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# MAX98089

## Low-Power, Stereo Audio Codec with FlexSound Technology

### General Description

The MAX98089 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.*

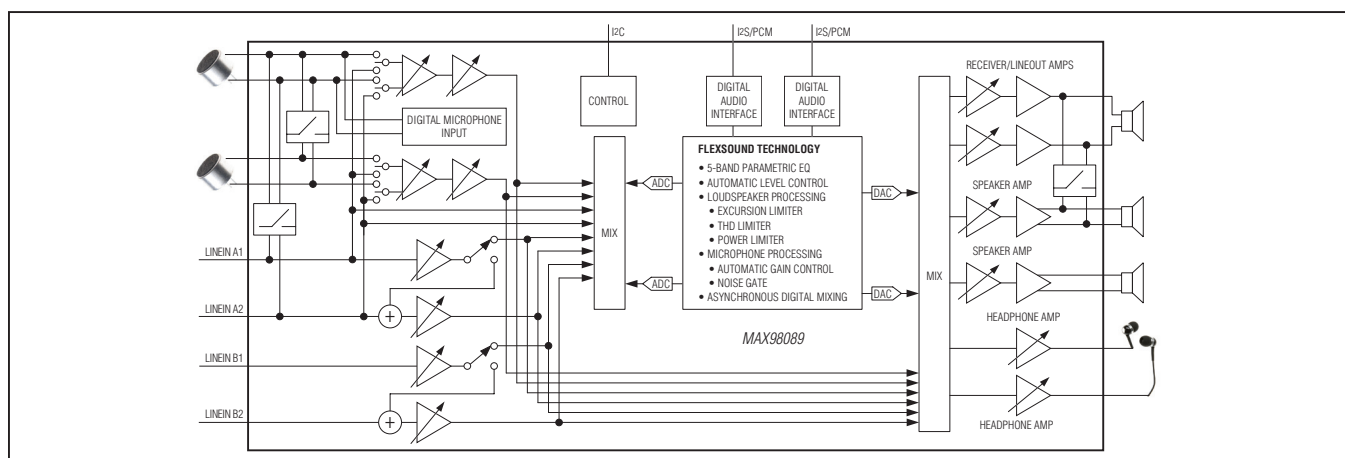
### Features

- ◆ 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
  - 1.7W/Channel (8Ω, V<sub>SPK\_VDD</sub> = 5.0V)
  - 2.9W/Channel (4Ω, V<sub>SPK\_VDD</sub> = 5.0V)
- ◆ 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) and 56-Pin TQFN Package (7mm x 7mm x 0.75mm)

*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/MAX98089.related](http://www.maxim-ic.com/MAX98089.related).

### Simplified Block Diagram



For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim's website at [www.maximintegrated.com](http://www.maximintegrated.com).

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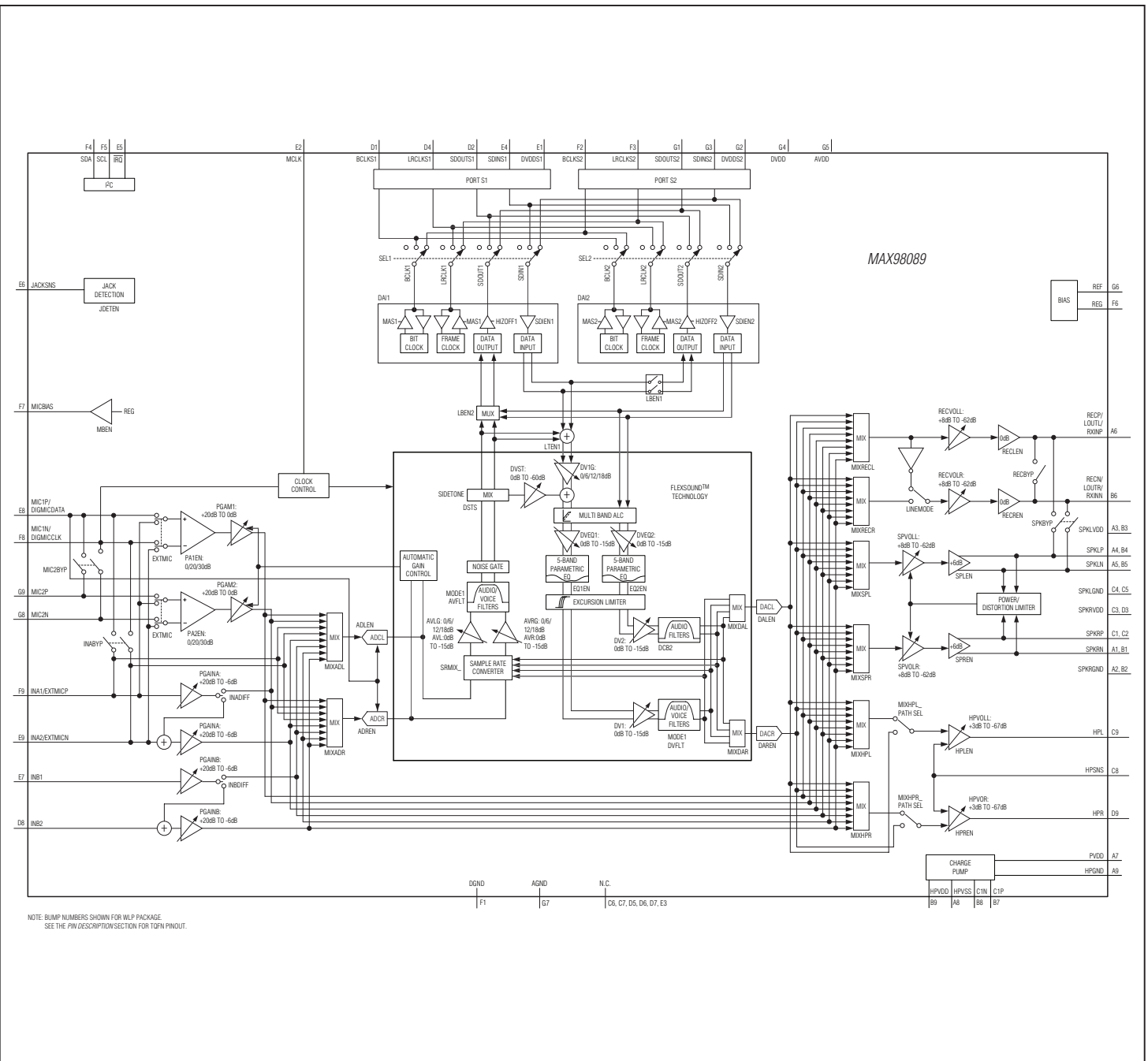
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## Low-Power, Stereo Audio Codec with FlexSound Technology

Functional Diagram



# MAX98089

## Low-Power, 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.....  | (VHPGND - 2.2V) to (VHPGND + 0.3V) |
| C1N.....  | (VHPVSS - 0.3V) to (VHPGND + 0.3V) |
| C1P.....  | (VHPGND - 0.3V) to (VHPVDD + 0.3V) |
| REF, MICBIAS.....   | -0.3V to (VSPKLVDD + 0.3V)         |
| MCLK, SDINS1, SDINS2, JACKSNS,<br>SDA, SCL, I <sup>2</sup> C.....                                       | -0.3V to +6.0V                     |
| LRCLKS1, BCLKS1, SDOUS1.....  | -0.3V to (VDVDS1 + 0.3V)           |
| LRCLKS2, BCLKS2, SDOUS2.....  | -0.3V to (VDVDS2 + 0.3V)           |
| REG, INA1/EXTMICP, INA2/EXTMICN, INB1, INB2,<br>MIC1P/DIGMICDATA, MIC1N/DIGMICCLK,<br>MIC2P, MIC2N..... | -0.3V to +2.2V                     |

|   |  |
|---|--|
| HPSNS.....  | (VHPGND - 0.3V) to (VHPGND + 0.3V)     |
| HPL, HPR.....   | (VHPVSS - 0.3V) to (VHPVDD + 0.3V)     |
| RECP/LOUTL/RXINP, RECP/LOUTR/<br>RXINN.....           | (VSPKLGND - 0.3V) to (VSPKLVDD + 0.3V) |
| SPKLP, SPKLN.....                                     | (VSPKLGND - 0.3V) to (VSPKLVDD + 0.3V) |
| SPKRP, SPKRN.....                                     | (VSPKRGND - 0.3V) to (VSPKRVDD + 0.3V) |
| Continuous Power Dissipation (T <sub>A</sub> = +70°C) |  |
| 63-Bump WLP (derate 25.6mW/°C above +70°C).....       | 2.05W                                  |
| 56-Pin TQFN (derate 40mW/°C above +70°C).....         | 3.2W                                   |
| Operating Temperature Range.....                      | -40°C to +85°C                         |
| Storage Temperature Range.....                        | -65°C to +150°C                        |
| Lead Temperature (TQFN only, soldering, 10s).....     | +300°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\_N. Headphone loads (R<sub>HP</sub>) connected from HPL or HPR to HPGND. Line out loads (R<sub>LOUT</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>HPL</sub> = 0dB, AV<sub>REC</sub> = 0dB, AV<sub>SPK</sub> = 0dB, MCLK = 12.288MHz, LRCLK = 48kHz, MAS = 0. T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Note 1)

| PARAMETER                               | SYMBOL | CONDITIONS  | MIN                  | TYP  | MAX   | UNITS  |     |
|---|--------|---|----------------------|------|-------|--------|-----|
| <b>POWER SUPPLY</b>                     |        |   |                      |      |       |        |     |
| Supply Voltage Range                    |        | Guaranteed by PSRR  | VSPKLVDD, VSPKRVDD   | 2.8  | 5.5   | V      |     |
|   |        |   | DVDD, VAVDD, VPVDD   | 1.65 | 1.8   |        | 2   |
|   |        |   | DVDDS1, DVDDS2       | 1.65 |       |        | 3.6 |
| Total Supply Current<br>(Notes 2 and 3) | IVDD   | Full-duplex 8kHz mono,<br>receiver output, MAS = 1          | Analog               |      | 4.5   | 8      | mA  |
|   |        |   | Speaker              |      | 1.6   | 2.3    |     |
|   |        |   | Digital              |      | 1.3   | 2      |     |
|   |        | DAC playback 48kHz<br>stereo, headphone<br>outputs, MAS = 1 | Analog               |      | 1.9   | 3      |     |
|   |        |   | Speaker              |      | 0.001 | 0.0058 |     |
|   |        |   | Digital              |      | 2.47  | 3.5    |     |
|   |        | DAC playback 48kHz<br>stereo, speaker outputs,<br>MAS = 1   | Analog               |      | 3.6   | 6.5    |     |
|   |        |   | Speaker              |      | 6.41  | 8.5    |     |
|   |        |   | Digital              |      | 2.49  | 3.5    |     |
| Shutdown Supply Current<br>(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    |        |     |

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## Low-Power, Stereo Audio Codec with FlexSound Technology

### ELECTRICAL CHARACTERISTICS (continued)

( $V_{AVDD} = V_{PVDD} = V_{DVDD} = V_{DVDDS1} = V_{DVDDS2} = 1.8V$ ,  $V_{SPKLVDD} = V_{SPKRVDD} = 3.7V$ . 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  $HPGND$ . Line out loads ( $R_{LOUT}$ ) connected from  $LOUTL$  or  $LOUTR$  to  $SPKLGND$ .  $R_{LOAD} = R_{HP} = \infty$ ,  $R_{REC} = \infty$ ,  $Z_{SPK} = \infty$ ,  $C_{REF} = 2.2\mu F$ ,  $C_{MICBIAS} = C_{REG} = 1\mu F$ ,  $C_{C1N-C1P} = 1\mu F$ ,  $CHPVDD = CHPVSS = 1\mu F$ .  $AV_{MICPRE\_} = +20dB$ ,  $AV_{MICPGA\_} = 0dB$ ,  $AV_{DACATTN} = 0dB$ ,  $AV_{DACGAIN} = 0dB$ ,  $AV_{ADCLVL} = 0dB$ ,  $AV_{ADCGAIN} = 0dB$ ,  $AV_{PGAIN\_} = 0dB$ ,  $AV_{HP\_} = 0dB$ ,  $AV_{REC} = 0dB$ ,  $AV_{SPK\_} = 0dB$ ,  $MCLK = 12.288MHz$ ,  $LRCLK = 48kHz$ ,  $MAS = 0$ .  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .) (Note 1)

| PARAMETER                         | SYMBOL          | CONDITIONS   | MIN                          | TYP  | MAX  | UNITS     |      |
|-----------------------------------|-----------------|--|------------------------------|------|------|-----------|------|
| <b>MICROPHONE TO ADC PATH</b>     |                 |  |                              |      |      |           |      |
| Dynamic Range                     | DR              | $f_S = 8kHz$ , $MODE = 0$ (IIR voice), $AV_{MICPRE\_} = 0dB$ (Note 4)                  |                              | 88   |      | dB        |      |
| Total Harmonic Distortion + Noise | THD+N           | $V_{IN} = 0.1VP-P$ , $f_S = 8kHz$ , $f = 1kHz$   |                              | -78  |      | dB        |      |
|                                   |                 | $AV_{MICPRE\_} = 0dB$ , $V_{IN} = 1VP-P$ , $f = 1kHz$                                  |                              | -85  |      |           |      |
|                                   |                 | $AV_{MICPRE\_} = +30dB$ , $V_{IN} = 32mVP-P$ , $f = 1kHz$                              |                              | -71  |      |           |      |
| Common-Mode Rejection Ratio       | CMRR            | $V_{IN} = 100mVP-P$ , $f = 217Hz$  |                              | 74   |      | dB        |      |
| Power-Supply Rejection Ratio      | PSRR            | $V_{AVDD} = 1.65V$ to $1.95V$ , input referred, MIC inputs unconnected                 | 50                           | 62   |      | dB        |      |
|                                   |                 | $f = 217Hz$ , $V_{RIPPLE} = 200mVP-P$ , input referred                                 |                              | 62   |      |           |      |
|                                   |                 | $f = 1kHz$ , $V_{RIPPLE} = 200mVP-P$ , input referred                                  |                              | 62   |      |           |      |
|                                   |                 | $f = 10kHz$ , $V_{RIPPLE} = 200mVP-P$ , input referred                                 |                              | 55   |      |           |      |
| 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                  |                 | $AV_{MICPRE\_} = 0dB$  |                              | 1.05 |      | $V_{P-P}$ |      |
| Preamplifier Gain                 | $AV_{MICPRE\_}$ | (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                          | $AV_{MICPGA\_}$ | (Note 5)   | $PGAM1/PGAM2 = 0x00$         | 19   | 20   | 21        | dB   |
|                                   |                 |  | $PGAM1/PGAM2 = 0x14$         |      | 0    |           |      |
| MIC Input Resistance              | $R_{IN\_MIC}$   | All gain settings, measured at $MIC1P/MIC1N/MIC2P/MIC2N$                               |                              | 50   |      | $k\Omega$ |      |



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## Low-Power, 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 (RLOUT) 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 = 0. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +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  |      | nV/√Hz |
| <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 unconnected, 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  |      |        |

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## Low-Power, 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 RECN. Headphone loads (RH P) connected from HPL or HPR to HPGND. Line out loads (RLOUT) 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 = 0. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

| PARAMETER  | SYMBOL    | CONDITIONS                    | MIN                           | TYP  | MAX | UNITS |    |
|--|-----------|-------------------------------|-------------------------------|------|-----|-------|----|
| <b>LINE INPUT PREAMP</b>                         |           |                               |                               |      |     |       |    |
| Full-Scale Input                                 | VIN       | AVPGAIN_ = 0dB                | 1                             |      |     | Vp-P  |    |
|  |           | AVPGAIN_ = -6dB               | 1.4                           |      |     |       |    |
| Level Adjust Gain                                | AVPGAIN_  | TA = +25°C<br>(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/INBEXT = 1             | TA = +25°C                    | 18   | 20  | 22    | kΩ |
|  |           |                               | TA = TMIN to TMAX             | 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                                  | 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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## Low-Power, 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 RECN. Headphone loads (RH P) connected from HPL or HPR to HPGND. Line out loads (RLOUT) 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 = 0. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

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

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## Low-Power, 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 RECN. Headphone loads (RH P) connected from HPL or HPR to HPGND. Line out loads (RLOUT) 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 = 0. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

| PARAMETER  | SYMBOL    | CONDITIONS   | MIN   | TYP      | MAX | UNITS |
|--|-----------|--|-------|----------|-----|-------|
| <b>STEREO AUDIO MODE DC BLOCKING HIGHPASS FILTER (MODE1 = 1)</b> |           |  |       |          |     |       |
| Passband Cutoff (-3dB from Peak)                                 | fAHPPB    | AVFLT ≠ 000  |       | 0.000125 |     | Hz    |
|  |           |  |       | x fS     |     |       |
| 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    |

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## Low-Power, 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 RECN. Headphone loads (RH P) connected from HPL or HPR to HPGND. Line out loads (RLOUT) 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 = 0. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +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    |

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## Low-Power, 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 RECN. Headphone loads (RH P) connected from HPL or HPR to HPGND. Line out loads (RLOUT) 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 = 0. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +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    |
| Output Offset Voltage   | V <sub>OS</sub>    | AVREC_ = -62dB, TA = +25°C, WLP package only          |                       | ±0.5 | ±4                        | mV    |
| 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> |                       | 80   |                           |       |
|   |                    | f = 1kHz, V <sub>RIPPLE</sub> = 200mV <sub>P-P</sub>  |                       | 80   |                           |       |
|   |                    | f = 10kHz, V <sub>RIPPLE</sub> = 200mV <sub>P-P</sub> |                       | 77   |                           |       |

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## Low-Power, 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 RECN. Headphone loads (RHHP) connected from HPL or HPR to HPGND. Line out loads (RLOUT) 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 = 0. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

| PARAMETER                                    | SYMBOL | CONDITIONS   |                 | MIN | TYP  | MAX | UNITS            |
|--|--------|--|-----------------|-----|------|-----|------------------|
| Click-and-Pop Level                          | KCP    | Peak voltage, A-weighted, 32 samples per second, AVREC = 0dB | Into shutdown   |     | -68  |     | dBV              |
|  |        |  | Out of shutdown |     | -72  |     |                  |
| <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                          | KCP    | Peak voltage, A-weighted, 32 samples per second, AVREC = 0dB | Into shutdown   |     | -51  |     | dBV              |
|  |        |  | Out of shutdown |     | -49  |     |                  |
| <b>RECEIVER AMPLIFIER</b>                    |        |  |                 |     |      |     |                  |
| Output Power                                 | POUT   | RREC = 32Ω, f = 1kHz, THD = 1%                               |                 |     | 92   |     | mW               |
| Full-Scale Output                            |        | (Note 7)   |                 |     | 1    |     | V <sub>RMS</sub> |
| Volume Control (Note 5)                      | AVREC  | 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                                    | RREC = 32Ω      |     | 500  |     | pF               |
|  |        |  | RREC = ∞        |     | 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                        | VOS    | AVREC_ = -62dB, TQFN package only                            |                 |     | ±0.5 | ±4  | mV               |
| Capacitive Drive Capability                  |        | No sustained oscillations, R <sub>L</sub> = 1kΩ              |                 |     | 500  |     | pF               |

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## Low-Power, 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 RECN. Headphone loads (RH P) connected from HPL or HPR to HPGND. Line out loads (RLOUT) 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 = 0. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +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   |      | μVRMS |
| 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 = 10%, Z <sub>SPK</sub> = 4Ω + 33μH                 | VSPKLVDD = VSPKRVDD = 5.0V |     | 2950 |      | mW    |
|  |                            |   | VSPKLVDD = VSPKRVDD = 4.2V |     | 2060 |      |       |
|  |                            |   | VSPKLVDD = VSPKRVDD = 3.7V |     | 1570 |      |       |
|  |                            |   | VSPKLVDD = VSPKRVDD = 3.0V |     | 1000 |      |       |
|  |                            | f = 1kHz, THD = 1%, Z <sub>SPK</sub> = 4Ω + 33μH                  | VSPKLVDD = VSPKRVDD = 5.0V |     | 2320 |      |       |
|  |                            |   | VSPKLVDD = VSPKRVDD = 4.2V |     | 1620 |      |       |
|  |                            |   | VSPKLVDD = VSPKRVDD = 3.7V |     | 1240 |      |       |
|  |                            |   | VSPKLVDD = VSPKRVDD = 3.0V |     | 785  |      |       |
|  |                            | f = 1kHz, THD = 10%, Z <sub>SPK</sub> = 8Ω + 68μH                 | VSPKLVDD = VSPKRVDD = 5.0V |     | 1730 |      |       |
|  |                            |   | VSPKLVDD = VSPKRVDD = 4.2V |     | 1210 |      |       |
|  |                            |   | VSPKLVDD = VSPKRVDD = 3.7V |     | 930  |      |       |
|  |                            |   | VSPKLVDD = VSPKRVDD = 3.0V |     | 600  |      |       |
| f = 1kHz, THD = 1%, Z <sub>SPK</sub> = 8Ω + 68μH | VSPKLVDD = VSPKRVDD = 5.0V |   | 1365                       |     |      |      |       |
|  | VSPKLVDD = VSPKRVDD = 4.2V |   | 955                        |     |      |      |       |
|  | VSPKLVDD = VSPKRVDD = 3.7V |   | 735                        |     |      |      |       |
|  | VSPKLVDD = VSPKRVDD = 3.0V |   | 475                        |     |      |      |       |
| Full-Scale Output                                |                            | (Note 7)  |                            | 2   |      | VRMS |       |
| Volume Control                                   | AVSPK_                     | (Note 5)  | SPVOLL/SPVOLR = 0x00       |     | -62  |      | dB    |
|  |                            |   | SPVOLL/SPVOLR = 0x1F       |     | +8   |      |       |



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## Low-Power, 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 RECN. Headphone loads (RH P) connected from HPL or HPR to HPGND. Line out loads (RLOUT) 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 = 0. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

| PARAMETER                       | SYMBOL | CONDITIONS  | MIN         | TYP  | MAX  | UNITS |
|---------------------------------|--------|---|-------------|------|------|-------|
| Volume Control Step Size        |        | +8dB to +6dB  |             | 0.5  |      | dB    |
|                                 |        | +6dB to +0dB  |             | 1    |      |       |
|                                 |        | 0dB to -14dB  |             | 2    |      |       |
|                                 |        | -14dB to -38dB  |             | 3    |      |       |
|                                 |        | -38dB to -64dB  |             | 4    |      |       |
| Mute Attenuation                |        | f = 1kHz  |             | 86   |      | dB    |
| Output Offset Voltage           | VOS    | AVSPK_ = -61dB, TA = +25°C                                  |             | ±0.5 | ±3   | mV    |
| <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, VSP-KLVDD = VSPKRVDD = 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, VSP-KLVDD = VSPKRVDD = 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  |      |       |

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## Low-Power, Stereo Audio Codec with FlexSound Technology

### ELECTRICAL CHARACTERISTICS (continued)

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| 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,<br>TA = +25°C                 | 95   | 97  |       |
| Total Harmonic Distortion + Noise             | THD+N  | f = 1kHz, POUT = 20mW  | RHP = 16Ω                                     | -84  | -64 | dB    |
|   |        |  | RHP = 32Ω                                     | -85  |     |       |
| Crosstalk                                     |        | HPL to HPR and HPR to HPL, POUT = 5mW,<br>f = 1kHz, RHP = 32Ω                          |   | -92  |     | dB    |
| Power-Supply Rejection Ratio                  | PSRR   | VA VDD = VP VDD = 1.65V to 2.0V  | f = 217Hz, VRIPPLE = 200mVP-P,<br>AVHP_ = 0dB | 46   | 54  | dB    |
|   |        |  | f = 1kHz, VRIPPLE = 200mVP-P,<br>AVHP_ = 0dB  | 72   |     |       |
|   |        |  | f = 1kHz, VRIPPLE = 200mVP-P,<br>AVHP_ = 0dB  | 63   |     |       |
|   |        |  | f = 10kHz, VRIPPLE = 200mVP-P,<br>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  |     |       |

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## Low-Power, 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 RECN. Headphone loads (RH P) connected from HPL or HPR to HPGND. Line out loads (RLOUT) 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 = 0. TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +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 × 0.2V, RHP = ∞  |                   | PVDD/2         |     | V                |
|  |        | VOUT > VPVDD × 0.2V, RHP = ∞  |                   | PVDD           |     |                  |
| Negative Charge-Pump Output Voltage  | HPVSS  | VOUT ≤ VPVDD × 0.2V, RHP = ∞  |                   | -PVDD/2        |     | V                |
|  |        | VOUT > VPVDD × 0.2V, 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<br>× 0.2 |     | V                |
| Full-Scale Output  |        | (Note 7)  |                   | 1              |     | V <sub>RMS</sub> |
| 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        | ±0.1           | ±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               |

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## Low-Power, Stereo Audio Codec with FlexSound Technology

### ELECTRICAL CHARACTERISTICS (continued)

( $V_{AVDD} = V_{PVDD} = V_{DVDD} = V_{DVDDS1} = V_{DVDDS2} = 1.8V$ ,  $V_{SPKLVDD} = V_{SPKRVDD} = 3.7V$ . 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  $HPGND$ . Line out loads ( $R_{LOUT}$ ) connected from  $LOUTL$  or  $LOUTR$  to  $SPKLGND$ .  $R_{LOAD} = R_{HP} = \infty$ ,  $R_{REC} = \infty$ ,  $Z_{SPK} = \infty$ ,  $C_{REF} = 2.2\mu F$ ,  $C_{MICBIAS} = C_{REG} = 1\mu F$ ,  $C_{C1N-C1P} = 1\mu F$ ,  $C_{HPVDD} = C_{HPVSS} = 1\mu F$ .  $AV_{MICPRE\_} = +20dB$ ,  $AV_{MICPGA\_} = 0dB$ ,  $AV_{DACATTN} = 0dB$ ,  $AV_{DACGAIN} = 0dB$ ,  $AV_{ADCLVL} = 0dB$ ,  $AV_{ADCGAIN} = 0dB$ ,  $AV_{PGAIN\_} = 0dB$ ,  $AV_{HP\_} = 0dB$ ,  $AV_{REC} = 0dB$ ,  $AV_{SPK\_} = 0dB$ ,  $MCLK = 12.288MHz$ ,  $LRCLK = 48kHz$ ,  $MAS = 0$ .  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .) (Note 1)

| PARAMETER                         | SYMBOL       | CONDITIONS  | MIN           | TYP           | MAX           | UNITS     |
|-----------------------------------|--------------|---|---------------|---------------|---------------|-----------|
| <b>RECEIVER BYPASS SWITCH</b>     |              |   |               |               |               |           |
| On-Resistance                     | $R_{ON}$     | $I_{RECP} = 100mA$ , $RECBYP = 1$ , $V_{RECN} = [0V, V_{SPKLVDD}]$  |               | 2             |               | $\Omega$  |
| Total Harmonic Distortion + Noise | THD+N        | $V_{IN} = 2VP-P$ , $V_{CM} = V_{SPKLVDD}/2$ , $Z_{SPK} = 8\Omega + 68\mu H$ , $f = 1kHz$ , $RECBYP = 1$ , $R_S = 0\Omega$ |               | 60            |               | %         |
| Off-Isolation                     |              | $V_{IN} = 2VP-P$ , $V_{CM} = V_{SPKLVDD}/2$ , $Z_{SPK} = 8\Omega + 68\mu H$ , $f = 1kHz$                                  |               | 84            |               | dB        |
| Off-Leakage Current               |              | $V_{RECP} = [0V, V_{SPKLVDD}]$ , $V_{RECN} = [V_{SPKLVDD}, 0V]$   | -15           |               | +15           | $\mu A$   |
| <b>JACK DETECTION</b>             |              |   |               |               |               |           |
| JACKSNS High Threshold            | $V_{TH1}$    | MICBIAS enabled   | 0.92 x        | 0.95 x        | 0.98 x        | V         |
|                                   |              |   | $V_{MICBIAS}$ | $V_{MICBIAS}$ | $V_{MICBIAS}$ |           |
| JACKSNS Low Threshold             | $V_{TH2}$    | MICBIAS enabled   | 0.06 x        | 0.10 x        | 0.17 x        | V         |
|                                   |              |   | $V_{MICBIAS}$ | $V_{MICBIAS}$ | $V_{MICBIAS}$ |           |
| JACKSNS Sense Voltage             |              | MICBIAS disabled, $JDWK = 1$  | 3.65          | 3.7           |               |           |
| JACKSNS Sense Resistance          | $R_{SENSE}$  | MICBIAS disabled, $JDWK = 0$  | 1.6           | 2.4           | 2.9           | $k\Omega$ |
| JACKSNS Weak Pullup Current       | $I_{WPU}$    | MICBIAS disabled, $JDWK = 1$  | 2             | 5             | 9.5           | $\mu A$   |
| JACKSNS Deglitch Period           | $t_{GLITCH}$ | $JDEB = 00$   |               | 25            |               | ms        |
|                                   |              | $JDEB = 11$   |               | 200           |               |           |
| <b>BATTERY ADC</b>                |              |   |               |               |               |           |
| Input Voltage Range               |              |   | 2.6           |               | 5.6           | V         |
| LSB Size                          |              |   |               | 0.1           |               | V         |

### DIGITAL INPUT/OUTPUT 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   |
|-----------------------|------------------|---|-----|-----|-----|---------|
| <b>MCLK</b>           |                  |   |     |     |     |         |
| Input High Voltage    | $V_{IH}$         |   | 1.2 |     |     | V       |
| Input Low Voltage     | $V_{IL}$         |   |     |     | 0.6 | V       |
| Input Leakage Current | $I_{IH}, I_{IL}$ | $V_{DVDD} = 2.0V$ , $V_{IN} = 0V, 5.5V$ ; $T_A = +25^\circ C$ | -1  |     | +1  | $\mu A$ |
| Input Capacitance     |                  |   |     | 10  |     | pF      |

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## Low-Power, Stereo Audio Codec with FlexSound Technology

### DIGITAL INPUT/OUTPUT CHARACTERISTICS (continued)

(VAVDD = VPVDD = VD VDD = DVDD S1 = DVDD S2 = 1.8V, VSPKLVDD = VSPKRVDD = 3.7V, T<sub>A</sub> = +25°C, unless otherwise noted.)  
(Note 1)

| PARAMETER   | SYMBOL                            | CONDITIONS  | MIN              | TYP               | MAX           | UNITS |
|---|-----------------------------------|---|------------------|-------------------|---------------|-------|
| <b>SDINS1, BCLKS1, LRCLKS1—INPUT</b>                  |                                   |   |                  |                   |               |       |
| Input High Voltage                                    | V <sub>IH</sub>                   |   | 0.7 x<br>DVDD S1 |                   |               | V     |
| Input Low Voltage                                     | V <sub>IL</sub>                   |   |                  | 0.29 x<br>DVDD S1 |               | V     |
| Input Hysteresis                                      |                                   |   | 200              |                   |               | mV    |
| Input Leakage Current                                 | I <sub>IH</sub> , I <sub>IL</sub> | VDVDD S1 = 3.6V, V <sub>IN</sub> = 0V, 3.6V; T <sub>A</sub> = +25°C                       | -1               |                   | +1            | μA    |
| Input Capacitance                                     |                                   |   | 10               |                   |               | pF    |
| <b>BCLKS1, LRCLKS1, SDOUTS1—OUTPUT</b>                |                                   |   |                  |                   |               |       |
| Output Low Voltage                                    | V <sub>OL</sub>                   | VDVDD S1 = 1.65V, I <sub>OL</sub> = 3mA   |                  |                   | 0.4           | V     |
| Output High Voltage                                   | V <sub>OH</sub>                   | VDVDD S1 = 1.65V, I <sub>OH</sub> = 3mA   | DVDD S1<br>- 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,<br>high-impedance state | -1               |                   | +1            | μA    |
| <b>SDINS2, BCLKS2, LRCLKS2—INPUT</b>                  |                                   |   |                  |                   |               |       |
| Input High Voltage                                    | V <sub>IH</sub>                   |   | 0.7 x<br>DVDD S2 |                   |               | V     |
| Input Low Voltage                                     | V <sub>IL</sub>                   |   |                  | 0.29 x<br>DVDD S2 |               | V     |
| Input Hysteresis                                      |                                   |   | 200              |                   |               | mV    |
| Input Leakage Current                                 | I <sub>IH</sub> , I <sub>IL</sub> | VDVDD S2 = 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>                   | VDVDD S2 = 1.65V, I <sub>OL</sub> = 3mA   |                  |                   | 0.4           | V     |
| Output High Voltage                                   | V <sub>OH</sub>                   | VDVDD S2 = 1.65V, I <sub>OH</sub> = 3mA   | DVDD S2<br>- 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,<br>high-impedance state | -1               |                   | +1            | μA    |
| <b>SDA, SCL—INPUT</b>                                 |                                   |   |                  |                   |               |       |
| Input High Voltage                                    | V <sub>IH</sub>                   |   | 0.7 x<br>DVDD    |                   |               | V     |
| Input Low Voltage                                     | V <sub>IL</sub>                   |   |                  | 0.3 x<br>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<br>DVDD | V     |

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## Low-Power, Stereo Audio Codec with FlexSound Technology

### DIGITAL INPUT/OUTPUT CHARACTERISTICS (continued)

(VAVDD = VPVDD = VD VDD = VD VDDS1 = VD VDDS2 = 1.8V, VSPKLVDD = VSPKRVDD = 3.7V, TA = +25°C, unless otherwise noted.)  
(Note 1)

| PARAMETER               | SYMBOL                            | CONDITIONS   | MIN            | TYP | MAX            | UNITS |
|-------------------------|-----------------------------------|--|----------------|-----|----------------|-------|
| <b>DIGMICDATA—INPUT</b> |                                   |  |                |     |                |       |
| Input High Voltage      | V <sub>IH</sub>                   |  | 0.65 x<br>DVDD |     |                | V     |
| Input Low Voltage       | V <sub>IL</sub>                   |  |                |     | 0.35 x<br>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; TA = +25°C | -25            |     | +25            | μA    |
| Input Capacitance       |                                   |  |                | 10  |                | pF    |
| <b>DIGMICCLK—OUTPUT</b> |                                   |  |                |     |                |       |
| Output Low Voltage      | V <sub>OL</sub>                   | VDVDD = 1.65V, I <sub>OL</sub> = 1mA                 |                |     | 0.4            | V     |
| Output High Voltage     | V <sub>OH</sub>                   | VDVDD = 1.65V, I <sub>OH</sub> = 1mA                 | DVDD -<br>0.4  |     |                | V     |

### INPUT CLOCK CHARACTERISTICS

(VAVDD = VPVDD = VD VDD = VD VDDS1 = VD VDDS2 = 1.8V, VSPKLVDD = VSPKRVDD = 3.7V, TA = +25°C, unless otherwise noted.)  
(Note 1)

| PARAMETER                                   | SYMBOL            | CONDITIONS           | MIN    | TYP | MAX    | UNITS             |
|---|-------------------|----------------------|--------|-----|--------|-------------------|
| MCLK Input Frequency                        | f <sub>MCLK</sub> |                      | 10     |     | 60     | MHz               |
| MCLK Input Duty Cycle                       |                   | PSCLK = 01           | 40     | 50  | 60     | %                 |
|   |                   | PSCLK = 10 or 11     | 30     |     | 70     |                   |
| Maximum MCLK Input Jitter                   |                   |                      |        | 100 |        | ps <sub>RMS</sub> |
| LRCLK Sample Rate (Note 8)                  |                   | DHF <sub>-</sub> = 0 | 8      |     | 48     | kHz               |
|   |                   | DHF <sub>-</sub> = 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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## Low-Power, Stereo Audio Codec with FlexSound Technology

### AUDIO INTERFACE TIMING CHARACTERISTICS

(VAVDD = VPVDD = VD VDD = VD V D D S 1 = VD V D D S 2 = 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<br>BCLK Falling Edge to<br>High-Impedance State | t <sub>HIZOUT</sub>             | Master mode, TDM <sub>0</sub> = 1                                 |  | 42  |                             | ns    |
| LRCLK Rising Edge to SDOUT<br>MSB Delay                                     | t <sub>SYNCTX</sub>             | C <sub>L</sub> = 30pF, TDM <sub>0</sub> = 1, FSW <sub>0</sub> = 1 |  |     | 50                          | ns    |
| BCLK to SDOUT Delay   | t <sub>CLKTX</sub>              | C <sub>L</sub> = 30pF   | TDM <sub>0</sub> = 1, BCLK rising edge     |     | 50                          | ns    |
|   |                                 |   | TDM <sub>0</sub> = 0                       |     | 50                          |       |
| Delay Time from BCLK to LRCLK   | t <sub>CLKSYNC</sub>            | Master mode   | TDM <sub>0</sub> = 1                       | -15 | +15                         | ns    |
|   |                                 |   | TDM <sub>0</sub> = 0                       |     | 0.8 x<br>t <sub>BCLKL</sub> |       |
| Delay Time from LRCLK to BCLK<br>After LSB                                  | t <sub>ENDSYNC</sub>            | Master mode   | TDM <sub>0</sub> = 1, FSW <sub>0</sub> = 1 | 20  |                             | ns    |

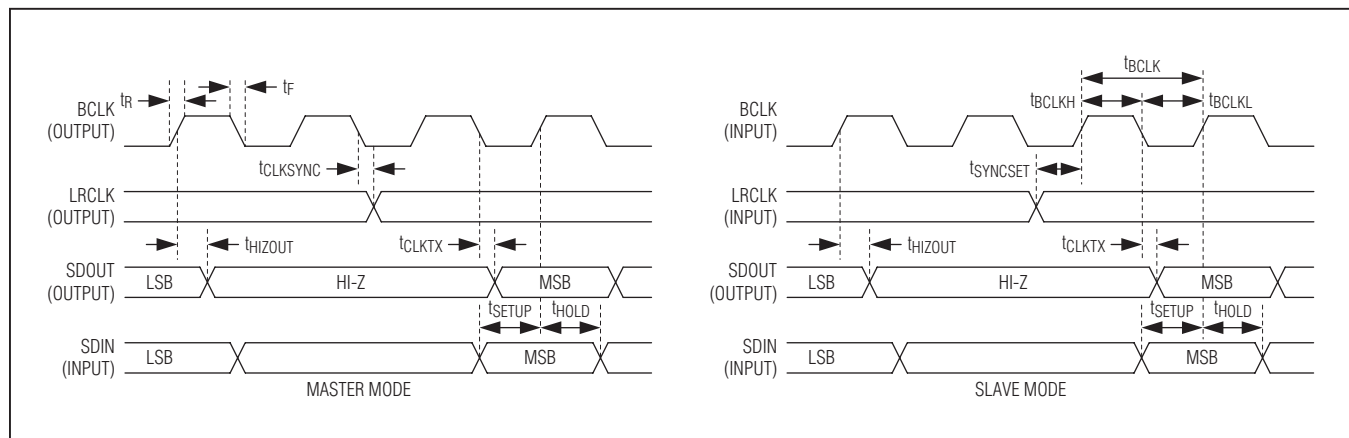


Figure 1. Non-TDM Audio Interface Timing Diagrams (TDM<sub>0</sub> = 0)

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## Low-Power, Stereo Audio Codec with FlexSound Technology

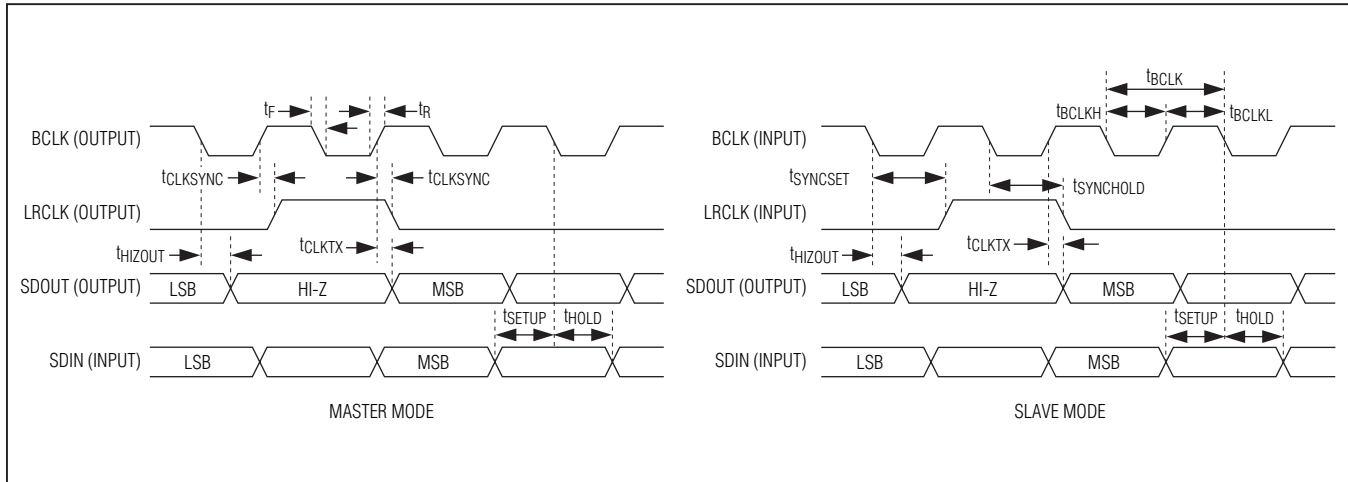


Figure 2. TDM Audio Interface Timing Diagram ( $TDM_ = 1, FSW_ = 0$ )

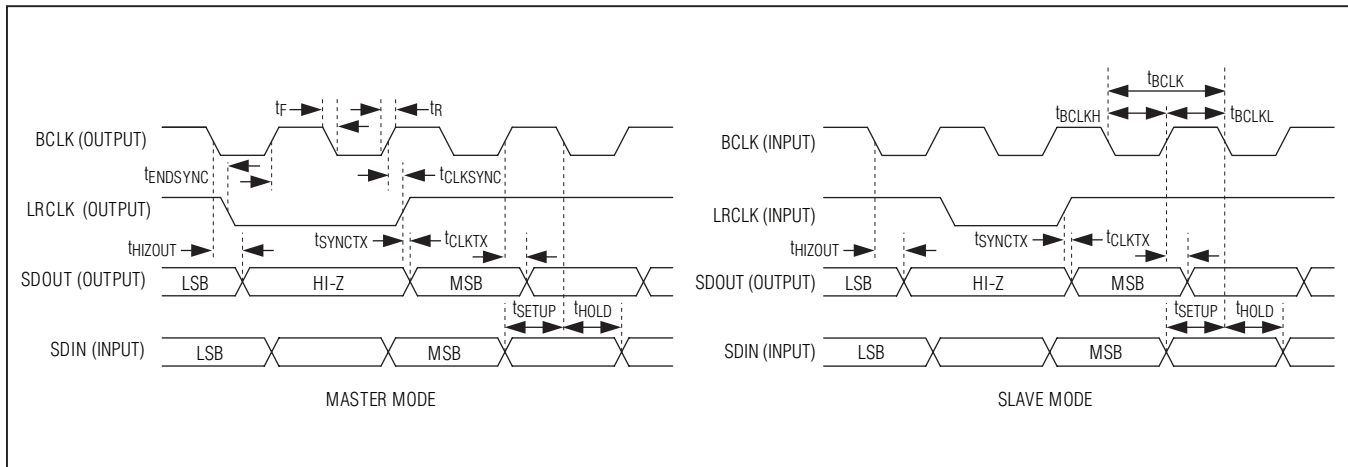


Figure 3. TDM Audio Interface Timing Diagram ( $TDM_ = 1, FSW_ = 1$ )

### DIGITAL MICROPHONE TIMING CHARACTERISTICS

( $V_{AVDD} = V_{HPVDD} = V_{DVDD} = V_{DVDD1} = V_{DVDD2} = 1.8V$ ,  $V_{SPKLVDD} = V_{SPKRVD} = 3.7V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)  
(Note 1)

| PARAMETER                          | SYMBOL       | CONDITIONS        | MIN | TYP              | MAX | UNITS |
|------------------------------------|--------------|-------------------|-----|------------------|-----|-------|
| DIGMICCLK Frequency                | $f_{MICCLK}$ | MICCLK = 00       |     | PCLK/8           |     | MHz   |
|                                    |              | MICCLK = 01       |     | PCLK/6           |     |       |
|                                    |              | MICCLK = 10       |     | 64 x $f_{LRCLK}$ |     |       |
| 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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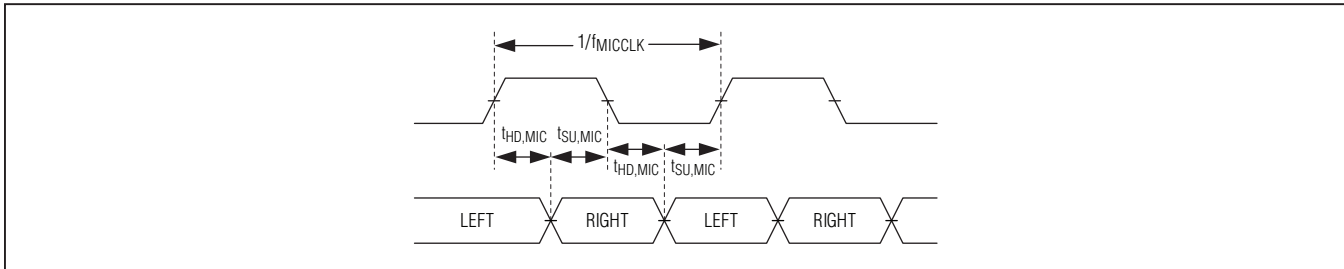


Figure 4. Digital Microphone Timing Diagram

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

(VAVDD = V<sub>VPVDD</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, T<sub>A</sub> = +25°C, unless otherwise noted.)  
(Note 1)

| PARAMETER                                       | SYMBOL              | CONDITIONS  | MIN                        | TYP | MAX | UNITS |
|---|---------------------|---|----------------------------|-----|-----|-------|
| Serial-Clock Frequency                          | f <sub>SCL</sub>    | Guaranteed by SCL pulse-width low and high                      | 0                          |     | 400 | kHz   |
| Bus Free Time Between STOP and START Conditions | t <sub>BUF</sub>    |   | 1.3                        |     |     | μs    |
| Hold Time (Repeated) START Condition            | t <sub>HD,STA</sub> |   | 0.6                        |     |     | μs    |
| SCL Pulse-Width Low                             | t <sub>LOW</sub>    |   | 1.3                        |     |     | μs    |
| SCL Pulse-Width High                            | t <sub>HIGH</sub>   |   | 0.6                        |     |     | μs    |
| Setup Time for a Repeated START Condition       | t <sub>SU,STA</sub> |   | 0.6                        |     |     | μs    |
| Data Hold Time                                  | t <sub>HD,DAT</sub> | R <sub>PU</sub> = 475Ω, C <sub>B</sub> = 100pF, 400pF           | 0                          |     | 900 | ns    |
| Data Setup Time                                 | t <sub>SU,DAT</sub> |   | 100                        |     |     | ns    |
| SDA and SCL Receiving Rise Time                 | t <sub>R</sub>      | (Note 10)   | 20 +<br>0.1C <sub>B</sub>  |     | 300 | ns    |
| SDA and SCL Receiving Fall Time                 | t <sub>F</sub>      | (Note 10)   | 20 +<br>0.1C <sub>B</sub>  |     | 300 | ns    |
| SDA Transmitting Fall Time                      | t <sub>F</sub>      | R <sub>PU</sub> = 475Ω, C <sub>B</sub> = 100pF, 400pF (Note 10) | 20 +<br>0.05C <sub>B</sub> |     | 250 | ns    |
| Setup Time for STOP Condition                   | t <sub>SU,STO</sub> |   | 0.6                        |     |     | μs    |
| Bus Capacitance                                 | C <sub>B</sub>      | Guaranteed by SDA transmitting fall time                        |                            |     | 400 | pF    |
| Pulse Width of Suppressed Spike                 | t <sub>SP</sub>     |   | 0                          |     | 50  | ns    |

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

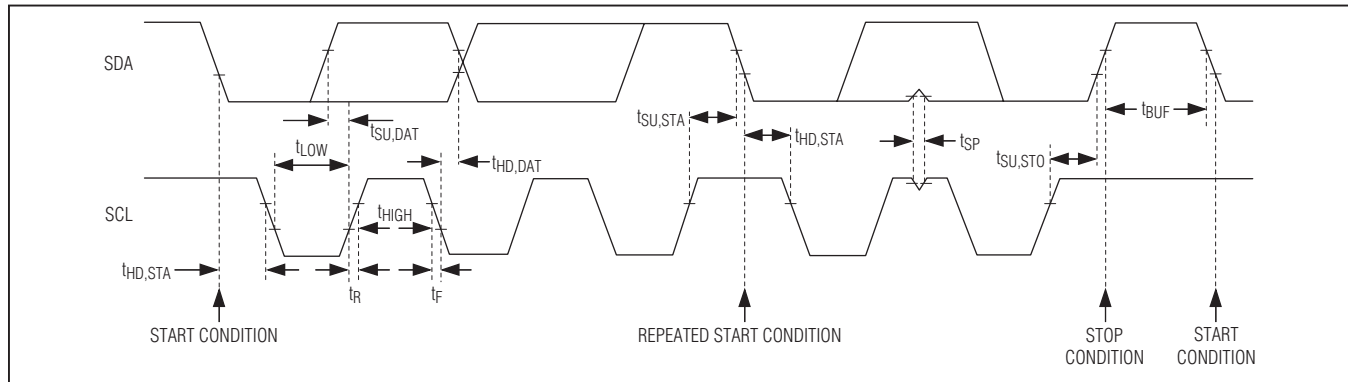


Figure 5. I<sup>2</sup>C Interface Timing Diagram

- 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>SPKL VDD</sub> + I<sub>SPKR VDD</sub>. Digital supply current = I<sub>D VDD</sub> + I<sub>D VDDS1</sub> + I<sub>D VDDS2</sub>.
- 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:** C<sub>B</sub> is in pF.

### Power Consumption

(VAVDD = VPVDD = VD VDD = VD VDDS1 = VD VDDS2 = 1.8V, VSPKL VDD = VSPKR VDD = 3.7V, MAS = 0.)

| MODE  | I <sub>AVDD</sub><br>(mA) | I <sub>PVDD</sub><br>(mA) | I <sub>SPKVDD</sub> +<br>I <sub>SPKL VDD</sub><br>(mA) | I <sub>D VDD</sub><br>(mA) | I <sub>D VDDS1</sub> +<br>I <sub>D VDDS2</sub><br>(mA) | POWER<br>(mW) | DYNAMIC<br>RANGE (dB) |
|---|---------------------------|---------------------------|--|----------------------------|--|---------------|-----------------------|
| <b>Playback to Headphone Only</b>   |                           |                           |  |                            |  |               |                       |
| <b>DAC Playback 48kHz Stereo HP</b><br>DAC → HP<br>Low power mode, 24-bit, music<br>filters, 256Fs  | 1.25                      | 0.47                      | 0.00   | 1.35                       | 0.01   | 5.55          | 97                    |
| <b>DAC Playback 48kHz Stereo HP</b><br>DAC → HP<br>Low power mode, 24-bit, music<br>filters, 256Fs, 0.1mW/channel,<br>R <sub>HP</sub> = 32Ω | 1.25                      | 1.81                      | 0.00   | 1.56                       | 0.01   | 8.32          | 97                    |