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Stereo Audio CODEC with FlexSound Technology

MAX9888

General Description

The MAX9888 is a full-featured audio CODEC whose high performance and low power consumption make it ideal for portable applications.

Class D speaker amplifiers provide efficient amplification for two speakers. Low radiated emissions enable completely filterless operation. Integrated bypass switches optionally connect an external amplifier to the transducer when the Class D amplifiers are disabled.

DirectDrive® headphone amplifiers provide a true ground-referenced output, eliminating the need for large DC-blocking capacitors. 1.8V headphone operation ensures low power consumption. The device also includes a differential receiver amplifier.

Three differential analog microphone inputs are available as well as support for two PDM digital microphones. Integrated switches allow microphone signals to be routed out to external devices. Two flexible single-ended or differential line inputs may be connected to an FM radio or other sources.

Integrated FlexSound™ technology improves loud-speaker performance by optimizing the signal level and frequency response while limiting the maximum distortion and power at the output to prevent speaker damage. Automatic gain control (AGC) and a noise gate optimize the signal level of microphone input signals to make best use of the ADC dynamic range.

The device is fully specified over the -40°C to +85°C extended temperature range.

DirectDrive is a registered trademark and FlexSound is a trademark of Maxim Integrated Products, Inc.

Features

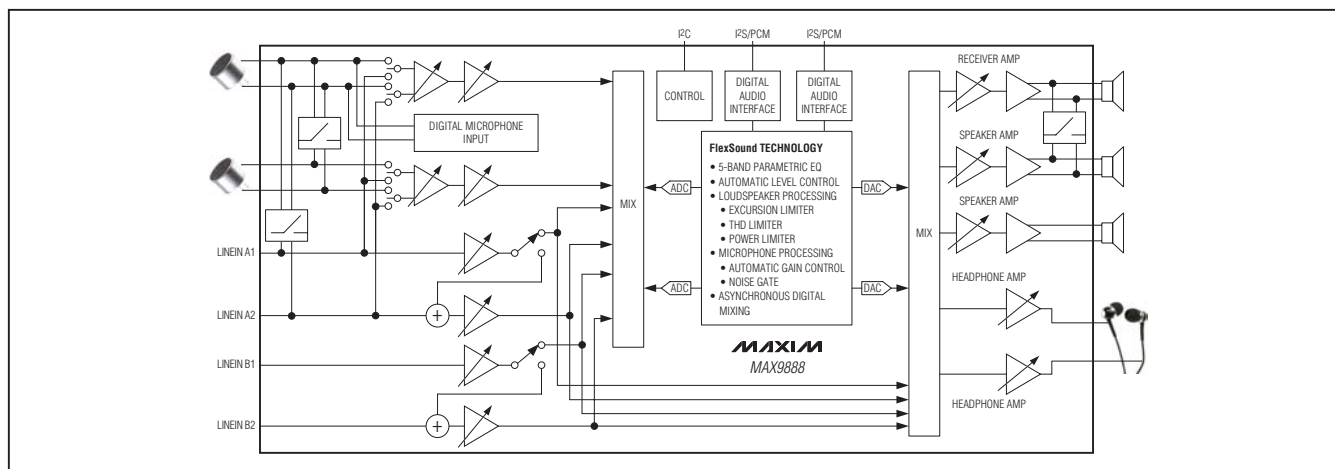
- ◆ 100dB DR Stereo DAC (8kHz < f_s < 96kHz)
- ◆ 91dB DR Stereo ADC (8kHz < f_s < 96kHz)
- ◆ Stereo Low EMI Class D Amplifiers
950mW/Channel (8Ω, V_{SPKVDD} = 4.2V)
- ◆ Stereo DirectDrive Headphone Amplifiers
- ◆ Differential Receiver Amplifier
- ◆ 2 Stereo Single-Ended/Mono Differential Line Inputs
- ◆ 3 Differential Microphone Inputs
- ◆ FlexSound Technology
 - 5-Band Parametric EQ
 - Automatic Level Control (ALC)
 - Excursion Limiter
 - Speaker Power Limiter
 - Speaker Distortion Limiter
 - Microphone Automatic Gain Control and Noise Gate
- ◆ Dual I²S/PCM/TDM Digital Audio Interfaces
- ◆ Asynchronous Digital Mixing
- ◆ Supports Master Clock Frequencies from 10MHz to 60MHz
- ◆ RF Immune Analog Inputs and Outputs
- ◆ Extensive Click-and-Pop Reduction Circuitry
- ◆ I²C Control Interface
- ◆ 63 WLP Package (3.80mm x 3.30mm, 0.4mm Pitch)

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX9888EWY+	-40°C to +85°C	63 WLP

+ Denotes lead(Pb)-free/RoHS-compliant package.

Simplified Block Diagram



Stereo Audio CODEC with FlexSound Technology

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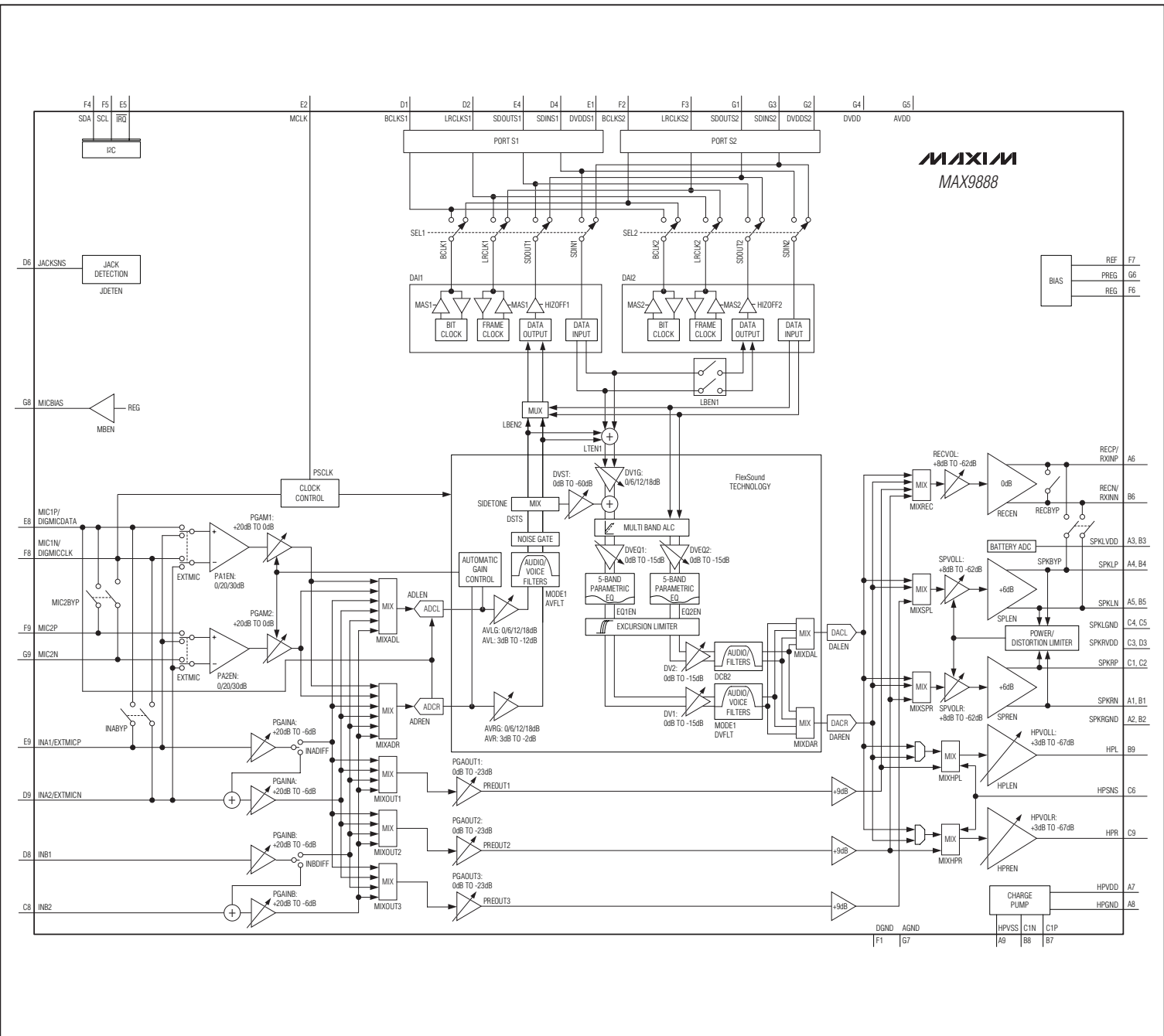
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Functional Diagram

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ABSOLUTE MAXIMUM RATINGS

(Voltages with respect to AGND.)

DVDD, AVDD, HPVDD	-0.3V to +2.2V
SPKLVD, SPKRVDD, DVDDS1, DVDDS2	-0.3V to +6.0V
DGND, HPGND, SPKLGND, SPKRGND	-0.1V to +0.1V
HPVSS	(HPGND - 2.2V) to (HPGND + 0.3V)
C1N	(HPVSS - 0.3V) to (HPGND + 0.3V)
C1P	(HPGND - 0.3V) to (HPVDD + 0.3V)
PREG	-0.3V to (AVDD + 0.3V)
REF, MICBIAS	-0.3V to (SPKLVDD + 0.3V)
MCLK, SDINS1, SDINS2, JACKSNS, SDA, SCL, \overline{TRQ}	-0.3V to +6.0V
LRCLKS1, BCLKS1, SDOUTS1	-0.3V to (DVDDS1 + 0.3V)
LRCLKS2, BCLKS2, SDOUTS2	-0.3V to (DVDDS2 + 0.3V)

REG, INA1, INA2, INB1, INB2, MIC1P/DIGMICDATA, MIC1N/DIGMICCLK, MIC2P, MIC2N	-0.3V to +2.2V
HPSNS	(HPGND - 0.3V) to (HPGND + 0.3V)
HPL, HPR	(HPVSS - 0.3V) to (HPVDD + 0.3V)
RECP, RECN	(SPKLGND - 0.3V) to (SPKLVDD + 0.3V)
SPKLP, SPKLN	(SPKLGND - 0.3V) to (SPKLVDD + 0.3V)
SPKRP, SPKRN	(SPKRGND - 0.3V) to (SPKRVDD + 0.3V)
Continuous Power Dissipation (TA = +70°C)	
63-Bump WLP (derate 25.6mW/°C above +70°C)	2.05W
Operating Temperature Range	-40°C to +85°C
Storage Temperature Range	-65°C to +150°C
Soldering Temperature (reflow)	+260°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.

ELECTRICAL CHARACTERISTICS

(VAVDD = VHPVDD = VDvDD = VDvDDS1 = VDvDDS2 = +1.8V, VSPKLVD = VSPKRVDD = 3.7V. Speaker loads (ZSPK) connected between SPK_P and SPK_N. Receiver load (RREC) connected between RECP and RECN. Headphone loads (RHP) connected from HPL or HPR to GND. RHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CPREG = CREG = 1μF, CC1N-C1P = 1μF, CHPVSS = 1μF. AVMICPRE_ = +20dB, AVMICPGA_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN_ = 0dB, AVPGAOUT_ = 0dB, AVHP_ = 0dB, AVREC = 0dB, AVSPK_ = 0dB, MCLK = 12.288MHz, LRCLK = 48kHz, MAS = 1. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	
POWER SUPPLY							
Supply Voltage Range		Guaranteed by PSRR	VSPKLVD, VSPKRVDD	2.8		5.5	V
			VDVDD, VAVDD, VHPVDD	1.65	1.8	2.0	
			VDVDDS1, DVDDS2	1.65		3.6	
Total Supply Current (Note 2)	IVDD	Full-duplex 8kHz mono, receiver output (Note 3)	Analog		6.37	10	mA
			Speaker		1.98	3.5	
			Digital		1.49	3	
		DAC playback 48kHz stereo, headphone outputs (Note 3)	Analog		2.71	4	
			Speaker		1.65	2.5	
			Digital		2.93	4.5	
		DAC playback 48kHz stereo, speaker outputs (Note 3)	Analog		1.85	3	
			Speaker		8.22	18	
			Digital		2.94	5	
		Full-duplex 48kHz stereo, microphone inputs, headphone outputs (Note 3)	Analog		12.75	18	
			Speaker		1.7	3	
			Digital		3.75	5.5	
Stereo line playback, IN_DIF = 0, INA1 to HPL, INA2 to HPR, VMCLK = 0V	Analog		5.11	7			
	Speaker		0.58	1			
	Digital		0.03	0.06			

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ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VHPVDD = VD VDD = VD VDD S1 = VD VDD S2 = +1.8V, VSPKL VDD = VSPKR VDD = 3.7V. Speaker loads (ZSPK) connected between SPK_P and SPK_N. Receiver load (RREC) connected between RECP and RECN. Headphone loads (RH P) connected from HPL or HPR to GND. RH P = ∞, RREC = ∞, ZSPK = ∞, CRE F = 2.2μF, CMICBIAS = CPREG = CRE G = 1μF, CC1N-C1P = 1μF, CHPVSS = 1μF. AVMICPRE_ = +20dB, AVMICPGA_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN_ = 0dB, AVPGAOUT_ = 0dB, AVHP_ = 0dB, AVREC = 0dB, AVSPK_ = 0dB, MCLK = 12.288MHz, LRCLK = 48kHz, MAS = 1. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Shutdown Supply Current (Note 2)		TA = +25°C	Analog	0.2	2	μA
			Speaker	0.1	1	
			Digital	1	5	
REF Voltage				2.5		V
PREG Voltage				1.6		V
REG Voltage				0.7		V
Shutdown to Full Operation		SLEW = 0		30		ms
		SLEW = 1		17		
MICROPHONE TO ADC PATH						
Dynamic Range (Note 4)	DR	fS = 8kHz, MODE = 0 (IIR voice), AVMICPRE_ = 0dB	75	88		dB
Total Harmonic Distortion + Noise	THD+N	VIN = 0.1Vp-p, MCLK = 12.288MHz, fS = 8kHz, f = 1kHz		-77	-65	dB
		AVMICPRE_ = 0dB, VIN = 1Vp-p, f = 1kHz		-82		
		AVMICPRE_ = +30dB, VIN = 32mVp-p, f = 1kHz		-71		
Common-Mode Rejection Ratio	CMRR	VIN = 100mVp-p, f = 217Hz		65		dB
Power-Supply Rejection Ratio	PSRR	VAVDD = 1.65V to 2.0V, input referred, MIC inputs floating	60	100		dB
		f = 217Hz, VRI PPLE = 100mVp-p, AVADC = 0dB, input referred		100		
		f = 1kHz, VRI PPLE = 100mVp-p, AVADC = 0dB, input referred		91		
		f = 10kHz, VRI PPLE = 100mVp-p, AVADC = 0dB, input referred		70		
Path Phase Delay		1kHz, 0dB input, highpass filter disabled measured from analog input to digital output	MODE = 0 (IIR voice) 8kHz	2.2		ms
			MODE = 0 (IIR voice) 16kHz	1.1		
			MODE = 1 (FIR audio) 8kHz	4.5		
			MODE = 1 (FIR audio) 48kHz	0.76		

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ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VHPVDD = VDVDD = VDVDDS1 = VDVDDS2 = +1.8V, VSPKLVDD = VSPKRVDD = 3.7V. Speaker loads (ZSPK) connected between SPK_P and SPK_N. Receiver load (RREC) connected between RECP and RECN. Headphone loads (RHP) connected from HPL or HPR to GND. RHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CPREG = CREG = 1μF, CC1N-C1P = 1μF, CHPVSS = 1μF. AVMICPRE_ = +20dB, AVMICPGA_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN_ = 0dB, AVPGAOUT_ = 0dB, AVHP_ = 0dB, AVREC = 0dB, AVSPK_ = 0dB, MCLK = 12.288MHz, LRCLK = 48kHz, MAS = 1. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	
MICROPHONE PREAMP							
Full-Scale Input		AVMICPRE_ = 0dB		1.05		V _{P-P}	
Preamplifier Gain	AVMICPRE_	(Note 5) PA1EN/PA2EN = 01		0		dB	
			PA1EN/PA2EN = 10	19.5	20		20.5
			PA1EN/PA2EN = 11	29.4	30		30.5
PGA Gain	AVMICPGA_	(Note 5) PGAM1/PGAM2 = 0x00		19.5	20	20.5	dB
			PGAM1/PGAM2 = 0x14		0		
MIC Input Resistance	R _{IN_MIC}	All gain settings, measured at MIC1P/MIC1N/ MIC2P/MIC2N	30	50		kΩ	
MICROPHONE BIAS							
MICBIAS Output Voltage	VMICBIAS	I _{LOAD} = 1mA	2.14	2.2	2.25	V	
Load Regulation		I _{LOAD} = 1mA to 2mA		0.5	11	mV	
Line Regulation		VSPKLVDD = 2.8V to 5.5V		100		μV	
Ripple Rejection		f = 217Hz, V _{RIPPLE} (SPKLVDD) = 100mV _{P-P}		92		dB	
		f = 10kHz, V _{RIPPLE} (SPKLVDD) = 100mV _{P-P}		83			
Noise Voltage		A-weighted, f = 20Hz to 20kHz		3.8		μV _{RMS}	
		P-weighted, f = 20Hz to 4kHz		2.1			
		f = 1kHz		33		nV/√Hz	
MICROPHONE BYPASS SWITCH							
On-Resistance	R _{ON}	I _{MIC1_} = 100mA, INABYP = MIC2BYP = 1, V _{MIC2_} = V _{INA_} = (0V, VAVDD)		3.5	20	Ω	
Total Harmonic Distortion + Noise	THD+N	V _{IN} = 2V _{P-P} , V _{CM} = 0.9V, R _L = 10kΩ, f = 1kHz, INABYP = MIC2BYP = 1		-80		dB	
Off-Isolation		V _{IN} = 2V _{P-P} , V _{CM} = 0.9V, R _L = 10kΩ, f = 1kHz		60		dB	
Off-Leakage Current		V _{MIC1_} = (0V, VAVDD), V _{MIC2_} /V _{INA_} = (VAVDD, 0V)	-2.5		+2.5	μA	
LINE INPUT TO ADC PATH							
Dynamic Range (Note 4)	DR	f _S = 48kHz, MCLK = 12.288MHz, MODE = 1 (FIR audio)		91		dB	
Total Harmonic Distortion + Noise	THD+N	V _{IN} = 1V _{P-P} , f = 1kHz		-77		dB	
Gain Error		DC accuracy		1	5	%	

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ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VHPVDD = VD VDD = VD VDD S1 = VD VDD S2 = +1.8V, VSPKLVDD = VSPKR VDD = 3.7V. Speaker loads (ZSPK) connected between SPK_P and SPK_N. Receiver load (RREC) connected between RECP and RECN. Headphone loads (RHP) connected from HPL or HPR to GND. RHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CPREG = CREG = 1μF, CC1N-C1P = 1μF, CHPVSS = 1μF. AVMICPRE_ = +20dB, AVMICPGA_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN_ = 0dB, AVPGAOUT_ = 0dB, AVHP_ = 0dB, AVREC = 0dB, AVSPK_ = 0dB, MCLK = 12.288MHz, LRCLK = 48kHz, MAS = 1. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
LINE INPUT PREAMP							
Full-Scale Input	VIN	AVPGAIN_ = 0dB		1			VP-P
		AVPGAIN_ = -6dB		1.4			
Level Adjust Gain	AVPGAIN_	PGAINA/PGAINB = 0x0		19	20	21	dB
		PGAINA/PGAINB = 0x1		13	14	15	
		PGAINA/PGAINB = 0x2	(Note 5)	2	3	4	
		PGAINA/PGAINB = 0x3	TA = +25°C	0			
		PGAINA/PGAINB = 0x4		-4	-3	-2	
		PGAINA/PGAINB = 0x5, 0x6, 0x7		-7	-6	-5	
Input Resistance	RIN	AVPGAIN_ = +20dB		14.6	21	27.4	kΩ
		AVPGAIN_ = +14dB		20			
		AVPGAIN_ = +3dB		20			
		AVPGAIN_ = 0dB		7.3	10	13.7	
		AVPGAIN_ = -3dB		20			
		AVPGAIN_ = -6dB		20			
Feedback Resistance	RIN_FB	INAEXT/INBEXT = 1	TA = +25°C	18.5	20	21.5	kΩ
			TA = TMIN to TMAX	17.5			
ADC LEVEL CONTROL							
ADC Level Adjust Range	AVADCLVL	AVL/AVR = 0xF to 0x0 (Note 5)		-12		+3	dB
ADC Level Adjust Step Size					1		dB
ADC Gain Adjust Range	AVADCGAIN	AVLG/AVRG = 00 to 11 (Note 5)		0		18	dB
ADC Gain Adjust Step Size					6		dB
ADC DIGITAL FILTERS							
VOICE MODE IIR LOWPASS FILTER (MODE1 = 0)							
Passband Cutoff	fPLP	Ripple limit cutoff		0.441 x fs			Hz
		-3dB cutoff		0.449 x fs			
Passband Ripple		f < fPLP		-0.1		+0.1	dB
Stopband Cutoff	fSLP					0.47 x fs	Hz
Stopband Attenuation (Note 6)		f > fSLP		74			dB

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ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VHPVDD = VD VDD = VD VDD S1 = VD VDD S2 = +1.8V, VSPKL VDD = VSPKR VDD = 3.7V. Speaker loads (ZSPK) connected between SPK_P and SPK_N. Receiver load (RREC) connected between RECP and REC N. Headphone loads (RHP) connected from HPL or HPR to GND. RHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CPREG = CREG = 1μF, CC1N-C1P = 1μF, CHPVSS = 1μF. AVMICPRE_ = +20dB, AVMICPGA_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN_ = 0dB, AVPGAOUT_ = 0dB, AVHP_ = 0dB, AVREC = 0dB, AVSPK_ = 0dB, MCLK = 12.288MHz, LRCLK = 48kHz, MAS = 1. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
VOICE MODE IIR HIGHPASS FILTER (MODE1 = 0)						
Passband Cutoff (-3dB from Peak)	f _{AHPPB}	AVFLT = 0x1 (elliptical tuned for f _s = 16kHz + 217Hz notch)			0.0161 x f _s	Hz
		AVFLT = 0x2 (500Hz Butterworth tuned for f _s = 16kHz)			0.0319 x f _s	
		AVFLT = 0x3 (elliptical tuned for f _s = 8kHz + 217Hz notch)			0.0321 x f _s	
		AVFLT = 0x4 (500Hz Butterworth tuned for f _s = 8kHz)			0.0632 x f _s	
		AVFLT = 0x5 (f _s /240 Butterworth)			0.0043 x f _s	
Stopband Cutoff (-30dB from Peak)	f _{AHPSB}	AVFLT = 0x1 (elliptical tuned for f _s = 16kHz + 217Hz notch)		0.0139 x f _s		Hz
		AVFLT = 0x2 (500Hz Butterworth tuned for f _s = 16kHz)		0.0156 x f _s		
		AVFLT = 0x3 (elliptical tuned for f _s = 8kHz + 217Hz notch)		0.0279 x f _s		
		AVFLT = 0x4 (500Hz Butterworth tuned for f _s = 8kHz)		0.0312 x f _s		
		AVFLT = 0x5 (f _s /240 Butterworth)		0.002 x f _s		
DC Attenuation	DCATTEN	AVFLT ≠ 000		90		dB
STEREO AUDIO MODE FIR LOWPASS FILTER (MODE1 = 1, DHF1 = 0, LRCLK < 50kHz)						
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 (Note 6)		f < f _{SLP}	60			dB
ADC STEREO AUDIO MODE FIR LOWPASS FILTER (MODE1 = 1, DHF1 = 1, LRCLK > 50kHz)						
Passband Cutoff	f _{PLP}	Ripple limit cutoff		0.208 x f _s		Hz
		-3dB cutoff		0.28 x f _s		

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ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VHPVDD = VD VDD = VD VDD S1 = VD VDD S2 = +1.8V, VSPKLVDD = VSPKRVDD = 3.7V. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. Receiver load (R_{REC}) connected between RECP and RECN. Headphone loads (R_{HP}) connected from HPL or HPR to GND. R_{HP} = ∞, R_{REC} = ∞, Z_{SPK} = ∞, C_{REF} = 2.2μF, C_{MICBIAS} = C_{PREG} = C_{REG} = 1μF, C_{C1N-C1P} = 1μF, C_{HPVSS} = 1μF. AV_{MICPRE_} = +20dB, AV_{MICPGA_} = 0dB, AV_{DACATTN} = 0dB, AV_{DACGAIN} = 0dB, AV_{ADCLVL} = 0dB, AV_{ADCGAIN} = 0dB, AV_{PGAIN_} = 0dB, AV_{PGAOUT_} = 0dB, AV_{HP_} = 0dB, AV_{REC} = 0dB, AV_{SPK_} = 0dB, MCLK = 12.288MHz, LRCLK = 48kHz, MAS = 1. T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Passband Ripple		f < f _{PLP}	-0.1		+0.1	dB
Stopband Cutoff	f _{SLP}				0.417 x f _s	Hz
Stopband Attenuation		f < f _{SLP}	60			dB
ADC STEREO AUDIO MODE DC-BLOCKING HIGHPASS FILTER (MODE1 = 1)						
Passband Cutoff (-3dB from Peak)	f _{AHPPB}	AVFLT ≠ 000			0.000125 x f _s	Hz
DC Attenuation	DC _{Atten}	AVFLT ≠ 000		90		dB
MICROPHONE AUTOMATIC GAIN CONTROL						
AGC Hold Duration		AGCHLD = 01		50		ms
		AGCHLD = 11		400		
AGC Attack Time		AGCATK = 00		2		ms
		AGCATK = 11		123		
AGC Release Time		AGCRLS = 000		0.078		s
		AGCRLS = 111		10		
AGC Threshold Level		AGCTH = 0x0 to 0xF	-3		+18	dB
AGC Threshold Step Size				1		dB
AGC Gain		(Note 5)	0		20	dB
ADC NOISE GATE						
NG Threshold Level		ANTH = 0x3 to 0xF, referred to 0dBFS	-64		-16	dB
NG Attenuation		(Note 5)	0		12	dB
ADC-TO-DAC DIGITAL SIDETONE (MODE = 0)						
Sidetone Gain Adjust Range	AVSTGA	DVST = 0x01		-0.5		dB
		DVST = 0x1F		-60.5		
Sidetone Gain Adjust Step Size				2		dB
Sidetone Path Phase Delay		1kHz, 0dB input, highpass filter disabled	8kHz		2.2	ms
			16kHz		1.1	
ADC-TO-DAC DIGITAL LOOP-THROUGH PATH						
Dynamic Range (Note 4)	DR	f _s = 48kHz, MCLK = 12.288MHz, MODE = 1 (FIR audio)		89		dB
Total Harmonic Distortion	THD	f = 1kHz, f _s = 48kHz, MCLK = 12.288MHz, MODE = 1 (FIR audio)		-71	-66	dB
DAC LEVEL CONTROL						
DAC Attenuation Range	AV _{DACATTN}	DV1DV2 = 0xF to 0x0 (Note 5)	-15		0	dB
DAC Attenuation Step Size				1		dB
DAC Gain Adjust Range	AV _{DACGAIN}	DV1G = 00 to 11 (Note 5)	0		18	dB
DAC Gain Adjust Step Size				6		dB

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ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VHPVDD = VD VDD = VD VDD S1 = VD VDD S2 = +1.8V, VSPKLVDD = VSPKRVDD = 3.7V. Speaker loads (ZSPK) connected between SPK_P and SPK_N. Receiver load (RREC) connected between RECP and RECN. Headphone loads (RH P) connected from HPL or HPR to GND. RH P = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CPREG = CREG = 1μF, CC1N-C1P = 1μF, CHPVSS = 1μF. AVMICPRE_ = +20dB, AVMICPGA_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN_ = 0dB, AVPGAOUT_ = 0dB, AVHP_ = 0dB, AVREC = 0dB, AVSPK_ = 0dB, MCLK = 12.288MHz, LRCLK = 48kHz, MAS = 1. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
DAC DIGITAL FILTERS						
VOICE MODE IIR LOWPASS FILTER (MODE1 = 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 6)		f > f _{SLP}	75			dB
VOICE MODE IIR HIGHPASS FILTER (MODE1 = 0)						
Passband Cutoff (-3dB from Peak)	f _{DHPPB}	DVFLT = 0x1 (elliptical tuned for f _s = 16kHz + 217Hz notch)			0.0161 x f _s	Hz
		DVFLT = 0x2 (500Hz Butterworth tuned for f _s = 16kHz)			0.0312 x f _s	
		DVFLT = 0x3 (elliptical tuned for f _s = 8kHz + 217Hz notch)			0.0321 x f _s	
		DVFLT = 0x4 (500Hz Butterworth tuned for f _s = 8kHz)			0.0625 x f _s	
		DVFLT = 0x5 (f _s /240 Butterworth)			0.0042 x f _s	
Stopband Cutoff (-30dB from Peak)	f _{DHPSB}	DVFLT = 0x1 (elliptical tuned for f _s = 16kHz + 217Hz notch)			0.0139 x f _s	Hz
		DVFLT = 0x2 (500Hz Butterworth tuned for f _s = 16kHz)			0.0156 x f _s	
		DVFLT = 0x3 (elliptical tuned for f _s = 8kHz + 217Hz notch)			0.0279 x f _s	
		DVFLT = 0x4 (500Hz Butterworth tuned for f _s = 8kHz)			0.0312 x f _s	
		DVFLT = 0x5 (f _s /240 Butterworth)			0.002 x f _s	
DC Attenuation	DCATTEN	DVFLT ≠ 000		85		dB

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ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VHPVDD = VD VDD = VD VDD S1 = VD VDD S2 = +1.8V, VSPKL VDD = VSPKR VDD = 3.7V. Speaker loads (ZSPK) connected between SPK_P and SPK_N. Receiver load (RREC) connected between RECP and RECN. Headphone loads (RHP) connected from HPL or HPR to GND. RHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CPREG = CREG = 1μF, CC1N-C1P = 1μF, CHPVSS = 1μF. AVMICPRE_ = +20dB, AVMICPGA_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN_ = 0dB, AVPGAOUT_ = 0dB, AVHP_ = 0dB, AVREC = 0dB, AVSPK_ = 0dB, MCLK = 12.288MHz, LRCLK = 48kHz, MAS = 1. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
STEREO AUDIO MODE FIR LOWPASS FILTER (MODE1 = 1, DHF1/DHF2 = 0, LRCLK < 50kHz)						
Passband Cutoff	f _{PLP}	Ripple limit cutoff	0.43			Hz
		-3dB cutoff	0.47			
		-6.02dB cutoff	0.5			
Passband Ripple		f < f _{PLP}	-0.1		+0.1	dB
Stopband Cutoff	f _{SLP}				0.58	Hz
Stopband Attenuation (Note 6)		f > f _{SLP}	60			dB
STEREO AUDIO MODE FIR LOWPASS FILTER (MODE1 = 1, DHF1/DHF2 = 1 for LRCLK > 50kHz)						
Passband Cutoff	f _{PLP}	Ripple limit cutoff	0.24			Hz
		-3dB cutoff	0.31			
Passband Ripple		f < f _{PLP}	-0.1		+0.1	dB
Stopband Cutoff	f _{SLP}				0.477	Hz
Stopband Attenuation (Note 6)		f < f _{SLP}	60			dB
STEREO AUDIO MODE DC-BLOCKING HIGHPASS FILTER						
Passband Cutoff (-3dB from Peak)	f _{DHPPB}	DVFLT ≠ 000 (DAI1), DCB2 = 1 (DAI2)			0.000104	Hz
DC Attenuation	DCATTEN	DVFLT ≠ 000 (DAI1), DCB2 = 1 (DAI2)		90		dB
AUTOMATIC LEVEL CONTROL						
Dual Band Lowpass Corner Frequency		ALCMB = 1		5		kHz
Dual Band Highpass Corner Frequency		ALCMB = 1		5		kHz
Gain Range			0		12	dB
Low Signal Threshold		ALCTH = 111 to 001	-48		-12	dBFS
Release Time		ALCRLS = 101		0.25		s
		ALCRLS = 000		8		
PARAMETRIC EQUALIZER						
Number of Bands				5		Bands
Per Band Gain Range			-12		+12	dB
Preattenuator Gain Range		(Note 5)	-15		0	dB
Preattenuator Step Size				1		dB

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ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VHPVDD = VD VDD = VD VDD S1 = VD VDD S2 = +1.8V, VSPKLVDD = VSPKR VDD = 3.7V. Speaker loads (ZSPK) connected between SPK_P and SPK_N. Receiver load (RREC) connected between RECP and RECN. Headphone loads (RHP) connected from HPL or HPR to GND. RHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CPREG = CREG = 1μF, CC1N-C1P = 1μF, CHPVSS = 1μF. AVMICPRE_ = +20dB, AVMICPGA_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN_ = 0dB, AVPGAOUT_ = 0dB, AVHP_ = 0dB, AVREC = 0dB, AVSPK_ = 0dB, MCLK = 12.288MHz, LRCLK = 48kHz, MAS = 1. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
DAC-TO-RECEIVER AMPLIFIER PATH							
Dynamic Range (Note 4)	DR	fS = 48kHz, MCLK = 12.288MHz, f = 1kHz			96		dB
Total Harmonic Distortion + Noise	THD+N	f = 1kHz, POUT = 25mW, RREC = 32Ω			-70	-63	dB
Click and Pop Level	KCP	Peak voltage, A-weighted, 32 samples per second, AVREC = 0dB	Into shutdown		-70		dBV
			Out of shutdown		-73		
PREOUTPUT MIXERS							
Level Adjust Gain	AVPGAOUT_	(Note 5)	PGAOUTA/PGAOUTB/ PGAOUTC = 0x0		0		dB
			PGAOUTA/PGAOUTB/ PGAOUTC = 0xC		-25	-23.4	
Level Adjust Step Size					2		dB
Mute Attenuation			f = 1kHz		85		dB
LINE INPUT-TO-RECEIVER AMPLIFIER PATH							
Dynamic Range (Note 4)	DR	Referenced to full-scale output level			92		dB
Total Harmonic Distortion + Noise	THD+N				-70		dB
Power-Supply Rejection Ratio	PSRR	VSPKLVDD = 2.8V to 5.5V		54	89		dB
		f = 217Hz, VRIPPLE = 100mVp-p			-63		
		f = 1kHz, VRIPPLE = 100mVp-p			-63		
		f = 10kHz, VRIPPLE = 100mVp-p			-65		
Click-and-Pop Level	KCP	Peak voltage, A-weighted, 32 samples per second, AVREC = 0dB	Into shutdown		-57		dBV
			Out of shutdown		-55		
RECEIVER AMPLIFIER							
Output Power	POUT	RREC = 32Ω, f = 1kHz, THD = 1%			100		mW
Full-Scale Output		(Note 7)			1		V _{RMS}
Volume Control	AVREC	(Note 5)	RECVOL = 0x00	-65	-62	-58	dB
			RECVOL = 0x1F	+7.5	+8	+8.5	
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		95		dB
Output Offset Voltage	VOS	AVREC = -62dB	TA = +25°C		±0.13	±1	mV
Capacitive Drive Capability		No sustained oscillations	RREC = 32Ω		500		pF
			RREC = ∞		100		

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ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VHPVDD = VDVDD = VDVDDSD1 = VDVDDSD2 = +1.8V, VSPKLVDD = VSPKRVD = 3.7V. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. Receiver load (R_{REC}) connected between RECP and RECN. Headphone loads (R_{HP}) connected from HPL or HPR to GND. R_{HP} = ∞, R_{REC} = ∞, Z_{SPK} = ∞, C_{REF} = 2.2μF, C_{MICBIAS} = C_{PREG} = C_{REG} = 1μF, C_{C1N-C1P} = 1μF, C_{HPVSS} = 1μF. AV_{MICPRE_} = +20dB, AV_{MICPGA_} = 0dB, AV_{DACATTN} = 0dB, AV_{DACGAIN} = 0dB, AV_{ADCLVL} = 0dB, AV_{ADCGAIN} = 0dB, AV_{PGAIN_} = 0dB, AV_{PGAOUT_} = 0dB, AV_{HP_} = 0dB, AV_{REC} = 0dB, AV_{SPK_} = 0dB, MCLK = 12.288MHz, LRCLK = 48kHz, MAS = 1. T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
DAC-TO-SPEAKER AMPLIFIER PATH							
Total Harmonic Distortion + Noise	THD+N	f = 1kHz, P _{OUT} = 250mW, Z _{SPK} = 8Ω + 68μH			-71		dB
Crosstalk		SPKL to SPKR and SPKR to SPKL, P _{OUT} = 640mW, f = 1kHz			-75		dB
Output Noise		A-weighted			43		μVRMS
Click-and-Pop Level	KCP	Peak voltage, A-weighted, 32 samples per second, AV _{SPK_} = 0dB	Into shutdown		-65		dBV
			Out of shutdown		-65		
LINE INPUT-TO-SPEAKER AMPLIFIER PATH							
Total Harmonic Distortion + Noise	THD+N	f = 1kHz, P _{OUT} = 200mW, Z _{SPK} = 8Ω + 68μH			-66		dB
Output Noise		A-weighted			56		μVRMS
Power-Supply Rejection Ratio	PSRR	V _{SPKLVDD} = V _{RIPPLE} = 2.8V to 5.5V		43	60		dB
		f = 217Hz, V _{RIPPLE} = 100mV			75		
		f = 1kHz, V _{RIPPLE} = 100mV			73		
		f = 10kHz, V _{RIPPLE} = 100mV			50		
Click-and-Pop Level	KCP	Peak voltage, A-weighted, 32 samples per second, AV _{SPK_} = 0dB	Into shutdown		-48		dBV
			Out of shutdown		-50		
SPEAKER AMPLIFIER							
Output Power	P _{OUT}	f = 1kHz, THD = 1%, Z _{SPK} = 8Ω + 68μH	V _{SPKLVDD} = V _{SPKRVD} = 5.0V		1370		mW
			V _{SPKLVDD} = V _{SPKRVD} = 4.2V		954		
			V _{SPKLVDD} = V _{SPKRVD} = 3.7V		733		
			V _{SPKLVDD} = V _{SPKRVD} = 3.2V		544		
Full-Scale Output		(Note 7)			2		V _{RMS}
Volume Control (Note 5)	AV _{SPK_}	SPVOLL/SPVOLR = 0x00		-69	-64	-59	dB
		SPVOLL/SPVOLR = 0x1F		+7.5	+8	+8.5	
Volume Control Step Size		+8dB to +6dB			0.5		dB
		+6dB to +0dB			1		
		0dB to -14dB			2		
		-14dB to -38dB			3		
		-38dB to -64dB			4		

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ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VHPVDD = VD VDD = VD VDD S1 = VD VDD S2 = +1.8V, VSPKLVDD = VSPKRVDD = 3.7V. Speaker loads (ZSPK) connected between SPK_P and SPK_N. Receiver load (RREC) connected between RECP and RECN. Headphone loads (RHP) connected from HPL or HPR to GND. RHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CPREG = CREG = 1μF, CC1N-C1P = 1μF, CHPVSS = 1μF. AVMICPRE_ = +20dB, AVMICPGA_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN_ = 0dB, AVPGAOUT_ = 0dB, AVHP_ = 0dB, AVREC = 0dB, AVSPK_ = 0dB, MCLK = 12.288MHz, LRCLK = 48kHz, MAS = 1. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Mute Attenuation		f = 1kHz			86		dB
Output Offset Voltage	VOS	AVSPK_ = -64dB, TA = +25°C			±0.25	±1.25	mV
EXCURSION LIMITER							
Upper-Corner Frequency Range		DHPUCF = 001 to 100		400		1000	Hz
Lower-Corner Frequency		DHPLCF = 01 to 10			400		Hz
Biquad Minimum Corner Frequency		DHPUCF = 000 (fixed mode)			100		Hz
		DHPUCF = 001			200		
		DHPUCF = 010			300		
		DHPUCF = 011			400		
		DHPUCF = 100			500		
Threshold Voltage		ZSPK = 8Ω + 68μH, VSPKLVDD = VSPKRVDD = 5.5V, AVSPK_ = +8dB	DHPH = 000		0.34		Vp
			DHPH = 111		4.95		
Release Time		ALCRLS = 101			0.25		s
		ALCRLS = 000			4		
POWER LIMITER							
Attenuation					-64		dB
Threshold		ZSPK = 8Ω + 68μH, VSPKLVDD = VSPKRVDD = 5.5V, AVSPK_ = +8dB	PWRTH = 0x1		0.05		W
			PWRTH = 0xF		1.80		
Time Constant 1	tPWR1	PWRT1 = 0x1			0.5		s
		PWRT1 = 0xF			8.7		
Time Constant 2	tPWR2	PWRT2 = 0x1 to 0xF			0.5		min
		PWRT2 = 0xF			8.7		
Weighting Factor	kPWR	PWRK = 000 to 111		12.5		100	%
DISTORTION LIMITER							
Distortion Limit		THDCLP = 0x1			< 1		%
		THDCLP = 0xF			24		
Release Time Constant		THDT1 = 000			0.76		s
		THDT1 = 111			6.2		
DAC-TO-HEADPHONE AMPLIFIER PATH							
Dynamic Range (Note 4)	DR	fS = 48kHz, MCLK = 12.288MHz	Master or slave mode		100		dB
			Slave mode		94		
Total Harmonic Distortion + Noise	THD+N	fS = 48kHz, MCLK = 12.288MHz, f = 1kHz, POUT = 20mW	RHP = 16Ω		-71	-64	dB
			RHP = 32Ω		-75		
			fS = 48kHz, MCLK = 12.288MHz, f = 1kHz, VOUT = 1VRMS, RHP = 10kΩ			-79	

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ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VHPVDD = VDVDD = VDVDDS1 = VDVDDS2 = +1.8V, VSPKLVDD = VSPKRVD = 3.7V. Speaker loads (ZSPK) connected between SPK_P and SPK_N. Receiver load (RREC) connected between RECP and RECN. Headphone loads (RHP) connected from HPL or HPR to GND. RHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CPREG = CREG = 1μF, CC1N-C1P = 1μF, CHPVSS = 1μF. AVMICPRE_ = +20dB, AVMICPGA_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN_ = 0dB, AVPGAOUT_ = 0dB, AVHP_ = 0dB, AVREC = 0dB, AVSPK_ = 0dB, MCLK = 12.288MHz, LRCLK = 48kHz, MAS = 1. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Crosstalk		f = 1kHz, Input = -1dBFS, RHP = 10kΩ			-82		dB
		HPL to HPR and HPR to HPL, POUT = 5mW, f = 1kHz, RHP = 32Ω			-82		dB
Power-Supply Rejection Ratio	PSRR	VAVDD = VHPVDD = 1.65V to 2.0V		60	84		dB
		f = 217Hz, VRIPPLE = 100mV, AVVOL = 0dB			92		
		f = 1kHz, VRIPPLE = 100mV, AVVOL = 0dB			91		
		f = 10kHz, VRIPPLE = 100mV, AVVOL = 0dB			57		
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			%
Channel Gain Mismatch				0.5			%
Click-and-Pop Level	KCP	Peak voltage, A-weighted, 32 samples per second, AVHP_ = 0dB	Into shutdown		-66		dBV
			Out of shutdown		-67		
LINE INPUT-TO-HEADPHONE AMPLIFIER PATH							
Total Harmonic Distortion + Noise	THD+N	VIN = 1VP-P, f = 1kHz, RHP = 32Ω			-70		dB
Dynamic Range (Note 4)	DR				91		dB
Power-Supply Rejection Ratio	PSRR	VAVDD = VHPVDD = 1.65V to 2.0V		42	66		dB
		f = 217Hz, VRIPPLE = 100mVP-P			62		
		f = 1kHz, VRIPPLE = 100mVP-P			57		
		f = 10kHz, VRIPPLE = 100mVP-P			41		
Click and Pop Level	KCP	Peak voltage, A-weighted, 32 samples per second, AVHP_ = 0dB	Into shutdown		-62		dBV
			Out of shutdown		-60		
HEADPHONE AMPLIFIER							
Output Power	POUT	f = 1kHz, THD = 1%	RHP = 32Ω		32		mW
			RHP = 16Ω		40		
Full-Scale Output		(Note 7)			1		V _{RMS}
Volume Control	AVHP_	TA = +25°C (Note 5)	HPVOL_ = 0x00	-71	-67	-66	dB
			HPVOL_ = 0x1F	2.4	3	3.5	

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ELECTRICAL CHARACTERISTICS (continued)

($V_{AVDD} = V_{HPVDD} = V_{DVDD} = V_{DVDD1} = V_{DVDD2} = +1.8V$, $V_{SPKLVD} = V_{SPKRVDD} = 3.7V$. Speaker loads (Z_{SPK}) connected between SPK_P and SPK_N. Receiver load (R_{REC}) connected between RECP and RECN. Headphone loads (R_{HP}) connected from HPL or HPR to GND. $R_{HP} = \infty$, $R_{REC} = \infty$, $Z_{SPK} = \infty$, $C_{REF} = 2.2\mu F$, $C_{MICBIAS} = C_{PREG} = C_{REG} = 1\mu F$, $C_{C1N-C1P} = 1\mu F$, $C_{HPVSS} = 1\mu F$. $AV_{MICPRE_} = +20dB$, $AV_{MICPGA_} = 0dB$, $AV_{DACATTN} = 0dB$, $AV_{DACGAIN} = 0dB$, $AV_{ADCLVL} = 0dB$, $AV_{ADCGAIN} = 0dB$, $AV_{PGAIN_} = 0dB$, $AV_{PGAOUT_} = 0dB$, $AV_{HP_} = 0dB$, $AV_{REC} = 0dB$, $AV_{SPK_} = 0dB$, $MCLK = 12.288MHz$, $LRCLK = 48kHz$, $MAS = 1$. $T_A = T_{MIN}$ to T_{MAX} , unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
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		82		dB	
Output Offset Voltage	VOS	AV _{HP} _ = -67dB	T _A = +25°C	±0.2	±1	mV	
			T _A = T _{MIN} to T _{MAX}		±2		
Capacitive Drive Capability		No sustained oscillations	R _{HP} = 32Ω	500		pF	
			R _{HP} = ∞	100			
Charge Pump Oscillator Frequency	f _{CP}			300	667	900	kHz
		Slow mode		74			
SPEAKER BYPASS SWITCH							
On-Resistance	RON	I _{SPKL} _ = 100mA, SPKBYP = 1, V _{RXIN} _ = [0V, V _{SPKLVD}]		2.8	4.5	Ω	
Total Harmonic Distortion + Noise	THD+N	V _{IN} = 2V _{P-P} , V _{CM} = V _{SPKLVD} /2, Z _{SPK} = 8Ω + 68μH, f = 1kHz, SPKBYP = 1	R _S = 10Ω	-77		dB	
			R _S = 0Ω	-60			
Off-Isolation		V _{IN} = 2V _{P-P} , V _{CM} = V _{SPKLVD} /2, Z _L = 8Ω + 68μH, f = 1kHz		96		dB	
Off-Leakage Current		V _{RXIN} _ = [0V, V _{SPKLVD}], V _{SPKL} _ = [V _{SPKLVD} , 0V]		-1	+1	μA	
RECEIVER BYPASS SWITCH							
On-Resistance	RON	I _{RECP} = 100mA, RECBYP = 1, V _{RECN} = [0V, V _{SPKLVD}]		1.2	2	Ω	
Total Harmonic Distortion + Noise	THD+N	V _{IN} = 2V _{P-P} , V _{CM} = V _{SPKLVD} /2, R _L = 32Ω, f = 1kHz, RECBYP = 1		-66		%	
Off-Isolation		V _{IN} = 2V _{P-P} , V _{CM} = V _{SPKLVD} /2, R _L = 32Ω, f = 1kHz		80		dB	
Off-Leakage Current		V _{RECP} = [0V, V _{SPKLVD}], V _{RECN} = [V _{SPKLVD} , 0V]		-15	+15	μA	

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ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VHPVDD = VD VDD = VD VDD S1 = VD VDD S2 = +1.8V, VSPKL VDD = VSPKR VDD = 3.7V. Speaker loads (ZSPK) connected between SPK_P and SPK_N. Receiver load (RREC) connected between RECP and RECN. Headphone loads (RHP) connected from HPL or HPR to GND. RHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CPREG = CREG = 1μF, CC1N-C1P = 1μF, CHPVSS = 1μF. AVMICPRE_ = +20dB, AVMICPGA_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN_ = 0dB, AVPGAOUT_ = 0dB, AVHP_ = 0dB, AVREC = 0dB, AVSPK_ = 0dB, MCLK = 12.288MHz, LRCLK = 48kHz, MAS = 1. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
JACK DETECTION						
JACKSNS High Threshold	VTH1	MICBIAS enabled	0.92 x	0.95 x	0.98 x	V
		MICBIAS disabled	VMICBIAS	VMICBIAS	VMICBIAS	
JACKSNS Low Threshold	VTH2	MICBIAS enabled	0.92 x	0.95 x	0.98 x	V
		MICBIAS disabled	VSPKL VDD	VSPKL VDD	VSPKL VDD	
JACKSNS Sense Voltage	VSENSE	MICBIAS disabled	0.06 x 0.10 x 0.17 x			V
JACKSNS Sense Resistance	RSENSE	MICBIAS disabled, JDWK = 0	1.7	2.4	2.9	kΩ
JACKSNS Weak Pullup Current	IWPU	MICBIAS disabled, JDWK = 1	2	5	9.5	μA
JACKSNS Deglitch Period	tGLITCH	JDEB = 00	25			ms
		JDEB = 11	200			
BATTERY ADC						
Input Voltage Range			2.8		5.5	V
LSB Size				0.1		V

DIGITAL INPUT/OUTPUT CHARACTERISTICS

(VAVDD = VHPVDD = VD VDD = VD VDD S1 = VD VDD S2 = 1.65V to 2.0V, VSPKL VDD = VSPKR VDD = 3.7V, TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
MCLK						
Input High Voltage	VIH		1.2			V
Input Low Voltage	VIL				0.6	V
Input Leakage Current	I IH, I IL	VD VDD = 2.0V, VIN = 0V, 5.5V, TA = +25°C	-1		+1	μA
Input Capacitance				10		pF
SDINS1, BCLKS1, LRCLKS1—INPUT						
Input High Voltage	VIH		0.7 x			V
Input Low Voltage	VIL				0.29 x	V
Input Hysteresis				200		mV
Input Leakage Current	I IH, I IL	VD VDD S1 = 3.6V, VIN = 0V, 3.6V; TA = +25°C	-1		+1	μA
Input Capacitance				10		pF

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DIGITAL INPUT/OUTPUT CHARACTERISTICS (continued)

($V_{AVDD} = V_{HPVDD} = V_{DVDD} = V_{DVDDS1} = V_{DVDDS2} = 1.65V$ to $2.0V$, $V_{SPKLVDD} = V_{SPKRVDD} = 3.7V$, $T_A = T_{MIN}$ to T_{MAX} , unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
BCLKS1, LRCLKS1, SDOUTS1—OUTPUT						
Output Low Voltage	V_{OL}	$V_{DVDDS1} = 1.65V$, $I_{OL} = 3mA$			0.4	V
Output High Voltage	V_{OH}	$V_{DVDDS1} = 1.65V$, $I_{OH} = 3mA$	$DVDDS1$ - 0.4			V
Input Leakage Current	I_{IH} , I_{IL}	$V_{DVDD} = 2.0V$, $V_{IN} = 0V$, $5.5V$; $T_A = +25^\circ C$, high-impedance state	-1		+1	μA
SDINS2, BCLKS2, LRCLKS2—INPUT						
Input High Voltage	V_{IH}		$0.7 \times$ $DVDDS2$			V
Input Low Voltage	V_{IL}			$0.29 \times$ $DVDDS2$		V
Input Hysteresis				200		mV
Input Leakage Current	I_{IH} , I_{IL}	$V_{DVDDS2} = 3.6V$, $V_{IN} = 0V$, $3.6V$; $T_A = +25^\circ C$	-1		+1	μA
Input Capacitance				10		pF
BCLKS2, LRCLKS2, SDOUTS2—OUTPUT						
Output Low Voltage	V_{OL}	$V_{DVDDS2} = 1.65V$, $I_{OL} = 3mA$			0.4	V
Output High Voltage	V_{OH}	$V_{DVDDS2} = 1.65V$, $I_{OH} = 3mA$	$DVDDS2$ - 0.4			V
Input Leakage Current	I_{IH} , I_{IL}	$V_{DVDD} = 2.0V$, $V_{IN} = 0V$, $5.5V$; $T_A = +25^\circ C$, high-impedance state	-1		+1	μA
SDA, SCL—INPUT						
Input High Voltage	V_{IH}		$0.7 \times$ $DVDD$			V
Input Low Voltage	V_{IL}			$0.3 \times$ $DVDD$		V
Input Hysteresis				210		mV
Input Leakage Current	I_{IH} , I_{IL}	$V_{DVDD} = 2.0V$, $V_{IN} = 0V$, $5.5V$; $T_A = +25^\circ C$	-1		+1	μA
Input Capacitance				10		pF
SDA, IRQ—OUTPUT						
Output High Current	I_{OH}	$V_{OUT} = 5.5V$, $T_A = +25^\circ C$			1	mA
Output Low Voltage	V_{OL}	$V_{DVDD} = 1.65V$, $I_{OL} = 3mA$			$0.2 \times$ $DVDD$	V
DIGMICDATA—INPUT						
Input High Voltage	V_{IH}		$0.65 \times$ $DVDD$			V
Input Low Voltage	V_{IL}			$0.35 \times$ $DVDD$		V
Input Hysteresis				125		mV
Input Leakage Current	I_{IH} , I_{IL}	$V_{DVDD} = 2.0V$, $V_{IN} = 0V$, $2.0V$; $T_A = +25^\circ C$	-25		+25	μA
Input Capacitance				10		pF

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DIGITAL INPUT/OUTPUT CHARACTERISTICS (continued)

(VAVDD = VHPVDD = VD VDD = VD VDD S1 = VD VDD S2 = 1.65V to 2.0V, VSPKL VDD = VSPKR VDD = 3.7V, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
DIGMICCLK—OUTPUT						
Output Low Voltage	V _{OL}	V _{DVDD} = 1.65V, I _{OL} = 1mA			0.4	V
Output High Voltage	V _{OH}	V _{DVDD} = 1.65V, I _{OH} = 1mA	DVDD - 0.4			V

INPUT CLOCK CHARACTERISTICS

(VAVDD = VHPVDD = VD VDD = VD VDD S1 = VD VDD S2 = +1.8V, VSPKL VDD = VSPKR VDD = 3.7V, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
MCLK Input Frequency	f _{MCLK}		10		60	MHz
MCLK Input Duty Cycle		PSCLK = 01	40	50	60	%
		PSCLK = 10 or 11	30		70	
Maximum MCLK Input Jitter				100		pSRMS
LRCLK Sample Rate (Note 8)		DHF ₋ = 0	8		48	kHz
		DHF ₋ = 1	48		96	
DAI1 LRCLK Average Frequency Error (Note 9)		FREQ1 = 0x8 to 0xF	0		0	%
		FREQ1 = 0x0	-0.025		+0.025	
DAI2 LRCLK Average Frequency Error (Note 9)			-0.025		+0.025	%
PLL Lock Time		Rapid lock mode		2	7	ms
		Nonrapid lock mode		12	25	
Maximum LRCLK Jitter to Maintain PLL Lock					100	ns
Soft-Start/Stop Time				10		ms

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AUDIO INTERFACE TIMING CHARACTERISTICS

(VAVDD = VHPVDD = VDvDD = VDvDDS1 = VDvDDS2 = 1.65V, VSPKLVDD = VSPKRVDD = 2.8V, TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
BCLK Cycle Time	t _{BCLK}	Slave mode	90			ns
BCLK High Time	t _{BCLKH}	Slave mode	20			ns
BCLK Low Time	t _{BCLKL}	Slave mode	20			ns
BCLK or LRCLK Rise and Fall Time	t _R , t _F	Master mode, C _L = 15pF				ns
SDIN to BCLK Setup Time	t _{SETUP}		20			ns
LRCLK to BCLK Setup Time	t _{SYNCSET}	Slave mode	20			ns
SDIN to BCLK Hold Time	t _{HOLD}		20			ns
LRCLK to BCLK Hold Time	t _{SYNHOLD}	Slave mode	20			ns
Minimum Delay Time from LSB BCLK Falling Edge to High-Impedance State	t _{HIZOUT}	Master mode, TDM ₀ = 1		42		ns
LRCLK Rising Edge to SDOUT MSB Delay	t _{SYNCTX}	C _L = 30pF, TDM ₀ = 1, FSW ₀ = 1			50	ns
BCLK to SDOUT Delay	t _{CLKTX}	C _L = 30pF, TDM ₀ = 1, BCLK rising edge			50	ns
		TDM ₀ = 0			50	
Delay Time from BCLK to LRCLK	t _{CLKSYNC}	Master mode	TDM ₀ = 1	-15	+15	ns
			TDM ₀ = 0		0.8 x t _{BCLKL}	
Delay Time from LRCLK to BCLK After LSB	t _{ENDSYNC}	Master mode, TDM ₀ = 1, FSW ₀ = 1	20			ns

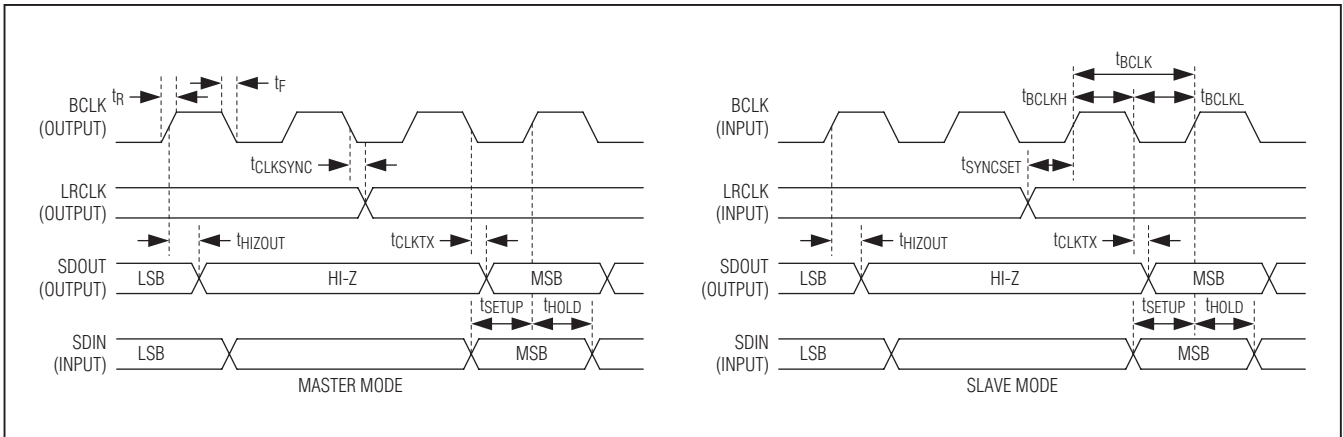


Figure 1. Non-TDM Audio Interface Timing Diagrams (TDM₀ = 0)

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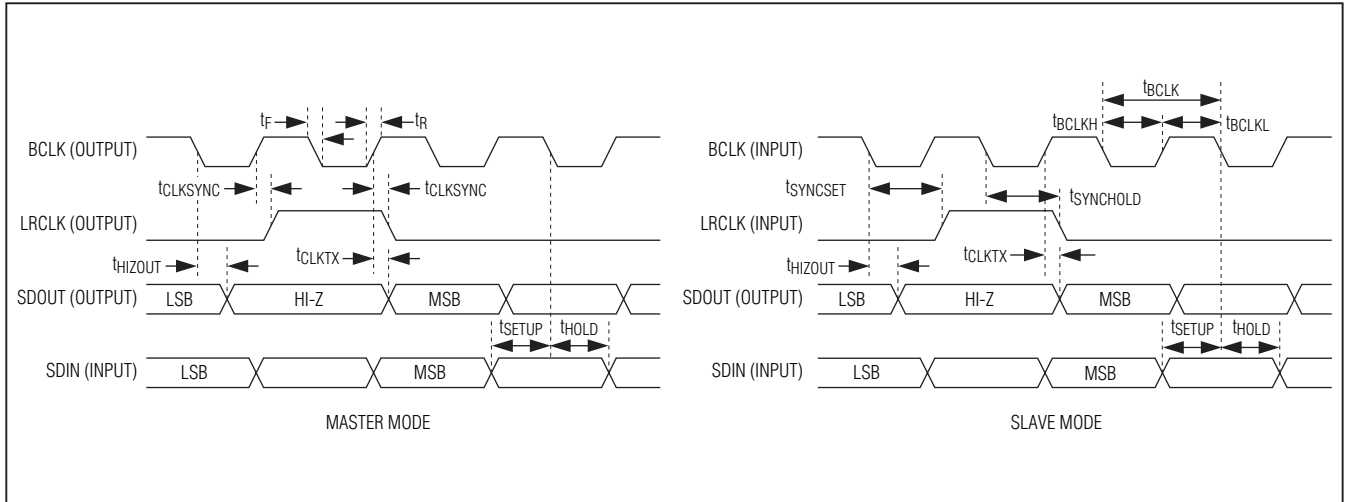


Figure 2. TDM Audio Interface Timing Diagram ($TDM_ = 1, FSW_ = 0$)

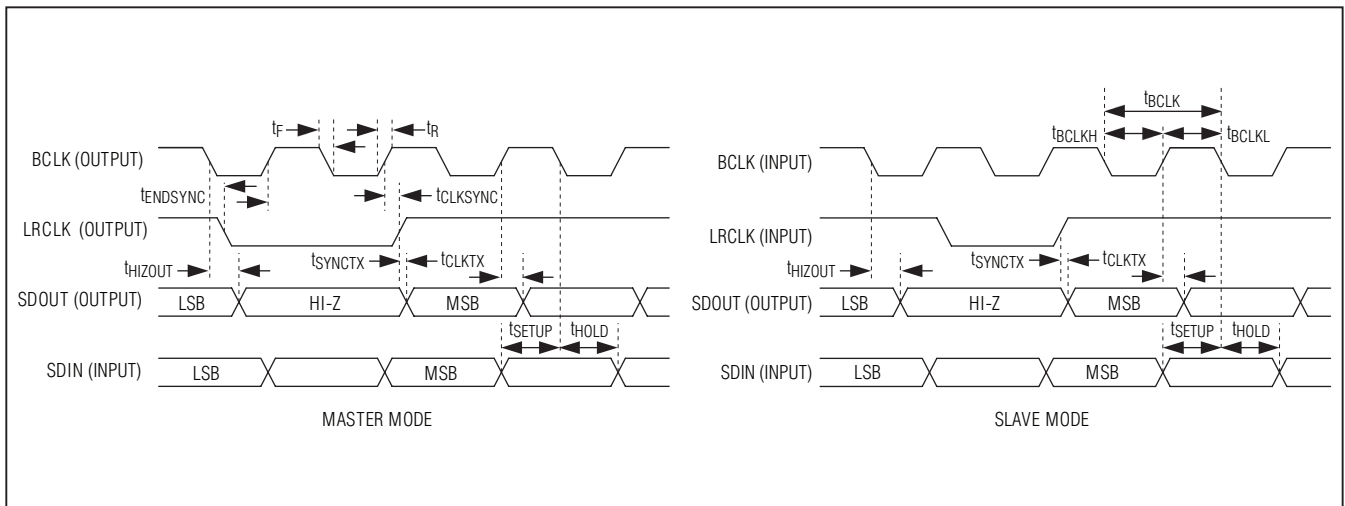


Figure 3. TDM Audio Interface Timing Diagram ($TDM_ = 1, FSW_ = 1$)

DIGITAL MICROPHONE TIMING CHARACTERISTICS

($V_{AVDD} = V_{HPVDD} = V_{DVDD} = V_{DVDD1} = V_{DVDD2} = 2.0V$, $V_{SPKLVDD} = V_{SPKRVD} = 2.8V$, $T_A = T_{MIN}$ to T_{MAX} , unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
DIGMICCLK Frequency	f_{MICCLK}	MICCLK = 00		MCLK/8		MHz
		MICCLK = 01		MCLK/6		
DIGMICDATA to DIGMICCLK Setup Time	$t_{SU,MIC}$	Either clock edge	20			ns
DIGMICDATA to DIGMICCLK Hold Time	$t_{HD,MIC}$	Either clock edge	0			ns

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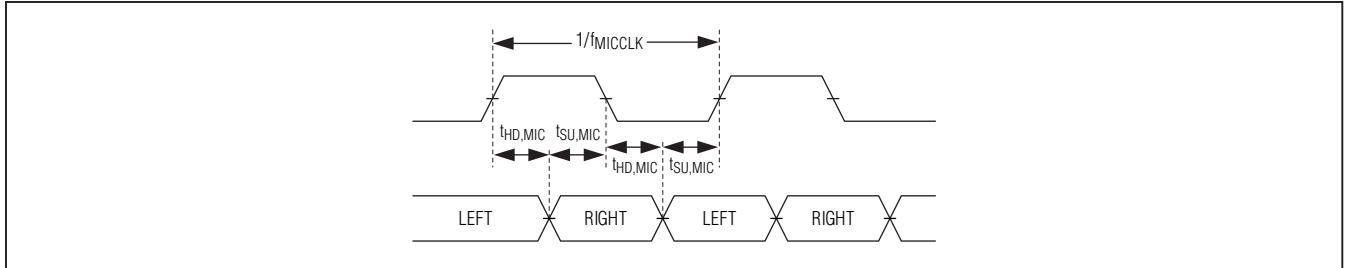


Figure 4. Digital Microphone Timing Diagram

I²C TIMING CHARACTERISTICS

($V_{AVDD} = V_{HPVDD} = V_{DVDD} = V_{DVDDS1} = V_{DVDDS2} = 1.65V$ to $2.0V$, $V_{SPKLVDD} = V_{SPKRVDD} = 3.7V$, $T_A = T_{MIN}$ to T_{MAX} , unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Serial-Clock Frequency	f_{SCL}	Guaranteed by SCL pulse-width low and high	0		400	kHz
Bus Free Time Between STOP and START Conditions	t_{BUF}		1.3			μs
Hold Time (Repeated) START Condition	$t_{HD,STA}$		0.6			μs
SCL Pulse-Width Low	t_{LOW}		1.3			μs
SCL Pulse-Width High	t_{HIGH}		0.6			μs
Setup Time for a Repeated START Condition	$t_{SU,STA}$		0.6			μs
Data Hold Time	$t_{HD,DAT}$	$R_{PU} = 475\Omega$, $C_B = 100pF$, $400pF$	0		900	ns
Data Setup Time	$t_{SU,DAT}$		100			ns
SDA and SCL Receiving Rise Time	t_R	(Note 10)	$20 + 0.1C_B$		300	ns
SDA and SCL Receiving Fall Time	t_F	(Note 10)	$20 + 0.1C_B$		300	ns
SDA Transmitting Fall Time	t_F	$R_{PU} = 475\Omega$, $C_B = 100pF$, $400pF$ (Note 10)	$20 + 0.05C_B$		250	ns
Setup Time for STOP Condition	$t_{SU,STO}$		0.6			μs
Bus Capacitance	C_B	Guaranteed by SDA transmitting fall time			400	pF
Pulse Width of Suppressed Spike	t_{SP}		0		50	ns

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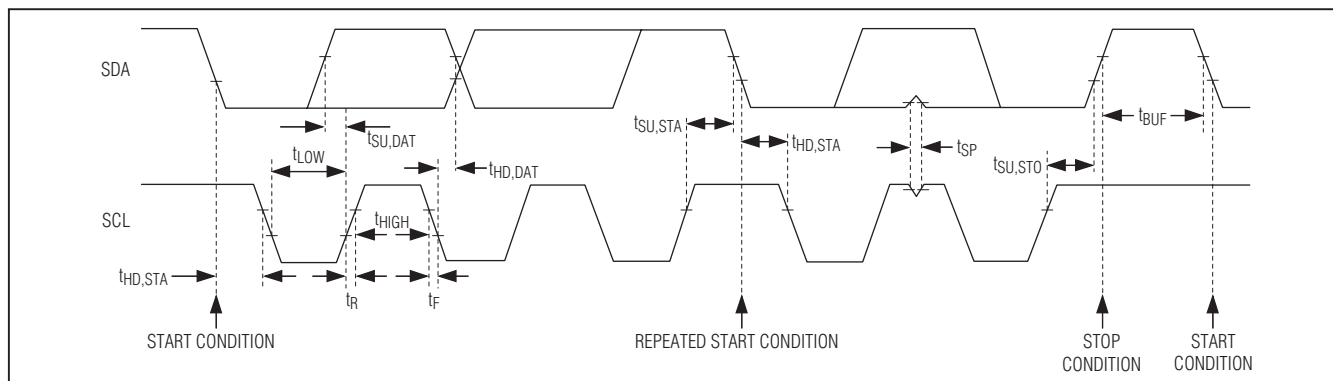


Figure 5. I²C Interface Timing Diagram

- Note 1:** The IC is 100% production tested at $T_A = +25^\circ\text{C}$. Specifications over temperature limits are guaranteed by design.
- Note 2:** Analog supply current = $I_{AVDD} + I_{HPVDD}$. Speaker supply current = $I_{SPKLVD} + I_{SPKRVD}$. Digital supply current = $I_{DVDD} + I_{DVDD1} + I_{DVDD2}$.
- Note 3:** Clocking all zeros into the DAC. Slave mode.
- Note 4:** Dynamic range measured using the EIAJ method. -60dBFS, 1kHz output signal, A-weighted and normalized to 0dBFS. $f = 20\text{Hz}$ to 20kHz .
- Note 5:** Gain measured relative to the 0dB setting.
- Note 6:** The filter specification is accurate only for synchronous clocking modes, where NI is a multiple of 0×1000 .
- Note 7:** 0dBFS for DAC input. 1Vp-p for INA/INB inputs.
- Note 8:** LRCLK may be any rate in the indicated range. Asynchronous or noninteger MCLK/LRCLK ratios may exhibit some full-scale performance degradation compared to synchronous integer related MCLK/LRCLK ratios.
- Note 9:** In master-mode operation, the accuracy of the MCLK input proportionally determines the accuracy of the sample clock rate.
- Note 10:** CB is in pF.

Power Consumption

($V_{AVDD} = V_{HPVDD} = V_{DVDD} = V_{DVDD1} = V_{DVDD2} = +1.8\text{V}$, $V_{SPKLVD} = V_{SPKRVD} = 3.7\text{V}$)

MODE	I_{AVDD} (mA)	I_{HPVDD} (mA)	$I_{SPKLVD} + I_{SPKRVD}$ (mA)	I_{DVDD} (mA)	$I_{DVDD1} + I_{DVDD2}$ (mA)	POWER (mW)
DAC Playback 48kHz Stereo HP DAC → HP 24-bit, music filters	1.35	1.37	1.65	2.91	0.02	16.25
DAC Playback 48kHz Stereo HP DAC → HP 24-bit, music filters, 0.1mW/channel, $R_{HP} = 32\Omega$	1.35	4.19	1.65	3.02	0.02	21.55
DAC Playback 48kHz Stereo HP DAC → HP 24-bit, music filters, ALC enabled	1.35	1.37	1.65	2.96	0.02	16.36