

# LM4949 Boomer® Audio Power Amplifier Series

## Stereo Class D Audio Subsystem with OCL Headphone Amplifier

### General Description

The LM4949 is a fully integrated audio subsystem designed for stereo cell phone applications. The LM4949 combines a 2.5W stereo Class D amplifier plus a separate 190mW stereo headphone amplifier, volume control, and input mixer into a single device. The filterless class D amplifiers deliver 1.19W/channel into an 8Ω load with <1% THD+N from a 5V supply. The headphone amplifier features National's Output Capacitor-less (OCL) architecture that eliminates the output coupling capacitors required by traditional headphone amplifiers. Additionally, the headphone amplifiers can be configured with capacitively coupled (CC) loads, or used to drive an external headphone amplifier. When configured for an external amplifier, the  $V_{DD}/2$  output (VOC) controls the external amplifier's shutdown input.

For improved noise immunity, the LM4949 features fully differential left, right and mono inputs. The three inputs can be mixed/multiplexed to either the speaker or headphone amplifiers. The left and right inputs can be used as separate single-ended inputs, mixing multiple stereo audio sources. The mixer, volume control, and device mode select are controlled through an I<sup>2</sup>C compatible interface.

Output short circuit and thermal shutdown protection prevent the device from being damaged during fault conditions. Superior click and pop suppression eliminates audible transients on power-up/down and during shutdown.

### Key Specifications

|                                              |        |
|----------------------------------------------|--------|
| ■ Efficiency $V_{DD} = 3.6V$ , 400mW into 8Ω | 86.5%  |
| ■ Efficiency $V_{DD} = 5V$ , 1W into 8Ω      | 87.4%  |
| ■ Quiescent Power Supply Current @ 3.6V      | 9.36mA |
| ■ Power Output at $V_{DD} = 5V$              |        |
| Speaker:                                     |        |
| $R_L = 4\Omega$ , THD+N ≤ 1%                 | 2W     |
| $R_L = 8\Omega$ , THD+N ≤ 1%                 | 1.19W  |
| $R_L = 4\Omega$ , THD+N ≤ 10%                | 2.5W   |
| Headphone:                                   |        |
| $R_L = 16\Omega$ , THD+N ≤ 1%                | 153mW  |
| $R_L = 32\Omega$ , THD+N ≤ 1%                | 89mW   |
| ■ Shutdown Current                           | 0.1μA  |

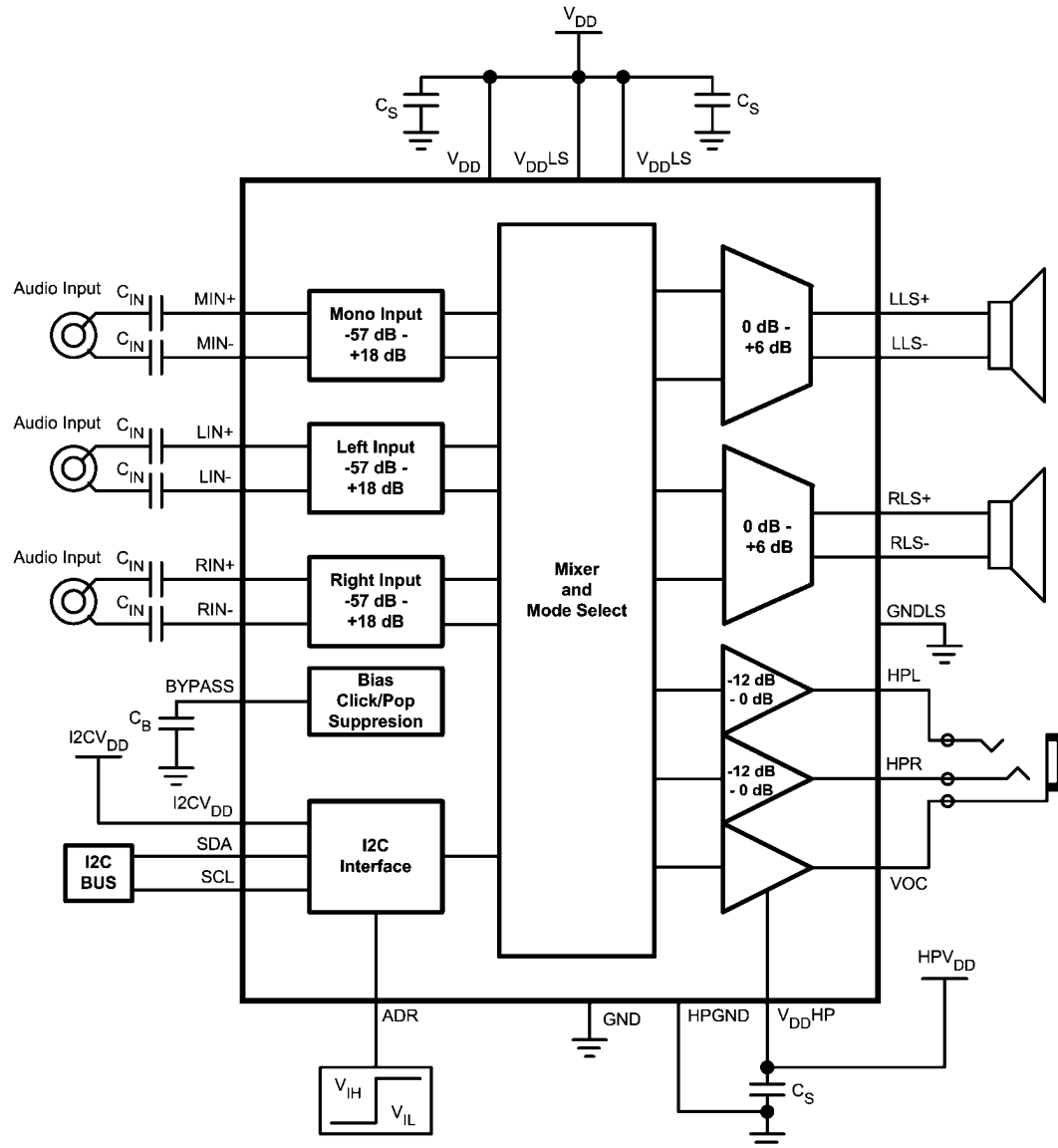
### Features

- Output Short Circuit Protection
- Thermal Shutdown
- Stereo filterless Class D operation
- Selectable OCL/CC Headphone Drivers
- RF Suppression
- I<sup>2</sup>C Control Interface
- 32-step digital volume control
- Independent Speaker and Headphone Gain Settings
- Minimum external components
- Click and Pop suppression
- Micro-power shutdown
- Available in space-saving 25 bump μSMD package

### Applications

- Mobile phones
- PDAs
- Laptops

## Typical Application

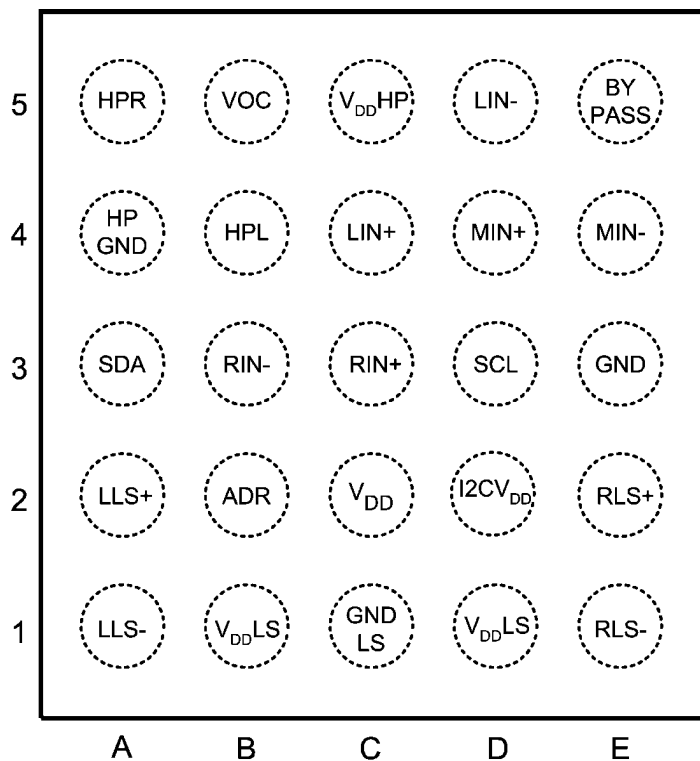


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FIGURE 1. Typical Audio Amplifier Application Circuit

## Connection Diagrams

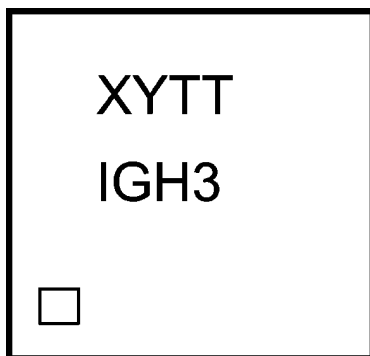
TL Package  
2.68mm x 2.68mm x 0.6mm



202001c7

Top View  
Order Number LM4949TL  
See NS Package Number TLA25JJA

LM4949TL Marking



202001c0

Top View  
XY — 2 digit datecode  
TT — Die traceability

**Absolute Maximum Ratings** (Note 2)

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

|                             |                          |
|-----------------------------|--------------------------|
| Supply Voltage (Note 1)     | 6.0V                     |
| Storage Temperature         | -65°C to +150°C          |
| Input Voltage               | -0.3V to $V_{DD} + 0.3V$ |
| Power Dissipation (Note 3)  | Internally Limited       |
| ESD Susceptibility (Note 4) | 2000V                    |
| ESD Susceptibility (Note 5) | 200V                     |
| Junction Temperature        | 150°C                    |

Thermal Resistance

 $\theta_{JA}$ 

35.1°C/W

**Operating Ratings**

Temperature Range

 $T_{MIN} \leq T_A \leq T_{MAX}$  $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$ Supply Voltage ( $V_{DD}$ ,  $V_{DDLS}$ ,  $V_{DDHP}$ ) $2.7V \leq V_{DD} \leq 5.5V$  $I^2C$  Voltage ( $I^2CV_{DD}$ ) $2.4V \leq I^2CV_{DD} \leq 5.5V$ **Electrical Characteristics**  $V_{DD} = 3.0V$  (Notes 1, 2)

The following specifications apply for  $A_V = 0dB$ ,  $R_L$  (SP) =  $15\mu H + 8\Omega + 15\mu H$ ,  $R_{L(HP)} = 32\Omega$ ,  $f = 1kHz$  unless otherwise specified. Limits apply for  $T_A = 25^\circ\text{C}$ .

| Symbol    | Parameter               | Conditions                     | LM4949   |              | Units<br>(Limits) |
|-----------|-------------------------|--------------------------------|----------|--------------|-------------------|
|           |                         |                                | Typical  | Limit        |                   |
|           |                         |                                | (Note 6) | (Notes 7, 8) |                   |
| $I_{DD}$  | Supply Current          | LS Mode                        |          |              |                   |
|           |                         | Stereo                         | 6        | 8.75         | mA (max)          |
|           |                         | Mono                           | 4.5      |              | mA                |
|           |                         | OCL HP Mode                    |          |              |                   |
|           |                         | Stereo                         | 5.0      | 6.5          | mA (max)          |
|           |                         | Mono                           | 4.3      |              | mA                |
|           |                         | CC HP Mode                     |          |              |                   |
|           |                         | Stereo                         | 4.0      | 5.25         | mA (max)          |
| $I_{SD}$  | Shutdown Supply Current | Mono                           | 3.3      |              | mA                |
|           |                         | Stereo LS + HP Mode            | 8.6      |              | mA                |
| $V_{OS}$  | Output Offset Voltage   | Speaker (mode 1)               | 0.03     | 2            | $\mu A$ (max)     |
|           |                         | OCL HP (mode 1)                | 8.9      | 48.9         | mV (max)          |
| $P_{OUT}$ | Output Power            | Speaker (mode 1)               | 5.6      | 24.5         | mV (max)          |
|           |                         | LS Mode, $f = 1kHz$            |          |              |                   |
|           |                         | $R_L = 4\Omega$ , THD+N = 10%  | 820      |              | mW                |
|           |                         | $R_L = 4\Omega$ , THD+N = 1%   | 662      |              | mW                |
|           |                         | $R_L = 8\Omega$ , THD+N = 10%  | 515      |              | mW                |
|           |                         | $R_L = 8\Omega$ , THD+N = 1%   | 415      | 340          | mW (min)          |
|           |                         | OCP HP Mode, $f = 1kHz$        |          |              |                   |
|           |                         | $R_L = 16\Omega$ , THD+N = 10% | 62.5     |              | mW                |
|           |                         | $R_L = 16\Omega$ , THD+N = 1%  | 50       |              | mW                |
|           |                         | $R_L = 32\Omega$ , THD+N = 10% | 37.5     |              | mW                |
|           |                         | $R_L = 32\Omega$ , THD+N = 1%  | 30.3     |              | mW                |
|           |                         | CC HP Mode, $f = 1kHz$         |          |              |                   |
|           |                         | $R_L = 16\Omega$ , THD+N = 10% | 63       |              | mW                |
|           |                         | $R_L = 16\Omega$ , THD+N = 1%  | 50       |              | mW                |
|           |                         | $R_L = 32\Omega$ , THD+N = 10% | 38       |              | mW                |
|           |                         | $R_L = 32\Omega$ , THD+N = 1%  | 30       |              | mW (min)          |

| Symbol           | Parameter                         | Conditions                                                                       | LM4949   |              | Units<br>(Limits) |
|------------------|-----------------------------------|----------------------------------------------------------------------------------|----------|--------------|-------------------|
|                  |                                   |                                                                                  | Typical  | Limit        |                   |
|                  |                                   |                                                                                  | (Note 6) | (Notes 7, 8) |                   |
| THD+N            | Total Harmonic Distortion + Noise | Differential Mode, f = 1kHz                                                      |          |              |                   |
|                  |                                   | HP Mode, R <sub>L</sub> = 16Ω, P <sub>OUT</sub> = 35mW                           |          |              |                   |
|                  |                                   | OCL                                                                              | 0.015    |              | %                 |
|                  |                                   | CC                                                                               | 0.012    |              | %                 |
|                  |                                   | HP Mode, R <sub>L</sub> = 32Ω, P <sub>OUT</sub> = 20mW                           |          |              |                   |
| THD+N            | Total Harmonic Distortion + Noise | OCL                                                                              | 0.017    |              | %                 |
|                  |                                   | CC                                                                               | 0.018    |              | %                 |
|                  |                                   | LS Mode                                                                          |          |              |                   |
|                  |                                   | R <sub>L</sub> = 4Ω, P <sub>OUT</sub> = 300mW                                    | 0.023    |              | %                 |
|                  |                                   | R <sub>L</sub> = 8Ω, P <sub>OUT</sub> = 150mW                                    | 0.02     |              | %                 |
| THD+N            | Total Harmonic Distortion + Noise | Single-Ended Input Mode, f = 1kHz                                                |          |              |                   |
|                  |                                   | HP Mode, R <sub>L</sub> = 16Ω, P <sub>OUT</sub> = 35mW                           |          |              |                   |
|                  |                                   | OCL                                                                              | 0.023    |              | %                 |
|                  |                                   | CC                                                                               | 0.017    |              | %                 |
|                  |                                   | HP Mode, R <sub>L</sub> = 32Ω, P <sub>OUT</sub> = 20mW                           |          |              |                   |
| THD+N            | Total Harmonic Distortion + Noise | OCL                                                                              | 0.019    |              | %                 |
|                  |                                   | CC                                                                               | 0.013    |              | %                 |
|                  |                                   | LS Mode                                                                          |          |              |                   |
|                  |                                   | R <sub>L</sub> = 4Ω, P <sub>OUT</sub> = 300mW                                    | 0.05     |              | %                 |
|                  |                                   | R <sub>L</sub> = 8Ω, P <sub>OUT</sub> = 150mW                                    | 0.03     |              | %                 |
| e <sub>N</sub>   | Noise                             | Differential Input, A-weighted, Input Referred                                   |          |              |                   |
|                  |                                   | Mono Input                                                                       |          |              |                   |
|                  |                                   | OCL                                                                              | 16.4     |              | μV                |
|                  |                                   | CC                                                                               | 15.5     |              | μV                |
|                  |                                   | LS                                                                               | 43       |              | μV                |
|                  |                                   | All Inputs ON                                                                    |          |              |                   |
|                  |                                   | OCL                                                                              | 29.8     |              | μV                |
|                  |                                   | CC                                                                               | 29.2     |              | μV                |
|                  |                                   | LS                                                                               | 46.6     |              | μV                |
|                  |                                   | Single-Ended Input, A-weighted, Input Referred                                   |          |              |                   |
|                  |                                   | Stereo Input                                                                     |          |              |                   |
|                  |                                   | OCL                                                                              | 12       |              | μV                |
|                  |                                   | CC                                                                               | 11       |              | μV                |
| LA               | 45                                |                                                                                  | μV       |              |                   |
| e <sub>N</sub>   | Noise                             | All Inputs ON                                                                    |          |              |                   |
|                  |                                   | OCL                                                                              | 23.7     |              | μV                |
|                  |                                   | CC                                                                               | 22.9     |              | μV                |
|                  |                                   | LS                                                                               | 52       |              | μV                |
| η                | Efficiency                        | LS Mode, P <sub>OUT</sub> = 400mW, R <sub>L</sub> = 8Ω                           | 85.3     |              | %                 |
| Xtalk            | Crosstalk                         | LS Mode, f = 1kHz, R <sub>L</sub> = 8Ω, V <sub>IN</sub> = 1V <sub>P-P</sub>      |          |              |                   |
|                  |                                   | Differential Input Mode                                                          | 84.7     |              | dB                |
|                  |                                   | OCL HP Mode, f = 1kHz, R <sub>L</sub> = 32Ω, V <sub>IN</sub> = 1V <sub>P-P</sub> |          |              |                   |
|                  |                                   | Differential Input Mode                                                          | 68       |              | dB                |
| T <sub>ON</sub>  | Turn on Time                      | CC Mode                                                                          | 68       |              | ms                |
|                  |                                   | OCL Mode                                                                         | 14       |              | ms                |
|                  |                                   | LS Mode                                                                          | 29       |              | ms                |
| T <sub>OFF</sub> | Turn off Time                     | From any mode                                                                    | 683      |              | ms                |
| Z <sub>IN</sub>  | Input Impedance                   | Maximum Gain                                                                     | 24.8     |              | kΩ                |
|                  |                                   | Minimum Gain                                                                     | 222.7    |              | kΩ                |

| Symbol | Parameter                    | Conditions                                                                | LM4949   |              | Units<br>(Limits) |
|--------|------------------------------|---------------------------------------------------------------------------|----------|--------------|-------------------|
|        |                              |                                                                           | Typical  | Limit        |                   |
|        |                              |                                                                           | (Note 6) | (Notes 7, 8) |                   |
| $A_v$  | Gain                         | Volume Control                                                            |          |              |                   |
|        |                              | Minimum Gain                                                              | -57      |              | dB                |
|        |                              | Maximum Gain                                                              | 18       |              | dB                |
|        |                              | LS Second Gain Stage                                                      |          |              |                   |
|        |                              | Step 0                                                                    |          |              |                   |
|        |                              | Differential Input                                                        | 6        |              | dB                |
|        |                              | Single-Ended Input                                                        | 12       |              | dB                |
|        |                              | Step 1                                                                    |          |              |                   |
|        |                              | Differential Input                                                        | 4        |              | dB                |
|        |                              | Single-Ended Input                                                        | 10       |              | dB                |
|        |                              | Step 2                                                                    |          |              |                   |
|        |                              | Differential Input                                                        | 2        |              | dB                |
|        |                              | Single-Ended Input                                                        | 8        |              | dB                |
|        |                              | Step 3                                                                    |          |              |                   |
|        |                              | Differential Input                                                        | 0        |              | dB                |
|        |                              | Single-Ended Input                                                        | 6        |              | dB                |
|        |                              | HP Second Gain Stage                                                      |          |              |                   |
|        |                              | Step 0                                                                    | 0        |              | dB                |
|        |                              | Step 1                                                                    | -6       |              | dB                |
|        |                              | Step 2                                                                    | -12      |              | dB                |
| Mute   | Mute Attenuation             | Speaker Mode                                                              | -103     |              | dB                |
|        |                              | Headphone Mode                                                            | -123     |              | dB                |
| CMRR   | Common Mode Rejection Ratio  | Speaker Mode, $f = 1\text{kHz}$ ,<br>$V_{IN} = 200\text{mV}_{P-P}$        | 66.1     |              | dB                |
|        |                              | OCL Headphone Mode, $f = 1\text{kHz}$ ,<br>$V_{IN} = 200\text{mV}_{P-P}$  | 70       |              | dB                |
| PSRR   | Power Supply Rejection Ratio | Differential Input Mode, $V_{RIPPLE} = 200\text{mV}_{P-P}$                |          |              |                   |
|        |                              | OCL HP Mode, $f = 217\text{Hz}$                                           | 78.1     |              | dB                |
|        |                              | OCL HP Mode, $f = 1\text{kHz}$                                            | 75.4     |              | dB                |
|        |                              | LS Mode, $f = 217\text{Hz}$                                               | 74       |              | dB                |
|        |                              | LS Mode, $f = 1\text{kHz}$                                                | 72.9     |              | dB                |
| PSRR   | Power Supply Rejection Ratio | Single-Ended Input Mode, $V_{RIPPLE} = 200\text{mV}_{P-P}$                |          |              |                   |
|        |                              | OCL HP Mode, $f = 217\text{Hz}$                                           | 77.5     |              | dB                |
|        |                              | OCL HP Mode, $f = 1\text{kHz}$                                            | 81       |              | dB                |
|        |                              | LS Mode, $f = 217\text{Hz}$                                               | 69       |              | dB                |
|        |                              | LS Mode, $f = 70.31\text{kHz}$                                            | 72.8     |              | dB                |
| PSRR   | Power Supply Rejection Ratio | All Inputs ON, Single-Ended Input Mode, $V_{RIPPLE} = 200\text{mV}_{P-P}$ |          |              |                   |
|        |                              | OCL HP Mode, $f = 217\text{Hz}$                                           | 66.1     |              | dB                |
|        |                              | OCL HP Mode, $f = 1\text{kHz}$                                            | 70.5     |              | dB                |
|        |                              | LS Mode, $f = 217\text{Hz}$                                               | 65.4     |              | dB                |
|        |                              | LS Mode, $f = 1\text{kHz}$                                                | 72.2     |              | dB                |

**Electrical Characteristics  $V_{DD} = 3.6V$** 

(Notes 1, 2) The following specifications apply for  $A_V = 0dB$ ,  $R_{L(SP)} = 15\mu H + 8\Omega + 15\mu H$ ,  $R_{L(HP)} = 32\Omega$ ,  $f = 1kHz$  unless otherwise specified. Limits apply for  $T_A = 25^\circ C$ .

| Symbol    | Parameter                         | Conditions                                      | LM4949   |              | Units<br>(Limits) |
|-----------|-----------------------------------|-------------------------------------------------|----------|--------------|-------------------|
|           |                                   |                                                 | Typical  | Limit        |                   |
|           |                                   |                                                 | (Note 6) | (Notes 7, 8) |                   |
| $I_{DD}$  | Supply Current                    | LS Mode                                         |          |              |                   |
|           |                                   | Stereo                                          | 6.8      | 7.3          | mA (max)          |
|           |                                   | Mono                                            | 4.9      | 5.3          | mA (max)          |
|           |                                   | OCL HP Mode                                     |          |              |                   |
|           |                                   | Stereo                                          | 5.8      | 6.5          | mA (max)          |
|           |                                   | Mono                                            | 4.9      | 5.5          | mA (max)          |
|           |                                   | CC HP Mode                                      |          |              |                   |
|           |                                   | Stereo                                          | 4.7      | 5.2          | mA (max)          |
| $I_{SD}$  | Shutdown Supply Current           | Mono                                            | 4.1      | 4.6          | mA (max)          |
|           |                                   | Stereo LS + HP Mode                             | 9.36     |              | mA                |
| $V_{OS}$  | Output Offset Voltage             | Headphone                                       | 6.7      | 20           | mV (max)          |
|           |                                   | Speaker                                         | 8.9      | 49           | mV (max)          |
| $P_{OUT}$ | Output Power                      | LS Mode, $f = 1 kHz$                            |          |              |                   |
|           |                                   | $R_L = 4\Omega$ , THD+N = 10%                   | 1.24     |              | W                 |
|           |                                   | $R_L = 4\Omega$ , THD+N = 1%                    | 1        |              | W                 |
|           |                                   | $R_L = 8\Omega$ , THD+N = 10%                   | 0.765    |              | W                 |
|           |                                   | $R_L = 8\Omega$ , THD+N = 1%                    | 0.615    |              | W                 |
|           |                                   | OCL HP Mode, $f = 1 kHz$                        |          |              |                   |
|           |                                   | $R_L = 16\Omega$ , THD+N = 10%                  | 94       |              | mW                |
|           |                                   | $R_L = 16\Omega$ , THD+N = 1%                   | 76       |              | mW                |
|           |                                   | $R_L = 32\Omega$ , THD+N = 10%                  | 55       |              | mW                |
|           |                                   | $R_L = 32\Omega$ , THD+N = 1%                   | 45       |              | mW                |
|           |                                   | CC HP Mode, $f = 1 kHz$                         |          |              |                   |
|           |                                   | $R_L = 16\Omega$ , THD+N = 10%                  | 93       |              | mW                |
|           |                                   | $R_L = 16\Omega$ , THD+N = 1%                   | 75       |              | mW                |
|           |                                   | $R_L = 32\Omega$ , THD+N = 10%                  | 56       |              | mW                |
|           |                                   | $R_L = 32\Omega$ , THD+N = 1%                   | 45       |              | mW                |
| THD+N     | Total Harmonic Distortion + Noise | Differential Mode, $f = 1kHz$                   |          |              |                   |
|           |                                   | HP Mode, $R_L = 16\Omega$ , $P_{OUT} = 50mW$    |          |              |                   |
|           |                                   | OCL                                             | 0.021    |              | %                 |
|           |                                   | CC                                              | 0.021    |              | %                 |
|           |                                   | HP Mode, $R_L = 32\Omega$ ,<br>$P_{OUT} = 30mW$ |          |              |                   |
|           |                                   | OCL                                             | 0.01     |              | %                 |
|           |                                   | CC                                              | 0.01     |              | %                 |
|           |                                   | LS Mode                                         |          |              |                   |
|           |                                   | $R_L = 4\Omega$ , $P_{OUT} = 400mW$             | 0.023    |              | %                 |
|           |                                   | $R_L = 8\Omega$ , $P_{OUT} = 300mW$             | 0.02     |              | %                 |

| Symbol           | Parameter                         | Conditions                                                                       | LM4949   |              | Units<br>(Limits) |
|------------------|-----------------------------------|----------------------------------------------------------------------------------|----------|--------------|-------------------|
|                  |                                   |                                                                                  | Typical  | Limit        |                   |
|                  |                                   |                                                                                  | (Note 6) | (Notes 7, 8) |                   |
| THD+N            | Total Harmonic Distortion + Noise | Single-Ended Input Mode, f = 1kHz                                                |          |              |                   |
|                  |                                   | HP Mode, R <sub>L</sub> = 16Ω, P <sub>OUT</sub> = 50mW                           |          |              |                   |
|                  |                                   | OCL                                                                              | 0.021    |              | %                 |
|                  |                                   | CC                                                                               | 0.017    |              | %                 |
|                  |                                   | HP Mode, R <sub>L</sub> = 32Ω, P <sub>OUT</sub> = 30mW                           |          |              |                   |
|                  |                                   | OCL                                                                              | 0.02     |              | %                 |
| e <sub>N</sub>   | Noise                             | CC                                                                               | 0.015    |              | %                 |
|                  |                                   | LS Mode                                                                          |          |              |                   |
|                  |                                   | R <sub>L</sub> = 4Ω, P <sub>OUT</sub> = 400mW                                    | 0.05     |              | %                 |
|                  |                                   | R <sub>L</sub> = 8Ω, P <sub>OUT</sub> = 300mW                                    | 0.034    |              | %                 |
|                  |                                   | Differential Mode, A-weighted, Input Referred                                    |          |              |                   |
|                  |                                   | Mono Input                                                                       |          |              |                   |
| η                | Efficiency                        | OCL                                                                              | 16.4     |              | μV                |
|                  |                                   | CC                                                                               | 15.5     |              | μV                |
|                  |                                   | LS                                                                               | 43       |              | μV                |
|                  |                                   | All Inputs ON                                                                    |          |              |                   |
|                  |                                   | OCL                                                                              | 29.8     |              | μV                |
|                  |                                   | CC                                                                               | 29.2     |              | μV                |
|                  |                                   | LS                                                                               | 46.6     |              | μV                |
|                  |                                   | Single-Ended Input, A-weighted, Input Referred                                   |          |              |                   |
|                  |                                   | Stereo Input                                                                     |          |              |                   |
|                  |                                   | OCL                                                                              | 12       |              | μV                |
|                  |                                   | CC                                                                               | 11       |              | μV                |
|                  |                                   | LS                                                                               | 45       |              | μV                |
| Xtalk            | Crosstalk                         | All Inputs ON                                                                    |          |              |                   |
|                  |                                   | OCL                                                                              | 23.7     |              | μV                |
|                  |                                   | CC                                                                               | 22.9     |              | μV                |
|                  |                                   | LS                                                                               | 52       |              | μV                |
| T <sub>ON</sub>  | Turn on Time                      | LS Mode, P <sub>OUT</sub> = 400mW, R <sub>L</sub> = 8Ω                           | 86.5     |              | %                 |
| T <sub>OFF</sub> | Turn off Time                     | LS Mode, f = 1kHz, R <sub>L</sub> = 8Ω, V <sub>IN</sub> = 1V <sub>P-P</sub>      |          |              |                   |
|                  |                                   | Differential Input Mode                                                          | 86       |              | dB                |
|                  |                                   | OCL HP Mode, f = 1kHz, R <sub>L</sub> = 32Ω, V <sub>IN</sub> = 1V <sub>P-P</sub> |          |              |                   |
|                  |                                   | Differential Input Mode                                                          | 68       |              | dB                |
| Z <sub>IN</sub>  | Input Impedance                   | CC Mode                                                                          | 75       |              | ms                |
|                  |                                   | OCL Mode                                                                         | 14       |              | ms                |
|                  |                                   | LS Mode                                                                          | 31       |              | ms                |
| Z <sub>IN</sub>  | Input Impedance                   | From any mode                                                                    | 692      |              | ms                |
|                  |                                   | Maximum Gain                                                                     | 24.8     |              | kΩ                |
|                  |                                   | Minimum Gain                                                                     | 222.7    |              | kΩ                |

| Symbol | Parameter                    | Conditions                                                                | LM4949   |              | Units<br>(Limits) |
|--------|------------------------------|---------------------------------------------------------------------------|----------|--------------|-------------------|
|        |                              |                                                                           | Typical  | Limit        |                   |
|        |                              |                                                                           | (Note 6) | (Notes 7, 8) |                   |
| $A_v$  | Gain                         | Volume Control                                                            |          |              |                   |
|        |                              | Minimum Gain                                                              | −57      |              | dB                |
|        |                              | Maximum Gain                                                              | 18       |              | dB                |
|        |                              | LS Second Gain Stage                                                      |          |              |                   |
|        |                              | Step 0                                                                    |          |              |                   |
|        |                              | Differential Input                                                        | 6        |              | dB                |
|        |                              | Single-Ended Input                                                        | 12       |              | dB                |
|        |                              | Step 2                                                                    |          |              |                   |
|        |                              | Differential Input                                                        | 4        |              | dB                |
|        |                              | Single-Ended Input                                                        | 10       |              | dB                |
|        |                              | Step 2                                                                    |          |              |                   |
|        |                              | Differential Input                                                        | 2        |              | dB                |
|        |                              | Single-Ended Input                                                        | 8        |              | dB                |
|        |                              | Step 3                                                                    |          |              |                   |
|        |                              | Differential Input                                                        | 0        |              | dB                |
|        |                              | Single-Ended Input                                                        | 6        |              | dB                |
|        |                              | HP Second Gain Stage                                                      |          |              |                   |
|        |                              | Step 0                                                                    | 0        |              |                   |
|        |                              | Step 1                                                                    | −6       |              | dB                |
|        |                              | Step 2                                                                    | −12      |              | dB                |
| Mute   | Mute Attenuation             | Speaker Mode                                                              | −84      |              | dB                |
|        |                              | Headphone Mode                                                            | −95      |              | dB                |
| CMRR   | Common Mode Rejection Ratio  | Speaker Mode, $f = 1\text{kHz}$ ,<br>$V_{IN} = 200\text{mV}_{P-P}$        | 66       |              | dB                |
|        |                              | OCL Headphone Mode, $f = 1\text{kHz}$ ,<br>$V_{IN} = 200\text{mV}_{P-P}$  | 68.6     |              | dB                |
| PSRR   | Power Supply Rejection Ratio | Differential Input Mode, $V_{RIPPLE} = 200\text{mV}_{P-P}$                |          |              |                   |
|        |                              | OCL HP Mode, $f = 217\text{Hz}$                                           | 75       |              | dB                |
|        |                              | OCL HP Mode, $f = 1\text{kHz}$                                            | 75       |              | dB                |
|        |                              | LS Mode, $f = 217\text{Hz}$                                               | 73       |              | dB                |
|        |                              | LS Mode, $f = 1\text{kHz}$                                                | 73       |              | dB                |
| PSRR   | Power Supply Rejection Ratio | Single-Ended Input Mode, $V_{RIPPLE} = 200\text{mV}_{P-P}$                |          |              |                   |
|        |                              | OCL HP Mode, $f = 217\text{Hz}$                                           | 75       |              | dB                |
|        |                              | OCL HP Mode, $f = 1\text{kHz}$                                            | 75       |              | dB                |
|        |                              | LS Mode, $f = 217\text{Hz}$                                               | 67       |              | dB                |
|        |                              | LS Mode, $f = 1\text{kHz}$                                                | 71       |              | dB                |
| PSRR   | Power Supply Rejection Ratio | All Inputs ON, Single-Ended Input Mode, $V_{RIPPLE} = 200\text{mV}_{P-P}$ |          |              |                   |
|        |                              | OCL HP Mode, $f = 217\text{Hz}$                                           | 72       |              | dB                |
|        |                              | OCL HP Mode, $f = 1\text{kHz}$                                            | 70       |              | dB                |
|        |                              | LS Mode, $f = 217\text{Hz}$                                               | 60       |              | dB                |
|        |                              | LS Mode, $f = 1\text{kHz}$                                                | 65       |              | dB                |

# Electrical Characteristics $V_{DD} = 5.0V$ (Notes 1, 2) The following specifications apply for $A_V = 0dB$ , $R_L$ $(SP) = 15\mu H + 8\Omega + 15\mu H$ , $R_{L(HP)} = 32\Omega$ , $f = 1kHz$ unless otherwise specified. Limits apply for $T_A = 25^\circ C$ .

| Symbol    | Parameter                         | Conditions                                    | LM4949   |              | Units<br>(Limits) |
|-----------|-----------------------------------|-----------------------------------------------|----------|--------------|-------------------|
|           |                                   |                                               | Typical  | Limit        |                   |
|           |                                   |                                               | (Note 6) | (Notes 7, 8) |                   |
| $I_{DD}$  | Supply Current                    | LS Mode                                       |          |              |                   |
|           |                                   | Stereo                                        | 9.9      | 10.9         | mA (max)          |
|           |                                   | Mono                                          | 6.6      | 7.2          | mA (max)          |
|           |                                   | OCL HP Mode                                   |          |              |                   |
|           |                                   | Stereo                                        | 6.6      | 7.3          | mA (max)          |
|           |                                   | Mono                                          | 5.5      | 6.2          | mA (max)          |
|           |                                   | CC HP Mode                                    |          |              |                   |
|           |                                   | Stereo                                        | 5.4      | 5.9          | mA (max)          |
| $I_{SD}$  | Shutdown Supply Current           | Mono                                          | 4.3      | 4.8          | mA (max)          |
|           |                                   | Stereo LS + HP Mode                           | 13       |              | mA                |
| $V_{OS}$  | Output Offset Voltage             | Headphone                                     | 10       | 52           | mV (max)          |
|           |                                   | Speaker                                       | 9.6      | 50           | mV (max)          |
| $P_{OUT}$ | Output Power                      | LS Mode, $f = 1 kHz$                          |          |              |                   |
|           |                                   | $R_L = 4\Omega$ , THD+N = 10%                 | 2.5      |              | W                 |
|           |                                   | $R_L = 4\Omega$ , THD+N = 1%                  | 2.01     |              | W                 |
|           |                                   | $R_L = 8\Omega$ , THD+N = 10%                 | 1.48     |              | W                 |
|           |                                   | $R_L = 8\Omega$ , THD+N = 1%                  | 1.19     |              | W                 |
|           |                                   | OCL HP Mode, $f = 1 kHz$                      |          |              |                   |
|           |                                   | $R_L = 16\Omega$ , THD+N = 10%                | 190      |              | mW                |
|           |                                   | $R_L = 16\Omega$ , THD+N = 1%                 | 154      |              | mW                |
|           |                                   | $R_L = 32\Omega$ , THD+N = 10%                | 109      |              | mW                |
|           |                                   | $R_L = 32\Omega$ , THD+N = 1%                 | 89       |              | mW                |
|           |                                   | CC HP Mode, $f = 1 kHz$                       |          |              |                   |
|           |                                   | $R_L = 16\Omega$ , THD+N = 10%                | 188      |              | mW                |
|           |                                   | $R_L = 16\Omega$ , THD+N = 1%                 | 153      |              | mW                |
|           |                                   | $R_L = 32\Omega$ , THD+N = 10%                | 105      |              | mW                |
|           |                                   | $R_L = 32\Omega$ , THD+N = 1%                 | 88       |              | mW                |
| THD + N   | Total Harmonic Distortion + Noise | Differential Input Mode, $f = 1kHz$           |          |              |                   |
|           |                                   | HP Mode, $R_L = 16\Omega$ , $P_{OUT} = 100mW$ |          |              |                   |
|           |                                   | OCL                                           | 0.02     |              | %                 |
|           |                                   | CC                                            | 0.027    |              | %                 |
|           |                                   | HP Mode, $R_L = 32\Omega$ , $P_{OUT} = 50mW$  |          |              |                   |
|           |                                   | OCL                                           | 0.02     |              | %                 |
|           |                                   | CC                                            | 0.022    |              | %                 |
|           |                                   | LS Mode                                       |          |              |                   |
|           |                                   | $R_L = 4\Omega$ , $P_{OUT} = 1W$              | 0.022    |              | %                 |
|           |                                   | $R_L = 8\Omega$ , $P_{OUT} = 600mW$           | 0.02     |              | %                 |

| Symbol    | Parameter                         | Conditions                                                              | LM4949   |              | Units<br>(Limits) |
|-----------|-----------------------------------|-------------------------------------------------------------------------|----------|--------------|-------------------|
|           |                                   |                                                                         | Typical  | Limit        |                   |
|           |                                   |                                                                         | (Note 6) | (Notes 7, 8) |                   |
| THD + N   | Total Harmonic Distortion + Noise | Single-Ended Input Mode, $f = 1\text{kHz}$                              |          |              |                   |
|           |                                   | HP Mode, $R_L = 16\Omega$ , $P_{OUT} = 100\text{mW}$                    |          |              |                   |
|           |                                   | OCL                                                                     | 0.021    |              | %                 |
|           |                                   | CC                                                                      | 0.02     |              | %                 |
|           |                                   | HP Mode, $R_L = 32\Omega$ , $P_{OUT} = 50\text{mW}$                     |          |              |                   |
| $e_N$     | Noise                             | OCL                                                                     | 0.02     |              | %                 |
|           |                                   | CC                                                                      | 0.017    |              | %                 |
|           |                                   | LS Mode                                                                 |          |              |                   |
|           |                                   | $R_L = 4\Omega$ , $P_{OUT} = 1\text{W}$                                 | 0.05     |              | %                 |
|           |                                   | $R_L = 8\Omega$ , $P_{OUT} = 600\text{mW}$                              | 0.033    |              | %                 |
|           |                                   | Differential Input, A-weighted, Input Referred                          |          |              |                   |
|           |                                   | Mono Input                                                              |          |              |                   |
|           |                                   | OCL                                                                     | 16.4     |              | $\mu\text{V}$     |
|           |                                   | CC                                                                      | 15.5     |              | $\mu\text{V}$     |
|           |                                   | LS                                                                      | 43       |              | $\mu\text{V}$     |
| $\eta$    | Efficiency                        | All Inputs ON                                                           |          |              |                   |
|           |                                   | OCL                                                                     | 29.8     |              | $\mu\text{V}$     |
|           |                                   | CC                                                                      | 29.2     |              | $\mu\text{V}$     |
|           |                                   | LS                                                                      | 46.6     |              | $\mu\text{V}$     |
|           |                                   | Single-Ended Input, A-weighted, Input Referred                          |          |              |                   |
|           |                                   | Stereo Input                                                            |          |              |                   |
|           |                                   | OCL                                                                     | 12       |              | $\mu\text{V}$     |
|           |                                   | CC                                                                      | 11       |              | $\mu\text{V}$     |
|           |                                   | LS                                                                      | 45       |              | $\mu\text{V}$     |
|           |                                   | All Inputs ON                                                           |          |              |                   |
| Xtalk     | Crosstalk                         | OCL                                                                     | 23.7     |              | $\mu\text{V}$     |
|           |                                   | CC                                                                      | 22.9     |              | $\mu\text{V}$     |
|           |                                   | LS                                                                      | 52       |              | $\mu\text{V}$     |
|           |                                   |                                                                         |          |              |                   |
| $T_{ON}$  | Turn on Time                      | LS Mode, $P_{OUT} = 1\text{W}$ , $R_L = 8\Omega$                        | 87.4     |              | %                 |
|           |                                   |                                                                         |          |              |                   |
|           |                                   |                                                                         |          |              |                   |
|           |                                   |                                                                         |          |              |                   |
| $T_{OFF}$ | Turn off Time                     | LS Mode, $f = 1\text{kHz}$ , $R_L = 8\Omega$ , $V_{IN} = 1V_{P-P}$      |          |              |                   |
|           |                                   | Differential Input Mode                                                 | 105.8    |              | dB                |
|           |                                   | OCL HP Mode, $f = 1\text{kHz}$ , $R_L = 32\Omega$ , $V_{IN} = 1V_{P-P}$ |          |              |                   |
|           |                                   | Differential Input Mode                                                 | 69.6     |              | dB                |
| $Z_{IN}$  | Input Impedance                   | CC Mode                                                                 | 89       |              | ms                |
|           |                                   | OCL Mode                                                                | 14       |              | ms                |
|           |                                   | LS Mode                                                                 | 35       |              | ms                |
| $Z_{IN}$  | Input Impedance                   | From any mode                                                           | 716      |              | ms                |
|           |                                   |                                                                         |          |              |                   |
| $Z_{IN}$  | Input Impedance                   | Maximum Gain                                                            | 24.8     |              | $k\Omega$         |
|           |                                   | Minimum Gain                                                            | 222.7    |              | $k\Omega$         |

| Symbol | Parameter                    | Conditions                                                                | LM4949   |              | Units<br>(Limits) |
|--------|------------------------------|---------------------------------------------------------------------------|----------|--------------|-------------------|
|        |                              |                                                                           | Typical  | Limit        |                   |
|        |                              |                                                                           | (Note 6) | (Notes 7, 8) |                   |
| $A_V$  | Gain                         | Volume Control<br>Minimum Gain                                            | -57      |              | dB                |
|        |                              | Maximum Gain                                                              | 18       |              | dB                |
|        |                              | LS Second Gain Stage                                                      |          |              |                   |
|        |                              | Step 0                                                                    |          |              |                   |
|        |                              | Differential Input                                                        | 6        |              | dB                |
|        |                              | Single-Ended Input                                                        | 12       |              | dB                |
|        |                              | Step 1                                                                    |          |              |                   |
|        |                              | Differential Input                                                        | 4        |              | dB                |
|        |                              | Single-Ended Input                                                        | 10       |              | dB                |
|        |                              | Step 2                                                                    |          |              |                   |
|        |                              | Differential Input                                                        | 8        |              | dB                |
|        |                              | Single-Ended Input                                                        | 2        |              | dB                |
|        |                              | Step 3                                                                    |          |              |                   |
|        |                              | Differential Input                                                        | 0        |              | dB                |
|        |                              | Single-Ended Input                                                        | 6        |              | dB                |
|        |                              | HP Second Gain Stage                                                      |          |              |                   |
|        |                              | Step 0                                                                    | 0        |              | dB                |
|        |                              | Step 1                                                                    | -6       |              | dB                |
|        |                              | Step 2                                                                    | -12      |              | dB                |
| Mute   | Mute Attenuation             | Speaker Mode                                                              | -102.7   |              | dB                |
|        |                              | Headphone Mode                                                            | -123     |              | dB                |
| CMRR   | Common Mode Rejection Ratio  | Speaker Mode, $f = 1\text{kHz}$ ,<br>$V_{IN} = 200\text{mV}_{P-P}$        | 64.4     |              | dB                |
|        |                              | OCL Headphone Mode, $f = 1\text{kHz}$ ,<br>$V_{IN} = 200\text{mV}_{P-P}$  | 74.3     |              | dB                |
| PSRR   | Power Supply Rejection Ratio | Differential Input Mode, $V_{RIPPLE} = 200\text{mV}_{P-P}$                |          |              |                   |
|        |                              | OCL HP Mode, $f = 217\text{Hz}$                                           | 68.3     |              | dB                |
|        |                              | OCL HP Mode, $f = 1\text{kHz}$                                            | 67.9     |              | dB                |
|        |                              | LS Mode, $f = 217\text{Hz}$                                               | 73.8     |              | dB                |
|        |                              | LS Mode, $f = 1\text{kHz}$                                                | 72       |              | dB                |
| PSRR   | Power Supply Rejection Ratio | Single-Ended Input Mode, $V_{RIPPLE} = 200\text{mV}_{P-P}$                |          |              |                   |
|        |                              | OCL HP Mode, $f = 217\text{Hz}$                                           | 70.55    |              | dB                |
|        |                              | OCL HP Mode, $f = 1\text{kHz}$                                            | 63.05    |              | dB                |
|        |                              | LS Mode, $f = 217\text{Hz}$                                               | 64.6     |              | dB                |
|        |                              | LS Mode, $f = 1\text{kHz}$                                                | 70.3     |              | dB                |
| PSRR   | Power Supply Rejection Ratio | All Inputs ON, Single-Ended Input Mode, $V_{RIPPLE} = 200\text{mV}_{P-P}$ |          |              |                   |
|        |                              | OCL HP Mode, $f = 217\text{Hz}$                                           | 63.1     |              | dB                |
|        |                              | OCL HP Mode, $f = 1\text{kHz}$                                            | 66.4     |              | dB                |
|        |                              | LS Mode, $f = 217\text{Hz}$                                               | 59.1     |              | dB                |
|        |                              | LS Mode, $f = 1\text{kHz}$                                                | 69.3     |              | dB                |

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

**Note 2:** *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur. *Operating Ratings* indicate conditions for which the device is functional, but do not guarantee specific performance limits. *Electrical Characteristics* state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

**Note 3:** The maximum power dissipation must be derated at elevated temperatures and is dictated by  $T_{JMAX}$ ,  $\theta_{JA}$ , and the ambient temperature  $T_A$ . The maximum allowable power dissipation is  $P_{DMAX} = (T_{JMAX} - T_A) / \theta_{JA}$  or the number given in Absolute Maximum Ratings, whichever is lower. For the LM4949, see power derating currents for additional information.

**Note 4:** Human body model, 100pF discharged through a 1.5k $\Omega$  resistor.

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

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

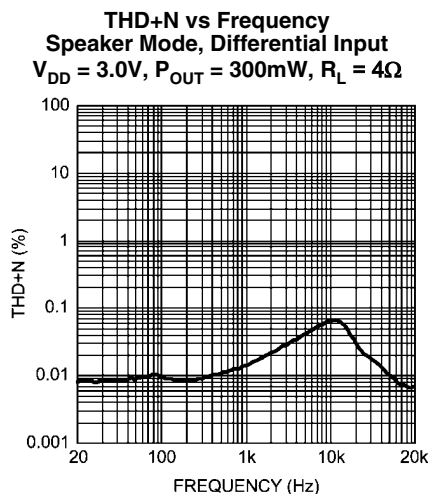
**Note 7:** Limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

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

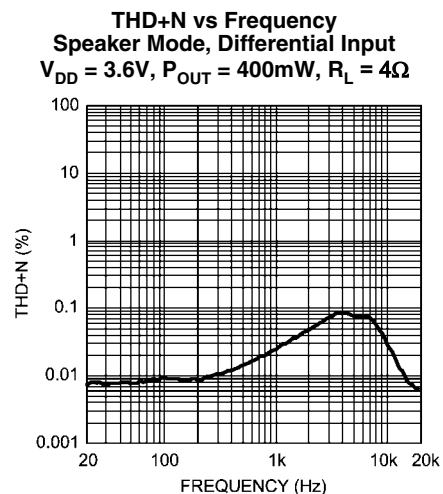
TABLE 1. Bump Description

| BUMP | NAME                | DESCRIPTION                                    |
|------|---------------------|------------------------------------------------|
| A1   | LLS-                | Left Channel Loudspeaker Inverting Output      |
| A2   | LLS+                | Left Channel Loudspeaker Non-inverting Output  |
| A3   | SDA                 | Serial Data Input                              |
| A4   | HPGND               | Headphone Ground                               |
| A5   | HPR                 | Right Channel Headphone Output                 |
| B1   | VDDL                | Speaker Power Supply                           |
| B2   | ADR                 | Address Select Bit                             |
| B3   | RIN-                | Right Channel Inverting Input                  |
| B4   | HPL                 | Left Channel Headphone Output                  |
| B5   | VOC                 | Headphone Return Bias Output                   |
| C1   | GNDL                | Speaker Ground                                 |
| C2   | VDD                 | Power Supply                                   |
| C3   | RIN+                | Right Channel Non-Inverting Input              |
| C4   | LIN+                | Left Channel Non-inverting Input               |
| C5   | VDDHP               | Headphone Power Supply                         |
| D1   | VDDL                | Speaker Power Supply                           |
| D2   | I <sup>2</sup> CVDD | I <sup>2</sup> C Power Supply                  |
| D3   | SCL                 | Serial Clock Input                             |
| D4   | MIN+                | Mono Channel Non-inverting Input               |
| D5   | LIN-                | Left Channel Inverting Input                   |
| E1   | RLS-                | Right Channel Loudspeaker Inverting Output     |
| E2   | RLS+                | Right Channel Loudspeaker Non-inverting Output |
| E3   | GND                 | Ground                                         |
| E4   | MIN-                | Mono Channel Inverting Input                   |
| E5   | BYPASS              | Mid-rail Bias Bypass                           |

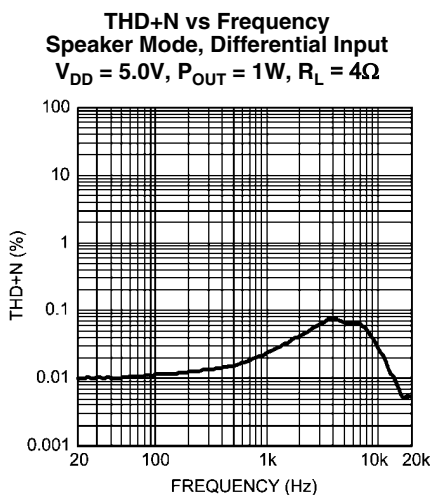
## Typical Performance Characteristics



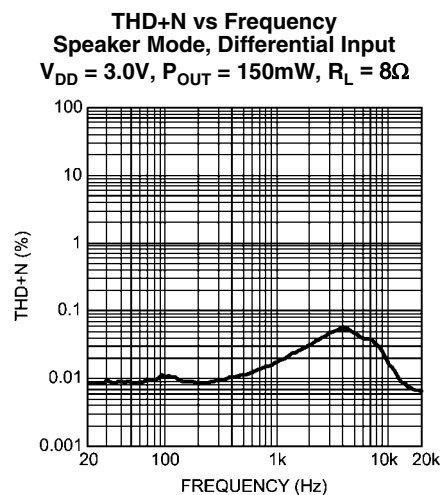
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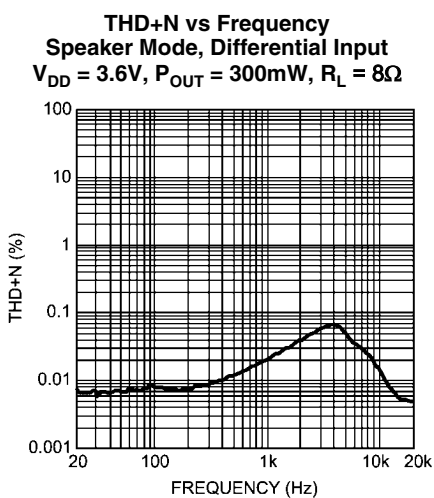
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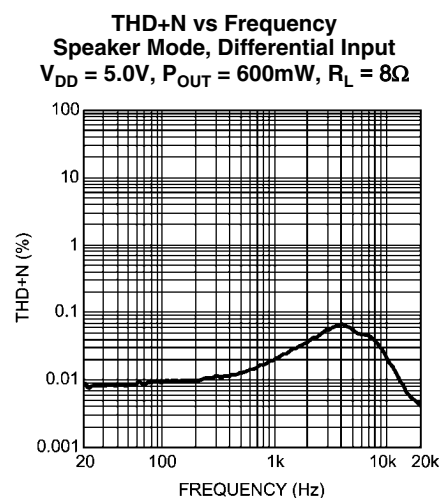
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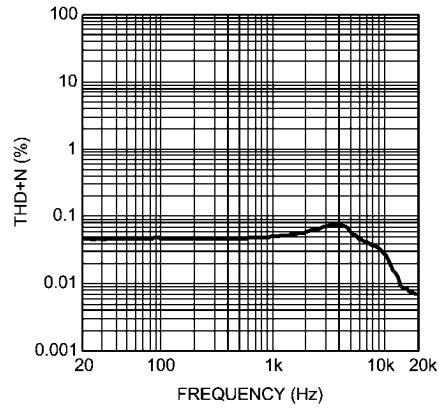


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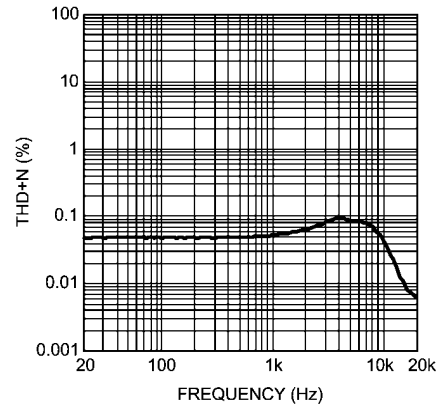
20200115

**THD+N vs Frequency**  
**Speaker Mode, Single-Ended Input**  
 $V_{DD} = 3.0V$ ,  $P_{OUT} = 300mW$ ,  $R_L = 4\Omega$



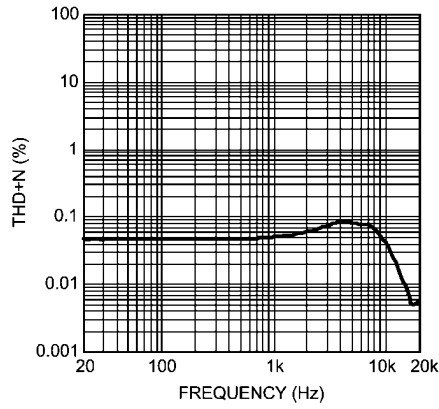
202001f6

**THD+N vs Frequency**  
**Speaker Mode, Single-Ended Input**  
 $V_{DD} = 3.6V$ ,  $P_{OUT} = 400mW$ ,  $R_L = 4\Omega$



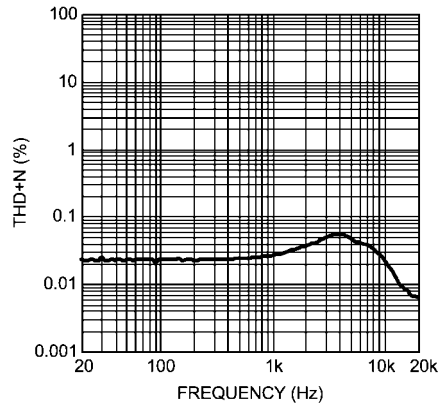
202001f7

**THD+N vs Frequency**  
**Speaker Mode, Single-Ended Input**  
 $V_{DD} = 5.0V$ ,  $P_{OUT} = 1W$ ,  $R_L = 4\Omega$



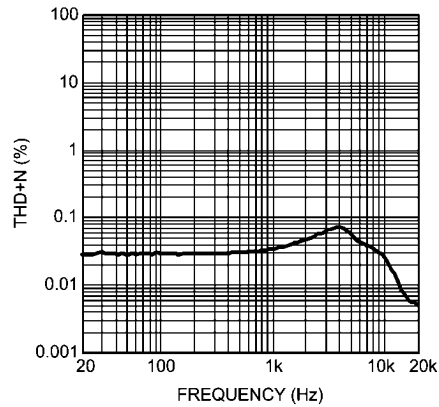
202001f8

**THD+N vs Frequency**  
**Speaker Mode, Single-Ended Input**  
 $V_{DD} = 3.0V$ ,  $P_{OUT} = 150mW$ ,  $R_L = 8\Omega$



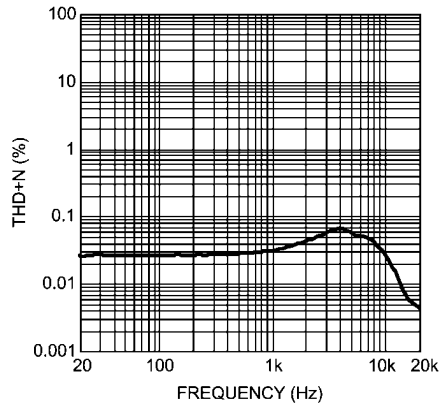
202001f9

**THD+N vs Frequency**  
**Speaker Mode, Single-Ended Input**  
 $V_{DD} = 3.6V$ ,  $P_{OUT} = 300mW$ ,  $R_L = 8\Omega$



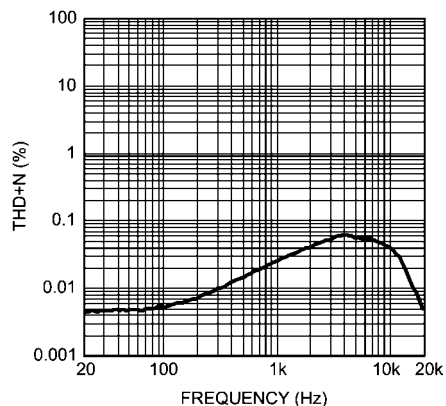
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**THD+N vs Frequency**  
**Speaker Mode, Single-Ended Input**  
 $V_{DD} = 5.0V$ ,  $P_{OUT} = 600mW$ ,  $R_L = 8\Omega$



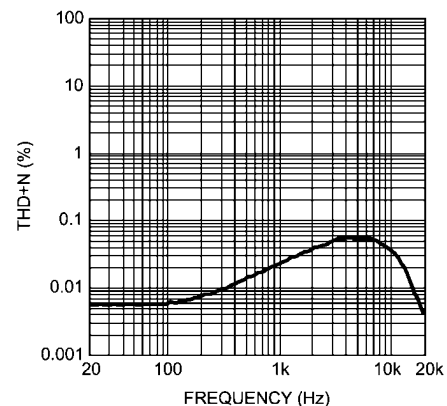
202001g1

**THD+N vs Frequency**  
**OCL Headphone Mode, Differential Input**  
 $V_{DD} = 3.0V$ ,  $P_{OUT} = 35mW$ ,  $R_L = 16\Omega$



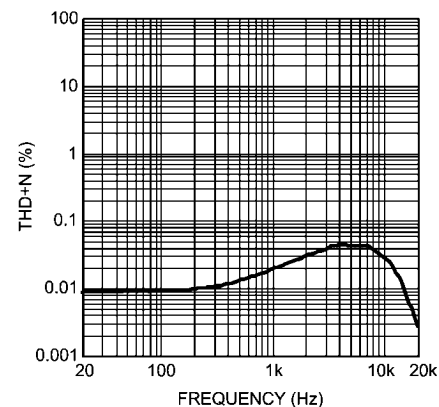
202001g2

**THD+N vs Frequency**  
**OCL Headphone Mode, Differential Input**  
 $V_{DD} = 3.6V$ ,  $P_{OUT} = 50mW$ ,  $R_L = 16\Omega$



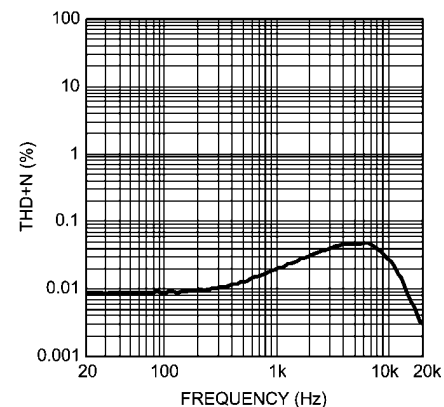
202001g3

**THD+N vs Frequency**  
**OCL Headphone Mode, Differential Input**  
 $V_{DD} = 5.0V$ ,  $P_{OUT} = 100mW$ ,  $R_L = 16\Omega$



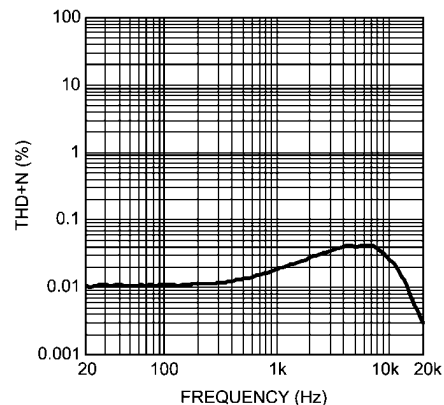
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**THD+N vs Frequency**  
**OCL Headphone Mode, Differential Input**  
 $V_{DD} = 3.0V$ ,  $P_{OUT} = 20mW$ ,  $R_L = 32\Omega$



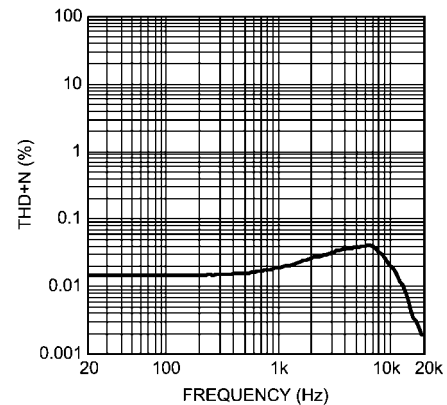
202001g5

**THD+N vs Frequency**  
**OCL Headphone Mode, Differential Input**  
 $V_{DD} = 3.6V$ ,  $P_{OUT} = 30mW$ ,  $R_L = 32\Omega$



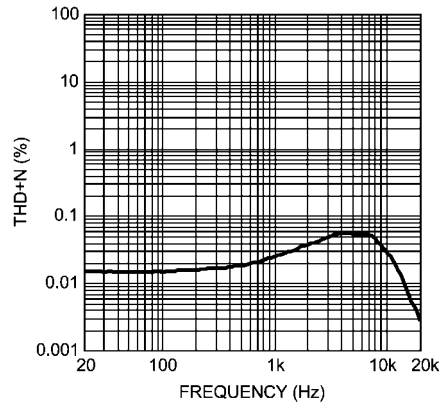
202001g6

**THD+N vs Frequency**  
**OCL Headphone Mode, Differential Input**  
 $V_{DD} = 5.0V$ ,  $P_{OUT} = 50mW$ ,  $R_L = 32\Omega$



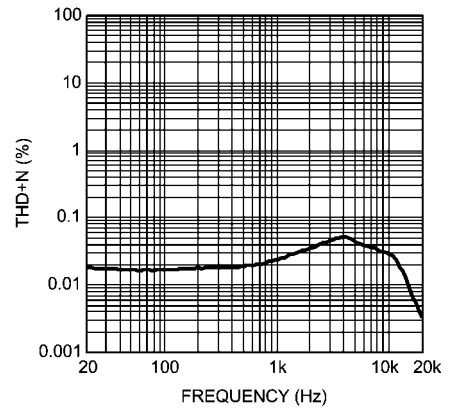
202001g7

**THD+N vs Frequency**  
**OCL Headphone Mode, Single-Ended Input**  
 $V_{DD} = 3.0V$ ,  $P_{OUT} = 35mW$ ,  $R_L = 16\Omega$



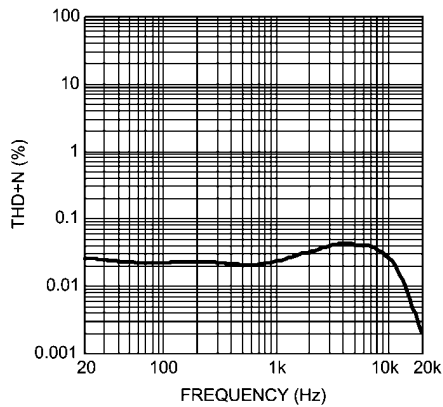
202001g8

**THD+N vs Frequency**  
**OCL Headphone Mode, Single-Ended Input**  
 $V_{DD} = 3.6V$ ,  $P_{OUT} = 50mW$ ,  $R_L = 16\Omega$



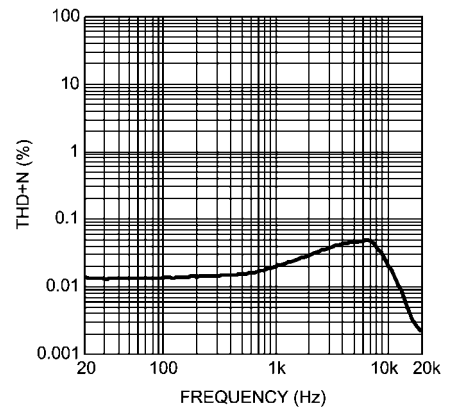
202001g9

**THD+N vs Frequency**  
**OCL Headphone Mode, Single-Ended Input**  
 $V_{DD} = 5.0V$ ,  $P_{OUT} = 100mW$ ,  $R_L = 16\Omega$



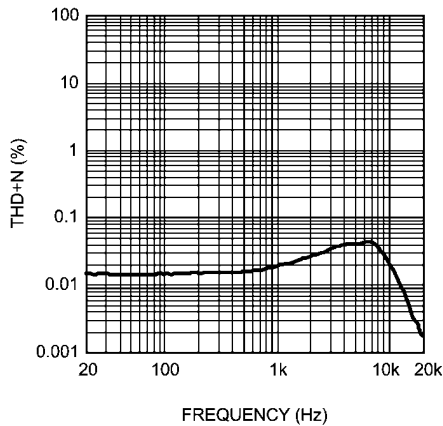
202001h0

**THD+N vs Frequency**  
**OCL Headphone Mode, Single-Ended Input**  
 $V_{DD} = 3.0V$ ,  $P_{OUT} = 20mW$ ,  $R_L = 32\Omega$



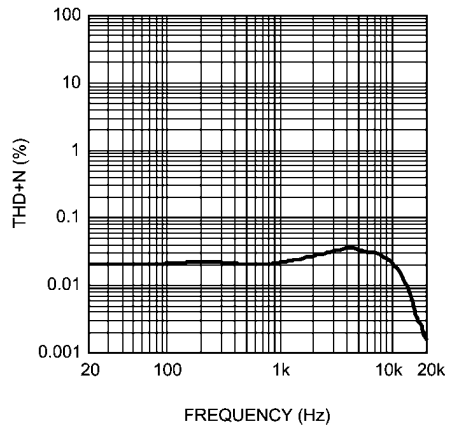
202001h1

**THD+N vs Frequency**  
**OCL Headphone Mode, Single-Ended Input**  
 $V_{DD} = 3.6V$ ,  $P_{OUT} = 30mW$ ,  $R_L = 32\Omega$



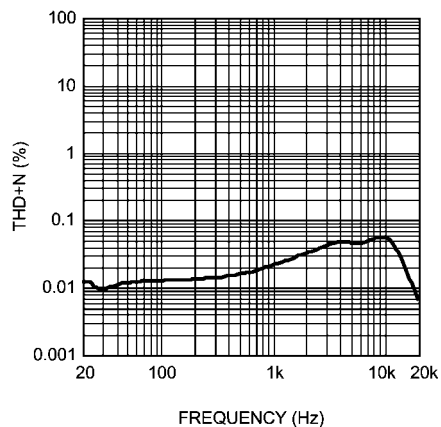
202001h2

**THD+N vs Frequency**  
**OCL Headphone Mode, Single-Ended Input**  
 $V_{DD} = 5.0V$ ,  $P_{OUT} = 50mW$ ,  $R_L = 32\Omega$



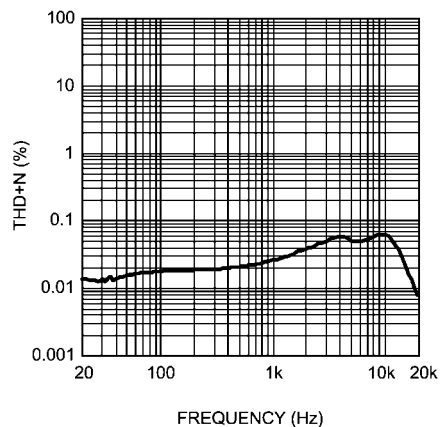
202001h3

**THD+N vs Frequency**  
**CC Headphone Mode, Differential Input**  
 $V_{DD} = 3.0V$ ,  $P_{OUT} = 35mW$ ,  $R_L = 16\Omega$



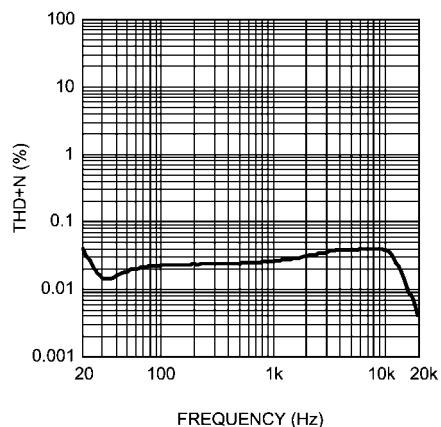
202001h4

**THD+N vs Frequency**  
**CC Headphone Mode, Differential Input**  
 $V_{DD} = 3.6V$ ,  $P_{OUT} = 50mW$ ,  $R_L = 16\Omega$



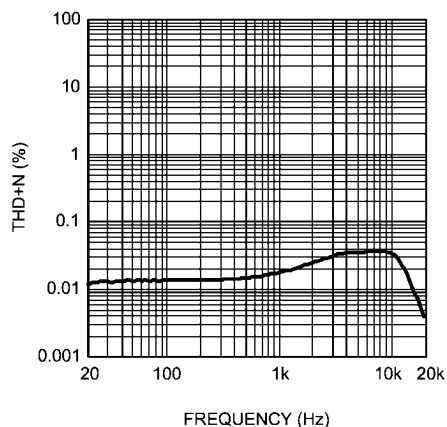
202001h5

**THD+N vs Frequency**  
**CC Headphone Mode, Differential Input**  
 $V_{DD} = 5.0V$ ,  $P_{OUT} = 100mW$ ,  $R_L = 16\Omega$



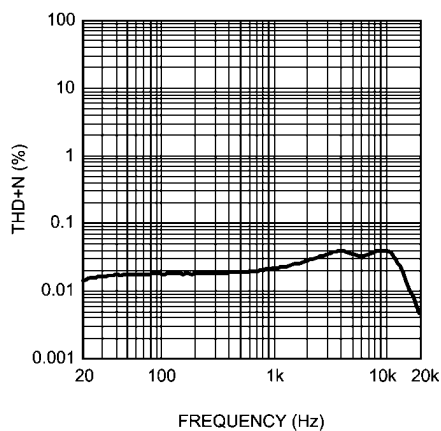
202001h6

**THD+N vs Frequency**  
**CC Headphone Mode, Differential Input**  
 $V_{DD} = 3.0V$ ,  $P_{OUT} = 20mW$ ,  $R_L = 32\Omega$



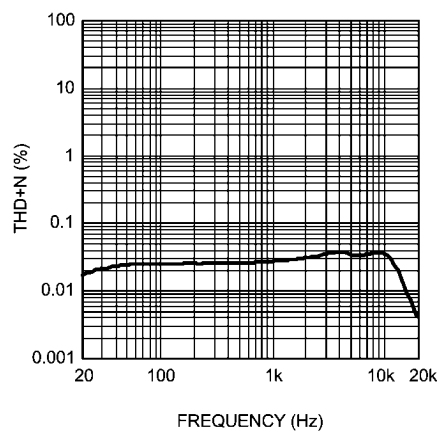
202001h7

**THD+N vs Frequency**  
**CC Headphone Mode, Differential Input**  
 $V_{DD} = 3.6V$ ,  $P_{OUT} = 30mW$ ,  $R_L = 32\Omega$



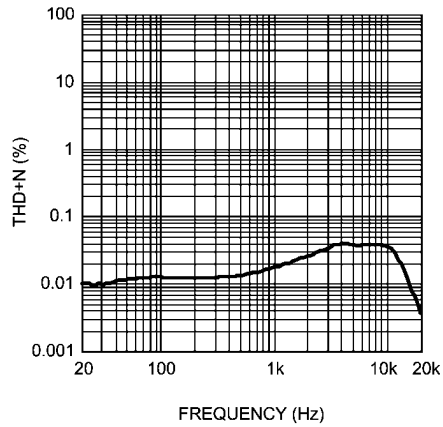
202001h8

**THD+N vs Frequency**  
**CC Headphone Mode, Differential Input**  
 $V_{DD} = 5.0V$ ,  $P_{OUT} = 50mW$ ,  $R_L = 32\Omega$



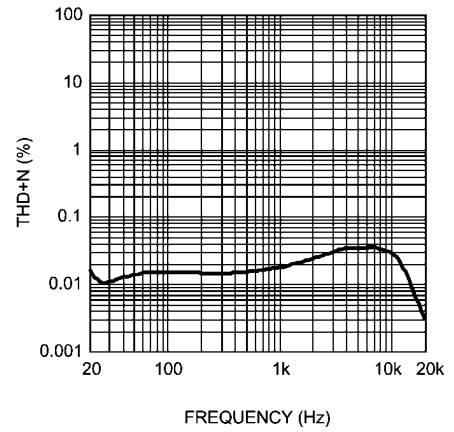
202001h9

**THD+N vs Frequency**  
**CC Headphone Mode, Single-Ended Input**  
 $V_{DD} = 3.0V$ ,  $P_{OUT} = 35mW$ ,  $R_L = 16\Omega$



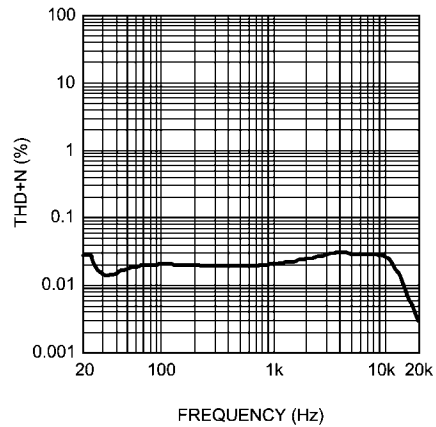
20200113

**THD+N vs Frequency**  
**CC Headphone Mode, Single-Ended Input**  
 $V_{DD} = 3.6V$ ,  $P_{OUT} = 50mW$ ,  $R_L = 16\Omega$



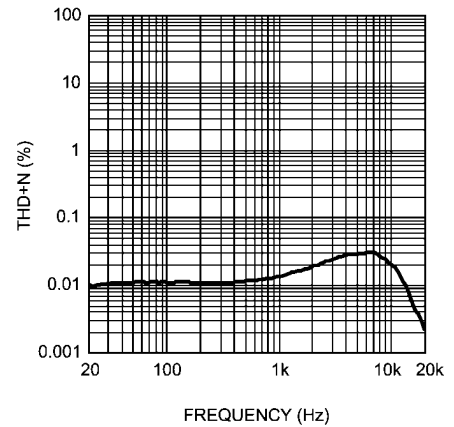
20200114

**THD+N vs Frequency**  
**CC Headphone Mode, Single-Ended Input**  
 $V_{DD} = 5.0V$ ,  $P_{OUT} = 100mW$ ,  $R_L = 16\Omega$



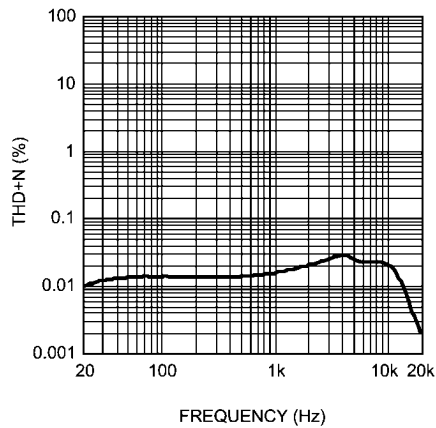
20200115

**THD+N vs Frequency**  
**CC Headphone Mode, Single-Ended Input**  
 $V_{DD} = 3.0V$ ,  $P_{OUT} = 20mW$ ,  $R_L = 32\Omega$



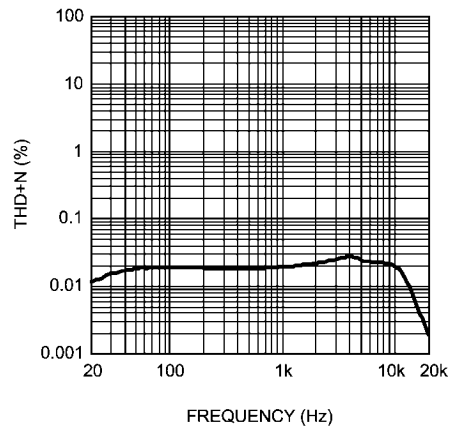
20200116

**THD+N vs Frequency**  
**CC Headphone Mode, Single-Ended Input**  
 $V_{DD} = 3.6V$ ,  $P_{OUT} = 30mW$ ,  $R_L = 32\Omega$



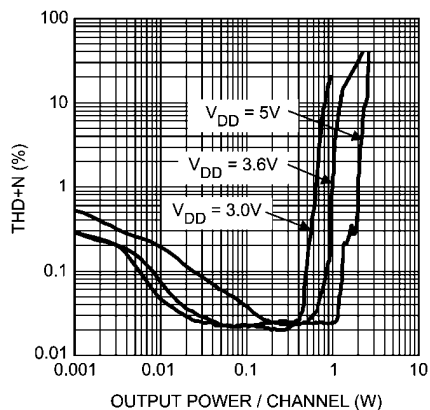
20200117

**THD+N vs Frequency**  
**CC Headphone Mode, Single-Ended Input**  
 $V_{DD} = 5.0V$ ,  $P_{OUT} = 50mW$ ,  $R_L = 32\Omega$



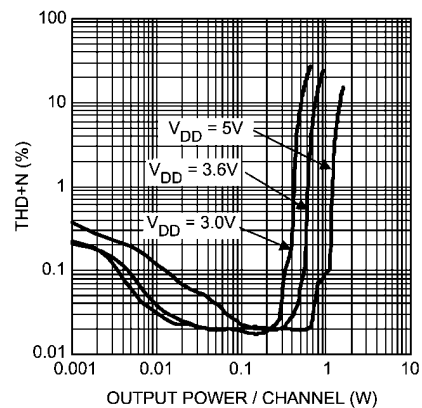
20200118

**THD+N vs Output Power**  
**Speaker Mode, Differential Input**  
 $A_V = 6\text{dB}$ ,  $R_L = 4\Omega$ ,  $f = 1\text{kHz}$



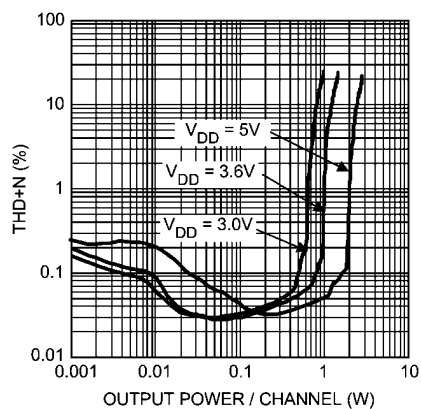
202001d0

**THD+N vs Output Power**  
**Speaker Mode, Differential Input**  
 $A_V = 6\text{dB}$ ,  $R_L = 8\Omega$ ,  $f = 1\text{kHz}$



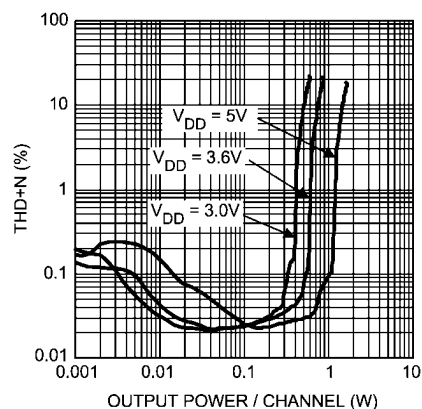
202001d1

**THD+N vs Output Power**  
**Speaker Mode, Single-Ended Input**  
 $A_V = 6\text{dB}$ ,  $R_L = 4\Omega$ ,  $f = 1\text{kHz}$



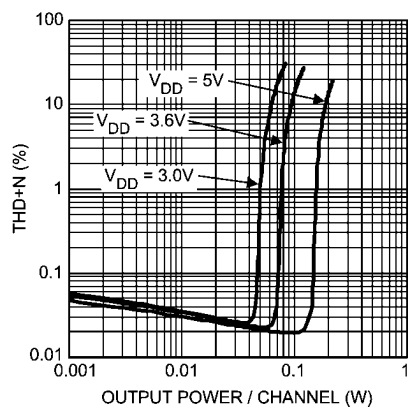
202001d2

**THD+N vs Output Power**  
**Speaker Mode, Single-Ended Input**  
 $A_V = 6\text{dB}$ ,  $R_L = 8\Omega$ ,  $f = 1\text{kHz}$



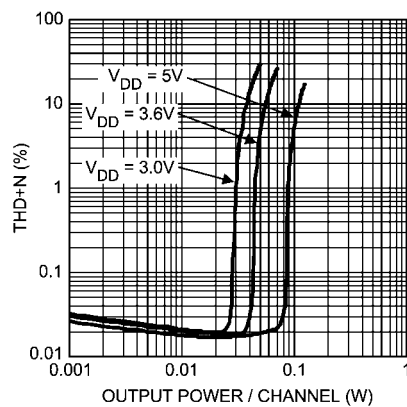
202001d3

**THD+N vs Output Power**  
**OCL Headphone Mode, Differential Input**  
 $A_V = 0\text{dB}$ ,  $R_L = 16\Omega$ ,  $f = 1\text{kHz}$



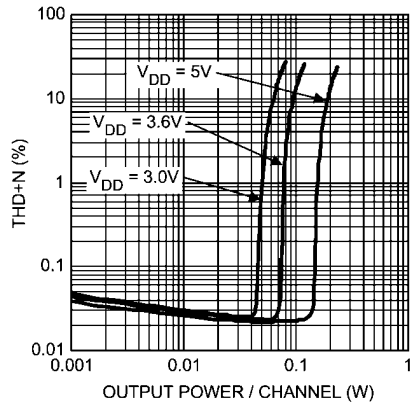
202001d4

**THD+N vs Output Power**  
**OCL Headphone Mode, Differential Input**  
 $A_V = 0\text{dB}$ ,  $R_L = 32\Omega$ ,  $f = 1\text{kHz}$



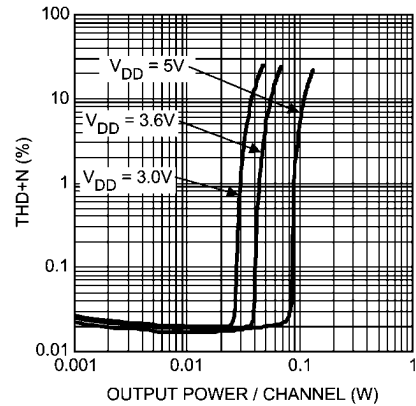
202001d5

**THD+N vs Output Power**  
**OCL Headphone Mode, Single-Ended Input**  
 $A_V = 0\text{dB}$ ,  $R_L = 16\Omega$ ,  $f = 1\text{kHz}$



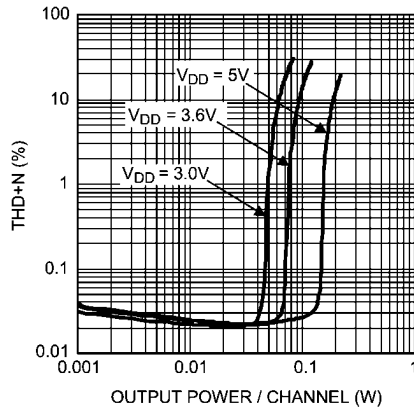
202001d6

**THD+N vs Output Power**  
**OCL Headphone Mode, Single-Ended Input**  
 $A_V = 0\text{dB}$ ,  $R_L = 32\Omega$ ,  $f = 1\text{kHz}$



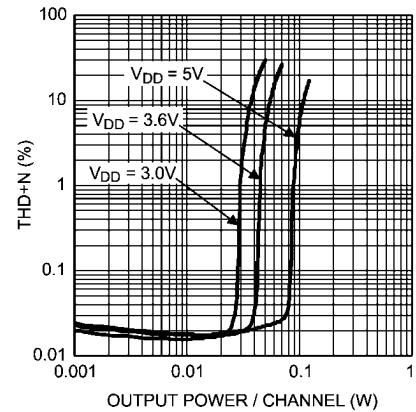
202001d7

**THD+N vs Output Power**  
**CC Headphone Mode, Differential Input**  
 $A_V = 0\text{dB}$ ,  $R_L = 16\Omega$ ,  $f = 1\text{kHz}$



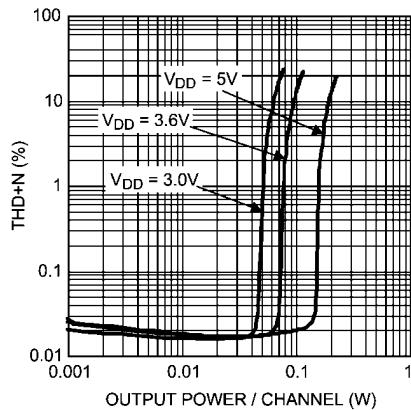
202001d8

**THD+N vs Output Power**  
**CC Headphone Mode, Differential Input**  
 $A_V = 0\text{dB}$ ,  $R_L = 32\Omega$ ,  $f = 1\text{kHz}$



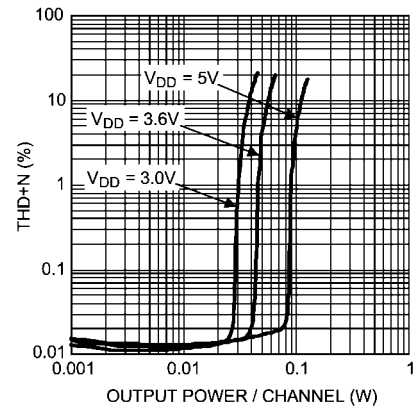
202001d9

**THD+N vs Output Power**  
**CC Headphone Mode, Single-Ended Input**  
 $A_V = 0\text{dB}$ ,  $R_L = 16\Omega$ ,  $f = 1\text{kHz}$



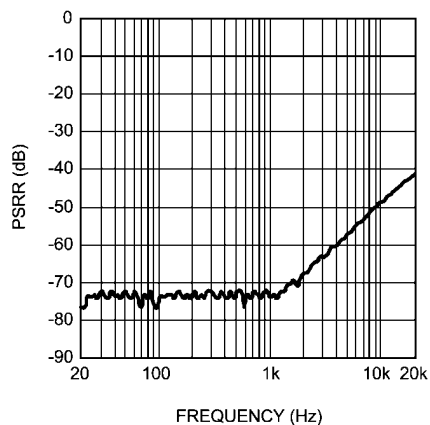
202001e0

**THD+N vs Output Power**  
**CC Headphone Mode, Single-Ended Input**  
 $A_V = 0\text{dB}$ ,  $R_L = 32\Omega$ ,  $f = 1\text{kHz}$



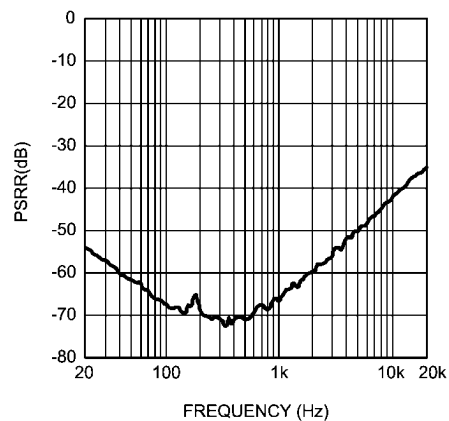
202001e1

**PSRR vs Frequency**  
**Speaker Mode, Differential Input**  
 $V_{DD} = 3.6V$ ,  $V_{RIPPLE} = 200mV_{P-P}$ ,  $R_L = 8\Omega$



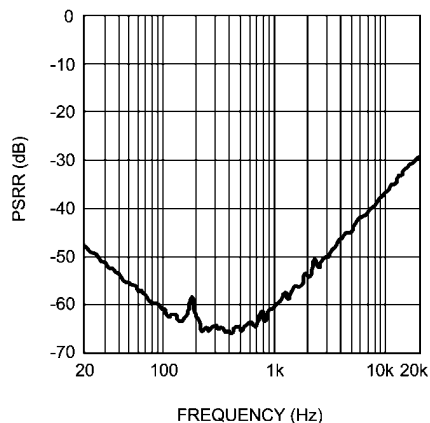
202001i9

**PSRR vs Frequency**  
**Speaker Mode, Differential Input**  
 $V_{DD} = 3.6V$ ,  $V_{RIPPLE} = 200mV_{P-P}$ ,  $R_L = 8\Omega$



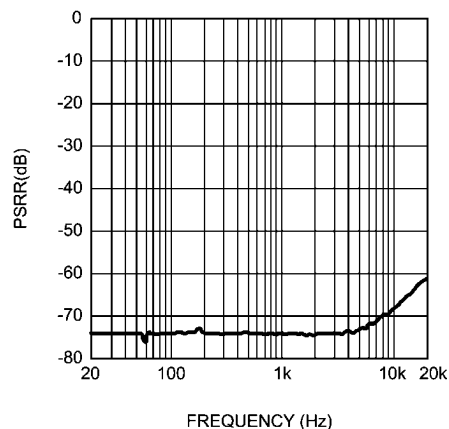
202001j0

**PSRR vs Frequency**  
**Speaker Mode, Single-Ended Input**  
**Stereo and Mono Inputs Active**  
 $V_{DD} = 3.6V$ ,  $V_{RIPPLE} = 200mV_{P-P}$ ,  $R_L = 8\Omega$



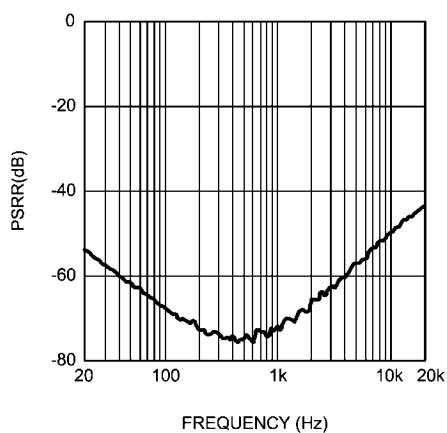
202001j1

**PSRR vs Frequency**  
**OCL Headphone Mode, Differential Input**  
 $V_{DD} = 3.6V$ ,  $V_{RIPPLE} = 200mV_{P-P}$ ,  $R_L = 32\Omega$



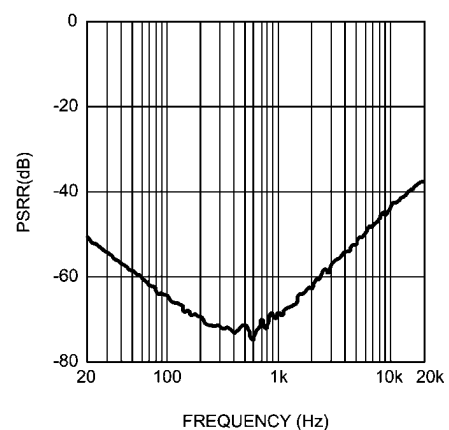
202001j2

**PSRR vs Frequency**  
**OCL Headphone Mode, Single-Ended Input**  
 $V_{DD} = 3.6V$ ,  $V_{RIPPLE} = 200mV_{P-P}$ ,  $R_L = 32\Omega$



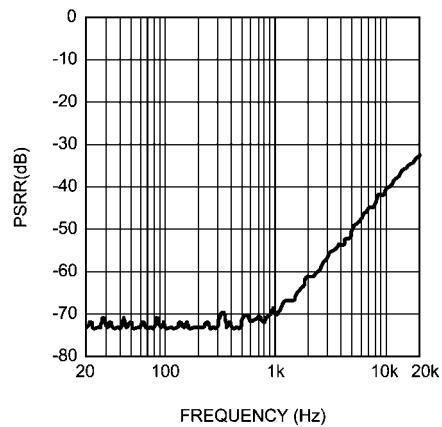
202001j3

**PSRR vs Frequency**  
**OCL Headphone Mode, Single-Ended Input**  
**Stereo and Mono Inputs Active**  
 $V_{DD} = 3.6V$ ,  $V_{RIPPLE} = 200mV_{P-P}$ ,  $R_L = 32\Omega$



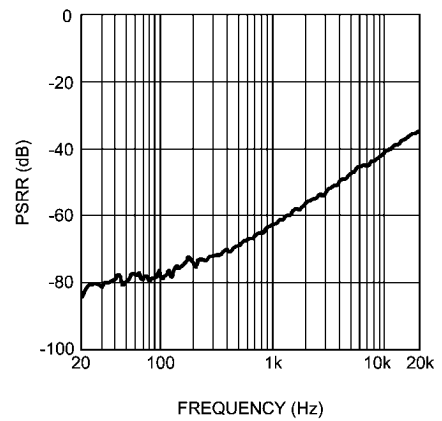
202001j4

**PSRR vs Frequency**  
**CC Headphone Mode, Differential Input**  
 $V_{DD} = 3.6V$ ,  $V_{RIPPLE} = 200mV_{P-P}$ ,  $R_L = 32\Omega$



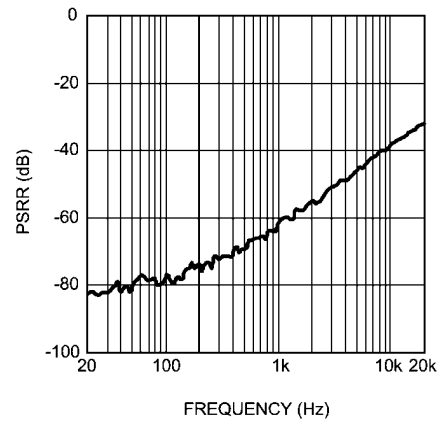
202001j5

**PSRR vs Frequency**  
**CC Headphone Mode, Single-Ended Input**  
 $V_{DD} = 3.6V$ ,  $V_{RIPPLE} = 200mV_{P-P}$ ,  $R_L = 32\Omega$



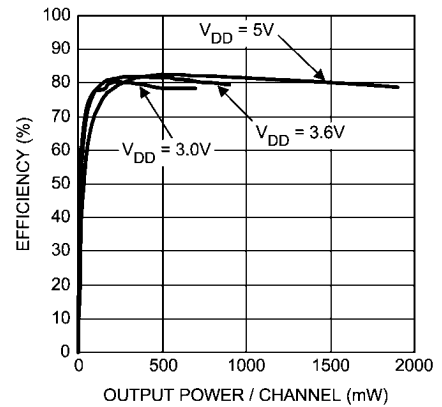
202001j6

**PSRR vs Frequency**  
**CC Headphone Mode, Single-Ended Input**  
**Stereo and Mono Inputs Active**  
 $V_{DD} = 3.6V$ ,  $V_{RIPPLE} = 200mV_{P-P}$ ,  $R_L = 32\Omega$



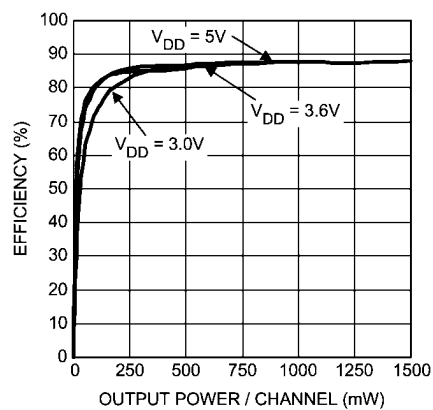
202001j7

**Efficiency vs Output Power**  
**Speaker Mode**  
 $R_L = 32\Omega$ ,  $f = 1kHz$



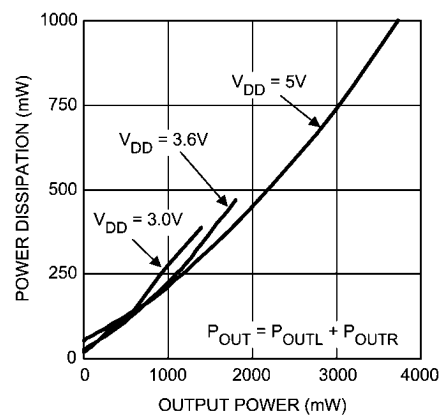
202001e2

**Efficiency vs Output Power**  
**Speaker Mode**  
 $R_L = 8\Omega$ ,  $f = 1kHz$



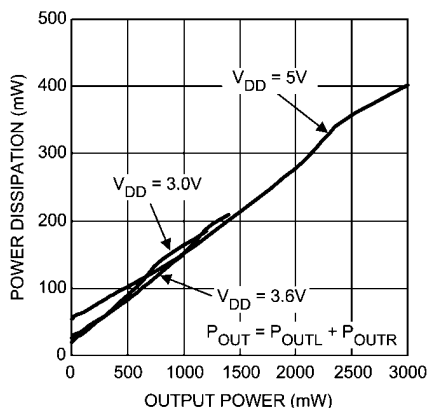
202001e3

**Power Dissipation vs Output Power**  
**Speaker Mode**  
 $R_L = 4\Omega$ ,  $f = 1kHz$



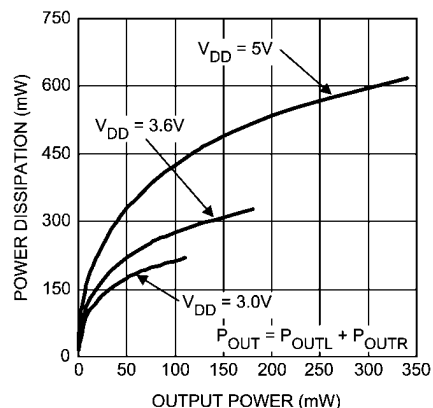
20200139

**Power Dissipation vs Output Power  
Speaker Mode**  
 $R_L = 8\Omega$ ,  $f = 1\text{kHz}$



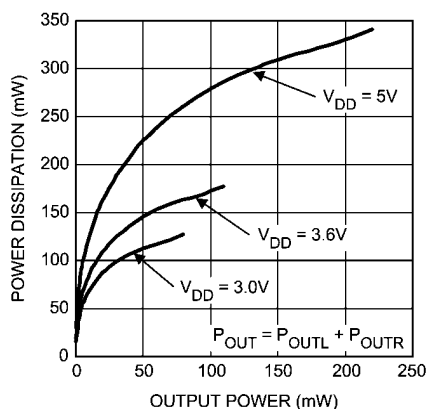
20200140

**Power Dissipation vs Output Power  
OCL Headphone Mode**  
 $R_L = 16\Omega$ ,  $f = 1\text{kHz}$



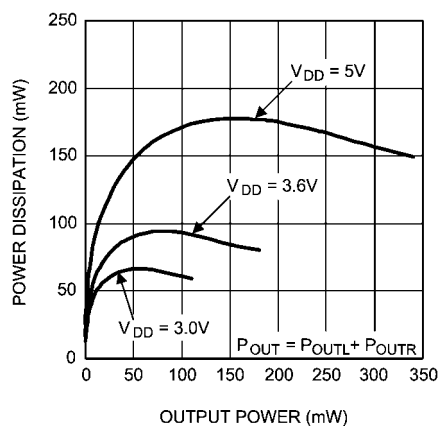
20200168

**Power Dissipation vs Output Power  
OCL Headphone Mode**  
 $R_L = 32\Omega$ ,  $f = 1\text{kHz}$



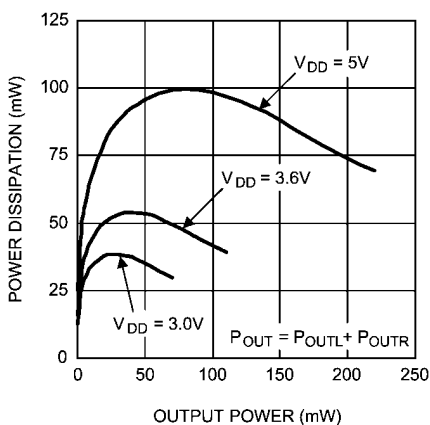
20200169

**Power Dissipation vs Output Power  
CC Headphone Mode**  
 $R_L = 16\Omega$ ,  $f = 1\text{kHz}$



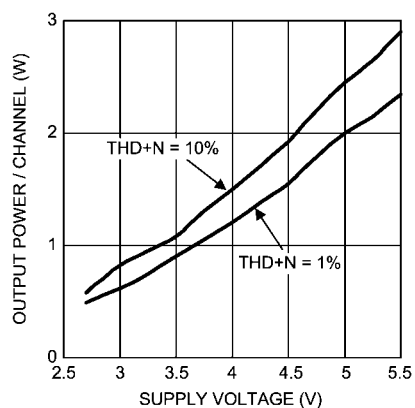
20200195

**Power Dissipation vs Output Power  
CC Headphone Mode**  
 $R_L = 32\Omega$ ,  $f = 1\text{kHz}$



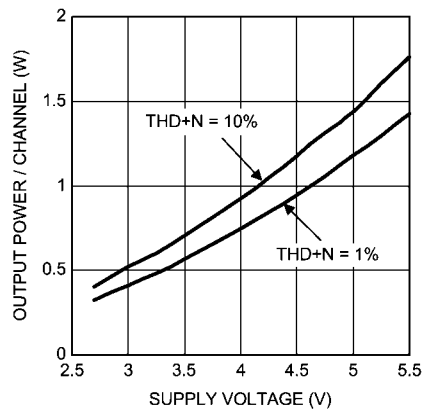
20200196

**Output Power vs Supply Voltage  
Speaker Mode**  
 $R_L = 4\Omega$ ,  $f = 1\text{kHz}$



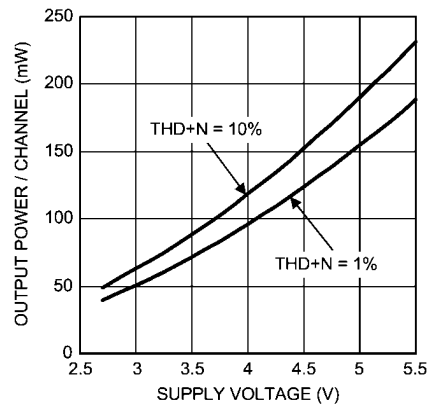
202001e4

**Output Power vs Supply Voltage**  
**Speaker Mode**  
 $R_L = 8\Omega$ ,  $f = 1\text{kHz}$



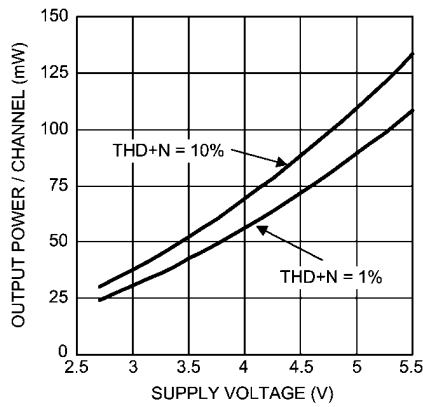
202001e5

**Output Power vs Supply Voltage**  
**OCL Headphone Mode**  
 $R_L = 16\Omega$ ,  $f = 1\text{kHz}$



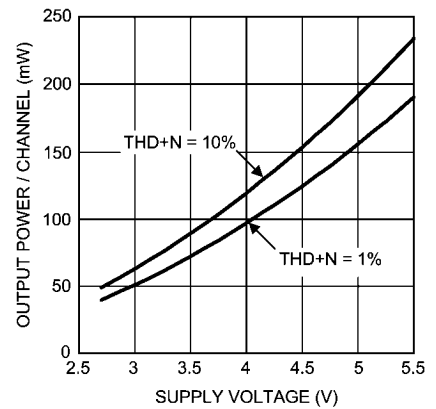
202001e6

**Output Power vs Supply Voltage**  
**OCL Headphone Mode**  
 $R_L = 32\Omega$ ,  $f = 1\text{kHz}$



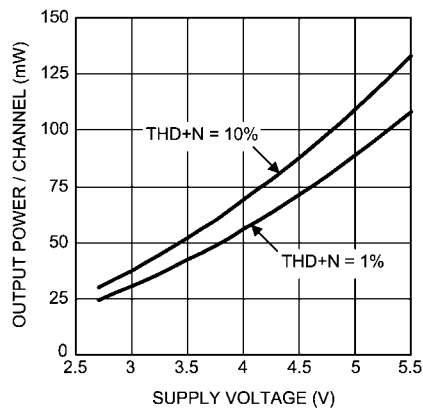
202001e7

**Output Power vs Supply Voltage**  
**CC Headphone Mode**  
 $R_L = 16\Omega$ ,  $f = 1\text{kHz}$



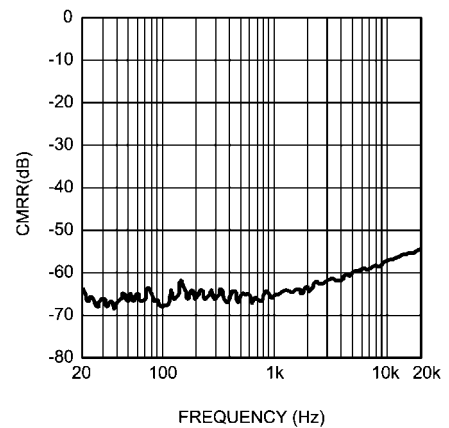
202001e8

**Output Power vs Supply Voltage**  
**CC Headphone Mode**  
 $R_L = 32\Omega$ ,  $f = 1\text{kHz}$

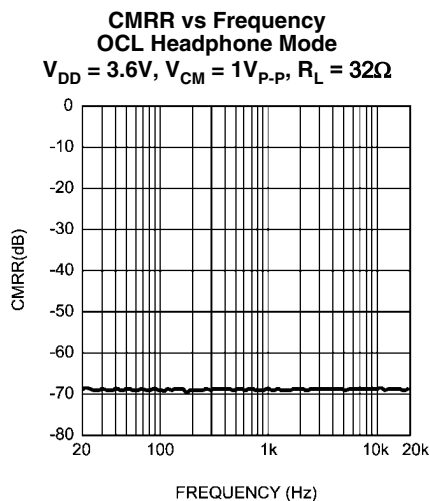


202001e9

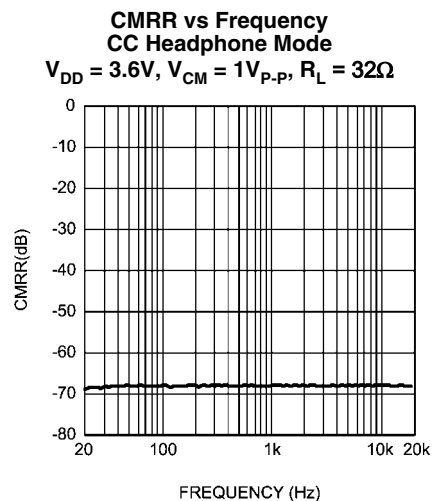
**CMRR vs Frequency**  
**Speaker Mode, Differential Input**  
 $V_{DD} = 3.6\text{V}$ ,  $V_{CM} = 1\text{V}_{P-P}$ ,  $R_L = 8\Omega$ ,  $f = 1\text{kHz}$



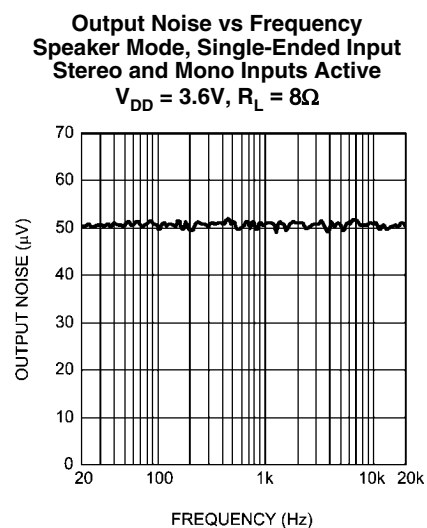
202001j8



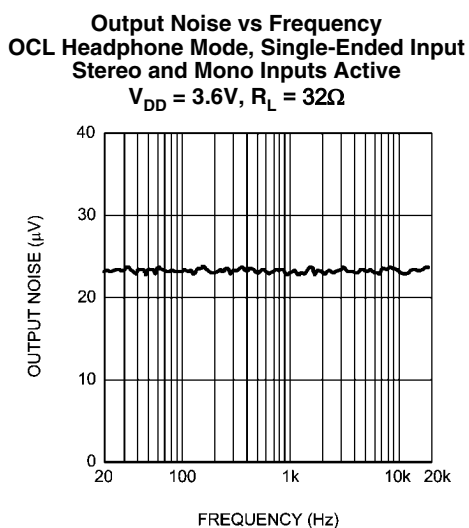
202001j9



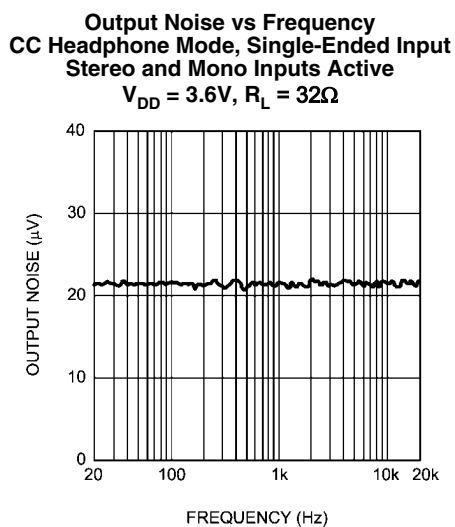
202001k3



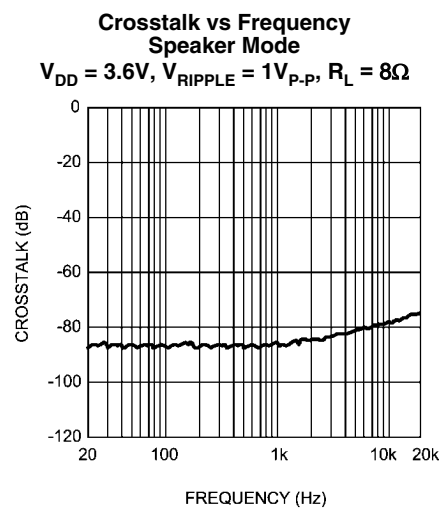
202001k0



202001k1

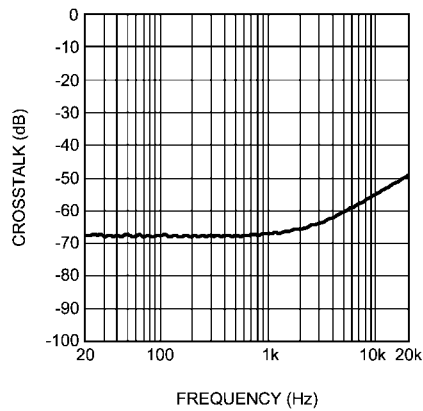


202001k2



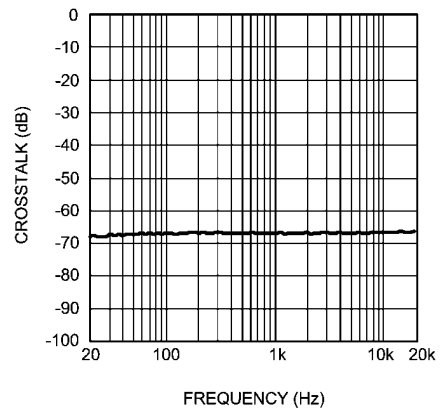
202001i0

**Crosstalk vs Frequency**  
**OCL Headphone Mode**  
 $V_{DD} = 3.6V$ ,  $V_{RIPPLE} = 1V_{P-P}$ ,  $R_L = 32\Omega$



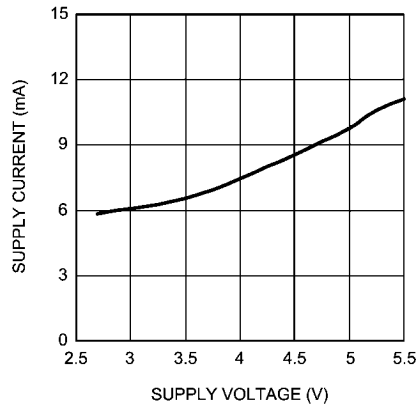
20200111

**Crosstalk vs Frequency**  
**CC Headphone Mode**  
 $V_{DD} = 3.6V$ ,  $V_{RIPPLE} = 1V_{P-P}$ ,  $R_L = 32\Omega$



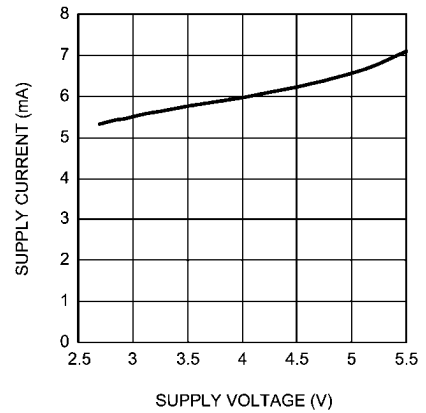
20200112

**Supply Current vs Supply Voltage**  
**Speaker Mode, No Load**



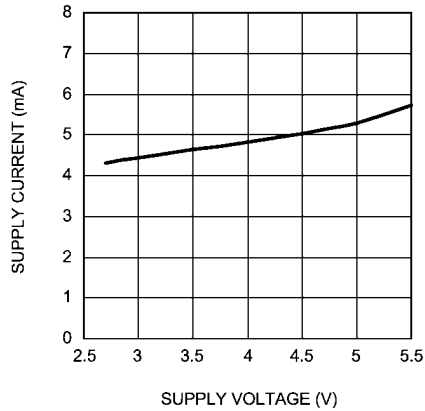
202001b1

**Supply Current vs Supply Voltage**  
**OCL Headphone Mode, No Load**



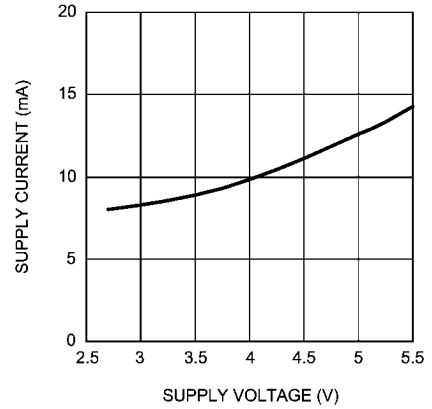
202001b4

**Supply Current vs Supply Voltage**  
**CC Headphone Mode, No Load**



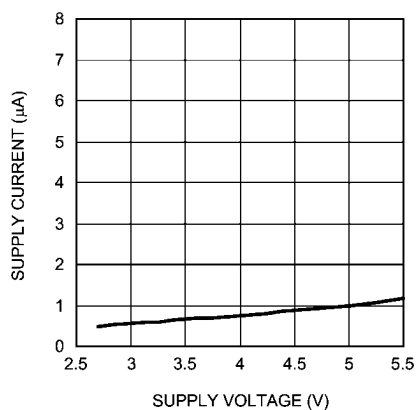
202001b7

**Supply Current vs Supply Voltage**  
**Speaker and OCL Headphone Mode, No Load**



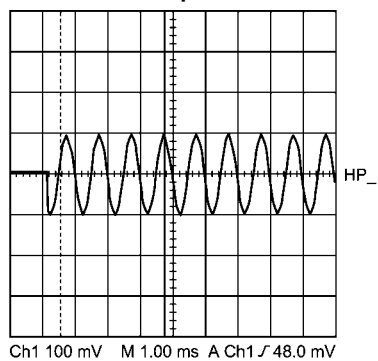
202001b8

**Supply Current vs Supply Voltage  
Shutdown Mode, No Load**



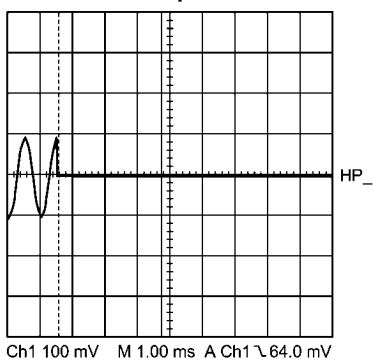
202001b9

**Turn-On  
OCL Headphone Mode**



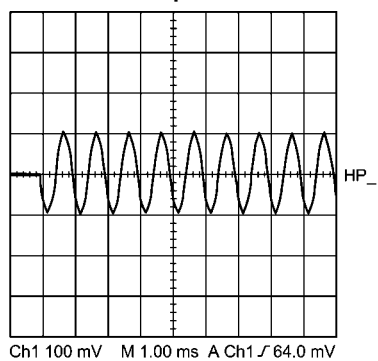
20200113

**Turn-Off  
OCL Headphone Mode**



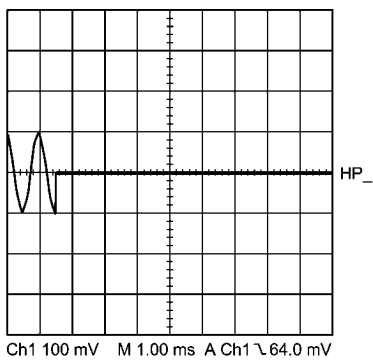
20200114

**Turn-On  
CC Headphone Mode**



20200115

**Turn-Off  
CC Headphone Mode**



20200116

## Application Information

### I<sup>2</sup>C COMPATIBLE INTERFACE

The LM4949 is controlled through an I<sup>2</sup>C compatible serial interface that consists of two wires; clock (SCL) and data (SDA). The clock line is uni-directional. The data line is bi-directional (open-collector) although the LM4949 does not

write to the I<sup>2</sup>C bus. The maximum clock frequency specified by the I<sup>2</sup>C standard is 400kHz.

To avoid an address conflict with another device on the I<sup>2</sup>C bus, the LM4949 address is determined by the ADR pin, the state of ADR determines address bit A1 (Table 2). When ADR = 0, the address is 1111 1000. When ADR = 1 the device address is 1111 1010.

TABLE 2. Device Address

| ADR | A7 | A6 | A5 | A4 | A3 | A2 | A1 | A0 |
|-----|----|----|----|----|----|----|----|----|
| X   | 1  | 1  | 1  | 1  | 1  | 0  | X  | 0  |
| 0   | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 0  |
| 1   | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 0  |

### BUS FORMAT

The I<sup>2</sup>C bus format is shown in Figure 2. The “start” signal is generated by lowering the data signal while the clock is high. The start signal alerts all devices on the bus that a device address is being written to the bus.

The 8-bit device address is written to the bus next, most significant bit first. The data is latched in on the rising edge of the clock. Each address bit must be stable while the clock is high. After the last address bit is sent, the master device releases the data line, during which time, an acknowledge clock pulse

is generated. If the LM4949 receives the address correctly, then the LM4949 pulls the data line low, generating an acknowledge bit (ACK).

Once the master device has registered the ACK bit, the 8-bit register address/data word is sent. Each data bit should be stable while the clock level is high. After the 8-bit word is sent, the LM4949 sends another ACK bit. Following the acknowledgement of the data word, the master device issues a “stop” bit, allowing SDA to go high while the clock signal is high.

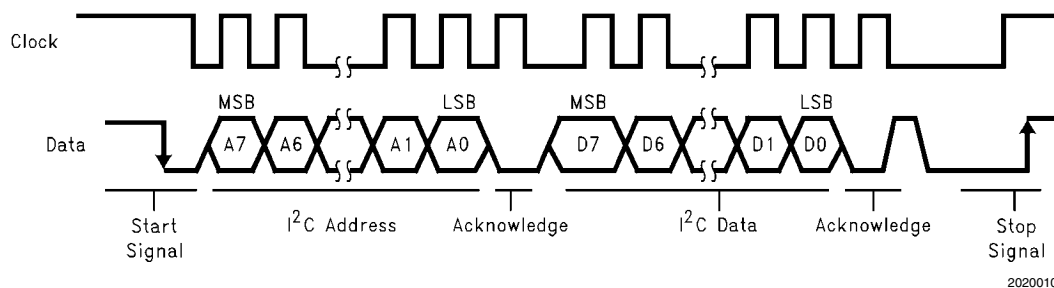


FIGURE 2. I<sup>2</sup>C Bus Format

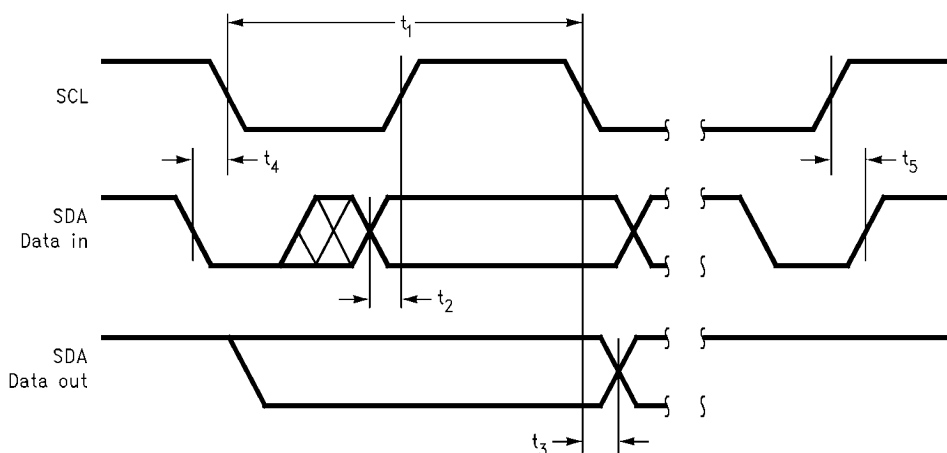


FIGURE 3. I<sup>2</sup>C Timing Diagram

TABLE 3. I<sup>2</sup>C Control Registers

| REGISTER | REGISTER NAME                       | D7 | D6 | D5 | D4      | D3       | D2        | D1        | D0         |
|----------|-------------------------------------|----|----|----|---------|----------|-----------|-----------|------------|
| 0.0      | Shutdown Control                    | 0  | 0  | 0  | 0       | 0        | OCL_LGC * | OCL *     | PWR_ON     |
| 0.1      | Stereo Input Mode Control           | 0  | 0  | 0  | 1       | L1_INSEL | L2_INSEL  | SDB_HPSEL | SDB_MUXSEL |
| 1        | Speaker Output Mux Control          | 0  | 0  | 1  | LS_XSEL | LSR_MSEL | LSR_SSEL  | LSL_MSEL  | LSL_SSEL   |
| 2        | Headphone Output Mux Control        | 0  | 1  | 0  | HP_XSEL | HPR_MSEL | HPR_SSEL  | HPL_MSEL  | HPL_SSEL   |
| 3.0      | Output On/Off Control               | 0  | 1  | 1  | 0       | HPR_ON   | HPL_ON    | LSR_ON    | LSL_ON     |
| 3.1      | Reserved                            | 0  | 1  | 1  | 1       | RESERVED | RESERVED  | RESERVED  | RESERVED   |
| 4.0      | Headphone Output Stage Gain Control | 1  | 0  | 0  | 0       | HPG1     | HPG0      | RESERVED  | RESERVED   |
| 4.1      | Speaker Output Stage Gain Control   | 1  | 0  | 0  | 1       | LSRG1    | LSRG0     | LSLG1     | LSLG0      |
| 5        | Mono Input Gain Control             | 1  | 0  | 1  | MG4     | MG3      | MG2       | MG1       | MG0        |
| 6        | Left Input Gain Control             | 1  | 1  | 0  | LG4     | LG3      | LG2       | LG1       | LG0        |
| 7        | Right Input Gain Control            | 1  | 1  | 1  | RG4     | RG3      | RG2       | RG1       | RG0        |

\* Note: OCL\_LGC = 1 and OCL = 1 at the same time is not allowed.

## GENERAL AMPLIFIER FUNCTION

### Class D Amplifier

The LM4949 features a high-efficiency, filterless, Class D stereo amplifier. The LM4949 Class D amplifiers feature a filterless modulation scheme, the differential outputs of each channel switch at 300kHz, from  $V_{DD}$  to GND. When there is no input signal applied, the two outputs ( $_{LS+}$  and  $_{LS-}$ ) switch with a 50% duty cycle, with both outputs in phase. Because the outputs of the LM4949 are differential, the two signals cancel each other. This results in no net voltage across the speaker, thus no load current during the idle state, conserving power.

When an input signal is applied, the duty cycle (pulse width) changes. For increasing output voltages, the duty cycle of  $_{LS+}$  increases, while the duty cycle of  $_{LS-}$  decreases. For decreasing output voltages, the converse occurs, the duty cycle of  $_{LS-}$  increases while the duty cycle of  $_{LS+}$  decreases. The difference between the two pulse widths yields the differential output voltage.

### Headphone Amplifier

The LM4949 headphone amplifier features three different operating modes, output capacitorless (OCL), capacitor-coupled (CC), and external amplifier mode.

The OCL architecture eliminates the bulky, expensive output coupling capacitors required by traditional headphone amplifiers. The LM4949 headphone section uses three amplifiers. Two amplifiers drive the headphones while the third (VOC) is set to the internally generated bias voltage (typically  $V_{DD}/2$ ). The third amplifier is connected to the return terminal of the headphone jack. In this configuration, the signal side of the headphones are biased to  $V_{DD}/2$ , the return is biased to  $V_{DD}/2$ , thus there is no net DC voltage across the headphone, eliminating the need for an output coupling capacitor. Re-

moving the output coupling capacitors from the headphone signal path reduces component count, reducing system cost and board space consumption, as well as improving low frequency performance.

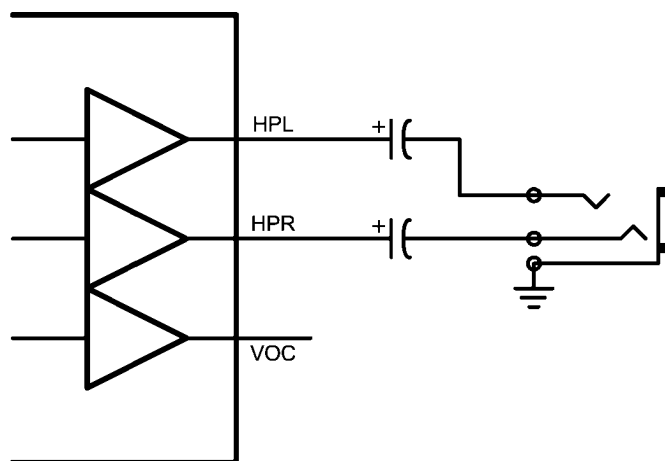
In OCL mode, the headphone return sleeve is biased to  $V_{DD}/2$ . When driving headphones, the voltage on the return sleeve is not an issue. However, if the headphone output is used as a line out, the  $V_{DD}/2$  can conflict with the GND potential that a line-in would expect on the return sleeve. When the return of the headphone jack is connected to GND, the VOC amplifier of the LM4949 detects an output short circuit condition and is disabled, preventing damage to the LM4949, and allowing the headphone return to be biased at GND.

### Capacitor Coupled Headphone Mode

In capacitor coupled (CC) mode, the VOC pin is disabled, and the headphone outputs are coupled to the jack through series capacitors, allowing the headphone return to be connected to GND (Figure 4). In CC mode, the LM4949 requires output coupling capacitors to block the DC component of the amplifier output, preventing DC current from flowing to the load. The output capacitor and speaker impedance form a high pass filter with a -3dB roll-off determined by:

$$f_{-3dB} = 1 / 2\pi R_L C_{OUT}$$

Where  $R_L$  is the headphone impedance, and  $C_{OUT}$  is the output coupling capacitor. Choose  $C_{OUT}$  such that  $f_{-3dB}$  is well below the lowest frequency of interest. Setting  $f_{-3dB}$  too high results in poor low frequency performance. Select capacitor dielectric types with low ESR to minimize signal loss due to capacitor series resistance and maximize power transfer to the load.



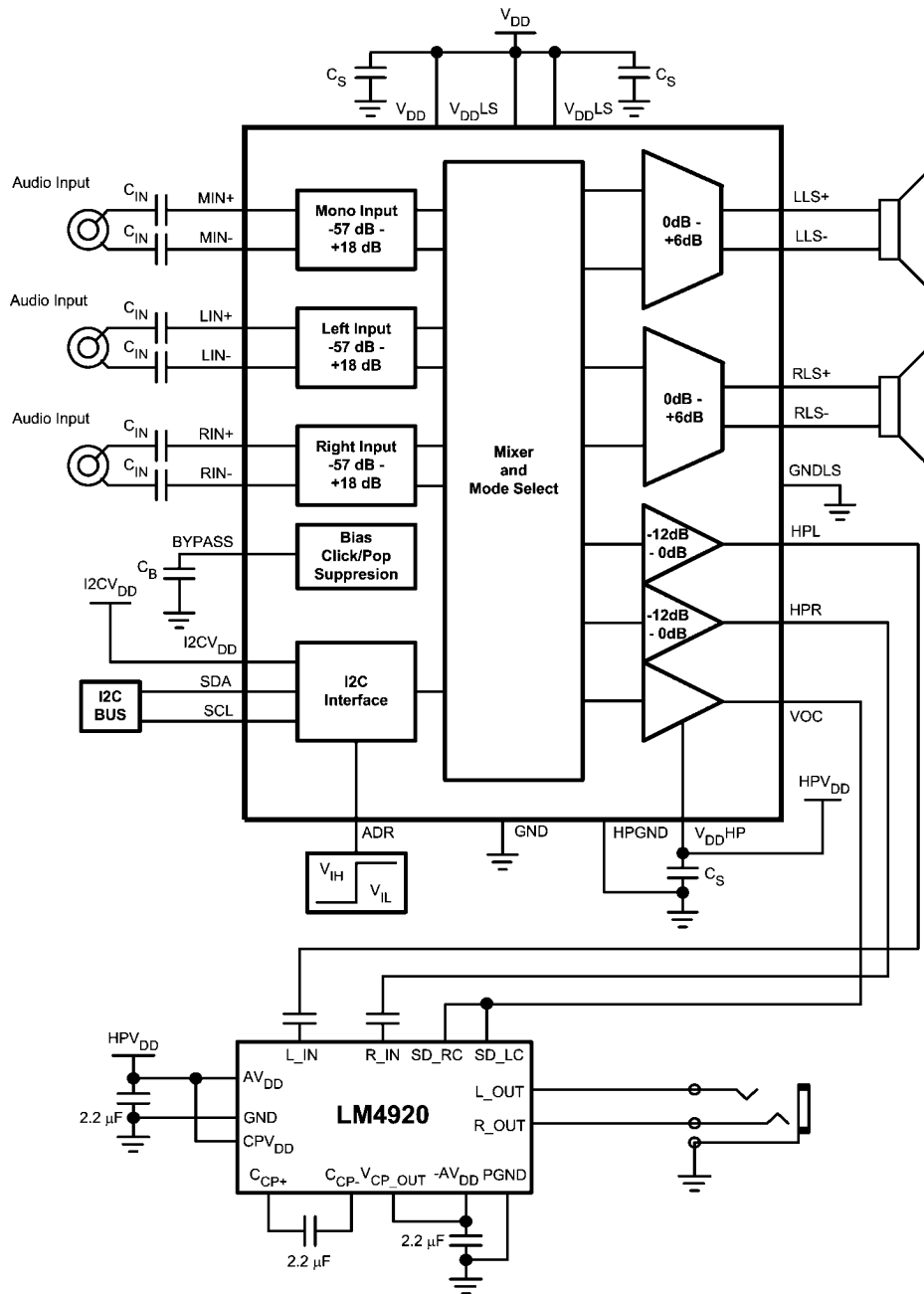
20200105

FIGURE 4. Capacitor Coupled Headphone Mode

### External Headphone Amplifier

The LM4949 features the ability to drive and control a separate headphone amplifier for applications that require a True Ground headphone output (Figure 5). Configure the LM4949 into external headphone amplifier mode by setting bit D2 (OCL\_LGC) in register 0.0 to 1 and bit D1 (OCL) to 0. In this mode the VOC output becomes a logic output used to drive the shutdown input of the external amplifier. The output level of VOC is controlled by bits D1 (SDB\_HPSEL) and D2

(SDB\_MUXSEL) in register 0.1. SDB\_MUXSEL determines the source of the VOC control signal. With SDB\_MUXSEL = 0, the VOC signal comes from the internal start-up circuitry of the LM4949. This allows the external headphone amplifier to be turned on and off simultaneously with the LM4949. When SDB\_MUXSEL = 1, the VOC signal comes from the I<sup>2</sup>C bus, bit D1. With SDB\_HPSEL = 0, VOC is a logic low, with SDB\_HPSEL = 1, VOC is a logic high.



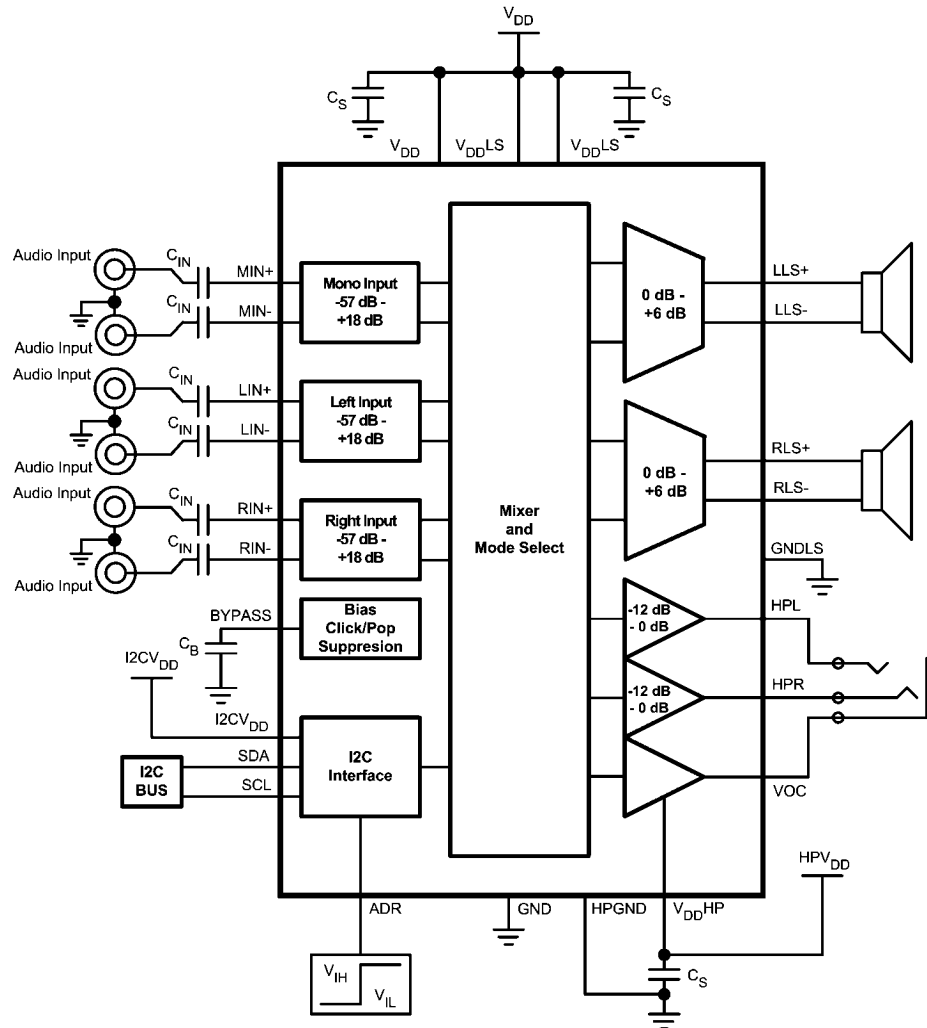
202001c8

FIGURE 5. Driving an External Headphone Amplifier

### Single-Ended Input

The left and right stereo inputs of the LM4949 can be configured for single-ended sources (Figure 6). In single-ended input mode, the LM4949 can accept up to 4 different single-ended audio sources. Set bits L1\_INSEL = 1 and L2\_INSEL

= 0 to use the RIN+ and LIN+ inputs. Set L1\_INSEL = 0 and L2\_INSEL = 1 to use the RIN- and LIN- inputs. Set L1\_INSEL = L2\_INSEL = 1 to use both input pairs. Table 4 shows the single ended input combinations.



202001c9

**FIGURE 6. Single-Ended Input Configuration**

**TABLE 4. Single-Ended Stereo Input Modes**

| INPUT MODE | L1_INSEL | L2_INSEL | INPUT DESCRIPTION                                                 |
|------------|----------|----------|-------------------------------------------------------------------|
| 0          | 0        | 0        | Fully Differential Input Mode                                     |
| 1          | 0        | 1        | Single-ended input. RIN- and LIN- selected                        |
| 2          | 1        | 0        | Single-ended input. RIN+ and LIN+ selected                        |
| 3          | 1        | 1        | Single-ended input. RIN+ mixed with RIN- and LIN+ mixed with LIN- |

### Input Mixer / Multiplexer

The LM4949 includes a comprehensive mixer/multiplexer controlled through the I2C interface. The mixer/multiplexer allows any input combination to appear on any output of the LM4949. Control bits LSR\_SSEL and LSL\_SSEL (loudspeakers), and HPR\_SSEL and HPL\_SSEL (headphones) select the individual stereo input channels; for example, LSR\_SSEL = 1 outputs the right channel stereo input on the right channel loudspeaker, while LSL\_SSEL = 1 outputs the left channel stereo input on the left channel loudspeaker. Control bits LSR\_MSEL and LSL\_MSEL (loudspeaker), and HPR\_MSEL and HPL\_MSEL (headphones) direct the mono input to the selected output. Setting HPR\_MSEL = 1 outputs the mono input on the right channel headphone. Control bits LS\_XSEL

(loudspeaker) and HP\_XSEL (headphone) selects both stereo input channels and directs the signals to the opposite outputs, for example, LS\_XSEL = 1 outputs the right channel stereo input on the left channel loudspeaker, while the left channel stereo input is output on the right channel loudspeaker. Setting \_\_XSEL = selects both stereo inputs simultaneously, unlike the \_\_SSEL controls which select the stereo input channels individually.

Multiple input paths can be selected simultaneously. Under these conditions, the selected inputs are mixed together and output on the selected channel. Tables 5 and 6 show how the input signals are mixed together for each possible input selection combination.

**TABLE 5. Loudspeaker Multiplexer Control**

| LS MODE | LS_XSEL | LSR_MSEL/<br>LSL_MSEL | LSR_SSEL/<br>LSL_SSEL | LEFT CHANNEL OUTPUT                                                                     | RIGHT CHANNEL OUTPUT                                                                    |
|---------|---------|-----------------------|-----------------------|-----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| 0       |         | 0                     | 0                     | MUTE                                                                                    | MUTE                                                                                    |
| 1       | 0       | 1                     | 0                     | MONO                                                                                    | MONO                                                                                    |
| 2       | 0       | 0                     | 1                     | LEFT (DIFF)/ /LIN+/LIN-/ (LIN+ - LIN-)                                                  | RIGHT (DIFF)/ /RIN+/RIN-/ (RIN+ - RIN-)                                                 |
| 3       | 0       | 1                     | 1                     | MONO + LEFT (DIFF)/ /LIN+/LIN-/ (LIN+ - LIN-)                                           | MONO + RIGHT (DIFF)/ /RIN+/RIN-/ (RIN+ - RIN-)                                          |
| 4       | 1       | 0                     | 1                     | LEFT (DIFF)/ /LIN+/LIN-/ (LIN+ - LIN-) + RIGHT (DIFF)/ /RIN+/RIN-/ (RIN+ - RIN-)        | LEFT (DIFF)/ /LIN+/LIN-/ (LIN+ - LIN-) + RIGHT (DIFF)/ /RIN+/RIN-/ (RIN+ - RIN-)        |
| 5       | 1       | 1                     | 1                     | MONO + LEFT (DIFF)/ /LIN+/LIN-/ (LIN+ - LIN-) + RIGHT (DIFF)/ /RIN+/RIN-/ (RIN+ - RIN-) | MONO + LEFT (DIFF)/ /LIN+/LIN-/ (LIN+ - LIN-) + RIGHT (DIFF)/ /RIN+/RIN-/ (RIN+ - RIN-) |

**TABLE 6. Headphone Multiplexer Control**

| HP MODE | HP_XSEL | HPR_MSEL/<br>HPL_MSEL | HPR_SSEL/<br>HPL_SSEL | LEFT CHANNEL OUTPUT                                                                     | RIGHT CHANNEL OUTPUT                                                                    |
|---------|---------|-----------------------|-----------------------|-----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| 0       |         | 0                     | 0                     | MUTE                                                                                    | MUTE                                                                                    |
| 1       | 0       | 1                     | 0                     | MONO                                                                                    | MONO                                                                                    |
| 2       | 0       | 0                     | 1                     | LEFT (DIFF)/ /LIN+/LIN-/ (LIN+ - LIN-)                                                  | RIGHT (DIFF)/ /RIN+/RIN-/ (RIN+ - RIN-)                                                 |
| 3       | 0       | 1                     | 1                     | MONO + LEFT (DIFF)/ /LIN+/LIN-/ (LIN+ - LIN-)                                           | MONO + RIGHT (DIFF)/ /RIN+/RIN-/ (RIN+ - RIN-)                                          |
| 4       | 1       | 0                     | 1                     | LEFT (DIFF)/ /LIN+/LIN-/ (LIN+ - LIN-) + RIGHT (DIFF)/ /RIN+/RIN-/ (RIN+ - RIN-)        | LEFT (DIFF)/ /LIN+/LIN-/ (LIN+ - LIN-) + RIGHT (DIFF)/ /RIN+/RIN-/ (RIN+ - RIN-)        |
| 5       | 1       | 1                     | 1                     | MONO + LEFT (DIFF)/ /LIN+/LIN-/ (LIN+ - LIN-) + RIGHT (DIFF)/ /RIN+/RIN-/ (RIN+ - RIN-) | MONO + LEFT (DIFF)/ /LIN+/LIN-/ (LIN+ - LIN-) + RIGHT (DIFF)/ /RIN+/RIN-/ (RIN+ - RIN-) |

### Power Supplies

The LM4949 uses different supplies for each portion of the device, allowing for the optimum combination of headroom, power dissipation and noise immunity. The speaker amplifier gain stage is powered from VDD, while the output stage is powered from VDDL. The headphone amplifiers, input amplifiers and volume control stages are powered from VDDHP. The separate power supplies allow the speakers to operate from a higher voltage for maximum headroom, while the headphones operate from a lower voltage, improving power

dissipation. VDDHP may be driven by a linear regulator to further improve performance in noisy environments. The I2C portion if powered from I2CVDD, allowing the I2C portion of the LM4949 to interface with lower voltage digital controllers.

### Shutdown Function

The LM4949 features five shutdown modes, configured through the I2C interface. Bit D0 (PWR\_ON) in the Shutdown Control register shuts down/turns on the entire device. Set PWR\_ON = 1 to enable the LM4949, set PWR\_ON 0 to disable the device. Bits D0 – D3 in the Output On/Off Control

shutdown/turn on the individual channels. HPR\_ON (D3) controls the right channel headphone output, HPL\_ON (D2) controls the left channel headphone output, LSR\_ON (D1) controls the right channel loudspeaker output, and LRL\_ON (D0) controls the left channel loudspeaker output. The PWR\_ON bit takes precedence over the individual channel controls.

#### Audio Amplifier Gain Setting

Each channel of the LM4949 has two separate gain stages. Each input stage features a 32 step volume control with a range of -57dB to +18dB (Table 7). Each speaker output stage has 4 gain settings (Table 8); 0dB, 2dB, 4dB, and 6dB when either a fully differential signal or two single ended signals are applied on the \_IN+ and \_IN- pins; and 6dB, 8dB,

10dB and 12dB in single-ended input mode with only one signal applied. The headphone gain is not affected by the input mode. Each headphone output stage has 3 gain settings (Table 9), 0dB, -6dB, and -12dB. This allows for a maximum separation of 24dB between the speaker and headphone outputs when both are active.

Calculate the total gain of a given signal path as follows:

$$A_{VOL} + A_{OS} = A_{TOTAL}$$

Where  $A_{VOL}$  is the volume control level,  $A_{OS}$  is the gain setting of the output stage, and  $A_{TOTAL}$  is the total gain for the signal path.

TABLE 7. 32 Step Volume Control

| Volume Step | MG4/LG4/RG4 | MG3/LG3/RG3 | MG2/LG2/RG2 | MG1/LG1/RG1 | MG0/LG0/RG0 | Gain (dB) |
|-------------|-------------|-------------|-------------|-------------|-------------|-----------|
| 1           | 0           | 0           | 0           | 0           | 0           | -57       |
| 2           | 0           | 0           | 0           | 0           | 1           | -49       |
| 3           | 0           | 0           | 0           | 1           | 0           | -42       |
| 4           | 0           | 0           | 0           | 1           | 1           | -34.5     |
| 5           | 0           | 0           | 1           | 0           | 0           | -30.5     |
| 6           | 0           | 0           | 1           | 0           | 1           | -27       |
| 7           | 0           | 0           | 1           | 1           | 0           | -24       |
| 8           | 0           | 0           | 1           | 1           | 1           | -21       |
| 9           | 0           | 1           | 0           | 0           | 0           | -18       |
| 10          | 0           | 1           | 0           | 0           | 1           | -15       |
| 11          | 0           | 1           | 0           | 1           | 0           | -13.5     |
| 12          | 0           | 1           | 0           | 1           | 1           | -12       |
| 13          | 0           | 1           | 1           | 0           | 0           | -10.5     |
| 14          | 0           | 1           | 1           | 0           | 1           | -9        |
| 15          | 0           | 1           | 1           | 1           | 0           | -7.5      |
| 16          | 0           | 1           | 1           | 1           | 1           | -6        |
| 17          | 1           | 0           | 0           | 0           | 0           | -4.5      |
| 18          | 1           | 0           | 0           | 0           | 1           | -3        |
| 19          | 1           | 0           | 0           | 1           | 0           | -1.5      |
| 20          | 1           | 0           | 0           | 1           | 1           | 0         |
| 21          | 1           | 0           | 1           | 0           | 0           | 1.5       |
| 22          | 1           | 0           | 1           | 0           | 1           | 3         |
| 23          | 1           | 0           | 1           | 1           | 0           | 4.5       |
| 24          | 1           | 0           | 1           | 1           | 1           | 6         |
| 25          | 1           | 1           | 0           | 0           | 0           | 7.5       |
| 26          | 1           | 1           | 0           | 0           | 1           | 9         |
| 27          | 1           | 1           | 0           | 1           | 0           | 10.5      |
| 28          | 1           | 1           | 0           | 1           | 1           | 12        |
| 29          | 1           | 1           | 1           | 0           | 0           | 13.5      |
| 30          | 1           | 1           | 1           | 0           | 1           | 15        |
| 31          | 1           | 1           | 1           | 1           | 0           | 16.5      |
| 32          | 1           | 1           | 1           | 1           | 1           | 18        |

TABLE 8. Loudspeaker Gain Setting

| LSRG1/LSLG1 | LSRG0/LSLG0 | Gain (dB)    |             |
|-------------|-------------|--------------|-------------|
|             |             | _IN+    _IN- | _IN+ = _IN- |
| 0           | 0           | 12           | 6           |
| 0           | 1           | 10           | 4           |
| 1           | 0           | 8            | 2           |
| 1           | 1           | 6            | 0           |

TABLE 9. Headphone Gain Setting

| HPG1 | HPG0 | Gain (dB) |
|------|------|-----------|
| 0    | 0    | 0         |
| 0    | 1    | -6        |
| 1    | 0    | -12       |

### Differential Audio Amplifier Configuration

As logic supply voltages continue to shrink, system designers increasingly turn to differential signal handling to preserve signal to noise ratio with decreasing voltage swing. The LM4949 can be configured as a fully differential amplifier, amplifying the difference between the two inputs. The advantage of the differential architecture is any signal component that is common to both inputs is rejected, improving common-mode rejection (CMRR) and increasing the SNR of the amplifier by 6dB over a single-ended architecture. The improved CMRR and SNR of a differential amplifier reduce sensitivity to ground offset related noise injection, especially important in noisy applications such as cellular phones. Driving the LM4949 differentially also allows the inputs to be DC coupled, eliminating two external capacitors per channel. Set bits L1\_INSEL and L2\_INSEL = 0 for differential input mode. The left and right stereo inputs have selectable differential or single-ended input modes, while the mono input is always differential.

### Single-Ended Audio Amplifier Configuration

In single-ended input mode, the audio sources must be capacitively coupled to the LM4949. With LIN+ LIN- and RIN+ RIN-, the loud speaker gain is 6dB more than in differential input mode, or when LIN+ = LIN- and RIN+ = RIN-. The headphone gain does not change. The mono input channel is not affected by L1\_INSEL and L2\_INSEL, and is always configured as a differential input.

### Power Dissipation and Efficiency

The major benefit of Class D amplifiers is increased efficiency versus Class AB. The efficiency of the LM4949 speaker amplifiers is attributed to the output transistors' region of operation. The Class D output stage acts as current steering switches, consuming negligible amounts of power compared to their Class AB counterparts. Most of the power loss associated with the output stage is due to the IR loss of the MOSFET on-resistance, along with the switching losses due to gate charge.

The maximum power dissipation per headphone channel in Capacitor-Coupled mode is given by:

$$P_{\text{DMAX}} = V_{\text{DD}}^2 / 2\pi^2 R_L$$

In OCL mode, the maximum power dissipation per headphone channel increases due to the use of a third amplifier as a buffer. The power dissipation is given by:

$$P_{\text{DMAX}} = V_{\text{DD}}^2 / \pi^2 R_L$$

## PROPER SELECTION OF EXTERNAL COMPONENTS

### Audio Amplifier Power Supply Bypassing / Filtering

Proper power supply bypassing is critical for low noise performance and high PSRR. Place the supply bypass capacitors

as close to the device as possible. Typical applications employ a voltage regulator with 10μF and 0.1μF bypass capacitors that increase supply stability. These capacitors do not eliminate the need for bypassing of the LM4949 supply pins. A 1μF ceramic capacitor placed close to each supply pin is recommended.

### Bypass Capacitor Selection

The LM4949 generates a  $V_{\text{DD}}/2$  common-mode bias voltage internally. The BYPASS capacitor,  $C_B$ , improves PSRR and THD+N by reducing noise at the BYPASS node. Use a 1μF capacitor, placed as close to the device as possible for  $C_B$ .

### Audio Amplifier Input Capacitor Selection

Input capacitors,  $C_{\text{IN}}$ , in conjunction with the input impedance of the LM4949 forms a high pass filter that removes the DC bias from an incoming signal. The AC-coupling capacitor allows the amplifier to bias the signal to an optimal DC level. Assuming zero source impedance, the -3dB point of the high pass filter is given by:

$$f_{-3\text{dB}} = 1 / 2\pi R_{\text{IN}} C_{\text{IN}}$$

Choose  $C_{\text{IN}}$  such that  $f_{-3\text{dB}}$  is well below the lowest frequency of interest. Setting  $f_{-3\text{dB}}$  too high affects the low-frequency response of the amplifier. Use capacitors with low voltage coefficient dielectrics, such as tantalum or aluminum electrolytic. Capacitors with high-voltage coefficients, such as ceramics, may result in increased distortion at low frequencies. Other factors to consider when designing the input filter include the constraints of the overall system. Although high fidelity audio requires a flat frequency response between 20Hz and 20kHz, portable devices such as cell phones may only concentrate on the frequency range of the spoken human voice (typically 300Hz to 4kHz). In addition, the physical size of the speakers used in such portable devices limits the low frequency response; in this case, frequencies below 150Hz may be filtered out.

## PCB LAYOUT GUIDELINES

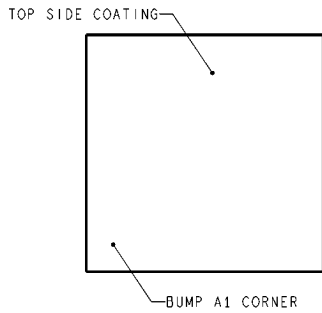
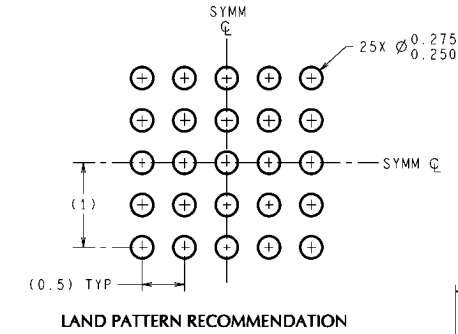
Minimize trace impedance of the power, ground and all output traces for optimum performance. Voltage loss due to trace resistance between the LM4949 and the load results in decreased output power and efficiency. Trace resistance between the power supply and GND of the LM4949 has the same effect as a poorly regulated supply, increased ripple and reduced peak output power. Use wide traces for power-supply inputs and amplifier outputs to minimize losses due to trace resistance, as well as route heat away from the device. Proper grounding improves audio performance, minimizes crosstalk between channels and prevents switching noise from interfering with the audio signal. Use of power and ground planes is recommended.

Place all digital components and digital signal traces as far as possible from analog components and traces. Do not run digital and analog traces in parallel on the same PCB layer.

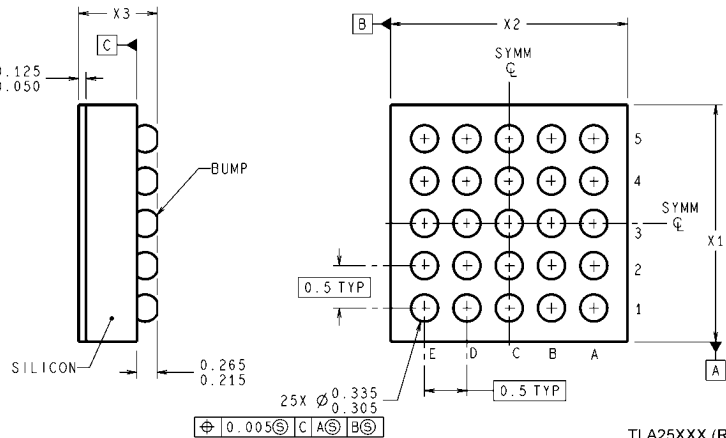
## Revision History

| Rev | Date     | Description                                                                         |
|-----|----------|-------------------------------------------------------------------------------------|
| 1.0 | 09/06/06 | Initial release.                                                                    |
| 1.1 | 09/27/06 | Fixed some of the Typical Performance Curves.                                       |
| 1.2 | 01/17/07 | Added the X1, X2, and X3 numerical values of the TLA25JJA mktg outline (back page). |

# Physical Dimensions inches (millimeters) unless otherwise noted



DIMENSIONS ARE IN MILLIMETERS  
DIMENSIONS IN ( ) FOR REFERENCE ONLY



TLA25XXX (Rev D)

micro SMD Package  
Order Number LM4949TL  
NS Package Number TLA25JJA  
X1 = 2.722, X2 = 2.722, X3 = 0.600

## Notes

## Notes

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