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# MAX98088

## Stereo Audio Codec with FlexSound Technology

### General Description

The MAX98088 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.

The IC features a stereo Class H headphone amplifier that utilizes a dual-mode charge pump to maximize efficiency while outputting a ground referenced signal that does not require output coupling capacitors.

The IC also features a mono differential amplifier that can also be configured as a stereo line output.

Two differential analog microphone inputs are available as well as support for two PDM digital microphones. Integrated switches allow for an additional microphone input as well as 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 loudspeaker 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.

*FlexSound is a trademark of Maxim Integrated Products, Inc.*

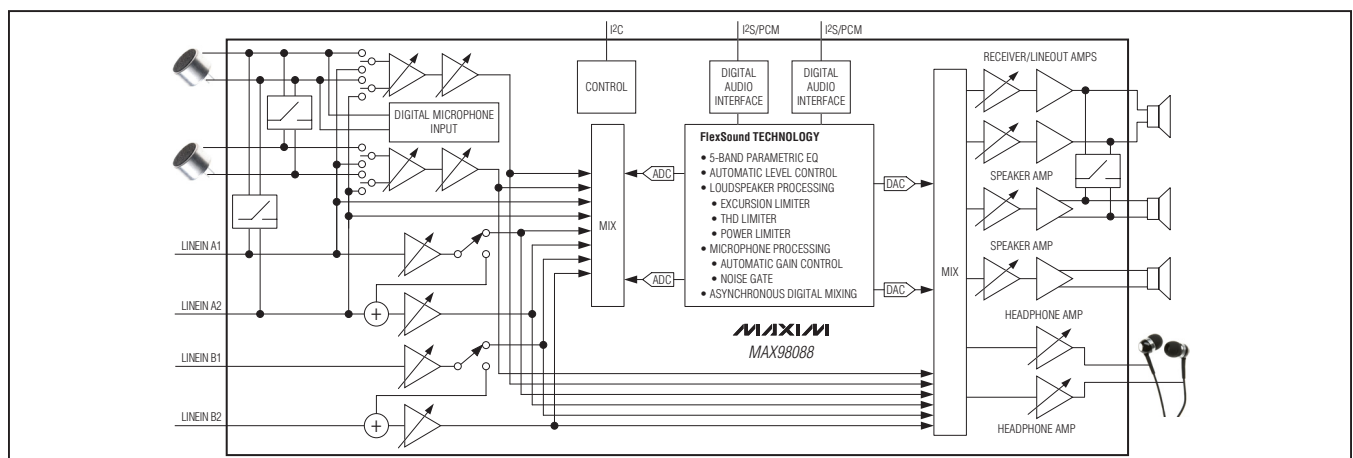
### Features

- ◆ 5.6mW Power Consumption (DAC to HP at 97dB DR)
- ◆ 101dB DR Stereo DAC (8kHz < f<sub>S</sub> < 96kHz)
- ◆ 93dB DR Stereo ADC (8kHz < f<sub>S</sub> < 96kHz)
- ◆ Stereo Low EMI Class D Amplifiers  
950mW/Channel (8Ω, V<sub>SPKVDD\_</sub> = 4.2V)
- ◆ Efficient Class H Headphone Amplifier
- ◆ Differential Receiver Amplifier/Stereo Line Outputs
- ◆ 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 I<sup>2</sup>S/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
- ◆ Available in 63-Bump WLP Package (3.80mm x 3.30mm, 0.4mm Pitch)

Ordering Information appears at end of data sheet.

For related parts and recommended products to use with this part, refer to [www.maxim-ic.com/MAX98088.related](http://www.maxim-ic.com/MAX98088.related).

### Simplified Block Diagram



# MAX98088

## Stereo Audio Codec with FlexSound Technology

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### TABLE OF CONTENTS

---

General Description . . . . .	1
Features . . . . .	1
Simplified Block Diagram . . . . .	1
Functional Diagram . . . . .	5
Absolute Maximum Ratings . . . . .	6
Electrical Characteristics . . . . .	6
Digital Input/Output Characteristics . . . . .	19
Input Clock Characteristics . . . . .	21
Audio Interface Timing Characteristics . . . . .	22
Digital Microphone Timing Characteristics . . . . .	23
I <sup>2</sup> C Timing Characteristics . . . . .	24
Power Consumption . . . . .	25
Typical Operating Characteristics . . . . .	28
Microphone to ADC . . . . .	28
Line to ADC . . . . .	32
Line-In Pin Direct to ADC . . . . .	33
Digital Loopback . . . . .	33
Analog Loopback . . . . .	34
DAC to Receiver . . . . .	35
Line to Receiver . . . . .	37
DAC to Line Output . . . . .	38
Line to Line Output . . . . .	38
DAC to Speaker . . . . .	39
Line to Speaker . . . . .	43
DAC to Headphone . . . . .	44
Line to Headphone . . . . .	51
Speaker Bypass Switch . . . . .	52
Pin Configuration . . . . .	53
Pin Description . . . . .	54
Detailed Description . . . . .	56
I <sup>2</sup> C Slave Address . . . . .	57
Registers . . . . .	57
Power Management . . . . .	63
Microphone Inputs . . . . .	65
Line Inputs . . . . .	67
ADC Input Mixers . . . . .	68

**Stereo Audio Codec  
with FlexSound Technology****TABLE OF CONTENTS (continued)**

Record Path Signal Processing . . . . .	69
Microphone AGC . . . . .	69
Noise Gate . . . . .	69
ADC Record Level Control . . . . .	72
Sidetone . . . . .	73
Digital Audio Interfaces . . . . .	74
Clock Control . . . . .	81
Sample Rate Converter . . . . .	84
Passband Filtering . . . . .	85
Playback Path Signal Processing . . . . .	88
Automatic Level Control . . . . .	88
Parametric Equalizer . . . . .	89
Playback Level Control . . . . .	91
DAC Input Mixers . . . . .	92
Receiver Amplifier . . . . .	93
Receiver Output Mixer . . . . .	94
Receiver Output Volume . . . . .	95
Speaker Amplifiers . . . . .	96
Speaker Output Mixers . . . . .	97
Speaker Amplifier Signal Processing . . . . .	98
Excursion Limiter . . . . .	98
Speaker Output Volume . . . . .	98
Power Limiter . . . . .	101
Distortion Limiter . . . . .	102
Headphone . . . . .	103
DirectDrive Headphone Amplifier . . . . .	103
Charge Pump . . . . .	103
Class H Operation . . . . .	104
Headphone Output Mixers . . . . .	105
Headphone Output Volume . . . . .	106
Output Bypass Switches . . . . .	107
Click-and-Pop Reduction . . . . .	108
Jack Detection . . . . .	109
Jack Detection and Removal . . . . .	109
Battery Measurement . . . . .	110
Device Status . . . . .	111

# MAX98088

## Stereo Audio Codec with FlexSound Technology

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### TABLE OF CONTENTS (CONTINUED)

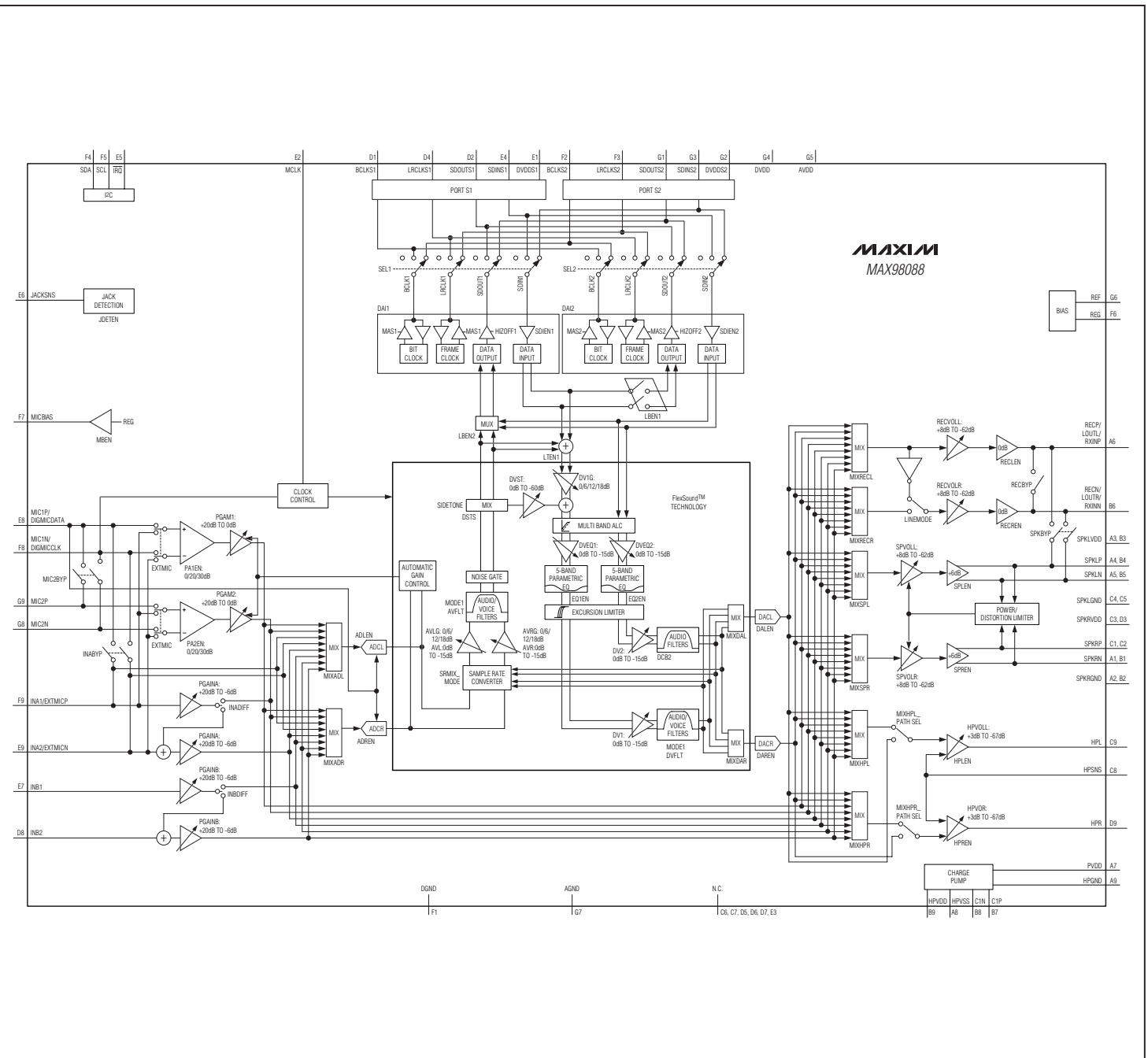
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I <sup>2</sup> C Serial Interface . . . . .	112
Bit Transfer . . . . .	112
START and STOP Conditions . . . . .	112
Early STOP Conditions . . . . .	112
Device Revision . . . . .	112
Slave Address . . . . .	113
Acknowledge . . . . .	113
Write Data Format . . . . .	113
Read Data Format . . . . .	114
Applications Information . . . . .	115
Typical Operating Circuits . . . . .	115
Filterless Class D Operation . . . . .	117
RF Susceptibility . . . . .	117
Startup/Shutdown Sequencing . . . . .	117
Component Selection . . . . .	118
Optional Ferrite Bead Filter . . . . .	118
Input Capacitor . . . . .	118
Charge-Pump Capacitor Selection . . . . .	118
Charge-Pump Flying Capacitor . . . . .	119
Charge-Pump Holding Capacitor . . . . .	119
Unused Pins . . . . .	119
Recommended PCB Routing . . . . .	120
Supply Bypassing, Layout, and Grounding . . . . .	120
WLP Applications Information . . . . .	121
Ordering Information . . . . .	121
Package Information . . . . .	122
Revision History . . . . .	123

# MAX98088

## Stereo Audio Codec with FlexSound Technology

### Functional Diagram



## Stereo Audio Codec with FlexSound Technology

### ABSOLUTE MAXIMUM RATINGS

(Voltages with respect to AGND.)

DVDD, AVDD, PVDD, HPVDD.....	-0.3V to +2.2V
SPKLVDD, 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)
REF, MICBIAS.....	-0.3V to (SPKLVDD + 0.3V)
MCLK, SDINS1, SDINS2, JACKSNS, SDA, SCL, I <sup>2</sup> C.....	-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/EXTMICP, INA2/EXTMICN, 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/LOUTL/RXINP, REC�/LOUTR/ RXINN.....	(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 (T <sub>A</sub> = +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

(V<sub>AVDD</sub> = V<sub>PVDD</sub> = V<sub>DVDD</sub> = V<sub>DVDDS1</sub> = V<sub>DVDDS2</sub> = +1.8V, V<sub>SPKLVDD</sub> = V<sub>SPKRVDD</sub> = 3.7V. Speaker loads (Z<sub>SPK</sub>) connected between SPK\_P and SPK\_N. Receiver load (R<sub>REC</sub>) connected between RECP and REC�. Headphone loads (R<sub>HP</sub>) connected from HPL or HPR to HPGND. Line out loads (R<sub>LOAD</sub>) connected from LOUTL or LOUTR to SPKLGND. R<sub>LOAD</sub> = R<sub>HP</sub> = ∞, R<sub>REC</sub> = ∞, Z<sub>SPK</sub> = ∞, C<sub>REF</sub> = 2.2μF, C<sub>MICBIAS</sub> = C<sub>REG</sub> = 1μF, C<sub>C1N-C1P</sub> = 1μF, C<sub>HPVDD</sub> = C<sub>HPVSS</sub> = 1μF. AV<sub>MICPRE</sub> = +20dB, AV<sub>MICPGA</sub> = 0dB, AV<sub>DACATTN</sub> = 0dB, AV<sub>DACGAIN</sub> = 0dB, AV<sub>ADCLVL</sub> = 0dB, AV<sub>ADCGAIN</sub> = 0dB, AV<sub>PGAIN</sub> = 0dB, AV<sub>HP</sub> = 0dB, AV<sub>REC</sub> = 0dB, AV<sub>SPK</sub> = 0dB, MCLK = 12.288MHz, LRCLK = 48kHz, MAS = 1. T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	
<b>POWER SUPPLY</b>							
Supply Voltage Range		Guaranteed by PSRR	V <sub>SPKLVDD</sub> , V <sub>SPKRVDD</sub>	2.8		5.5	V
			V <sub>DVDD</sub> , V <sub>AVDD</sub> , V <sub>PVDD</sub>	1.65	1.8	2	
			V <sub>DVDDS1</sub> , V <sub>DVDDS2</sub>	1.65		3.6	
Total Supply Current (Notes 2 and 3)	I <sub>VDD</sub>	Full-duplex 8kHz mono, receiver output, MAS = 1	Analog		4.5	8	mA
			Speaker		1.6	2.3	
			Digital		1.3	2	
		DAC playback 48kHz stereo, headphone outputs, MAS = 1	Analog		1.9	3	
			Speaker		0.001	0.0058	
			Digital		2.47	3.5	
		DAC playback 48kHz stereo, speaker outputs, MAS = 1	Analog		3.6	6.5	
			Speaker		6.41	8.5	
			Digital		2.49	3.5	
Shutdown Supply Current (Note 2)		T <sub>A</sub> = +25°C	Analog		0.2	2	μA
			Speaker		0.01	1	
			Digital		1	5	
REF Voltage				2.5		V	
REG Voltage				0.79		V	
Shutdown to Full Operation		V <sub>SEN</sub> = 0		30		ms	
		V <sub>SEN</sub> = 1		17			

## Stereo Audio Codec with FlexSound Technology

### ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VPVDD = 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 REC\_N. Headphone loads (RHP) connected from HPL or HPR to HPGND. Line out loads (RLOAD) connected from LOU\_TL or LOU\_TR to SPKLGND. RLOAD = RHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CREG = 1μF, CC1N-C1P = 1μF, CHPVDD = CHPVSS = 1μF. AVMICPRE\_ = +20dB, AVMICPGA\_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN\_ = 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 +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS	
<b>MICROPHONE TO ADC PATH</b>								
Dynamic Range	DR	fS = 8kHz, MODE = 0 (IIR voice), AVMICPRE_ = 0dB (Note 4)			88		dB	
Total Harmonic Distortion + Noise	THD+N	VIN = 0.1Vp-p, fS = 8kHz, f = 1kHz			-78		dB	
		AVMICPRE_ = 0dB, VIN = 1Vp-p, f = 1kHz			-85			
		AVMICPRE_ = +30dB, VIN = 32mVp-p, f = 1kHz			-71			
Common-Mode Rejection Ratio	CMRR	VIN = 100mVp-p, f = 217Hz			74		dB	
Power-Supply Rejection Ratio	PSRR	VAVDD = 1.65V to 1.95V, input referred, MIC inputs floating		50	62		dB	
		f = 217Hz, VRIPPLE = 200mVp-p, input referred			62			
		f = 1kHz, VRIPPLE = 200mVp-p, input referred			62			
		f = 10kHz, VRIPPLE = 200mVp-p, input referred			53			
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			
<b>MICROPHONE PREAMP</b>								
Full-Scale Input		AVMICPRE_ = 0dB			1.05		Vp-p	
Preamplifier Gain	AVMICPRE_	(Note 5)	PA1EN/PA2EN = 01		0		dB	
			PA1EN/PA2EN = 10		19.5	20		20.5
			PA1EN/PA2EN = 11		29.5	30		30.5
PGA Gain	AVMICPGA_	(Note 5)	PGAM1/PGAM2 = 0x00		19	20	21	dB
			PGAM1/PGAM2 = 0x14		0			
MIC Input Resistance	RIN_MIC	All gain settings, measured at MIC1P/ MIC1N/MIC2P/MIC2N			50		kΩ	



## Stereo Audio Codec with FlexSound Technology

### ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VPVDD = 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 REC N. Headphone loads (RH P) connected from HPL or HPR to HPGND. Line out loads (RLOAD) connected from LOU TL or LOU TR to SPKLGND. RLOAD = RH P = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CREG = 1μF, CC1N-C1P = 1μF, CHPVDD = CHPVSS = 1μF. AVMICPRE\_ = +20dB, AVMICPGA\_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN\_ = 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 +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>MICROPHONE BIAS</b>						
MICBIAS Output Voltage	VMICBIAS	ILOAD = 1mA	2.15	2.2	2.25	V
Load Regulation		ILOAD = 1mA to 2mA		0.5	4.5	mV
Line Regulation		VSPKLVDD = 2.8V to 5.5V		110		μV
Ripple Rejection		f = 217Hz, VRIPPLE (SPKLVDD) = 100mVp-p		92		dB
		f = 10kHz, VRIPPLE (SPKLVDD) = 100mVp-p		83		
Noise Voltage		A-weighted, f = 20Hz to 20kHz		3.9		μVRMS
		P-weighted, f = 20Hz to 4kHz		2.1		
		f = 1kHz		50		
<b>MICROPHONE BYPASS SWITCH</b>						
On-Resistance	RON	IMIC1_ = 100mA, INABYP = MIC2BYP = 1, VMIC2_ = VINA_ = 0V, AVDD, TA = +25°C		5	30	Ω
Total Harmonic Distortion + Noise	THD+N	VIN = 2Vp-p, VCM = 0.9V, RL = 10kΩ, f = 1kHz, INABYP = MIC2BYP = 1		-80		dB
Off-Isolation		VIN = 2Vp-p, VCM = 0.9V, RL = 10kΩ, f = 1kHz		60		dB
Off-Leakage Current		VMIC1_ = [0V, AVDD], VMIC2_/VINA_ = [AVDD, 0V]	-1		+1	μA
<b>LINE INPUT TO ADC PATH</b>						
Dynamic Range (Note 4)	DR	INA pin direct, fS = 48kHz, MODE = 1 (FIR audio)		93		dB
Total Harmonic Distortion + Noise	THD+N	VIN = 1Vp-p, f = 1kHz		-82	-74	dB
Gain Error		DC accuracy		1		%
Power-Supply Rejection Ratio	PSRR	VAVDD = 1.65V to 1.95V, input referred, line inputs floating, TA = +25°C	57	68		dB
		f = 217Hz, VRIPPLE = 200mVp-p, AVADC = 0dB, input referred		63		
		f = 1kHz, VRIPPLE = 200mVp-p, AVADC = 0dB, input referred		63		
		f = 10kHz, VRIPPLE = 200mVp-p, AVADC = 0dB, input referred		57		

## Stereo Audio Codec with FlexSound Technology

### ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VPVDD = 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 REC\_N. Headphone loads (RHP) connected from HPL or HPR to HPGND. Line out loads (RLOAD) connected from LOU\_TL or LOU\_TR to SPKLGND. RLOAD = RHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CREG = 1μF, CC1N-C1P = 1μF, CHPVDD = CHPVSS = 1μF. AVMICPRE\_ = +20dB, AVMICPGA\_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN\_ = 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 +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS	
<b>LINE INPUT PREAMP</b>								
Full-Scale Input	VIN	AVPGAIN_ = 0dB			1		V <sub>P-P</sub>	
		AVPGAIN_ = -6dB			1.4			
Level Adjust Gain	AVPGAIN_	TA = +25°C (Note 5)	PGAINA/PGAINB = 0x0	19	20	21	dB	
			PGAINA/PGAINB = 0x1	13	14	15		
			PGAINA/PGAINB = 0x2	2	3	4		
			PGAINA/PGAINB = 0x3		0			
			PGAINA/PGAINB = 0x4	-4	-3	-2		
			PGAINA/PGAINB = 0x5, 0x6, 0x7	-7	-6	-5		
Input Resistance	RIN	AVPGAIN_ = +20dB		14.5	21	28	kΩ	
		AVPGAIN_ = +14dB			20			
		AVPGAIN_ = +3dB			20			
		AVPGAIN_ = 0dB		7.5	10	14		
		AVPGAIN_ = -3dB			20			
		AVPGAIN_ = -6dB			20			
Feedback Resistance	RIN_FB	INAEXT/IINBEXT = 1			18	20	22	kΩ
					16		24	
<b>ADC LEVEL CONTROL</b>								
ADC Level Adjust Range	AVADCLVL	AVL/AVR = 0xF to 0x0 (Note 5)		-12		+3	dB	
ADC Level 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	
<b>ADC DIGITAL FILTERS</b>								
<b>VOICE MODE IIR LOWPASS FILTER (MODE1 = 0)</b>								
Passband Cutoff	f <sub>PLP</sub>	Ripple limit cutoff		0.441 x fs			Hz	
		-3dB cutoff		0.449 x fs				
Passband Ripple		f < f <sub>PLP</sub>		-0.1		+0.1	dB	
Stopband Cutoff	f <sub>SLP</sub>					0.47 x fs	Hz	
Stopband Attenuation (Note 6)		f > f <sub>SLP</sub>		74			dB	

## Stereo Audio Codec with FlexSound Technology

### ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VPVDD = 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 REC\_N. Headphone loads (RH P) connected from HPL or HPR to HPGND. Line out loads (RLOAD) connected from LOU TL or LOU TR to SPKLGND. RLOAD = RH P = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CREG = 1μF, CC1N-C1P = 1μF, CHPVDD = CHPVSS = 1μF. AVMICPRE\_ = +20dB, AVMICPGA\_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN\_ = 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 +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>VOICE MODE IIR HIGHPASS FILTER (MODE1 = 0)</b>						
Passband Cutoff (-3dB from Peak)	fAHPPB	AVFLT = 0x1 (Elliptical tuned for fs = 16kHz + 217Hz notch)			0.0161 x fs	Hz
		AVFLT = 0x2 (500Hz Butterworth tuned for fs = 16kHz)			0.0319 x fs	
		AVFLT = 0x3 (Elliptical tuned for fs = 8kHz + 217Hz notch)			0.0321 x fs	
		AVFLT = 0x4 (500Hz Butterworth tuned for fs = 8kHz)			0.0632 x fs	
		AVFLT = 0x5 (fs/240 Butterworth)			0.0043 x fs	
Stopband Cutoff (-30dB from Peak)	fAHPSB	AVFLT = 0x1 (Elliptical tuned for fs = 16kHz + 217Hz notch)	0.0139 x fs			Hz
		AVFLT = 0x2 (500Hz Butterworth tuned for fs = 16kHz)	0.0156 x fs			
		AVFLT = 0x3 (Elliptical tuned for fs = 8kHz + 217Hz notch)	0.0279 x fs			
		AVFLT = 0x4 (500Hz Butterworth tuned for fs = 8kHz)	0.0312 x fs			
		AVFLT = 0x5 (fs/240 Butterworth)	0.0018 x fs			
DC Attenuation	DCATTEN	AVFLT ≠ 000		90		dB
<b>STEREO AUDIO MODE FIR LOWPASS FILTER (MODE1 = 1, DHF1 = 0, LRCLK &lt; 50kHz)</b>						
Passband Cutoff	fPLP	Ripple limit cutoff	0.43 x fs			Hz
		-3dB cutoff	0.48 x fs			
		-6.02dB cutoff	0.5 x fs			
Passband Ripple		f < fPLP	-0.1	+0.1		dB
Stopband Cutoff	fSLP			0.58 x fs		Hz
Stopband Attenuation (Note 6)		f < fSLP	60			dB
<b>ADC STEREO AUDIO MODE FIR LOWPASS FILTER (MODE1 = 1, DHF1 = 1, LRCLK &gt; 50kHz)</b>						
Passband Cutoff	fPLP	Ripple limit cutoff	0.208 x fs			Hz
		-3dB cutoff	0.28 x fs			
Passband Ripple		f < fPLP	-0.1	+0.1		dB
Stopband Cutoff	fSLP			0.417 x fs		Hz
Stopband Attenuation		f < fSLP	60			dB

## Stereo Audio Codec with FlexSound Technology

### ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VPVDD = 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 REC N. Headphone loads (RH P) connected from HPL or HPR to HPGND. Line out loads (RLOAD) connected from LOU TL or LOU TR to SPKLGND. RLOAD = RH P = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CREG = 1μF, CC1N-C1P = 1μF, CHPVDD = CHPVSS = 1μF. AVMICPRE\_ = +20dB, AVMICPGA\_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN\_ = 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 +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>ADC STEREO AUDIO MODE DC BLOCKING HIGHPASS FILTER (MODE1 = 1)</b>						
Passband Cutoff (-3dB from Peak)	fAHPPB	AVFLT ≠ 000		0.000125 x fs		Hz
DC Attenuation	DCAtten	AVFLT ≠ 000		90		dB
<b>MICROPHONE AUTOMATIC GAIN CONTROL</b>						
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
<b>ADC NOISE GATE</b>						
NG Threshold Level		ANTH = 0x3 to 0xF, referred to 0dBFS	-64		-16	dB
NG Attenuation		(Note 5)	0		12	dB
<b>ADC-TO-DAC DIGITAL SIDETONE (MODE = 0)</b>						
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	
<b>ADC-TO-DAC DIGITAL LOOP-THROUGH PATH</b>						
Dynamic Range (Note 4)	DR	fs = 48kHz, MCLK = 12.288MHz, MODE = 1 (FIR audio), MIC to HP output, TA = +25°C	83	93		dB
Total Harmonic Distortion + Noise	THD+N	f = 1kHz, fs = 48kHz, MCLK = 12.288MHz, MODE = 1 (FIR audio), MIC to HP output		81		dB
<b>DAC LEVEL CONTROL</b>						
DAC Attenuation Range	AVDACATTN	DV_ = 0xF to 0x0 (Note 5)	-15		0	dB
DAC Attenuation Step Size				1		dB
DAC Gain Adjust Range	AVDACGAIN	DV1G = 00 to 11 (Note 5)	0		18	dB
DAC Gain Adjust Step Size				6		dB

## Stereo Audio Codec with FlexSound Technology

### ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VPVDD = 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 REC N. Headphone loads (RHP) connected from HPL or HPR to HPGND. Line out loads (RLOAD) connected from LOU TL or LOU TR to SPKLGND. RLOAD = RHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CREG = 1μF, CC1N-C1P = 1μF, CHPVDD = CHPVSS = 1μF. AVMICPRE\_ = +20dB, AVMICPGA\_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN\_ = 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 +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>DAC DIGITAL FILTERS</b>						
<b>VOICE MODE IIR LOWPASS FILTER (MODE1 = 0)</b>						
Passband Cutoff	f <sub>PLP</sub>	Ripple limit cutoff	0.448 x f <sub>s</sub>			Hz
		-3dB cutoff	0.451 x f <sub>s</sub>			
Passband Ripple		f < f <sub>PLP</sub>	-0.1		+0.1	dB
Stopband Cutoff	f <sub>SLP</sub>			0.476 x f <sub>s</sub>		Hz
Stopband Attenuation (Note 6)		f > f <sub>SLP</sub>	75			dB
<b>VOICE MODE IIR HIGHPASS FILTER (MODE1 = 0)</b>						
Passband Cutoff (-3dB from Peak)	f <sub>DHPPB</sub>	DVFLT = 0x1 (Elliptical tuned for f <sub>s</sub> = 16kHz + 217Hz notch)			0.0161 x f <sub>s</sub>	Hz
		DVFLT = 0x2 (500Hz Butterworth tuned for f <sub>s</sub> = 16kHz)			0.0312 x f <sub>s</sub>	
		DVFLT = 0x3 (Elliptical tuned for f <sub>s</sub> = 8kHz + 217Hz notch)			0.0321 x f <sub>s</sub>	
		DVFLT = 0x4 (500Hz Butterworth tuned for f <sub>s</sub> = 8kHz)			0.0625 x f <sub>s</sub>	
		DVFLT = 0x5 (f <sub>s</sub> /240 Butterworth)			0.0042 x f <sub>s</sub>	
Stopband Cutoff (-30dB from Peak)	f <sub>DHPSB</sub>	DVFLT = 0x1 (Elliptical tuned for f <sub>s</sub> = 16kHz + 217Hz notch)	0.0139 x f <sub>s</sub>			Hz
		DVFLT = 0x2 (500Hz Butterworth tuned for f <sub>s</sub> = 16kHz)	0.0156 x f <sub>s</sub>			
		DVFLT = 0x3 (Elliptical tuned for f <sub>s</sub> = 8kHz + 217Hz notch)	0.0279 x f <sub>s</sub>			
		DVFLT = 0x4 (500Hz Butterworth tuned for f <sub>s</sub> = 8kHz)	0.0312 x f <sub>s</sub>			
		DVFLT = 0x5 (f <sub>s</sub> /240 Butterworth)	0.0021 x f <sub>s</sub>			
DC Attenuation	DCATTEN	DVFLT ≠ 000	85			dB
<b>STEREO AUDIO MODE FIR LOWPASS FILTER (MODE1 = 1, DHF1/DHF2 = 0, LRCLK &lt; 50kHz)</b>						
Passband Cutoff	f <sub>PLP</sub>	Ripple limit cutoff	0.43 x f <sub>s</sub>			Hz
		-3dB cutoff	0.47 x f <sub>s</sub>			
		-6.02dB cutoff	0.5 x f <sub>s</sub>			
Passband Ripple		f < f <sub>PLP</sub>	-0.1		+0.1	dB
Stopband Cutoff	f <sub>SLP</sub>			0.58 x f <sub>s</sub>		Hz
Stopband Attenuation (Note 6)		f > f <sub>SLP</sub>	60			dB

## Stereo Audio Codec with FlexSound Technology

### ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VPVDD = 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 REC N. Headphone loads (RHP) connected from HPL or HPR to HPGND. Line out loads (RLOAD) connected from LOU TL or LOU TR to SPKLGND. RLOAD = RHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CREG = 1μF, CC1N-C1P = 1μF, CHPVDD = CHPVSS = 1μF. AVMICPRE\_ = +20dB, AVMICPGA\_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN\_ = 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 +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>STEREO AUDIO MODE FIR LOWPASS FILTER (MODE1 = 1, DHF1/DHF2 = 1 for LRCLK &gt; 50kHz)</b>						
Passband Cutoff	f <sub>PLP</sub>	Ripple limit cutoff	0.24 x f <sub>S</sub>			Hz
		-3dB cutoff	0.31 x f <sub>S</sub>			
Passband Ripple		f < f <sub>PLP</sub>	-0.1		+0.1	dB
Stopband Cutoff	f <sub>SLP</sub>				0.477 x f <sub>S</sub>	Hz
Stopband Attenuation (Note 6)		f < f <sub>SLP</sub>	60			dB
<b>STEREO AUDIO MODE DC BLOCKING HIGHPASS FILTER</b>						
Passband Cutoff (-3dB from Peak)	f <sub>DHPPB</sub>	DVFLT ≠ 000 (DAI1), DCB2 = 1 (DAI2)			0.000104 x f <sub>S</sub>	Hz
DC Attenuation	DCATTEN	DVFLT ≠ 000 (DAI1), DCB2 = 1 (DAI2)		90		dB
<b>AUTOMATIC LEVEL CONTROL</b>						
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		
<b>PARAMETRIC EQUALIZER</b>						
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
<b>DAC TO RECEIVER AMPLIFIER PATH</b>						
Dynamic Range	DR	f <sub>S</sub> = 48kHz, f = 1kHz (Note 4)		96		dB
Total Harmonic Distortion + Noise	THD+N	f = 1kHz, P <sub>OUT</sub> = 15mW, RREC = 32Ω		-70	-63	dB
Power-Supply Rejection Ratio	PSRR	VSPKLVDD = 2.8V to 5.5V, TA = +25°C	64	75		dB
		f = 217Hz, V <sub>RIPPLE</sub> = 200mV <sub>P-P</sub>		-59		
		f = 1kHz, V <sub>RIPPLE</sub> = 200mV <sub>P-P</sub>		-59		
		f = 10kHz, V <sub>RIPPLE</sub> = 200mV <sub>P-P</sub>		-59		
Click-and-Pop Level	KCP	Peak voltage, A-weighted, 32 samples per second, AVREC = 0dB	Into shutdown		-68	dBV
			Out of shutdown		-72	

## Stereo Audio Codec with FlexSound Technology

### ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VPVDD = VD VDD = VD VDD S1 = VD VDD S2 = +1.8V, VSPKLVDD = VSPKRVDD = 3.7V. Speaker loads (Z<sub>SPK</sub>) connected between SPK\_P and SPK\_N. Receiver load (R<sub>REC</sub>) connected between RECP and REC\_N. Headphone loads (R<sub>HP</sub>) connected from HPL or HPR to HPGND. Line out loads (R<sub>LOAD</sub>) connected from LOU<sub>T</sub>L or LOU<sub>T</sub>R to SPKLGND. R<sub>LOAD</sub> = R<sub>HP</sub> = ∞, R<sub>REC</sub> = ∞, Z<sub>SPK</sub> = ∞, C<sub>REF</sub> = 2.2μF, C<sub>MICBIAS</sub> = C<sub>REG</sub> = 1μF, C<sub>C1N-C1P</sub> = 1μF, C<sub>HPVDD</sub> = C<sub>HPVSS</sub> = 1μF. AV<sub>MICPRE\_</sub> = +20dB, AV<sub>MICPGA\_</sub> = 0dB, AV<sub>DACATTN</sub> = 0dB, AV<sub>DACGAIN</sub> = 0dB, AV<sub>ADCLVL</sub> = 0dB, AV<sub>ADCGAIN</sub> = 0dB, AV<sub>PGAIN\_</sub> = 0dB, AV<sub>HP\_</sub> = 0dB, AV<sub>REC</sub> = 0dB, AV<sub>SPK\_</sub> = 0dB, MCLK = 12.288MHz, LRCLK = 48kHz, MAS = 1. T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
<b>LINE INPUT TO RECEIVER AMPLIFIER PATH</b>							
Dynamic Range (Note 4)	DR	Referenced to full-scale output level			94		dB
Total Harmonic Distortion + Noise	THD+N				-64		dB
Click-and-Pop Level	K <sub>CP</sub>	Peak voltage, A-weighted, 32 samples per second, AV <sub>REC</sub> = 0dB	Into shutdown		-51		dBV
			Out of shutdown		-49		
<b>RECEIVER AMPLIFIER</b>							
Output Power	P <sub>OUT</sub>	R <sub>REC</sub> = 32Ω, f = 1kHz, THD = 1%			83		mW
Full-Scale Output		(Note 7)			1		V <sub>RMS</sub>
Volume Control (Note 5)	AV <sub>REC</sub>	RECVOL = 0x00			-62		dB
		RECVOL = 0x1F			8		
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			88		dB
Capacitive Drive Capability		No sustained oscillations	R <sub>REC</sub> = 32Ω		500		pF
			R <sub>REC</sub> = ∞		100		
<b>DAC TO LINE OUT AMPLIFIER PATH</b>							
Dynamic Range (Note 4)	DR	f <sub>S</sub> = 48kHz, f = 1kHz		83	96		dB
Total Harmonic Distortion + Noise	THD+N	f = 1kHz, R <sub>L</sub> = 1kΩ			-78	-72	dB
<b>LINE INPUT TO LINE OUT AMPLIFIER PATH</b>							
Dynamic Range (Note 4)	DR	Referenced to full-scale output level			92		dB
Total Harmonic Distortion + Noise	THD+N	f = 1kHz, R <sub>L</sub> = 10kΩ			76		dB
Full-Scale Output		(Note 7)			2		V <sub>P-P</sub>
Mute Attenuation		f = 1kHz			85		dB
Output Offset Voltage	V <sub>OS</sub>	AV <sub>REC_</sub> = -62dB			±3.0	±4	mV
Capacitive Drive Capability		No sustained oscillations, R <sub>L</sub> = 1kΩ			500		pF

## Stereo Audio Codec with FlexSound Technology

### ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VPVDD = 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 REC N. Headphone loads (RHP) connected from HPL or HPR to HPGND. Line out loads (RLOAD) connected from LOU TL or LOU TR to SPKLGND. RLOAD = RHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CREG = 1μF, CC1N-C1P = 1μF, CHPVDD = CHPVSS = 1μF. AVMICPRE\_ = +20dB, AVMICPGA\_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN\_ = 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 +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
<b>DAC TO SPEAKER AMPLIFIER PATH</b>							
Total Harmonic Distortion + Noise	THD+N	f = 1kHz, P <sub>OUT</sub> = 200mW, Z <sub>SPK</sub> = 8Ω + 68μH			-68		dB
Crosstalk		SPKL to SPKR and SPKR to SPKL, P <sub>OUT</sub> = 640mW, f = 1kHz			-88		dB
Output Noise					53		μV <sub>RMS</sub>
Click-and-Pop Level	KCP	Peak voltage, A-weighted, 32 samples per second, AVSPK_ = 0dB	Into shutdown		65		dBV
			Out of shutdown		66		
<b>MIC INPUT TO SPEAKER AMPLIFIER PATH</b>							
Dynamic Range (Note 4)	DR	Referenced to full-scale output level, AVSPK_ = 0dB			82		dB
Total Harmonic Distortion + Noise	THD+N	f = 1kHz, P <sub>OUT</sub> = 200mW, R <sub>L</sub> = 8Ω + 68μH			71		dB
Click-and-Pop Level	KCP	Peak voltage, A-weighted, 32 samples per second, AVSPK_ = 0dB	Into shutdown		55		dBV
			Out of shutdown		52		
<b>SPEAKER AMPLIFIER</b>							
Output Power	P <sub>OUT</sub>	f = 1kHz, THD = 1%, Z <sub>SPK</sub> = 8Ω + 68μH	VSPKLVDD = VSPKRVDD = 5.0V		1323		mW
			VSPKLVDD = VSPKRVDD = 4.2V		914		
			VSPKLVDD = VSPKRVDD = 3.7V		700		
			VSPKLVDD = VSPKRVDD = 3.2V		514		
Full-Scale Output		(Note 7)			2		V <sub>RMS</sub>
Volume Control	AVSPK_	(Note 5)	SPVOLL/SPVOLR = 0x00		-62		dB
			SPVOLL/SPVOLR = 0x1F		+8		
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		
Mute Attenuation		f = 1kHz			86		dB
Output Offset Voltage	VOS	AVSPK_ = -61dB, TA = +25°C			±0.5	±3	mV



## Stereo Audio Codec with FlexSound Technology

### ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VPVDD = 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 HPGND. Line out loads (RLOAD) connected from LOU TL or LOU TR to SPK LGND. RLOAD = RHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CREG = 1μF, CC1N-C1P = 1μF, CHPVDD = CHPVSS = 1μF. AVMICPRE\_ = +20dB, AVMICPGA\_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN\_ = 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 +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>EXCURSION LIMITER</b>						
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, VSPKL VDD = VSPKR VDD = 5.5V, AVSPK_ = 8dB	DHPTH = 000		0.34	Vp
			DHPTH = 111		0.95	
Release Time		ALCRLS = 101		0.25		s
		ALCRLS = 000		4		
<b>POWER LIMITER</b>						
Attenuation				-64		dB
Threshold		ZSPK = 8Ω + 68μH, VSPKL VDD = VSPKR VDD = 5.5V, AVSPK_ = 8dB	PWRTH = 0x1		0.08	W
			PWRTH = 0xF		1.23	
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	%
<b>DISTORTION LIMITER</b>						
Distortion Limit		THDCLP = 0x1		< 1		%
		THDCLP = 0xF		24		
Release Time Constant		THDT1 = 000		0.76		s
		THDT1 = 111		6.2		

## Stereo Audio Codec with FlexSound Technology

### ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VPVDD = VD VDD = VD VDD S1 = VD VDD S2 = +1.8V, VSPKLVDD = VSPKRVD D = 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 HPGND. Line out loads (RLOAD) connected from LOU TL or LOU TR to SPKLGND. RLOAD = RHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CREG = 1μF, CC1N-C1P = 1μF, CHPVDD = CHPVSS = 1μF. AVMICPRE\_ = +20dB, AVMICPGA\_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN\_ = 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 +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
<b>DAC TO HEADPHONE AMPLIFIER PATH</b>							
Dynamic Range (Note 4)	DR	fS = 48kHz	Master or slave mode	101		dB	
			Slave mode	97			
			Low power mode, TA = +25°C	95	97		
Total Harmonic Distortion + Noise	THD+N	f = 1kHz, POUT = 20mW	RHP = 16Ω	-85	-64	dB	
			RHP = 32Ω	-92			
Crosstalk		HPL to HPR and HPR to HPL, POUT = 5mW, f = 1kHz, RHP = 32Ω		79.5			dB
Power-Supply Rejection Ratio	PSRR	VAVDD = VPVDD = 1.65V to 2.0V		46	54	dB	
		f = 217Hz, VRIPPLE = 200mVP-P, AVHP_ = 0dB		72			
		f = 1kHz, VRIPPLE = 200mVP-P, AVHP_ = 0dB		63			
		f = 10kHz, VRIPPLE = 200mVP-P, AVHP_ = 0dB		43			
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			%
Click-and-Pop Level	KCP	Peak voltage, A-weighted, 32 samples per second, AVHP_ = 0dB	Into shutdown	-62		dBV	
			Out of shutdown	-63			
<b>LINE INPUT TO HEADPHONE AMPLIFIER PATH</b>							
Total Harmonic Distortion + Noise	THD+N	VIN = 1VP-P, f = 1kHz, RHP = 32Ω		81			dB
Dynamic Range (Note 4)				92.5			dB
Click-and-Pop Level	KCP	Peak voltage, A-weighted, 32 samples per second, AVHP_ = 0dB	Into shutdown	-62		dBV	
			Out of shutdown	-63			

## Stereo Audio Codec with FlexSound Technology

### ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VPVDD = 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 REC\_N. Headphone loads (RHHP) connected from HPL or HPR to HPGND. Line out loads (RLOAD) connected from LOU\_TL or LOU\_TR to SPKLGND. RLOAD = RHHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CREG = 1μF, CC1N-C1P = 1μF, CHPVDD = CHPVSS = 1μF. AVMICPRE\_ = +20dB, AVMICPGA\_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN\_ = 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 +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>HEADPHONE AMPLIFIER</b>						
Output Power	POUT	f = 1kHz, THD = 1%	RHP = 32Ω	30		mW
			RHP = 16Ω	38		
Positive Charge-Pump Output Voltage	HPVDD	VOUT ≤ VPVDD × 0.25V, RHP = ∞		PVDD/2		V
		VOUT > VPVDD × 0.25V, RHP = ∞		PVDD		
Negative Charge-Pump Output Voltage	HPVSS	VOUT ≤ VPVDD × 0.25V, RHP = ∞		-PVDD/2		V
		VOUT > VPVDD × 0.25V, RHP = ∞		-PVDD		
Output Voltage Threshold (Output Voltage at which the Charge Pump Switches Modes; VOUT Rising; Transition from Split to Invert Mode)	VTH	RL = ∞		±PVDD × 0.25		V
Full-Scale Output		(Note 7)		1		VRMS
Volume Control	AVHP_	(Note 5)	HPVOL_ = 0x00	-67		dB
			HPVOL_ = 0x1F	+3		
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		100		dB
Output Offset Voltage	VOS	AVHP_ = -67dB	TA = +25°C	±0.5	±1	mV
			TA = TMIN to TMAX		±3	
Capacitive Drive Capability		No sustained oscillations	RHP = 32Ω	500		pF
			RHP = ∞	100		
<b>SPEAKER BYPASS SWITCH</b>						
On-Resistance	RON	ISPKL_ = 100mA, SPKBYP = 1, VRXIN_ = [0V, VSPKLVDD]		2.8		Ω
Total Harmonic Distortion + Noise	THD+N	VIN = 2VP-P, VCM = VSPKLVDD/2, ZSPK = 8Ω + 68μH, f = 1kHz, SPKBYP = 1	RS = 10Ω	60		dB
			RS = 0Ω	60		
Off-Isolation		VIN = 2VP-P, VCM = VSPKLVDD/2, ZSPK = 8Ω + 68μH, f = 1kHz		96		dB
Off-Leakage Current		VRXIN_ = [0V, VSPKLVDD], VSPKL_ = [VSPKLVDD, 0V]	-20		+20	μA

## Stereo Audio Codec with FlexSound Technology

### ELECTRICAL CHARACTERISTICS (continued)

(VAVDD = VPVDD = 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 REC\_N. Headphone loads (RHP) connected from HPL or HPR to HPGND. Line out loads (RLOAD) connected from LOU\_TL or LOU\_TR to SPKLGND. RLOAD = RHP = ∞, RREC = ∞, ZSPK = ∞, CREF = 2.2μF, CMICBIAS = CREG = 1μF, CC1N-C1P = 1μF, CHPVDD = CHPVSS = 1μF. AVMICPRE\_ = +20dB, AVMICPGA\_ = 0dB, AVDACATTN = 0dB, AVDACGAIN = 0dB, AVADCLVL = 0dB, AVADCGAIN = 0dB, AVPGAIN\_ = 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 +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>RECEIVER BYPASS SWITCH</b>						
On-Resistance	RON	I <sub>RECP</sub> = 100mA, RECBYP = 1, V <sub>REC_N</sub> = [0V, V <sub>SPKLVDD</sub> ]		2		Ω
Total Harmonic Distortion + Noise	THD+N	V <sub>IN</sub> = 2V <sub>P-P</sub> , V <sub>CM</sub> = V <sub>SPKLVDD</sub> /2, Z <sub>SPK</sub> = 8Ω + 68μH, f = 1kHz, RECBYP = 1, R <sub>S</sub> = 0Ω		60		dB
Off-Isolation		V <sub>IN</sub> = 2V <sub>P-P</sub> , V <sub>CM</sub> = V <sub>SPKLVDD</sub> /2, Z <sub>SPK</sub> = 8Ω + 68μH, f = 1kHz		84		dB
Off-Leakage Current		V <sub>RECP</sub> = [0V, V <sub>SPKLVDD</sub> ], V <sub>REC_N</sub> = [V <sub>SPKLVDD</sub> , 0V]	-15		+15	μA
<b>JACK DETECTION</b>						
JACKSNS Threshold		$\overline{\text{SHDN}} = 1$ , JACKSNS rising	0.92 x	0.95 x	0.98 x	V
		$\overline{\text{SHDN}} = 0$ , JKSNS	SPKLVDD - 0.7			
JACKSNS Sense Voltage		$\overline{\text{SHDN}} = 0$	SPKLVDD			V
JACKSNS Sense Current		V <sub>JACKSNS</sub> = 0V		4	10	μA
<b>BATTERY ADC</b>						
Input Voltage Range			2.6		5.6	V
LSB Size				0.1		V

### DIGITAL INPUT/OUTPUT CHARACTERISTICS

(VAVDD = VPVDD = VD VDD = VD VDD S1 = VD VDD S2 = +1.8V, VSPKLVDD = VSPKRVDD = 3.7V, TA = +25°C, unless otherwise noted.) (Note 1)

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

## Stereo Audio Codec with FlexSound Technology

### DIGITAL INPUT/OUTPUT CHARACTERISTICS (continued)

(VAVDD = VPVDD = VD VDD = VD VDDS1 = VD VDDS2 = +1.8V, VSPKL VDD = VSPKR VDD = 3.7V, T<sub>A</sub> = +25°C, unless otherwise noted.)  
(Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>BCLKS1, LRCLKS1, SDOUTS1—OUTPUT</b>						
Output Low Voltage	V <sub>OL</sub>	VDVDDS1 = 1.65V, I <sub>OL</sub> = 3mA			0.4	V
Output High Voltage	V <sub>OH</sub>	VDVDDS1 = 1.65V, I <sub>OH</sub> = 3mA	DVDDS1 - 0.4			V
Input Leakage Current	I <sub>IH</sub> , I <sub>IL</sub>	VDVDD = 2.0V, V <sub>IN</sub> = 0V, 5.5V; T <sub>A</sub> = +25°C, high-impedance state	-1		+1	μA
<b>SDINS2, BCLKS2, LRCLKS2—INPUT</b>						
Input High Voltage	V <sub>IH</sub>		0.7 x DVDDS2			V
Input Low Voltage	V <sub>IL</sub>			0.29 x DVDDS2		V
Input Hysteresis				200		mV
Input Leakage Current	I <sub>IH</sub> , I <sub>IL</sub>	VDVDDS2 = 3.6V, V <sub>IN</sub> = 0V, 3.6V; T <sub>A</sub> = +25°C	-1		+1	μA
Input Capacitance				10		pF
<b>BCLKS2, LRCLKS2, SDOUTS2—OUTPUT</b>						
Output Low Voltage	V <sub>OL</sub>	VDVDDS2 = 1.65V, I <sub>OL</sub> = 3mA			0.4	V
Output High Voltage	V <sub>OH</sub>	VDVDDS2 = 1.65V, I <sub>OH</sub> = 3mA	DVDDS2 - 0.4			V
Input Leakage Current	I <sub>IH</sub> , I <sub>IL</sub>	VDVDD = 2.0V, V <sub>IN</sub> = 0V, 5.5V; T <sub>A</sub> = +25°C, high-impedance state	-1		+1	μA
<b>SDA, SCL—INPUT</b>						
Input High Voltage	V <sub>IH</sub>		0.7 x DVDD			V
Input Low Voltage	V <sub>IL</sub>			0.3 x DVDD		V
Input Hysteresis				210		mV
Input Leakage Current	I <sub>IH</sub> , I <sub>IL</sub>	VDVDD = 2.0V, V <sub>IN</sub> = 0V, 5.5V; T <sub>A</sub> = +25°C	-1		+1	μA
Input Capacitance				10		pF
<b>SDA, <math>\overline{\text{IRQ}}</math>—OUTPUT</b>						
Output High Current	I <sub>OH</sub>	V <sub>OUT</sub> = 5.5V, T <sub>A</sub> = +25°C			1	mA
Output Low Voltage	V <sub>OL</sub>	VDVDD = 1.65V, I <sub>OL</sub> = 3mA			0.2 x DVDD	V
<b>DIGMICDATA—INPUT</b>						
Input High Voltage	V <sub>IH</sub>		0.65 x DVDD			V
Input Low Voltage	V <sub>IL</sub>			0.35 x DVDD		V
Input Hysteresis				125		mV
Input Leakage Current	I <sub>IH</sub> , I <sub>IL</sub>	VDVDD = 2.0V, V <sub>IN</sub> = 0V, 2.0V; T <sub>A</sub> = +25°C	-25		+25	μA
Input Capacitance				10		pF

# MAX98088

## Stereo Audio Codec with FlexSound Technology

### DIGITAL INPUT/OUTPUT CHARACTERISTICS (continued)

(VAVDD = VPVDD = VDVDD = VDVDDS1 = VDVDDS2 = +1.8V, VSPKLVD = VSPKRVDD = 3.7V, TA = +25°C, unless otherwise noted.)  
(Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>DIGMICCLK—OUTPUT</b>						
Output Low Voltage	VOL	VDVDD = 1.65V, IOL = 1mA			0.4	V
Output High Voltage	VOH	VDVDD = 1.65V, IOH = 1mA	DVDD - 0.4			V

### INPUT CLOCK CHARACTERISTICS

(VAVDD = VPVDD = VDVDD = VDVDDS1 = VDVDDS2 = +1.8V, VSPKLVD = VSPKRVDD = 3.7V, TA = +25°C, unless otherwise noted.)  
(Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
MCLK Input Frequency	fMCLK		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

## Stereo Audio Codec with FlexSound Technology

### AUDIO INTERFACE TIMING CHARACTERISTICS

(VAVDD = VPVDD = VDvDD = VDvDdS1 = VDvDdS2 = +1.8V, VSPKLVDD = VSPKRVDD = 3.7V, TA = +25°C, unless otherwise noted.)  
(Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
BCLK Cycle Time	t <sub>BCLK</sub>	Slave mode	90			ns
BCLK High Time	t <sub>BCLKH</sub>	Slave mode	20			ns
BCLK Low Time	t <sub>BCLKL</sub>	Slave mode	20			ns
BCLK or LRCLK Rise and Fall Time	t <sub>R</sub> , t <sub>F</sub>	Master mode, C <sub>L</sub> = 15pF		5		ns
SDIN to BCLK Setup Time	t <sub>SETUP</sub>		20			ns
LRCLK to BCLK Setup Time	t <sub>SYNCSET</sub>	Slave mode	20			ns
SDIN to BCLK Hold Time	t <sub>HOLD</sub>		20			ns
LRCLK to BCLK Hold Time	t <sub>SYNCHOLD</sub>	Slave mode	20			ns
Minimum Delay Time from LSB BCLK Falling Edge to High-Impedance State	t <sub>HIZOUT</sub>	Master mode, TDM <sub>-</sub> = 1		42		ns
LRCLK Rising Edge to SDOUT MSB Delay	t <sub>SYNCTX</sub>	C <sub>L</sub> = 30pF, TDM <sub>-</sub> = 1, FSW <sub>-</sub> = 1			50	ns
BCLK to SDOUT Delay	t <sub>CLKTX</sub>	C <sub>L</sub> = 30pF, TDM <sub>-</sub> = 1, BCLK rising edge			50	ns
		TDM <sub>-</sub> = 0			50	
Delay Time from BCLK to LRCLK	t <sub>CLKSYNC</sub>	Master mode	TDM <sub>-</sub> = 1	-15	+15	ns
			TDM <sub>-</sub> = 0		0.8 x t <sub>BCLKL</sub>	
Delay Time from LRCLK to BCLK After LSB	t <sub>ENDSYNC</sub>	Master mode, TDM <sub>-</sub> = 1, FSW <sub>-</sub> = 1	20			ns

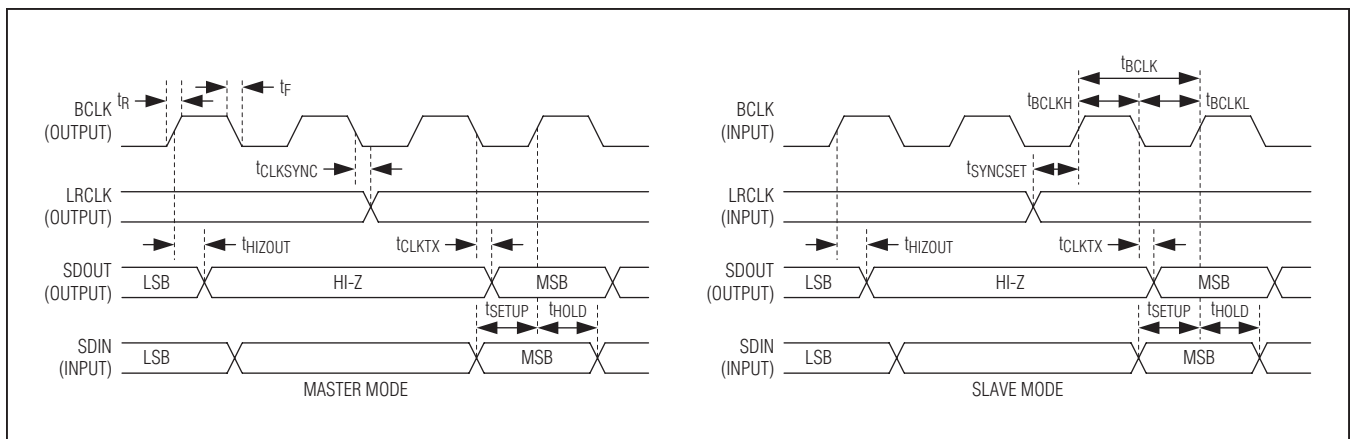


Figure 1. Non-TDM Audio Interface Timing Diagrams (TDM<sub>-</sub> = 0)

## Stereo Audio Codec with FlexSound Technology

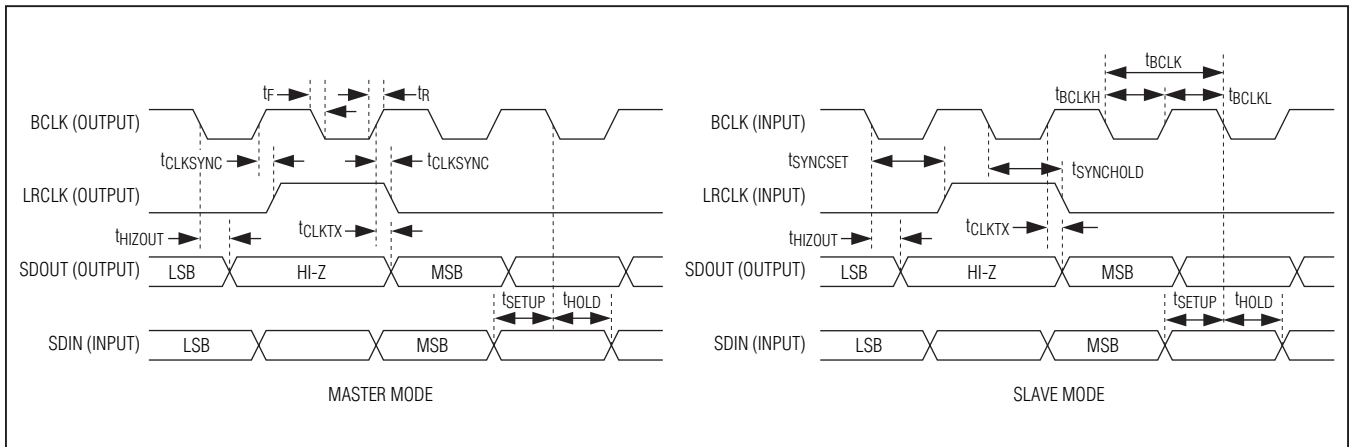


Figure 2. TDM Audio Interface Timing Diagram ( $TDM\_ = 1, FSW\_ = 0$ )

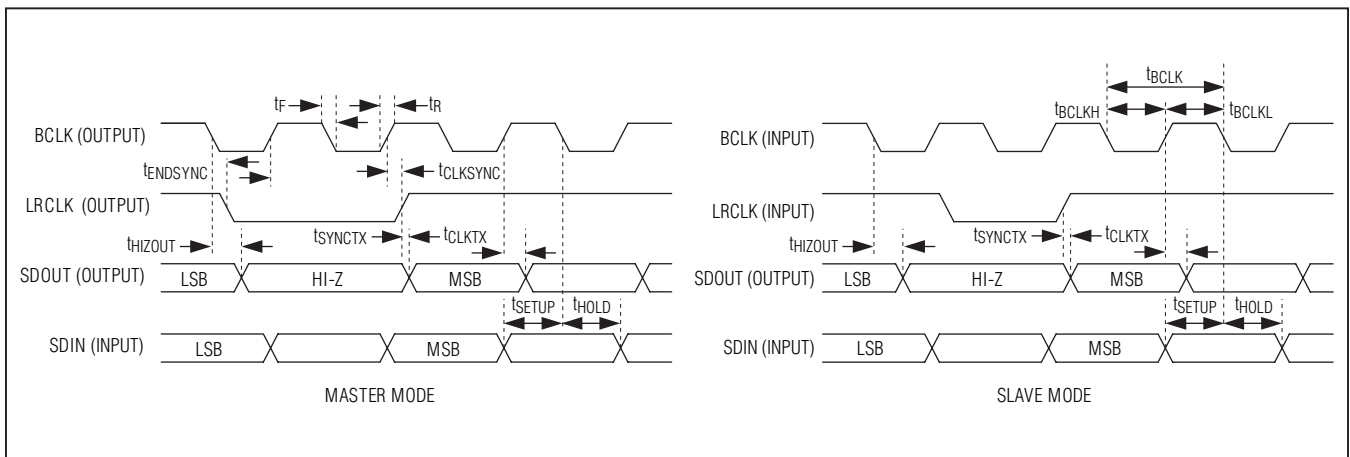


Figure 3. TDM Audio Interface Timing Diagram ( $TDM\_ = 1, FSW\_ = 1$ )

### DIGITAL MICROPHONE TIMING CHARACTERISTICS

( $V_{AVDD} = V_{PVDD} = V_{DVDD} = V_{DVDD1} = V_{DVDD2} = +1.8V$ ,  $V_{SPKLVDD} = V_{SPKRVDD} = 3.7V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)  
(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



# MAX98088

## Stereo Audio Codec with FlexSound Technology

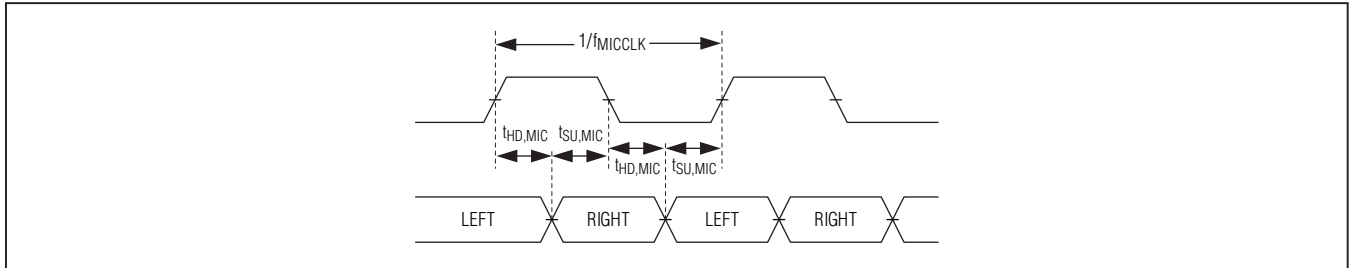


Figure 4. Digital Microphone Timing Diagram

### I<sup>2</sup>C TIMING CHARACTERISTICS

( $V_{AVDD} = V_{PVDD} = V_{DVDD} = V_{DVDDS1} = V_{DVDDS2} = +1.8V$ ,  $V_{SPKLVDD} = V_{SPKRVDD} = 3.7V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)  
(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			$\mu s$
Hold Time (Repeated) START Condition	$t_{HD,STA}$		0.6			$\mu s$
SCL Pulse-Width Low	$t_{LOW}$		1.3			$\mu s$
SCL Pulse-Width High	$t_{HIGH}$		0.6			$\mu s$
Setup Time for a Repeated START Condition	$t_{SU,STA}$		0.6			$\mu s$
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			$\mu s$
Bus Capacitance	$C_B$	Guaranteed by SDA transmitting fall time			400	pF
Pulse Width of Suppressed Spike	$t_{SP}$		0		50	ns

## Stereo Audio Codec with FlexSound Technology

### I<sup>2</sup>C TIMING CHARACTERISTICS (continued)

(V<sub>AVDD</sub> = V<sub>PVDD</sub> = V<sub>DVDD</sub> = V<sub>DVDD</sub>S1 = V<sub>DVDD</sub>S2 = +1.8V, V<sub>SPKLVD</sub> = V<sub>SPKRVD</sub> = 3.7V. T<sub>A</sub> = +25°C, unless otherwise noted.)  
(Note 1)

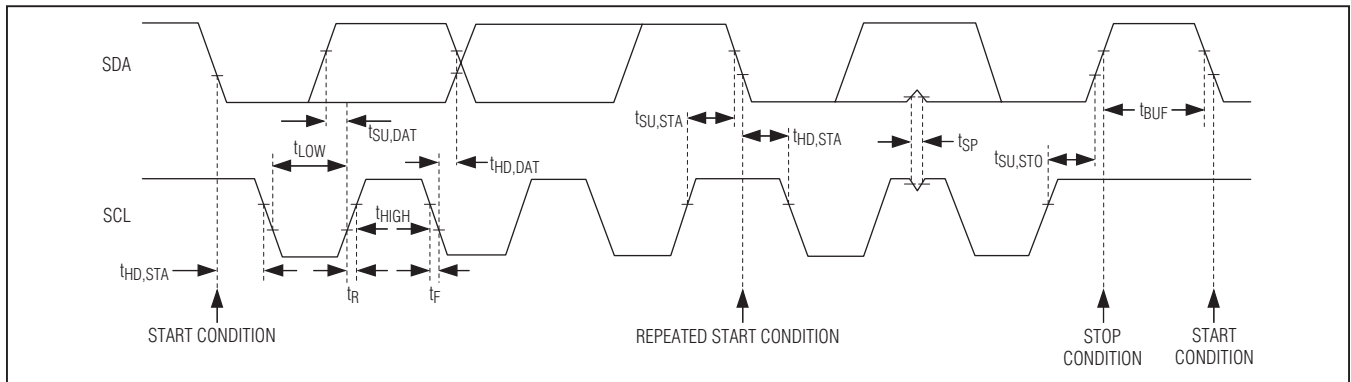


Figure 5. I<sup>2</sup>C Interface Timing Diagram

- Note 1:** The IC is 100% production tested at T<sub>A</sub> = +25°C. Specifications over temperature limits are guaranteed by design.
- Note 2:** Analog supply current = I<sub>AVDD</sub> + I<sub>HPVDD</sub>. Speaker supply current = I<sub>SPKLVD</sub> + I<sub>SPKRVD</sub>. Digital supply current = I<sub>DVDD</sub> + I<sub>DVDD</sub>S1 + I<sub>DVDD</sub>S2.
- Note 3:** Clocking all zeros into the DAC.
- Note 4:** Dynamic range measured using the EIAJ method. -60dBFS, 1kHz output signal, A-weighted and normalized to 0dBFS. f = 20Hz 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 0x1000.
- Note 7:** 0dBFS for DAC input. 1V<sub>p-p</sub> 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<sub>AVDD</sub> = V<sub>PVDD</sub> = V<sub>DVDD</sub> = V<sub>DVDD</sub>S1 = V<sub>DVDD</sub>S2 = 1.8V, V<sub>SPKLVD</sub> = V<sub>SPKRVD</sub> = 3.7V)

MODE	I <sub>AVDD</sub> (mA)	I <sub>PVDD</sub> (mA)	I <sub>SPKVDD</sub> + I <sub>SPKLVDD</sub> (mA)	I <sub>DVDD</sub> (mA)	I <sub>DVDD</sub> S1 + I <sub>DVDD</sub> S2 (mA)	POWER (mW)	DYNAMIC RANGE (dB)
<b>PLAYBACK TO HEADPHONE ONLY</b>							
<b>DAC Playback 48kHz Stereo HP</b> DAC → HP Low power mode, 24-bit, music filters, 256Fs	1.25	0.47	0.00	1.35	0.01	5.55	97
<b>DAC Playback 48kHz Stereo HP</b> DAC → HP Low power mode, 24-bit, music filters, 256Fs, 0.1mW/channel, R <sub>HP</sub> = 32Ω	1.25	1.81	0.00	1.56	0.01	8.32	97