

## 24-bit, 192kHz Stereo ADC

### DESCRIPTION

The WM8786 is a stereo audio ADC with differential inputs designed for high performance recordable media applications. Data is provided as a PCM output.

Stereo 24-bit multi-bit sigma-delta ADCs are used with digital audio output word lengths of 16 to 32 bits, and sampling rates from 8kHz to 192kHz. The device also has a high pass filter to remove residual DC offsets.

The device is hardware controlled. Pin programming provides access to all features including oversampling rate, audio format, powerdown, master/slave control and digital signal manipulation. The device is supplied in a 20-lead SSOP package.

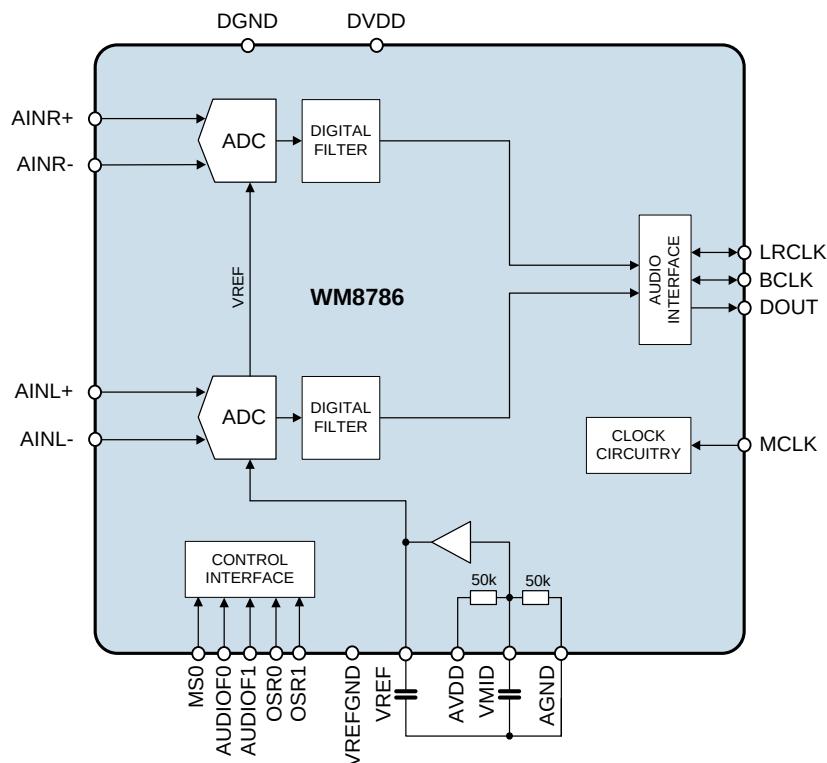
### FEATURES

- SNR 111dB ('A' weighted @ 48kHz)
- THD -102dB (at -0.1dB)
- Sampling Frequency: 8 – 192kHz
- Hardware Control Interface
- Master or Slave Clocking Mode
- Programmable Audio Data Interface Modes
  - I<sup>2</sup>S, Left, Right Justified or DSP
  - 24-Bit Word Length
- Supply Voltages
  - Analogue 4.5 to 5.5V
  - Digital core: 2.7V to 3.6V
- 20-lead SSOP package

### APPLICATIONS

- Recordable DVD Players
- Personal Video Recorders
- High End Sound Cards
- Studio Audio Processing Equipment

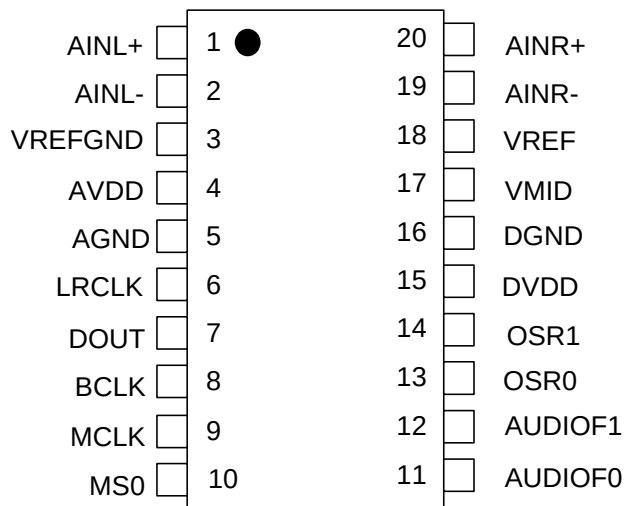
### BLOCK DIAGRAM



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**PIN CONFIGURATION**

**ORDERING INFORMATION**

| ORDER CODE    | TEMPERATURE RANGE | PACKAGE                                | MOISTURE SENSITIVITY LEVEL | PEAK SOLDERING TEMPERATURE |
|---------------|-------------------|----------------------------------------|----------------------------|----------------------------|
| WM8786GEDS/V  | -40°C to +85°C    | 20-lead SSOP (Pb-free)                 | MSL3                       | 260°C                      |
| WM8786GEDS/RV | -40°C to +85°C    | 20-lead SSOP, (Pb-free, tape and reel) | MSL3                       | 260°C                      |

**Note:**

Reel quantity = 2,000

**PIN DESCRIPTION**

| PIN | NAME                    | TYPE                   | DESCRIPTION                                                                                                                                                                            |
|-----|-------------------------|------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | AINL+                   | Analogue Input         | Left Channel Positive Input                                                                                                                                                            |
| 2   | AINL-                   | Analogue Input         | Left Channel Negative Input                                                                                                                                                            |
| 3   | VREFGND                 | Analogue Reference     | Negative Reference Connection                                                                                                                                                          |
| 4   | AVDD                    | Supply                 | Analogue Supply                                                                                                                                                                        |
| 5   | AGND                    | Supply                 | Analogue Ground (return path for AVDD)                                                                                                                                                 |
| 6   | LRCLK                   | Digital Input / Output | Audio Interface Left / Right Clock                                                                                                                                                     |
| 7   | DOUT                    | Digital Output         | ADC Digital Audio Data                                                                                                                                                                 |
| 8   | BCLK                    | Digital Input / Output | Audio Interface Bit Clock                                                                                                                                                              |
| 9   | MCLK                    | Digital Input          | Master Clock                                                                                                                                                                           |
| 10  | MS0<br>(pull down pad)  | Digital Input          | Master/Slave Control<br>0 = Slave Mode Audio Interface<br>1 = Master Mode Audio Interface @ 256fs (or @128fs in quad rate)                                                             |
| 11  | AUDIOF0                 | Digital Input          | Audio Format Selection<br>00 = 24 bit right justified audio data format<br>01 = 24 bit left audio data format<br>10 = I <sup>2</sup> S audio data format<br>11 = DSP audio data format |
| 12  | AUDIOF1                 | Digital Input          |                                                                                                                                                                                        |
| 13  | OSR0<br>(pull down pad) | Digital Input          | Oversampling Rate Control<br>00 = Single rate (48kHz)<br>01 = Dual rate (96kHz)<br>10 = Quad rate (192kHz)<br>11 = Not valid                                                           |
| 14  | OSR1                    | Digital Input          |                                                                                                                                                                                        |
| 15  | DVDD                    | Supply                 | Digital Supply                                                                                                                                                                         |
| 16  | DGND                    | Supply                 | Digital Ground (return path for DVDD)                                                                                                                                                  |
| 17  | VMID                    | Analogue Output        | Midrail Voltage Decoupling Capacitor                                                                                                                                                   |
| 18  | VREF                    | Analogue Reference     | Reference Voltage Decoupling Capacitor                                                                                                                                                 |
| 19  | AINR-                   | Analogue Input         | Right Channel Negative Input                                                                                                                                                           |
| 20  | AINR+                   | Analogue Input         | Right Channel Positive Input                                                                                                                                                           |

## ABSOLUTE MAXIMUM RATINGS

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



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

Cirrus 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                | DGND -0.3V | DVDD + 0.3V |
| Voltage range analogue inputs               | AGND -0.3V | AVDD +0.3V  |
| Master Clock Frequency                      |            | 40MHz       |
| Operating temperature range, T <sub>A</sub> | -40°C      | +85°C       |
| Storage temperature after soldering         | -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      |                 | 4.5 |     | 5.5 | V    |
| Ground                | DGND,AGND |                 |     | 0   |     | V    |

## ELECTRICAL CHARACTERISTICS

### Test Conditions

DVDD = 3.3V, AVDD = 5.0V, T<sub>A</sub> = +25°C,

1kHz signal, A-weighted, f<sub>s</sub> = 48kHz, MCLK = 256fs, 24-bit audio data, Slave Mode unless otherwise stated.

| PARAMETER                                            | SYMBOL            | TEST CONDITIONS                          | MIN        | TYP        | MAX        | UNIT             |
|------------------------------------------------------|-------------------|------------------------------------------|------------|------------|------------|------------------|
| ADC Performance                                      |                   |                                          |            |            |            |                  |
| Full Scale Input Signal Level<br>(for ADC 0dB Input) |                   |                                          |            | 2.0        |            | V <sub>rms</sub> |
| Input resistance                                     |                   |                                          |            | 10         |            | kΩ               |
| Input capacitance                                    |                   |                                          |            | 10         |            | pF               |
| Signal to Noise Ratio                                | SNR               | A-weighted,<br>@ fs = 48kHz              | 102        | 111        |            | dB               |
|                                                      |                   | Unweighted,<br>@ fs = 48kHz              |            | 108        |            |                  |
| Signal to Noise Ratio                                | SNR               | A-weighted,<br>@ fs = 96kHz              |            | 111        |            | dB               |
|                                                      |                   | Unweighted,<br>@ fs = 96kHz              |            | 108        |            |                  |
| Signal to Noise Ratio                                | SNR               | A-weighted,<br>@ fs = 192kHz             |            | 111        |            | dB               |
|                                                      |                   | Unweighted,<br>@ fs = 192kHz             |            | 108        |            |                  |
| Total Harmonic Distortion                            | THD               | 1kHz, -0.1dB Full Scale<br>@ fs = 48kHz  |            | -102       | -92        | dB               |
|                                                      |                   | 1kHz, -0.1dB Full Scale<br>@ fs = 96kHz  |            | -102       |            |                  |
|                                                      |                   | 1kHz, -0.1dB Full Scale<br>@ fs = 192kHz |            | -102       |            |                  |
| Total Harmonic Distortion                            | THD               | 1kHz, -0.1dB Full Scale<br>@ fs = 48kHz  |            | 0.0008     | 0.0025     | %                |
|                                                      |                   | 1kHz, -0.1dB Full Scale<br>@ fs = 96kHz  |            | 0.0008     |            |                  |
|                                                      |                   | 1kHz, -0.1dB Full Scale<br>@ fs = 192kHz |            | 0.0008     |            |                  |
| Dynamic Range                                        | DNR               | -60dBFS                                  | 102        | 111        |            | dB               |
| Channel Level Matching                               |                   | 20kHz signal                             |            | 0.1        |            | dB               |
| Power Supply Rejection Ratio<br>(AVDD, DVDD)         | PSRR              | 100mV (peak-peak) 1kHz                   |            | 50         |            | dB               |
|                                                      |                   | 100mV (peak-peak)<br>20Hz to 20kHz       |            | 45         |            |                  |
| Digital Logic Levels (CMOS Levels)                   |                   |                                          |            |            |            |                  |
| Input LOW level                                      | V <sub>IL</sub>   |                                          |            |            | 0.3 x DVDD | V                |
| Input HIGH level                                     | V <sub>IH</sub>   |                                          | 0.7 x DVDD |            |            | V                |
| Input leakage current                                |                   |                                          | -1         | ±0.2       | +1         | μA               |
| Input capacitance                                    |                   |                                          |            | 5          |            | pF               |
| Output LOW                                           | V <sub>OL</sub>   | I <sub>OL</sub> =-1mA                    |            |            | 0.1 x DVDD | V                |
| Output HIGH                                          | V <sub>OH</sub>   | I <sub>OH</sub> = 1mA                    | 0.9 x DVDD |            |            | V                |
| Analogue Reference Levels                            |                   |                                          |            |            |            |                  |
| Midrail Reference Voltage                            | VMID              | AVDD to VMID<br>and VMID to VREFGND      | −3%        | AVDD/2     | +3%        | V                |
| Potential Divider Resistance                         | R <sub>VMID</sub> | AVDD to VMID<br>and VMID to GND          |            | 50         |            | kΩ               |
| Buffered Reference Voltage                           | VREF              |                                          | −3%        | 0.8 x AVDD | +3%        | V                |

**Test Conditions**

DVDD = 3.3V, AVDD = 5.0V, T<sub>A</sub> = +25°C,  
1kHz signal, A-weighted, fs = 48kHz, MCLK = 256fs, 24-bit audio data, Slave Mode unless otherwise stated.

| PARAMETER               | SYMBOL | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-------------------------|--------|-----------------|-----|-----|-----|------|
| <b>Supply Current</b>   |        |                 |     |     |     |      |
| Analogue supply current |        |                 |     | 27  |     | mA   |
| Digital supply current  |        |                 |     | 5   |     | mA   |
| Power Down              |        |                 |     | 22  |     | uA   |

**Note:**

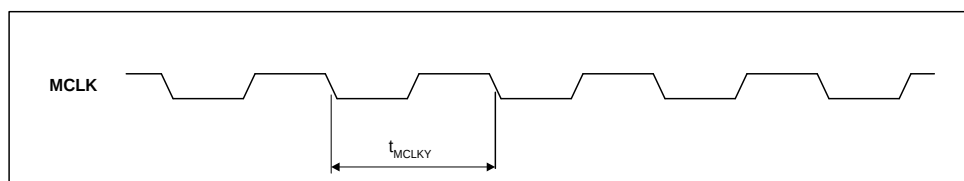
1. The VMID and VREF pins should be decoupled with a 10μF electrolytic capacitor (ESR < 1.5Ω across all operating temperatures) and a 0.1μF ceramic capacitor. Device operation with other decoupling is not recommended, and may affect performance.

**TERMINOLOGY**

1. Signal-to-noise ratio (dB) – Ratio of output level with 1kHz full scale input, to the output level with all zeros into the digital input, over a 20Hz to 20kHz bandwidth. (No Auto-zero or Automute function is employed in achieving these results).
2. Dynamic range (dB) - DR 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. 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.
5. All performance measurements are done with a 20kHz low pass filter, and where noted an A-weight filter, except where noted. 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 this is not audible, it may affect dynamic specification values.

## SIGNAL TIMING REQUIREMENTS

### SYSTEM CLOCK TIMING



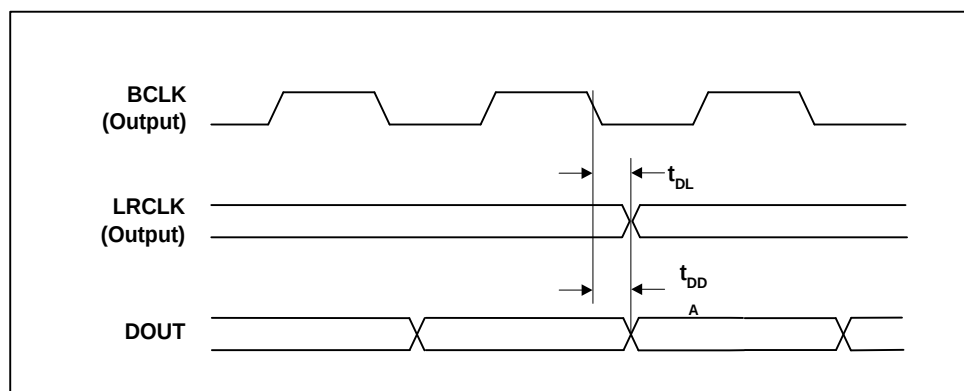
**Figure 1 System Clock Timing Requirements**

#### Test Conditions

DVDD = 3.3V, DGND = 0V, T<sub>A</sub> = +25°C, Slave Mode, fs = 48kHz, MCLK = 256fs, 24-bit data, unless otherwise stated.

| PARAMETER                              | SYMBOL              | MIN   | TYP | MAX   | UNIT |
|----------------------------------------|---------------------|-------|-----|-------|------|
| <b>System Clock Timing Information</b> |                     |       |     |       |      |
| MCLK System clock cycle time           | T <sub>MCLKY</sub>  | 25    |     |       | ns   |
| MCLK duty cycle                        | T <sub>MCLKDS</sub> | 60:40 |     | 40:60 |      |

### AUDIO INTERFACE TIMING – MASTER MODE, PCM DATA



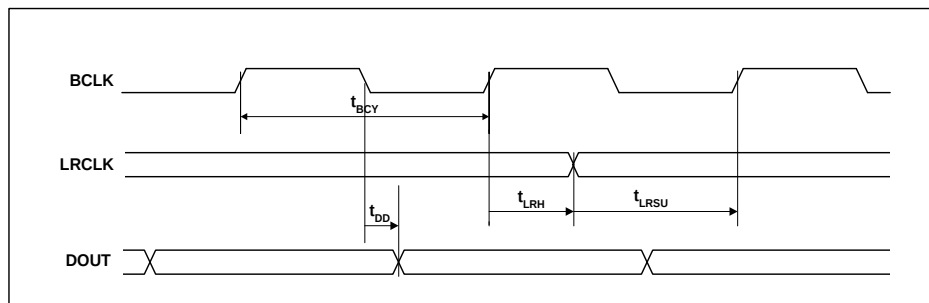
**Figure 2 Digital Audio Data Timing – Master Mode (see Control Interface)**

#### Test Conditions

DVDD = 3.3V, DGND = 0V, T<sub>A</sub> = +25°C, Master Mode, fs = 48kHz, MCLK = 256fs, 24-bit data, unless otherwise stated.

| PARAMETER                                      | SYMBOL           | MIN | TYP | MAX | UNIT |
|------------------------------------------------|------------------|-----|-----|-----|------|
| <b>Audio Data Input Timing Information</b>     |                  |     |     |     |      |
| LRCLK propagation delay from BCLK falling edge | t <sub>DL</sub>  | 0   |     | 10  | ns   |
| DOUT propagation delay from BCLK falling edge  | t <sub>DDA</sub> | 0   |     | 11  | ns   |



**AUDIO INTERFACE TIMING – SLAVE MODE, PCM DATA**

**Figure 3 Digital Audio Data Timing – Slave Mode**
**Test Conditions**

DVDD = 3.3V, DGND = 0V, T<sub>A</sub> = +25°C, Slave Mode, f<sub>s</sub> = 48kHz, MCLK = 256fs, 24-bit data, unless otherwise stated.

| PARAMETER                                     | SYMBOL            | MIN | TYP | MAX | UNIT |
|-----------------------------------------------|-------------------|-----|-----|-----|------|
| <b>Audio Data Input Timing Information</b>    |                   |     |     |     |      |
| BCLK cycle time                               | t <sub>BCY</sub>  | 25  |     |     | ns   |
| LRCLK set-up time to BCLK rising edge         | t <sub>LRSU</sub> | 10  |     |     | ns   |
| LRCLK hold time from BCLK rising edge         | t <sub>LRH</sub>  | 10  |     |     | ns   |
| DOUT propagation delay from BCLK falling edge | t <sub>DD</sub>   | 0   |     | 11  | ns   |

## POWER-ON RESET

The WM8786 has an internal power-on reset circuit. The reset sequence is entered at power-on or power-up (DVDD). Until the internal reset is removed, DOUT is forced to zero. DOUT remains zero for a count equal to 32 sample clocks, after power up. (This count is driven by MCLK and is independent of any external LRCLK).

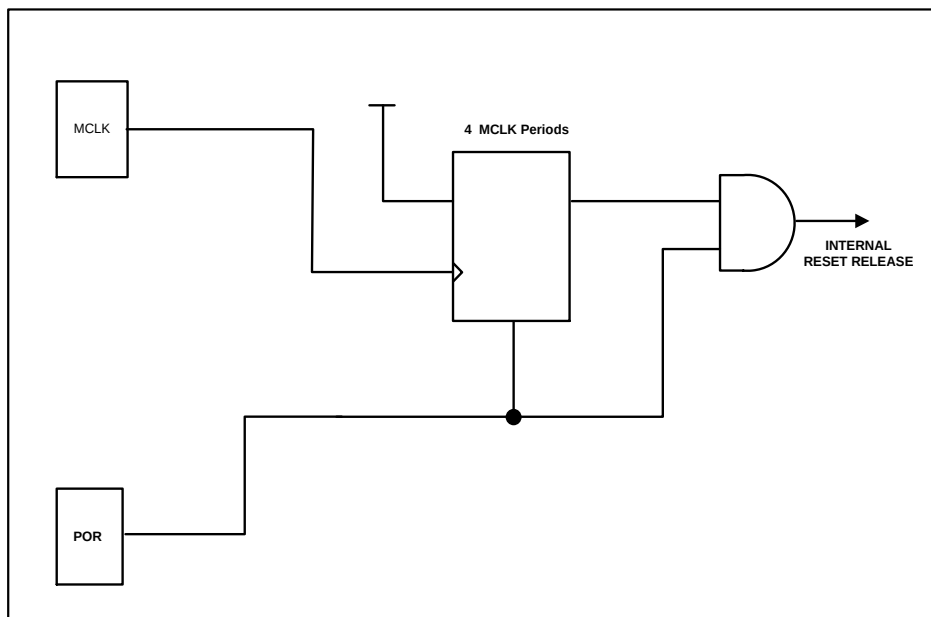


Figure 4 POR Circuit

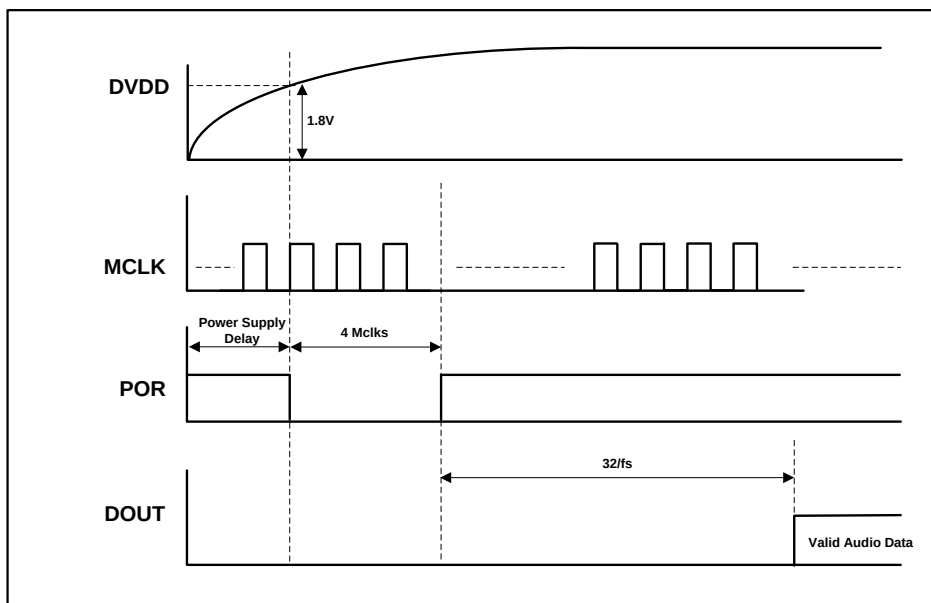


Figure 5 POR Timing

## DIGITAL FILTER CHARACTERISTICS

The WM8786 digital filter characteristics scale with sample rate.

| PARAMETER                                             | TEST CONDITIONS | MIN     | TYP    | MAX       | UNIT |
|-------------------------------------------------------|-----------------|---------|--------|-----------|------|
| <b>ADC Sample Rate (Single Rate - 48Hz typically)</b> |                 |         |        |           |      |
| Passband                                              | +/- 0.005dB     | 0       |        | 0.454fs   |      |
|                                                       | -6dB            |         | 0.5fs  |           |      |
| Passband Ripple                                       |                 |         |        | +/- 0.005 | dB   |
| Stopband                                              |                 | 0.546fs |        |           |      |
| Stopband Attenuation                                  | f > 0.546fs     | -85     |        |           | dB   |
| Group Delay                                           |                 |         | 32/fs  |           | s    |
| <b>ADC Sample Rate (Dual Rate - 96kHz typically)</b>  |                 |         |        |           |      |
| Passband                                              | +/- 0.005dB     | 0       |        | 0.454fs   |      |
|                                                       | -6dB            |         | 0.5fs  |           |      |
| Passband Ripple                                       |                 |         |        | +/- 0.005 | dB   |
| Stopband                                              |                 | 0.546fs |        |           |      |
| Stopband Attenuation                                  | f > 0.546fs     | -85     |        |           | dB   |
| Group Delay                                           |                 |         | 32/fs  |           | s    |
| <b>ADC Sample Rate (Quad Rate - 192kHz typically)</b> |                 |         |        |           |      |
| Passband                                              | +/- 0.005dB     | 0       |        | 0.25fs    |      |
|                                                       | -3dB            |         | 0.45fs |           |      |
|                                                       | -6dB            |         | 0.5fs  |           |      |
| Passband Ripple                                       |                 |         |        | +/- 0.005 | dB   |
| Stopband                                              |                 | 0.75fs  |        |           |      |
| Stopband Attenuation                                  | f > 0.75fs      | -85     |        |           | dB   |
| Group Delay                                           |                 |         | 10/fs  |           | s    |
| <b>ADC High Pass Filter</b>                           |                 |         |        |           |      |
| Corner Frequency                                      | -3dB            |         | 3.7    |           | Hz   |
|                                                       | -0.5dB          |         | 10.4   |           |      |
|                                                       | -0.1dB          |         | 21.6   |           |      |

**Table 1 Digital Filter Characteristics**

## TERMINOLOGY

1. Stop Band Attenuation (dB) - the degree to which the frequency spectrum is attenuated (outside audio band)
2. Pass-band Ripple – any variation of the frequency response in the pass-band region

## HIGH PASS FILTER TRANSFER CHARACTERISTIC

The high pass filter response is defined by the following polynomial:

$$H(z) = \frac{1 - z^{-1}}{1 - (1 - \alpha)z^{-1}}$$

where  $\alpha = 2^{-11}$  for single rate (48k) mode

$\alpha = 2^{-12}$  for dual rate (96k) mode

$\alpha = 2^{-13}$  for quad rate (192k) mode

## FILTER RESPONSES

### SINGLE RATE 48K

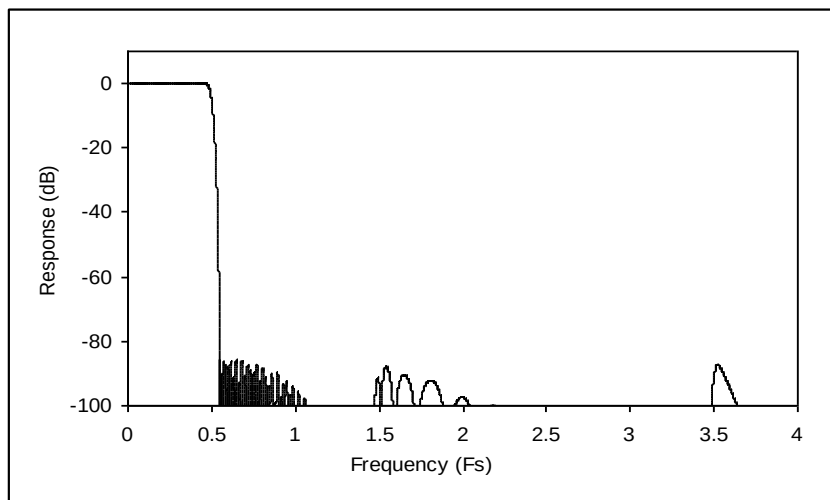


Figure 6 Single Rate 48k Filter Response

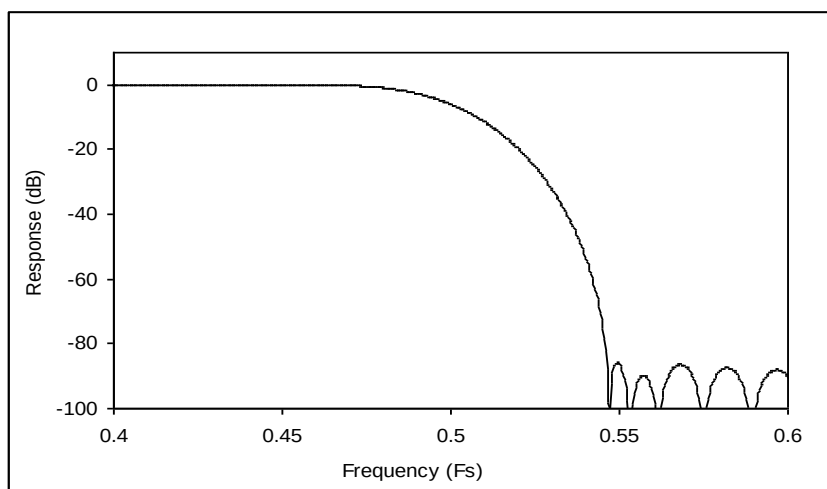
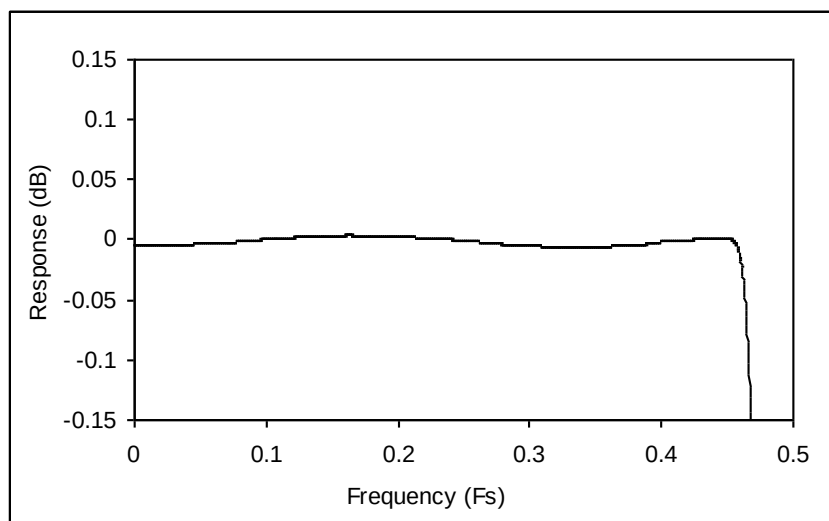
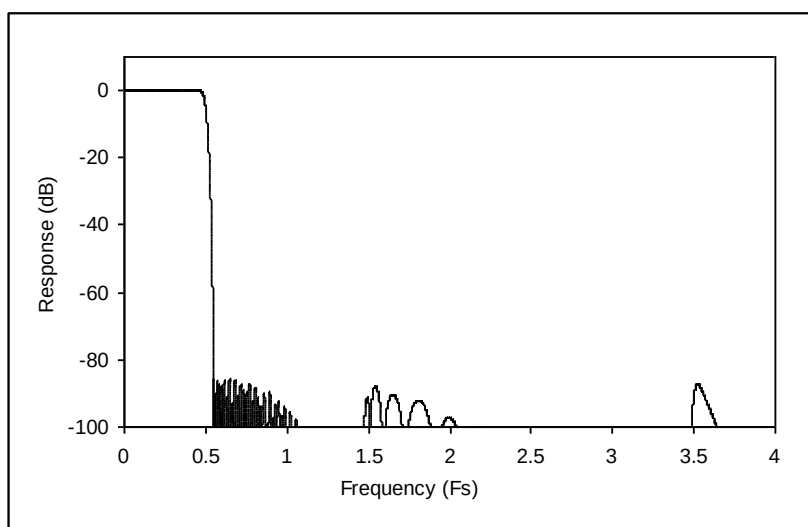


Figure 7 Single Rate 48k Filter Response

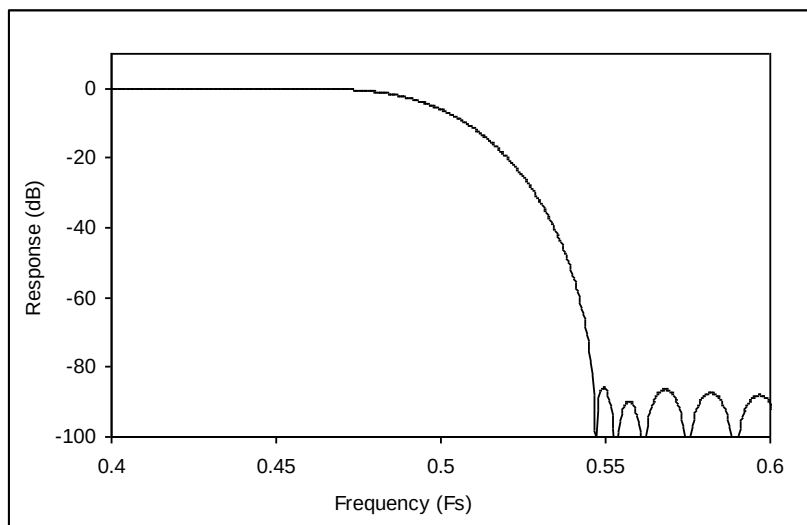


**Figure 8 Single Rate 48k Filter Response**

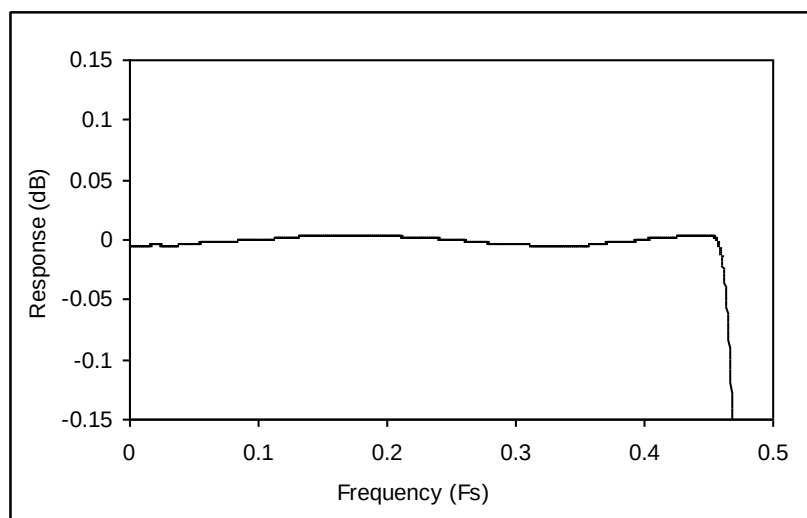
## DUAL RATE 96K



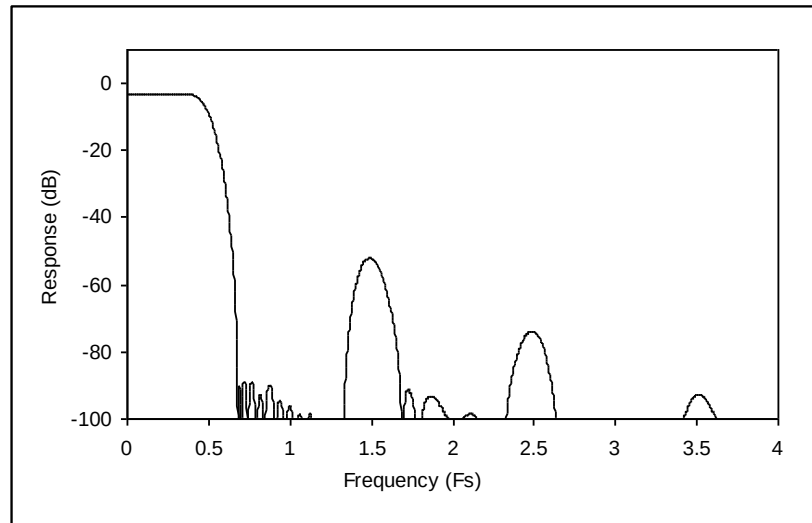
**Figure 9 Dual Rate 96k Filter Response**



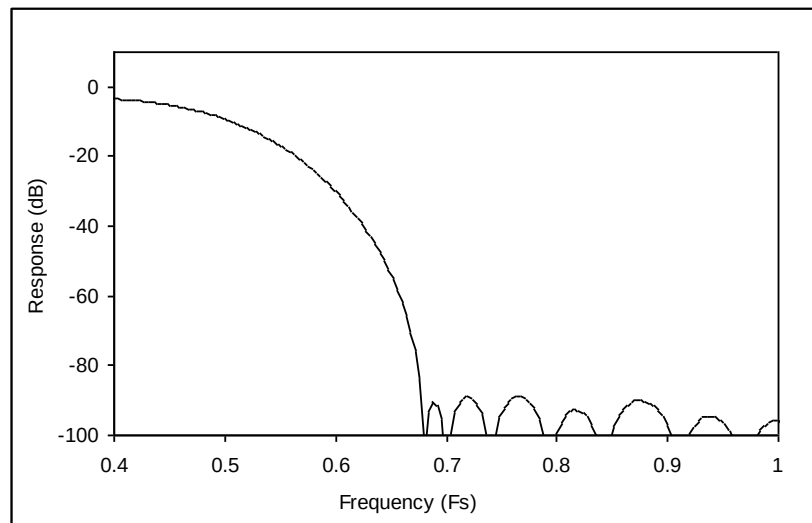
**Figure 10 Dual Rate 96k Filter Response**



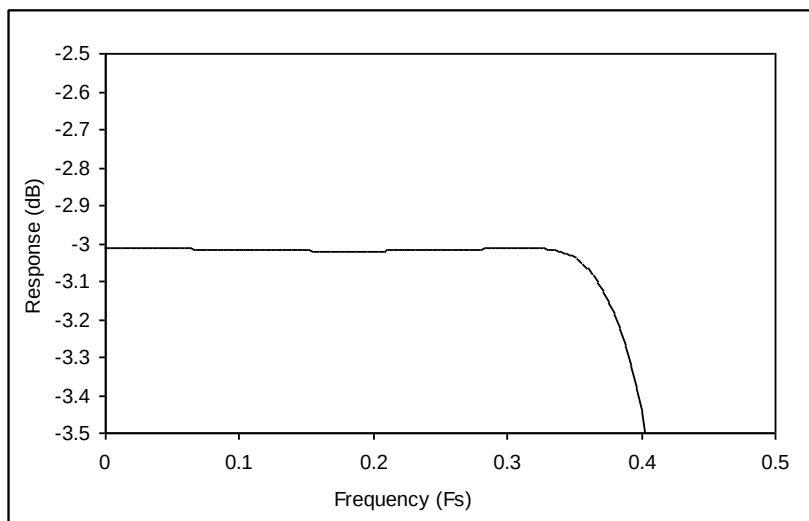
**Figure 11 Dual Rate 96k Filter Response**

**QUAD RATE 192K**


**Figure 12 Quad Rate 192k Filter Response**

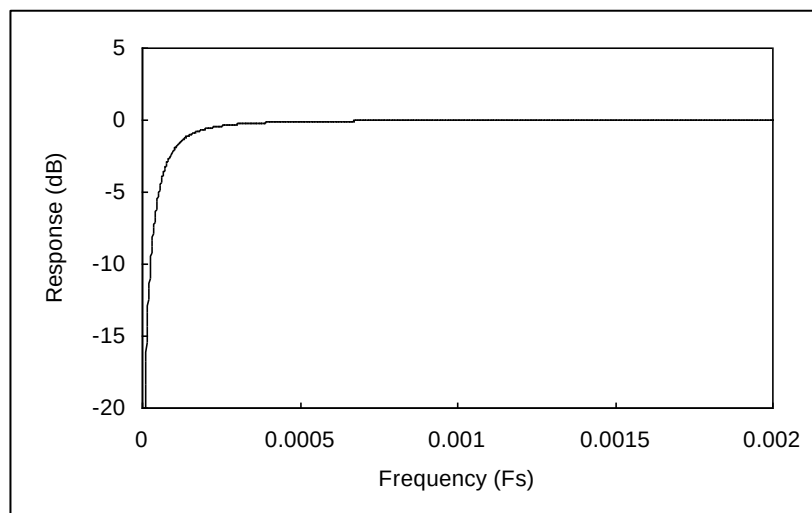


**Figure 13 Quad Rate 192k Filter Response**



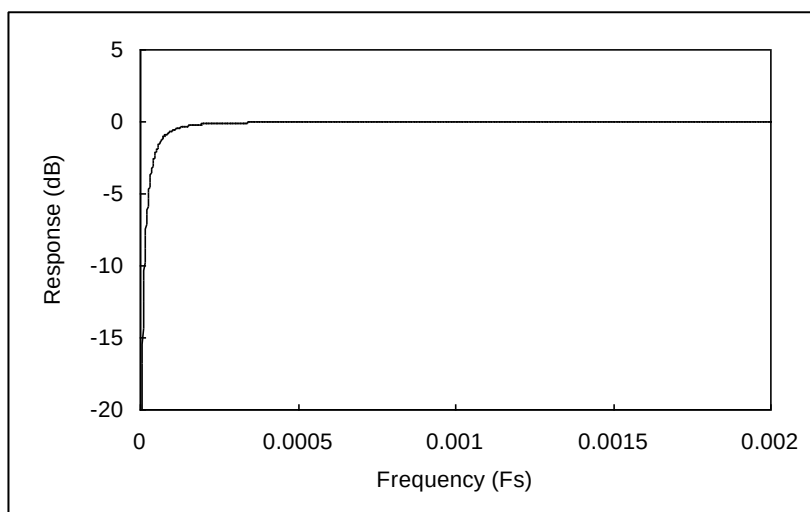
**Figure 14 Quad Rate 192k Filter Response**

## HIGH PASS FILTER

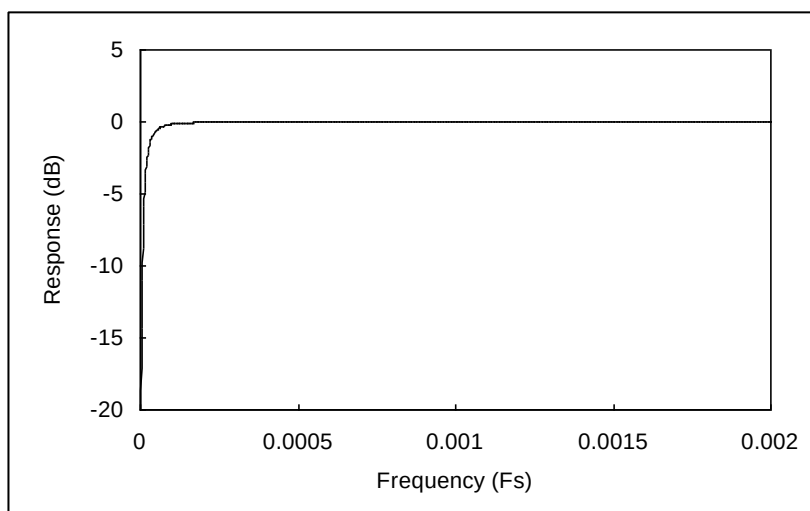


**Figure 15 Single Rate 48k High Pass Filter Response**





**Figure 16 Dual Rate 96k High Pass Filter Response**



**Figure 17 Quad Rate 192k High Pass Filter Response**

## DEVICE DESCRIPTION

### INTRODUCTION

The WM8786 is a high performance stereo audio ADC designed for demanding recording applications such as DVD recorders, studio mixers, PVRs, and AV amplifiers. The WM8786 consists of stereo line level inputs, followed by a sigma-delta modulator and digital filtering.

The WM8786 uses a multi-bit high-order oversampling architecture delivering high SNR operating at oversampling ratios from 128fs to 32fs according to the sample rate. Sample rates from 8kHz to 192kHz are supported. The WM8786 supports master clock rates from 128fs to 768fs.

The digital filter is a high performance linear phase FIR filter. The digital filters are optimised for each sample rate. Also included is a high pass filter to remove residual DC offsets from the input signal.

The output from the ADC is available on a configurable digital audio interface. It supports a number of audio data formats including I<sup>2</sup>S, Left justified and Right justified or DSP, and can operate in master or slave modes.

The WM8786 functionality is controlled in hardware via specific pins. It is fully compatible and an ideal partner for a range of industry standard microprocessors, controllers and DSPs.

The WM8786 can be powered down to reduce system power consumption.

### DIGITAL AUDIO INTERFACE

The digital audio interface uses three pins:

- DOUT: ADC data output
- LRCLK: ADC data alignment clock
- BCLK: Bit clock, for synchronisation

The digital audio interface takes the data from the internal ADC digital filters and places it on DOUT and LRCLK. DOUT is the formatted digital audio data stream output from the ADC digital filters with left and right channels multiplexed together. LRCLK is an alignment clock that controls whether Left or Right channel data is present on the DOUT line. DOUT and LRCLK are synchronous with the BCLK signal with each data bit transition signified by a BCLK high to low transition. DOUT is always an output. BCLK and LRCLK may be inputs or outputs, depending whether the device is in Master or Slave mode (see Master and Slave Mode Operation, below).

Four different audio data formats are supported:

- Left justified
- Right justified
- I<sup>2</sup>S
- DSP

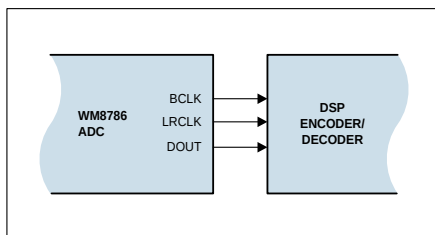
The data formats are described in Audio Data Formats, below. Refer to the Signal Timing Requirements section for timing information.

### MASTER AND SLAVE MODE OPERATION

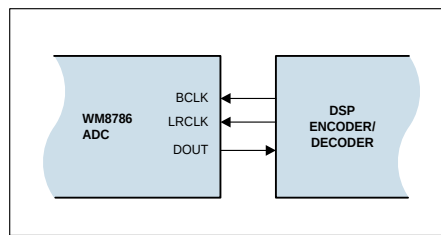
The WM8786 can be configured as either a master or slave mode device. As a master device the WM8786 generates BCLK and LRCLK and thus controls sequencing of the data transfer on DOUT. In slave mode, the WM8786 responds with data to clocks it receives over the digital audio interface. The mode can be selected using the MS0 pin. Master and slave modes are illustrated below.

| MS0 PIN STATUS | INTERFACE FORMAT                                            |
|----------------|-------------------------------------------------------------|
| Low            | Slave                                                       |
| High           | Master (@256fs in oversampling ratio = single or dual rate) |
| High           | Master (@192fs in oversampling ratio = quad rate)           |

**Table 2 Control Interface Mode Selection**



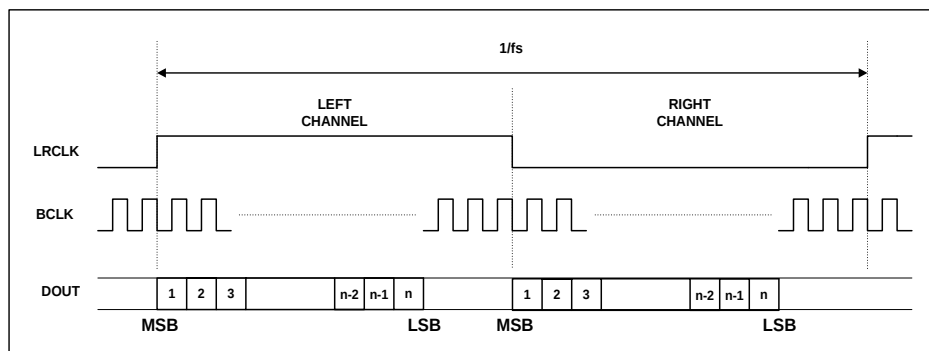
**Figure 18a Master Mode**



**Figure 18b Slave Mode**

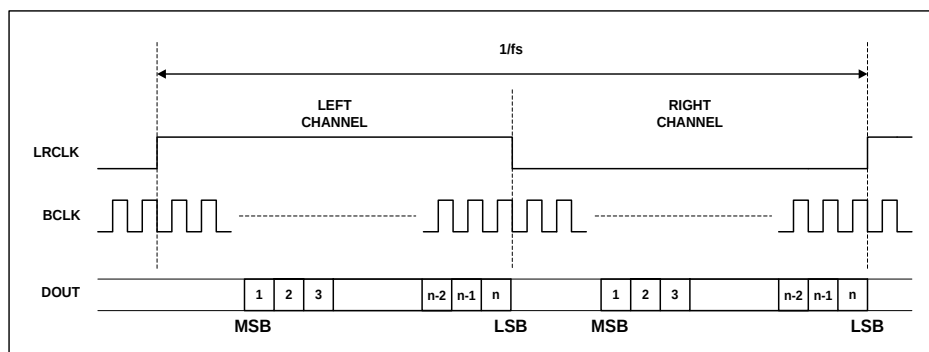
## AUDIO DATA FORMATS

In Left Justified mode, the MSB is available on the first rising edge of BCLK following an LRCLK transition. The other bits up to the LSB are then transmitted in order. Depending on word length, BCLK frequency and sample rate, there may be unused BCLK cycles before each LRCLK transition.



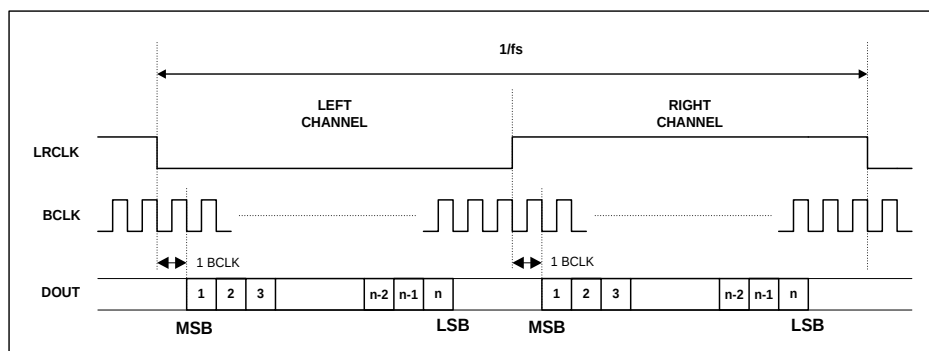
**Figure 19 Left Justified Audio Interface (assuming n-bit word length)**

In Right Justified mode, the LSB is available on the last rising edge of BCLK before an LRCLK transition. All other bits are transmitted before (MSB first). Depending on word length, BCLK frequency and sample rate, there may be unused BCLK cycles after each LRCLK transition.



**Figure 20 Right Justified Audio Interface (assuming n-bit word length)**

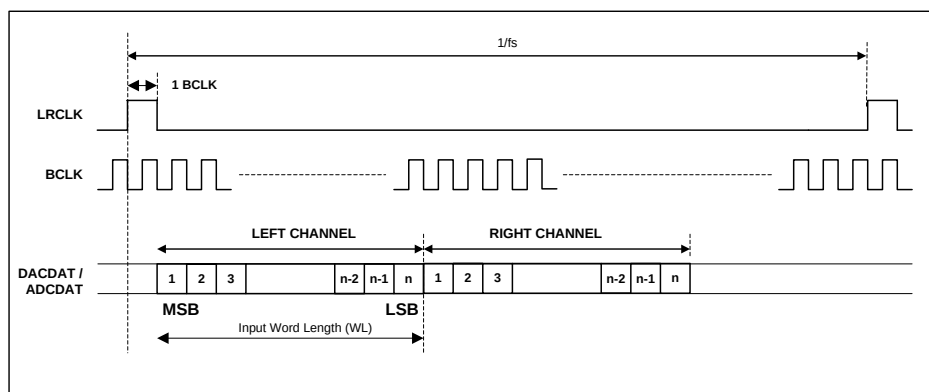
In I<sup>2</sup>S mode, the MSB is available on the second rising edge of BCLK following an LRCLK transition. The other bits up to the LSB are then transmitted in order. Depending on word length, BCLK frequency and sample rate, there may be unused BCLK cycles between the LSB of one sample and the MSB of the next.



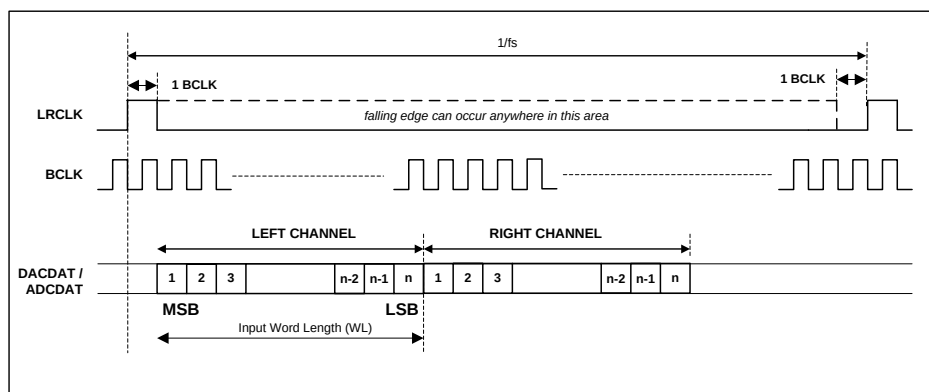
**Figure 21 I²S Justified Audio Interface (assuming n-bit word length)**

In DSP/PCM mode, the left channel MSB is available on the 2<sup>nd</sup> rising edge of BCLK 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 22. In device slave mode, shown in Figure 23 it is possible to use any length of frame pulse less than  $1/f_s$ , providing the falling edge of the frame pulse occurs greater than one BCLK period before the rising edge of the next frame pulse.



**Figure 22 DSP/PCM Mode Audio Interface (mode A, Master)**



**Figure 23 DSP/PCM Mode Audio Interface (mode A, Slave)**

## AUDIO INTERFACE CONTROL

The audio interface is controlled using the AUDIOF0 and AUDIOF1 pins. Dynamically changing the audio format may cause erroneous operation of the interfaces and is therefore not recommended.

All ADC data is signed 2's complement. The length of the digital audio data is always 24 bits.

| AUDIOF1 PIN STATUS | AUDIOF0 PIN STATUS | AUDIO INTERFACE FORMAT  |
|--------------------|--------------------|-------------------------|
| Low                | Low                | 24-bit right justified  |
| Low                | High               | 24-bit left justified   |
| High               | Low                | 24-bit I <sup>2</sup> S |
| High               | High               | 24-bit DSP              |

**Table 3 Audio Interface Format Selection**

## OVERSAMPLING RATIOS AND SIGMA-DELTA MODULATOR FREQUENCY

For correct operation of the device and optimal performance, the user must select the appropriate ADC modulator oversampling ratio. The oversampling ratio is selected using the OSR0 and OSR1 pins.

| OSR1 PIN STATUS | OSR0 PIN STATUS | OVERSAMPLING RATIO CONTROL |
|-----------------|-----------------|----------------------------|
| Low             | Low             | Single Rate (128fs)        |
| Low             | High            | Dual Rate (64fs)           |
| High            | Low             | Quad Rate (32fs)           |
| High            | High            | Not Valid                  |

**Table 4 Oversampling Ratio Selection**

The WM8786 can operate at sample rates from 8kHz to 192kHz. The WM8786 uses a sigma-delta modulator that operates at frequencies between 1.024MHz and 6.144MHz

| SAMPLING RATE (LRCLK) | OVERSAMPLING RATIO  | SIGMA-DELTA MODULATOR FREQUENCY (MHZ) |
|-----------------------|---------------------|---------------------------------------|
| 8kHz                  | Single Rate (128fs) | 1.024                                 |
| 32kHz                 | Single Rate (128fs) | 4.096                                 |
| 44.1kHz               | Single Rate (128fs) | 5.6448                                |
| 48kHz                 | Single Rate (128fs) | 6.144                                 |
| 96kHz                 | Dual Rate (64fs)    | 6.144                                 |
| 192kHz                | Quad Rate (32fs)    | 6.144                                 |

**Table 5 Sigma-delta Modulator Frequency**

## MASTER CLOCK AND AUDIO SAMPLE RATES

The Master clock (MCLK) is used to operate the digital filters and the noise shaping circuits. The WM8786 supports a wide range of master clock frequencies, and can generate many commonly used audio sample rates directly from the master clock. The following tables show the recommended Master clock frequencies for different sample rates.

In Master Mode, with oversampling ratio = single rate or dual rate, Master clock frequency of 256 is supported.

| SAMPLING RATE<br>(LRCLK) | OVERSAMPLING<br>RATIO | MASTER CLOCK FREQUENCY (MHz) |
|--------------------------|-----------------------|------------------------------|
|                          |                       | 256fs                        |
| 32kHz                    | Single Rate           | 8.192                        |
| 44.1kHz                  | Single Rate           | 11.2896                      |
| 48kHz                    | Single Rate           | 12.288                       |
| 96kHz                    | Dual Rate             | 24.576                       |

**Table 6 Master Mode: Recommended Master Clock Frequency Selection**

In Master Mode, with oversampling ratio = quad rate, Master clock frequency of 192 is supported.

| SAMPLING RATE<br>(LRCLK) | OVERSAMPLING<br>RATIO | MASTER CLOCK FREQUENCY (MHz) |
|--------------------------|-----------------------|------------------------------|
|                          |                       | 128fs                        |
| 192kHz                   | Quad Rate             | 24.576                       |

**Table 7 Master Mode: Recommended Master Clock Frequency Selection**

In Slave Mode, Master clock frequencies of 128fs, 192fs, 256fs, 384fs, 512fs and 768fs are supported. The WM8786 automatically detects the audio sample rate, in slave mode.

| SAMPLING RATE<br>(LRCLK) | OVERSAMPLING<br>RATIO | MASTER CLOCK FREQUENCY (MHz) |        |         |         |         |         |
|--------------------------|-----------------------|------------------------------|--------|---------|---------|---------|---------|
|                          |                       | 128fs                        | 192fs  | 256fs   | 384fs   | 512fs   | 768fs   |
| 32kHz                    | Single Rate           | -                            | -      | 8.192   | 12.288  | 16.384  | 24.576  |
| 44.1kHz                  | Single Rate           | -                            | -      | 11.2896 | 16.9344 | 22.5792 | 33.8688 |
| 48kHz                    | Single Rate           | -                            | -      | 12.288  | 18.432  | 24.576  | 36.864  |
| 96kHz                    | Dual Rate             | -                            | -      | 24.576  | 36.864  | -       | -       |
| 192kHz                   | Quad Rate             | 24.576                       | 36.864 | -       | -       | -       | -       |

**Table 8 Slave Mode: Recommended Master Clock Frequency Selection**

## MLCK AND LRCLK PHASE RELATIONSHIP

The WM8786 does not require a specific phase relationship between MLCK and LRCLK. If the relationship between MCLK and LRCLK changes by more than  $\pm 8$  BCLKs in a 64 BCLK frame, the WM8786 will attempt to re-synchronise. During re-synchronisation, data samples may be dropped or duplicated.

## APPLICATIONS INFORMATION

### RECOMMENDED EXTERNAL COMPONENTS

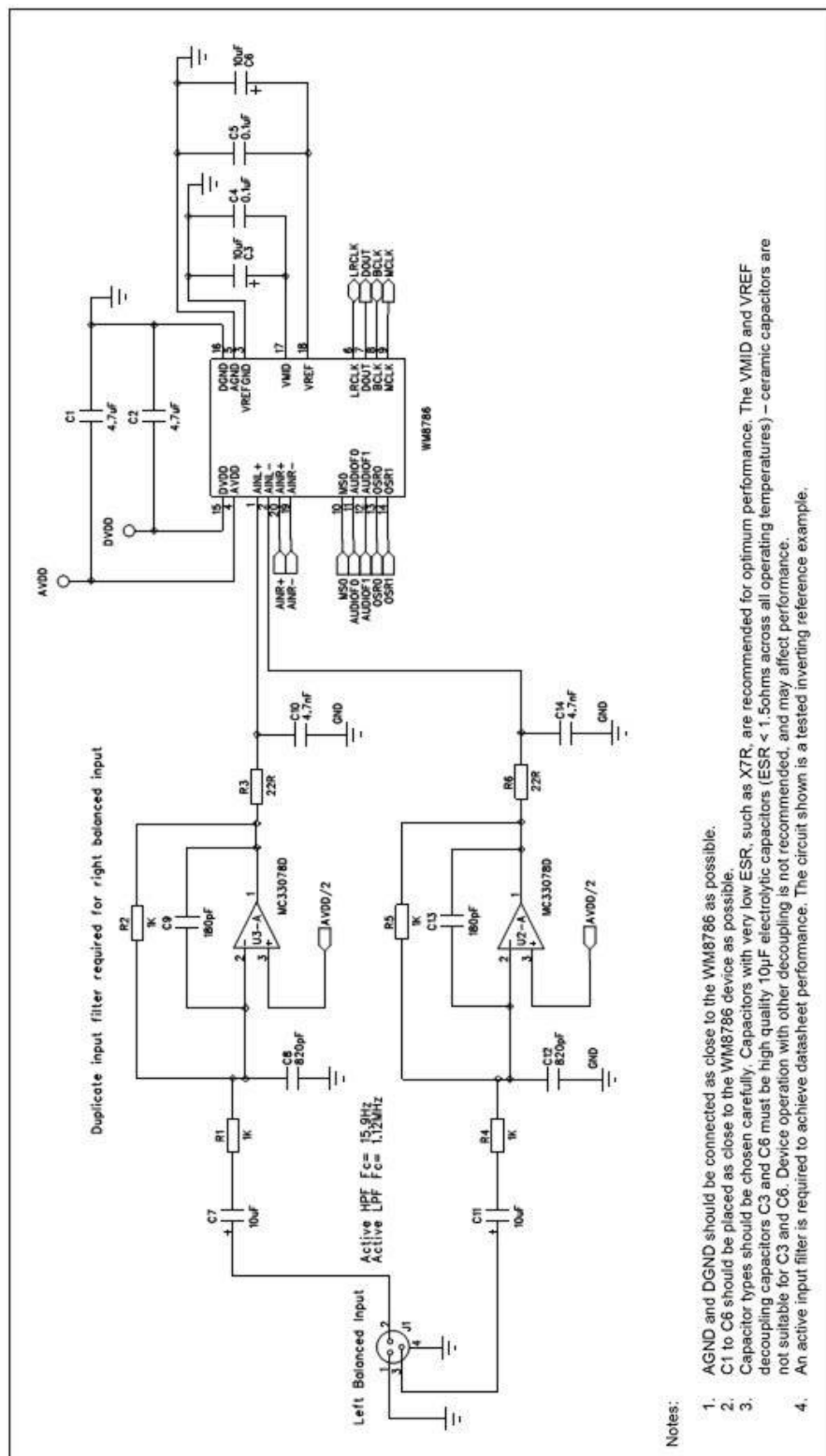
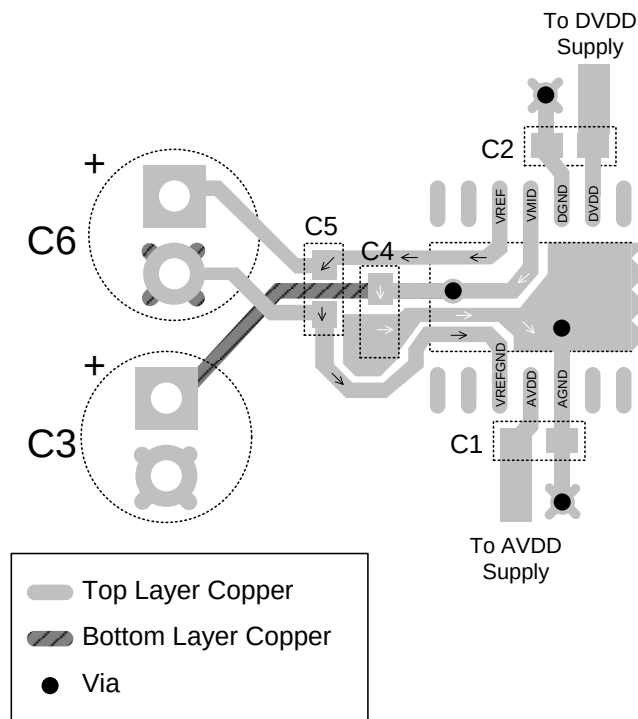


Figure 24 External Component Diagram

## RECOMMENDED PCB LAYOUT

The WM8786 is sensitive to the routing of the ground return currents for VREF, VMID, and AVDD; care should be taken to ensure that these currents do not interfere. Figure 25 below shows a recommended PCB layout (with high frequency current paths) for the WM8786 that will demonstrate datasheet performance:

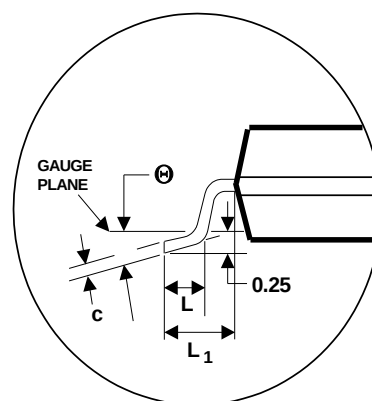
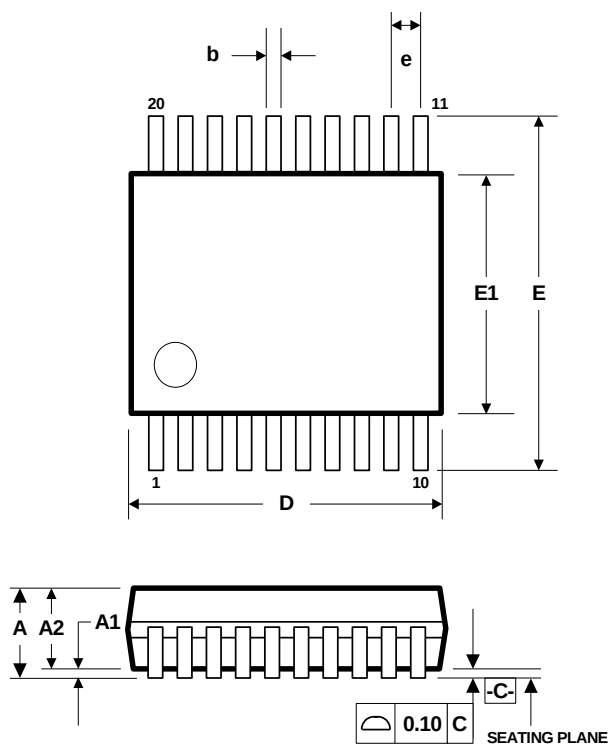


**Figure 25 Recommended PCB Layout for VREF, VMID, AVDD and DVDD Decoupling**

### Notes:

1. High frequency noise on VREF is decoupled through C5, and the return path should be directly to VREFGND.
2. The route from the negative terminal of C6 to C5 and then to VREFGND should be made on the top layer only and should not connect to the ground flood on the top layer. This ensures that the VREF return current is returned directly to VREFGND as shown by the black arrows.
3. The negative terminal of C6 should be connected to the ground plane on the underside of the board only.
4. High frequency noise on VMID is decoupled through C4, and the return path should be directly to AGND.
5. Via to bottom layer on VMID used to connect to bottom layer route to positive terminal of C3.
6. The route from C4 to AGND should be made on the top layer only. This ensures that the VMID return current is returned to AGND as shown by the white arrows.
7. AVDD is decoupled to AGND through C1. The ground return currents are not shown in this diagram.
8. DVDD is decoupled to DGND through C2. The ground return currents are not shown in this diagram.
9. DGND should not be connected directly to the ground flood on the top layer under the WM8786. This will ensure that noise in the digital ground does not interfere with the critical routing of VREF and VMID.
10. Bottom layer ground flood not shown for clarity.
11. See the WM8786 Evaluation Board for an example of this layout in use.



**PACKAGE DIMENSIONS**
**DS: 20 PIN SSOP (7.2 x 5.3 x 1.75 mm)**
**DM0015.C**


| Symbols        | Dimensions (mm)  |       |       |
|----------------|------------------|-------|-------|
|                | MIN              | NOM   | MAX   |
| A              | -----            | ----- | 2.0   |
| A <sub>1</sub> | 0.05             | ----- | ----- |
| A <sub>2</sub> | 1.65             | 1.75  | 1.85  |
| b              | 0.22             | 0.30  | 0.38  |
| c              | 0.09             | ----- | 0.25  |
| D              | 6.90             | 7.20  | 7.50  |
| e              | 0.65 BSC         |       |       |
| E              | 7.40             | 7.80  | 8.20  |
| E <sub>1</sub> | 5.00             | 5.30  | 5.60  |
| L              | 0.55             | 0.75  | 0.95  |
| L <sub>1</sub> | 1.25 REF         |       |       |
| θ              | 0°               | 4°    | 8°    |
| REF:           | 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 = AE. REFER TO THIS SPECIFICATION FOR FURTHER DETAILS.

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**IMPORTANT NOTICE**

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**REVISION HISTORY**

| DATE     | REV | DESCRIPTION OF CHANGES                            | PAGE  | CHANGED BY |
|----------|-----|---------------------------------------------------|-------|------------|
| 26/01/15 | 4.4 | Clarifications to external component requirements | 7, 23 | PH         |

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