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MAX98090

Ultra-Low Power Stereo Audio Codec

General Description

The MAX98090 is a fully integrated audio codec whose high-performance, ultra-low power consumption and small footprint make it ideal for portable applications.

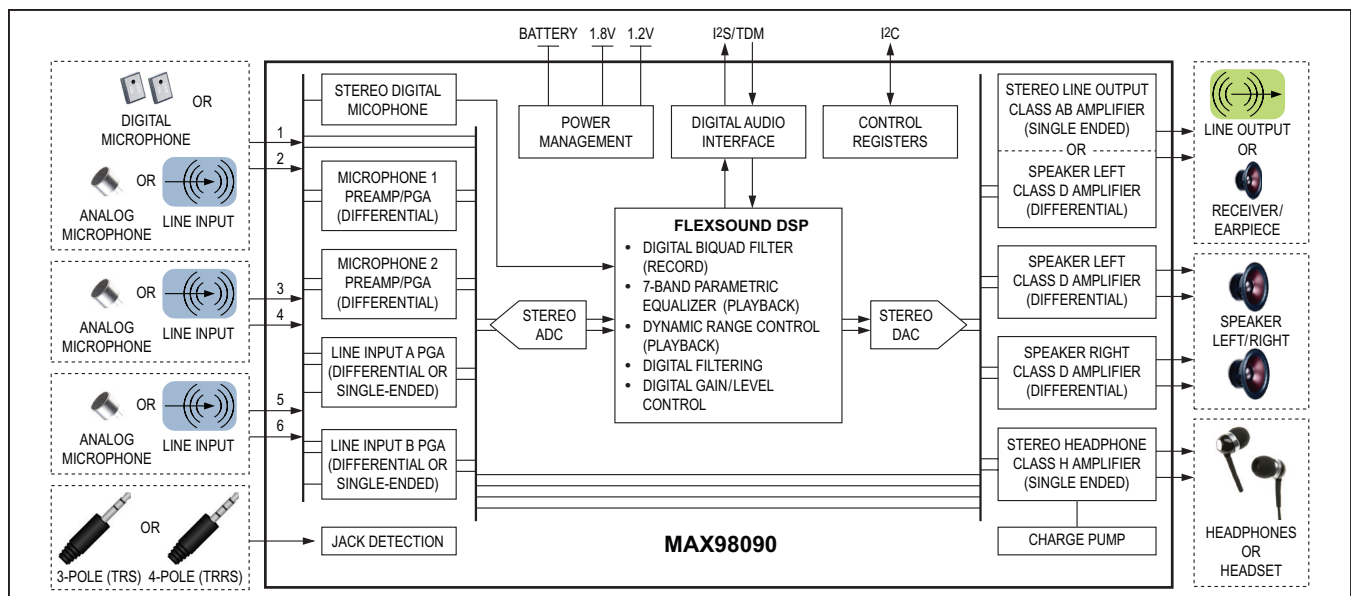
The device features a highly flexible input scheme with six input pins (WLP) that can be configured as analog or digital microphone inputs, differential or single-ended line inputs, or as full-scale direct differential inputs. Analog inputs can be routed to the record path ADC or directly to any analog output mixer.

The device accepts master clock frequencies of either $256 \times f_S$ or from 10MHz to 60MHz. The digital audio interface supports master or slave mode operation, sample rates from 8kHz to 96kHz, and standard PCM formats such as I²S, left/right-justified, and TDM.

The record/playback paths feature FlexSound® technology DSP. This includes digital gain and filtering, a biquad filter (record), dynamic range control (playback), and a seven band parametric equalizer (playback) that can improve loud-speaker performance by optimizing the frequency response.

The stereo Class D speaker amplifier provides efficient amplification, features low radiated emissions, supports filterless operation, and can drive both 4Ω and 8Ω loads. The DirectDrive® stereo Class H headphone amplifier provides a ground referenced output eliminating the need for large DC-blocking capacitors. The device also includes a differential receiver (earpiece) amplifier that can be reconfigured as a stereo single-ended line output.

Simplified Block Diagram



For related parts and recommended products to use with this part, refer to www.maximintegrated.com/MAX98090.related.

Ordering Information appears at end of data sheet.

Features and Benefits

- 102dB DR Stereo DAC to HP ($8\text{kHz} < f_S < 96\text{kHz}$)
- 3.6mW Stereo Playback Power Consumption
- 99dB DR Stereo ADC ($8\text{kHz} < f_S < 96\text{kHz}$)
- 4.2mW Stereo Record Power Consumption
- 3 Stereo Single-Ended/Differential Analog Microphone/Line Inputs (WLP Version)
- Stereo PDM Digital Microphone Input
- Master Clock Frequencies from $256 \times f_S$ to 60MHz
- I²S/LJ/RJ/TDM Digital Audio Interface
- FlexSound Technology Signal Processing
 - Record Path Biquad Filter
 - Playback Path 7-Band Parametric EQ
 - Playback Path Automatic Level Control
 - Digital Filtering and Gain/Level Control
- Stereo Low EMI Class D Speaker Amplifiers
 - 3.2W/Channel ($R_L = 4\Omega$, $V_{SPK_VDD} = 5V$, WLP)
 - 1.8W/Channel ($R_L = 8\Omega$, $V_{SPK_VDD} = 5V$, WLP)
- Stereo DirectDrive Class H Headphone Amplifier Jack Detection and Identification
- Differential Receiver Amplifier/Stereo Line Output
- Extensive Click-and-Pop Reduction Circuitry
- RF Immune Analog Inputs and Outputs
- Programmable Microphone Bias
- I²C Control Interface with Two Address Options
- 49-Bump 0.4mm WLP and 40-Pin TQFN Packages

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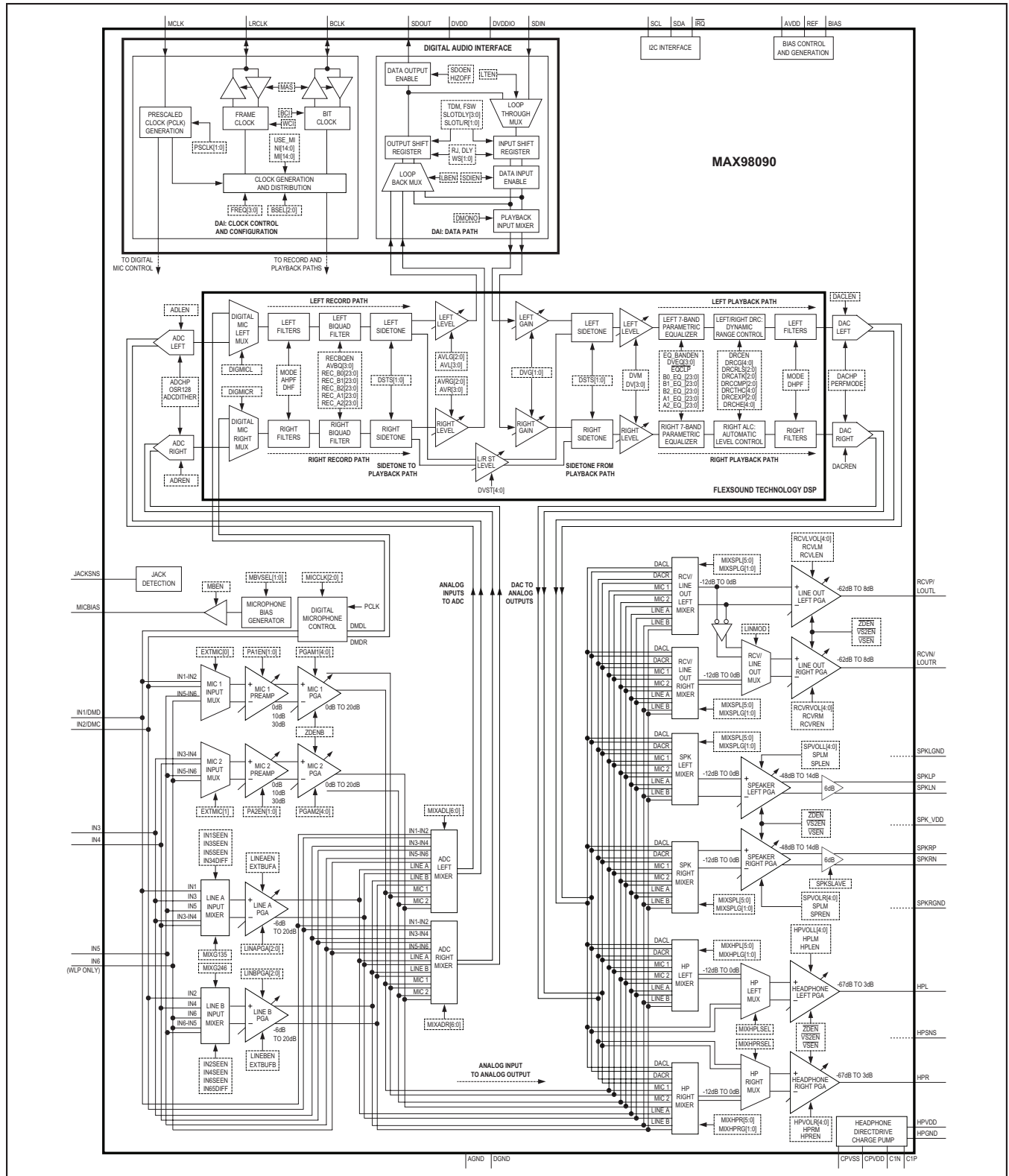
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Functional Diagram



Absolute Maximum Ratings

(Voltages with respect to AGND, unless otherwise noted.)

| | |
|---|--|
| AVDD, DVDD, HPVDD | -0.3V to +2.2V |
| SPKLVDD, SPKRVDD, DVDDIO | -0.3V to +6.0V |
| DGND, HPGND, SPKLGND, SPKRGND | -0.1V to +0.1V |
| CPVDD | (V _{HPGND} - 0.3V) to (V _{HPGND} + 2.2V) |
| CPVSS | (V _{HPGND} - 2.2V) to (V _{HPGND} + 0.3V) |
| C1N | (V _{CPVSS} - 0.3V) to (V _{HPGND} + 0.3V) |
| C1P | (V _{HPGND} - 0.3V) to (V _{CPVDD} + 0.3V) |
| MICBIAS | -0.3V to (V _{SPKLVDD} + 0.3V) |
| REF, BIAS | -0.3V to (V _{AVDD} + 0.3V) |
| MCLK, SDIN, SDA, SCL, $\overline{\text{IRQ}}$ | -0.3V to +6.0V |
| LRCLK, BCLK, SDOUT | -0.3V to (V _{DVDDIO} + 0.3V) |
| IN1, IN2, IN3, IN4, IN5, IN6 | -0.3V to +2.2V |

| | |
|---|--|
| HPSNS | (V _{HPGND} - 0.3V) to (V _{HPGND} + 0.3V) |
| HPL, HPR | (V _{CPVSS} - 0.3V) to (V _{CPVDD} + 0.3V) |
| RCVP/LOUTL | (V _{SPKLGND} - 0.3V) to (V _{SPKLVDD} + 0.3V) |
| RCVN/LOUTR | (V _{SPKLGND} - 0.3V) to (V _{SPKLVDD} + 0.3V) |
| SPKLP, SPKLN | (V _{SPKLGND} - 0.3V) to (V _{SPKLVDD} + 0.3V) |
| SPKRP, SPKRN | (V _{SPKRGND} - 0.3V) to (V _{SPKRVDD} + 0.3V) |
| JACKSNS | -0.3V to +6.0V |
| Continuous Power Dissipation (T _A = +70°C) | |
| WLP (derate 23.8mW/°C above +70°C) | 1.9W |
| TQFN (derate 35.7mW/°C above +70°C) | 2.86W |
| Operating Temperature Range | -40°C to +85°C |
| Storage Temperature Range | -65°C to +150°C |

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Package Thermal Characteristics (Note 1)

WLP

Junction-to-Ambient Thermal Resistance (θ_{JA})42°C/W

TQFN

Junction-to-Ambient Thermal Resistance (θ_{JA})28°C/W
 Junction-to-Case Thermal Resistance (θ_{JC})2°C/W

Note 1: Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to www.maximintegrated.com/thermal-tutorial.

Electrical Characteristics

(V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V, V_{DVDD} = 1.2V, V_{SPKLVDD} = V_{SPKRVDD} = V_{SPKVDD} = 3.7V. Receiver load (R_{RCV}) connected between RCVP/LOUTL and RCVN/LOUTR (LINMOD = 0). Line output loads (R_{LOUT}) connected between from RCVP/LOUTL and RCVN/LOUTR to GND (LINMOD = 1). Headphone loads (R_{HP}) connected from HPL or HPR to GND. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. R_{RCV} = ∞, R_{LOUT} = ∞, R_{HP} = ∞, Z_{SPK} = ∞. C_{REF} = 2.2μF, C_{BIAS} = C_{MICBIAS} = 1μF, C_{C1N-C1P} = C_{CPVDD} = C_{CPVSS} = 1μF. A_{V_MICPRE_} = A_{V_MICPGA_} = A_{V_LINEPGA_} = 0dB, A_{V_ADCLVL} = A_{V_ADGAIN} = 0dB, A_{V_DACLVL} = A_{V_DACGAIN} = 0dB, A_{V_MIXGAIN} = 0dB, A_{V_RCV} = A_{V_LOUT} = A_{V_HP} = A_{V_SPK} = 0dB. f_{MCLK} = 12.288MHz, f_{LRCLK} = 48kHz, MAS = 0, 20-bit source data. T_A = T_{MIN} to T_{MAX} unless otherwise noted. Typical values are at T_A = +25°C.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS | |
|-----------------------------------|------------------|--|---|------|------|-------|----|
| POWER SUPPLY | | | | | | | |
| Supply Voltage Range | | Guaranteed by PSRR (Note 3) | V _{SPKLVDD} , V _{SPKVDD} , V _{SPKRVDD} | 2.8 | 3.7 | 5.5 | V |
| | | | V _{AVDD} , V _{HPVDD} | 1.65 | 1.8 | 2 | |
| | | | V _{DVDD} | 1.08 | 1.2 | 1.98 | |
| | | | V _{DVDDIO} | 1.65 | 1.8 | 3.6 | |
| Quiescent Supply Current (Note 4) | I _{VDD} | Full-duplex 8kHz mono, receiver output | Analog | | 1.94 | 3.5 | mA |
| | | | Speaker | | 0.73 | 2 | |
| | | | Digital | | 0.97 | 1.2 | |
| | | DAC playback 48kHz stereo, headphone outputs | Analog | | 1.45 | 2 | |
| | | | Speaker | | 0 | 0.005 | |
| | | | Digital | | 1.04 | 1.3 | |
| | | DAC playback 48kHz stereo, speaker outputs | Analog | | 0.91 | 2.4 | |
| | | | Speaker | | 2.18 | 3 | |
| Digital | | | 1.05 | 1.3 | | | |

Electrical Characteristics (continued)

($V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V$, $V_{DVDD} = 1.2V$, $V_{SPKLVDD} = V_{SPKRVDD} = V_{SPKVDD} = 3.7V$. Receiver load (R_{RCV}) connected between RCV/LOUTL and RCVN/LOUTR (LINMOD = 0). Line output loads (R_{LOUT}) connected between RCV/LOUTL and RCVN/LOUTR to GND (LINMOD = 1). Headphone loads (R_{HP}) connected from HPL or HPR to GND. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. $R_{RCV} = \infty$, $R_{LOUT} = \infty$, $R_{HP} = \infty$, $Z_{SPK} = \infty$. $C_{REF} = 2.2\mu F$, $C_{BIAS} = C_{MICBIAS} = 1\mu F$, $C_{C1N-C1P} = C_{CPVDD} = C_{CPVSS} = 1\mu F$. $A_{V_MICPRE_} = A_{V_MICPGA_} = A_{V_LINEPGA_} = 0dB$, $A_{V_ADCLVL} = A_{V_ADCGAIN} = 0dB$, $A_{V_DACLVL} = A_{V_DACGAIN} = 0dB$, $A_{V_MIXGAIN} = 0dB$, $A_{V_RCV} = A_{V_LOUT} = A_{V_HP} = A_{V_SPK} = 0dB$. $f_{MCLK} = 12.288MHz$, $f_{LRCLK} = 48kHz$, MAS = 0, 20-bit source data. $T_A = T_{MIN}$ to T_{MAX} unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|--|--------|--|------------------------|-----|------|-----|---------|
| REF Voltage | | | | | 1.25 | | V |
| BIAS Voltage | | BIAS from resistive division (BIAS_MODE = 0) | | | 0.90 | | V |
| | | BIAS from bandgap (BIAS_MODE = 1) | | | 0.78 | | |
| Shutdown Supply Current (Note 4) | | $T_A = +25^\circ C$ | Analog | | 1 | 10 | μA |
| | | | Speaker | | 1 | 5 | |
| | | | Digital | | 2.1 | 20 | |
| Shutdown to Full Operation | | | | | 10 | | ms |
| DIFFERENTIAL INPUT (ANALOG MICROPHONE) TO ADC RECORD PATH | | | | | | | |
| Dynamic Range (Note 5) | DR | $f_S = 48kHz$, MODE = 1 (FIR audio), A-weighting filter applied | | | 97 | | dB |
| | | $f_S = 8kHz$, MODE = 0 (IIR voice), A-weighting filter applied | | 90 | 96 | | dB |
| Total Harmonic Distortion + Noise | THD+N | $A_{V_MICPRE} = 20dB$, $V_{IN} = 90mV_{RMS}$, $f = 1kHz$ | | | -82 | -75 | dB |
| | | $A_{V_MICPRE} = 0dB$, $V_{IN} = 900mV_{RMS}$, $f = 1kHz$ | | | -91 | | |
| | | $A_{V_MICPRE} = 30dB$, $V_{IN} = 28.5mV_{RMS}$, $f = 1kHz$ | | | -73 | | |
| Common-Mode Rejection Ratio | CMRR | $f = 217Hz$, $V_{IN_CM} = 100mV_{P-P}$ | | | 59 | | dB |
| Power-Supply Rejection Ratio (Note 3) | PSRR | $V_{AVDD} = 1.65V$ to $2.0V$, input referred | | 40 | 57 | | dB |
| | | $V_{RIPPLE} = 100mV_{P-P}$, input referred | $f = 217Hz$ | | 60 | | |
| | | | $f = 1kHz$ | | 60 | | |
| | | $f = 10kHz$ | | 59 | | | |
| Path Phase Delay | | 1kHz, 0dB input, highpass filter disabled measured from analog input to digital output | MODE = 0 (voice) 8kHz | | 2.2 | | ms |
| | | | MODE = 0 (voice) 16kHz | | 1.1 | | |
| | | | MODE = 1 (music) 8kHz | | 4.5 | | |
| | | | MODE = 1 (music) 48kHz | | 0.8 | | |

Electrical Characteristics (continued)

($V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V$, $V_{DVDD} = 1.2V$, $V_{SPKLVDD} = V_{SPKRVDD} = V_{SPKVDD} = 3.7V$. Receiver load (R_{RCV}) connected between RCV/LOUTL and RCVN/LOUTR (LINMOD = 0). Line output loads (R_{LOUT}) connected between RCV/LOUTL and RCVN/LOUTR to GND (LINMOD = 1). Headphone loads (R_{HP}) connected from HPL or HPR to GND. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. $R_{RCV} = \infty$, $R_{LOUT} = \infty$, $R_{HP} = \infty$, $Z_{SPK} = \infty$. $C_{REF} = 2.2\mu F$, $C_{BIAS} = C_{MICBIAS} = 1\mu F$, $C_{C1N-C1P} = C_{CPVDD} = C_{CPVSS} = 1\mu F$. $A_{V_MICPRE_} = A_{V_MICPGA_} = A_{V_LINEPGA_} = 0dB$, $A_{V_ADCLVL} = A_{V_ADCGAIN} = 0dB$, $A_{V_DACLVL} = A_{V_DACGAIN} = 0dB$, $A_{V_MIXGAIN} = 0dB$, $A_{V_RCV} = A_{V_LOUT} = A_{V_HP} = A_{V_SPK} = 0dB$. $f_{MCLK} = 12.288MHz$, $f_{LRCLK} = 48kHz$, MAS = 0, 20-bit source data. $T_A = T_{MIN}$ to T_{MAX} unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS | |
|--|-----------------|---|---|-------------|------------|----------------|----|
| Gain Error | | DC accuracy | | 1 | 6.2 | % | |
| DIFFERENTIAL (ANALOG MICROPHONE) PREAMP and PGA | | | | | | | |
| Full-Scale Input | | $A_{V_MICPRE} = 0dB$ | | 1 | | V_{RMS} | |
| Microphone Preamp Gain | A_{V_MICPRE} | (Note 6) | $PA_EN[1:0] = 01$ | 0 | | dB | |
| | | | $PA_EN[1:0] = 10$ | 19 | 20 | | 21 |
| | | | $PA_EN[1:0] = 11$ | 29 | 30 | | 31 |
| Microphone Level Adjust Gain (PGA) | A_{V_MICPGA} | (Note 6) | $PGAM_ [4:0] = 0x00$ | 19 | 20 | 21 | dB |
| | | | $PGAM_ [4:0] = 0x14$ | | 0 | | |
| MIC Input Resistance | R_{IN_MIC} | All gain settings, measured at $IN_$ (measured single-ended) | 28 | 50 | | k Ω | |
| MICROPHONE BIAS | | | | | | | |
| MICBIAS Output Voltage | $V_{MICBIAS}$ | | $I_{LOAD} = 1mA$, $MBVSEL[1:0] = 00$ | 2.1 | 2.2 | 2.3 | V |
| | | | $I_{LOAD} = 1mA$, $MBVSEL[1:0] = 01$ | 2.3 | 2.4 | 2.5 | |
| | | | $I_{LOAD} = 1mA$, $MBVSEL[1:0] = 10$ | 2.475 | 2.57 | 2.7 | |
| | | | $I_{LOAD} = 1mA$, $MBVSEL[1:0] = 11$ | 2.7 | 2.8 | 2.9 | |
| Load Regulation | | $I_{LOAD} = 1mA$ to $2mA$, $MBVSEL[1:0] = 00$ | WLP | ± 0.085 | ± 0.5 | mV | |
| | | | TQFN | ± 0.085 | ± 0.75 | | |
| Line Regulation | | $V_{SPKLVDD} = 2.8V$ to $5.5V$, $MBVSEL[1:0] = 00$ | | ± 0.01 | ± 1 | mV | |
| Ripple Rejection | | V_{RIPPLE} (SPKLVDD) = $100mV_{P-P}$ | $f = 217Hz$ | 95 | | dB | |
| | | | $f = 1kHz$ | 97 | | | |
| | | | $f = 10kHz$ | 85 | | | |
| Noise Voltage | | | A-weighted, $f = 20Hz$ to $20kHz$ | 7.4 | | μV_{RMS} | |
| | | | $f = 1kHz$ | 52.3 | | nV/\sqrt{Hz} | |
| SINGLE-ENDED (LINE) INPUT TO ADC PATH | | | | | | | |
| Dynamic Range (Note 5) | DR | $f_S = 48kHz$, $f_{MCLK} = 12.288MHz$, MODE = 1 (FIR audio) | | 98 | | dB | |
| Total Harmonic Distortion + Noise | THD+N | $V_{IN} = 0.222V_{RMS}$, $f = 1kHz$ | | -85 | -80 | dB | |
| SINGLE-ENDED (LINE) INPUT PGA | | | | | | | |
| Full-Scale Input | V_{IN} | | | 0.5 | | V_{RMS} | |
| | | | $A_{V_EXTERNAL} = -6dB$, $EXTBUF = 1$ | 1 | | | |

Electrical Characteristics (continued)

($V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V$, $V_{DVDD} = 1.2V$, $V_{SPKLVDD} = V_{SPKRVDD} = V_{SPKVDD} = 3.7V$. Receiver load (R_{RCV}) connected between RCV/LOUTL and RCVN/LOUTR (LINMOD = 0). Line output loads (R_{LOUT}) connected between from RCV/LOUTL and RCVN/LOUTR to GND (LINMOD = 1). Headphone loads (R_{HP}) connected from HPL or HPR to GND. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. $R_{RCV} = \infty$, $R_{LOUT} = \infty$, $R_{HP} = \infty$, $Z_{SPK} = \infty$. $C_{REF} = 2.2\mu F$, $C_{BIAS} = C_{MICBIAS} = 1\mu F$, $C_{C1N-C1P} = C_{CPVDD} = C_{CPVSS} = 1\mu F$. $A_{V_MICPRE_} = A_{V_MICPGA_} = A_{V_LINEPGA_} = 0dB$, $A_{V_ADCLVL} = A_{V_ADCGAIN} = 0dB$, $A_{V_DACLVL} = A_{V_DACGAIN} = 0dB$, $A_{V_MIXGAIN} = 0dB$, $A_{V_RCV} = A_{V_LOUT} = A_{V_HP} = A_{V_SPK} = 0dB$. $f_{MCLK} = 12.288MHz$, $f_{LRCLK} = 48kHz$, MAS = 0, 20-bit source data. $T_A = T_{MIN}$ to T_{MAX} unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS | |
|---|------------------|---|------------------------|------|-----|------------|----|
| Line Input Level Adjust Gain (PGA) | $A_{V_LINEPGA}$ | (Note 6) | PGALIN = 0x0 | 18 | 20 | 21.5 | dB |
| | | | PGALIN = 0x1 | 13 | 14 | 15 | |
| | | | PGALIN = 0x2 | 2 | 3 | 4 | |
| | | | PGALIN = 0x3 | -1 | 0 | +1 | |
| | | | PGALIN = 0x4 | -4 | -3 | -2 | |
| | | | PGALIN = 0x5, 0x6, 0x7 | -7 | -6 | -5 | |
| Line Input Amplifier Gain | $A_{V_LINEAMP}$ | Single-ended only | | 6 | | dB | |
| Input Resistance | R_{IN} | | 14 | 20 | | k Ω | |
| Feedback Resistance | R_{IN_FB} | $T_A = +25^\circ C$ | 19 | 20 | 21 | k Ω | |
| DIGITAL LOOP-THROUGH: RECORD OUTPUT TO PLAYBACK INPUT PATH | | | | | | | |
| Dynamic Range (Note 5) | DR | $f_S = 48kHz$, $f_{MCLK} = 12.288MHz$, MODE = 1 (FIR audio) | | 97 | | dB | |
| Total Harmonic Distortion + Noise | THD+N | $f_{IN} = 1kHz$, $f_S = 48kHz$, $f_{MCLK} = 12.288MHz$, MODE = 1 (FIR audio) | | -83 | -72 | dB | |
| DAC PLAYBACK PATH TO RECEIVER AMPLIFIER PATH | | | | | | | |
| Dynamic Range (Note 5) | DR | $f_S = 48kHz$, $f_{MCLK} = 12.288MHz$ | | 100 | | dB | |
| Total Harmonic Distortion + Noise | THD+N | $f = 1kHz$, $P_{OUT} = 20mW$, $R_{REC} = 32\Omega$ | | -68 | -58 | dB | |
| DIFFERENTIAL ANALOG INPUT TO RECEIVER AMPLIFIER PATH | | | | | | | |
| Dynamic Range (Note 5) | DR | | 90 | 96 | | dB | |
| Total Harmonic Distortion + Noise | THD+N | | | -71 | | dB | |
| Power-Supply Rejection Ratio (Note 3) | PSRR | $V_{SPKLVDD} = 2.8V$ to $5.5V$ | 68.4 | 80 | | dB | |
| | | $V_{RIPPLE} = 100mV_{P-P}$ | $f = 217Hz$ | | 77 | | |
| | | | $f = 1kHz$ | | 77 | | |
| | | | $f = 10kHz$ | | 69 | | |
| RECEIVER AMPLIFIER (Note 7) | | | | | | | |
| Output Power | P_{OUT} | $R_{REC} = 32\Omega$, $f = 1kHz$, THD < 1%, BIAS_ MODE = 0 | | 97 | | mW | |
| | | $R_{REC} = 32\Omega$, $f = 1kHz$, THD < 1%, BIAS_ MODE = 1 | | 74 | | | |
| Full-Scale Output | | $A_{V_RECPGA} = 0dB$ (Note 8) | | 1 | | V_{RMS} | |
| Receiver Volume Control (PGA) | A_{V_RECPGA} | (Notes 6 and 9) | RCVLVOL = 0x00 | -63 | -61 | -59.5 | dB |
| | | | RCVLVOL = 0x1F | +7.2 | +8 | +8.75 | |

Electrical Characteristics (continued)

($V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V$, $V_{DVDD} = 1.2V$, $V_{SPKLVDD} = V_{SPKRVDD} = V_{SPKVDD} = 3.7V$. Receiver load (R_{RCV}) connected between RCV/LOUTL and RCVN/LOUTR (LINMOD = 0). Line output loads (R_{LOUT}) connected between from RCV/LOUTL and RCVN/LOUTR to GND (LINMOD = 1). Headphone loads (R_{HP}) connected from HPL or HPR to GND. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. $R_{RCV} = \infty$, $R_{LOUT} = \infty$, $R_{HP} = \infty$, $Z_{SPK} = \infty$. $C_{REF} = 2.2\mu F$, $C_{BIAS} = C_{MICBIAS} = 1\mu F$, $C_{C1N-C1P} = C_{CPVDD} = C_{CPVSS} = 1\mu F$. $A_{V_MICPRE_} = A_{V_MICPGA_} = A_{V_LINEPGA_} = 0dB$, $A_{V_ADCLVL} = A_{V_ADCGAIN} = 0dB$, $A_{V_DACLVL} = A_{V_DACGAIN} = 0dB$, $A_{V_MIXGAIN} = 0dB$, $A_{V_RCV} = A_{V_LOUT} = A_{V_HP} = A_{V_SPK} = 0dB$. $f_{MCLK} = 12.288MHz$, $f_{LRCLK} = 48kHz$, MAS = 0, 20-bit source data. $T_A = T_{MIN}$ to T_{MAX} unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|------------------|---|------------------|-------|-----|---------|-----------|
| Volume Control Step Size (Note 9) | | +8dB to +6dB | | 0.5 | | dB | |
| | | +6dB to +0dB | | 1 | | | |
| | | 0dB to -14dB | | 2 | | | |
| | | -14dB to -38dB | | 3 | | | |
| | | -38dB to -62dB | | 4 | | | |
| Mute Attenuation | | f = 1kHz | | 87 | 97 | | dB |
| Output Offset Voltage | V_{OS} | $A_{V_REC} = -62dB$, $T_A = +25^\circ C$ | | | | ± 3 | mV |
| Click-and-Pop Level | K_{CP} | Peak voltage, A-weighted, 32 samples per second, $A_{V_REC} = 0dB$ | Into shutdown | -67 | | dBV | |
| | | | Out of shutdown | -68 | | | |
| Capacitive Drive Capability | | No sustained oscillations | $R_L = 32\Omega$ | 500 | | pF | |
| | | | $R_L = \infty$ | 100 | | | |
| DAC PLAYBACK PATH TO LINEOUT AMPLIFIER PATH | | | | | | | |
| Dynamic Range (Note 5) | DR | $f_S = 48kHz$, $f_{MCLK} = 12.288MHz$ | | 100 | | | dB |
| Total Harmonic Distortion + Noise | THD+N | f = 1kHz, $R_{LOUT} = 10k\Omega$ ($0.5V_{RMS}$ output level) | | -86 | -70 | | dB |
| SINGLE-ENDED ANALOG INPUT TO LINE OUT AMPLIFIER PATH | | | | | | | |
| Dynamic Range (Note 5) | DR | | | 98 | | | dB |
| Total Harmonic Distortion + Noise | THD+N | f = 1kHz, $R_{LOUT} = 10k\Omega$ ($0.5V_{RMS}$ output level) | | -86 | | | dB |
| Power-Supply Rejection Ratio (Note 3) | PSRR | $V_{SPK_VDD} = 2.8V$ to $5.5V$ | | 60 | 74 | dB | |
| | | $V_{RIPPLE} = 100mV_{P-P}$ | f = 217Hz | 74 | | | |
| | | | f = 1kHz | 74 | | | |
| | | | f = 10kHz | 73 | | | |
| LINE OUT AMPLIFIER (Note 7) | | | | | | | |
| Full-Scale Output | | (Note 8) | | 0.707 | | | V_{RMS} |
| Line Output Amplifier Gain | $A_{V_LOUTAMP}$ | | | -3 | | | dB |

Electrical Characteristics (continued)

($V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V$, $V_{DVDD} = 1.2V$, $V_{SPKLVDD} = V_{SPKRVDD} = V_{SPKVDD} = 3.7V$. Receiver load (R_{RCV}) connected between RCVN/LOUTL and RCVN/LOUTR (LINMOD = 0). Line output loads (R_{LOUT}) connected between from RCVN/LOUTL and RCVN/LOUTR to GND (LINMOD = 1). Headphone loads (R_{HP}) connected from HPL or HPR to GND. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. $R_{RCV} = \infty$, $R_{LOUT} = \infty$, $R_{HP} = \infty$, $Z_{SPK} = \infty$. $C_{REF} = 2.2\mu F$, $C_{BIAS} = C_{MICBIAS} = 1\mu F$, $C_{C1N-C1P} = C_{CPVDD} = C_{CPVSS} = 1\mu F$. $A_{V_MICPRE_} = A_{V_MICPGA_} = A_{V_LINEPGA_} = 0dB$, $A_{V_ADCLVL} = A_{V_ADCGAIN} = 0dB$, $A_{V_DACLVL} = A_{V_DACGAIN} = 0dB$, $A_{V_MIXGAIN} = 0dB$, $A_{V_RCV} = A_{V_LOUT} = A_{V_HP} = A_{V_SPK} = 0dB$. $f_{MCLK} = 12.288MHz$, $f_{LRCLK} = 48kHz$, MAS = 0, 20-bit source data. $T_A = T_{MIN}$ to T_{MAX} unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS | |
|--|------------------|---|-----------------------|------|-----|---------------|----|
| Line Output Volume Control (PGA) | $A_{V_LOUTPGA}$ | (Notes 6 and 9) | $RCV_VOL = 0x00$ | -63 | -61 | -59.5 | dB |
| | | | $RCV_VOL = 0x1F$ | +7.2 | +8 | +8.75 | |
| Volume Control Step Size (Note 9) | | | 8dB to 6dB | 0.5 | | dB | |
| | | | 6dB to 0dB | 1 | | | |
| | | | 0dB to -14dB | 2 | | | |
| | | | -14dB to -38dB | 3 | | | |
| | | | -38dB to -62dB | 4 | | | |
| Mute Attenuation | | $f = 1kHz$ | 87 | 97 | | dB | |
| Capacitive Drive Capability | | No sustained oscillations | $R_{LOUT} = 1k\Omega$ | 500 | | pF | |
| | | | $R_{LOUT} = \infty$ | 100 | | | |
| DAC PLAYBACK PATH TO SPEAKER AMPLIFIER PATH | | | | | | | |
| Dynamic Range (Note 5) | DR | | | 91 | | dB | |
| Total Harmonic Distortion + Noise | THD+N | $f = 1kHz$, $P_{OUT} = 200mW$, $Z_{SPK} = 8\Omega + 68\mu H$, $f_{MCLK} = 12.288MHz$ | | -70 | | dB | |
| Crosstalk | | SPKL to SPKR and SPKR to SPKL, $P_{OUT} = 640mW$, $f = 1kHz$ | | -104 | | dB | |
| Output Noise | | | | 27 | | μV_{RMS} | |
| DIFFERENTIAL ANALOG INPUT TO SPEAKER AMPLIFIER PATH | | | | | | | |
| Dynamic Range (Note 5) | DR | Output referenced to $2V_{RMS}$ | | 91 | | dB | |
| Total Harmonic Distortion + Noise | THD+N | $f = 1kHz$, $P_{OUT} = 200mW$, $Z_{SPK} = 8\Omega + 68\mu H$ | | -70 | | dB | |
| Output Noise | | | | 28 | | μV_{RMS} | |
| Power-Supply Rejection Ratio (Note 3) | PSRR | $V_{SPK_VDD} = 2.8V$ to $5.5V$ $V_{RIPPLE} = 100mV_{P-P}$ | | 50 | 80 | dB | |
| | | | $f = 217Hz$ | 68 | | | |
| | | | $f = 1kHz$ | 67 | | | |
| | | | $f = 10kHz$ | 61 | | | |

Electrical Characteristics (continued)

($V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V$, $V_{DVDD} = 1.2V$, $V_{SPKLVDD} = V_{SPKRVDD} = V_{SPKVDD} = 3.7V$. Receiver load (R_{RCV}) connected between RCVN/LOUTL and RCVN/LOUTR (LINMOD = 0). Line output loads (R_{LOUT}) connected between from RCVN/LOUTL and RCVN/LOUTR to GND (LINMOD = 1). Headphone loads (R_{HP}) connected from HPL or HPR to GND. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. $R_{RCV} = \infty$, $R_{LOUT} = \infty$, $R_{HP} = \infty$, $Z_{SPK} = \infty$. $C_{REF} = 2.2\mu F$, $C_{BIAS} = C_{MICBIAS} = 1\mu F$, $C_{C1N-C1P} = C_{CPVDD} = C_{CPVSS} = 1\mu F$. $A_{V_MICPRE_} = A_{V_MICPGA_} = A_{V_LINEPGA} = 0dB$, $A_{V_ADCLVL} = A_{V_ADCGAIN} = 0dB$, $A_{V_DACLVL} = A_{V_DACGAIN} = 0dB$, $A_{V_MIXGAIN} = 0dB$, $A_{V_RCV} = A_{V_LOUT} = A_{V_HP} = A_{V_SPK} = 0dB$. $f_{MCLK} = 12.288MHz$, $f_{LRCLK} = 48kHz$, MAS = 0, 20-bit source data. $T_A = T_{MIN}$ to T_{MAX} unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS | |
|-----------------------------------|-----------------|--|-----------------------|------|-----|-----------|----|
| SPEAKER AMPLIFIER (Note 7) | | | | | | | |
| Output Power | P_{OUT} | f = 1kHz, THD+N = 1%, $Z_{SPK} = 8\Omega + 68\mu H$, WLP package | $V_{SPK_VDD} = 5.0V$ | 1450 | | mW | |
| | | | $V_{SPK_VDD} = 4.2V$ | 1000 | | | |
| | | | $V_{SPK_VDD} = 3.7V$ | 780 | | | |
| | | | $V_{SPK_VDD} = 3.3V$ | 600 | | | |
| | | | $V_{SPK_VDD} = 3.0V$ | 500 | | | |
| | | f = 1kHz, THD+N = 10%, $Z_{SPK} = 8\Omega + 68\mu H$, WLP package | $V_{SPK_VDD} = 5.0V$ | 1800 | | | |
| | | | $V_{SPK_VDD} = 4.2V$ | 1250 | | | |
| | | | $V_{SPK_VDD} = 3.7V$ | 970 | | | |
| | | | $V_{SPK_VDD} = 3.3V$ | 760 | | | |
| | | | $V_{SPK_VDD} = 3.0V$ | 620 | | | |
| Output Power | P_{OUT} | f = 1kHz, THD+N = 1%, $Z_{SPK} = 4\Omega + 33\mu H$, WLP package | $V_{SPK_VDD} = 5.0V$ | 2600 | | mW | |
| | | | $V_{SPK_VDD} = 4.2V$ | 1800 | | | |
| | | | $V_{SPK_VDD} = 3.7V$ | 1400 | | | |
| | | | $V_{SPK_VDD} = 3.3V$ | 1100 | | | |
| | | | $V_{SPK_VDD} = 3.0V$ | 900 | | | |
| | | f = 1kHz, THD+N = 10%, $Z_{SPK} = 4\Omega + 33\mu H$, WLP package | $V_{SPK_VDD} = 5.0V$ | 3250 | | | |
| | | | $V_{SPK_VDD} = 4.2V$ | 2250 | | | |
| | | | $V_{SPK_VDD} = 3.7V$ | 1700 | | | |
| | | | $V_{SPK_VDD} = 3.3V$ | 1350 | | | |
| | | | $V_{SPK_VDD} = 3.0V$ | 1100 | | | |
| Full-Scale Output | | $A_{V_SPK} = +6dB$ (Note 8) | | 2 | | V_{RMS} | |
| Speaker Output Amplifier Gain | A_{V_SPKAMP} | | | +6 | | dB | |
| Speaker Volume Control (PGA) | A_{V_SPKPGA} | (Notes 6 and 9) | SPVOLL = 0x00 | -51 | -48 | -44.5 | dB |
| | | | SPVOLR = 0x1F | 13 | 14 | 15 | |
| Volume Control Step Size (Note 9) | | 14dB to 9dB | | 0.5 | | dB | |
| | | +9dB to -6dB | | 1 | | | |
| | | -6dB to -14dB | | 2 | | | |
| | | -14dB to -32dB | | 3 | | | |
| | | -32dB to -48dB | | 4 | | | |
| Mute Attenuation | | f = 1kHz | 76 | 84 | | dB | |

Electrical Characteristics (continued)

($V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V$, $V_{DVDD} = 1.2V$, $V_{SPKLVDD} = V_{SPKRVDD} = V_{SPKVDD} = 3.7V$. Receiver load (R_{RCV}) connected between RCV/LOUTL and RCVN/LOUTR (LINMOD = 0). Line output loads (R_{LOUT}) connected between from RCV/LOUTL and RCVN/LOUTR to GND (LINMOD = 1). Headphone loads (R_{HP}) connected from HPL or HPR to GND. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. $R_{RCV} = \infty$, $R_{LOUT} = \infty$, $R_{HP} = \infty$, $Z_{SPK} = \infty$. $C_{REF} = 2.2\mu F$, $C_{BIAS} = C_{MICBIAS} = 1\mu F$, $C_{C1N-C1P} = C_{CPVDD} = C_{CPVSS} = 1\mu F$. $A_{V_MICPRE_} = A_{V_MICPGA_} = A_{V_LINEPGA} = 0dB$, $A_{V_ADCLVL} = A_{V_ADCGAIN} = 0dB$, $A_{V_DACLVL} = A_{V_DACGAIN} = 0dB$, $A_{V_MIXGAIN} = 0dB$, $A_{V_RCV} = A_{V_LOUT} = A_{V_HP} = A_{V_SPK} = 0dB$. $f_{MCLK} = 12.288MHz$, $f_{LRCLK} = 48kHz$, MAS = 0, 20-bit source data. $T_A = T_{MIN}$ to T_{MAX} unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|--|----------|--|---|-----|-----------|---------|-------|
| Output Offset Voltage | V_{OS} | $A_{V_SPKPGA} = -62dB$, $T_A = +25^\circ C$ | | | ± 0.5 | ± 4 | mV |
| Click-and-Pop Level | K_{CP} | Peak voltage, A-weighted, 32 samples per second, $A_{V_SPK} = 0dB$ | Into shutdown | | -65 | | dBV |
| | | | Out of shutdown | | -65 | | |
| DAC PLAYBACK PATH TO HEADPHONE AMPLIFIER PATH | | | | | | | |
| Dynamic Range (Note 5) | DR | $f_S = 48kHz$, $f_{MCLK} = 12.288MHz$ | Master or slave mode | | 102 | | dB |
| | | | Slave mode | | 94 | | |
| Total Harmonic Distortion + Noise | THD+N | $f = 1kHz$, $P_{OUT} = 10mW$ | $R_{HP} = 16\Omega$ | | -86 | -77 | dB |
| | | | $R_{HP} = 32\Omega$ | | -88 | | |
| | | | $f = 1kHz$, $V_{OUT} = 1V_{RMS}$, $R_{HP} = 10k\Omega$ | | -88 | | |
| Crosstalk | | $f = 1kHz$, $V_{IN} = -1dBFS$, $R_{HP} = 10k\Omega$ | HPL to HPR and HPR to HPL, $P_{OUT} = 5mW$, $f = 1kHz$, $R_{HP} = 32\Omega$ | | -105 | | dB |
| | | | | | -104 | | |
| Power-Supply Rejection Ratio (Note 3) | PSRR | $V_{AVDD} = V_{HPVDD} = 1.65V$ to $2.0V$ $V_{RIPPLE} = 100mV_{P-P}$, $A_{V_HP} = 0dB$ | $f = 217Hz$ | | 70 | 80 | dB |
| | | | $f = 1kHz$ | | 79 | | |
| | | | $f = 10kHz$ | | 79 | | |
| | | | | | 74 | | |
| DAC Path Phase Delay | | 1kHz, 0dB input, highpass filter disabled measured from digital input to analog output | MODE = 0 (voice) 8kHz | | 2.2 | | ms |
| | | | MODE = 0 (voice) 16kHz | | 1.1 | | |
| | | | MODE = 1 (music) 8kHz | | 4.5 | | |
| | | | MODE = 1 (music) 48kHz | | 0.76 | | |
| Gain Error | | | | | 1 | 5 | % |
| Channel Gain Mismatch | | | | | 1 | | % |
| SINGLE-ENDED ANALOG INPUT TO HEADPHONE AMPLIFIER PATH | | | | | | | |
| Dynamic Range (Note 5) | | $A_{V_LINE} = 0dB$ $A_{V_HPPGA} = 0dB$ | | | 101 | | dB |
| Total Harmonic Distortion + Noise | THD+N | $V_{IN} = 250mV_{RMS}$, $f = 1kHz$ | | | -80 | | dB |
| Crosstalk | | HPL to HPR and HPR to HPL, $P_{OUT} = 5mW$, $f = 1kHz$, $R_{HP} = 32\Omega$ | | | -94 | | dB |

Electrical Characteristics (continued)

($V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V$, $V_{DVDD} = 1.2V$, $V_{SPKLVDD} = V_{SPKRVD} = V_{SPKVDD} = 3.7V$. Receiver load (R_{RCV}) connected between RCV/LOUTL and RCVN/LOUTR (LINMOD = 0). Line output loads (R_{LOUT}) connected between RCV/LOUTL and RCVN/LOUTR to GND (LINMOD = 1). Headphone loads (R_{HP}) connected from HPL or HPR to GND. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. $R_{RCV} = \infty$, $R_{LOUT} = \infty$, $R_{HP} = \infty$, $Z_{SPK} = \infty$. $C_{REF} = 2.2\mu F$, $C_{BIAS} = C_{MICBIAS} = 1\mu F$, $C_{C1N-C1P} = C_{CPVDD} = C_{CPVSS} = 1\mu F$. $A_{V_MICPRE_} = A_{V_MICPGA_} = A_{V_LINEPGA_} = 0dB$, $A_{V_ADCLVL} = A_{V_ADCGAIN} = 0dB$, $A_{V_DACLVL} = A_{V_DACGAIN} = 0dB$, $A_{V_MIXGAIN} = 0dB$, $A_{V_RCV} = A_{V_LOUT} = A_{V_HP} = A_{V_SPK} = 0dB$. $f_{MCLK} = 12.288MHz$, $f_{LRCLK} = 48kHz$, MAS = 0, 20-bit source data. $T_A = T_{MIN}$ to T_{MAX} unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS | |
|--|----------------|--|------------------------------|----------------------|----------------------|-----------|----|
| Power-Supply Rejection Ratio (Note 3) | PSRR | $V_{AVDD} = V_{HPVDD} = 1.65V$ to $2.0V$ | 40 | 60 | | dB | |
| | | $V_{RIPPLE} = 100mV_{P-P}$, $A_{V_TOTAL} = 0dB$ | $f = 217Hz$ | | 61 | | |
| | | | $f = 1kHz$ | | 61 | | |
| | | | $f = 10kHz$ | | 60 | | |
| HEADPHONE AMPLIFIER (Note 7) | | | | | | | |
| Output Power | P_{OUT} | $f = 1kHz$, THD = 1% | $R_{HP} = 16\Omega$ | 20 | 40 | mW | |
| | | | $R_{HP} = 32\Omega$ | | 30 | | |
| Total Harmonic Distortion + Noise | THD+N | $R_{HP} = 16\Omega$, $P_{OUT} = 10mW$, $f = 1kHz$ | | -88 | -77 | dB | |
| | | $R_{HP} = 10k\Omega$, $V_{OUT} = 1V_{RMS}$, $f = 1kHz$ | | -88 | | | |
| Full-Scale Output | | $A_{VHP} = 0dB$ (Note 8) | | 1 | | V_{RMS} | |
| Headphone Volume Control (PGA) | A_{V_HPPGA} | | HPVOL_ = 0x00 | -69 | -67 | -65 | dB |
| | | | HPVOL_ = 0x1F | 2.5 | 3 | 3.5 | |
| Volume Control Step Size (Note 9) | | | +3dB to +1dB | | 0.5 | dB | |
| | | | +1dB to -5dB | | 1 | | |
| | | | -5dB to -19dB | | 2 | | |
| | | | -19dB to -43dB | | 3 | | |
| | | | -43dB to -67dB | | 4 | | |
| Mute Attenuation | | $f = 1kHz$ | | 110 | | dB | |
| Output Offset Voltage | V_{OS} | $A_{V_HP} = -67dB$ | $T_A = +25^\circ C$ | ± 0.5 | ± 1 | mV | |
| | | | $T_A = T_{MIN}$ to T_{MAX} | | ± 3 | | |
| Capacitive Drive Capability | | No sustained oscillations | $R_{HP} = 32\Omega$ | 500 | | pF | |
| | | | $R_{HP} = \infty$ | 100 | | | |
| Click-and-Pop Level | K_{CP} | Peak voltage, A-weighted, 32 samples per second, $A_{V_HP} = -67dB$ | Into shutdown | -73 | | dBV | |
| | | | Out of shutdown | -73 | | | |
| JACK DETECTION | | | | | | | |
| JACKSNS High Threshold | V_{TH_HIGH} | MICBIAS enabled | 0.80 x $V_{MICBIAS}$ | 0.95 x $V_{MICBIAS}$ | 0.98 x $V_{MICBIAS}$ | V | |
| | | MICBIAS disabled | 0.80 x $V_{SPKLVDD}$ | 0.95 x $V_{SPKLVDD}$ | 0.98 x $V_{SPKLVDD}$ | | |

Electrical Characteristics (continued)

($V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V$, $V_{DVDD} = 1.2V$, $V_{SPKLVDD} = V_{SPKRVDD} = V_{SPKVDD} = 3.7V$. Receiver load (R_{RCV}) connected between RCVN/LOUTL and RCVN/LOUTR (LINMOD = 0). Line output loads (R_{LOUT}) connected between RCVN/LOUTL and RCVN/LOUTR to GND (LINMOD = 1). Headphone loads (R_{HP}) connected from HPL or HPR to GND. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. $R_{RCV} = \infty$, $R_{LOUT} = \infty$, $R_{HP} = \infty$, $Z_{SPK} = \infty$. $C_{REF} = 2.2\mu F$, $C_{BIAS} = C_{MICBIAS} = 1\mu F$, $C_{C1N-C1P} = C_{CPVDD} = C_{CPVSS} = 1\mu F$. $A_{V_MICPRE_} = A_{V_MICPGA_} = A_{V_LINEPGA_} = 0dB$, $A_{V_ADCLVL} = A_{V_ADCGAIN} = 0dB$, $A_{V_DACLVL} = A_{V_DACGAIN} = 0dB$, $A_{V_MIXGAIN} = 0dB$, $A_{V_RCV} = A_{V_LOUT} = A_{V_HP} = A_{V_SPK} = 0dB$. $f_{MCLK} = 12.288MHz$, $f_{LRCLK} = 48kHz$, MAS = 0, 20-bit source data. $T_A = T_{MIN}$ to T_{MAX} unless otherwise noted. Typical values are at $T_A = +25^{\circ}C$.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|----------------------------------|---------------|----------------------------|---------------------------|---------------------------|---------------------------|------------|
| JACKSNS Low Threshold | V_{TH_LOW} | MICBIAS enabled | $0.06 \times V_{MICBIAS}$ | $0.10 \times V_{MICBIAS}$ | $0.17 \times V_{MICBIAS}$ | V |
| | | MICBIAS disabled | $0.06 \times V_{SPKLVDD}$ | $0.10 \times V_{SPKLVDD}$ | $0.17 \times V_{SPKLVDD}$ | |
| JACKSNS Sense Voltage | V_{SENSE} | MICBIAS disabled | $V_{SPKLVDD}$ | | | V |
| JACKSNS Strong Pullup Resistance | R_{SPU} | MICBIAS disabled, JDWK = 0 | 1.9 | 2.4 | 2.7 | k Ω |
| JACKSNS Weak Pullup Current | I_{WPU} | MICBIAS disabled, JDWK = 1 | 5 | | | μA |
| JACKSNS Glitch Debounce Period | t_{GLITCH} | JDEB = 00 | 25 | | | ms |
| | | JDEB = 11 | 200 | | | |

Digital Filter Specifications

($V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V$, $V_{DVDD} = 1.2V$, $V_{SPKLVD} = V_{SPKRVD} = V_{SPKVDD} = 3.7V$. Receiver load (R_{RCV}) connected between RCV/LOUTL and RCVN/LOUTR (LINMOD = 0). Line Output loads (R_{LOUT}) connected between from RCV/LOUTL and RCVN/LOUTR to GND (LINMOD = 1). Headphone loads (R_{HP}) connected from HPL or HPR to GND. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. $R_{RCV} = \infty$, $R_{LOUT} = \infty$, $R_{HP} = \infty$, $Z_{SPK} = \infty$. $C_{REF} = 2.2\mu F$, $C_{BIAS} = C_{MICBIAS} = 1\mu F$, $C_{C1N-C1P} = C_{CPVDD} = C_{CPVSS} = 1\mu F$. $A_{V_MICPRE_} = A_{V_MICPGA_} = A_{V_LINEPGA} = 0dB$, $A_{V_ADCLVL} = A_{V_ADCGAIN} = 0dB$, $A_{V_DACLVL} = A_{V_DACGAIN} = 0dB$, $A_{V_MIXGAIN} = 0dB$, $A_{V_RCV} = A_{V_LOUT} = A_{V_HP} = A_{V_SPK} = 0dB$. $f_{MCLK} = 12.288MHz$, $f_{LRCLK} = 48kHz$, MAS = 0, 20-bit source data. $T_A = T_{MIN}$ to T_{MAX} unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Notes 2, 10)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--|------------------|---------------------------------|-----------------------|-----|----------------------|-------|
| RECORD PATH LEVEL CONTROL | | | | | | |
| Record Level Adjust Range | A_{V_ADCLVL} | AVL/AVR = 0xF to 0x0 (Note 6) | -12 | | +3 | dB |
| Record Level Adjust Step Size | | | | 1 | | dB |
| Record Gain Adjust Range | $A_{V_ADCGAIN}$ | AVLG/AVRG = 0x0 to 0x3 (Note 6) | 0 | | 42 | dB |
| Record Gain Adjust Step Size | | | | 6 | | dB |
| RECORD PATH VOICE MODE IIR LOWPASS FILTER (MODE = 0) | | | | | | |
| Passband Cutoff | f_{PLP} | Ripple limit cutoff | 0.444 $\times f_S$ | | | Hz |
| | | -3dB cutoff | 0.449 $\times f_S$ | | | |
| Passband Ripple | | $f < f_{PLP}$ | -0.1 | | 0.1 | dB |
| Stopband Cutoff | f_{SLP} | | | | 0.47 $\times f_S$ | Hz |
| Stopband Attenuation | | $f > f_{SLP}$ | 74 | | | dB |
| RECORD PATH STEREO MUSIC MODE FIR LOWPASS FILTER (MODE = 1, DHF = 0, $f_{LRCLK} < 50kHz$) | | | | | | |
| Passband Cutoff | f_{PLP} | Ripple limit cutoff | 0.43 $\times f_S$ | | | Hz |
| | | -3dB cutoff | 0.48 $\times f_S$ | | | |
| | | -6.02dB cutoff | 0.5 $\times f_S$ | | | |
| Passband Ripple | | $f < f_{PLP}$ | -0.1 | | +0.1 | dB |
| Stopband Cutoff | f_{SLP} | | | | 0.58 $\times f_S$ | Hz |
| Stopband Attenuation | | $f < f_{SLP}$ | 60 | | | dB |
| RECORD PATH STEREO MUSIC MODE FIR LOWPASS FILTER (MODE = 1, DHF = 1, $f_{LRCLK} > 50kHz$) | | | | | | |
| Passband Cutoff | f_{PLP} | Ripple Limit cutoff | 0.208 $\times f_S$ | | | Hz |
| | | -3dB cutoff | 0.28 $\times f_S$ | | | |
| Passband Ripple | | $f < f_{PLP}$ | -0.1 | | +0.1 | dB |
| Stopband Cutoff | f_{SLP} | | | | 0.45 $\times f_S$ | Hz |
| Stopband Attenuation | | $f < f_{SLP}$ | 60 | | | dB |

Digital Filter Specifications (continued)

($V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V$, $V_{DVDD} = 1.2V$, $V_{SPKLVDD} = V_{SPKRVDD} = V_{SPKVDD} = 3.7V$. Receiver load (R_{RCV}) connected between RCVN/LOUTL and RCVN/LOUTR (LINMOD = 0). Line Output loads (R_{LOUT}) connected between RCVN/LOUTL and RCVN/LOUTR to GND (LINMOD = 1). Headphone loads (R_{HP}) connected from HPL or HPR to GND. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. $R_{RCV} = \infty$, $R_{LOUT} = \infty$, $R_{HP} = \infty$, $Z_{SPK} = \infty$. $C_{REF} = 2.2\mu F$, $C_{BIAS} = C_{MICBIAS} = 1\mu F$, $C_{C1N-C1P} = C_{CPVDD} = C_{CPVSS} = 1\mu F$. $A_{V_MICPRE_} = A_{V_MICPGA_} = A_{V_LINEPGA_} = 0dB$, $A_{V_ADCLVL} = A_{V_ADCGAIN} = 0dB$, $A_{V_DACLVL} = A_{V_DACGAIN} = 0dB$, $A_{V_MIXGAIN} = 0dB$, $A_{V_RCV} = A_{V_LOUT} = A_{V_HP} = A_{V_SPK} = 0dB$. $f_{MCLK} = 12.288MHz$, $f_{LRCLK} = 48kHz$, MAS = 0, 20-bit source data. $T_A = T_{MIN}$ to T_{MAX} unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Notes 2, 10)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--|------------------|---|------------------------|-----|------|-------|
| RECORD PATH DC-BLOCKING HIGHPASS FILTER | | | | | | |
| DC Attenuation | A_{V_ADCHPF} | AHPF = 1 | | 90 | | dB |
| RECORD PATH PROGRAMMABLE BIQUAD FILTER | | | | | | |
| Preattenuator Gain Range | | | -15 | | 0 | dB |
| Preattenuator Step Size | | | | 1 | | dB |
| Cutoff Frequency | | Highpass filter | 0.0008 $\times f_S$ | | | Hz |
| | | High-frequency shelving filter | 0.02 $\times f_S$ | | | |
| | | Lowpass filter | 0.002 $\times f_S$ | | | |
| | | Low-frequency shelving filter | 0.0008 $\times f_S$ | | | |
| | | Peak filter | 0.0008 $\times f_S$ | | | |
| Quality Factor | Q | Peak filter | | | 10 | |
| DIGITAL SIDETONE: RECORD PATH TO PLAYBACK PATH (MODE = 0) | | | | | | |
| Sidetone Level Adjust Range | A_{V_STLVL} | DVST = 0x1F to 0x01 | -60.5 | | -0.5 | dB |
| Sidetone Level Adjust Step Size | | | | 2 | | dB |
| Sidetone Path Phase Delay | | $f_{IN} = 1kHz$, full-scale amplitude, highpass filter disabled | $f_S = 8kHz$ | 1.8 | | ms |
| | | | $f_S = 16kHz$ | 0.9 | | |
| PLAYBACK PATH LEVEL CONTROL | | | | | | |
| Playback Path Attenuation Range | A_{V_DACLVL} | DV = 0xF to 0x0 (Note 6) | -15 | | 0 | dB |
| Playback Path Attenuation Step Size | | | | 1 | | dB |
| Playback Path Gain Adjust Range | $A_{V_DACGAIN}$ | DVG = 00 to 11 (Note 6) | 0 | | 18 | dB |

Digital Filter Specifications (continued)

($V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V$, $V_{DVDD} = 1.2V$, $V_{SPKLVDD} = V_{SPKRVDD} = V_{SPKVDD} = 3.7V$. Receiver load (R_{RCV}) connected between RCV/LOUTL and RCVN/LOUTR (LINMOD = 0). Line Output loads (R_{LOUT}) connected between RCV/LOUTL and RCVN/LOUTR to GND (LINMOD = 1). Headphone loads (R_{HP}) connected from HPL or HPR to GND. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. $R_{RCV} = \infty$, $R_{LOUT} = \infty$, $R_{HP} = \infty$, $Z_{SPK} = \infty$. $C_{REF} = 2.2\mu F$, $C_{BIAS} = C_{MICBIAS} = 1\mu F$, $C_{C1N-C1P} = C_{CPVDD} = C_{CPVSS} = 1\mu F$. $A_{V_MICPRE_} = A_{V_MICPGA_} = A_{V_LINEPGA} = 0dB$, $A_{V_ADCLVL} = A_{V_ADCGAIN} = 0dB$, $A_{V_DACLVL} = A_{V_DACGAIN} = 0dB$, $A_{V_MIXGAIN} = 0dB$, $A_{V_RCV} = A_{V_LOUT} = A_{V_HP} = A_{V_SPK} = 0dB$. $f_{MCLK} = 12.288MHz$, $f_{LRCLK} = 48kHz$, MAS = 0, 20-bit source data. $T_A = T_{MIN}$ to T_{MAX} unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Notes 2, 10)

| Playback Path Gain Adjust Step Size | | | 6 | | dB | | |
|--|-----------|---------------------|---------|-------|-------|-------|---------|
| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS | |
| PLAYBACK PATH VOICE MODE IIR LOWPASS FILTER (MODE = 0) | | | | | | | |
| Passband Cutoff | f_{PLP} | Ripple limit cutoff | 0.448 | | | Hz | |
| | | -3dB cutoff | $x f_S$ | 0.451 | | | $x f_S$ |
| Passband Ripple | | $f < f_{PLP}$ | -0.1 | | +0.1 | dB | |
| Stopband Cutoff | f_{SLP} | | | | 0.476 | Hz | |
| Stopband Attenuation (Note 11) | | $f > f_{SLP}$ | 75 | | | dB | |
| PLAYBACK PATH STEREO MUSIC MODE FIR LOWPASS FILTER (MODE = 1, DHF = 0, $f_{LRCLK} < 50kHz$) | | | | | | | |
| Passband Cutoff | f_{PLP} | Ripple limit cutoff | 0.43 | | | Hz | |
| | | -3dB cutoff | $x f_S$ | 0.47 | | | $x f_S$ |
| | | -6.02dB cutoff | $x f_S$ | 0.5 | | | $x f_S$ |
| Passband Ripple | | $f < f_{PLP}$ | -0.1 | | +0.1 | dB | |
| Stopband Cutoff | f_{SLP} | | | | 0.58 | Hz | |
| Stopband Attenuation (Note 11) | | $f > f_{SLP}$ | 60 | | | dB | |
| PLAYBACK PATH STEREO MUSIC MODE FIR LOWPASS FILTER (MODE1 = 1, DHF = 1 for $f_{LRCLK} > 50kHz$) | | | | | | | |
| Passband Cutoff | f_{PLP} | Ripple limit cutoff | 0.24 | | | Hz | |
| | | -3dB cutoff | $x f_S$ | 0.31 | | | $x f_S$ |
| Passband Ripple | | $f < f_{PLP}$ | -0.1 | | +0.1 | dB | |
| Stopband Cutoff | f_{SLP} | | | | 0.477 | Hz | |
| Stopband Attenuation (Note 11) | | $f < f_{SLP}$ | 60 | | | dB | |

Digital Filter Specifications (continued)

($V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V$, $V_{DVDD} = 1.2V$, $V_{SPKLVDD} = V_{SPKRVDD} = V_{SPKVDD} = 3.7V$. Receiver load (R_{RCV}) connected between RCVN/LOUTL and RCVN/LOUTR (LINMOD = 0). Line Output loads (R_{LOUT}) connected between RCVN/LOUTL and RCVN/LOUTR to GND (LINMOD = 1). Headphone loads (R_{HP}) connected from HPL or HPR to GND. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. $R_{RCV} = \infty$, $R_{LOUT} = \infty$, $R_{HP} = \infty$, $Z_{SPK} = \infty$. $C_{REF} = 2.2\mu F$, $C_{BIAS} = C_{MICBIAS} = 1\mu F$, $C_{C1N-C1P} = C_{CPVDD} = C_{CPVSS} = 1\mu F$. $A_{V_MICPRE_} = A_{V_MICPGA_} = A_{V_LINEPGA_} = 0dB$, $A_{V_ADCLVL} = A_{V_ADCGAIN} = 0dB$, $A_{V_DACLVL} = A_{V_DACGAIN} = 0dB$, $A_{V_MIXGAIN} = 0dB$, $A_{V_RCV} = A_{V_LOUT} = A_{V_HP} = A_{V_SPK} = 0dB$. $f_{MCLK} = 12.288MHz$, $f_{LRCLK} = 48kHz$, MAS = 0, 20-bit source data. $T_A = T_{MIN}$ to T_{MAX} unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Notes 2, 10)

| PLAYBACK PATH DC-BLOCKING HIGHPASS FILTER | | | | | | |
|---|--------|--------------------------------|------------------------|-----|-----|-------|
| DC Attenuation | | DHPF = 1 | 89 | | | dB |
| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
| PLAYBACK PATH DYNAMIC RANGE CONTROL | | | | | | |
| Gain Range | | | 0 | | 12 | dB |
| Compression Threshold | | | -31 | | 0 | dBFS |
| Expansion Threshold | | | -66 | | -35 | dBFS |
| Attack Time | | | 0.0005 | | 0.2 | s |
| Release Time | | | 0.0625 | | 8 | s |
| PLAYBACK PATH PARAMETRIC EQUALIZER | | | | | | |
| Number of Bands | | | 7 | | | Bands |
| Per Band Gain Range | | | -12 | | +12 | dB |
| Preattenuator Gain Range | | | -15 | | 0 | dB |
| Preattenuator Step Size | | | 1 | | | dB |
| Cutoff Frequency | | Highpass filter | 0.0008 $\times f_S$ | | | Hz |
| | | High-frequency shelving filter | 0.02 $\times f_S$ | | | |
| | | Lowpass filter | 0.002 $\times f_S$ | | | |
| | | Low-frequency shelving filter | 0.0008 $\times f_S$ | | | |
| | | Peak filter | 0.0008 $\times f_S$ | | | |
| Quality Factor | Q | Peak filter | 10 | | | |

Digital Input/Output Characteristics

($V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V$, $V_{DVDD} = 1.2V$, $V_{SPKLVDD} = V_{SPKRVDD} = V_{SPKVDD} = 3.7V$. Receiver load (R_{RCV}) connected between RCVPL/LOUTL and RCVN/LOUTR (LINMOD = 0). Line output loads (R_{LOUT}) connected between from RCVPL/LOUTL and RCVN/LOUTR to GND (LINMOD = 1). Headphone loads (R_{HP}) connected from HPL or HPR to GND. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. $R_{RCV} = \infty$, $R_{LOUT} = \infty$, $R_{HP} = \infty$, $Z_{SPK} = \infty$. $C_{REF} = 2.2\mu F$, $C_{BIAS} = C_{MICBIAS} = 1\mu F$, $C_{C1N-C1P} = C_{CPVDD} = C_{CPVSS} = 1\mu F$. $A_{V_MICPRE_} = A_{V_MICPGA_} = A_{V_LINEPGA_} = 0dB$, $A_{V_ADCLVL} = A_{V_ADCGAIN} = 0dB$, $A_{V_DACLVL} = A_{V_DACGAIN} = 0dB$, $A_{V_MIXGAIN} = 0dB$, $A_{V_RCV} = A_{V_LOUT} = A_{V_HP} = A_{V_SPK} = 0dB$. $f_{MCLK} = 12.288MHz$, $f_{LRCLK} = 48kHz$, MAS = 0, 20-bit source data. $T_A = T_{MIN}$ to T_{MAX} unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--|---------------------|--|-------------------------|-----|-------------------------|---------|
| MCLK | | | | | | |
| Input High Voltage | V_{IH} | | 1.26 | | | V |
| Input Low Voltage | V_{IL} | | | | 0.6 | V |
| Input Leakage Current | I_{IH} , I_{IL} | $V_{DVDDIO} = 2.0V$, $T_A = +25^\circ C$ | -1 | | +1 | μA |
| Input Capacitance | | | | 10 | | pF |
| SDIN, BCLK, LRCLK (Input) | | | | | | |
| Input High Voltage | V_{IH} | | $0.7 \times V_{DVDDIO}$ | | | V |
| Input Low Voltage | V_{IL} | | | | $0.3 \times V_{DVDDIO}$ | V |
| Input Hysteresis | | | | 100 | | mV |
| Input Leakage Current | I_{IH} , I_{IL} | $V_{DVDDIO} = 3.6V$, $T_A = +25^\circ C$ | -1 | | +1 | μA |
| Input Capacitance | | | | 10 | | pF |
| BCLK, LRCLK, SDOUT (Output) | | | | | | |
| Output High Voltage | V_{OH} | $I_{OH} = 3mA$ | $V_{DVDDIO} - 0.4$ | | | V |
| Output Low Voltage | V_{OL} | $I_{OL} = 3mA$ | | | 0.4 | V |
| Input Leakage Current | I_{IH} , I_{IL} | $V_{DVDDIO} = 2.0V$, $T_A = +25^\circ C$, high-impedance state | -1 | | +1 | μA |
| SDA, SCL (Input) | | | | | | |
| Input High Voltage | V_{IH} | | $0.7 \times V_{DVDDIO}$ | | | V |
| Input Low Voltage | V_{IL} | | | | $0.3 \times V_{DVDDIO}$ | V |
| Input Hysteresis | | | | 100 | | mV |
| Input Leakage Current | I_{IH} , I_{IL} | $V_{DVDDIO} = 2.0V$, $T_A = +25^\circ C$ | -1 | | +1 | μA |
| Input Capacitance | | | | 10 | | pF |
| SDA, \overline{IRQ} (Output) | | | | | | |
| Output Low Voltage | V_{OL} | $V_{DVDDIO} = 1.65V$, $I_{OH} = 3mA$ | | | $0.2 \times V_{DVDDIO}$ | V |
| Output High Current | I_{OH} | $V_{DVDDIO} = 1.65V$, $I_{OL} = 3mA$ | | | 1 | μA |

Digital Input/Output Characteristics (continued)

($V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V$, $V_{DVDD} = 1.2V$, $V_{SPKLVDD} = V_{SPKRVDD} = V_{SPKVDD} = 3.7V$. Receiver load (R_{RCV}) connected between RCV/LOUTL and RCVN/LOUTR (LINMOD = 0). Line output loads (R_{LOUT}) connected between RCV/LOUTL and RCVN/LOUTR to GND (LINMOD = 1). Headphone loads (RHP) connected from HPL or HPR to GND. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. $R_{RCV} = \infty$, $R_{LOUT} = \infty$, $R_{HP} = \infty$, $Z_{SPK} = \infty$. $C_{REF} = 2.2\mu F$, $C_{BIAS} = C_{MICBIAS} = 1\mu F$, $C_{C1N-C1P} = C_{CPVDD} = C_{CPVSS} = 1\mu F$. $A_{V_MICPRE_} = A_{V_MICPGA_} = A_{V_LINEPGA_} = 0dB$, $A_{V_ADCLVL} = A_{V_ADCGAIN} = 0dB$, $A_{V_DACLVL} = A_{V_DACGAIN} = 0dB$, $A_{V_MIXGAIN} = 0dB$, $A_{V_RCV} = A_{V_LOUT} = A_{V_HP} = A_{V_SPK} = 0dB$. $f_{MCLK} = 12.288MHz$, $f_{LRCLK} = 48kHz$, MAS = 0, 20-bit source data. $T_A = T_{MIN}$ to T_{MAX} unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--|---------------------|---|------------------------|-----|------------------------|---------|
| DIGITAL MICROPHONE DATA (DMD) INPUT | | | | | | |
| Input High Voltage | V_{IH} | | 0.65 x V_{DVDDIO} | | | V |
| Input Low Voltage | V_{IL} | | | | 0.35 x V_{DVDDIO} | V |
| Input Hysteresis | | | | 100 | | mV |
| Input Leakage Current | I_{IH} , I_{IL} | $V_{DVDDIO} = 2.0V$, $T_A = +25^\circ C$ | -25 | | +25 | μA |
| Input Capacitance | | | | 10 | | pF |
| DIGITAL MICROPHONE CLOCK (DMC) OUTPUT | | | | | | |
| Output High Voltage | V_{OH} | $I_{OH} = 3mA$ | $V_{AVDD} -$ 0.4 | | | V |
| Output Low Voltage | V_{OL} | $I_{OL} = 3mA$ | | | 0.4 | V |