



DESCRIPTION

The WM8706 is a high performance stereo DAC designed for audio applications such as DVD, home theatre systems, and digital TV. The WM8706 supports data input word lengths from 16 to 32-bits and sampling rates up to 192kHz. The WM8706 can implement 2 channels at 192kHz for high-end DVD-Audio. The WM8706 consists of a serial interface port, digital interpolation filters, multi-bit sigma delta modulators and stereo DAC in a small 28-pin SSOP package. The WM8706 also includes a digitally controllable mute and attenuate function on each channel.

The WM8706 supports a variety of connection schemes for audio DAC control. The MPU serial port provides access to a wide range of features including on-chip mute, attenuation and phase reversal. A hardware controllable interface is also available. It is pin-compatible with the WM8716 provided the oscillator circuit on WM8716 is not required in the application.

The WM8706 is an ideal device to interface to AC-3™, DTS™, and MPEG audio decoders for surround sound applications, or for use in DVD players supporting DVD-A.

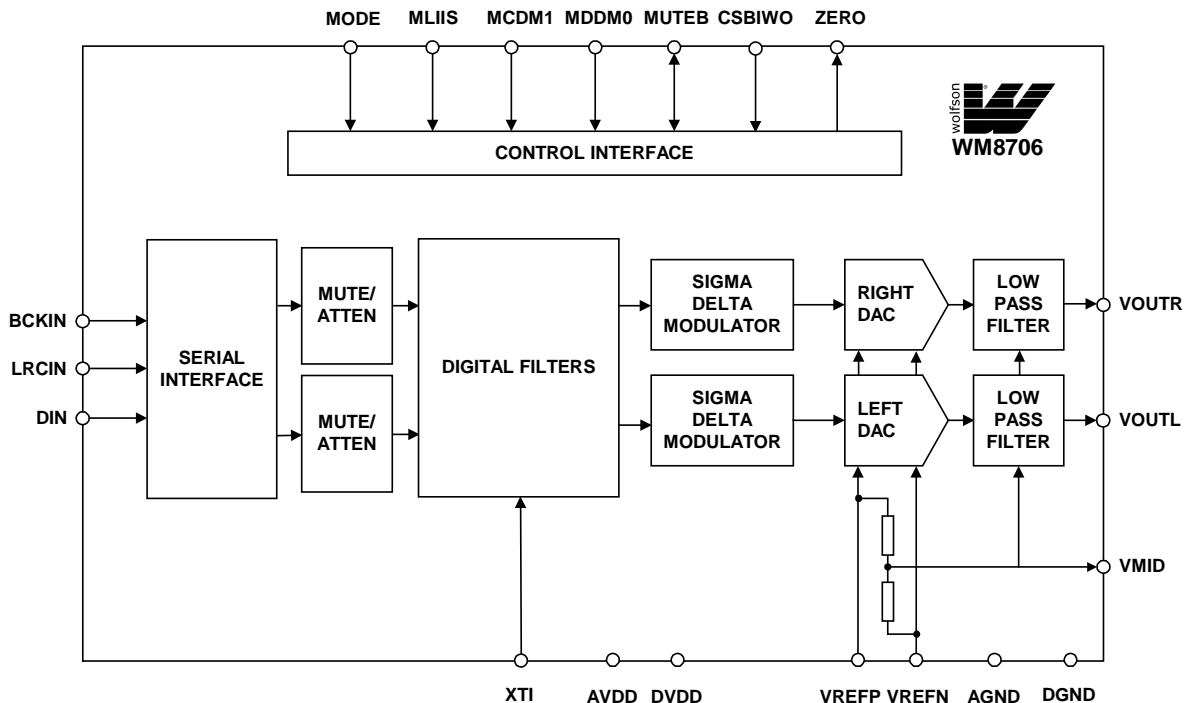
FEATURES

- Stereo DAC
- Audio Performance
  - 106dB SNR ('A' weighted @ 48kHz) DAC
  - -97dB THD
- DAC Sampling Frequency: 8kHz – 192kHz
- 3-Wire Serial Control Interface or Hardware Control
- Programmable Audio Data Interface Modes
  - I<sup>2</sup>S, Left, Right Justified, DSP
  - 16/20/24/32 bit Word Lengths
- Independent Digital Volume Control on Each Channel with 127.5dB Range in 0.5dB Steps
- 3.0V – 5.5V Supply Operation
- 28-Pin SSOP Package
- Exceeds Dolby Class A Performance Requirements

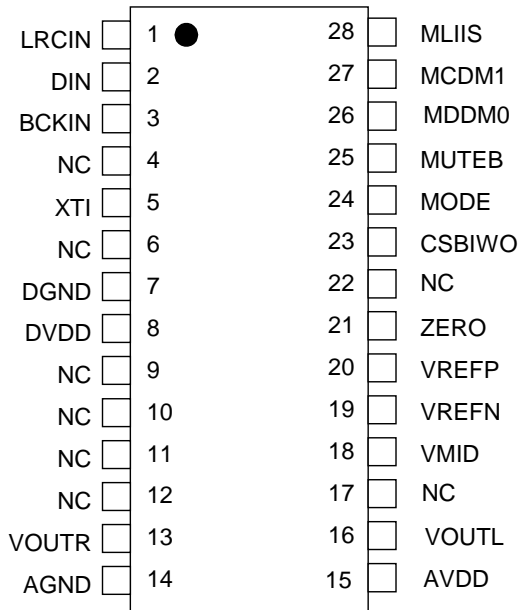
APPLICATIONS

- DVD-Audio and DVD 'Universal' Players
- Home theatre systems
- Digital TV
- Digital broadcast receivers

BLOCK DIAGRAM



**PIN CONFIGURATION**



**ORDERING INFORMATION**

| DEVICE     | TEMP. RANGE  | PACKAGE     |
|------------|--------------|-------------|
| XWM8706EDS | -25 to +85°C | 28-pin SSOP |

## PIN DESCRIPTION

| PIN | NAME   | TYPE                   | DESCRIPTION   |
|-----|--------|------------------------|---|
| 1   | LRCIN  | Digital Input          | DAC Sample Rate Clock Input   |
| 2   | DIN    | Digital Input          | Serial Audio Data Input   |
| 3   | BCKIN  | Digital Input          | Audio Data Bit Clock Input.   |
| 4   |        | NC                     | No internal connection  |
| 5   | XTI    | Analogue Input         | Master Clock Input  |
| 6   |        | NC                     | No Internal Connection  |
| 7   | DGND   | Supply                 | Digital Ground Supply   |
| 8   | DVDD   | Supply                 | Digital Positive Supply   |
| 9   |        | NC                     | No Internal Connection  |
| 10  |        | NC                     | No Internal Connection  |
| 11  |        | NC                     | No Internal Connection  |
| 12  |        | NC                     | No Internal Connection  |
| 13  | VOUTR  | Analogue Output        | Right Channel DAC Output  |
| 14  | AGND   | Supply                 | Analogue Ground Supply  |
| 15  | AVDD   | Supply                 | Analogue Positive Supply  |
| 16  | VOUTL  | Analogue Output        | Left Channel DAC Output   |
| 17  |        | NC                     | No Internal Connection  |
| 18  | VMID   | Analogue Output        | Mid Rail Decoupling Point   |
| 19  | VREFN  | Supply                 | DAC Negative Reference – normally AGND, must not be below AGND  |
| 20  | VREFP  | Supply                 | DAC Positive Reference – normally AVDD, must not be below AVDD  |
| 21  | ZERO   | Digital Output         | Infinite Zero Detect Flag   |
| 22  |        | NC                     | No Internal Connection  |
| 23  | CSBIWO | Digital Input          | Software Mode: 3-Wire Serial Control Chip Select<br>Hardware Mode: Input Word Length, Pull Up         |
| 24  | MODE   | Digital Input          | Control Mode Selection (Low = Hardware, High = Software), Pull Down                                   |
| 25  | MUTEB  | Digital Bi-directional | Mute Control (L = Mute on, H = Mute off, Z = Automute Enabled), Pull Up                               |
| 26  | MDDM0  | Digital Bi-directional | Software Mode: 3-Wire Serial Control Data Input:<br>Hardware Mode: De-Emphasis                        |
| 27  | MCDM1  | Digital Input          | Software Mode: 3-Wire Serial Control Clock Input<br>Hardware Mode: De-Emphasis, Pull Down             |
| 28  | MLIIS  | Digital Input          | Software Mode 3-Wire Serial Control Load Input<br>Hardware Mode: Input Data Format Selection, Pull Up |

**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.

| CONDITION                                       | MIN        | MAX        |
|---|------------|------------|
| Digital supply voltage                          | -0.3V      | +7V        |
| 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 (XT1)                    |            | 50MHz      |
| Operating temperature range, T <sub>A</sub>     | -25°C      | +85°C      |
| Storage temperature                             | -65°C      | +150°C     |
| Package body temperature (soldering 10 seconds) |            | +240°C     |
| Package body temperature (soldering 2 minutes)  |            | +183°C     |

**Note:**

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

## DC ELECTRICAL CHARACTERISTICS

| PARAMETER               | SYMBOL     | TEST CONDITIONS | MIN  | TYP | MAX  | UNIT |
|-------------------------|------------|-----------------|------|-----|------|------|
| Digital supply range    | DVDD       |                 | 3.0  |     | 5.5  | V    |
| Analogue supply range   | AVDD       |                 | 3.0  |     | 5.5  | V    |
| Ground                  | AGND, DGND |                 |      | 0   |      | V    |
| Difference DGND to AGND |            |                 | -0.3 | 0   | +0.3 | V    |
| Analogue supply current |            | AVDD = 5V       |      | 19  |      | mA   |
| Digital supply current  |            | DVDD = 5V       |      | 8   |      | mA   |
| Analogue supply current |            | AVDD = 3.3V     |      | 18  |      | mA   |
| Digital supply current  |            | DVDD = 3.3V     |      | 4   |      | mA   |

## ELECTRICAL CHARACTERISTICS

### Test Conditions

AVDD, DVDD = 5V, AGND, DGND = 0V, T<sub>A</sub> = +25°C, f<sub>s</sub> = 48kHz, XT1 = 256fs unless otherwise stated.

| PARAMETER                                 | SYMBOL            | TEST CONDITIONS  | MIN                      | TYP               | MAX                      | UNIT             |
|---|-------------------|--|--------------------------|-------------------|--------------------------|------------------|
| <b>Digital Logic Levels (TTL Levels)</b>  |                   |  |                          |                   |                          |                  |
| Input LOW level                           | V <sub>IL</sub>   |  |                          |                   | 0.8                      | V                |
| Input HIGH level                          | V <sub>IH</sub>   |  | 2.0                      |                   |                          | V                |
| Output LOW                                | V <sub>OL</sub>   | I <sub>OL</sub> = 1mA  |                          |                   | AGND + 0.3V              | V                |
| Output HIGH                               | V <sub>OH</sub>   | I <sub>OH</sub> = 1mA  | AVDD - 0.3V              |                   |                          | V                |
| <b>Analogue Reference Levels</b>          |                   |  |                          |                   |                          |                  |
| Reference voltage                         |                   | VMID   | (VREFP - VREFN)/2 - 50mV | (VREFP - VREFN)/2 | (VREFP - VREFN)/2 + 50mV | V                |
| Potential divider resistance              | R <sub>VMID</sub> |  |                          | 12k               |                          | ohms             |
| <b>DAC Output (Load = 10K ohms. 50pF)</b> |                   |  |                          |                   |                          |                  |
| 0dBfs Full scale output voltage           |                   | At DAC outputs   |                          | 1.1 x AVDD/5      |                          | V <sub>rms</sub> |
| SNR (Note 1,2,3)                          |                   | A-weighted,<br>@ f <sub>s</sub> = 48kHz                      | 100                      | 106               |                          | dB               |
| SNR (Note 1,2,3)                          |                   | A-weighted<br>@ f <sub>s</sub> = 96kHz                       |                          | 106               |                          | dB               |
| SNR (Note 1,2,3)                          |                   | A-weighted<br>@ f <sub>s</sub> = 192kHz                      |                          | 106               |                          | dB               |
| SNR (Note 1,2,3)                          |                   | A-weighted,<br>@ f <sub>s</sub> = 48kHz<br>AVDD, DVDD = 3.3V |                          | 105               |                          | dB               |
| SNR (Note 1,2,3)                          |                   | A-weighted<br>@ f <sub>s</sub> = 96kHz<br>AVDD, DVDD = 3.3V  |                          | 103               |                          | dB               |
| SNR (Note 1,2,3)                          |                   | Non 'A' weighted @ f <sub>s</sub><br>= 48kHz                 |                          | 106               |                          | dB               |
| THD (Note 1,2,3)                          |                   | 1kHz, 0dBfs  |                          | -97               |                          | dB               |
| THD+N (Dynamic range, Note 2)             |                   | 1kHz, -60dBfs  | 100                      | 106               |                          | dB               |
| DAC channel separation                    |                   |  |                          | 100               |                          | dB               |

**Test Conditions**

AVDD, DVDD = 5V, AGND, DGND = 0V, T<sub>A</sub> = +25°C, fs = 48kHz, XTI = 256fs unless otherwise stated.

| PARAMETER                           | SYMBOL | TEST CONDITIONS                                | MIN | TYP                  | MAX | UNIT             |
|-------------------------------------|--------|--|-----|----------------------|-----|------------------|
| <b>Analogue Output Levels</b>       |        |  |     |                      |     |                  |
| Output level                        |        | Load = 10k ohms,<br>0dBFS                      |     | 1.1                  |     | V <sub>RMS</sub> |
|                                     |        | Load = 10k ohms,<br>0dBFS,<br>(AVDD = 3.3V)    |     | 0.726                |     | V <sub>RMS</sub> |
| Gain mismatch<br>channel-to-channel |        |  |     | ±1                   |     | %FSR             |
| Minimum resistance load             |        | To midrail or a.c.<br>coupled                  |     | 1                    |     | kohms            |
|                                     |        | To midrail or a.c.<br>coupled<br>(AVDD = 3.3V) |     | 600                  |     | ohms             |
| Maximum capacitance load            |        | 5V or 3.3V                                     |     | 100                  |     | pF               |
| Output d.c. level                   |        |  |     | (VREFP -<br>VREFN)/2 |     | V                |
| <b>Power On Reset (POR)</b>         |        |  |     |                      |     |                  |
| POR threshold                       |        |  |     | 2.4                  |     | V                |

**Notes:**

- Ratio of output level with 1kHz full scale input, to the output level with all zeros into the digital input, measured 'A' weighted over a 20Hz to 20kHz bandwidth.
- 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.
- VMID decoupled with 10uF and 0.1uF capacitors (smaller values may result in reduced performance).

**TERMINOLOGY**

- 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).
- 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).
- THD+N (dB) - THD+N is a ratio, of the rms values, of (Noise + Distortion)/Signal.
- Stop band attenuation (dB) - Is the degree to which the frequency spectrum is attenuated (outside audio band).
- 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.

### MASTER CLOCK TIMING

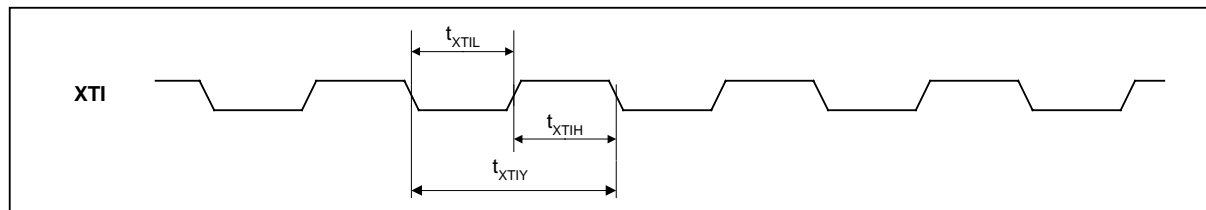


Figure 1 Master Clock Timing Requirements

**Test Conditions**

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

| PARAMETER                              | SYMBOL     | TEST CONDITIONS | MIN   | TYP | MAX   | UNIT |
|--|------------|-----------------|-------|-----|-------|------|
| <b>Master Clock Timing Information</b> |            |                 |       |     |       |      |
| XTI Master clock pulse width high      | $t_{XTIH}$ |                 | 13    |     |       | ns   |
| XTI Master clock pulse width low       | $t_{XTIL}$ |                 | 13    |     |       | ns   |
| XTI Master clock cycle time            | $t_{XTIY}$ |                 | 26    |     |       | ns   |
| XTI Duty cycle                         |            |                 | 40:60 |     | 60:40 |      |

### DIGITAL AUDIO INTERFACE

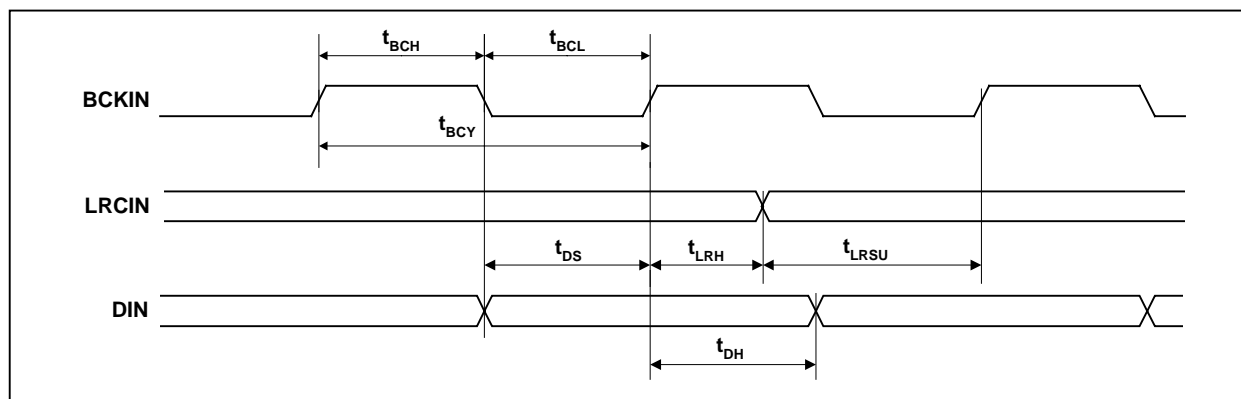


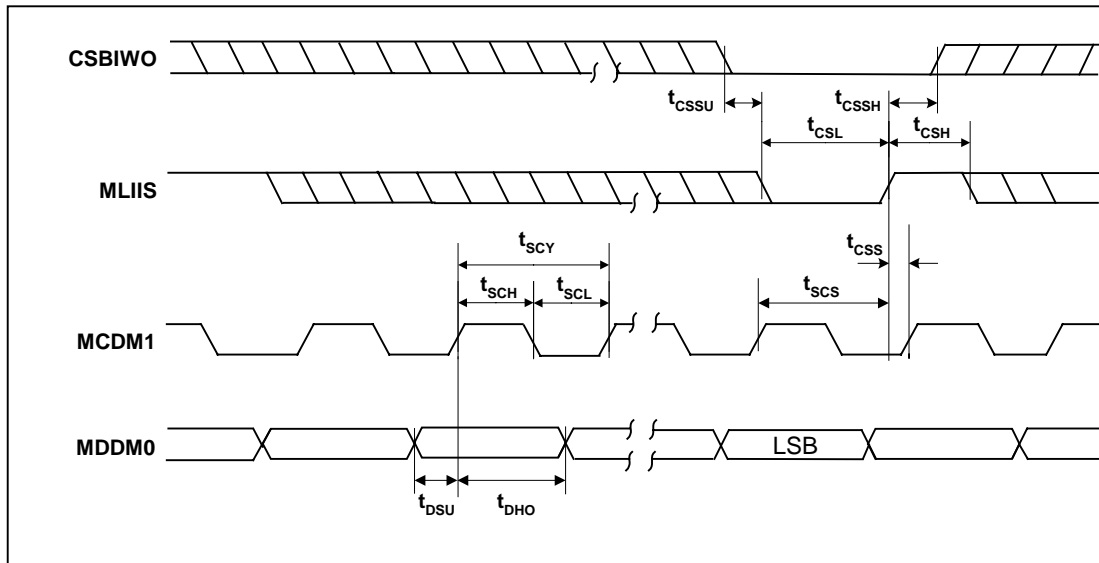
Figure 2 Digital Audio Data Timing

**Test Conditions**

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

| PARAMETER                                  | SYMBOL     | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|------------|-----------------|-----|-----|-----|------|
| <b>Audio Data Input Timing Information</b> |            |                 |     |     |     |      |
| BCKIN cycle time                           | $t_{BCY}$  |                 | 40  |     |     | ns   |
| BCKIN pulse width high                     | $t_{BCH}$  |                 | 16  |     |     | ns   |
| BCKIN pulse width low                      | $t_{BCL}$  |                 | 16  |     |     | ns   |
| LRCIN set-up time to BCKIN rising edge     | $t_{LRSU}$ |                 | 8   |     |     | ns   |
| LRCIN hold time from BCKIN rising edge     | $t_{LRH}$  |                 | 8   |     |     | ns   |
| DIN set-up time to BCKIN rising edge       | $t_{DS}$   |                 | 8   |     |     | ns   |
| DIN hold time from BCKIN rising edge       | $t_{DH}$   |                 | 8   |     |     | ns   |

**MPU INTERFACE TIMING**



**Figure 3 Program Register Input Timing - 3-Wire Serial Control Mode**

**Test Conditions**

AVDD, DVDD = 5V, AGND, DGND = 0V, TA = +25°C, fs = 48kHz, XT1 = 256fs unless otherwise stated.

| PARAMETER                                 | SYMBOL            | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|-------------------|-----------------|-----|-----|-----|------|
| <b>Program Register Input Information</b> |                   |                 |     |     |     |      |
| MCDM1 rising edge to MLIIS rising edge    | t <sub>scs</sub>  |                 | 40  |     |     | ns   |
| MCDM1 pulse cycle time                    | t <sub>scy</sub>  |                 | 80  |     |     | ns   |
| MCDM1 pulse width low                     | t <sub>scl</sub>  |                 | 20  |     |     | ns   |
| MCDM1 pulse width high                    | t <sub>sch</sub>  |                 | 20  |     |     | ns   |
| MDDM0 to MCDM1 set-up time                | t <sub>dsu</sub>  |                 | 20  |     |     | ns   |
| MCDM1 to MDDM0 hold time                  | t <sub>dho</sub>  |                 | 20  |     |     | ns   |
| MLIIS pulse width low                     | t <sub>csl</sub>  |                 | 20  |     |     | ns   |
| MLIIS pulse width high                    | t <sub>csh</sub>  |                 | 20  |     |     | ns   |
| MLIIS rising to SCLK rising               | t <sub>cscs</sub> |                 | 20  |     |     | ns   |
| CSBIWO to MLIIS set-up time               | t <sub>cssu</sub> |                 | 20  |     |     | Ns   |
| MLIIS to CSBIWO hold time                 | t <sub>cssh</sub> |                 | 20  |     |     | ns   |



## DEVICE DESCRIPTION

### INTRODUCTION

The WM8706 is a high performance DAC designed for digital consumer audio applications. Its range of features make it ideally suited for use in DVD players, AV receivers and other high end consumer audio equipment.

The WM8706 is a complete 2-channel stereo audio digital-to-analogue converter, including digital interpolation filter, multi-bit sigma delta with dither, and switched capacitor multi-bit stereo DAC and output smoothing filters. The WM8706 includes an on-board digital volume control, configurable digital audio interface and a 3 wire MPU control interface. It is fully compatible and an ideal partner for a range of industry standard microprocessors, controllers and DSPs.

Control of internal functionality of the device is by either hardware control (pin programmed) or software control (3-wire serial control interface). The MODE pin selects between hardware and software control. The software control interface may be asynchronous to the audio data interface. Control data will be re-synchronised to the audio processing internally.

Operation using master clocks of 256fs, 384fs, 512fs or 768fs is provided, selection between clock rates being automatically controlled in hardware mode, or serial controlled when in software mode. Sample rates (fs) from less than 8ks/s to 96ks/s are allowed, provided the appropriate master clock is input. Support is also provided for up to 192ks/s using a master clock of 128fs or 192fs.

The audio data interface supports right, left and I<sup>2</sup>S (Philips left justified, one bit delayed) interface formats along with a highly flexible DSP serial port interface. When in hardware mode, the three serial interface pins become control pins to allow selection of input data format type (I<sup>2</sup>S or right justified), input word length (16, 20, or 24-bit) and de-emphasis functions.

The device is packaged in a small 28-pin SSOP and is a pin-compatible alternative to the WM8716.

### CLOCKING SCHEMES

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 XTI input pin with no software configuration necessary for sample rate selection.

Note that on the WM8706, XTI is used to derive clocks for the DAC path. The DAC path consists of DAC sampling clock, DAC digital filter clock and DAC digital audio interface timing. 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 DAC.

### DIGITAL AUDIO INTERFACE

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
- I<sup>2</sup>S mode
- DSP Early mode
- DSP Late mode

All 5 formats send the MSB first and support word lengths of 16, 20, 24 and 32 bits. The exception is that 32 bit data is not supported in right justified mode. DIN and LRCIN are sampled on the rising, or falling edge of BCKIN depending on the format selected.

In left justified, right justified and I<sup>2</sup>S modes, the digital audio interface receives data on the DIN input. Audio Data is time multiplexed with LRCIN indicating whether the left or right channel is present. LRCIN 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 BCKINs per LRCIN period is 2 times the selected word length. LRCIN must be high for a minimum of word length BCKINs and low for a minimum of word length BCKINs. Any mark to space ratio on LRCIN is acceptable provided the above requirements are met. The WM8706 will automatically detect when data with a LRCIN period of exactly 32 is sent, and select 16 bit mode - overriding any previously programmed word length. Word length will revert to the previously programmed value when a LRCIN period other than 32 is detected. (see Figure 4, Figure 5 and Figure 6).

In DSP early or DSP late mode, the data is time multiplexed onto DIN. LRCIN is used as a frame sync signal to identify the MSB of the first word. The minimum number of BCKINs per LRCIN period is 2 times the selected word length. Any mark to space ratio on LRCIN provided the rising edge is correctly positioned (see Figure 7 and Figure 8).

**LEFT JUSTIFIED MODE**

In left justified mode, the MSB is sampled on the first rising edge of BCKIN following a LRCIN transition. LRCIN is high during the left samples and low during the right samples.

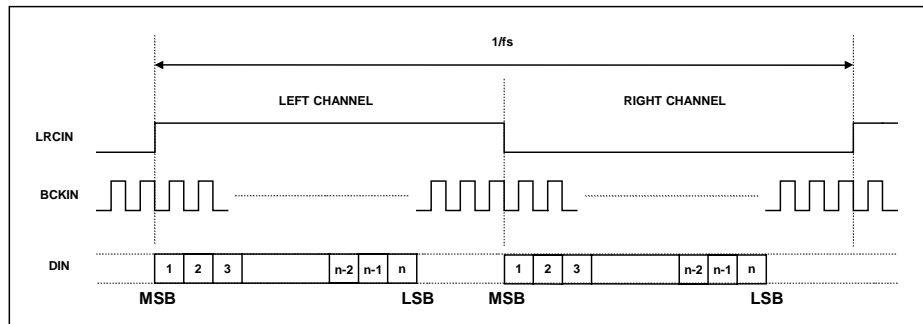


Figure 4 Left Justified Mode Timing Diagram

**RIGHT JUSTIFIED MODE**

In right justified mode, the LSB is sampled on the rising edge of BCKIN preceding a LRCIN transition. LRCIN is high during the left samples and low during the right samples.

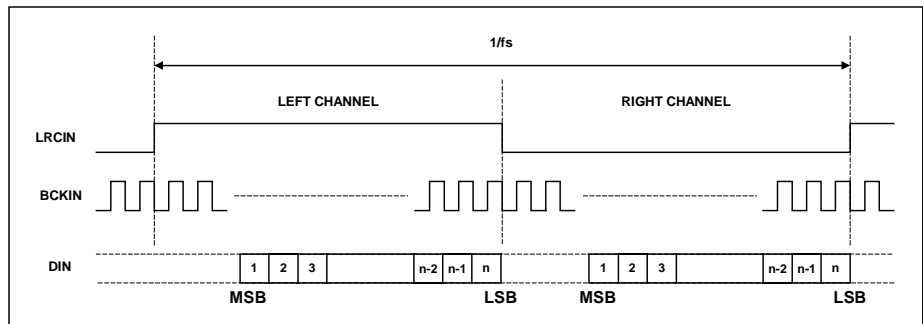
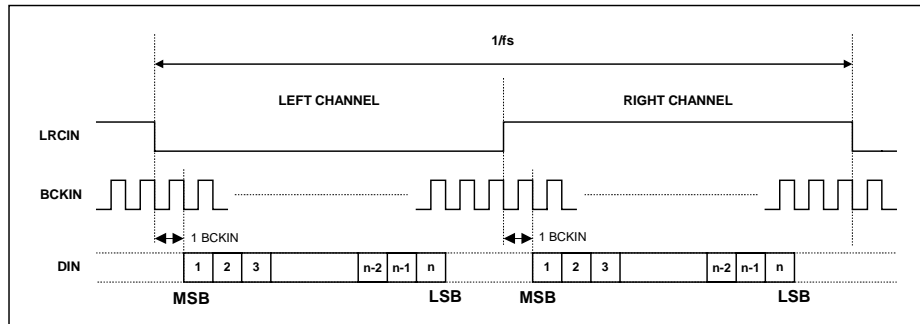


Figure 5 Right Justified Mode Timing Diagram

**I<sup>2</sup>S MODE**

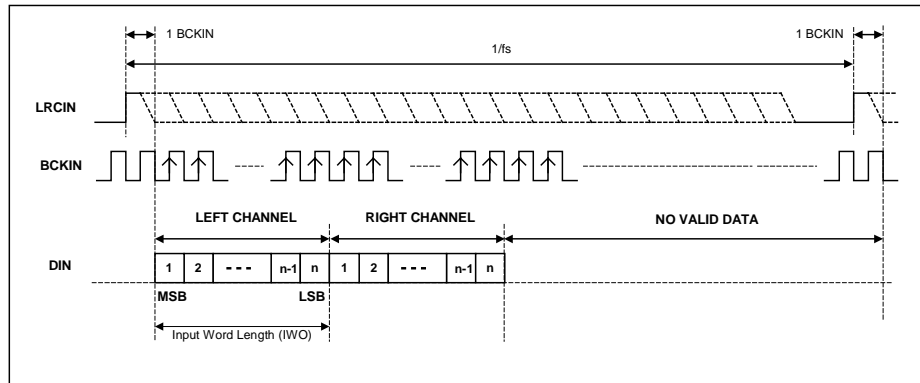
In I<sup>2</sup>S mode, the MSB is sampled on the second rising edge of BCKIN following a LRCIN transition. LRCIN is low during the left samples and high during the right samples.



**Figure 6 I<sup>2</sup>S Mode Timing Diagram**

**DSP EARLY MODE**

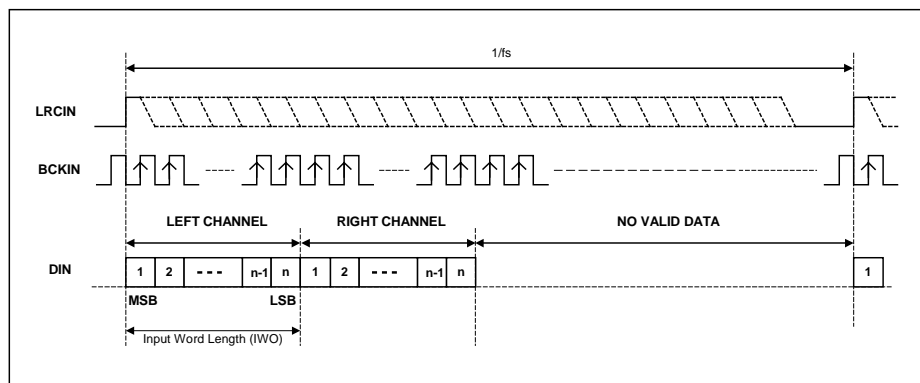
In DSP early mode, the first bit is sampled on the BCKIN rising edge following the one which detects a low to high transition on LRCIN. No BCKIN edges are allowed between the data words. The word order is DIN left, DIN right.



**Figure 7 DSP Early Mode Timing Diagram**

**DSP LATE MODE**

In DSP late mode, the first bit is sampled on the BCKIN rising edge which detects a low to high transition on LRCIN. No BCKIN edges are allowed between the data words. The word order is DIN left, DIN right.



**Figure 8 DSP Late Mode Timing Diagram**

## AUDIO DATA SAMPLING RATES

The master clock for WM8706 supports audio sampling rates from 128fs to 768fs, where fs is the audio sampling frequency (LRCIN) typically 32kHz, 44.1kHz, 48kHz, 96kHz or 192kHz. The master clock is used to operate the digital filters and the noise shaping circuits.

The WM8706 has a master clock detection circuit that automatically determines the relation between the master clock frequency and the sampling rate (to within +/- 32 master clocks). If there is a greater than 8 clocks error, the interface shuts down the DAC and mutes the output. The master clock should be synchronised with LRCIN, although the WM8706 is tolerant of phase differences or jitter on this clock.

| SAMPLING RATE (LRCIN) | MASTER CLOCK FREQUENCY (MHZ) (XTI) |        |             |             |             |             |
|-----------------------|------------------------------------|--------|-------------|-------------|-------------|-------------|
|                       | 128fs                              | 192fs  | 256fs       | 384fs       | 512fs       | 768fs       |
| 32kHz                 | 4.096                              | 6.144  | 8.192       | 12.288      | 16.384      | 24.576      |
| 44.1kHz               | 5.6448                             | 8.467  | 11.2896     | 16.9340     | 22.5792     | 33.8688     |
| 48kHz                 | 6.114                              | 9.216  | 12.288      | 18.432      | 24.576      | 36.864      |
| 96kHz                 | 12.288                             | 18.432 | 24.576      | 36.864      | Unavailable | Unavailable |
| 192kHz                | 24.576                             | 36.864 | Unavailable | Unavailable | Unavailable | Unavailable |

**Table 1 Typical Relationships Between System Frequency and Sampling Rates.**

## HARDWARE CONTROL MODES

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

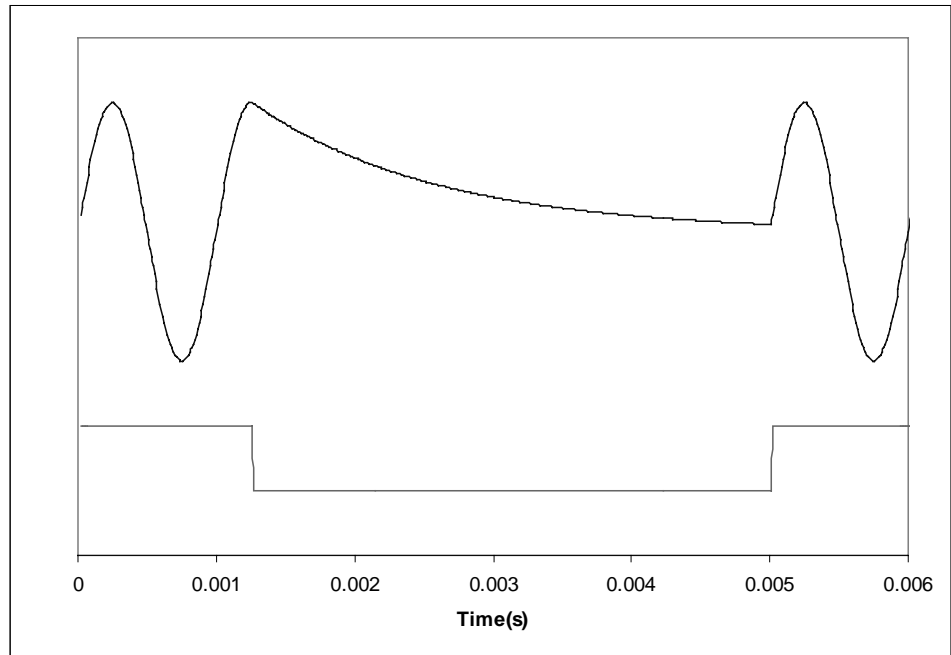
### MUTE AND AUTOMUTE OPERATION

In both hardware and software modes, pin 25 (MUTEB) controls selection of MUTE directly, and can be used to enable and disable the automute function, or as an output of the automuted signal.

| MUTEB PIN | DESCRIPTION  |
|-----------|--|
| 0         | Mute DAC channels  |
| 1         | Normal Operation   |
| Floating  | Enable IZD, MUTEB becomes an output to indicate when IZD occurs. |

**Table 2 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.



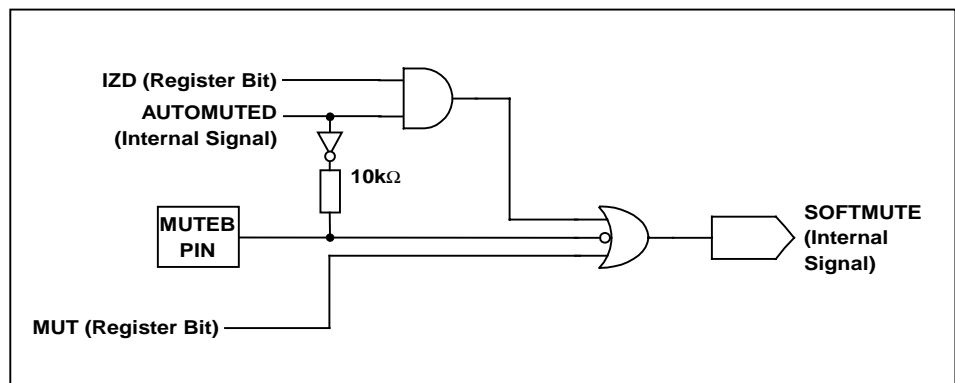
**Figure 9 Application and Release of Soft Mute**

The MUTE pin is an input to select mute or not mute. MUTE pin is active low; taking the pin low causes the filters to soft mute, ramping down the audio signal over a few milliseconds. Taking MUTE pin high again allows data into the filter.

The automute function detects a series of zero value audio samples of 1024 samples long being applied to both channels. After such an event, a latch is set whose output (AUTOMUTED) is wire OR'ed through a 10kohm resistor to the MUTE pin. Thus if the MUTE pin is not being driven, the automute function will assert mute.

If MUTE pin is tied high, AUTOMUTE is overridden and will not mute unless the IZD register bit is set. If MUTE pin is driven from a bi-directional source, then both MUTE and automute functions are available. If MUTE pin is not driven, AUTOMUTED appears as a weak output (10k source impedance) so can be used to drive external mute circuits. Automute will be removed as soon as any channel receives a non-zero input.

A diagram showing how the various Mute modes interact is shown below in Figure 10.



**Figure 10 Selection Logic for MUTE Modes**

### INPUT FORMAT SELECTION

In hardware mode, MLIIS (pin 28) and CSBIWO (pin 23) become input controls for selection of input data format type and input data word length.

| MLIIS | CSBIWO | INPUT DATA MODE          |
|-------|--------|--------------------------|
| 0     | 0      | 24-bit right justified** |
| 0     | 1      | 20-bit right justified   |
| 1     | 0      | 16-bit I <sup>2</sup> S  |
| 1     | 1      | 24-bit I <sup>2</sup> S  |

**Table 3 Input Format Selection**

**Note:**

In 24 bit I<sup>2</sup>S mode, any width of 24 bits or less is supported provided that LRCIN is high for a minimum of 24 BCKINs and low for a minimum of 24 BCKINs.

\*\* This mode differs from the WM8716 which does 16-bit right justified in this mode. The previous mode is still available by using exactly 32 BCKIN per LRCIN cycle, 16 for left and right. This mode is automatically detected within the hardware and overrides the data width specified but **not** the format.

### DE-EMPHASIS CONTROL

In hardware mode, MCDM1 (pin 27) and MDDM0 (pin 26) become input controls for selection of de-emphasis filtering to be applied.

| MCDM1 | MDDM0 | DE-EMPHASIS** |
|-------|-------|---------------|
| 0     | 0     | Off           |
| 0     | 1     | 48kHz         |
| 1     | 0     | 44.1kHz       |
| 1     | 1     | 32kHz         |

**Table 4 De-emphasis Control**

**Note:**

\*\* The actual de-emphasis within the WM8706 is the same for all data rates. This differs from WM8716 which has a different response for each sample rate.

## SOFTWARE CONTROL INTERFACE

### SELECTION OF CONTROL MODE

The WM8706 may be programmed to operate in hardware or software control modes. This is achieved by setting the state of the MODE pin.

| MODE | INTERFACE FORMAT      |
|------|-----------------------|
| 0    | Hardware Control Mode |
| 1    | Software Control Mode |

**Table 5 Control Interface Mode Selection**

### 3-WIRE (SPI COMPATIBLE) SERIAL CONTROL MODE

The WM8706 can be controlled using a 3-wire serial interface. MDDM0 is used for the program data, MCDM1 is used to clock in the program data and MLIIS is used to latch in the program data. The 3-wire interface protocol is shown in Figure 11.

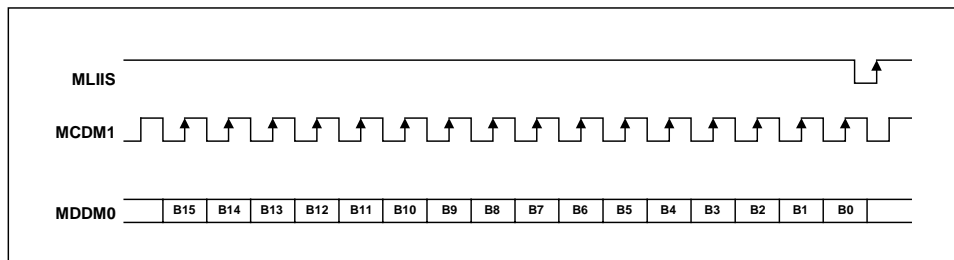


Figure 11 3-Wire Serial Interface

**Notes:**

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

### REGISTER MAP

WM8706 uses a total of 4 programme registers, which are 16-bits long. These registers are all loaded through input pin MDDM0. After the 16 data bits are clocked in, MLIIS is used to latch in the data to the appropriate register. Table 6 shows the complete mapping of the 4 registers.

|           | B15            | B14 | B13 | B12 | B11 | B10 | B9 | B8          | B7   | B6   | B5   | B4   | B3   | B2    | B1    | B0               |
|-----------|----------------|-----|-----|-----|-----|-----|----|-------------|------|------|------|------|------|-------|-------|------------------|
| <b>M0</b> | 0              | 0   | 0   | 0   | 0   | 0   | 0  | UPDATEL     | LAT7 | LAT6 | LAT5 | LAT4 | LAT3 | LAT2  | LAT1  | LAT0             |
| <b>M1</b> | 0              | 0   | 0   | 0   | 0   | 0   | 1  | UPDATER     | RAT7 | RAT6 | RAT5 | RAT4 | RAT3 | RAT2  | RAT1  | RAT0             |
| <b>M2</b> | 0              | 0   | 0   | 0   | 0   | 1   | 0  | 0           | 0    | 0    | IW2  | IW1  | IW0  | PWRDN | EEMPH | MUT              |
| <b>M3</b> | 0              | 0   | 0   | 0   | 0   | 1   | 1  | IZD         | SF1  | SF0  | BCP  | REV  | 0    | ATC   | LRP   | I <sup>2</sup> S |
|           | <b>ADDRESS</b> |     |     |     |     |     |    | <b>DATA</b> |      |      |      |      |      |       |       |                  |

Table 6 Mapping of Program Registers

| REGISTER ADDRESS<br>A2, A1, A0    | BITS  | LABEL            | DEFAULT        | DESCRIPTION  |
|-----------------------------------|-------|------------------|----------------|--|
| 000                               | [7:0] | LAT[7:0]         | 11111111 (0dB) | Attenuation data for left channel in 0.5dB steps.  |
| A2, A1, A0<br>DACL<br>Attenuation | 8     | UPDATEL          | 0              | Attenuation data load control for left channel.<br>0: Store DACL in intermediate latch (no change to output)<br>1: Store DACL and update attenuation on all channels.  |
| 001                               | [7:0] | RAT[7:0]         | 11111111 (0dB) | Attenuation data for right channel in 0.5dB steps.   |
| DACR<br>Attenuation               | 8     | UPDATER          | 0              | Attenuation data load control for right channel.<br>0: Store DACR in intermediate latch (no change to output)<br>1: Store DACR and update attenuation on all channels. |
| 010<br>DAC Control                | 0     | MUT              | 0              | Left and right DACs soft mute control.<br>0: No mute<br>1: Mute  |
|                                   | 1     | DEEMPH           | 0              | De-emphasis control.<br>0: De-emphasis off<br>1: De-emphasis on  |
|                                   | 2     | PWDN             | 0              | Left and Right DACs Power-down Control<br>0: All DACs running, output is active<br>1: All DACs in power saving mode, output muted                                      |
|                                   | [5:3] | IW[2:0]          | 000            | Audio data format select.  |
| 011<br>Interface Control          | 0     | I <sup>2</sup> S | 0              | Audio data format select.  |
|                                   | 1     | LRP              | 0              | Polarity select for LRCIN/DSP mode select.<br>0: normal LRCIN polarity/DSP late mode<br>1: inverted LRCIN polarity/DSP early mode                                      |
|                                   | 2     | ATC              | 0              | Attenuator Control.<br>0: All DACs use attenuations as programmed.<br>1: Right channel DACs use corresponding left DAC attenuations                                    |
|                                   | 4     | REV              | 0              | Output phase reverse.  |
|                                   | 5     | BCP              | 0              | BCKIN Polarity<br>0 : normal BCKIN polarity<br>1: inverted BCKIN polarity  |
|                                   | [7:6] | SF[1:0]          | 00             | De-Emphasis sample rate select.  |
|                                   | 8     | IZD              | 0              | Infinite zero detection circuit control and automute control<br>0: Infinite zero detect disabled<br>1: Infinite zero detect enabled                                    |

Table 7 Register Bit Descriptions



## ATTENUATION CONTROL

Each DAC channel can be attenuated digitally before being applied to the digital filter. Attenuation is 0dB by default but can be set between 0 and 127.5dB in 0.5dB steps using the 8 Attenuation control bits. All attenuation registers are double latched allowing new values to be pre-latched to both channels before being updated synchronously. Setting the UPDATE bit on any attenuation write will cause all pre-latched values to be immediately applied to the DAC channels.

| REGISTER ADDRESS<br>A2, A1, A0 | BIT | LABEL    | DEFAULT           | DESCRIPTION   |
|--------------------------------|-----|----------|-------------------|---|
| 000<br>DACL<br>Attenuation     | 7:0 | LAT[7:0] | 11111111<br>(0dB) | Attenuation data for Left channel DACL in 0.5dB steps.  |
|                                | 8   | UPDATEL  | 0                 | Controls simultaneous update of all Attenuation Latches<br>0: Store DACL in intermediate latch (no change to output)<br>1: Store DACL and update attenuation on all channels. |
| 001<br>DACR<br>Attenuation     | 7:0 | RAT[7:0] | 11111111<br>(0dB) | Attenuation data for Right channel DACR in 0.5dB steps.   |
|                                | 8   | UPDATER  | 0                 | Controls simultaneous update of all Attenuation Latches<br>0: Store DACR in intermediate latch (no change to output)<br>1: Store DACR and update attenuation on all channels. |

**Table 8 Attenuation Register Map**

**Note:**

- The UPDATE bit is not latched. If UPDATE=0, the Attenuation value will be written to the pre-latch but not applied to the relevant DAC. If UPDATE=1, all pre-latched values will be applied from the next input sample.
- Care should be used in reducing the attenuation as rapid large volume changes can introduce zipper noise.

### DAC OUTPUT ATTENUATION

Registers LAT and RAT control the left and right channel attenuation. Table 9 shows how the attenuation levels are selected from the 8-bit words.

| XAT[7:0] | ATTENUATION LEVEL |
|----------|-------------------|
| 00(hex)  | ∞dB (mute)        |
| 01(hex)  | 127.5dB           |
| :        | :                 |
| :        | :                 |
| :        | :                 |
| FE(hex)  | 0.5dB             |
| FF(hex)  | 0dB               |

**Table 9 Attenuation Control Levels**

### MUTE MODES

Setting the MUT register bit will apply a 'soft' mute to the input of the digital filters:

| REGISTER ADDRESS   | BIT | LABEL | DEFAULT | DESCRIPTION   |
|--------------------|-----|-------|---------|---|
| 010<br>DAC Control | 0   | MUT   | 0       | Soft Mute select<br>0 : Normal Operation<br>1: Soft mute all channels |

**Table 10 Mute Control**

### DE-EMPHASIS MODE

Setting the DEEMPH register bit puts the all the digital filters into de-emphasis mode:

| REGISTER ADDRESS   | BIT | LABEL  | DEFAULT | DESCRIPTION  |
|--------------------|-----|--------|---------|--|
| 010<br>DAC Control | 1   | DEEMPH | 0       | De-emphasis mode select:<br>0 : De-emphasis Off<br>1: De-emphasis On |

**Table 11 De-emphasis Control**

**POWERDOWN MODE**

Setting the PWDN register bit immediately connects all outputs to  $V_{MID}$  and selects a low power mode. All trace of the previous input samples is removed, and all register settings are cleared. When PWDN is cleared again the first 16 input samples will be ignored as the FIR will repeat it's power-on initialisation sequence.

| REGISTER ADDRESS   | BIT | LABEL | DEFAULT | DESCRIPTION  |
|--------------------|-----|-------|---------|--|
| 010<br>DAC Control | 2   | PWDN  | 0       | Power Down Mode Select:<br>0 : Normal Mode<br>1: Power Down Mode |

Table 12 Powerdown Control

**DIGITAL AUDIO INTERFACE CONTROL REGISTERS**

The WM8706 has a fully featured digital audio interface that is a superset of that contained in the WM8716. Interface format is selected via the IW[2:0] register bits in register M2 and the I<sup>2</sup>S register bit in M3.

| REGISTER ADDRESS   | BIT | LABEL   | DEFAULT | DESCRIPTION             |
|--------------------|-----|---------|---------|-------------------------|
| 010<br>DAC Control | 5:3 | IW[2:0] | 000     | Interface format Select |

Table 13 Interface Format Controls

| REGISTER ADDRESS         | BIT | LABEL            | DEFAULT | DESCRIPTION             |
|--------------------------|-----|------------------|---------|-------------------------|
| 011<br>Interface Control | 0   | I <sup>2</sup> S | 0       | Interface format Select |

Table 14 Interface Format Control

| IW2 | I <sup>2</sup> S | IW1 | IW0 | AUDIO INTERFACE DESCRIPTION **         |
|-----|------------------|-----|-----|--|
| 0   | 0                | 0   | 0   | 16 bit right justified mode            |
| 0   | 0                | 0   | 1   | 20 bit right justified mode            |
| 0   | 0                | 1   | 0   | 24 bit right justified mode            |
| 0   | 0                | 1   | 1   | 24 bit left justified mode             |
| 0   | 1                | 0   | 0   | 16 bit I <sup>2</sup> S mode           |
| 0   | 1                | 0   | 1   | 24 bit I <sup>2</sup> S mode           |
| 0   | 1                | 1   | 0   | 20 bit I <sup>2</sup> S mode           |
| 0   | 1                | 1   | 1   | 20 bit left justified (MSB first) mode |
| 1   | 0                | 0   | 0   | 16 bit DSP mode                        |
| 1   | 0                | 0   | 1   | 20 bit DSP mode                        |
| 1   | 0                | 1   | 0   | 24 bit DSP mode                        |
| 1   | 0                | 1   | 1   | 32 bit DSP mode                        |
| 1   | 1                | 0   | 0   | 16 bit left justified mode             |

Table 15 Audio Data Input Format

**Note:**

\*\* 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 WM8706 pads the unused LSBs with zeros. If the DAC is programmed into 32 bit mode, the 4 LSBs are ignored.

**SELECTION OF LRCIN POLARITY**

In left justified, right justified or I<sup>2</sup>S modes, the LRP register bit controls the polarity of LRCIN. If this bit is set high, the expected polarity of LRCIN will be the opposite of that shown in Figure 4, Figure 5 and Figure 6. 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.

| REGISTER ADDRESS         | BIT | LABEL | DEFAULT | DESCRIPTION  |
|--------------------------|-----|-------|---------|--|
| 011<br>Interface Control | 1   | LRP   | 0       | LRCIN Polarity (normal)<br>0 : normal LRCIN polarity<br>1: inverted LRCIN polarity |

Table 16 LRCIN Polarity Control

In DSP modes, the LRCIN register bit is used to select between early and late modes:

| REGISTER ADDRESS         | BIT | LABEL | DEFAULT | DESCRIPTION  |
|--------------------------|-----|-------|---------|--|
| 011<br>Interface Control | 1   | LRP   | 0       | DSP Format (DSP modes)<br>0 : Early DSP mode<br>1: Late DSP mode |

**Table 17 DSP Format Control**

In DSP early mode, the first bit is sampled on the BCKIN rising edge following the one that detects a low to high transition on LRCIN. In DSP late mode, the first bit is sampled on the BCKIN edge, which detects a low to high transition on LRCIN. No BCKIN rising edges are allowed between the data words. The word order is DIN left, DIN right.

#### 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   |
|--------------------------|-----|-------|---------|---|
| 011<br>Interface Control | 2   | ATC   | 0       | Attenuate Control Mode:<br>0 : Right channels use Right attenuation<br>1: Right Channels use Left Attenuation |

**Table 18 Attenuation Control Select**

#### OUTPUT PHASE REVERSAL

The REV register bit controls the phase of the output signal. Setting the REV bit causes the phase of the output signal to be inverted.

| REGISTER ADDRESS         | BIT | LABEL | DEFAULT | DESCRIPTION                                       |
|--------------------------|-----|-------|---------|---|
| 011<br>Interface Control | 4   | REV   | 0       | Analogue Output Phase<br>0: Normal<br>1: Inverted |

**Table 19 Output Phase Control**

#### BCKIN POLARITY

By default, LRCIN and DIN are sampled on the rising edge of BCKIN and should ideally change on the falling edge. Data sources which change LRCIN and DIN on the rising edge of BCKIN can be supported by setting the BCP register bit. Setting BCP to 1 inverts the polarity of BCKIN to the inverse of that shown in Figure 4, Figure 5, Figure 6, Figure 7 and Figure 8.

| REGISTER ADDRESS         | BIT | LABEL | DEFAULT | DESCRIPTION   |
|--------------------------|-----|-------|---------|---|
| 011<br>Interface Control | 5   | BCP   | 0       | BCKIN Polarity<br>0 : normal BCKIN polarity<br>1: inverted BCKIN polarity |

**Table 20 BCKIN Polarity Control**

#### DE-EMPHASIS SAMPLE RATE SELECTION

The SF[1:0] bits are used to select the de-emphasis rate.

| REGISTER ADDRESS          | BIT | LABEL   | DEFAULT | DESCRIPTION **   |
|---------------------------|-----|---------|---------|--|
| 0011<br>Interface Control | 7:6 | SF[1:0] | 00      | De-Emphasis Sample Rate Selection<br>00 : De-Emphasis Off<br>01: 48kHz<br>10: 44.1kHz<br>11: 32kHz |

**Table 21 De-emphasis Control**

#### Note:

\*\* There is only one internal de-emphasis mode optimised for 44.1kHz. This is in contrast to WM8716 which is individually optimised for each sample rate.

**INFINITE ZERO DETECTION**

Setting the IZD register bit determines whether the device is automuted when a sequence of more than 1024 zeros is detected.

| REGISTER ADDRESS         | BIT | LABEL | DEFAULT | DESCRIPTION   |
|--------------------------|-----|-------|---------|---|
| 011<br>Interface Control | 8   | IZD   | 0       | Infinite zero detection circuit control and automute control<br>0: Infinite zero detect disabled<br>1: Infinite zero detect enabled |

Table 22 IZD Control

**DIGITAL FILTER CHARACTERISTICS**

| PARAMETER            | SYMBOL | TEST CONDITIONS | MIN | TYP     | MAX        | UNIT |
|----------------------|--------|-----------------|-----|---------|------------|------|
| Passband Edge        |        | -3dB            |     | 0.487fs |            |      |
| Passband Ripple      |        | $f < 0.444f_s$  |     |         | $\pm 0.05$ | dB   |
| Stopband Attenuation |        | $f > 0.555f_s$  | -60 |         |            | dB   |

Table 23 Digital Filter Characteristics

**DAC FILTER RESPONSES**

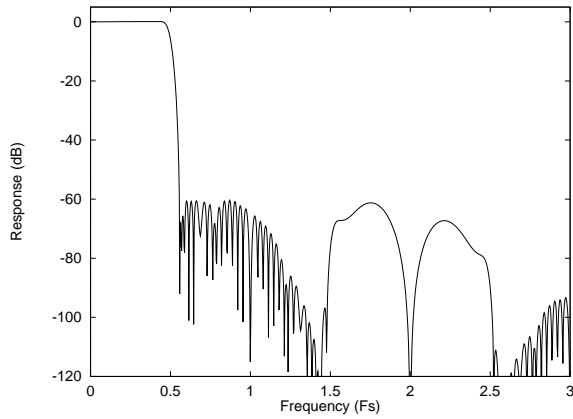


Figure 12 DAC Digital Filter Frequency Response - 44.1, 48 and 96kHz

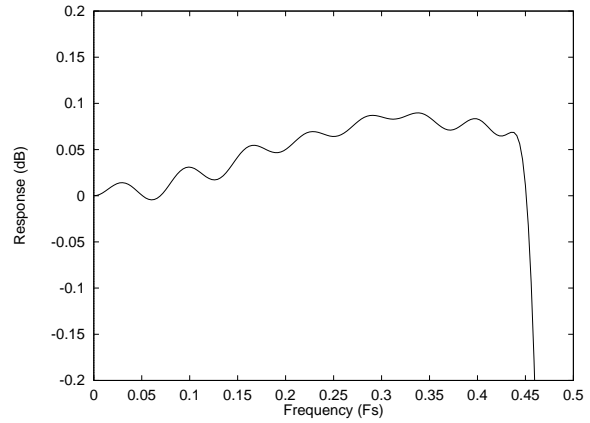


Figure 13 DAC Digital Filter Ripple - 44.1, 48 and 96kHz

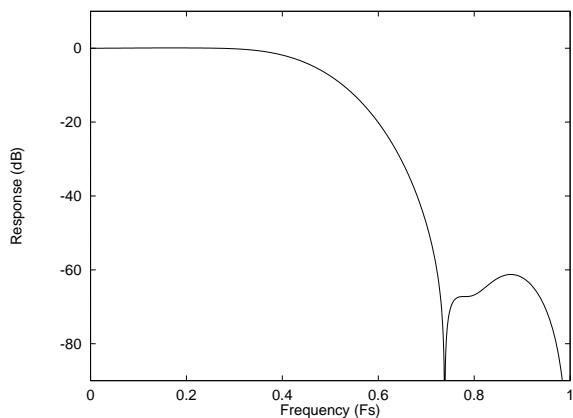


Figure 14 DAC Digital Filter Frequency Response - 192kHz

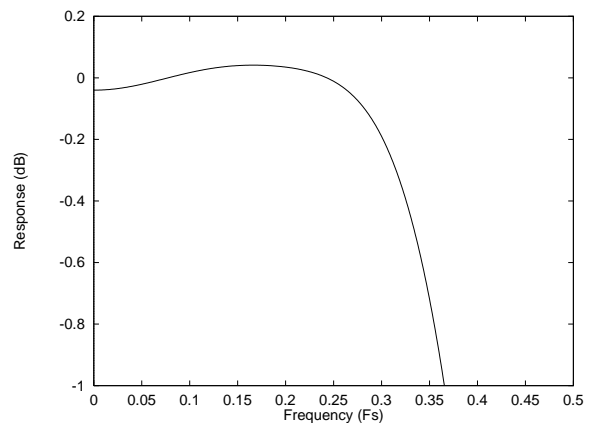


Figure 15 DAC Digital Filter Ripple - 192kHz

### DIGITAL DE-EMPHASIS CHARACTERISTICS

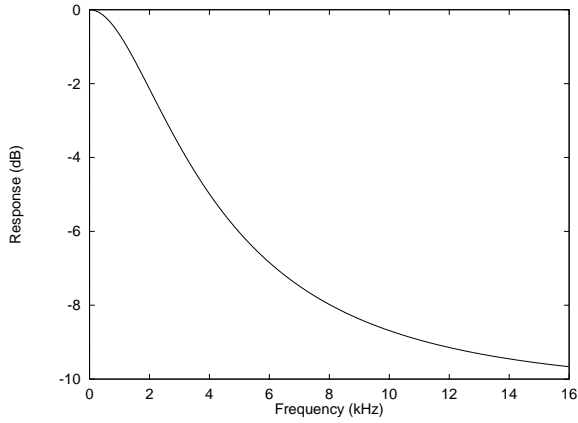


Figure 16 De-Emphasis Frequency Response (32kHz)

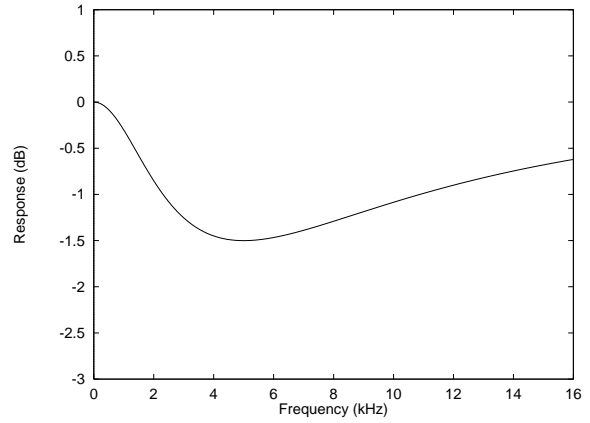


Figure 17 De-Emphasis Error (32kHz)

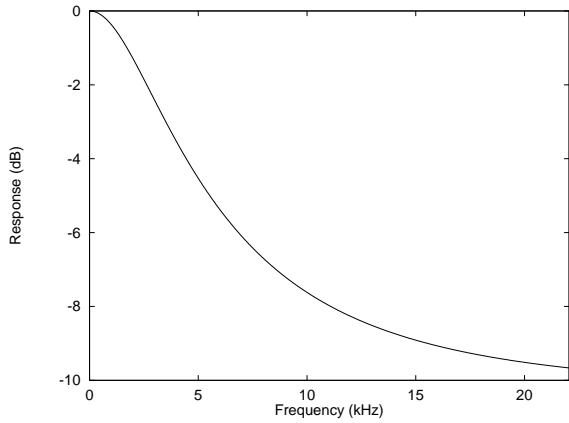


Figure 18 De-Emphasis Frequency Response (44.1kHz)

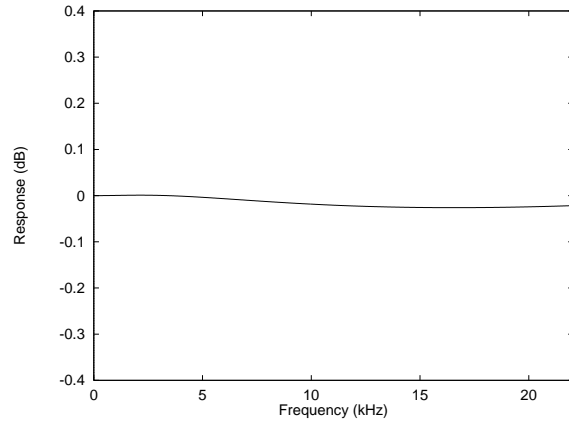


Figure 19 De-Emphasis Error (44.1kHz)

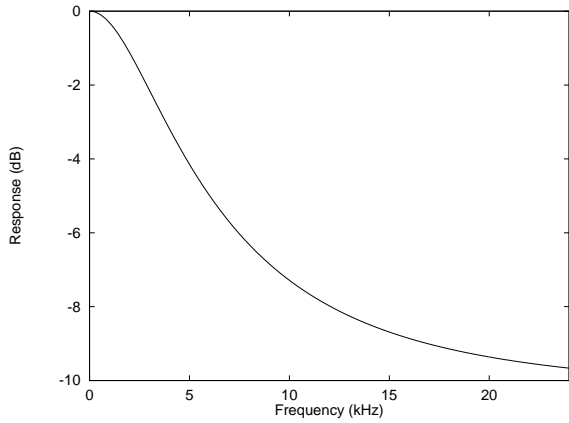


Figure 20 De-Emphasis Frequency Response (48kHz)

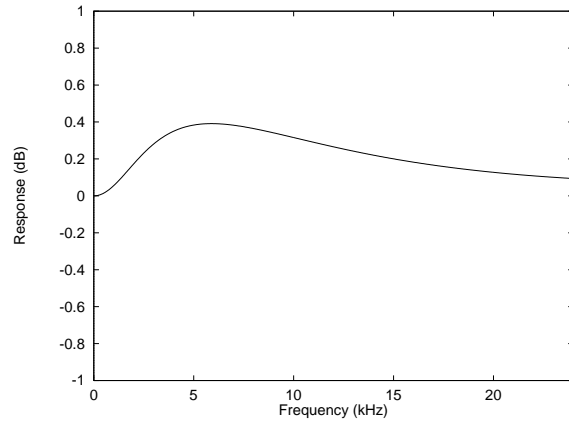


Figure 21 De-Emphasis Error (48kHz)

### RECOMMENDED EXTERNAL COMPONENTS

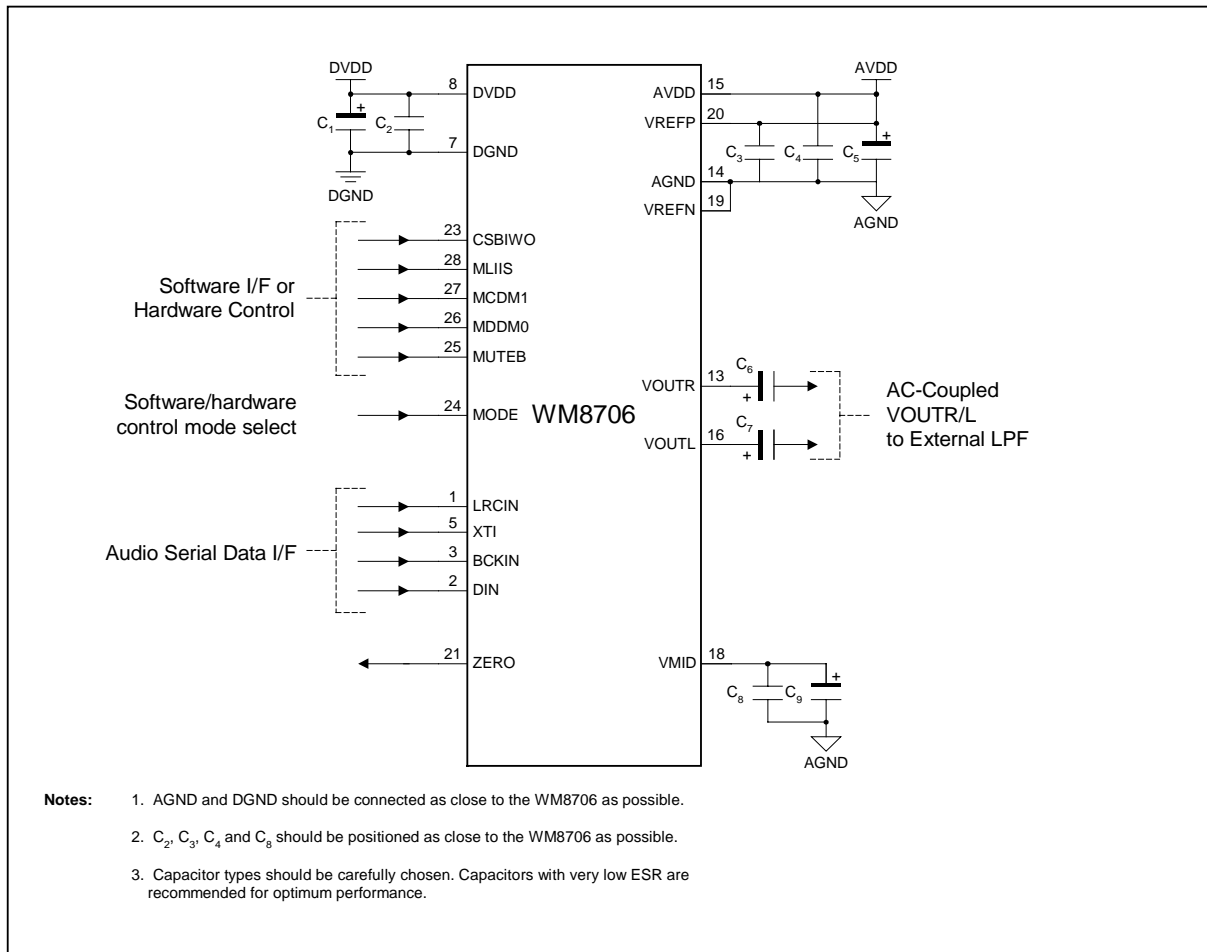


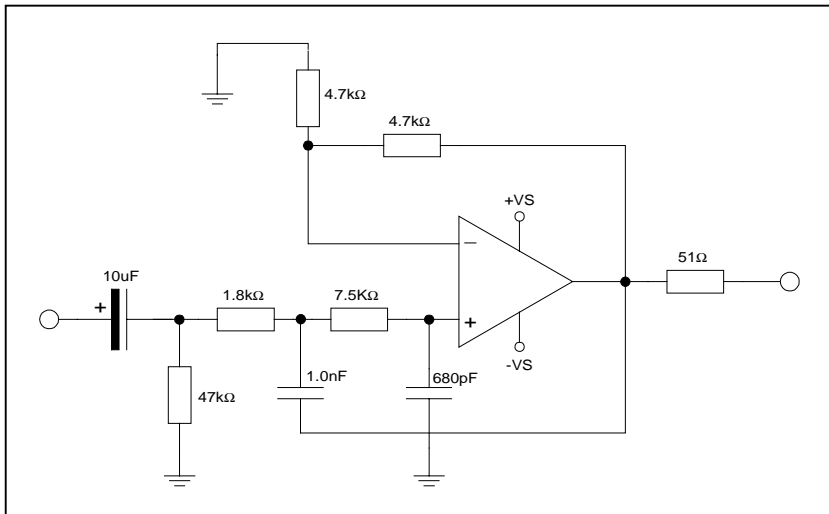
Figure 22 External Components Diagram

### RECOMMENDED EXTERNAL COMPONENT VALUES

| COMPONENT REFERENCE | SUGGESTED VALUE | DESCRIPTION  |
|---------------------|-----------------|--|
| C1 and C5           | 10µF            | De-coupling for DVDD and AVDD/VREFP                              |
| C2 to C4            | 0.1µF           | De-coupling for DVDD and AVDD/VREFP                              |
| C6 and C7           | 10µF            | Output AC coupling caps to remove midrail DC level from outputs. |
| C8                  | 0.1µF           | Reference de-coupling capacitors for VMID pin.                   |
| C9                  | 10µF            |  |

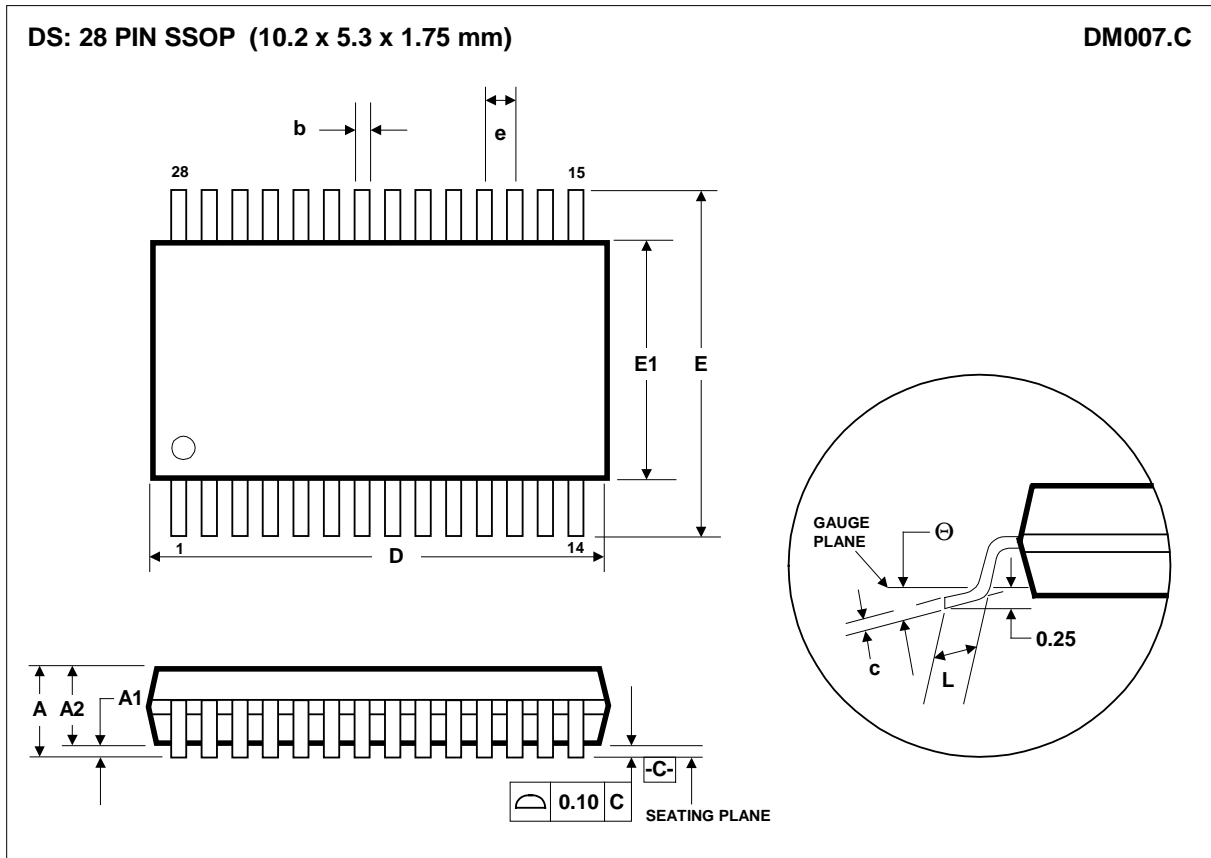
Table 24 External Components Description

**RECOMMENDED ANALOGUE LOW PASS FILTER (OPTIONAL)**



**Figure 23 Recommended Low Pass Filter (Optional)**

PACKAGE DIMENSIONS



| Symbols              | Dimensions (mm)  |       |       |
|----------------------|------------------|-------|-------|
|                      | MIN              | NOM   | MAX   |
| <b>A</b>             | -----            | ----- | 2.0   |
| <b>A<sub>1</sub></b> | 0.05             | ----- | ----- |
| <b>A<sub>2</sub></b> | 1.62             | 1.75  | 1.85  |
| <b>b</b>             | 0.22             | ----- | 0.38  |
| <b>c</b>             | 0.09             | ----- | 0.25  |
| <b>D</b>             | 9.90             | 10.20 | 10.50 |
| <b>e</b>             | 0.65 BSC         |       |       |
| <b>E</b>             | 7.40             | 7.80  | 8.20  |
| <b>E<sub>1</sub></b> | 5.00             | 5.30  | 5.60  |
| <b>L</b>             | 0.55             | 0.75  | 0.95  |
| <b>θ</b>             | 0°               | 4°    | 8°    |
| <b>REF:</b>          | JEDEC.95, MO-150 |       |       |

- NOTES:  
 A. ALL LINEAR DIMENSIONS ARE IN MILLIMETERS.  
 B. THIS DRAWING IS SUBJECT TO CHANGE WITHOUT NOTICE.  
 C. BODY DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSION, NOT TO EXCEED 0.20MM.  
 D. MEETS JEDEC.95 MO-150, VARIATION = AH. REFER TO THIS SPECIFICATION FOR FURTHER DETAILS.