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24-bit, 192kHz 8-Channel DAC

DESCRIPTION

The WM8768 is a multi-channel audio DAC ideal for DVD and surround sound processing applications for home hi-fi, automotive and other audio visual equipment.

Four stereo 24-bit multi-bit sigma delta DACs are used with oversampling digital interpolation filters. Digital audio input word lengths from 16-32 bits and sampling rates from 8kHz to 192kHz are supported. Each DAC channel has independent digital volume and mute control.

The audio data interface supports I²S, left justified, right justified and DSP digital audio formats.

The device is controlled either via a 3 wire serial interface or directly using the hardware interface. These interfaces provide access to features including channel selection, volume controls, mutes, de-emphasis and power management facilities. The device is available in a 28-lead SSOP.

FEATURES

- 8-Channel DAC with PCM.
- Audio Performance
 - 103dB SNR ('A' weighted @ 48kHz) DAC
- DAC Sampling Frequency: 8kHz – 192kHz
- 3-Wire SPI Serial or Hardware Control Interface
- Programmable Audio Data Interface Modes
 - I²S, Left, Right Justified or DSP
 - 16/20/24/32 bit Word Lengths
- Four Independent stereo DAC outputs with independent digital volume controls
- Master or Slave Audio Data Interface
- 2.7V to 5.5V Analogue, 2.7V to 3.6V Digital supply Operation
- 28 lead SSOP Package

APPLICATIONS

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

BLOCK DIAGRAM

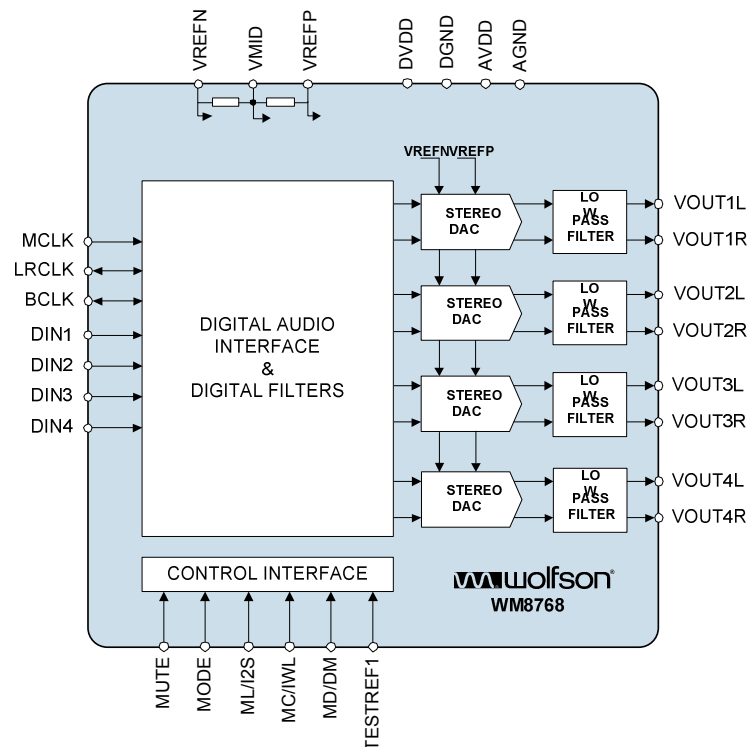


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PIN CONFIGURATION 28 LEAD SSOP

MODE	<input type="checkbox"/> 1 ●	28	<input type="checkbox"/> AVDD
MCLK	<input type="checkbox"/> 2	27	<input type="checkbox"/> AGND
BCLK	<input type="checkbox"/> 3	26	<input type="checkbox"/> VOUT3R
LRCLK	<input type="checkbox"/> 4	25	<input type="checkbox"/> VOUT3L
DVDD	<input type="checkbox"/> 5	24	<input type="checkbox"/> VOUT2R
DGND	<input type="checkbox"/> 6	23	<input type="checkbox"/> VOUT2L
DIN1	<input type="checkbox"/> 7	22	<input type="checkbox"/> VOUT1R
DIN2	<input type="checkbox"/> 8	21	<input type="checkbox"/> VOUT1L
DIN3	<input type="checkbox"/> 9	20	<input type="checkbox"/> VOUT4R
DIN4	<input type="checkbox"/> 10	19	<input type="checkbox"/> VOUT4L
ML/I2S	<input type="checkbox"/> 11	18	<input type="checkbox"/> VMID
MC/IWL	<input type="checkbox"/> 12	17	<input type="checkbox"/> VREFP
MD/DM	<input type="checkbox"/> 13	16	<input type="checkbox"/> VREFN
MUTE	<input type="checkbox"/> 14	15	<input type="checkbox"/> TESTREF1

ORDERING INFORMATION

DEVICE	TEMPERATURE RANGE	PACKAGE	MOISTURE SENSITIVITY LEVEL	PEAK SOLDERING TEMPERATURE
WM8768GEDS/V	-25 to +85°C	28-lead SSOP (Pb-free)	MSL3	260°C
WM8768GEDS/RV	-25 to +85°C	28-lead SSOP (IPb-free, tape and reel)	MSL3	260°C

Note:

Reel quantity = 2,000

PIN DESCRIPTION – 28 LEAD SSOP

PIN	NAME	TYPE	DESCRIPTION
1	MODE	Digital input	Control format selection 0 = Software control 1 = Hardware control
2	MCLK	Digital input	Master clock; 128, 192, 256, 384, 512, 768fs or 1152fs (fs = word clock frequency)
3	BCLK	Digital input/output	Audio interface bit clock
4	LRCLK	Digital input/output	Audio left/right word clock
5	DVDD	Supply	Digital positive supply
6	DGND	Supply	Digital negative supply
7	DIN1	Digital input	DAC channel 1 data input
8	DIN2	Digital input	DAC channel 2 data input
9	DIN3	Digital input	DAC channel 3 data input
10	DIN4	Digital input	DAC channel 4 data input
11	ML/I2S	Digital input	Software Mode: Serial interface Latch signal Hardware Mode: Input Audio Data Format
12	MC/IWL	Digital input	Software Mode: Serial control interface clock Hardware Mode: Audio data input word length
13	MD/DM	Digital input	Software Mode: Serial interface data Hardware Mode: De-emphasis selection
14	MUTE	Digital input/output	DAC Zero Flag output or DAC mute input
15	TESTREF1	Analogue output	Test Pin
16	VREFN	Analogue input	DAC negative reference supply
17	VREFP	Analogue input	DAC positive reference supply
18	VMID	Analogue output	Midrail divider decoupling pin; 10uF external decoupling
19	VOUT4L	Analogue output	DAC channel 4 left output
20	VOUT4R	Analogue output	DAC channel 4 right output
21	VOUT1L	Analogue output	DAC channel 1 left output
22	VOUT1R	Analogue output	DAC channel 1 right output
23	VOUT2L	Analogue output	DAC channel 2 left output
24	VOUT2R	Analogue output	DAC channel 2 right output
25	VOUT3L	Analogue output	DAC channel 3 left output
26	VOUT3R	Analogue output	DAC channel 3 right output
27	AGND	Supply	Analogue negative supply and substrate connection
28	AVDD	Supply	Analogue positive supply

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	+5V
Analogue supply voltage	-0.3V	+7V
Voltage range digital inputs	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
Storage temperature after soldering	-65°C	+150°C

Notes:

- Analogue and digital grounds must always be within 0.3V of each other for normal operation of the device.

RECOMMENDED OPERATING CONDITIONS

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Digital supply range	DVDD		2.7		3.6	V
Analogue reference supply	VREFP		2.7		5.5	V
Analogue supply range	AVDD		2.7		5.5	V
Ground	AGND, VREFN, 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 for normal operation of the device.

ELECTRICAL CHARACTERISTICS

Test Conditions

AVDD, VREFP = 5V, DVDD = 3.3V, AGND, VREFN = 0V, DGND = 0V, $T_A = +25^\circ\text{C}$, $f_s = 48\text{kHz}$, MCLK = 256fs, unless otherwise stated.

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Digital Logic Levels (CMOS Levels)						
Input LOW level	V_{IL}				0.3 x DVDD	V
Input HIGH level	V_{IH}		0.7 x DVDD			V
Output LOW	V_{OL}	$I_{OL}=1\text{mA}$			0.1 x DVDD	V
Output HIGH	V_{OH}	$I_{OH}=-1\text{mA}$	0.9 x DVDD			V
Analogue Reference Levels						
Reference voltage	V_{VMID}			VREFP/2		V
Potential divider resistance	R_{VMID}	VREFP to VMID and VMID to VREFN		100		$k\Omega$
DAC Performance (Load = 10kΩ, 50pF)						
0dBfs Full scale output voltage				1.0 x VREFP/5		Vrms
SNR (Note 1,2,4)		A-weighted, @ $f_s = 48\text{kHz}$	95	103		dB
SNR (Note 1,2,4)		A-weighted @ $f_s = 96\text{kHz}$		101		dB
SNR (Note 1,2,4)		A-weighted @ $f_s = 192\text{kHz}$		101		dB
SNR (Note 1,2,4)		A-weighted @ $f_s = 48\text{kHz}$, AVDD = 3.3V		101		dB
SNR (Note 1,2,4)		A-weighted @ $f_s = 96\text{kHz}$, AVDD = 3.3V		96		dB
Dynamic Range (Note 2,4)	DNR	A-weighted, -60dB full scale input	95	103		dB
Total Harmonic Distortion (THD) (Note 4)		1kHz, 0dBfs		-90	-83	dB
Mute Attenuation		1kHz Input, 0dB gain		100		dB
DAC channel separation				100		dB
Power Supply Rejection Ratio	PSRR	1kHz 100mVpp		50		dB
		20Hz to 20kHz 100mVp-p		45		dB
Supply Current						
Analogue supply current		AVDD = 5V		18.4		mA
Digital Supply Current		DVDD = 3.3V		14.6		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. The performance of each DAC is measured separately

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 crosstalk. 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

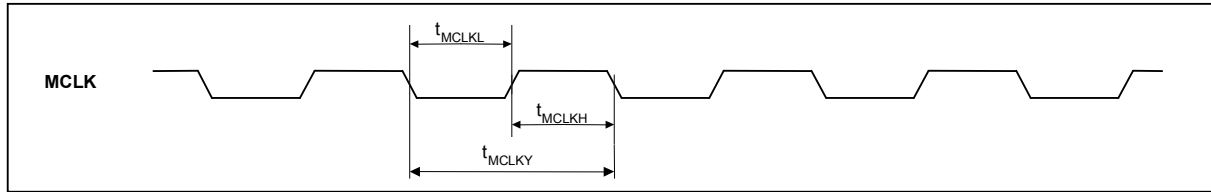


Figure 1 DAC Master Clock Timing Requirements

Test Conditions

AVDD, VREFP = 5V, DVDD = 3.3V, AGND, VREFN = 0V, DGND = 0V, $T_A = +25^\circ\text{C}$, $f_s = 48\text{kHz}$, 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	Us
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 and DACs are powered down with internal digital audio filters being reset. In this power-saving mode, all registers will retain their values and can be accessed in the normal manner through the control interface. Once MCLK is restored, the DACs are automatically powered up, but a write to the volume update register bit is required to restore the correct volume settings.

DIGITAL AUDIO INTERFACE – MASTER MODE

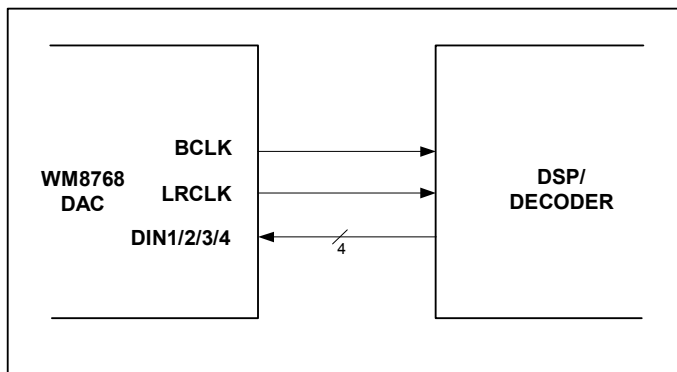


Figure 2 Audio Interface - Master Mode

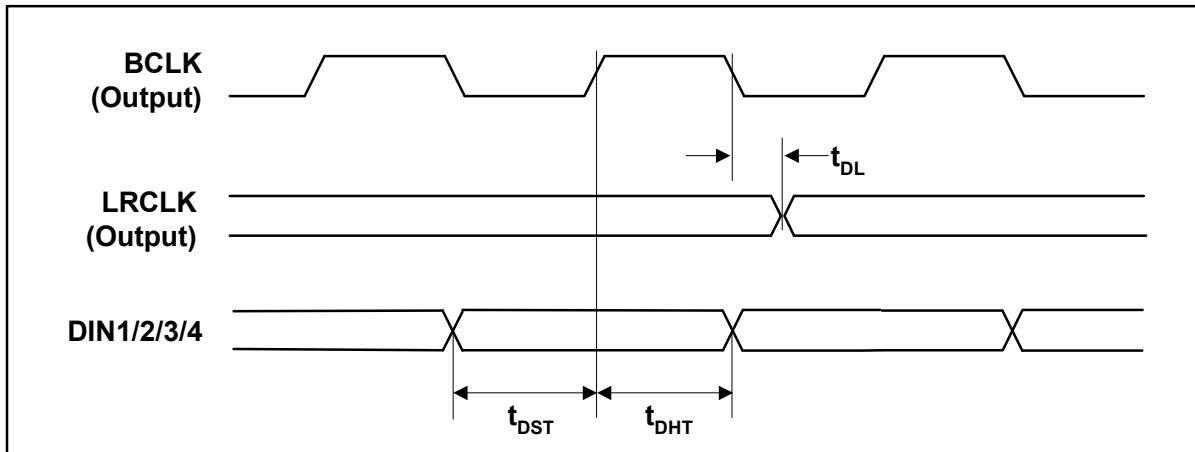


Figure 3 Digital Audio Data Timing – Master Mode

Test Conditions

AVDD, VREFP = 5V, DVDD = 3.3V, AGND, VREFN, 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						
LRCLK propagation delay from BCLK falling edge	t _{DL}		0		10	ns
DIN1/2/3/4 setup time to BCLK rising edge	t _{DST}		10			ns
DIN1/2/3/4 hold time from BCLK rising edge	t _{DHT}		10			ns

Table 2 Digital Audio Data Timing – Master Mode

DIGITAL AUDIO INTERFACE – SLAVE MODE

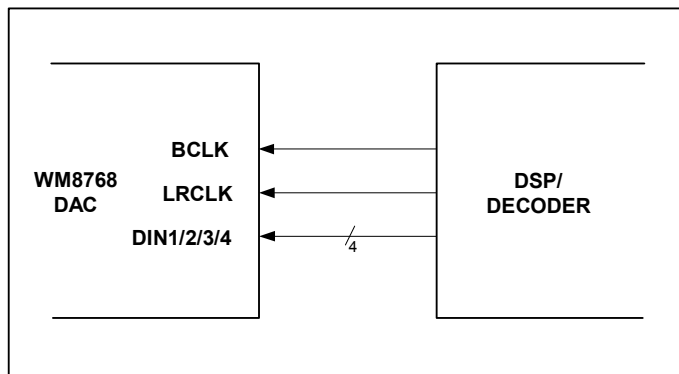


Figure 4 Audio Interface – Slave Mode

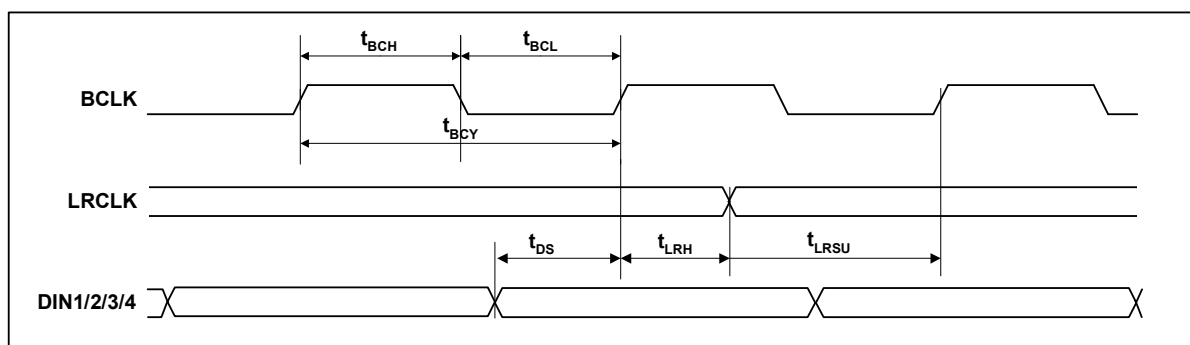


Figure 5 Digital Audio Data Timing – Slave Mode

Test Conditions

AVDD = 5V, DVDD = 3.3V, AGND = 0V, DGND = 0V, $T_A = +25^\circ\text{C}$, Slave Mode, $f_s = 48\text{kHz}$, 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
LRCLK set-up time to BCLK rising edge	t_{LRSU}		10			ns
LRCLK hold time from BCLK rising edge	t_{LRH}		10			ns
DIN1/2/3/4 set-up time to BCLK rising edge	t_{DS}		10			ns
DIN1/2/3/4 hold time from BCLK rising edge	t_{DH}		10			ns

Table 3 Digital Audio Data Timing – Slave Mode

MPU INTERFACE TIMING

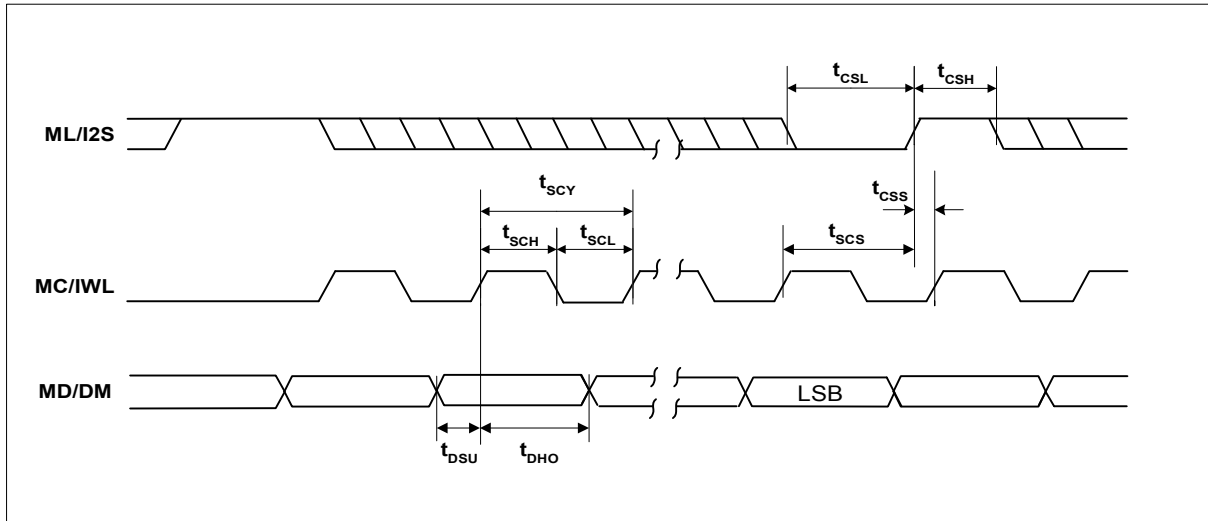


Figure 6 SPI Compatible Control Interface Input Timing

Test Conditions					
AVDD = 5V, DVDD = 3.3V, AGND, DGND = 0V, T _A = +25°C, fs = 48kHz, MCLK = 256fs unless otherwise stated					
PARAMETER	SYMBOL	MIN	TYP	MAX	UNIT
MC/IWL rising edge to ML/I2S rising edge	t _{SCS}	60			ns
MC/IWL pulse cycle time	t _{SCY}	80			ns
MC/IWL pulse width low	t _{SCL}	30			ns
MC/IWL pulse width high	t _{SCH}	30			ns
MD/DM to MC/IWL set-up time	t _{DSU}	20			ns
MC/IWL to MD/DM hold time	t _{DHO}	20			ns
ML/I2S pulse width low	t _{CSL}	20			ns
ML/I2S pulse width high	t _{CSH}	20			ns
ML/I2S rising to MC/IWL rising	t _{CSS}	20			ns

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

INTERNAL POWER ON RESET CIRCUIT

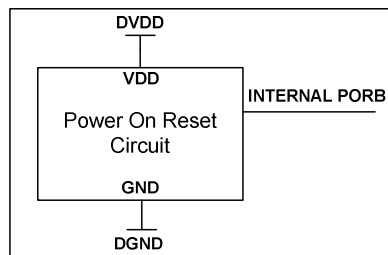


Figure 7 Internal Power on Reset Circuit Schematic

The WM8768 includes an internal Power-On-Reset Circuit, as shown in Figure 7, which is used reset the digital logic into a default state after power up. The POR circuit is powered from DVDD and monitors DVDD. It asserts PORB low if DVDD is below a minimum threshold.

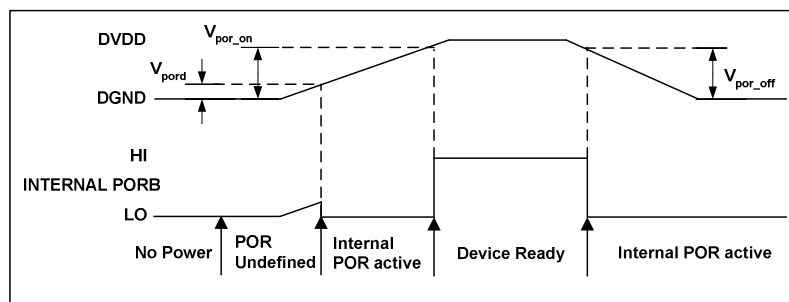


Figure 8 Typical Power-Up Sequence

Figure 8 shows a typical power-up sequence. When DVDD goes above the minimum threshold, V_{por_on} , there is enough voltage for the circuit to guarantee PORB is asserted low and the chip is held in reset. In this condition, all writes to the control interface are ignored. When DVDD rises to V_{por_on} , PORB is released high and all registers are in their default state and writes to the control interface may take place.

On power down, PORB is asserted low whenever DVDD drops below the minimum threshold V_{por_off} .

SYMBOL	MIN	TYP	MAX	UNIT
V_{por_d}	0.3	0.5	0.8	V
V_{por_on}	1.3	1.7	2.0	V
V_{por_off}	1.3	1.7	2.0	V

Table 5 Typical POR Operation (typical values, not tested)

DEVICE DESCRIPTION

INTRODUCTION

WM8768 is a complete 8-channel DAC including digital interpolation and decimation filters and switched capacitor multi-bit sigma delta DACs with digital volume controls on each channel and output smoothing filters.

The device is implemented as four separate stereo DACs in a single package and controlled by a single interface.

Each stereo DAC has its own data input DIN1/2/3/4. DAC word clock LRCLK, DAC bit clock BCLK and DAC master clock MCLK are shared between them.

The Audio Interface may be configured to operate in either master or slave mode. In Slave mode, LRCLK and BCLK are all inputs. In Master mode, LRCLK and BCLK are all outputs.

Each DAC has its own digital volume control that is adjustable in 0.5dB steps. The digital volume controls may be operated independently. In addition, a zero cross detect circuit is provided for each DAC for the digital volume controls. The digital volume control detects a transition through the zero point before updating the volume. This minimises audible clicks and 'zipper' noise as the gain values change.

Control of internal functionality of the device is by 3-wire serial or pin programmable control interface. The software control interface may be asynchronous to the audio data interface as control data will be re-synchronised to the audio processing internally.

Operation using master clocks of 128fs, 192fs, 256fs, 384fs, 512fs, 768fs or 1152fs is provided for the DAC. In Slave mode selection between clock rates is automatically controlled. Audio sample rates (fs) from less than 8ks/s up to 192ks/s are allowed for the DAC, provided the appropriate master clock is input.

In PCM mode, the audio data interface supports right justified, left justified and I²S (Philips left justified, one bit delayed) interface formats along with a highly flexible DSP serial port interface.

PCM 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 DAC MCLK input pin(s) with no software configuration necessary.

The DAC master clock for WM8768 supports audio sampling rates from 128fs to 1152fs, where fs is the audio sampling frequency (LRCLK) typically 32kHz, 44.1kHz, 48kHz, 96kHz or 192kHz. The master clock is used to operate the digital filters and the noise shaping circuits.

In Slave mode the WM8768 has a master clock detection circuit that automatically determines the relationship between the system clock frequency and the sampling rate (to within +/- 32 master clocks). If there is a greater than 32 clocks error the interface defaults to 1152fs mode. The WM8768 is tolerant of phase variations or jitter on the master clock. Table 6 shows the typical master clock frequency inputs for the WM8768.

The signal processing for the WM8768 typically operates at an oversampling rate of 128fs. The exception to this is for operation with a 128/192fs system clock, e.g. for 192kHz operation, when the oversampling rate is 64fs.

SAMPLING RATE (LRCLK)	SYSTEM CLOCK FREQUENCY (MHZ)						
	128fs	192fs	256fs	384fs	512fs	768fs	1152fs
32kHz	4.096	6.144	8.192	12.288	16.384	24.576	36.864
44.1kHz	5.6448	8.467	11.2896	16.9340	22.5792	33.8688	Unavailable
48kHz	6.144	9.216	12.288	18.432	24.576	36.864	Unavailable
96kHz	12.288	18.432	24.576	36.864	Unavailable	Unavailable	Unavailable
192kHz	24.576	36.864	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable

Table 6 System Clock Frequencies Versus Sampling Rate

HARDWARE CONTROL MODES

When the MODE pin is held high, the following hardware modes of operation are available.

MUTE AND AUTOMUTE OPERATION

In both hardware and software modes, the MUTE pin controls the selection of MUTE directly, and can be used to enable and disable the automute function. This pin becomes an output when left floating and indicates infinite zero detect (IZD) has been detected.

	DESCRIPTION
0	Normal Operation
1	Mute DAC channels
Floating	Enable IZD, MUTE pin becomes an output to indicate when IZD occurs. L=IZD not detected, H=IZD detected.

Table 7 Mute and Automute Control

Figure 9 shows the application and release of MUTE whilst a full amplitude sinusoid is being played at 48kHz sampling rate. When MUTE (lower trace) is asserted, the output (upper trace) begins to decay exponentially from the DC level of the last input sample. The output will decay towards V_{MID} with a time constant of approximately 64 input samples. When MUTE is de-asserted, the output will restart almost immediately from the current input sample.

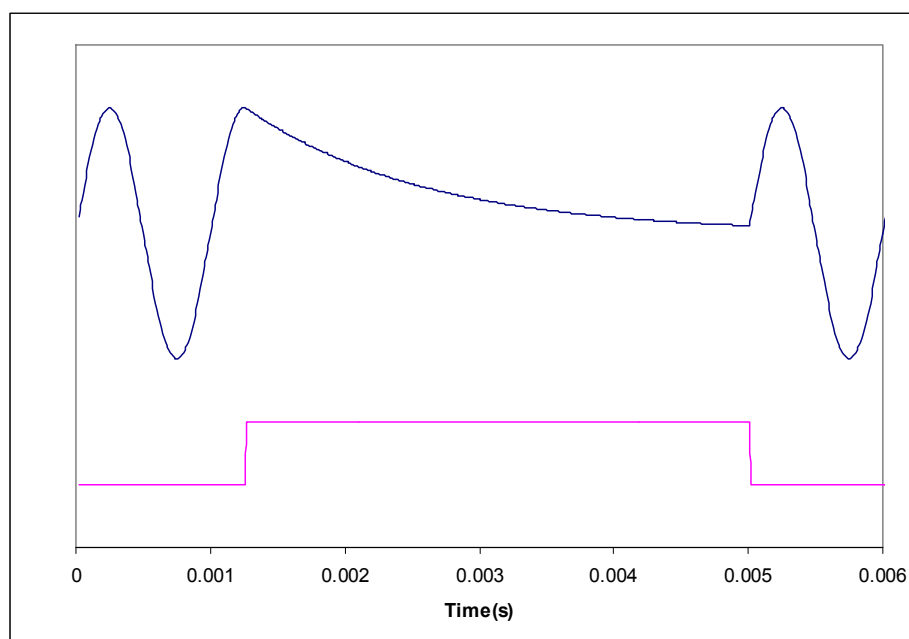


Figure 9 Application and Release of Soft Mute

In hardware mode (MODE pin set high) the MUTE pin becomes a bi-directional pin. Therefore if it is driven low the device will never softmute. If it is driven high then all channels will softmute immediately.

However if the pin is connected to a high impedance, or left floating, then when all four internal zero flags are raised, the WM8768 will also drive a weak logic high signal on the MUTE pin (output impedance 10kOhms) which can be used to drive an external device.

It is not possible to perform analogue mute in Hardware mode.

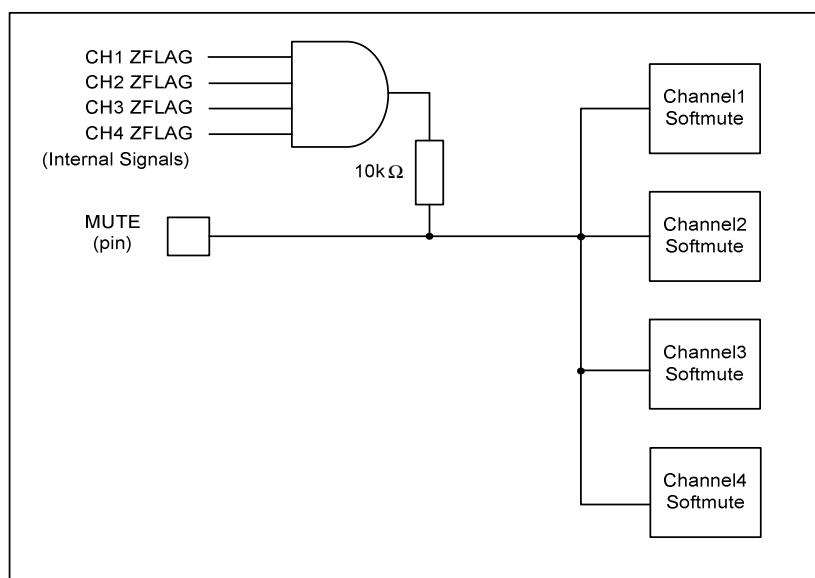


Figure 10 MUTE Logic in Hardware Mode

INPUT FORMAT SELECTION

In hardware mode, ML/I2S and MC/IWL become input controls for selection of input data format type and input data word length for the DAC.

ML/I2S	MC/IWL	INPUT DATA MODE
0	0	24-bit right justified
0	1	20-bit right justified
1	0	16-bit I ² S
1	1	24-bit I ² S

Table 8 Input Format Selection

Note:

In 24 bit I²S mode, any width of 24 bits or less is supported provided that the left/right clocks (LRCLK) are high for a minimum of 24 bit clocks (BCLK) and low for a minimum of 24 bit clocks. If exactly 32 bit clocks occur in one left/right clock (16 high, 16 low) the chip will auto detect and run a 16 bit data mode.

DE-EMPHASIS CONTROL

In hardware mode, the MD/DM pin becomes an input control for selection of de-emphasis filtering to be applied.

MD/DM	DE-EMPHASIS
0	Off
1	On

Table 9 De-emphasis Control

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 DIN1/2/3/4 are always inputs to the WM8768. The default is Slave mode.

In Slave mode, LRCLK and BCLK are inputs to the WM8768 (Figure 11). DIN1/2/3/4 and LRCLK are sampled by the WM8768 on the rising edge of BCLK.

By setting the control bit BCP the polarity of BCLK may be reversed so that DIN1/2/3/4 and LRCLK are sampled on the falling edge of BCLK.

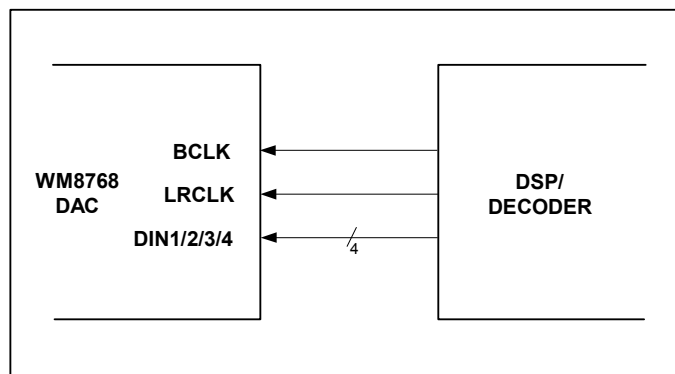


Figure 11 Slave Mode

In Master mode, LRCLK and BCLK are outputs from the WM8768 (Figure 12). LRCLK and BCLK are generated by the WM8768. DIN1/2/3/4 are sampled by the WM8768 on the rising edge of BCLK so the controller must output DAC data that changes on the falling edge of BCLK.

By setting control bit BCP the polarity of BCLK may be reversed so that DIN1/2/3/4 are sampled on the falling edge of BCLK..

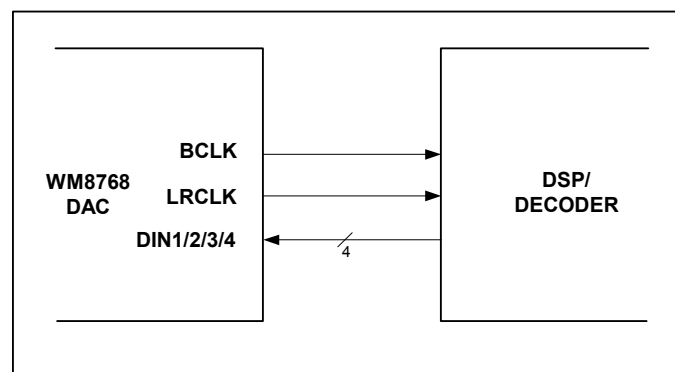


Figure 12 Master Mode

AUDIO INTERFACE FORMATS

Audio data is applied to the internal DAC filters via the Digital Audio Interface. 5 popular interface formats are supported:

- Left Justified mode
- Right Justified mode
- I²S 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 I²S modes, the digital audio interface receives DAC data on the DIN1/2/3/4 inputs. Audio data for each stereo channel is time multiplexed with LRCLK indicating whether the left or right channel is present. LRCLK is also used as a timing reference to indicate the beginning or end of the data words.

In left justified, right justified and I²S modes, the minimum number of BCLKs per LRCLK period is 2 times the selected word length. LRCLK 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 LRCLK is acceptable provided the above requirements are met.

In DSP modes A or B, all 8 DAC channels are time multiplexed onto DIN1. LRCLK is used as a frame sync signal to identify the MSB of the first word. The minimum number of BCLKs per LRCLK period is 8 times the selected word length. Any mark to space ratio is acceptable on LRCLK provided the rising edge is correctly positioned.

LEFT JUSTIFIED MODE

In left justified mode, the MSB of DIN1/2/3/4 is sampled by the WM8768 on the first rising edge of BCLK following a LRCLK transition. LRCLK is high during the left samples and low during the right samples (Figure 13).

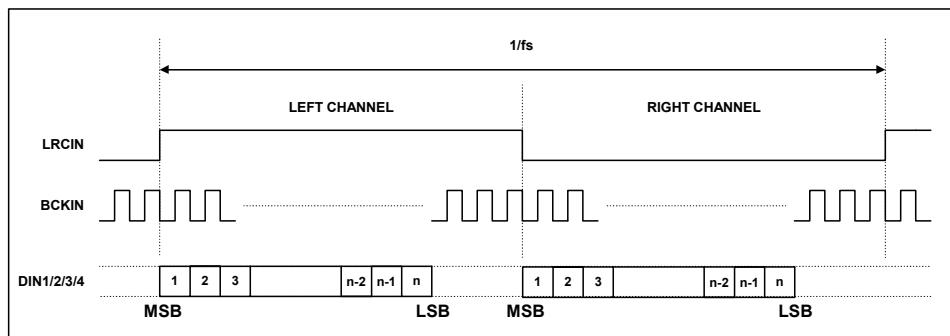


Figure 13 Left Justified Mode Timing Diagram

RIGHT JUSTIFIED MODE

In right justified mode, the LSB of DIN1/2/3/4 is sampled by the WM8768 on the rising edge of BCLK preceding a LRCLK transition. LRCLK are high during the left samples and low during the right samples (Figure 14).

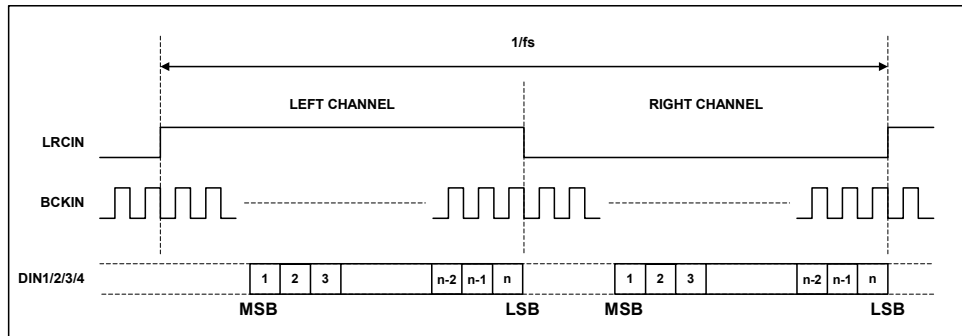


Figure 14 Right Justified Mode Timing Diagram

I²S MODE

In I²S mode, the MSB of DIN1/2/3/4 is sampled by the WM8768 on the second rising edge of BCLK following a LRCLK transition. LRCLK are low during the left samples and high during the right samples.

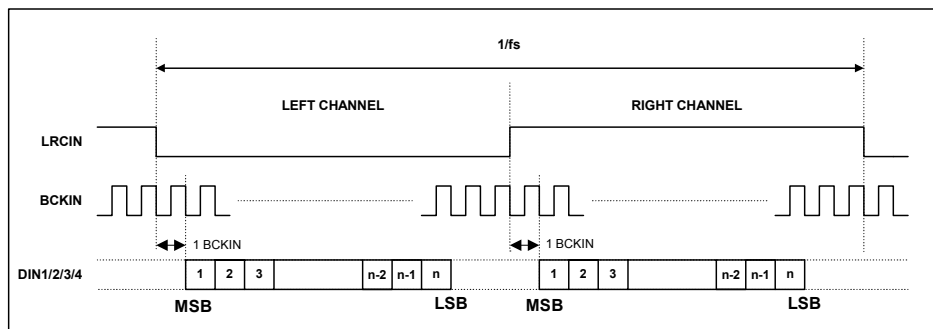


Figure 15 I²S Mode Timing Diagram

DSP MODE A

In DSP mode A, the MSB of DAC channel 1 left data is sampled by the WM8768 on the second rising edge on BCLK following a LRCLK rising edge. DAC channel 1 right and DAC channels 2/3/4 data follow DAC channel 1 left data (Figure 16).

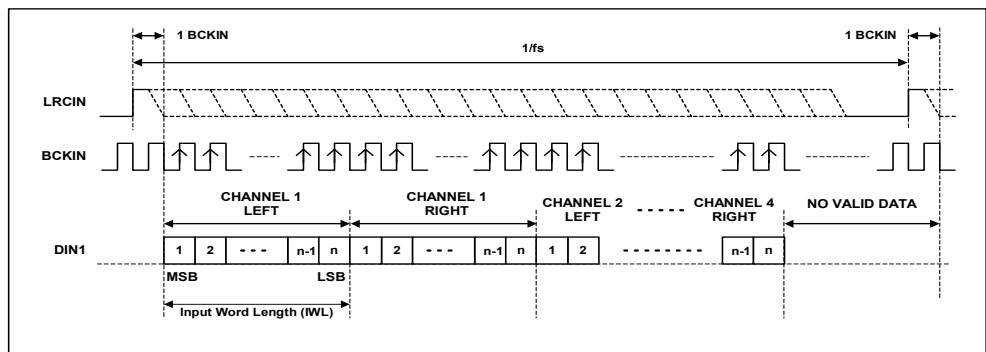


Figure 16 DSP Mode A Timing Diagram – DAC data input

DSP MODE B

In DSP mode B, the MSB of DAC channel 1 left data is sampled by the WM8768 on the first BCLK rising edge following a LRCLK rising edge. DAC channel 1 right and DAC channels 2/3/4 data follow DAC channel 1 left data (Figure 17).

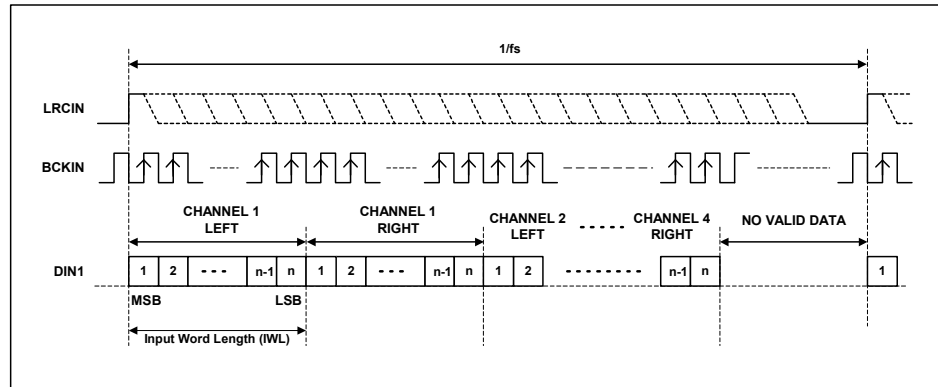


Figure 17 DSP Mode B Timing Diagram – DAC data input

In both DSP modes A and B, DACL1 is always sent first, followed immediately by DACR1 and the data words for the other 8 channels. No BCLK edges are allowed between the data words. The word order is DAC1 left, DAC1 right, DAC2 left, DAC2 right, DAC3 left, DAC3 right, DAC4 left, DAC4 right .

POWERDOWN MODES

The WM8768 has powerdown control bits allowing specific parts of the WM8768 to be powered off when not being used. The four stereo DACs each have a separate powerdown control bit, DACD[2:0] & DACD4, allowing individual stereo DACs to be powered off when not in use. Setting DACD will power down everything except the reference VMID. This may be powered down by setting PDWN. Setting PDWN will override all other powerdown control bits. It is recommended that the DACs are powered down before setting PDWN.

SOFTWARE CONTROL INTERFACE OPERATION

The WM8768 is controlled using a 3-wire serial interface in software mode or pin programmable in hardware mode.

The control mode is selected by the state of the MODE pin.

3-WIRE (SPI COMPATIBLE) SERIAL CONTROL MODE

MD/DM is used for the program data, MC/IWL is used to clock in the program data and ML/I2S is used to latch the program data. MD/DM is sampled on the rising edge of MC/IWL. The 3-wire interface protocol is shown in Figure 18.

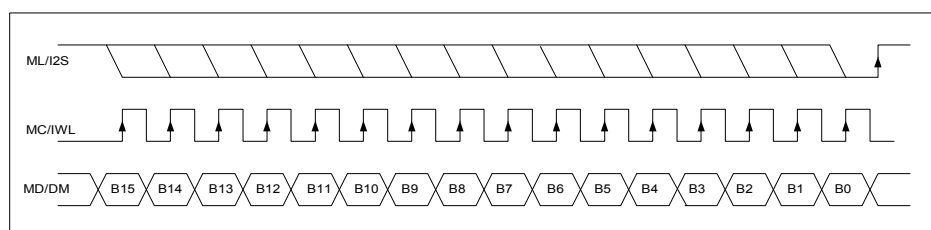


Figure 18 3-wire SPI Compatible Interface

1. B[15:9] are Control Address Bits
2. B[8:0] are Control Data Bits
3. ML/I2S is edge sensitive – the data is latched on the rising edge of ML/I2S.

CONTROL INTERFACE REGISTERS

ATTENUATOR CONTROL MODE

Setting the ATC register bit causes the left channel attenuation settings to be applied to both left and right channel DACs from the next audio input sample. No update to the attenuation registers is required for ATC to take effect.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
0000010 DAC Channel Control	3	ATC	0	Attenuator Control Mode: 0 : Right channels use Right attenuations 1: Right Channels use Left Attenuations

DAC OUTPUT CONTROL

The DAC output control word determines how the left and right inputs to the audio Interface are applied to the left and right DACs:

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION		
0000010 DAC Control	8:5	PL[3:0]	1001	PL[3:0]	Left Output	Right Output
				0000	Mute	Mute
				0001	Left	Mute
				0010	Right	Mute
				0011	(L+R)/2	Mute
				0100	Mute	Left
				0101	Left	Left
				0110	Right	Left
				0111	(L+R)/2	Left
				1000	Mute	Right
				1001	Left	Right
				1010	Right	Right
				1011	(L+R)/2	Right
				1100	Mute	(L+R)/2
				1101	Left	(L+R)/2
				1110	Right	(L+R)/2
1111	(L+R)/2	(L+R)/2				

DAC DIGITAL AUDIO INTERFACE CONTROL REGISTER

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

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
0000011 Interface Control	1:0	FMT [1:0]	00	Interface format Select 00 : right justified mode 01: left justified mode 10: I ² S mode 11: DSP Modes A or B

In left justified, right justified or I²S modes, the LRP register bit controls the polarity of LRCLK. If this bit is set high, the expected polarity of LRCLK 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
0000011 Interface Control	2	LRP	0	In left/right/I ² S modes: LRCLK Polarity (normal) 0 : normal LRCLK polarity 1: inverted LRCLK polarity
				In DSP mode: 0 : DSP mode A 1: DSP mode B

By default, LRCLK and DIN1/2/3/4 are sampled on the rising edge of BCLK and should ideally change on the falling edge. Data sources that change LRCLK and DIN1/2/3/4 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 Figure 13, Figure 14, Figure 15, Figure 16, Figure 17 and Figure 18.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
0000011 Interface Control	3	BCP	0	BCLK Polarity 0 : normal BCLK polarity 1: inverted BCLK polarity

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

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
0000011 Interface Control	5:4	IWL [1:0]	00	Input Word Length 00 : 16 bit data 01: 20 bit data 10: 24 bit data 11: 32 bit data

Note: If 32-bit mode is selected in right justified mode, the WM8768 defaults to 24 bits.

In all modes, the data is signed 2's complement. The digital filters always input 24-bit data. If the DAC is programmed to receive 16 or 20 bit data, the WM8768 pads the unused LSBs with zeros. If the DAC is programmed into 32 bit mode, the 8 LSBs are ignored.

Note: In 24 bit I²S mode, any width of 24 bits or less is supported provided that LRCLK is high for a minimum of 24 BCLKs and low for a minimum of 24 BCLKs. If exactly 32 bit clocks occur in one left/right clock (16 high, 16 low) the chip will auto detect and run a 16 bit data mode.

A number of options are available to control how data from the Digital Audio Interface is applied to the DAC channels.

DAC OUTPUT PHASE

The DAC phase control word determines whether the output of each DAC is non-inverted or inverted

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION		
				Bit	DAC	Phase
0000011 DAC Phase	8:6	PHASE [2:0]	000	0	DAC1L/R	1 = invert
				1	DAC2L/R	1 = invert
				2	DAC3L/R	1 = invert
0001111 DAC4 Control	3	PHASE4	0	N/A	DAC4L/R	1 = invert

DIGITAL ZERO CROSS-DETECT

The digital volume control also incorporates a zero cross detect circuit which detects a transition through the zero point before updating the digital volume control with the new volume. This is enabled by control bit DZCEN.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
0001001 DAC Control	0	DZCEN	0	DAC Digital Volume Zero Cross Enable: 0: Zero cross detect enabled 1: Zero cross detect disabled

SOFTMUTE

The digital muting function used in Software and Hardware mode applies a softmute with the operating characteristics shown in Figure 19.

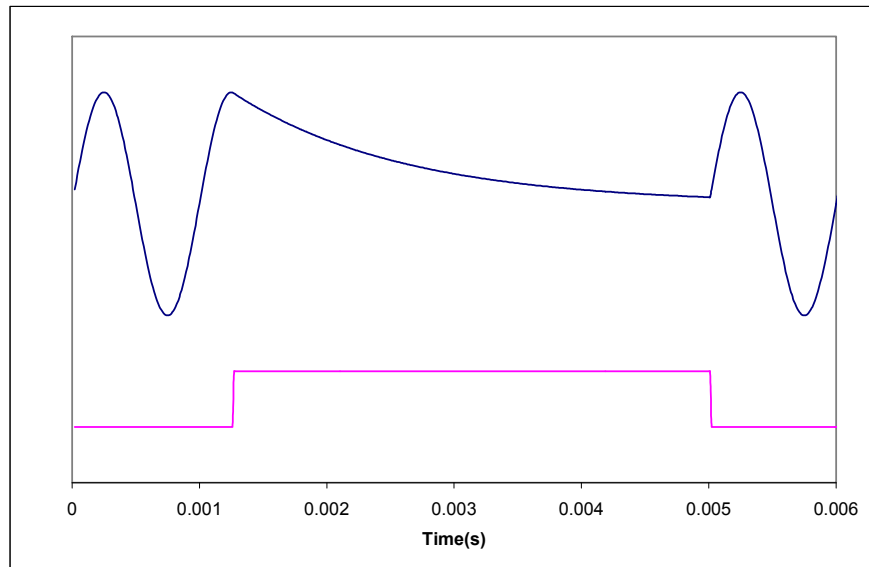


Figure 19 Soft Mute Operation

When the softmute is applied the output of the device will decay towards V_{MID} with a time constant of approximately 64 input samples. When the mute is released, either manually or automatically by the chip, the output will restart immediately from the current input sample.

ANALOGUE MUTE

Analogue mute can only be used in software mode and will cause the output of the selected DAC to perform an analogue mute that clamps the output of the DAC to V_{MID} . This function is dependent in the IZD bit which is described in section INFINITE ZERO DETECT, later.

SOFTWARE MUTE MODES

The WM8768 can be muted in a number of different ways when in software mode (MODE pin pulled low). Refer to Figure 20 which shows a representation of the interaction between functions described below.

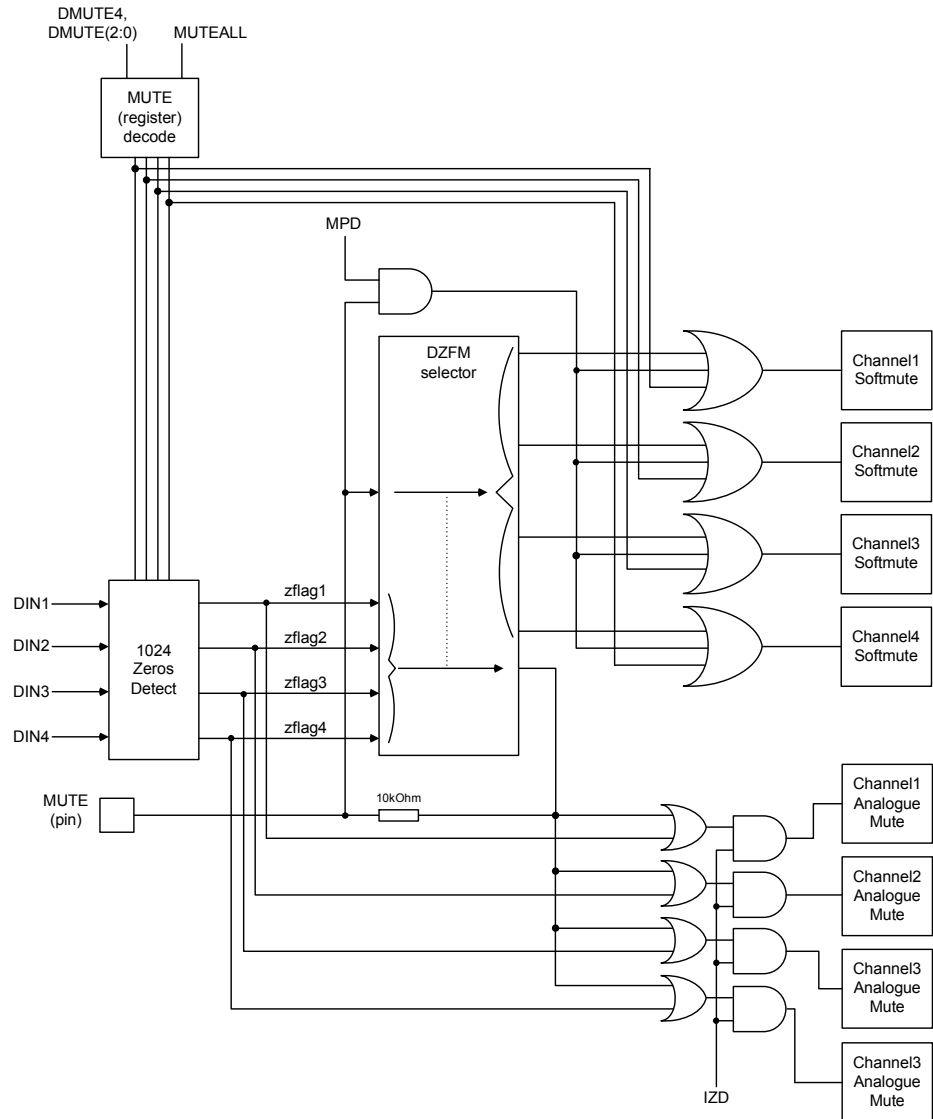


Figure 20 Internal Mute Logic

DMUTE AND MUTEALL

The WM8768 can be directly muted using the DMUTE and DMUTE4 register bits to control which channels are muted. The mute happens as soon as the serial write is performed.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
0001001 DAC Mute	5:3	DMUTE [2:0]	000	DAC 3,2 and 1 Soft Mute select
0001111 DAC4 Control	2	DMUTE4	0	DAC 4 Soft Mute select

{DMUTE4,DMUTE [2:0]}	DAC CHANNEL 4	DAC CHANNEL 3	DAC CHANNEL 2	DAC CHANNEL 1
0000	Not MUTE	Not MUTE	Not MUTE	Not MUTE
0001	Not MUTE	Not MUTE	Not MUTE	MUTE
0010	Not MUTE	Not MUTE	MUTE	Not MUTE
0011	Not MUTE	Not MUTE	MUTE	MUTE
0100	Not MUTE	MUTE	Not MUTE	Not MUTE
0101	Not MUTE	MUTE	Not MUTE	MUTE
0110	Not MUTE	MUTE	MUTE	Not MUTE
0111	Not MUTE	MUTE	MUTE	MUTE
1000	MUTE	Not MUTE	Not MUTE	Not MUTE
1001	MUTE	Not MUTE	Not MUTE	MUTE
1010	MUTE	Not MUTE	MUTE	Not MUTE
1011	MUTE	Not MUTE	MUTE	MUTE
1100	MUTE	MUTE	Not MUTE	Not MUTE
1101	MUTE	MUTE	Not MUTE	MUTE
1110	MUTE	MUTE	MUTE	Not MUTE
1111	MUTE	MUTE	MUTE	MUTE

Table 10 DAC Mute Control

An overall MUTE to all channels can be applied by using the MUTEALL register.

REGISTER ADDRESS	BIT	LABEL	DEFAULT	DESCRIPTION
0000010 DAC Mute	0	MUTEALL	0	Soft Mute Select: 0 : Normal operation 1: Soft mute all channels