

### ■ GENERAL DESCRIPTION

The PT5301 is an audio power amplifier mainly designed for applications in mobile phones and other portable communication device applications. It is capable of delivering 1.25 watts of continuous average power to an 8Ω load and 2 watts of continuous average power to a 4Ω load with less than 1% distortion (THD+N+N) from a 5V power supply. The PT5301 does not require output coupling capacitors or bootstrap capacitors, and therefore is ideally suited for mobile phone and other low voltage applications where minimal power consumption is a primary requirement.

The PT5301 features a low-power shutdown mode and improved pop & click circuitry that attenuates noise which would otherwise occur during turn on and turn off transactions. The PT5301 is delivered with miniature MSOP-8 and SMD-9 packages (Pd free).

### ■ FEATURES

- Ultra low shutdown current
- Improved pop & click noise eliminating function
- No need for output coupling or bootstrap capacitors
- 2.2 -5.5V operation supply voltage
- Thermal protection
- External gain configuration capability
- Pd free MSOP-8, and SMD-9 packages
- Unity-gain stable

### ■ APPLICATIONS

- Mobil Phones
- PDAs
- Portable electronic devices

### ■ TYPICAL APPLICATIONS

### ■ KEY PERFORMANCE CHART

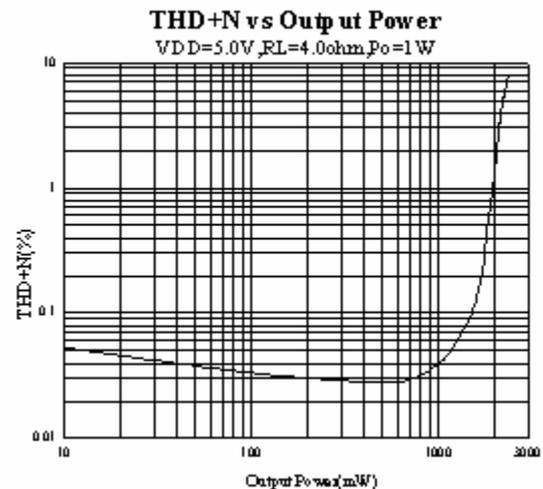
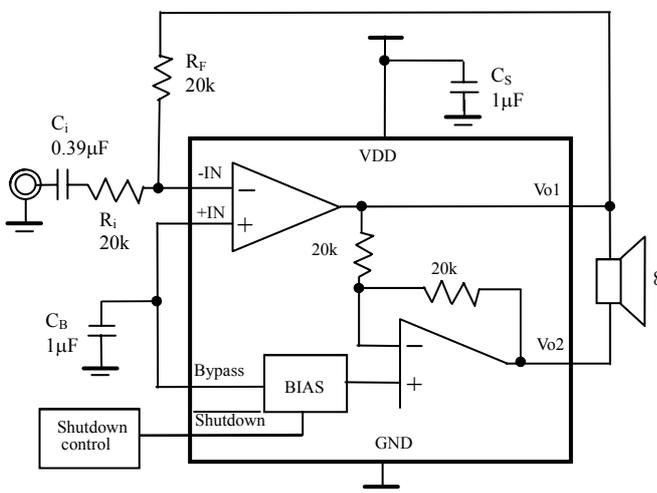
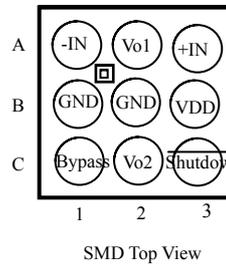
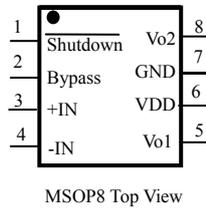


Figure 1. Typical Audio Amplifier Application Circuit.

### ■ ORDER INFORMATION

Pd-Free Package	Temperature	Order Part Number	Transport Media	Marking
MSOP-8	-40°C to 85°C	PT5301EMSO	Tape and Reel	
SMD-9	-40°C to 85°C	PT5301ESMD	Tape and Reel	

### ■ PIN ASSIGNMENT



### ■ PIN DESCRIPTIONS

MSOP8	SMD9	Names	Description
1	C3	Shutdown	Turn-on or turn-off the chip
2	C1	Bypass	Set the common voltage
3	A3	+IN	The non-inverting input node
4	A1	-IN	The inverting input node
5	A2	Vo1	The 1 <sup>st</sup> node of outputs
6	B3	VDD	Power supply 2.5~5.5V
7	B1, B2	GND	ground
8	C2	Vo2	The 2 <sup>nd</sup> node of outputs

### ■ ABSOLUTE MAXIMUM RATINGS (Note 1)

ITEMS	VALUE	UNIT
Supply Voltage	6	V
Input Voltage	-0.3 ~ VDD+0.3	V
Thermal Resistance, MSOP8: $\Theta_{JA}/\Theta_{JC}$	190/56	/W
Thermal Resistance, BGA9: $\Theta_{JA}/\Theta_{JC}$ (Note 4)	180/56	/W
Power Dissipation (Notes 9, 10)	Internal limited	
Operating Temperature	-40 to 85	
ESD Susceptibility (Note 5)	2500	V
Storage Temperature	-65 to 150	
Package Lead Soldering Temperature	260 , 10s	

### ■ OPERATING RANGE (Note 2)

SYMBOL	PARAMETER	VALUE
$T_A$	Temperature Range	-40 °C $T_A$ 85 °C
$V_{DD}$	Supply Voltage	2.2V $V_{DD}$ 5.5V

## 2 Watts Audio Power Amplifier

### ■ ELECTRICAL CHARACTERISTICS $V_{DD} = 5V$ (Notes 3, 6)

The following specifications apply for the circuit shown in Figure 1, unless otherwise specified.  $T_A = 25^\circ C$ .

Symbol	Items	Conditions	Typical	Limit	Units
$I_{dd}$	Quiescent Power Supply Current	$V_{in}=0V, I_o=0A, \text{No Load}$	2.9	4.5	mA
		$V_{in}=0V, I_o=0A, 8 \text{ Load}$	2.9	5	mA
$I_{sd}$	Shutdown current	$V_{shutdown}=0$ (Note 7)	0.1	2	$\mu A$
$V_{sdih}$	Shutdown Voltage Input High		1.6		V
$V_{sdil}$	Shutdown Voltage Input Low		1.4		V
$V_{os}$	Output Offset Voltage		1.3	7	mV
$P_o$	Output Power ( 8 Load )	$F=1k; THD+N=1\% (\text{max})$	1.25	0.9	W
	Output Power ( 4 Load )	$F=1k; THD+N=1\% (\text{max})$	2		W
$T_{wu}$	Wake-up time		146		mS
THD	Total Harmonic Distortion + Noise	$P_o=0.5W_{rms}; f=1k, 8 \text{ Load}$	0.1		%
PSRR	Power Supply Rejection Ratio	$V_{ripple}=200mV \text{ sine wave p-p}$	71 ( $F=217Hz$ ), 69 ( $f=1k$ )	57 (min)	dB
$R_o$	Resistor Output to GND (Note 8)		11.0	9.7	k (min)
				12.5	k (max)

### ■ ELECTRICAL CHARACTERISTICS $V_{DD} = 3V$ (Notes 3, 6)

The following specifications apply for the circuit shown in Figure 1, unless otherwise specified.  $T_A = 25^\circ C$ .

Symbol	Items	Conditions	Typical	Limit	Units
$I_{dd}$	Quiescent Power Supply Current	$V_{in}=0V, I_o=0A, \text{No Load}$	2.8	4.3	mA
		$V_{in}=0V, I_o=0A, 8 \text{ Load}$	2.8	5	mA
$I_{sd}$	Shutdown current	$V_{shutdown}=0$ (Note 7)	0.1	2	$\mu A$
$V_{sdih}$	Shutdown Voltage Input High		1.1		V
$V_{sdil}$	Shutdown Voltage Input Low		1.0		V
$V_{os}$	Output Offset Voltage		1.3	7	mV
$P_o$	Output Power ( 8 Load )	$F=1k; THD+N=1\% (\text{max})$	425		mW
	Output Power ( 4 Load )	$F=1k; THD+N=1\% (\text{max})$	600		mW
$T_{wu}$	Wake-up time		150		mS
THD	Total Harmonic Distortion + Noise	$P_o=0.25W_{rms}; f=1k, 8 \text{ Load}$	0.1		%
PSRR	Power Supply Rejection Ratio	$V_{ripple}=200mV \text{ sine p-p}$	67( $f=217$ ), 68( $f=1k$ )	55 (min)	dB
$R_o$	Resistor Output to GND (Note 8)		11.0	9.7	k (min)
				12.5	k (max)

## 2 Watts Audio Power Amplifier

### ■ ELECTRICAL CHARACTERISTICS $V_{DD} = 2.6V$ (Notes 3, 6)

The following specifications apply for the circuit shown in Figure 1, unless otherwise specified.  $T_A = 25^\circ C$ .

Symbol	Items	Conditions	Typical	Limit	Units
$I_{dd}$	Quiescent Power Supply Current	$V_{in}=0V, I_o=0A$ , No Load	2.8	4.3	mA
		$V_{in}=0V, I_o=0A$ , 8 Load	2.8	5	mA
$I_{sd}$	Shutdown current	$V_{shutdown}=0$ (Note 7)	0.1	2	$\mu A$
$V_{sdih}$	Shutdown Voltage Input High		1		V
$V_{sdil}$	Shutdown Voltage Input Low		0.9		V
$V_{os}$	Output Offset Voltage		1.3	7	mV
$P_o$	Output Power ( 8 Load )	$F=1k; THD+N=1\%$ (max)	300		mW
	Output Power ( 4 Load )	$F=1k; THD+N=1\%$ (max)	400		mW
$T_{wu}$	Wake-up time		153		mS
THD	Total Harmonic Distortion + Noise	$P_o=0.15W_{rms}; f=1k, 8$ Load	0.1		%
PSRR	Power Supply Rejection Ratio	$V_{ripple}=200mV$ sine p-p	66( $f=217$ ), 68( $f=1k$ )		dB
$R_o$	Resistor Output to GND (Note 8)		11.0	9.7	k (min)
				12.5	k (max)

Note 1: *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur.

Note 2: *Operating Ratings* indicate conditions for which the device is functional, but do not guarantee specific performance limits.

Note 3: *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 4: All bumps have the thermal resistance and contribute equally when used to lower thermal resistance. All bumps must be connected to achieve specified thermal resistance.

Note 5: Human body model, 100pF discharged through a 1.5k $\Omega$  resistor.

Note 6: "Typical" means that measured at 25 $^\circ C$  and represent the parametric norm. "Limit" indicates that are guaranteed by PowTech's quality control standards. Datasheet min/max specification limits are guaranteed by design, test, or statistical analysis.

Note 7: For micro SMD package, shutdown current is measured in a Normal Room Environment. Exposure to direct sunlight will increase  $I_{SD}$  by a maximum of 2 $\mu A$ .

Note 8:  $R_o$  is measured from the output pin to ground. This value represents the parallel combination of the 15k $\Omega$  output resistors and the two 20k $\Omega$  resistors.

Note 9: The maximum power dissipation must be derated at elevated temperatures and is dictated by  $T_{JMAX}$ ,  $\theta_{JA}$ , and the ambient temperature  $T_A$ . The maximum allowable power dissipation is  $P_{DMAX} = (T_{JMAX} - T_A) / \theta_{JA}$  or the number given in Absolute Maximum Ratings, whichever is lower. For the PT5301, see power derating curves for additional information.

## 2 Watts Audio Power Amplifier

Note 10: Maximum power dissipation in the device ( $P_{DMAX}$ ) occurs at an output power level significantly below full output power.  $P_{DMAX}$  can be calculated using Equation 1 shown in the **Application Information** section. It may also be obtained from the power dissipation graphs.

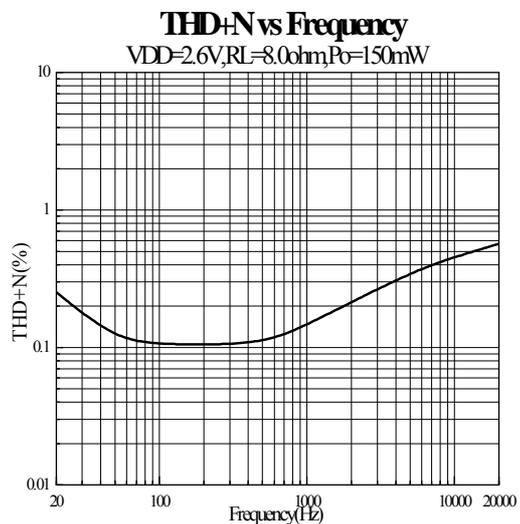
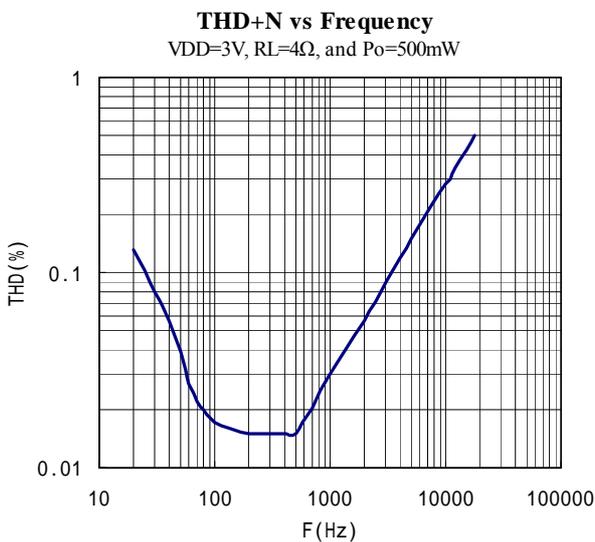
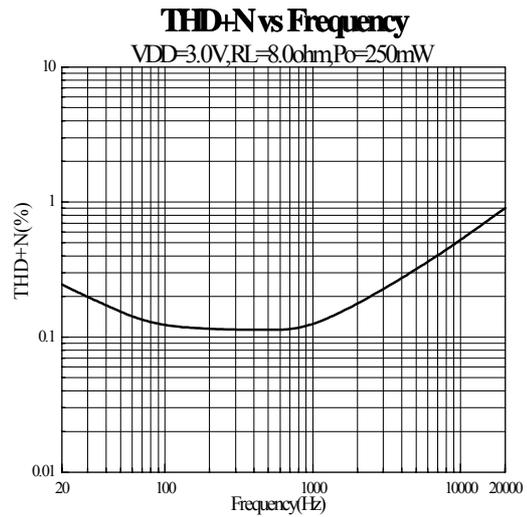
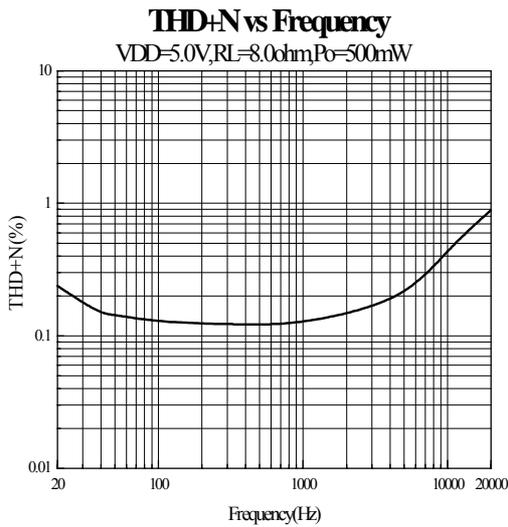
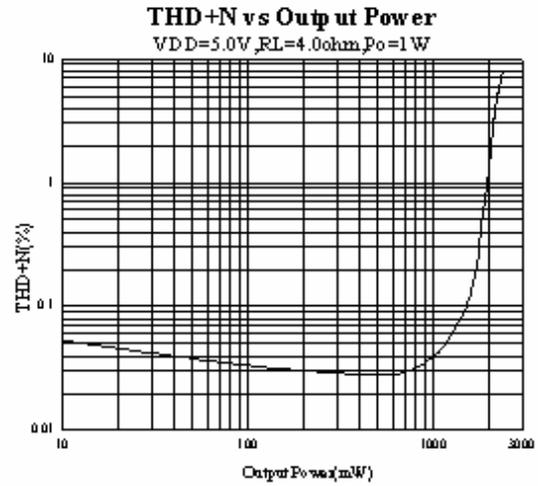
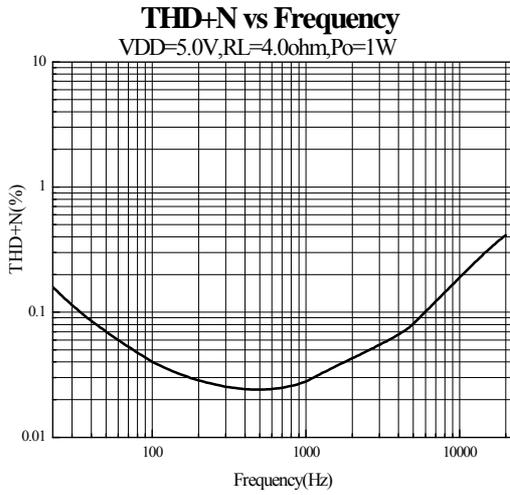
### ■ EXTERNAL COMPONENTS DESCRIPTION

See Figure. 1

Components		Functional Description
1	$R_i$	Inverting input resistor that sets the closed-loop gain together with $R_F$ . This resistor also performs as a high pass filter with $C_i$ at $f_C = 1/(2\pi R_i C_i)$
2	$C_i$	Input coupling capacitor which blocks the DC voltage at the input terminals. It also creates a high pass filter with $R_i$ at $f_C = 1/(2\pi R_i C_i)$ . For more details of how to determine the value of $C_i$ , look at the section of <b>Proper Selection of External Components</b> .
3	$R_F$	Feedback resistor which sets the closed-loop gain together with $R_i$ .
4	$C_S$	Supply bypass capacitor which provides supply voltage filtering. For more details of how to determine the value of $C_B$ , refer to the section of <b>Power Supply Bypassing</b> .
5	$C_B$	Bypass pin capacitor which provides half-supply filtering. For more details of how to determine the value of $C_B$ , look at the section of <b>Proper Selection of External Components</b> .

## 2 Watts Audio Power Amplifier

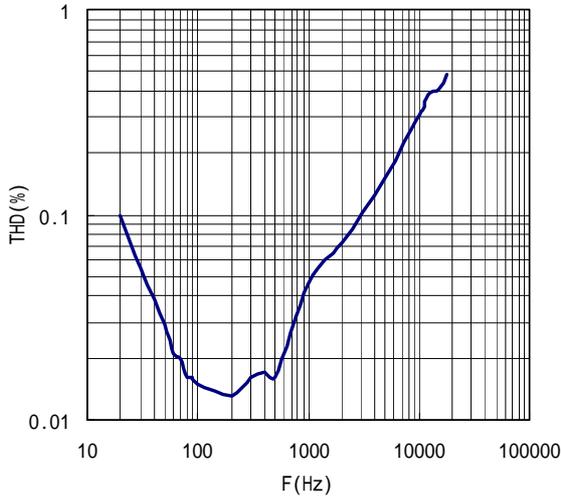
### ■ TYPICAL PERFORMANCE CHARACTERISTICS



## 2 Watts Audio Power Amplifier

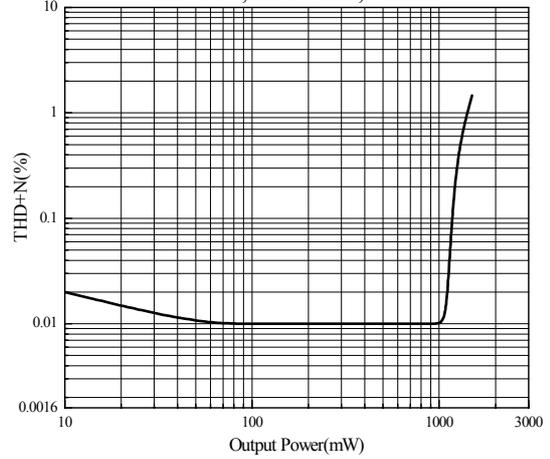
**THD+N vs Frequency**

VDD=2.6V, RL=4Ω, Po=150mW



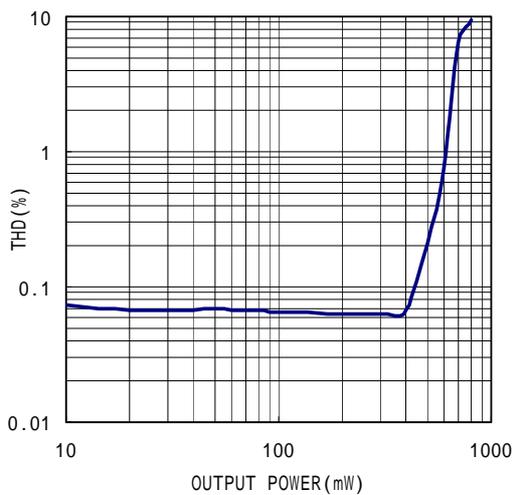
**THD+N vs Output Power**

VDD=5.0V, RL=8.0 ohm, f=1KHz



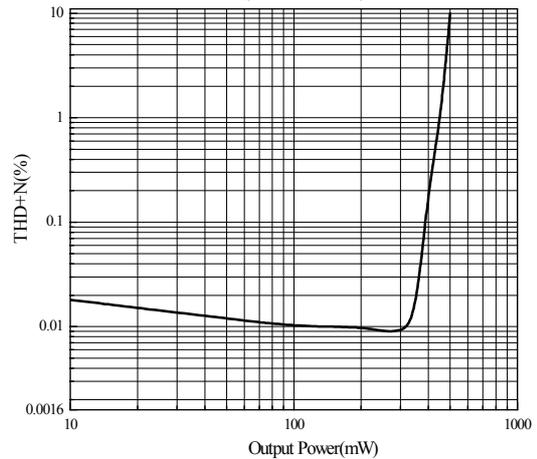
**THD+N vs Output Power**

Vdd=3V, RL=4Ω, and f=1kHz



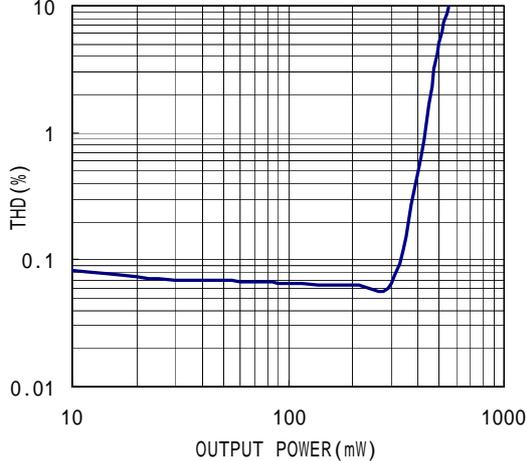
**THD+N vs Output Power**

VDD=3.0V, RL=8.0 ohm, f=1KHz



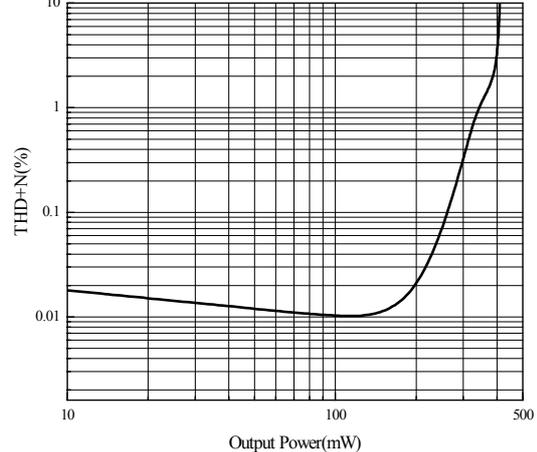
**THD+N vs Ouput Power**

Vdd=2.6V, RL=4Ω, f=1KHz

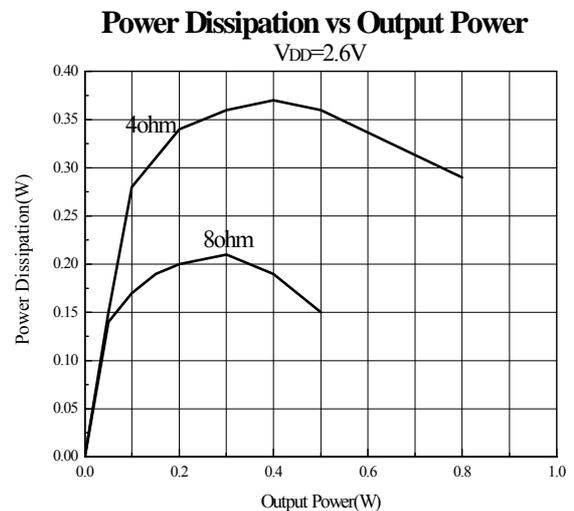
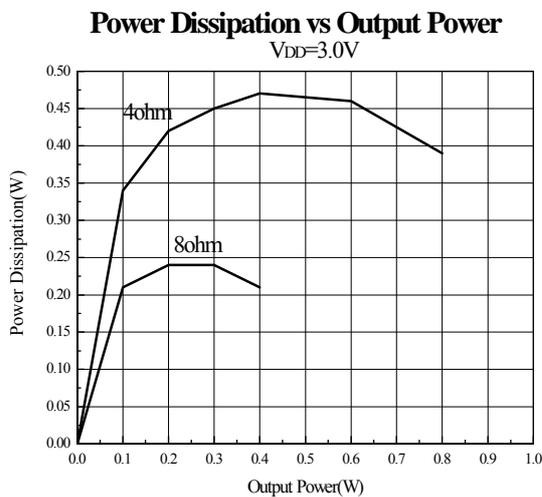
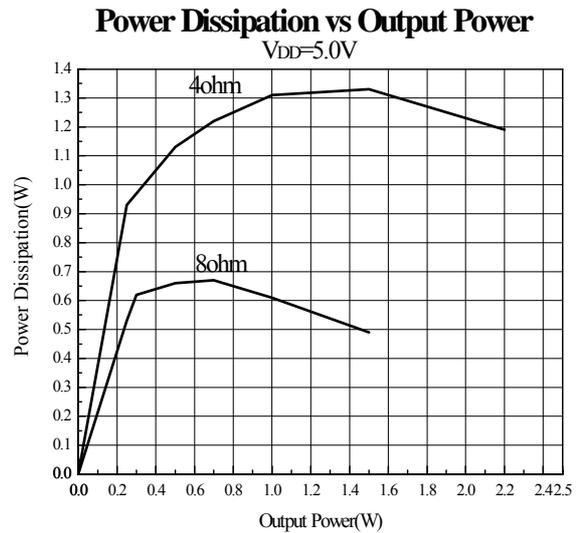
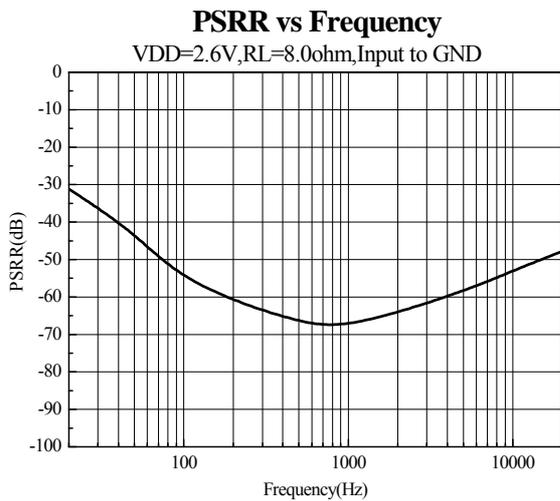
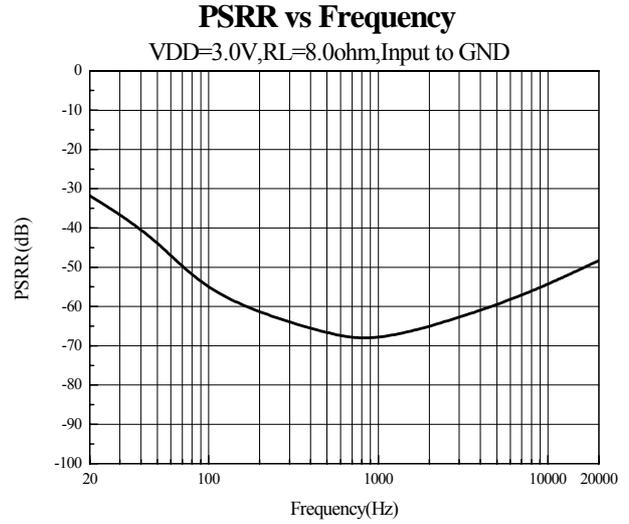
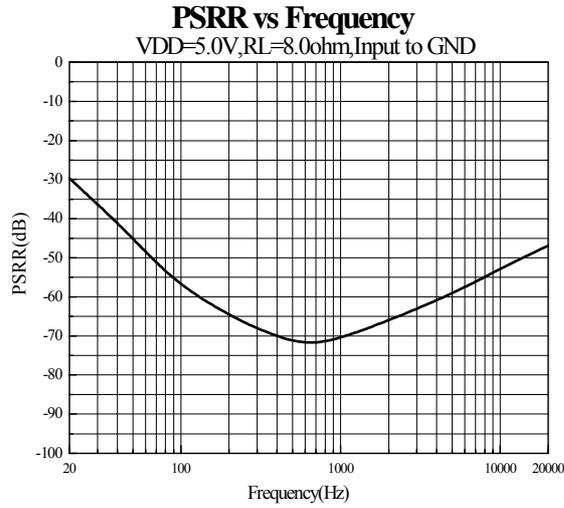


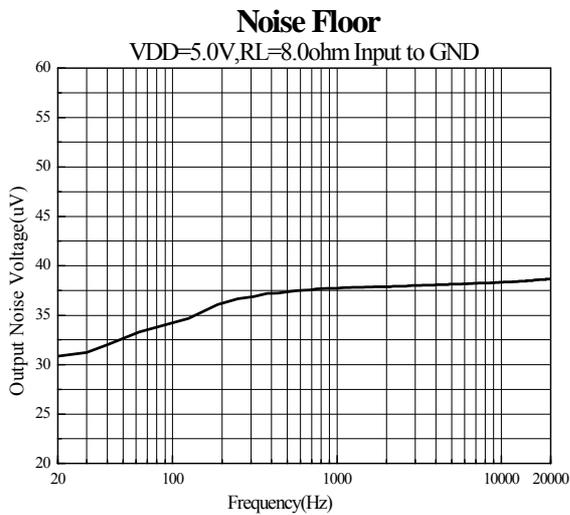
**THD+N vs Output Power**

VDD=2.6V, RL=8.0ohm, f=1KHz



## 2 Watts Audio Power Amplifier





### ■ APPLICATION INFORMATION

#### Bridge Configuration Explanation

As shown in *Figure 1*, the PT5301 has two internal operational amplifiers. The first amplifier's gain is externally configurable, while the second amplifier is internally fixed in a unity-gain, inverting configuration. The closed-loop gain of the first amplifier is set by selecting the ratio of  $R_F$  to  $R_i$  while the second amplifier's gain is fixed by the two internal  $20k\Omega$  resistors. *Figure 1* shows that the output of amplifier one serves as the input to amplifier two which results in both amplifiers producing signals identical in magnitude, but out of phase by  $180^\circ$ . Consequently, the differential gain for the IC is

$$A_{VD} = 2 * (R_F/R_i)$$

By driving the load differentially through outputs  $V_{o1}$  and  $V_{o2}$ , an amplifier configuration commonly referred to as "bridged mode" is established. Bridged mode operation is different from the classical single-ended amplifier configuration where one side of the load is connected to ground.

A bridge amplifier design has a few distinct advantages over the single-ended configuration, as it provides differential drive to the load, thus doubling output swing for a specified supply voltage. Four times the output power is possible as compared to a single-ended amplifier under the same conditions. This increase in attainable output power assumes that the amplifier is not current limited or clipped. In order to choose an amplifier's closed-loop gain without causing excessive clipping, please refer to the **Audio Power Amplifier Design** section.

A bridge configuration, such as the one used in PT5301, also creates a second advantage over single-ended amplifiers. Since the differential outputs,  $V_{o1}$  and  $V_{o2}$ , are biased at half-supply, no net DC voltage exists across the load. This eliminates the need for an output coupling capacitor which is required in a single supply, single-ended amplifier configuration. Without an output coupling capacitor, the half-supply bias across the load would result in both increased internal IC power dissipation and also possible loudspeaker damage.

#### Power Dissipation

Power dissipation is a major concern when designing a successful amplifier, whether the amplifier is bridged or single-ended. A direct consequence of the increased power delivered to the load by a bridge amplifier is an increase in internal power dissipation. Since the PT5301 has two operational amplifiers in one package, the maximum internal power dissipation is 4 times that of a single-ended amplifier. The maximum power dissipation for a given application can be derived from the power dissipation graphs or from Equation 1.

## 2 Watts Audio Power Amplifier

$$P_{\text{DMAX}} = 4 * (V_{\text{DD}})^2 / (2\pi R_L) \quad (1)$$

It is critical that the maximum junction temperature  $T_{\text{JMAX}}$  of 150°C is not exceeded.  $T_{\text{JMAX}}$  can be determined from the power derating curves by using  $P_{\text{DMAX}}$  and the PC board foil area. By adding copper foil, the thermal resistance of the application can be reduced from the free air value of  $\theta_{\text{JA}}$ , resulting in higher  $P_{\text{DMAX}}$  values without thermal shutdown protection circuitry being activated. Additional copper foil can be added to any of the leads connected to the PT5301. It is especially effective when connected to  $V_{\text{DD}}$ , GND, and the output pins. If  $T_{\text{JMAX}}$  still exceeds 150°C, then additional changes must be made. These changes can include reduced supply voltage, higher load impedance, or reduced ambient temperature. Internal power dissipation is a function of output power. Refer to the **Typical Performance Characteristics** curves for power dissipation information for different output powers and output loading.

### Power Supply Bypassing

As with any amplifier, proper supply bypassing is critical for low noise performance and high power supply rejection. The capacitor location on both the bypass and power supply pins should be as close to the device as possible. Typical applications employ a 5V regulator with 10 $\mu$ F tantalum or electrolytic capacitor and a ceramic bypass capacitor which aid in supply stability. This does not eliminate the need for bypassing the supply nodes of the PT5301. The selection of a bypass capacitor, especially  $C_{\text{B}}$ , is dependent upon PSRR requirements, click and pop performance (as explained in the section, **Proper Selection of External Components**), system cost, and size constraints.

### Shutdown Function

In order to reduce power consumption while not in use, the PT5301 contains shutdown circuitry that is used to turn off the amplifier's bias circuitry whenever the Shutdown pin is put at logical "low". While the device may be disabled with shutdown voltages in between ground and supply, the idle current may be greater than the typical value of 0.1 $\mu$ A. Therefore, the shutdown pin should be tied to a definite voltage to avoid unwanted state changes.

In many applications, a microcontroller or microprocessor output is used to control the shutdown circuitry, which provides a quick, smooth transition to shutdown. Another solution is to use a single-throw switch in conjunction with an external pull-up resistor (or pull-down, depending on shutdown high or low application). This scheme guarantees that the shutdown pin will not float, thus preventing unwanted state changes.

### Proper Selection of External Components

Proper selection of external components in applications using integrated power amplifiers is critical to optimize device and system performance. While the PT5301 is tolerant of external component combinations, consideration to component values must be used to maximize overall system quality.

The PT5301 is unity-gain stable which gives the designer maximum system flexibility. The PT5301 should be used in low gain configurations to minimize THD+N+N values, and maximize the signal to noise ratio. Low gain configurations require large input signals to obtain a given output power. Input signals equal to or greater than 1Vrms are available from sources such as audio codecs. Please refer to the section, **Audio Power Amplifier Design**, for a more complete explanation of proper gain selection.

Besides gain, one of the major considerations is the closed loop bandwidth of the amplifier. To a large extent, the bandwidth is dictated by the choice of external components shown in *Figure 1*. The input coupling capacitor,  $C_{\text{i}}$ , forms a first order high pass filter which limits low frequency response. This value should be chosen based on needed frequency response for a few distinct reasons.

Large input capacitors are both expensive and space hungry for portable designs. Clearly, a certain sized capacitor is needed to couple in low frequencies without severe attenuation. But in many cases the speakers used in portable systems, whether internal or external, have little ability to reproduce signals below 100Hz to 150Hz. Thus, using a large input capacitor may not increase actual system performance.

In addition to system cost and size, click and pop performance is effected by the size of the input coupling capacitor, i. A larger input coupling capacitor requires more charge to reach its quiescent DC voltage (nominally 1/2 VDD). This charge comes from the output via the feedback and is apt to create pops upon device enable. Thus, by minimizing the capacitor size based on necessary low frequency response, turn-on pops can be minimized.

## 2 Watts Audio Power Amplifier

Besides minimizing the input capacitor size, careful consideration should be paid to the bypass capacitor value. Bypass capacitor,  $C_B$ , is the most critical component to minimize turn-on pops since it determines how fast the PT5301 turns on. The slower the PT5301's outputs ramp to their quiescent DC voltage (nominally  $1/2 V_{DD}$ ), the smaller the turn-on pop. Choosing  $C_B$  equal to  $1.0\mu\text{F}$  along with a small value of  $C_i$  (in the range of  $0.1\mu\text{F}$  to  $0.39\mu\text{F}$ ), should produce a virtually pop & click free shutdown function. While the device will function properly, (no oscillations or motorboating), with  $C_B$  equal to  $0.1\mu\text{F}$ , the device will be much more susceptible to turn-on clicks and pops. Thus, a value of  $C_B$  equal to  $1.0\mu\text{F}$  is recommended in all but the most cost sensitive designs.

### Audio Power Amplifier Design

#### A 1W/8Ω Audio Amplifier

Given:

Power Output	1Wrms
Load Impedance	8Ω
Input Level	1Vrms
Input Impedance	20kΩ
Bandwidth	100Hz–20kHz ± 0.25dB

5V is a standard voltage in most applications, it is chosen for the supply rail. Extra supply voltage creates headroom that allows the PT5301 to reproduce peaks in excess of 1W without producing audible distortion. At this time, the designer must make sure that the power supply choice along with the output impedance does not violate the conditions explained in the **Power Dissipation** section.

Once the power dissipation equations have been addressed, the required differential gain can be determined from Equation 2.

$$A_{VD} = \sqrt{(P_o P_L)} / (V_{IN}) = V_{orms} / V_{irms} \quad (2)$$

$$R_F / R_i = A_{VD} / 2$$

From Equation 2, the minimum  $A_{VD}$  is 2.83; use  $A_{VD} = 3$ . Since the desired input impedance was  $20\text{k}\Omega$ , and with an  $A_{VD}$  impedance of 2, a ratio of 1.5:1 of  $R_F$  to  $R_i$  results in an allocation of  $R_i = 20\text{k}\Omega$  and  $R_F = 30\text{k}\Omega$ . The final design step is to address the bandwidth requirements which must be stated as a pair of -3dB frequency points. Five times away from a -3dB point is 0.17dB down from passband response which is better than the required  $\pm 0.25\text{dB}$  specified.

$$f_L = 100\text{Hz}/5 = 20\text{Hz}$$

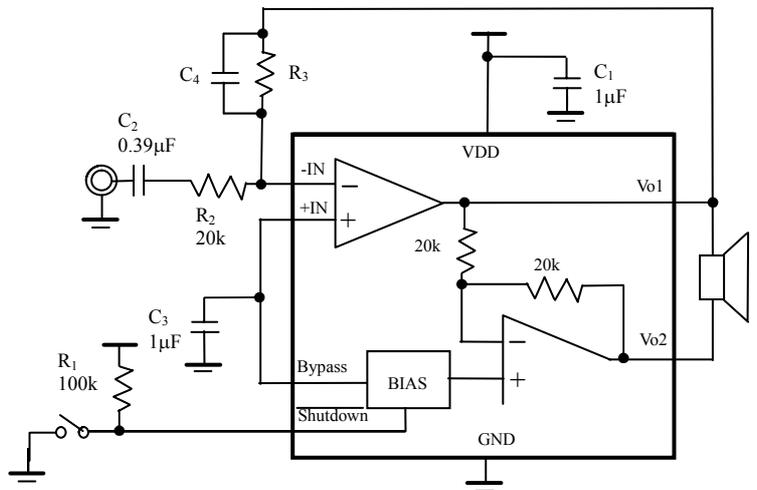
$$f_H = 20\text{kHz} \times 5 = 100\text{kHz}$$

As mentioned in the **External Components** section,  $R_i$  in conjunction with  $C_i$  create a high-pass filter.

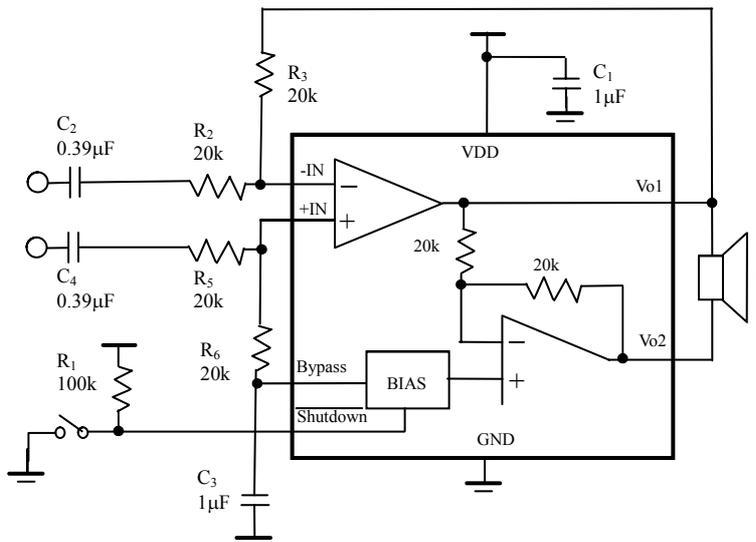
$$C_i \geq 1 / (2\pi \times 20\text{k}\Omega \times 20\text{Hz}) = 0.397\mu\text{F}; \quad \text{use } 0.39\mu\text{F}$$

The high frequency pole is determined by the product of the desired frequency pole,  $f_H$ , and the differential gain,  $A_{VD}$ . With an  $A_{VD} = 3$  and  $f_H = 100\text{kHz}$ , the resulting GBWP =  $300\text{kHz}$  which is much smaller than the PT5301 GBWP of  $2.0\text{MHz}$ . This figure displays that if a designer has a need to design an amplifier with a higher differential gain, the PT5301 can still be used without running into bandwidth limitations.

The PT5301 is unity gain stable and requires no external components besides gain-setting resistors, an input coupling capacitor, and proper supply bypass in the typical application. However, if a closed-loop gain is much greater than the normal setting value (i.e. gain = 10), a feedback capacitor ( $C_4$ ) may be required as shown in Figure 2. to limit the bandwidth of the amplifier. The feedback capacitor creates a low pass filter that eliminates the possible high frequency oscillations. Be aware that an possible inadequate combination of  $R_3$  and  $C_4$  will cause roll-off before  $20\text{kHz}$ . A typical combination is  $R_3 = 20\text{k}\Omega$  and  $C_4 = 25\text{pf}$ . Users could refer this combination when design a high gain audio amplifier.



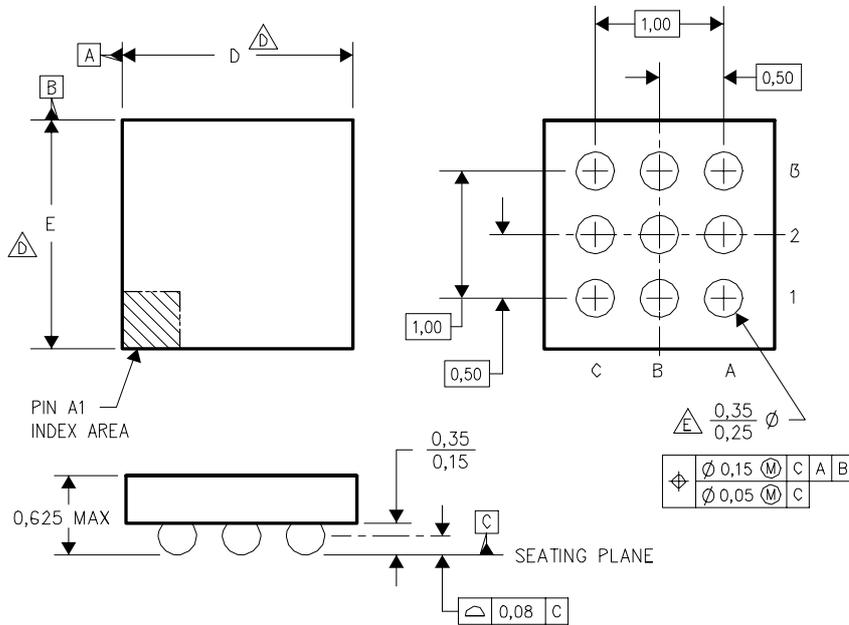
**Figure 2. High Gain Audio Amplifier**



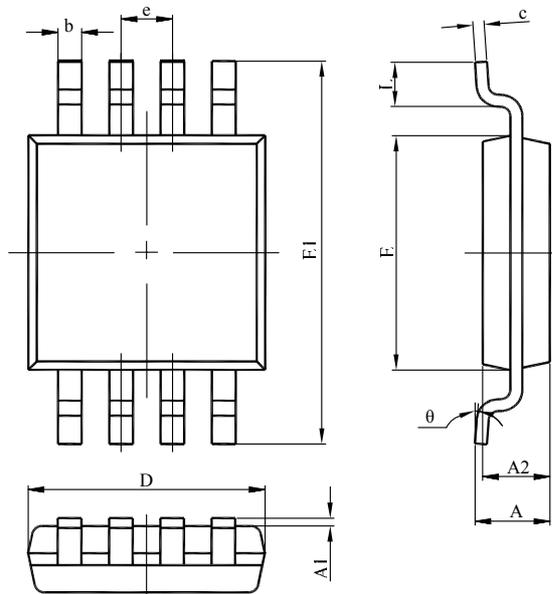
**Figure 3. Fully-differential Application for PT5301**

### ■ PACKAGE INFORMATION

#### SMD9 Package



#### MSOP8 Package



Symbol	Millimeters		Inches	
	Min	Max	Min	Min
A	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
e	0.650(BSC)		0.026(BSC)	
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
L	0.400	0.800	0.016	0.031
$\theta$	0°	6°	0°	6°