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TS4999

Filter-free stereo 2.8 W class D audio power amplifier with selectable 3D sound effects

Features

- Operates from V_{CC} = 2.4 to 5.5 V
- Dedicated standby mode active low/channel
- Output power per channel: 2.8 W at 5 V into 4 Ω with 10% THD+N or 0.7 W at 3.6 V into 8 Ω with 1% THD+N max.
- Selectable 3D sound effect
- Four gain setting steps: 3.5, 6, 9.5 and 12 dB
- Low current consumption
- PSSR: 63 dB typical at 217 Hz.
- Fast start up phase: 7.8 ms
- Short-circuit and thermal shutdown protection
- Flip chip 18-bump lead-free package

Applications

- Cellular phones
- PDAs
- Notebook PCs

Description

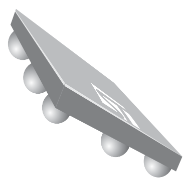
The TS4999 is a stereo fully-differential class D power amplifier. It can drive up to 1.35 W into a 8 Ω load at 5 V per channel. The device has four different gain settings utilizing two discrete pins, G0 and G1.

Pop and click reduction circuitry provides low on/off switch noise while allowing the device to start within 8 ms. 3D enhancement effects are selected through one digital input pin that allows more amazing stereo audio sound.

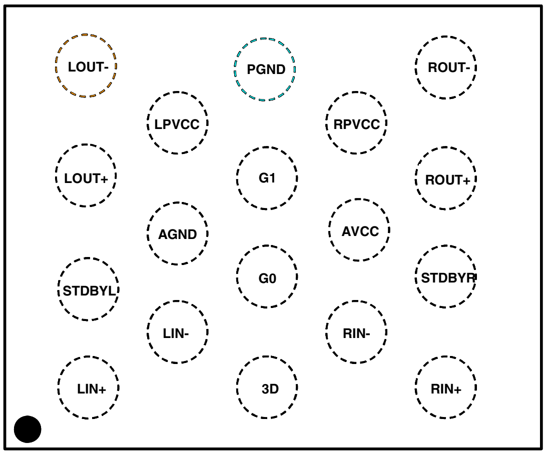
Two standby pins (active low) allow each channel to be switched off separately.

The TS4999 is available in a flip chip, 18-bump, lead-free package.

Flip chip 18-bump package



Pin connections (top view)



Contents

1 Absolute maximum ratings

Table 1. Key parameters and their absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage(1)	6	V
V_{in}	Input voltage(2)	GND to V_{CC}	V
T_{oper}	Operating free air temperature range	-40 to + 85	°C
T_{stg}	Storage temperature	-65 to +150	°C
T_j	Maximum junction temperature	150	°C
R_{thja}	Thermal resistance junction to ambient (3)	200	°C/W
Pd	Power dissipation	Internally Limited(4)	
ESD	HBM: human body model(5)	2	kV
ESD	MM: machine model(6)	200	V
Latch-up	Latch-up immunity	200	mA
V_{STBY}	Standby pin voltage maximum voltage	GND to V_{CC}	V
	Lead temperature (soldering, 10 secs)	260	°C
	Output short-circuit protection(7)		

1. All voltages values are measured with respect to the ground pin.
2. The magnitude of input signal must never exceed V_{CC} + 0.3 V / GND - 0.3 V
3. Device is protected in case of over temperature by a thermal shutdown active at 150° C.
4. Exceeding the power derating curves during a long period, involves abnormal operating condition.
5. Human body model: 100 pF discharged through a 1.5 kΩ resistor between two pins of the device, done for all couples of pin combinations with other pins floating.
6. Machine model: a 200 pF capacitor is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5 Ω), done for all couples of pin combinations with other pins floating.
7. Implemented short-circuit protection protects the amplifier against damage by short-circuit between positive and negative outputs of each channel and between outputs and ground.

Table 2. Operating conditions

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage(1)	2.4 to 5.5	V
V_{in}	Input voltage range	GND to V_{CC}	
VSTBY	Standby voltage input(2) Device ON Device OFF	 $1.4 \leq V_{STBY} \leq V_{CC}$ $GND \leq V_{STBY} \leq 0.4$(3)	V
RL	Load resistor	≥4	Ω
VIH	G0, G1, 3D, High Level Input Voltage(4)	$1.4 \leq V_{IH} \leq V_{CC}$	V
VIL	G0, G1, 3D, Low Level Input Voltage	$GND \leq V_{IL} \leq 0.4$	V
R_{thja}	Thermal Resistance Junction to Ambient (5)	90	°C/W

1. For V_{CC} from 2.4 to 2.5 V, the operating temperature range is reduced to 0° C $\leq T_{amb} \leq$ 70° C
2. Without any signal on V_{STBY}, the device will be in standby (internal 300 kΩ (+/-20 %) pull down resistor)
3. Minimum current consumption is obtained when V_{STBY} = GND
4. Between G0, G1, 3D pins and GND, there is an internal 300 kΩ (+/-20 %) pull-down resistor. When pins are floating, the gain is 3.5 dB and 3D effect is off. In full standby (left and right channels OFF), these resistors are disconnected (HiZ input).
5. With a 4-layer PCB.

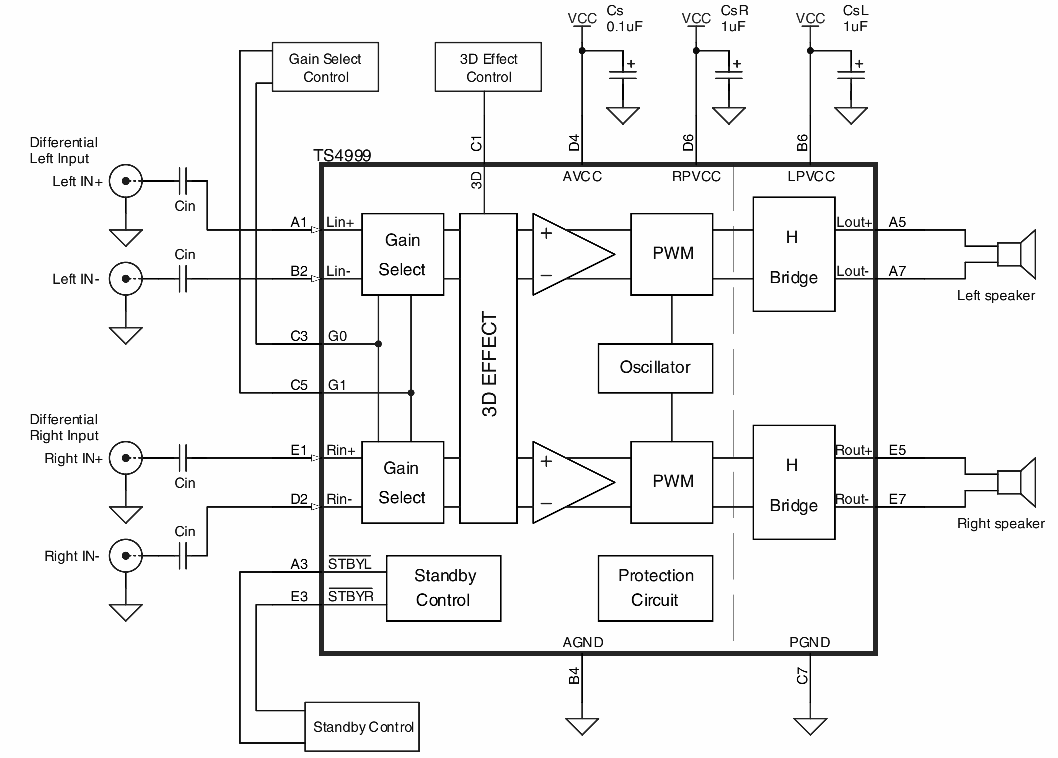
Table 3. 3D effect pin and STANDBY pins setting truth table

3D	STBYL	STBYR	3D Effect	Left channel	Right channel
0	0	0	X	STDBY	STDBY
0	0	1	OFF	STDBY	ON
0	1	0	OFF	ON	STDBY
0	1	1	OFF	ON	ON
1	0	0	X	STDBY	STDBY
1	0	1	N/A	N/A	N/A
1	1	0	N/A	N/A	N/A
1	1	1	ON	ON	ON

Note: When the 3D effect is switched on, both channels must be in operation or in shutdown mode at the same time.

2 Application information

Figure 1. Typical application schematic



Note: *See Section 4.9: Output filter considerations on page 29.*

Table 4. External component description

Components	Functional description
C_S, C_{SL}, C_{SR}	Supply capacitor that provides power supply filtering.
C_{in}	Input coupling capacitors that block the DC voltage at the amplifier input terminal. The capacitors also form a high pass filter with Z_{in} ($F_{cl} = 1 / (2 \times \pi \times Z_{in} \times C_{in})$). Note that the value of Z_{in} changes with each gain setting. These coupling capacitors are mandatory.

Table 5. Pin description

Bump	Name	Function
A1	LIN+	Left channel positive differential input
B2	LIN-	Left channel negative differential input
C1	3D	3D effect digital input pin
E1	RIN+	Right channel *positive* differential input
D2	RIN-	Right channel *negative* differential input
A3	STBYL	Standby input pin (active low) for left channel output
C3	G0	Gain select input pin (LSB)
E3	STBYR	Standby input pin (active low) for right channel output
B4	AGND	Analog ground
D4	AVCC	Analog supply voltage
A5	LOUT+	Left channel negative output
C5	G1	Gain select input pin (MSB)
E5	ROUT+	Right channel positive output
B6	LPVCC	Left channel power supply voltage
D6	RPVCC	Right channel power supply voltage
A7	LOUT-	Left channel negative output
C7	PGND	Power ground
E7	ROUT-	Right channel negative output

Table 6. Truth table for output gain settings

G1	G0	Gain value (dB)
0	0	3.5
0	1	6
1	0	9.5
1	1	12

Note: See Table 3 on page 4.

Table 7. Truth table for 3D effects pin settings

3D	3D effect
0	OFF
1	ON

3 Electrical characteristics

Table 8. V_{CC} = +5 V, GND = 0 V, T_{amb} = 25° C (unless otherwise specified)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
I_{CC}	Supply current	No input signal, no load, both channels		5	7	mA
$I_{STANDBY}$	Standby current	No input signal, Vstdby = GND		1	2	µA
Voo	Output offset voltage	Floating inputs, RL = 8Ω, G = 3.5dB, 3D effect off			20	mV
Po	Output power	THD = 1% max, F = 1kHz, R_L = 4Ω		2.25		W
		THD = 1% max, F = 1kHz, R_L = 8Ω		1.35		
		THD = 10% max, F = 1kHz, R_L = 4Ω		2.8		W
		THD = 10% max, F = 1kHz, R_L = 8Ω		1.7		W
THD+N	Total harmonic distortion + noise	Po = 0.9W/Ch, G = 6dB, F=1kHz, R_L = 8Ω		0.2		%
Efficiency	Efficiency per channel	Po = 2.3 W_{RMS}, R_L = 4Ω+15µH		82		%
		Po = 1.4 W_{RMS}, R_L = 8Ω+ 15µH		89		
PSRR	Power supply rejection ratio with inputs grounded	C_{in} = 1µF [(1)],3D effects off F = 217Hz, R_L = 8Ω, gain = 6dB, Vripple = 200mVpp, Inputs grounded		65		dB
Crosstalk	Channel separation	F = 1kHz, R_L = 8Ω, 3D effects off		100		dB
CMRR	Common mode rejection ratio	C_{in}=1µF, F = 217Hz, R_L = 8Ω, gain = 6dB, ΔV_{IC} = 200mV_{pp}, 3D effects OFF		57		dB
Gain	Gain value with no load	G1 = G0 = "0"	3	3.5	4	dB
		G1 = "0" & G0 = "1"	5.5	6	6.5	
		G1 = "1" & G0 = "0"	9	9.5	10	
		G1 = G0 = "1"	11.5	12	12.5	
Z_{IN}	Single-ended input impedance referred to GND	G1 = G0 = 3D = "0" or G1 = "0" & G0 = "1" & 3D = "0" or G1 = "1" & G0 = "0" & 3D = "0"	24	30	36	kΩ
		G1 = "1" & G0 = "1" & 3D = "0"	12	15	18	kΩ
		G1 = G0 = "0" & 3D = "1" or G1 = "0" & G0 = "1" & 3D = "1" or G1 = "1" & G0 = "0" & 3D = "1"	13.5	17.1	20.5	kΩ
		G1 = "1" & G0 = "1" & G3D = "1"	6.5	8.6	10.5	
F_{PWM}	Pulse width modulator base frequency		190	280	370	kHz
SNR	Signal to noise ratio	P_o = 1.3W, A-weighting, R_L = 8Ω, Gain = 6dB, 3D effects OFF		99		dB
t_{WU}	Wake-up time	Total wake-up time[(2)]	9	13	16.5	ms

Table 8. V_{CC} = +5 V, GND = 0 V, T_{amb} = 25° C (unless otherwise specified) (continued)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
t_{STBY}	Standby time	Standby time(2)	11	15.8	20	ms
V_N	Output voltage noise	F = 20Hz to 20kHz, A-weighted, Gain = 3.5dB Filterless, 3D effect off, R_L = 4Ω Filterless, 3D effect on, R_L = 4Ω With LC output filter, 3D effect off, R_L = 4Ω With LC output filter, 3D effect on, R_L = 4Ω Filterless, 3D effect off, R_L = 8Ω Filterless, 3D effect on, R_L = 8Ω With LC output filter, 3D effect off, R_L = 8Ω With LC output filter, 3D effect on, R_L = 8Ω		31 50 30 48 32 51 31 50		μV_{RMS}

1. Dynamic measurements - 20*log(rms(Vout)/rms(Vripple)). Vripple is the super-imposed sinus signal to V_{CC} at f = 217 Hz with fixed Cin cap (input decoupling capacitor).
2. See *Section 4.6: Wakeup (t_{WU}) and shutdown (t_{STBY}) times on page 26*.

Table 9. V_{CC} = +3.6V, GND = 0V, T_{amb} = 25°C (unless otherwise specified)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
I_{CC}	Supply current	No input signal, no load, both channels		3.5	5.5	mA
$I_{STANDBY}$	Standby current	No input signal, Vstdby = GND		1	2	µA
Voo	Output offset voltage	Floating inputs, RL = 8Ω, G = 3.5dB, 3D effect off			20	mV
Po	Output power	THD = 1% max, F = 1kHz, R_L = 4Ω		1.15		W
		THD = 1% max, F = 1kHz, R_L = 8Ω		0.7		
		THD = 10% max, F = 1kHz, R_L = 4Ω		1.45		W
		THD = 10% max, F = 1kHz, R_L = 8Ω		0.86		W
THD+N	Total harmonic distortion + noise	Po = 0.45W/Ch, G = 6dB, F=1kHz, R_L = 8Ω		0.15		%
Efficiency	Efficiency per channel	Po = 1.15 W_{RMS}, R_L = 4Ω+15µH		82		%
		Po = 0.7 W_{RMS}, R_L = 8Ω+ 15µH		89		
PSRR	Power supply rejection ratio with inputs grounded	C_{in} = 1µF (1),3D effects off F = 217Hz, R_L = 8Ω, gain = 6dB, Vripple = 200mVpp, inputs grounded		64		dB
Crosstalk	Channel separation	F = 1kHz, R_L = 8Ω, 3D effects off		102		dB
CMRR	Common mode rejection ratio	C_{in}=1µF, F = 217Hz, R_L = 8Ω, gain = 6dB, ΔV_{IC} = 200mV_{pp}, 3D effects off		55		dB
Gain	Gain value with no load	G1 = G0 = "0"	3	3.5	4	dB
		G1 = "0" & G0 = "1"	5.5	6	6.5	
		G1 = "1" & G0 = "0"	9	9.5	10	
		G1 = G0 = "1"	11.5	12	12.5	
Z_{IN}	Single-ended input impedance referred to GND	G1 = G0 = 3D = "0" or G1 = "0" & G0 = "1" & 3D = "0" or G1 = "1" & G0 = "0" & 3D = "0"	24	30	36	kΩ
		G1 = "1" & G0 = "1" & 3D = "0"	12	15	18	kΩ
		G1 = G0 = "0" & 3D = "1" or G1 = "0" & G0 = "1" & 3D = "1" or G1 = "1" & G0 = "0" & 3D = "1"	13.5	17.1	20.5	kΩ
		G1 = "1" & G0 = "1" & G3D = "1"	6.5	8.6	10.5	kΩ
F_{PWM}	Pulse width modulator base frequency		190	280	370	kHz
SNR	Signal to noise ratio	P_o = 0.67W, A-weighting, R_L = 8Ω, Gain = 6dB, 3D effects OFF		97		dB
t_{WU}	Wake-up time	Total wake-up time(2)	7.5	11.3	15	ms

Table 9. V_{CC} = +3.6V, GND = 0V, T_{amb} = 25°C (unless otherwise specified) (continued)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
t_{STBY}	Standby time	Standby time(2)	10	13.8	18	ms
V_N	Output voltage noise	F = 20Hz to 20kHz, A-Weighted, Gain = 3.5dB Filterless, 3D effect off, R_L = 4Ω Filterless, 3D effect on, R_L = 4Ω With LC output filter, 3D effect off, R_L = 4Ω With LC output filter, 3D effect on, R_L = 4Ω Filterless, 3D effect off, R_L = 8Ω Filterless, 3D effect on, R_L = 8Ω With LC output filter, 3D effect off, R_L = 8Ω With LC output filter, 3D effect on, R_L = 8Ω		 29 49 28 48 29 50 29 50		μV_{RMS}

1. Dynamic measurements - 20*log(rms(Vout)/rms(Vripple)). Vripple is the super-imposed sinus signal to V_{CC} at f = 217 Hz with fixed Cin cap (input decoupling capacitor).
2. See *Section 4.6: Wakeup (t_{WU}) and shutdown (t_{STBY}) times on page 26*.

Table 10. V_{CC} = +2.5 V, GND = 0V, T_{amb} = 25° C (unless otherwise specified)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
I_{CC}	Supply current	No input signal, no load, both channels		2.8	4	mA
$I_{STANDBY}$	Standby current	No input signal, Vstdby = GND		1	2	µA
Voo	Output offset voltage	Floating inputs, RL = 8Ω, G = 3.5dB, 3D effect off			20	mV
Po	Output power	THD = 1% max, F = 1kHz, R_L = 4Ω		0.53		W
		THD = 1% max, F = 1kHz, R_L = 8Ω		0.33		
		THD = 10% max, F = 1kHz, R_L = 4Ω		0.67		W
		THD = 10% max, F = 1kHz, R_L = 8Ω		0.4		W
THD+N	Total harmonic distortion + noise	Po = 0.2W/Ch, G = 6dB, F=1kHz, R_L = 8Ω		0.07		%
Efficiency	Efficiency per channel	Po = 0.52 W_{RMS}, R_L = 4Ω+15µH		81		%
		Po = 0.33 W_{RMS}, R_L = 8Ω+ 15µH		88		
PSRR	Power supply rejection ratio with inputs grounded	C_{in} = 1µF [(1)],3D effects off F = 217Hz, R_L = 8Ω, gain = 6dB, Vripple = 200mVpp, Inputs grounded		63		dB
Crosstalk	Channel separation	F = 1kHz, R_L = 8Ω, 3D effects off		104		dB
CMRR	Common mode rejection ratio	C_{in}=1µF, F = 217Hz, R_L = 8Ω, gain = 6dB, ΔV_{IC} = 200mV_{pp}, 3D effects off		55		dB
Gain	Gain value with no load	G1 = G0 = "0"	3	3.5	4	dB
		G1 = "0" & G0 = "1"	5.5	6	6.5	
		G1 = "1" & G0 = "0"	9	9.5	10	
		G1 = G0 = "1"	11.5	12	12.5	
Z_{IN}	Single-ended input impedance referred to GND	G1 = G0 = 3D = "0" or G1 = "0" & G0 = "1" & 3D = "0" or G1 = "1" & G0 = "0" & 3D = "0"	24	30	36	kΩ
		G1 = "1" & G0 = "1" & 3D = "0"	12	15	18	kΩ
		G1 = G0 = "0" & 3D = "1" or G1 = "0" & G0 = "1" & 3D = "1" or G1 = "1" & G0 = "0" & 3D = "1"	13.5	17.1	20.5	kΩ
		G1 = "1" & G0 = "1" & G3D = "1"	6.5	8.6	10.5	kΩ
F_{PWM}	Pulse width modulator base frequency		190	280	370	kHz
SNR	Signal to noise ratio	P_o = 0.3W, A-weighting, R_L = 8Ω, Gain = 6dB, 3D effects OFF		94		dB
t_{WU}	Wake-up time	Total wake-up time[(2)]	3	7.8	12	ms

Table 10. V_{CC} = +2.5 V, GND = 0V, T_{amb} = 25° C (unless otherwise specified) (continued)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
t_{STBY}	Standby time	Standby time(2)	8	12	16	ms
V_N	Output voltage noise	F = 20Hz to 20kHz, A-Weighted, Gain = 3.5dB Filterless, 3D effect off, R_L = 4Ω Filterless, 3D effect on, R_L = 4Ω With LC output filter, 3D effect off, R_L = 4Ω With LC output filter, 3D effect on, R_L = 4Ω Filterless, 3D effect off, R_L = 8Ω Filterless, 3D effect on, R_L = 8Ω With LC output filter, 3D effect off, R_L = 8Ω With LC output filter, 3D effect on, R_L = 8Ω		 28 47 27 45 28 48 28 47		μV_{RMS}

1. Dynamic measurements - 20*log(rms(Vout)/rms(Vripple)). Vripple is the super-imposed sinus signal to V_{CC} at f = 217 Hz with fixed Cin cap (input decoupling capacitor).

2. See *Section 4.6: Wakeup (t_{WU}) and shutdown (t_{STBY}) times on page 26*.

3.1 Electrical characteristic curves

The graphs shown in this section use the following abbreviations.

- R_L+ 15 µH or 30 µH = pure resistor + very low series resistance inductor.
- Filter = LC output filter (1 µF+ 30 µH for 4 Ω and 0.5 µF+15 µH for 8 Ω).

All measurements are done with C_{SL}= C_{SR}=1 µF and C_S = 100 nF (see *Figure 2*), except for the PSRR where C_{SL}, C_{SR} is removed (see *Figure 3*).

Figure 2. Measurement test diagram

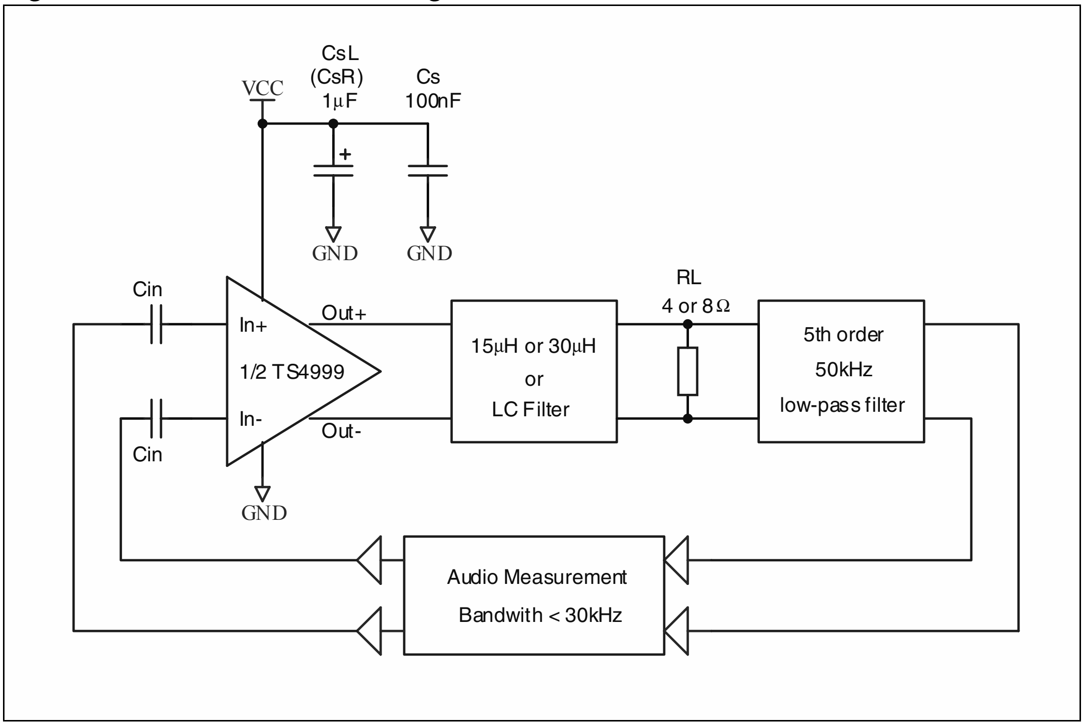


Figure 3. PSRR measurement test diagram

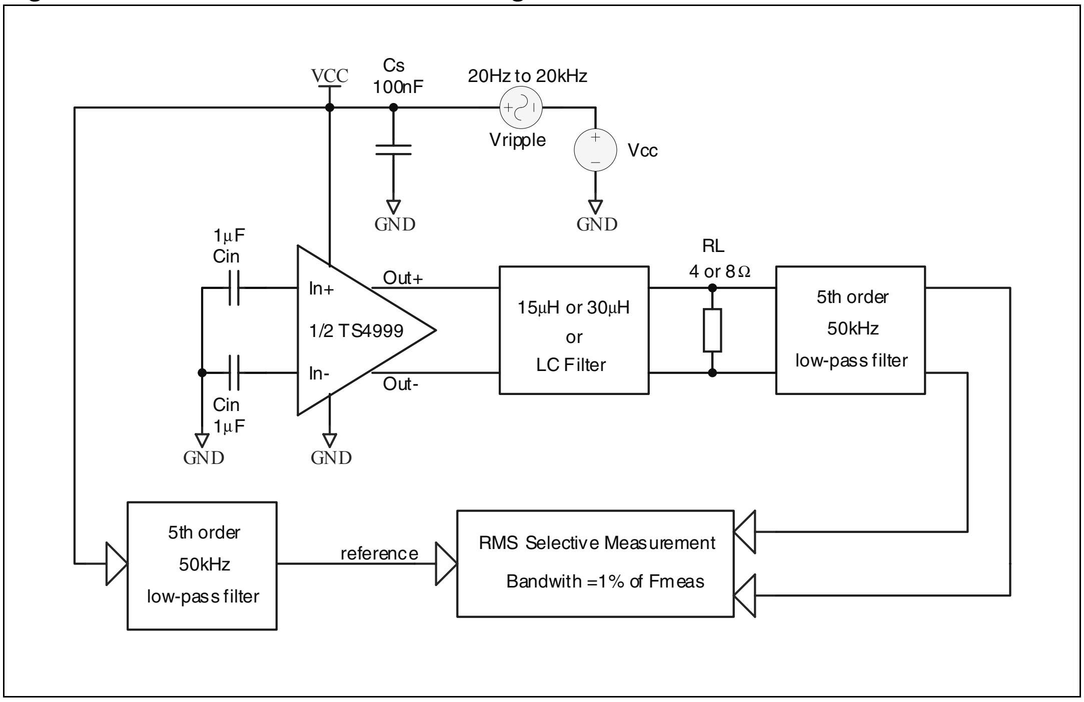


Figure 4. Current consumption vs. power supply voltage

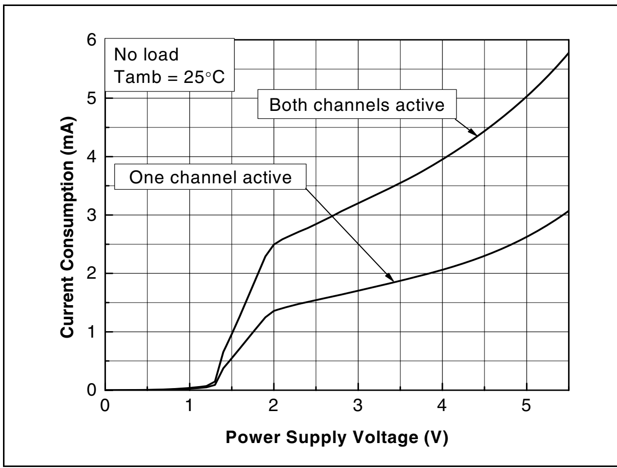


Figure 5. Current consumption vs. standby voltage (one channel)

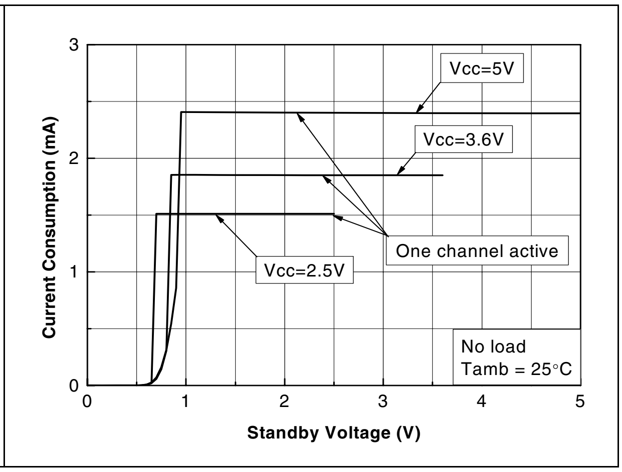


Figure 6. Standby current consumption vs. power supply voltage

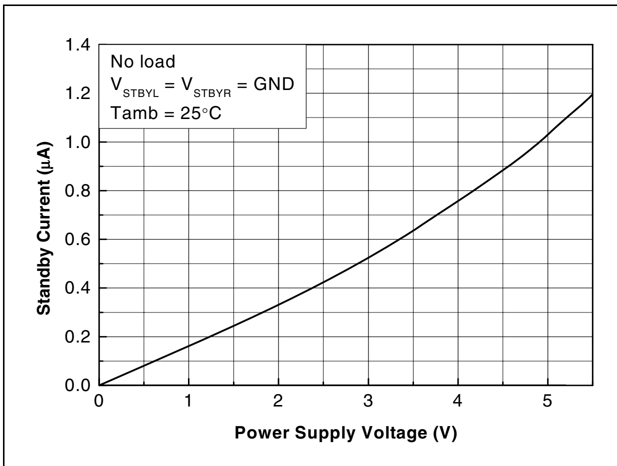


Figure 7. Efficiency vs. output power (one channel)

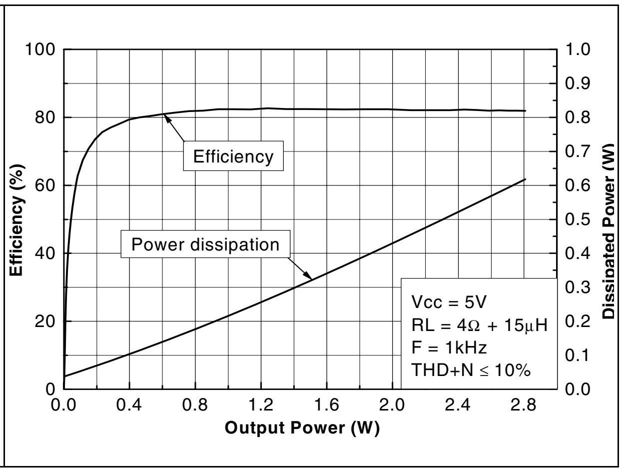


Figure 8. Efficiency vs. output power (one channel)

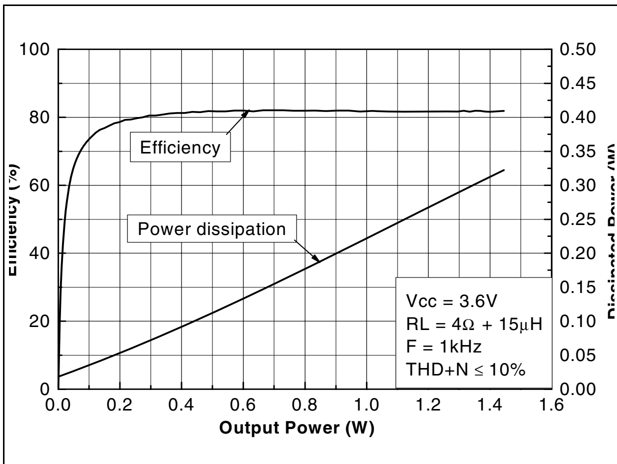


Figure 9. Efficiency vs. output power (one channel)

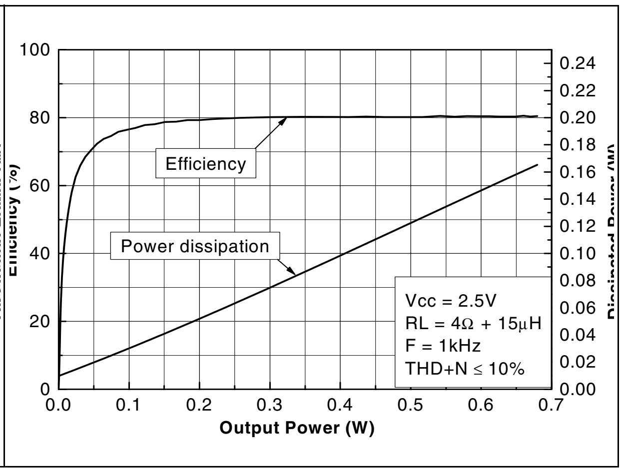


Figure 10. Efficiency vs. output power (one channel)

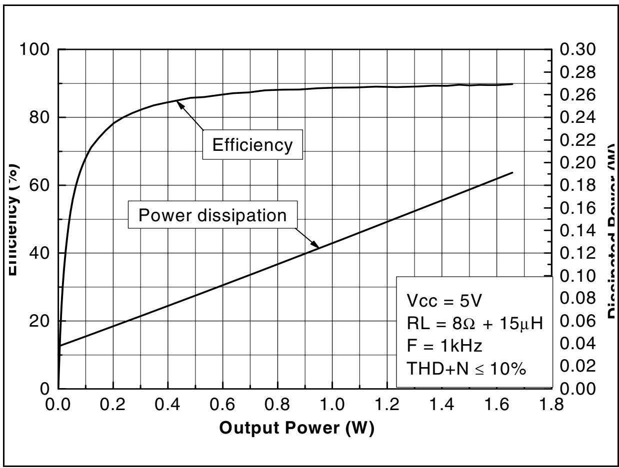


Figure 11. Efficiency vs. output power (one channel)

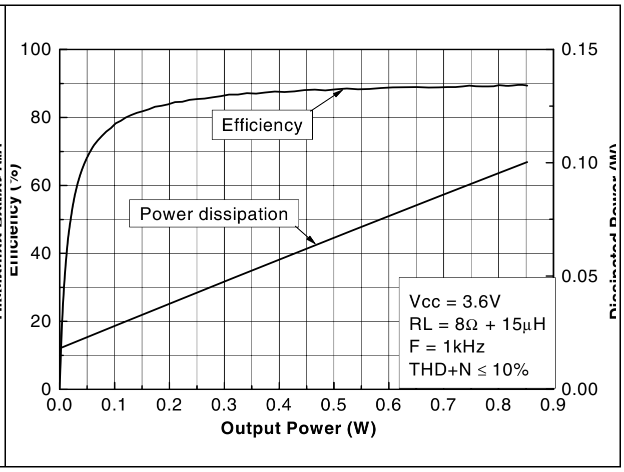


Figure 12. Efficiency vs. output power (one channel)

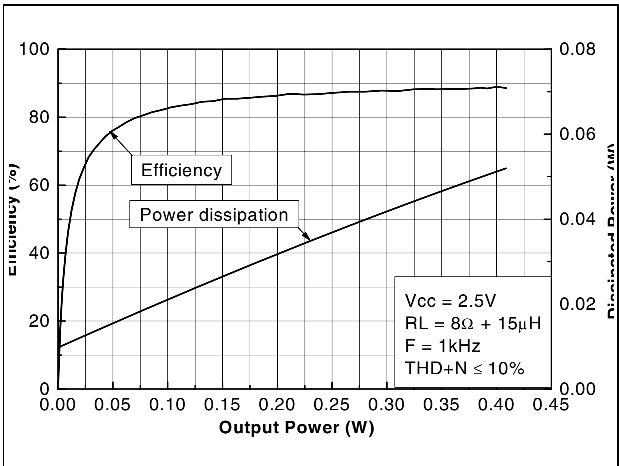


Figure 13. THD+N vs. output power

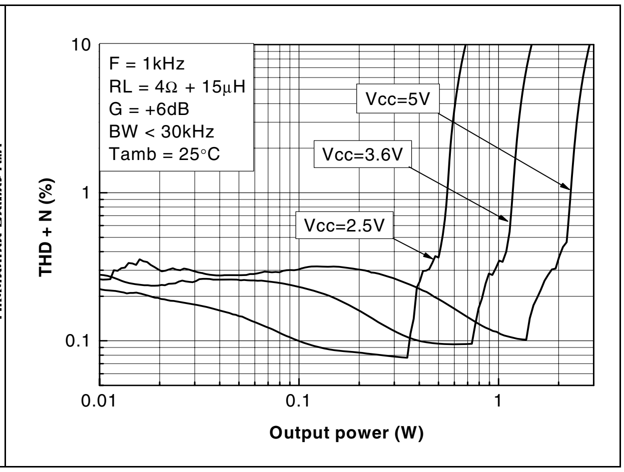


Figure 14. THD+N vs. output power

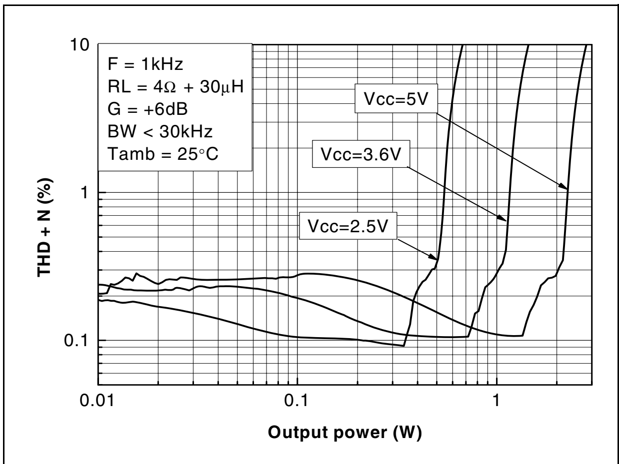


Figure 15. THD+N vs. output power

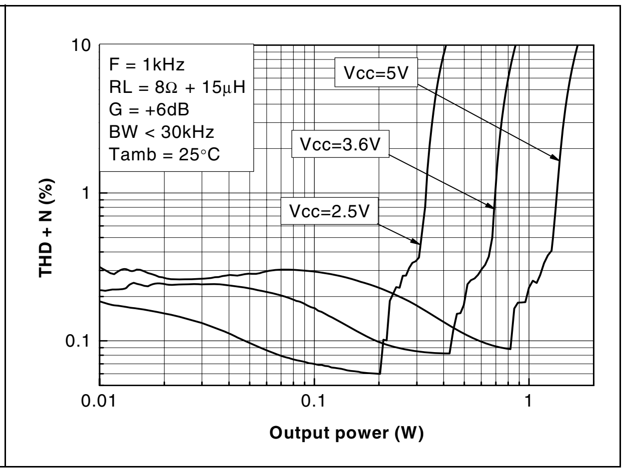


Figure 16. THD+N vs. output power

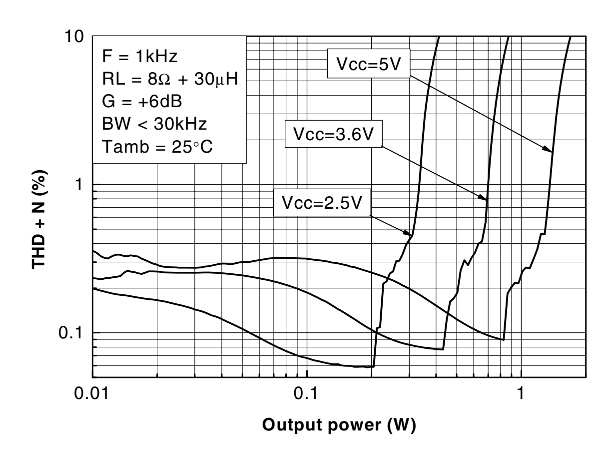


Figure 17. THD+N vs. frequency

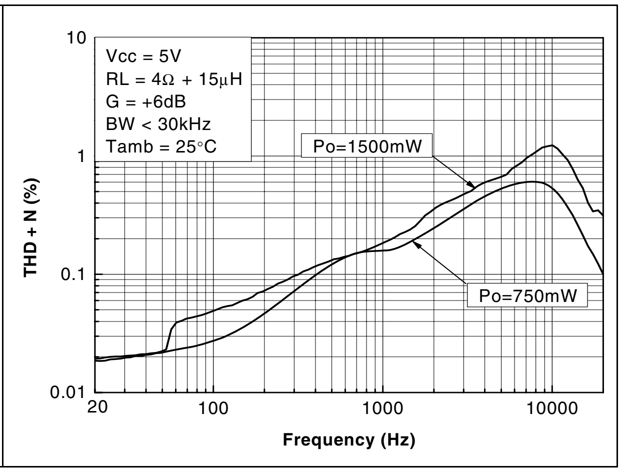


Figure 18. THD+N vs. frequency

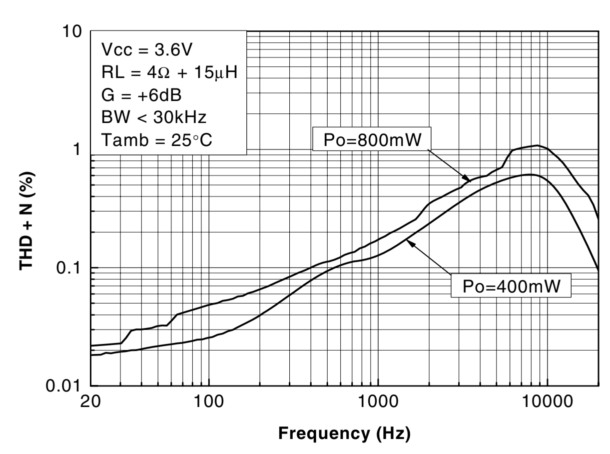


Figure 19. THD+N vs. frequency

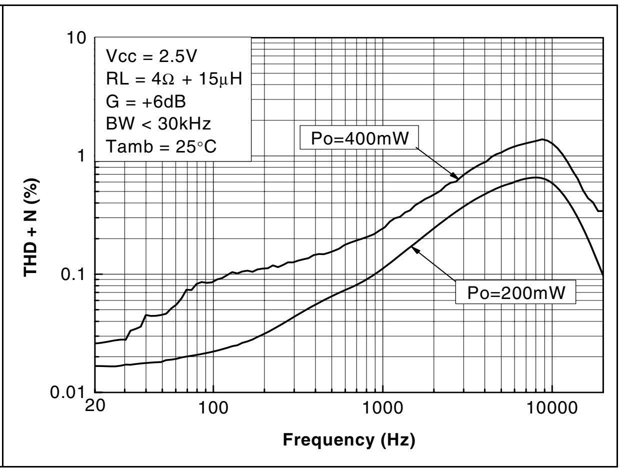


Figure 20. THD+N vs. frequency

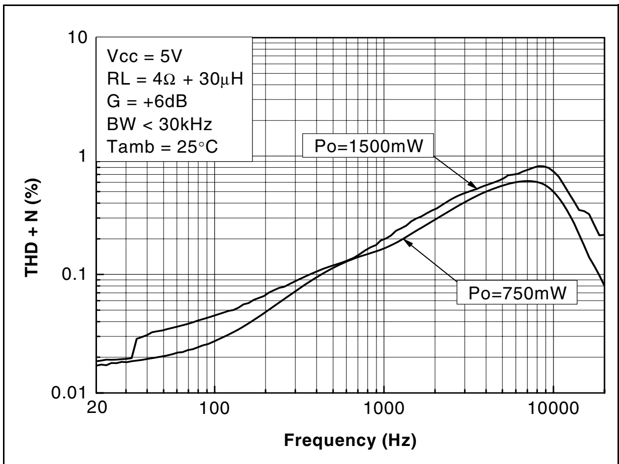


Figure 21. THD+N vs. frequency

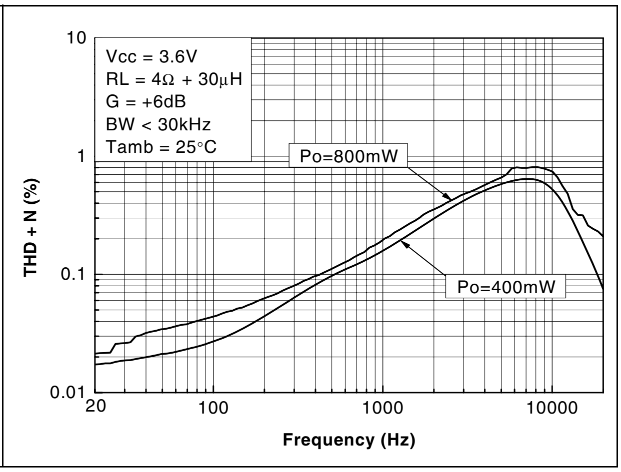


Figure 22. THD+N vs. frequency

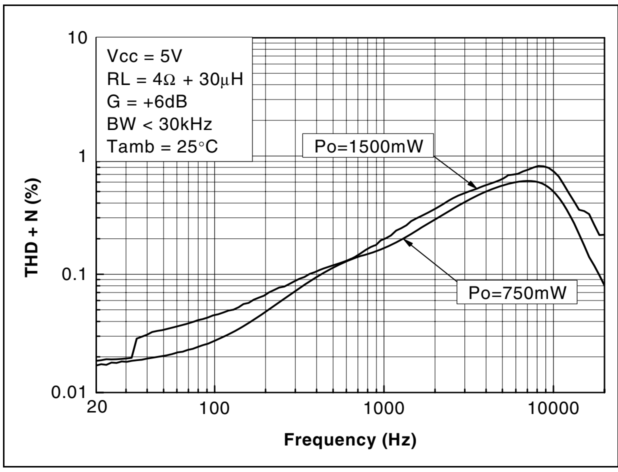


Figure 23. THD+N vs. frequency

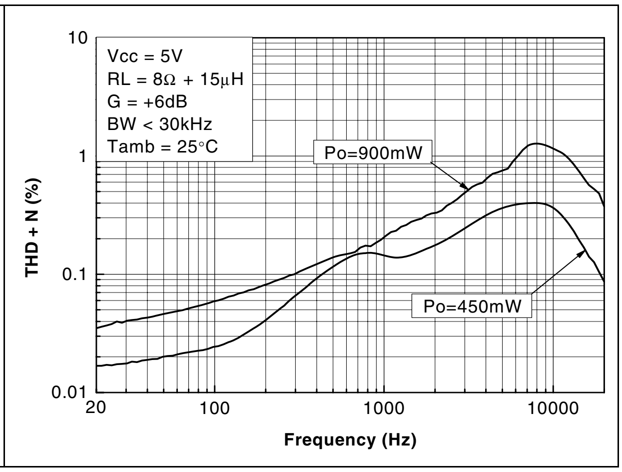


Figure 24. THD+N vs. frequency

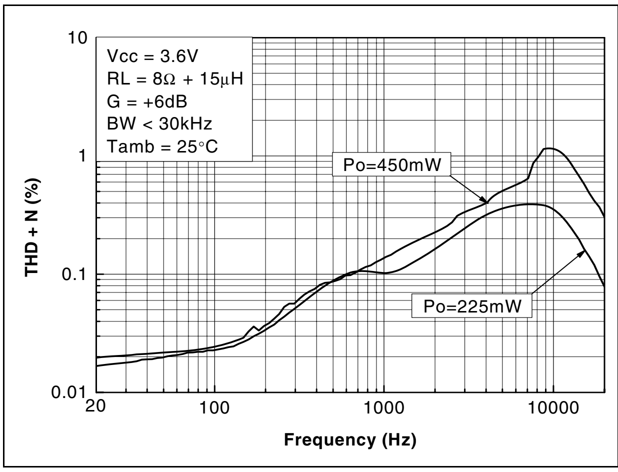


Figure 25. THD+N vs. frequency

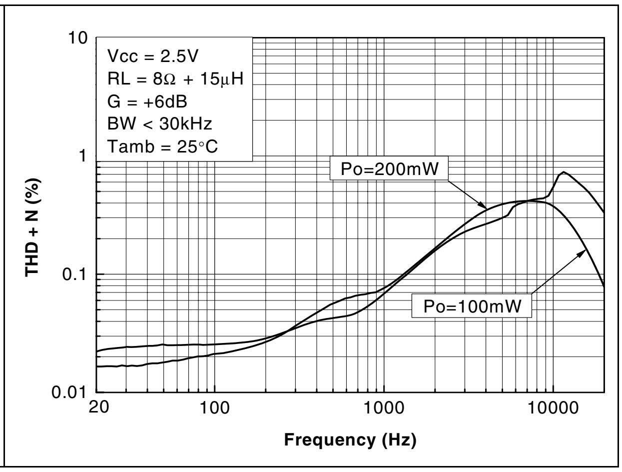


Figure 26. THD+N vs. frequency

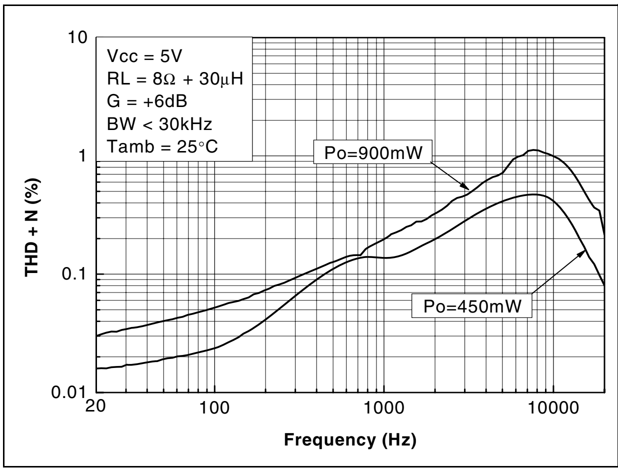


Figure 27. THD+N vs. frequency

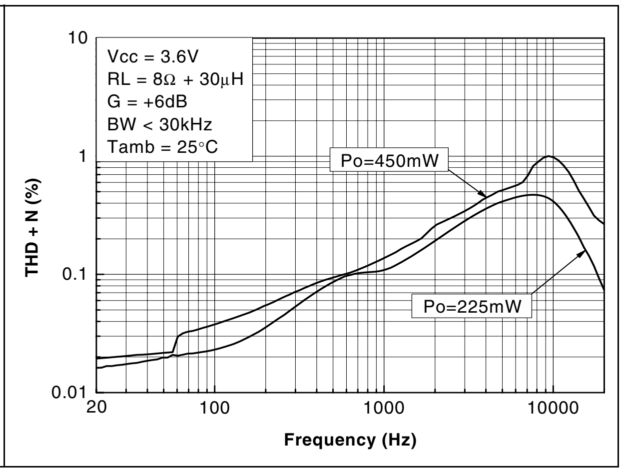


Figure 28. THD+N vs. frequency

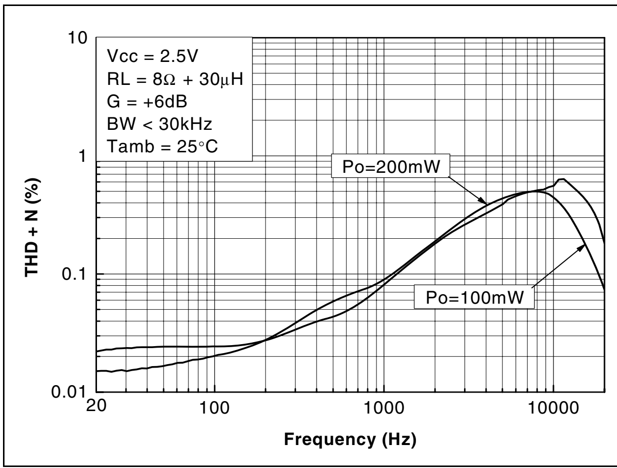


Figure 29. Output power vs. power supply voltage

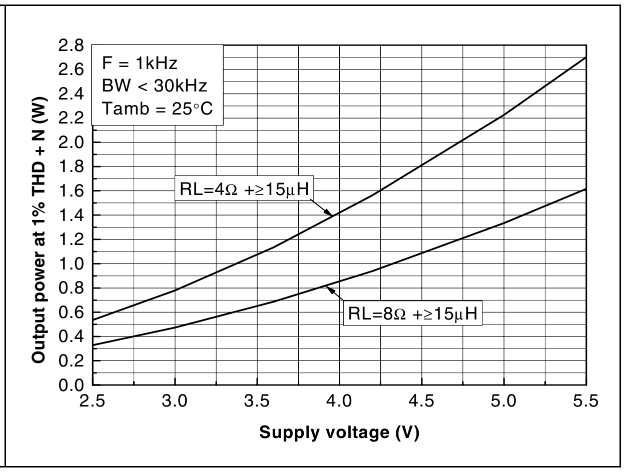


Figure 30. Output power vs. power supply voltage

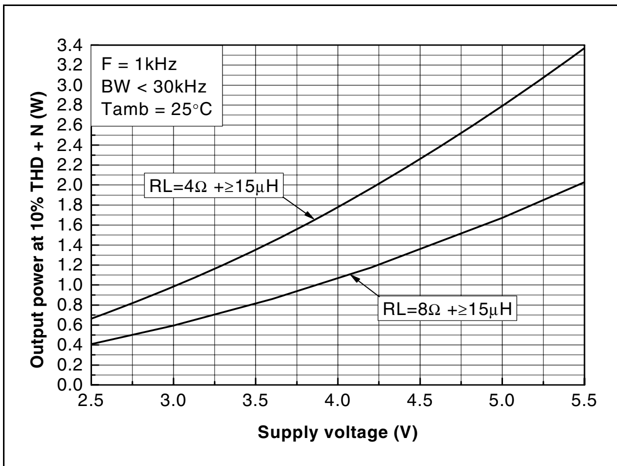


Figure 31. Crosstalk vs. frequency (3D effect off)

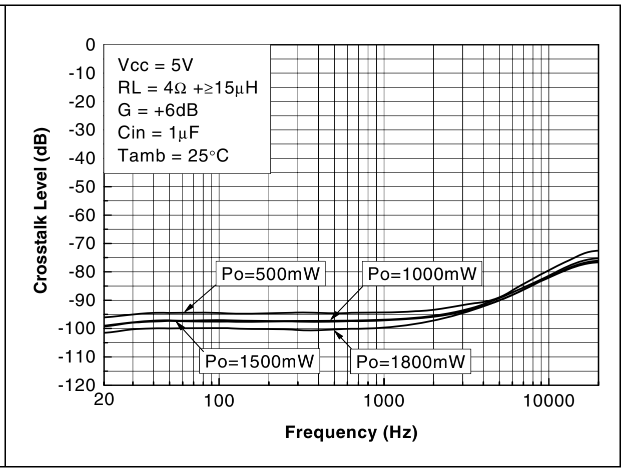


Figure 32. Crosstalk vs. frequency (3D effect off)

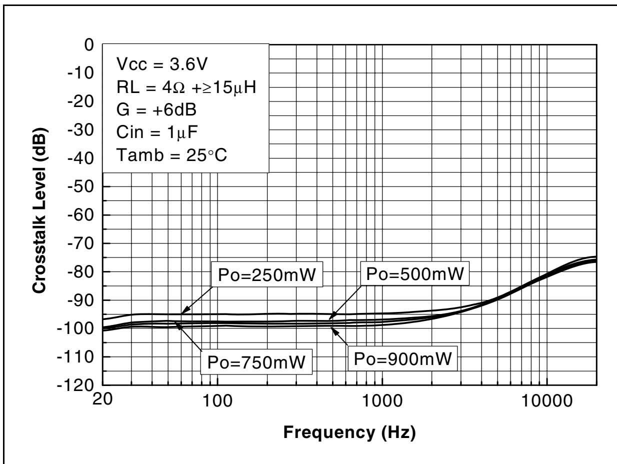


Figure 33. Crosstalk vs. frequency (3D effect off)

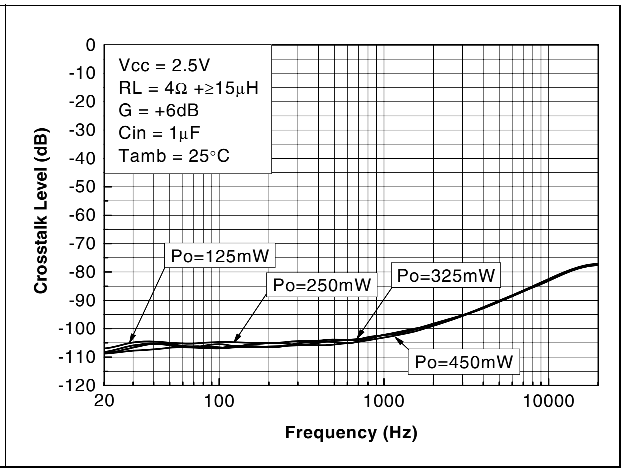


Figure 34. Crosstalk vs. frequency (3D effect off)

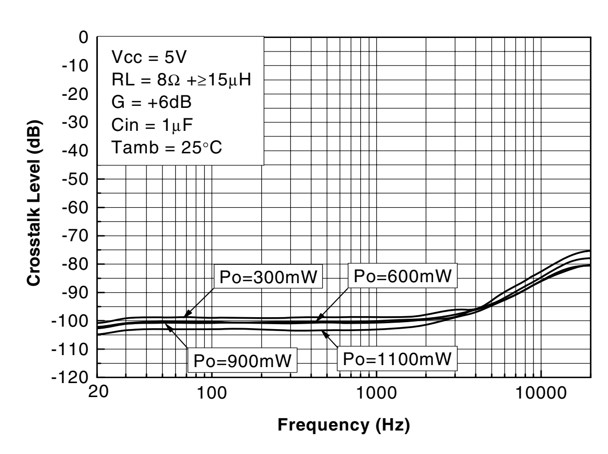


Figure 35. Crosstalk vs. frequency (3D effect off)

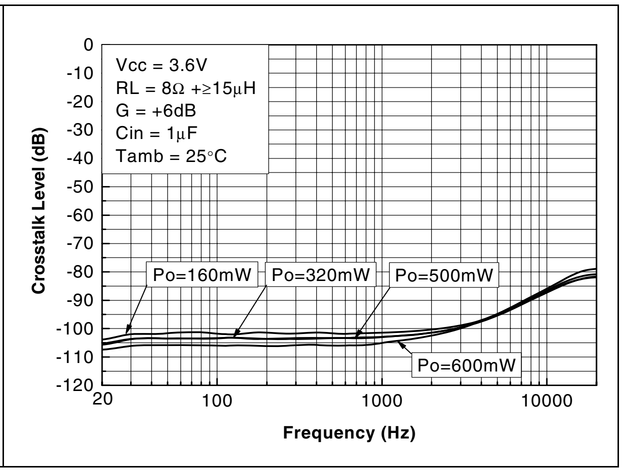


Figure 36. Crosstalk vs. frequency (3D effect off)

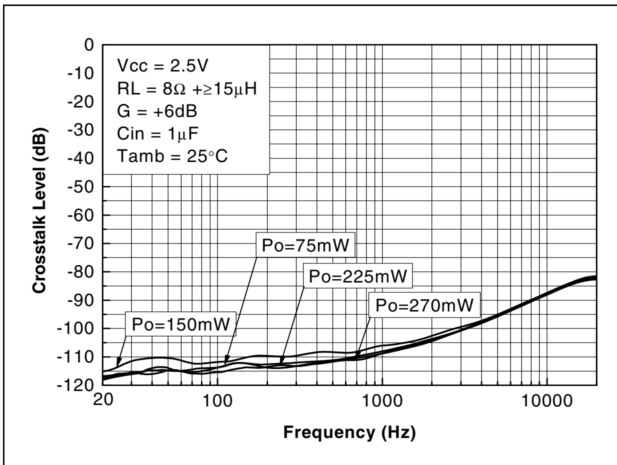


Figure 37. Gain vs. frequency (3D effect off)

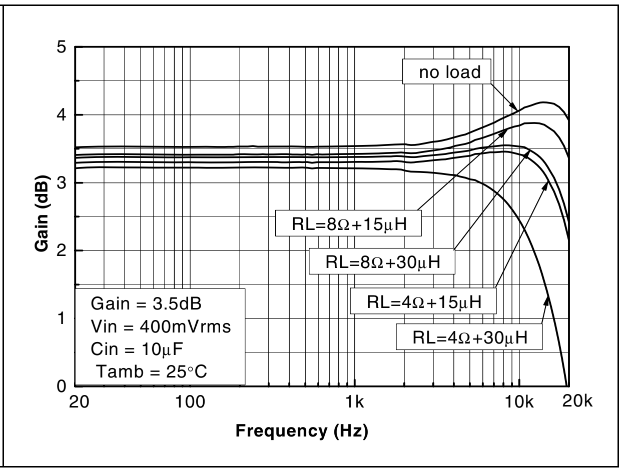


Figure 38. Gain vs. frequency (3D effect off)

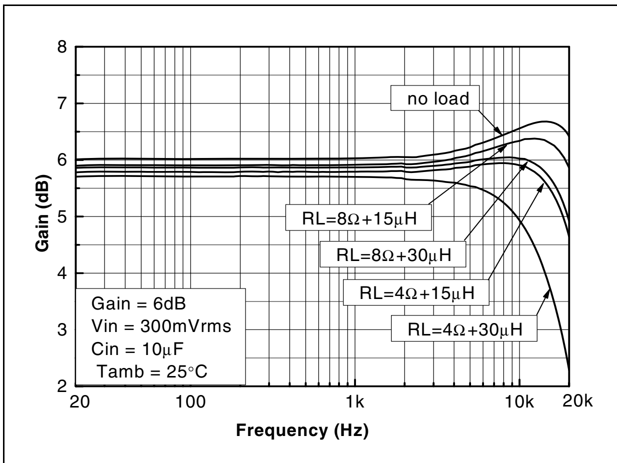


Figure 39. Gain vs. frequency (3D effect off)

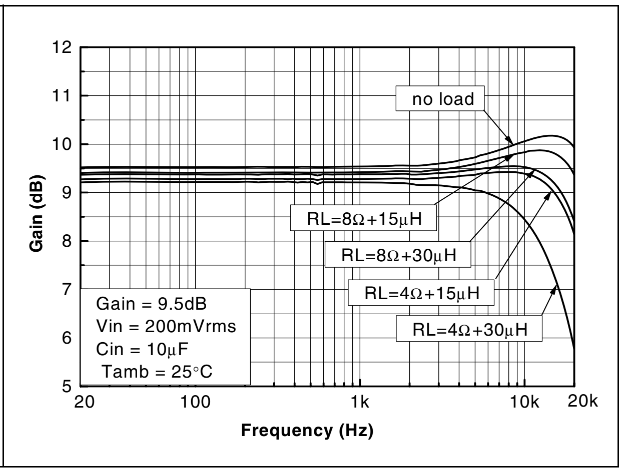


Figure 40. Gain vs. frequency (3D effect off)

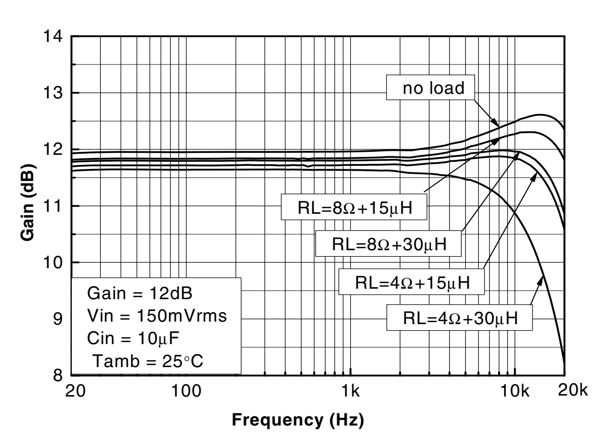


Figure 41. PSRR vs. frequency (3D effect off)

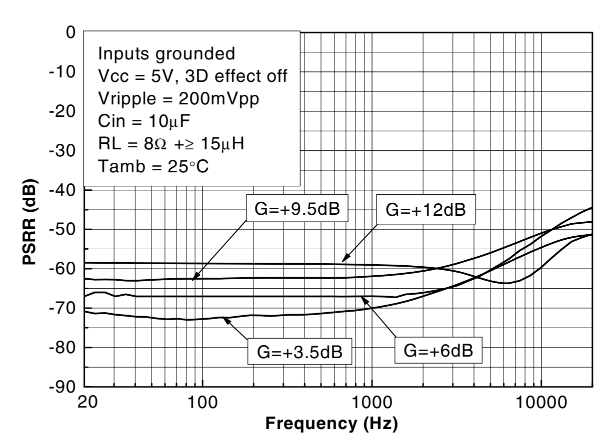


Figure 42. PSRR vs. frequency (3D effect off)

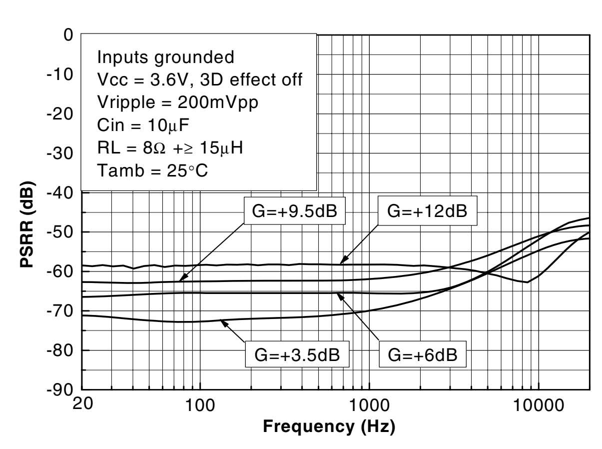


Figure 43. PSRR vs. frequency (3D effect off)

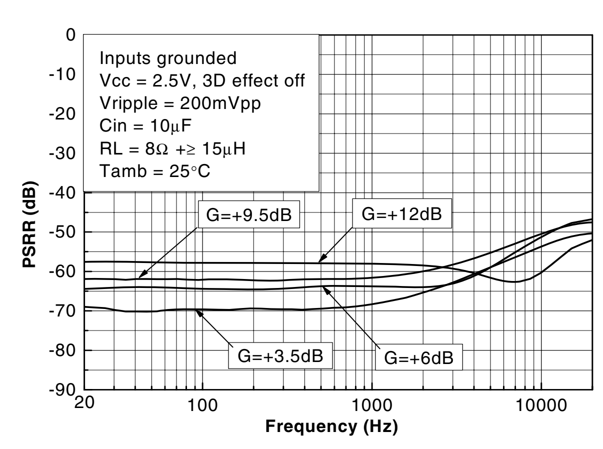


Figure 44. PSRR vs. frequency (3D effect on)

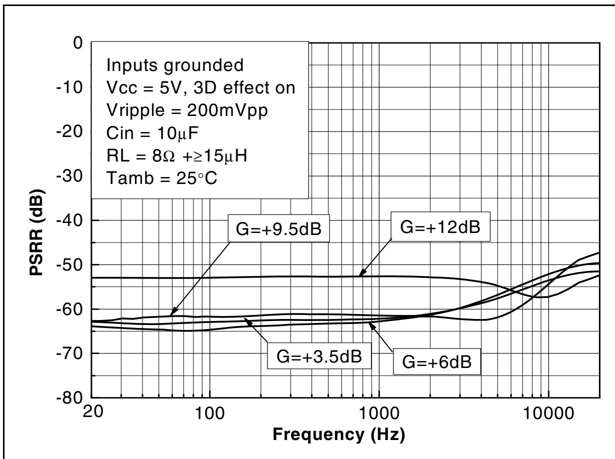


Figure 45. PSRR vs. frequency (3D effect on)

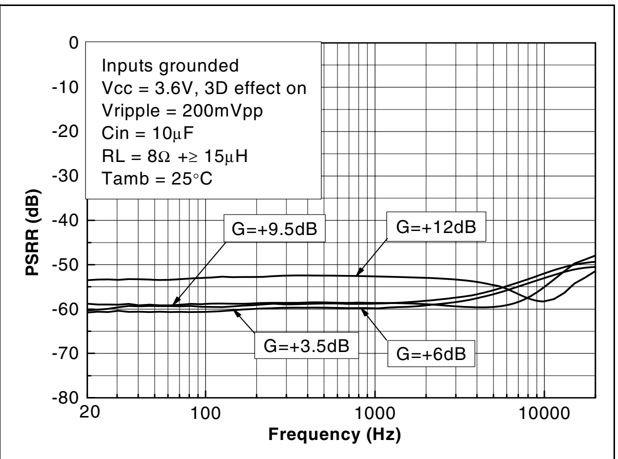


Figure 46. PSRR vs. frequency (3D effect on)

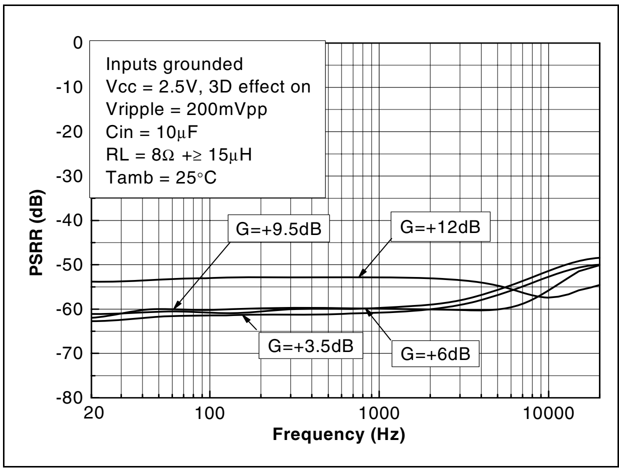


Figure 47. CMRR vs. frequency (3D effect off)

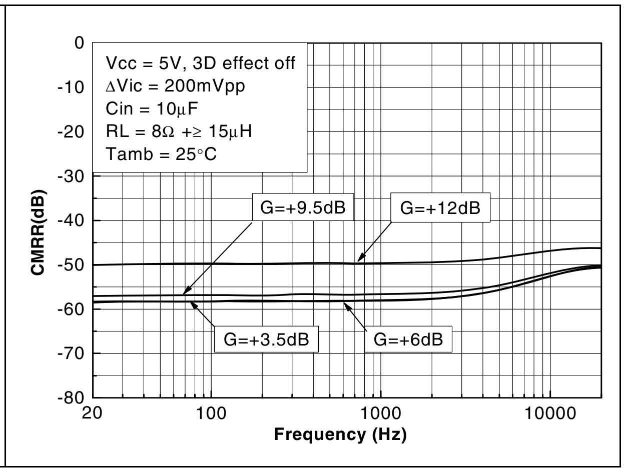


Figure 48. CMRR vs. frequency (3D effect off)

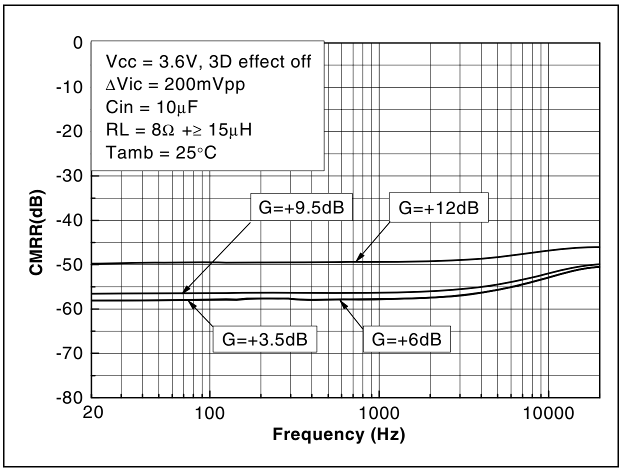


Figure 49. CMRR vs. frequency (3D effect off)

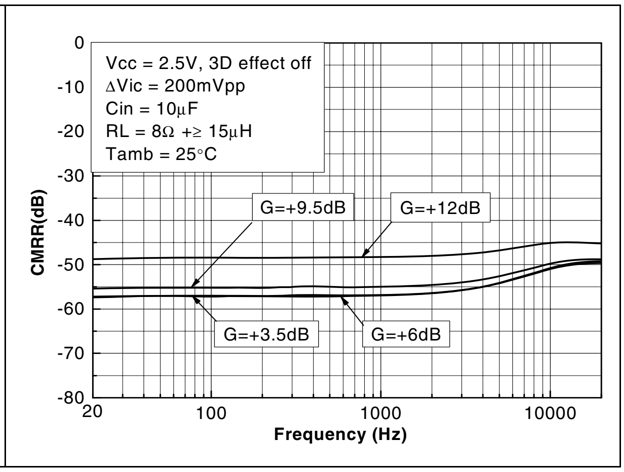


Figure 50. CMRR vs. frequency (3D effect on)

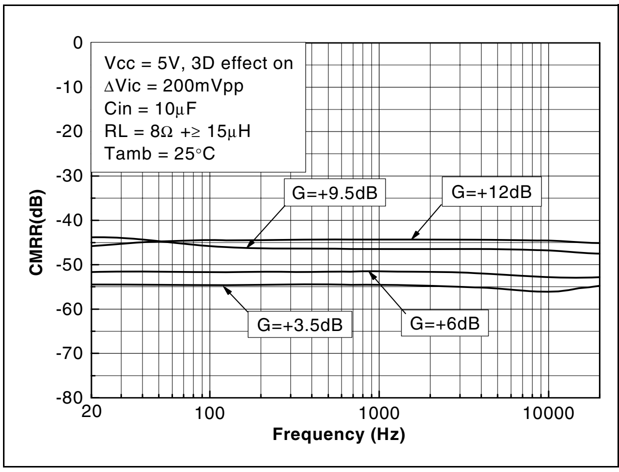


Figure 51. CMRR vs. frequency (3D effect on)

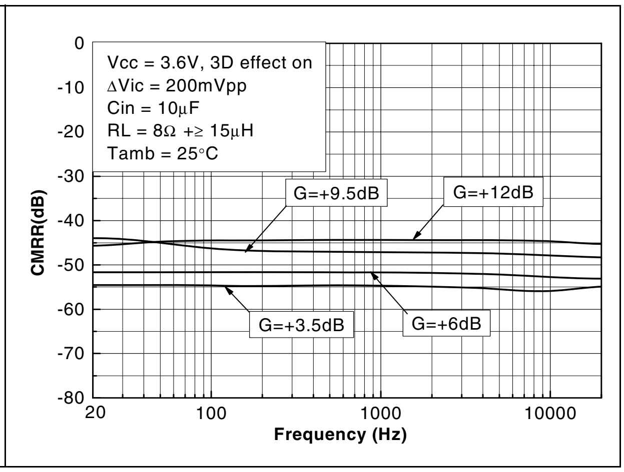


Figure 52. CMRR vs. frequency (3D effect on)

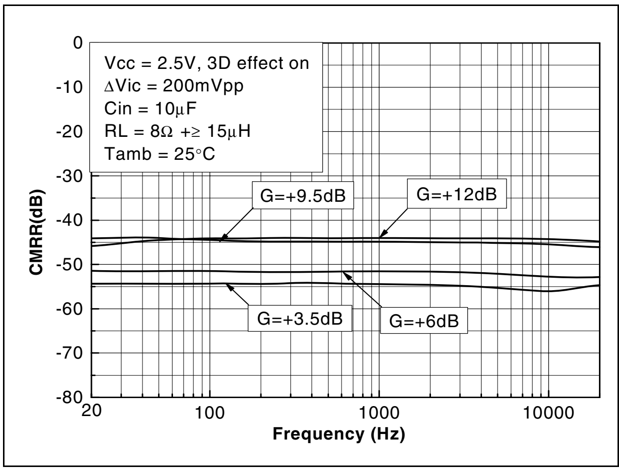


Figure 53. Power derating curves

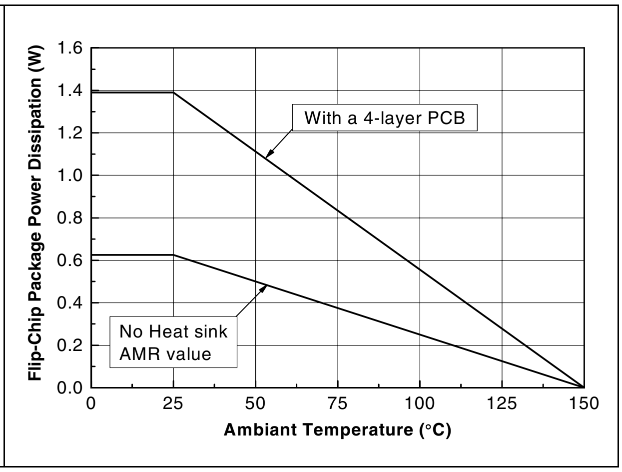


Figure 54. Startup and shutdown phase V_{CC}= 5 V, G= 6 dB, C_{in}= 1 µF, V_{in}= 2 V_{pp}, F= 500 Hz

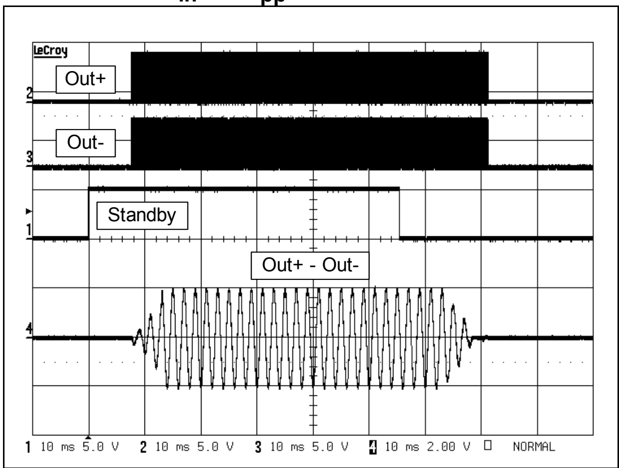
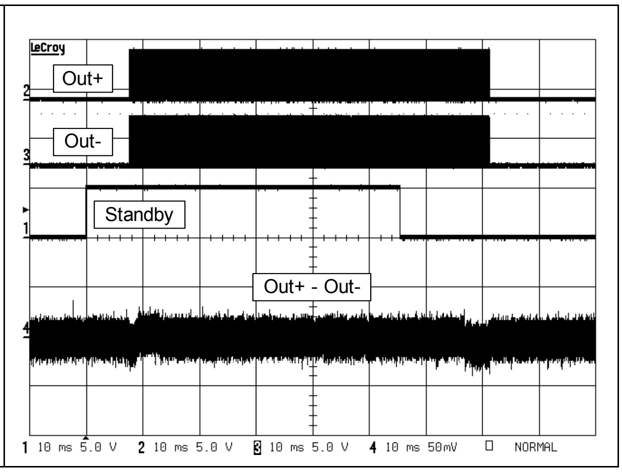


Figure 55. Startup and shutdown phase V_{CC}= 5 V, G= 6 dB, C_{in}= 1 µF, inputs grounded



4 Application information

4.1 Differential configuration principle

The TS4999 is a monolithic fully-differential input/output class D stereo power amplifier. The TS4999 also features 3D effect enhancement that can be switched on or off by one digital pin. Additionally, since the load is connected differentially compared to a single-ended topology, the output is four times higher for the same power supply voltage.

A fully-differential amplifier offers the following advantages.

- A high PSRR (power supply rejection ratio).
- A high common mode noise rejection.
- Virtually zero pop with no additional circuitry, giving a faster start-up time compared to conventional single-ended input amplifiers.
- Easier interfacing with differential output audio DACs.

4.2 Gain settings

In the flat region of the frequency-response curve (no input coupling capacitor or internal feedback loop + load effect), the differential gain can be set to 3.5, 6, 9.5 or 12 dB, depending on the logic level of the G0 and G1 pins, as shown in *Table 11*.

Table 11. Gain settings with G0 and G1 pins

G1	G0	Gain (dB)	Gain (V/V)
0	0	3.5	1.5
0	1	6	2
1	0	9.5	3
1	1	12	4

Note: Between pins G0, G1 and GND there is an internal 300 kΩ (+/-20%) resistor. When the pins are floating, the gain is 6 dB. In full standby (left and right channels OFF), these resistors are disconnected (HiZ input).

4.3 3D effect enhancement

The TS4999 features 3D audio effects which can be switched off and switched on through input pin 3D when used as a digital interface. The relation between the logic level of this pin and the on/off 3D effect is shown in *Table 3 on page 4* and *Table 7 on page 6*.

The 3D audio effect evokes the perception of spatial hearing of stereo audio signals and improves this effect in cases where the stereo speakers are too close to each other, such as in small or portable devices.

The perceived amount of 3D effect also depends on many factors such as speaker position, distance between speakers, listener/frequency spectrum of the audio signal, as well as the difference of signal between the left and right channel.

In some cases, the speaker volume can increase when the 3D effect is switched on. This factor is dependent on the composition and frequency spectrum of listened stereo audio signal.

Note: 1 When the 3D effect is switched on, both channels must be in operation or shutdown mode at the same time.

2 Between pin 3D and GND there is an internal 300 kΩ (+/-20%) resistor. When the pin is floating, the 3D effect is off. In full standby (left and right channels OFF), this resistor is disconnected (HiZ input).

4.4 Low frequency response

If a low frequency bandwidth limitation is required, input coupling capacitors can be used. In the low frequency region, the input coupling capacitor C_{in} starts to have an effect. C_{in} forms, with the input impedance Z_{in}, a first order high-pass filter with a -3 dB cut-off frequency.

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

So, for a desired cut-off frequency F_{CL}, C_{in} is calculated as follows:

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

with F_{CL} in Hz, Z_{in} in Ω and C_{in} in F.

The input impedance Z_{in} is for the whole power supply voltage range and changes with the gain setting. There is also a tolerance around the typical values (see *Table 8*, *Table 9* and *Table 10*.

Figure 56. Cut-off frequency vs. input capacitor