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WM8941

Mono CODEC with Speaker Driver and Video Buffer

DESCRIPTION

The WM8941 is a low power, high quality mono CODEC designed for portable applications such as digital still cameras or camcorders.

The device integrates support for a differential or single ended mic, and includes drivers for speakers or headphone, and mono line output. External component requirements are reduced as no separate microphone or headphone amplifiers are required. A high performance, low power current-mode video buffer provides inherent short circuit protection.

An integrated video buffer is provided which has programmable gain from 0-6dB (6-12dB unloaded), sync-tip clamp and a 3rd order input low pass filter for signal re-construction.

Advanced Sigma Delta Converters are used along with digital decimation and interpolation filters to give high quality audio at sample rates from 8 to 48ks/s. A selectable high pass filter and four fully-programmable notch filters are available in the ADC path. An advanced mixed signal ALC function with noise gate is provided, while readback of PGA gain during ALC operation is supported. The digital audio interface supports A-law and μ-law companding.

An on-chip PLL is provided to generate the required Master Clock from an external reference clock. The PLL clock can also be output if required elsewhere in the system.

The WM8941 operates at supply voltages from 2.5 to 3.6V, although the digital supplies can operate at voltages down to 1.71V to save power. Different sections of the chip can also be powered down under software control using the selectable two or three wire control interface.

WM8941 is supplied in a very small 4x4mm QFN package, offering high levels of functionality in minimum board area, with high thermal performance.

FEATURES

- **Mono CODEC:**
- Audio sample rates:8, 11.025, 16, 22.05, 24, 32, 44.1, 48kHz
- DAC SNR 98dB, THD -80dB ('A'-weighted @ 8 – 48ks/s)
- ADC SNR 91dB, THD -83dB ('A'-weighted @ 8 – 48ks/s)
- On-chip Headphone/Speaker Driver
  - 40mW output power into 16Ω
  - BTL speaker drive 0.4W into 8Ω
- Additional MONO Line output
- Multiple analog or 'Aux' inputs, plus analog bypass path

- **Mic Preamps :**
- Differential or single end Microphone Interface
  - Programmable preamp gain
  - Pseudo differential inputs with common mode rejection
  - Programmable ALC / Noise Gate in ADC path
- Low-noise bias supplied for electret microphones

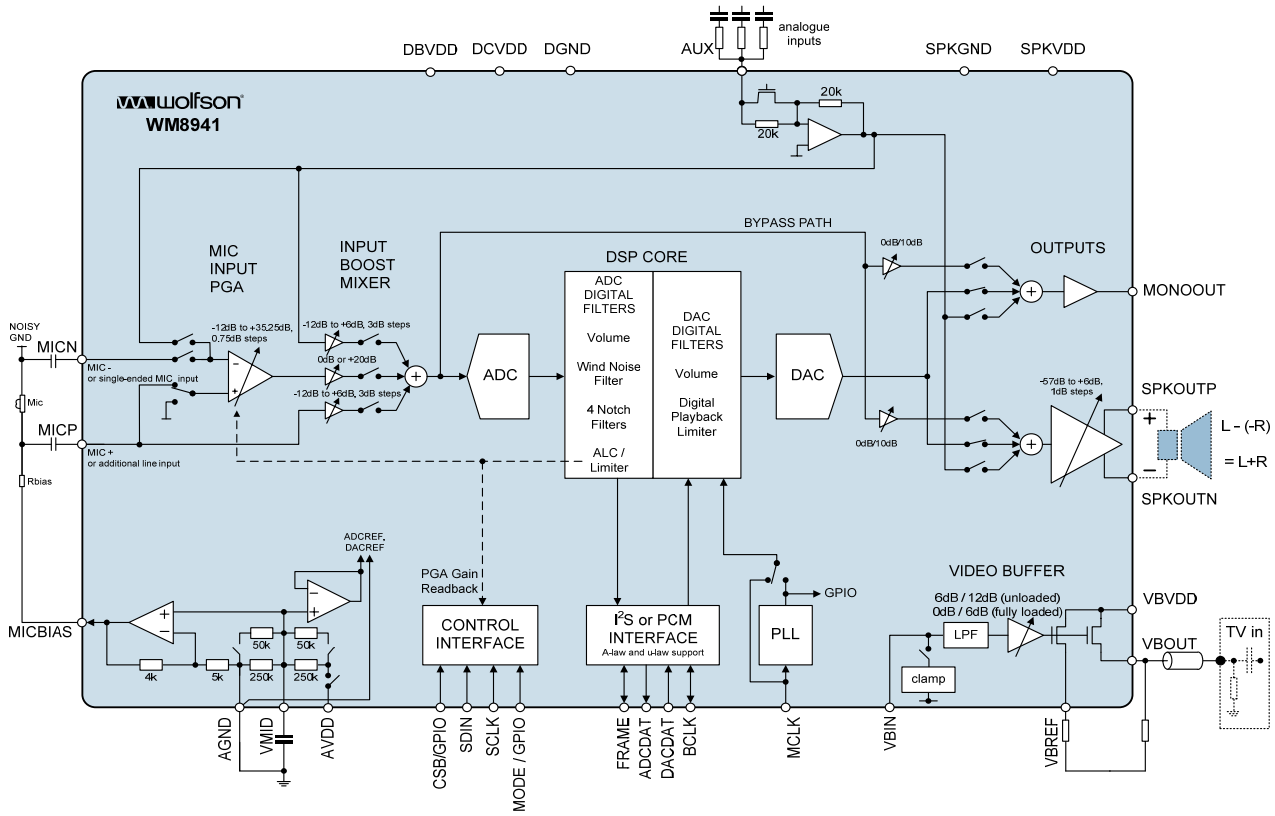
OTHER FEATURES

- Integrated video buffer with LPF and clamp.
- Digital Playback Limiter
- Programmable high pass filter (wind noise reduction)
- 4 notch filters (narrowband noise suppression)
- On-chip PLL
- Low power, low voltage
  - 2.5V to 3.6V (digital: 1.71V to 3.6V)
- 4x4x0.75mm 28 lead QFN package

APPLICATIONS

- Digital still cameras and camcorders
- General purpose mono audio CODEC with video buffer

BLOCK DIAGRAM



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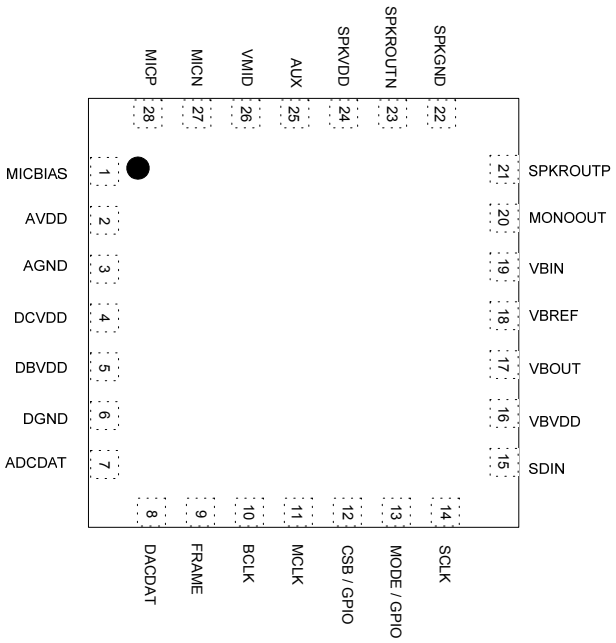
PIN CONFIGURATION



ORDERING INFORMATION

ORDER CODE	TEMPERATURE RANGE	PACKAGE	MOISTURE SENSITIVITY LEVEL	PACKAGE BODY TEMPERATURE
WM8941GEFL/V	-25°C to +85°C	28-lead QFN (4x4x0.75mm) (Pb-free)	MSL3	260°C
WM8941GEFL/RV	-25°C to +85°C	28-lead QFN (4x4x0.75mm) (Pb-free, tape and reel)	MSL3	260°C

Note:

Reel Quantity = 3,500

PIN DESCRIPTION

PIN	NAME	TYPE	DESCRIPTION
1	MICBIAS	Analogue Output	Microphone bias
2	AVDD	Supply	Analogue supply
3	AGND	Supply	Analogue ground
4	DCVDD	Supply	Digital Supply (Core)
5	DBVDD	Supply	Digital supply (Input/Output)
6	DGND	Supply	Digital ground
7	ADCDAT	Digital Output	ADC digital audio data output
8	DACDAT	Digital Input	DAC digital audio data input
9	FRAME	Digital Input / Output	DAC and ADC sample rate clock or frame synch
10	BCLK	Digital Input / Output	Digital audio port clock
11	MCLK	Digital Input	Master clock input
12	CSB/GPIO	Digital Input / Output	3-Wire control interface chip select or GPIO pin
13	MODE/GPIO	Digital Input	Control interface mode selection or GPIO pin
14	SCLK	Digital Input	3-Wire control interface clock Input / 2-Wire control interface clock input
15	SDIN	Digital Input / Output	3-Wire control interface data Input / 2-Wire control interface data input
16	VBVDD	Supply	Vide buffer supply
17	VBOUT	Analogue Output	Video buffer TV output
18	VBREF	Analogue Output	Video buffer reference pin
19	VBIN	Analogue Input	Video buffer input
20	MONOOUT	Analogue Output	Mono output
21	SPKOUTP	Analogue Output	Speaker output positive
22	SPKGND	Supply	Speaker ground
23	SPKOUTN	Analogue Output	Speaker output negative
24	SPKVDD	Supply	Speaker supply
25	AUX	Analogue Input	Auxiliary analogue input
26	VMID	Reference	Decoupling for midrail reference voltage
27	MICN	Analogue Input	Microphone negative input (common mode)
28	MICP	Analogue Input	Microphone positive input

Note:

1. It is recommended that the QFN ground paddle should be connected to analogue ground on the application PCB.
2. Refer to the application note WAN_0118 on “Guidelines on How to Use QFN Packages and Create Associated PCB Footprints”

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.

Wolfson 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
DBVDD, DCVDD, AVDD, VBVDD, SPKVDD supply voltages	-0.3V	+4.2
Voltage range digital inputs	DGND -0.3V[1]	DVDD +0.3V[1]
Voltage range analogue inputs	AGND -0.3V[1]	AVDD +0.3V[1]
Operating temperature range, T_A	-25°C	+85°C
Storage temperature prior to soldering	30°C max / 85% RH max	
Storage temperature after soldering	-65°C	+150°C

Notes

1. Analogue and digital grounds must always be within 0.3V of each other.
2. All digital and analogue supplies are completely independent from each other.

RECOMMENDED OPERATING CONDITIONS

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Digital supply range (Core)	DCVDD		1.71		3.6	V
Digital supply voltage (Buffer)	DBVDD		1.71		3.6	V
Analogue supplies range	AVDD, SPKVDD, VBVDD[1]		2.5		3.6	V
Ground	DGND,AGND, SPKGND			0		V

Notes

1. Analogue supply voltages must not be less than the digital supply voltages.
2. DBVDD must be ≥ DCVDD

ELECTRICAL CHARACTERISTICS

Test Conditions

DCVDD=1.8V, DBVDD=3.3V, AVDD=3.3V, SPKVDD =3.3V, , VBVDD=3.3V, T_A = +25°C, 1kHz signal, fs = 48kHz, 24-bit audio data unless otherwise stated.

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Microphone Input PGA Inputs (MICN, MICP) **INPPGAVOL and PGABOOST = 0dB**						
Full-scale Input Signal Level – Single-ended input via LIN/RIN [1]				AVDD/3.3		V_{rms}
Full-scale Input Signal Level – Pseudo-differential input [1,2]				AVDD*0.7/ 3.3		V_{rms}
Input PGA equivalent input noise		INPPGAVOL = +35.25dB No input signal 0 to 20kHz		76.5		dB
MICN input resistance		INPPGAVOL = +35.25dB		2		kΩ
MICN input resistance		INPPGAVOL = 0dB		58.5		kΩ
MICN input resistance		INPPGAVOL = -12dB		97.5		kΩ
MICP input resistance		All gain settings		124.5		kΩ
Input Capacitance		All analogue input pins		10		pF
Maximum Input PGA Programmable Gain		Gain adjusted by INPPGAVOL	+33.25	+35.25	+37.25	dB
Minimum Input PGA Programmable Gain		Gain adjusted by INPPGAVOL	-14.00	-12	-10.00	dB
Programmable Gain Step Size		Guaranteed monotonic		0.75		dB
Input PGA Mute Attenuation		INPPGAMUTE		92		dB
Input Gain Boost		PGABOOST= 0		0		dB
Input Gain Boost		PGABOOST = 1		+20		dB
Auxiliary Analogue Inputs (AUX)						
Full-scale Input Signal Level [2]				AVDD/3.3		V_{rms}
Input Resistance		Input boost and mixer enabled, at 0dB gain		20		kΩ
Input Capacitance		All analogue Inputs		10		pF
Maximum Gain from AUX input PGA mixers		Gain adjusted by AUX2BOOSTVOL	+4.00	+6	+7.50	dB
Minimum Gain from AUX input PGA mixers		Gain adjusted by AUX2BOOSTVOL	-14.00	-12	-9.00	dB
AUX2BOOSTVOL step size		Guaranteed monotonic		3		dB
Analogue to Digital Converter (ADC) - Input from MICN and MICP in differential configuration to input PGA **INPPGAVO, PGABOOST and ADCVOL = 0dB**						
Signal to Noise Ratio [3]	SNR	A-weighted AVDD=3.3V	81	91		dB
Total Harmonic Distortion [4]	THD	-1dBV Input AVDD=3.3V		-83	-74	dB
Total Harmonic Distortion + Noise [5]	THD+N	-1dBV Input AVDD=3.3V		-77	-68	dB

Test Conditions

DCVDD=1.8V, DBVDD=3.3V, AVDD=3.3V, SPKVDD =3.3V, , VBVDD=3.3V, T_A = +25°C, 1kHz signal, fs = 48kHz, 24-bit audio data unless otherwise stated.

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Digital to Analogue Converter (DAC) to MONO Output with 10kΩ / 50pF load and DACVOL 0dB						
Full-scale output [1]		DACVOL = 0dB	0.9*AVDD /3.3	AVDD/3.3	1.05*AVDD /3.3	V_{rms}
Signal to Noise Ratio [3]	SNR	A-weighted AVDD=SPKVDD=3.3V	90	98		dB
		A-weighted AVDD=SPKVDD=2.5V		96		dB
Total Harmonic Distortion [4]	THD	0dBFS input AVDD=SPKVDD=3.3V		-80	-70	dBFS
Total Harmonic Distortion + Noise [5]	THD+N	0dBFS input AVDD=SPKVDD=3.3V		-78	-68	dBFS
Channel Separation [6]		1kHz signal		100		dB
MICP and MICN input PGA to input boost stage into 10kΩ / 50pF load on SPKOUTP and SPKOUTP INPPGAVOL, PGABOOST = 0dB						
Full-scale output voltage, 0dB gain			0.9*SPKVDD/ 3.3	SPKVDD/3.3	1.05*SPKVD D/3.3	V_{rms}
Signal to Noise Ratio [3]	SNR	A-weighted AVDD=SPKVDD=3.3V		98		dB
Total Harmonic Distortion [4]	THD	full-scale signal AVDD=SPKVDD=3.3V		-80		dBFS
Total Harmonic Distortion + Noise [5]	THD+N	full-scale signal AVDD=SPKVDD=3.3V		-78		dBFS
Channel Separation [6]				100		dB
Speaker Output (SPKOUTP, SPKOUTN with 8Ω bridge tied load)						
Output Power	Po	Output power is closely correlated with THD see below				
Total Harmonic Distortion [4]	THD	Po=150mW, RL = 8Ω SPKVDD=3.3V		0.03 68		% dB
		Po=350mW, RL = 8Ω SPKVDD=3.3V		2.944 -30.6		% dB
Signal to Noise Ratio [3]	SNR	A-weighted SPKVDD=3.3V		-98		dB
Power Supply Rejection Ratio (50Hz-22kHz)	PSRR	R_L = 8Ω BTL		50		dB
Headphone Output (SPKOUTP, SPKOUTN with resistive load to GND)						
Signal to Noise Ratio [3]	SNR	A-weighted SPKVDD=3.3V		98		dB
Total Harmonic Distortion [4]	THD	Po=20mW, RL = 16Ω SPKVDD=3.3V		0.02 -72		% dB
Video Buffer						
Maximum output voltage swing	Vom	f=100kHz, THD=1%	1.10	1.25	1.50	Vp-p
Maximum Programmable Voltage Gain [7]	Av	R_{VBREF}=187Ω, R_{OUT}=75Ω, R_{LOAD}=75 Ω	5.08	6	7.94	dB
Minimum Programmable Voltage Gain [7]	Av	R_{VBREF}=187Ω, R_{OUT}=75Ω, R_{LOAD}=75 Ω	-0.92	0	1.94	dB
Step Size				6		dB
Differential gain	DG	Vin=1Vp-p	-2.0	0.3	+2.0	%
Differential phase	DP	Vin=1Vp-p	-2.0	0.7	+2.0	Deg
Signal to Noise Ratio	VSNR		+40	+60	+100	dB
SYNC tip offset above GND		VBDISOFF=0, Av = +6dB	0	40	75	mV

Test Conditions

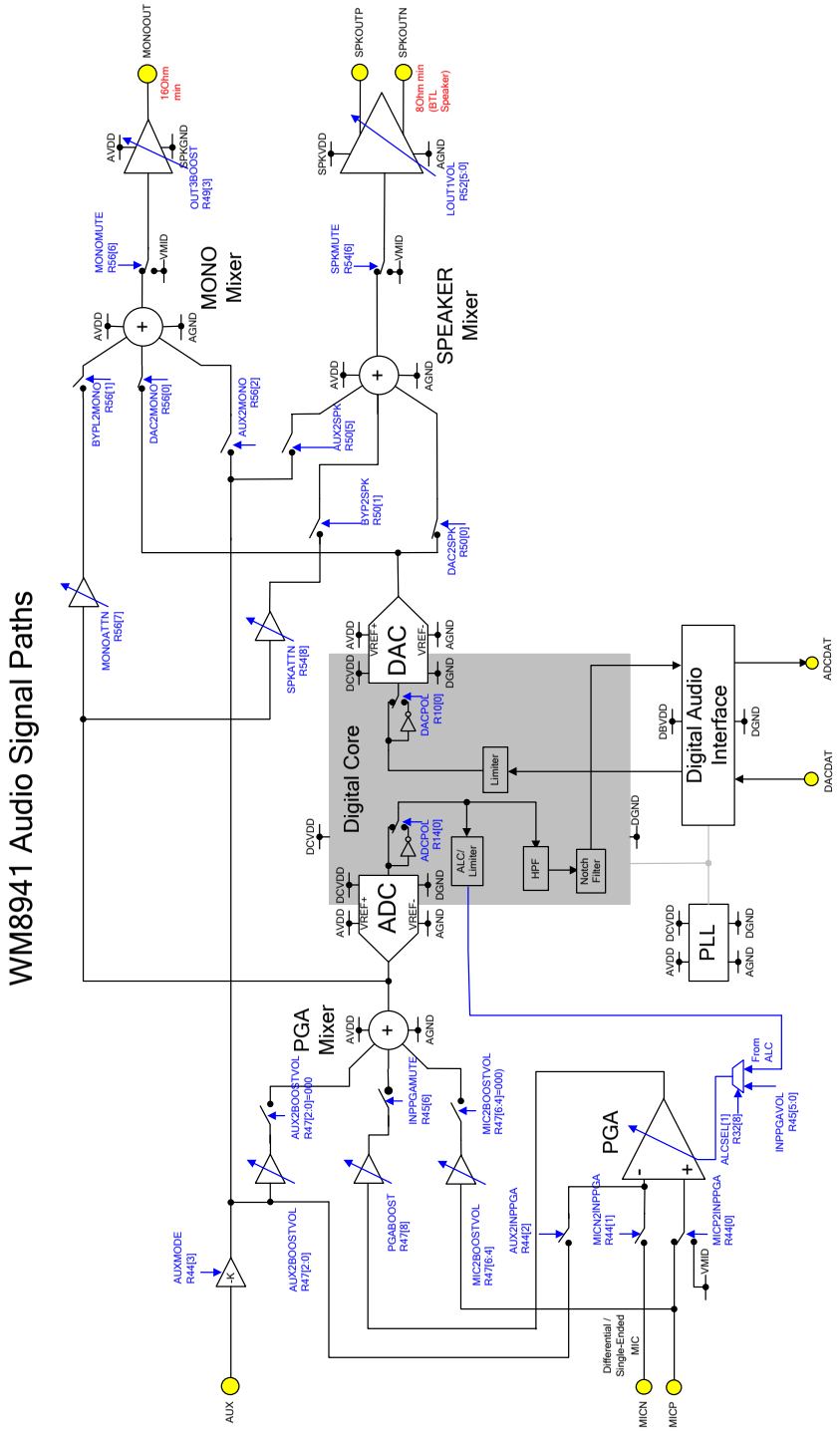
DCVDD=1.8V, DBVDD=3.3V, AVDD=3.3V, SPKVDD =3.3V, , VBVDD=3.3V, T_A = +25°C, 1kHz signal, fs = 48kHz, 24-bit audio data unless otherwise stated.

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Low pass filter order				3rd order		
Low Pass Filter Response (referenced to 100kHz)						
Response at 2.4MHz		R_{VBREF}=187Ω, R_{OUT}=75Ω, R_{LOAD}=75Ω, 0dB gain	-0.1	0	0.1	dB
Response at 5.13MHz			-0.5	-0.2	0.1	dB
Response at 9.04MHz			-3.0	-1.6	0	dB
Response at 13.32MHz			-11.0	-7.0	-3.0	dB
Microphone Bias						
Bias Voltage		MBVSEL=0	0.85* AVDD	0.9*AVDD	0.95* AVDD	V
		MBVSEL=1		0.65*AVDD		V
Bias Current Source		for $V_{MICBIAS}$ within +/-3%			3	mA
Output Noise Voltage		1kHz to 20kHz		15		nV/√Hz
Digital Input / Output						
Input HIGH Level	V_{IH}		0.7× DBVDD		DBVDD+0.7	V
Input LOW Level	V_{IL}		GND-0.7		0.3×DBVDD	V
Output HIGH Level	V_{OH}	I_{OL}=1mA	0.9× DBVDD		DBVDD	V
Output LOW Level	V_{OL}	I_{OH}-1mA	GND		0.1xDBVDD	V
Input Capacitance		All digital pins		10		pF
Input leakage		All digital pins except MODE	-900		+900	nA
		MODE pin	-90		+90	µA

TERMINOLOGY

1. Full-scale input and output levels scale in relation to AVDD or SPKVDD depending upon the input or output used. For example, when AVDD = 3.3V, 0dBFS = 1V_{rms} (0dBV). When AVDD < 3.3V the absolute level of 0dBFS will decrease with a linear relationship to AVDD.
2. Input level to RIP and LIP in differential configurations is limited to a maximum of -3dB or performance will be reduced.
3. Signal-to-noise ratio (dB) – SNR is the difference in level between a reference full scale output signal and the device output with no signal applied. This ratio is also called idle channel noise. (No Auto-zero or Automute function is employed in achieving these results).
4. Total Harmonic Distortion (dB) – THD is the difference in level between a reference output signal and the first seven harmonics of that signal. The reference output signal need not be at full scale amplitude; THD is typically measured using an output power of 20mW into a 16ohm load, corresponding to a reference signal level of -5dB. However the stated test conditions include input signal level, signal gain settings, output load characteristics and power supply voltages To calculate the ratio, the fundamental frequency of the output signal is notched out and an RMS value of the next seven harmonics is calculated.
5. Total Harmonic Distortion plus Noise (dB) – THD+N is the difference in level between a reference output signal and the sum of the harmonics, wide-band noise and interference on the output signal. To calculate the ratio, the fundamental frequency of the output signal is notched out and an RMS value of the total harmonics, wide-band noise and interference is calculated.
6. The Gain is dependant on the external resistor values of R_{VBREF}, R_{OUT}, and $R_{LOAD.}$ The specified values are using the nominal values shown.

AUDIO PATHS OVERVIEW



Power Consumption

Typical current consumption for various scenarios is shown below.

MODE	AVDD (3V3) MA	SPKVDD (3V3) MA	VBVDD (3V3) MA	DVDD (1.8V) MA	TOTAL POWER (MW)
Power OFF (No Clocks)	0.038	0	0	0	0.125
Sleep (VMID maintained, No Clocks)	0.190	0	0	0	0.627
Mono Record (MIC input, +20dB gain, 8kHz, quiescent) SLAVE	4.1	0	0	0.3	14.2
Mono Record (MIC input, +20dB gain, 44.1kHz, PLL, quiescent) MASTER	5.3	0	0	2.1	21.1
Mono 16Ω HP Playback (0.1mW, 1kHz sine wave, ac coupled) SLAVE	2.8	1.5	0	1.6	17.1
Mono 8Ω BTL speaker Playback (44.1kHz, 200mW, 1kHz sine wave) SLAVE	2.8	62.0 *	0	1.6	216.8 *
Mono 8Ω BTL speaker Playback (44.1kHz, PLL, quiescent) MASTER	3.9	1.5	0	1.9	21.2
Mono 8Ω BTL speaker Playback (44.1kHz, PLL, quiescent) MASTER and Video Buffer (0dB gain, unloaded, quiescent)	3.9	1.5	4.8	1.9	36.9
Mono 8Ω BTL speaker Playback (44.1kHz, 200mW, 1kHz sine wave) SLAVE and Video Buffer (1Vpp Multiburst, AC coupled, Clamp Enabled, 0dB gain, 75Ω load)	2.8	62.0 *	22.0	1.6	289.3 *
Mono 8Ω BTL speaker Playback (44.1kHz, 200mW, 1kHz sine wave) SLAVE and Video Buffer (0.5Vpp Multiburst, AC coupled, Clamp enabled, +6dB gain, 75Ω load)	2.8	62.0 *	23.7	1.6	294.9 *

Table 1 Power Consumption

Note: Power consumption figures include any power dissipated in the load (e.g. in the headphone or speaker)

SIGNAL TIMING REQUIREMENTS

SYSTEM CLOCK TIMING

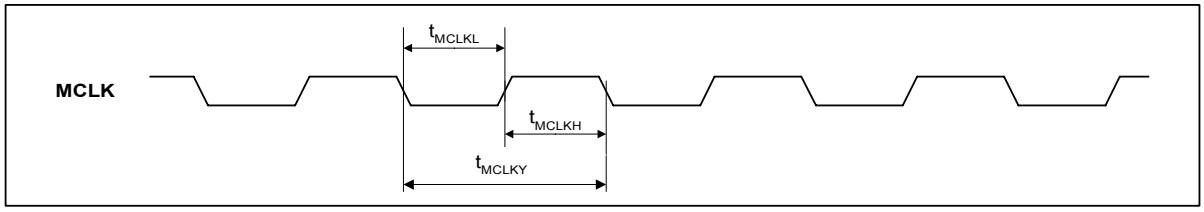


Figure 1 System Clock Timing Requirements

Test Conditions

DVDD=1.8V, AVDD=SPKVDD=3.3V, DGND=AGND=SPKGND=0V, T_A = +25°C

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
System Clock Timing Information						
MCLK cycle time	T_{MCLKY}	MCLK=SYSCLK (=256fs)	81.38			ns
		MCLK input to PLL [Note 1]	20			ns
MCLK duty cycle	T_{MCLKDS}		60:40		40:60	

Note 1:

PLL pre-scaling and PLL N and K values should be set appropriately so that SYSCLK is no greater than 12.288MHz.

AUDIO INTERFACE TIMING – MASTER MODE

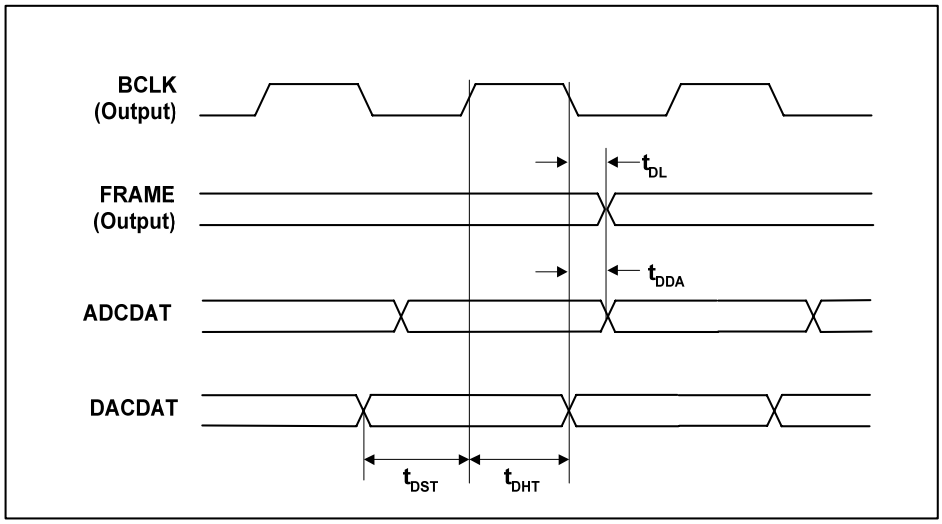


Figure 2 Digital Audio Data Timing – Master Mode (see Control Interface)

Test Conditions

DVDD=1.8V, AVDD=SPKVDD=3.3V, DGND=AGND=SPKGND=0V, T_A=+25°C, Slave Mode, fs=48kHz, MCLK=256fs, 24-bit data, unless otherwise stated.

PARAMETER	SYMBOL	MIN	TYP	MAX	UNIT
Audio Data Input Timing Information					
FRAME propagation delay from BCLK falling edge	t_{DL}			10	ns
ADCDAT propagation delay from BCLK falling edge	t_{DDA}			15	ns
DACDAT setup time to BCLK rising edge	t_{DST}	10			ns
DACDAT hold time from BCLK rising edge	t_{DHT}	10			ns

AUDIO INTERFACE TIMING – SLAVE MODE

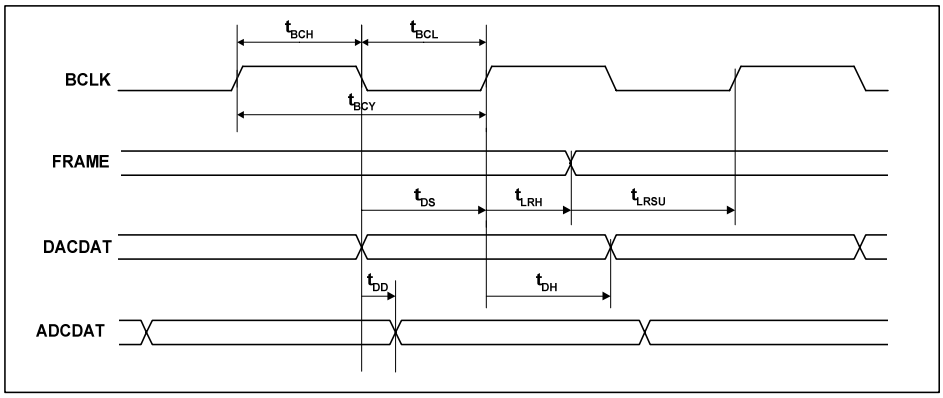


Figure 3 Digital Audio Data Timing – Slave Mode

Test Conditions

DVDD=1.8V, AVDD=SPKVDD=3.3V, DGND=AGND=SPKGND=0V, T_A=+25°C, Slave Mode, fs=48kHz, MCLK= 256fs, 24-bit data, unless otherwise stated.

PARAMETER	SYMBOL	MIN	TYP	MAX	UNIT
Audio Data Input Timing Information					
BCLK cycle time	t_{BCY}	81.38			ns
BCLK pulse width high	t_{BCH}	32.55			ns
BCLK pulse width low	t_{BCL}	32.55			ns
FRAME set-up time to BCLK rising edge	t_{LRSU}	10			ns
FRAME hold time from BCLK rising edge	t_{LRH}	10			ns
DACDAT hold time from BCLK rising edge	t_{DH}	10			ns
DACDAT set-up time to BCLK rising edge	t_{DS}	10			ns
ADCDAT propagation delay from BCLK falling edge	t_{DD}			15	ns

Note:

BCLK period should always be greater than or equal to MCLK period.

CONTROL INTERFACE TIMING – 3-WIRE MODE

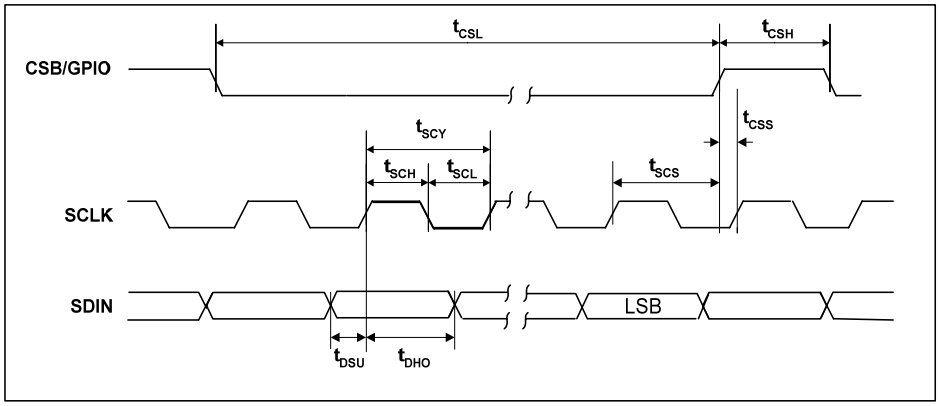


Figure 4 Control Interface Timing – 3-Wire Serial Control Mode

Test Conditions

DVDD = 1.8V, AVDD = SPKVDD = 3.3V, DGND = AGND = SPKGND = 0V, T_A = +25°C, Slave Mode, fs = 48kHz, MCLK = 256fs, 24-bit data, unless otherwise stated.

PARAMETER	SYMBOL	MIN	TYP	MAX	UNIT
Program Register Input Information					
SCLK rising edge to CSB rising edge	t_{SCS}	80			ns
SCLK pulse cycle time	t_{SCY}	200			ns
SCLK pulse width low	t_{SCL}	80			ns
SCLK pulse width high	t_{SCH}	80			ns
SDIN to SCLK set-up time	t_{DSU}	40			ns
SCLK to SDIN hold time	t_{DHO}	40			ns
CSB pulse width low	t_{CSL}	40			ns
CSB pulse width high	t_{CSH}	40			ns
CSB rising to SCLK rising	t_{CSS}	40			ns
Pulse width of spikes that will be suppressed	t_{ps}	0		5	ns

CONTROL INTERFACE TIMING – 2-WIRE MODE

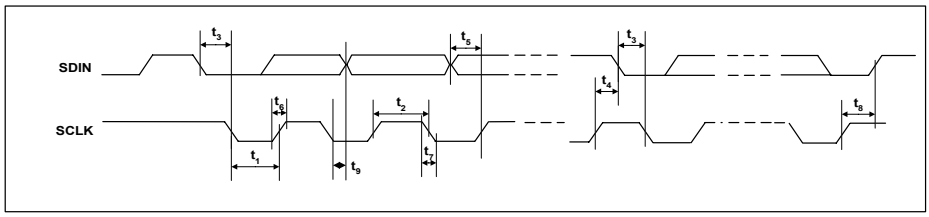


Figure 5 Control Interface Timing – 2-Wire Serial Control Mode

Test Conditions

DVDD=1.8V, AVDD=SPKVDD=3.3V, DGND=AGND=SPKGND=0V, T_A = +25°C, Slave Mode, fs = 48kHz, MCLK = 256fs, 24-bit data, unless otherwise stated.

PARAMETER	SYMBOL	MIN	TYP	MAX	UNIT
Program Register Input Information					
SCLK Frequency		0		526	kHz
SCLK Low Pulse-Width	t_1	1.3			us
SCLK High Pulse-Width	t_2	600			ns
Hold Time (Start Condition)	t_3	600			ns
Setup Time (Start Condition)	t_4	600			ns
Data Setup Time	t_5	100			ns
SDIN, SCLK Rise Time	t_6			300	ns
SDIN, SCLK Fall Time	t_7			300	ns
Setup Time (Stop Condition)	t_8	600			ns
Data Hold Time	t_9			900	ns
Pulse width of spikes that will be suppressed	t_{ps}	0		5	ns

DEVICE DESCRIPTION

INTRODUCTION

The WM8941 is a low power audio codec combining a high quality mono audio DAC and ADC, with flexible line and microphone input and output processing. Applications for this device include digital still cameras or camcorders with mono audio, record and playback capability. An integrated video buffer provides a seamless transition from video DAC output to TV input, saving space and external components.

FEATURES

The chip offers great flexibility in use, and so can support many different modes of operation as follows:

MICROPHONE INPUTS

Two microphone inputs are provided, allowing for either a differential microphone input or a single ended microphone to be connected. These inputs have a user programmable gain range of -12dB to +35.25dB using internal resistors. After the input PGA stage comes a boost stage which can add a further 20dB of gain. A microphone bias is output from the chip which can be used to bias the microphones. The signal routing can be configured to allow manual adjustment of mic levels, or to allow the ALC loop to control the level of mic signal that is transmitted.

Total gain through the microphone paths of up to +55.25dB can be selected.

PGA AND ALC OPERATION

A programmable gain amplifier is provided in the input path to the ADC. This may be used manually or in conjunction with a mixed analogue/digital automatic level control (ALC) which keeps the recording volume constant.

AUX INPUT

The device includes a mono input, AUX, that can be used as an input for warning tones (beep) etc. The output from this circuit can be summed into the mono output and/or the speaker output paths, so allowing for mixing of audio with 'backing music' etc as required. This path can also be summed into the input in a flexible fashion, either to the input PGA as a second microphone input or as a line input. The configuration of this circuit, with integrated on-chip resistors allows several analogue signals to be summed into the single AUX input if required.

ADC

The mono ADC uses a multi-bit high-order oversampling architecture to deliver optimum performance with low power consumption. Various sample rates are supported, from the 8ks/s rate typically used in voice dictation, up to the 48ks/s rate used in high quality audio applications.

HI-FI DAC

The hi-fi DAC provides high quality audio playback suitable for all portable mono audio type applications.

DIGITAL FILTERING

Advanced Sigma Delta Converters are used along with digital decimation and interpolation filters to give high quality audio at sample rates from 8ks/s to 48ks/s.

Application specific digital filters are also available which help to reduce the effect of specific noise sources such as wind noise or narrowband noise from other parts of the system. The filters include a programmable ADC high pass filter and four fully programmable ADC notch filters.

OUTPUT MIXING AND VOLUME ADJUST

Flexible mixing is provided on the outputs of the device; a mixer is provided for the speaker outputs, and an additional mono summer for the mono output. These mixers allow the output of the DAC, the output of the ADC volume control and the Auxiliary input to be combined. The output volume can be adjusted using the integrated digital volume control and there is additional analogue gain adjustment capability on the speaker output.

AUDIO INTERFACES

The WM8941 has a standard audio interface, to support the transmission of audio data to and from the chip. This interface is a 4 wire standard audio interface which supports a number of audio data formats including I^2S, DSP Mode, MSB-First, left justified and MSB-First, right justified, and can operate in master or slave modes.

CONTROL INTERFACES

To allow full software control over all its features, the WM8941 supports 2 or 3 wire control interface. It is fully compatible and an ideal partner for a wide range of industry standard microprocessors, controllers and DSPs. The selection between 2-wire mode and 3-wire mode is determined by the state of the MODE / GPIO pin. If MODE / GPIO is high then 3-wire control mode is selected, if MODE is low then 2-wire control mode is selected.

In 2 wire mode, only slave operation is supported, and the address of the device is fixed as 0011010.

CLOCKING SCHEMES

WM8941 offers the normal audio DAC clocking scheme operation, where 256fs MCLK is provided to the DAC/ADC.

However, a PLL is also included which may be used to generate the internal master clock frequency in the event that this is not available from the system controller. This PLL uses an input clock, typically the 12MHz USB or ilink clock, to generate high quality audio clocks. If this PLL is not required for generation of these clocks, it can be reconfigured to generate alternative clocks which may then be output on the GPIO pin and used elsewhere in the system.

POWER CONTROL

The design of the WM8941 has given much attention to power consumption without compromising performance. It operates at low supply voltages, and includes the facility to power off any unused parts of the circuitry under software control.

As a power saving measure, ADC or DAC logic in the DSP core is held in its last enabled state when the ADC or DAC is disabled. In order to prevent pops and clicks on restart due to residual data in the filters, the master clock must remain for at least 64 input samples after the ADC or DAC has been disabled.

INPUT SIGNAL PATH

The WM8941 has 3 flexible analogue inputs: two microphone inputs, and an auxiliary input. These inputs can be used in a variety of ways. The input signal path before the ADC has a flexible PGA block which then feeds into a gain boost/mixer stage.

MICROPHONE INPUTS

The WM8941 can accommodate a variety of microphone configurations including single ended and differential inputs. The inputs through the MICN, MICP and optionally AUX pins are amplified through the input PGA as shown in Figure 6 .

A pseudo differential input is the preferential configuration where the positive terminal of the input PGA is connected to the MICP input pin by setting MICP2INPPGA=1. The microphone ground should then be connected to MICN (when MICN2INPPGA=1) or optionally to AUX (when AUX2INPPGA=1) input pins.

Alternatively a single ended microphone can be connected to the MICN input with MICN2INPPGA set to 1. The non-inverting terminal of the input PGA should be connected internally to VMID by setting MICP2INPPGA to 0.

In pseudo-differential mode the larger signal should be input to MICP and the smaller (e.g. noisy ground connections) should be input to MICN.

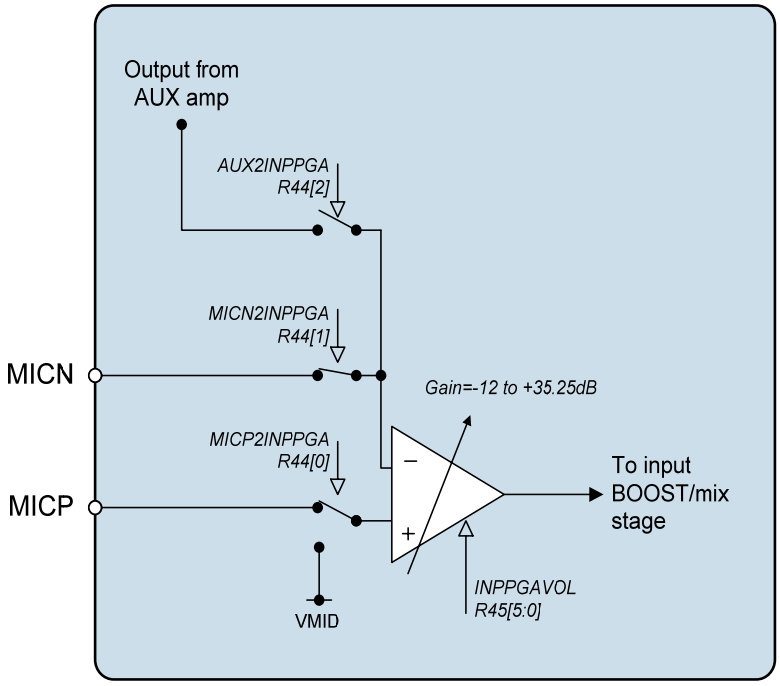


Figure 6 Microphone Input PGA Circuit (switch positions shown are for differential mic input)

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R44 Input Control	2	AUX2INPPGA	0	Select AUX amplifier output as input PGA signal source. 0=AUX not connected to input PGA 1=AUX connected to input PGA amplifier negative terminal.
	1	MICN2INPPGA	1	Connect MICN to input PGA negative terminal. 0=MICN not connected to input PGA 1=MICN connected to input PGA amplifier negative terminal.
	0	MICP2INPPGA	0	Connect input PGA amplifier positive terminal to MICP or VMID. 0 = input PGA amplifier positive terminal connected to VMID 1 = input PGA amplifier positive terminal connected to MICP through variable resistor string

Table 2 Input Control

The input PGA is enabled by the IPPGAEN register bit.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R2 Power Management 2	2	INPPGAEN	0	Input microphone PGA enable 0 = disabled 1 = enabled

Table 3 Input PGA Enable Control

INPUT PGA VOLUME CONTROL

The input microphone PGA has a gain range from -12dB to +35.25dB in 0.75dB steps. The gain from the MICN input to the PGA output and from the AUX amplifier to the PGA output are always common and controlled by the register bits INPPGAVOL[5:0]. These register bits also affect the MICP pin when MICP2INPPGA=1.

When the Automatic Level Control (ALC) is enabled the input PGA gain is then controlled automatically and the INPPGAVOL bits should not be used.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R45 Input PGA volume control	7	INPPGAZC	0	Input PGA zero cross enable: 0=Update gain when gain register changes 1=Update gain on 1st zero cross after gain register write.
	6	INPPGAMUTE	1	Mute control for input PGA: 0=Input PGA not muted, normal operation 1=Input PGA muted (and disconnected from the following input BOOST stage).
	5:0	INPPGAVOL	010000	Input PGA volume 000000 = -12dB 000001 = -11.25db . 010000 = 0dB . 111111 = 35.25dB
R32 ALC control 1	8	ALCSEL	0	ALC function select: 0=ALC off (PGA gain set by INPPGAVOL register bits) 1=ALC on (ALC controls PGA gain)

Table 4 Input PGA Volume Control

AUXILLIARY INPUT

An auxiliary input circuit (Figure 7) is provided which consists of an amplifier which can be configured either as an inverting buffer for a single input signal or as a mixer/summer for multiple inputs with the use of external resistors. The circuit is enabled by the register bit AUXEN.

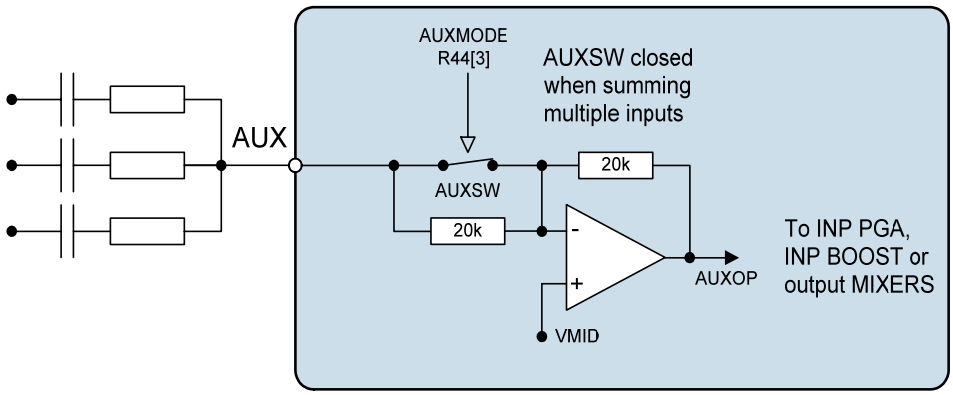


Figure 7 Auxiliary Input Circuit

The AUXMODE register bit controls the auxiliary input mode of operation:

In buffer mode (AUXMODE=0) the switch labelled AUXSW in Figure 7 is open and the signal at the AUX pin will be buffered and inverted through the aux circuit using only the internal components.

In mixer mode (AUXMODE=1) the on-chip input resistor is bypassed, this allows the user to sum in multiple inputs with the use of external resistors. When used in this mode there will be gain variations through this path from part to part due to the variation of the internal 20kΩ resistors relative to the higher tolerance external resistors.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R1 Power management 1	6	AUXEN	0	Auxiliary input buffer enable 0 = OFF 1 = ON
R44 Input control	3	AUXMODE	0	0 = inverting buffer 1 = mixer (on-chip input resistor bypassed)

Table 5 Auxiliary Input Buffer Control

INPUT BOOST

The input BOOST circuit has 3 selectable inputs: the input microphone PGA output, the AUX amplifier output and the MICP input pin (when not using a differential microphone configuration). These three inputs can be mixed together and have individual gain boost/adjust as shown in Figure 8.

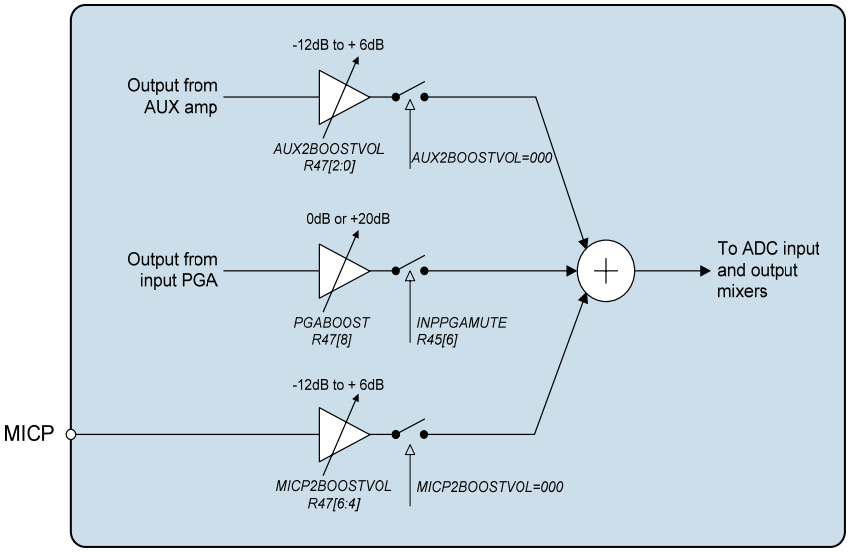


Figure 8 Input Boost Stage

The input PGA path can have a +20dB boost (PGABOOST=1) a 0dB pass through (PGABOOST=0) or be completely isolated from the input boost circuit (INPPGAMUTE=1).

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R45 Input PGA gain control	6	INPPGAMUTE	1	Mute control for input PGA: 0=Input PGA not muted, normal operation 1=Input PGA muted (and disconnected from the following input BOOST stage).
R47 Input BOOST control	8	PGABOOST	0	0 = PGA output has +0dB gain through input BOOST stage. 1 = PGA output has +20dB gain through input BOOST stage.

Table 6 Input BOOST Stage Control

The Auxiliary amplifier path to the BOOST stage is controlled by the AUX2BOOSTVOL[2:0] register bits. When AUX2BOOSTVOL=000 this path is completely disconnected from the BOOST stage. Settings 001 through to 111 control the gain in 3dB steps from -12dB to +6dB.

The MICP path to the BOOST stage is controlled by the MICP2BOOSTVOL[2:0] register bits. When MICP2BOOSTVOL=000 this input pin is completely disconnected from the BOOST stage. Settings 001 through to 111 control the gain in 3dB steps from -12dB to +6dB.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R47 Input BOOST control	6:4	MICP2BOOSTVOL	000	Controls the MICP pin to the input boost stage (NB, when using this path set MICP2INPPGA=0): 000=Path disabled (disconnected) 001=-12dB gain through boost stage 010=-9dB gain through boost stage … 111=+6dB gain through boost stage
	2:0	AUX2BOOSTVOL	000	Controls the auxiliary amplifier to the input boost stage: 000=Path disabled (disconnected) 001=-12dB gain through boost stage 010=-9dB gain through boost stage … 111=+6dB gain through boost stage

Table 7 Input BOOST Stage Control

The BOOST stage is enabled under control of the BOOSTEN register bit.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R2 Power management 2	4	BOOSTEN	0	Input BOOST enable 0 = Boost stage OFF 1 = Boost stage ON

Table 8 Input BOOST Enable Control

MICROPHONE BIASING CIRCUIT

The MICBIAS output provides a low noise reference voltage suitable for biasing electret type microphones and the associated external resistor biasing network. Refer to the Applications Information section for recommended external components. The MICBIAS voltage can be altered via the MBVSEL register bit. When MBVSEL=0, MICBIAS=0.9*AVDD and when MBVSEL=1, MICBIAS=0.65*AVDD. The output can be enabled or disabled using the MICBEN control bit.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R1 Power management 1	4	MICBEN	0	Microphone Bias Enable 0 = OFF (high impedance output) 1 = ON

Table 9 Microphone Bias Enable

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R44 Input Control	8	MBVSEL	0	Microphone Bias Voltage Control 0 = 0.9 * AVDD 1 = 0.65 * AVDD

Table 10 Microphone Bias Voltage Control

The internal MICBIAS circuitry is shown in Figure 9. Note that the maximum source current capability for MICBIAS is 3mA. The external biasing resistors therefore must be large enough to limit the MICBIAS current to 3mA.

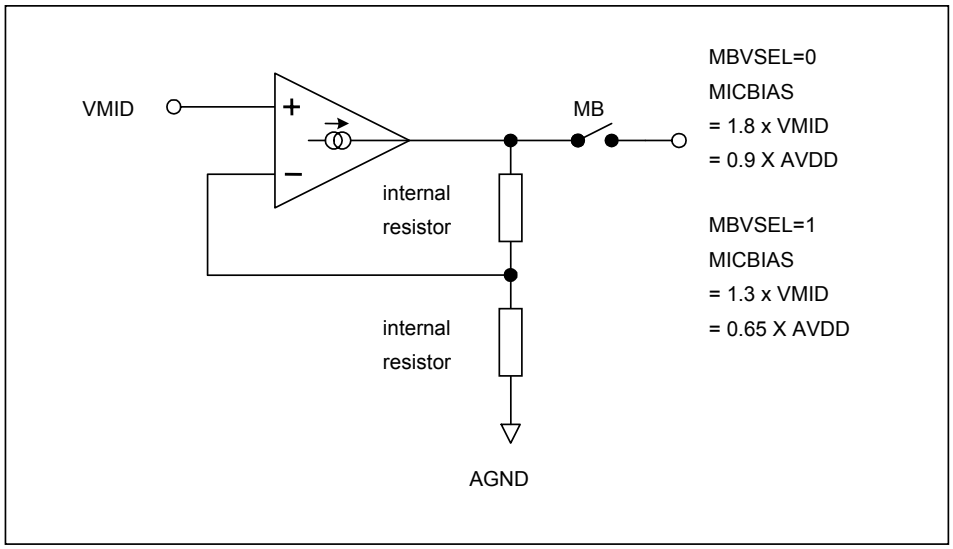


Figure 9 Microphone Bias Schematic

ANALOGUE TO DIGITAL CONVERTER (ADC)

The WM8941 uses a multi-bit, oversampled sigma-delta ADC channel. The use of multi-bit feedback and high oversampling rates reduces the effects of jitter and high frequency noise. The ADC Full Scale input level is proportional to AVDD. With a 3.3V supply voltage, the full scale level is $1.0V_{rms}$. Any voltage greater than full scale may overload the ADC and cause distortion.

ADC DIGITAL FILTERS

The ADC filters perform true 24 bit signal processing to convert the raw multi-bit oversampled data from the ADC to the correct sampling frequency to be output on the digital audio interface. The digital filter path is illustrated in Figure 10.

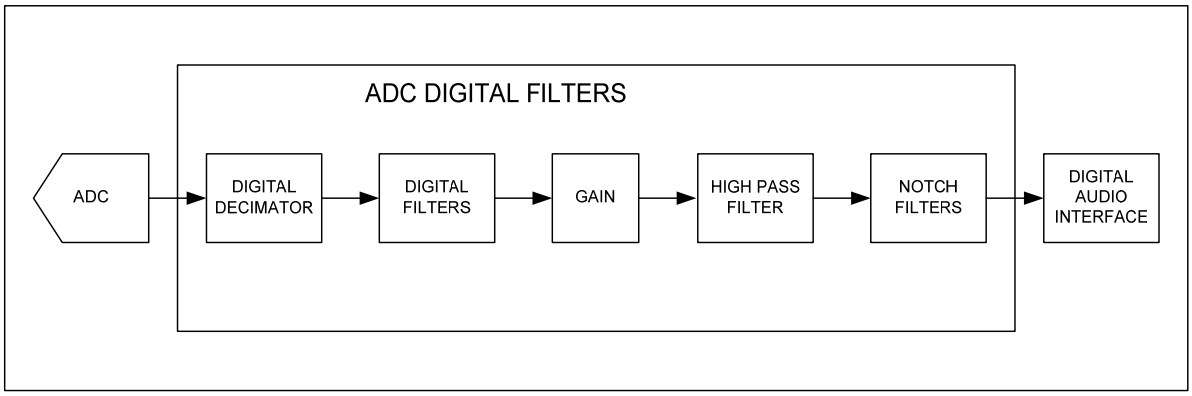


Figure 10 ADC Digital Filter Path

The ADC is enabled by the ADCEN register bit.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R2 Power management 2	0	ADCEN	0	0 = ADC disabled 1 = ADC enabled

Table 11 ADC Enable

The polarity of the output signal can also be changed under software control using the ADCPOL register bit.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R14 ADC Control	0	ADCPOL	0	0=normal 1=inverted

Table 12 ADC Polarity

SELECTABLE HIGH PASS FILTER

A selectable high pass filter is provided. To disable this filter set HPFEN=0. The filter has two modes controlled by HPFAPP. In Audio Mode (HPFAPP=0) the filter is first order, with a cut-off frequency of 3.7Hz. In Application Mode (HPFAPP=1) the filter is second order, with a cut-off frequency selectable via the HPFCUT register. The cut-off frequencies when HPFAPP=1 are shown in Table 14.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R14 ADC Control	8	HPFEN	1	High Pass Filter Enable 0=disabled 1=enabled
	7	HPFAPP	0	Select audio mode or application mode 0=Audio mode (1st order, fc = ~3.7Hz) 1=Application mode (2nd order, fc = HPFCUT)
	6:4	HPFCUT	000	Application mode cut-off frequency See Table 14 for details.

Table 13 ADC Filter Select