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WM8993

Audio Hub Codec for Multimedia Phones

DESCRIPTION

The WM8993 is a highly integrated ultra-low power hi-fi CODEC designed for portable devices such as multimedia phones.

A stereo 1W/channel speaker driver can operate in class D or AB mode. Low leakage and high PSRR across the audio band enable direct battery connection for the speaker supply.

Class W headphone drivers provide a dramatic reduction in playback power and are ground-referenced. Active ground loop noise rejection and DC offset correction help prevent pop noise and ground noise from degrading headphone output quality.

Powerful mixing capability allows the device to support a huge range of architectures and use cases. A highly flexible input configuration supports multiple microphone or line inputs (mono or stereo, single-ended or differential).

Fully differential internal architecture and on-chip RF noise filters ensure a very high degree of noise immunity.

ReTune™ Mobile parametric EQ with fully programmable coefficients is integrated for optimization of speaker characteristics. Programmable dynamic range control is also available for maximizing loudness, protecting speakers from clipping and preventing premature shutdown due to battery droop.

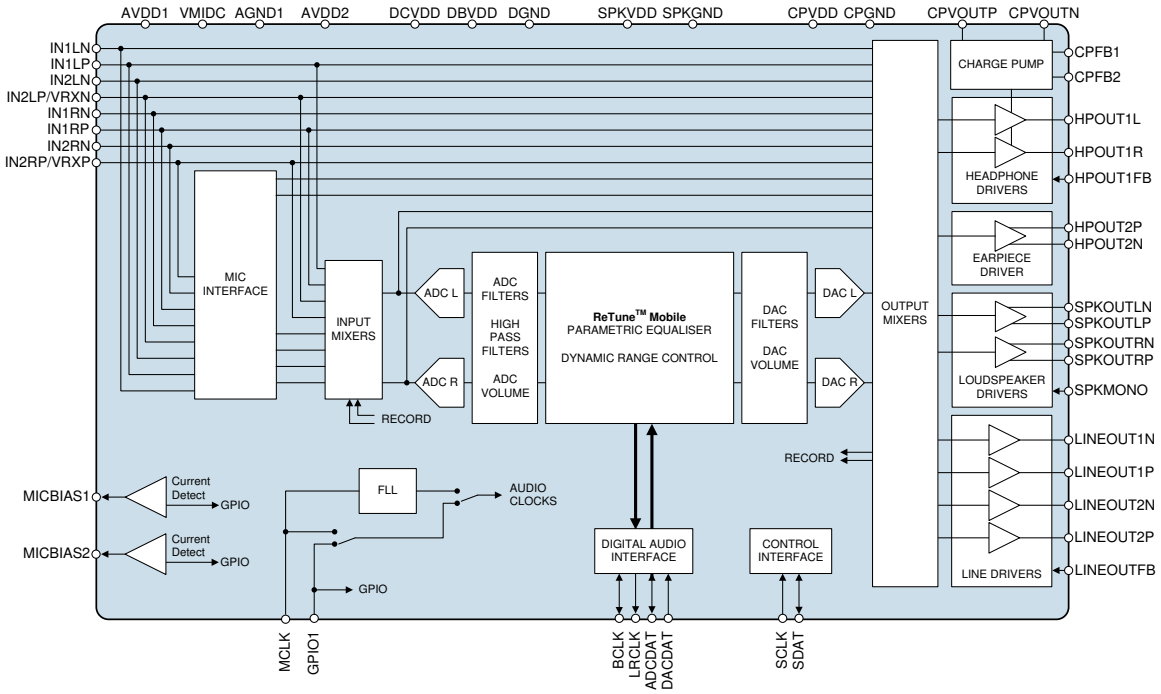
The WM8993 is supplied in very small and thin 48-ball W-CSP package, ideal for portable systems.

FEATURES

- 100dB SNR during DAC playback ('A' weighted)
- Low power, low noise MIC interface
- Class D or AB stereo speaker driver
  - Stereo1W into 8Ω BTL speaker at <1% THD
  - Mono 2W into 4Ω BTL speaker
- ReTune Mobile parametric equalizer
- Dynamic range controller
- Low power Class W headphone drivers
  - Integrated charge pump and DC offset correction
  - 5mW total power for DAC playback to headphones
- Digital audio interface
  - All standard data formats and 2-channel TDM supported
  - All standard sample rates from 8kHz to 48kHz
- Low power FLL
  - Provides all necessary internal clocks
  - 32kHz to 27MHz input frequency
  - Free-running mode for class D and charge pump
- 4 highly flexible line outputs (single-ended or differential)
- Dedicated earpiece driver
- "Direct voice" and "Direct DAC" paths to outputs
  - Low noise paths bypass all internal mixers
  - Low power consumption
- Active noise reduction
  - DC offset correction removes pops and clicks
  - Ground loop noise cancellation
- 48-ball W-CSP package (3.65x3.55x0.546mm, 0.5mm pitch)

APPLICATIONS

- Multimedia phones



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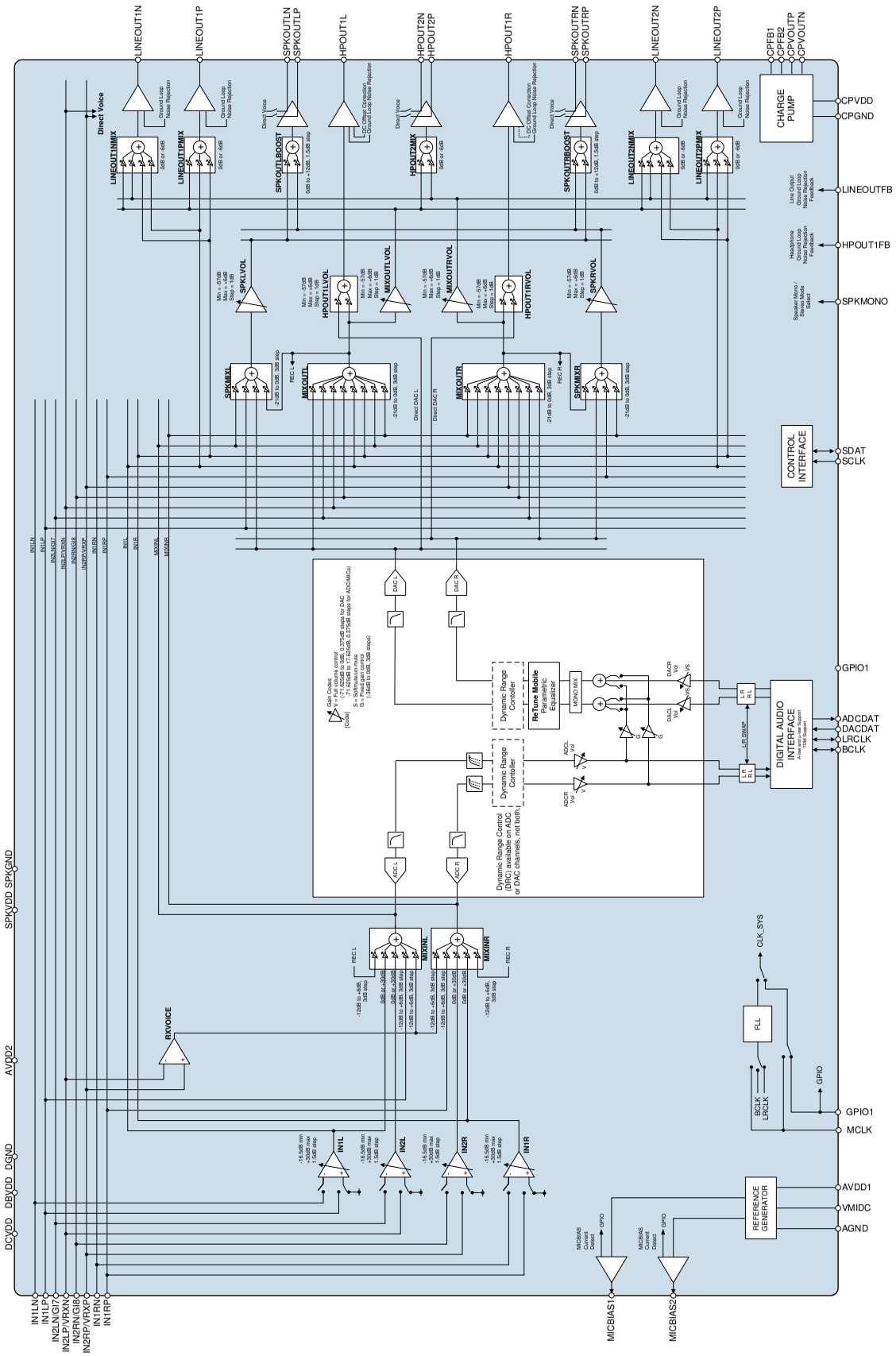
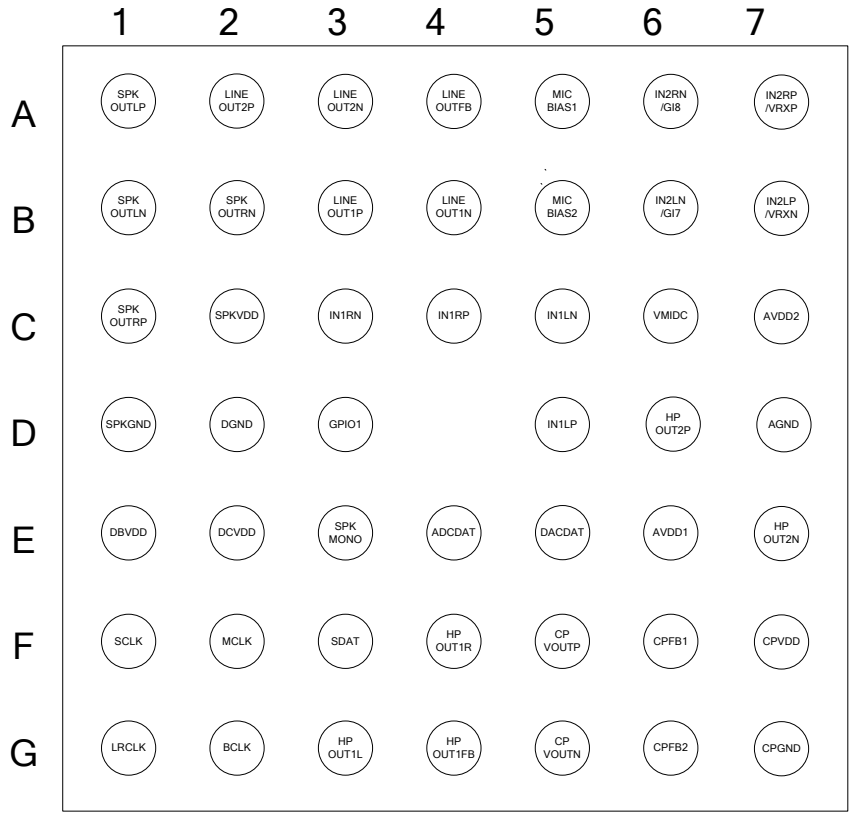
BLOCK DIAGRAM



PIN CONFIGURATION



TOP VIEW

ORDERING INFORMATION

ORDER CODE	TEMPERATURE RANGE	PACKAGE	MOISTURE SENSITIVITY LEVEL	PEAK SOLDERING TEMPERATURE
WM8993ECS/RV	-40°C to +85°C	48-ball W-CSP (Pb-free, Tape and reel)	MSL1	260°C

Note:
Reel quantity = 3500

PIN DESCRIPTION

PIN NO	NAME	TYPE	DESCRIPTION
A5	MICBIAS1	Analogue Output	Microphone bias
B5	MICBIAS2	Analogue Output	Microphone bias
C5	IN1LN	Analogue Input	Left channel single-ended MIC input / Left channel negative differential MIC input
D5	IN1LP	Analogue Input	Left channel line input / Left channel positive differential MIC input
B6	IN2LN/GI7	Analogue Input / Digital Input	Left channel line input / Left channel negative differential MIC input /

PIN NO	NAME	TYPE	DESCRIPTION
B7	IN2LP/VRXN	Analogue Input	Left channel line input / Left channel positive differential MIC input / Mono differential negative input (RXVOICE -)
C3	IN1RN	Analogue Input	Right channel single-ended MIC input / Right channel negative differential MIC input
C4	IN1RP	Analogue Input	Right channel line input / Right channel positive differential MIC input
A6	IN2RN/GI8	Analogue Input / Digital Input	Right channel line input / Right channel negative differential MIC input /
A7	IN2RP/VRXP	Analogue Input	Left channel line input / Left channel positive differential MIC input / Mono differential positive input (RXVOICE +)
E2	DCVDD	Supply	Digital core supply
D2	DGND	Supply	Digital ground (Return path for both DCVDD and DBVDD)
E1	DBVDD	Supply	Digital buffer (I/O) supply
E6	AVDD1	Supply	Analogue core supply
C7	AVDD2	Supply	Analogue class D and FLL supply
D7	AGND	Supply	Analogue ground (Return path for AVDD1)
F7	CPVDD	Supply	Charge pump supply
G7	CPGND	Supply	Charge pump ground (Return path for CPVDD)
C2	SPKVDD	Supply	Supply for speaker driver
D1	SPKGND	Supply	Ground for speaker driver (Return path from SPKVDD)
F5	CPVOUTP	Analogue Output	Charge pump positive supply decoupling pin (HPOUT1L, HPOUT1R)
G5	CPVOUTN	Analogue Output	Charge pump negative supply decoupling pin (HPOUT1L, HPOUT1R)
F6	CPFB1	Analogue Output	Charge pump flyback capacitor pin
G6	CPFB2	Analogue Output	Charge pump flyback capacitor pin
F2	MCLK	Digital Input	Master clock
G2	BCLK	Digital Input / Output	Audio interface bit clock
G1	LRCLK	Digital Input / Output	Audio interface left / right clock
E5	DACDAT	Digital Input	DAC digital audio data
E4	ADCDAT	Digital Output	ADC digital audio data
F1	SCLK	Digital Input	Control interface clock input
F3	SDAT	Digital Input / Output	Control interface data input and output / 2-wire acknowledge output
A1	SPKOUTLP	Analogue Output	Left speaker positive output
B1	SPKOUTLN	Analogue Output	Left speaker negative output
C1	SPKOUTRP	Analogue Output	Right speaker positive output
B2	SPKOUTRN	Analogue Output	Right speaker negative output
E3	SPKMONO	Digital Input	2W Mono/1W Stereo speaker select
G3	HPOUT1L	Analogue Output	Left headphone output
F4	HPOUT1R	Analogue Output	Right headphone output
G4	HPOUT1FB	Analogue Input	HPOUT1L and HPOUT1R ground loop noise rejection feedback
D6	HPOUT2P	Analogue Output	Earpiece speaker non-inverted output
E7	HPOUT2N	Analogue Output	Earpiece speaker inverted output
B4	LINEOUT1N	Analogue Output	Negative mono line output / Positive left or right line output
B3	LINEOUT1P	Analogue Output	Positive mono line output / Positive left line output
A3	LINEOUT2N	Analogue Output	Negative mono line output / Positive left or right line output
A2	LINEOUT2P	Analogue Output	Positive mono line output / Positive left line output
A4	LINEOUTFB	Analogue Input	Line output ground loop noise rejection feedback
C6	VMIDC	Analogue Output	Midrail voltage decoupling capacitor
D3	GPIO1	Digital Input / Output	GPIO pin

ABSOLUTE MAXIMUM RATINGS

Absolute Maximum Ratings are stress ratings only. Permanent damage to the device may be caused by continuously operating at or beyond these limits. Device functional operating limits and guaranteed performance specifications are given under Electrical Characteristics at the test conditions specified.

ESD Sensitive Device. This device is manufactured on a CMOS process. It is therefore generically susceptible to damage from excessive static voltages. Proper ESD precautions must be taken during handling and storage of this device.

Cirrus Logic tests its package types according to IPC/JEDEC J-STD-020B for Moisture Sensitivity to determine acceptable storage conditions prior to surface mount assembly. These levels are:

MSL1 = unlimited floor life at <30°C / 85% Relative Humidity. Not normally stored in moisture barrier bag.
MSL2 = out of bag storage for 1 year at <30°C / 60% Relative Humidity. Supplied in moisture barrier bag.
MSL3 = out of bag storage for 168 hours at <30°C / 60% Relative Humidity. Supplied in moisture barrier bag.

The Moisture Sensitivity Level for each package type is specified in Ordering Information.

CONDITION	MIN	MAX
Supply voltages (AVDD1, DBVDD)	-0.3V	+4.5V
Supply voltages (AVDD2, DCVDD)	-0.3V	+2.5V
Supply voltages (CPVDD)	-0.3V	+2.2V
Supply voltages (SPKVDD)	-0.3V	+7.0V
Voltage range digital inputs	DGND -0.3V	DBVDD +0.3V
Voltage range analogue inputs	AGND -0.3V	AVDD1 +0.3V
Operating temperature range, T_A	-40ºC	+85ºC
Junction temperature, T_{JMAX}	-40ºC	+150ºC
Storage temperature after soldering	-65ºC	+150ºC

RECOMMENDED OPERATING CONDITIONS

PARAMETER	SYMBOL	MIN	TYP	MAX	UNIT
Digital supply range (Core)	DCVDD	1.08	1.2	2.0	V
Digital supply range (I/O)	DBVDD	1.62	1.8	3.6	V
Analogue supply 1 range	AVDD1	2.4	3.0	3.3	V
Analogue supply 2 range	AVDD2	1.71	1.8	2.0	V
Charge Pump supply range	CPVDD	1.71	1.8	2.0	V
Speaker supply range	SPKVDD	2.7	5.0	5.5	V
Ground	DGND, AGND, CPGND, SPKGND		0		V

Notes

1. Analogue, digital and speaker grounds must always be within 0.3V of each other.
2. There is no power sequencing requirement; the supplies may be enabled in any order.
3. DCVDD must be less than or equal to AVDD1 and AVDD2.
4. DCVDD must be less than or equal to DBVDD.
5. AVDD1 must be less than or equal to SPKVDD.

THERMAL PERFORMANCE

Thermal analysis should be performed in the intended application to prevent the WM8993 from exceeding maximum junction temperature. Several contributing factors affect thermal performance most notably the physical properties of the mechanical enclosure, location of the device on the PCB in relation to surrounding components and the number of PCB layers. Connecting the GND balls through thermal vias and into a large ground plane will aid heat extraction.

Three main heat transfer paths exist to surrounding air as illustrated below in Figure 1:

- Package top to air (radiation).
- Package bottom to PCB (radiation).
- Package balls to PCB (conduction).

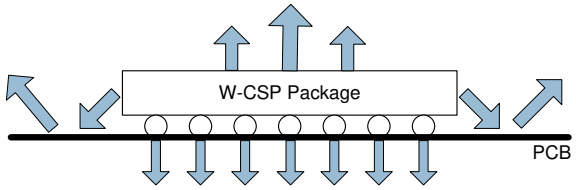


Figure 1 Heat Transfer Paths

The temperature rise T_R is given by $T_R = P_D * \Theta_{JA}$

- P_D is the power dissipated in the device.
- Θ_{JA} is the thermal resistance from the junction of the die to the ambient temperature and is therefore a measure of heat transfer from the die to surrounding air. Θ_{JA} is determined with reference to JEDEC standard JESD51-9.

The junction temperature T_J is given by $T_J = T_A + T_R$, where T_A is the ambient temperature.

PARAMETER	SYMBOL	MIN	TYP	MAX	UNIT
Operating temperature range	T_A	-40		85	°C
Operating junction temperature	T_J	-40		125	°C
Thermal Resistance	Θ_{JA}		TBC		°C/W

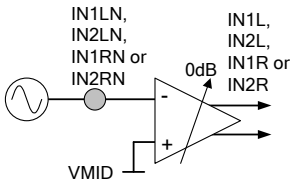
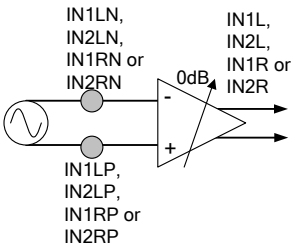
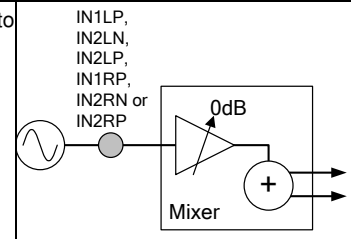
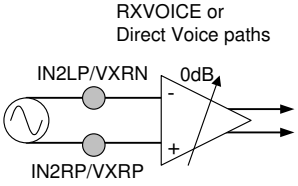
Notes:

1. Junction temperature is a function of ambient temperature and of the device operating conditions. The ambient temperature limits and junction temperature limits must both be observed.

ELECTRICAL CHARACTERISTICS

Test Conditions

DCVDD = 1.2V, AVDD2 = DBVDD = CPVDD = 1.8V, AVDD1 = 3.0V, SPKVDD = 5V, DGND=AGND=CPGND=SPKGND=0V,
T_A = +25ºC, 1kHz sinusoidal signal, fs = 48kHz, PGA gain = 0dB, 24-bit audio data unless otherwise stated.

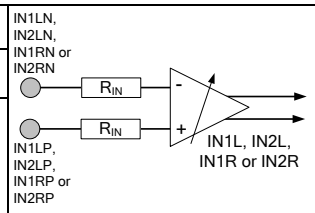
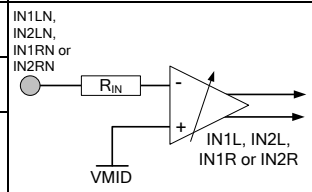
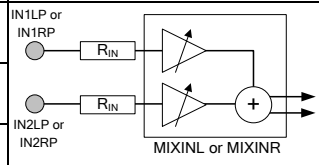
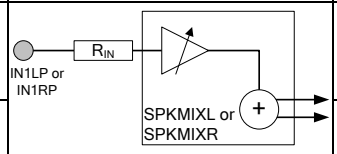
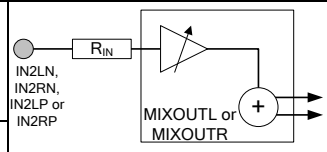
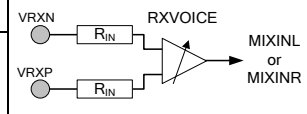
PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Analogue Input Pin Maximum Signal Levels (IN1LN, IN1LP, IN2LN, IN2LP, IN1RN, IN1RP, IN2RN, IN2RP)							
A1	Maximum Full-Scale PGA Input Signal Level Note 1,2 and 3	Single-ended PGA input			1.0 0		Vrms dBV
		Differential PGA input			1.0 0		Vrms dBV
A2	Maximum Full-Scale Line Input Signal Level Note 1, 2 and 3	Single-ended Line input to mixers			1.0 0		Vrms dBV
		Differential mono line input on VRXP/VRXN to RXVOICE or Direct Voice paths to speaker outputs or earpiece output			1.0 0		Vrms dBV

Notes:

1. This changes in proportion to AVDD1 (AVDD1/3.0)
2. When mixing line inputs, input PGA outputs and DAC outputs the total signal must not exceed 1Vrms (0dBV).
3. A 1.0Vrms differential signal equates to 0.5Vrms/-6dBV per input.

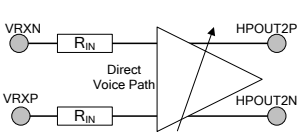
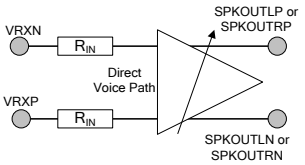
Test Conditions

DCVDD = 1.2V, AVDD2 = DBVDD = CPVDD = 1.8V, AVDD1 = 3.0V, SPKVDD = 5V, DGND=AGND=CPGND=SPKGND=0V,
T_A = +25ºC, 1kHz sinusoidal signal, fs = 48kHz, PGA gain = 0dB, 24-bit audio data unless otherwise stated.

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Analogue Input Pin Impedances (IN1LN, IN1LP, IN2LN, IN2LP, IN1RN, IN1RP, IN2RN, IN2RP)							
B1	PGA Input Resistance Differential Mode Note 4 See "Applications Information" for details of Input resistance at all PGA Gain settings.	PGA Gain = -16.5dB			52.5		kΩ
		PGA Gain = 0dB			25.1		kΩ
		PGA Gain = +30dB			1.3		kΩ
B2	PGA Input Resistance Single-Ended Mode Note 4 See "Applications Information" for details of Input resistance at all PGA Gain settings.	PGA Gain = -16.5dB			58.0		kΩ
		PGA Gain = 0dB			36.2		kΩ
		PGA Gain = +30dB			2.5		kΩ
B3	Line Input Resistance Note 4	IN1LP or IN1RP to INMIXL or INMIXR (-12dB)			56.0		kΩ
		IN1LP or IN1RP to INMIXL or INMIXR (0dB)			17.4		kΩ
		IN1LP or IN1RP to INMIXL or INMIXR (+6dB)			9.8		kΩ
		IN1LP to SPKMIXL or IN1RP to SPKMIXR (SPKATTN = -12dB)			88.5		kΩ
		IN1LP to SPKMIXL or IN1RP to SPKMIXR (SPKATTN = 0dB)			26.7		kΩ
		IN2LN, IN2RN, IN2LP or IN2RP to MIXOUTL or MIXOUTR (-21dB)			150.9		kΩ
		IN2LN, IN2RN, IN2LP or IN2RP to MIXOUTL or MIXOUTR (0dB)			18.2		kΩ
		VRXP-VRXN via RXVOICE to MIXINL or MIXINR (Gain = -12dB)			47.7		kΩ
		VRXP-VRXN via RXVOICE to MIXINL or MIXINR (Gain = 0dB)			12.0		kΩ
		VRXP-VRXN via RXVOICE to MIXINL or MIXINR (Gain = +6dB)			6.0		kΩ

Test Conditions

DCVDD = 1.2V, AVDD2 = DBVDD = CPVDD = 1.8V, AVDD1 = 3.0V, SPKVDD = 5V, DGND=AGND=CPGND=SPKGND=0V,
T_A = +25ºC, 1kHz sinusoidal signal, fs = 48kHz, PGA gain = 0dB, 24-bit audio data unless otherwise stated.

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
		Direct Voice to Earpiece Driver (Gain = -6dB)			33.3		kΩ
		Direct Voice to Earpiece Driver (Gain = 0dB)			16.7		kΩ
		Direct Voice to Speaker Driver (Gain = 0dB)			170.0		kΩ
		Direct Voice to Speaker Driver (Gain = +6dB)			85.2		kΩ
		Direct Voice to Speaker Driver (Gain = +9dB)			60.3		kΩ
		Direct Voice to Speaker Driver (Gain = +12dB)			42.7		kΩ

Note:

4. Input resistance will be seen in parallel with the resistance of other enabled input paths from the same pins

Test Conditions

DCVDD = 1.2V, AVDD2 = DBVDD = CPVDD = 1.8V, AVDD1 = 3.0V, SPKVDD = 5V, DGND=AGND=CPGND=SPKGND=0V,
T_A = +25ºC, 1kHz sinusoidal signal, fs = 48kHz, PGA gain = 0dB, 24-bit audio data unless otherwise stated.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input Programmable Gain Amplifiers (PGAs) IN1L, IN2L, IN1R and IN2R						
C1	Minimum Programmable Gain			-16.5		dB
C2	Maximum Programmable Gain			30		dB
C3	Programmable Gain Step Size	Guaranteed monotonic		1.5		dB
C4	Mute Attenuation	Inputs disconnected		90		dB
C5	Common Mode Rejection Ratio (217Hz input)	Single PGA in differential mode, gain = +30dB		70		dB
		Single PGA in differential mode, gain = 0dB		60		dB
		Single PGA in differential mode, gain = -16.5dB		55		dB
Input Mixers MIXINL and MIXINR						
C6	Minimum Programmable Gain	PGA Outputs to MIXINL and MIXINR		0		dB
C7	Maximum Programmable Gain	PGA Outputs to MIXINL and MIXINR		+30		dB
C8	Programmable Gain Step Size	PGA Outputs to MIXINL and MIXINR		30		dB
C9	Minimum Programmable Gain	Line Inputs and Record path to MIXINL and MIXINR		-12		dB
C10	Maximum Programmable Gain	Line Inputs and Record path to MIXINL and MIXINR		+6		dB
C11	Programmable Gain Step Size	Line Inputs and Record path to MIXINL and MIXINR		3		dB
C12	Minimum Programmable Gain	RXVOICE to MIXINL and MIXINR		-12		dB
C13	Maximum Programmable Gain	RXVOICE to MIXINL and MIXINR		+6		dB
C14	Programmable Gain Step Size	RXVOICE to MIXINL and MIXINR		3		dB
C16	Common Mode Rejection Ratio (217Hz input)	RXVOICE to MIXINL or MIXINR, gain = +6dB		60		dB
		RXVOICE to MIXINL or MIXINR, gain = 0dB		65		dB
		RXVOICE to MIXINL or MIXINR, gain = -12dB		65		dB

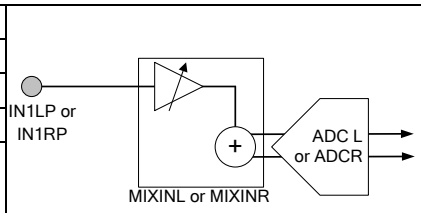
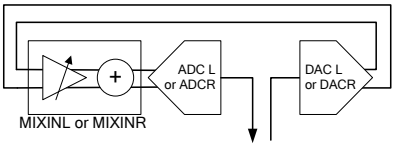
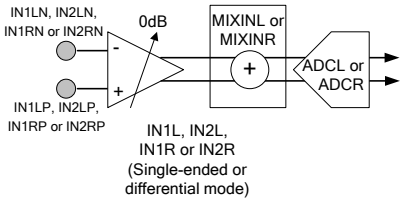
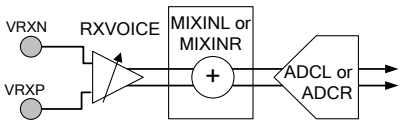
Test Conditions

DCVDD = 1.2V, AVDD2 = DBVDD = CPVDD = 1.8V, AVDD1 = 3.0V, SPKVDD = 5V, DGND=AGND=CPGND=SPKGND=0V, T_A = +25ºC, 1kHz sinusoidal signal, fs = 48kHz, PGA gain = 0dB, 24-bit audio data unless otherwise stated.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output Mixers MIXOUTL and MIXOUTR						
C17	Minimum Programmable Gain			-21		dB
C18	Maximum Programmable Gain			0		dB
C19	Programmable Gain Step Size			3		dB
C20	Mute attenuation			-67		dB
Speaker Mixers SPKMIXL and SPKMIXR						
C21	Minimum Programmable Gain			-15		dB
C22	Maximum Programmable Gain			0		dB
C23	Programmable Gain Step Size			3		dB
C24	Mute attenuation			-67		dB
Output Programmable Gain Amplifiers (PGAs) HPOUT1LVOL, HPOUT1RVOL, MIXOUTLVOL, MIXOUTRVOL, SPKLVOL and SPKRVOL						
C25	Minimum Programmable Gain			-57		dB
C26	Maximum Programmable Gain			+6		dB
C27	Programmable Gain Step Size	Guaranteed monotonic		1		dB
C28	Mute attenuation			-69		dB
Line Output Driver Programmable Gain LINEOUT1NMIX, LINEOUT1PMIX, LINEOUT2NMIX and LINEOUT2PMIX						
C29	Minimum Programmable Gain			-6		dB
C30	Maximum Programmable Gain			0		dB
C31	Programmable Gain Step Size			6		dB
Earpiece Driver Programmable Gain HPOUT2MIX						
C33	Minimum Programmable Gain			-6		dB
C34	Maximum Programmable Gain			0		dB
C35	Programmable Gain Step Size			6		dB
C37	Common Mode Rejection Ratio (217Hz input)	Direct Voice path to HPOUT2, gain = 0dB		50		dB
Speaker Output Driver Programmable Gain SPKOUTLBOOST and SPKOUTRBOOST						
C38	Minimum Programmable Gain			0		dB
C39	Maximum Programmable Gain			+12		dB
C40	Programmable Gain Step Size			1.5		dB
C42	Mute attenuation	Class AB mode		-78		dB
C43	Common Mode Rejection Ratio (217Hz input)	Direct Voice path to SPKOUTL or SPKOUTR, gain = 0dB		50		dB
		Direct Voice path to SPKOUTL or SPKOUTR, gain = +12dB		50		dB

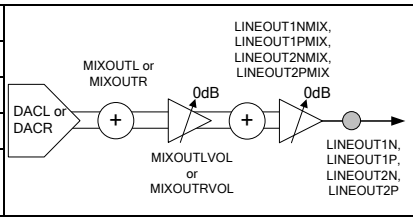
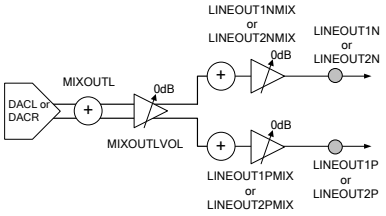
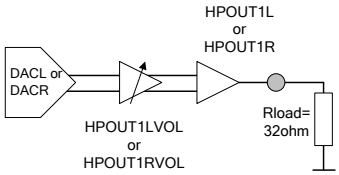
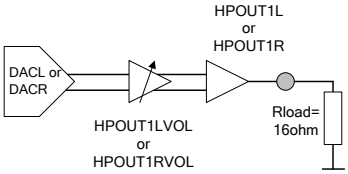
Test Conditions

DCVDD = 1.2V, AVDD2 = DBVDD = CPVDD = 1.8V, AVDD1 = 3.0V, SPKVDD = 5V, DGND=AGND=CPGND=SPKGND=0V,
T_A = +25°C, 1kHz sinusoidal signal, fs = 48kHz, PGA gain = 0dB, 24-bit audio data unless otherwise stated.

	PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
ADC Input Path Performance							
D1	**Line Inputs to ADC via MIXINL and MIXINR**						
	SNR (A-weighted)				94		dB
	THD (-1dBFS input)				-83		dB
	THD+N (-1dBFS input)				-81		dB
	Crosstalk (L/R)				-100		dB
	PSRR (all other supplies 217Hz)	100mVpk-pk			-78		dB
D2	**Record Path (DACs to ADCs via MIXINL and MIXINR)**						
	SNR (A-weighted)			83	94		dB
	THD (-1dBFS input)				-74	-64	dB
	THD+N (-1dBFS input)				-72	-62	dB
	Crosstalk (L/R)				-95		dB
D3	**Input PGAs to ADC via MIXINL or MIXINR**						
	SNR (A-weighted)			86	95		dB
	THD (-1dBFS input)				-82	-72	dB
	THD+N (-1dBFS input)				-80	-70	dB
	Crosstalk (L/R)				-100		dB
	PSRR (AVDD1 217Hz)	100mVpk-pk			-100		dB
D4	**VRXP-VRXN to one ADC via RXVOICE**						
	SNR (A-weighted)				95		dB
	THD (-1dBFS input)				-83		dB
	THD+N (-1dBFS input)				-81		dB

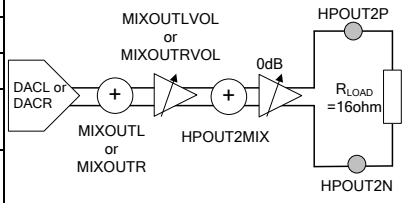
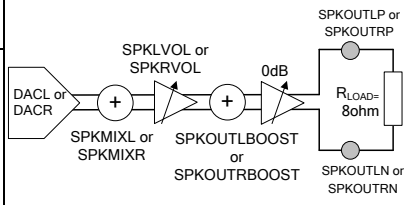
Test Conditions

DCVDD = 1.2V, AVDD2 = DBVDD = CPVDD = 1.8V, AVDD1 = 3.0V, SPKVDD = 5V, DGND=AGND=CPGND=SPKGND=0V,
T_A = +25ºC, 1kHz sinusoidal signal, fs = 48kHz, PGA gain = 0dB, 24-bit audio data unless otherwise stated.

	PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
DAC Output Path Performance							
E1	**DAC to Single-Ended Line Output (10kΩ / 50pF)**						
	SNR (A-weighted)			84	94		dB
	THD	0dBFS input			-71	-61	dB
	THD+N	0dBFS input			-70	-60	dB
	Crosstalk (L/R)				-75		dB
	PSRR (all other supplies 217Hz)	100mVpk-pk			-36		dB
E2	**DAC to Differential Line Output (10kΩ / 50pF)**						
	SNR (A-weighted)			87	97		dB
	THD	0dBFS input			-76		dB
	THD+N	0dBFS input			-75		dB
	Crosstalk (L/R)				-90		dB
	PSRR (all other supplies 217Hz)	100mVpk-pk			-51		dB
E3	Minimum Line Output Resistance	LINEOUT1N, LINEOUT1P, LINEOUT2N, LINEOUT2P		2			kΩ
E4	Line Output Capacitance	LINEOUT1N, LINEOUT1P, LINEOUT2N, LINEOUT2P	Direct connection			100	pF
			Connection via 1kΩ series resistor			2000	pF
E5	**DAC to Headphone on HPOUT1L or HPOUT1R (R_L=32Ω)**						
	SNR (A-weighted)	OSR = 128fs			100		dB
		OSR = 64fs			97		dB
	THD (P_O=20mW)				-79		dB
	THD+N (P_O=20mW)				-77		dB
	THD (P_O=5mW)				-83		dB
	THD+N (P_O=5mW)				-81		dB
	Crosstalk (L/R)				-95		dB
	PSRR (all other supplies 217Hz)	100mVpk-pk			-51		dB
E6	**DAC to Headphone on HPOUT1L or HPOUT1R (R_L=16Ω)**						
	SNR (A-weighted)	OSR = 128fs		90	100		dB
		OSR = 64fs			97		dB
	THD (P_O=20mW)				-85		dB
	THD+N (P_O=20mW)				-83		dB
	THD (P_O=5mW)				-83	-73	dB
	THD+N (P_O=5mW)				-81	-71	dB
	Crosstalk (L/R)				-95		dB
	PSRR (all other supplies 217Hz)	100mVpk-pk			-51		dB

Test Conditions

DCVDD = 1.2V, AVDD2 = DBVDD = CPVDD = 1.8V, AVDD1 = 3.0V, SPKVDD = 5V, DGND=AGND=CPGND=SPKGND=0V,
T_A = +25ºC, 1kHz sinusoidal signal, fs = 48kHz, PGA gain = 0dB, 24-bit audio data unless otherwise stated.

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
E7	Minimum Headphone Resistance	HPOUT1L or HPOUT1R	Normal operation	15			Ω
			Device survival with load applied indefinitely	1			Ω
E8	Headphone Capacitance	HPOUT1L or HPOUT1R				2	nF
E9	**DAC to Earpiece Driver (R_L=16Ω BTL)**						
	SNR (A-weighted)				97		dB
	THD (P_O=50mW)				-69		dB
	THD+N (P_O=50mW)				-67		dB
	PSRR (all other supplies 217Hz)	100mVpk-pk			-51		dB
	DC Offset at Load				5		mV
E10	Earpiece Resistance			15			Ω
E11	Earpiece Capacitance		Direct connection			200	pF
E12	**DAC to Speaker Outputs (R_L=8Ω + 10µH BTL, Stereo Mode)**						
	SNR (A-weighted)	Class D mode SPK Boost=+12dB		84	94		dB
	THD (P_O=0.5W)				-63	-53	dB
	THD+N (P_O=0.5W)				-62	-52	dB
	THD (P_O=1.0W)				-67		dB
	THD+N (P_O=1.0W)				-66		dB
	PSRR (all supplies 217Hz)				-43		dB
	Crosstalk (L/R)				-80		dB
	SNR (A-weighted)	Class AB mode SPK Boost=+12dB			97		dB
	THD (P_O=0.5W)				-68		dB
	THD+N (P_O=0.5W)				-65		dB
	THD (P_O=1.0W)				-70		dB
	THD+N (P_O=1.0W)				-68		dB
	PSRR (all supplies 217Hz)				-43		dB
	Crosstalk (L/R)				-80		dB
	DC Offset at Load	Class AB mode SPK Boost=0dB			10		mV

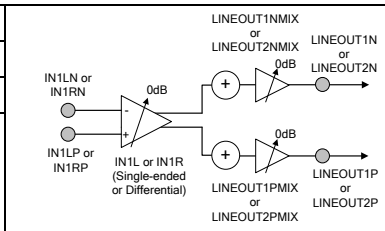
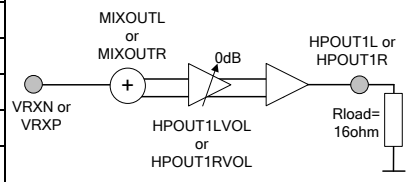
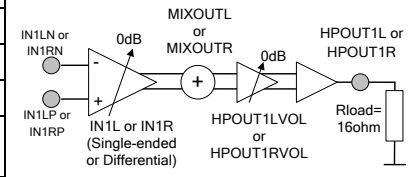
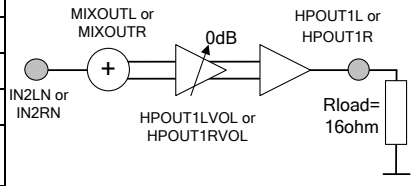
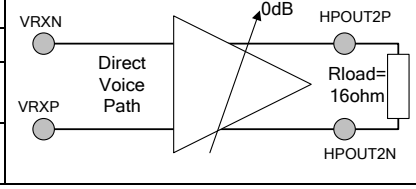
Test Conditions

DCVDD = 1.2V, AVDD2 = DBVDD = CPVDD = 1.8V, AVDD1 = 3.0V, SPKVDD = 5V, DGND=AGND=CPGND=SPKGND=0V, T_A = +25°C, 1kHz sinusoidal signal, fs = 48kHz, PGA gain = 0dB, 24-bit audio data unless otherwise stated.

	PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
E13	**Speaker Output Power (R_L=8Ω + 10µH BTL, Stereo Mode)**						
	Output Power	SPKVDD=5.0V THD+N ≤ 1%	Class AB		1		W
			Class D		1		
		SPKVDD=4.2V THD+N ≤ 1%	Class AB		0.86		W
			Class D		0.87		
		SPKVDD=3.7V THD+N ≤ 1%	Class AB		0.65		W
			Class D		0.66		
E14	**Speaker Output Power (R_L=8Ω + 10µH BTL, Mono Mode)**						
	Output Power	SPKVDD=5.0V THD+N ≤ 1%	Class AB		1		W
			Class D		1		
		SPKVDD=4.2V THD+N ≤ 1%	Class AB		0.99		W
			Class D		0.98		
		SPKVDD=3.7V THD+N ≤ 1%	Class AB		0.75		W
			Class D		0.75		
E15	**Speaker Output Power (R_L=4Ω + 10µH BTL, Mono Mode)**						
	Output Power	SPKVDD=5.0V THD+N ≤ 1%	Class AB		2		mW
			Class D		2		
E16	Speaker Resistance		Stereo Mode	8			Ω
			Mono Mode	4			Ω
E17	SPKVDD Leakage Current	SPKVDD=5.0V			1		µA

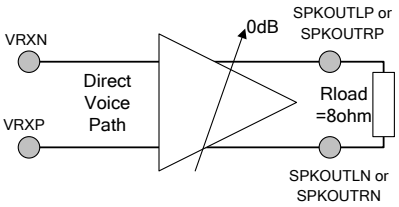
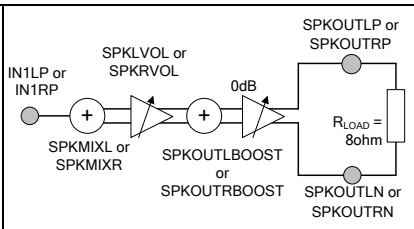
Test Conditions

DCVDD = 1.2V, AVDD2 = DBVDD = CPVDD = 1.8V, AVDD1 = 3.0V, SPKVDD = 5V, DGND=AGND=CPGND=SPKGND=0V,
T_A = +25°C, 1kHz sinusoidal signal, fs = 48kHz, PGA gain = 0dB, 24-bit audio data unless otherwise stated.

	PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Bypass Path Performance							
F1	**Input PGA to Differential Line Out (10kΩ / 50pF)**						
	SNR (A-weighted)			92	102		dB
	THD (0dB output)				-94	-84	dB
	THD+N (0dB output)				-92	-82	dB
	PSRR (all other supplies 217Hz)	100mVpk-pk			-45		dB
F2	**VRXP or VRXN to Headphone via MIXOUTL or MIXOUTR (R_L=16Ω)**						
	SNR (A-weighted)				101		dB
	THD (P_O=20mW)				-85		dB
	THD+N (P_O=20mW)				-83		dB
	THD (P_O=5mW)				-83		dB
	THD+N (P_O=5mW)				-81		dB
	PSRR (all other supplies 217Hz)	100mVpk-pk			-49		dB
F3	**Input PGA to Headphone via MIXOUTL or MIXOUTR (R_L=16Ω)**						
	SNR (A-weighted)				100		dB
	THD (P_O=20mW)				-85		dB
	THD+N (P_O=20mW)				-83		dB
	THD (P_O=5mW)				-83		dB
	THD+N (P_O=5mW)				-81		dB
	PSRR (all other supplies 217Hz)	100mVpk-pk			-49		dB
	Crosstalk (L/R)				-95		dB
F4	**Line Input to Headphone via MIXOUTL and MIXOUTR (R_L=16Ω)**						
	SNR (A-weighted)			92	100		dB
	THD (P_O=20mW)				-85	-75	dB
	THD+N (P_O=20mW)				-83	-73	dB
	THD (P_O=5mW)				-83		dB
	THD+N (P_O=5mW)				-81		dB
	PSRR (all other supplies 217Hz)	100mVpk-pk			-49		dB
	Crosstalk (L/R)				-95		dB
F5	**VRXP-VRXN Direct Voice Path to Earpiece Driver (R_L=16Ω BTL)**						
	SNR (A-weighted)			90	104		dB
	THD (P_O=50mW)				-69	-60	dB
	THD+N (P_O=50mW)				-67	-58	dB
	PSRR (all other supplies 217Hz)	100mVpk-pk			-91		dB
	DC Offset at Load				5		mV

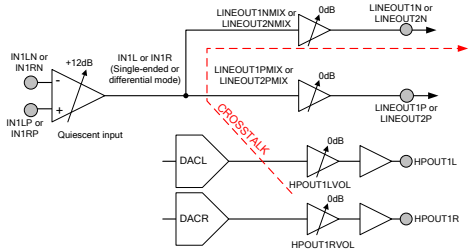
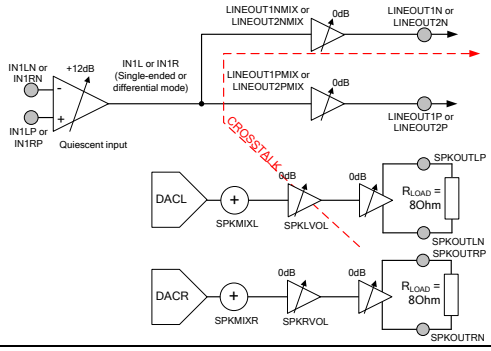
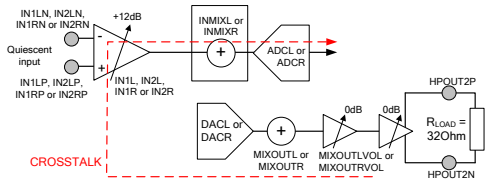
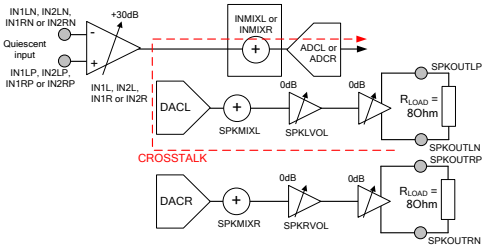
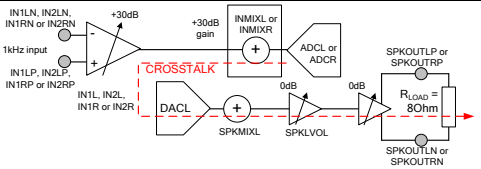
Test Conditions

DCVDD = 1.2V, AVDD2 = DBVDD = CPVDD = 1.8V, AVDD1 = 3.0V, SPKVDD = 5V, DGND=AGND=CPGND=SPKGND=0V,
T_A = +25ºC, 1kHz sinusoidal signal, fs = 48kHz, PGA gain = 0dB, 24-bit audio data unless otherwise stated.

	PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
F6	**VRXP-VRXN Direct Voice Path to Speaker Outputs (R_L=8Ω BTL)**						
	SNR (A-weighted)	Class D Mode SPK Boost=+12dB			97		dB
	THD (P_O=0.5W)				-63		dB
	THD+N (P_O=0.5W)				-62		dB
	THD (P_O=1.0W)				-67		dB
	THD+N (P_O=1.0W)				-65		dB
	PSRR (all supplies 217Hz)				-63		dB
	SNR (A-weighted)	Class AB Mode SPK Boost=+12dB			104		dB
	THD (P_O=0.5W)				-68		dB
	THD+N (P_O=0.5W)				-65		dB
	THD (P_O=1.0W)				-70		dB
	THD+N (P_O=1.0W)				-68		dB
	PSRR (all supplies 217Hz)				-67		dB
	DC Offset at Load	Class AB Mode SPK Boost=0dB			10		mV
F7	**Line Input to Speaker Outputs via SPKMIXL or SPKMIXR (R_L=8Ω BTL)**						
	SNR (A-weighted)	Class D Mode SPK Boost =+12dB			93		dB
	THD (P_O=0.5W)				-63		dB
	THD+N (P_O=0.5W)				-62		dB
	THD (P_O=1.0W)				-67		dB
	THD+N (P_O=1.0W)				-65		dB
	PSRR (all other supplies 217Hz)				-47		dB
	SNR (A-weighted)	Class AB Mode SPK Boost=+12dB		86	96		dB
	THD (P_O=0.5W)				-68	-59	dB
	THD+N (P_O=0.5W)				-65	-57	dB
	THD (P_O=1.0W)				-70		dB
	THD+N (P_O=1.0W)				-68		dB
	PSRR (all other supplies 217Hz)				-47		dB
	DC Offset at Load	Class AB Mode SPK Boost=0dB			10		mV

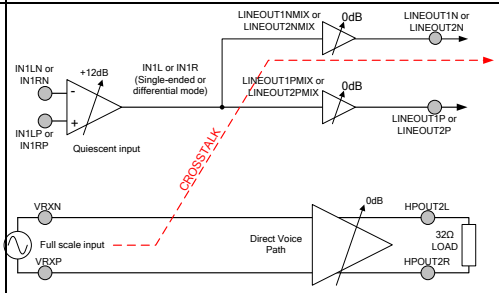
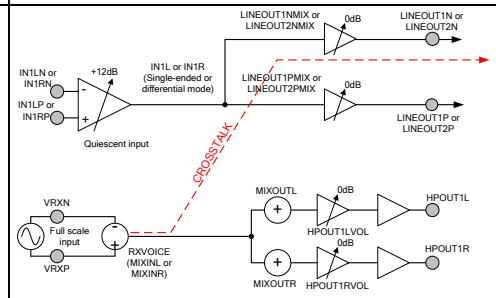
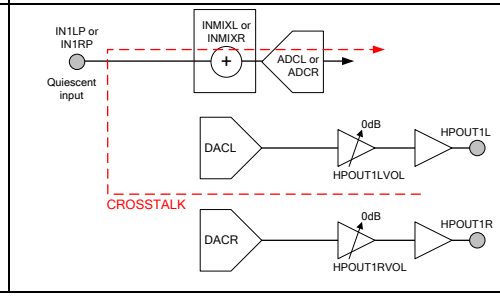
Test Conditions

DCVDD = 1.2V, AVDD2 = DBVDD = CPVDD = 1.8V, AVDD1 = 3.0V, SPKVDD = 5V, DGND=AGND=CPGND=SPKGND=0V, T_A = +25°C, 1kHz sinusoidal signal, fs = 48kHz, PGA gain = 0dB, 24-bit audio data unless otherwise stated.

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Multi-Path Channel Separation						
G1	Headset Voice Call: DAC/Headset to Tx Voice Separation 1kHz 0dBFS DAC playback direct to HPOUT1L and HPOUT1R; Quiescent input on IN1LN/P or IN1RN/P (Gain=+12dB), differential line output; Measure crosstalk at differential line output			85		dB
G2	Headset Voice Call: DAC/Speaker to Tx Voice Separation 1kHz 0dBFS DAC playback to speakers, 1W/chan output; Quiescent input on IN1LN/P or IN1RN/P (Gain=+12dB), differential line output; Measure crosstalk at differential line output			100		dB
G3	Earpiece PCM Voice Call: RXVOICE to Tx Voice Separation fs=8kHz for ADC and DAC, DAC_SB_FILT=1; -5dBFS, DAC output to HPOUT2P-HPOUT2N; Quiescent input on input PGA (Gain=+12dB) to ADC via MIXINL or MIXINR; Measure crosstalk at ADC output			110		dB
G4	Speakerphone PCM Voice Call: DAC/Speaker to ADC Separation fs=8kHz for ADC and DAC, DAC_SB_FILT=1; 0dBFS DAC output to speaker (1W output); ADC record from input PGA (Gain=+30dB); Measure crosstalk on ADC output			90		dB
G5	Speakerphone PCM Voice Call: ADC to DAC/Speaker Separation fs=8kHz for ADC and DAC, DAC_SB_FILT=1; Quiescent DAC output to speaker; ADC record from input PGA (Gain=+30dB + 30dB boost); Measure crosstalk on speaker output			95		dB

Test Conditions

DCVDD = 1.2V, AVDD2 = DBVDD = CPVDD = 1.8V, AVDD1 = 3.0V, SPKVDD = 5V, DGND=AGND=CPGND=SPKGND=0V, T_A = +25°C, 1kHz sinusoidal signal, fs = 48kHz, PGA gain = 0dB, 24-bit audio data unless otherwise stated.

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
G6	Earpiece Speaker Voice Call: Tx Voice and RXVOICE Separation 1kHz Full scale differential input on VRXP-VRXN, output to HPOUT2P-HPOUT2N; Quiescent input on IN1LN/P or IN1RN/P (Gain=+12dB), differential line output; Measure crosstalk at differential line output			100		dB
G7	Headset Voice Call: Tx Voice and RXVOICE Separation 1kHz full scale differential input on VRXP-VRXN via RXVOICE to MIXOUTL and MIXOUTR, output to HPOUT1L and HPOUT1R; Quiescent input on IN1LN/P or IN1RN/P (Gain=+12dB), differential line output; Measure crosstalk at differential line output			90		dB
G8	Stereo Line Record and Playback: DAC/Headset to ADC Separation -5dBFS input to DACs, playback to HPOUT1L and HPOUT1R; ADC record from line input; Measure crosstalk on ADC output			95		dB

Test Conditions

DCVDD = 1.2V, AVDD2 = DBVDD = CPVDD = 1.8V, AVDD1 = 3.0V, SPKVDD = 5V, DGND=AGND=CPGND=SPKGND=0V,
T_A = +25ºC, 1kHz sinusoidal signal, fs = 48kHz, PGA gain = 0dB, 24-bit audio data unless otherwise stated.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Analogue Reference Levels						
H1	VMID Midrail Reference Voltage		-3%	AVDD1/2	+3%	V
Microphone Bias (MICBIAS1 and MICBIAS2)						
H2	Bias Voltage	2.4mA load current MICB1_LVL=0	-5%	0.9×AVDD1	+5%	V
		2.4mA load current MICB1_LVL=1	-5%	0.65×AVDD1	+5%	V
H3	Bias Current Source				2.4	mA
H4	Output Noise Spectral Density	1kHz to 20kHz		100		nV/√Hz
H6	MIC Current Detect Thresholds	JD_THR = 00		150		µA
		JD_THR = 01		300		µA
		JD_THR = 10		600		µA
		JD_THR = 11		1200		µA
	MIC Short Circuit Detect Thresholds	JD_SCTHR = 00		300		µA
		JD_SCTHR = 01		600		µA
		JD_SCTHR = 10		1200		µA
		JD_SCTHR = 11		2400		µA
	Current detect and short circuit detect thresholds are subject to a +/-30% across temperature, supply and part-to-part variation. This should be factored into any application design.					
Charge Pump						
H7	Start-up Time				500	µs
H8	Supply Voltage		1.71		2.0	V
H9	CPVOUTP	Normal mode		CPVDD		V
		Low power mode		CPVDD/2		V
H10	CPVOUTN	Normal mode		-CPVDD		V
		Low power mode		-CPVDD/2		V
H13	Flyback Capacitor (between CPFB1 and CPFB2)	at 2V	1	2.2		µF
H14	CPVOUTP Capacitor	at 2V	2	2.2		µF
H15	CPVOUTN Capacitor	at 2V	2	2.2		µF
Digital Input / Output						
H16	Input HIGH Level		0.8×DBVDD			V
H17	Input LOW Level				0.2×DBVDD	V
Note that digital input pins should not be left unconnected / floating.						
H18	Output HIGH Level	I_{OL}=1mA	0.8×DBVDD			V
H19	Output LOW Level	I_{OH}=-1mA			0.2×DBVDD	V
H20	Input capacitance			10		pF
H21	Input leakage		-0.9		0.9	uA

Test Conditions

DCVDD = 1.2V, AVDD2 = DBVDD = CPVDD = 1.8V, AVDD1 = 3.0V, SPKVDD = 5V, DGND=AGND=CPGND=SPKGND=0V,
T_A = +25ºC, 1kHz sinusoidal signal, fs = 48kHz, PGA gain = 0dB, 24-bit audio data unless otherwise stated.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
FLL						
H22	Input Frequency	FLL_CLK_REF_DIV = 00	0.032		13.5	MHz
		FLL_CLK_REF_DIV = 01	0.032		27	MHz
H23	Lock time	F_{REF}=32kHz, F_{OUT}=12.288MHz		2.5		ms
		F_{REF}=12MHz, F_{OUT}=12.288MHz		300		µs
H24	Free-running mode start-up time	VMID enabled		100		µs
H25	Free-running mode frequency accuracy	Reference supplied initially		+/-10		%
		No reference provided		+/-30		%
GPIO						
H26	Interrupt response time for accessory / button detect	Input de-bounced	2^{19} / f_{CLK_SYS}		2^{22} / f_{CLK_SYS}	s
		Input not de-bounced		0		s

TERMINOLOGY

1. Signal-to-Noise Ratio (dB) – SNR is a measure of the difference in level between the maximum full scale output signal and the output with no input signal applied.
2. Total Harmonic Distortion (dB) – THD is the level of the rms value of the sum of harmonic distortion products relative to the amplitude of the measured output signal.
3. Total Harmonic Distortion plus Noise (dB) – THD+N is the level of the rms value of the sum of harmonic distortion products plus noise in the specified bandwidth relative to the amplitude of the measured output signal.
4. Crosstalk (L/R) (dB) – left-to-right and right-to-left channel crosstalk is the measured signal level in the idle channel at the test signal frequency relative to the signal level at the output of the active channel. The active channel is configured and supplied with an appropriate input signal to drive a full scale output, with signal measured at the output of the associated idle channel.
5. Multi-Path Channel Separation (dB) – is the measured signal level in the idle path at the test signal frequency relative to the signal level at the output of the active path. The active path is configured and supplied with an appropriate input signal to drive a full scale output, with signal measured at the output of the specified idle path.
6. Mute Attenuation – This is a measure of the difference in level between the full scale output signal and the output with mute applied.
7. All performance measurements carried out with 20kHz low pass filter, and where noted an A-weighted filter. Failure to use such a filter will result in higher THD and lower SNR readings than are found in the Electrical Characteristics. The low pass filter removes out of band noise; although it is not audible it may affect dynamic specification values.

TYPICAL PERFORMANCE

POWER CONSUMPTION

Mode	Other settings	AVDD1 (V)	SPKVDD (V)	AVDD2 (V)	CPVDD (V)	DBVDD (V)	DCVDD (V)	iAVDD1 (µA)	iSPKVDD (µA)	iAVDD2 (µA)	iCPVDD (µA)	iDBVDD (µA)	iDCVDD (µA)	TOTAL (mW)
Battery Leakage														
All supplies except SPKVDD disabled		0.0	2.7	0.0	0.0	0.0	0.0	0.000	0.392	0.000	0.000	0.000	0.000	0.001
		0.0	3.7	0.0	0.0	0.0	0.0	0.000	0.451	0.000	0.000	0.000	0.000	0.002
		0.0	4.2	0.0	0.0	0.0	0.0	0.000	0.514	0.000	0.000	0.000	0.000	0.002
		0.0	5.0	0.0	0.0	0.0	0.0	0.000	0.627	0.000	0.000	0.000	0.000	0.003
		0.0	5.5	0.0	0.0	0.0	0.0	0.000	0.795	0.000	0.000	0.000	0.000	0.004
Standby / Sleep Leakage														
OFF (hermal sensor disabled)	No clocks	2.24	2.7	1.71	1.71	1.62	1.08	4.711	0.631	4.059	4.352	4.545	0.972	0.035
		3.0	5.0	1.8	1.8	1.8	1.2	5.919	1.463	4.215	4.223	6.352	1.015	0.053
		3.3	5.5	2.0	2.0	3.6	2.0	6.410	1.987	4.423	4.243	38.094	1.619	0.190
OFF (thermal sensor enabled) Default state at power-up	No clocks	2.24	2.7	1.71	1.71	1.62	1.08	4.801	0.576	23.707	4.223	4.454	0.998	0.068
		3.0	5.0	1.8	1.8	1.8	1.2	5.673	1.454	23.977	4.251	6.359	1.045	0.088
		3.3	5.5	2.0	2.0	3.6	2.0	6.186	1.942	24.657	4.523	38.016	1.585	0.229
OFF (thermal sensor enabled) Default state at power-up	With clocks	2.24	2.7	1.71	1.71	1.62	1.08	4.663	0.761	23.701	3.988	6.872	201.000	0.288
		3.0	5.0	1.8	1.8	1.8	1.2	5.737	1.467	24.029	4.132	9.075	225.000	0.362
		3.3	5.5	2.0	2.0	3.6	2.0	6.409	1.975	24.564	4.451	48.040	420.000	1.103
DAC Playback								**(mA)**	**(mA)**	**(mA)**	**(mA)**	**(mA)**	**(mA)**	**(mW)**
DAC to Headphone 16ohm	fs=48kHz	2.24	2.7	1.71	1.71	1.62	1.08	1.424	0.000	0.103	0.908	0.007	0.796	5.789
(DAC->HPOUTVOL->HPOUT1)		3.0	5.0	1.8	1.8	1.8	1.2	1.950	0.001	0.149	1.248	0.009	0.888	9.453
		3.3	5.5	2.0	2.0	3.6	2.0	2.165	0.002	0.305	2.637	0.046	1.594	16.392
DAC to Stereo Speaker AB 8ohm	fs=48kHz	2.24	2.7	1.71	1.71	1.62	1.08	1.617	6.083	0.098	0.004	0.007	0.768	21.062
(DAC->SPKMIX->SPKVOL->SPKOUT)		3.0	5.0	1.8	1.8	1.8	1.2	2.213	9.098	0.119	0.004	0.009	0.857	53.396
		3.3	5.5	2.0	2.0	3.6	2.0	2.457	10.237	0.131	0.004	0.045	1.538	67.922
DAC to Stereo Speaker D 8ohm	fs=48kHz	2.24	2.7	1.71	1.71	1.62	1.08	1.627	0.577	0.891	0.004	0.007	0.773	7.579
(DAC->SPKMIX->SPKVOL->SPKOUT)		3.0	5.0	1.8	1.8	1.8	1.2	2.231	1.078	1.190	0.004	0.009	0.863	15.285
		3.3	5.5	2.0	2.0	3.6	2.0	2.476	1.202	1.334	0.005	0.046	1.547	20.717
ADC Record														
ADC Record	fs=48kHz	2.24	2.7	1.71	1.71	1.62	1.08	6.393	0.000	0.043	0.004	0.021	0.941	15.452
(IN1LN/P & IN1RN/P->IN1L/IN1R->MIXIN->ADC)		3.0	5.0	1.8	1.8	1.8	1.2	7.149	0.001	0.045	0.004	0.025	1.049	22.846
		3.3	5.5	2.0	2.0	3.6	2.0	7.430	0.002	0.048	0.004	0.075	1.890	28.685
Analogue Bypass														
VRX to Earpiece 16ohm		2.24	2.7	1.71	1.71	1.62	1.08	4.120	0.000	0.043	0.004	0.004	0.001	9.318
(VRXN/P->HPOUT2)		3.0	5.0	1.8	1.8	1.8	1.2	5.704	0.001	0.045	0.004	0.006	0.001	17.221
		3.3	5.5	2.0	2.0	3.6	2.0	6.335	0.002	0.048	0.004	0.038	0.002	21.161

Notes:

1. Power in the load is included.
2. All figures are quoted at T_A = 25°C.
3. All figures are quoted as quiescent current unless otherwise stated.

AUDIO SIGNAL PATHS DIAGRAM