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WM8775

24-bit, 96kHz ADC with 4 Channel I/P Multiplexer

DESCRIPTION

The WM8775 is a high performance, stereo audio ADC with a 4 channel input mixer. The WM8775 is ideal for digitising multiple analogue sources for surround sound processing applications for home hi-fi, automotive and other audio visual equipment.

A stereo 24-bit multi-bit sigma delta ADC is used with a four stereo channel input selector. Each channel has programmable gain control. Digital audio output word lengths from 16-32 bits and sampling rates from 32kHz to 96kHz are supported.

The audio data interface supports I^2S, left justified, right justified and DSP digital audio formats.

The device is controlled via a 2 or 3 wire serial interface. The interface provides access to all features including channel selection, volume controls, mutes, de-emphasis and power management facilities.

The device is available in a 28-lead SSOP package. The WM8775 is software compatible with the WM8776.

FEATURES

- Audio Performance
  - 102dB SNR ('A' weighted @ 48kHz)
  - -90dB THD
- ADC Sampling Frequency: 32kHz – 96kHz
- Four stereo ADC inputs with analogue gain adjust from +24dB to –21dB in 0.5dB steps
- Digital gain adjust from -21.5dB to -103dB.
- Programmable Automatic Level Control (ALC) or Limiter on ADC input
- 3-Wire SPI Compatible or 2-wire Serial Control Interface
- Master or Slave Clocking Mode
- Programmable Audio Data Interface Modes
  - I^2S, Left, Right Justified or DSP
  - 16/20/24/32 bit Word Lengths
- 2.7V to 5.5V Analogue, 2.7V to 3.6V Digital supply Operation

APPLICATIONS

- Surround Sound AV Processors and Hi-Fi systems
- Automotive Audio

BLOCK DIAGRAM

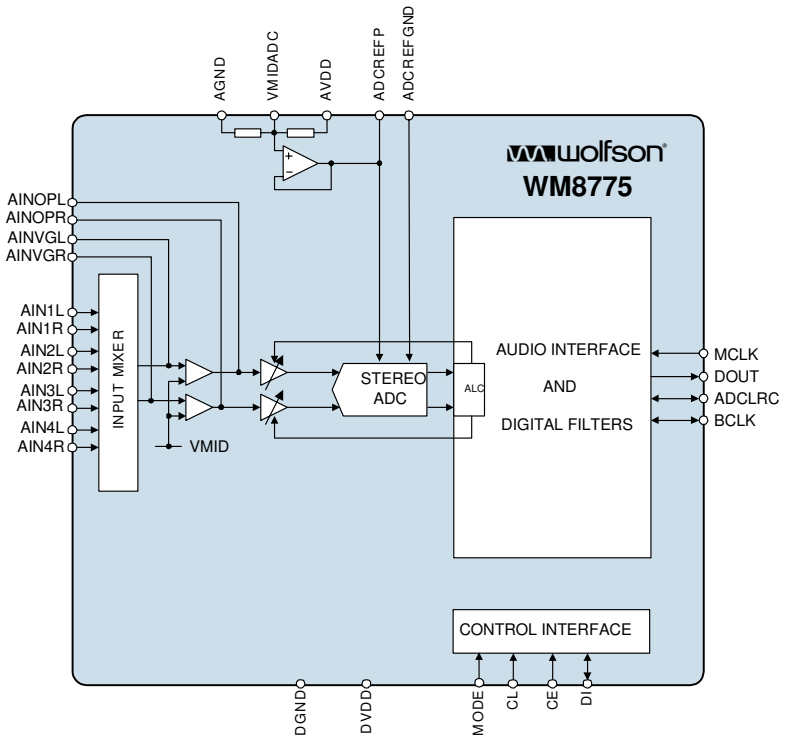
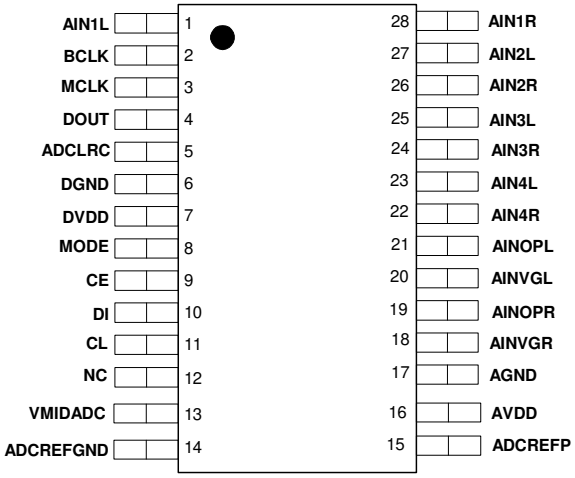


TABLE OF CONTENTS

DESCRIPTION 1
FEATURES 1
BLOCK DIAGRAM 1
PIN CONFIGURATION 3
ORDERING INFORMATION 3
PIN DESCRIPTION 4
ABSOLUTE MAXIMUM RATINGS 5
RECOMMENDED OPERATING CONDITIONS 5
ELECTRICAL CHARACTERISTICS 6
TERMINOLOGY 7
MASTER CLOCK TIMING 7
DIGITAL AUDIO INTERFACE – MASTER MODE 8
DIGITAL AUDIO INTERFACE – SLAVE MODE 9
3-WIRE MPU INTERFACE TIMING 10
2-WIRE MPU INTERFACE TIMING 10
INTERNAL POWER ON RESET CIRCUIT 12
DEVICE DESCRIPTION 14
INTRODUCTION 14
AUDIO DATA SAMPLING RATES 14
POWERDOWN MODES 15
DIGITAL AUDIO INTERFACE 16
CONTROL INTERFACE OPERATION 20
CONTROL INTERFACE REGISTERS 21
LIMITER / AUTOMATIC LEVEL CONTROL (ALC) 26
REGISTER MAP 31
DIGITAL FILTER CHARACTERISTICS 35
ADC FILTER RESPONSES 35
ADC HIGH PASS FILTER 35
APPLICATIONS INFORMATION 36
EXTERNAL CIRCUIT CONFIGURATION 36
RECOMMENDED EXTERNAL COMPONENTS 37
PACKAGE DIMENSIONS 38
IMPORTANT NOTICE 39
ADDRESS: 39

PIN CONFIGURATION



ORDERING INFORMATION

DEVICE	TEMPERATURE RANGE	PACKAGE	MOISTURE SENSITIVITY LEVEL	PEAK SOLDERING TEMPERATURE
WM8775SEDS/V	-25 to +85°C	28-lead SSOP (Pb-free)	MSL2	260°C
WM8775SEDS/RV	-25 to +85°C	28-lead SSOP (Pb-free, tape and reel)	MSL2	260°C

Note:
Reel quantity = 2,000

PIN DESCRIPTION

PIN	NAME	TYPE	DESCRIPTION
1	AIN1L	Analogue Input	Channel 1 left input multiplexor virtual ground
2	BCLK	Digital input/output	ADC audio interface bit clock
3	MCLK	Digital input	Master ADC clock; 256, 384, 512 or 768fs (fs = word clock frequency)
4	DOUT	Digital output	ADC data output
5	ADCLRC	Digital input/output	ADC left/right word clock
6	DGND	Supply	Digital negative supply
7	DVDD	Supply	Digital positive supply
8	MODE	Digital Input	Serial Interface Mode select
9	CE	Digital Input	Serial Interface Latch signal
10	DI	Digital input/output	Serial interface data
11	CL	Digital input	Serial interface clock
12		NC	No connection
13	VMIDADC	Analogue Output	ADC midrail divider decoupling pin; 10uF external decoupling
14	ADCREFGND	Supply	ADC negative supply and substrate connection
15	ADCREFP	Analogue Output	ADC positive reference decoupling pin; 10uF external decoupling
16	AVDD	Supply	Analogue positive supply
17	AGND	Supply	Analogue negative supply and substrate connection
18	AINVGR	Analogue Input	Right channel multiplexor virtual ground
19	AINOPR	Analogue Output	Right channel multiplexor output
20	AINVGL	Analogue Input	Left channel multiplexor virtual ground
21	AINOPL	Analogue Output	Left channel multiplexor output
22	AIN4R	Analogue Input	Channel 4 right input multiplexor virtual ground
23	AIN4L	Analogue Input	Channel 4 left input multiplexor virtual ground
24	AIN3R	Analogue Input	Channel 3 right input multiplexor virtual ground
25	AIN3L	Analogue Input	Channel 3 left input multiplexor virtual ground
26	AIN2R	Analogue Input	Channel 2 right input multiplexor virtual ground
27	AIN2L	Analogue Input	Channel 2 left input multiplexor virtual ground
28	AIN1R	Analogue Input	Channel 1 right input multiplexor virtual ground

Note : Digital input pins have Schmitt trigger input buffers.

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
Digital supply voltage	-0.3V	+3.63V
Analogue supply voltage	-0.3V	+7V
Voltage range digital inputs (MCLK, ADCLRC, BCLK, DI, CL, CE and MODE)	DGND -0.3V	DVDD + 0.3V
Voltage range analogue inputs	AGND -0.3V	AVDD +0.3V
Master Clock Frequency		37MHz
Operating temperature range, T_A	-25°C	+85°C
Junction Temperature, T_J	-25°C	+125°C
Storage temperature	-65°C	+150°C

Notes:

1. Analogue and digital grounds must always be within 0.3V of each other.

RECOMMENDED OPERATING CONDITIONS

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Digital supply range	DVDD		2.7		3.6	V
Analogue supply range	AVDD		2.7		5.5	V
Ground	AGND, DGND			0		V
Difference DGND to AGND			-0.3	0	+0.3	V

Note: Digital supply DVDD must never be more than 0.3V greater than AVDD.

ELECTRICAL CHARACTERISTICS

Test Conditions

AVDD = 5V, DVDD = 3.3V, AGND = 0V, DGND = 0V, T_A = +25°C, fs = 48kHz, MCLK = 256fs unless otherwise stated.

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Digital Logic Levels (TTL Levels)						
Input LOW level	V_{IL}				0.8	V
Input HIGH level	V_{IH}		2.0			V
Output LOW	V_{OL}	I_{OL}=1mA			0.1 x DVDD	V
Output HIGH	V_{OH}	I_{OH}=1mA	0.9 x DVDD			V
Analogue Reference Levels						
Reference voltage	V_{VMID}			AVDD/2		V
Potential divider resistance	R_{VMID}			50k		Ω
ADC Performance						
Input Signal Level (0dB)				1.0 x AVDD/5		Vrms
SNR (Note 1,2)		A-weighted, 0dB gain @ fs = 48kHz	93	102		dB
SNR (Note 1,2)		A-weighted, 0dB gain @ fs = 96kHz 64xOSR		99		dB
Dynamic Range (note 2)		A-weighted, -60dB full scale input		102		dB
Total Harmonic Distortion (THD)		1 kHz, 0dBFs		-92		dB
		1kHz, -1dBFs		-95	-85	dB
ADC Channel Separation		1kHz Input		90		dB
Programmable Gain Step Size			0.25	0.5	0.75	dB
Programmable Gain Range (Analogue)		1kHz Input	-21		+24	dB
Programmable Gain Range (Digital)		1kHz Input	-82		+0	dB
Analogue Mute Attenuation (Note 5)		1kHz Input, 0dB gain		76		dB
Power Supply Rejection Ratio	PSRR	1kHz 100mVpp		50		dB
		20Hz to 20kHz 100mVpp		45		dB
Supply Current						
Analogue supply current		AVDD = 5V		48		mA
Digital supply current		DVDD = 3.3V		4.5		mA

Notes:

1. Ratio of output level with 1kHz full scale input, to the output level with all zeros into the digital input, measured 'A' weighted.
2. All performance measurements done with 20kHz low pass filter, and where noted an A-weight filter. Failure to use such a filter will result in higher THD+N and lower SNR and Dynamic Range 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.
3. VMID decoupled with 10uF and 0.1uF capacitors (smaller values may result in reduced performance).
4. All performance measurement done using certain timing conditions (please refer to section 'Digital Audio Interface').
5. A full digital MUTE can be achieved if the ADC gain (LAG/RAG) is set to minimum.

TERMINOLOGY

1. Signal-to-noise ratio (dB) - SNR is a measure of the difference in level between the full scale output and the output with no signal applied. (No Auto-zero or Automute function is employed in achieving these results).
2. Dynamic range (dB) - DNR is a measure of the difference between the highest and lowest portions of a signal. Normally a THD+N measurement at 60dB below full scale. The measured signal is then corrected by adding the 60dB to it. (e.g. THD+N @ -60dB= -32dB, DR= 92dB).
3. THD+N (dB) - THD+N is a ratio, of the rms values, of (Noise + Distortion)/Signal.
4. Stop band attenuation (dB) - Is the degree to which the frequency spectrum is attenuated (outside audio band).
5. Channel Separation (dB) - Also known as Cross-Talk. This is a measure of the amount one channel is isolated from the other. Normally measured by sending a full scale signal down one channel and measuring the other.
6. Pass-Band Ripple - Any variation of the frequency response in the pass-band region.

MASTER CLOCK TIMING

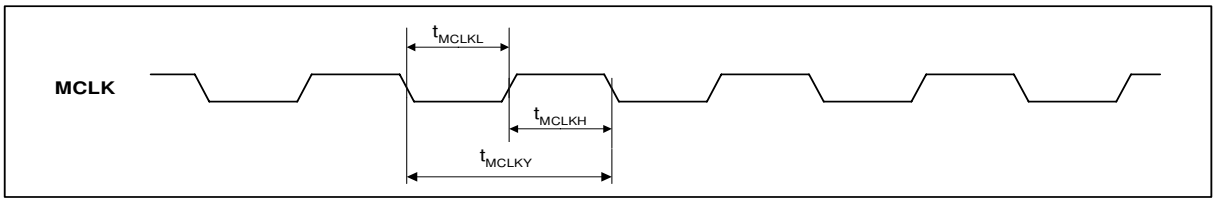


Figure 1 Master Clock Timing Requirements

Test Conditions

AVDD = 5V, DVDD = 3.3V, AGND = 0V, DGND = 0V, T_A = +25°C, fs = 48kHz, MCLK = 256fs unless otherwise stated.

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
System Clock Timing Information						
MCLK System clock pulse width high	t_{MCLKH}		11			ns
MCLK System clock pulse width low	t_{MCLKL}		11			ns
MCLK System clock cycle time	t_{MCLKY}		28		1000	ns
MCLK Duty cycle			40:60		60:40	
Power-saving mode activated		After MCLK stopped	2		10	µs
Normal mode resumed		After MCLK re-started	0.5		1	MCLK cycle

Table 1 Master Clock Timing Requirements

Note:

If MCLK period is longer than maximum specified above, power-saving mode is entered. In this power-saving mode, all registers will retain their values and can be accessed in the normal manner through the control interface.

DIGITAL AUDIO INTERFACE – MASTER MODE

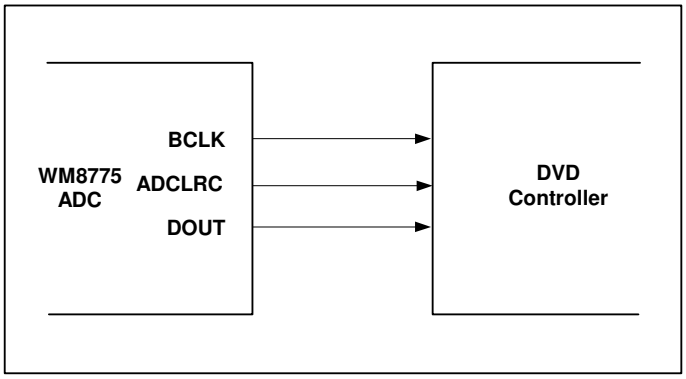


Figure 2 Audio Interface - Master Mode

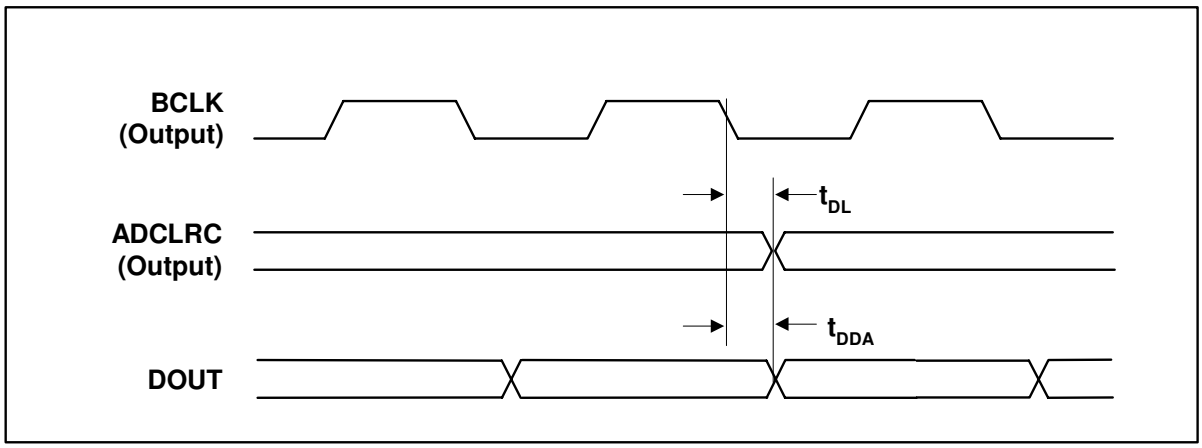


Figure 3 Digital Audio Data Timing – Master Mode

Test Conditions

AVDD = 5V, DVDD = 3.3V, AGND=0V, DGND = 0V, T_A = +25°C, Master Mode, fs = 48kHz, MCLK = 256fs unless otherwise stated.

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Audio Data Input Timing Information						
ADCLRC propagation delay from BCLK falling edge	t_{DL}		0		10	ns
DOUT propagation delay from BCLK falling edge	t_{DDA}		0		10	ns

Table 2 Digital Audio Data Timing – Master Mode

DIGITAL AUDIO INTERFACE – SLAVE MODE

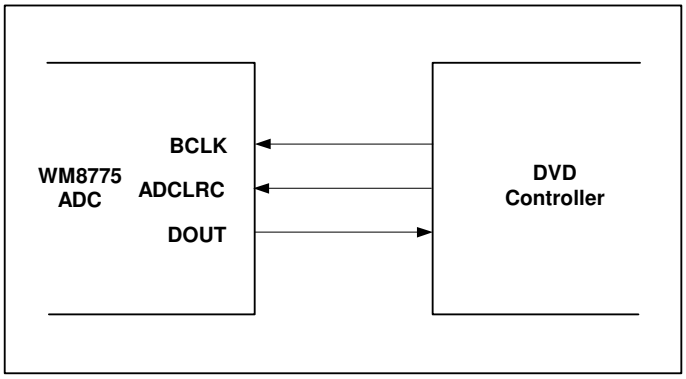


Figure 4 Audio Interface – Slave Mode

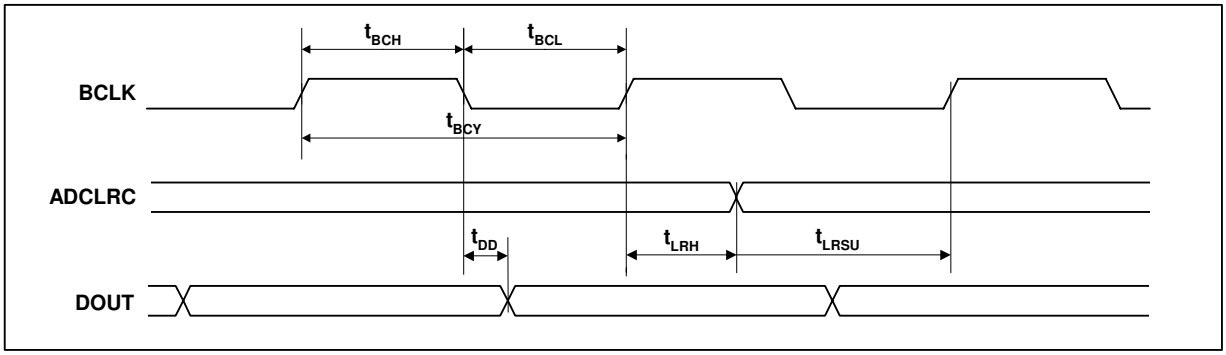


Figure 5 Digital Audio Data Timing – Slave Mode

Test Conditions

AVDD = 5V, DVDD = 3.3V, AGND = 0V, DGND = 0V, T_A = +25°C, Slave Mode, fs = 48kHz, MCLK = 256fs unless otherwise stated.

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Audio Data Input Timing Information						
BCLK cycle time	t_{BCY}		50			ns
BCLK pulse width high	t_{BCH}		20			ns
BCLK pulse width low	t_{BCL}		20			ns
ADCLRC set-up time to BCLK rising edge	t_{LRSU}		10			ns
ADCLRC hold time from BCLK rising edge	t_{LRH}		10			ns
DOUT propagation delay from BCLK falling edge	t_{DD}		0		10	ns

Table 3 Digital Audio Data Timing – Slave Mode

Note:

ADCLRC should be synchronous with MCLK, although the WM8775 interface is tolerant of phase variations or jitter on these signals.

3-WIRE MPU INTERFACE TIMING

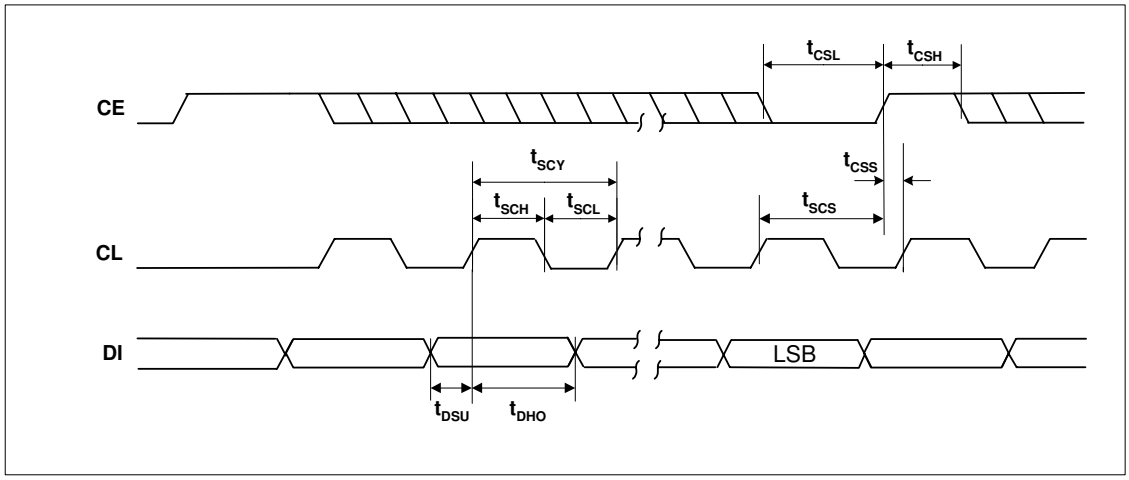


Figure 6 SPI Compatible Control Interface Input Timing (MODE=1)

Test Conditions

AVDD = 5V, DVDD = 3.3V, AGND = 0V, DGND = 0V, T_A = +25°C, fs = 48kHz, MCLK = 256fs unless otherwise stated

PARAMETER	SYMBOL	MIN	TYP	MAX	UNIT
CL rising edge to CE rising edge	t_{SCS}	60			ns
CL pulse cycle time	t_{SCY}	80			ns
CL pulse width low	t_{SCL}	30			ns
CL pulse width high	t_{SCH}	30			ns
DI to CL set-up time	t_{DSU}	20			ns
CL to DI hold time	t_{DHO}	20			ns
CE pulse width low	t_{CSL}	20			ns
CE pulse width high	t_{CSH}	20			ns
CE rising to CL rising	t_{CSS}	20			ns

Table 4 3-Wire SPI Compatible Control Interface Input Timing Information

2-WIRE MPU INTERFACE TIMING

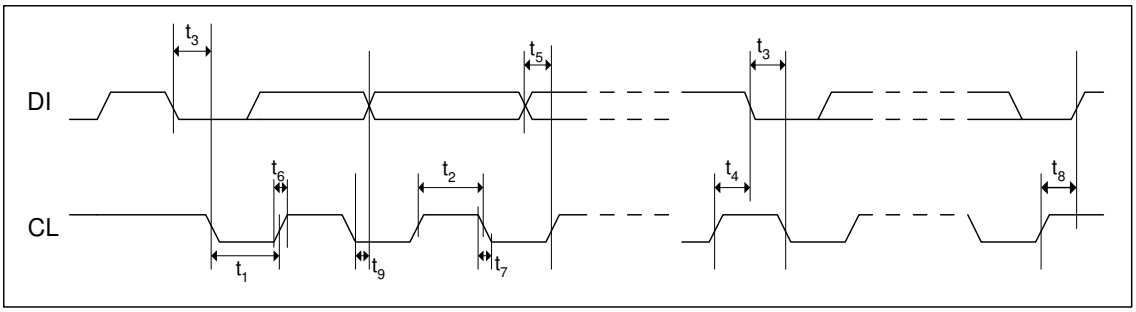


Figure 7 Control Interface Timing – 2-Wire Serial Control Mode (MODE=0)

Test Conditions

AVDD = 5V, DVDD = 3.3V, AGND = 0V, DGND = 0V, T_A = +25°C, fs = 48kHz, MCLK = 256fs unless otherwise stated

PARAMETER	SYMBOL	MIN	TYP	MAX	UNIT
Program Register Input Information					
CL Frequency		0		526	kHz
CL Low Pulse-Width	t_1	1.3			us
CL 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
DI, CL Rise Time	t_6			300	ns
DI, CL 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

Table 5 2-Wire Control Interface Timing Information

INTERNAL POWER ON RESET CIRCUIT

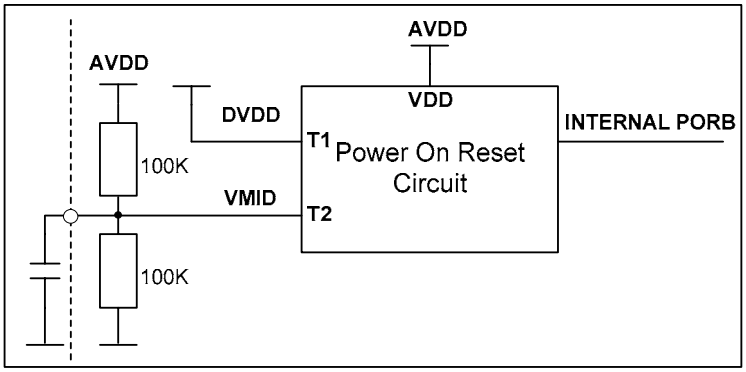


Figure 8 Internal Power on Reset Circuit Schematic

The WM8775 includes an internal Power on Reset Circuit which is used reset the digital logic into a default state after power up.

Figure 8 shows a schematic of the internal POR circuit. The POR circuit is powered from AVDD. The circuit monitors DVDD and VMID and asserts PORB low if DVDD or VMID are below the minimum threshold Vpor_off.

On power up, the POR circuit requires AVDD to be present to operate. PORB is asserted low until AVDD and DVDD and VMID are established. When AVDD, DVDD, and VMID have been established, PORB is released high, all registers are in their default state and writes to the digital interface may take place.

On power down, PORB is asserted low whenever DVDD or VMID drop below the minimum threshold Vpor_off.

If AVDD is removed at any time, the internal Power on Reset circuit is powered down and PORB will follow AVDD.

In most applications the time required for the device to release PORB high will be determined by the charge time of the VMID node.

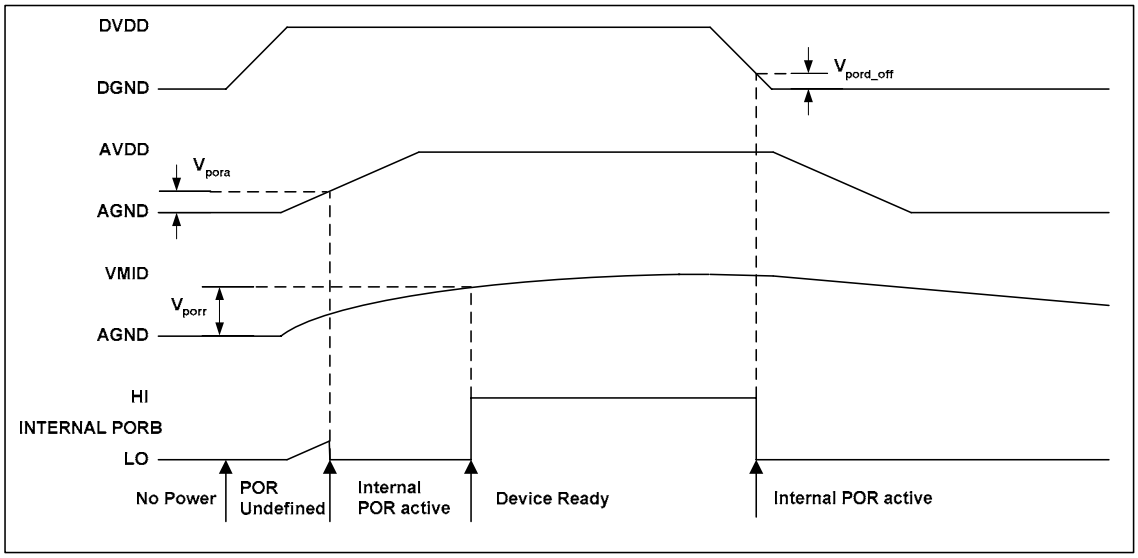


Figure 9 Typical Power up Sequence where DVDD is Powered before AVDD

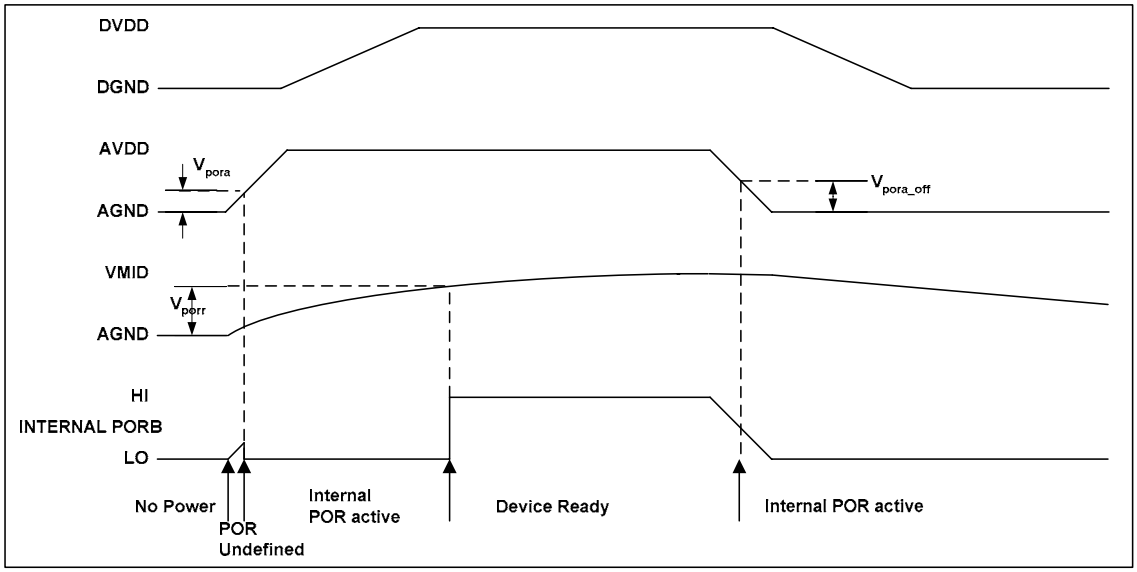


Figure 10 Typical Power up Sequence where AVDD is Powered before DVDD

Typical POR Operation (typical values, not tested)

SYMBOL	MIN	TYP	MAX	UNIT
V_{pora}	0.5	0.7	1.0	V
V_{porr}	0.5	0.7	1.1	V
V_{pora_off}	1.0	1.4	2.0	V
V_{pord_off}	0.6	0.8	1.0	V

In a real application the designer is unlikely to have control of the relative power up sequence of AVDD and DVDD. Using the POR circuit to monitor VMID ensures a reasonable delay between applying power to the device and Device Ready.

Figure 9 and Figure 10 show typical power up scenarios in a real system. Both AVDD and DVDD must be established and VMID must have reached the threshold Vporr before the device is ready and can be written to. Any writes to the device before Device Ready will be ignored.

Figure 9 shows DVDD powering up before AVDD. Figure 10 shows AVDD powering up before DVDD. In both cases, the time from applying power to Device Ready is dominated by the charge time of VMID.

A 10uF cap is recommended for decoupling on VMID. The charge time for VMID will dominate the time required for the device to become ready after power is applied. The time required for VMID to reach the threshold is a function of the VMID resistor string and the decoupling capacitor. The Resistor string has an typical equivalent resistance of 50kΩ (+/-20%). Assuming a 10uF capacitor, the time required for VMID to reach threshold of 1V is approx 110ms.

DEVICE DESCRIPTION

INTRODUCTION

WM8775 is a stereo audio ADC, with a flexible four input multiplexor. It is available in a single package and controlled by either a 3-wire or a 2-wire interface.

The input multiplexor to the ADC is configured to allow large signal levels to be input to the ADC, using external resistors to reduce the amplitude of larger signals to within the normal operating range of the ADC. The ADC has an analogue input PGA and a digital gain control, accessed by one register write. The input PGA allows input signals to be gained up to +24dB and attenuated down to -21dB in 0.5dB steps. The digital gain control allows attenuation from -21.5dB to -103dB in 0.5dB steps. This allows the user maximum flexibility in the use of the ADC.

The Audio Interface may be configured to operate in either master or slave mode. In Slave mode ADCLRC and BCLK are all inputs. In Master mode ADCLRC and BCLK are outputs. The audio data interface supports right, left and I^2S interface formats along with a highly flexible DSP serial port interface. Operation using system clock of 256fs, 384fs, 512fs or 768fs is provided. In Slave mode selection between clock rates is automatically controlled. In master mode the master clock to sample rate ratio is set by control bit ADCRATE. Master clock sample rates (fs) from less than 32kHz up to 96kHz are allowed, provided the appropriate system clock is input.

Control of internal functionality of the device is by 3-wire SPI compatible or 2-wire serial control interface. Either interface may be asynchronous to the audio data interface as control data will be re-synchronised to the audio processing internally.

AUDIO DATA SAMPLING RATES

In a typical digital audio system there is only one central clock source producing a reference clock to which all audio data processing is synchronised. This clock is often referred to as the audio system's Master Clock. The external master system clock can be applied directly through the MCLK input pin with no software configuration necessary. In a system where there are a number of possible sources for the reference clock it is recommended that the clock source with the lowest jitter be used to optimise the performance of the ADC.

The master clock for WM8775 supports ADC audio sampling rates from 256fs to 768fs, where fs is the audio sampling frequency (ADCLRC) typically 32kHz, 44.1kHz, 48kHz or 96kHz. The master clock is used to operate the digital filters and the noise shaping circuits.

In Slave mode, the WM8775 has a master detection circuit that automatically determines the relationship between the master clock frequency and the sampling rate (to within +/- 32 system clocks). If there is a greater than 32 clocks error the interface is disabled and maintains the output level at the last sample. The master clock must be synchronised with ADCLRC, although the WM8775 is tolerant of phase variations or jitter on this clock. Table 6 shows the typical master clock frequency inputs for the WM8775.

The signal processing for the WM8775 typically operates at an oversampling rate of 128fs. For ADC operation at 96kHz, it is recommended that the user set the ADCOSR bit. This changes the ADC signal processing oversample rate to 64fs.

SAMPLING RATE (ADCLRC)	System Clock Frequency (MHz)			
	256fs	384fs	512fs	768fs
32kHz	8.192	12.288	16.384	24.576
44.1kHz	11.2896	16.9340	22.5792	33.8688
48kHz	12.288	18.432	24.576	36.864
96kHz	24.576	36.864	Unavailable	Unavailable

Table 6 System Clock Frequencies Versus Sampling Rate

In Master mode BCLK and ADCLRC are generated by the WM8775. The frequency of ADCLRC is set by setting the required ratio of MCLK to ADCLRC using the ADCRATE control bit (Table 7).

ADCRATE[2:0]	MCLK:ADCLRC RATIO
010	256fs
011	384fs
100	512fs
101	768fs

Table 7 Master Mode MCLK:ADCLRC Ratio Select

Table 8 shows the settings for ADCRATE for common sample rates and MCLK frequencies.

SAMPLING RATE (ADCLRC)	System Clock Frequency (MHz)			
	256fs	384fs	512fs	768fs
	ADCRATE =010	ADCRATE =011	ADCRATE =100	ADCRATE =101
32kHz	8.192	12.288	16.384	24.576
44.1kHz	11.2896	16.9340	22.5792	33.8688
48kHz	12.288	18.432	24.576	36.864
96kHz	24.576	36.864	Unavailable	Unavailable

Table 8 Master Mode ADCLRC Frequency Selection

BCLK is also generated by the WM8775. The frequency of BCLK depends on the mode of operation. If using 256, 384, 512 or 768fs (ADCRATE=010, 011,100 or 101) BCLK = MCLK/4. However if DSP mode is selected as the audio interface mode then BCLK=MCLK.

POWERDOWN MODES

The WM8775 has powerdown control bits allowing specific parts of the WM8775 to be powered off when not being used. The 4-channel input source selector and input buffer may be powered down using control bit AINPD. When AINPD is set all inputs to the source selector (AIN1l/R to AIN4L/R) are switched to a buffered VMIDADC. Control bit ADCPD powers off the ADC and also the ADC input PGAs. Setting AINPD and ADCPD will powerdown everything except the references VMIDADC and ADCREFP. These may be powered down by setting PDWN. Setting PDWN will override all other powerdown control bits. It is recommended that the 4-channel input mux and buffer AINPD and ADCPD are powered down before setting PDWN. The default is for all powerdown bits to be 0 i.e. enabled.

DIGITAL AUDIO INTERFACE

MASTER AND SLAVE MODES

The audio interface operates in either Slave or Master mode, selectable using the MS control bit. In both Master and Slave modes ADCDAT is always an output. The default is Slave mode.

In Slave mode (MS=0) ADCLRC and BCLK are inputs to the WM8775 (Figure 11). ADCLRC is sampled by the WM8775 on the rising edge of BCLK. ADC data is output on DOUT and changes on the falling edge of BCLK. By setting control bit BCLKINV the polarity of BCLK may be reversed so that ADCLRC is sampled on the falling edge of BCLK and DOUT changes on the rising edge of BCLK.

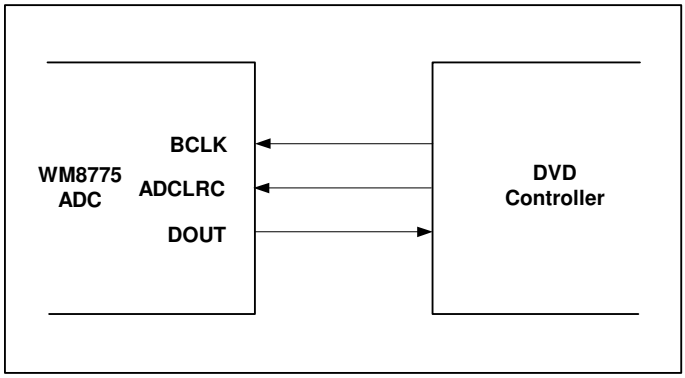


Figure 11 Slave Mode

In Master mode (MS=1) ADCLRC and BCLK are outputs from the WM8775 (Figure 12). ADCLRC and BITCLK are generated by the WM8775. ADCDAT is output on DOUT and changes on the falling edge of BCLK. By setting control bit BCLKINV, the polarity of BCLK may be reversed so that DOUT changes on the rising edge of BCLK.

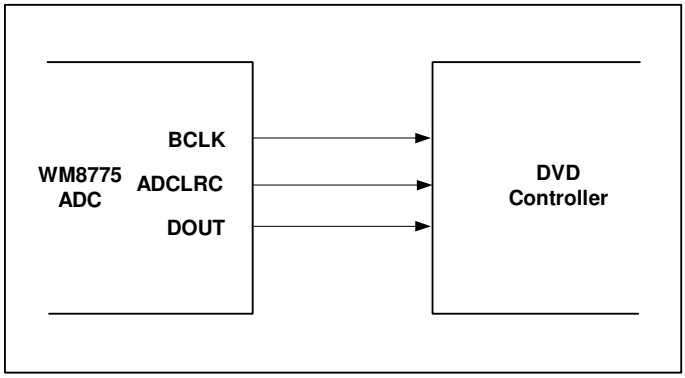


Figure 12 Master Mode

AUDIO INTERFACE FORMATS

Audio data output from the ADC filters, via the Digital Audio Interface. 5 popular interface formats are supported:

- Left Justified mode
- Right Justified mode
- I^2S mode
- DSP Mode A
- DSP Mode B

All 5 formats send the MSB first and support word lengths of 16, 20, 24 and 32 bits, with the exception of 32 bit right justified mode, which is not supported.

In left justified, right justified and I^2S modes, the digital audio interface outputs ADC data on DOUT. Audio Data for each stereo channel is time multiplexed with ADCLRC indicating whether the left or right channel is present. ADCLRC is also used as a timing reference to indicate the beginning or end of the data words.

In left justified, right justified and I^2S modes, the minimum number of BCLKs per ADCLRC period is 2 times the selected word length. ADCLRC must be high for a minimum of word length BCLKs and low for a minimum of word length BCLKs. Any mark to space ratio on ADCLRC is acceptable provided the above requirements are met.

In DSP Mode A or B, the ADC data may also be output, with ADCLRC used as a frame sync to identify the MSB of the first word. The minimum number of BCLKs per ADCLRC period is 2 times the selected word length

LEFT JUSTIFIED MODE

In left justified mode, the MSB of the ADC data is output on DOUT and changes on the same falling edge of BCLK as ADCLRC and may be sampled on the rising edge of BCLK. ADCLRC is high during the left samples and low during the right samples (Figure 13).

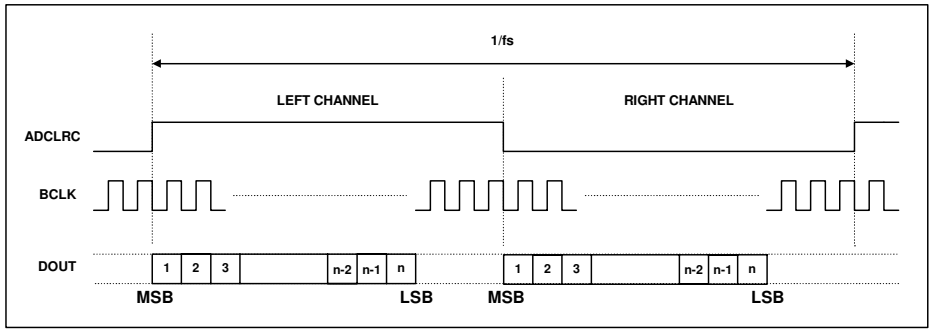


Figure 13 Left Justified Mode Timing Diagram

RIGHT JUSTIFIED MODE

In right justified mode, the LSB of the ADC data is output on DOUT and changes on the falling edge of BCLK preceding a ADCLRC transition and may be sampled on the rising edge of BCLK. ADCLRC is high during the left samples and low during the right samples (Figure 14).

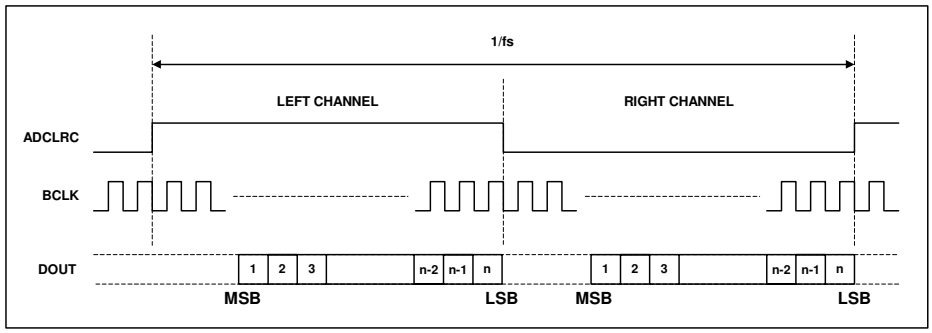


Figure 14 Right Justified Mode Timing Diagram

I²S MODE

In I²S mode, the MSB of the ADC data is output on DOUT and changes on the first falling edge of BCLK following an ADCLRC transition and may be sampled on the rising edge of BCLK. ADCLRC is low during the left samples and high during the right samples.

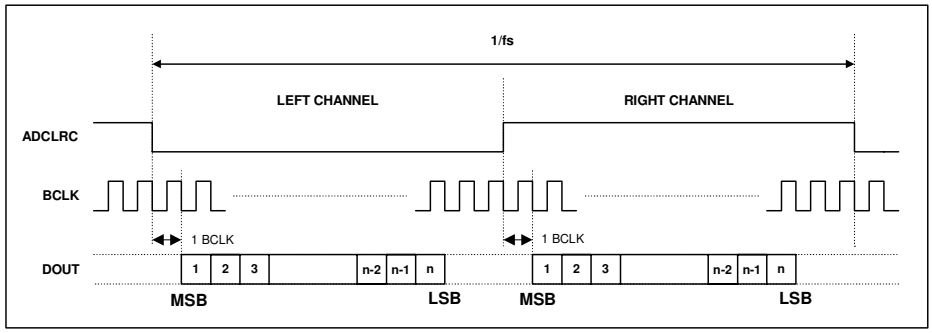


Figure 15 I²S Mode Timing Diagram

DSP MODE

In DSP/PCM mode, the left channel MSB is available on either the 1st (mode B) or 2nd (mode A) rising edge of BCLK (selectable by LRP) following a rising edge of LRC. Right channel data immediately follows left channel data. Depending on word length, BCLK frequency and sample rate, there may be unused BCLK cycles between the LSB of the right channel data and the next sample.

In device master mode, the LRC output will resemble the frame pulse shown in Figure 16 and Figure 17. In device slave mode, Figure 18 and Figure 19, it is possible to use any length of frame pulse less than 1/fs, providing the falling edge of the frame pulse occurs greater than one BCLK period before the rising edge of the next frame pulse.

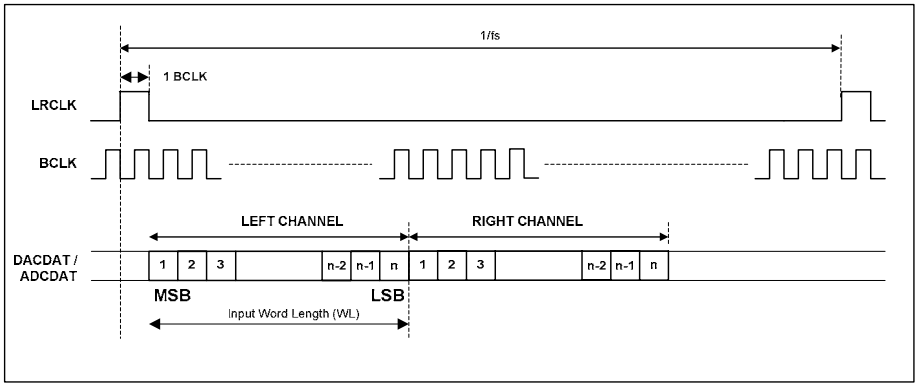


Figure 16 DSP/PCM Mode Audio Interface (mode A, LRP=0, Master)

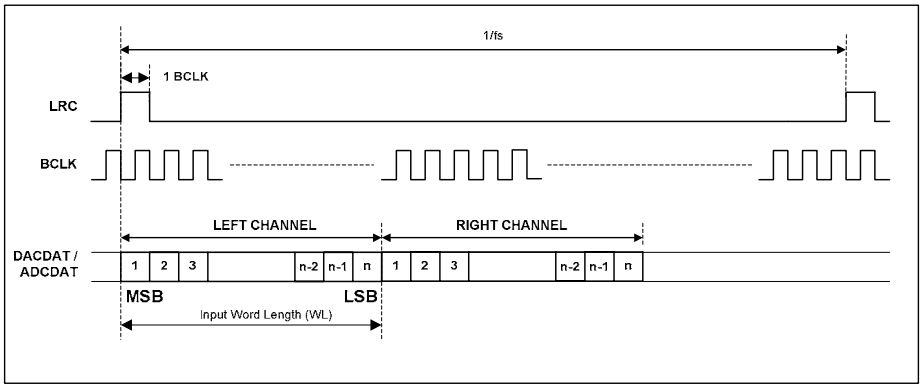


Figure 17 DSP/PCM Mode Audio Interface (mode B, LRP=1, Master)

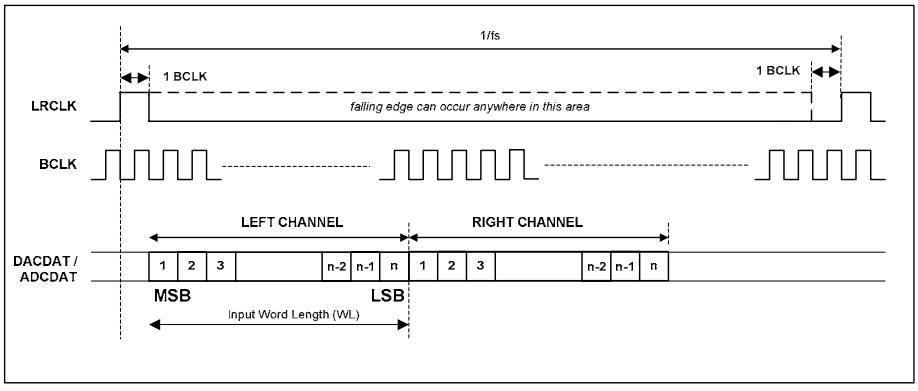


Figure 18 DSP/PCM Mode Audio Interface (mode A, LRP=0, Slave)

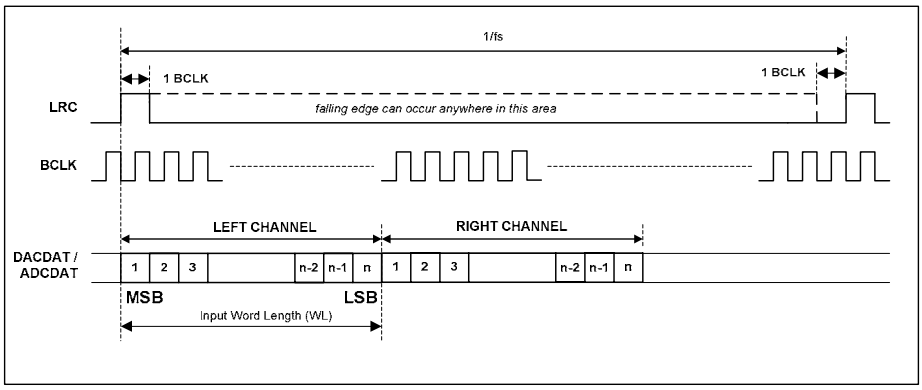


Figure 19 DSP/PCM Mode Audio Interface (mode B, LRP=0, Slave)

CONTROL INTERFACE OPERATION

The WM8775 is controlled using a 3-wire serial interface in a SPI compatible configuration or a 2-wire serial interface mode. The interface type is selected by the MODE pin as shown in Table 9.

MODE	Control Mode
0	2 wire interface
1	3 wire interface

Table 9 Control Interface Selection via MODE pin

3-WIRE (SPI COMPATIBLE) SERIAL CONTROL MODE

DI is used for the program data, CL is used to clock in the program data and CE is used to latch the program data. DI is sampled on the rising edge of CL. The 3-wire interface protocol is shown in Figure 20.

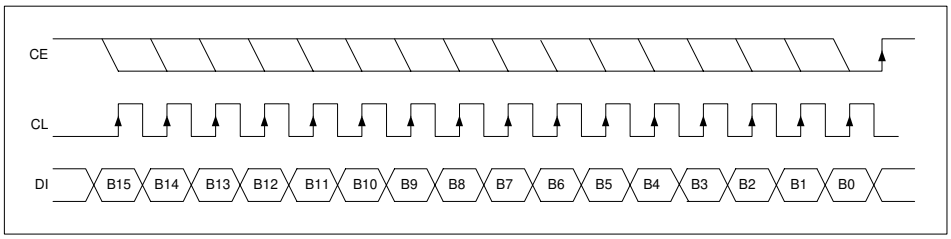


Figure 20 3-Wire SPI Compatible Interface

1. B[15:9] are Control Address Bits
2. B[8:0] are Control Data Bits
3. CE is edge sensitive – the data is latched on the rising edge of CE.

2-WIRE SERIAL CONTROL MODE

The WM8775 supports software control via a 2-wire serial bus. Many devices can be controlled by the same bus, and each device has a unique 7-bit address (this is not the same as the 7-bit address of each register in the WM8775).

The WM8775 operates as a slave device only. The controller indicates the start of data transfer with a high to low transition on DI while CL remains high. This indicates that a device address and data will follow. All devices on the 2-wire bus respond to the start condition and shift in the next eight bits on DI (7-bit address + Read/Write bit, MSB first). If the device address received matches the address of the WM8775 and the R/W bit is '0', indicating a write, then the WM8775 responds by pulling DI low on the next clock pulse (ACK). If the address is not recognised or the R/W bit is '1', the WM8775 returns to the idle condition and wait for a new start condition and valid address.

Once the WM8775 has acknowledged a correct address, the controller sends the first byte of control data (B15 to B8, i.e. the WM8775 register address plus the first bit of register data). The WM8775 then acknowledges the first data byte by pulling DI low for one clock pulse. The controller then sends the second byte of control data (B7 to B0, i.e. the remaining 8 bits of register data), and the WM8775 acknowledges again by pulling DI low.

The transfer of data is complete when there is a low to high transition on DI while CL is high. After receiving a complete address and data sequence the WM8775 returns to the idle state and waits for another start condition. If a start or stop condition is detected out of sequence at any point during data transfer (i.e. DI changes while CL is high), the device jumps to the idle condition.

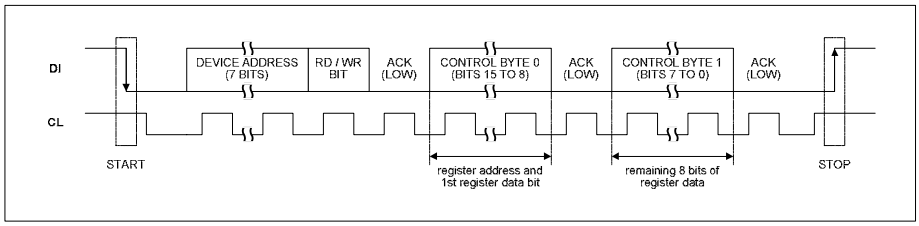


Figure 21 2-Wire Serial Interface

1. B[15:9] are Control Address Bits
2. B[8:0] are Control Data Bits

The WM8775 has two possible device addresses, which can be selected using the CE pin.

CE STATE	DEVICE ADDRESS
Low	0011010 (0 x 34h)
High	0011011 (0 x 36h)

Table 10 2-Wire MPU Interface Address Selection

CONTROL INTERFACE REGISTERS

DIGITAL AUDIO INTERFACE CONTROL REGISTER

Interface format is selected via the FMT[1:0] register bits:

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R11(0Bh) 0001011 ADC Interface Control	1:0	ADCFMT [1:0]	10	Interface format Select 00 : right justified mode 01: left justified mode 10: I^2S mode 11: DSP mode A or B

In left justified, right justified or I2S modes, the LRP register bit controls the polarity of ADCLRC. If this bit is set high, the expected polarity of ADCLRC will be the opposite of that shown Figure 13, Figure 14 and Figure 15. Note that if this feature is used as a means of swapping the left and right channels, a 1 sample phase difference will be introduced. In DSP modes, the LRP register bit is used to select between modes A and B.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R11(0Bh) 0001011 Interface Control	2	ADCLRP	0	In left/right/ I^2S modes: ADCLRC Polarity (normal) 0 : normal ADCLRC polarity 1: inverted ADCLRC polarity In DSP mode: 0 : DSP mode A 1: DSP mode B

By default, ADCLRC is sampled on the rising edge of BCLK and should ideally change on the falling edge. Data sources that change ADCLRC on the rising edge of BCLK can be supported by setting the BCP register bit. Setting BCP to 1 inverts the polarity of BCLK to the inverse of that shown in Figures 12, 13, 14, and 15.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R11(0Bh) 0001011 Interface Control	3	ADCBCP	0	BCLK Polarity (DSP modes) 0 : normal BCLK polarity 1: inverted BCLK polarity

The WL[1:0] bits are used to control the input word length.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R11(0Bh) 0001011 Interface Control	5:4	ADCWL [1:0]	10	Word Length 00 : 16 bit data 01: 20 bit data 10: 24 bit data 11: 32 bit data

Note:

1. If 32-bit mode is selected in right justified mode, the WM8775 defaults to 24 bits.
2. In 24 bit I^2S mode, any width of 24 bits or less is supported provided that ADCLRC is high for a minimum of 24 BCLKs and low for a minimum of 24 BCLKs.

When operating the ADC digital interface in slave mode, to optimise the performance of the ADC it is recommended that the ADCMCLK and ADCBCLK input signals do not have coinciding rising edges. The ADCMCLK bit provides the option to internally invert the ADCMCLK input signal when the input signals have coinciding rising edges.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R11(0Bh) 0001011 Interface Control	6	ADCMCLK	0	ADCMCLK Polarity 0 : non-inverted 1: inverted

ADC MASTER MODE

Control bit MS selects between audio interface Master and Slave Modes. In Master mode ADCLRC and BCLK are outputs and are generated by the WM8775. In Slave mode ADCLRC and BCLK are inputs to WM8775.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R12(0Ch) 0001100 Interface Control	8	ADCMS	0	Audio Interface Master/Slave Mode select: 0 : Slave Mode 1: Master Mode

MASTER MODE ADCLRC FREQUENCY SELECT

In Master mode the WM8775 generates ADCLRC and BCLK. These clocks are derived from the master clock. The ratio of MCLK to ADCLRC is set by ADCRATE.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R12(0Ch) 0001100 ADCLRC Frequency Select	2:0	ADCRATE[2:0]	010	Master Mode MCLK:ADCLRC ratio select: 010: 256fs 011: 384fs 100: 512fs 101: 768fs

ADC OVERSAMPLING RATE SELECT

For ADC operation at 96kHz it is recommended that the user set the ADCOSR bit. This changes the ADC signal processing oversample rate to 64fs.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R12(0Ch) 0001100 ADC Oversampling Rate	3	ADCOSR	0	ADC oversampling rate select 0: 128x oversampling 1: 64x oversampling

POWERDOWN MODE AND ADC DISABLE

Setting the PDWN register bit immediately powers down the WM8775, including the references, overriding all other powerdown control bits. All trace of the previous input samples is removed, but all control register settings are preserved. When PDWN is cleared, the digital filters will be re-initialised. It is recommended that the 4-channel input mux and buffer, and ADC are powered down before setting PDWN.

The ADC may also be powered down by setting the ADCPD disable bit. Setting ADCPD will disable the ADC and select a low power mode. The ADC digital filters will be reset and will reinitialise when ADCPD is reset.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R13(0Dh) 0001101 Powerdown Control	0	PDWN	0	Power Down Mode Select: 0 : Normal Mode 1: Power Down Mode
	1	ADCPD	0	ADC Disable: 0 : Normal Mode 1: Power Down Mode
	6	AINPD	0	Analogue Input Disable: 0 : Normal Mode 1 : Power Down Mode

ADC GAIN CONTROL

The ADC has an analogue input PGA and digital gain control for each stereo channel. Both the analogue and digital gains are adjusted by the same register, LAG for the left and RAG for the right. The analogue PGA has a range of +24dB to -21dB in 0.5dB steps. The digital gain control allows further attenuation (after the ADC) from -21.5dB to -103dB in 0.5dB steps. Table 11 shows how the register maps the analogue and digital gains.

LAG/RAG[7:0]	ATTENUATION LEVEL	ANALOGUE PGA	DIGITAL ATTENTUATION
00(hex)	-∞ dB (mute)	-21dB	Digital mute
01(hex)	-103dB	-21dB	-82dB
:	:	:	:
A4(hex)	-21.5dB	-21dB	-0.5dB
A5(hex)	-21dB	-21dB	0dB
:	:	:	:
CF(hex)	0dB	0dB	0dB
:	:	:	:
FE(hex)	+23.5dB	+23.5dB	0dB
FF(hex)	+24dB	+24dB	0dB

Table 11 Analogue and Digital Gain Mapping for ADC

Left and right inputs may also be independently muted. The LRBOTH control bit allows the user to write the same attenuation value to both left and right volume control registers, saving on software writes. The ADC volume and mute also applies to the bypass signal path.

In addition a zero cross detect circuit is provided for the input PGA. When ZCLA/ZCRA is set with a write, the gain will update only when the input signal approaches zero (midrail). This minimises audible clicks and 'zipper' noise as the gain values change. A timeout clock is also provided which will generate an update after a minimum of 131072 master clocks (= ~10.5ms with a master clock of 12.288MHz). The timeout clock may be disabled by setting TOD.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R7 (07h) 0000111 Timeout Clock Disable	3	TOD	0	Analogue PGA Zero cross detect timeout disable 0 : Timeout enabled 1: Timeout disabled

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R14(0Eh) 0001110 Attenuation ADCL	7:0	LAG[7:0]	11001111 (0dB)	Attenuation data for Left channel ADC gain in 0.5dB steps. See Table 11.
	8	ZCLA	0	Left channel ADC zero cross enable: 0: Zero cross disabled 1: Zero cross enabled
R15(0Fh) 0001111 Attenuation ADCR	7:0	RAG[7:0]	11001111 (0dB)	Attenuation data for right channel ADC gain in 0.5dB steps. See Table 11.
	8	ZCRA	0	Right channel ADC zero cross enable: 0: Zero cross disabled 1: Zero cross enabled
R21(15h) 0010101 ADC Input Mux	8	LRBOTH	0	Right channel input PGA controlled by left channel register 0 : Right channel uses RAG. 1 : Right channel uses LAG.
R21(15h) 0010101 ADC Mute	7	MUTELA	0	Mute for left channel ADC 0: Normal Operation 1: Mute ADC left
	6	MUTERA	0	Mute for right channel ADC 0: Normal operation 1: Mute ADC right

ADC HIGHPASS FILTER DISABLE

The ADC digital filters contain a digital high pass filter. This defaults to enabled and can be disabled using software control bit ADCHPD.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
R11(0Bh) 0001011 ADC Control	8	ADCHPD	0	ADC High pass filter disable: 0: High pass filter enabled 1: High pass filter disabled