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MAX98091

Ultra-Low Power Stereo Audio Codec

General Description

The MAX98091 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 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 x 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.

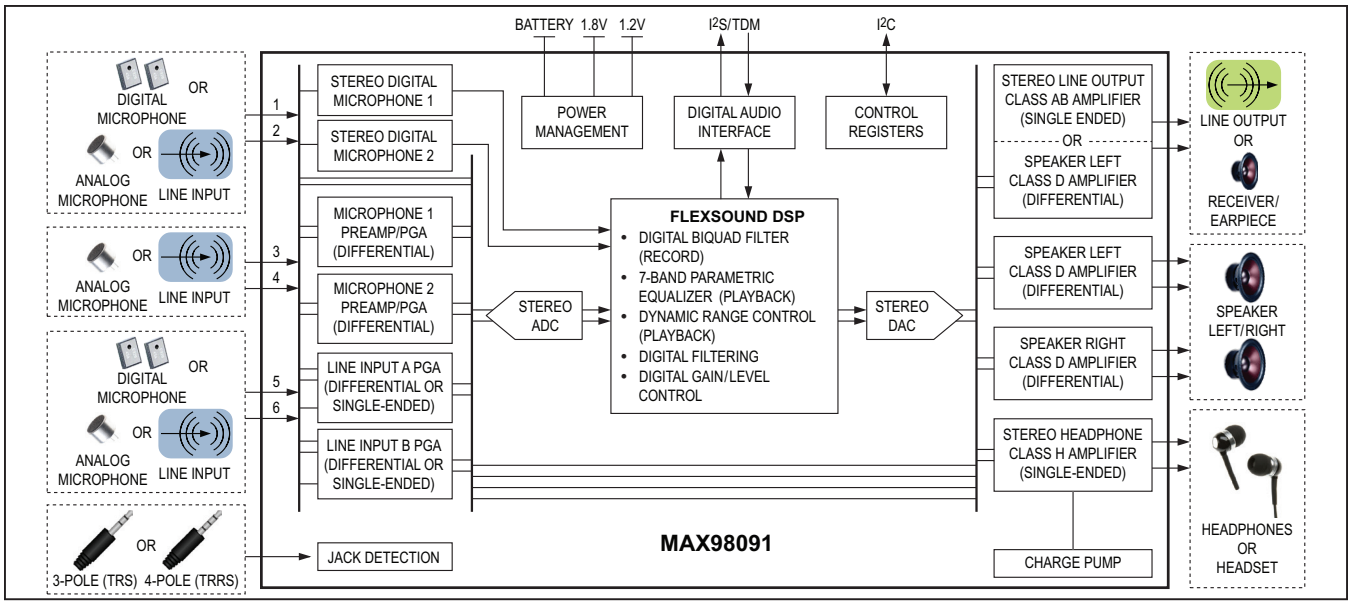
The record/playback paths feature FlexSound® technology DSP. This includes digital gain and filtering, a biquad filter (record), dynamic range control (playback), and a seven band parametric equalizer (playback) that can improve loudspeaker performance by optimizing the frequency response.

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.

Features and Benefits

- 102dB DR Stereo DAC to HP
- 4.1mW Stereo Playback Power Consumption
- 99dB DR Stereo ADC
- 4.5mW Stereo Record Power Consumption
- 3 Stereo Single-Ended/Differential Analog Microphone/Line Inputs
- Two PDM Digital Microphone Inputs
- Master Clock Frequencies from 256 x 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 = 4Ω, V_{SPKVDD} = 5V)
  - 1.8W/Channel (R_L = 8Ω, V_{SPKVDD} = 5V)
- 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
- 56-Bump 0.4mm WLP and 48-Pin 6mmx6mmx0.75mm TQFN Packages

Simplified Block Diagram



For related parts and recommended products to use with this part, refer to www.maximintegrated.com/MAX98091.related.

***Ordering Information* appears at end of data sheet.**

19-6700; Rev 2; 11/14

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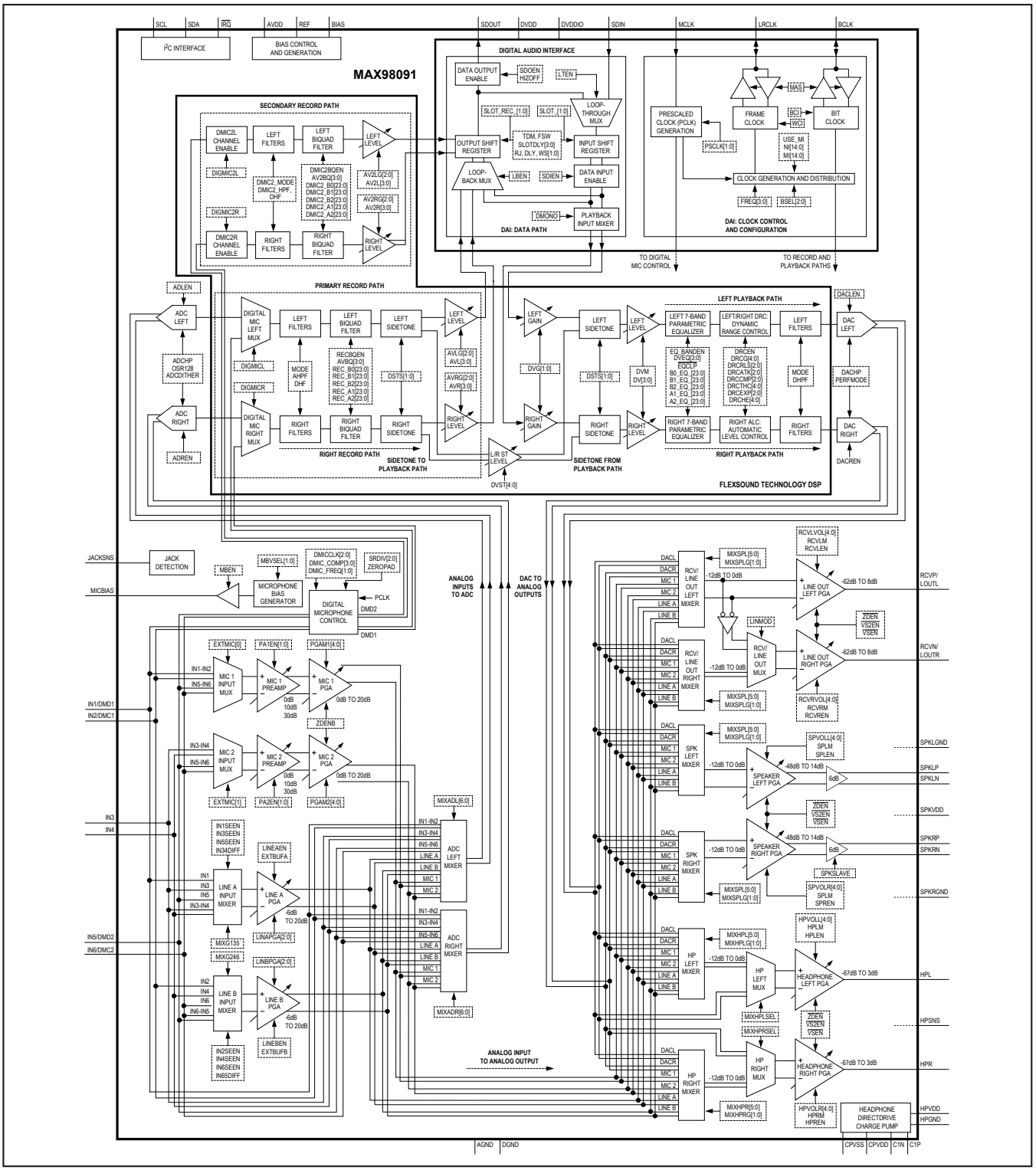
Functional Diagram



Absolute Maximum Ratings

(Voltages with respect to AGND, unless otherwise noted.)
AVDD, DVDD, HPVDD .....-0.3V to +2.2V
SPKVDD, 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_{SPKVDD} + 0.3V)
REF, BIAS ..... -0.3V to (V_{AVDD} + 0.3V)
MCLK, SDIN, SDA, SCL, $\overline{IRQ}$.....-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_{SPKVDD} + 0.3V)
RCVN/LOUTR.....($V_{SPKLGND}$ - 0.3V) to (V_{SPKVDD} + 0.3V)
SPKLP, SPKLN .....($V_{SPKLGND}$ - 0.3V) to (V_{SPKVDD} + 0.3V)
SPKRP, SPKRN ..... ($V_{SPKRGND}$ - 0.3V) to (V_{SPKVDD} + 0.3V)
JACKSNS.....-0.3V to +6.0V
Continuous Power Dissipation (T_A = +70°C)
WLP (derate 25mW/°C above +70°C).....1.9W
TQFN (derate 37mW/°C above +70°C).....2.96W
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}) .....40°C/W

TQFN
Junction-to-Case Thermal Resistance (θ_{JC}).....1°C/W
Junction-to-Ambient Thermal Resistance (θ_{JA}) .....27°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_{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} = $A_{V\_ADCGAIN}$ = 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°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
POWER SUPPLY							
Supply Voltage Range		Guaranteed by PSRR (Note 3)	V_{SPKVDD}	2.8	3.7	5.5	V
			V_{AVDD}, V_{HPVDD}	1.65	1.8	2	
			V_{DVDD} (WLP)	1.08	1.2	1.98	
			V_{DVDD} (TQFN)	1.08	1.2	1.65	
			V_{DVDDIO}	1.65	1.8	3.6	
Quiescent Supply Current (Note 4)	I_{VDD}	Full-duplex 8kHz mono, receiver output	Analog		1.94		mA
			Speaker		0.73		
			Digital		0.97		
		DAC playback 48kHz stereo, headphone outputs	Analog		1.45	2	
			Speaker		0	0.005	
			Digital		1.04	1.5	
		DAC playback 48kHz stereo, speaker outputs	Analog		0.91		
			Speaker		2.18		
			Digital		1.05		

Electrical Characteristics (continued)

(V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V, V_{DVDD} = 1.2V, 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} = $A_{V\_ADCGAIN}$ = 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°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°C	Analog		1	10	µA
			Speaker		1	5	
			Digital		2.1	5	
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			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_{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} = $A_{V\_ADCGAIN}$ = 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°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Gain Error		DC accuracy			1		%
DIFFERENTIAL (ANALOG MICROPHONE) PREAMP and PGA							
Full-Scale Input		A_{V_MICPRE} = 0dB			1		V_{RMS}
Microphone Preamplifier 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	31.25	
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		kΩ
MICROPHONE BIAS							
MICBIAS Output Voltage	$V_{MICBIAS}$	I_{LOAD} = 1mA, MBVSEL[1:0] = 00		2.1	2.2	2.29	V
		I_{LOAD} = 1mA, MBVSEL[1:0] = 01		2.29	2.4	2.46	
		I_{LOAD} = 1mA, MBVSEL[1:0] = 10		2.46	2.57	2.69	
		I_{LOAD} = 1mA, MBVSEL[1:0] = 11		2.69	2.8	2.9	
Load Regulation		I_{LOAD} = 1mA to 2mA, MBVSEL[1:0] = 00			±0.085		mV
Line Regulation		$V_{SPKLVDD}$ = 2.8V to 5.5V, MBVSEL[1:0] = 00			±0.01		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_{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} = $A_{V\_ADCGAIN}$ = 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°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		kΩ
Feedback Resistance	R_{IN_FB}	T_A = +25°C		19	20	21	kΩ
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		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} = 32Ω			-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_{SPKVDD} = 2.8V to 5.5V			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} = 32Ω, f = 1kHz, THD < 1%, BIAS_ MODE = 0			97		mW
		R_{REC} = 32Ω, 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_{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} = $A_{V\_ADCGAIN}$ = 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°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Volume Control Step Size		+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		85	97		dB
Output Offset Voltage	V_{OS}	A_{V_REC} = -62dB, T_A = +25°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 = 32Ω		500		pF
			R_L = ∞		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} = 10kΩ ($0.5V_{RMS}$ 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} = 10kΩ ($0.5V_{RMS}$ output level)			-86		dB
Power-Supply Rejection Ratio (Note 3)	PSRR	V_{SPKVDD} = 2.8V to 5.5V			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_{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} = $A_{V\_ADCGAIN}$ = 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°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		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		85	97		dB
Capacitive Drive Capability		No sustained oscillations	R_{LOUT} = 1kΩ		500		pF
			R_{LOUT} = ∞		**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} = 8Ω + 68µH, 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} = 8Ω + 68µH			-70		dB
Output Noise					28		$µV_{RMS}$
Power-Supply Rejection Ratio (Note 3)	PSRR	V_{SPKVDD}= 2.8V to 5.5V			80		dB
		V_{RIPPLE} = $100mV_{P-P}$	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_{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} = $A_{V\_ADCGAIN}$ = 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°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} = 8Ω + 68µH	V_{SPKVDD} = 5.0V		1450		mW
			V_{SPKVDD} = 4.2V		1000		
			V_{SPKVDD} = 3.7V		780		
			V_{SPKVDD} = 3.3V		600		
			V_{SPKVDD} = 3.0V		500		
		f = 1kHz, THD+N = 10%, Z_{SPK} = 8Ω + 68µH	V_{SPKVDD} = 5.0V		1800		
			V_{SPKVDD} = 4.2V		1250		
			V_{SPKVDD} = 3.7V		970		
			V_{SPKVDD} = 3.3V		760		
			V_{SPKVDD} = 3.0V		620		
Output Power	P_{OUT}	f = 1kHz, THD+N = 1%, Z_{SPK} = 4Ω + 33µH	V_{SPKVDD} = 5.0V		2600		mW
			V_{SPKVDD} = 4.2V		1800		
			V_{SPKVDD} = 3.7V		1400		
			V_{SPKVDD} = 3.3V		1100		
			V_{SPKVDD} = 3.0V		900		
		f = 1kHz, THD+N = 10%, Z_{SPK} = 4Ω + 33µH	V_{SPKVDD} = 5.0V		3250		
			V_{SPKVDD} = 4.2V		2250		
			V_{SPKVDD} = 3.7V		1700		
			V_{SPKVDD} = 3.3V		1350		
			V_{SPKVDD} = 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/ SPVOLR = 0x00	-51	-48	-44.5	dB
			SPVOLL/ SPVOLR = 0x1F	13	14	15	
Volume Control Step Size		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_{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} = $A_{V\_ADCGAIN}$ = 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°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Output Offset Voltage	V_{OS}	A_{V_SPKPGA} = -62dB, T_A = +25°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} = 16Ω		-86	-77	dB
			R_{HP} = 32Ω		-88		
		f = 1kHz, V_{OUT} = $1V_{RMS}$, R_{HP} = 10kΩ			-88		
Crosstalk		f = 1kHz, V_{IN} = -1dBFS, R_{HP} = 10kΩ			-105		dB
		HPL to HPR and HPR to HPL, P_{OUT} = 5mW, f = 1kHz, R_{HP} = 32Ω			-104		dB
Power-Supply Rejection Ratio (Note 3)	PSRR	V_{AVDD} = V_{HPVDD} = 1.65V to 2.0V			80		dB
		V_{RIPPLE} = $100mV_{P-P}$, A_{V_HP} = 0dB	f = 217Hz		79		
			f = 1kHz		79		
			f = 10kHz		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} = 0 dB			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} = 32Ω			-94		dB

Electrical Characteristics (continued)

(V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V, V_{DVDD} = 1.2V, 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} = $A_{V\_ADCGAIN}$ = 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°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			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} = 16Ω	20	40		mW
			R_{HP} = 32Ω		30		
Total Harmonic Distortion + Noise	THD+N	R_{HP} = 16Ω, P_{OUT} = 10mW, f = 1kHz			-88	-77	dB
		R_{HP} = 10kΩ, 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		-68	-67	-65	dB
		HPVOL_ = 0x1F		2.25	3	3.5	
Volume Control Step Size		+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}	AV_HP = -67dB	T_A = +25°C		±0.5	±1	mV
			T_A = T_{MIN} to T_{MAX}			±3	
Capacitive Drive Capability		No sustained oscillations	R_{HP} = 32Ω		500		pF
			R_{HP} = ∞		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		

Electrical Characteristics (continued)

(V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V, V_{DVDD} = 1.2V, 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} = $A_{V\_ADCGAIN}$ = 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°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
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_{SPKVDD}	0.95 x V_{SPKVDD}	0.98 x V_{SPKVDD}	
JACKSNS Low Threshold	V_{TH_LOW}	MICBIAS enabled	0.06 x $V_{MICBIAS}$	0.10 x $V_{MICBIAS}$	0.17 x $V_{MICBIAS}$	V
		MICBIAS disabled	0.06 x V_{SPKVDD}	0.10 x V_{SPKVDD}	0.17 x V_{SPKVDD}	
JACKSNS Sense Voltage	V_{SENSE}	MICBIAS disabled		V_{SPKVDD}		V
JACKSNS Strong Pullup Resistance	R_{SPU}	MICBIAS disabled, JDWK = 0	1.9	2.4	2.7	kΩ
JACKSNS Weak Pullup Current	I_{WPU}	MICBIAS disabled, JDWK = 1		5	12	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_{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} = $A_{V\_ADCGAIN}$ = 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°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 x f_S			Hz
		-3dB cutoff	0.449 x f_S			
Passband Ripple		f < f_{PLP}	-0.1		0.1	dB
Stopband Cutoff	f_{SLP}				0.47 x f_S	Hz
Stopband Attenuation		f > f_{SLP}	74			dB
RECORD PATH STEREO MUSIC MODE FIR LOWPASS FILTER (MODE = 1, DHF = 0, f_{LRCLK} < 48kHz)						
Passband Cutoff	f_{PLP}	Ripple limit cutoff	0.43 x f_S			Hz
		-3dB cutoff	0.48 x f_S			
		-6.02dB cutoff	0.5 x f_S			
Passband Ripple		f < f_{PLP}	-0.1		+0.1	dB
Stopband Cutoff	f_{SLP}				0.58 x f_S	Hz
Stopband Attenuation		f < f_{SLP}	60			dB
RECORD PATH STEREO MUSIC MODE FIR LOWPASS FILTER (MODE = 1, DHF = 1, f_{LRCLK} > 48kHz)						
Passband Cutoff	f_{PLP}	Ripple limit cutoff	0.208 x f_S			Hz
		-3dB cutoff	0.28 x f_S			
Passband Ripple		f < f_{PLP}	-0.1		+0.1	dB
Stopband Cutoff	f_{SLP}				0.45 x 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_{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} = $A_{V\_ADCGAIN}$ = 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°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 PROGRAMMALE BIQUAD FILTER							
Preattenuator Gain Range				-15		0	dB
Preattenuator Step Size					1		dB
Cutoff Frequency		Highpass filter			0.0008 x f_S		Hz
		High-frequency shelving filter			0.02 x f_S		
		Lowpass filter			0.002 x f_S		
		Low-frequency shelving filter			0.0008 x f_S		
		Peak filter			0.0008 x 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 Side					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
Playback Path Gain Adjust Step Size					6		dB

Digital Filter Specifications (continued)

(V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V, V_{DVDD}= 1.2V, 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} = $A_{V\_ADCGAIN}$ = 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°C.) (Notes 2, 10)

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 x f_S			Hz
		-3dB cutoff	0.451 x f_S			
Passband Ripple		f < f_{PLP}	-0.1		+0.1	dB
Stopband Cutoff	f_{SLP}				0.476 x f_S	Hz
Stopband Attenuation (Note 11)		f > f_{SLP}	75			dB
PLAYBACK PATH STEREO MUSIC MODE FIR LOWPASS FILTER (MODE = 1, DHF = 0, f_{LRCLK} < 48kHz)						
Passband Cutoff	f_{PLP}	Ripple limit cutoff	0.43 x f_S			Hz
		-3dB cutoff	0.47 x f_S			
		-6.02dB cutoff	0.5 x f_S			
Passband Ripple		f < f_{PLP}	-0.1		+0.1	dB
Stopband Cutoff	f_{SLP}				0.58 x f_S	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} > 48kHz)						
Passband Cutoff	f_{PLP}	Ripple limit cutoff	0.24 x f_S			Hz
		-3dB cutoff	0.31 x f_S			
Passband Ripple		f < f_{PLP}	-0.1		+0.1	dB
Stopband Cutoff	f_{SLP}				0.477 x f_S	Hz
Stopband Attenuation (Note 11)		f < f_{SLP}	60			dB
PLAYBACK PATH DC-BLOCKING HIGHPASS FILTER						
DC Attenuation		DHPF = 1		89		dB

Digital Filter Specifications (continued)

(V_{AVDD} = V_{HPVDD} = V_{DVDDIO} = 1.8V, V_{DVDD}= 1.2V, 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} = $A_{V\_ADCGAIN}$ = 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°C.) (Notes 2, 10)

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 x f_S			Hz
		High-frequency shelving filter	0.02 x f_S			
		Lowpass filter	0.002 x f_S			
		Low-frequency shelving filter	0.0008 x f_S			
		Peak filter	0.0008 x 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_{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} = $A_{V\_ADCGAIN}$ = 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°C.) (Notes 2, 10)

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°C	-1		+1	µA
Input Capacitance				10		pF
SDIN, BCLK, LRCLK (Input)						
Input High Voltage	V_{IH}		0.7 x V_{DVDDIO}			V
Input Low Voltage	V_{IL}				0.3 x V_{DVDDIO}	V
Input Hysteresis				100		mV
Input Leakage Current	I_{IH}, I_{IL}	V_{DVDDIO} = 3.6V, T_A = +25°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°C, high-impedance state	-1		+1	µA
SDA, SCL (Input)						
Input High Voltage	V_{IH}		0.7 x V_{DVDDIO}			V
Input Low Voltage	V_{IL}				0.3 x V_{DVDDIO}	V
Input Hysteresis				100		mV
Input Leakage Current	I_{IH}, I_{IL}	V_{DVDDIO} = 2.0V, T_A = +25°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 x V_{DVDDIO}	V