



WM8738

24 Bit Stereo ADC

DESCRIPTION

The WM8738 is a high performance stereo audio ADC designed for consumer applications.

Stereo line-level audio inputs are provided, along with a control input pin to allow operation of the audio interface in either one of two industry standard modes. The device also has a selectable digital high pass filter to remove residual DC offsets.

Stereo 24-bit multi-bit sigma delta ADCs are provided, along with oversampling digital interpolation filters. 24-bit digital audio output word lengths and sampling rates from 32kHz to 96kHz are supported.

The device is available in a small 14-pin SOIC package.

FEATURES

- Audio Performance
 - 90 dB SNR ('A' weighted @ 48kHz)
- 3.0 – 5.5V Analogue Supply Operation
- 3.0 – 3.6V Digital Supply Operation
- ADC Sampling Frequency: 32kHz – 96kHz
- Selectable ADC High Pass Filter
- Selectable Audio Data Interface Modes
 - I²S or Left Justified
- 14-pin SOIC Package

APPLICATIONS

- CD and Minidisc Recorders
- DVD Players
- General Purpose Audio Conversion

BLOCK DIAGRAM

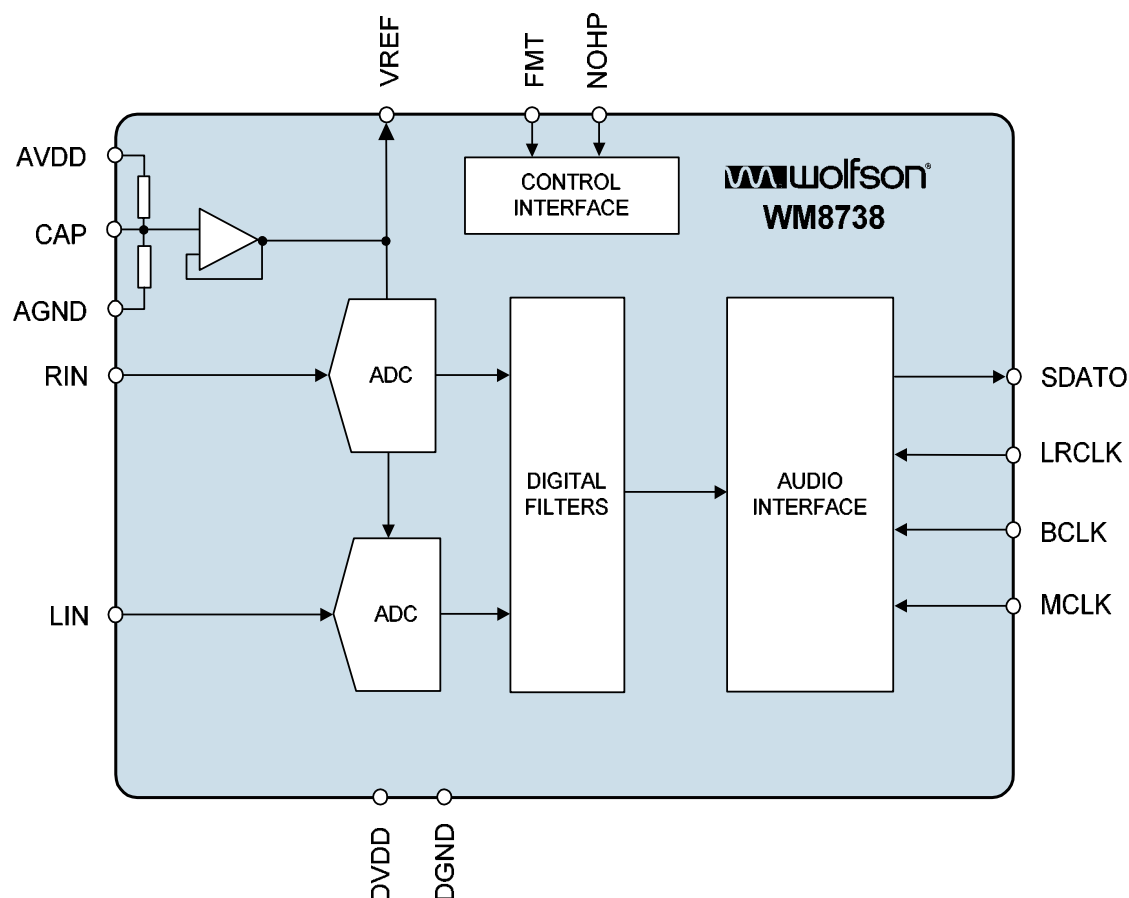
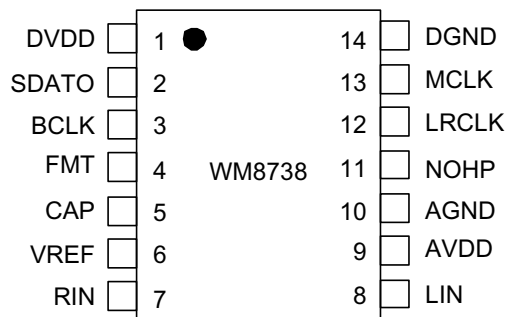


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PIN CONFIGURATION



ORDERING INFORMATION

| DEVICE | TEMPERATURE RANGE | PACKAGE | MOISTURE SENSITIVITY LEVEL | PEAK SOLDERING TEMPERATURE |
|--------------|-------------------|---|----------------------------|----------------------------|
| WM8738ED | -25 to +85°C | 14-pin SOIC | MSL 1 | 240°C |
| WM8738ED/R | -25 to +85°C | 14-pin SOIC (tape and reel) | MSL 1 | 240°C |
| WM8738GED/V | -25 to +85°C | 14-pin SOIC (lead free) | MSL 2 | 260°C |
| WM8738GED/RV | -25 to +85°C | 14-pin SOIC (lead free, tape and reel) | MSL 2 | 260°C |

Note:

Reel quantity = 3,000

PIN DESCRIPTION

| PIN | NAME | TYPE | DESCRIPTION |
|-----|-------|--------------------------------|--|
| 1 | DVDD | Supply | Digital positive supply |
| 2 | SDATO | Digital Output | ADC digital data output |
| 3 | BCLK | Digital Input | ADC audio interface data clock (5V tolerant) |
| 4 | FMT | Digital input (with pull down) | Audio interface format selection (5V tolerant) '0' = I ² S '1' = Left Justified |
| 5 | CAP | Analog | Reference de-coupling pin |
| 6 | VREF | Analogue output | Buffered reference decoupling pin |
| 7 | RIN | Analogue Input | Right channel ADC input |
| 8 | LIN | Analogue Input | Left channel ADC input |
| 9 | AVDD | Supply | Analogue positive supply |
| 10 | AGND | Supply | Analogue ground supply and chip substrate |
| 11 | NOHP | Digital input (with pull down) | Digital highpass filter bypass; (5V tolerant) '0' = Enabled '1' = Bypassed |
| 12 | LRCLK | Digital Input | Data left/right word clock (5V tolerant) |
| 13 | MCLK | Digital Input | Master clock input (5V tolerant) |
| 14 | DGND | Supply | Digital supply ground |

Notes

1. Digital input pins have Schmitt trigger input buffers and are 5V tolerant.

ABSOLUTE MAXIMUM RATINGS

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



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

Wolfson tests its package types according to IPC/JEDEC J-STD-020B for Moisture Sensitivity to determine acceptable storage conditions prior to surface mount assembly. These levels are:

MSL1 = unlimited floor life at <30°C / 85% Relative Humidity. Not normally stored in moisture barrier bag.

MSL2 = out of bag storage for 1 year at <30°C / 60% Relative Humidity. Supplied in moisture barrier bag.

MSL3 = out of bag storage for 168 hours at <30°C / 60% Relative Humidity. Supplied in moisture barrier bag.

| CONDITION | MIN | MAX |
|---|-----------------------|------------|
| Digital supply voltage | -0.3V | +4.2V |
| Analogue supply voltage | -0.3V | +7.0V |
| Voltage range digital inputs | DGND -0.3V | +7.0V |
| Voltage range analogue inputs | AGND -0.3V | AVDD +0.3V |
| Master Clock Frequency | | 37MHz |
| Operating temperature range, T _A | -25°C | +85°C |
| Storage temperature prior to soldering | 30°C max / 85% RH max | |
| Storage temperature after soldering | -65°C | +150°C |

Notes

1. Analogue and digital grounds must always be within 0.3V of each other.
2. The digital supply voltage must always be less than or equal to the analogue supply voltage.

RECOMMENDED OPERATING CONDITIONS

| PARAMETER | SYMBOL | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-------------------------------|------------|------------------------------------|-----|-----|-----|------|
| Digital supply range | DVDD | | 3.0 | | 3.6 | V |
| Analogue supply range | AVDD | | 3.0 | | 5.5 | V |
| Ground | DGND, AGND | | | 0 | | V |
| Analogue supply current | | AVDD = 5.0V, (DVDD at 3.3V) | | 30 | | mA |
| Analogue supply current | | AVDD = 3.3V, (DVDD at 3.3V) | | 19 | | mA |
| Supply Current Low Power Mode | | AVDD = 5.0V (DVDD at 3.3V) | | 180 | | µA |
| Supply Current Low Power Mode | | AVDD = 3.3V (DVDD at 3.3V) | | 110 | | µA |
| Digital supply current | | DVDD = 3.3V AVDD = 5.0V or 3.3V | | 4 | | mA |

ELECTRICAL CHARACTERISTICS

Test Conditions

AVDD = 5.0V, AGND = 0V, DVDD = 3.3V, DGND = 0V, T_A = +25°C, f_s = 48kHz, MCLK = 256fs unless otherwise stated.

| PARAMETER | SYMBOL | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|---------------------|---|-------------------------------|-----------------|-------------------------------|------------------|
| Digital Logic Levels (TTL Levels) | | | | | | |
| Input LOW level | V_{IL} | | | | 0.8 | V |
| Input HIGH level | V_{IH} | | 2.0 | | | V |
| Output LOW | V_{OL} | $I_{OL} = 1\text{mA}$ | | | $0.1 \times \text{DVDD}$ | V |
| Output HIGH | V_{OH} | $I_{OH} = 1\text{mA}$ | $0.9 \times \text{DVDD}$ | | | V |
| Pull down resistance (FMT, NOHP) | R_{PD} | | | 100 | | k Ω |
| Analogue Reference Levels | | | | | | |
| Reference voltage | V_{CAP} | | $\text{AVDD}/2 - 50\text{mV}$ | $\text{AVDD}/2$ | $\text{AVDD}/2 + 50\text{mV}$ | V |
| Buffered reference voltage | V_{REF} | | | V_{CAP} | | V |
| Potential divider output impedance | R_{CAP} | | 40 | 50 | 60 | k Ω |
| Input to ADC | | | | | | |
| Input Signal Level (0dB) | V_{RIN} / V_{LIN} | | | 1.0 | | V _{rms} |
| SNR (Note 1,2) | | A-weighted, 0dB gain @ $f_s = 48\text{kHz}$ | | 90 | | dB |
| SNR (Note 1,2) | | A-weighted, 0dB gain @ $f_s = 96\text{kHz}$ | | 90 | | dB |
| SNR (Note 1,2) | | A-weighted, 0dB gain @ $f_s = 48\text{kHz}$, AVDD = 3.3V | | 90 | | dB |
| Dynamic Range (Note 2) | DNR | A-weighted, -60dB full scale input | 90 | 97 | | dB |
| Total Harmonic Distortion (THD) (Note 4) | | -1dB input, 0dB gain | | -87 | | dB |
| ADC channel separation | | 1kHz input | | 95 | | dB |
| Power Supply Rejection Ratio | PSRR | 1kHz 100mV _{p-p} | | 50 | | dB |
| | | 20Hz to 20kHz 100mV _{p-p} | | 45 | | dB |
| Input Resistance | | | | 20 | | k Ω |
| Input Capacitance | | | | 10 | | pF |

Notes

- Ratio of output level with 1kHz full scale input, to the output level with the input open circuited, measured 'A' weighted over a 20Hz to 20kHz bandwidth using an Audio analyser.
- 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.
- VREF and CAP de-coupled with 10uF and 0.1uF capacitors (smaller values may result in reduced performance).
- This data is measured, using an active filter on the device inputs.

TERMINOLOGY

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

DIGITAL AUDIO INTERFACE TIMING

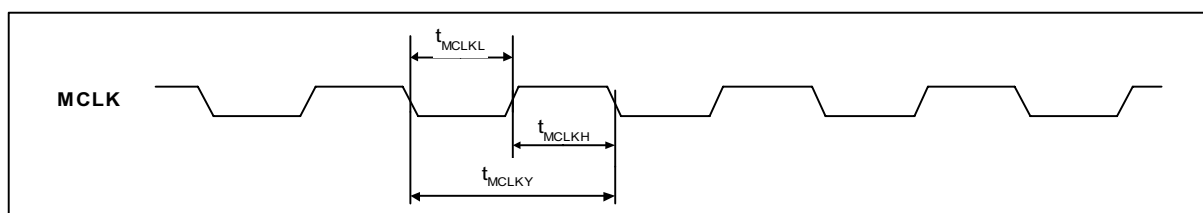


Figure 1 Master Clock Timing Requirements

Test Conditions

AVDD = 5.0V, AGND = 0V, DVDD = 3.3V, DGND = 0V, $T_A = +25^\circ\text{C}$, $f_s = 48\text{kHz}$, MCLK = 256fs unless otherwise stated.

| PARAMETER | SYMBOL | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|-------------|-----------------|-----|-----|-----|------|
| System Clock Timing Information | | | | | | |
| MCLK System clock pulse width high | T_{MCLKH} | | 10 | | | ns |
| MCLK System clock pulse width low | T_{MCLKL} | | 10 | | | ns |
| MCLK System clock cycle time | T_{MCLKY} | | 27 | | | ns |

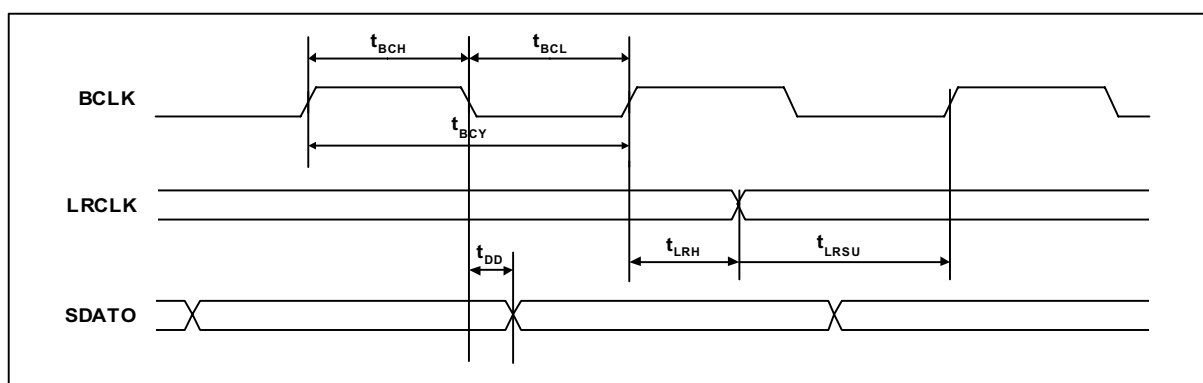


Figure 2 Digital Audio Data Timing

Test Conditions

AVDD = 5.0V, AGND = 0V, DVDD = 3.3V, DGND = 0V, $T_A = +25^\circ\text{C}$, $f_s = 48\text{kHz}$, MCLK = 256fs unless otherwise stated.

| PARAMETER | SYMBOL | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|------------|-----------------|-----|-----|-----|------|
| Audio Data Input Timing Information | | | | | | |
| BCLK cycle time | t_{BCY} | | | 80 | | ns |
| BCLK pulse width high | t_{BCH} | | | 40 | | ns |
| BCLK pulse width low | t_{BCL} | | | 40 | | ns |
| LRCLK set-up time to BCLK rising edge | t_{LRSU} | | | 10 | | ns |
| LRCLK hold time from BCLK rising edge | t_{LRH} | | | 10 | | ns |
| SDATO propagation delay from BCLK falling edge | t_{DD} | | | 10 | | ns |

DEVICE DESCRIPTION

INTRODUCTION

The WM8738 is an ADC designed for audio recording. Its features, performance and low power consumption make it ideal for recordable CD or DVD players, karaoke, MP3 players and mini-disc players.

The on-board stereo analogue to digital converter (ADC) is of a high quality using a multi-bit high-order oversampling architecture delivering optimum performance with low power consumption. The ADC includes a selectable digital high pass filter to remove unwanted DC components from the audio signal. The device supports system clock inputs of 256, 384, 512fs or 768fs (fs is the sampling rate)

The output from the ADC is available on the digital audio interface in either I²S or left justified audio data formats.

The line inputs are biased internally through the operational amplifier to V_{CAP} .

ADC

The WM8738 uses a multi-bit over sampled sigma-delta ADC. A single channel of the ADC is illustrated in Figure 3.

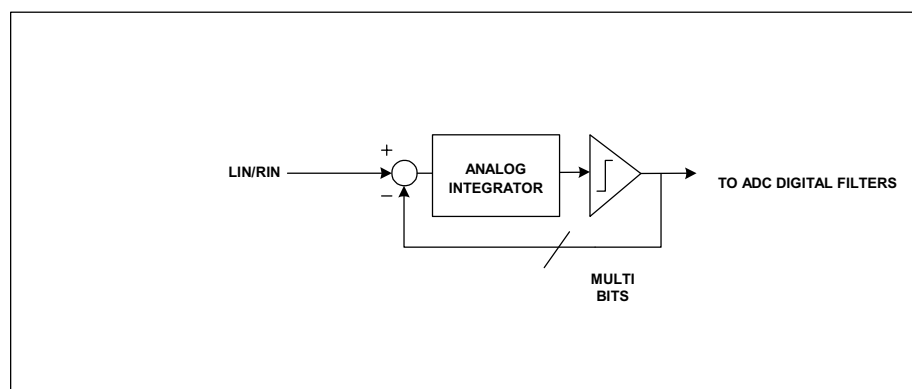


Figure 3 Multi-Bit Oversampling Sigma Delta ADC Schematic

The use of multi-bit feedback and high oversampling rates reduces the effects of jitter and high frequency noise.

The ADC Full Scale input is 1.0V rms at $AVDD = 5.0$ volts. Any voltage greater than full scale will possibly overload the ADC and cause distortion. Note that the full scale input tracks directly with $AVDD$.

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

ADC DIGITAL FILTER

The ADC digital filters contain a digital high pass filter, selectable via pin NOHP.

NOHP = 0 Digital high pass filter enabled

NOHP = 1 Digital high pass filter bypassed

The high-pass filter response detailed in Digital Filter Characteristics. The operation of the high pass filter removes residual DC offsets that are present on the audio signal.

AUDIO DATA SAMPLING RATES

In a typical digital audio system there is only one central clock source producing a reference clock to which all audio data processing is synchronised. This clock is often referred to as the audio system's Master Clock. The external master system clock can be applied directly through the MCLK input pin. In a system where there are a number of possible sources for the reference clock it is recommended that the clock source with the lowest jitter be used to optimise the performance of the ADC.

The master clock for WM8738 supports audio sampling rates from 256fs to 768fs, where fs is the audio sampling frequency LRCLK, typically 32kHz, 44.1kHz, 48kHz, or 96kHz. The master clock is used to operate the digital filters and the noise shaping circuits.

The WM8738 has a master clock detection circuit that automatically determines the relationship between the master clock frequency and the sampling rate (to within +/- 32 system clocks). If there is a greater than 32 clocks error the interface is disabled and maintains the output level at the last sample. The master clock must be synchronised with LRCLK, although the WM8738 is tolerant of phase variations or jitter on this clock. Table 1 shows the typical master clock frequency inputs for the WM8738.

If MCLK is stopped for greater than 10us then the device will enter a low power mode where the current taken from AVDD is greatly reduced. Note that when the device enters this mode the references are powered down.

Table 1 shows the common MCLK frequencies for different sample rates.

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

Table 1 Master Clock Frequency Selection

DIGITAL AUDIO INTERFACES

The WM8738 has two data output formats, selectable via the FMT pin.

FMT = 0 ADC audio data output is I²S

FMT = 1 ADC audio data output is Left Justified

Both of these modes are MSB first.

The digital audio interface takes the data from the internal ADC digital filter. SDATO 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 SDATO line. SDATO and LRCLK are synchronous with the BCLK signal with each data bit transition signified by a low to high BCLK transition.

LEFT JUSTIFIED MODE

In left justified mode, the MSB of the ADC data is output on SDATO and changes on the same falling edge of BCLK as LRCLK and may be sampled on the rising edge of BCLK. LRCLK is high during the left samples and low during the right samples.

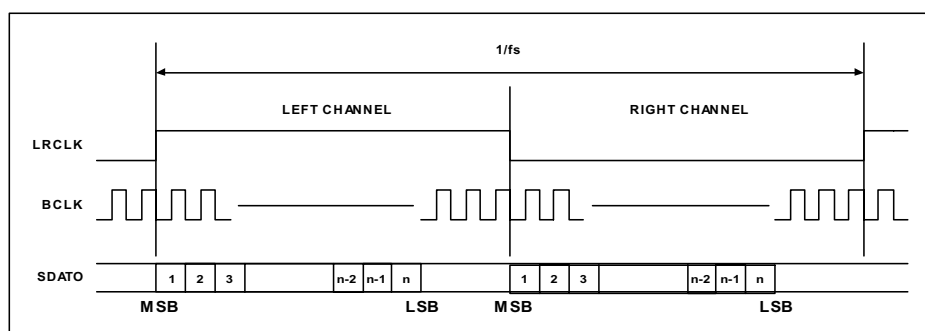


Figure 4 Left Justified Mode Timing Diagram

I²S MODE

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

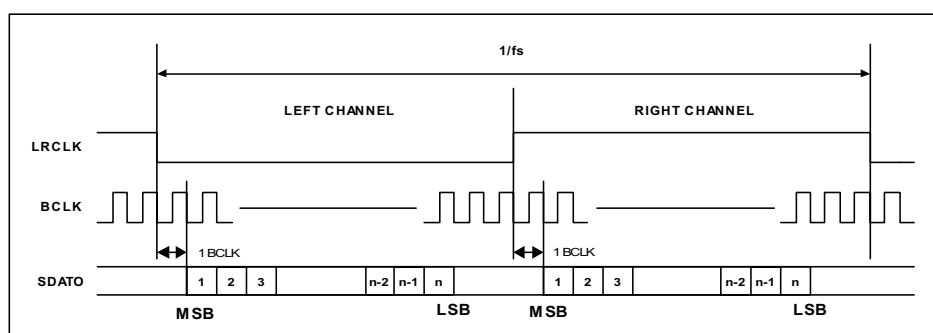


Figure 5 I²S Mode Timing Diagram

DIGITAL FILTER CHARACTERISTICS

| PARAMETER | SYMBOL | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|----------------------|--------|-----------------|----------|-------|------------|---------|
| Passband | | ± 0.01 dB | 0 | | 0.4535fs | dB |
| Stopband | | -6dB | | 0.5fs | | |
| Passband ripple | | | | | ± 0.01 | dB |
| Stopband | | | 0.5465fs | | | |
| Stopband Attenuation | | $f > 0.5465fs$ | | -65 | | dB |
| Group Delay | | | | 22 | | Samples |

Table 2 Digital Filter Characteristics

ADC FILTER RESPONSES

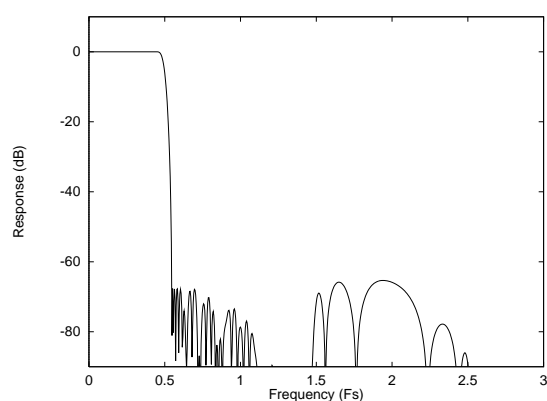


Figure 6 ADC Digital Filter Frequency Response

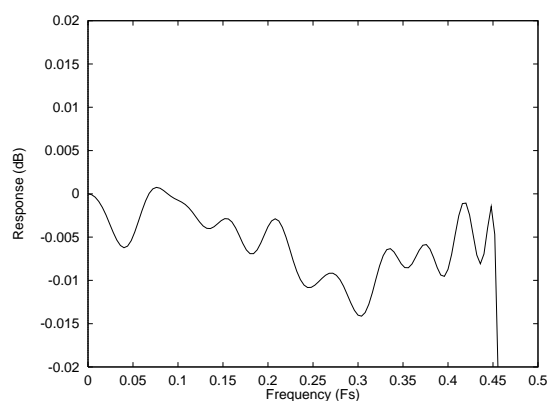


Figure 7 ADC Digital Filter Ripple

ADC HIGH PASS FILTER

The WM8738 has a selectable digital highpass filter to remove DC offsets. The filter response is characterised by the following polynomial.

$$H(z) = \frac{1 - z^{-1}}{1 - 0.9995z^{-1}}$$

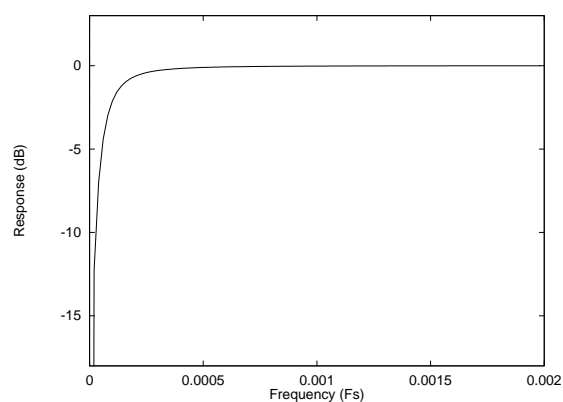


Figure 8 ADC Highpass Filter Response

APPLICATIONS INFORMATION

RECOMMENDED EXTERNAL COMPONENTS

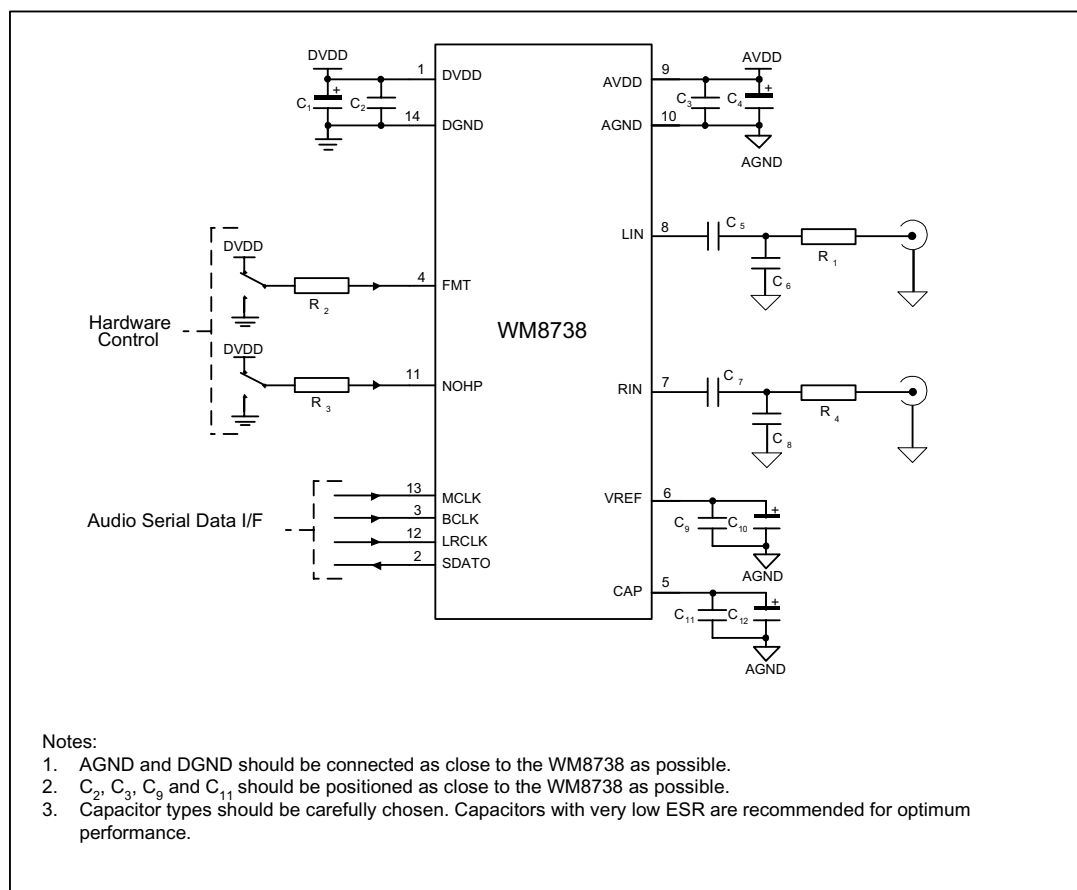


Figure 9 External Components Diagram

RECOMMENDED EXTERNAL COMPONENTS VALUES

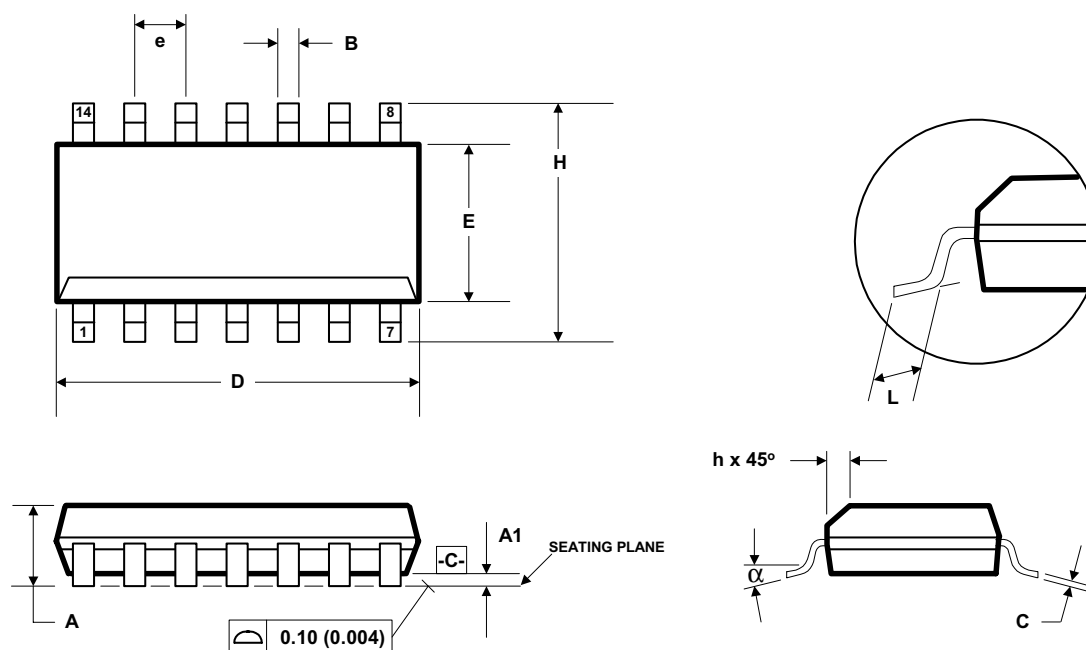
| COMPONENT REFERENCE | SUGGESTED VALUE | DESCRIPTION |
|---------------------|-----------------|---|
| C1 and C4 | 10 μ F | De-coupling for DVDD and AVDD |
| C2 and C3 | 0.1 μ F | De-coupling for DVDD and AVDD |
| C5 and C7 | 1 μ F | Analogue input AC coupling caps |
| C6 and C8 | 4.7nF | Analogue input filtering (RC) capacitor |
| R2 and R3 | 10k Ω | Current limiting resistors |
| R1 and R4 | 680 Ω | Analogue input filtering (RC) resistor |
| C9 | 0.1 μ F | Reference de-coupling capacitors for VREF pin |
| C10 | 10 μ F | |
| C11 | 0.1 μ F | Reference de-coupling capacitors for CAP pin |
| C12 | 10 μ F | |

Table 3 External Components Description

PACKAGE DIMENSIONS

D: 14 PIN SOIC 3.9mm Wide Body

DM001.C



| Symbols | Dimensions (mm) | | Dimensions (Inches) | |
|---------|------------------|------|---------------------|--------|
| | MIN | MAX | MIN | MAX |
| A | 1.35 | 1.75 | 0.0532 | 0.0688 |
| A1 | 0.10 | 0.25 | 0.0040 | 0.0098 |
| B | 0.33 | 0.51 | 0.0130 | 0.0200 |
| C | 0.19 | 0.25 | 0.0075 | 0.0098 |
| D | 8.55 | 8.75 | 0.3367 | 0.3444 |
| E | 3.80 | 4.00 | 0.1497 | 0.1574 |
| e | 1.27 BSC | | 0.05 BSC | |
| H | 5.80 | 6.20 | 0.2284 | 0.2440 |
| h | 0.25 | 0.50 | 0.0099 | 0.0196 |
| L | 0.40 | 1.27 | 0.0160 | 0.0500 |
| α | 0° | 8° | 0° | 8° |
| REF: | JEDEC.95, MS-012 | | | |

NOTES:

- A. ALL LINEAR DIMENSIONS ARE IN MILLIMETERS (INCHES).
 B. THIS DRAWING IS SUBJECT TO CHANGE WITHOUT NOTICE.
 C. BODY DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSION, NOT TO EXCEED 0.25MM (0.010IN).
 D. MEETS JEDEC.95 MS-012, VARIATION = AB. REFER TO THIS SPECIFICATION FOR FURTHER DETAILS.

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