

## 1.2W Audio Power Amplifier with Active-Low Standby Mode

- Operating from  $V_{CC} = 2.2V$  to  $5.5V$
- 1.2W Output power @  $V_{CC}=5V$ , THD=1%,  $f=1kHz$ , with  $8\Omega$  Load
- Ultra-low consumption in standby mode (10nA)
- 62dB PSRR @ 217Hz in grounded mode
- Near-zero POP & CLICK
- Ultra-low distortion (0.1%)
- Unity gain stable
- Available in a 9-bump Flip-Chip, MiniSO8 and DFN8 packages

### Description

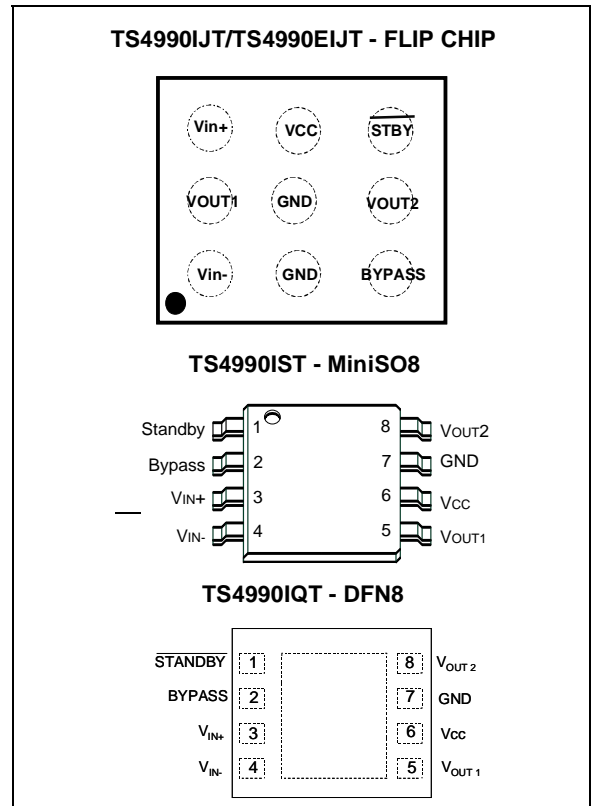
The TS4990 has been designed for demanding audio applications such as mobile phones and to minimize the number of external components.

This Audio Power Amplifier is capable of delivering 1.2W of continuous RMS Output Power into an  $8\Omega$  load @ 5V.

An externally-controlled standby mode reduces the supply current to less than 10nA. It also includes internal thermal shutdown protection.

The unity-gain stable amplifier can be configured by external gain setting resistors.

### Pin Connections (top view)



### Applications

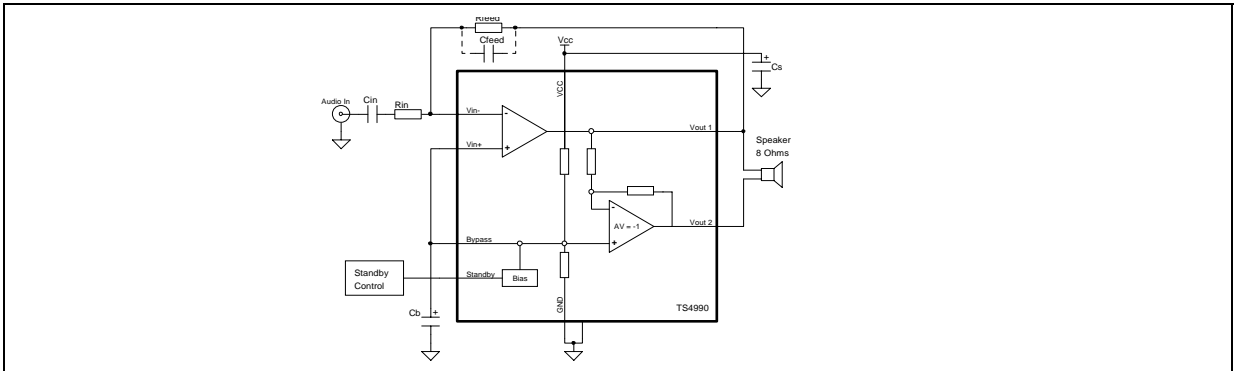
- Mobile phones (cellular / cordless)
- Laptop / notebook computers
- PDAs
- Portable audio devices

### Order Codes

Part Number	Temperature Range	Package	Packing	Marking
TS4990IJT TS4990EIJT <sup>1</sup>	-40, +85°C	Flip-Chip	Tape & Reel	A90
TS4990IST		mini SO	Tape & Reel	K990
TS4990IQT		DFN	Tape & Reel	K990
TS4990EKIJT	-40, +85°C	FC+Back coating	Tape & Reel	A90

1) Lead free Flip-Chip part number

Figure 1: Typical application schematic



1 Absolute Maximum Ratings

Table 1: Key parameters and their absolute maximum ratings

Symbol	Parameter	Value	Unit
V <sub>CC</sub>	Supply voltage <sup>1</sup>	6	V
V <sub>i</sub>	Input Voltage <sup>2</sup>	G <sub>ND</sub> to V <sub>CC</sub>	V
T <sub>oper</sub>	Operating Free Air Temperature Range	-40 to + 85	°C
T <sub>stg</sub>	Storage Temperature	-65 to +150	°C
T <sub>j</sub>	Maximum Junction Temperature	150	°C
R <sub>thja</sub>	Thermal Resistance Junction to Ambient Flip-Chip <sup>3</sup> MiniSO8 DFN8	250 215 120	°C/W
P <sub>d</sub>	Power Dissipation	Internally Limited	
ESD	Human Body Model	2	kV
ESD	Machine Model	200	V
	Latch-up Immunity	200mA	
	Lead Temperature (soldering, 10sec)	250	°C
	Lead Temperature (soldering, 10sec) for Lead-Free version	260	

- 1) All voltage values are measured with respect to the ground pin.
- 2) The magnitude of input signal must never exceed V<sub>CC</sub> + 0.3V / G<sub>ND</sub> - 0.3V
- 3) Device is protected in case of over temperature by a thermal shutdown active @ 150°C.

Table 2: Operating Conditions

Symbol	Parameter	Value	Unit
V <sub>CC</sub>	Supply Voltage	2.2 to 5.5	V
V <sub>ICM</sub>	Common Mode Input Voltage Range	1.2V to V <sub>CC</sub>	V
V <sub>STB</sub>	Standby Voltage Input: Device ON Device OFF	1.35 ≤ V <sub>STB</sub> ≤ V <sub>CC</sub> GND ≤ V <sub>STB</sub> ≤ 0.4	V
R <sub>L</sub>	Load Resistor	≥ 4	Ω
R <sub>OUT-GND</sub>	Resistor Output to GND (V <sub>STB</sub> = GND)	≥ 1	MΩ
T <sub>SD</sub>	Thermal Shutdown Temperature	150	°C
R <sub>THJA</sub>	Thermal Resistance Junction to Ambient Flip-Chip <sup>1</sup> MiniSO8 DFN8 <sup>2</sup>	100 190 40	°C/W

- 1) This thermal resistance is reached with a 100mm<sup>2</sup> copper heatsink surface.
- 2) When mounted on a 4-layer PCB.

## 2 Electrical Characteristics

**Table 3:Electrical characteristics when  $V_{CC} = +5V$ ,  $GND = 0V$ ,  $T_{amb} = 25^{\circ}C$  (unless otherwise specified)**

Symbol	Parameter	Min.	Typ.	Max.	Unit
$I_{CC}$	Supply Current No input signal, no load		3.7	6	mA
$I_{STANDBY}$	Standby Current <sup>1</sup> No input signal, $V_{stdby} = G_{ND}$ , $R_L = 8\Omega$		10	1000	nA
$V_{OO}$	Output Offset Voltage No input signal, $R_L = 8\Omega$		1	10	mV
$P_o$	Output Power THD = 1% Max, $F = 1kHz$ , $R_L = 8\Omega$	0.9	1.2		W
THD + N	Total Harmonic Distortion + Noise $P_o = 1W_{rms}$ , $A_v = 2$ , $20Hz \leq F \leq 20kHz$ , $R_L = 8\Omega$		0.2		%
PSRR	Power Supply Rejection Ratio <sup>2</sup> $R_L = 8\Omega$ , $A_v = 2$ , $V_{ripple} = 200mV_{pp}$ , Input Grounded $F = 217Hz$ $F = 1kHz$	55 55	62 64		dB
$T_{WU}$	Wake-Up Time ( $C_b = 1\mu F$ )		90	130	ms
$T_{STDB}$	Standby Time ( $C_b = 1\mu F$ )		10		$\mu s$
$V_{STDBH}$	Standby Voltage Level High			1.3	V
$V_{STDBL}$	Standby Voltage Level Low			0.4	V
$\Phi_M$	Phase Margin at Unity Gain $R_L = 8\Omega$ , $C_L = 500pF$		65		Degrees
GM	Gain Margin $R_L = 8\Omega$ , $C_L = 500pF$		15		dB
GBP	Gain Bandwidth Product $R_L = 8\Omega$		1.5		MHz

1) Standby mode is activated when  $V_{stdby}$  is tied to  $Gnd$

2) All PSRR data limits are guaranteed by production sampling tests  
Dynamic measurements -  $20 \cdot \log(\text{rms}(V_{out})/\text{rms}(V_{ripple}))$ .  $V_{ripple}$  is the sinusoidal signal superimposed upon  $V_{cc}$ .

**Table 4:Electrical Characteristics when  $V_{CC} = +3.3V$ ,  $GND = 0V$ ,  $T_{amb} = 25^{\circ}C$  (unless otherwise specified)**

Symbol	Parameter	Min.	Typ.	Max.	Unit
$I_{CC}$	Supply Current No input signal, no load		3.3	6	mA
$I_{STANDBY}$	Standby Current <sup>1</sup> No input signal, $V_{stdby} = G_{ND}$ , $R_L = 8\Omega$		10	1000	nA
$V_{OO}$	Output Offset Voltage No input signal, $R_L = 8\Omega$		1	10	mV
$P_o$	Output Power THD = 1% Max, $F = 1kHz$ , $R_L = 8\Omega$	375	500		mW
THD + N	Total Harmonic Distortion + Noise $P_o = 400mWrms$ , $A_v = 2$ , $20Hz \leq F \leq 20kHz$ , $R_L = 8\Omega$		0.1		%
PSRR	Power Supply Rejection Ratio <sup>2</sup> $R_L = 8\Omega$ , $A_v = 2$ , $V_{ripple} = 200mV_{pp}$ , Input Grounded $F = 217Hz$ $F = 1kHz$	55 55	61 63		dB
$T_{WU}$	Wake-Up Time ( $C_b = 1\mu F$ )		110	140	ms
$T_{STDB}$	Standby Time ( $C_b = 1\mu F$ )		10		$\mu s$
$V_{STDBH}$	Standby Voltage Level High			1.2	V
$V_{STDBL}$	Standby Voltage Level Low			0.4	V
$\Phi_M$	Phase Margin at Unity Gain $R_L = 8\Omega$ , $C_L = 500pF$		65		Degrees
GM	Gain Margin $R_L = 8\Omega$ , $C_L = 500pF$		15		dB
GBP	Gain Bandwidth Product $R_L = 8\Omega$		1.5		MHz

1) Standby mode is activated when  $V_{stdby}$  is tied to  $Gnd$

2) All PSRR data limits are guaranteed by production sampling tests  
Dynamic measurements -  $20 \cdot \log(\text{rms}(V_{out})/\text{rms}(V_{ripple}))$ .  $V_{ripple}$  is the sinusoidal signal superimposed upon  $V_{cc}$ .

**Table 5:Electrical characteristics when  $V_{CC} = 2.6V$ ,  $GND = 0V$ ,  $T_{amb} = 25^{\circ}C$  (unless otherwise specified)**

Symbol	Parameter	Min.	Typ.	Max.	Unit
$I_{CC}$	Supply Current No input signal, no load		3.1	6	mA
$I_{STANDBY}$	Standby Current <sup>1</sup> No input signal, $V_{stdby} = G_{ND}$ , $R_L = 8\Omega$		10	1000	nA
$V_{OO}$	Output Offset Voltage No input signal, $R_L = 8\Omega$		1	10	mV
$P_o$	Output Power THD = 1% Max, $F = 1kHz$ , $R_L = 8\Omega$	220	300		mW
THD + N	Total Harmonic Distortion + Noise $P_o = 200mWrms$ , $A_v = 2$ , $20Hz \leq F \leq 20kHz$ , $R_L = 8\Omega$		0.1		%
PSRR	Power Supply Rejection Ratio <sup>2</sup> $R_L = 8\Omega$ , $A_v = 2$ , $V_{ripple} = 200mVpp$ , Input Grounded $F = 217Hz$ $F = 1kHz$	55 55	60 62		dB
$T_{WU}$	Wake-Up Time ( $C_b = 1\mu F$ )		125	150	ms
$T_{STDB}$	Standby Time ( $C_b = 1\mu F$ )		10		$\mu s$
$V_{STDBH}$	Standby Voltage Level High			1.2	V
$V_{STDBL}$	Standby Voltage Level Low			0.4	V
$\Phi_M$	Phase Margin at Unity Gain $R_L = 8\Omega$ , $C_L = 500pF$		65		Degrees
GM	Gain Margin $R_L = 8\Omega$ , $C_L = 500pF$		15		dB
GBP	Gain Bandwidth Product $R_L = 8\Omega$		1.5		MHz

1) Standby mode is activated when  $V_{stdby}$  is tied to  $Gnd$

2) All PSRR data limits are guaranteed by production sampling tests  
Dynamic measurements -  $20 \cdot \log(rms(V_{out})/rms(V_{ripple}))$ .  $V_{ripple}$  is the sinusoidal signal superimposed upon  $V_{cc}$ .

**Table 6:Components description**

Components	Functional Description
$R_{in}$	Inverting input resistor which sets the closed loop gain in conjunction with $R_{feed}$ . This resistor also forms a high pass filter with $C_{in}$ ( $f_c = 1 / (2 \times \pi \times R_{in} \times C_{in})$ )
$C_{in}$	Input coupling capacitor which blocks the DC voltage at the amplifier input terminal.
$R_{feed}$	Feed back resistor which sets the closed loop gain in conjunction with $R_{in}$ .
$C_s$	Supply Bypass capacitor which provides power supply filtering.
$C_b$	Bypass pin capacitor which provides half supply filtering.
$C_{feed}$	Low pass filter capacitor allowing to cut the high frequency (low pass filter cut-off frequency $1 / (2 \times \pi \times R_{feed} \times C_{feed})$ )
$A_v$	Closed loop gain in BTL configuration = $2 \times (R_{feed} / R_{in})$
Exposed Pad	DFN8 Exposed pad is electrically connected to pin7. See page 24 for more information.

Figure 2: Open Loop Frequency Response

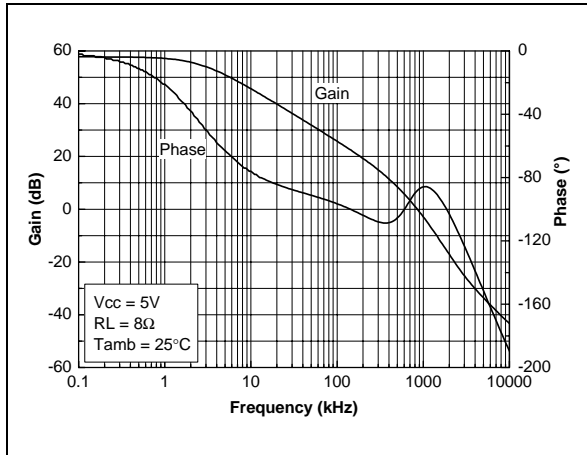


Figure 5: Open Loop Frequency Response

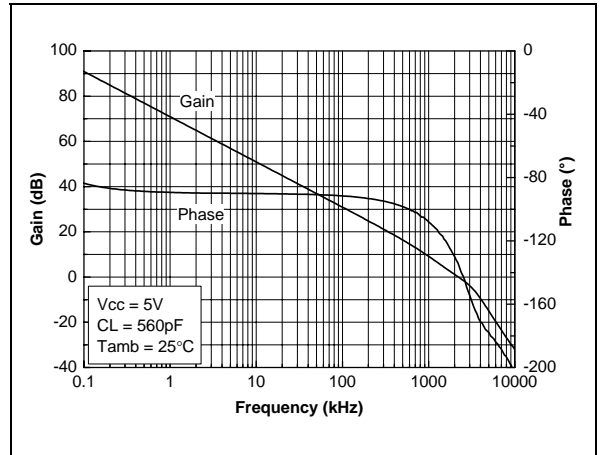


Figure 3: Open Loop Frequency Response

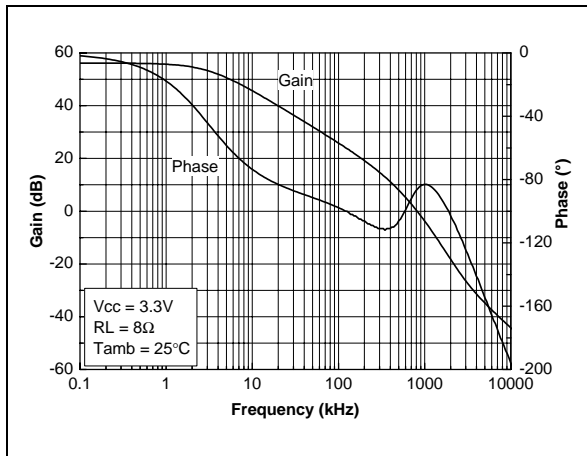


Figure 6: Open Loop Frequency Response

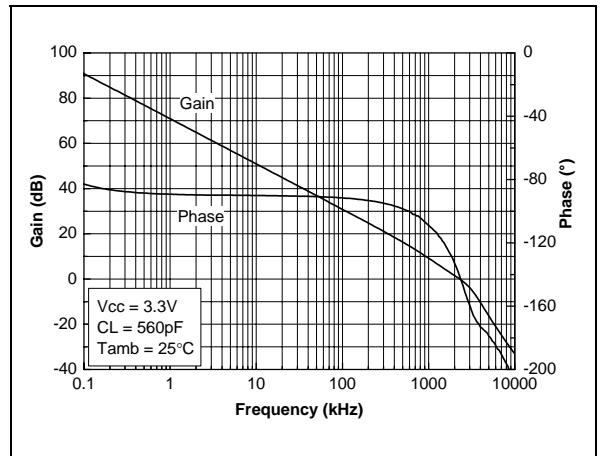


Figure 4: Open Loop Frequency Response

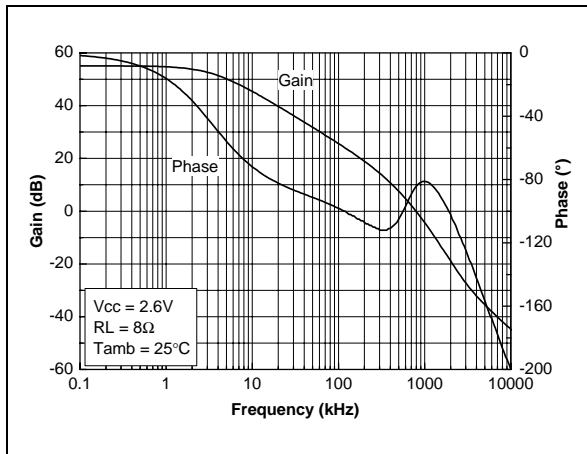
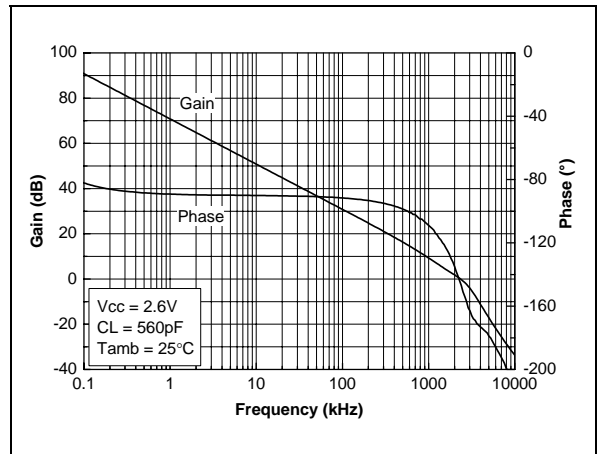
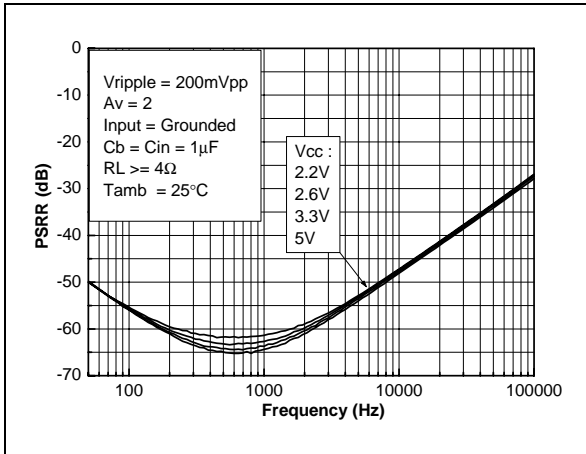


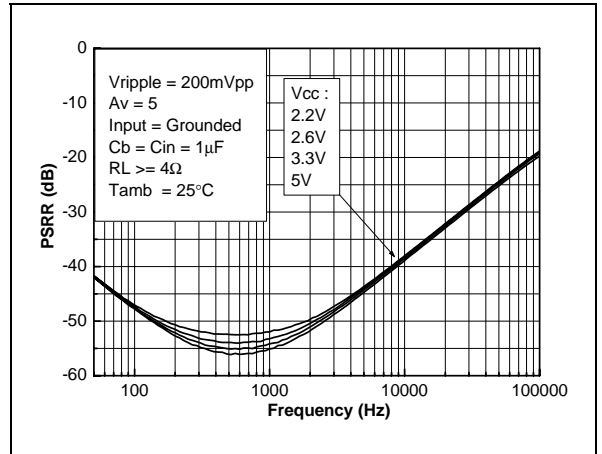
Figure 7: Open Loop Frequency Response



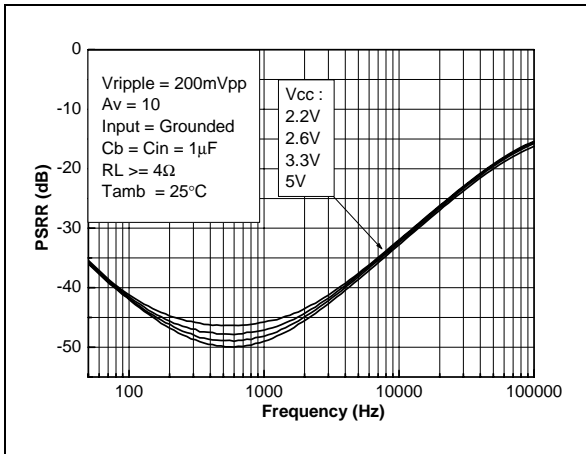
**Figure 8: Power Supply Rejection Ratio (PSRR) vs Power supply**



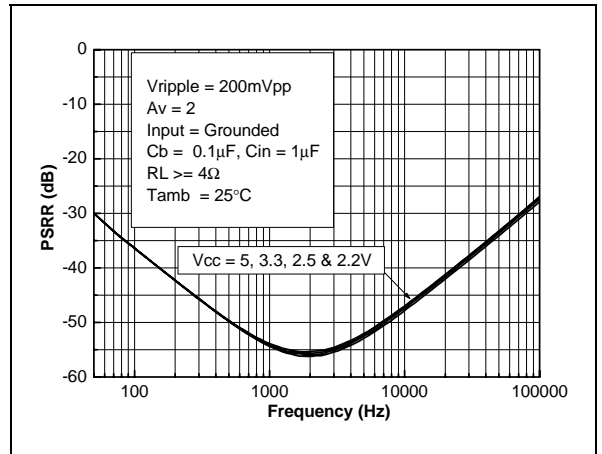
**Figure 11: Power Supply Rejection Ratio (PSRR) vs Power supply**



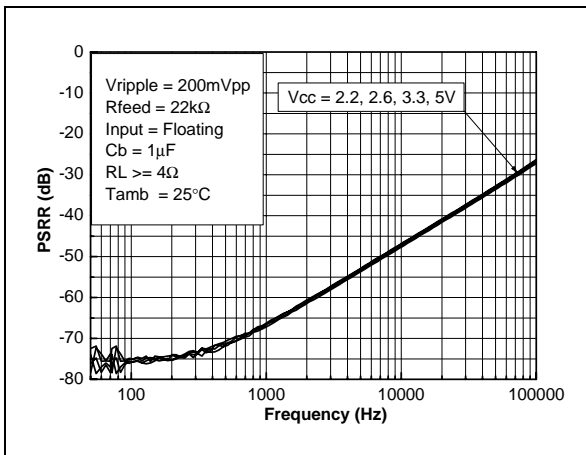
**Figure 9: Power Supply Rejection Ratio (PSRR) vs Power supply**



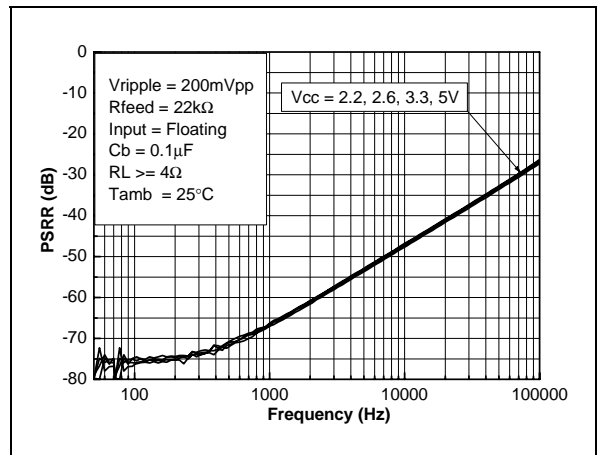
**Figure 12: Power Supply Rejection Ratio (PSRR) vs Power supply**



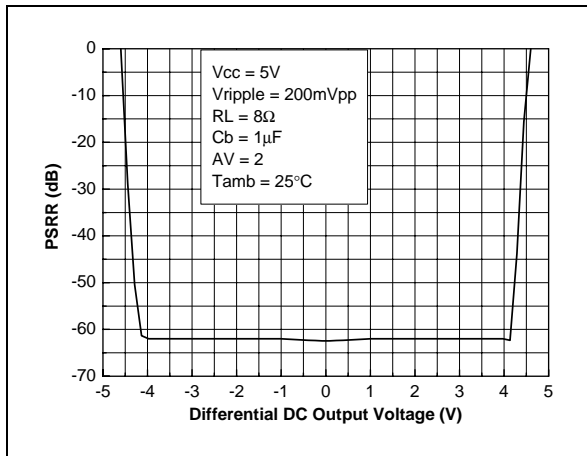
**Figure 10: Power Supply Rejection Ratio (PSRR) vs Power supply**



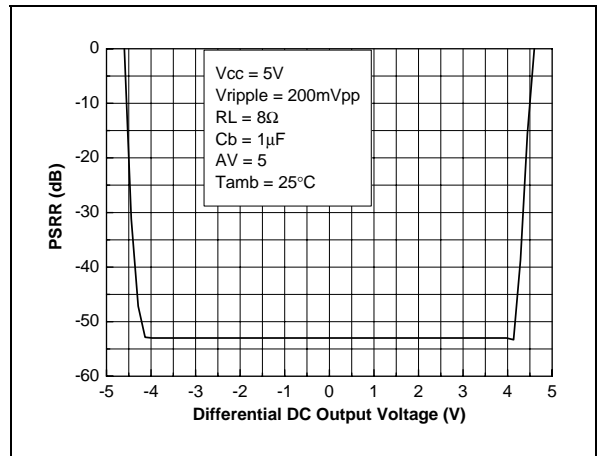
**Figure 13: Power Supply Rejection Ratio (PSRR) vs Power supply**



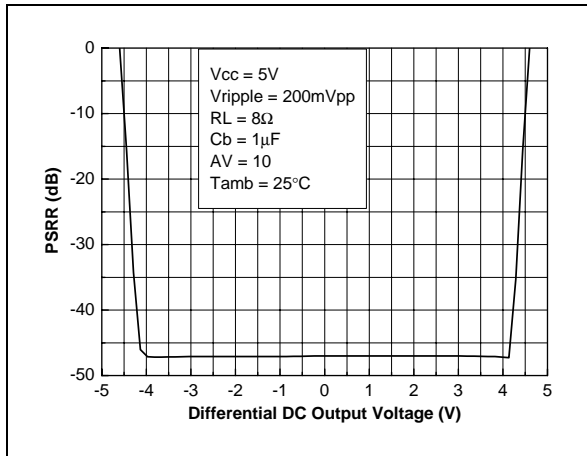
**Figure 14: Power Supply Rejection Ratio (PSRR) vs DC Output Voltage**



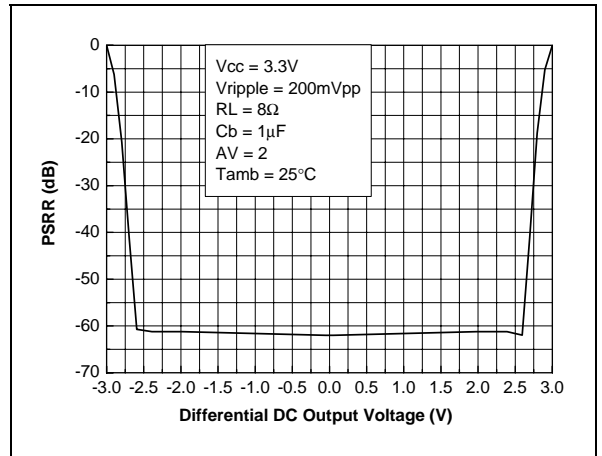
**Figure 17: Power Supply Rejection Ratio (PSRR) vs DC Output Voltage**



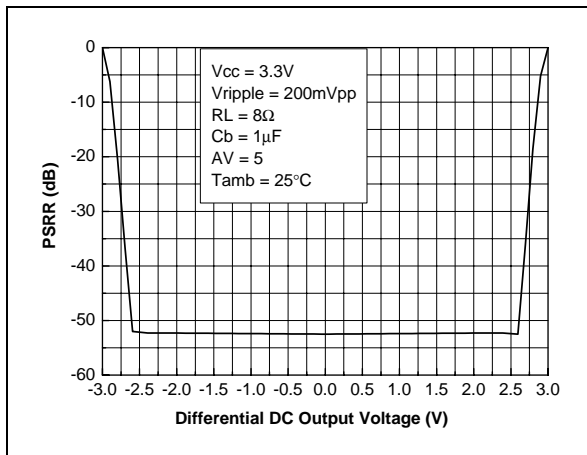
**Figure 15: Power Supply Rejection Ratio (PSRR) vs DC Output Voltage**



**Figure 18: Power Supply Rejection Ratio (PSRR) vs DC Output Voltage**



**Figure 16: Power Supply Rejection Ratio (PSRR) vs DC Output Voltage**



**Figure 19: Power Supply Rejection Ratio (PSRR) vs DC Output Voltage**

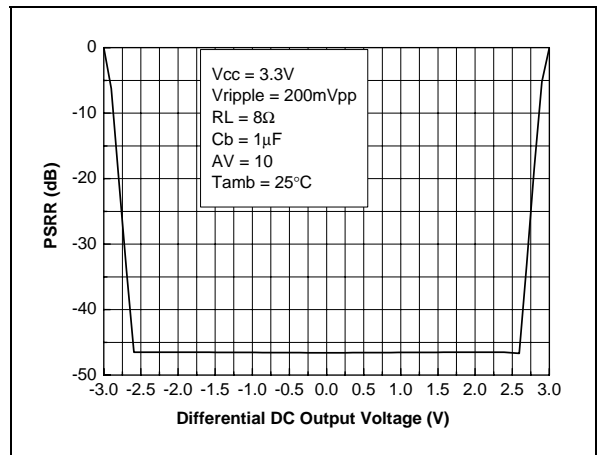




Figure 20: Power Supply Rejection Ratio (PSRR) vs DC Output Voltage

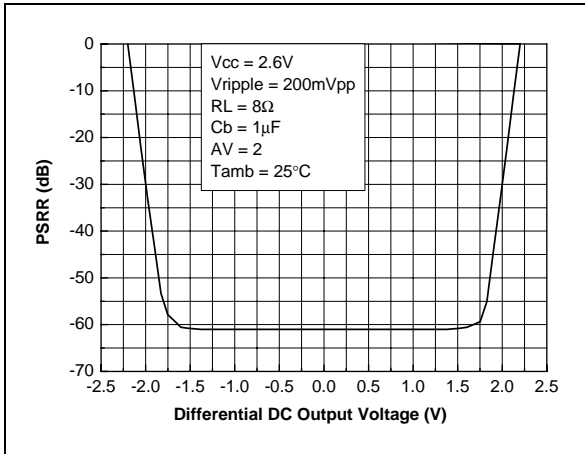


Figure 23: Power Supply Rejection Ratio (PSRR) vs DC Output Voltage

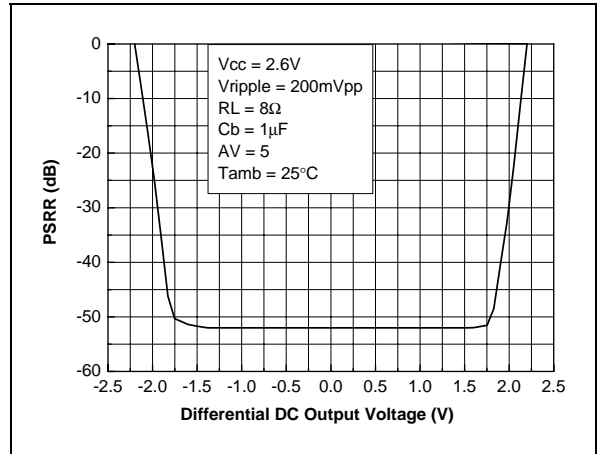


Figure 21: Power Supply Rejection Ratio (PSRR) vs DC Output Voltage

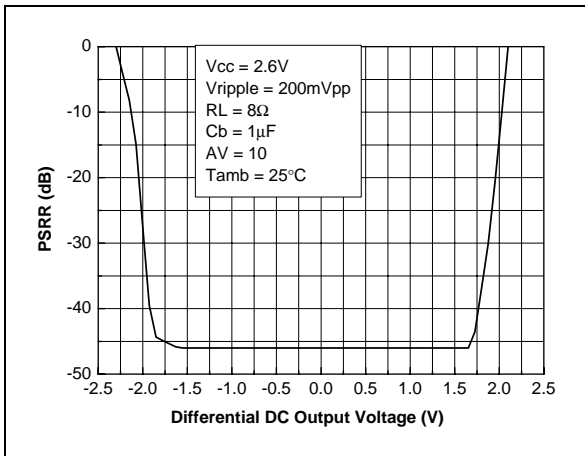


Figure 24: Power Supply Rejection Ratio (PSRR) at F=217Hz vs Bypass Capacitor

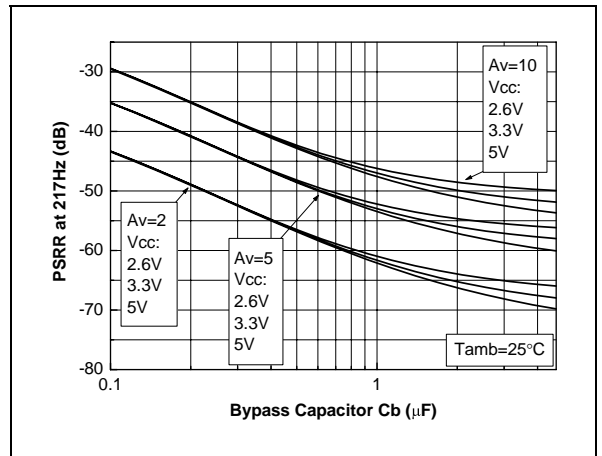


Figure 22: Output Power vs Power Supply Voltage

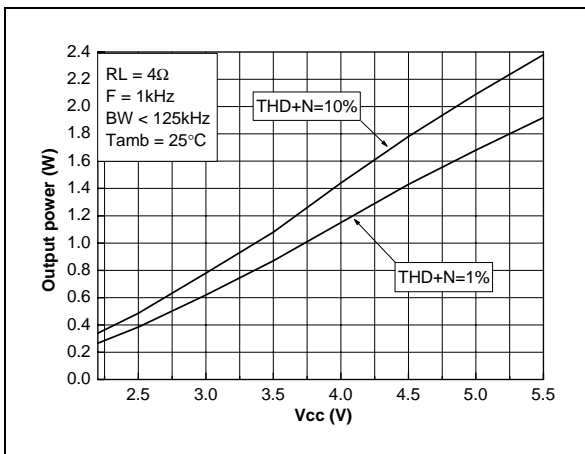


Figure 25: Output Power vs Power Supply Voltage

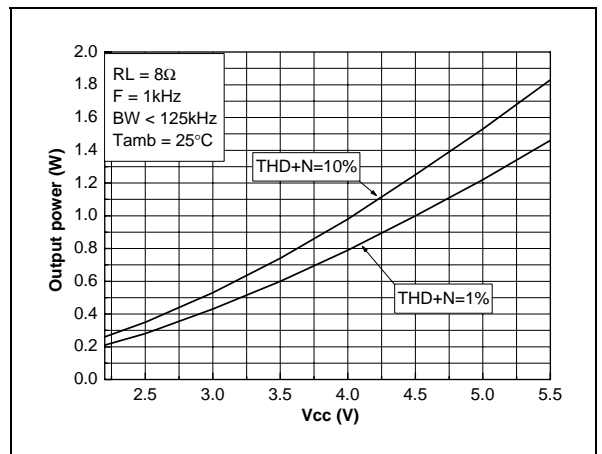


Figure 26: Output Power vs Power Supply Voltage

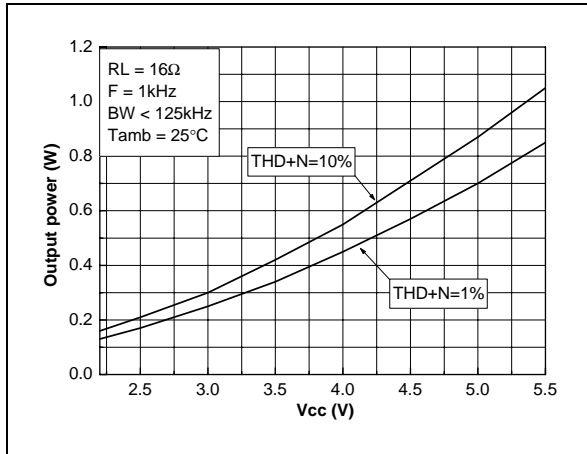


Figure 29: Output Power vs Power Supply Voltage

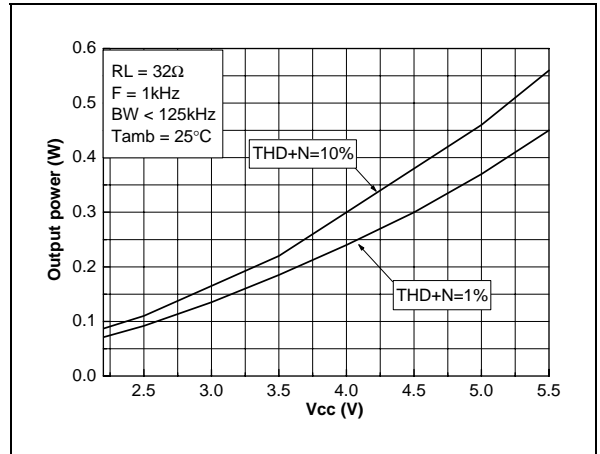


Figure 27: Output Power vs Load Resistor

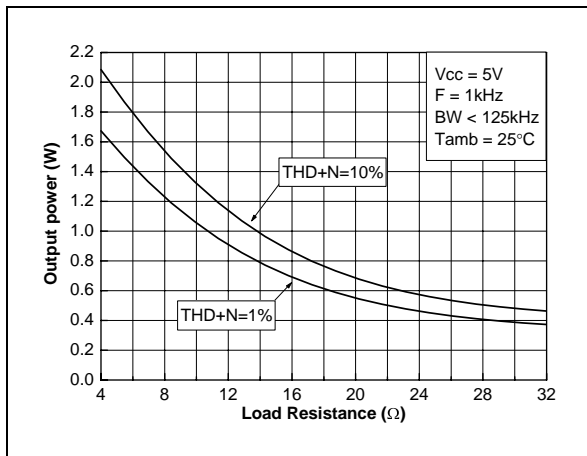


Figure 30: Output Power vs Load Resistor

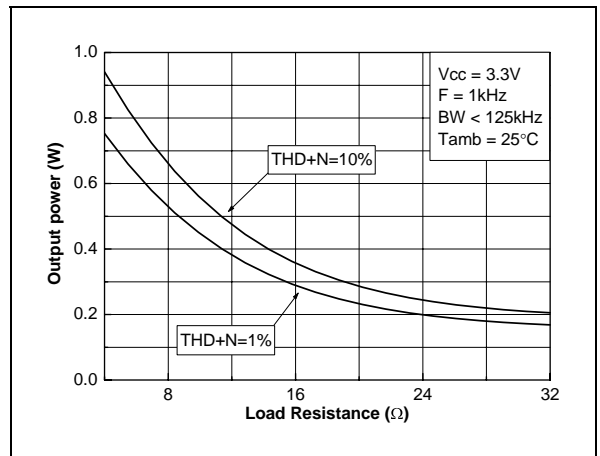


Figure 28: Output Power vs Load Resistor

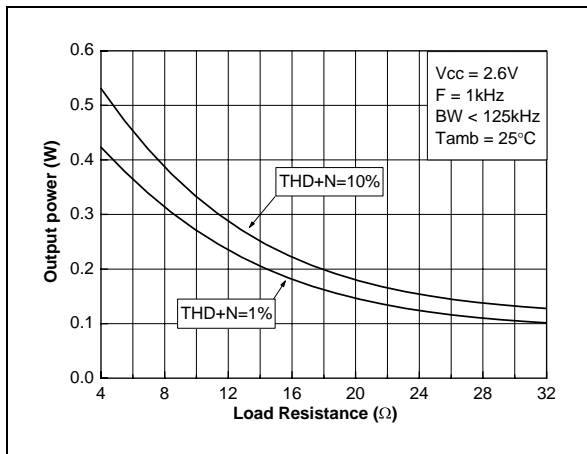


Figure 31: Power Dissipation vs Pout

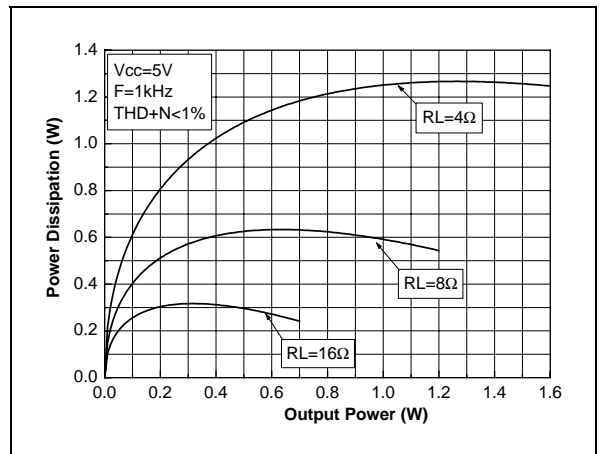


Figure 32: Power Dissipation vs Pout

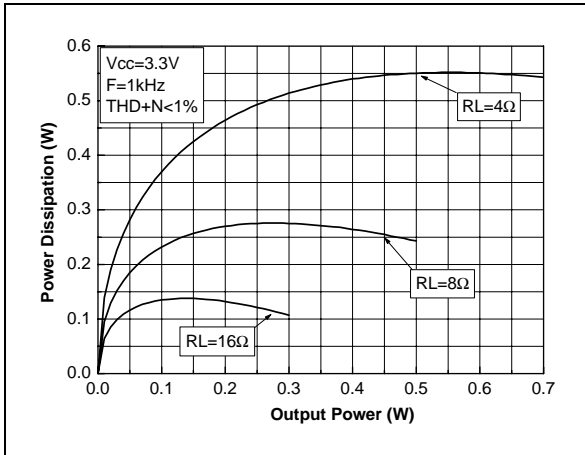


Figure 35: Power Dissipation vs Pout

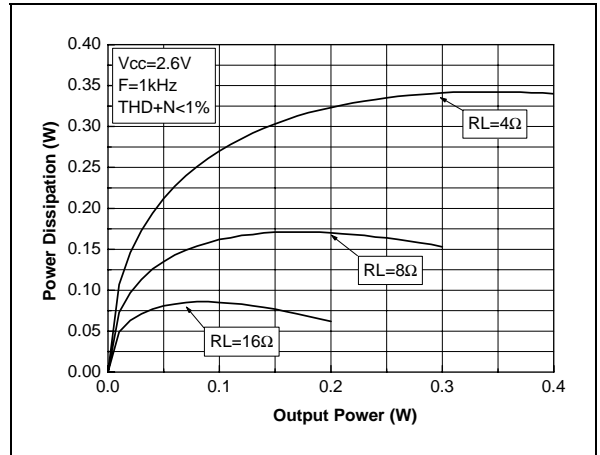


Figure 33: Power Derating Curves

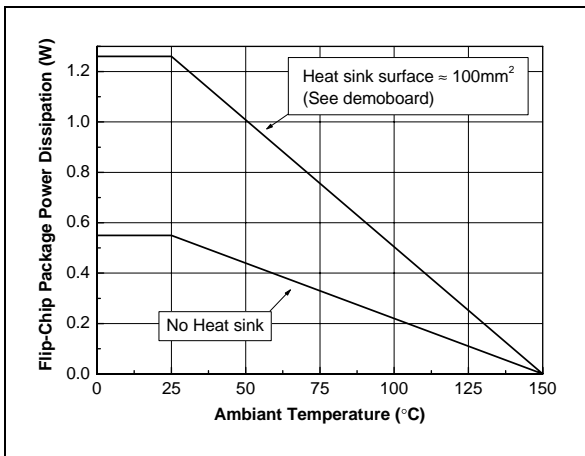


Figure 36: Clipping Voltage vs Power Supply Voltage and Load Resistor

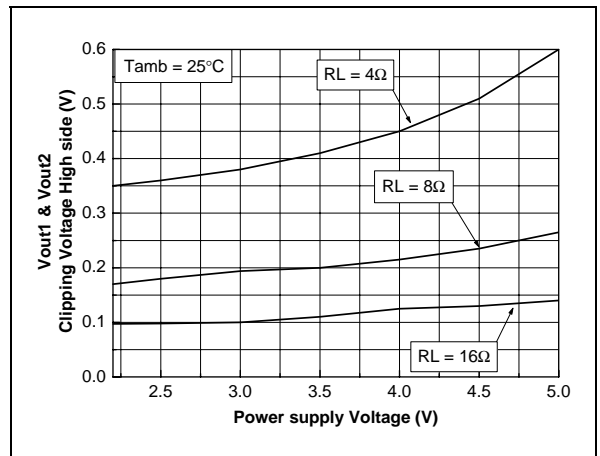


Figure 34: Clipping Voltage vs Power Supply Voltage and Load Resistor

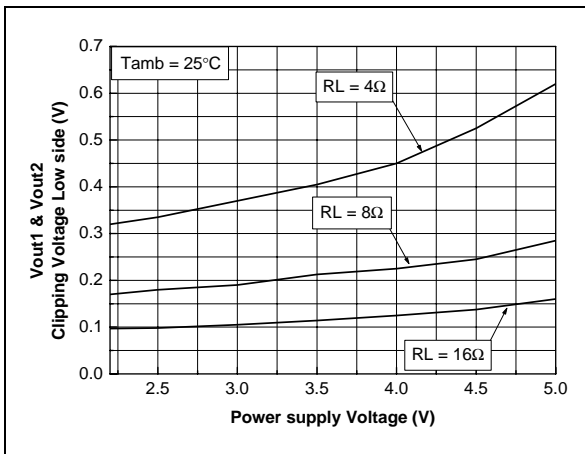


Figure 37: Current Consumption vs Power Supply Voltage

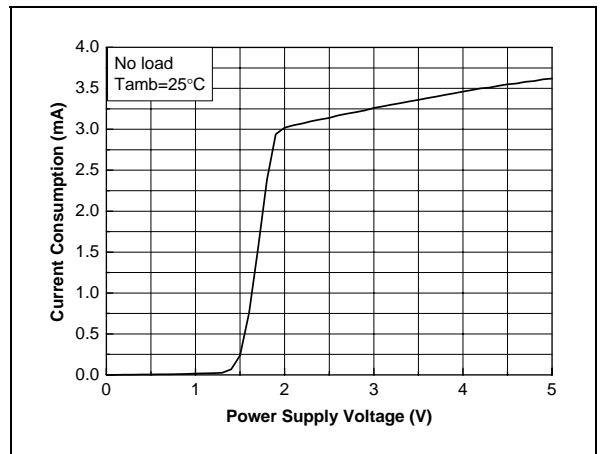


Figure 38: Current Consumption vs Standby Voltage @ Vcc = 5V

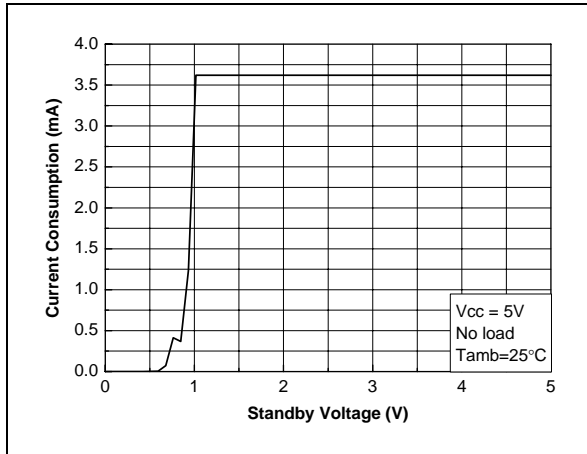


Figure 41: Current Consumption vs Standby Voltage @ Vcc = 3.3V

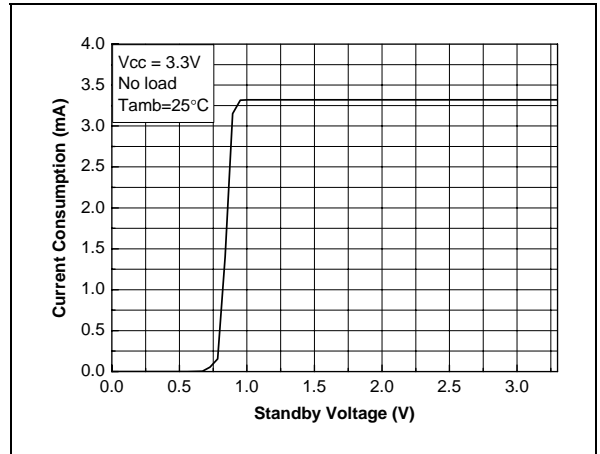


Figure 39: Current Consumption vs Standby Voltage @ Vcc = 2.6V

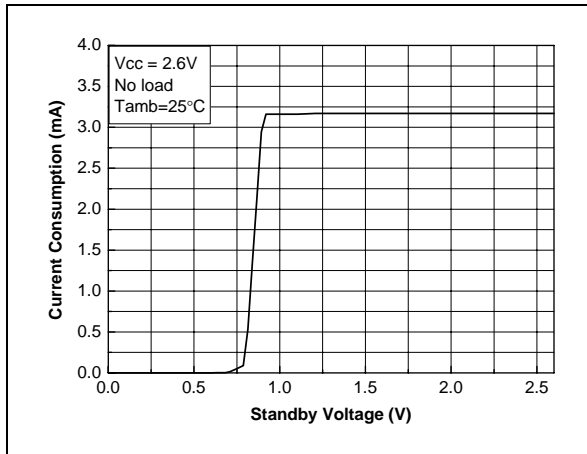


Figure 42: Current Consumption vs Standby Voltage @ Vcc = 2.2V

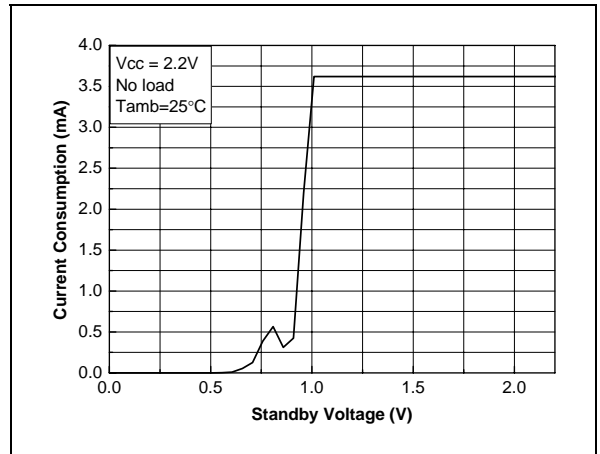


Figure 40: THD + N vs Output Power

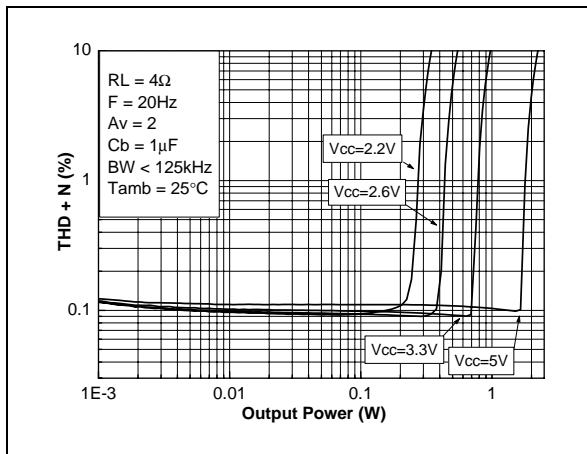


Figure 43: THD + N vs Output Power

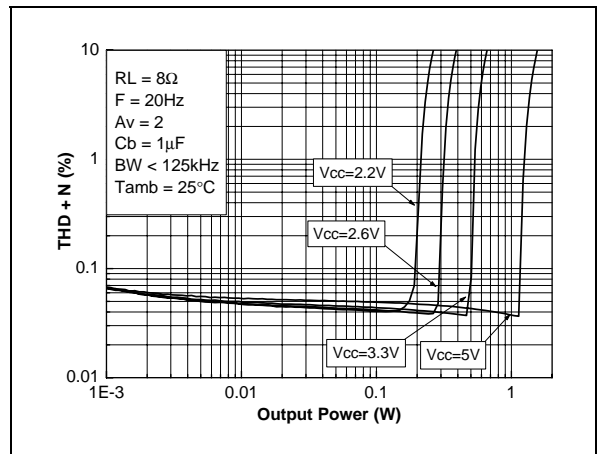


Figure 44: THD + N vs Output Power

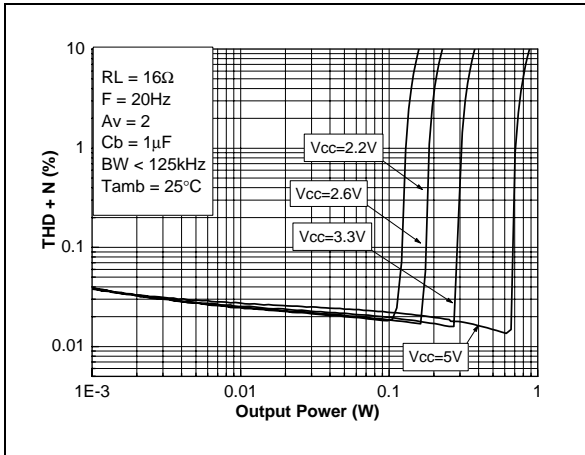


Figure 47: THD + N vs Output Power

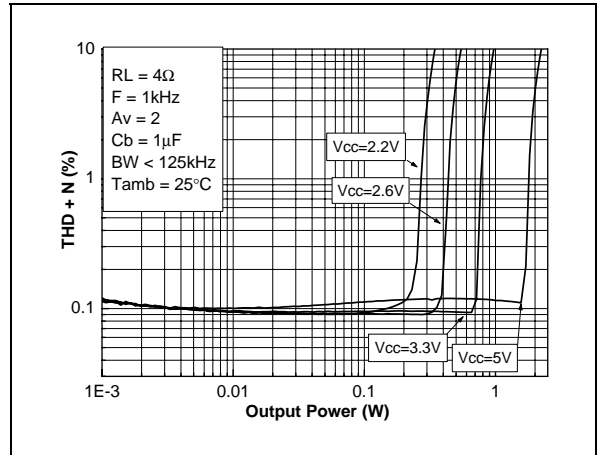


Figure 45: THD + N vs Output Power

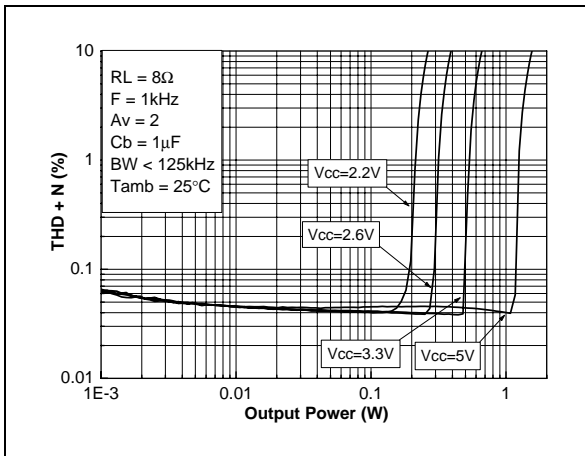


Figure 48: THD + N vs Output Power

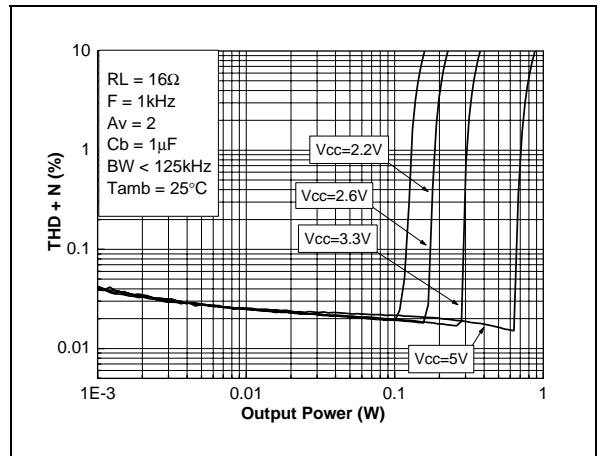


Figure 46: THD + N vs Output Power

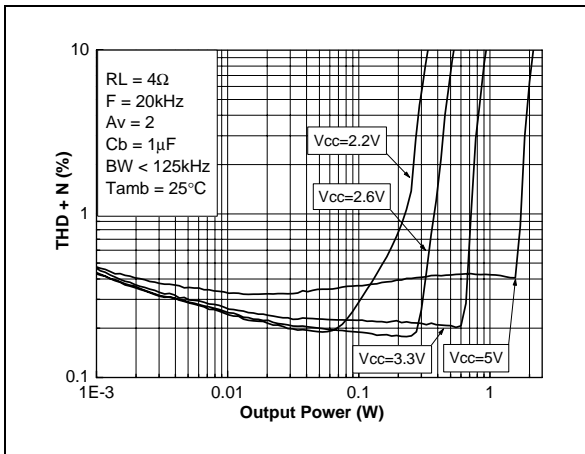


Figure 49: THD + N vs Output Power

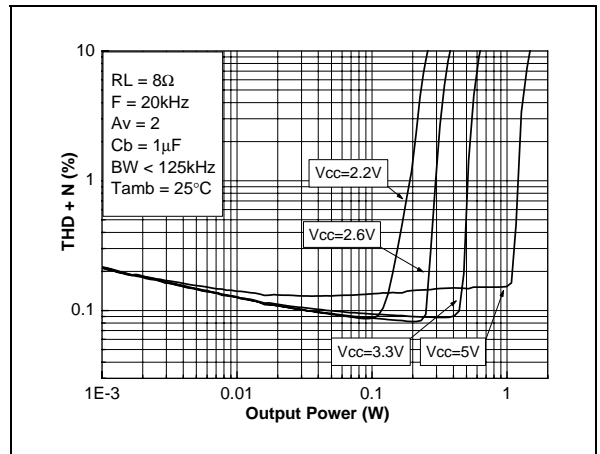


Figure 50: THD + N vs Output Power

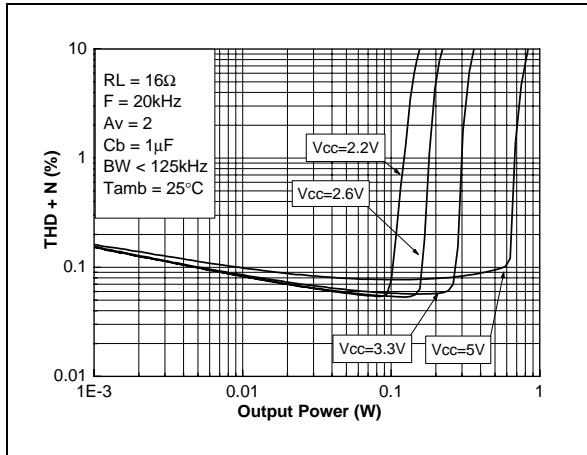


Figure 53: THD + N vs Frequency

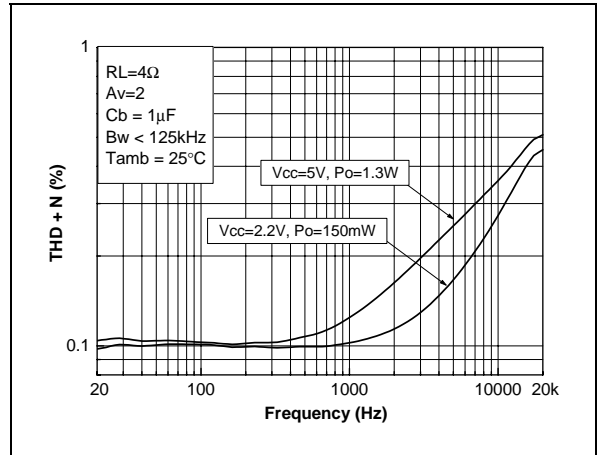


Figure 51: THD + N vs Frequency

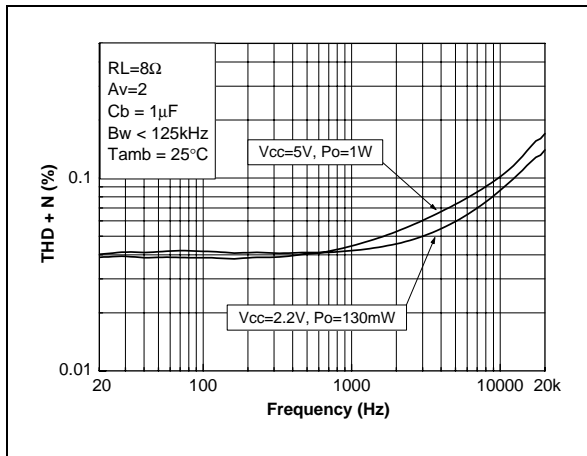


Figure 54: THD + N vs Frequency

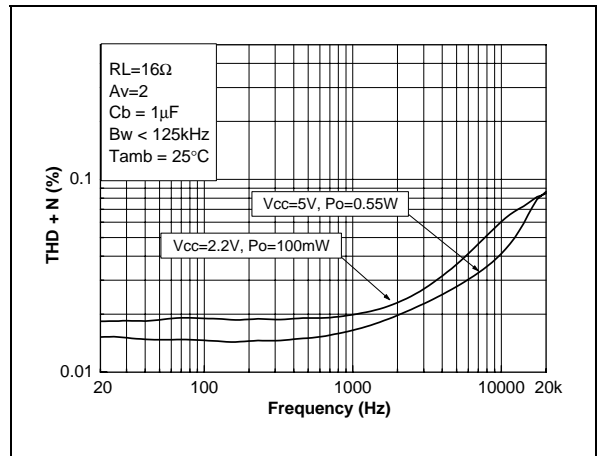


Figure 52: Signal to Noise Ratio vs Power Supply with Unweighted Filter (20Hz to 20kHz)

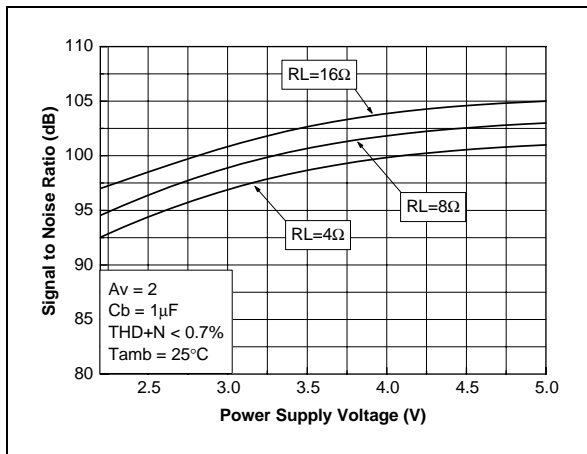


Figure 55: Signal to Noise Ratio vs Power Supply with Unweighted Filter (20Hz to 20kHz)

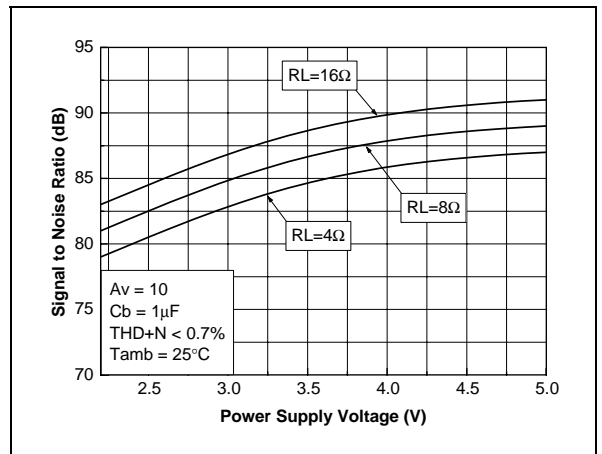


Figure 56: Signal to Noise Ratio vs Power Supply with A Weighted Filter

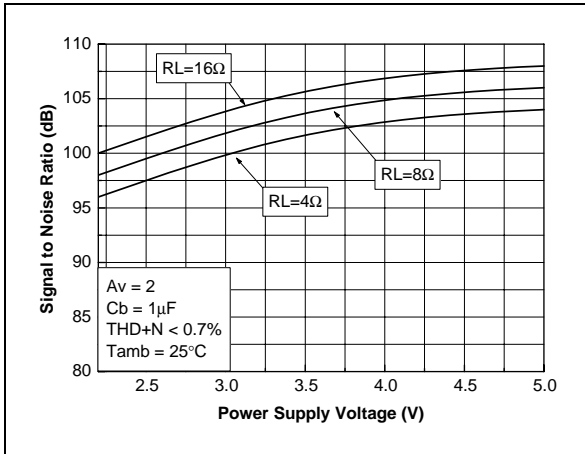


Figure 58: Signal to Noise Ratio vs Power Supply with A Weighted Filter

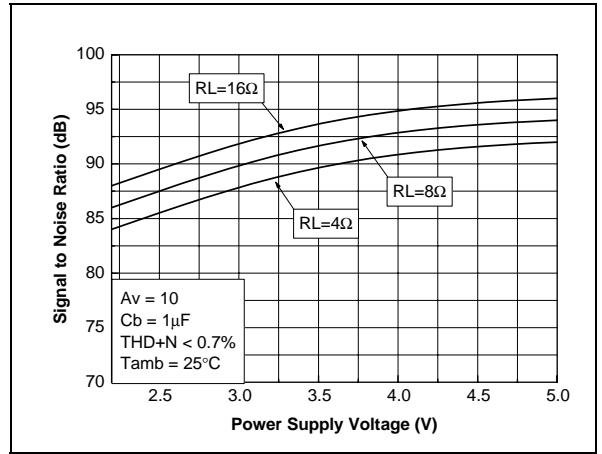


Figure 57: Output Noise Voltage device ON

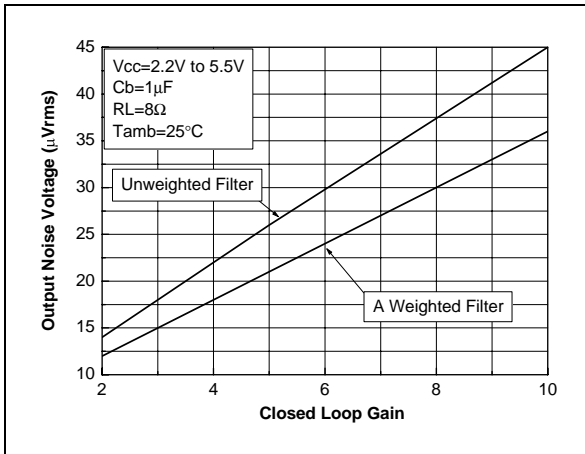
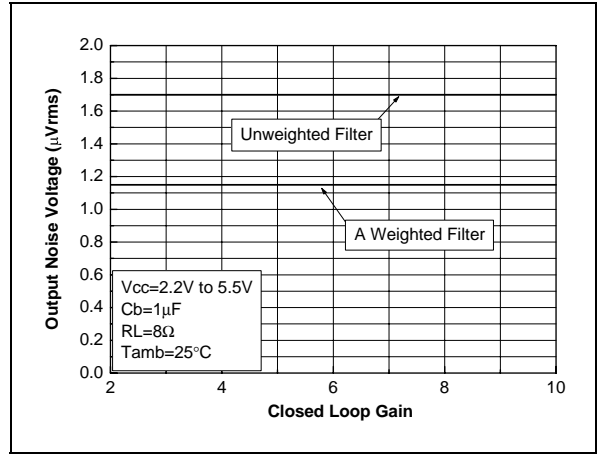


Figure 59: Output Noise Voltage device in Standby



### 3 Application Information

#### 3.1 BTL configuration principle

The TS4990 is a monolithic power amplifier with a BTL output type. BTL (Bridge Tied Load) means that each end of the load is connected to two single-ended output amplifiers. Thus, we have:

$$\text{Single-ended output 1} = V_{\text{out1}} = V_{\text{out}} \text{ (V)}$$

$$\text{Single ended output 2} = V_{\text{out2}} = -V_{\text{out}} \text{ (V)}$$

$$\text{and } V_{\text{out1}} - V_{\text{out2}} = 2V_{\text{out}} \text{ (V)}$$

The output power is:

$$P_{\text{out}} = \frac{(2V_{\text{outRMS}})^2}{R_L}$$

For the same power supply voltage, the output power in BTL configuration is four times higher than the output power in single ended configuration.

#### 3.2 Gain In typical application schematic

The typical application schematic is shown in page 1.

In the flat region (no  $C_{in}$  effect), the output voltage of the first stage is (in Volts):

$$V_{\text{out1}} = (-V_{in}) \frac{R_{\text{feed}}}{R_{in}}$$

For the second stage:  $V_{\text{out2}} = -V_{\text{out1}}$  (V)

The differential output voltage is (in Volts):

$$V_{\text{out2}} - V_{\text{out1}} = 2V_{in} \frac{R_{\text{feed}}}{R_{in}}$$

The differential gain named gain ( $G_v$ ) for more convenient usage is:

$$G_v = \frac{V_{\text{out2}} - V_{\text{out1}}}{V_{in}} = 2 \frac{R_{\text{feed}}}{R_{in}}$$

$V_{\text{out2}}$  is in phase with  $V_{in}$  and  $V_{\text{out1}}$  is phased  $180^\circ$  with  $V_{in}$ . This means that the positive terminal of the loudspeaker should be connected to  $V_{\text{out2}}$  and the negative to  $V_{\text{out1}}$ .

#### 3.3 Low and high frequency response

In the low frequency region,  $C_{in}$  starts to have an effect.  $C_{in}$  forms with  $R_{in}$  a high-pass filter with a -3dB cut-off frequency.  $F_{CL}$  is in Hz.

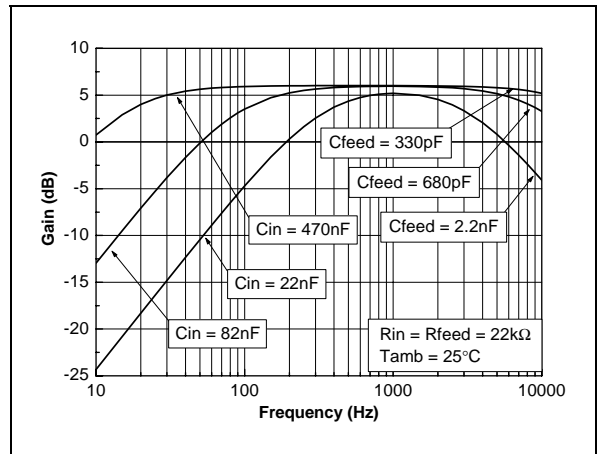
$$F_{CL} = \frac{1}{2\pi R_{in} C_{in}}$$

In the high frequency region, you can limit the bandwidth by adding a capacitor ( $C_{\text{feed}}$ ) in parallel with  $R_{\text{feed}}$ . It forms a low-pass filter with a -3dB cut-off frequency.  $F_{CH}$  is in Hz.

$$F_{CH} = \frac{1}{2\pi R_{\text{feed}} C_{\text{feed}}}$$

The following graph shows an example of  $C_{in}$  and  $C_{\text{feed}}$  influence.

**Figure 60: Frequency response gain vs  $C_{in}$ , &  $C_{\text{feed}}$**



#### 3.4 Power dissipation and efficiency

Hypotheses:

- Load voltage and current are sinusoidal ( $V_{\text{out}}$  and  $I_{\text{out}}$ )
- Supply voltage is a pure DC source ( $V_{cc}$ )

Regarding the load we have:

$$V_{\text{out}} = V_{\text{PEAK}} \sin \omega t \text{ (V)}$$



and

$$I_{\text{out}} = \frac{V_{\text{out}}}{R_L} \text{ (A)}$$

and

$$P_{\text{out}} = \frac{V_{\text{PEAK}}^2}{2R_L} \text{ (W)}$$

Therefore, the average current delivered by the supply voltage is:

$$I_{\text{CC AVG}} = 2 \frac{V_{\text{PEAK}}}{\pi R_L} \text{ (A)}$$

The power delivered by the supply voltage is:

$$P_{\text{supply}} = V_{\text{CC}} I_{\text{CC AVG}} \text{ (W)}$$

Then, the **power dissipated by each amplifier** is

$$P_{\text{diss}} = P_{\text{supply}} - P_{\text{out}} \text{ (W)}$$

$$P_{\text{diss}} = \frac{2\sqrt{2}V_{\text{CC}}}{\pi\sqrt{R_L}} \sqrt{P_{\text{out}}} - P_{\text{out}}$$

and the maximum value is obtained when:

$$\frac{\partial P_{\text{diss}}}{\partial P_{\text{out}}} = 0$$

and its value is:

$$P_{\text{diss max}} = \frac{2V_{\text{CC}}^2}{\pi^2 R_L} \text{ (W)}$$

*Note: This maximum value is only dependent on power supply voltage and load values.*

The **efficiency** is the ratio between the output power and the power supply

$$\eta = \frac{P_{\text{out}}}{P_{\text{supply}}} = \frac{\pi V_{\text{PEAK}}}{4V_{\text{CC}}}$$

The maximum theoretical value is reached when  $V_{\text{peak}} = V_{\text{CC}}$ , so

$$\frac{\pi}{4} = 78.5\%$$

### 3.5 Decoupling of the circuit

Two capacitors are needed to correctly bypass the TS4990. A power supply bypass capacitor  $C_S$  and a bias voltage bypass capacitor  $C_B$ .

$C_S$  has particular influence on the THD+N in the high frequency region (above 7kHz) and an indirect influence on power supply disturbances. With a value for  $C_S$  of 1 $\mu$ F, you can expect similar THD+N performances to those shown in the datasheet.

In the high frequency region, if  $C_S$  is lower than 1 $\mu$ F, it increases THD+N and disturbances on the power supply rail are less filtered.

On the other hand, if  $C_S$  is higher than 1 $\mu$ F, those disturbances on the power supply rail are more filtered.

$C_B$  has an influence on THD+N at lower frequencies, but its function is critical to the final result of PSRR (with input grounded and in the lower frequency region).

If  $C_B$  is lower than 1 $\mu$ F, THD+N increases at lower frequencies and PSRR worsens.

If  $C_B$  is higher than 1 $\mu$ F, the benefit on THD+N at lower frequencies is small, but the benefit to PSRR is substantial.

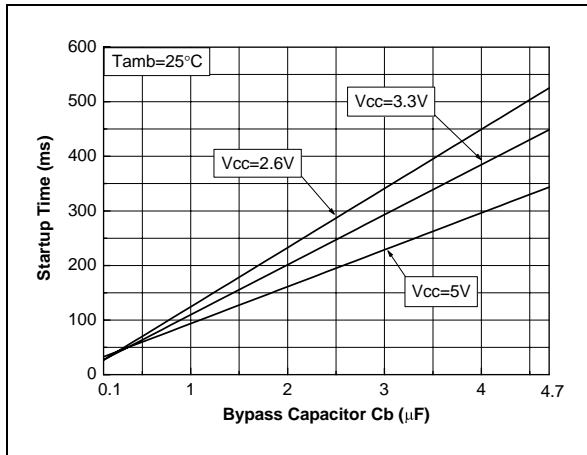
Note that  $C_{\text{in}}$  has a non-negligible effect on PSRR at lower frequencies. The lower the value of  $C_{\text{in}}$ , the higher the PSRR.

### 3.6 Wake-up time: $T_{\text{WU}}$

When the standby is released to put the device ON, the bypass capacitor  $C_B$  will not be charged immediately. As  $C_B$  is directly linked to the bias of the amplifier, the bias will not work properly until the  $C_B$  voltage is correct. The time to reach this voltage is called wake-up time or  $T_{\text{WU}}$  and specified in electrical characteristics table with  $C_B=1\mu$ F.

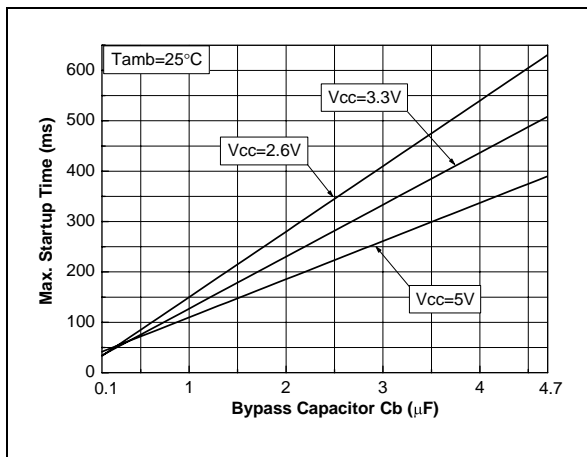
If  $C_B$  has a value other than 1 $\mu$ F, please refer to the graph in Figure 60 to establish the wake-up time value.

Figure 61: Typical wake-up time vs.  $C_b$



Due to process tolerances, the maximum value of wake-up time could be established by the graph in Figure 61:

Figure 62: Maximum wake-up time vs.  $C_b$



Note: Bypass capacitor  $C_b$  as also a tolerance of typically +/-20%. To calculate the wake-up time with this tolerance, refer to the previous graph (considering for example for  $C_b=1\mu\text{F}$  in the range of  $0.8\mu\text{F}\leq 1\mu\text{F}\leq 1.2\mu\text{F}$ ).

### 3.7 Shutdown time

When the standby command is set, the time required to put the two output stages in high impedance and the internal circuitry in shutdown mode is a few microseconds.

Note: In shutdown mode, Bypass pin and Vin- pin are short-circuited to ground by internal switches. This allows a quick discharge of  $C_b$  and  $C_{in}$  capacitors.

### 3.8 Pop performance

Pop performance is intimately linked with the size of the input capacitor  $C_{in}$  and the bias voltage bypass capacitor  $C_b$ .

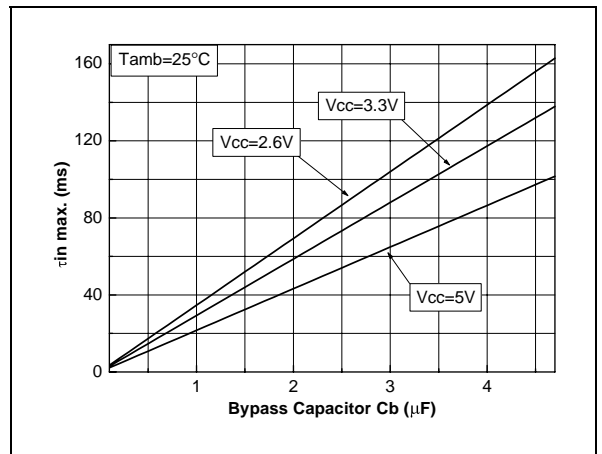
The size of  $C_{in}$  is dependent on the lower cut-off frequency and PSRR values requested. The size of  $C_b$  is dependent on THD+N and PSRR values requested at lower frequencies.

Moreover,  $C_b$  determines the speed with which the amplifier turns ON. In order to reach near zero pop and click, the equivalent input constant time,

$$\tau_{in} = (R_{in} + 2k\Omega) \times C_{in} \text{ (s) with } R_{in} \geq 5k\Omega$$

must not reach the  $\tau_{in}$  maximum value as indicated in the graph below.

Figure 63:  $\tau_{in}$  max. versus bypass capacitor



By following previous rules, the TS4990 can reach near zero pop and click even with high gains such as 20 dB.

#### Example:

With  $R_{in} = 22 \text{ k}\Omega$  and a 20 Hz, -3 db low cut-off frequency,  $C_{in}=361 \text{ nF}$ . So,  $C_{in}=390 \text{ nF}$  with standard value which gives a lower cut-off frequency equal to 18.5 Hz. In this case,  $(R_{in} + 2 \text{ k}\Omega) \times C_{in} = 9.36 \text{ ms}$ . When referring to the previous graph, if  $C_b = 1 \mu\text{F}$  and  $V_{cc} = 5 \text{ V}$ , we read 20 ms max. This value is twice as high as our current value, thus we can state that pop and click will be reduced to its lowest value.

Minimizing both  $C_{in}$  and the gain benefits both the pop phenomena, and the cost and size of the application.

### 3.9 Application: differential inputs btl power amplifier

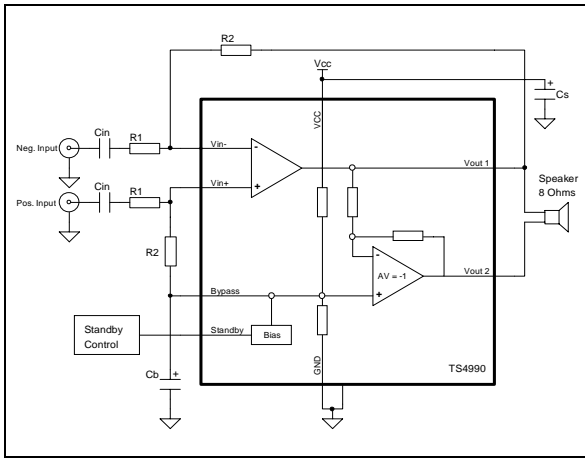
The schematic in Figure 63 shows how to design the TS4990 to work in a differential input mode.

The gain of the amplifier is:

$$G_{VDIFF} = 2 \frac{R_2}{R_1}$$

In order to reach the optimal performance of the differential function,  $R_1$  and  $R_2$  should be matched at 1% max.

**Figure 64: Differential input amplifier configuration**



The input capacitor  $C_{IN}$  could be calculated by the

following formula using the -3dB lower frequency required. ( $F_L$  is the lower frequency required)

$$C_{IN} \approx \frac{1}{2 \pi R_1 F_L} (F)$$

Note: This formula is true only if:

$$F_{CB} = \frac{1}{2 \pi (R_1 + R_2) C_B} (Hz)$$

is 5 times lower than  $F_L$ .

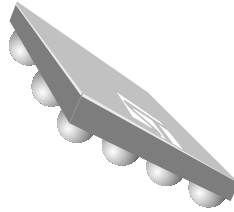
The following bill of material is an example of a differential amplifier with a gain of 2 and a -3dB lower cut-off frequency of about 80Hz.

**Components:**

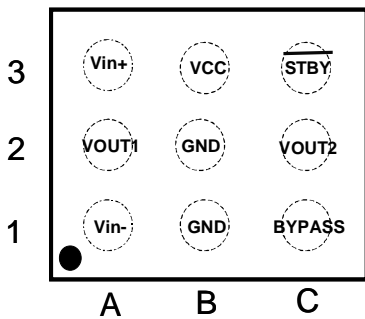
Designator	Part Type
R1	20k / 1%
R2	20k / 1%
$C_{in}$	100nF
$C_b=C_s$	1 $\mu$ F
U1	TS4990

## 4 Package Mechanical Data

### 4.1 TS4990IJT Pinout and Package Mechanical Data

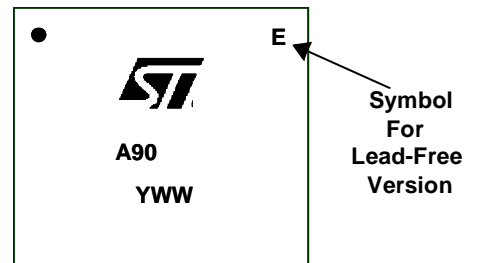


#### 4.1.1 Pinout (top view)



■ Balls are underneath

#### 4.1.2 Marking (top view)



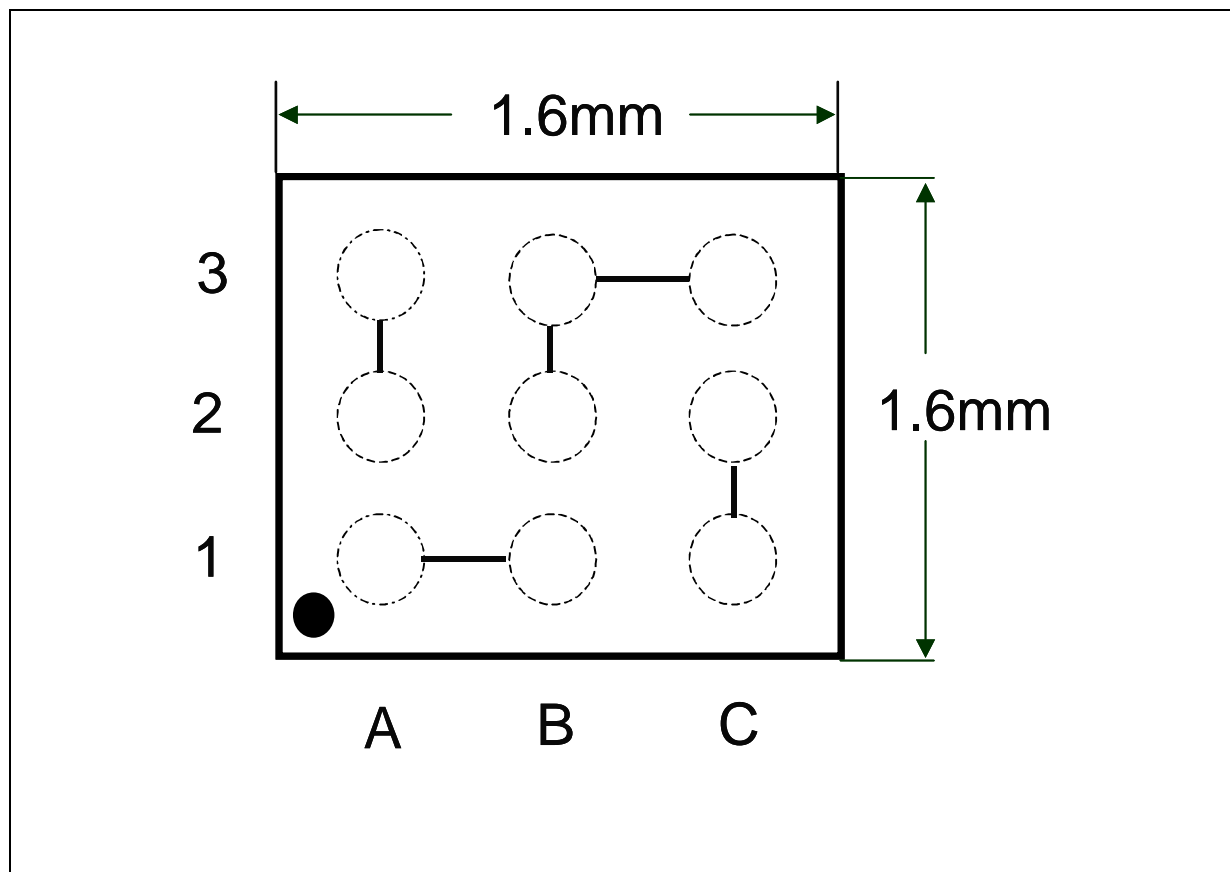
- ST Logo
- Part number: A90
- Three digits Datecode: YWW
- E symbol for lead-free only
- The dot is for marking pin A1

#### 4.1.3 Package Mechanical Data for 9-bump Flip-Chip

- Die size: 1.60 x 1.60 mm ±30μm
- Die height (including bumps): 600μm
- Bump Diameter: 315μm ±50μm
- Bump Diameter Before Reflow: 300μm ±10μm
- Bump Height: 250μm ±40μm
- Die Height: 350μm ±20μm
- Pitch: 500μm ±50μm
- Coplanarity: 60μm max
- \* Back coating height : 100μm ±10μm

\* Optional

4.1.4 Daisy Chain Mechanical Data



Remarks

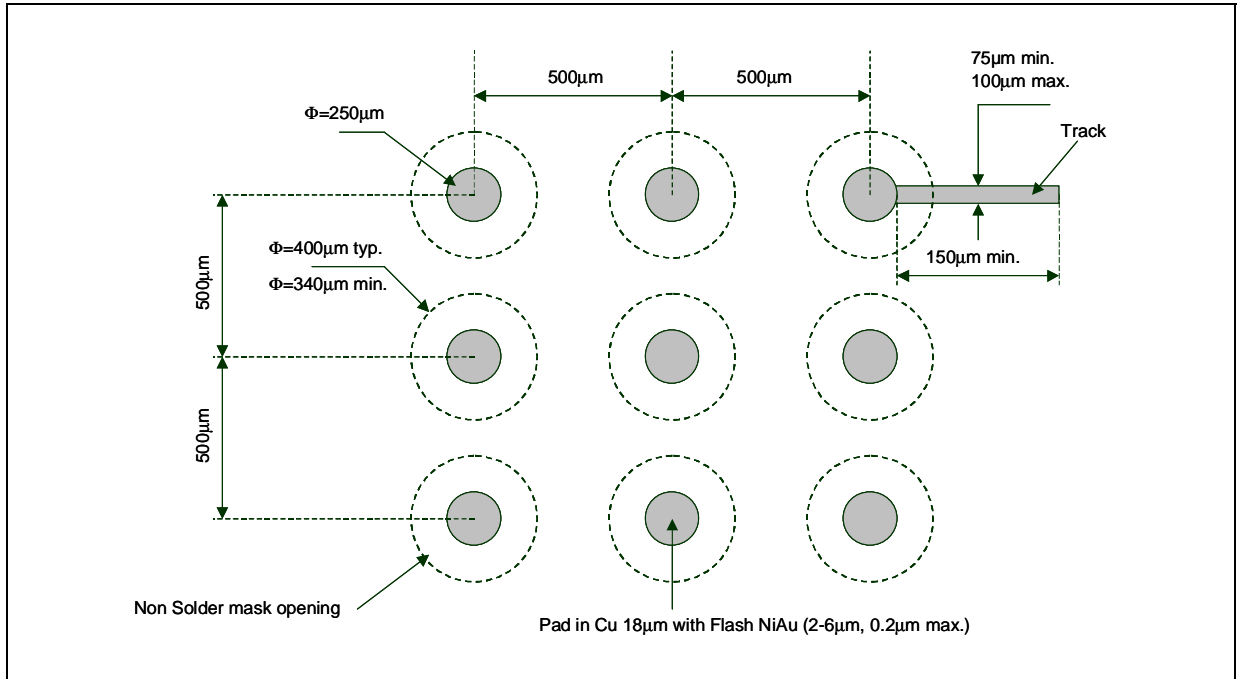
The daisy chain sample features two by two pin connections. The schematic above illustrates the way pins connect to each other. This sample is used to test continuity on your board. Your PCB needs to be designed the opposite way, so that pins that are unconnected in the daisy chain sample, are connected on your PCB. If you do this, by simply connecting a Ohmmeter between pin A1 and pin A3, the soldering process continuity can be tested.

Order code

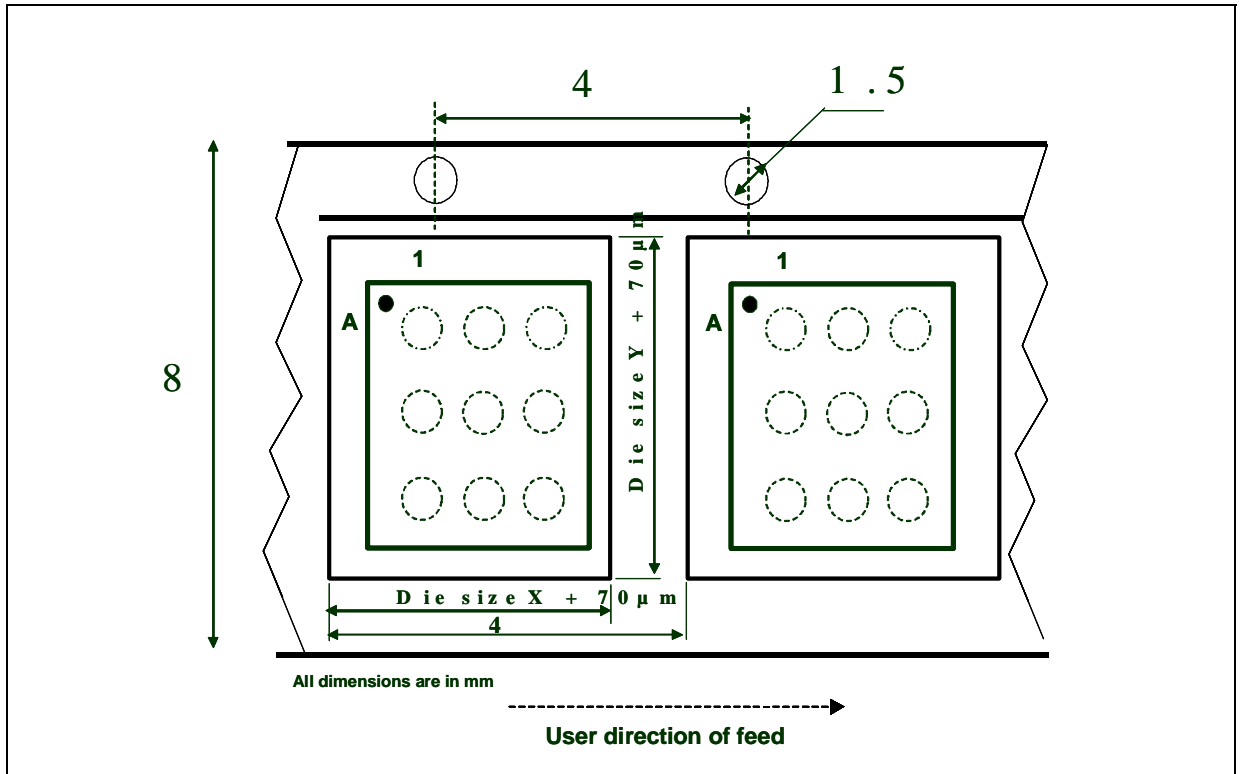
Part Number	Temperature Range	Package	Marking
		J	
TSDC05IJT	-40, +85°C	•	DC3
TSDC05EIJT <sup>1</sup>		•	DC3

1) Lead free Daisy Chain part number

4.1.5 TS4990 Footprint Recommendations



4.1.6 Tape & Reel Specification (top view)



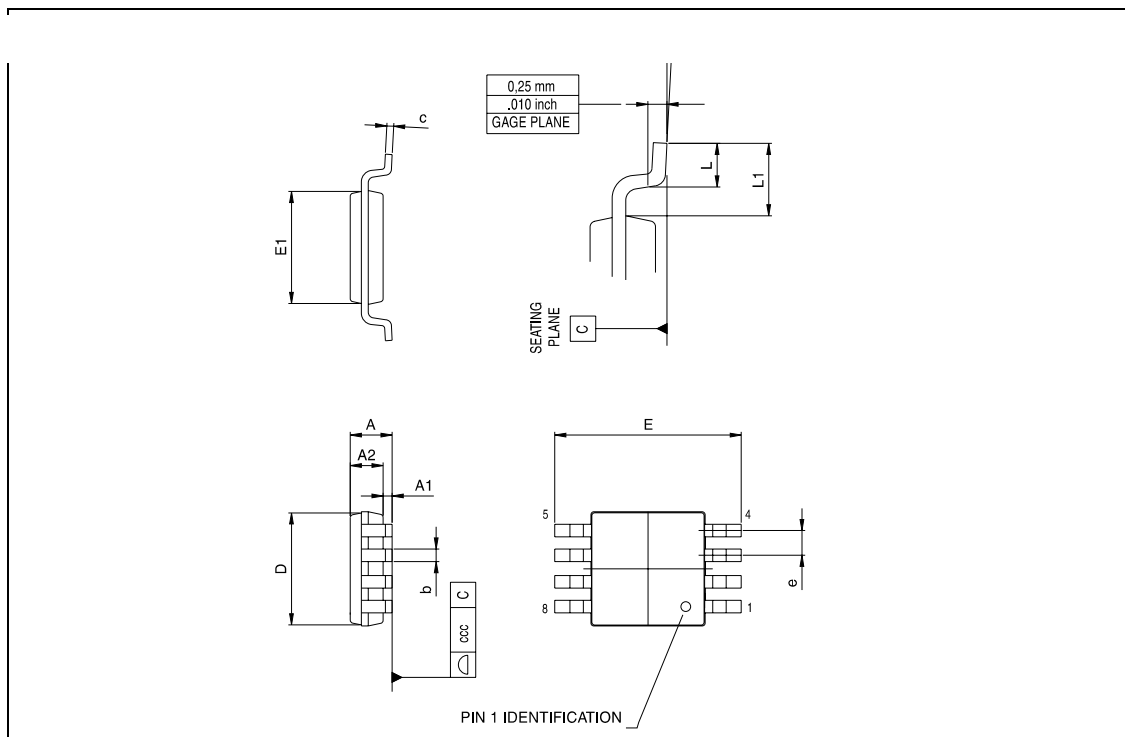
Device orientation

The devices are oriented in the carrier pocket with pin number A1 adjacent to the sprocket holes.

4.2 Mini SO8 Package Mechanical Data

**miniSO-8 MECHANICAL DATA**

DIM.	mm.			inch		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
A			1.1			0.043
A1	0.05	0.10	0.15	0.002	0.004	0.006
A2	0.78	0.86	0.94	0.031	0.031	0.037
b	0.25	0.33	0.40	0.010	0.13	0.013
c	0.13	0.18	0.23	0.005	0.007	0.009
D	2.90	3.00	3.10	0.114	0.118	0.122
E	4.75	4.90	5.05	0.187	0.193	0.199
E1	2.90	3.00	3.10	.0114	0.118	0.122
e		0.65			0.026	
K	0°		6°	0°		6°
L	0.40	0.55	0.70	0.016	0.022	0.028
L1			0.10			0.004



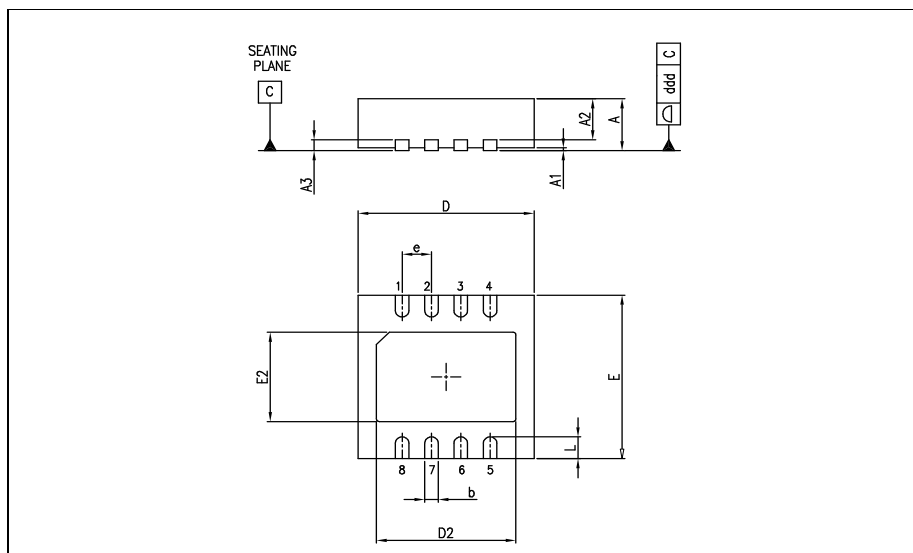
### 4.3 DFN8 Package Mechanical Data

DFN8 EXPOSED PAD (E2 X D2) IS CONNECTED TO PIN NUMBER 7.

FOR ENHANCED THERMAL PERFORMANCE, THE EXPOSED PAD MUST BE SOLDERED TO A COPPER AREA ON THE PCB, ACTING AS HEATSINK. THIS COPPER AREA CAN BE ELECTRICALLY CONNECTED TO PIN7 OR LEFT FLOATING.

**DFN8 (3x3) MECHANICAL DATA**

DIM.	mm.			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A	0.80	0.90	1.00	31.5	35.4	39.4
A1		0.02	0.05		0.8	2.0
A2		0.70			27.6	
A3		0.20			7.9	
b	0.18	0.23	0.30	7.1	9.1	11.8
D	2.875	3.00	3.125		118.1	
D2	2.23	2.38	2.48	87.8	93.7	97.7
E	2.875	3.00	3.125		118.1	
E2	1.49	1.64	1.74	58.7	64.6	68.5
e		0.50			19.7	
L	0.30	0.40	0.50	11.8	15.7	19.7





## 5 Revision History

Date	Revision	Description of Changes
July 2002	1	First Release
September 2003	2	Update Mechanical Data
October 2004	3	Order code for Back coating on Flip chip

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