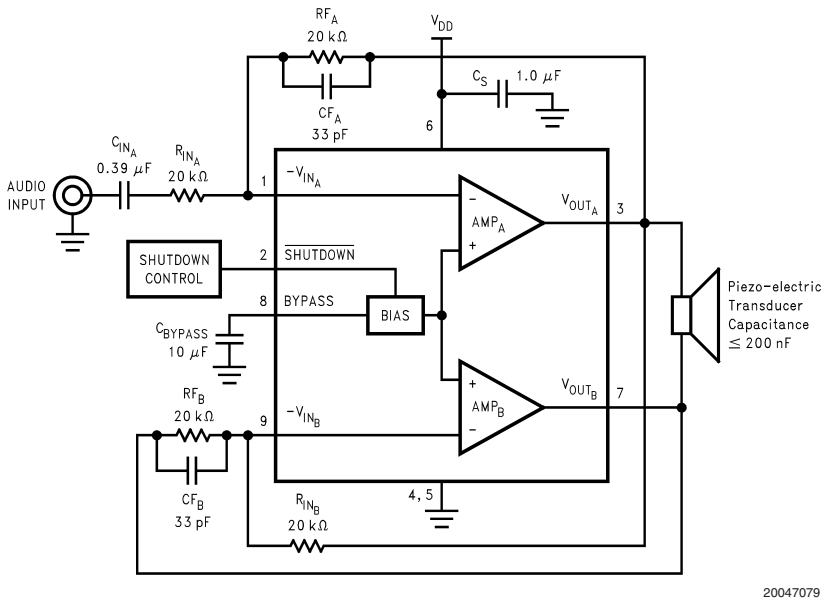


FIGURE 4. Piezo-electric Transducer Capacitance ≤ 200nF

AUDIO POWER AMPLIFIER DESIGN

Audio Amplifier Design: Driving 4W into an 8Ω BTL

The following are the desired operational parameters:

Power Output	$4W_{RMS}$
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 *Output Power vs Power Supply Voltage* curve in the **Typical Performance Characteristics** section. Another way, using Equation (8), 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 *Clipping Dropout Voltage vs Power Supply Voltage* in the **Typical Performance Characteristics** curves, must be added to the result obtained by Equation (8). The result is Equation (9).

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

$$V_{DD} = V_{OUTPEAK} + V_{ODTOP} + V_{ODBOT} \tag{9}$$

The *Output Power vs. Power Supply Voltage* graph for an 8Ω load indicates a minimum supply voltage of 10.2V. The commonly used 12V supply voltage easily meets this. The additional voltage creates the benefit of headroom, allowing the LM4950 to produce peak output power in excess of 4W 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 LM4950's power dissipation requirements, the minimum differential gain needed to achieve 4W dissipation in an 8Ω BTL load is found using Equation (10).

$$A_V \geq \sqrt{(P_O R_L)}/(V_{IN}) = V_{orms}/V_{inrms} \tag{10}$$

Thus, a minimum gain of 18.9 allows the LM4950's to reach full output swing and maintain low noise and THD+N performance. For this example, let $A_{V\text{-}BTL}$ = 19. The amplifier's overall BTL gain is set using the input (RIN_A) and feedback (R) 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_{IN} and R_f. With the desired input impedance set at 20kΩ, the feedback resistor is found using Equation (11).

$$R_f / R_{IN} = A_{V\text{-}BTL} / 2 \tag{11}$$

The value of R_f is 190kΩ (choose 191kΩ, the closest value). The nominal output power is 4W.

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

$$f_L = 50Hz / 5 = 10Hz \tag{12}$$

Application Information (Continued)

and an

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

As mentioned in the **SELECTING EXTERNAL COMPONENTS** section, R_{INA} and C_{INA} create a highpass filter that sets the amplifier's lower bandpass frequency limit. Find the coupling capacitor's value using Equation (14).

$$C_i = 1 / 2\pi R_{IN} f_L \quad (14)$$

The result is

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

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 LM4950'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

Figure 5 through *Figure 7* show the recommended two-layer PC board layout that is optimized for the TO263-packaged, SE-configured LM4950 and associated external components. *Figure 8* through *Figure 10* show the recommended two-layer PC board layout that is optimized for the TO263-packaged, BTL-configured LM4950 and associated external components. These circuits are designed for use with an external 12V supply and 4Ω(min)(SE) or 8Ω(min)(BTL) speakers.

These circuit boards are easy to use. Apply 12V and ground to the board's V_{DD} and GND pads, respectively. Connect a speaker between the board's OUT_A and OUT_Boutputs.

Demonstration Board Layout

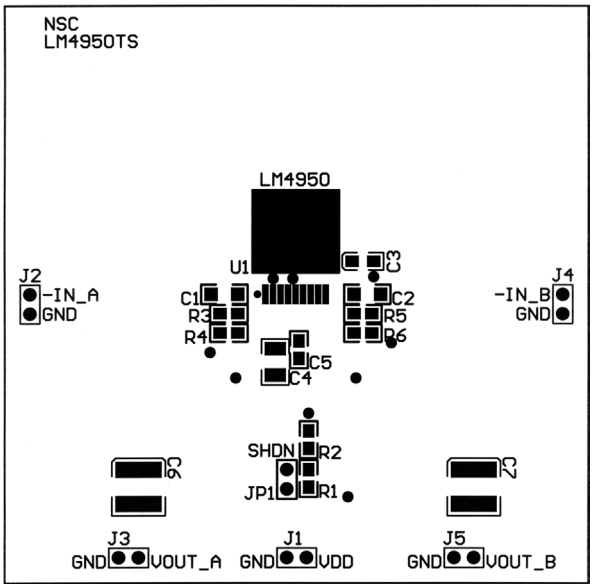


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FIGURE 5. Recommended TS SE PCB Layout: Top Silkscreen

Demonstration Board Layout (Continued)

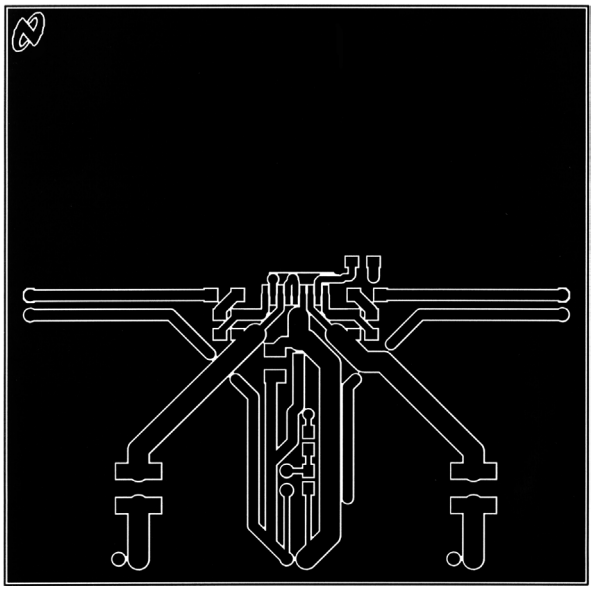

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FIGURE 6. Recommended TS SE PCB Layout: Top Layer

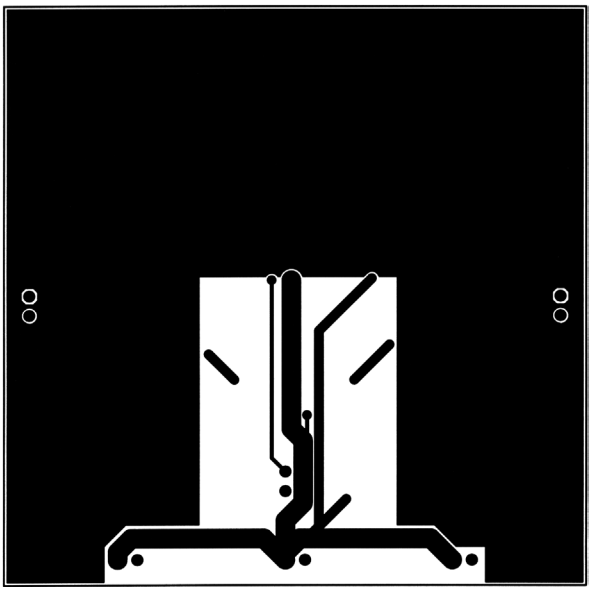

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FIGURE 7. Recommended TS SE PCB Layout: Bottom Layer

Demonstration Board Layout (Continued)

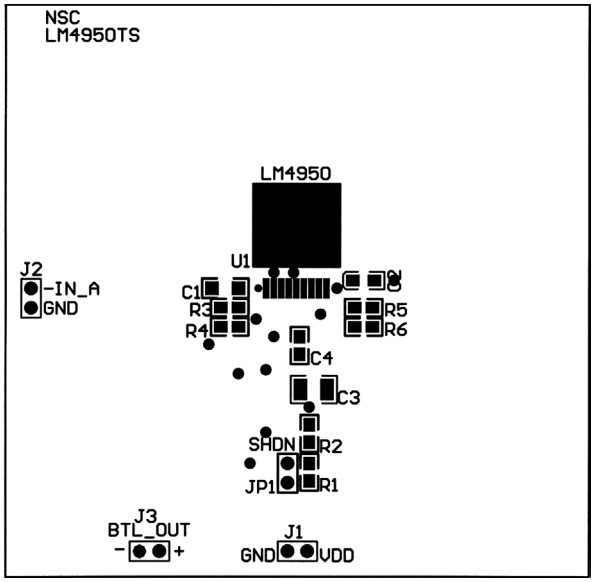

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FIGURE 8. Recommended TS BTL PCB Layout: Top Silkscreen

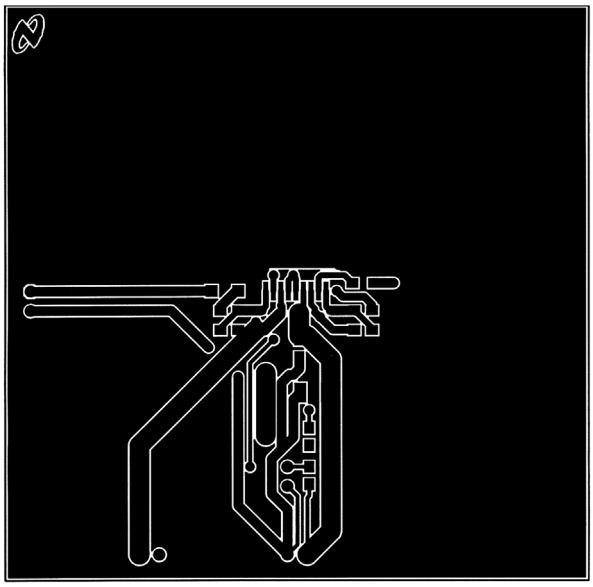

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FIGURE 9. Recommended TS BTL PCB Layout: Top Layer

Demonstration Board Layout (Continued)

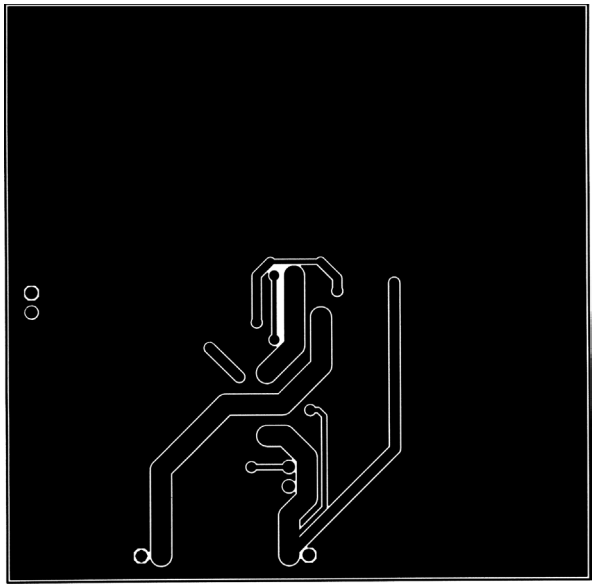

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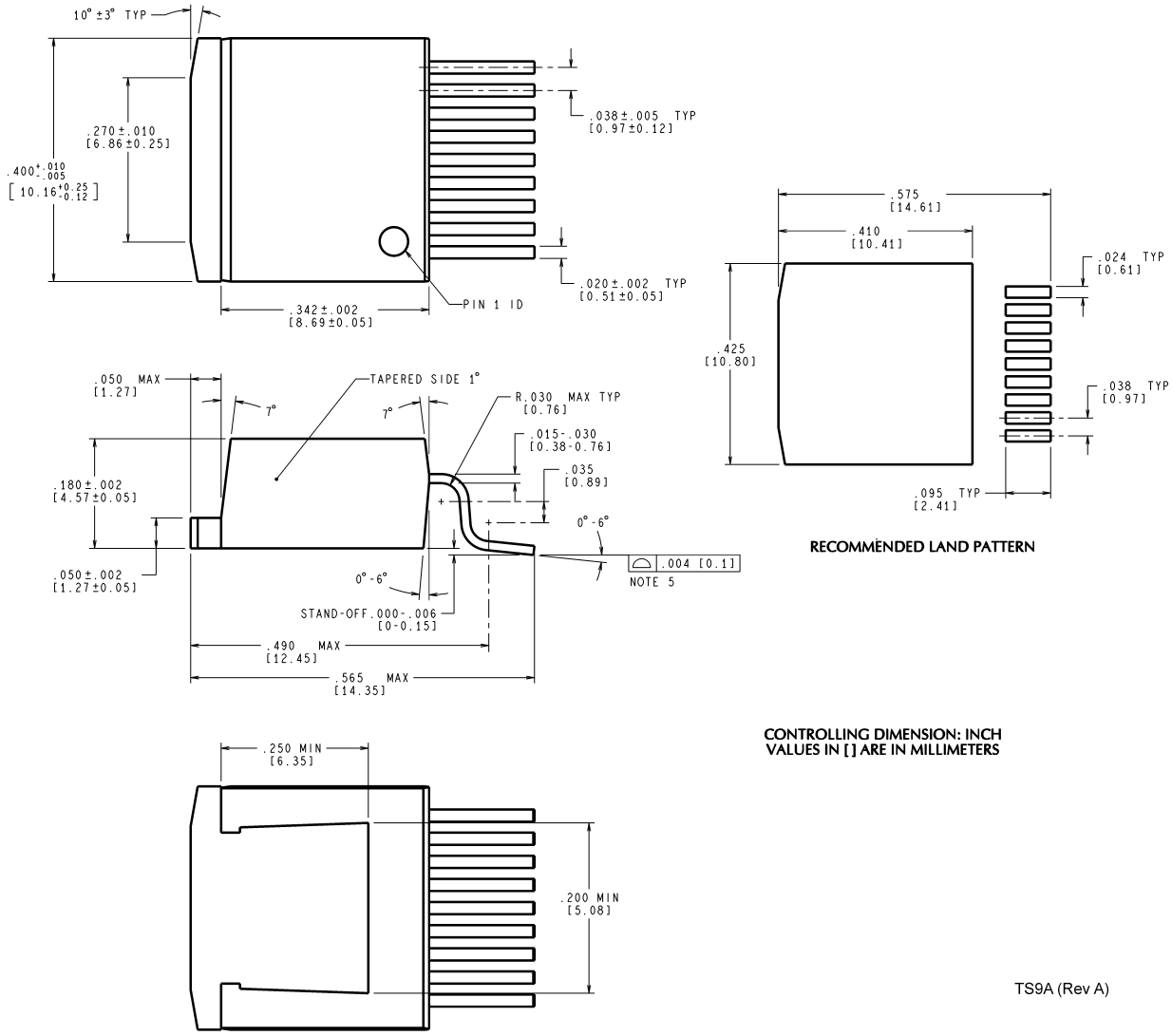
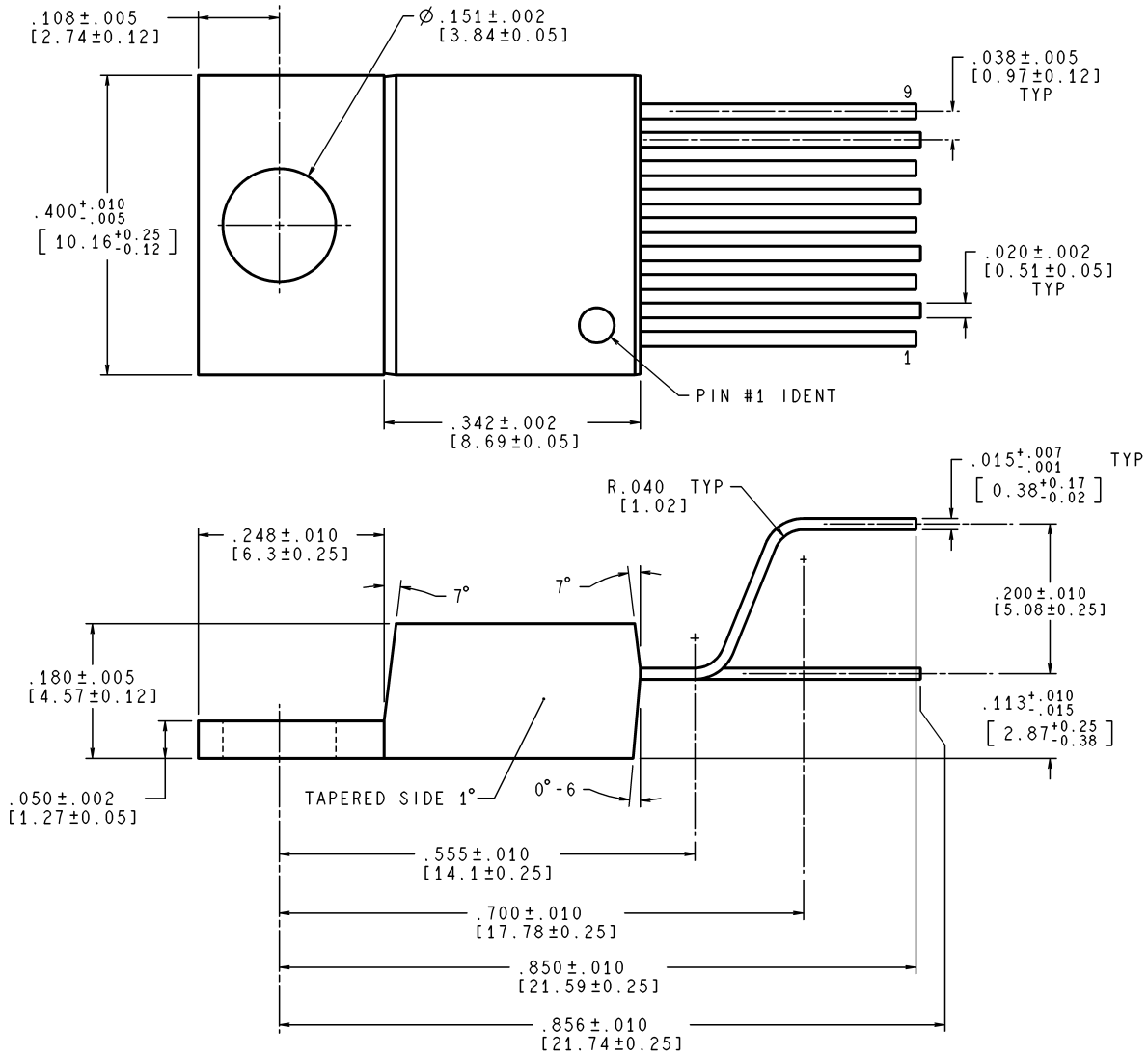
FIGURE 10. Recommended TS BTL PCB Layout: Bottom Layer

Physical Dimensions inches (millimeters) unless otherwise noted



Order Number LM4950TS
NS Package Number TS9A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



CONTROLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS

TA09A (Rev C)

For Staggered Lead Non-Isolated Package
Order Number LM4950TA
NS Package Number TA09A

Notes

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