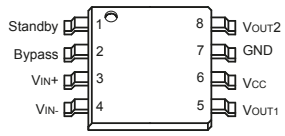
# TS419, TS421

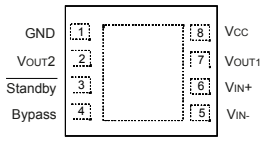
Datasheet

## 360 mW mono amplifier with standby mode

TS419IST : MiniSO8




TS421IQT : DFN8




## Features

- Operating from $V_{CC}$ = 2 V to 5.5 V
- Standby mode active high (TS419) or low (TS421)
- Output power into 16 Ω: 367 mW @ 5 V with 10% THD+N max or 295 mW @ 5 V and 110 mW @ 3.3 V with 1% THD+N max.
- Low current consumption: 2.5 mA max.
- High signal-to-noise ratio: 95 dB (A) at 5 V
- PSRR: 56 dB typ. at 1 kHz, 46 dB at 217 Hz
- Short-circuit limitation
- ON/OFF click reduction circuitry
- Available in MiniSO8 and DFN 3x3

## Applications

- 16/32 Ω earpiece or receiver speaker driver
- Mobile and cordless phones (analog / digital)
- PDAs & computers
- Portable appliances

## Description

The TS419/TS421 is a monaural audio power amplifier driving in BTL mode a 16 or 32 Ω earpiece or receiver speaker. The main advantage of this configuration is to get rid of bulky output capacitors.

Capable of descending to low voltages, it delivers up to 220 mW per channel (into 16 Ω loads) of continuous average power with 0.2% THD+N in the audio bandwidth from a 5 V power supply.

An externally controlled standby mode reduces the supply current to 10 nA (typ.). The TS419 / TS421 can be configured by external gain-setting resistors.

| Maturity status link |
| --- |
| TS3431 |

# 1 Maximum ratings

**Table 1. Absolute maximum ratings**

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| $V_{CC}$ | Supply voltage (1) | 6 | V |
| $V_i$ | Input voltage | -0.3 V to $V_{CC}$ +0.3 V | V |
| $T_{stg}$ | Storage temperature | -65 to +150 | °C |
| $T_j$ | Maximum junction temperature | 150 | °C |
| $R_{thja}$ | Thermal resistance junction-to-ambient<br>MiniSO8<br>DFN8 | <br>215<br>70 | °C/W |
| $P_d$ | Power dissipation (2)<br>MiniSO8<br>DFN8 | <br>0.58<br>1.79 | W |
| ESD | Human body model (pin to pin): TS419 (3), TS421 | 1.5 | kV |
| ESD | Machine Model - 220 pF - 240 pF (pin to pin) | 100 | V |
| Latch-up | Latch-up Immunity (All pins) | 200 | mA |
| | Lead temperature (soldering, 10 s) | 250 | °C |
| | Output short-circuit to $V_{CC}$ or GND | continuous (4) | |

1. *All voltage values are measured with respect to the ground pin.*
2. *Pd has been calculated with Tamb = 25 °C, Tj = 150 °C.*
3. *TS419 stands 1.5 KV on all pins except standby pin which stands 1 KV*
4. *Attention must be paid to continous power dissipation ($V_{DD}$ x 300 mA). Exposure of the IC to a short circuit for an extended time period is dramatically reducing product life expectancy.*

**Table 2. Operating conditions**

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| $V_{CC}$ | Supply voltage | 2 to 5.5 | V |
| $R_L$ | Load resistor | ≥ 16 | Ω |
| $T_{oper}$ | Operating free air temperature range | -40 to +85 | °C |
| $C_L$ | Load capacitor<br>$R_L$ = 16 to 100 Ω<br>$R_L$ > 100 Ω | <br>400<br>100 | pF |
| $V_{ICM}$ | Common mode input voltage range | GND to $V_{CC}$ - 1 V | V |
| $V_{STB}$ | Standby voltage input<br>TS421 ACTIVE / TS419 in STANDBY<br>TS421 in STANDBY / TS419 ACTIVE | $1.5 \le V_{STB} \le V_{CC}$<br>$GND \le V_{STB} \le 0.4$<br>(1) | V |
| $R_{thja}$ | Thermal resistance junction-to-ambient<br>MiniSO8<br>DFN8<br>(2) | <br>190<br>41 | °C/W |

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| $T_{wu}$ | Wake-up time from standby to active mode (Cb = 1 µF) (3) | ≥ 0.12 | s |

1. *The minimum current consumption ($I_{STANDBY}$) is guaranteed at $V_{CC}$ (TS419) or GND (TS421) for the whole temperature range.*
2. *When mounted on a 4-layer PCB.*
3. *For more details on $T_{WU}$, please refer to application note section on Wake-up time page 28.*

# 2 Typical application schematics

**Figure 1. Application schematics**

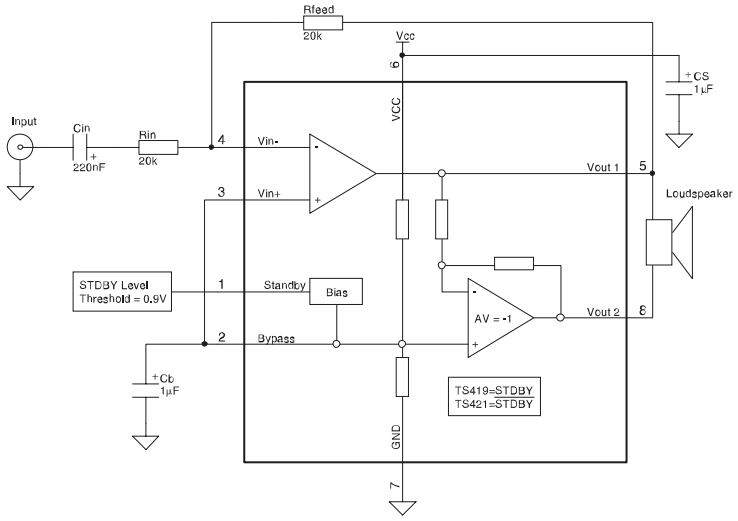



**Table 3. Application components information**

| 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 $C_{IN}$ ($f_{cl}$ = 1 / (2 x $P_i$ x $R_{IN}$ x $C_{IN}$)). |
| $C_{IN}$ | Input coupling capacitor which blocks the DC voltage at the amplifier's input terminal. |
| $R_{FEED}$ | Feedback resistor which sets the closed loop gain in conjunction with $R_{IN}$. $A_V$ = Closed Loop Gain= 2 x $R_{FEED}$ / $R_{IN}$. |
| $C_S$ | Supply bypass capacitor which provides power supply filtering. |
| $C_B$ | Bypass capacitor which provides half supply filtering. |

# 3 Electrical characteristics

**Table 4. Electrical characteristics $V_{CC}$ = +5 V, GND = 0 V, $T_{amb}$ = 25 °C (unless otherwise specified)**

| Symbol | Parameter | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| $I_{CC}$ | Supply current<br>No input signal, no load | | 6 | 8 | mA |
| $I_{STANDBY}$ | Standby current<br>No input signal, $V_{STANDBY}$ = GND for TS421<br>No input signal, $V_{STANDBY}$ = $V_{CC}$ for TS419 | | 10 | 1000 | nA |
| $V_{OO}$ | Output offset voltage<br>No input signal, $R_L$ = 16 Ω or 32 Ω, $R_{feed}$ = 20 kΩ | | 5 | 25 | mV |
| $P_O$ | Output power<br>THD+N = 0.1% Max, F = 1 kHz, $R_L$ = 32 Ω | | 190 | | mW |
| | Output power<br>THD+N = 1% Max, F = 1 kHz, $R_L$ = 32 Ω | 166 | 207 | | |
| | Output power<br>THD+N = 10% Max, F = 1 kHz, $R_L$ = 32 Ω | | 258 | | |
| | Output power<br>THD+N = 0.1% Max, F = 1 kHz, $R_L$ = 16 Ω | | 270 | | |
| | Output power<br>THD+N = 1% Max, F = 1 kHz, $R_L$ = 16 Ω | 240 | 295 | | |
| | Output power<br>THD+N = 10% Max, F = 1 kHz, $R_L$ = 16 Ω | | 367 | | |
| THD + N | Total harmonic distortion + noise (Av = 2)<br>$R_L$ = 32 Ω, $P_{out}$ = 150 mW, 20 Hz ≤ F ≤ 20 kHz<br>$R_L$ = 16 Ω, $P_{out}$ = 220 mW, 20 Hz ≤ F ≤ 20 kHz | | 0.15<br>0.2 | | % |
| PSRR | Power supply rejection ratio (Av = 2)<br>F = 1 kHz, $V_{ripple}$ = 200 mVpp, input grounded, $C_b$ = 1 µF | 50 | 56 | | dB |
| SNR | Signal-to-Noise Ratio (Filter Type A, Av = 2) (1)<br>($R_L$ = 32 Ω, THD +N < 0.5%, 20 Hz ≤ F ≤ 20 kHz) | 85 | 98 | | dB |
| $\phi_M$ | Phase margin at unity gain<br>$R_L$ = 16 Ω, $C_L$ = 400 pF | | 58 | | Degrees |
| GM | Gain margin<br>$R_L$ = 16 Ω, $C_L$ = 400 pF | | 18 | | dB |
| GBP | Gain bandwidth product<br>$R_L$ = 16 Ω | | 1.1 | | MHz |
| SR | Slew rate<br>$R_L$ = 16 Ω | | 0.4 | | V/µS |

1. *Guaranteed by design and evaluation.*

**Table 5. Electrical characteristics $V_{CC}$ = +3.3 V, GND = 0 V, $T_{amb}$ = 25 °C (unless otherwise specified)**

| Symbol | Parameter | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| $I_{CC}$ | Supply current<br>No input signal, no load | | 1.8 | 2.5 | mA |
| $I_{STANDBY}$ | Standby current<br>No input signal, $V_{STANDBY}$ = GND for TS421<br>No input signal, $V_{STANDBY}$ = $V_{CC}$ for TS419 | | 10 | 1000 | nA |
| $V_{OO}$ | Output offset voltage<br>No input signal, $R_L$ = 16 Ω or 32 Ω, $R_{feed}$ = 20 kΩ | | 5 | 25 | mV |
| $P_O$ | Output power<br>THD+N = 0.1% Max, F = 1 kHz, $R_L$ = 32 Ω | | 75 | | mW |
| | Output power<br>THD+N = 1% Max, F = 1 kHz, $R_L$ = 32 Ω | 65 | 81 | | |
| | Output power<br>THD+N = 10% Max, F = 1 kHz, $R_L$ = 32 Ω | | 102 | | |
| | Output power<br>THD+N = 0.1% Max, F = 1 kHz, $R_L$ = 16 Ω | | 104 | | |
| | Output power<br>THD+N = 1% Max, F = 1 kHz, $R_L$ = 16 Ω | 91 | 113 | | |
| | Output power<br>THD+N = 10% Max, F = 1 kHz, $R_L$ = 16 Ω | | 143 | | |
| THD + N | Total harmonic distortion + noise (Av = 2)<br>$R_L$ = 32 Ω, $P_{out}$ = 150 mW, 20 Hz ≤ F ≤ 20 kHz<br>$R_L$ = 16 Ω, $P_{out}$ = 220 mW, 20 Hz ≤ F ≤ 20 kHz | | 0.15<br>0.2 | | % |
| PSRR | Power supply rejection ratio (Av = 2)<br>F = 1 kHz, $V_{ripple}$ = 200 mVpp, input grounded, $C_b$ = 1 µF | 50 | 56 | | dB |
| SNR | Signal-to-Noise Ratio (Weighted A, Av = 2)<br>($R_L$ = 32 Ω, THD +N < 0.5%, 20 Hz ≤ F ≤ 20 kHz) | 82 | 94 | | dB |
| $\phi_M$ | Phase margin at unity gain<br>$R_L$ = 16 Ω, $C_L$ = 400 pF | | 58 | | Degrees |
| GM | Gain margin<br>$R_L$ = 16 Ω, $C_L$ = 400 pF | | 18 | | dB |
| GBP | Gain bandwidth product<br>$R_L$ = 16 Ω | | 1.1 | | MHz |
| SR | Slew rate<br>$R_L$ = 16 Ω | | 0.4 | | V/µS |

*Note: All electrical values are guaranted with correlation measurements at 2 V and 5 V.*

**Table 6. Electrical characteristics $V_{CC}$ = +2.5 V, GND = 0 V, $T_{amb}$ = 25 °C (unless otherwise specified)**

| Symbol | Parameter | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| $I_{CC}$ | Supply current<br>No input signal, no load | | 1.7 | 2.5 | mA |
| $I_{STANDBY}$ | Standby current<br>No input signal, $V_{STANDBY}$ = GND for TS421<br>No input signal, $V_{STANDBY}$ = $V_{CC}$ for TS419 | | 10 | 1000 | nA |
| $V_{OO}$ | Output offset voltage<br>No input signal, $R_L$ = 16 Ω or 32 Ω, $R_{feed}$ = 20 kΩ | | 5 | 25 | mV |
| $P_O$ | Output power<br>THD+N = 0.1% Max, F = 1 kHz, $R_L$ = 32 Ω | | 37 | | mW |
| | Output power<br>THD+N = 1% Max, F = 1 kHz, $R_L$ = 32 Ω | 32 | 41 | | |
| | Output power<br>THD+N = 10% Max, F = 1 kHz, $R_L$ = 32 Ω | | 52 | | |
| | Output power<br>THD+N = 0.1% Max, F = 1 kHz, $R_L$ = 16 Ω | | 50 | | |
| | Output power<br>THD+N = 1% Max, F = 1 kHz, $R_L$ = 16 Ω | 44 | 55 | | |
| | Output power<br>THD+N = 10% Max, F = 1 kHz, $R_L$ = 16 Ω | | 70 | | |
| THD + N | Total harmonic distortion + noise (Av = 2)<br>$R_L$ = 32 Ω, $P_{out}$ = 150 mW, 20 Hz ≤ F ≤ 20 kHz<br>$R_L$ = 16 Ω, $P_{out}$ = 220 mW, 20 Hz ≤ F ≤ 20 kHz | | 0.15<br>0.2 | | % |
| PSRR | Power supply rejection ratio (Av = 2)<br>F = 1 kHz, $V_{ripple}$ = 200 mVpp, input grounded, $C_b$ = 1 µF | 50 | 56 | | dB |
| SNR | Signal-to-Noise Ratio (Weighted A, Av = 2)<br>($R_L$ = 32 Ω, THD +N < 0.5%, 20 Hz ≤ F ≤ 20 kHz) | 80 | 91 | | dB |
| $\phi_M$ | Phase margin at unity gain<br>$R_L$ = 16 Ω, $C_L$ = 400 pF | | 58 | | Degrees |
| GM | Gain margin<br>$R_L$ = 16 Ω, $C_L$ = 400 pF | | 18 | | dB |
| GBP | Gain bandwidth product<br>$R_L$ = 16 Ω | | 1.1 | | MHz |
| SR | Slew rate<br>$R_L$ = 16 Ω | | 0.4 | | V/µS |

*Note: All electrical values are guaranted with correlation measurements at 2 V and 5 V.*

**Table 7. Electrical characteristics $V_{CC}$ = +2 V, GND = 0 V, $T_{amb}$ = 25 °C (unless otherwise specified)**

| Symbol | Parameter | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| $I_{CC}$ | Supply current<br>No input signal, no load | | 1.7 | 2.5 | mA |
| $I_{STANDBY}$ | Standby current<br>No input signal, $V_{STANDBY}$ = GND for TS421<br>No input signal, $V_{STANDBY}$ = $V_{CC}$ for TS419 | | 10 | 1000 | nA |
| $V_{OO}$ | Output offset voltage<br>No input signal, $R_L$ = 16 Ω or 32 Ω, $R_{feed}$ = 20 kΩ | | 5 | 25 | mV |
| $P_O$ | Output power<br>THD+N = 0.1% Max, F = 1 kHz, $R_L$ = 32 Ω | | 20 | | mW |
| | Output power<br>THD+N = 1% Max, F = 1 kHz, $R_L$ = 32 Ω | 19 | 23 | | |
| | Output power<br>THD+N = 10% Max, F = 1 kHz, $R_L$ = 32 Ω | | 30 | | |
| | Output power<br>THD+N = 0.1% Max, F = 1 kHz, $R_L$ = 16 Ω | | 26 | | |
| | Output power<br>THD+N = 1% Max, F = 1 kHz, $R_L$ = 16 Ω | 24 | 30 | | |
| | Output power<br>THD+N = 10% Max, F = 1 kHz, $R_L$ = 16 Ω | | 40 | | |
| THD + N | Total harmonic distortion + noise (Av = 2)<br>$R_L$ = 32 Ω, $P_{out}$ = 150 mW, 20 Hz ≤ F ≤ 20 kHz<br>$R_L$ = 16 Ω, $P_{out}$ = 220 mW, 20 Hz ≤ F ≤ 20 kHz | | 0.1<br>0.15 | | % |
| PSRR | Power supply rejection ratio (Av = 2) (1)<br>F = 1 kHz, $V_{ripple}$ = 200 mVpp, input grounded, $C_b$ = 1 µF | 49 | 54 | | dB |
| SNR | Signal-to-Noise Ratio (Weighted A, Av = 2) (1)<br>($R_L$ = 32 Ω, THD +N < 0.5%, 20 Hz ≤ F ≤ 20 kHz) | 80 | 89 | | dB |
| $\phi_M$ | Phase margin at unity gain<br>$R_L$ = 16 Ω, $C_L$ = 400 pF | | 58 | | Degrees |
| GM | Gain margin<br>$R_L$ = 16 Ω, $C_L$ = 400 pF | | 20 | | dB |
| GBP | Gain bandwidth product<br>$R_L$ = 16 Ω | | 1.1 | | MHz |
| SR | Slew rate<br>$R_L$ = 16 Ω | | 0.4 | | V/µS |

1. *Guaranteed by design and evaluation.*

# 4 Electrical characteristics curves

**Figure 2. Open loop gain and phase vs. frequency**

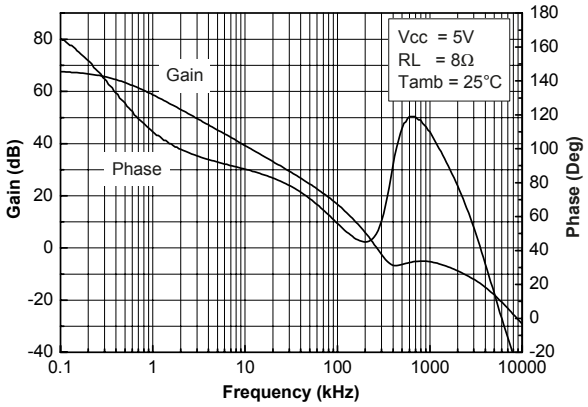



**Figure 3. Open loop gain and phase vs. frequency Vcc = 2 V**

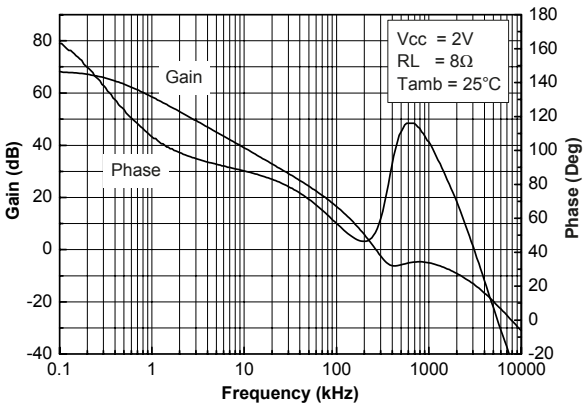



**Figure 4. Open loop gain and phase vs. frequency Vcc = 5 V**

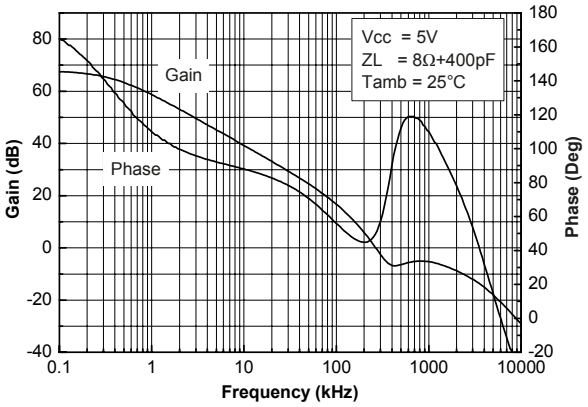



**Figure 5. Open loop gain and phase vs. frequency ZL = 8 Ω**

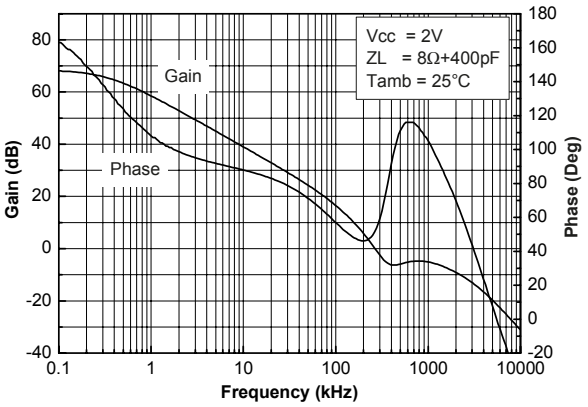


**Figure 6. Open loop gain and phase vs. frequency RL = 16 Ω**

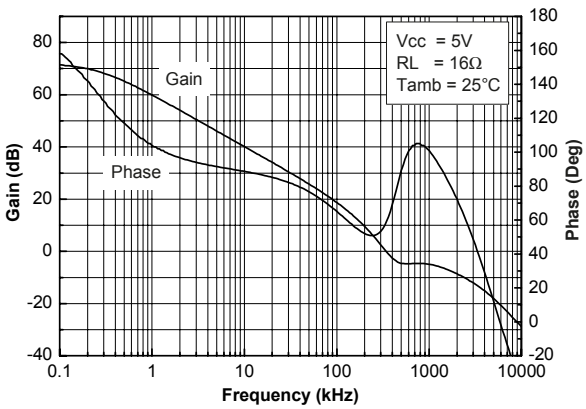



**Figure 7. Open loop gain and phase vs. frequency RL = 16 Ω, Vcc = 2 V**

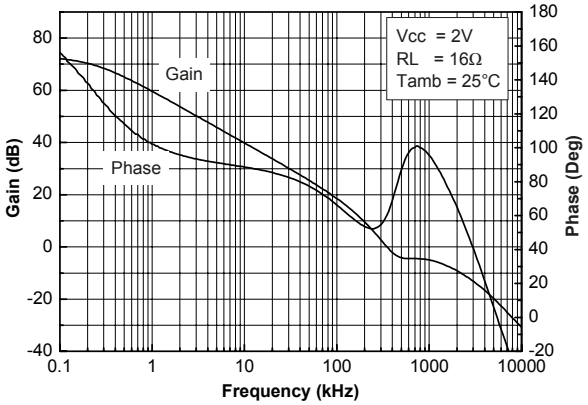



**Figure 8. Open loop gain and phase vs. frequency ZL = 16 Ω, Vcc = 5 V**

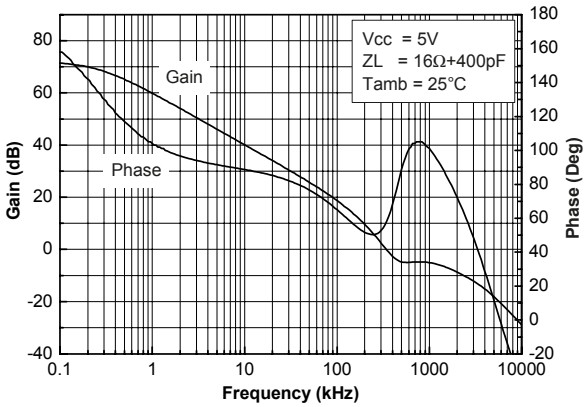



**Figure 9. Open loop gain and phase vs. frequency ZL = 16 Ω, Vcc = 2 V**

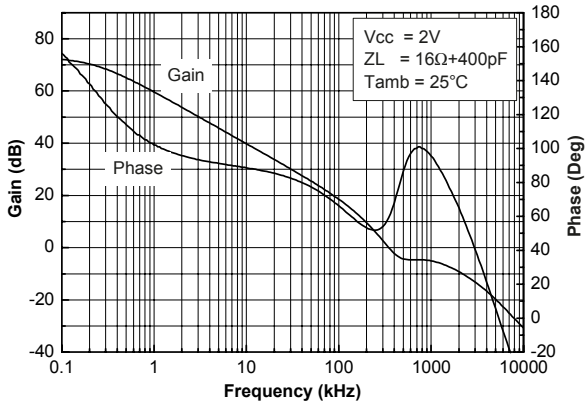


**Figure 10. Open loop gain and phase vs. frequency RL = 32 Ω**

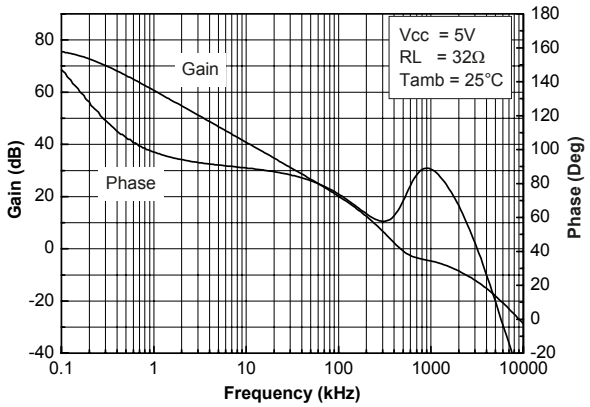



**Figure 11. Open loop gain and phase vs. frequency RL = 32 Ω, Vcc = 2 V**

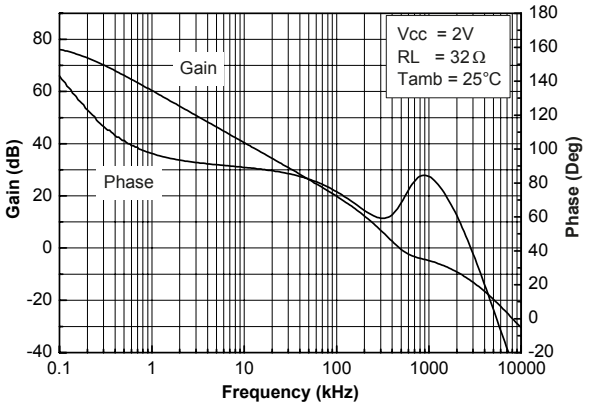



**Figure 12. Open loop gain and phase vs. frequency ZL = 32 Ω**

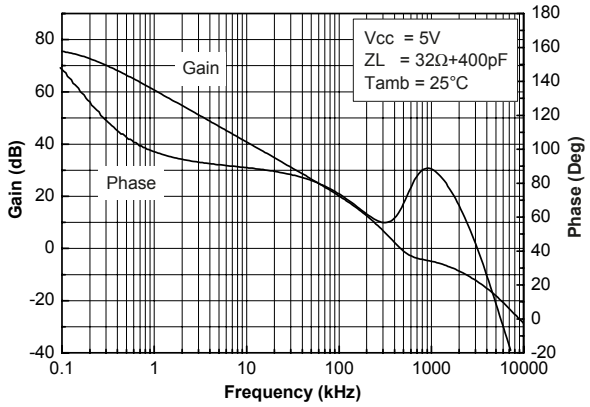



**Figure 13. Open loop gain and phase vs. frequency ZL = 32 Ω, Vcc = 2 V**

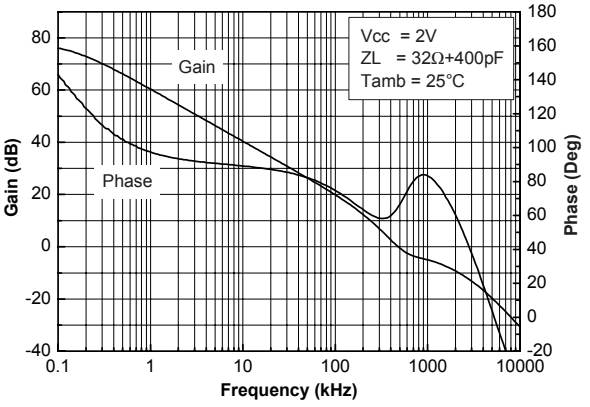


**Figure 14. Current consumption vs. power supply voltage**

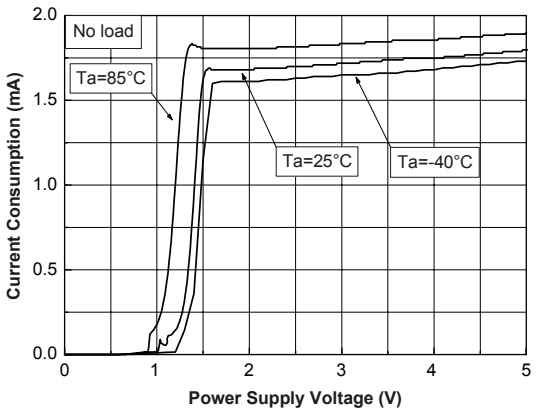



**Figure 15. Current consumption vs. standby voltage Vcc = 5 V**

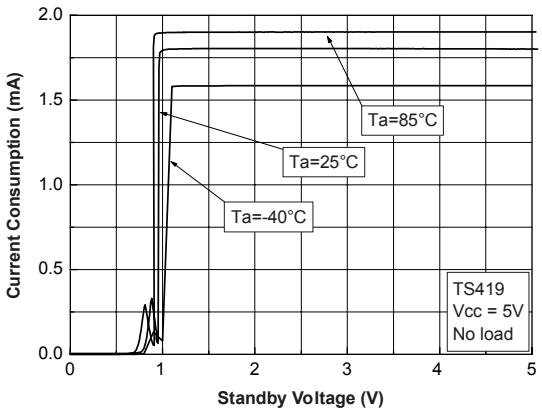



**Figure 16. Current consumption vs. standby voltage Vcc = 3.3 V**

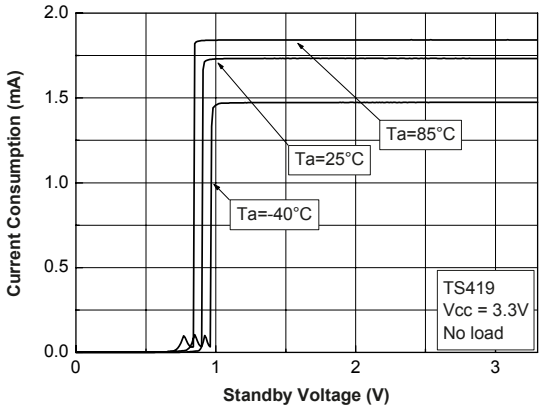



**Figure 17. Current consumption vs. standby voltage Vcc = 2 V**

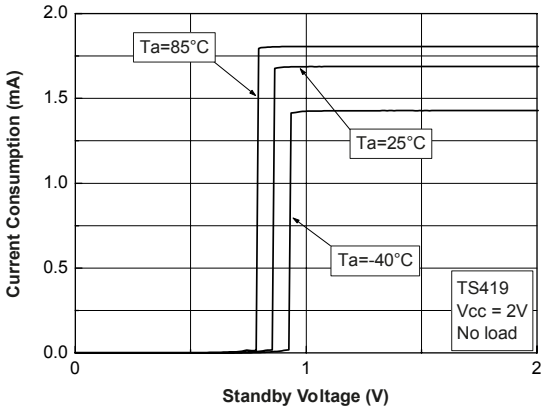


**Figure 18. Current consumption vs. standby voltage Vcc = 5 V (TS421)**

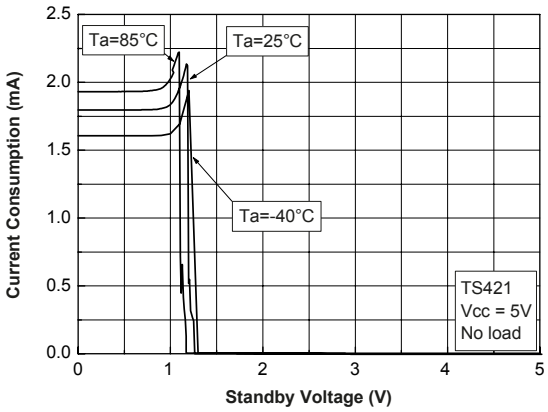



**Figure 19. Current consumption vs. standby voltage Vcc = 3.3 V (TS421)**

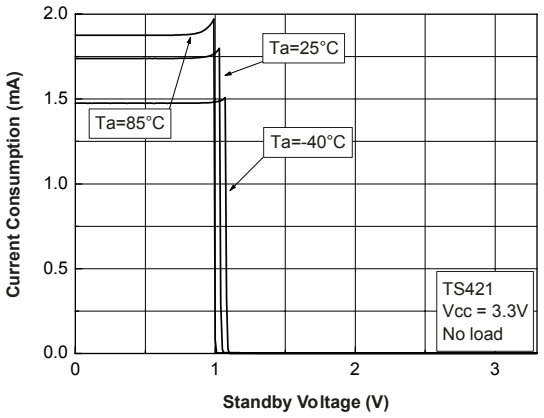



**Figure 20. Current consumption vs. standby voltage Vcc = 2 V (TS421)**

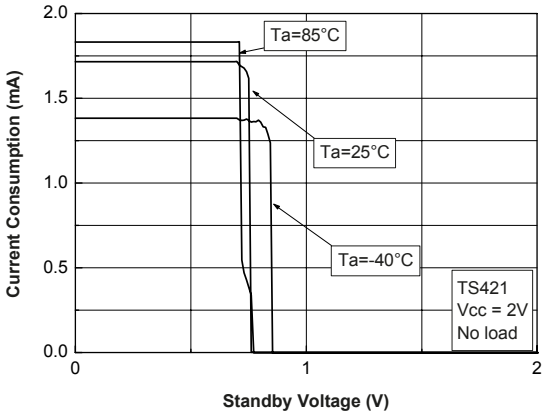



**Figure 21. Output power vs. power supply voltage RL = 8 Ω**

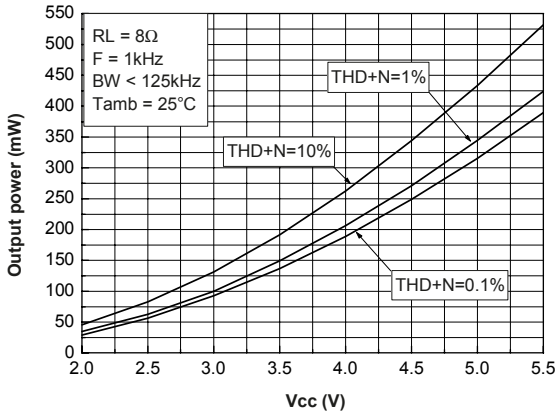


**Figure 22. Output power vs. power supply voltage RL = 16 Ω**

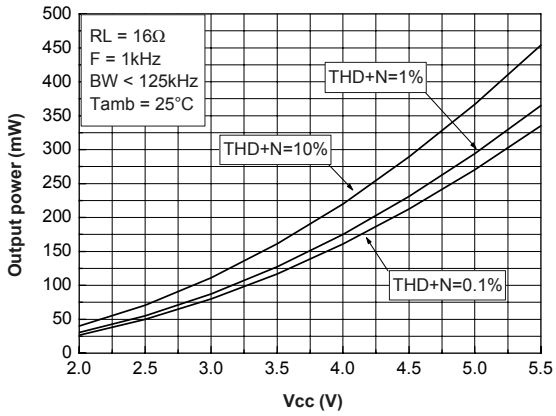



**Figure 23. Output power vs. power supply voltage RL = 32 Ω**

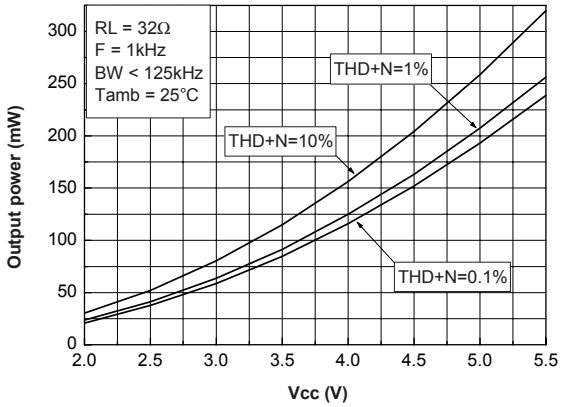



**Figure 24. Output power vs. power supply voltage RL = 64 Ω**

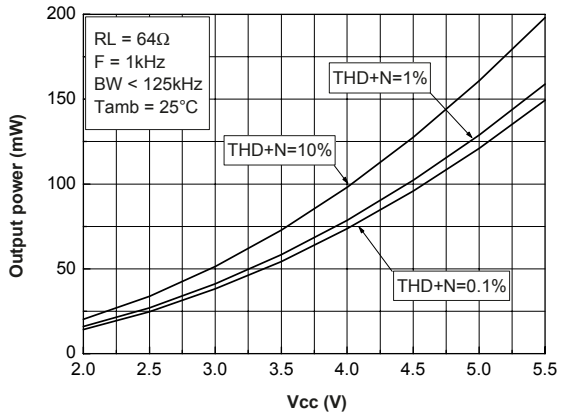



**Figure 25. Output power vs. load resistor Vcc = 5 V**

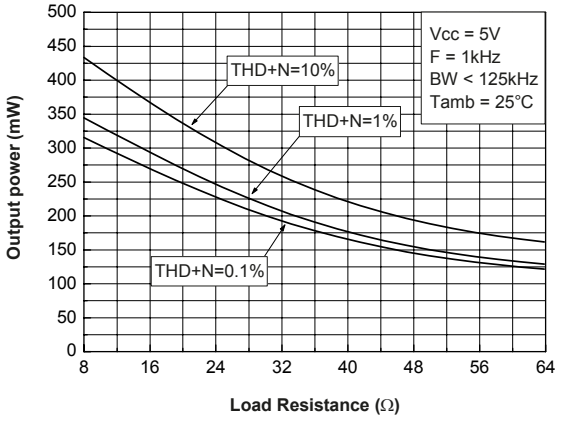


**Figure 26. Output power vs. load resistor Vcc = 3.3 V**

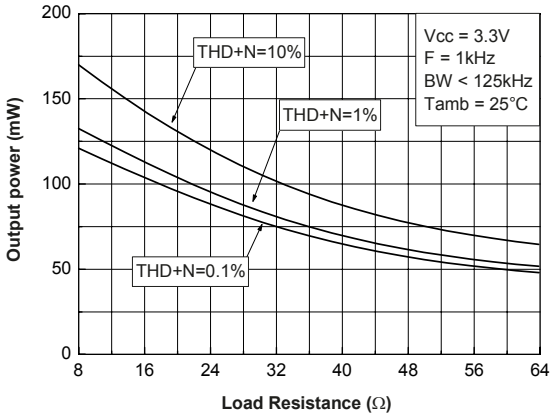



**Figure 27. Output power vs. load resistor Vcc = 2.5 V**

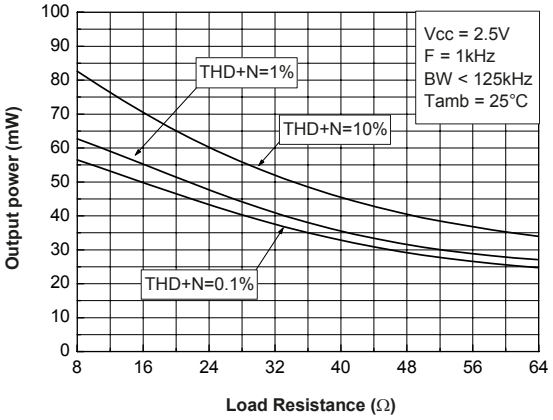



**Figure 28. Output power vs. load resistor Vcc = 2 V**

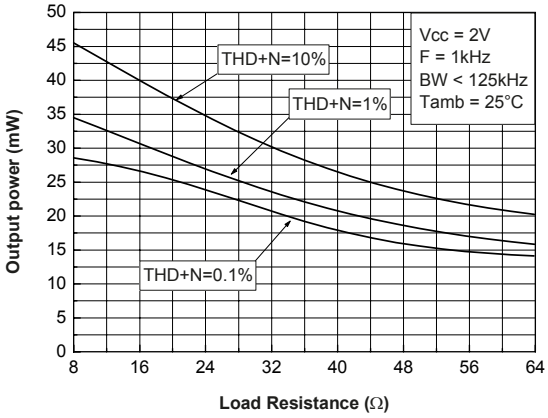



**Figure 29. Power dissipation vs. output power Vcc = 5 V**

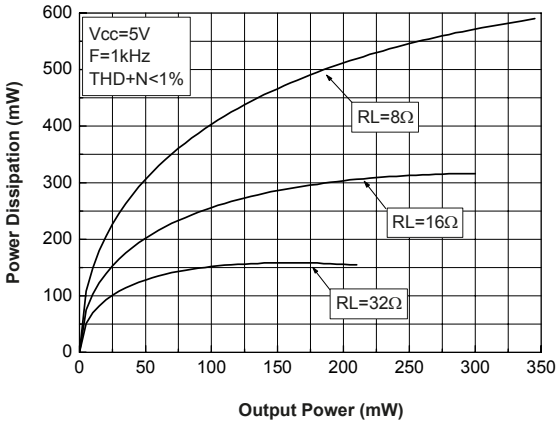


**Figure 30. Power dissipation vs. output power Vcc = 3.3 V**

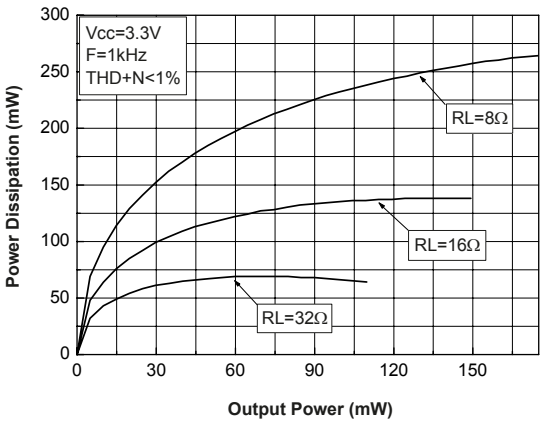



**Figure 31. Power dissipation vs. output power Vcc = 2.5 V**

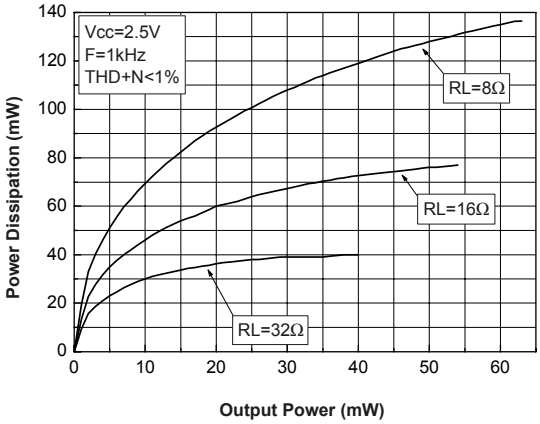



**Figure 32. Power dissipation vs. output power Vcc = 2 V**

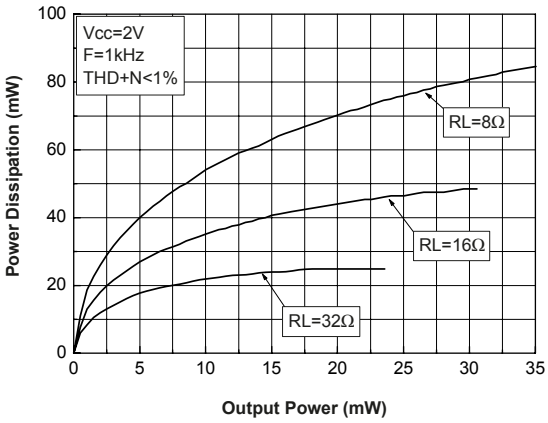



**Figure 33. Power derating curves**

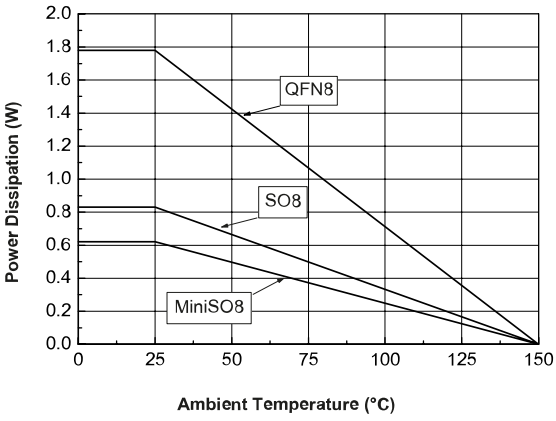


**Figure 34. Output voltage swing for one Amp. vs. power supply voltage**

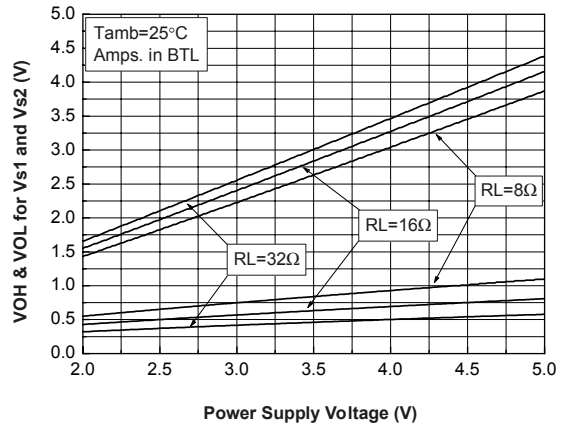



**Figure 35. THD + N vs. output power RL = 8 Ω**

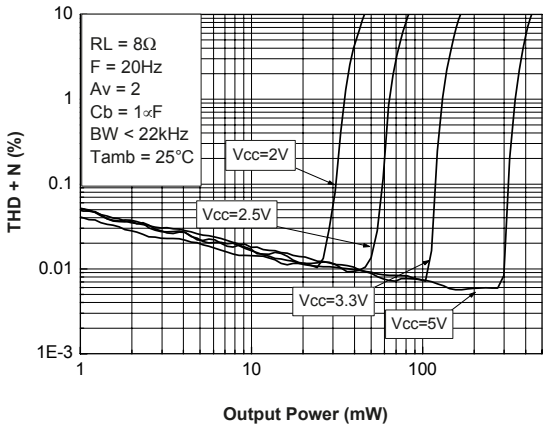



**Figure 36. THD + N vs. output power RL = 16 Ω**

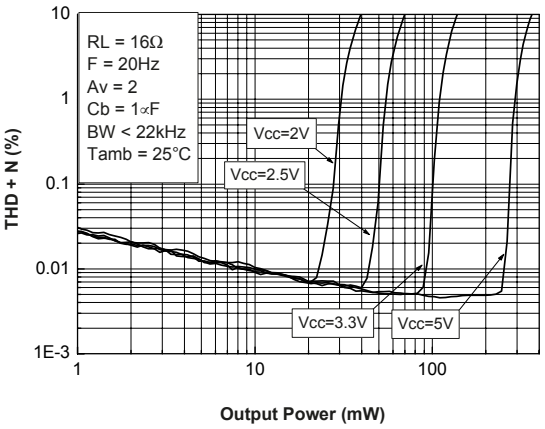


**Figure 37. THD + N vs. output power RL = 32 Ω**

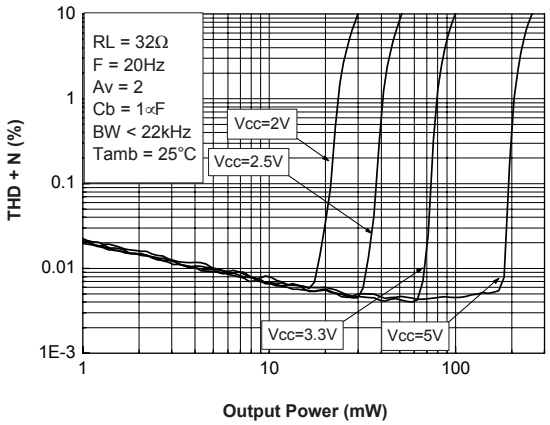



**Figure 38. THD + N vs. output power RL = 8 Ω, Av = 2**

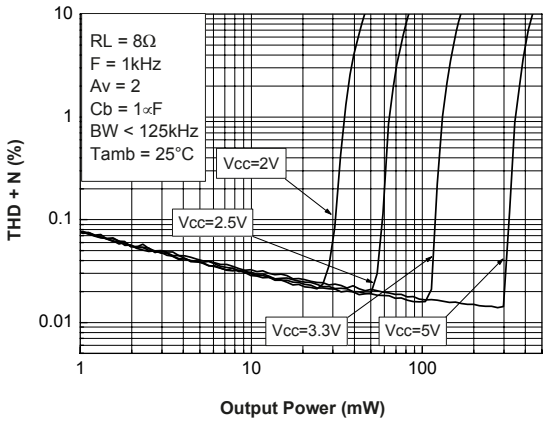



**Figure 39. THD + N vs. output power RL = 16 Ω, Av = 2**

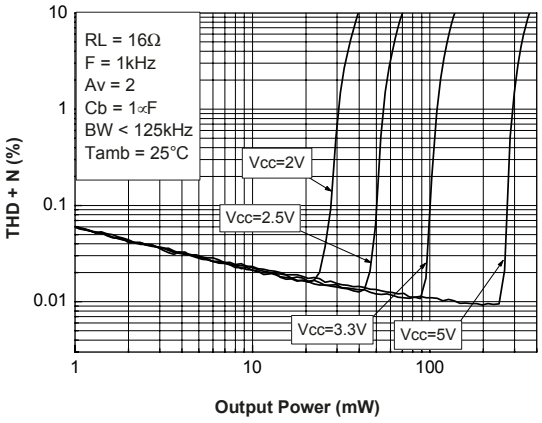



**Figure 40. THD + N vs. output power RL = 32 Ω, Av = 2**

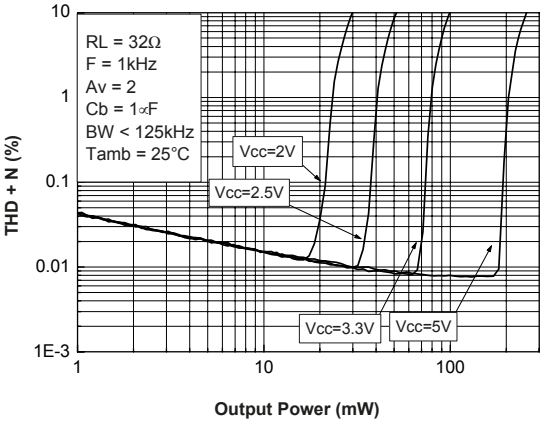


**Figure 41. THD + N vs. output power RL = 8 Ω, Cb = 1 µF**

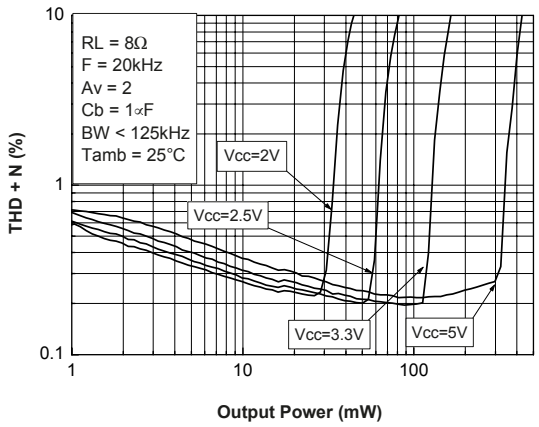



**Figure 42. THD + N vs. output power RL = 16 Ω, Cb = 1 µF**

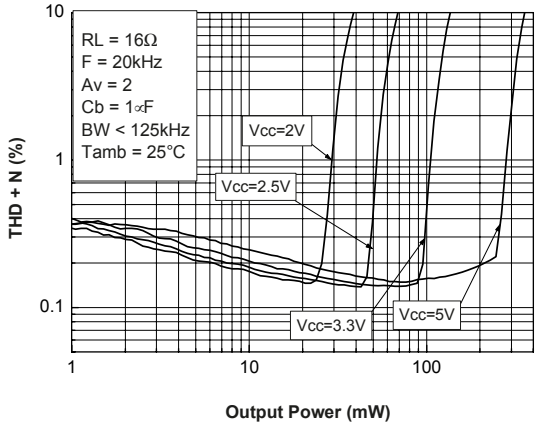



**Figure 43. THD + N vs. output power RL = 32 Ω, Cb = 1 µF**

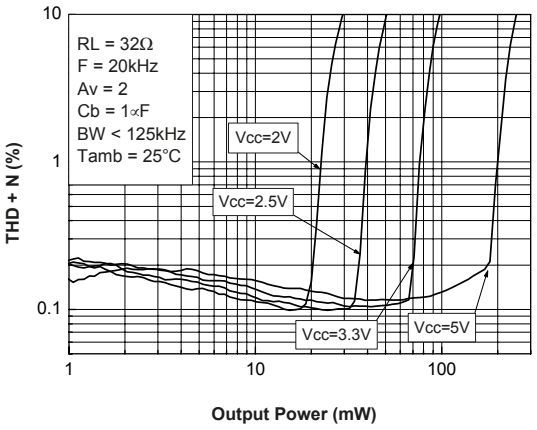



**Figure 44. THD + N vs. frequency RL = 8 Ω**

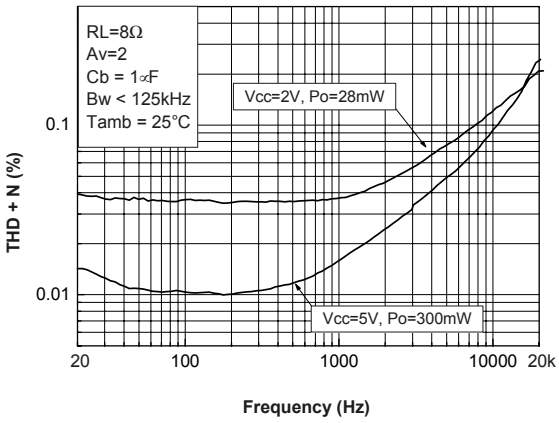


**Figure 45. THD + N vs. frequency RL = 16 Ω**

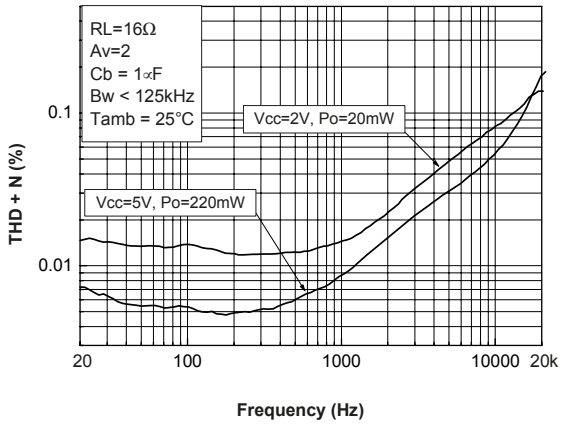



**Figure 46. THD + N vs. frequency RL = 32 Ω**

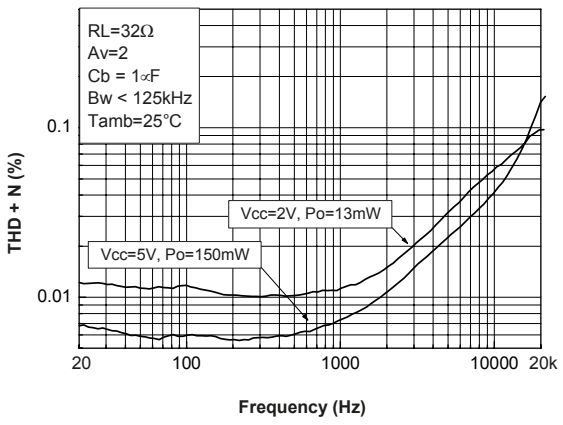



**Figure 47. Signal to noise ratio vs. power supply voltage with unweighted filter (20 Hz to 20 kHz)**

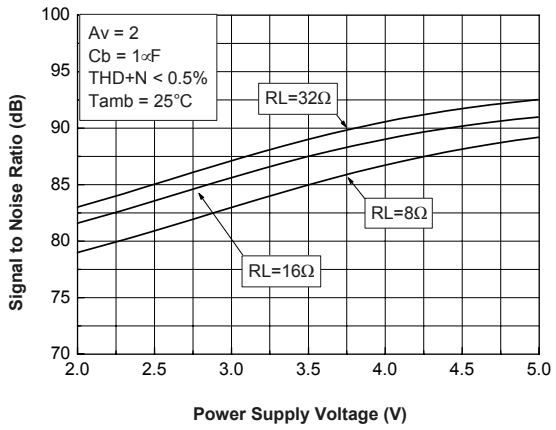



**Figure 48. Signal to noise ratio vs. power supply voltage with weighted filter Type A**

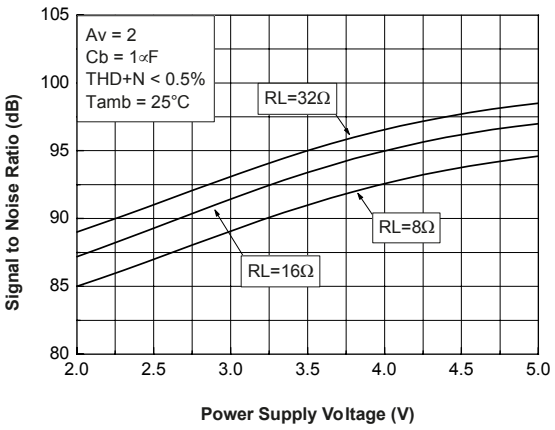


**Figure 49. Noise floor Vcc = 5 V**

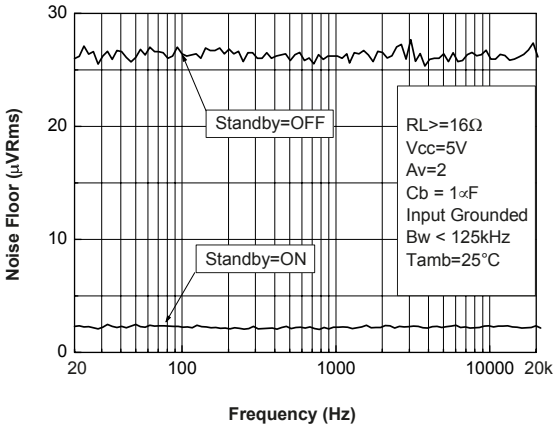



**Figure 50. Noise floor Vcc = 2 V**

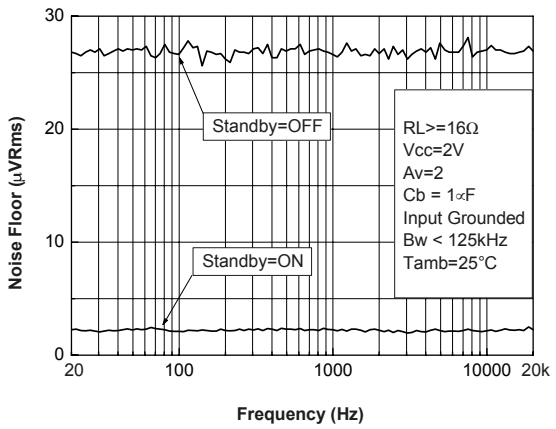



**Figure 51. PSRR vs. input capacitor**

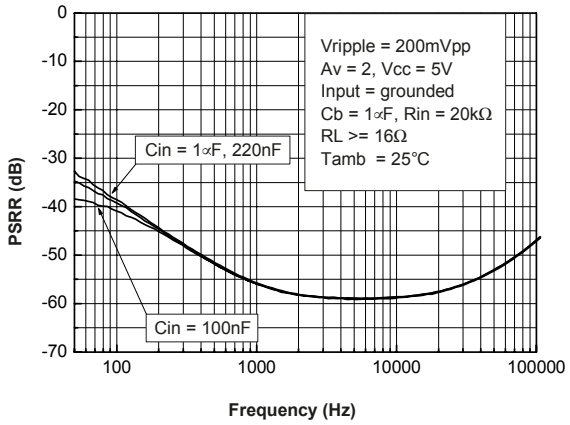



**Figure 52. PSRR vs. power supply voltage**

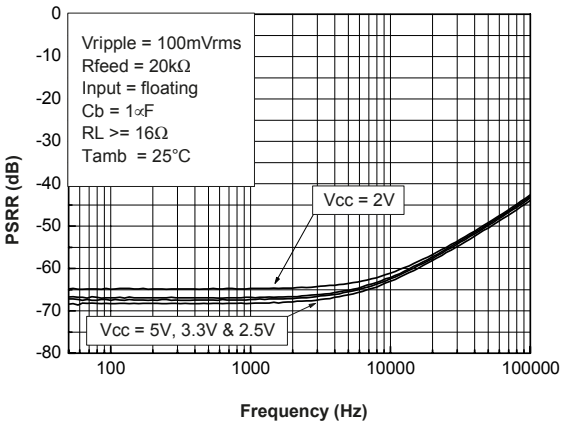


**Figure 53. PSRR vs. bypass capacitor Cb = Cin = 1 µF**

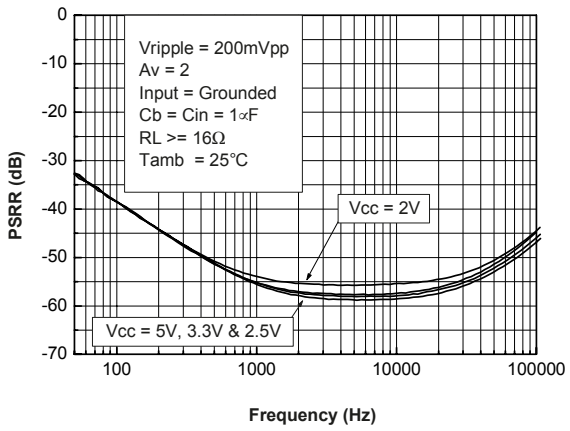



**Figure 54. PSRR vs. bypass capacitor Cb = 4.7 µF**

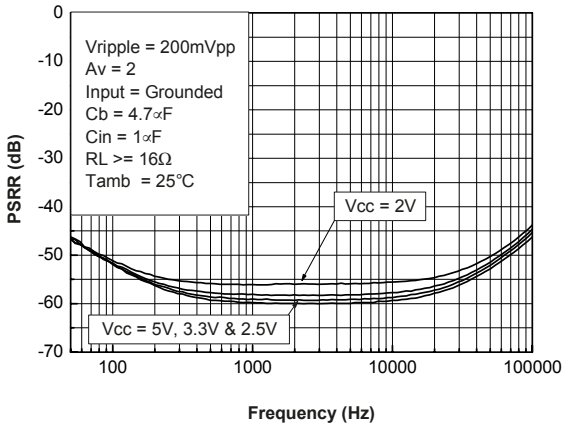



**Figure 55. PSRR vs. bypass capacitor Cb = 10 µF**

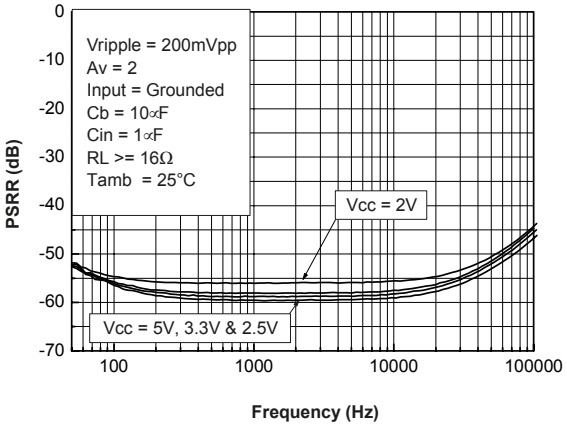



**Figure 56. THD + N vs. output power RL = 8 Ω**

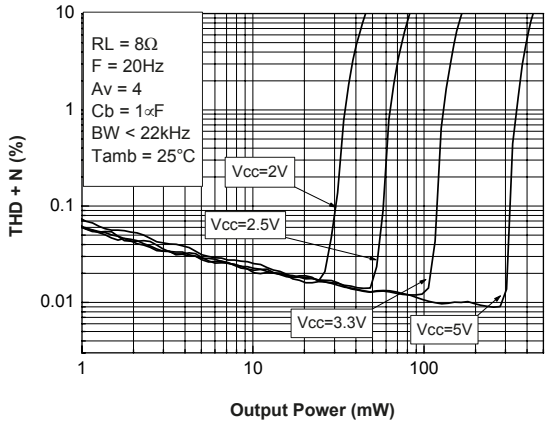


**Figure 57. THD + N vs. output power RL = 16 Ω**

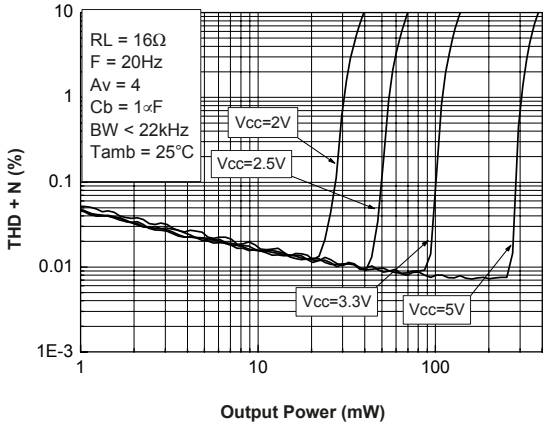



**Figure 58. THD + N vs. output power RL = 32 Ω**

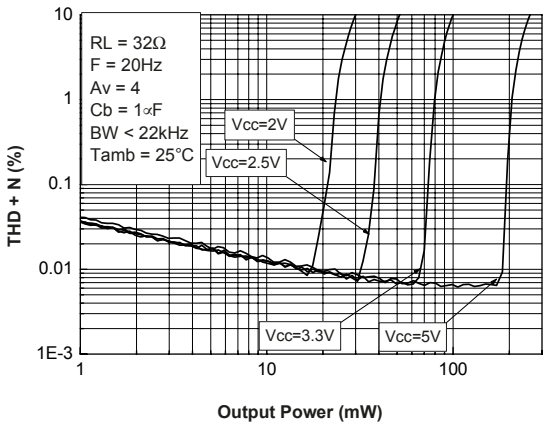



**Figure 59. THD + N vs. output power RL = 8 Ω, Av = 4**

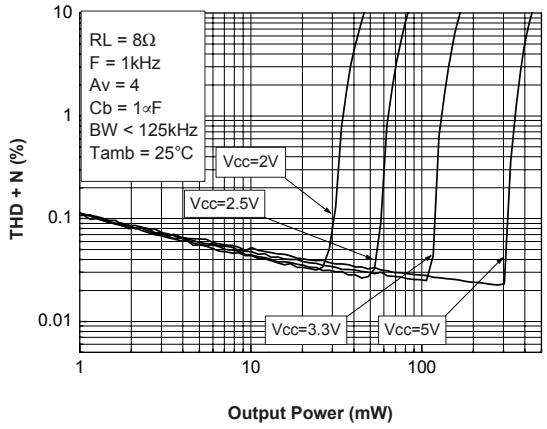



**Figure 60. THD + N vs. output power RL = 16 Ω, Av = 4**

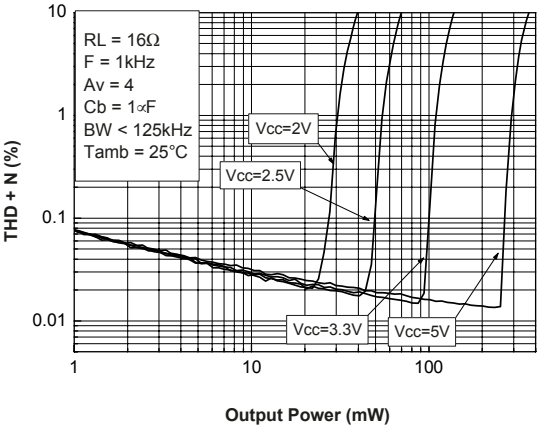


**Figure 61. THD + N vs. output power RL = 32 Ω, Av = 4**

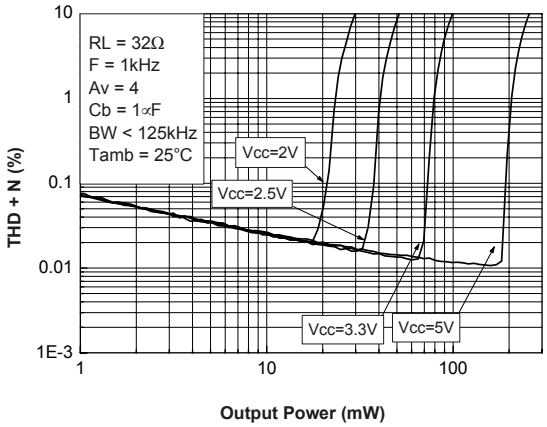



**Figure 62. THD + N vs. output power RL = 8 Ω**

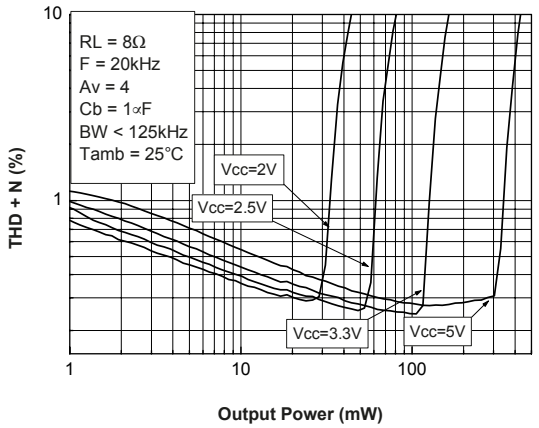



**Figure 63. THD + N vs. output power RL = 16 Ω**

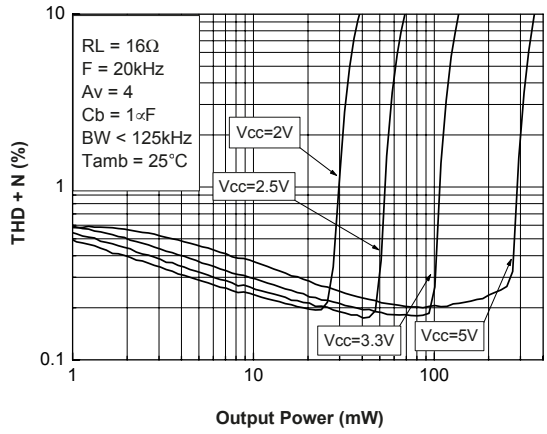



**Figure 64. THD + N vs. output power RL = 32 Ω**

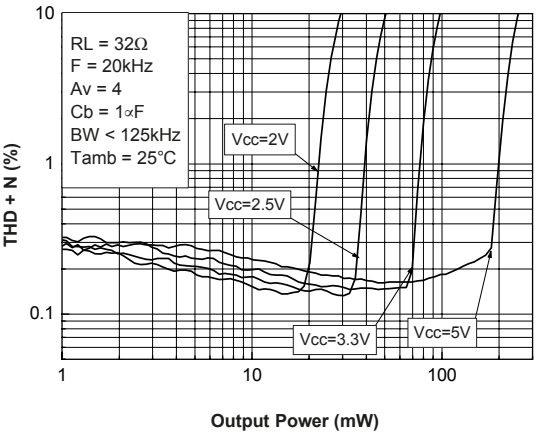


**Figure 65. THD + N vs. frequency RL = 8 Ω**

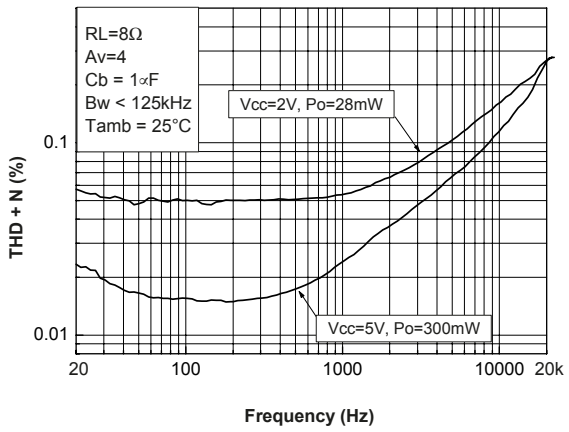



**Figure 66. THD + N vs. frequency RL = 16 Ω**

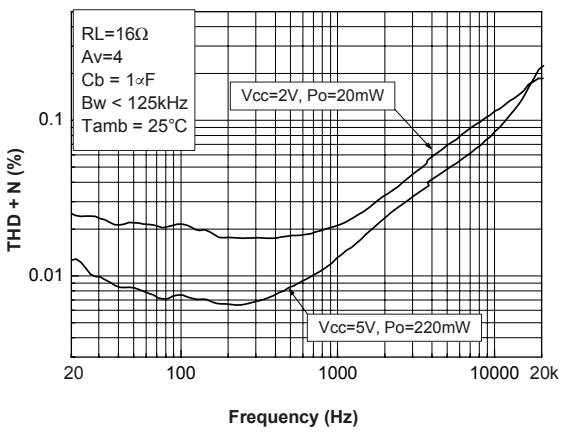



**Figure 67. THD + N vs. frequency RL = 32 Ω**

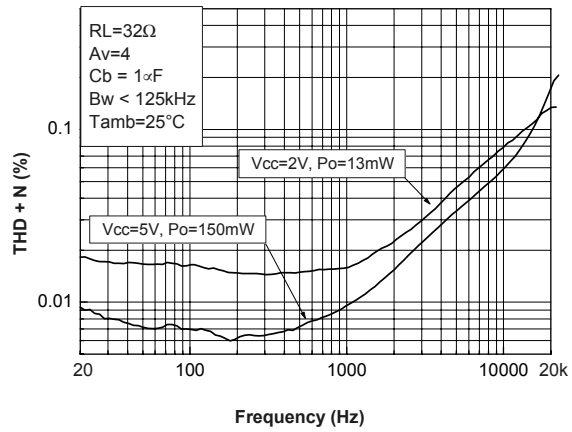



**Figure 68. Signal-to-noise ratio vs. power supply voltage with unweighted filter (20 Hz to 20 kHz)**

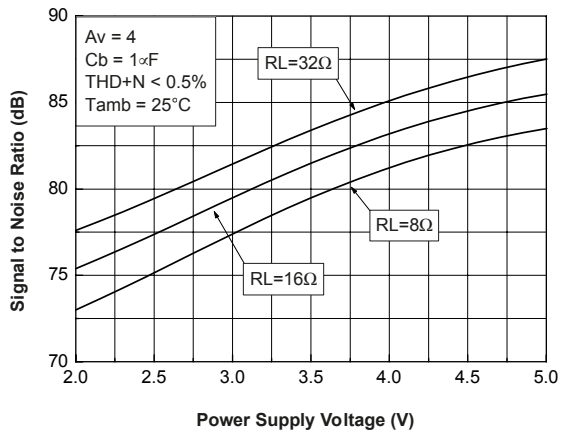


**Figure 69. Signal-to-noise ratio vs power supply voltage with weighted filter Type A**

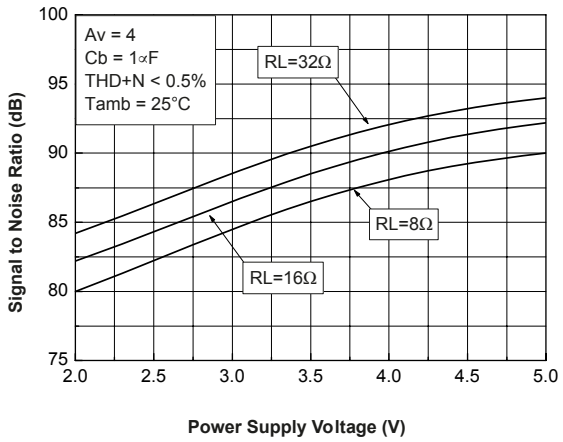



**Figure 70. Noise floor Vcc = 5 V**

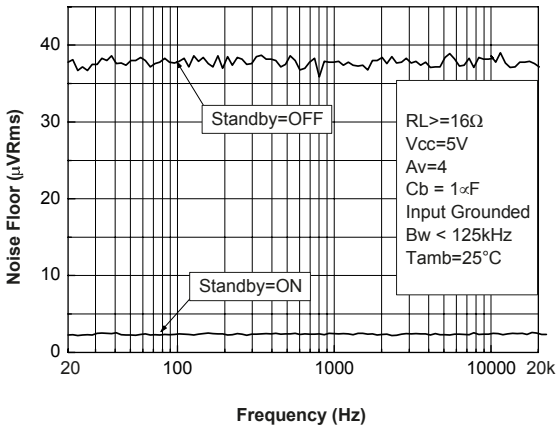



**Figure 71. Noise floor Vcc = 2 V**

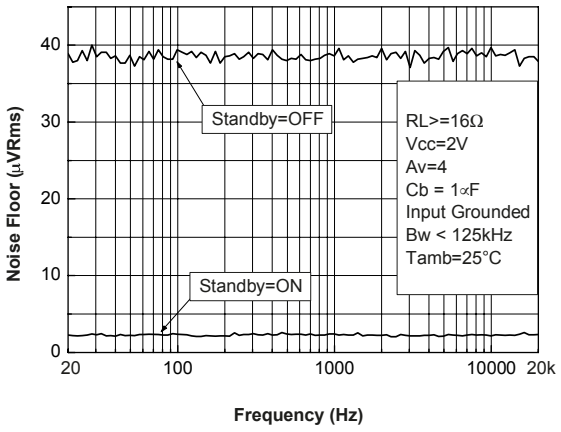



**Figure 72. PSRR vs. power supply voltage**

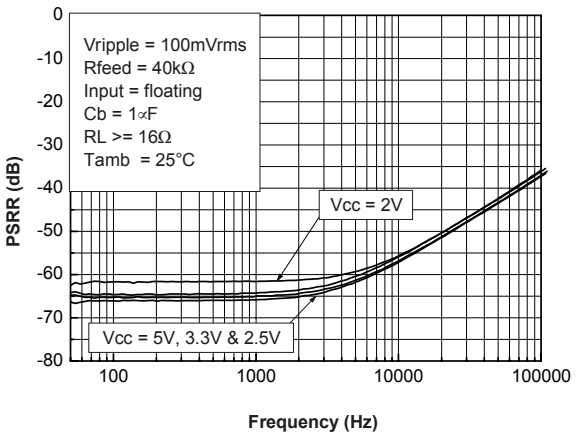


**Figure 73. PSRR vs. input capacitor**

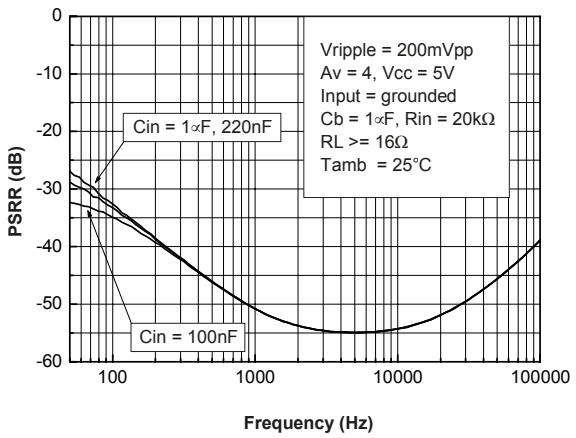



**Figure 74. PSRR vs. bypass capacitor Cb = Cin = 1 µF**

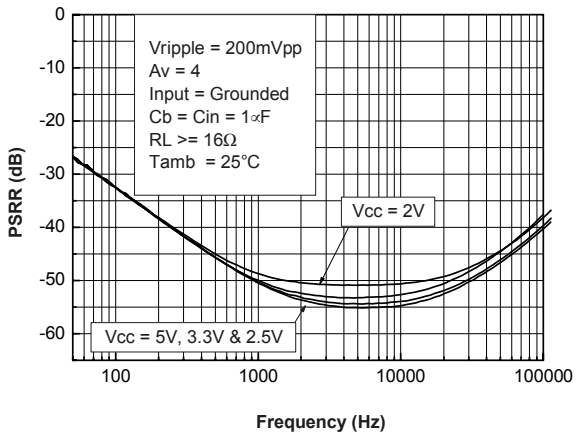



**Figure 75. PSRR vs. bypass capacitor Cb = Cin = 4.7 µF**

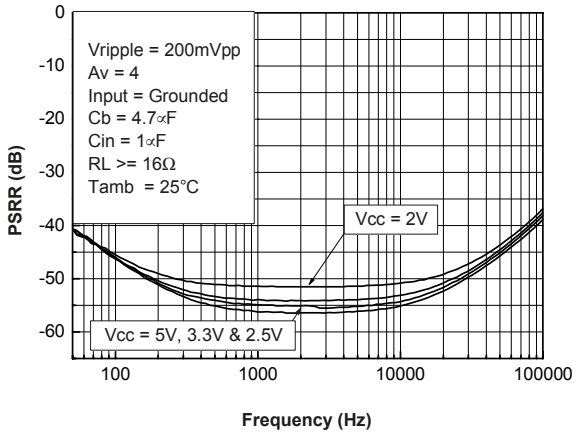



**Figure 76. PSRR vs. bypass capacitor Cb = Cin = 10 µF**

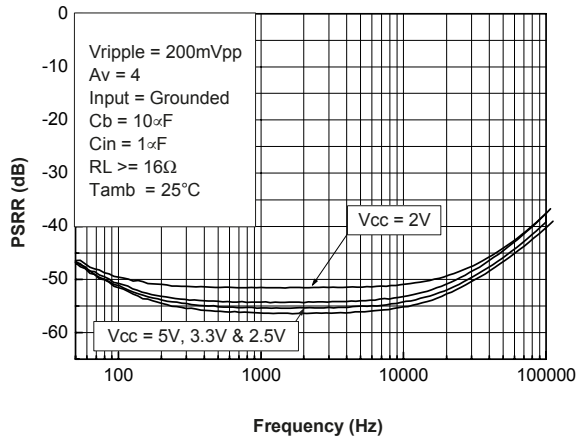


**Figure 77. THD + N vs. output power RL = 8 Ω**

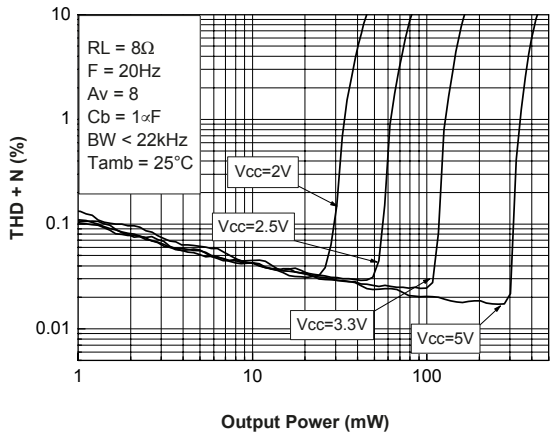



**Figure 78. THD + N vs. output power RL = 16 Ω**

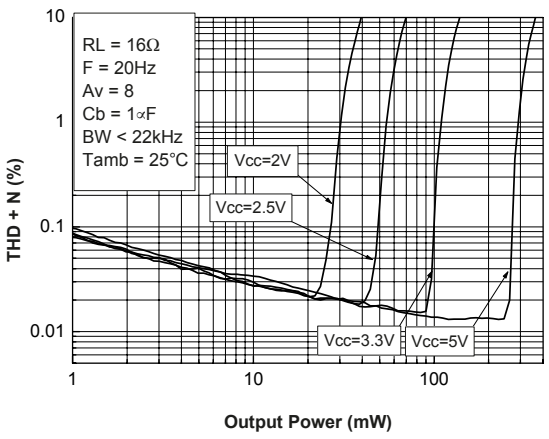



**Figure 79. THD + N vs. output power RL = 32 Ω**

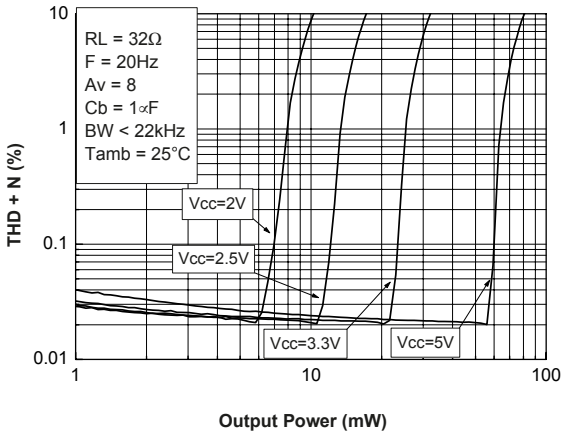



**Figure 80. THD + N vs. output power RL = 8 Ω, Av = 8**

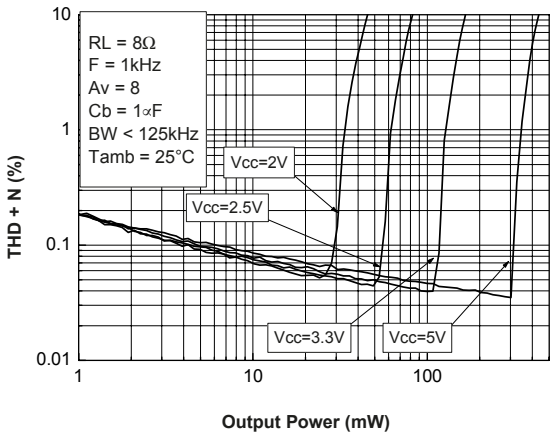


**Figure 81. THD + N vs. output power RL = 16 Ω, Av = 8**

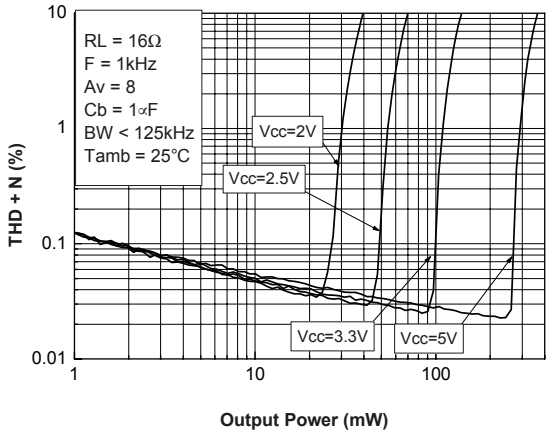



**Figure 82. THD + N vs. output power RL = 32 Ω, Av = 8**

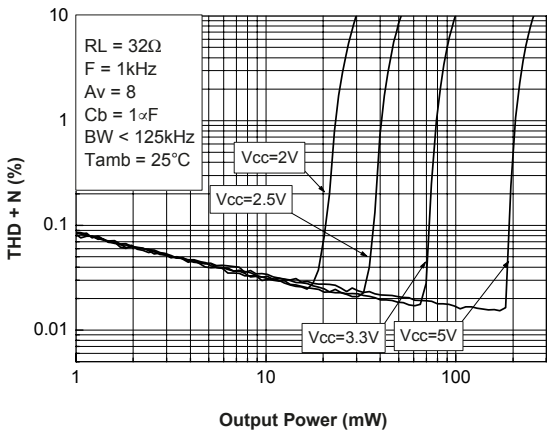



**Figure 83. THD + N vs. output power RL = 8 Ω, Cb = 1 µF**

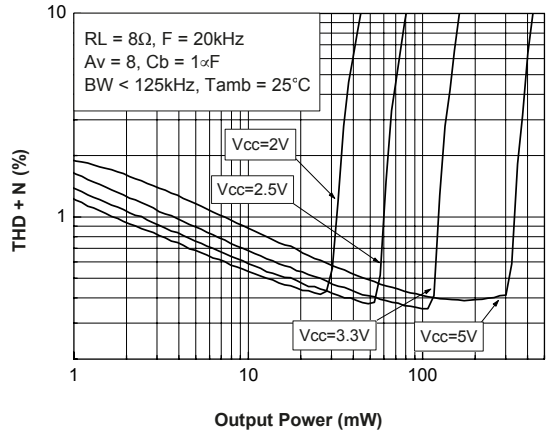



**Figure 84. THD + N vs. output power RL = 16 Ω, Cb = 1 µF**

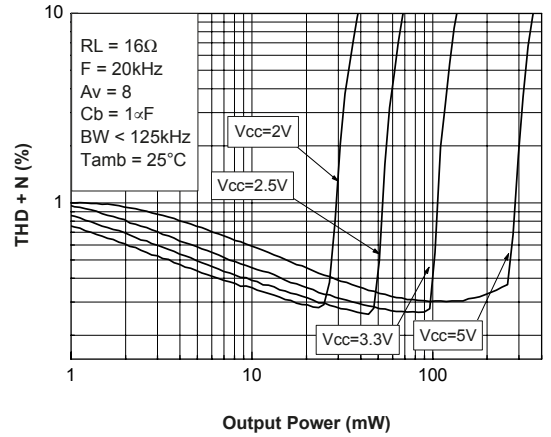


**Figure 85. THD + N vs. output power RL = 32 Ω, Cb = 1 µF**

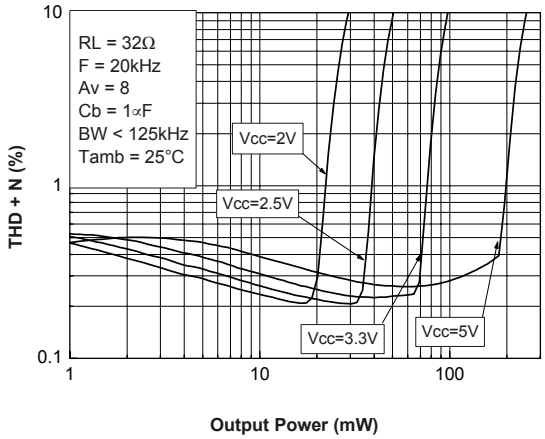



**Figure 86. THD + N vs. frequency RL = 8 Ω**

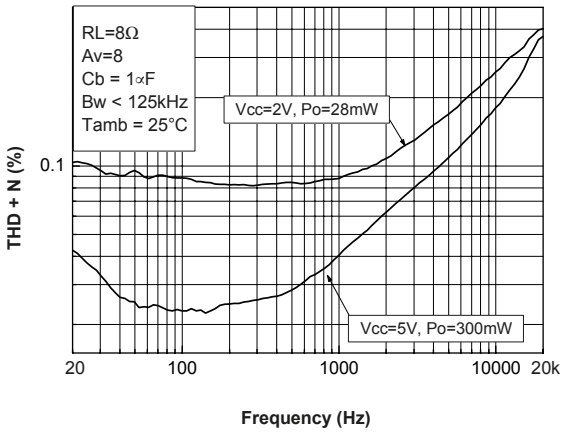



**Figure 87. THD + N vs. frequency RL = 16 Ω**

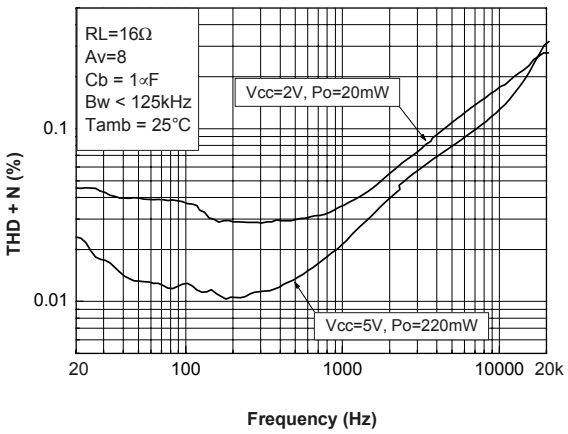



**Figure 88. THD + N vs. frequency RL = 32 Ω**

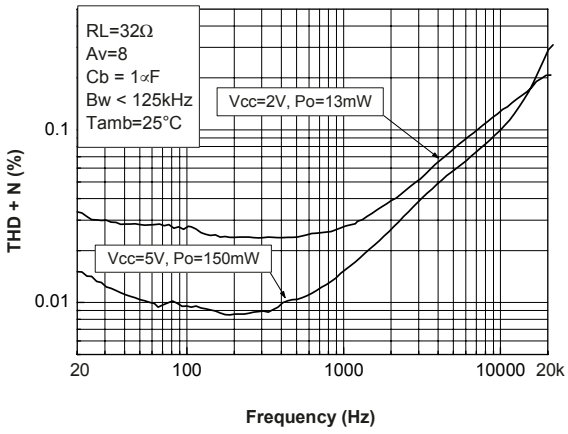


**Figure 89. Signal to noise ratio vs. power supply voltage with unweighted filter (20 Hz to 20 kHz)**

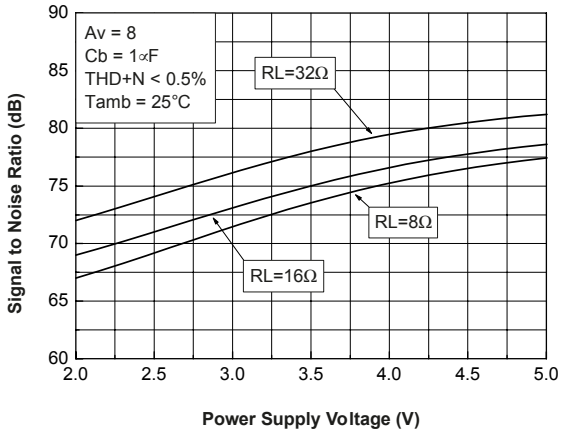



**Figure 90. Signal to noise ratio vs. power supply voltage with weighted filter Type A**

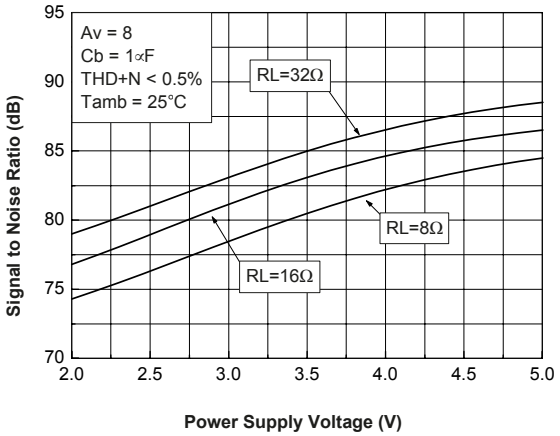



**Figure 91. Noise floor Vcc = 5 V**

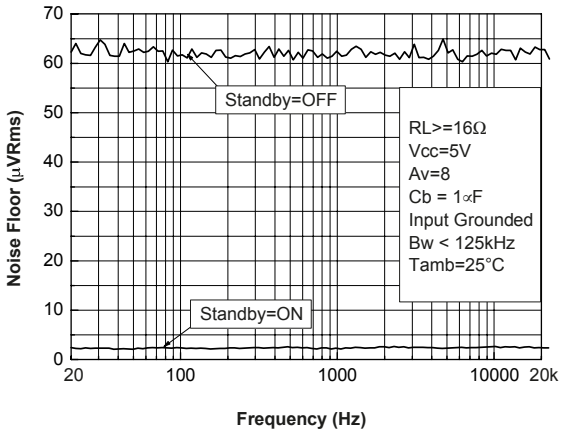



**Figure 92. Noise floor Vcc = 2 V**

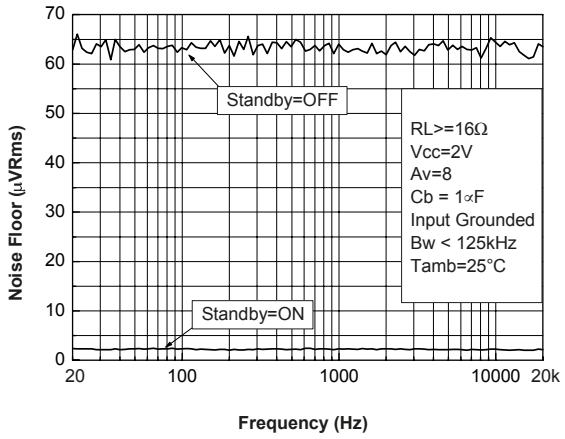


**Figure 93. PSRR vs. power supply voltage**

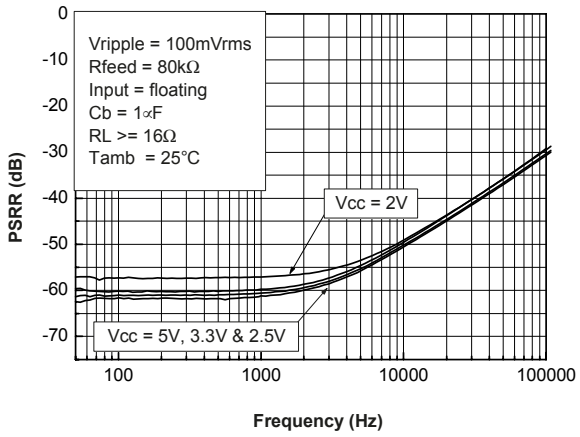



**Figure 94. PSRR vs. input capacitor**

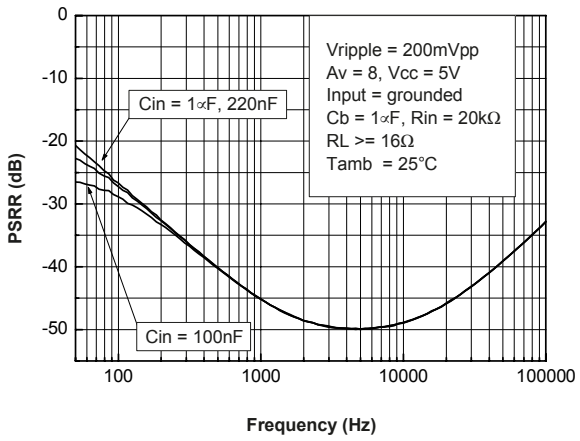



**Figure 95. PSRR vs. bypass capacitor Cb = Cin = 1 µF**

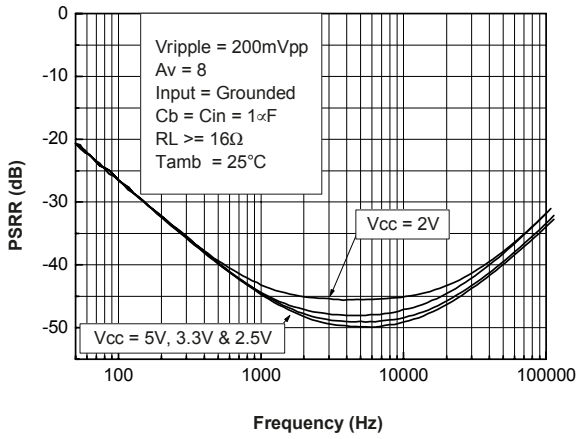



**Figure 96. PSRR vs. bypass capacitor Cb = 4.7 µF**

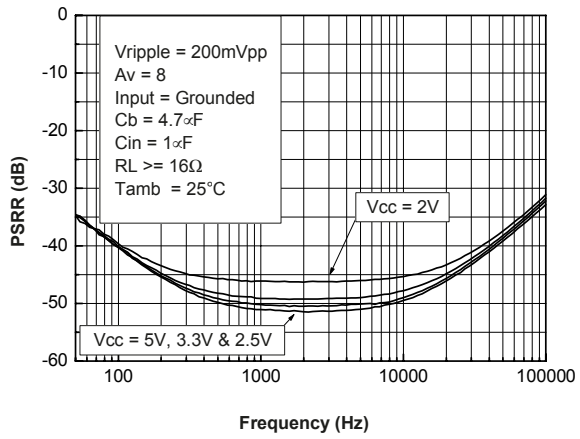
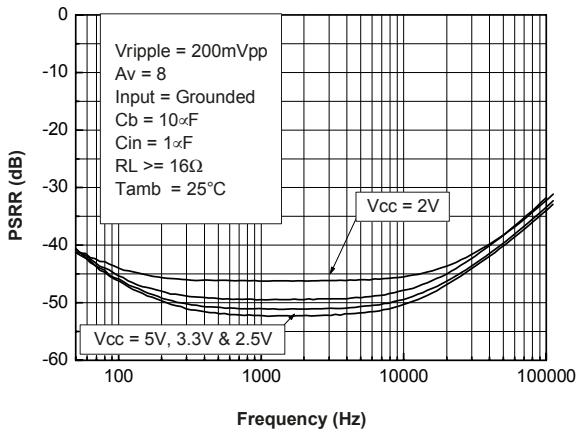


Figure 97. **PSRR vs. bypass capacitor Cb = 1 µF**



# 5 Application information

## 5.1 BTL configuration principle

The TS419 and TS421 are monolithic power amplifiers 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:

Single ended output 1 = Vout1 = Vout (V)

Single ended output 2 = Vout2 = -Vout (V)

And Vout1 - Vout2 = 2Vout (V)

The output power is:

Pout $(2Vout_{RMS})^2$ / $R_L$ (W)

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

## 5.2 Gain in typical application schematic

In flat region (no effect of Cin), the output voltage of the first stage is:

$$Vout = -Vin\frac{Rfeed}{Rin}\left(V\right) \quad (1)$$

For the second stage : Vout2 = -Vout1 (V)

The differential output voltage is:

$$Vout2 - Vout1 = 2Vin\frac{Rfeed}{Rin}\left(V\right) \quad (2)$$

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

$$Gv = \frac{Vout2 - Vout1}{Vin} = 2\frac{Rfeed}{Rin} \quad (3)$$

Remark : Vout2 is in phase with Vin and Vout1 is 180° phased with Vin. It means that the positive terminal of the loud speaker should be connected to Vout2 and the negative to Vout1.

## 5.3 Low and high frequency response

In low frequency region, the effect of Cin starts. Cin with Rin forms a high pass filter with a -3 dB cut-off frequency

$$F_{CL} = \frac{1}{2\pi RinCin}\left(Hz\right)$$

In high frequency region, you can limit the bandwidth by adding a capacitor (Cfeed) in parallel on Rfeed. Its form a low pass filter with a -3 dB cut-off frequency.

$$F_{CH} = \frac{1}{2\pi RfeedCfeed}\left(Hz\right)$$

## 5.4 Power dissipation and efficiency

Hypothesis:

- Voltage and current in the load are sinusoidal (Vout and Iout)
- Supply voltage is a pure DC source (Vcc)

Regarding the load we have:

$$V_{OUT} = V_{PEAK}\sin\ \omega t(t) \quad (4)$$

and

$$I_{OUT} = \frac{V_{OUT}}{R_L}\left(A\right) \quad (5)$$

$$P_{OUT} = \frac{V_{PEAK}{}^2}{2R_L}\left(W\right) \quad (6)$$

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

$$Icc_{AVG} = 2\frac{V_{PEAK}}{\pi R_L}\left(A\right) \quad (7)$$

The power delivered by the supply voltage is Psupply = Vcc $Icc_{AVG}$ (W)

Then, the power dissipated by the amplifier is Pdiss = Psupply - Pout (W)

$$Pdiss = \frac{2\sqrt{2Vcc}}{\pi\sqrt{R_L}}\sqrt{P_{OUT}} - P_{OUT}\left(W\right) \quad (8)$$

and the maximum value is obtained when:

$$\frac{\partial Pdiss}{\partial P_{OUT}} = 0 \quad (9)$$

and its value is:

$$Pdiss\max = \frac{2V_{CC}{}^2}{\pi^2 R_L}\left(W\right) \quad (10)$$

Remark : This maximum value is only depending on power supply voltage and load values.

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

$$\eta = \frac{P_{OUT}}{P_{\mathrm{supply}}} = \frac{\pi V_{PEAK}}{4V_{CC}} \quad (11)$$

The maximum theoretical value is reached when

Vpeak = Vcc, so

$$\frac{\pi}{4} = 78.5\,\% \quad (12)$$

## 5.5 Decoupling of the circuit

Two capacitors are needed to bypass properly the TS419/TS421. 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 7 kHz) and an indirect influence on power supply disturbances.

With 1 µF, 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 µF, 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 µF, 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 µF, THD+N increases at lower frequencies and PSRR worsens.

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

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

## 5.6 Wake-up time: $T_{WU}$

When standby is released to put the device ON, the bypass capacitor $C_B$ will not be charged immediatly. 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 $T_{WU}$ and typically equal to:

$T_{WU}$ = 0.15x$C_B$ (s) with $C_B$ in µF.

Due to process tolerances, the range of the wake-up time is:

$0.12xCb < T_{WU} < 0.18xC_B$ (s) with $C_B$ in µF

*Note: When the standby command is set, the time to put the device in shutdown mode is a few microseconds.*

## 5.7 Pop performance

Pop performance is intimately linked with the size of the input capacitor Cin 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. The slower the speed is, the softer the turn ON noise is.

The charge time of $C_B$ is directly proportional to the internal generator resistance 150 kΩ.

Then, the charge time constant for $C_B$ is

$\tau_B = 150\ k\Omega \times C_B$ (s)

As $C_B$ is directly connected to the non-inverting input (pin 2 & 3) and if we want to minimize, in amplitude and duration, the output spike on Vout1 (pin 5), $C_{IN}$ must be charged faster than $C_B$. The equivalent charge time constant of $C_{IN}$ is:

$\tau_{IN} = (Rin + Rfeed) \times C_{IN}$ (s)

Thus we have the relation:

$\tau_{IN} < \tau_B$ (s)

Proper respect of this relation allows to minimize the pop noise.

Remark : Minimizing $C_{IN}$ and $C_B$ benefits both the pop phenomena, and the cost and size of the application.

## 5.8 Application : Differential inputs BTL power amplifier

The schematic on figure 98, shows how to design the TS419/21 to work in a differential input mode.

The gain of the amplifier is:

$$G_{VDIFF} = 2\frac{R_2}{R_1} \quad (13)$$

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

**Figure 98. Differential input amplifier configuration**

Input capacitance C can be calculated by the following formula using the -3 dB lower frequency required. ($F_L$ is the lower frequency required).

$$C \approx \frac{1}{2\pi R_1 F_L}\left(F\right) \quad (14)$$

Note : This formula is true only if:

$$F_{CB} = \frac{1}{942000 \times C_B}\left(Hz\right) \quad (15)$$

is ten times lower than $F_L$.

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

**Table 8. Components**

| Designator | Part type |
|---|---|
| R1 | 20 k / 1% |
| R2 | 20 k / 1% |
| C | 100 nF |
| $C_B = C_S$ | 1 µF |
| U1 | TS419/21 |

# 6 Package information

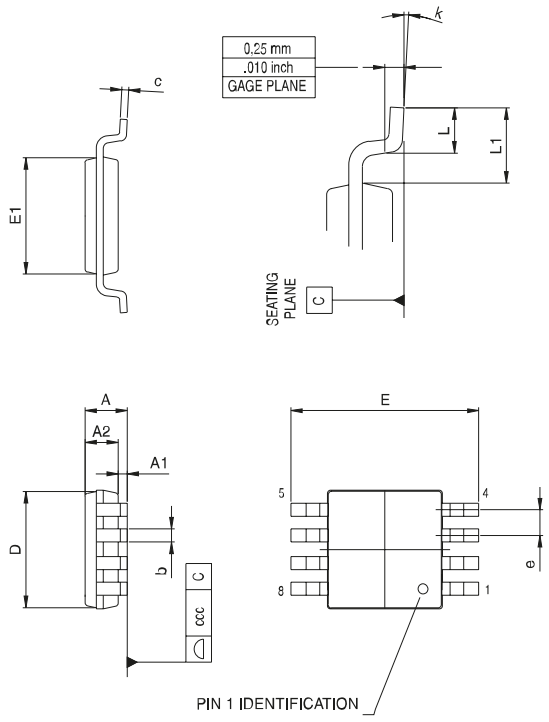
In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.

## 6.1 MiniSO-8 mechanical data

**Table 9. 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 | 0.005 |
| A2 | 0.78 | 0.86 | 0.94 | 0.031 | 0.031 | 0.037 |
| b | 0.25 | 0.33 | 0.4Q | 0.010 | 0.13 | 0.013 |
| c | 0.13 | 0.16 | 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 | 0.114 | 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 |

**Figure 99. MiniSO-8 drawing**

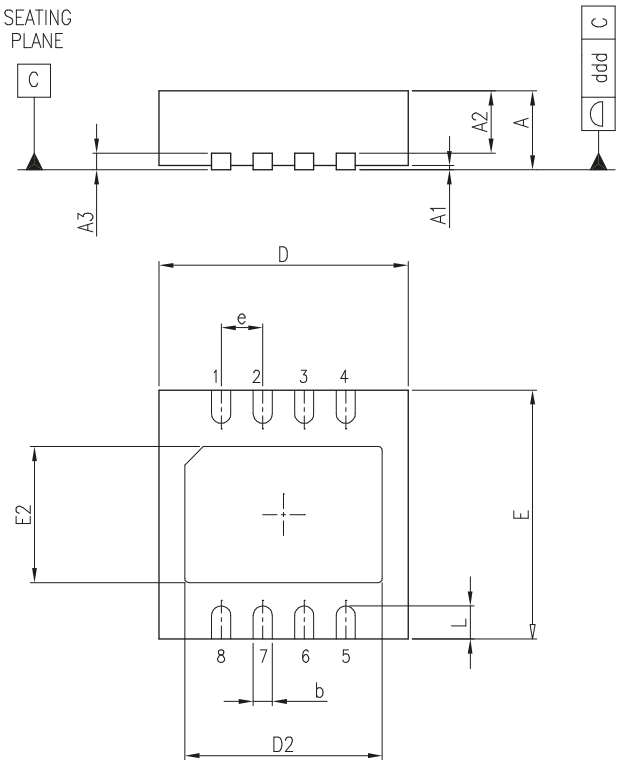


## 6.2 DFN8 (3x3) mechanical data

**Table 10. 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 | | 3.00 | | | 118.1 | |
| D2 | 2.23 | 2.38 | 2.48 | 87.8 | 93.7 | 97.7 |
| E | | 3.00 | | | 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 |

**Figure 100. DFN8 (3x3) drawing**



# 7 Ordering information

Table 11. **Order codes**

| Order code | Temperature range | Package | Packing | Marking |
|---|---|---|---|---|
| TS419IST | -40°C to 85°C | miniSO8 | Tape and reel | K19A |
| TS421IQT | | DFN8 | | K21A |

## Revision history

Table 12. **Document revision history**

| Date | Revision | Changes |
|---|---|---|
| 06-Feb-2013 | 4 | No history because of migration. |
| 29-May-2019 | 5 | Removed the part numbers TS419IDT, TS421IDT and all its reference throughout the document. |

# Contents

# List of tables

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