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## Mobile Multimedia CODEC with 1W Speaker Driver

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### DESCRIPTION

The WM8983 is a low power, high quality stereo CODEC designed for portable multimedia applications. Highly flexible analogue mixing functions enable new application features, combining hi-fi quality audio with voice communication.

The device integrates preamps for stereo differential mics, and includes drivers for speaker, headphone and differential or stereo line output. External component requirements are reduced as no separate microphone or headphone amplifiers are required.

Advanced on-chip digital signal processing includes a 5-band equaliser, a mixed signal Automatic Level Control for the microphone or line input through the ADC as well as a purely digital limiter function for record or playback. A programmable high pass filter in the ADC path is provided for wind noise reduction and an IIR with programmable coefficients can be used as a notch filter to suppress fixed-frequency noise.

The WM8983 digital audio interface can operate in master or slave mode, while an integrated PLL supports flexible clocking schemes. A-law and  $\mu$ -law companding are fully supported.

The WM8983 operates at analogue supply voltages from 2.5V to 3.3V, although the digital core can operate at voltages down to 1.71V to save power. Speaker supplies can operate up to 5V for increased speaker output power. Additional power management control enables individual sections of the chip to be powered down under software control.

### FEATURES

#### Stereo CODEC:

- DAC SNR 98dB, THD -84dB ('A' weighted @ 48kHz)
- ADC SNR 95dB, THD -84dB ('A' weighted @ 48kHz)
- Speaker driver (1W into 8 $\Omega$  BTL with 5V supply)
  - SNR 90dB
  - PSRR 80dB
- Headphone driver with 'capless' option
  - 40mW/channel output power into 16 $\Omega$  / 3.3V AVDD2
- Pop and click suppression

#### Mic Preamps:

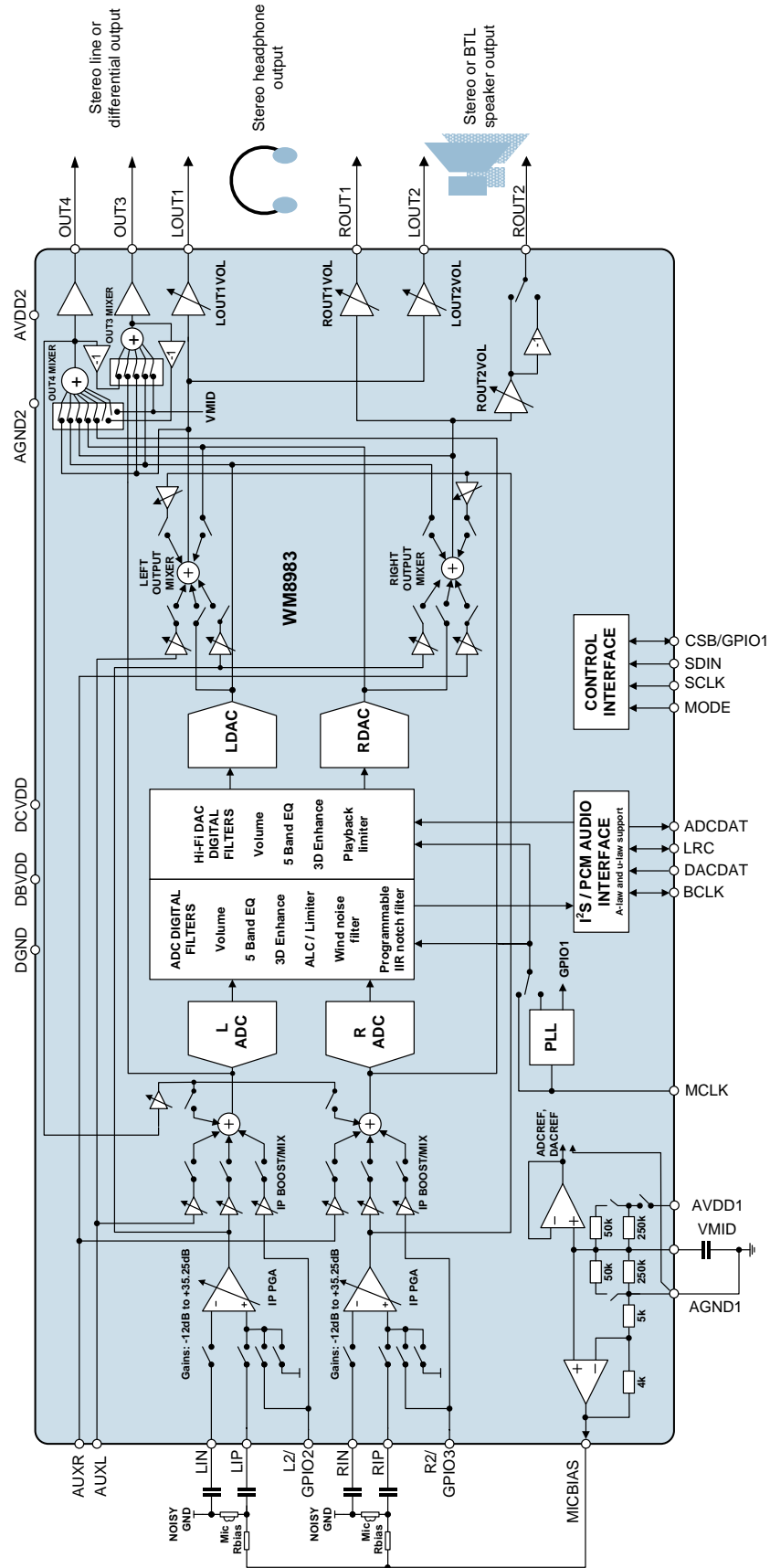
- Stereo Differential or mono microphone Interfaces
- Programmable preamp gain
- Pseudo differential inputs with common mode rejection
- Programmable ALC / Noise Gate in ADC path
- Low-noise bias supplied for electret microphones

#### Other Features:

- Enhanced 3-D function for improved stereo separation
- Highly flexible mixing functions
- 5-band equaliser (ADC or DAC path)
- ADC Programmable high pass filter (wind noise reduction)
- ADC Programmable IIR notch filter
- Aux inputs for stereo analog input signals or 'beep'
- PLL supporting various clocks between 8MHz-50MHz
- Sample rates supported (kHz): 8, 11.025, 16, 12, 16, 22.05, 24, 32, 44.1, 48
- 2.5V to 3.6V analogue supplies
- 1.71V to 3.6V digital supplies
- 2.5V to 5.5V speaker supplies
- 5x5mm 32-lead QFN package

### APPLICATIONS

- Multimedia mobile phones

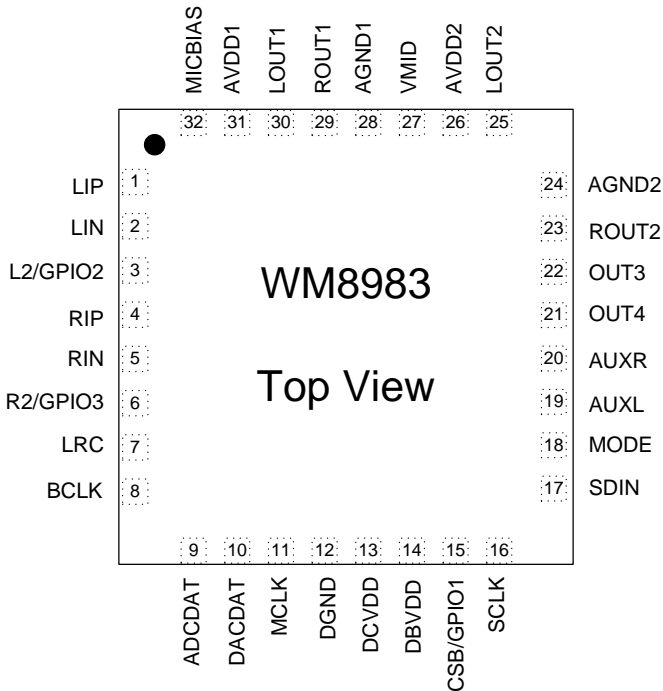
**BLOCK DIAGRAM**


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**PIN CONFIGURATION**

**ORDERING INFORMATION**

| ORDER CODE    | TEMPERATURE RANGE | PACKAGE  | MOISTURE SENSITIVITY LEVEL | PEAK SOLDERING TEMPERATURE |
|---------------|-------------------|--|----------------------------|----------------------------|
| WM8983GEFL/V  | -25°C to +85°C    | 32-lead QFN (5 x 5 mm)<br>(pb-free)                | MSL3                       | 260°C                      |
| WM8983GEFL/RV | -25°C to +85°C    | 32-lead QFN (5 x 5 mm)<br>(pb-free, tape and reel) | MSL3                       | 260°C                      |

**Note:**

Reel quantity = 3,500

**PIN DESCRIPTION**

| PIN | NAME      | TYPE                   | DESCRIPTION   |
|-----|-----------|------------------------|---|
| 1   | LIP       | Analogue input         | Left MIC pre-amp positive input   |
| 2   | LIN       | Analogue input         | Left MIC pre-amp negative input   |
| 3   | L2/GPIO2  | Analogue input         | Left channel line input/secondary mic pre-amp positive input/GPIO2 pin  |
| 4   | RIP       | Analogue input         | Right MIC pre-amp positive input  |
| 5   | RIN       | Analogue input         | Right MIC pre-amp negative input  |
| 6   | R2/GPIO3  | Analogue input         | Right channel line input/secondary mic pre-amp positive input/GPIO3 pin   |
| 7   | LRC       | Digital Input / Output | DAC and ADC sample rate clock   |
| 8   | BCLK      | Digital Input / Output | Digital audio bit clock   |
| 9   | ADCDAT    | Digital Output         | ADC digital audio data output   |
| 10  | DACDAT    | Digital Input          | DAC digital audio data input  |
| 11  | MCLK      | Digital Input          | Master clock input  |
| 12  | DGND      | Supply                 | Digital ground  |
| 13  | DCVDD     | Supply                 | Digital core logic supply   |
| 14  | DBVDD     | Supply                 | Digital buffer (I/O) supply   |
| 15  | CSB/GPIO1 | Digital Input / Output | 3-Wire control interface chip Select / GPIO1 pin  |
| 16  | SCLK      | Digital Input          | 3-Wire control interface clock input / 2-wire control interface clock input   |
| 17  | SDIN      | Digital Input / Output | 3-Wire control interface data input / 2-Wire control interface data input   |
| 18  | MODE      | Digital Input          | Control interface selection   |
| 19  | AUXL      | Analogue input         | Left auxiliary input  |
| 20  | AUXR      | Analogue input         | Right auxiliary input   |
| 21  | OUT4      | Analogue Output        | right line output or mono mix output  |
| 22  | OUT3      | Analogue Output        | mono or left line output  |
| 23  | ROUT2     | Analogue Output        | Headphone or line output right 2  |
| 24  | AGND2     | Supply                 | Analogue ground (feeds ROUT2/LOUT2 and OUT3/OUT4)   |
| 25  | LOUT2     | Analogue Output        | Headphone or line output left 2   |
| 26  | AVDD2     | Supply                 | Analogue supply (feeds output amplifiers ROUT2/LOUT2 and OUT3/OUT4)   |
| 27  | VMID      | Reference              | Decoupling for ADC and DAC reference voltage  |
| 28  | AGND1     | Supply                 | Analogue ground (feeds all input amplifiers, PLL, ADC and DAC, internal bias circuits, output amplifiers LOUT1, ROUT1)  |
| 29  | ROUT1     | Analogue Output        | Headphone or line output right 1  |
| 30  | LOUT1     | Analogue Output        | Headphone or line output left 1   |
| 31  | AVDD1     | Supply                 | Analogue supply (feeds all input amplifiers, PLL, ADC and DAC, internal bias circuits, output amplifiers LOUT1, LOUT2)) |
| 32  | MICBIAS   | Analogue Output        | Microphone bias   |

**Note:**

It is recommended that the QFN ground paddle should be connected to analogue ground on the application PCB. Refer to the application note WAN\_0118 on “Guidelines on How to Use QFN Packages and Create Associated PCB Footprints”

## 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-020 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                          |
|--|------------------------------|------------------------------|
| DBVDD, DCVDD, AVDD1 supply voltages    | -0.3V                        | +4.5V                        |
| AVDD2 supply voltage                   | -0.3V                        | +7V                          |
| Voltage range digital inputs           | DGND - 0.3V                  | DVDD + 0.3V                  |
| Voltage range analogue inputs          | AGND1 - 0.3V<br>AGND2 - 0.3V | AVDD1 + 0.3V<br>AVDD2 + 0.3V |
| 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. All digital and analogue supplies are completely independent from each other.
3. Analogue supply voltages should not be less than digital supply voltages.
4. In non-boosted mode AVDD2 should be  $\geq$  AVDD1. In boost mode, AVDD2 should be  $\geq 1.5 \times$  AVDD1.
5. DBVDD must be greater than or equal to DCVDD.

## RECOMMENDED OPERATING CONDITIONS

| PARAMETER                     | SYMBOL             | TEST CONDITIONS | MIN               | TYP | MAX | UNIT |
|-------------------------------|--------------------|-----------------|-------------------|-----|-----|------|
| Digital supply range (Core)   | DCVDD              |                 | 1.71              |     | 3.6 | V    |
| Digital supply range (Buffer) | DBVDD              |                 | 1.71 <sup>2</sup> |     | 3.6 | V    |
| Analogue supply range         | AVDD1              |                 | 2.5               |     | 3.6 | V    |
| Speaker supply range          | AVDD2              |                 | 2.5               |     | 5.5 | V    |
| Ground                        | DGND, AGND1, AGND2 |                 |                   | 0   |     | V    |

### Notes:

1. Analogue supply voltages should not be less than digital supply voltages.
2. DBVDD should be  $\geq 1.9V$  when using the PLL.

**ELECTRICAL CHARACTERISTICS**
**Test Conditions**

 DCVDD=1.8V, AVDD1=AVDD2=DBVDD=3.3V, T<sub>A</sub> = +25°C, 1kHz signal, fs = 48kHz, 24-bit audio data unless otherwise stated.

| PARAMETER   | SYMBOL | TEST CONDITIONS  | MIN | TYP              | MAX    | UNIT             |
|---|--------|--|-----|------------------|--------|------------------|
| <b>Microphone Input PGA Inputs (LIP, LIN, RIP, RIN, L2, R2)</b>             |        |  |     |                  |        |                  |
| <b>INPPGAVOLL, INPPGAVOLR, PGABOOSTL and PGABOOSTR = 0dB</b>                |        |  |     |                  |        |                  |
| Full-scale Input Signal Level – Single-ended input via LIN/RIN <sup>1</sup> |        |  |     | AVDD/3.3         |        | V <sub>rms</sub> |
| Full-scale Input Signal Level – Pseudo-differential input <sup>1,2</sup>    |        |  |     | AVDD*0.7/<br>3.3 |        | V <sub>rms</sub> |
| Input PGA equivalent input noise  |        | INPPGAVOLL/R = +35.25dB<br>No input signal<br>22Hz to 20kHz                  |     | 150              |        | μV               |
| LIN, RIN input resistance   |        | INPPGAVOLL and<br>INPPGAVOLR = +35.25dB                                      |     | 1.7              |        | kΩ               |
| LIN, RIN input resistance   |        | INPPGAVOLL and<br>INPPGAVOLR = 0dB   |     | 47               |        | kΩ               |
| LIN, RIN input resistance   |        | INPPGAVOLL and<br>INPPGAVOLR = -12dB   |     | 76               |        | kΩ               |
| LIP, RIP input resistance   |        | All gain settings  |     | 95               |        | kΩ               |
| L2, R2 input resistance   |        | L2_2INPPGA and<br>R2_2INPPGA = 1<br>L2_2BOOSTVOL and<br>R2_2BOOSTVOL = 000   |     | 90               |        | kΩ               |
| L2, R2 input resistance   |        | L2_2INPPGA and<br>R2_2INPPGA = 0<br>L2_2BOOSTVOL and<br>R2_2BOOSTVOL = +6dB  |     | 11               |        | kΩ               |
| L2, R2 input resistance   |        | L2_2INPPGA and<br>R2_2INPPGA = 0<br>L2_2BOOSTVOL and<br>R2_2BOOSTVOL = 0dB   |     | 22               |        | kΩ               |
| L2, R2 input resistance   |        | L2_2INPPGA and<br>R2_2INPPGA = 0<br>L2_2BOOSTVOL and<br>R2_2BOOSTVOL = -12dB |     | 60               |        | kΩ               |
| Input Capacitance   |        | All analogue input pins  |     | 10               |        | pF               |
| Input PGA Programmable Gain   |        | Gain adjusted by<br>INPPGAVOLL and<br>INPPGAVOLR                             | -12 |                  | +35.25 | dB               |
| Programmable Gain Step Size   |        | Guaranteed monotonic   |     | 0.75             |        | dB               |
| Input PGA Mute Attenuation  |        | INPPGAMUTEL and<br>INPPGAMUTER = 1   |     | 100              |        | dB               |
| Input Gain Boost  |        | PGABOOSTL and<br>PGABOOSTR = 0   |     | 0                |        | dB               |
| Input Gain Boost  |        | PGABOOSTL and<br>PGABOOSTR = 1   |     | +20              |        | dB               |



### Test Conditions

DCVDD=1.8V, AVDD1=AVDD2=DBVDD=3.3V, T<sub>A</sub> = +25°C, 1kHz signal, fs = 48kHz, 24-bit audio data unless otherwise stated.

| PARAMETER  | SYMBOL | TEST CONDITIONS                                   | MIN | TYP      | MAX | UNIT             |
|--|--------|---|-----|----------|-----|------------------|
| <b>Auxiliary Analogue Inputs (AUXL, AUXR)</b>  |        |   |     |          |     |                  |
| Full-scale Input Signal Level <sup>2</sup>   |        |   |     | AVDD/3.3 |     | V <sub>rms</sub> |
| Input Resistance   |        | Left Input boost and mixer enabled, at +6dB       |     | 4.3      |     | kΩ               |
|  |        | Left Input boost and mixer enabled, at 0dB gain   |     | 8.6      |     | kΩ               |
|  |        | Left Input boost and mixer enabled, at -12dB gain |     | 39.1     |     | kΩ               |
|  |        | Right Input boost, mixer enabled, at +6dB gain    |     | 3        |     | kΩ               |
|  |        | Right Input boost, mixer enabled, at 0dB gain     |     | 6        |     | kΩ               |
|  |        | Right Input boost, mixer enabled, at -12dB gain   |     | 29       |     | kΩ               |
| Input Capacitance  |        | All analogue Inputs                               |     | 10       |     | pF               |
| Gain range from AUXL and AUXR input to left and right input PGA mixers   |        | Gain adjusted by AUXL2BOOSTVOL and AUXR2BOOSTVOL  | -12 |          | +6  | dB               |
| AUXLBOOSTVOL and AUXRBOOSTVOL step size  |        |   |     | 3        |     | dB               |
| <b>L2, R2 Line Input Programmable Gain</b>   |        |   |     |          |     |                  |
| Gain range from L2/R2 input to left and right input PGA mixers   |        | Gain adjusted by L2_2BOOSTVOL and R2_2BOOSTVOL    | -12 |          | +6  | dB               |
| L2/R2_2BOOSTVOL step size  |        |   |     | 3        |     | dB               |
| L2/R2_2BOOSTVOL mute attenuation   |        |   |     | 100      |     | dB               |
| <b>OUT4 to left or right input boost record path</b>   |        |   |     |          |     |                  |
| Gain range into left and right input PGA mixers  |        | Gain adjusted by OUT4_2ADCVOL                     | -6  |          | +12 | dB               |
| OUT4_2ADCVOL gain step size  |        |   |     | 3        |     | dB               |
| OUT4_2ADCVOL mute attenuation  |        |   |     | 100      |     | dB               |
| <b>Analogue to Digital Converter (ADC) - Input from LIN/P and RIN/P in differential configuration to input PGA INPPGAVOLL, INPPGAVOLR, PGABOOSTL, PGABOOSTR, ADCLVOL and ADCRVOL = 0dB</b> |        |   |     |          |     |                  |
| Signal to Noise Ratio <sup>3</sup>   | SNR    | A-weighted<br>AVDD1=AVDD2=3.3V                    |     | 93       |     | dB               |
|  |        | A-weighted<br>AVDD1=AVDD2=2.5V                    |     | 91.5     |     | dB               |
| Total Harmonic Distortion <sup>4</sup>   | THD    | -12dBV Input<br>AVDD1=AVDD2=3.3V                  |     | -78      |     | dBFS             |
|  |        | -12dBV Input<br>AVDD1=AVDD2=2.5V                  |     | -75      |     | dBFS             |
| Total Harmonic Distortion + Noise <sup>5</sup>   | THD+N  | -12dBV Input<br>AVDD1=AVDD2=3.3V                  |     | -75      |     | dBFS             |
|  |        | -12dBV Input<br>AVDD1=AVDD2=2.5V                  |     | -72      |     | dBFS             |
| Channel Separation <sup>6</sup>  |        | 1kHz full scale input signal                      |     | 100      |     | dBFS             |

### Test Conditions

DCVDD=1.8V, AVDD1=AVDD2=DBVDD=3.3V, T<sub>A</sub> = +25°C, 1kHz signal, fs = 48kHz, 24-bit audio data unless otherwise stated.

| PARAMETER   | SYMBOL | TEST CONDITIONS                 | MIN | TYP       | MAX | UNIT             |
|---|--------|---------------------------------|-----|-----------|-----|------------------|
| <b>Analogue to Digital Converter (ADC) - Input from L2, R2 into right PGA mixer. L2_2INPPGA and R2_2INPPGA = 0. INPPGAVOLL, INPPGAVOLR, L2_2BOOSTVOL, R2_2BOOSTVOL, ADCLVOL and ADCRVOL = 0dB</b> |        |                                 |     |           |     |                  |
| Signal to Noise Ratio <sup>3</sup>  | SNR    | A-weighted<br>AVDD1=AVDD2=3.3V  |     | 95        |     | dB               |
|   |        | A-weighted<br>AVDD1=AVDD2=2.5V  |     | 93        |     | dB               |
| Total Harmonic Distortion <sup>4</sup>  | THD    | -3dBV Input<br>AVDD1=AVDD2=3.3V |     | -86       |     | dBFS             |
|   |        | -3dBV Input<br>AVDD1=AVDD2=2.5V |     | -78       |     | dBFS             |
| Total Harmonic Distortion + Noise <sup>5</sup>  | THD+N  | -3dBV Input<br>AVDD1=AVDD2=3.3V |     | -80       |     | dBFS             |
|   |        | -3dBV Input<br>AVDD1=AVDD2=2.5V |     | -76       |     | dBFS             |
| Channel Separation <sup>6</sup>   |        | 1kHz input signal               |     | 100       |     | dBFS             |
| <b>DAC to left and right mixers into 10kΩ / 50pF load on LOUT1 and ROUT1<br/>LOUT1VOL, ROUT1VOL, DACLVOL and DACRVOL = 0dB</b>  |        |                                 |     |           |     |                  |
| Full-scale output <sup>1</sup>  |        | LOUT1VOL and<br>ROUTVOL = 0dB   |     | AVDD1/3.3 |     | V <sub>rms</sub> |
| Signal to Noise Ratio <sup>3</sup>  | SNR    | A-weighted<br>AVDD1=AVDD2=3.3V  |     | 100       |     | dB               |
|   |        | A-weighted<br>AVDD1=AVDD2=2.5V  |     | 99        |     | dB               |
| Total Harmonic Distortion <sup>4</sup>  | THD    | 0dBFS input<br>AVDD1=AVDD2=3.3V |     | -84       |     | dBFS             |
|   |        | 0dBFS input<br>AVDD1=AVDD2=2.5V |     | -86       |     | dBFS             |
| Total Harmonic Distortion + Noise <sup>5</sup>  | THD+N  | 0dBFS input<br>AVDD1=AVDD2=3.3V |     | -83       |     | dBFS             |
|   |        | 0dBFS input<br>AVDD1=AVDD2=2.5V |     | -84       |     | dBFS             |
| Channel Separation <sup>6</sup>   |        | 1kHz signal                     |     | 100       |     | dB               |
| <b>DAC to L/R mixer into 10kΩ / 50pF load on L/ROUT2<br/>LOUT2VOL, ROUT2VOL, DACLVOL and DACRVOL = 0dB</b>  |        |                                 |     |           |     |                  |
| Full-scale output <sup>1</sup>  |        |                                 |     | AVDD1/3.3 |     | V <sub>rms</sub> |
| Signal to Noise Ratio <sup>3</sup>  | SNR    | A-weighted<br>AVDD1=AVDD2=3.3V  |     | 100       |     | dB               |
|   |        | A-weighted<br>AVDD1=AVDD2=2.5V  |     | 96        |     | dB               |
| Total Harmonic Distortion <sup>4</sup>  | THD    | 0dBFS input<br>AVDD1=AVDD2=3.3V |     | -84       |     | dBFS             |
|   |        | 0dBFS input<br>AVDD1=AVDD2=2.5V |     | -82       |     | dBFS             |
| Total Harmonic Distortion + Noise <sup>5</sup>  | THD+N  | 0dBFS input<br>AVDD1=AVDD2=3.3V |     | -82       |     | dBFS             |
|   |        | 0dBFS input<br>AVDD1=AVDD2=2.5V |     | -80       |     | dBFS             |
| Channel Separation <sup>6</sup>   |        | 1kHz input signal               |     | 100       |     | dB               |

**Test Conditions**

 DCVDD=1.8V, AVDD1=AVDD2=DBVDD=3.3V, T<sub>A</sub> = +25°C, 1kHz signal, fs = 48kHz, 24-bit audio data unless otherwise stated.

| PARAMETER   | SYMBOL | TEST CONDITIONS   | MIN | TYP       | MAX | UNIT             |
|---|--------|---|-----|-----------|-----|------------------|
| <b>DAC to OUT3 and OUT4 mixers to OUT3/OUT4 outputs into 10kΩ / 50pF load. DACLVOL and DACRVOL = 0dB</b>                          |        |   |     |           |     |                  |
| Full-scale output voltage   |        |   |     | AVDD2/3.3 |     | V <sub>rms</sub> |
| Signal to Noise Ratio <sup>3</sup>  | SNR    | A-weighted<br>AVDD1=AVDD2=3.3V                                |     | 101.5     |     | dB               |
| Total Harmonic Distortion <sup>4</sup>  | THD    | full-scale signal<br>AVDD1=AVDD2=3.3V                         |     | -80       |     | dBFS             |
|   |        | full-scale signal<br>AVDD1=AVDD2=2.5V                         |     | -87       |     | dBFS             |
| Total Harmonic Distortion + Noise <sup>5</sup>  | THD+N  | full-scale signal<br>AVDD1=AVDD2=3.3V                         |     | -77       |     | dBFS             |
|   |        | full-scale signal<br>AVDD1=AVDD2=2.5V                         |     | -85       |     | dBFS             |
| Channel Separation <sup>6</sup>   |        | 1kHz signal   |     | 100       |     | dBFS             |
| <b>DAC to left and right mixer into headphone (16Ω load) on LOUT2 and ROUT2<br/>LOUT2VOL, ROUT2VOL, DACLVOL and DACRVOL = 0dB</b> |        |   |     |           |     |                  |
| Full-scale output   |        |   |     | AVDD1/3.3 |     | V <sub>rms</sub> |
| Signal to Noise Ratio <sup>3</sup>  | SNR    | A-weighted<br>AVDD1=AVDD2=3.3V                                |     | 98        |     | dB               |
| Total Harmonic Distortion <sup>4</sup>  | THD    | P <sub>o</sub> = 20mW, RL=16Ω                                 |     | -76       |     | dBFS             |
| Total Harmonic Distortion + Noise <sup>5</sup>  | THD+N  | P <sub>o</sub> = 20mW, RL=16Ω                                 |     | -72       |     | dBFS             |
| Channel Separation <sup>6</sup>   |        | 1kHz signal   |     | 100       |     | dB               |
| <b>Bypass paths to left and right output mixers. BYPL2LMIX = 1 and BYPR2RMIX = 1</b>  |        |   |     |           |     |                  |
| PGA gain range into mixer   |        | Gain adjusted by<br>BYPLMIXVOL and<br>BYPRMIXVOL              | -15 | 0         | +6  | dB               |
| BYPLMIXVOL and BYPRMIXVOL<br>gain step into mixer   |        |   |     | 3         |     | dB               |
| Mute attenuation  |        | BYPL2LMIX = 0<br>BYPR2RMIX = 0                                |     | 100       |     | dB               |
| <b>Analogue outputs (LOUT1, ROUT1, LOUT2, ROUT2)</b>  |        |   |     |           |     |                  |
| Programmable Gain range   |        | Gain adjusted by<br>L/ROUT1VOL and<br>L/ROUT2VOL              | -57 | 0         | +6  | dB               |
| Programmable Gain step size   |        | Guaranteed monotonic  |     | 1         |     | dB               |
| Mute attenuation  |        | 1kHz, full scale signal<br>L/ROUT1MUTE = 1<br>L/ROUT2MUTE = 1 |     | 85        |     | dB               |

### Test Conditions

DCVDD=1.8V, AVDD1=AVDD2=DBVDD=3.3V, T<sub>A</sub> = +25°C, 1kHz signal, fs = 48kHz, 24-bit audio data unless otherwise stated.

| PARAMETER  | SYMBOL | TEST CONDITIONS                       | MIN | TYP       | MAX | UNIT             |
|--|--------|---------------------------------------|-----|-----------|-----|------------------|
| <b>LIN and RIN input PGA to input boost stage into 10kΩ / 50pF load on OUT3/OUT4 outputs</b> |        |                                       |     |           |     |                  |
| <b>INPPGAVOLL, INPPGAVOLR, PGABOOSTL and PGABOOSTR = 0dB</b>                                 |        |                                       |     |           |     |                  |
| Full-scale output voltage, 0dB gain  |        |                                       |     | AVDD2/3.3 |     | V <sub>rms</sub> |
| Signal to Noise Ratio <sup>3</sup>   | SNR    | A-weighted<br>AVDD1=AVDD2=3.3V        | 90  | 98        |     | dB               |
|  |        | A-weighted<br>AVDD1=AVDD2=2.5V        |     | 96        |     | dB               |
|  |        | 22Hz to 22kHz<br>AVDD1=AVDD2=3.3V     |     | 95.5      |     | dBFS             |
|  |        | 22Hz to 22kHz<br>AVDD1=AVDD2=2.5V     |     | 93.5      |     | dBFS             |
| Total Harmonic Distortion <sup>4</sup>   | THD    | full-scale signal<br>AVDD1=AVDD2=3.3V |     | -84       |     | dBFS             |
|  |        | full-scale signal<br>AVDD1=AVDD2=2.5V |     | -82       |     | dBFS             |
| Total Harmonic Distortion + Noise <sup>5</sup>   | THD+N  | full-scale signal<br>AVDD1=AVDD2=3.3V |     | -82       |     | dBFS             |
|  |        | full-scale signal<br>AVDD1=AVDD2=2.5V |     | -80       |     | dBFS             |
| Channel Separation <sup>6</sup>  |        |                                       |     | 100       |     | dB               |
| <b>LIN and RIN into input PGA Bypass to LOUT1 and ROUT1 into 10kΩ / 50pF loads</b>           |        |                                       |     |           |     |                  |
| <b>BYPLMIXVOL, BYPRMIXVOL, LOU1VOL and ROUT1VOL = 0dB</b>                                    |        |                                       |     |           |     |                  |
| Full-scale output voltage, 0dB gain  |        |                                       |     | AVDD1/3.3 |     | V <sub>rms</sub> |
| SIGNAL TO NOISE RATIO <sup>3</sup>   | SNR    | A-weighted<br>AVDD1=AVDD2=3.3V        | 90  | 100       |     | dB               |
|  |        | A-weighted<br>AVDD1=AVDD2=2.5V        |     | 96        |     | dB               |
|  |        | 22Hz to 22kHz<br>AVDD1=AVDD2=3.3V     |     | 95.5      |     | dB               |
|  |        | 22Hz to 22kHz<br>AVDD1=AVDD2=2.5V     |     | 93.5      |     | dB               |
| Total Harmonic Distortion <sup>4</sup>   | THD    | full-scale signal<br>AVDD1=AVDD2=3.3V |     | -87       | -75 | dBFS             |
|  |        | full-scale signal<br>AVDD1=AVDD2=2.5V |     | -69       |     | dBFS             |
| Total Harmonic Distortion + Noise <sup>5</sup>   | THD+N  | full-scale signal<br>AVDD1=AVDD2=3.3V |     | -85       | -73 | dBFS             |
|  |        | full-scale signal<br>AVDD1=AVDD2=2.5V |     | -68       |     | dBFS             |
| Channel separation <sup>6</sup>  |        | 1kHz full scale signal                |     | 100       |     | dB               |

**Test Conditions**

 DCVDD=1.8V, AVDD1=AVDD2=DBVDD=3.3V, T<sub>A</sub> = +25°C, 1kHz signal, fs = 48kHz, 24-bit audio data unless otherwise stated.

| PARAMETER   | SYMBOL          | TEST CONDITIONS   | MIN            | TYP                 | MAX            | UNIT    |
|---|-----------------|---|----------------|---------------------|----------------|---------|
| <b>Speaker Output (LOUT2, ROUT2 with 8Ω bridge tied load, INVROUT2=1)</b> |                 |   |                |                     |                |         |
| Full scale output voltage, 0dB gain. <sup>7</sup>                         |                 | SPKBOOST=0  |                | AVDD2/<br>3.3       |                | Vrms    |
|   |                 | SPKBOOST=1  |                | (AVDD2/<br>3.3)*1.5 |                |         |
| Output Power  | P <sub>O</sub>  | Output power is very closely correlated with THD; see below |                |                     |                |         |
| Total Harmonic Distortion   | THD             | P <sub>O</sub> =200mW, R <sub>L</sub> = 8Ω,<br>AVDD2=3.3V   |                | 0.04<br>-68         |                | %<br>dB |
|   |                 | P <sub>O</sub> =320mW, R <sub>L</sub> = 8Ω,<br>AVDD2=3.3V   |                | 1.0<br>-40          |                | %<br>dB |
|   |                 | P <sub>O</sub> =500mW, R <sub>L</sub> = 8Ω,<br>AVDD2=5V     |                | 0.02<br>-74         |                | %<br>dB |
|   |                 | P <sub>O</sub> =860mW, R <sub>L</sub> = 8Ω,<br>AVDD2=5V     |                | 1.0<br>-40          |                | %<br>dB |
| Signal to Noise Ratio   | SNR             | AVDD2=3.3V,<br>R <sub>L</sub> = 8Ω                          |                | 90                  |                | dB      |
|   |                 | AVDD2=5V,<br>R <sub>L</sub> = 8Ω                            |                | 90                  |                | dB      |
| Power Supply Rejection Ratio<br>(50Hz-22kHz)                              | PSRR            | R <sub>L</sub> = 8Ω BTL                                     |                | 80                  |                | dB      |
|   |                 | R <sub>L</sub> = 8Ω BTL AVDD2=5V<br>(boost)                 |                | 69                  |                | dB      |
| <b>Microphone Bias</b>  |                 |   |                |                     |                |         |
| Bias Voltage  |                 | MBVSEL=0  |                | 0.9 x<br>AVDD1      |                | V       |
|   |                 | MBVSEL=1  |                | 0.65 x<br>AVDD1     |                | V       |
| Bias Current Source   |                 | for V <sub>MICBIAS</sub> within +/-3%                       |                |                     | 3              | mA      |
| Output Noise Voltage  |                 | 1kHz to 20kHz   |                | 15                  |                | nV/√Hz  |
| <b>Digital Input / Output</b>   |                 |   |                |                     |                |         |
| Input HIGH Level  | V <sub>IH</sub> |   | 0.7 x<br>DBVDD |                     |                | V       |
| Input LOW Level   | V <sub>IL</sub> |   |                |                     | 0.3 x<br>DBVDD | V       |
| Output HIGH Level   | V <sub>OH</sub> | I <sub>OL</sub> =1mA  | 0.9 x<br>DBVDD |                     |                | V       |
| Output LOW Level  | V <sub>OL</sub> | I <sub>OH</sub> =1mA  |                |                     | 0.1 x<br>DBVDD | V       |
| Input Capacitance   |                 | All digital pins  |                | 10                  |                | pF      |

## TERMINOLOGY

1. Full-scale input and output levels scale in relation to AVDD or AVDD2 depending upon the input or output used. For example, when AVDD = 3.3V, 0dBFS =  $1V_{rms}$  (0dBV). When AVDD < 3.3V the absolute level of 0dBFS will decrease with a linear relationship to AVDD.
2. Input level to RIP and LIP in differential configurations is limited to a maximum of -3dB or performance will be reduced.
3. Signal-to-noise ratio (dBFS) – SNR is the difference in level between a reference full scale output signal and the device output with no signal applied. This ratio is also called idle channel noise. (No Auto-zero or Automute function is employed in achieving these results).
4. Total Harmonic Distortion (dBFS) – THD is the difference in level between a reference full scale output signal and the first seven odd harmonics of the output signal. To calculate the ratio, the fundamental frequency of the output signal is notched out and an RMS value of the next seven harmonics is calculated.
5. Total Harmonic Distortion plus Noise (dBFS) – THD+N is the difference in level between a reference full scale output signal and the sum of the harmonics, wide-band noise and interference on the output signal. To calculate the ratio, the fundamental frequency of the output signal is notched out and an RMS value of the total harmonics, wide-band noise and interference is calculated.
6. 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.
7. The maximum output voltage can be limited by the speaker power supply. If SPKBOOST is set, then AVDD2 should be  $1.5 \times AVDD$  to prevent clipping taking place in the output stage (when PGA gains are set to 0dB).

## TYPICAL PERFORMANCE

### SPEAKER OUTPUT THD VERSUS POWER

Audio Precision

WM8983 THD+N vs. Output Power -- SPKVDD=3.6V

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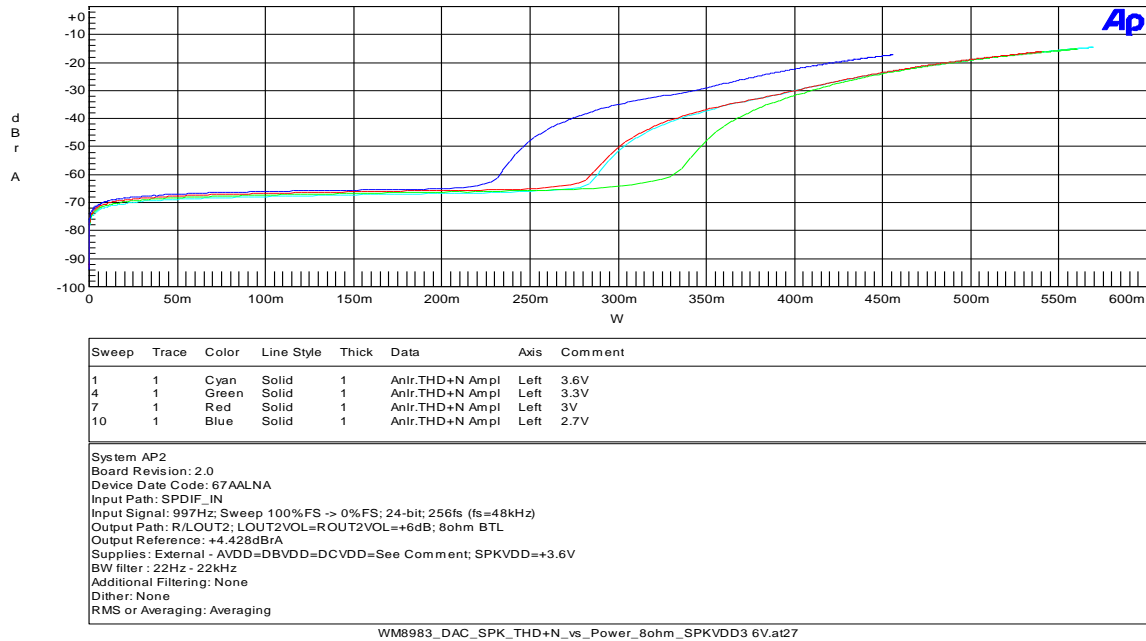


Figure 1 Speaker THD+N vs Output Power (Boost Disabled: SPKVDD=3.6V; SPKBOOST=0; AVDD Range =3.6-2.7V)

Audio Precision

WM8983 THD+N vs. Output Power -- SPKVDD=4.2V

08/29/06 12:57:21

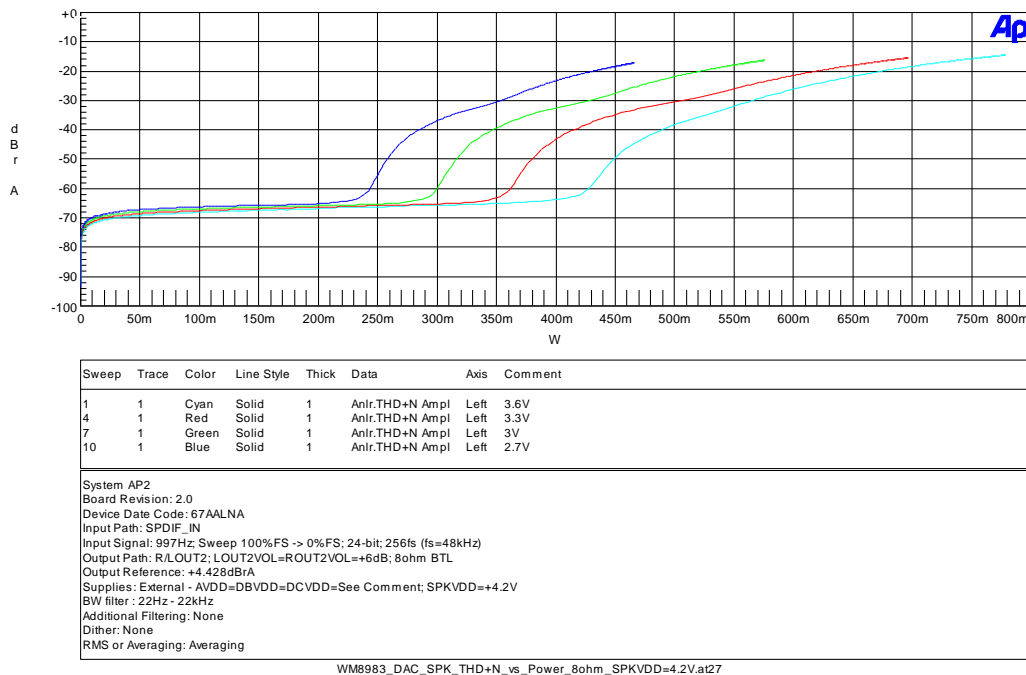
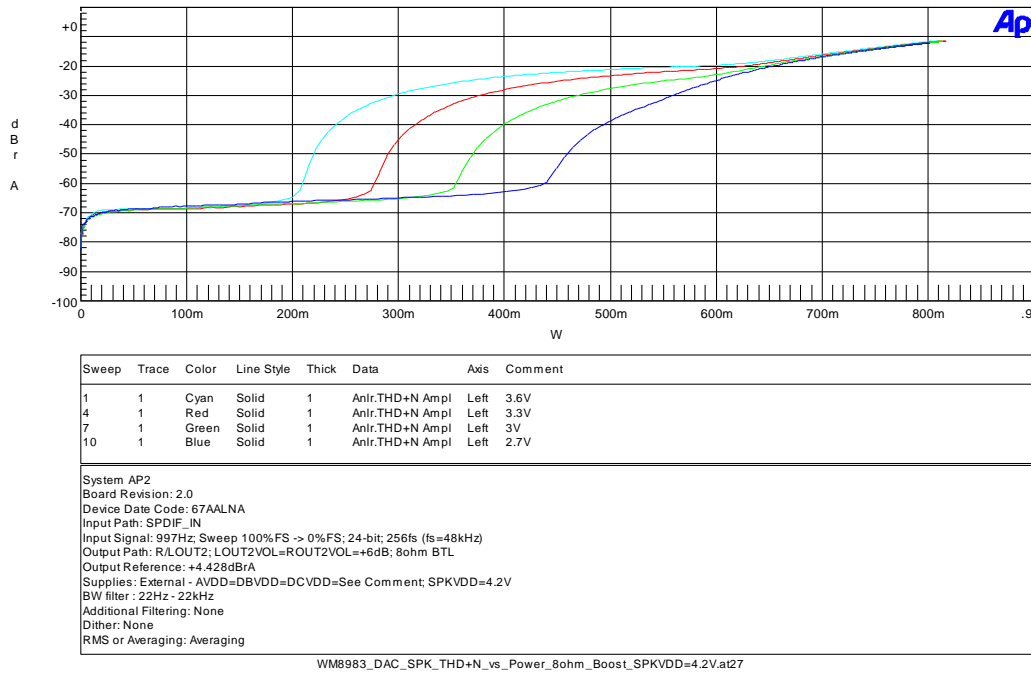
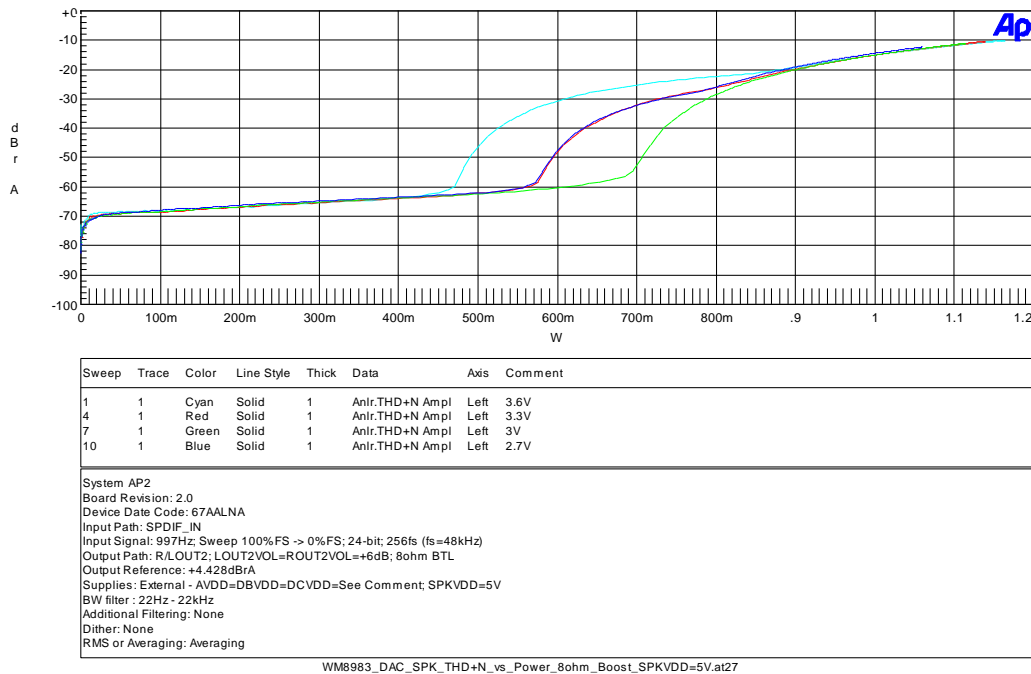


Figure 2 Speaker THD+N vs Output Power (Boost Disabled: SPKVDD=4.2V; SPKBOOST=0; AVDD Range =3.6-2.7V)



**Figure 3 Speaker THD+N vs Output Power (Boost Mode: SPKVDD=4.2V; SPKBOOST=1; AVDD Range =3.6-2.7V)**



**Figure 4 Speaker THD+N vs Output Power (Boost Mode: SPKVDD=5V; SPKBOOST=1; AVDD Range =3.6-2.7V)**



**TYPICAL POWER CONSUMPTION**

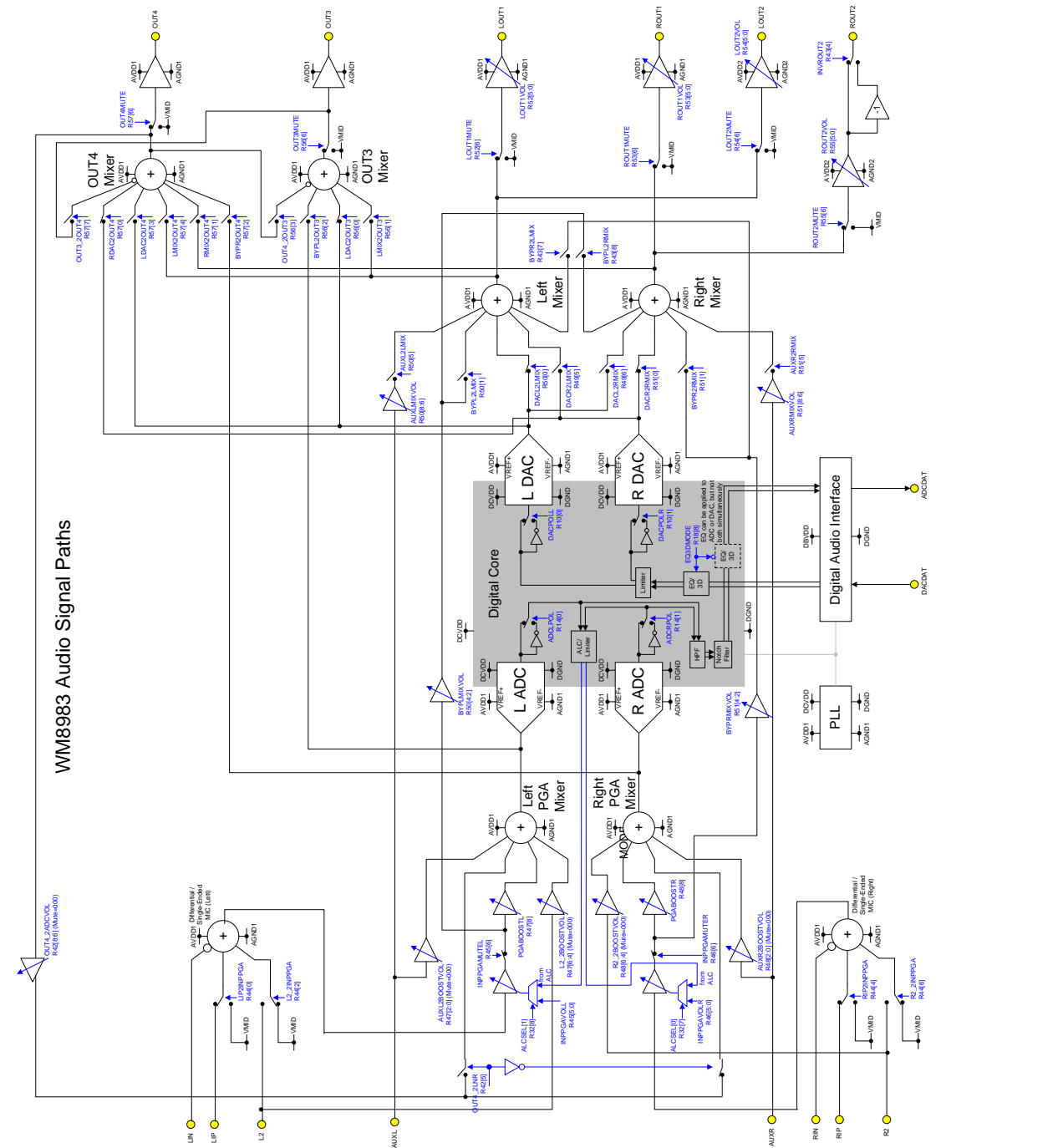
Estimated current consumption for typical scenarios are shown below.

Power delivered to the load is not included.

| <b>MODE</b>   | <b>I<sub>AVDD1</sub> mA<br/>(3.3V)</b> | <b>I<sub>AVDD2</sub> mA<br/>(3.3V)</b> | <b>I<sub>DCVDD</sub> mA<br/>(1.8V)</b> | <b>I<sub>DBVDD</sub> mA<br/>(1.8V)</b> | <b>TOTAL<br/>mW</b> |
|---|--|--|--|--|---------------------|
| Off (No clocks, temperature sensor disabled)          | 0.010                                  | 0.010                                  | 0.001                                  | 0.002                                  | 0.071               |
| Sleep (VREF maintained)                               | 0.100                                  | 0.001                                  | 0.012                                  | 0.003                                  | 0.360               |
| Mono Record from Differential MIC (8kHz, PLL enabled) | 4.000                                  | 0.001                                  | 0.400                                  | 0.030                                  | 13.97               |
| Stereo HP Playback (44.1kHz, PLL enabled)             | 3.700                                  | 0.950                                  | 2.100                                  | 0.100                                  | 19.31               |

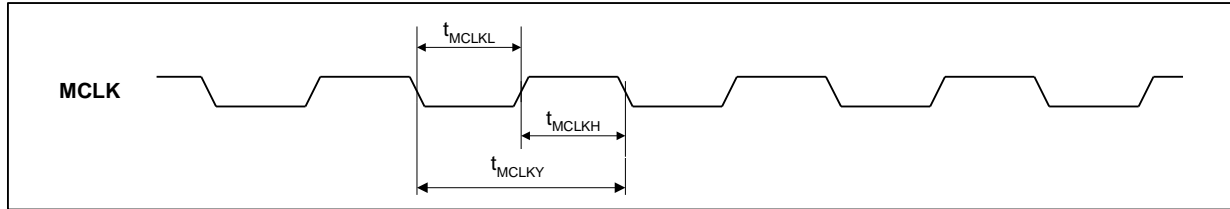
**Table 1 Power Consumption**

## AUDIO PATHS OVERVIEW



## SIGNAL TIMING REQUIREMENTS

### SYSTEM CLOCK TIMING



**Figure 5 System Clock Timing Requirements**

**Test Conditions**

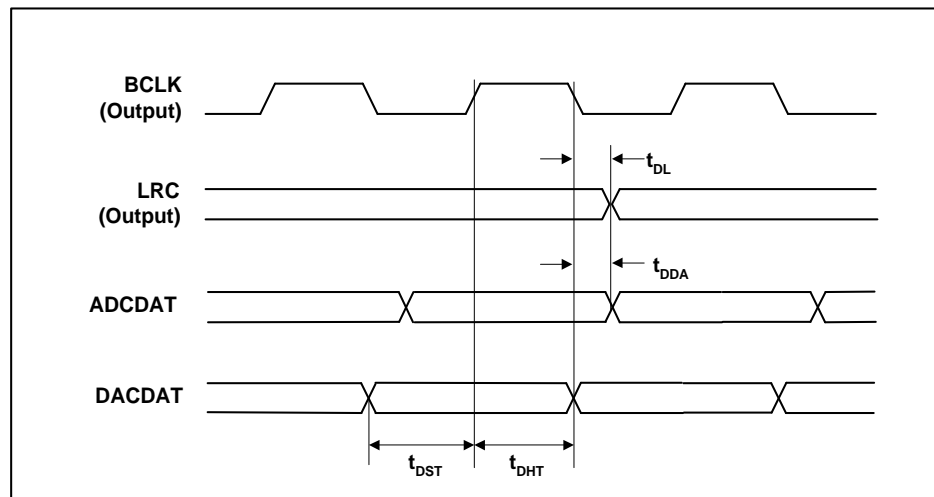
DCVDD=1.8V, DBVDD=AVDD1=AVDD2=3.3V, DGND=AGND1=AGND2=0V, T<sub>A</sub> = +25°C, Slave Mode

| PARAMETER                              | SYMBOL              | CONDITIONS                          | MIN   | TYP | MAX   | UNIT |
|--|---------------------|-------------------------------------|-------|-----|-------|------|
| <b>System Clock Timing Information</b> |                     |                                     |       |     |       |      |
| MCLK cycle time                        | T <sub>MCLKY</sub>  | MCLK=SYSCLK (=256fs)                | 81.38 |     |       | ns   |
|  |                     | MCLK input to PLL <sup>Note 1</sup> | 20    |     |       | ns   |
| MCLK duty cycle                        | T <sub>MCLKDS</sub> |                                     | 60:40 |     | 40:60 |      |

**Note:**

1. PLL pre-scaling and PLL N and K values should be set appropriately so that SYSCLK is no greater than 12.288MHz.

### AUDIO INTERFACE TIMING – MASTER MODE

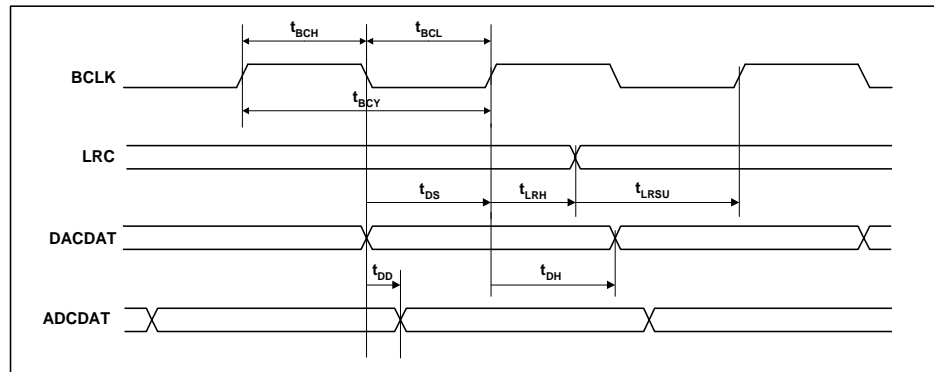


**Figure 6 Digital Audio Data Timing – Master Mode (see Control Interface)**

**Test Conditions**

DCVDD=1.8V, DBVDD=AVDD1=AVDD2=3.3V, DGND=AGND1=AGND2=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>      |                  |     |     |     |      |
| LRC propagation delay from BCLK falling edge    | t <sub>DL</sub>  |     |     | 10  | ns   |
| ADCDAT propagation delay from BCLK falling edge | t <sub>DDA</sub> |     |     | 25  | ns   |
| DACDAT setup time to BCLK rising edge           | t <sub>DST</sub> | 10  |     |     | ns   |
| DACDAT hold time from BCLK rising edge          | t <sub>DHT</sub> | 10  |     |     | ns   |

**AUDIO INTERFACE TIMING – SLAVE MODE**

**Figure 7 Digital Audio Data Timing – Slave Mode**
**Test Conditions**

DCVDD=1.8V, DBVDD=AVDD1=AVDD2=3.3V, DGND=AGND1=AGND2=0V, T<sub>A</sub>=+25°C, Slave Mode, fs=48kHz, MCLK= 256fs, 24-bit data, unless otherwise stated.

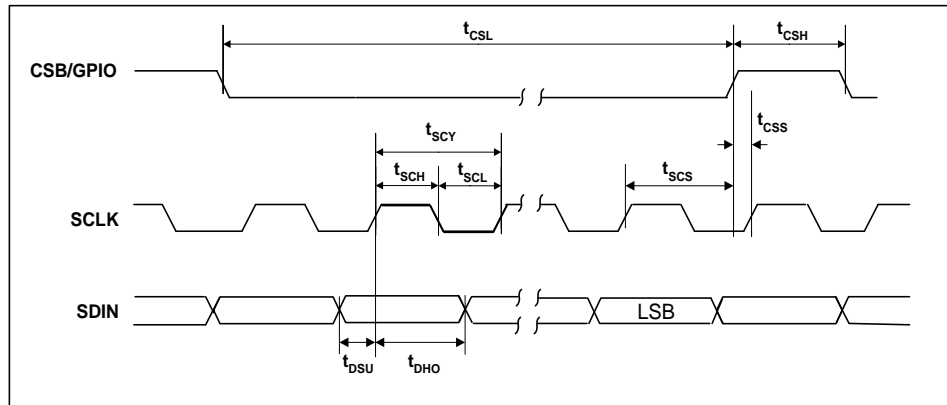
| PARAMETER                                       | SYMBOL            | MIN | TYP | MAX | UNIT |
|---|-------------------|-----|-----|-----|------|
| <b>Audio Data Input Timing Information</b>      |                   |     |     |     |      |
| BCLK cycle time                                 | t <sub>BCY</sub>  | 50  |     |     | ns   |
| BCLK pulse width high                           | t <sub>BCH</sub>  | 20  |     |     | ns   |
| BCLK pulse width low                            | t <sub>BCL</sub>  | 20  |     |     | ns   |
| LRC set-up time to BCLK rising edge             | t <sub>LRSU</sub> | 10  |     |     | ns   |
| LRC hold time from BCLK rising edge             | t <sub>LRH</sub>  | 10  |     |     | ns   |
| DACDAT hold time from BCLK rising edge          | t <sub>DH</sub>   | 10  |     |     | ns   |
| DACDAT set-up time to BCLK rising edge          | t <sub>DS</sub>   | 10  |     |     | ns   |
| ADCDAT propagation delay from BCLK falling edge | t <sub>DD</sub>   |     |     | 25  | ns   |

**Note:**

BCLK period should always be greater than or equal to MCLK period.

**CONTROL INTERFACE TIMING – 3-WIRE MODE**

3-wire mode is selected by connecting the MODE pin high.



**Figure 8 Control Interface Timing – 3-Wire Serial Control Mode**

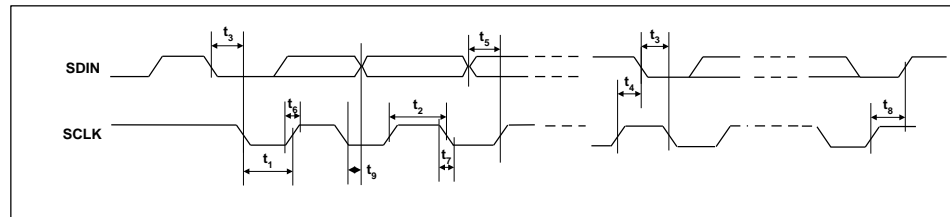
**Test Conditions**

DCVDD=1.8V, DBVDD=AVDD1=AVDD2=3.3V, DGND=AGND1=AGND2=0V,  $T_A=+25^\circ\text{C}$ , Slave Mode,  $f_s=48\text{kHz}$ , MCLK=256fs, 24-bit data, unless otherwise stated.

| PARAMETER                                     | SYMBOL    | MIN | TYP | MAX | UNIT |
|---|-----------|-----|-----|-----|------|
| <b>Program Register Input Information</b>     |           |     |     |     |      |
| SCLK rising edge to CSB rising edge           | $t_{SCS}$ | 80  |     |     | ns   |
| SCLK pulse cycle time                         | $t_{SCY}$ | 200 |     |     | ns   |
| SCLK pulse width low                          | $t_{SCL}$ | 80  |     |     | ns   |
| SCLK pulse width high                         | $t_{SCH}$ | 80  |     |     | ns   |
| SDIN to SCLK set-up time                      | $t_{DSU}$ | 40  |     |     | ns   |
| SCLK to SDIN hold time                        | $t_{DHO}$ | 40  |     |     | ns   |
| CSB pulse width low                           | $t_{CSL}$ | 40  |     |     | ns   |
| CSB pulse width high                          | $t_{CSH}$ | 40  |     |     | ns   |
| CSB rising to SCLK rising                     | $t_{CSS}$ | 40  |     |     | ns   |
| Pulse width of spikes that will be suppressed | $t_{ps}$  | 0   |     | 5   | ns   |

**CONTROL INTERFACE TIMING – 2-WIRE MODE**

2-wire mode is selected by connecting the MODE pin low.

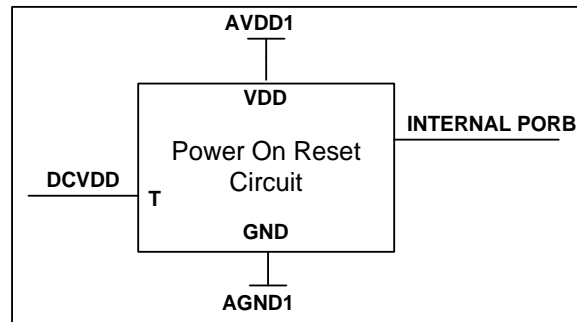


**Figure 9 Control Interface Timing – 2-Wire Serial Control Mode**

**Test Conditions**

DCVDD=1.8V, DBVDD=AVDD1=AVDD2=3.3V, DGND=AGND1=AGND2=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>Program Register Input Information</b>     |                 |     |     |     |      |
| SCLK Frequency                                |                 | 0   |     | 526 | kHz  |
| SCLK Low Pulse-Width                          | t <sub>1</sub>  | 1.3 |     |     | us   |
| SCLK High Pulse-Width                         | t <sub>2</sub>  | 600 |     |     | ns   |
| Hold Time (Start Condition)                   | t <sub>3</sub>  | 600 |     |     | ns   |
| Setup Time (Start Condition)                  | t <sub>4</sub>  | 600 |     |     | ns   |
| Data Setup Time                               | t <sub>5</sub>  | 100 |     |     | ns   |
| SDIN, SCLK Rise Time                          | t <sub>6</sub>  |     |     | 300 | ns   |
| SDIN, SCLK Fall Time                          | t <sub>7</sub>  |     |     | 300 | ns   |
| Setup Time (Stop Condition)                   | t <sub>8</sub>  | 600 |     |     | ns   |
| Data Hold Time                                | t <sub>9</sub>  |     |     | 900 | ns   |
| Pulse width of spikes that will be suppressed | t <sub>ps</sub> | 0   |     | 5   | ns   |

**INTERNAL POWER ON RESET CIRCUIT**

**Figure 10 Internal Power on Reset Circuit Schematic**

The WM8983 includes an internal Power-On-Reset Circuit, as shown in Figure 10, which is used to reset the digital logic into a default state after power up. The POR circuit is powered from AVDD1 and monitors DCVDD. It asserts PORB low if AVDD1 or DCVDD is below a minimum threshold.

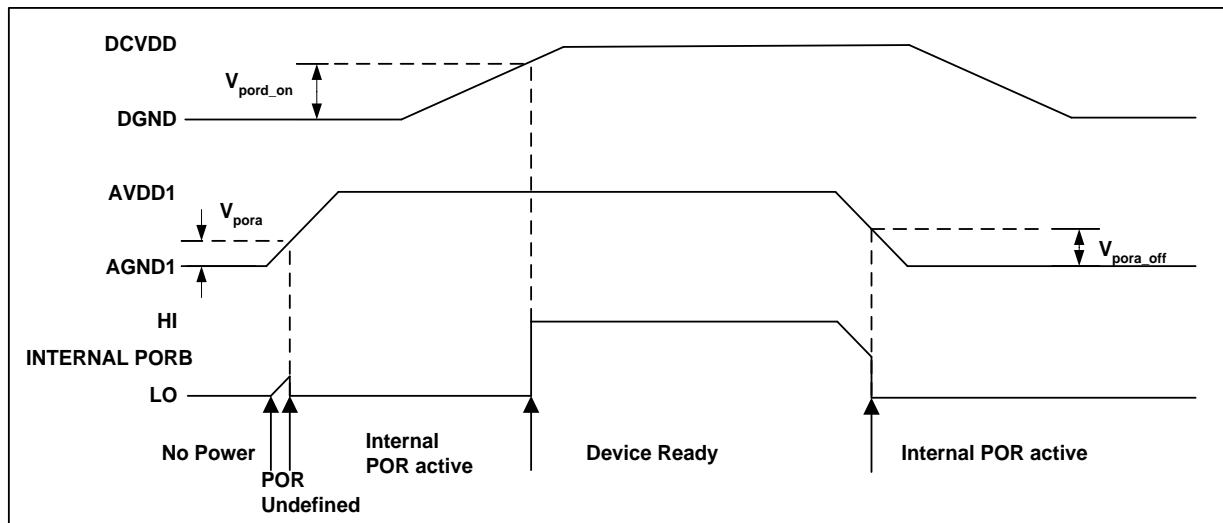
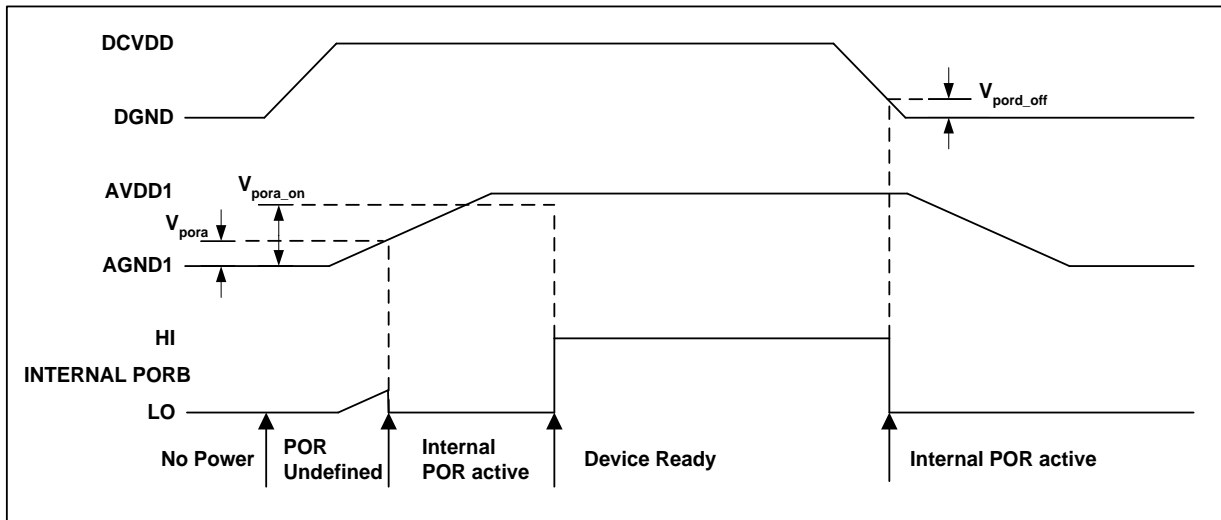

**Figure 11 Typical Power up Sequence where AVDD1 is powered before DCVDD**

Figure 11 shows a typical power-up sequence where AVDD1 comes up first. When AVDD1 goes above the minimum threshold,  $V_{pora}$ , there is enough voltage for the circuit to guarantee PORB is asserted low and the chip is held in reset. In this condition, all writes to the control interface are ignored. Now AVDD1 is at full supply level. Next DCVDD rises to  $V_{pord\_on}$  and PORB is released high and all registers are in their default state and writes to the control interface may take place.

On power down, where AVDD1 falls first, PORB is asserted low whenever AVDD1 drops below the minimum threshold  $V_{pora\_off}$ .



**Figure 12 Typical Power up Sequence where DCVDD is Powered before AVDD1**

Figure 12 shows a typical power-up sequence where DCVDD comes up first. First it is assumed that DCVDD is already up to specified operating voltage. When AVDD1 goes above the minimum threshold,  $V_{pora}$ , there is enough voltage for the circuit to guarantee PORB is asserted low and the chip is held in reset. In this condition, all writes to the control interface are ignored. When AVDD1 rises to  $V_{pora\_on}$ , PORB is released high and all registers are in their default state and writes to the control interface may take place.

On power down, where DCVDD falls first, PORB is asserted low whenever DCVDD drops below the minimum threshold  $V_{pord\_off}$ .

| SYMBOL          | MIN | TYP | MAX | UNIT |
|-----------------|-----|-----|-----|------|
| $V_{pora}$      | 0.4 | 0.6 | 0.8 | V    |
| $V_{pora\_on}$  | 0.9 | 1.2 | 1.6 | V    |
| $V_{pora\_off}$ | 0.4 | 0.6 | 0.8 | V    |
| $V_{pord\_on}$  | 0.5 | 0.7 | 0.9 | V    |
| $V_{pord\_off}$ | 0.4 | 0.6 | 0.8 | V    |

**Table 2 Typical POR Operation (Typical Simulated Values)**

**Notes:**

1. If AVDD1 and DCVDD suffer a brown-out (i.e. drop below the minimum recommended operating level but do not go below  $V_{pora\_off}$  or  $V_{pord\_off}$ ), then the chip will not reset and will resume normal operation when the voltage is back to the recommended level again.
2. The chip will enter reset at power down when AVDD1 or DCVDD falls below  $V_{pora\_off}$  or  $V_{pord\_off}$ . This may be important if the supply is turned on and off frequently by a power management system.
3. The minimum  $t_{por}$  period is maintained even if DCVDD and AVDD1 have zero rise time. This specification is guaranteed by design rather than test.



## RECOMMENDED CONTROL SEQUENCES

### POWER UP/DOWN SEQUENCE

In order to minimise output pop and click noise, it is recommended that the WM8983 device is powered up and down under control using the following sequences:

#### Power Up:

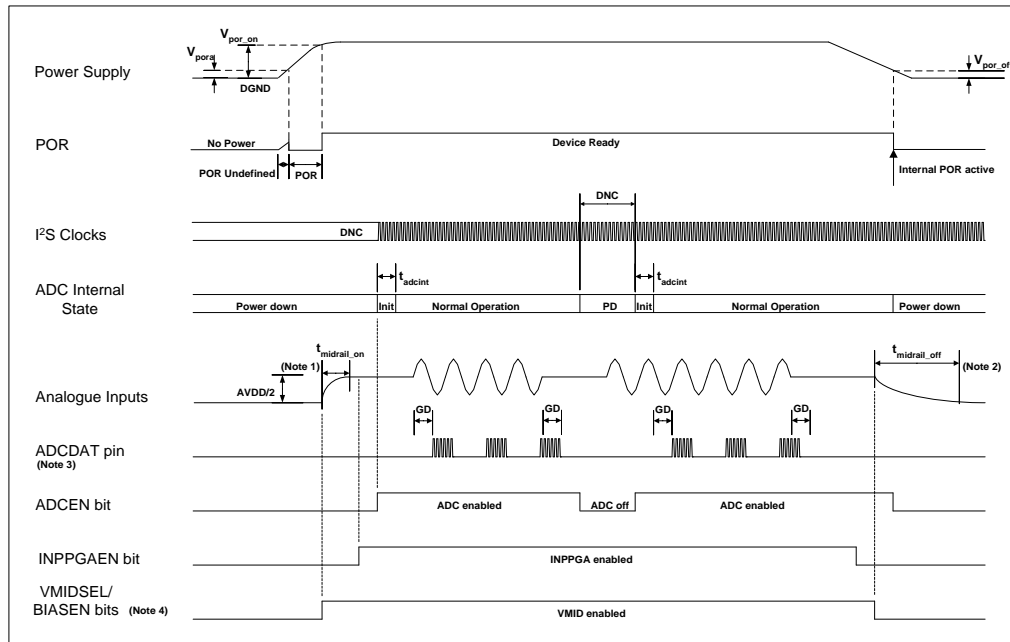
- Turn on external power supplies. Wait for supply voltage to settle.
- Set low bias mode, BIASCUT = 1.
- Mute all Outputs and set PGAs to minimum gain, R52 to R57 = 0x140h.
- Enable VMID independent current bias, POBCTRL = 1, DELEN = 1.
- Enable required outputs, DACs and mixers.
- Enable analogue bias, BIASEN, and VMID with required charge time e.g. VMIDSEL=01 = 100kΩ.
- Setup digital interface, input amplifiers, PLL, ADCs and DACs for desired operation.
- Unmute L/ROUT1 and set desired volume, e.g. for 0dB R52 and R53 = 0x139h.
- Unmute L/ROUT2 and set desired volume, e.g. for 0dB R54 and R55 = 0x139h.
- Disable VMID independent current bias, POBCTRL = 0, DELEN = 0.

#### Power Down:

- Disable Thermal shutdown
- Disable VMIDSEL=00 and BIASEN=0
- Wait for VMID to discharge
- Power off registers R1, R2, R3 = 0x000h
- Remove external power supplies

#### Note:

Charging time constant is determined by impedance selected by VMIDSEL and the value of decoupling capacitor connected to VMID pin.



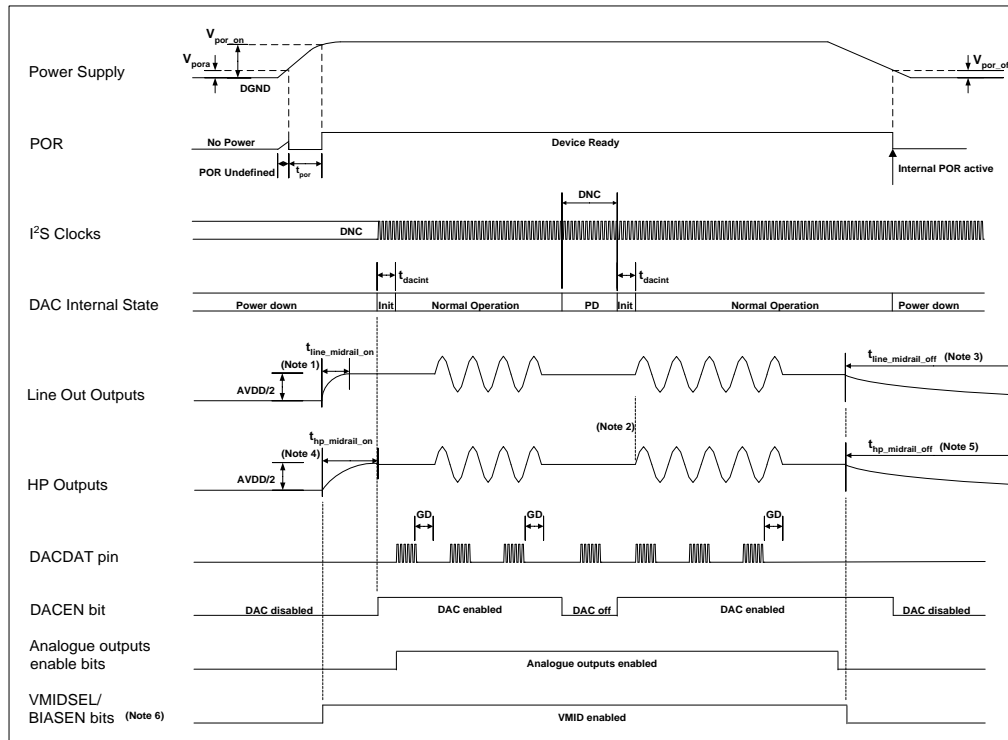
**Figure 13 ADC Power Up and Down Sequence (not to scale)**

| SYMBOL                    | MIN | TYPICAL | MAX | UNIT |
|---------------------------|-----|---------|-----|------|
| $t_{\text{midrail\_on}}$  |     | 300     |     | ms   |
| $t_{\text{midrail\_off}}$ |     | >6      |     | s    |
| $t_{\text{adcint}}$       |     | 2/fs    |     | s    |
| ADC Group Delay           |     | 29/fs   |     | s    |

**Table 3 Typical POR Operation (typical simulated values)**

**Notes:**

1. The analogue input pin charge time,  $t_{\text{midrail\_on}}$ , is determined by the VMID pin charge time. This time is dependent upon the value of VMID decoupling capacitor and VMID pin input resistance and AVDD power supply rise time.
2. The analogue input pin discharge time,  $t_{\text{midrail\_off}}$ , is determined by the analogue input coupling capacitor discharge time. The time,  $t_{\text{midrail\_off}}$ , is measured using a 1 $\mu$ F capacitor on the analogue input but will vary dependent upon the value of input coupling capacitor.
3. While the ADC is enabled, there will be LSB data bit activity on the ADCDAT pin due to system noise, but no significant digital output will be present.
4. The VMIDSEL and BIASEN bits must be set to enable analogue input midrail voltage and for normal ADC operation.
5. ADCDAT data output delay from power up – with power supplies starting from 0V – is determined primarily by the VMID charge time. ADC initialisation and power management bits may be set immediately after POR is released; VMID charge time will be significantly longer and will dictate when the device is stabilised for analogue input.
6. ADCDAT data output delay at power up from device standby (power supplies already applied) is determined by ADC initialisation time, 2/fs.



**Figure 14 DAC Power Up and Down Sequence (not to scale)**

| SYMBOL                   | MIN | TYPICAL | MAX | UNIT |
|--------------------------|-----|---------|-----|------|
| $t_{line\_midrail\_on}$  |     | 300     |     | ms   |
| $t_{line\_midrail\_off}$ |     | >6      |     | s    |
| $t_{hp\_midrail\_on}$    |     | 300     |     | ms   |
| $t_{hp\_midrail\_off}$   |     | >6      |     | s    |
| $t_{dacint}$             |     | 2/fs    |     | s    |
| DAC Group Delay          |     | 29/fs   |     | s    |

**Table 4 Typical POR Operation (typical simulated values)**

**Notes:**

1. The lineout charge time,  $t_{line\_midrail\_on}$ , is determined by the VMID pin charge time. This time is dependent upon the value of VMID decoupling capacitor and VMID pin input resistance and AVDD power supply rise time. The values above were measured using a 4.7µF capacitor.
2. It is not advisable to allow DACDAT data input during initialisation of the DAC. If the DAC data value is not zero at point of initialisation, then this is likely to cause a pop noise on the analogue outputs. The same is also true if the DACDAT is removed at a non-zero value, and no mute function has been applied to the signal beforehand.
3. The lineout discharge time,  $t_{line\_midrail\_off}$ , is determined by the VMID pin discharge time. This time is dependent upon the value of VMID decoupling capacitor and VMID pin input resistance. The values above were measured using a 4.7µF capacitor.
4. The headphone charge time,  $t_{hp\_midrail\_on}$ , is dependent upon the value of VMID decoupling capacitor and VMID pin input resistance and AVDD power supply rise time. The values above were measured using a 4.7µF VMID decoupling capacitor.
5. The headphone discharge time,  $t_{hp\_midrail\_off}$ , is dependent upon the value of VMID decoupling capacitor and VMID pin input resistance. The values above were measured using a 4.7µF VMID decoupling capacitor.
6. The VMIDSEL and BIASSEN bits must be set to enable analogue output midrail voltage and for normal DAC operation.

## LOUT1/ROUT1 ENABLE SEQUENCE

In order to minimise click noise, it is recommended that the WM8983 headphone outputs are enabled using the following sequence:

- Activate dual enable function DELEN = 1 (R42).
- Enable L/ROUT1 amplifier core, LOUT1EN = 1, ROUT1EN = 1 (R2).
- Enable output FETs, OUT1DEL = 1 (R42).
- Disable DELEN = 0.
- Reset OUT1DEL = 0.

### Notes:

All outputs on WM8983 can also be enabled with a single write to enable bits in registers 2 and 3 without click minimisation. Disabling outputs does not require click minimisation.

## DEVICE DESCRIPTION

### INTRODUCTION

The WM8983 is a low power audio CODEC combining a high quality stereo audio DAC and ADC, with flexible line and microphone input and output processing.

### FEATURES

The chip offers great flexibility in use, and so can support many different modes of operation as follows:

### MICROPHONE INPUTS

Two pairs of stereo microphone inputs are provided, allowing a pair of stereo microphones to be pseudo-differentially connected, with user defined gain. The provision of the common mode input pin for each stereo input allows for rejection of common mode noise on the microphone inputs (level depends on gain setting chosen). A microphone bias is output from the chip which can be used to bias both microphones. The signal routing can be configured to allow manual adjustment of mic levels, or to allow the ALC loop to control the level of mic signal that is transmitted.

Total gain through the microphone paths of up to +55.25dB can be selected.

### PGA AND ALC OPERATION

A programmable gain amplifier is provided in the input path to the ADC. This may be used manually or in conjunction with a mixed analogue/digital automatic level control (ALC) which keeps the recording volume constant.

### LINE INPUTS (AUXL, AUXR)

AUXL and AUXR, can be used as a stereo line input or as an input for warning tones (or 'beeps') etc. These inputs can be summed into the record paths, along with the microphone preamp outputs, so allowing for mixing of audio with 'backing music' etc as required.

### ADC

The stereo ADC uses a 24-bit high-order oversampling architecture to deliver optimum performance with low power consumption.

### HI-FI DAC

The hi-fi DAC provides high quality audio playback suitable for all portable audio hi-fi type applications, including MP3 players, portable multimedia devices and portable disc players of all types.

### OUTPUT MIXERS

Flexible mixing is provided on the outputs of the device. A stereo mixer is provided for the stereo headphone or line outputs, LOUT1/ROUT1, and additional summers on the OUT3/OUT4 outputs allow for an optional differential or stereo line output on these pins. Gain adjustment PGAs are provided for the LOUT1/ROUT1 and LOUT2/ROUT2 outputs, and signal switching is provided to allow for all possible signal combinations.

OUT3 and OUT4 can be configured to provide an additional stereo or mono differential lineout from the output of the DACs, the mixers or the input microphone boost stages. They can also provide a midrail reference for pseudo differential inputs to external amplifiers.

### **AUDIO INTERFACES**

The WM8983 has a standard audio interface to support the transmission of stereo data to and from the chip. This interface is a 3 wire standard audio interface which supports a number of audio data formats including:

- I<sup>2</sup>S
- DSP/PCM Mode (a burst mode in which LRC sync plus 2 data packed words are transmitted)
- MSB-First, left justified
- MSB-First, right justified

The interface can operate in master or slave modes.

### **CONTROL INTERFACES**

To allow full software control over all features, the WM8983 offers a choice of 2 or 3 wire control interface. It is fully compatible and an ideal partner for a wide range of industry standard microprocessors, controllers and DSPs.

Selection of the mode is via the MODE pin. In 2 wire mode, the address of the device is fixed as 0011010.

### **CLOCKING SCHEMES**

WM8983 offers the normal audio DAC clocking scheme operation, where 256fs MCLK is provided to the DAC and ADC.

A PLL is included which may be used to generate these clocks in the event that they are not available from the system controller. This PLL can accept a range of common input clock frequencies between 8MHz and 50MHz to generate high quality audio clocks. If this PLL is not required for generation of these clocks, it can be reconfigured to generate alternative clocks which may then be output on the GPIO pins and used elsewhere in the system.

### **POWER CONTROL**

The design of the WM8983 has given much attention to power consumption without compromising performance. It operates at very low voltages, includes the ability to power off any unused parts of the circuitry under software control, and includes standby and power off modes.

### **AUXILIARY ANALOG INPUT SUPPORT**

Additional stereo analog signals might be connected to the Line inputs of WM8983 (e.g. melody chip or FM radio), and the stereo signal listened to via headphones, or recorded, simultaneously if required.

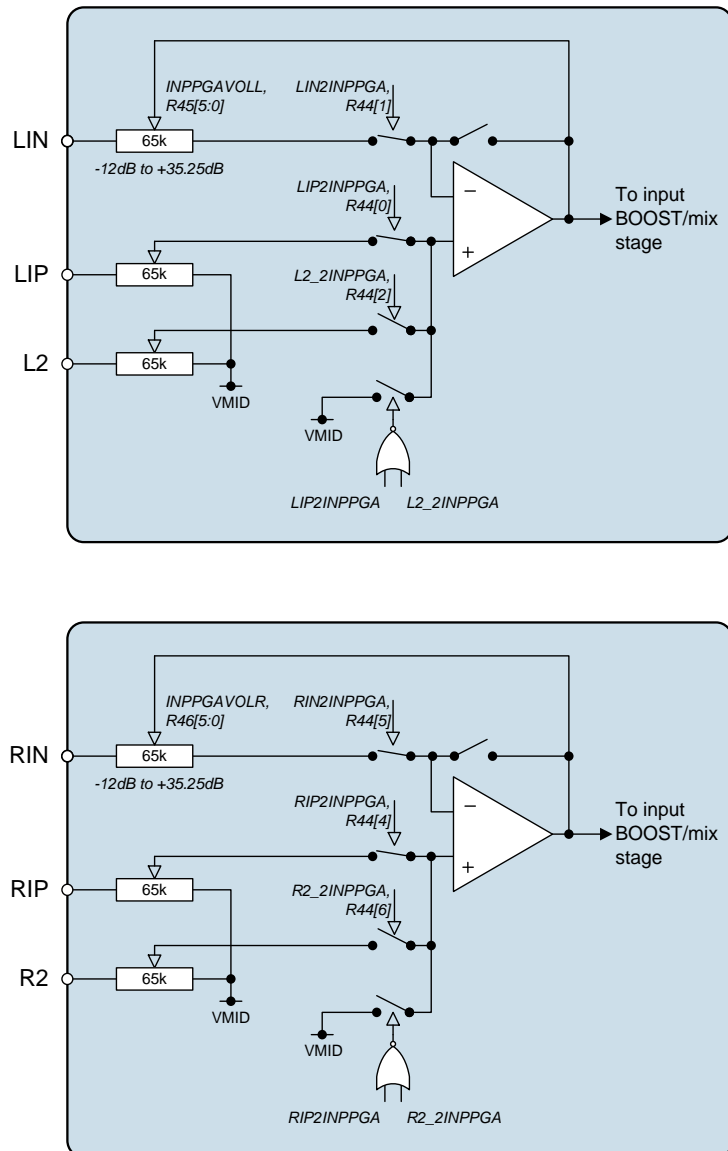
**INPUT SIGNAL PATH**

The WM8983 has a number of flexible analogue inputs. There are two input channels, Left and Right, each of which consists of an input PGA stage followed by a boost/mix stage which drives into the hi-fi ADC. Each input path has three input pins which can be configured in a variety of ways to accommodate single-ended, differential or dual differential microphones. There are two auxiliary input pins which can be fed into to the input boost/mix stage as well as driving into the output path. A bypass path exists from the output of the boost/mix stage into the output left/right mixers.

**MICROPHONE INPUTS**

The WM8983 can accommodate a variety of microphone configurations including single ended and pseudo differential inputs. The inputs to the left pseudo differential input PGA are LIP and L2. The inputs to the right pseudo differential input PGA are RIP and R2. LIN and RIN are used for a.c. coupled ground inputs.

In single-ended microphone input configuration, the microphone signal should be input to LIN or RIN and the non-inverting input of the input PGA clamped to VMID.



**Figure 15 Microphone Input PGA Circuit**

The input PGAs are enabled by the INPPGAENL and INPPGAENR register bits.

| REGISTER ADDRESS         | BIT | LABEL     | DEFAULT | DESCRIPTION   |
|--------------------------|-----|-----------|---------|---|
| R2<br>Power Management 2 | 2   | INPPGAENL | 0       | Left channel input PGA enable<br>0 = disabled<br>1 = enabled  |
|                          | 3   | INPPGAENR | 0       | Right channel input PGA enable<br>0 = disabled<br>1 = enabled |

**Table 5 Input PGA Enable Register Settings**

| REGISTER ADDRESS     | BIT | LABEL      | DEFAULT | DESCRIPTION  |
|----------------------|-----|------------|---------|--|
| R44<br>Input Control | 0   | LIP2INPPGA | 1       | Connect LIP pin to left channel input PGA amplifier positive terminal.<br>0 = LIP not connected to input PGA<br>1 = input PGA amplifier positive terminal connected to LIP (constant input impedance)                |
|                      | 1   | LIN2INPPGA | 1       | Connect LIN pin to left channel input PGA negative terminal.<br>0 = LIN not connected to input PGA<br>1 = LIN connected to input PGA amplifier negative terminal.  |
|                      | 2   | L2_2INPPGA | 0       | Connect L2 pin to left channel input PGA positive terminal.<br>0 = L2 not connected to input PGA<br>1 = L2 connected to input PGA amplifier positive terminal (constant input impedance).                            |
|                      | 4   | RIP2INPPGA | 1       | Connect RIP pin to right channel input PGA amplifier positive terminal.<br>0 = RIP not connected to input PGA<br>1 = right channel input PGA amplifier positive terminal connected to RIP (constant input impedance) |
|                      | 5   | RIN2INPPGA | 1       | Connect RIN pin to right channel input PGA negative terminal.<br>0 = RIN not connected to input PGA<br>1 = RIN connected to right channel input PGA amplifier negative terminal.                                     |
|                      | 6   | R2_2INPPGA | 0       | Connect R2 pin to right channel input PGA positive terminal.<br>0 = R2 not connected to input PGA<br>1 = R2 connected to input PGA amplifier positive terminal (constant input impedance).                           |

**Table 6 Input PGA Control**

### INPUT PGA VOLUME CONTROLS

The input microphone PGAs have a gain range from -12dB to +35.25dB in 0.75dB steps. The gain from the LIN/RIN input to the PGA output and from the L2/R2 amplifier to the PGA output are always common and controlled by the register bits INPPGAVOLL/R[5:0]. These register bits also affect the LIP pin when LIP2INPPGA=1, the L2 pin when L2\_2INPPGA=1, the RIP pin when RIP2INPPGA=1 and the R2 pin when R2\_2INPPGA=1.

When the Automatic Level Control (ALC) is enabled the input PGA gains are controlled automatically



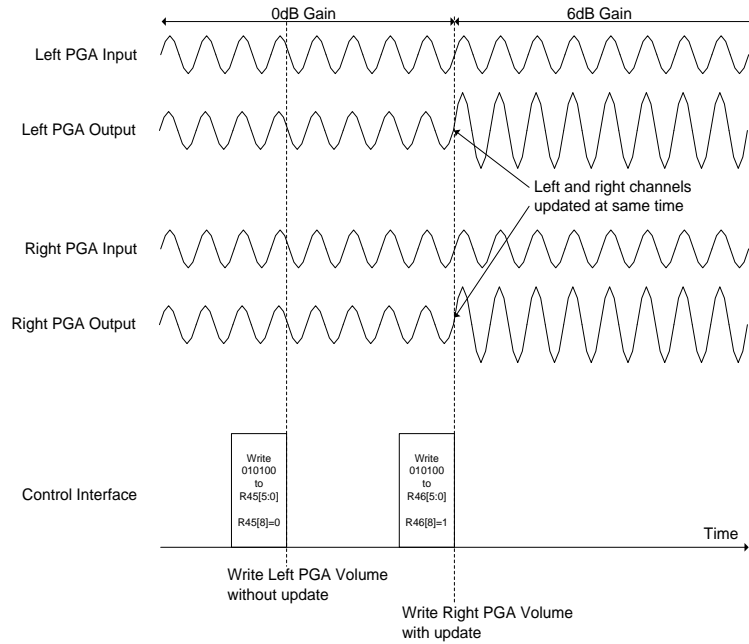
and the INPPGAVOLL/R bits should not be used.

| REGISTER ADDRESS                              | BIT | LABEL       | DEFAULT     | DESCRIPTION  |
|---|-----|-------------|-------------|--|
| R45<br>Left channel input PGA volume control  | 5:0 | INPPGAVOLL  | 010000      | Left channel input PGA volume<br>000000 = -12dB<br>000001 = -11.25dB<br>.<br>010000 = 0dB<br>.<br>111111 = +35.25dB  |
|   | 6   | INPPGAMUTEL | 0           | Mute control for left channel input PGA:<br>0 = Input PGA not muted, normal operation<br>1 = Input PGA muted (and disconnected from the following input BOOST stage).  |
|   | 7   | INPPGAZCL   | 0           | Left channel input PGA zero cross enable:<br>0 = Update gain when gain register changes<br>1 = Update gain on 1 <sup>st</sup> zero cross after gain register write.    |
|   | 8   | INPPGAVU    | Not latched | INPPGA left and INPPGA right volume do not update until a 1 is written to INPPGAVU (in reg 45 or 46)<br>(See "Volume Updates" below)                                   |
| R46<br>Right channel input PGA volume control | 5:0 | INPPGAVOLR  | 010000      | Right channel input PGA volume<br>000000 = -12dB<br>000001 = -11.25db<br>.<br>010000 = 0dB<br>.<br>111111 = +35.25dB   |
|   | 6   | INPPGAMUTER | 0           | Mute control for right channel input PGA:<br>0 = Input PGA not muted, normal operation<br>1 = Input PGA muted (and disconnected from the following input BOOST stage). |
|   | 7   | INPPGAZCR   | 0           | Right channel input PGA zero cross enable:<br>0 = Update gain when gain register changes<br>1 = Update gain on 1 <sup>st</sup> zero cross after gain register write.   |
|   | 8   | INPPGAVU    | Not latched | INPPGA left and INPPGA right volume do not update until a 1 is written to INPPGAVU (in reg 45 or 46)<br>(See "Volume Updates" below)                                   |
| R32<br>ALC control 1                          | 8:7 | ALCSEL      | 00          | ALC function select:<br>00 = ALC disabled<br>01 = Right channel ALC enabled<br>10 = Left channel ALC enabled<br>11 = Both channels ALC enabled                         |

**Table 7 Input PGA Volume Control**

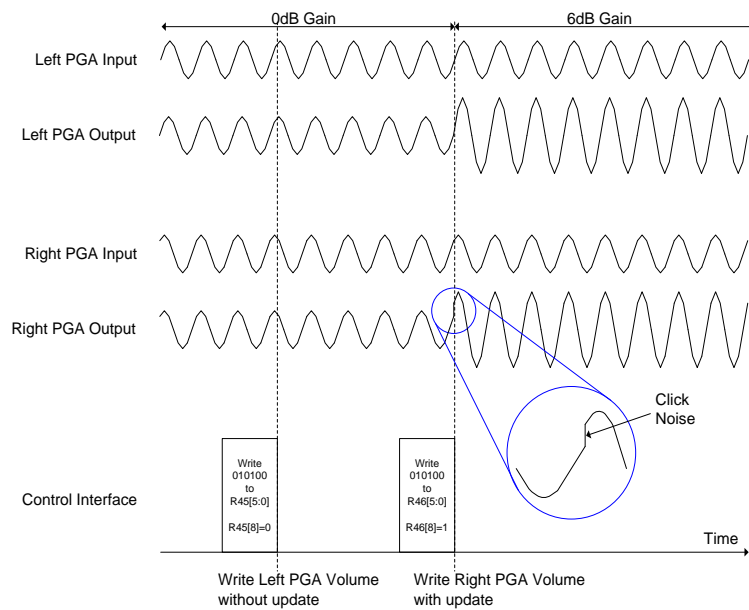
**VOLUME UPDATES**

Volume settings will not be applied to the PGAs until a '1' is written to one of the INPPGAVU bits. This is to allow left and right channels to be updated at the same time, as shown in Figure 16.



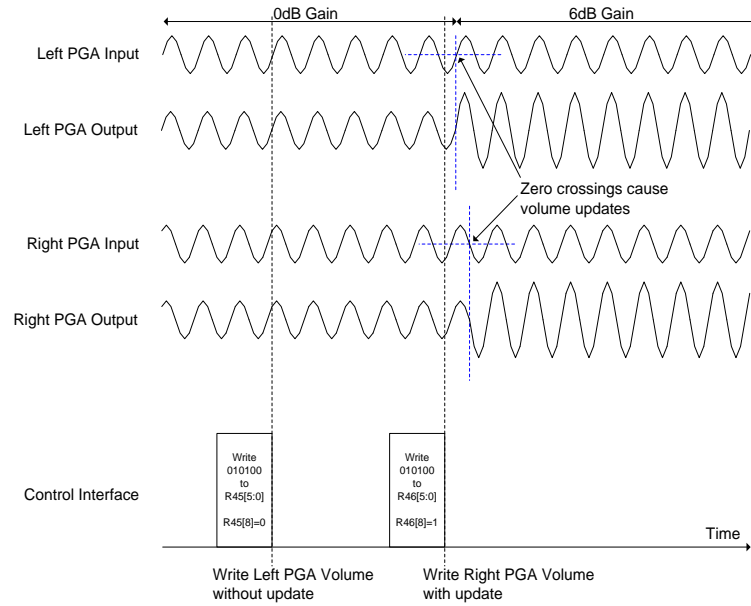
**Figure 16 Simultaneous Left and Right Volume Updates**

If the volume is adjusted while the signal is a non-zero value, an audible click can occur as shown in Figure 17.



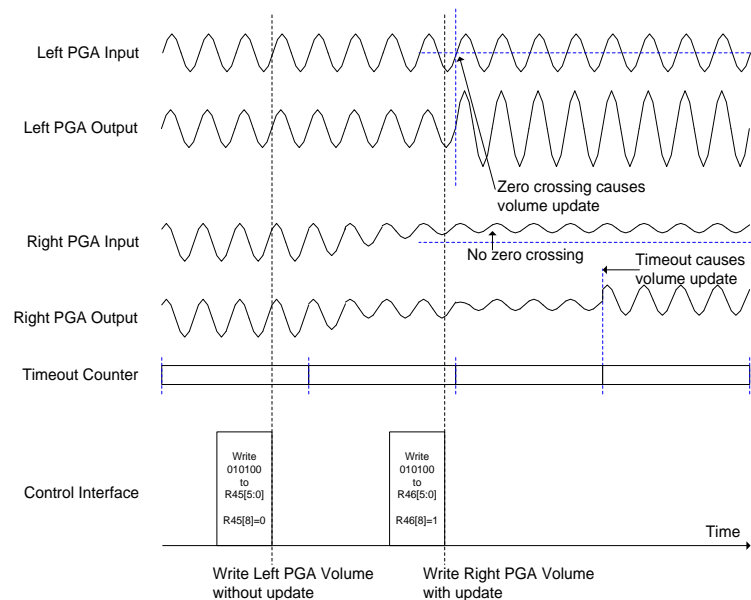
**Figure 17 Click Noise during Volume Update**

In order to prevent this click noise, a zero cross function is provided. When enabled, this will cause the PGA volume to update only when a zero crossing occurs, minimising click noise as shown in Figure 18.



**Figure 18 Volume Update Using Zero Cross Detection**

If there is a long period where no zero-crossing occurs, a timeout circuit in the WM8983 will automatically update the volume. The volume updates will occur between one and two timeout periods, depending on when the INPPGAVU bit is set as shown in Figure 19.



**Figure 19 Volume Update after Timeout**

### AUXILIARY INPUTS

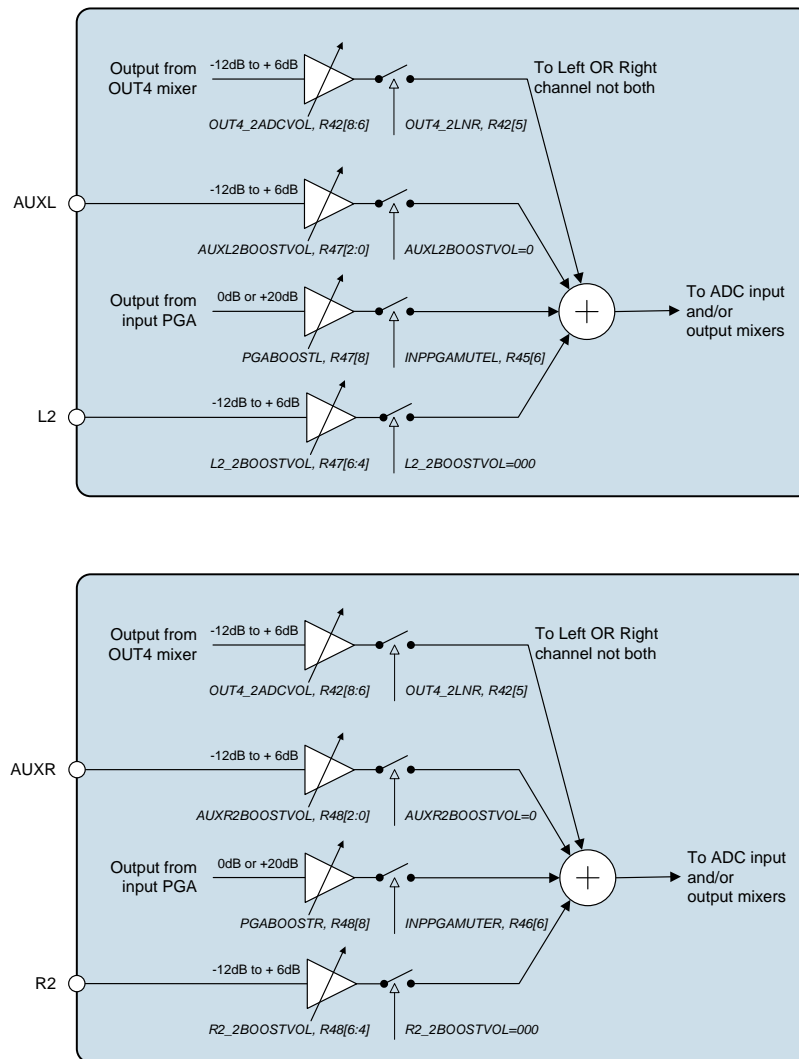
There are two auxiliary inputs, AUXL and AUXR which can be used for a variety of purposes such as stereo line inputs or as a 'beep' input signal to be mixed with the outputs.

As signal inputs, AUXL/R inputs can be used as a line input to the input BOOST stage which has adjustable gain of -12dB to +6dB in 3dB steps, with an additional "off" state (i.e. not connected to ADC input). See the INPUT BOOST section for further details.

The AUXL/R inputs can also be mixed into the output channel mixers, with a gain of -15dB to +6dB plus off.

### INPUT BOOST

Each of the stereo input PGA stages is followed by an input BOOST circuit. The input BOOST circuit has 4 selectable inputs: the input microphone PGA output, the AUX amplifier output and the L2/R2 and AUXL/AUXR input pins (L2/R2 can be used as a line input, bypassing the input PGA). These four inputs can be mixed together and have individual gain boost/adjust as shown in Figure 20.



**Figure 20 Input Boost Stage**

The input PGA paths can have a +20dB boost (PGABOOSTL/R=1) , a 0dB pass through (PGABOOSTL/R=0) or be completely isolated from the input boost circuit (INPPGAMUTEL/R=1).

| REGISTER ADDRESS                 | BIT | LABEL     | DEFAULT | DESCRIPTION  |
|----------------------------------|-----|-----------|---------|--|
| R47<br>Left Input BOOST control  | 8   | PGABOOSTL | 1       | Boost enable for left channel input PGA:<br>0 = PGA output has +0dB gain through input BOOST stage.<br>1 = PGA output has +20dB gain through input BOOST stage.  |
| R48<br>Right Input BOOST control | 8   | PGABOOSTR | 1       | Boost enable for right channel input PGA:<br>0 = PGA output has +0dB gain through input BOOST stage.<br>1 = PGA output has +20dB gain through input BOOST stage. |

**Table 8 Input BOOST Stage Control**

The Auxiliary amplifier path to the BOOST stages is controlled by the AUXL2BOOSTVOL[2:0] and AUXR2BOOSTVOL[2:0] register bits. When AUXL2BOOSTVOL/AUXR2BOOSTVOL=000, this path is completely disconnected from the BOOST stage. Settings 001 through to 111 control the gain in 3dB steps from -12dB to +6dB.

The L2/R2 path to the BOOST stage is controlled by the L2\_2BOOSTVOL[2:0] and the R2\_2BOOSTVOL[2:0] register bits. When L2\_2BOOSTVOL/R2\_2BOOSTVOL=000, the L2/R2 input pin is completely disconnected from the BOOST stage. Settings 001 through to 111 control the gain in 3dB steps from -12dB to +6dB.

The OUT4 mixer path to the BOOST stage is controlled by the OUT4\_2ADCVOL[2:0] and OUT4\_2LNR register bits. The OUT4 mixer signal can be routed to the Left Boost or the Right Boost stage, but not both at the same time. When OUT4\_2ADCVOL=000, the OUT4 mixer path is completely disconnected from the BOOST stage.

| REGISTER ADDRESS   | BIT | LABEL        | DEFAULT | DESCRIPTION   |
|--------------------|-----|--------------|---------|---|
| R42<br>OUT4 to ADC | 8:6 | OUT4_2ADCVOL | 000     | Controls the OUT4 to ADC input boost stage:<br>000 = Path disabled (disconnected)<br>001 = -12dB gain<br>010 = -9dB gain<br>011 = -6dB gain<br>100 = -3dB gain<br>101 = +0dB gain<br>110 = +3dB gain<br>111 = +6dB gain |
|                    | 5   | OUT4_2LNR    | 0       | OUT4 to L or R ADC input<br>0 = Right ADC input<br>1 = Left ADC input   |

| REGISTER ADDRESS                               | BIT | LABEL         | DEFAULT | DESCRIPTION  |
|--|-----|---------------|---------|--|
| R47<br>Left channel<br>Input BOOST<br>control  | 2:0 | AUXL2BOOSTVOL | 000     | Controls the auxiliary amplifier to the left channel input boost stage:<br>000 = Path disabled (disconnected)<br>001 = -12dB gain<br>010 = -9dB gain<br>011 = -6dB gain<br>100 = -3dB gain<br>101 = +0dB gain<br>110 = +3dB gain<br>111 = +6dB gain  |
|  | 6:4 | L2_2BOOSTVOL  | 000     | Controls the L2 pin to the left channel input boost stage:<br>000 = Path disabled (disconnected)<br>001 = -12dB gain<br>010 = -9dB gain<br>011 = -6dB gain<br>100 = -3dB gain<br>101 = +0dB gain<br>110 = +3dB gain<br>111 = +6dB gain               |
| R48<br>Right channel<br>Input BOOST<br>control | 2:0 | AUXR2BOOSTVOL | 000     | Controls the auxiliary amplifier to the right channel input boost stage:<br>000 = Path disabled (disconnected)<br>001 = -12dB gain<br>010 = -9dB gain<br>011 = -6dB gain<br>100 = -3dB gain<br>101 = +0dB gain<br>110 = +3dB gain<br>111 = +6dB gain |
|  | 6:4 | R2_2BOOSTVOL  | 000     | Controls the R2 pin to the right channel input boost stage:<br>000 = Path disabled (disconnected)<br>001 = -12dB<br>010 = -9dB gain<br>011 = -6dB gain<br>100 = -3dB gain<br>101 = +0dB gain<br>110 = +3dB gain<br>111 = +6dB gain                   |

**Table 9 Input BOOST Stage Control**

The BOOST stage is enabled under control of the BOOSTEN register bit.

| REGISTER ADDRESS         | BIT | LABEL    | DEFAULT | DESCRIPTION   |
|--------------------------|-----|----------|---------|---|
| R2<br>Power management 2 | 4   | BOOSTENL | 0       | Left channel Input BOOST enable<br>0 = Boost stage OFF<br>1 = Boost stage ON  |
|                          | 5   | BOOSTENR | 0       | Right channel Input BOOST enable<br>0 = Boost stage OFF<br>1 = Boost stage ON |

**Table 10 Input BOOST Enable Control**

### MICROPHONE BIASING CIRCUIT

The MICBIAS output provides a low noise reference voltage suitable for biasing electret type microphones and the associated external resistor biasing network. Refer to the Applications Information section for recommended external components. The MICBIAS voltage can be altered via the MBVSEL register bit. When MBVSEL=0, MICBIAS=0.9\*AVDD1 and when MBVSEL=1, MICBIAS=0.65\*AVDD1. The output can be enabled or disabled using the MICBEN control bit.

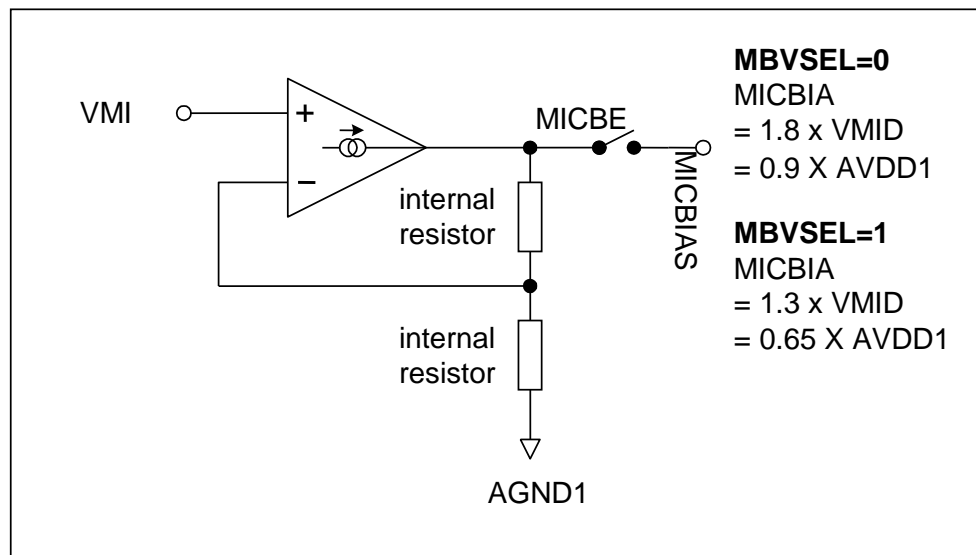
| REGISTER ADDRESS         | BIT | LABEL  | DEFAULT | DESCRIPTION   |
|--------------------------|-----|--------|---------|---|
| R1<br>Power management 1 | 4   | MICBEN | 0       | Microphone Bias Enable<br>0 = OFF (high impedance output)<br>1 = ON |

**Table 11 Microphone Bias Enable Control**

| REGISTER ADDRESS     | BIT | LABEL  | DEFAULT | DESCRIPTION  |
|----------------------|-----|--------|---------|--|
| R44<br>Input control | 8   | MBVSEL | 0       | Microphone Bias Voltage Control<br>0 = 0.9 * AVDD1<br>1 = 0.65 * AVDD1 |

**Table 12 Microphone Bias Voltage Control**

The internal MICBIAS circuitry is shown in Figure 21. Note that the maximum source current capability for MICBIAS is 3mA. The external biasing resistors therefore must be large enough to limit the MICBIAS current to 3mA.



**Figure 21 Microphone Bias Schematic**

## ANALOGUE TO DIGITAL CONVERTER (ADC)

The WM8983 uses stereo multi-bit, oversampled sigma-delta ADCs. The use of multi-bit feedback and high oversampling rates reduces the effects of jitter and high frequency noise. The ADC Full Scale input level is proportional to AVDD1. With a 3.3V supply voltage, the full scale level is  $1.0V_{rms}$ . Any voltage greater than full scale may overload the ADC and cause distortion.

### ADC DIGITAL FILTERS

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. The digital filter path for each ADC channel is illustrated in Figure 22.

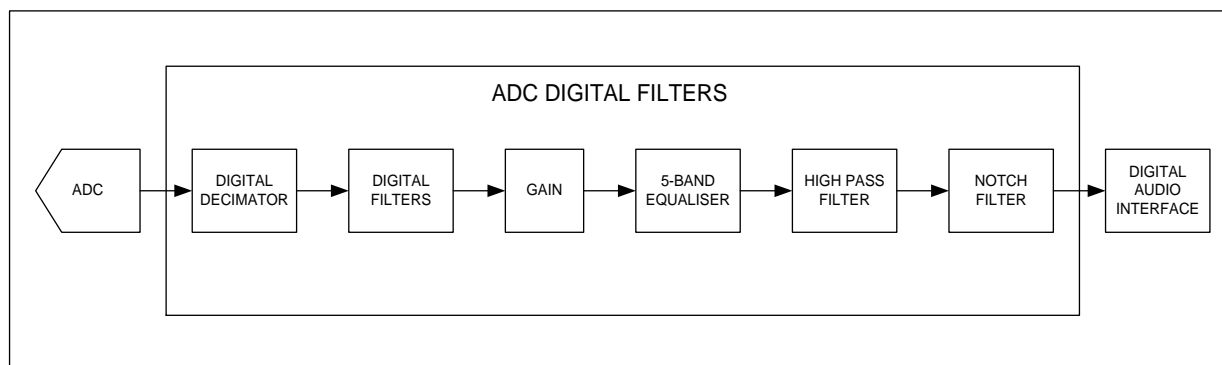


Figure 22 ADC Digital Filter Path

The ADCs are enabled by the ADCENL/R register bit.

| REGISTER ADDRESS         | BIT | LABEL  | DEFAULT | DESCRIPTION  |
|--------------------------|-----|--------|---------|--|
| R2<br>Power management 2 | 0   | ADCENL | 0       | Enable ADC left channel:<br>0 = ADC disabled<br>1 = ADC enabled  |
|                          | 1   | ADCENR | 0       | Enable ADC right channel:<br>0 = ADC disabled<br>1 = ADC enabled |

Table 13 ADC Enable Control

The polarity of the output signal can also be changed under software control using the ADCLPOL/ADCRPOL register bit. The oversampling rate of the ADC can be adjusted using the ADCOSR128 register bit. With ADCOSR128=0 the oversample rate is 64x which gives lowest power operation and when ADCOSR128=1 the oversample rate is 128x which gives best performance.

| REGISTER ADDRESS   | BIT | LABEL     | DEFAULT | DESCRIPTION  |
|--------------------|-----|-----------|---------|--|
| R14<br>ADC Control | 0   | ADCLPOL   | 0       | ADC left channel polarity adjust:<br>0 = normal<br>1 = inverted                      |
|                    | 1   | ADCRPOL   | 0       | ADC right channel polarity adjust:<br>0 = normal<br>1 = inverted                     |
|                    | 3   | ADCOSR128 | 0       | ADC oversample rate select:<br>0 = 64x (lowest power)<br>1 = 128x (best performance) |

Table 14 ADC Control



**SELECTABLE HIGH PASS FILTER**

A selectable high pass filter is provided. To disable this filter, set HPFEN=0. The filter has two modes controlled by HPFAPP. In Audio Mode (HPFAPP=0), the filter is first order, with a cut-off frequency of 3.7Hz. In Application Mode (HPFAPP=1), the filter is second order, with a cut-off frequency selectable via the HPFCUT register. The cut-off frequencies when HPFAPP=1 are shown in Table 15.

| REGISTER ADDRESS   | BIT | LABEL  | DEFAULT | DESCRIPTION   |
|--------------------|-----|--------|---------|---|
| R14<br>ADC Control | 8   | HPFEN  | 1       | High Pass Filter Enable<br>0 = disabled<br>1 = enabled  |
|                    | 7   | HPFAPP | 0       | Select audio mode or application mode<br>0 = Audio mode (1 <sup>st</sup> order, fc = ~3.7Hz)<br>1 = Application mode (2 <sup>nd</sup> order, fc = HPFCUT) |
|                    | 6:4 | HPFCUT | 000     | Application mode cut-off frequency<br>See Table 16 for details.   |

**Table 15 ADC Enable Control**

| HPFCUT<br>[2:0] | SR=101/100 |        |     | SR=011/010 |       |     | SR=001/000 |      |     |
|-----------------|------------|--------|-----|------------|-------|-----|------------|------|-----|
|                 | fs (kHz)   |        |     |            |       |     |            |      |     |
|                 | 8          | 11.025 | 12  | 16         | 22.05 | 24  | 32         | 44.1 | 48  |
| 000             | 82         | 113    | 122 | 82         | 113   | 122 | 82         | 113  | 122 |
| 001             | 102        | 141    | 153 | 102        | 141   | 153 | 102        | 141  | 153 |
| 010             | 131        | 180    | 156 | 131        | 180   | 156 | 131        | 180  | 196 |
| 011             | 163        | 225    | 245 | 163        | 225   | 245 | 163        | 225  | 245 |
| 100             | 204        | 281    | 306 | 204        | 281   | 306 | 204        | 281  | 306 |
| 101             | 261        | 360    | 392 | 261        | 360   | 392 | 261        | 360  | 392 |
| 110             | 327        | 450    | 490 | 327        | 450   | 490 | 327        | 450  | 490 |
| 111             | 408        | 563    | 612 | 408        | 563   | 612 | 408        | 563  | 612 |

**Table 16 High Pass Filter Cut-off Frequencies (HPFAPP=1)**

Note that the High Pass filter values (when HPFAPP=1) are calculated on the assumption that the SR register bits are set correctly for the actual sample rate as shown in Table 16. Sampling rate (SR) is selected using register bits R7[3:1].

**PROGRAMMABLE IIR NOTCH FILTER**

A programmable notch filter is provided. This filter has a variable centre frequency and bandwidth, programmable via two coefficients,  $a_0$  and  $a_1$ .  $a_0$  and  $a_1$  are represented by the register bits NFA0[13:0] and NFA1[13:0]. Because these coefficient values require four register writes to setup there is an NFU (Notch Filter Update) flag which should be set only when all four registers are setup.

| REGISTER ADDRESS      | BIT | LABEL      | DEFAULT | DESCRIPTION  |
|-----------------------|-----|------------|---------|--|
| R27<br>Notch Filter 1 | 6:0 | NFA0[13:7] | 0       | Notch Filter $a_0$ coefficient, bits [13:7]  |
|                       | 7   | NFEN       | 0       | Notch filter enable:<br>0 = Disabled<br>1 = Enabled  |
|                       | 8   | NFU        | 0       | Notch filter update. The notch filter values used internally only update when one of the NFU bits is set high. |
| R28<br>Notch Filter 2 | 6:0 | NFA0[6:0]  | 0       | Notch Filter $a_0$ coefficient, bits [6:0]   |
|                       | 8   | NFU        | 0       | Notch filter update. The notch filter values used internally only update when one of the NFU bits is set high. |
| R29<br>Notch Filter 3 | 6:0 | NFA1[13:7] | 0       | Notch Filter $a_1$ coefficient, bits [13:7]  |
|                       | 8   | NFU        | 0       | Notch filter update. The notch filter values used internally only update when one of the NFU bits is set high. |
| R30<br>Notch Filter 4 | 0-6 | NFA1[6:0]  | 0       | Notch Filter $a_1$ coefficient, bits [6:0]   |
|                       | 8   | NFU        | 0       | Notch filter update. The notch filter values used internally only update when one of the NFU bits is set high. |

**Table 17 Notch Filter Function**

The coefficients are calculated as follows:

$$a_0 = \frac{1 - \tan(w_b/2)}{1 + \tan(w_b/2)}$$

$$a_1 = -(1 + a_0)\cos(w_0)$$

Where:

$$w_0 = 2\pi f_c / f_s$$

$$w_b = 2\pi f_b / f_s$$

$f_c$  = centre frequency in Hz,  $f_b$  = -3dB bandwidth in Hz,  $f_s$  = sample frequency in Hz

The actual register values can be determined from the coefficients as follows:

$$\text{NFA0} = -a_0 \times 2^{13}$$

$$\text{NFA1} = -a_1 \times 2^{12}$$

**NOTCH FILTER WORKED EXAMPLE**

The following example illustrates how to calculate the  $a_0$  and  $a_1$  coefficients for a desired centre frequency and -3dB bandwidth.

$$F_c = 1000 \text{ Hz}$$

$$f_b = 100 \text{ Hz}$$

$$f_s = 48000 \text{ Hz}$$

$$w_0 = \frac{2\pi f_c}{f_s} = 2\pi \left( \frac{1000}{48000} \right) = 0.1308996939 \text{ rads}$$

$$w_b = \frac{2\pi f_b}{f_s} = 2\pi \left( \frac{100}{48000} \right) = 0.01308996939 \text{ rads}$$

$$a_0 = \frac{1 - \tan(w_b/2)}{1 + \tan(w_b/2)} = \frac{1 - \tan(0.01308996939/2)}{1 + \tan(0.01308996939/2)} = 0.9869949627$$

$$a_1 = -(1 + a_0) \cos(w_0) = -(1 + 0.9869949627) \cos(0.1308996939) = -1.969995945$$

$$\text{NFA0} = -a_0 \times 2^{13} = -8085 \text{ (rounded to nearest whole number)}$$

$$\text{NFA1} = -a_1 \times 2^{12} = 8069 \text{ (rounded to nearest whole number)}$$

These values are then converted to a 2's complement notation:

$$\text{NFA0}[13:0] = 14'h1F95; \text{ Converting to 2's complement NFA0} = 14'h4000 - 14'h1F95 = 14'h206B$$

$$\text{NFA1}[13:0] = 14'h1F85; \text{ Converting to 2's complement NFA1} = 14'h1F85$$

**DIGITAL ADC VOLUME CONTROL**

The output of the ADCs can be digitally attenuated over a range from -127dB to 0dB in 0.5dB steps. The gain for a given eight-bit code X is given by:

$$0.5 \times (G-255) \text{ dB for } 1 \leq G \leq 255; \quad \text{MUTE for } G = 0$$

| REGISTER ADDRESS                              | BIT | LABEL            | DEFAULT             | DESCRIPTION  |
|---|-----|------------------|---------------------|--|
| R15<br>Left channel<br>ADC Digital<br>Volume  | 7:0 | ADCLVOL<br>[7:0] | 11111111<br>( 0dB ) | Left ADC Digital Volume Control<br>0000 0000 = Digital Mute<br>0000 0001 = -127dB<br>0000 0010 = -126.5dB<br>... 0.5dB steps up to<br>1111 1111 = 0dB  |
|   | 8   | ADCVU            | Not<br>latched      | ADC left and ADC right volume do not<br>update until a 1 is written to ADCVU (in<br>reg 15 or 16)  |
| R16<br>Right channel<br>ADC Digital<br>Volume | 7:0 | ADCRVOL<br>[7:0] | 11111111<br>( 0dB ) | Right ADC Digital Volume Control<br>0000 0000 = Digital Mute<br>0000 0001 = -127dB<br>0000 0010 = -126.5dB<br>... 0.5dB steps up to<br>1111 1111 = 0dB |
|   | 8   | ADCVU            | Not<br>latched      | ADC left and ADC right volume do not<br>update until a 1 is written to ADCVU (in<br>reg 15 or 16)  |

**Table 18 ADC Digital Volume Control**

**INPUT LIMITER / AUTOMATIC LEVEL CONTROL (ALC)**

The WM8983 has an automatic PGA gain control circuit, which can function as an input peak limiter or as an automatic level control (ALC).

The Automatic Level Control (ALC) provides continuous adjustment of the input PGA in response to the amplitude of the input signal. A digital peak detector monitors the input signal amplitude and compares it to a register defined threshold level (ALCLVL).

If the signal is below the threshold, the ALC will increase the gain of the PGA at a rate set by ALCDCY. If the signal is above the threshold, the ALC will reduce the gain of the PGA at a rate set by ALCATK.

The ALC has two modes selected by the ALCMODE register: normal mode and peak limiter mode. The ALC/limiter function is enabled by settings the register bits R32[8:7] ALCSEL.

| REGISTER ADDRESS              | BIT | LABEL           | DEFAULT     | DESCRIPTION   |
|-------------------------------|-----|-----------------|-------------|---|
| R32 (20h)<br>ALC Control<br>1 | 2:0 | ALCMIN<br>[2:0] | 000 (-12dB) | Set minimum gain of PGA<br>000 = -12dB<br>001 = -6dB<br>010 = 0dB<br>011 = +6dB<br>100 = +12dB<br>101 = +18dB<br>110 = +24dB<br>111 = +30dB |

| REGISTER ADDRESS              | BIT | LABEL           | DEFAULT           | DESCRIPTION  |
|-------------------------------|-----|-----------------|-------------------|--|
|                               | 5:3 | ALCMAX<br>[2:0] | 111<br>(+35.25dB) | Set Maximum Gain of PGA<br>111 = +35.25dB<br>110 = +29.25dB<br>101 = +23.25dB<br>100 = +17.25dB<br>011 = +11.25dB<br>010 = +5.25dB<br>001 = -0.75dB<br>000 = -6.75dB   |
|                               | 8:7 | ALCSEL          | 00                | ALC function select<br>00 = ALC disabled<br>01 = Right channel ALC enabled<br>10 = Left channel ALC enabled<br>11 = Both channels ALC enabled  |
| R33 (21h)<br>ALC Control<br>2 | 3:0 | ALCLVL<br>[3:0] | 1011<br>(-6dB)    | ALC target – sets signal level at ADC input<br>1111 = -1.5dBFS<br>1110 = -1.5dBFS<br>1101 = -3dBFS<br>1100 = -4.5dBFS<br>1011 = -6dBFS<br>1010 = -7.5dBFS<br>1001 = -9dBFS<br>1000 = -10.5dBFS<br>0111 = -12dBFS<br>0110 = -13.5dBFS<br>0101 = -15dBFS<br>0100 = -16.5dBFS<br>0011 = -18dBFS<br>0010 = -19.5dBFS<br>0001 = -21dBFS<br>0000 = -22.5dBFS |
|                               | 7:4 | ALCHLD<br>[3:0] | 0000<br>(0ms)     | ALC hold time before gain is increased.<br>0000 = 0ms<br>0001 = 2.67ms<br>0010 = 5.33ms<br>0011 = 10.66ms<br>0100 = 21.32ms<br>0101 = 42.64ms<br>0110 = 85.28ms<br>0111 = 0.17s<br>1000 = 0.34s<br>1001 = 0.68s<br>1010 = 1.36s<br>1011 = 2.7s<br>1100 = 5.4s<br>1101 = 10.9s<br>1110 = 21.8 s<br>1111 = 43.7s   |
| R34 (22h)<br>ALC Control<br>3 | 8   | ALCMODE         | 0                 | Determines the ALC mode of operation:<br>0 = ALC mode (Normal Operation)<br>1 = Limiter mode.  |

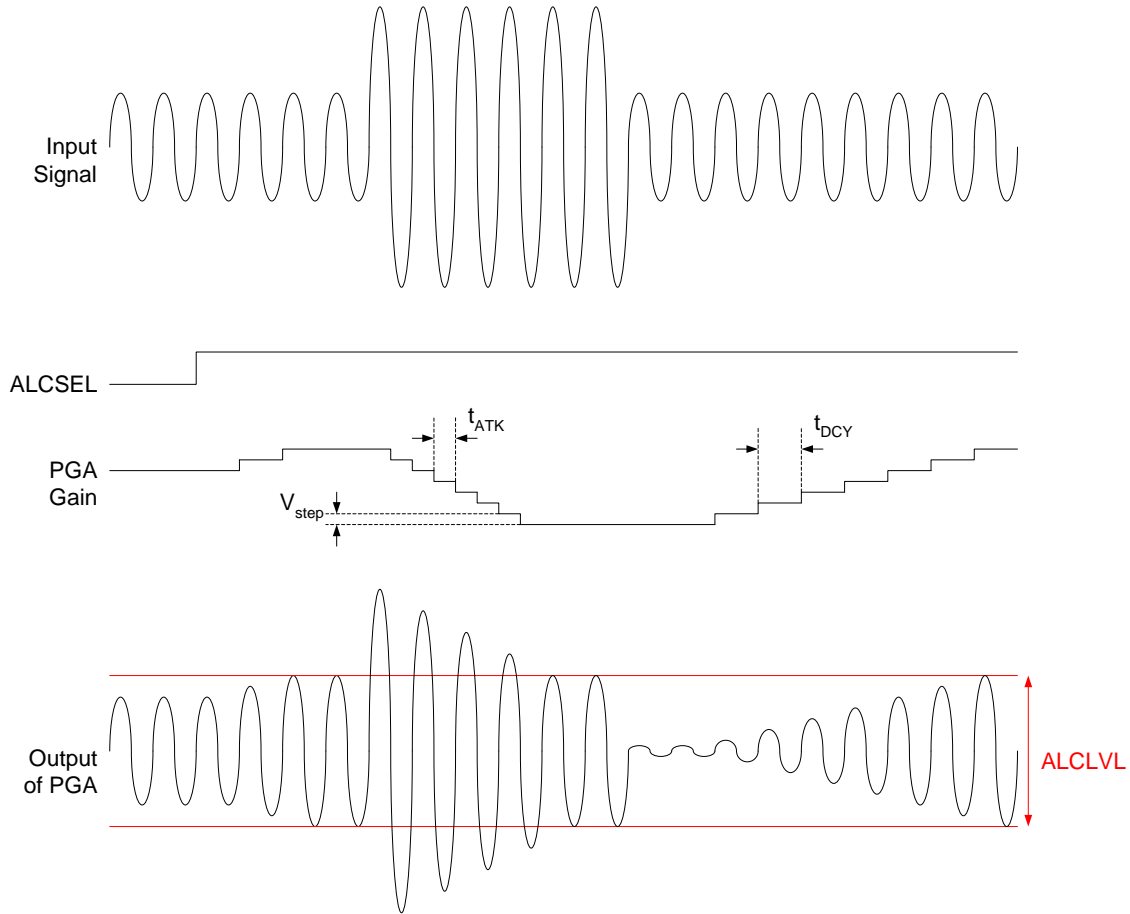
| REGISTER ADDRESS                   | BIT                                | LABEL        | DEFAULT   | DESCRIPTION                             |   |              |              |
|------------------------------------|------------------------------------|--------------|---|---|---|--------------|--------------|
|                                    | 7:4                                | ALCDCY [3:0] | 0011 (13ms/6dB)                                 | Decay (gain ramp-up) time (ALCMODE ==0) |   |              |              |
|                                    |                                    |              |   |   | Per step  | Per 6dB      | 90% of range |
|                                    |                                    |              |   | 0000                                    | 410us   | 3.3ms        | 24ms         |
|                                    |                                    |              |   | 0001                                    | 820us   | 6.6ms        | 48ms         |
|                                    |                                    |              |   | 0010                                    | 1.64ms  | 13.1ms       | 192ms        |
|                                    |                                    |              |   | ... (time doubles with every step)      |   |              |              |
|                                    |                                    |              | 1010 or higher                                  | 420ms                                   | 3.36s   | 24.576s      |              |
|                                    |                                    |              | 0011 (2.9ms/6dB)                                | Decay (gain ramp-up) time (ALCMODE ==1) |   |              |              |
|                                    |                                    |              |   |   | Per step  | Per 6dB      | 90% of range |
|                                    |                                    |              |   | 0000                                    | 90.8us  | 726.4us      | 5.26ms       |
|                                    | 0001                               | 181.6us      |   | 1.453ms                                 | 10.53ms   |              |              |
|                                    | 0010                               | 363.2us      |   | 2.905ms                                 | 21.06ms   |              |              |
|                                    | ... (time doubles with every step) |              |   |   |   |              |              |
|                                    | 1010                               | 93ms         |   | 744ms                                   | 5.39s   |              |              |
|                                    | 3:0                                | ALCATK [3:0] |   | 0010 (832us/6dB)                        | ALC attack (gain ramp-down) time (ALCMODE == 0) |              |              |
|                                    |                                    |              |   |   | Per step  | Per 6dB      | 90% of range |
|                                    |                                    |              | 0000  |   | 104us   | 832us        | 6ms          |
|                                    |                                    |              | 0001  |   | 208us   | 1.66ms       | 12ms         |
| 0010                               |                                    |              | 416us   |   | 3.32ms  | 24.1ms       |              |
| ... (time doubles with every step) |                                    |              |   |   |   |              |              |
| 1010 or higher                     |                                    |              | 106ms   | 852ms                                   | 6.18s   |              |              |
| 0010 (182us/6dB)                   |                                    |              | ALC attack (gain ramp-down) time (ALCMODE == 1) |   |   |              |              |
|                                    |                                    |              |   | Per step                                | Per 6dB   | 90% of range |              |
|                                    |                                    |              | 0000  | 22.7us                                  | 182.4us   | 1.31ms       |              |
|                                    | 0001                               | 45.4us       | 363.2us   | 2.62ms                                  |   |              |              |
|                                    | 0010                               | 90.8us       | 726.4us   | 5.26ms                                  |   |              |              |
| ... (time doubles with every step) |                                    |              |   |   |   |              |              |
| 1010                               | 23.2ms                             | 186ms        | 1.348s  |   |   |              |              |

**Table 19 ALC Control Registers**

When the ALC is disabled, the input PGA remains at the last controlled value of the ALC. An input gain update must be made by writing to the INPPGAVOLL/R register bits.

**NORMAL MODE**

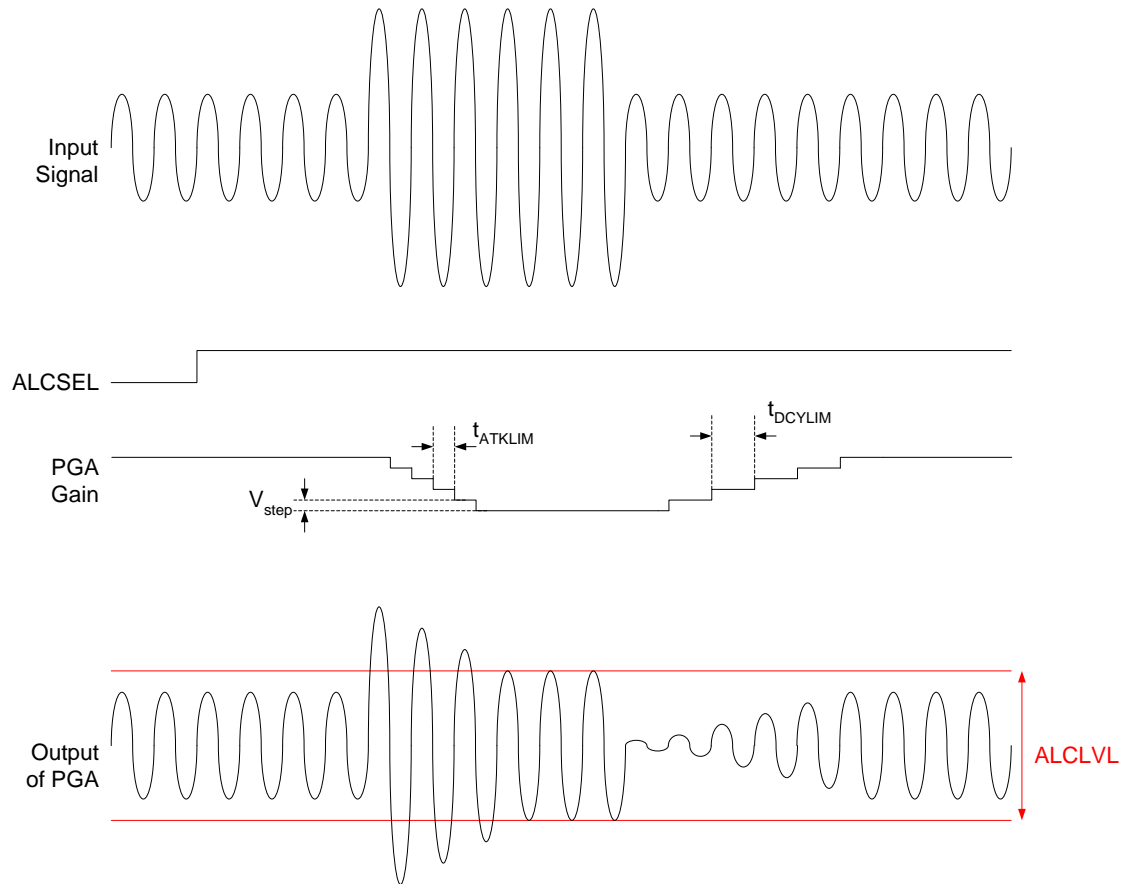
In normal mode, the ALC will attempt to maintain a constant signal level by increasing or decreasing the gain of the PGA. The following diagram shows an example of this.



**Figure 23 ALC Normal Mode Operation**

**LIMITER MODE**

In limiter mode, the ALC will reduce peaks that go above the threshold level, but will not increase the PGA gain beyond the starting level. The starting level is the PGA gain setting when the ALC is enabled in limiter mode. If the ALC is started in limiter mode, this is the gain setting of the PGA at startup. If the ALC is switched into limiter mode after running in ALC mode, the starting gain will be the gain at switchover. The diagram below shows an example of limiter mode.



**Figure 24 ALC Limiter Mode Operation**



### ALC LIMITER MODE INITIALISATION SEQUENCE

In order to correctly initialise the ALC in limiter mode, the following sequence of register writes is required. MCLK must be applied during the initialisation sequence

1. R45 - Set left input PGA gain (INPPGAVOLL) to level required for operation.
2. R46 - Set right input PGA gain (INPPGAVOLR) to level required for operation.
3. R44 - Enable analogue inputs as required.
4. R2 - Disable input PGA (INPPGAENL=0, INPPGAENR=0).
5. R59 = 0x0003 - Enable ALC test mode.
6. R32 - Set ALCMAX and ALCMIN to the level required for operation.
7. R33 - Set limiter level (ALCLVL) to the level required for operation.
8. R34 = 0x0000 - Enable ALC mode (ALCMODE = 0).
9. Insert 1ms delay to allow input PGA gain update by the limiter circuit.
10. R34 = 0x0100 - Enable Limiter mode (ALCMODE = 1).
11. Insert 1ms delay to allow input PGA gain update by the limiter circuit.
12. R59 = 0x0000 - Turn off ALC test mode.
13. R2 - Enable input PGA (INPPGAENL=1, INPPGAENR=1).

**Note:** R32, R33, R45 and R46 register settings above need to be changed to reflect settings required in the target application.

### ATTACK AND DECAY TIMES

The attack and decay times set the update times for the PGA gain. The attack time is the time constant used when the gain is reducing. The decay time is the time constant used when the gain is increasing. In limiter mode, the time constants are faster than in ALC mode. The time constants are shown below in terms of a single gain step, a change of 6dB and a change of 90% of the PGAs gain range.

Note that, these times will vary slightly depending on the sample rate used (specified by the SR register).

### NORMAL MODE

| ALCMODE = 0 (Normal Mode) |                  |                     |                     |
|---------------------------|------------------|---------------------|---------------------|
| Attack Time (s)           |                  |                     |                     |
| ALCATK                    | t <sub>ATK</sub> | t <sub>ATK6dB</sub> | t <sub>ATK90%</sub> |
| 0000                      | 104µs            | 832µs               | 6ms                 |
| 0001                      | 208µs            | 1.66ms              | 12ms                |
| 0010                      | 416µs            | 3.33ms              | 24ms                |
| 0011                      | 832µs            | 6.66ms              | 48ms                |
| 0100                      | 1.66ms           | 13.32ms             | 96ms                |
| 0101                      | 3.33ms           | 26.64ms             | 192ms               |
| 0110                      | 6.66ms           | 53.28ms             | 384ms               |
| 0111                      | 13.32ms          | 106.6ms             | 768ms               |
| 1000                      | 26.64ms          | 213.2ms             | 1.53s               |
| 1001                      | 53.28ms          | 426.4ms             | 3.07s               |
| 1010                      | 106.6ms          | 852.8ms             | 6.14s               |

| ALCMODE = 0 (Normal Mode) |                  |                     |                     |
|---------------------------|------------------|---------------------|---------------------|
| Decay Time (s)            |                  |                     |                     |
| ALCDCY                    | t <sub>DCY</sub> | t <sub>DCY6dB</sub> | t <sub>DCY90%</sub> |
| 0000                      | 410µs            | 3.3ms               | 24ms                |
| 0001                      | 820µs            | 6.6ms               | 48ms                |
| 0010                      | 1.64ms           | 13.1ms              | 96ms                |
| 0011                      | 3.28ms           | 26.2ms              | 192ms               |
| 0100                      | 6.56ms           | 52.5ms              | 384ms               |
| 0101                      | 13.12ms          | 105ms               | 768ms               |
| 0110                      | 26.24ms          | 210ms               | 1.53s               |
| 0111                      | 52.5ms           | 420ms               | 3.07s               |
| 1000                      | 105ms            | 840ms               | 6.14s               |
| 1001                      | 210ms            | 1.68s               | 12.28s              |
| 1010                      | 420ms            | 3.36s               | 24.57s              |

**Table 20 ALC Normal Mode (Attack and Decay times)**
**LIMITER MODE**

| ALCMODE = 1 (Limiter Mode) |                     |                        |                        |
|----------------------------|---------------------|------------------------|------------------------|
| Attack Time (s)            |                     |                        |                        |
| ALCATK                     | t <sub>ATKLIM</sub> | t <sub>ATKLIM6dB</sub> | t <sub>ATKLIM90%</sub> |
| 0000                       | 22.7µs              | 182.4µs                | 1.31ms                 |
| 0001                       | 45.4µs              | 363.2µs                | 2.62ms                 |
| 0010                       | 90.8µs              | 726.4µs                | 5.24ms                 |
| 0011                       | 182µs               | 1.45ms                 | 10.48ms                |
| 0100                       | 363µs               | 2.9ms                  | 20.9ms                 |
| 0101                       | 726µs               | 5.81ms                 | 41.9ms                 |
| 0110                       | 1.45ms              | 11.62ms                | 83.8ms                 |
| 0111                       | 2.9ms               | 23.2ms                 | 167.7ms                |
| 1000                       | 5.81ms              | 46.5ms                 | 335.4ms                |
| 1001                       | 11.62ms             | 93ms                   | 670.8ms                |
| 1010                       | 23.2ms              | 186ms                  | 1.34s                  |

| ALCMODE = 1 (Limiter Mode) |                     |                        |                        |
|----------------------------|---------------------|------------------------|------------------------|
| Attack Time (s)            |                     |                        |                        |
| ALCDCY                     | t <sub>DCYLIM</sub> | t <sub>DCYLIM6dB</sub> | t <sub>DCYLIM90%</sub> |
| 0000                       | 90.8µs              | 726.4µs                | 5.24ms                 |
| 0001                       | 182µs               | 1.45ms                 | 10.48ms                |
| 0010                       | 363µs               | 2.9ms                  | 20.9ms                 |
| 0011                       | 726µs               | 5.81ms                 | 41.9ms                 |
| 0100                       | 1.45ms              | 11.62ms                | 83.8ms                 |
| 0101                       | 2.9ms               | 23.2ms                 | 167.7ms                |
| 0110                       | 5.81ms              | 46.5ms                 | 335.4ms                |
| 0111                       | 11.62ms             | 93ms                   | 670.8ms                |
| 1000                       | 23.2ms              | 186ms                  | 1.34s                  |
| 1001                       | 46.4ms              | 372ms                  | 2.68s                  |
| 1010                       | 92.8ms              | 744ms                  | 5.36s                  |

**Table 21 ALC Limiter Mode (Attack and Decay times)**

**MINIMUM AND MAXIMUM GAIN**

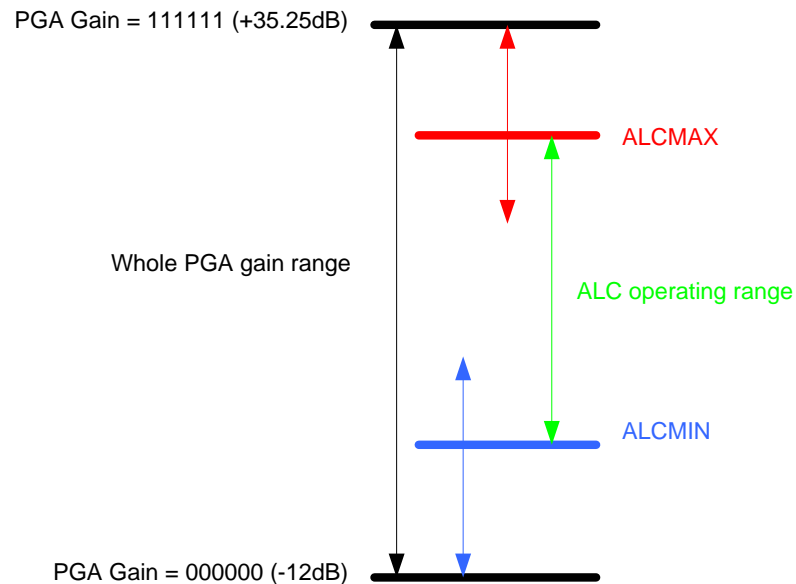
The ALCMIN and ALCMAX register bits set the minimum/maximum gain value that the PGA can be set to whilst under the control of the ALC. This has no effect on the PGA when ALC is not enabled.

| REGISTER ADDRESS        | BIT | LABEL  | DEFAULT | DESCRIPTION  |
|-------------------------|-----|--------|---------|--|
| R32<br>ALC Control<br>1 | 5:3 | ALCMAX | 111     | Set Maximum Gain of PGA<br>(see Table 19 for definition) |
|                         | 2:0 | ALCMIN | 000     | Set minimum gain of PGA<br>(see Table 19 for definition) |

**Table 22 ALC Max/Min Gain**

In normal mode, ALCMAX sets the maximum boost which can be applied to the signal. In limiter mode, ALCMAX will normally have no effect (assuming the starting gain value is less than the maximum gain specified by ALCMAX) because the maximum gain is set at the starting gain level.

ALCMIN sets the minimum gain value which can be applied to the signal.


**Figure 25 ALC Min/Max Gain**

| ALCMAX | Maximum Gain (dB) |
|--------|-------------------|
| 111    | 35.25             |
| 110    | 29.25             |
| 101    | 23.25             |
| 100    | 17.25             |
| 011    | 11.25             |
| 010    | 5.25              |
| 001    | -0.75             |
| 000    | -6.75             |

**Table 23 ALC Max Gain Values**

| ALCMIN | Minimum Gain (dB) |
|--------|-------------------|
| 000    | -12               |
| 001    | -6                |
| 010    | 0                 |
| 011    | 6                 |
| 100    | 12                |
| 101    | 18                |
| 110    | 24                |
| 111    | 30                |

**Table 24 ALC Min Gain Values**

Note that if the ALC gain setting strays outside the ALC operating range, either by starting the ALC outside of the range or changing the ALCMAX or ALCMIN settings during operation, the ALC will immediately adjust the gain to return to the ALC operating range. It is recommended that the ALC starting gain is set between the ALCMAX and ALCMIN limits.

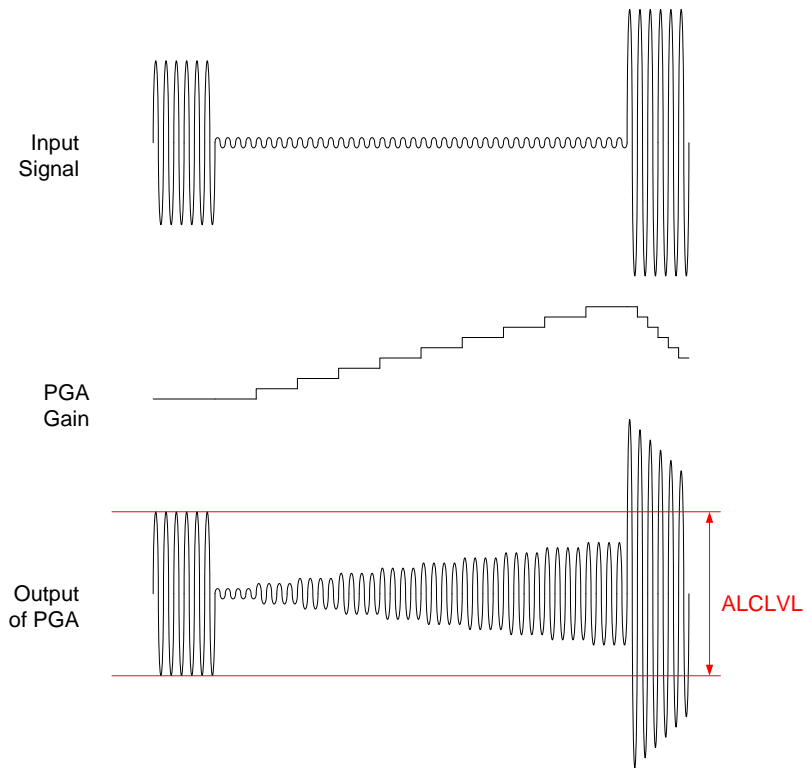
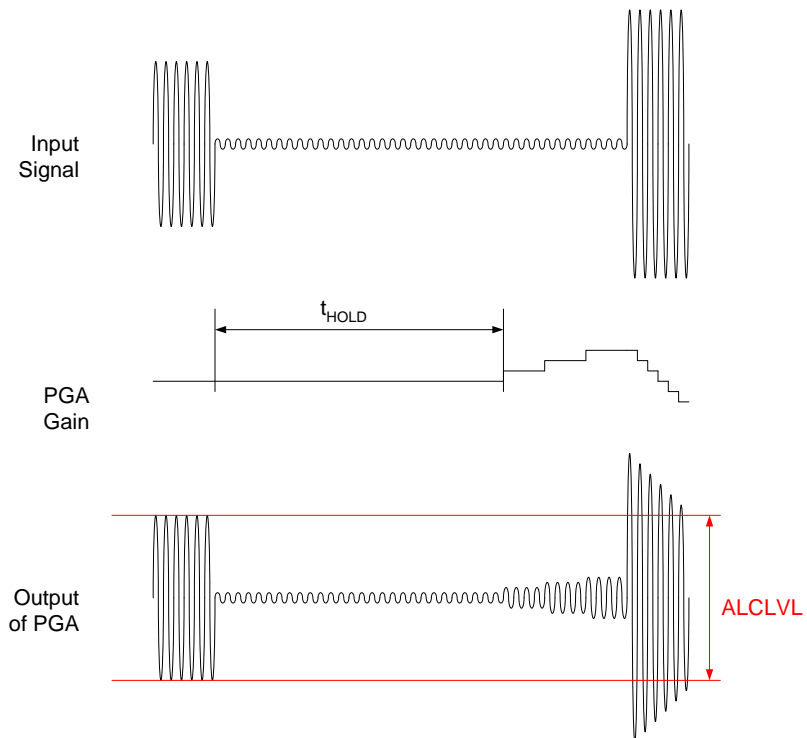
#### ALC HOLD TIME (NORMAL MODE ONLY)

In Normal mode, the ALC has an adjustable hold time which sets a time delay before the ALC begins its decay phase (gain increasing). The hold time is set by the ALCHLD register.

| REGISTER ADDRESS        | BIT | LABEL  | DEFAULT | DESCRIPTION  |
|-------------------------|-----|--------|---------|--|
| R33<br>ALC Control<br>2 | 7:4 | ALCHLD | 0000    | ALC hold time before gain is increased.<br>(see Table 19 for definition) |

**Table 25 ALC Hold Time**

If the hold time is exceeded, this indicates that the signal has reached a new average level and the ALC will increase the gain to adjust for that new average level. If the signal goes above the threshold during the hold period, the hold phase is abandoned and the ALC returns to normal operation.


**Figure 26 ALCLVL**

**Figure 27 ALC Hold Time**

| ALCHLD | t <sub>HOLD</sub> (s) |
|--------|-----------------------|
| 0000   | 0                     |
| 0001   | 2.67ms                |
| 0010   | 5.34ms                |
| 0011   | 10.7ms                |
| 0100   | 21.4ms                |
| 0101   | 42.7ms                |
| 0110   | 85.4ms                |
| 0111   | 171ms                 |
| 1000   | 342ms                 |
| 1001   | 684ms                 |
| 1010   | 1.37s                 |

**Table 26 ALC Hold Time Values**

### PEAK LIMITER

To prevent clipping when a large signal occurs just after a period of quiet, the ALC circuit includes a limiter function. If the ADC input signal exceeds 87.5% of full scale (−1.16dB), the PGA gain is ramped down at the maximum attack rate (as when ALCATK = 0000), until the signal level falls below 87.5% of full scale. This function is automatically enabled whenever the ALC is enabled.

**Note:** If ALCATK = 0000, then the limiter makes no difference to the operation of the ALC. It is designed to prevent clipping when long attack times are used.

### NOISE GATE (NORMAL MODE ONLY)

When the signal is very quiet and consists mainly of noise, the ALC function may cause “noise pumping”, i.e. loud hissing noise during silence periods. The WM8985 has a noise gate function that prevents noise pumping by comparing the signal level at the input pins against a noise gate threshold, NGTH. The noise gate cuts in when:

$$\text{Signal level at ADC [dBFS]} < \text{NGTH [dBFS]} + \text{PGA gain [dB]} + \text{Mic Boost gain [dB]}$$

This is equivalent to:

$$\text{Signal level at input pin [dBFS]} < \text{NGTH [dBFS]}$$

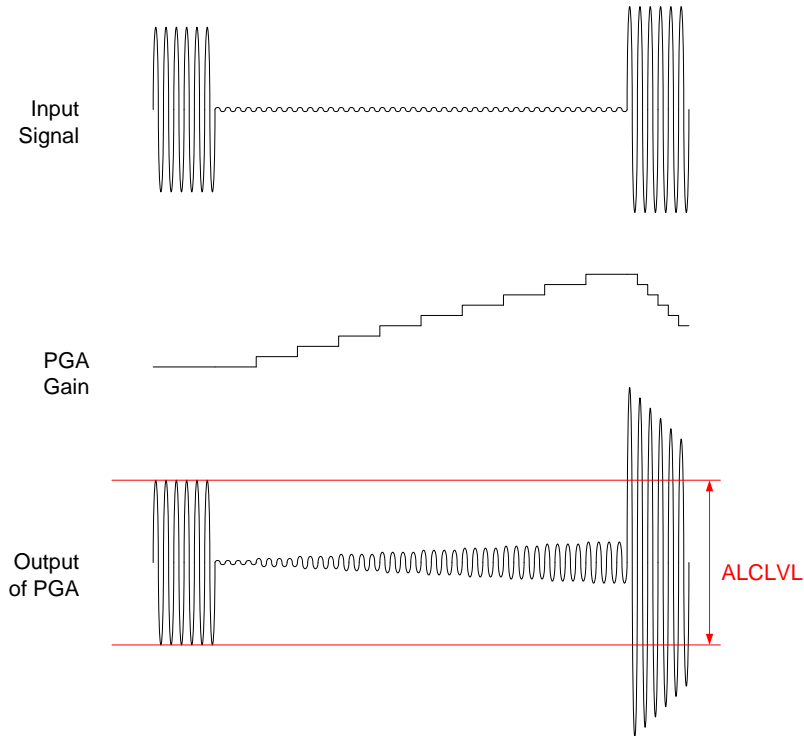
The PGA gain is then held constant (preventing it from ramping up as it normally would when the signal is quiet).

The table below summarises the noise gate control register. The NGTH control bits set the noise gate threshold with respect to the ADC full-scale range. The threshold is adjusted in 6dB steps. Levels at the extremes of the range may cause inappropriate operation, so care should be taken with set-up of the function. The noise gate only operates in conjunction with the ALC and cannot be used in limiter mode.

| REGISTER ADDRESS                    | BIT | LABEL | DEFAULT | DESCRIPTION   |
|-------------------------------------|-----|-------|---------|---|
| R35 (23h)<br>ALC Noise Gate Control | 2:0 | NGTH  | 000     | ALC Noise gate threshold:<br>000 = -39dB<br>001 = -45dB<br>010 = -51dB<br>011 = -57dB<br>100 = -63dB<br>101 = -70dB<br>110 = -76dB<br>111 = -81dB |
|                                     | 3   | NGEN  | 0       | ALC Noise gate function enable<br>1 = enable<br>0 = disable   |

**Table 27 ALC Noise Gate Control**

The diagrams below show the response of the system to the same signal with and without noise gate.


**Figure 28 ALC Operation Above Noise Gate Threshold**

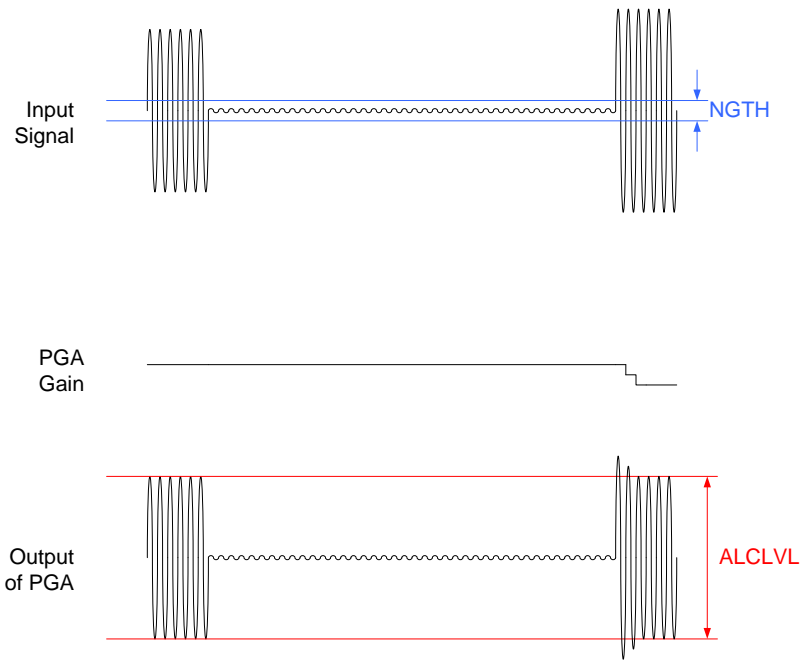


Figure 29 Noise Gate Operation



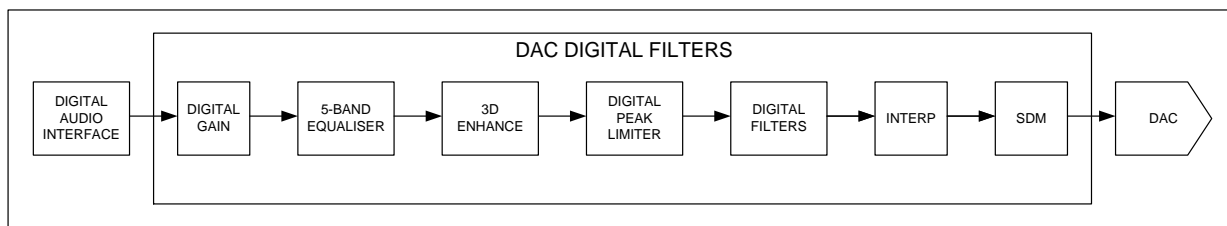
## OUTPUT SIGNAL PATH

The WM8983 output signal paths consist of digital application filters, up-sampling filters, stereo Hi-Fi DACs, analogue mixers, stereo headphone and stereo line/mono/midrail output drivers. The digital filters and DAC are enabled by register bits DACENL And DACENR. The mixers and output drivers can be separately enabled by individual control bits (see Analogue Outputs). Thus it is possible to utilise the analogue mixing and amplification provided by the WM8983, irrespective of whether the DACs are running or not.

The WM8983 DACs receive digital input data on the DACDAT pin. The digital filter block processes the data to provide the following functions:

- Digital volume control
- Graphic equaliser
- A digital peak limiter.
- Sigma-Delta Modulation

High performance sigma-delta audio DAC converts the digital data into an analogue signal.



**Figure 30 DAC Digital Filter Path**

The analogue outputs from the DACs can then be mixed with the aux analogue inputs and the ADC analogue inputs. The mix is fed to the output drivers for headphone (LOUT1/ROUT1, LOUT2/ROUT2) or line (OUT3/OUT4). OUT3 and OUT4 have additional mixers which allow them to output different signals to the headphone and line outputs.

## DIGITAL PLAYBACK (DAC) PATH

Digital data is passed to the WM8983 via the flexible audio interface and is then passed through a variety of advanced digital filters as shown in Figure 30 to the hi-fi DACs. The DACs are enabled by the DACENL/R register bits.

| REGISTER ADDRESS         | BIT | LABEL  | DEFAULT | DESCRIPTION   |
|--------------------------|-----|--------|---------|---|
| R3<br>Power Management 3 | 0   | DACENL | 0       | Left channel DAC enable<br>0 = DAC disabled<br>1 = DAC enabled  |
|                          | 1   | DACENR | 0       | Right channel DAC enable<br>0 = DAC disabled<br>1 = DAC enabled |

**Table 28 DAC Enable Control**

The WM8983 also has a Soft Mute function, which when enabled, gradually attenuates the volume of the digital signal to zero. When disabled, the gain will ramp back up to the digital gain setting. This function is enabled by default. To play back an audio signal, it must first be disabled by setting the SOFTMUTE bit to zero.

| REGISTER ADDRESS   | BIT | LABEL     | DEFAULT | DESCRIPTION  |
|--------------------|-----|-----------|---------|--|
| R10<br>DAC Control | 0   | DACLPOL   | 0       | Left DAC output polarity:<br>0 = non-inverted<br>1 = inverted (180 degrees phase shift)  |
|                    | 1   | DACRPOL   | 0       | Right DAC output polarity:<br>0 = non-inverted<br>1 = inverted (180 degrees phase shift) |
|                    | 2   | AMUTE     | 0       | Automute enable<br>0 = Amute disabled<br>1 = Amute enabled                               |
|                    | 3   | DACOSR128 | 0       | DAC oversampling rate:<br>0 = 64x (lowest power)<br>1 = 128x (best performance)          |
|                    | 6   | SOFTMUTE  | 0       | Softmute enable:<br>0 = Enabled<br>1 = Disabled  |

**Table 29 DAC Control Register**

The digital audio data is converted to oversampled bit streams in the on-chip, true 24-bit digital interpolation filters. The bitstream data enters the multi-bit, sigma-delta DACs, which convert it to a high quality analogue audio signal. The multi-bit DAC architecture reduces high frequency noise and sensitivity to clock jitter. It also uses a Dynamic Element Matching technique for high linearity and low distortion.

The DAC output phase defaults to non-inverted. Setting DACLPOL will invert the DAC output phase on the left channel and DACRPOL inverts the phase on the right channel.

### **AUTO-MUTE**

The DAC has an auto-mute function which applies an analogue mute when 1024 consecutive zeros are detected. The mute is released as soon as a non-zero sample is detected. Auto-mute can be disabled using the AMUTE control bit.

### DIGITAL HI-FI DAC VOLUME (GAIN) CONTROL

The signal volume from each Hi-Fi DAC can be controlled digitally. The gain range is -127dB to 0dB in 0.5dB steps. The level of attenuation for an eight-bit code X is given by:

$$0.5 \times (X-255) \text{ dB for } 1 \leq X \leq 255; \quad \text{MUTE for } X = 0$$

| REGISTER ADDRESS                   | BIT | LABEL            | DEFAULT             | DESCRIPTION  |
|------------------------------------|-----|------------------|---------------------|--|
| R11<br>Left DAC<br>Digital Volume  | 7:0 | DACLVOL<br>[7:0] | 11111111<br>( 0dB ) | Left DAC Digital Volume Control<br>0000 0000 = Digital Mute<br>0000 0001 = -127dB<br>0000 0010 = -126.5dB<br>... 0.5dB steps up to<br>1111 1111 = 0dB  |
|                                    | 8   | DACVU            | Not<br>latched      | DAC left and DAC right volume do<br>not update until a 1 is written to<br>DACVU (in reg 11 or 12)  |
| R12<br>Right DAC<br>Digital Volume | 7:0 | DACRVOL<br>[7:0] | 11111111<br>( 0dB ) | Right DAC Digital Volume Control<br>0000 0000 = Digital Mute<br>0000 0001 = -127dB<br>0000 0010 = -126.5dB<br>... 0.5dB steps up to<br>1111 1111 = 0dB |
|                                    | 8   | DACVU            | Not<br>latched      | DAC left and DAC right volume do<br>not update until a 1 is written to<br>DACVU (in reg 11 or 12)  |

**Table 30 DAC Digital Volume Control**

**Note:** An additional gain of up to 12dB can be added using the gain block embedded in the digital peak limiter circuit (see DAC DIGITAL OUTPUT LIMITER section).

### 5-BAND EQUALISER

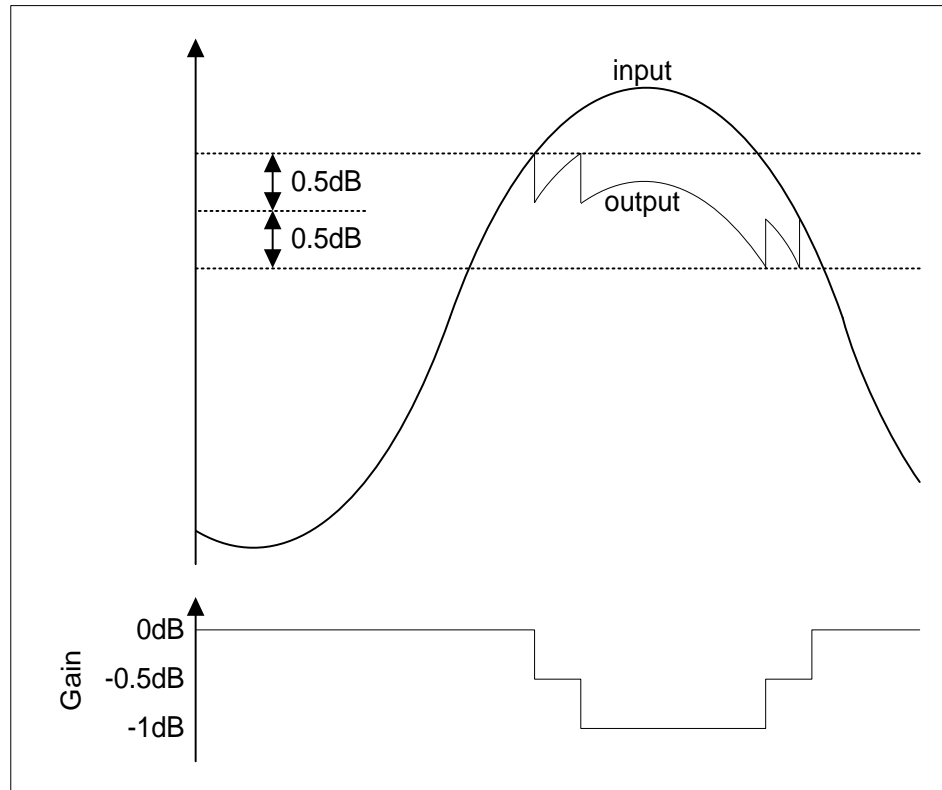
A 5-band graphic equaliser function which can be used to change the output frequency levels to suit the environment. This can be applied to the ADC or DAC path and is described in the 5-BAND GRAPHIC EQUALISER section for further details on this feature.

### 3-D ENHANCEMENT

The WM8983 has an advanced digital 3-D enhancement feature which can be used to vary the perceived stereo separation of the left and right channels. Like the 5-band equaliser, this feature can be applied to either the ADC record path or the DAC playback path but not both simultaneously. Refer to the 3D STEREO ENHANCEMENT section for further details on this feature.

### DAC DIGITAL OUTPUT LIMITER

The WM8983 has a digital output limiter function. The operation of this is shown in Figure 31. In this diagram, the upper graph shows the envelope of the input/output signals and the lower graph shows the gain characteristic.



**Figure 31 DAC Digital Limiter Operation**

The limiter has a programmable upper threshold which is close to 0dB. Referring to Figure 31, in normal operation (LIMBOOST=000 => limit only), signals below this threshold are unaffected by the limiter. Signals above the upper threshold are attenuated at a specific attack rate (set by the LIMATK register bits) until the signal falls below the threshold. The limiter also has a lower threshold 1dB below the upper threshold. When the signal falls below the lower threshold, the signal is amplified at a specific decay rate (controlled by LIMDCY register bits) until a gain of 0dB is reached. Both threshold levels are controlled by the LIMLVL register bits. The upper threshold is 0.5dB above the value programmed by LIMLVL, and the lower threshold is 0.5dB below the LIMLVL value.

### **VOLUME BOOST**

The limiter has programmable upper gain which boosts signals below the threshold to compress the dynamic range of the signal and increase its perceived loudness. This operates as an ALC function with limited boost capability. The volume boost is from 0dB to +12dB in 1dB steps, controlled by the LIMBOOST register bits.

The output limiter volume boost can also be used as a stand alone digital gain boost when the limiter is disabled.

| REGISTER ADDRESS                     | BIT | LABEL    | DEFAULT | DESCRIPTION  |
|--------------------------------------|-----|----------|---------|--|
| R24<br>DAC digital limiter control 1 | 3:0 | LIMATK   | 0010    | DAC Limiter Attack time (per 6dB gain change) for 44.1kHz sampling. Note that these are proportionally related to sample rate.<br>0000 = 94us<br>0001 = 188s<br>0010 = 375us<br>0011 = 750us<br>0100 = 1.5ms<br>0101 = 3ms<br>0110 = 6ms<br>0111 = 12ms<br>1000 = 24ms<br>1001 = 48ms<br>1010 = 96ms<br>1011 to 1111 = 192ms   |
|                                      | 7:4 | LIMDCY   | 0011    | DAC Limiter Decay time (per 6dB gain change) for 44.1kHz sampling. Note that these are proportionally related to sample rate:<br>0000 = 750us<br>0001 = 1.5ms<br>0010 = 3ms<br>0011 = 6ms<br>0100 = 12ms<br>0101 = 24ms<br>0110 = 48ms<br>0111 = 96ms<br>1000 = 192ms<br>1001 = 384ms<br>1010 = 768ms<br>1011 to 1111 = 1.536s |
|                                      | 8   | LIMEN    | 0       | Enable the DAC digital limiter:<br>0 = disabled<br>1 = enabled   |
| R25<br>DAC digital limiter control 2 | 3:0 | LIMBOOST | 0000    | DAC Limiter volume boost (can be used as a stand alone volume boost when LIMEN=0):<br>0000 = 0dB<br>0001 = +1dB<br>0010 = +2dB<br>0011 = +3dB<br>0100 = +4dB<br>0101 = +5dB<br>0110 = +6dB<br>0111 = +7dB<br>1000 = +8dB<br>1001 = +9dB<br>1010 = +10dB<br>1011 = +11dB<br>1100 = +12dB<br>1101 to 1111 = reserved             |
|                                      | 6:4 | LIMLVL   | 000     | Programmable signal threshold level (determines level at which the DAC limiter starts to operate)<br>000 = -1dB<br>001 = -2dB<br>010 = -3dB<br>011 = -4dB<br>100 = -5dB<br>101 to 111 = -6dB   |

**Table 31 DAC Digital Limiter Control**

**5-BAND GRAPHIC EQUALISER**

A 5-band graphic equaliser is provided, which can be applied to the ADC or DAC path, together with 3D enhancement, under control of the EQ3DMODE register bit.

| REGISTER ADDRESS    | BIT | LABEL    | DEFAULT | DESCRIPTION  |
|---------------------|-----|----------|---------|--|
| R18<br>EQ Control 1 | 8   | EQ3DMODE | 1       | 0 = Equaliser and 3D Enhancement applied to ADC path<br>1 = Equaliser and 3D Enhancement applied to DAC path |

**Table 32 EQ and 3D Enhancement DAC or ADC Path Select**

**Note:** The ADCs and DACs must be disabled before changing the EQ3DMODE bit.

The equaliser consists of low and high frequency shelving filters (Band 1 and 5) and three peak filters for the centre bands. Each has adjustable cut-off or centre frequency, and selectable boost (+/- 12dB in 1dB steps). The peak filters have selectable bandwidth.

| REGISTER ADDRESS            | BIT | LABEL | DEFAULT        | DESCRIPTION   |
|-----------------------------|-----|-------|----------------|---|
| R18<br>EQ Band 1<br>Control | 4:0 | EQ1G  | 01100<br>(0dB) | EQ Band 1 Gain Control. See Table 38 for details.                                   |
|                             | 6:5 | EQ1C  | 01             | EQ Band 1 Cut-off Frequency:<br>00 = 80Hz<br>01 = 105Hz<br>10 = 135Hz<br>11 = 175Hz |

**Table 33 EQ Band 1 Control**

| REGISTER ADDRESS            | BIT | LABEL | DEFAULT        | DESCRIPTION   |
|-----------------------------|-----|-------|----------------|---|
| R19<br>EQ Band 2<br>Control | 4:0 | EQ2G  | 01100<br>(0dB) | EQ Band 2 Gain Control. See Table 38 for details.                                   |
|                             | 6:5 | EQ2C  | 01             | EQ Band 2 Centre Frequency:<br>00 = 230Hz<br>01 = 300Hz<br>10 = 385Hz<br>11 = 500Hz |
|                             | 8   | EQ2BW | 0              | EQ Band 2 Bandwidth Control<br>0 = narrow bandwidth<br>1 = wide bandwidth           |

**Table 34 EQ Band 2 Control**

| REGISTER ADDRESS            | BIT | LABEL | DEFAULT        | DESCRIPTION   |
|-----------------------------|-----|-------|----------------|---|
| R20<br>EQ Band 3<br>Control | 4:0 | EQ3G  | 01100<br>(0dB) | EQ Band 3 Gain Control. See Table 38 for details.                                     |
|                             | 6:5 | EQ3C  | 01             | EQ Band 3 Centre Frequency:<br>00 = 650Hz<br>01 = 850Hz<br>10 = 1.1kHz<br>11 = 1.4kHz |
|                             | 8   | EQ3BW | 0              | EQ Band 3 Bandwidth Control<br>0 = narrow bandwidth<br>1 = wide bandwidth             |

**Table 35 EQ Band 3 Control**

| REGISTER ADDRESS            | BIT | LABEL | DEFAULT        | DESCRIPTION   |
|-----------------------------|-----|-------|----------------|---|
| R21<br>EQ Band 4<br>Control | 4:0 | EQ4G  | 01100<br>(0dB) | EQ Band 4 Gain Control. See Table 38 for details  |
|                             | 6:5 | EQ4C  | 01             | EQ Band 4 Centre Frequency:<br>00 = 1.8kHz<br>01 = 2.4kHz<br>10 = 3.2kHz<br>11 = 4.1kHz |
|                             | 8   | EQ4BW | 0              | EQ Band 4 Bandwidth Control<br>0 = narrow bandwidth<br>1 = wide bandwidth               |

**Table 36 EQ Band 4 Control**

| REGISTER ADDRESS                 | BIT | LABEL | DEFAULT        | DESCRIPTION   |
|----------------------------------|-----|-------|----------------|---|
| R22<br>EQ Band 5<br>Gain Control | 4:0 | EQ5G  | 01100<br>(0dB) | EQ Band 5 Gain Control. See Table 38 for details.                                       |
|                                  | 6:5 | EQ5C  | 01             | EQ Band 5 Cut-off Frequency:<br>00 = 5.3kHz<br>01 = 6.9kHz<br>10 = 9kHz<br>11 = 11.7kHz |

**Table 37 EQ Band 5 Control**

| GAIN REGISTER  | GAIN     |
|----------------|----------|
| 00000          | +12dB    |
| 00001          | +11dB    |
| 00010          | +10dB    |
| 00011          | +9dB     |
| 00100          | +8dB     |
| 00101          | +7dB     |
| 00110          | +6dB     |
| 00111          | +5dB     |
| 01000          | +4dB     |
| 01001          | +3dB     |
| 01010          | +2dB     |
| 01011          | +1dB     |
| 01100          | 0dB      |
| 01101          | -1dB     |
| 11000          | -12dB    |
| 11001 to 11111 | Reserved |

**Table 38 Gain Register Table**

See also Figure 60 to Figure 77 for equaliser and high pass filter responses.

### 3D STEREO ENHANCEMENT

The WM8983 has a digital 3D enhancement option to increase the perceived separation between the left and right channels. Selection of 3D for record or playback is controlled by register bit EQ3DMODE. Switching this bit from record to playback or from playback to record may only be done when ADC and DAC are disabled. The WM8983 control interface will only allow EQ3DMODE to be changed when ADC and DAC are disabled (ie ADCENL = 0, ADCENR = 0, DACENL = 0 and DACENR = 0).

The DEPTH3D setting controls the degree of stereo expansion.

| REGISTER ADDRESS        | BIT | LABEL        | DEFAULT | DESCRIPTION  |
|-------------------------|-----|--------------|---------|--|
| R41 (29h)<br>3D Control | 3:0 | DEPTH3D[3:0] | 0000    | Stereo depth<br>0000 = Disabled<br>0001 = 6.67%<br>0010 = 13.3%<br>0011 = 20%<br>0100 = 26.7%<br>0101 = 33.3%<br>0110 = 40%<br>0111 = 46.6%<br>1000 = 53.3%<br>1001 = 60%<br>1010 = 66.7%<br>1011 = 73.3%<br>1100 = 80%<br>1101 = 86.7%<br>1110 = 93.3%<br>1111 = 100% (maximum 3D effect) |

**Table 39 3D Stereo Enhancement Function**

**Note:** When 3D enhancement is used, it may be necessary to attenuate the signal by 6dB to avoid limiting.

### ANALOGUE OUTPUTS

The WM8983 has three sets of stereo analogue outputs. These are:

- LOUT1 and ROUT1 which are normally used to drive a headphone load.
- LOUT2 and ROUT2 – which can be used as speaker, headphone or line drivers.
- OUT3 and OUT4 – can be configured as a stereo line out (OUT3 is left output and OUT4 is right output). OUT4 can also be used to provide a mono mix of left and right channels.

The outputs LOUT2, ROUT2, OUT3 and OUT4 are powered from AVDD2 and are capable of driving a 1V rms signal (AVDD1/3.3) in non-boost mode and AVDD1\*1.5/3.3 in boost mode.

LOUT1 and ROUT1 are supplied from AVDD1 and can drive out a 1V rms signal (AVDD1/3.3).

LOUT1, ROUT1, LOUT2 and ROUT2 have individual analogue volume PGAs with -57dB to +6dB gain ranges.

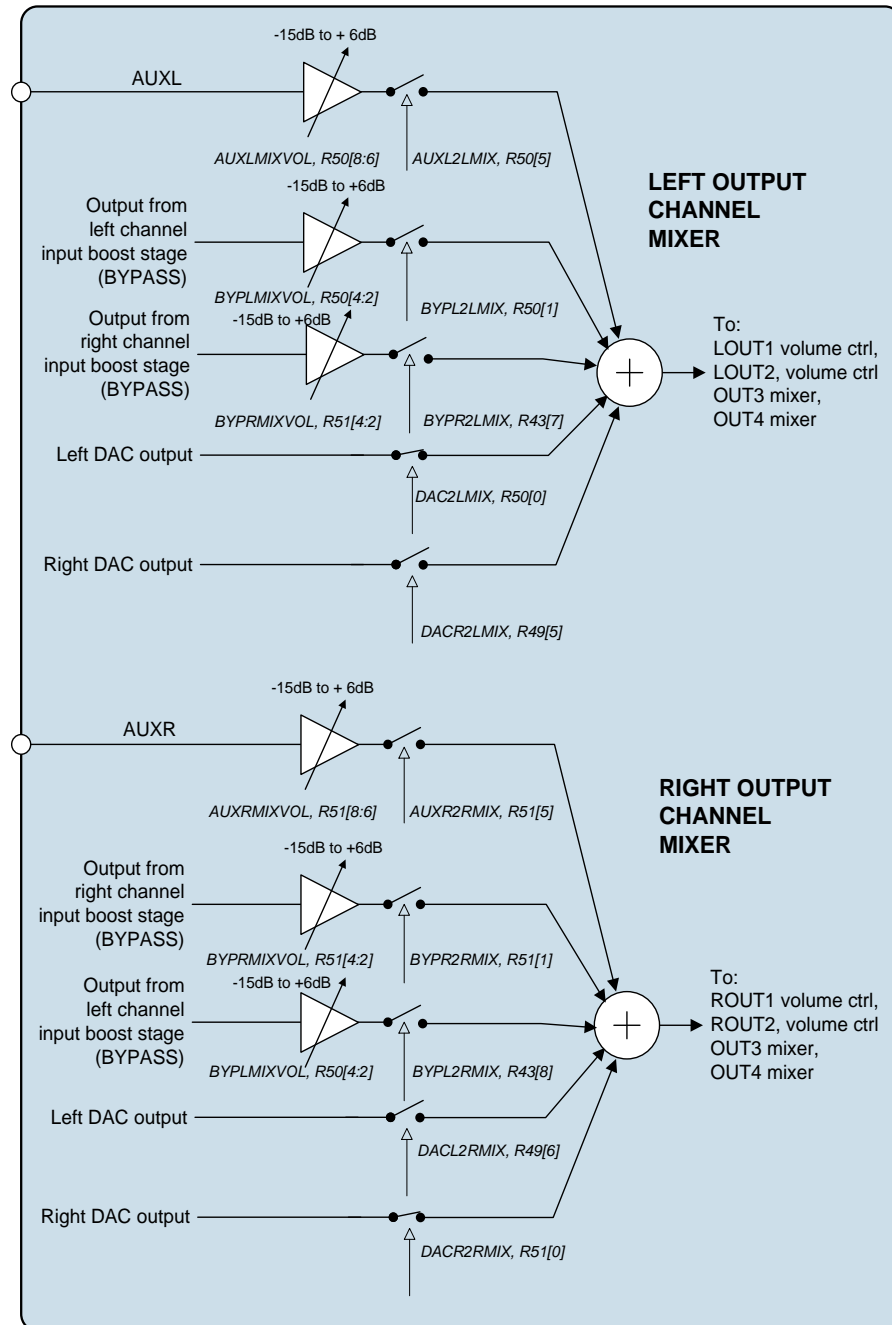
There are four output mixers in the output signal path, the left and right channel mixers which control the signals to headphone (and optionally the line outputs) and also dedicated OUT3 and OUT4 mixers.



**LEFT AND RIGHT OUTPUT CHANNEL MIXERS**

The left and right output channel mixers are shown in Figure 32. These mixers allow the AUX inputs, the ADC bypass and the DAC left and right channels to be combined as desired. This allows a mono mix of the DAC channels to be performed as well as mixing in external line-in from the AUX or speech from the input bypass path.

The AUX and bypass inputs have individual volume control from -15dB to +6dB, and the DAC volume can be adjusted in the digital domain if required. The output of these mixers is connected to the headphone outputs (LOUT1, ROUT1, LOUT2 and ROUT2) and can optionally be connected to the OUT3 and OUT4 mixers.



**Figure 32 Left/Right Output Channel Mixers**

| REGISTER ADDRESS                         | BIT | LABEL      | DEFAULT | DESCRIPTION   |
|--|-----|------------|---------|---|
| R43<br>Output mixer control              | 8   | BYPL2RMIX  | 0       | Left bypass path (from the Left channel input PGA stage) to right output mixer<br>0 = not selected<br>1 = selected  |
|  | 7   | BYPR2LMIX  | 0       | Right bypass path (from the right channel input PGA stage) to Left output mixer<br>0 = not selected<br>1 = selected   |
| R49<br>Output mixer control              | 5   | DACR2LMIX  | 0       | Right DAC output to left output mixer<br>0 = not selected<br>1 = selected   |
|  | 6   | DACL2RMIX  | 0       | Left DAC output to right output mixer<br>0 = not selected<br>1 = selected   |
| R50<br>Left channel output mixer control | 0   | DACL2LMIX  | 1       | Left DAC output to left output mixer<br>0 = not selected<br>1 = selected  |
|  | 1   | BYPL2LMIX  | 0       | Left bypass path (from the left channel input PGA stage) to left output mixer<br>0 = not selected<br>1 = selected   |
|  | 4:2 | BYPLMIXVOL | 000     | Left bypass volume control to output channel mixer:<br>000 = -15dB<br>001 = -12dB<br>010 = -9dB<br>011 = -6dB<br>100 = -3dB<br>101 = 0dB<br>110 = +3dB<br>111 = +6dB  |
|  | 5   | AUXL2LMIX  | 0       | Left Auxiliary input to left channel output mixer:<br>0 = not selected<br>1 = selected  |
|  | 8:6 | AUXLMIXVOL | 000     | Aux left channel input to left mixer volume control:<br>000 = -15dB<br>001 = -12dB<br>010 = -9dB<br>011 = -6dB<br>100 = -3dB<br>101 = 0dB<br>110 = +3dB<br>111 = +6dB |

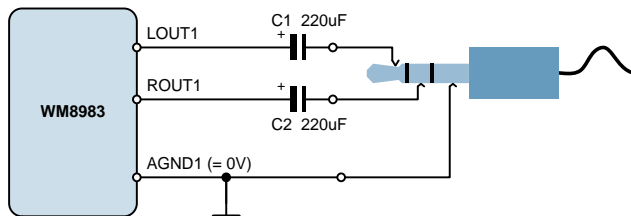
| REGISTER ADDRESS                          | BIT | LABEL      | DEFAULT | DESCRIPTION   |
|---|-----|------------|---------|---|
| R51<br>Right channel output mixer control | 0   | DACR2RMIX  | 1       | Right DAC output to right output mixer<br>0 = not selected<br>1 = selected  |
|   | 1   | BYPR2RMIX  | 0       | Right bypass path (from the right channel input PGA stage) to right output mixer<br>0 = not selected<br>1 = selected  |
|   | 4:2 | BYPRMIXVOL | 000     | Right bypass volume control to output channel mixer:<br>000 = -15dB<br>001 = -12dB<br>010 = -9dB<br>011 = -6dB<br>100 = -3dB<br>101 = 0dB<br>110 = +3dB<br>111 = +6dB   |
|   | 5   | AUXR2RMIX  | 0       | Right Auxiliary input to right channel output mixer:<br>0 = not selected<br>1 = selected  |
|   | 8:6 | AUXRMIXVOL | 000     | Aux right channel input to right mixer volume control:<br>000 = -15dB<br>001 = -12dB<br>010 = -9dB<br>011 = -6dB<br>100 = -3dB<br>101 = 0dB<br>110 = +3dB<br>111 = +6dB |
| R3<br>Power management<br>3               | 2   | LMIXEN     | 0       | Left output channel mixer enable:<br>0 = disabled<br>1 = enabled  |
|   | 3   | RMIXEN     | 0       | Right output channel mixer enable:<br>0 = disabled<br>1 = enabled   |

**Table 40 Left and Right Output Mixer Control**

## HEADPHONE OUTPUTS (LOUT1 AND ROUT1)

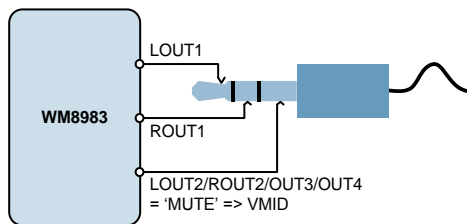
The headphone outputs LOUT1 and ROUT1 can drive a 16Ω or 32Ω headphone load, either through DC blocking capacitors, or DC-coupled to a buffered midrail reference as shown in Figure 33. OUT3, OUT4, LOUT2 or ROUT2 could be used as this buffered reference if one of these outputs is not being used, saving decoupling capacitors, at the expense of increased power consumption. For fully independent left and right channels, two separate midrail references can be used, eliminating crosstalk caused by headphone ground impedances, at the expense of increased power consumption.

### Headphone Output using DC Blocking Capacitors:



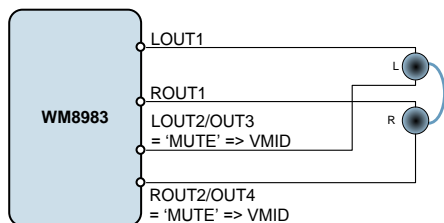
Lowest power consumption (Two outputs enabled);  
Large and expensive capacitors;  
Bass response may be reduced for smaller capacitors;  
Impedance in common ground may introduce crosstalk.

### DC Coupled Headphone Output:



Higher power consumption (Three outputs enabled);  
Improved PSRR if AVDD2 connected to AVDD1;  
Impedance in common ground may introduce crosstalk;  
Improved bass response (DC connection).

### DC Coupled with Fully Independent Left / Right Drive:



Highest power consumption (Four outputs enabled);  
Improved PSRR if AVDD2 connected to AVDD1;  
Independent L/R pseudo-ground eliminates crosstalk;  
Improved bass response (DC connection);  
Non-standard headphone connection may not be suitable for some applications.

**Figure 33 Recommended Headphone Output Configurations**

Each headphone output has an analogue volume control PGA with a gain range of -57dB to +6dB.

When DC blocking capacitors are used, their capacitance and the load resistance together determine the lower cut-off frequency of the output signal,  $f_c$ . Increasing the capacitance lowers  $f_c$ , improving the bass response. Smaller capacitance values will diminish the bass response. Assuming a 16Ω load and  $C_1, C_2 = 220\mu\text{F}$ :

$$f_c = 1 / 2\pi R_L C_1 = 1 / (2\pi \times 16\Omega \times 220\mu\text{F}) = 45 \text{ Hz}$$

In the DC coupled configuration, the headphone “ground” is connected to the VMID pin. The OUT3/4 pins can be configured as a DC output driver by setting the OUT3MUTE and OUT4MUTE register bit. The DC voltage on VMID in this configuration is equal to the DC offset on the LOUT1 and ROUT1 pins; therefore, no DC blocking capacitors are required. This saves space and material cost in portable applications.

Note that LOUT2, ROUT2, OUT3 and OUT4 have an optional output boost of 1.5x. When these are configured in this output boost mode (SPKBOOST/OUT3BOOST/OUT4BOOST=1), then the VMID value of these outputs will be equal to  $1.5 \times \text{AVDD}/2$  and will not match the VMID of the headphone drivers. Do not use the DC coupled output mode in this configuration.

It is recommended to connect the DC coupled outputs only to headphones, and not to the line input of another device. Although the built-in short circuit protection will prevent any damage to the headphone outputs, such a connection may be noisy, and may not function properly if the other device is grounded.

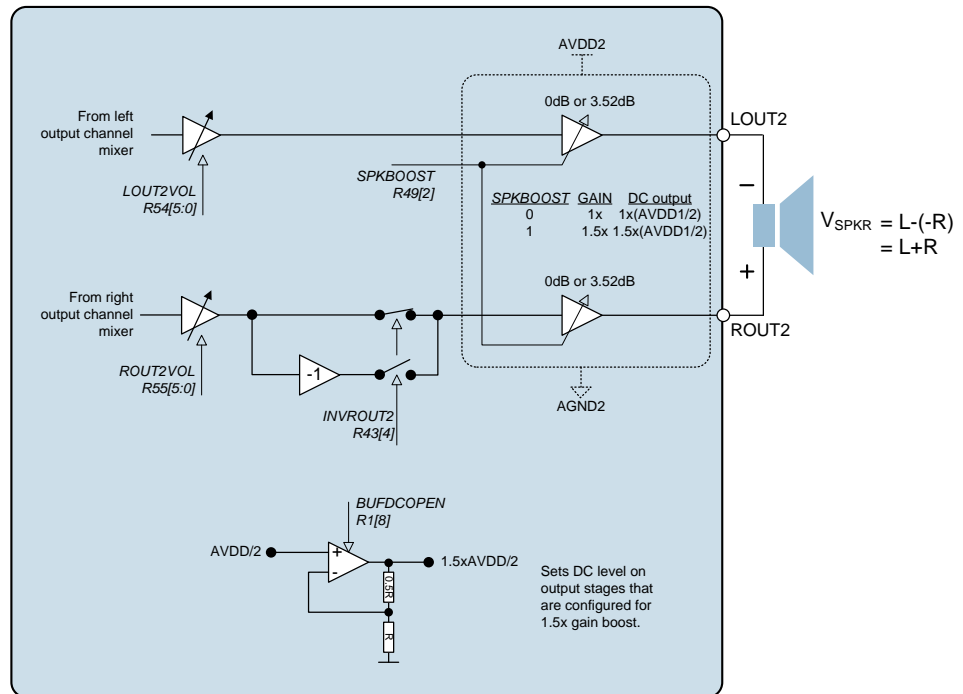
| REGISTER ADDRESS               | BIT | LABEL     | DEFAULT     | DESCRIPTION   |
|--------------------------------|-----|-----------|-------------|---|
| R52<br>LOUT1<br>Volume control | 7   | LOUT1ZC   | 0           | Headphone volume zero cross enable:<br>1 = Change gain on zero cross only<br>0 = Change gain immediately          |
|                                | 6   | LOUT1MUTE | 0           | Left headphone output mute:<br>0 = Normal operation<br>1 = Mute   |
|                                | 5:0 | LOUT1VOL  | 111001      | Left headphone output volume:<br>000000 = -57dB<br>000001 = -56dB<br>...<br>111001 = 0dB<br>...<br>111111 = +6dB  |
|                                | 8   | OUT1VU    | Not latched | LOUT1 and ROUT1 volumes do not update until a 1 is written to OUT1VU (in reg 52 or 53)                            |
| R53<br>ROUT1<br>Volume control | 7   | ROUT1ZC   | 0           | Headphone volume zero cross enable:<br>1 = Change gain on zero cross only<br>0 = Change gain immediately          |
|                                | 6   | ROUT1MUTE | 0           | Right headphone output mute:<br>0 = Normal operation<br>1 = Mute  |
|                                | 5:0 | ROUT1VOL  | 111001      | Right headphone output volume:<br>000000 = -57dB<br>000001 = -56dB<br>...<br>111001 = 0dB<br>...<br>111111 = +6dB |
|                                | 8   | OUT1VU    | Not latched | LOUT1 and ROUT1 volumes do not update until a 1 is written to OUT1VU (in reg 52 or 53)                            |

**Table 41 OUT1 Volume Control**

**SPEAKER OUTPUTS (LOUT2 AND ROUT2)**

The outputs LOUT2 and ROUT2 are designed to drive an 8Ω BTL speaker but can optionally drive two headphone loads of 16Ω/32Ω or a line output (see Headphone Output and Line Output sections, respectively). Each output has an individual volume control PGA, an output boost/level shift bit, a mute and an enable as shown in Figure 34. LOUT2 and ROUT2 output the left and right channel mixer outputs respectively.

The ROUT2 signal path also has an optional invert function; this is controlled using the INVROUT2 register bit.

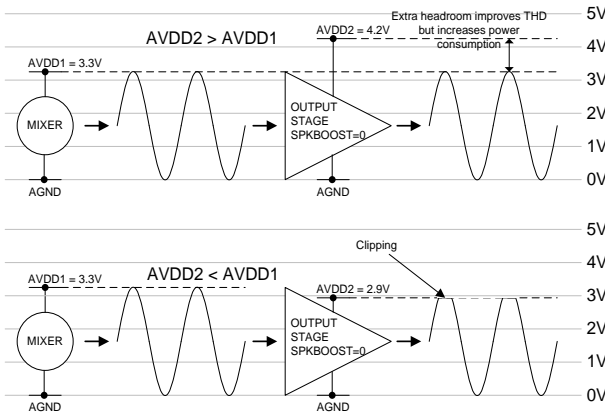
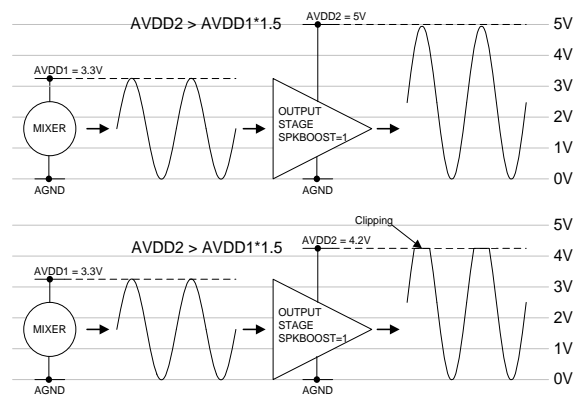


**Figure 34 Speaker Outputs LOUT2 and ROUT2**

**SPEAKER BOOST MODE**

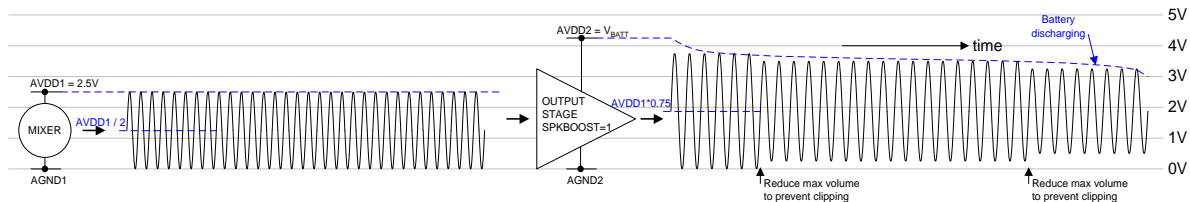
To support speaker boost mode, AVDD2 should be at least  $1.5 \cdot AVDD1$ . A higher AVDD2 will improve THD performance at the expense of power consumption while lower AVDD2 will cause clipping.

Variations in AVDD1 and AVDD2 should be taken into account when using speaker boost mode as shown in Figure 35 and Figure 36.


**Figure 35 Non-Boost Mode Output Operation**

**Figure 36 Boost Mode Output Operation**

LOUT2 and ROUT2 outputs can be connected directly to a Lithium battery to improve THD performance in non-boost mode. When using a 4.2V lithium battery, maximum power output is achieved without using speaker boost and by setting AVDD1 = 3.6V.

Although direct battery connection is also possible in boost mode, the discharge characteristic of the battery can lead to clipping after a relatively short period of time as shown in Figure 37. Reducing the maximum permitted volume and keeping AVDD1 to a minimum will allow boost mode to operate for longer.


**Figure 37 Output Boost Mode with Direct Battery Connection**

As the full scale output falls close to AVDD1, it becomes more effective to use non-boost mode to generate a louder output, although SPKBOOST should NOT be changed while the speaker output is driving out a signal. As a general rule:

if  $AVDD2 - (AVDD1 \cdot 0.75) > AVDD1 / 2$  boost mode provides more power output;

if  $AVDD2 - (AVDD1 \cdot 0.75) < AVDD1 / 2$  non-boost mode provides more power output.

| REGISTER ADDRESS                  | BIT | LABEL     | DEFAULT     | DESCRIPTION   |
|-----------------------------------|-----|-----------|-------------|---|
| R54<br>LOUT2<br>Volume<br>control | 7   | LOUT2ZC   | 0           | Left speaker volume zero cross enable:<br>1 = Change gain on zero cross only<br>0 = Change gain immediately     |
|                                   | 6   | LOUT2MUTE | 0           | Left speaker output mute:<br>0 = Normal operation<br>1 = Mute   |
|                                   | 5:0 | LOUT2VOL  | 111001      | Left speaker output volume:<br>000000 = -57dB<br>000001 = -56dB<br>...<br>111001 = 0dB<br>...<br>111111 = +6dB  |
|                                   | 8   | OUT2VU    | Not latched | LOUT2 and ROUT2 volumes do not update until a 1 is written to OUT2VU (in reg 54 or 55)                          |
| R55<br>ROUT2<br>Volume<br>control | 7   | ROUT2ZC   | 0           | Right speaker volume zero cross enable:<br>1 = Change gain on zero cross only<br>0 = Change gain immediately    |
|                                   | 6   | ROUT2MUTE | 0           | Right speaker output mute:<br>0 = Normal operation<br>1 = Mute  |
|                                   | 5:0 | ROUT2VOL  | 111001      | Right speaker output volume:<br>000000 = -57dB<br>000001 = -56dB<br>...<br>111001 = 0dB<br>...<br>111111 = +6dB |
|                                   | 8   | OUT2VU    | Not latched | LOUT2 and ROUT2 volumes do not update until a 1 is written to OUT2VU (in reg 54 or 55)                          |

**Table 42 OUT2 Volume Control**

The signal output on LOUT2/ROUT2 comes from the Left/Right Mixer circuits and can be any combination of the DAC output, the Bypass path (output of the input boost stage) and the AUX input. The LOUT2/ROUT2 volume is controlled by the LOUT2VOL/ ROUT2VOL register bits. Gains over 0dB may cause clipping if the signal is large. The LOUT2MUTE/ ROUT2MUTE register bits cause the speaker outputs to be muted (the output DC level is driven out). The output pins remain at the same DC level (DCOP), so that no click noise is produced when muting or un-muting

The speaker output stages also have a selectable gain boost of 1.5x (3.52dB). When this boost is enabled, the output DC level is also level shifted (from AVDD1/2 to 1.5xAVDD1/2) to prevent the signal from clipping. A dedicated amplifier BUFDCOP, as shown in Figure 34, is used to perform the DC level shift operation. This buffer must be enabled using the BUFDCOPEN register bit for this operating mode. It should also be noted that if AVDD2 is not equal to or greater than 1.5xAVDD1 this boost mode may result in signals clipping. Table 44 summarises the effect of the SPKBOOST control bits.



| REGISTER ADDRESS         | BIT | LABEL     | DEFAULT | DESCRIPTION   |
|--------------------------|-----|-----------|---------|---|
| R49<br>Output control    | 2   | SPKBOOST  | 0       | Speaker Gain<br>0 = speaker gain = -1;<br>DC = AVDD1 / 2<br>1 = speaker gain = +1.5;<br>DC = 1.5 x AVDD1 / 2      |
| R1<br>Power management 1 | 8   | BUFDCOPEN | 0       | Output stage 1.5xAVDD/2 driver enable<br>0 = Buffer disabled<br>1 = Buffer enabled (required for 1.5x gain boost) |

**Table 43 Speaker Boost Stage Control**

| SPKBOOST | OUTPUT STAGE GAIN | OUTPUT DC LEVEL | OUTPUT STAGE CONFIGURATION |
|----------|-------------------|-----------------|----------------------------|
| 0        | 1x (0dB)          | AVDD1/2         | Inverting                  |
| 1        | 1.5x (3.52dB)     | 1.5xAVDD1/2     | Non-inverting              |

**Table 44 Output Boost Stage Details**

| REGISTER ADDRESS    | BIT | LABEL    | DEFAULT | DESCRIPTION   |
|---------------------|-----|----------|---------|---|
| R43<br>Beep control | 4   | INVROUT2 | 0       | Invert ROUT2 output<br>0 = Not inverted<br>1 = Inverted |

**Table 45 ROUT2 Phase Invert Control**

### ZERO CROSS TIMEOUT

A zero-cross timeout function is provided so that if zero cross is enabled on the input or output PGAs, the gain will automatically update after a timeout period if a zero cross has not occurred. This is enabled by setting SLOWCLKEN. The timeout period is dependent on the clock input to the digital and is equal to  $2^{21} * \text{SYSCLK period}$ .

| REGISTER ADDRESS         | BIT | LABEL     | DEFAULT | DESCRIPTION  |
|--------------------------|-----|-----------|---------|--|
| R7<br>Additional Control | 0   | SLOWCLKEN | 0       | Slow clock enable.<br>Used for both the jack insert detect debounce circuit and the zero cross timeout.<br>0 = slow clock disabled<br>1 = slow clock enabled |

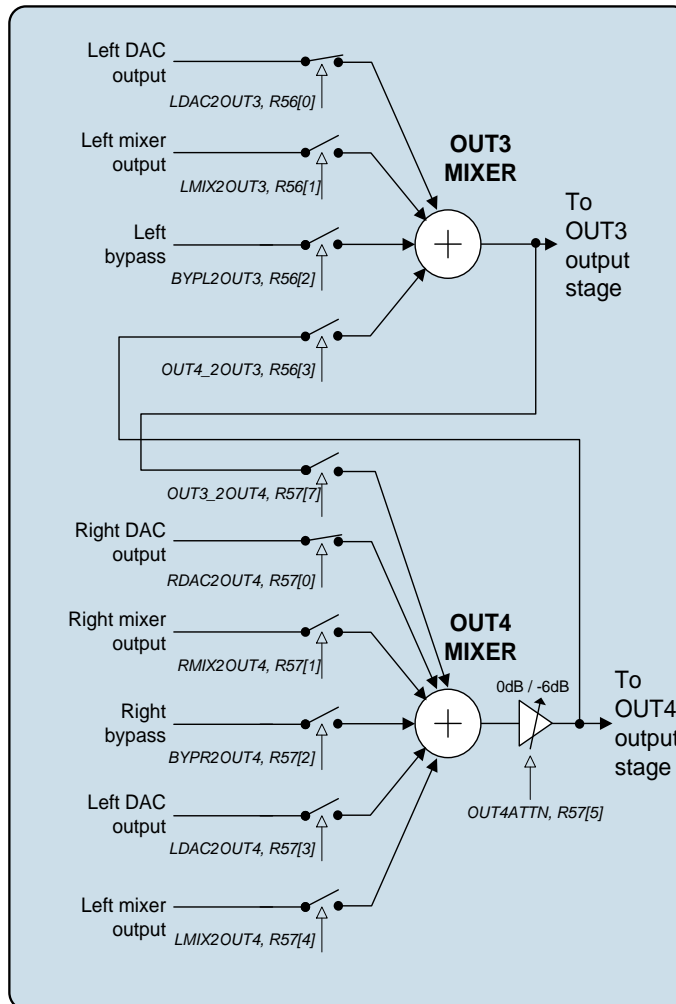
**Table 46 Timeout Clock Enable Control**

**Note:** SLOWCLKEN is also used for the jack insert detect debounce circuit

**OUT3/OUT4 MIXERS AND OUTPUT STAGES**

The OUT3/OUT4 pins provide an additional stereo line output, a mono output, or a pseudo ground connection for headphones. There is a dedicated analogue mixer for OUT3 and one for OUT4 as shown in Figure 38.

The OUT3 and OUT4 output stages are powered from AVDD2 and AGND2. These individually-controllable outputs also incorporate an optional 1.5x boost and level shifting stage.



**Figure 38 OUT3 and OUT4 Mixers**

OUT3 can provide a midrail reference, a left line output, or a mono mix line output

OUT4 can provide a midrail reference, a right line output, or a mono mix line output.

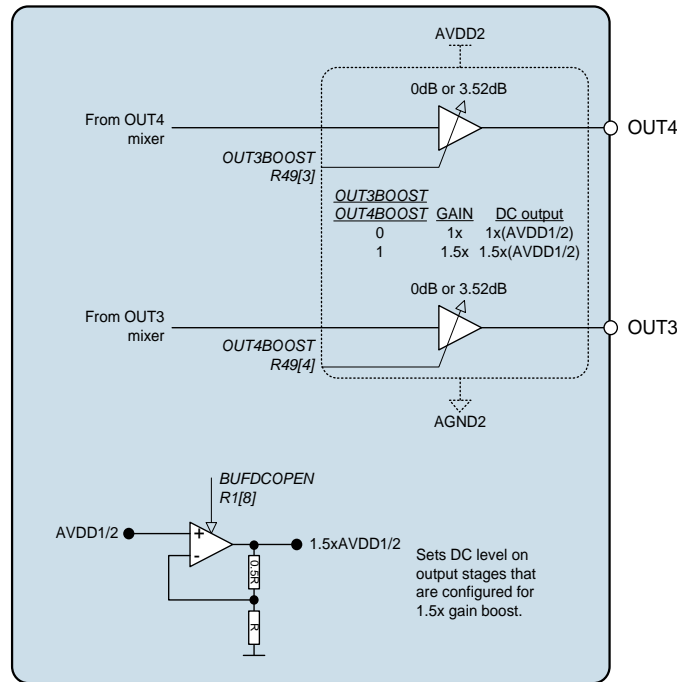
A 6dB attenuation function is provided for OUT4, to prevent clipping during mixing of left and right signals. This function is enabled by the OUT4ATTN register bit.

| REGISTER ADDRESS          | BIT | LABEL      | DEFAULT | DESCRIPTION  |
|---------------------------|-----|------------|---------|--|
| R1<br>Power Management 1  | 7   | OUT4MIXEN  | 0       | OUT4 mixer enable<br>0=disabled<br>1=enabled   |
|                           | 6   | OUT3MIXEN  | 0       | OUT3 mixer enable<br>0=disabled<br>1=enabled   |
| R56<br>OUT3 mixer control | 6   | OUT3MUTE   | 0       | 0 = Output stage outputs OUT3 mixer<br>1 = Output stage muted – drives out VMID. Can be used as VMID reference in this mode. |
|                           | 3   | OUT4_2OUT3 | 0       | OUT4 mixer output to OUT3<br>0 = disabled<br>1 = enabled   |
|                           | 2   | BYPL2OUT3  | 0       | Left ADC input to OUT3<br>0 = disabled<br>1 = enabled  |
|                           | 1   | LMIX2OUT3  | 0       | Left Output mixer to OUT3<br>0 = disabled<br>1 = enabled   |
|                           | 0   | LDAC2OUT3  | 1       | Left DAC output to OUT3<br>0 = disabled<br>1 = enabled   |
| R57<br>OUT4 mixer control | 7   | OUT3_2OUT4 | 0       | OUT3 mixer output to OUT4<br>0 = disabled<br>1 = enabled   |
|                           | 6   | OUT4MUTE   | 0       | 0 = Output stage outputs OUT4 mixer<br>1 = Output stage muted – drives out VMID. Can be used as VMID reference in this mode. |
|                           | 5   | OUT4ATTN   | 0       | 0 = OUT4 normal output<br>1 = OUT4 attenuated by 6dB   |
|                           | 4   | LMIX2OUT4  | 0       | Left Output mixer to OUT4<br>0 = disabled<br>1 = enabled   |
|                           | 3   | LDAC2OUT4  | 0       | Left DAC to OUT4<br>0 = disabled<br>1 = enabled  |
|                           | 2   | BYPR2OUT4  | 0       | Right ADC input to OUT4<br>0 = disabled<br>1 = enabled   |
|                           | 1   | RMIX2OUT4  | 0       | Right Output mixer to OUT4<br>0 = disabled<br>1 = enabled  |
|                           | 0   | RDAC2OUT4  | 1       | Right DAC output to OUT4<br>0 = disabled<br>1 = enabled  |

**Table 47 OUT3/OUT4 Mixer Registers**

The OUT3 and OUT4 output stages each have a selectable gain boost of 1.5x (3.52dB). When this boost is enabled, the output DC level is also level shifted (from AVDD1/2 to 1.5xAVDD1/2) to prevent the signal from clipping. A dedicated amplifier BUFDCOP, as shown in Figure 39, is used to perform the DC level shift operation. This buffer must be enabled using the BUFDCOPEN register bit for this operating mode. It should also be noted that if AVDD2 is not equal to or greater than 1.5xAVDD1, this boost mode may result in signals clipping. Table 44 summarises the effect of the OUT3BOOST and

OUT4BOOST control bits.


**Figure 39** Outputs OUT3 and OUT4

| REGISTER ADDRESS            | BIT | LABEL     | DEFAULT | DESCRIPTION  |
|-----------------------------|-----|-----------|---------|--|
| R49<br>Output control       | 3   | OUT3BOOST | 0       | Output 3 Gain<br>0 = OUT3 output gain = -1;<br>DC = AVDD1 / 2<br>1 = OUT3 output gain = +1.5<br>DC = 1.5 x AVDD1 / 2 |
|                             | 4   | OUT4BOOST | 0       | Output 4 Gain<br>0 = OUT4 output gain = -1;<br>DC = AVDD1 / 2<br>1 = OUT4 output gain = +1.5<br>DC = 1.5 x AVDD1 / 2 |
| R1<br>Power management<br>1 | 8   | BUFDCOPEN | 0       | Output stage 1.5xAVDD/2 driver enable<br>0=Buffer disabled<br>1=Buffer enabled (required for 1.5x gain boost)        |

**Table 48** OUT3 and OUT4 Boost Stages Control

| OUT3BOOST/<br>OUT4BOOST | OUTPUT<br>STAGE GAIN | OUTPUT DC<br>LEVEL | OUTPUT STAGE<br>CONFIGURATIO<br>N |
|-------------------------|----------------------|--------------------|-----------------------------------|
| 0                       | 1x                   | AVDD1/2            | Inverting                         |
| 1                       | 1.5x                 | 1.5xAVDD1/2        | Non-inverting                     |

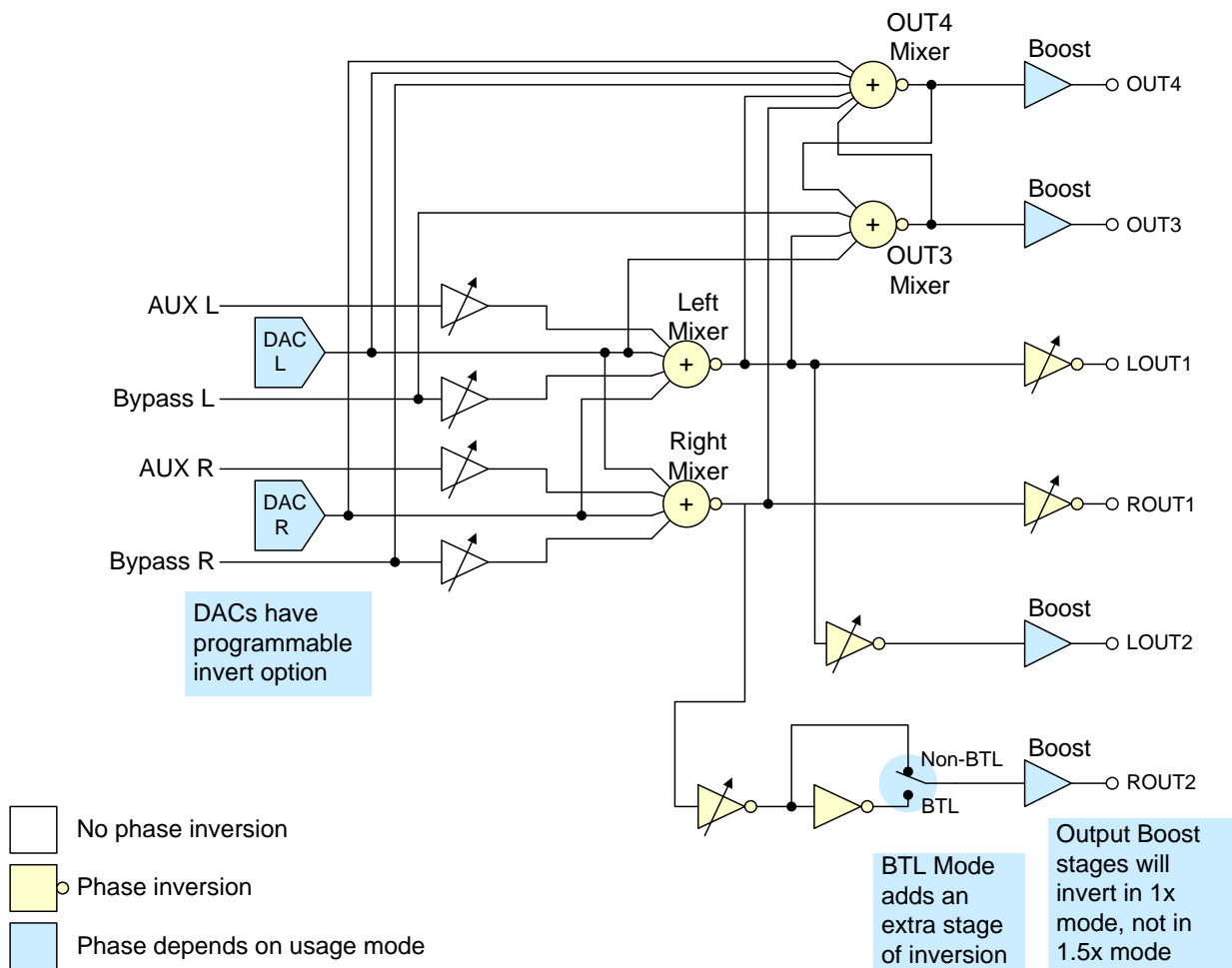
**Table 49** OUT3 and OUT4 Output Boost Stage Details

**OUTPUT PHASING**

The relative phases of the analogue outputs will depend upon the following factors:

1. DACLPOL and DACRPOL invert bits: Setting these bits to 1 will invert the DAC output.
2. Mixer configuration: The polarity of the signal will depend upon the route through the mixer path. For example, DACL can be directly input to the OUT3 mixer, giving a 180° phase shift at the OUT3 mixer output. However, if DACL is input to the OUT3 mixer via the left mixer, an additional phase shift will be introduced, giving 0° phase shift at the OUT3 mixer output.
3. Output boost set-up: When 1.5x boost is enabled on an output, no phase shift occurs. When 1.5x boost is not enabled, a 180° phase shift occurs.

Figure 32 shows where these phase inversions can occur in the output signal path.



**Figure 40 Output Signal Path Phasing**

Table 50 shows the polarities of the outputs in various configurations.

Unless otherwise stated, polarity is shown with respect to left DAC output in non-inverting mode.

Note that only registers relating to the mixer paths are shown here (Mixer enables, volume settings, output enables etc are not shown).

| CONFIGURATION   | DACLPOL | DACRPOL | INVROUT2 | SPKBOOST | OUT3BOOST | OUT4BOOST | MIXER PATH<br>REGISTERS<br>DIFFERENT<br>FROM DEFAULT     | OUT4<br>PHASE /<br>MAG | OUT3<br>PHASE /<br>MAG | LOUT1<br>PHASE /<br>MAG | ROUT1<br>PHASE /<br>MAG | LOUT2<br>PHASE /<br>MAG | ROUT2<br>PHASE /<br>MAG |
|---|---------|---------|----------|----------|-----------|-----------|--|------------------------|------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| Default:<br>Stereo DAC playback<br>to LOUT1/ROUT1,<br>LOUT2/ROUT2 and<br>OUT4/OUT3                            | 0       | 0       | 0        | 0        | 0         | 0         |  | 0°<br>1                | 0°<br>1                | 0°<br>1                 | 0°<br>1                 | 180°<br>1               | 180°<br>1               |
| DACs inverted   | 1       | 1       | 0        | 0        | 0         | 0         |  | 180°<br>1              | 180°<br>1              | 180°<br>1               | 180°<br>1               | 0°<br>1                 | 0°<br>1                 |
| Stereo DAC playback<br>to LOUT1/ROUT1 and<br>LOUT2/ROUT2 and<br>OUT4/OUT3<br>(Speaker boost<br>enabled)       | 0       | 0       | 0        | 1        | 0         | 0         |  | 0°<br>1                | 0°<br>1                | 0°<br>1                 | 0°<br>1                 | 0°<br>1.5               | 0°<br>1.5               |
| Stereo DAC playback<br>to LOUT1/ROUT1 and<br>LOUT2/ROUT2 and<br>OUT4/OUT3<br>(OUT3 and OUT4<br>boost enabled) | 0       | 0       | 0        | 0        | 1         | 1         |  | 180°<br>1.5            | 180°<br>1.5            | 0°<br>1                 | 0°<br>1                 | 180°<br>1               | 180°<br>1               |
| Stereo playback to<br>OUT3/OUT4 (DACs<br>input to OUT3/OUT4<br>mixers via left/right<br>mixers)               | 0       | 0       | 0        | 0        | 0         | 0         | LDAC2OUT3=0<br>RDAC2OUT4=0<br>LMIX2OUT3=1<br>RMIX2OUT4=1 | 180°<br>1              | 180°<br>1              | 0°<br>1                 | 0°<br>1                 | 180°<br>1               | 180°<br>1               |
| Differential output of<br>right bypass path via<br>OUT3/OUT4 (Phase<br>shown relative to right<br>bypass)     | 0       | 0       | 0        | 0        | 0         | 0         | BYPR2OUT4=1<br>OUT4_2OUT3=1                              | 180°<br>1              | 0°<br>1                | X                       | X                       | X                       | X                       |
| Differential output of<br>mono mix of DACs via<br>LOUT2/ROUT2 (e.g.<br>BTL speaker drive)                     | 0       | 0       | 1        | 0        | 0         | 0         |  | 0°<br>1                | 0°<br>1                | 0°<br>1                 | 0°<br>1                 | 180°<br>1               | 0°<br>1                 |
| High power speaker<br>drive   | 0       | 0       | 1        | 1        | 0         | 0         |  | 0°<br>1                | 0°<br>1                | 0°<br>1                 | 0°<br>1                 | 0°<br>1.5               | 180°<br>1.5             |

**Table 50 Relative Output Phases**

Note that differential output should not be set up by combining outputs in boost mode with outputs which are not in boost mode as this would cause a DC offset current on the outputs.

**ENABLING THE OUTPUTS**

Each analogue output of the WM8983 can be independently enabled or disabled. The analogue mixer associated with each output has a separate enable bit. All outputs are disabled by default. To save power, unused parts of the WM8983 should remain disabled.

Outputs can be enabled at any time, but it is not recommended to do so when BUFIO is disabled (BUFIOEN=0), as this may cause pop noise (see “Power Management” and “Applications Information” sections).

| REGISTER ADDRESS            | BIT | LABEL     | DEFAULT | DESCRIPTION   |
|-----------------------------|-----|-----------|---------|---|
| R1<br>Power Management<br>1 | 2   | BUFIOEN   | 0       | Unused input/output bias buffer enable<br>0=disabled<br>1=enabled   |
|                             | 6   | OUT3MIXEN | 0       | OUT3 mixer enable<br>0=disabled<br>1=enabled  |
|                             | 7   | OUT4MIXEN | 0       | OUT4 mixer enable<br>0=disabled<br>1=enabled  |
|                             | 8   | BUFDCOPEN | 0       | Output stage 1.5xAVDD/2 driver enable<br>0 = Buffer disabled<br>1 = Buffer enabled (required for 1.5x gain boost)                 |
| R2<br>Power Management<br>2 | 8   | ROUT1EN   | 0       | ROUT1 output enable<br>0=disabled<br>1=enabled  |
|                             | 7   | LOUT1EN   | 0       | LOUT1 output enable<br>0=disabled<br>1=enabled  |
|                             | 6   | SLEEP     | 0       | Sleep Mode enable<br>0 = Normal device operation<br>1 = Supply current reduced in device standby mode if clocks are still running |
| R3<br>Power Management<br>3 | 2   | LMIXEN    | 0       | Left output channel mixer enable<br>0 = disabled<br>1 = enabled   |
|                             | 3   | RMIXEN    | 0       | Right output channel mixer enable<br>0 = disabled<br>1 = enabled  |
|                             | 5   | ROUT2EN   | 0       | ROUT2 output enable<br>0 = disabled<br>1 = enabled  |
|                             | 6   | LOUT2EN   | 0       | LOUT2 output enable<br>0 = disabled<br>1 = enabled  |
|                             | 7   | OUT3EN    | 0       | OUT3 enable<br>0 = disabled<br>1 = enabled  |
|                             | 8   | OUT4EN    | 0       | OUT4 enable<br>0 = disabled<br>1 = enabled  |

|                     |   |         |   |  |
|---------------------|---|---------|---|--|
| R42<br>Output ctrl1 | 2 | POBCTRL | 0 | Power-On Bias Control<br>(Use during power Up. Reset when VMID bias is stable)<br>0 = Bias derived from VMID<br>1 = Bias derived from AVDD |
|                     | 1 | DELEN   | 0 | 2 <sup>nd</sup> enable bit for L/ROUT1   |
|                     | 0 | OUT1DEL | 0 | 2 stage enable for L/ROUT1   |

**Table 51 Output Stages Power Management Control**

OUT1DEL enables lower pop noise power-up option for LOUT1 and ROUT1. See Recommended Control Sequences (in 2 stage enable method, normal enable bit is set, followed shortly later by the delayed enable DELEN).

### THERMAL SHUTDOWN

To protect the WM8983 from overheating, a thermal shutdown circuit is included. If the device temperature reaches approximately 125°C and the thermal shutdown circuit is enabled (TSDEN=1), the L/ROUT2 amplifiers will be disabled. The thermal shutdown may also be configured to generate an interrupt. See the GPIO and Interrupt Controller section for details.

| REGISTER ADDRESS      | BIT | LABEL | DEFAULT | DESCRIPTION  |
|-----------------------|-----|-------|---------|--|
| R49<br>Output Control | 1   | TSDEN | 1       | Thermal Shutdown Enable<br>0 : thermal shutdown disabled<br>1 : thermal shutdown enabled |

**Table 52 Thermal Shutdown**

### UNUSED ANALOGUE INPUTS/OUTPUTS

Whenever an analogue input/output is disabled, it remains connected to a voltage source (either AVDD1/2 or 1.5xAVDD1/2 as appropriate) through a resistor. This helps to prevent pop noise when the output is re-enabled. The resistance between the voltage buffer and the output pins can be controlled using the VROI control bit. The default impedance is low, so that any capacitors on the outputs can charge up quickly at start-up. If a high impedance is desired for disabled outputs, VROI can then be set to 1, increasing the resistance to about 30kΩ.

A dedicated buffer is available for biasing unused analogue I/O pins as shown in Figure 41. This buffer can be enabled using the BUFIOEN register bit.

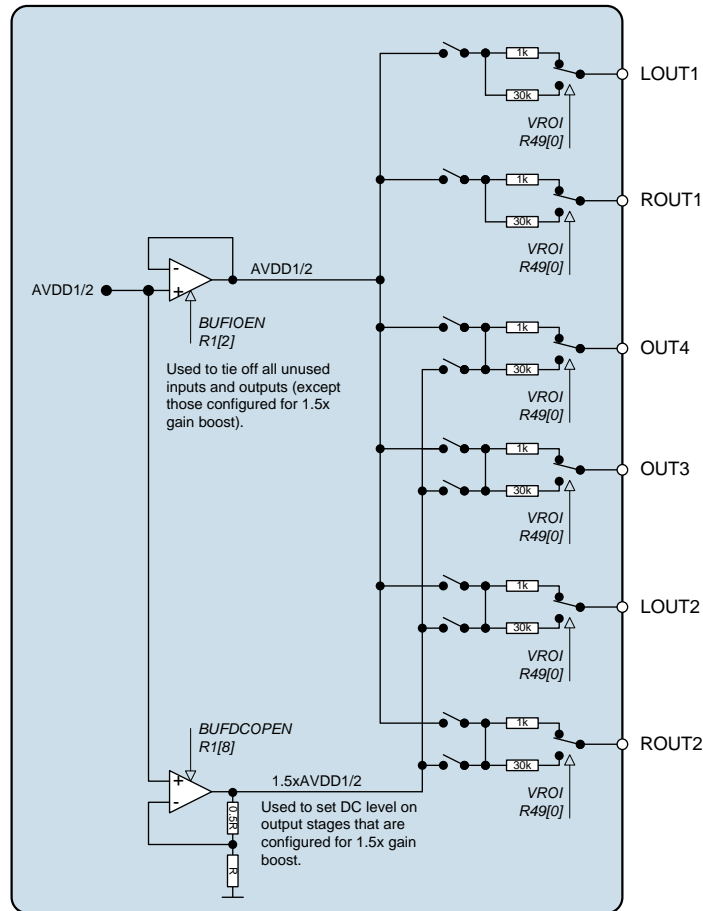
If the SPKBOOST, OUT3BOOST or OUT4BOOST bits are set, then the relevant outputs will be tied to the output of the DC level shift buffer at 1.5xAVDD/2 when disabled.

| REGISTER ADDRESS         | BIT | LABEL   | DEFAULT | DESCRIPTION  |
|--------------------------|-----|---------|---------|--|
| R1<br>Power Management 1 | 2   | BUFIOEN | 0       | Unused input/output bias buffer enable<br>0=disabled<br>1=enabled                              |
| R49<br>Output Control    | 0   | VROI    | 0       | VREF (AVDD1/2 or 1.5xAVDD/2) to analogue output resistance<br>0: approx 1kΩ<br>1: approx 30 kΩ |

**Table 53 Disabled Outputs to VREF Resistance**



Figure 41 summarises the bias options for the output pins.


**Figure 41 Unused Output Pin Tie-off Buffers**

| L/ROUT2EN/<br>OUT3/4EN | OUT3BOOST/<br>OUT4BOOST/<br>SPKBOOST | VROI | OUTPUT CONFIGURATION                  |
|------------------------|--------------------------------------|------|---------------------------------------|
| 0                      | 0                                    | 0    | 1kΩ tie-off to AVDD1/2                |
| 0                      | 0                                    | 1    | 30kΩ tie-off to AVDD1/2               |
| 0                      | 1                                    | 0    | 1kΩ tie-off to 1.5xAVDD1/2            |
| 0                      | 1                                    | 1    | 30kΩ tie-off to 1.5xAVDD1/2           |
| 1                      | 0                                    | X    | Output enabled (DC level=AVDD1/2)     |
| 1                      | 1                                    | X    | Output enabled (DC level=1.5xAVDD1/2) |

**Table 54 Unused Output Pin Bias Options**

## DIGITAL AUDIO INTERFACES

The audio interface has four pins:

- ADCDAT: ADC data output
- DACDAT: DAC data input
- LRC: Data Left/Right alignment clock
- BCLK: Bit clock, for synchronisation

The clock signals BCLK, and LRC can be outputs when the WM8983 operates as a master, or inputs when it is a slave (see Master and Slave Mode Operation, below).

Five different audio data formats are supported:

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

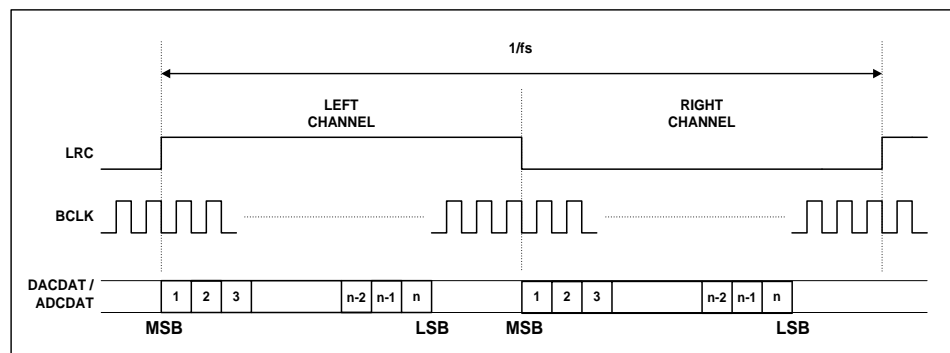
All of these modes are MSB first. They are described in Audio Data Formats, below. Refer to the Electrical Characteristic section for timing information.

### MASTER AND SLAVE MODE OPERATION

The WM8983 audio interface may be configured as either master or slave. As a master interface device, the WM8983 generates BCLK and LRC and thus controls sequencing of the data transfer on ADCDAT and DACDAT. To set the device to master mode, register bit MS should be set high. In slave mode (MS=0), the WM8983 responds with data to clocks it receives over the digital audio interfaces.

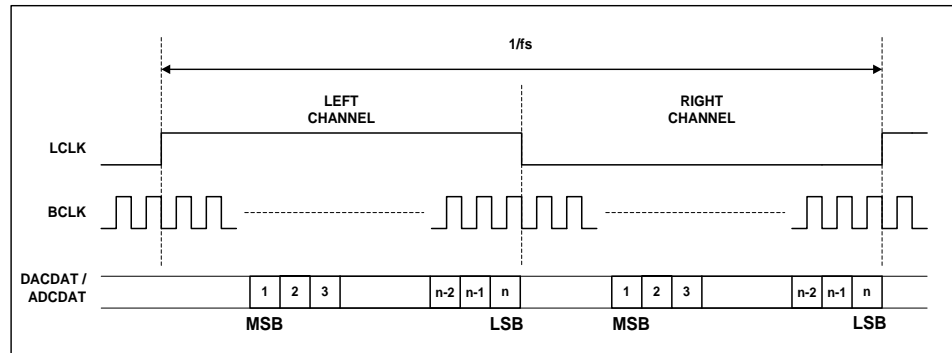
### AUDIO DATA FORMATS

In Left Justified mode, the MSB is available on the first rising edge of BCLK following an LRC 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 LRC transition.



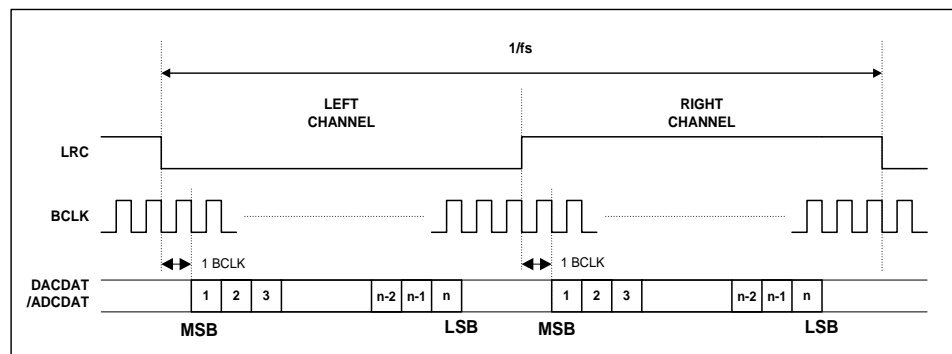
**Figure 42 Left Justified Audio Interface (assuming n-bit word length)**

In Right Justified mode, the LSB is available on the last rising edge of BCLK before a LRC 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 LRC transition.



**Figure 43 Right Justified Audio Interface (assuming n-bit word length)**

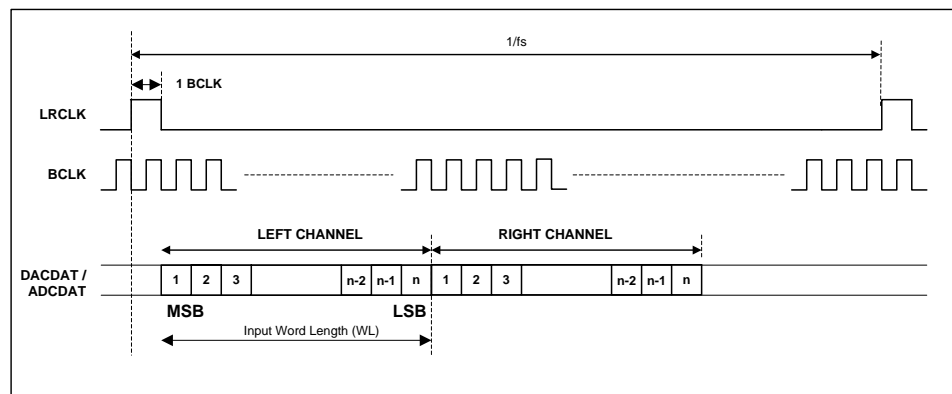
In I<sup>2</sup>S mode, the MSB is available on the second rising edge of BCLK following a LRC transition. The other bits up to the LSB are then transmitted in order. Depending on word length, BCLK frequency and sample rate, there may be unused BCLK cycles between the LSB of one sample and the MSB of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



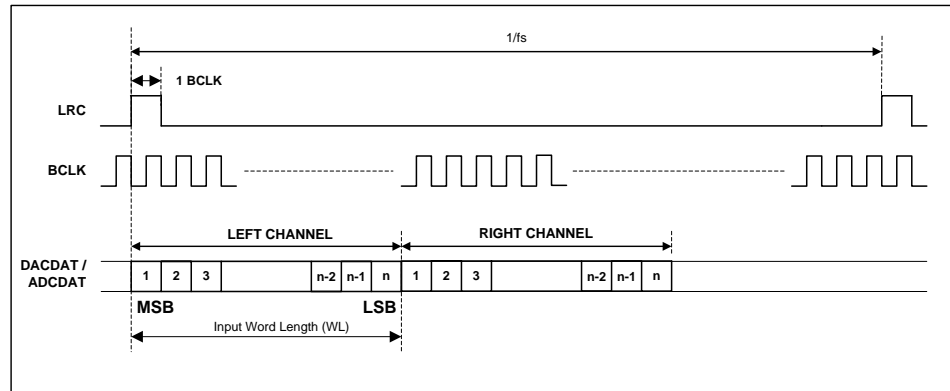
**Figure 44 I<sup>2</sup>S Audio Interface (assuming n-bit word length)**

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

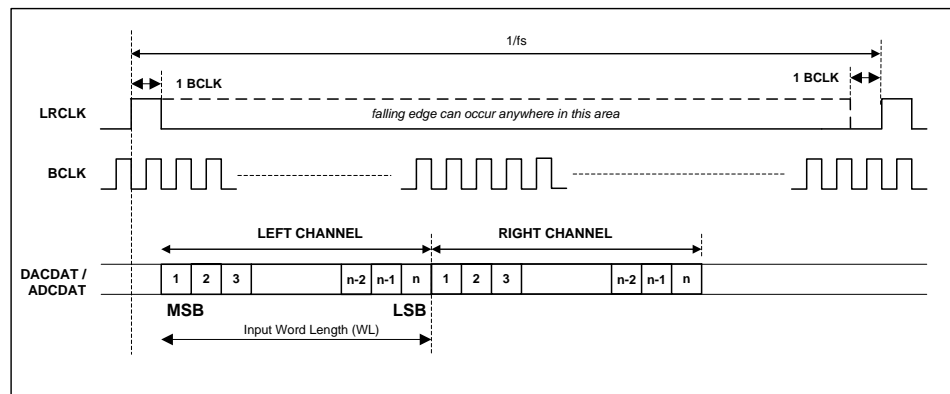
In device master mode, the LRC output will resemble the LRC pulse shown in Figure 45 and Figure 46. In device slave mode, shown in Figure 47 and Figure 48, it is possible to use any length of LRC pulse less than 1/fs, providing the falling edge of the LRC pulse occurs greater than one BCLK period before the rising edge of the next LRC pulse.



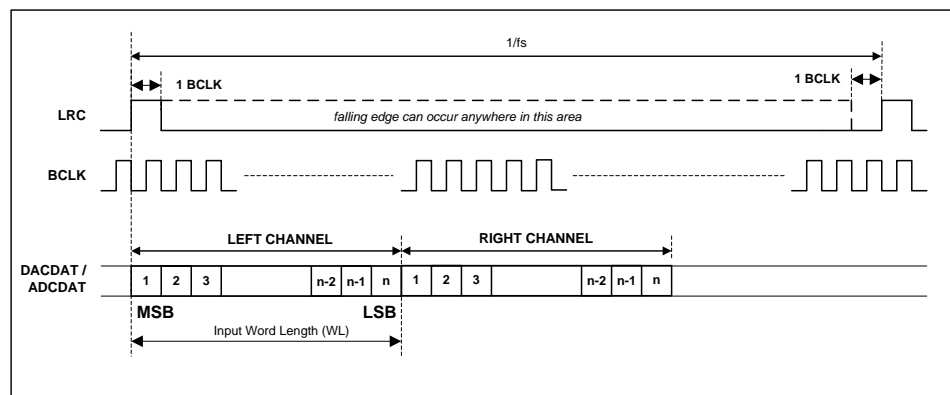
**Figure 45 DSP/PCM Mode Audio Interface (mode A, LRP=0, Master)**



**Figure 46 DSP/PCM Mode Audio Interface (mode B, LRP=1, Master)**



**Figure 47 DSP/PCM Mode Audio Interface (mode A, LRP=0, Slave)**



**Figure 48 DSP/PCM Mode Audio Interface (mode B, LRP=0, Slave)**

| REGISTER ADDRESS              | BIT | LABEL    | DEFAULT | DESCRIPTION   |
|-------------------------------|-----|----------|---------|---|
| R4<br>Audio Interface Control | 0   | MONO     | 0       | Selects between stereo and mono device operation:<br>0 = Stereo device operation<br>1 = Mono device operation. Data appears in 'left' phase of LRC.   |
|                               | 1   | ALRSWAP  | 0       | Controls whether ADC data appears in 'right' or 'left' phases of LRC clock:<br>0=ADC left data appears in 'left' phase of LRC and right data in 'right' phase<br>1=ADC left data appears in 'right' phase of LRC and right data in 'left' phase |
|                               | 2   | DLRSWAP  | 0       | Controls whether DAC data appears in 'right' or 'left' phases of LRC clock:<br>0=DAC left data appears in 'left' phase of LRC and right data in 'right' phase<br>1=DAC left data appears in 'right' phase of LRC and right data in 'left' phase |
|                               | 4:3 | FMT      | 10      | Audio interface Data Format Select:<br>00=Right Justified<br>01=Left Justified<br>10=I <sup>2</sup> S format<br>11= DSP/PCM mode  |
|                               | 6:5 | WL       | 10      | Word length<br>00=16 bits<br>01=20 bits<br>10=24 bits<br>11=32 bits (see note)  |
|                               | 7   | LRP      | 0       | LRC clock polarity<br>0=normal<br>1=inverted  |
|                               | 8   | BCLP     | 0       | BCLK polarity<br>0=normal<br>1=inverted   |
| R5                            | 0   | LOOPBACK | 0       | Digital loopback function<br>0=No loopback<br>1=Loopback enabled, ADC data output is fed directly into DAC data input.  |

**Table 55 Audio Interface Control**

**Note:** Right Justified Mode will only operate with a maximum of 24 bits. If 32-bit mode is selected the device will operate in 24-bit mode.

**AUDIO INTERFACE CONTROL**

The register bits controlling audio format, word length and master / slave mode are summarised below.

Register bit MS selects audio interface operation in master or slave mode. In Master mode, BCLK and LRC are outputs. The frequencies of BCLK and LRC in master mode are controlled using MCLKDIV; these clocks are divided down versions of PLL output clock (SYSCLK). The MCLKDIV default setting provides a SYSCLK/256 division rate for the LRC output clock.

It is possible to divide down the BCLK rate using BCLKDIV; care must be taken in choosing the correct BCLKDIV rate to maintain sufficient BCLK pulses per LRC period for the chosen data word length. The BCLKDIV default setting provides a BCLK = SYSCLK clock.

| REGISTER ADDRESS                     | BIT | LABEL   | DEFAULT | DESCRIPTION  |
|--------------------------------------|-----|---------|---------|--|
| R6<br>Clock<br>Generation<br>Control | 0   | MS      | 0       | Sets the chip to be master over LRC and BCLK<br>0=BCLK and LRC clock are inputs (Slave mode)<br>1=BCLK and LRC clock are outputs generated by the WM8983 (Master mode)   |
|                                      | 4:2 | BCLKDIV | 000     | Configures the BCLK and LRC output frequency, for use when the chip is in Master mode.<br>000=divide by 1 (BCLK=SYSCLK)<br>001=divide by 2 (BCLK=SYSCLK/2)<br>010=divide by 4<br>011=divide by 8<br>100=divide by 16<br>101=divide by 32<br>110=reserved<br>111=reserved |
|                                      | 7:5 | MCLKDIV | 010     | Sets the division for either the MCLK or PLL clock output (selected by CLKSEL)<br>000=divide by 1<br>001=divide by 1.5<br>010=divide by 2<br>011=divide by 3<br>100=divide by 4<br>101=divide by 6<br>110=divide by 8<br>111=divide by 12                                |
|                                      | 8   | CLKSEL  | 1       | Controls the source of the clock for all internal operation:<br>0=MCLK<br>1=PLL output   |

**Table 56 Clock Control**

The CLKSEL bit selects the internal source of the Master clock from the PLL (CLKSEL=1) or from MCLK (CLKSEL=0). When the internal clock is switched from one source to another using the CLKSEL bit, the clock originally selected must generate at least one falling edge after the CLKSEL has changed for the switching of clocks to be successful. For example the sequence for switching between the PLL and MCLK should be:

1. Change CLKSEL 1 -> 0
2. Wait for at least one falling edge from PLL generated clock
3. Disable the PLL (PLLEN=0)

## AUDIO SAMPLE RATES

The WM8983 filter characteristics for the ADCs and the DACs are set using the SR register bits; these bits do not change the rate of the audio interface output clocks in Master mode. The cut-offs for the digital filters and the ALC attack/decay times stated are determined using these values and assume a 256fs master clock rate.

If a sample rate is required which is not explicitly supported by the SR register settings, then the closest SR value to that sample rate should be chosen, and the filter characteristics and ALC attack, decay and hold times will scale appropriately.

| REGISTER ADDRESS         | BIT | LABEL | DEFAULT | DESCRIPTION  |
|--------------------------|-----|-------|---------|--|
| R7<br>Additional Control | 3:1 | SR    | 000     | Approximate sample rate (configures the coefficients for the internal digital filters):<br>000 = 48kHz<br>001 = 32kHz<br>010 = 24kHz<br>011 = 16kHz<br>100 = 12kHz<br>101 = 8kHz<br>110-111 = reserved |

**Table 57 Sample Rate Control**

## MASTER CLOCK AND PHASE LOCKED LOOP (PLL)

The WM8983 has an on-chip phase-locked loop (PLL) circuit that can be used to:

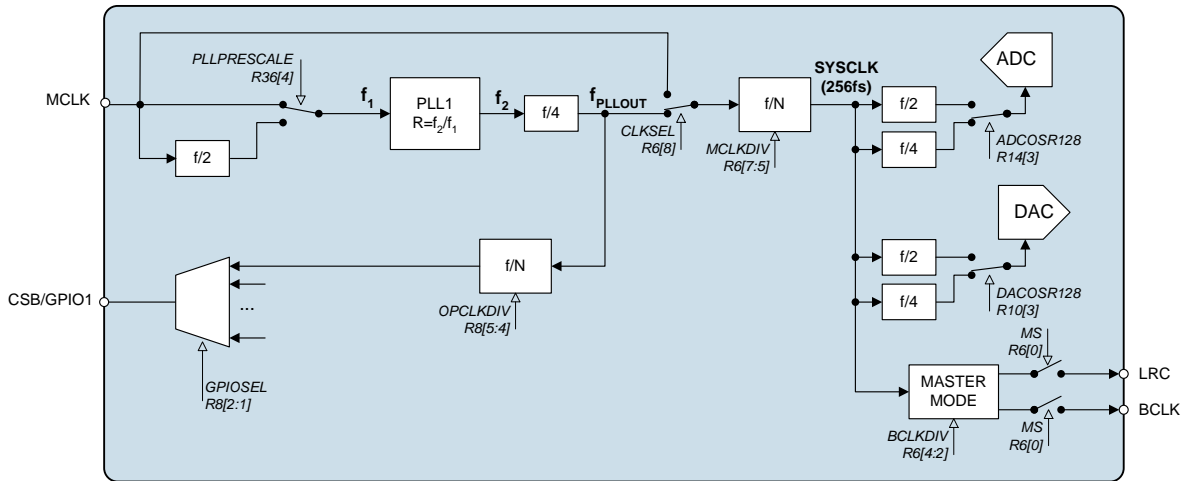
- Generate master clocks for the WM8983 audio functions from another external clock, e.g. in telecoms applications.
- Generate and output (on pin CSB/GPIO1) a clock for another part of the system that is derived from an existing audio master clock.

Figure 49 shows the PLL and internal clocking on the WM8983.

The PLL can be enabled or disabled by the PLEN register bit.

| REGISTER ADDRESS         | BIT | LABEL | DEFAULT | DESCRIPTION                             |
|--------------------------|-----|-------|---------|---|
| R1<br>Power management 1 | 5   | PLEN  | 0       | PLL enable<br>0 = PLL off<br>1 = PLL on |

**Table 58 PLEN Control Bit**



**Figure 49 PLL and Clock Select Circuit**

The PLL frequency ratio  $R = f_2/f_1$  (see Figure 49) can be set using the register bits PLLK and PLLN.

R should be chosen to ensure  $5 < PLLN < 13$ :

- $PLLN = \text{int } R$
- $PLLK = \text{int } (2^{24} (R - PLLN))$

**TO CALCULATE R:**

There is a fixed divide by 4 in the PLL, f/4, and a selectable divide by N after the PLL, MCLKDIV.

- $f_2 = \text{SYSCLK} \times 4 \times \text{MCLKDIV}$
- $R = f_2 / (\text{MCLK} / \text{PRESCALE}) = R$
- $PLLN = \text{int } R$
- $k = \text{int } (2^{24} \times (R - \text{int}R))$  – convert k to hex for PLLK

**EXAMPLE:**

MCLK=26MHz, required clock = 12.288MHz.

R should be chosen to ensure  $5 < PLLN < 13$ .

MCLKDIV = 2 sets the required division rate;

- $f_2 = 4 \times 2 \times 12.288\text{MHz} = 98.304\text{MHz}$ .
- $R = 98.304 / (26/2) = 7.561846$
- $PLLN = \text{int } R = 7$
- $k = \text{int } (2^{24} \times (7.561846 - 7)) = 9426214_{\text{dec}}$

Convert k to hex:

PLLK = 8FD526h

Convert PLLK to R36, R37, R38 and R39 hex values:

R36 = 7h; R37 = 23h; R38 = 1EAh; R39 = 126h



| REGISTER ADDRESS     | BIT | LABEL        | DEFAULT | DESCRIPTION   |
|----------------------|-----|--------------|---------|---|
| R36<br>PLL N value   | 4   | PLLPRESCALE  | 0       | 0 = MCLK input not divided (default)<br>1 = Divide MCLK by 2 before input to PLL                  |
|                      | 3:0 | PLLN         | 1000    | Integer (N) part of PLL input/output frequency ratio. Use values greater than 5 and less than 13. |
| R37<br>PLL K value 1 | 5:0 | PLLK [23:18] | 0Ch     | Fractional (K) part of PLL1 input/output frequency ratio (treat as one 24-digit binary number).   |
| R38<br>PLL K Value 2 | 8:0 | PLLK [17:9]  | 093h    |   |
| R39<br>PLL K Value 3 | 8:0 | PLLK [8:0]   | 0E9h    |   |

**Table 59 PLL Frequency Ratio Control**

The PLL performs best when  $f_2$  is around 90MHz. Its stability peaks at N=8. Some example settings are shown in Table 60.

| MCLK (MHz) (F1) | DESIRED OUTPUT (MHz) | F2 (MHz) | PRESCALE DIVIDE | MCLKDIV | R        | PLLN R36 (Hex) | K (Hex) | PLLK [23:18] R37 (Hex) | PLLK [17:9] R38 (Hex) | PLLK [8:0] R39 (Hex) |
|-----------------|----------------------|----------|-----------------|---------|----------|----------------|---------|------------------------|-----------------------|----------------------|
| 12              | 11.29                | 90.3168  | 1               | 2       | 7.5264   | 7              | 86C226  | 21                     | 161                   | 26                   |
| 12              | 12.288               | 98.304   | 1               | 2       | 8.192    | 8              | 3126E8  | C                      | 93                    | E9                   |
| 13              | 11.29                | 90.3168  | 1               | 2       | 6.947446 | 6              | F28BD4  | 3C                     | 145                   | 1D4                  |
| 13              | 12.288               | 98.304   | 1               | 2       | 7.561846 | 7              | 8FD525  | 23                     | 1EA                   | 126                  |
| 14.4            | 11.29                | 90.3168  | 1               | 2       | 6.272    | 6              | 45A1CA  | 11                     | D0                    | 1CA                  |
| 14.4            | 12.288               | 98.304   | 1               | 2       | 6.826667 | 6              | D3A06E  | 34                     | 1D0                   | 6D                   |
| 19.2            | 11.29                | 90.3168  | 2               | 2       | 9.408    | 9              | 6872AF  | 1A                     | 39                    | B0                   |
| 19.2            | 12.288               | 98.304   | 2               | 2       | 10.24    | A              | 3D70A3  | F                      | B8                    | A3                   |
| 19.68           | 11.29                | 90.3168  | 2               | 2       | 9.178537 | 9              | 2DB492  | B                      | DA                    | 92                   |
| 19.68           | 12.288               | 98.304   | 2               | 2       | 9.990243 | 9              | FD809F  | 3F                     | C0                    | 9F                   |
| 19.8            | 11.29                | 90.3168  | 2               | 2       | 9.122909 | 9              | 1F76F7  | 7                      | 1BB                   | F8                   |
| 19.8            | 12.288               | 98.304   | 2               | 2       | 9.929697 | 9              | EE009E  | 3B                     | 100                   | 9E                   |
| 24              | 11.29                | 90.3168  | 2               | 2       | 7.5264   | 7              | 86C226  | 21                     | 161                   | 26                   |
| 24              | 12.288               | 98.304   | 2               | 2       | 8.192    | 8              | 3126E8  | C                      | 93                    | E9                   |
| 26              | 11.29                | 90.3168  | 2               | 2       | 6.947446 | 6              | F28BD4  | 3C                     | 145                   | 1D4                  |
| 26              | 12.288               | 98.304   | 2               | 2       | 7.561846 | 7              | 8FD525  | 23                     | 1EA                   | 126                  |
| 27              | 11.29                | 90.3168  | 2               | 2       | 6.690133 | 6              | BOAC93  | 2C                     | 56                    | 94                   |
| 27              | 12.288               | 98.304   | 2               | 2       | 7.281778 | 7              | 482296  | 12                     | 11                    | 96                   |

**Table 60 PLL Frequency Examples for Common MCLK Rates**

### LOOPBACK

Setting the LOOPBACK register bit enables digital loopback. When this bit is set, the output data from the ADC audio interface is fed directly into the DAC data input.

See Table 55 for register definition.

**COMPANDING**

The WM8983 supports A-law and  $\mu$ -law companding on both transmit (ADC) and receive (DAC) sides. Companding can be enabled on the DAC or ADC audio interfaces by writing the appropriate value to the DAC\_COMP or ADC\_COMP register bits respectively.

| REGISTER ADDRESS         | BIT | LABEL    | DEFAULT | DESCRIPTION  |
|--------------------------|-----|----------|---------|--|
| R5<br>Companding Control | 2:1 | ADC_COMP | 0       | ADC companding<br>00 = off<br>01 = reserved<br>10 = $\mu$ -law<br>11 = A-law |
|                          | 4:3 | DAC_COMP | 0       | DAC companding<br>00 = off<br>01 = reserved<br>10 = $\mu$ -law<br>11 = A-law |
|                          | 5   | WL8      | 0       | 0 = off<br>1 = device operates in 8-bit mode.                                |

**Table 61 Companding Control**

Companding involves using a piecewise linear approximation of the following equations (as set out by ITU-T G.711 standard) for data compression:

$\mu$ -law (where  $\mu=255$  for the U.S. and Japan):

$$F(x) = \ln(1 + \mu|x|) / \ln(1 + \mu) \quad -1 \leq x \leq 1$$

A-law (where  $A=87.6$  for Europe):

$$F(x) = A|x| / (1 + \ln A) \quad \} \text{ for } x \leq 1/A$$

$$F(x) = (1 + \ln A|x|) / (1 + \ln A) \quad \} \text{ for } 1/A \leq x \leq 1$$

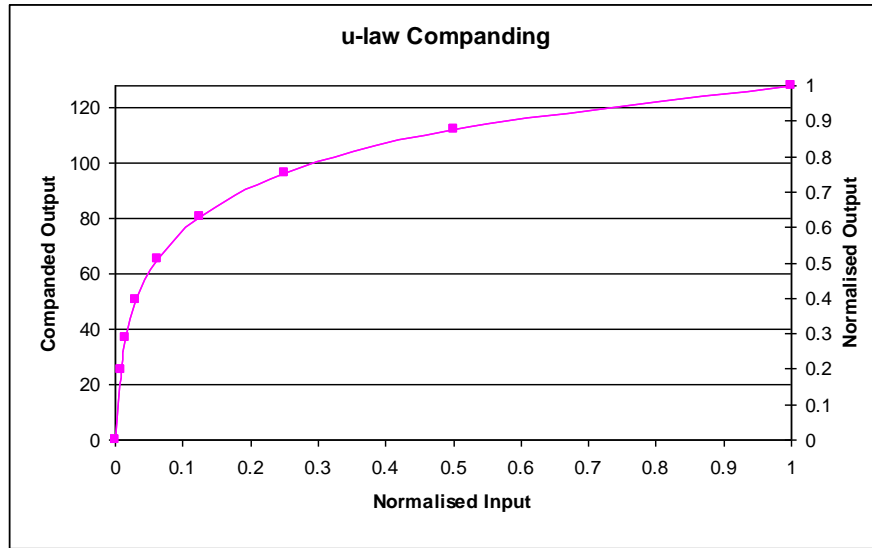
The companded data is also inverted as recommended by the G.711 standard (all 8 bits are inverted for  $\mu$ -law, all even data bits are inverted for A-law). The data will be transmitted as the first 8 MSB's of data.

Companding converts 13 bits ( $\mu$ -law) or 12 bits (A-law) to 8 bits using non-linear quantization. The input data range is separated into 8 levels, allowing low amplitude signals better precision than that of high amplitude signals. This is to exploit the operation of the human auditory system, where louder sounds do not require as much resolution as quieter sounds. The companded signal is an 8-bit word containing sign (1-bit), exponent (3-bits) and mantissa (4-bits).

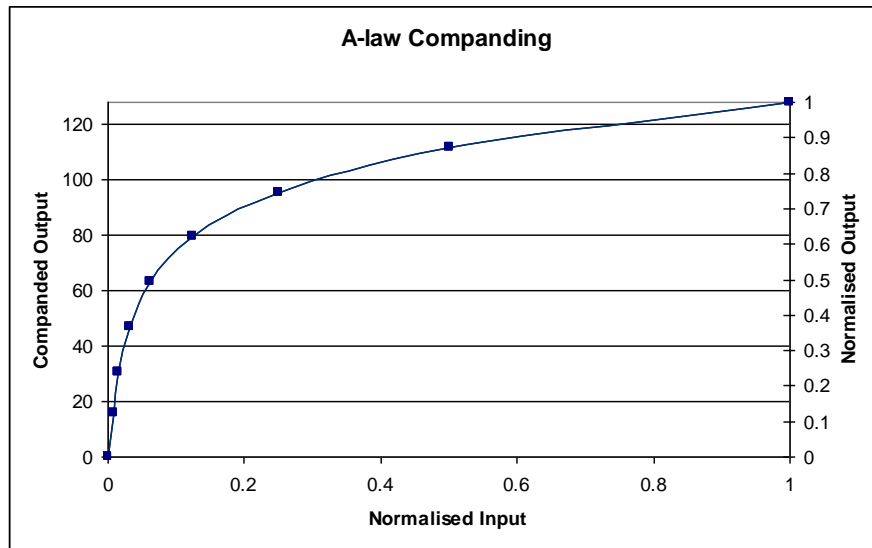
Setting the WL8 register bit allows the device to operate with 8-bit data. In this mode, it is possible to use 8 BCLK's per LRC frame. When using DSP mode B, this allows 8-bit data words to be output consecutively every 8 BCLK's and can be used with 8-bit data words using the A-law and  $\mu$ -law companding functions.

| BIT7 | BIT[6:4] | BIT[3:0] |
|------|----------|----------|
| SIGN | EXPONENT | MANTISSA |

**Table 62 8-bit Companded Word Composition**



**Figure 50  $\mu$ -Law Companding**



**Figure 51 A-Law Companding**

**GENERAL PURPOSE INPUT/OUTPUT**

The WM8983 has three dual purpose input/output pins.

- CSB/GPIO1: CSB / GPIO1 pin
- L2/GPIO2: Left channel line input / headphone detection input
- R2/GPIO3: Right channel line input / headphone detection input

The GPIO2 and GPIO3 functions are provided for use as jack detection inputs.

The GPIO1 and GPIO2 functions are provided for use as jack detection inputs or general purpose outputs.

The default configuration for the CSB/GPIO1 is to be an input.

When setup as an input, the CSB/GPIO1 pin can either be used as CSB or for jack detection, depending on how the MODE pin is set.

Table 63 illustrates the functionality of the GPIO1 pin when used as a general purpose output.

| REGISTER ADDRESS      | BIT | LABEL    | DEFAULT | DESCRIPTION  |
|-----------------------|-----|----------|---------|--|
| R8<br>GPIO<br>Control | 2:0 | GPIO1SEL | 000     | CSB/GPIO1 pin function select:<br>000= input (CSB/jack detection:<br>depending on MODE setting)<br>001 = reserved<br>010 = Temp ok<br>011 = Amute active<br>100 = PLL clk output<br>101 = PLL lock<br>110 = logic 0<br>111 = logic 1 |
|                       | 3   | GPIO1POL | 0       | GPIO1 Polarity invert<br>0 = Non inverted<br>1 = Inverted  |
|                       | 5:4 | OPCLKDIV | 00      | PLL Output clock division ratio<br>00 = divide by 1<br>01 = divide by 2<br>10 = divide by 3<br>11 = divide by 4  |

**Table 63 CSB/GPIO Control**

**Note:** If MODE is set to 3 wire mode, CSB/GPIO1 is used as CSB input irrespective of the GPIO1SEL[2:0] bits.

For further details of the jack detect operation see the OUTPUT SWITCHING section.

## OUTPUT SWITCHING (JACK DETECT)

When the device is operated using a 2-wire interface, the CSB/GPIO1 pin can be used as a switch control input to automatically disable one set of outputs and enable another; the most common use for this functionality is as jack detect circuitry. The L2/GPIO2 and R2/GPIO3 pins can also be used for this purpose.

The GPIO pins have an internal de-bounce circuit when in this mode in order to prevent the output enables from toggling multiple times due to input glitches. This de-bounce circuit is clocked from a slow clock with period  $2^{21} \times \text{MCLK}$  and is enabled by the SLOWCLKEN bit.

### Notes:

1. The SLOWCLKEN bit must be enabled for the jack detect circuitry to operate.
2. The GPIOPOL bit is not relevant for jack detection; it is the signal detected at the pin which is used.

Switching on/off of the outputs is fully configurable by the user. Each output, OUT1, OUT2, OUT3 and OUT4 has 2 associated enables. OUT1\_EN\_0, OUT2\_EN\_0, OUT3\_EN\_0 and OUT4\_EN\_0 are the output enable signals which are used if the selected jack detection pin is at logic 0 (after de-bounce). OUT1\_EN\_1, OUT2\_EN\_1, OUT3\_EN\_1 and OUT4\_EN\_1 are the output enable signals which are used if the selected jack detection pin is at logic 1 (after de-bounce).

The jack detection enables operate as follows:

All OUT\_EN signals have an AND function performed with their normal enable signals (in Table 51). When an output is normally enabled at per Table 51, the selected jack detection enable (controlled by selected jack detection pin polarity) is set 0; it will turn the output off. If the normal enable signal is already OFF (0), the jack detection signal will have no effect due to the AND function.

During jack detection if the user desires an output to be un-changed whether the jack is in or not, both the JD\_EN settings, i.e. JD\_EN0 and JD\_EN1, should be set to 0000.

If jack detection is not enabled (JD\_EN=0), the output enables default to all 1's, allowing the outputs to be controlled as normal via the normal output enables found in Table 51.

| REGISTER ADDRESS                 | BIT | LABEL  | DEFAULT | DESCRIPTION   |
|----------------------------------|-----|--------|---------|---|
| R9 (09h)<br>GPIO control         | 5:4 | JD_SEL | 00      | Pin selected as jack detection input<br>00 = GPIO1<br>01 = GPIO2<br>10 = GPIO3<br>11 = Reserved                                       |
|                                  | 6   | JD_EN  | 0       | Jack Detection Enable<br>0 = disabled<br>1 = enabled  |
| R13 (0Dh)<br>Jack Detect Control | 3:0 | JD_EN0 | 0000    | Output enables when selected jack detection input is logic 0.<br>[0]= OUT1_EN_0<br>[1]= OUT2_EN_0<br>[2]= OUT3_EN_0<br>[3]= OUT4_EN_0 |
|                                  | 7:4 | JD_EN1 | 0000    | Output enables when selected jack detection input is logic 1<br>[4]= OUT1_EN_1<br>[5]= OUT2_EN_1<br>[6]= OUT3_EN_1<br>[7]= OUT4_EN_1  |

**Table 64 Jack Detect Register Control Bits**

## CONTROL INTERFACE

### SELECTION OF CONTROL MODE AND 2-WIRE MODE ADDRESS

The control interface can operate as either a 3-wire or 2-wire control interface. The MODE pin determines the 2 or 3 wire mode as shown in Table 65.

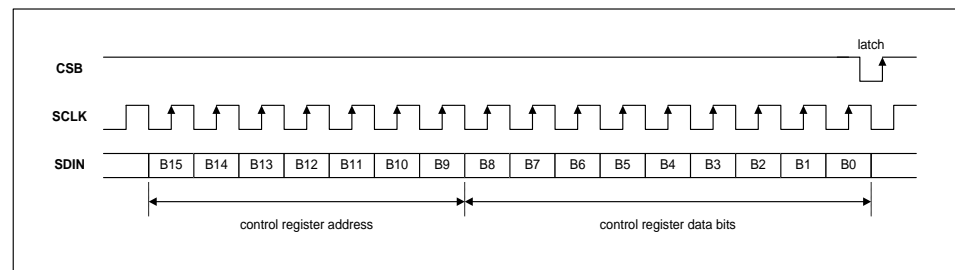
The WM8983 is controlled by writing to registers through a serial control interface. A control word consists of 16 bits. The first 7 bits (B15 to B9) are register address bits that select which control register is accessed. The remaining 9 bits (B8 to B0) are data bits, corresponding to the 9 data bits in each control register.

| MODE | INTERFACE FORMAT |
|------|------------------|
| Low  | 2 wire           |
| High | 3 wire           |

**Table 65 Control Interface Mode Selection**

### 3-WIRE SERIAL CONTROL MODE

In 3-wire mode, every rising edge of SCLK clocks in one data bit from the SDIN pin. A rising edge on CSB/GPIO latches in a complete control word consisting of the last 16 bits.



**Figure 52 3-Wire Serial Control Interface**

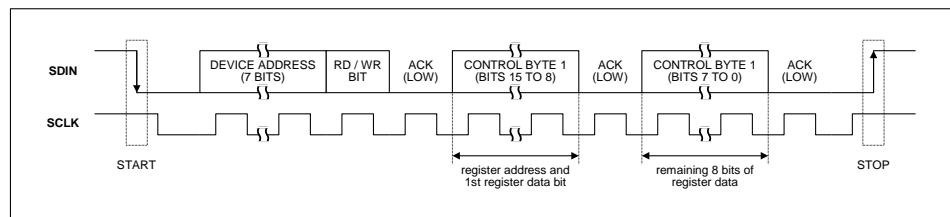
### 2-WIRE SERIAL CONTROL MODE

The WM8983 supports software control via a 2-wire serial bus. Many devices can be controlled by the same bus, and each device has a unique 7-bit device address (this is not the same as the 7-bit address of each register in the WM8983).

The WM8983 operates as a slave device only. The controller indicates the start of data transfer with a high to low transition on SDIN while SCLK remains high. This indicates that a device address and data will follow. All devices on the 2-wire bus respond to the start condition and shift in the next eight bits on SDIN (7-bit address + Read/Write bit, MSB first). If the device address received matches the address of the WM8983, the WM8983 responds by pulling SDIN low on the next clock pulse (ACK). If the address is not recognised or the R/W bit is '1' when operating in write only mode, the WM8983 returns to the idle condition and waits for a new start condition and valid address.

During a write, once the WM8983 has acknowledged a correct address, the controller sends the first byte of control data (B15 to B8, i.e. the WM8983 register address plus the first bit of register data). The WM8983 then acknowledges the first data byte by driving SDIN low for one clock cycle. The controller then sends the second byte of control data (B7 to B0, i.e. the remaining 8 bits of register data), and the WM8983 acknowledges again by pulling SDIN low.

Transfer is complete when there is a low to high transition on SDIN while SCLK is high. After a complete sequence, the WM8983 returns to the idle state and waits for another start condition. If a start or stop condition is detected out of sequence at any point during data transfer (i.e. SDIN changes while SCLK is high), the control interface returns to the idle condition.



**Figure 53 2-Wire Serial Control Interface**

In 2-wire mode the WM8983 has a fixed device address, 0011010.

## RESETTING THE CHIP

The WM8983 can be reset by performing a write of any value to the software reset register (address 0h). This will cause all register values to be reset to their default values. In addition to this there is a Power-On Reset (POR) circuit which ensures that the registers are initially set to default when the device is powered up.

## POWER SUPPLIES

The WM8983 requires four separate power supplies:

**AVDD1 and AGND1:** Analogue supply, powers all internal analogue functions and output drivers LOUT1 and ROUT1. AVDD1 must be between 2.5V and 3.6V and has the most significant impact on overall power consumption (except for power consumed in the headphones). Higher AVDD1 will improve audio quality.

**AVDD2 and AGND2:** Output driver supplies, power LOUT2, ROUT2, OUT3 and OUT4. AVDD2 must be between 2.5V and 5.5V. AVDD2 can be tied to AVDD1, but it requires separate layout and decoupling capacitors to curb harmonic distortion.

**DCVDD:** Digital core supply, powers all digital functions except the audio and control interfaces. DCVDD must be between 1.71V and 3.6V, and has no effect on audio quality. The return path for DCVDD is DGND, which is shared with DBVDD.

**DBVDD** must be between 1.71V and 3.6V. DBVDD return path is through DGND.

It is possible to use the same supply voltage for all four supplies. However, digital and analogue supplies should be routed and decoupled separately on the PCB to keep digital switching noise out of the analogue signal paths.

**POWER MANAGEMENT**
**SAVING POWER BY REDUCING OVERSAMPLING RATE**

The default mode of operation of the ADC and DAC digital filters is in 64x oversampling mode. Under the control of ADCOSR128 and DACOSR128, the oversampling rate may be doubled. 64x oversampling results in a slight decrease in noise performance compared to 128x but lowers the power consumption of the device.

| REGISTER ADDRESS   | BIT | LABEL     | DEFAULT | DESCRIPTION   |
|--------------------|-----|-----------|---------|---|
| R10<br>DAC control | 3   | DACOSR128 | 0       | DAC oversample rate select<br>0 = 64x (lowest power)<br>1 = 128x (best performance) |
| R14<br>ADC control | 3   | ADCOSR128 | 0       | ADC oversample rate select<br>0 = 64x (lowest power)<br>1 = 128x (best performance) |

**Table 66 ADC and DAC Oversampling Rate Selection**
**VMID**

The analogue circuitry will not operate unless VMID is enabled. The impedance of the VMID resistor string, together with the decoupling capacitor on the VMID pin will determine the start-up time of the VMID circuit.

| REGISTER ADDRESS         | BIT | LABEL   | DEFAULT | DESCRIPTION  |
|--------------------------|-----|---------|---------|--|
| R1<br>Power management 1 | 1:0 | VMIDSEL | 00      | Reference string impedance to VMID pin (Determines startup time):<br>00 = off (250kΩ VMID to AGND1)<br>01 = 100kΩ<br>10 = 500kΩ<br>11 = 10kΩ total (for fast start-up) |

**Table 67 VMID Impedance Control**
**BIASEN**

The analogue amplifiers will not operate unless BIASEN is enabled.

| REGISTER ADDRESS         | BIT | LABEL  | DEFAULT | DESCRIPTION  |
|--------------------------|-----|--------|---------|--|
| R1<br>Power management 1 | 3   | BIASEN | 0       | Analogue amplifier bias control<br>0 = disabled<br>1 = enabled |

**Table 68 Analogue Bias Control**
**BIAS CONTROL**

Control of the analog bias values is possible using BIASCUT.

| REGISTER ADDRESS    | BIT | LABEL   | DEFAULT  | DESCRIPTION                                   |
|---------------------|-----|---------|----------|---|
| R61<br>Bias control | 8   | BIASCUT | 0        | Global bias control<br>0 = normal<br>1 = 0.5x |
|                     | 7:0 |         | 000 0000 | Reserved                                      |

**Table 69 Analogue Bias Control**



**REGISTER MAP**

| ADDR B[15:9] |       | REGISTER NAME         | B8         | B7           | B6          | B5            | B4            | B3            | B2            | B1           | B0         | DEF'T VAL |     |
|--------------|-------|-----------------------|------------|--------------|-------------|---------------|---------------|---------------|---------------|--------------|------------|-----------|-----|
| D E C        | H E X |                       |            |              |             |               |               |               |               |              |            | (HEX)     |     |
| 0            | 00    | Software Reset        | RESET      |              |             |               |               |               |               |              |            |           |     |
| 1            | 01    | Power manage't 1      | BUFDC OPEN | OUT4 MIXEN   | OUT3 MIXEN  | PLLEN         | MICBEN        | BIASEN        | BUFIO EN      | VMIDSEL[1:0] |            | 000       |     |
| 2            | 02    | Power manage't 2      | ROUT1 EN   | LOUT1 EN     | SLEEP       | BOOST ENR     | BOOST ENL     | INPPGA ENR    | INPPGA ENL    | ADC ENR      | ADC ENL    | 000       |     |
| 3            | 03    | Power manage't 3      | OUT4EN     | OUT3EN       | LOUT2 EN    | ROUT2 EN      | 0             | RMIXEN        | LMIXEN        | DAC ENR      | DAC ENL    | 000       |     |
| 4            | 04    | Audio Interface       | BCP        | LRP          | WL[1:0]     |               | FMT[1:0]      |               | DLR SWAP      | ALR SWAP     | MONO       | 050       |     |
| 5            | 05    | Companding ctrl       | 0          | 0            | 0           | WL8           | DAC_COMP[1:0] |               | ADC_COMP[1:0] |              | LOOP BACK  | 000       |     |
| 6            | 06    | Clock Gen ctrl        | CLKSEL     | MCLKDIV[2:0] |             |               | BCLKDIV[2:0]  |               |               | 0            | MS         | 140       |     |
| 7            | 07    | Additional ctrl       | 0          | 0            | 0           | 0             | 0             | SR[2:0]       |               |              | SLOW CLKEN | 000       |     |
| 8            | 08    | GPIO Control          | 0          | 0            | 0           | OPCLKDIV[1:0] |               | GPIO1P OL     | GPIO1SEL[2:0] |              |            | 000       |     |
| 9            | 09    | Jack detect control   | 0          | 0            | JD_EN       | JD_SEL[1:0]   |               | 0             | 0             | 0            | 0          | 000       |     |
| 10           | 0A    | DAC Control           | 0          | 0            | SOFT MUTE   | 0             | 0             | DAC OSR128    | AMUTE         | DACR POL     | DACL POL   | 000       |     |
| 11           | 0B    | Left DAC digital Vol  | DACVU      | DACLVOL[7:0] |             |               |               |               |               |              |            |           | OFF |
| 12           | 0C    | Right DAC dig'l Vol   | DACVU      | DACRVOL[7:0] |             |               |               |               |               |              |            |           | OFF |
| 13           | 0D    | Jack Detect Control   | 0          | JD_EN1[3:0]  |             |               |               | JD_EN0[3:0]   |               |              |            | 000       |     |
| 14           | 0E    | ADC Control           | HPFEN      | HPFAPP       | HPFCUT[2:0] |               |               | ADC OSR128    | 0             | ADCR POL     | ADC LPOL   | 100       |     |
| 15           | 0F    | Left ADC Digital Vol  | ADCVU      | ADCLVOL[7:0] |             |               |               |               |               |              |            |           | OFF |
| 16           | 10    | Right ADC Digital Vol | ADCVU      | ADCRVOL[7:0] |             |               |               |               |               |              |            |           | OFF |
| 18           | 12    | EQ1 – low shelf       | EQ3D MODE  | 0            | EQ1C[1:0]   |               | EQ1G[4:0]     |               |               |              | 12C        |           |     |
| 19           | 13    | EQ2 – peak 1          | EQ2BW      | 0            | EQ2C[1:0]   |               | EQ2G[4:0]     |               |               |              | 02C        |           |     |
| 20           | 14    | EQ3 – peak 2          | EQ3BW      | 0            | EQ3C[1:0]   |               | EQ3G[4:0]     |               |               |              | 02C        |           |     |
| 21           | 15    | EQ4 – peak 3          | EQ4BW      | 0            | EQ4C[1:0]   |               | EQ4G[4:0]     |               |               |              | 02C        |           |     |
| 22           | 16    | EQ5 – high shelf      | 0          | 0            | EQ5C[1:0]   |               | EQ5G[4:0]     |               |               |              | 02C        |           |     |
| 24           | 18    | DAC Limiter 1         | LIMEN      | LIMDCY[3:0]  |             |               |               | LIMATK[3:0]   |               |              |            | 032       |     |
| 25           | 19    | DAC Limiter 2         | 0          | 0            | LIMLVL[2:0] |               |               | LIMBOOST[3:0] |               |              |            | 000       |     |
| 27           | 1B    | Notch Filter 1        | NFU        | NFEN         | NFA0[13:7]  |               |               |               |               |              |            | 000       |     |
| 28           | 1C    | Notch Filter 2        | NFU        | 0            | NFA0[6:0]   |               |               |               |               |              |            | 000       |     |
| 29           | 1D    | Notch Filter 3        | NFU        | 0            | NFA1[13:7]  |               |               |               |               |              |            | 000       |     |
| 30           | 1E    | Notch Filter 4        | NFU        | 0            | NFA1[6:0]   |               |               |               |               |              |            | 000       |     |
| 32           | 20    | ALC control 1         | ALCSEL     |              | 0           | ALCMAx[2:0]   |               |               | ALCMIx[2:0]   |              |            | 038       |     |
| 33           | 21    | ALC control 2         | 0          | ALCHLD[3:0]  |             |               |               | ALCLVL[3:0]   |               |              |            | 00B       |     |
| 34           | 22    | ALC control 3         | ALC MODE   | ALCDCY[3:0]  |             |               |               | ALCATK[3:0]   |               |              |            | 032       |     |
| 35           | 23    | Noise Gate            | 0          | 0            | 0           | 0             | 0             | NGEN          | NGTH[2:0]     |              |            | 000       |     |

| ADDR B[15:9] |       | REGISTER NAME           | B8                | B7          | B6                | B5              | B4              | B3                 | B2          | B1          | B0          | DEF'T VAL |
|--------------|-------|-------------------------|-------------------|-------------|-------------------|-----------------|-----------------|--------------------|-------------|-------------|-------------|-----------|
| D E C        | H E X |                         |                   |             |                   |                 |                 |                    |             |             |             | (HEX)     |
| 36           | 24    | PLL N                   | 0                 | 0           | 0                 | 0               | PLLPRE SCALE    | PLLK[3:0]          |             |             | 008         |           |
| 37           | 25    | PLL K 1                 | 0                 | 0           | 0                 | PLLK[23:18]     |                 |                    |             |             | 00C         |           |
| 38           | 26    | PLL K 2                 | PLLK[17:9]        |             |                   |                 |                 |                    |             |             |             | 093       |
| 39           | 27    | PLL K 3                 | PLLK[8:0]         |             |                   |                 |                 |                    |             |             |             | 0E9       |
| 41           | 29    | 3D control              | 0                 | 0           | 0                 | 0               | 0               | DEPTH3D[3:0]       |             |             | 000         |           |
| 42           | 2A    | OUT4 to ADC             | OUT4_2ADCVOL[2:0] |             |                   | OUT4_2 LNR      | 0               | 0                  | POB CTRL    | DELEN       | OUT1 DEL    | 000       |
| 43           | 2B    | Beep control            | BYPL2 RMIX        | BYPR2 LMIX  | 0                 | 0               | INV ROUT2       | 0                  | 0           | 0           | 000         |           |
| 44           | 2C    | Input ctrl              | MBVSEL            | 0           | R2_2 INPPGA       | RIN2 INPPGA     | RIP2 INPPGA     | 0                  | L2_2 INPPGA | LIN2 INPPGA | LIP2 INPPGA | 033       |
| 45           | 2D    | Left INP PGA gain ctrl  | INPGAVU           | INPPGA ZCL  | INPPGA MUTEL      | INPPGAVOLL[5:0] |                 |                    |             |             | 010         |           |
| 46           | 2E    | Right INP PGA gain ctrl | INPGAVU           | INPPGA ZCR  | INPPGA MUTER      | INPPGAVOLR[5:0] |                 |                    |             |             | 010         |           |
| 47           | 2F    | Left ADC Boost ctrl     | PGA BOOSTL        | 0           | L2_2BOOSTVOL[2:0] |                 | 0               | AUXL2BOOSTVOL[2:0] |             |             | 100         |           |
| 48           | 30    | Right ADC Boost ctrl    | PGA BOOSTR        | 0           | R2_2BOOSTVOL[2:0] |                 | 0               | AUXR2BOOSTVOL[2:0] |             |             | 100         |           |
| 49           | 31    | Output ctrl             | 0                 | 0           | DACL2 RMIX        | DACR2 LMIX      | OUT4 BOOST      | OUT3 BOOST         | SPK BOOST   | TSDEN       | VROI        | 002       |
| 50           | 32    | Left mixer ctrl         | AUXLMIXVOL[2:0]   |             |                   | AUXL2 LMIX      | BYPLMIXVOL[2:0] |                    |             | BYPL2 LMIX  | DACL2 LMIX  | 001       |
| 51           | 33    | Right mixer ctrl        | AUXRMIXVOL[2:0]   |             |                   | AUXR2 RMIX      | BYPRMIXVOL[2:0] |                    |             | BYPR2 RMIX  | DACR2 RMIX  | 001       |
| 52           | 34    | LOUT1 (HP) volume ctrl  | OUT1VU            | LOUT1 ZC    | LOUT1 MUTE        | LOUT1VOL[5:0]   |                 |                    |             |             | 039         |           |
| 53           | 35    | ROUT1 (HP) volume ctrl  | OUT1VU            | ROUT1 ZC    | ROUT1 MUTE        | ROUT1VOL[5:0]   |                 |                    |             |             | 039         |           |
| 54           | 36    | LOUT2 (SPK) volume ctrl | OUT2VU            | LOUT2 ZC    | LOUT2 MUTE        | LOUT2VOL[5:0]   |                 |                    |             |             | 039         |           |
| 55           | 37    | ROUT2 (SPK) volume ctrl | OUT2VU            | ROUT2 ZC    | ROUT2 MUTE        | ROUT2VOL[5:0]   |                 |                    |             |             | 039         |           |
| 56           | 38    | OUT3 mixer ctrl         | 0                 | 0           | OUT3 MUTE         | 0               | 0               | OUT4_2OUT3         | BYPL2 OUT3  | LMIX2 OUT3  | LDAC2 OUT3  | 001       |
| 57           | 39    | OUT4 (MONO) mixer ctrl  | 0                 | OUT3_2 OUT4 | OUT4 MUTE         | OUT4 ATTN       | LMIX2 OUT4      | LDAC2 OUT4         | BYPR2 OUT4  | RMIX2 OUT4  | RDAC2 OUT4  | 001       |
| 59           | 3B    | ALC Test Mode           | 0                 | 0           | 0                 | 0               | 0               | 0                  | 0           | ALCTST[1:0] |             | 000       |
| 61           | 3D    | Bias Control            | BIASCUT           | 0           | 0                 | 0               | 0               | 0                  | 0           | 0           | 0           | 000       |

**Table 70 WM8983 Register Map**

**REGISTER BITS BY ADDRESS**
**Notes:**

1. Default values of N/A indicate non-latched data bits (e.g. software reset or volume update bits).
2. Register bits marked "Reserved" should not be changed from the default.

| REGISTER ADDRESS | BIT   | LABEL     | DEFAULT | DESCRIPTION  | REFER TO                                 |
|------------------|-------|-----------|---------|--|--|
| 0 (00h)          | [8:0] | RESET     | N/A     | Software reset   | Resetting the Chip                       |
| 1 (01h)          | 8     | BUFDCOPEN | 0       | Output stage 1.5xAVDD/2 driver enable<br>0 = Buffer disabled<br>1 = Buffer enabled (required for 1.5x gain boost)  | Analogue Outputs                         |
|                  | 7     | OUT4MIXEN | 0       | OUT4 mixer enable<br>0=disabled<br>1=enabled   | Power Management                         |
|                  | 6     | OUT3MIXEN | 0       | OUT3 mixer enable<br>0=disabled<br>1=enabled   | Power Management                         |
|                  | 5     | PLLEN     | 0       | PLL enable<br>0=PLL off<br>1=PLL on  | Master Clock and Phase Locked Loop (PLL) |
|                  | 4     | MICBEN    | 0       | Microphone Bias Enable<br>0 = OFF (high impedance output)<br>1 = ON  | Input Signal Path                        |
|                  | 3     | BIASEN    | 0       | Analogue amplifier bias control<br>0=disabled<br>1=enabled   | Power Management                         |
|                  | 2     | BUFIOEN   | 0       | Unused input/output tie off buffer enable<br>0=disabled<br>1=enabled   | Power Management                         |
|                  | 1:0   | VMIDSEL   | 00      | Reference string impedance to VMID pin (Determines startup time):<br>00 = off (250kΩ VMID to AGND1)<br>01 = 100kΩ<br>10 = 500kΩ<br>11 = 10kΩ total (for fast start-up) | Power Management                         |
| 2 (02h)          | 8     | ROUT1EN   | 0       | ROUT1 output enable<br>0=disabled<br>1=enabled   | Power Management                         |
|                  | 7     | LOUT1EN   | 0       | LOUT1 output enable<br>0=disabled<br>1=enabled   | Power Management                         |
|                  | 6     | SLEEP     | 0       | Sleep Mode enable<br>0 = normal device operation<br>1 = residual current reduced in device standby mode  | Power Management                         |
|                  | 5     | BOOSTENR  | 0       | Right channel Input BOOST enable<br>0 = Boost stage OFF<br>1 = Boost stage ON  | Power Management                         |
|                  | 4     | BOOSTENL  | 0       | Left channel Input BOOST enable<br>0 = Boost stage OFF<br>1 = Boost stage ON   | Power Management                         |

| REGISTER ADDRESS | BIT | LABEL     | DEFAULT | DESCRIPTION   | REFER TO                            |
|------------------|-----|-----------|---------|---|-------------------------------------|
|                  | 3   | INPPGAENR | 0       | Right channel input PGA enable<br>0 = disabled<br>1 = enabled       | Power Management                    |
|                  | 2   | INPPGAENL | 0       | Left channel input PGA enable<br>0 = disabled<br>1 = enabled        | Power Management                    |
|                  | 1   | ADCENR    | 0       | Enable ADC right channel:<br>0 = ADC disabled<br>1 = ADC enabled    | Analogue to Digital Converter (ADC) |
|                  | 0   | ADCENL    | 0       | Enable ADC left channel:<br>0 = ADC disabled<br>1 = ADC enabled     | Analogue to Digital Converter (ADC) |
| R3 (03h)         | 8   | OUT4EN    | 0       | OUT4 enable<br>0 = disabled<br>1 = enabled                          | Power Management                    |
|                  | 7   | OUT3EN    | 0       | OUT3 enable<br>0 = disabled<br>1 = enabled                          | Power Management                    |
|                  | 6   | LOUT2EN   | 0       | LOUT2 enable<br>0 = disabled<br>1 = enabled                         | Power Management                    |
|                  | 5   | ROUT2EN   | 0       | ROUT2 enable<br>0 = disabled<br>1 = enabled                         | Power Management                    |
|                  | 4   |           | 0       | Reserved  | Analogue Outputs                    |
|                  | 3   | RMIXEN    | 0       | Right output channel mixer enable:<br>0 = disabled<br>1 = enabled   | Analogue Outputs                    |
|                  | 2   | LMIXEN    | 0       | Left output channel mixer enable:<br>0 = disabled<br>1 = enabled    | Analogue Outputs                    |
|                  | 1   | DACENR    | 0       | Right channel DAC enable<br>0 = DAC disabled<br>1 = DAC enabled     | Analogue Outputs                    |
|                  | 0   | DACENL    | 0       | Left channel DAC enable<br>0 = DAC disabled<br>1 = DAC enabled      | Analogue Outputs                    |
| 4 (04h)          | 8   | BCP       | 0       | BCLK polarity<br>0=normal<br>1=inverted                             | Digital Audio Interfaces            |
|                  | 7   | LRP       | 0       | LRC clock polarity<br>0=normal<br>1=inverted                        | Digital Audio Interfaces            |
|                  | 6:5 | WL        | 10      | Word length<br>00=16 bits<br>01=20 bits<br>10=24 bits<br>11=32 bits | Digital Audio Interfaces            |

| REGISTER ADDRESS | BIT | LABEL    | DEFAULT | DESCRIPTION   | REFER TO                 |
|------------------|-----|----------|---------|---|--------------------------|
|                  | 4:3 | FMT      | 10      | Audio interface Data Format Select:<br>00=Right Justified<br>01=Left Justified<br>10=I <sup>2</sup> S format<br>11= DSP/PCM mode  | Digital Audio Interfaces |
|                  | 2   | DLRSWAP  | 0       | Controls whether DAC data appears in 'right' or 'left' phases of LRC clock:<br>0=DAC data appears in 'left' phase of LRC<br>1=DAC data appears in 'right' phase of LRC  | Digital Audio Interfaces |
|                  | 1   | ALRSWAP  | 0       | Controls whether ADC data appears in 'right' or 'left' phases of LRC clock:<br>0=ADC data appears in 'left' phase of LRC<br>1=ADC data appears in 'right' phase of LRC  | Digital Audio Interfaces |
|                  | 0   | MONO     | 0       | Selects between stereo and mono device operation:<br>0=Stereo device operation<br>1=Mono device operation. Data appears in 'left' phase of LRC  | Digital Audio Interfaces |
| 5 (05h)          | 8:6 |          | 000     | Reserved  |                          |
|                  | 5   | WL8      | 0       | Companding Control 8-bit mode<br>0=off<br>1=device operates in 8-bit mode   | Digital Audio Interfaces |
|                  | 4:3 | DAC_COMP | 00      | DAC companding<br>00=off<br>01=reserved<br>10= $\mu$ -law<br>11=A-law   | Digital Audio Interfaces |
|                  | 2:1 | ADC_COMP | 00      | ADC companding<br>00=off<br>01=reserved<br>10= $\mu$ -law<br>11=A-law   | Digital Audio Interfaces |
|                  | 0   | LOOPBACK | 0       | Digital loopback function<br>0=No loopback<br>1=Loopback enabled, ADC data output is fed directly into DAC data input.  | Digital Audio Interfaces |
| 6 (06h)          | 8   | CLKSEL   | 1       | Controls the source of the clock for all internal operation:<br>0=MCLK<br>1=PLL output  | Digital Audio Interfaces |
|                  | 7:5 | MCLKDIV  | 010     | Sets the scaling for either the MCLK or PLL clock output (under control of CLKSEL)<br>000=divide by 1<br>001=divide by 1.5<br>010=divide by 2<br>011=divide by 3<br>100=divide by 4<br>101=divide by 6<br>110=divide by 8<br>111=divide by 12 | Digital Audio Interfaces |

| REGISTER ADDRESS | BIT | LABEL          | DEFAULT | DESCRIPTION  | REFER TO                            |
|------------------|-----|----------------|---------|--|-------------------------------------|
|                  | 4:2 | BCLKDIV        | 000     | Configures the BCLK output frequency, for use when the chip is in Master mode.<br>000=divide by 1 (BCLK= SYSCLK)<br>001=divide by 2 (BCLK= SYSCLK/2)<br>010=divide by 4<br>011=divide by 8<br>100=divide by 16<br>101=divide by 32<br>110=reserved<br>111=reserved | Digital Audio Interfaces            |
|                  | 1   |                | 0       | Reserved   |                                     |
|                  | 0   | MS             | 0       | Sets the chip to be master over LRC and BCLK<br>0=BCLK and LRC clock are inputs<br>1=BCLK and LRC clock are outputs generated by the WM8983 (Master Mode)  | Digital Audio Interfaces            |
| 7 (07h)          | 3:1 | SR             | 000     | Approximate sample rate (configures the coefficients for the internal digital filters):<br>000=48kHz<br>001=32kHz<br>010=24kHz<br>011=16kHz<br>100=12kHz<br>101=8kHz<br>110-111=reserved   | Audio Sample Rates                  |
|                  | 0   | SLOWCLKEN      | 0       | Slow clock enable.<br>Used for both the jack insert detect debounce circuit and the zero cross timeout.<br>0 = slow clock disabled<br>1 = slow clock enabled   | Analogue Outputs                    |
| 8 (08h)          | 5:4 | OPCLKDIV       | 00      | PLL Output clock division ratio<br>00=divide by 1<br>01=divide by 2<br>10=divide by 3<br>11=divide by 4  | General Purpose Input/Output (GPIO) |
|                  | 3   | GPIO1POL       | 0       | GPIO1 Polarity invert<br>0=Non inverted<br>1=Inverted  | General Purpose Input/Output (GPIO) |
|                  | 2:0 | GPIO1SEL [2:0] | 000     | CSB/GPIO1 pin function select:<br>000= input (CSB/jack detection: depending on MODE setting)<br>001= reserved<br>010=Temp ok<br>011=Amute active<br>100=PLL clk output<br>101=PLL lock<br>110=logic 0<br>111=logic 1   | General Purpose Input/Output (GPIO) |

| REGISTER ADDRESS | BIT | LABEL     | DEFAULT  | DESCRIPTION  | REFER TO                            |
|------------------|-----|-----------|----------|--|-------------------------------------|
| 9 (09h)          | 8:7 |           | 00       | Reserved   |                                     |
|                  | 6   | JD_EN     | 0        | Jack Detection Enable<br>0=disabled<br>1=enabled   | Output Switching (Jack Detect)      |
|                  | 5:4 | JD_SEL    | 00       | Pin selected as jack detection input<br>00 = GPIO1<br>01 = GPIO2<br>10 = GPIO3<br>11 = Reserved  | Output Switching (Jack Detect)      |
|                  | 3:0 |           | 0        | Reserved   | Output Switching (Jack Detect)      |
| 10 (0Ah)         | 8:7 |           | 00       | Reserved   |                                     |
|                  | 6   | SOFTMUTE  | 0        | Softmute enable:<br>0=Disabled<br>1=Enabled  | Output Signal Path                  |
|                  | 5:4 |           | 00       | Reserved   |                                     |
|                  | 3   | DACOSR128 | 0        | DAC oversample rate select<br>0 = 64x (lowest power)<br>1 = 128x (best performance)  | Power Management                    |
|                  | 2   | AMUTE     | 0        | Automute enable<br>0 = Amute disabled<br>1 = Amute enabled   | Output Signal Path                  |
|                  | 1   | DACRPOL   | 0        | Right DAC output polarity:<br>0 = non-inverted<br>1 = inverted (180 degrees phase shift)   | Output Signal Path                  |
|                  | 0   | DACLPOL   | 0        | Left DAC output polarity:<br>0 = non-inverted<br>1 = inverted (180 degrees phase shift)  | Output Signal Path                  |
| 11 (0Bh)         | 8   | DACVU     | N/A      | DAC left and DAC right volume do not update until a 1 is written to DACVU (in reg 11 or 12)  | Digital to Analogue Converter (DAC) |
|                  | 7:0 | DACLVOL   | 11111111 | Left DAC Digital Volume Control<br>0000 0000 = Digital Mute<br>0000 0001 = -127dB<br>0000 0010 = -126.5dB<br>... 0.5dB steps up to<br>1111 1111 = 0dB  | Digital to Analogue Converter (DAC) |
| 12 (0Ch)         | 8   | DACVU     | N/A      | DAC left and DAC right volume do not update until a 1 is written to DACVU (in reg 11 or 12)  | Output Signal Path                  |
|                  | 7:0 | DACRVOL   | 11111111 | Right DAC Digital Volume Control<br>0000 0000 = Digital Mute<br>0000 0001 = -127dB<br>0000 0010 = -126.5dB<br>... 0.5dB steps up to<br>1111 1111 = 0dB | Output Signal Path                  |

| REGISTER ADDRESS | BIT | LABEL     | DEFAULT  | DESCRIPTION  | REFER TO                            |
|------------------|-----|-----------|----------|--|-------------------------------------|
| 13 (0Dh)         | 8   |           | 0        | Reserved   |                                     |
|                  | 7:4 | JD_EN1    | 0000     | Output enabled when selected jack detection input is logic 1<br>[4]= OUT1_EN_1<br>[5]= OUT2_EN_1<br>[6]= OUT3_EN_1<br>[7]= OUT4_EN_1                   | Output Switching (Jack Detect)      |
|                  | 3:0 | JD_EN0    | 0000     | Output enabled when selected jack detection input is logic 0.<br>[0]= OUT1_EN_0<br>[1]= OUT2_EN_0<br>[2]= OUT3_EN_0<br>[3]= OUT4_EN_0                  | Output Switching (Jack Detect)      |
| 14 (0Eh)         | 8   | HPFEN     | 1        | High Pass Filter Enable<br>0=disabled<br>1=enabled   | Analogue to Digital Converter (ADC) |
|                  | 7   | HPFAPP    | 0        | Select audio mode or application mode<br>0=Audio mode (1 <sup>st</sup> order, fc = ~3.7Hz)<br>1=Application mode (2 <sup>nd</sup> order, fc = HPFCUT)  | Analogue to Digital Converter (ADC) |
|                  | 6:4 | HPFCUT    | 000      | Application mode cut-off frequency<br>See Table 16 for details   | Analogue to Digital Converter (ADC) |
|                  | 3   | ADCOsr128 | 0        | ADC oversample rate select<br>0 = 64x (lowest power)<br>1 = 128x (best performance)  | Power Management                    |
|                  | 2   |           | 0        | Reserved   |                                     |
|                  | 1   | ADCRPOL   | 0        | ADC right channel polarity adjust:<br>0=normal<br>1=inverted   | Analogue to Digital Converter (ADC) |
|                  | 0   | ADCLPOL   | 0        | ADC left channel polarity adjust:<br>0=normal<br>1=inverted  | Analogue to Digital Converter (ADC) |
| 15 (0Fh)         | 8   | ADCVU     | N/A      | ADC left and ADC right volume do not update until a 1 is written to ADCVU (in reg 16 or 17)  | Analogue to Digital Converter (ADC) |
|                  | 7:0 | ADCLVOL   | 11111111 | Left ADC Digital Volume Control<br>0000 0000 = Digital Mute<br>0000 0001 = -127dB<br>0000 0010 = -126.5dB<br>... 0.5dB steps up to<br>1111 1111 = 0dB  | Analogue to Digital Converter (ADC) |
| 16 (10h)         | 8   | ADCVU     | N/A      | ADC left and ADC right volume do not update until a 1 is written to ADCVU (in reg 16 or 17)  | Analogue to Digital Converter (ADC) |
|                  | 7:0 | ADCRVOL   | 11111111 | Right ADC Digital Volume Control<br>0000 0000 = Digital Mute<br>0000 0001 = -127dB<br>0000 0010 = -126.5dB<br>... 0.5dB steps up to<br>1111 1111 = 0dB | Analogue to Digital Converter (ADC) |



| REGISTER ADDRESS | BIT | LABEL    | DEFAULT | DESCRIPTION  | REFER TO           |
|------------------|-----|----------|---------|--|--------------------|
| 18 (12h)         | 8   | EQ3DMODE | 1       | 0 = Equaliser and 3D Enhancement applied to ADC path<br>1 = Equaliser and 3D Enhancement applied to DAC path | Output Signal Path |
|                  | 7   |          | 0       | Reserved   |                    |
|                  | 6:5 | EQ1C     | 01      | EQ Band 1 Cut-off Frequency:<br>00=80Hz<br>01=105Hz<br>10=135Hz<br>11=175Hz                                  | Output Signal Path |
|                  | 4:0 | EQ1G     | 01100   | EQ Band 1 Gain Control. See Table 38 for details.  | Output Signal Path |
| 19 (13h)         | 8   | EQ2BW    | 0       | EQ Band 2 Bandwidth Control<br>0=narrow bandwidth<br>1=wide bandwidth  | Output Signal Path |
|                  | 7   |          | 0       | Reserved   | Output Signal Path |
|                  | 6:5 | EQ2C     | 01      | EQ Band 2 Centre Frequency:<br>00=230Hz<br>01=300Hz<br>10=385Hz<br>11=500Hz                                  | Output Signal Path |
|                  | 4:0 | EQ2G     | 01100   | EQ Band 2 Gain Control. See Table 38 for details.  | Output Signal Path |
| 20 (14h)         | 8   | EQ3BW    | 0       | EQ Band 3 Bandwidth Control<br>0=narrow bandwidth<br>1=wide bandwidth  | Output Signal Path |
|                  | 7   |          | 0       | Reserved   | Output Signal Path |
|                  | 6:5 | EQ3C     | 01      | EQ Band 3 Centre Frequency:<br>00=650Hz<br>01=850Hz<br>10=1.1kHz<br>11=1.4kHz                                | Output Signal Path |
|                  | 4:0 | EQ3G     | 01100   | EQ Band 3 Gain Control. See Table 38 for details.  | Output Signal Path |
| 21 (15h)         | 8   | EQ4BW    | 0       | EQ Band 4 Bandwidth Control<br>0=narrow bandwidth<br>1=wide bandwidth  | Output Signal Path |
|                  | 7   |          | 0       | Reserved   | Output Signal Path |
|                  | 6:5 | EQ4C     | 01      | EQ Band 4 Centre Frequency:<br>00=1.8kHz<br>01=2.4kHz<br>10=3.2kHz<br>11=4.1kHz                              | Output Signal Path |
|                  | 4:0 | EQ4G     | 01100   | EQ Band 4 Gain Control. See Table 38 for details.  | Output Signal Path |
| 22 (16h)         | 8:7 |          | 0       | Reserved   | Output Signal Path |
|                  | 6:5 | EQ5C     | 01      | EQ Band 5 Cut-off Frequency:<br>00=5.3kHz<br>01=6.9kHz<br>10=9kHz<br>11=11.7kHz                              | Output Signal Path |
|                  | 4:0 | EQ5G     | 01100   | EQ Band 5 Gain Control. See Table 38 for details.  | Output Signal Path |

| REGISTER ADDRESS | BIT | LABEL    | DEFAULT | DESCRIPTION  | REFER TO                            |
|------------------|-----|----------|---------|--|-------------------------------------|
| 24 (18h)         | 8   | LIMEN    | 0       | Enable the DAC digital limiter:<br>0=disabled<br>1=enabled   | Output Signal Path                  |
|                  | 7:4 | LIMDCY   | 0011    | DAC Limiter Decay time (per 6dB gain change) for 44.1kHz sampling. Note that these will scale with sample rate:<br>0000=750us<br>0001=1.5ms<br>0010=3ms<br>0011=6ms<br>0100=12ms<br>0101=24ms<br>0110=48ms<br>0111=96ms<br>1000=192ms<br>1001=384ms<br>1010=768ms  | Output Signal Path                  |
|                  | 3:0 | LIMATK   | 0010    | DAC Limiter Attack time (per 6dB gain change) for 44.1kHz sampling. Note that these will scale with sample rate.<br>0000=94us<br>0001=188s<br>0010=375us<br>0011=750us<br>0100=1.5ms<br>0101=3ms<br>0110=6ms<br>0111=12ms<br>1000=24ms<br>1001=48ms<br>1010=96ms<br>1011 to 1111=192ms                             | Output Signal Path                  |
| 25 (19h)         | 8:7 |          | 00      | Reserved   |                                     |
|                  | 6:4 | LIMLVL   | 000     | Programmable signal threshold level (determines level at which the DAC limiter starts to operate)<br>000=-1dB<br>001=-2dB<br>010=-3dB<br>011=-4dB<br>100=-5dB<br>101 to 111=-6dB   | Output Signal Path                  |
|                  | 3:0 | LIMBOOST | 0000    | DAC Limiter volume boost (can be used as a stand alone volume boost when LIMEN=0):<br>0000 = 0dB<br>0001 = +1dB<br>0010 = +2dB<br>0011 = +3dB<br>0100 = +4dB<br>0101 = +5dB<br>0110 = +6dB<br>0111 = +7dB<br>1000 = +8dB<br>1001 = +9dB<br>1010 = +10dB<br>1011 = +11dB<br>1100 = +12dB<br>1101 to 1111 = reserved | Output Signal Path                  |
| 27 (1Bh)         | 8   | NFU      | 0       | Notch filter update. The notch filter values used internally only update when one of the NFU bits is set high.   | Analogue to Digital Converter (ADC) |

| REGISTER ADDRESS | BIT | LABEL      | DEFAULT | DESCRIPTION  | REFER TO                                     |
|------------------|-----|------------|---------|--|--|
|                  | 7   | NFEN       | 0       | Notch filter enable:<br>0=Disabled<br>1=Enabled  | Analogue to Digital Converter (ADC)          |
|                  | 6:0 | NFA0[13:7] | 0000000 | Notch Filter $a_0$ coefficient, bits [13:7]  | Analogue to Digital Converter (ADC)          |
| 28 (1Ch)         | 8   | NFU        | 0       | Notch filter update. The notch filter values used internally only update when one of the NFU bits is set high.                                       | Analogue to Digital Converter (ADC)          |
|                  | 7   |            | 0       | Reserved   |  |
|                  | 6:0 | NFA0[6:0]  | 0000000 | Notch Filter $a_0$ coefficient, bits [6:0]   | Analogue to Digital Converter (ADC)          |
| 29 (1Dh)         | 8   | NFU        | 0       | Notch filter update. The notch filter values used internally only update when one of the NFU bits is set high.                                       | Analogue to Digital Converter (ADC)          |
|                  | 7   |            | 0       | Reserved   |  |
|                  | 6:0 | NFA1[13:7] | 0000000 | Notch Filter $a_1$ coefficient, bits [13:7]  | Analogue to Digital Converter (ADC)          |
| 30 (1Eh)         | 8   | NFU        | 0       | Notch filter update. The notch filter values used internally only update when one of the NFU bits is set high.                                       | Analogue to Digital Converter (ADC)          |
|                  | 7   |            | 0       | Reserved   |  |
|                  | 6:0 | NFA1[6:0]  | 0000000 | Notch Filter $a_1$ coefficient, bits [6:0]   | Analogue to Digital Converter (ADC)          |
| 32 (20h)         | 8:7 | ALCSEL     | 00      | ALC function select:<br>00 = ALC disabled<br>01 = Right channel ALC enabled<br>10 = Left channel ALC enabled<br>11 = Both channels ALC enabled       | Input Limiter/ Automatic Level Control (ALC) |
|                  | 6   |            | 0       | Reserved   |  |
|                  | 5:3 | ALCMAX     | 111     | Set Maximum Gain of PGA<br>111=+35.25dB<br>110=+29.25dB<br>101=+23.25dB<br>100=+17.25dB<br>011=+11.25dB<br>010=+5.25dB<br>001=-0.75dB<br>000=-6.75dB | Input Limiter/ Automatic Level Control (ALC) |

| REGISTER ADDRESS                   | BIT      | LABEL           | DEFAULT      | DESCRIPTION   | REFER TO  |          |         |              |      |       |       |      |      |       |       |      |      |        |        |       |                                    |  |  |  |
|------------------------------------|----------|-----------------|--------------|---|---|----------|---------|--------------|------|-------|-------|------|------|-------|-------|------|------|--------|--------|-------|------------------------------------|--|--|--|
|                                    | 2:0      | ALCMIN          | 000          | Set minimum gain of PGA<br>000=-12dB<br>001=-6dB<br>010=0dB<br>011=+6dB<br>100=+12dB<br>101=+18dB<br>110=+24dB<br>111=+30dB   | Input Limiter/<br>Automatic<br>Level Control<br>(ALC) |          |         |              |      |       |       |      |      |       |       |      |      |        |        |       |                                    |  |  |  |
| 33 (21h)                           | 7:4      | ALCHLD          | 0000         | ALC hold time before gain is increased.<br>0000 = 0ms<br>0001 = 2.67ms<br>0010 = 5.33ms<br>0011 = 10.66ms<br>0100 = 21.32ms<br>0101 = 42.64ms<br>0110 = 85.28ms<br>0111 = 0.17s<br>1000 = 0.34s<br>1001 = 0.68s<br>1010 = 1.36s<br>1011 = 2.7s<br>1100 = 5.4s<br>1101 = 10.9s<br>1110 = 21.8 s<br>1111 = 43.7s  | Input Limiter/<br>Automatic<br>Level Control<br>(ALC) |          |         |              |      |       |       |      |      |       |       |      |      |        |        |       |                                    |  |  |  |
|                                    | 3:0      | ALCLVL          | 1011         | ALC target – sets signal level at ADC input<br>1111 = -1.5dBFS<br>1110 = -1.5dBFS<br>1101 = -3dBFS<br>1100 = -4.5dBFS<br>1011 = -6dBFS<br>1010 = -7.5dBFS<br>1001 = -9dBFS<br>1000 = -10.5dBFS<br>0111 = -12dBFS<br>0110 = -13.5dBFS<br>0101 = -15dBFS<br>0100 = -16.5dBFS<br>0011 = -18dBFS<br>0010 = -19.5dBFS<br>0001 = -21dBFS<br>0000 = -22.5dBFS  | Input Limiter/<br>Automatic<br>Level Control<br>(ALC) |          |         |              |      |       |       |      |      |       |       |      |      |        |        |       |                                    |  |  |  |
| 34 (22h)                           | 8        | ALCMODE         | 0            | Determines the ALC mode of operation:<br>0=ALC mode (Normal Operation)<br>1=Limiter mode  | Input Limiter/<br>Automatic<br>Level Control<br>(ALC) |          |         |              |      |       |       |      |      |       |       |      |      |        |        |       |                                    |  |  |  |
|                                    | 7:4      | ALCDCY<br>[3:0] | 0011         | Decay (gain ramp-up) time<br>(ALCMODE ==0)<br><table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th>Per step</th> <th>Per 6dB</th> <th>90% of range</th> </tr> </thead> <tbody> <tr> <td>0000</td> <td>410us</td> <td>3.3ms</td> <td>24ms</td> </tr> <tr> <td>0001</td> <td>820us</td> <td>6.6ms</td> <td>48ms</td> </tr> <tr> <td>0010</td> <td>1.64ms</td> <td>13.1ms</td> <td>192ms</td> </tr> <tr> <td colspan="4">... (time doubles with every step)</td> </tr> </tbody> </table> |   | Per step | Per 6dB | 90% of range | 0000 | 410us | 3.3ms | 24ms | 0001 | 820us | 6.6ms | 48ms | 0010 | 1.64ms | 13.1ms | 192ms | ... (time doubles with every step) |  |  |  |
|                                    | Per step | Per 6dB         | 90% of range |   |   |          |         |              |      |       |       |      |      |       |       |      |      |        |        |       |                                    |  |  |  |
| 0000                               | 410us    | 3.3ms           | 24ms         |   |   |          |         |              |      |       |       |      |      |       |       |      |      |        |        |       |                                    |  |  |  |
| 0001                               | 820us    | 6.6ms           | 48ms         |   |   |          |         |              |      |       |       |      |      |       |       |      |      |        |        |       |                                    |  |  |  |
| 0010                               | 1.64ms   | 13.1ms          | 192ms        |   |   |          |         |              |      |       |       |      |      |       |       |      |      |        |        |       |                                    |  |  |  |
| ... (time doubles with every step) |          |                 |              |   |   |          |         |              |      |       |       |      |      |       |       |      |      |        |        |       |                                    |  |  |  |

| REGISTER ADDRESS | BIT                                | LABEL        | DEFAULT | DESCRIPTION   |          |   |              | REFER TO  |
|------------------|------------------------------------|--------------|---------|---|----------|---|--------------|---|
|                  |                                    |              | 0011    | 1010 or higher  | 420ms    | 3.36s   | 24.576s      | Input Limiter/<br>Automatic Level Control (ALC) |
|                  |                                    |              |         | Decay (gain ramp-up) time (ALCMODE == 1)  |          |   |              |   |
|                  |                                    |              |         |   | Per step | Per 6dB   | 90% of range |   |
|                  |                                    |              |         | 0000  | 90.8us   | 726.4us   | 5.26ms       |   |
|                  |                                    |              |         | 0001  | 181.6us  | 1.453ms   | 10.53ms      |   |
|                  |                                    |              |         | 0010  | 363.2us  | 2.905ms   | 21.06ms      |   |
|                  |                                    |              |         | ... (time doubles with every step)  |          |   |              |   |
|                  |                                    |              |         | 1010  | 93ms     | 744ms   | 5.39s        |   |
|                  | 3:0                                | ALCATK       | 0010    | ALC attack (gain ramp-down) time (ALCMODE == 0)   |          |   |              |   |
|                  |                                    |              |         |   | Per step | Per 6dB   | 90% of range |   |
|                  |                                    |              |         | 0000  | 104us    | 832us   | 6ms          |   |
|                  |                                    |              |         | 0001  | 208us    | 1.664ms   | 12ms         |   |
|                  |                                    |              |         | 0010  | 416us    | 3.328ms   | 24.1ms       |   |
|                  |                                    |              |         | ... (time doubles with every step)  |          |   |              |   |
| 1010 or higher   |                                    |              |         | 106ms   | 852ms    | 6.18s   |              |   |
| 0010             |                                    |              |         |   | 0010     | ALC attack (gain ramp-down) time (ALCMODE == 1) |              |   |
|                  |                                    | Per step     | Per 6dB |   |          | 90% of range                                    |              |   |
|                  | 0000                               | 22.7us       | 182.4us |   |          | 1.31ms  |              |   |
|                  | 0001                               | 45.4us       | 363.2us |   |          | 2.62ms  |              |   |
|                  | 0010                               | 90.8us       | 726.4us |   |          | 5.26ms  |              |   |
|                  | ... (time doubles with every step) |              |         |   |          |   |              |   |
|                  | 1010                               | 23.2ms       | 186ms   |   |          | 1.348s  |              |   |
|                  | 35 (23h)                           | 8:4          |         |   |          | 00000   | Reserved     |   |
| 3                |                                    | NGEN         | 0       | ALC Noise gate function enable<br>1 = enable<br>0 = disable   |          |   |              | Input Limiter/<br>Automatic Level Control (ALC) |
| 2:0              |                                    | NGTH         | 000     | ALC Noise gate threshold:<br>000 = -39dB<br>001 = -45dB<br>010 = -51dB<br>011 = -57dB<br>100 = -63dB<br>101 = -70dB<br>110 = -76dB<br>111 = -81dB |          |   |              | Input Limiter/<br>Automatic Level Control (ALC) |
| 36 (24h)         | 8:5                                |              | 0000    | Reserved  |          |   |              |   |
|                  | 4                                  | PLL PRESCALE | 0       | 0 = MCLK input not divided (default)<br>1 = Divide MCLK by 2 before input to PLL  |          |   |              | Master Clock and Phase Locked Loop (PLL)        |
|                  | 3:0                                | PLLN[3:0]    | 1000    | Integer (N) part of PLL input/output frequency ratio. Use values greater than 5 and less than 13.   |          |   |              | Master Clock and Phase Locked Loop (PLL)        |
| 37 (25h)         | 8:6                                |              | 000     | Reserved  |          |   |              |   |

| REGISTER ADDRESS | BIT | LABEL        | DEFAULT   | DESCRIPTION  | REFER TO                                 |
|------------------|-----|--------------|-----------|--|--|
|                  | 5:0 | PLLK[23:18]  | 01100     | Fractional (K) part of PLL1 input/output frequency ratio (treat as one 24-digit binary number).  | Master Clock and Phase Locked Loop (PLL) |
| 38 (26h)         | 8:0 | PLLK[17:9]   | 010010011 | Fractional (K) part of PLL1 input/output frequency ratio (treat as one 24-digit binary number).  | Master Clock and Phase Locked Loop (PLL) |
| 39 (27h)         | 8:0 | PLLK[8:0]    | 011101001 | Fractional (K) part of PLL1 input/output frequency ratio (treat as one 24-digit binary number).  | Master Clock and Phase Locked Loop (PLL) |
| 41 (29h)         | 8:4 |              | 00000     | Reserved   |  |
|                  | 3:0 | DEPTH3D      | 0000      | Stereo depth<br>0000 = Disabled<br>0001 = 6.67%<br>0010 = 13.3%<br>0011 = 20%<br>0100 = 26.7%<br>0101 = 33.3%<br>0110 = 40%<br>0111 = 46.6%<br>1000 = 53.3%<br>1001 = 60%<br>1010 = 66.7%<br>1011 = 73.3%<br>1100 = 80%<br>1101 = 86.7%<br>1110 = 93.3%<br>1111 = 100% (maximum 3D effect) | 3D Stereo Enhancement                    |
| 42 (2Ah)         | 8:6 | OUT4_2ADCVOL | 000       | Controls the OUT4 to ADC input boost stage:<br>000 = Path disabled (disconnected)<br>001 = -12dB gain<br>010 = -9dB gain<br>011 = -6dB gain<br>100 = -3dB gain<br>101 = +0dB gain<br>110 = +3dB gain<br>111 = +6dB gain  | Analogue Outputs                         |
|                  | 5   | OUT4_2LNR    | 0         | OUT4 to L or R ADC input<br>0 = Right ADC input<br>1 = Left ADC input  | Analogue Outputs                         |
|                  | 4:3 |              | 000       | Reserved   |  |
|                  | 2   | POBCTRL      | 0         | Power-On Bias Control<br>(Use during power Up. Reset when VMID bias is stable)<br>0 = Bias derived from VMID<br>1 = Bias derived from AVDD   |  |
|                  | 1   | DELEN        | 0         | 2 <sup>nd</sup> enable bit for L/ROUT1   |  |
|                  | 0   | OUT1DEL      | 0         | 2 stage enable for L/ROUT1   |  |
| 43 (2Bh)         | 8   | BYPL2RMIX    | 0         | Left bypass path (from the Left channel input PGA stage) to right output mixer<br>0 = not selected<br>1 = selected   | Analogue Outputs                         |

| REGISTER ADDRESS | BIT | LABEL       | DEFAULT | DESCRIPTION  | REFER TO          |
|------------------|-----|-------------|---------|--|-------------------|
|                  | 7   | BYPR2LMIX   | 0       | Right bypass path (from the right channel input PGA stage) to Left output mixer<br>0 = not selected<br>1 = selected  | Analogue Outputs  |
|                  | 6:5 |             | 00      | Reserved   |                   |
|                  | 4   | INVROUT2    | 0       | Invert ROUT2 output<br>0 = Not inverted<br>1 = Inverted  | Analogue Outputs  |
|                  | 3:0 |             | 0000    | Reserved   |                   |
| 44 (2Ch)         | 8   | MBVSEL      | 0       | Microphone Bias Voltage Control<br>0 = 0.9 * AVDD1<br>1 = 0.65 * AVDD1   | Input Signal Path |
|                  | 7   |             | 0       | Reserved   |                   |
|                  | 6   | R2_2INPPGA  | 0       | Connect R2 pin to right channel input PGA positive terminal.<br>0=R2 not connected to input PGA<br>1=R2 connected to input PGA amplifier positive terminal (constant input impedance).                               | Input Signal Path |
|                  | 5   | RIN2INPPGA  | 1       | Connect RIN pin to right channel input PGA negative terminal.<br>0=RIN not connected to input PGA<br>1=RIN connected to right channel input PGA amplifier negative terminal.   | Input Signal Path |
|                  | 4   | RIP2INPPGA  | 1       | Connect RIP pin to right channel input PGA amplifier positive terminal.<br>0 = RIP not connected to input PGA<br>1 = right channel input PGA amplifier positive terminal connected to RIP (constant input impedance) | Input Signal Path |
|                  | 3   |             | 0       | Reserved   |                   |
|                  | 2   | L2_2INPPGA  | 0       | Connect L2 pin to left channel input PGA positive terminal.<br>0=L2 not connected to input PGA<br>1=L2 connected to input PGA amplifier positive terminal (constant input impedance).                                | Input Signal Path |
|                  | 1   | LIN2INPPGA  | 1       | Connect LIN pin to left channel input PGA negative terminal.<br>0=LIN not connected to input PGA<br>1=LIN connected to input PGA amplifier negative terminal.  | Input Signal Path |
| 45 (2Dh)         | 8   | INPPGAVU    | N/A     | INPPGA left and INPPGA right volume do not update until a 1 is written to INPPGAVU (in reg 45 or 46)   | Input Signal Path |
|                  | 7   | INPPGAZCL   | 0       | Left channel input PGA zero cross enable:<br>0=Update gain when gain register changes<br>1=Update gain on 1 <sup>st</sup> zero cross after gain register write.  | Input Signal Path |
|                  | 6   | INPPGAMUTEL | 0       | Mute control for left channel input PGA:<br>0=Input PGA not muted, normal operation<br>1=Input PGA muted (and disconnected from the following input BOOST stage).  | Input Signal Path |

| REGISTER ADDRESS | BIT | LABEL         | DEFAULT | DESCRIPTION   | REFER TO          |
|------------------|-----|---------------|---------|---|-------------------|
|                  | 5:0 | INPPGAVOLL    | 010000  | Left channel input PGA volume<br>000000 = -12dB<br>000001 = -11.25dB<br>.<br>010000 = 0dB<br>.<br>111111 = 35.25dB  | Input Signal Path |
| 46 (2Eh)         | 8   | INPPGAVU      | N/A     | INPPGA left and INPPGA right volume do not update until a 1 is written to INPPGAUPDATE (in reg 45 or 46)  | Input Signal Path |
|                  | 7   | INPPGAZCR     | 0       | Right channel input PGA zero cross enable:<br>0=Update gain when gain register changes<br>1=Update gain on 1 <sup>st</sup> zero cross after gain register write.  | Input Signal Path |
|                  | 6   | INPPGAMUTER   | 0       | Mute control for right channel input PGA:<br>0=Input PGA not muted, normal operation<br>1=Input PGA muted (and disconnected from the following input BOOST stage).  | Input Signal Path |
|                  | 5:0 | INPPGAVOLR    | 010000  | Right channel input PGA volume<br>000000 = -12dB<br>000001 = -11.25db<br>.<br>010000 = 0dB<br>.<br>111111 = +35.25dB  | Input Signal Path |
| 47 (2Fh)         | 8   | PGABOOSTL     | 1       | Boost enable for left channel input PGA:<br>0 = PGA output has +0dB gain through input BOOST stage.<br>1 = PGA output has +20dB gain through input BOOST stage.   | Input Signal Path |
|                  | 7   |               | 0       | Reserved  |                   |
|                  | 6:4 | L2_2BOOSTVOL  | 000     | Controls the L2 pin to the left channel input boost stage:<br>000=Path disabled (disconnected)<br>001 = -12dB gain<br>010 = -9dB gain<br>011 = -6dB gain<br>100 = -3dB gain<br>101 = +0dB gain<br>110 = +3dB gain<br>111 = +6dB gain              | Input Signal Path |
|                  | 3   |               | 0       | Reserved  |                   |
|                  | 2:0 | AUXL2BOOSTVOL | 000     | Controls the auxiliary amplifier to the left channel input boost stage:<br>000=Path disabled (disconnected)<br>001 = -12dB gain<br>010 = -9dB gain<br>011 = -6dB gain<br>100 = -3dB gain<br>101 = +0dB gain<br>110 = +3dB gain<br>111 = +6dB gain | Input Signal Path |



| REGISTER ADDRESS | BIT | LABEL         | DEFAULT | DESCRIPTION  | REFER TO          |
|------------------|-----|---------------|---------|--|-------------------|
| 48 (30h)         | 8   | PGABOOSTR     | 1       | Boost enable for right channel input PGA:<br>0 = PGA output has +0dB gain through input BOOST stage.<br>1 = PGA output has +20dB gain through input BOOST stage.   | Input Signal Path |
|                  | 7   |               | 0       | Reserved   |                   |
|                  | 6:4 | R2_2BOOSTVOL  | 000     | Controls the R2 pin to the right channel input boost stage:<br>000=Path disabled (disconnected)<br>001 = -12dB<br>010 = -9dB gain<br>011 = -6dB gain<br>100 = -3dB gain<br>101 = +0dB gain<br>110 = +3dB gain<br>111 = +6dB gain                   | Input Signal Path |
|                  | 3   |               | 0       | Reserved   |                   |
|                  | 2:0 | AUXR2BOOSTVOL | 000     | Controls the auxiliary amplifier to the right channel input boost stage:<br>000=Path disabled (disconnected)<br>001 = -12dB gain<br>010 = -9dB gain<br>011 = -6dB gain<br>100 = -3dB gain<br>101 = +0dB gain<br>110 = +3dB gain<br>111 = +6dB gain | Input Signal Path |
| 49 (31h)         | 8:7 |               | 00      | Reserved   |                   |
|                  | 6   | DACL2RMIX     | 0       | Left DAC output to right output mixer<br>0 = not selected<br>1 = selected  | Analogue Outputs  |
|                  | 5   | DACR2LMIX     | 0       | Right DAC output to left output mixer<br>0 = not selected<br>1 = selected  | Analogue Outputs  |
|                  | 3   | OUT3BOOST     | 0       | Output 3 Gain<br>0 = OUT3 output gain = -1;<br>DC = AVDD1 / 2<br>1 = OUT3 output gain = +1.5<br>DC = 1.5 x AVDD1 / 2   | Analogue Outputs  |
|                  | 4   | OUT4BOOST     | 0       | Output 4 Gain<br>0 = OUT4 output gain = -1;<br>DC = AVDD1 / 2<br>1 = OUT4 output gain = +1.5<br>DC = 1.5 x AVDD1 / 2   | Analogue Outputs  |
|                  | 2   | SPKBOOST      | 0       | Speaker Gain<br>0 = speaker gain = -1;<br>DC = AVDD1 / 2<br>1 = speaker gain = +1.5;<br>DC = 1.5 x AVDD1 / 2   | Analogue Outputs  |
|                  | 1   | TSDEN         | 1       | Thermal Shutdown Enable<br>0 : thermal shutdown disabled<br>1 : thermal shutdown enabled   | Analogue Outputs  |

| REGISTER ADDRESS | BIT | LABEL      | DEFAULT | DESCRIPTION   | REFER TO         |
|------------------|-----|------------|---------|---|------------------|
|                  | 0   | VROI       | 0       | VREF (AVDD/2 or 1.5xAVDD/2) to analogue output resistance<br>0: approx 1kΩ<br>1: approx 30 kΩ   | Analogue Outputs |
| 50 (32h)         | 8:6 | AUXLMIXVOL | 000     | Aux left channel input to left mixer volume control:<br>000 = -15dB<br>001 = -12dB<br>...<br>101 = 0dB<br>110 = +3dB<br>111 = +6dB                                      | Analogue Outputs |
|                  | 5   | AUXL2LMIX  | 0       | Left Auxiliary input to left channel output mixer:<br>0 = not selected<br>1 = selected  | Analogue Outputs |
|                  | 4:2 | BYPLMIXVOL | 000     | Left bypass volume control to output channel mixer:<br>000 = -15dB<br>001 = -12dB<br>010 = -9dB<br>011 = -6dB<br>100 = -3dB<br>101 = 0dB<br>110 = +3dB<br>111 = +6dB    | Analogue Outputs |
|                  | 1   | BYPL2LMIX  | 0       | Left bypass path (from the left channel input PGA stage) to left output mixer<br>0 = not selected<br>1 = selected   | Analogue Outputs |
|                  | 0   | DACL2LMIX  | 1       | Left DAC output to left output mixer<br>0 = not selected<br>1 = selected  | Analogue Outputs |
| 51 (33h)         | 8:6 | AUXRMIXVOL | 000     | Aux right channel input to right mixer volume control:<br>000 = -15dB<br>001 = -12dB<br>010 = -9dB<br>011 = -6dB<br>100 = -3dB<br>101 = 0dB<br>110 = +3dB<br>111 = +6dB | Analogue Outputs |
|                  | 5   | AUXR2RMIX  | 0       | Right Auxiliary input to right channel output mixer:<br>0 = not selected<br>1 = selected  | Analogue Outputs |

| REGISTER ADDRESS | BIT | LABEL      | DEFAULT | DESCRIPTION   | REFER TO         |
|------------------|-----|------------|---------|---|------------------|
|                  | 4:2 | BYPRMIXVOL | 000     | Right bypass volume control to output channel mixer:<br>000 = -15dB<br>001 = -12dB<br>010 = -9dB<br>011 = -6dB<br>100 = -3dB<br>101 = 0dB<br>110 = +3dB<br>111 = +6dB | Analogue Outputs |
|                  | 1   | BYPR2RMIX  | 0       | Right bypass path (from the right channel input PGA stage) to right output mixer<br>0 = not selected<br>1 = selected  | Analogue Outputs |
|                  | 0   | DACR2RMIX  | 1       | Right DAC output to right output mixer<br>0 = not selected<br>1 = selected  | Analogue Outputs |
| 52 (34h)         | 8   | OUT1VU     | N/A     | LOUT1 and ROUT1 volumes do not update until a 1 is written to OUT1VU (in reg 52 or 53)  | Analogue Outputs |
|                  | 7   | LOUT1ZC    | 0       | Headphone volume zero cross enable:<br>1 = Change gain on zero cross only<br>0 = Change gain immediately  | Analogue Outputs |
|                  | 6   | LOUT1MUTE  | 0       | Left headphone output mute:<br>0 = Normal operation<br>1 = Mute   | Analogue Outputs |
|                  | 5:0 | LOUT1VOL   | 111001  | Left headphone output volume:<br>000000 = -57dB<br>000001 = -56dB<br>...<br>111001 = 0dB<br>...<br>111111 = +6dB  | Analogue Outputs |
| 53 (35h)         | 8   | OUT1VU     | N/A     | LOUT1 and ROUT1 volumes do not update until a 1 is written to OUT1VU (in reg 52 or 53)  | Analogue Outputs |
|                  | 7   | ROUT1ZC    | 0       | Headphone volume zero cross enable:<br>1 = Change gain on zero cross only<br>0 = Change gain immediately  | Analogue Outputs |
|                  | 6   | ROUT1MUTE  | 0       | Right headphone output mute:<br>0 = Normal operation<br>1 = Mute  | Analogue Outputs |
|                  | 5:0 | ROUT1VOL   | 111001  | Right headphone output volume:<br>000000 = -57dB<br>000001 = -56dB<br>...<br>111001 = 0dB<br>...<br>111111 = +6dB   | Analogue Outputs |
| 54 (36h)         | 8   | OUT2VU     | N/A     | LOUT2 and ROUT2 volumes do not update until a 1 is written to OUT2VU (in reg 54 or 55)  | Analogue Outputs |
|                  | 7   | LOUT2ZC    | 0       | Left speaker volume zero cross enable:<br>1 = Change gain on zero cross only<br>0 = Change gain immediately   | Analogue Outputs |

| REGISTER ADDRESS | BIT | LABEL      | DEFAULT | DESCRIPTION   | REFER TO         |
|------------------|-----|------------|---------|---|------------------|
|                  | 6   | LOUT2MUTE  | 0       | Left speaker output mute:<br>0 = Normal operation<br>1 = Mute   | Analogue Outputs |
|                  | 5:0 | LOUT2VOL   | 111001  | Left speaker output volume:<br>000000 = -57dB<br>000001 = -56dB<br>...<br>111001 = 0dB<br>...<br>111111 = +6dB            | Analogue Outputs |
| 55 (37h)         | 8   | OUT2VU     | N/A     | LOUT2 and ROUT2 volumes do not update until a 1 is written to OUT2VU (in reg 54 or 55)                                    | Analogue Outputs |
|                  | 7   | ROUT2ZC    | 0       | Right speaker volume zero cross enable:<br>1 = Change gain on zero cross only<br>0 = Change gain immediately              | Analogue Outputs |
|                  | 6   | ROUT2MUTE  | 0       | Right speaker output mute:<br>0 = Normal operation<br>1 = Mute  | Analogue Outputs |
|                  | 5:0 | ROUT2VOL   | 111001  | Right speaker output volume:<br>000000 = -57dB<br>000001 = -56dB<br>...<br>111001 = 0dB<br>...<br>111111 = +6dB           | Analogue Outputs |
| 56 (38h)         | 8:7 |            | 00      | Reserved  |                  |
|                  | 6   | OUT3MUTE   | 0       | 0 = Output stage outputs OUT3 mixer<br>1 = Output stage muted – drives out VMID. Can be used as VMID buffer in this mode. | Analogue Outputs |
|                  | 5:4 |            | 00      | Reserved  |                  |
|                  | 3   | OUT4_2OUT3 | 0       | OUT4 mixer output to OUT3<br>0 = disabled<br>1 = enabled  | Analogue Outputs |
|                  | 2   | BYPL2OUT3  | 0       | Left ADC input to OUT3<br>0 = disabled<br>1 = enabled   | Analogue Outputs |
|                  | 1   | LMIX2OUT3  | 0       | Left Output mixer to OUT3<br>0 = disabled<br>1 = enabled  | Analogue Outputs |
|                  | 0   | LDAC2OUT3  | 1       | Left DAC output to OUT3<br>0 = disabled<br>1 = enabled  | Analogue Outputs |
| 57 (39h)         | 8   |            | 0       | Reserved  |                  |
|                  | 7   | OUT3_2OUT4 | 0       | OUT3 mixer output to OUT4<br>0 = disabled<br>1 = enabled  | Analogue Outputs |
|                  | 6   | OUT4MUTE   | 0       | 0 = Output stage outputs OUT4 mixer<br>1 = Output stage muted – drives out VMID. Can be used as VMID buffer in this mode. | Analogue Outputs |
|                  | 5   | OUT4ATTN   | 0       | 0 = OUT4 normal output<br>1 = OUT4 attenuated by 6dB  | Analogue Outputs |

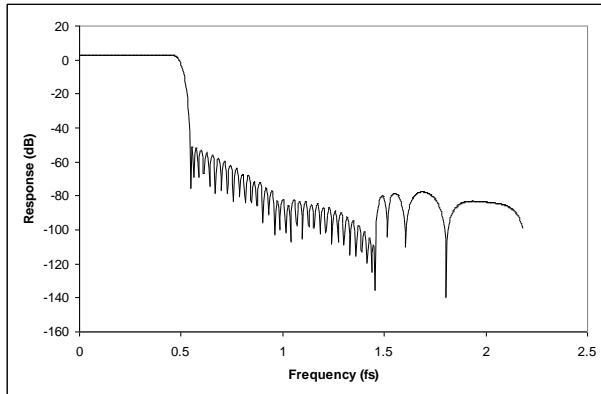
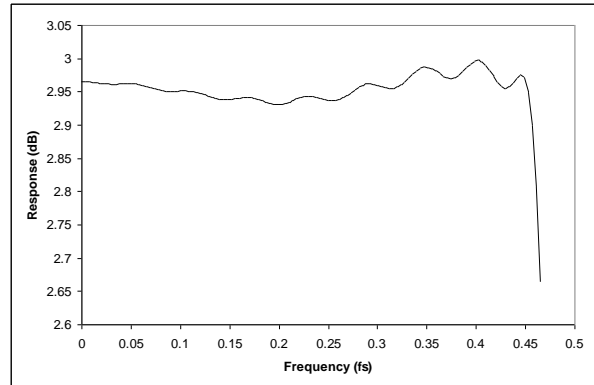
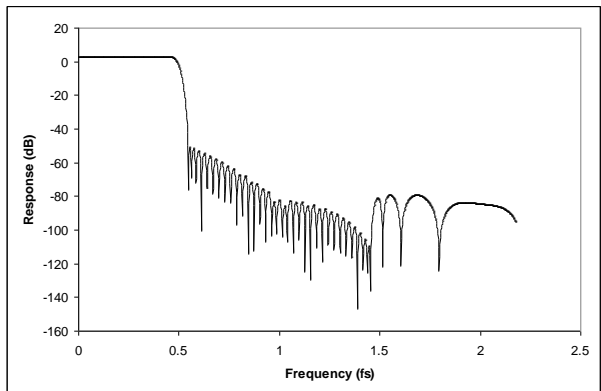
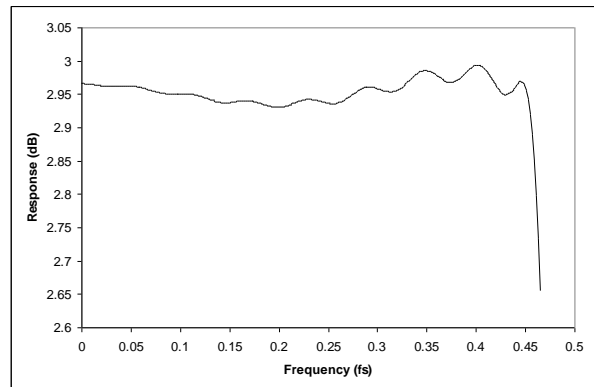
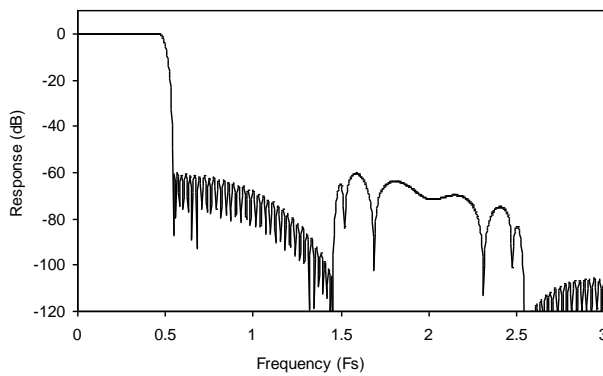
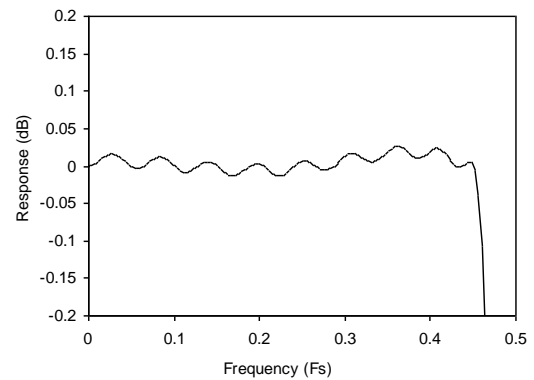
| REGISTER ADDRESS | BIT | LABEL     | DEFAULT  | DESCRIPTION   | REFER TO         |
|------------------|-----|-----------|----------|---|------------------|
|                  | 4   | LMIX2OUT4 | 0        | Left Output mixer to OUT4<br>0 = disabled<br>1 = enabled  | Analogue Outputs |
|                  | 3   | LDAC2OUT4 | 0        | Left DAC to OUT4<br>0 = disabled<br>1 = enabled           | Analogue Outputs |
|                  | 2   | BYPR2OUT4 | 0        | Right ADC input to OUT4<br>0 = disabled<br>1 = enabled    | Analogue Outputs |
|                  | 1   | RMIX2OUT4 | 0        | Right Output mixer to OUT4<br>0 = disabled<br>1 = enabled | Analogue Outputs |
|                  | 0   | RDAC2OUT4 | 1        | Right DAC output to OUT4<br>0 = disabled<br>1 = enabled   | Analogue Outputs |
| 59 (3Bh)         | 8:2 |           | 0000000  | Reserved  |                  |
|                  | 1:0 | ALCTST    | 00       | ALC Test Mode<br>00 = disabled<br>11 = enabled            | ALC Test Mode    |
| 61 (3Dh)         | 8   | BIASCUT   | 0        | Global bias control<br>0 = normal<br>1 = 0.5x             | Bias Control     |
|                  | 7:0 |           | 00000000 | Reserved  |                  |

**DIGITAL FILTER CHARACTERISTICS**

| PARAMETER                         | TEST CONDITIONS | MIN     | TYP   | MAX       | UNIT |
|-----------------------------------|-----------------|---------|-------|-----------|------|
| <b>ADC Filter</b>                 |                 |         |       |           |      |
| Passband                          | +/- 0.025dB     | 0       |       | 0.454fs   |      |
|                                   | -6dB            |         | 0.5fs |           |      |
| Passband Ripple                   |                 |         |       | +/- 0.025 | dB   |
| Stopband                          |                 | 0.546fs |       |           |      |
| Stopband Attenuation              | f > 0.546fs     | -60     |       |           | dB   |
| Group Delay                       |                 |         | 21/fs |           |      |
| <b>ADC High Pass Filter</b>       |                 |         |       |           |      |
| High Pass Filter Corner Frequency | -3dB            |         | 3.7   |           | Hz   |
|                                   | -0.5dB          |         | 10.4  |           |      |
|                                   | -0.1dB          |         | 21.6  |           |      |
| <b>DAC Filter</b>                 |                 |         |       |           |      |
| Passband                          | +/- 0.035dB     | 0       |       | 0.454fs   |      |
|                                   | -6dB            |         | 0.5fs |           |      |
| Passband Ripple                   |                 |         |       | +/-0.035  | dB   |
| Stopband                          |                 | 0.546fs |       |           |      |
| Stopband Attenuation              | f > 0.546fs     | -55     |       |           | dB   |
| Group Delay                       |                 |         | 29/fs |           |      |

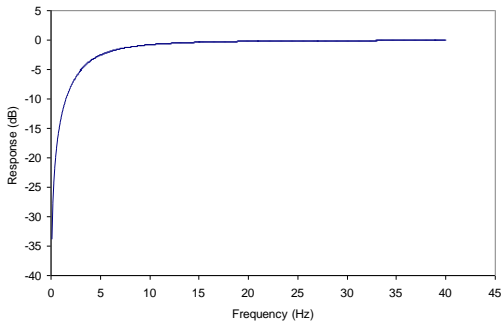
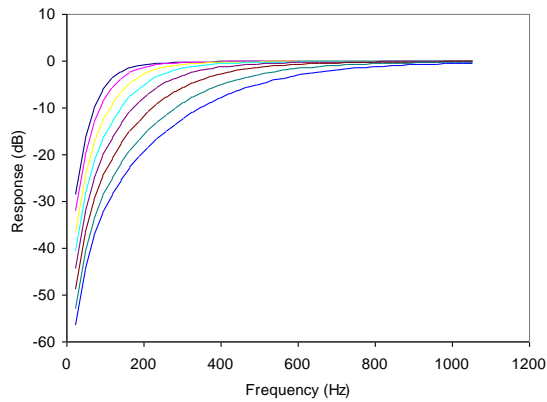
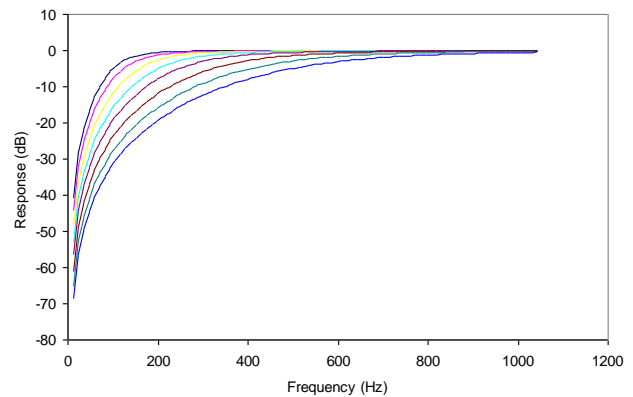
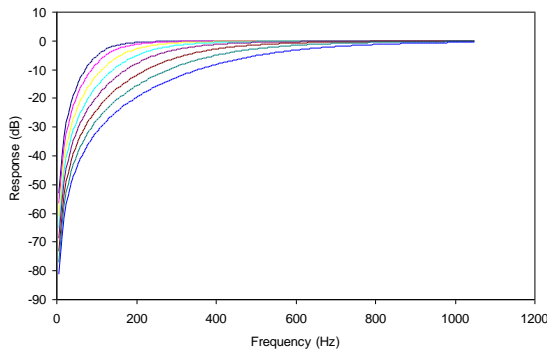
**Table 71 Digital Filter Characteristics**
**TERMINOLOGY**

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

**DAC FILTER RESPONSES**

**Figure 54 DAC Digital Filter Frequency Response (128xOSR)**

**Figure 55 DAC Digital Filter Ripple (128xOSR)**

**Figure 56 DAC Digital Filter Frequency Response (64xOSR)**

**Figure 57 DAC Digital Filter Ripple (64xOSR)**
**ADC FILTER RESPONSES**

**Figure 58 ADC Digital Filter Frequency Response**

**Figure 59 ADC Digital Filter Ripple**

**HIGHPASS FILTER**

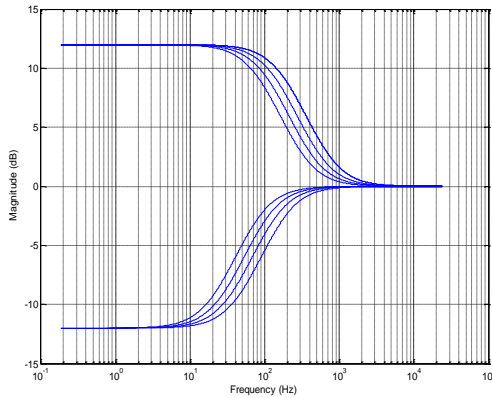
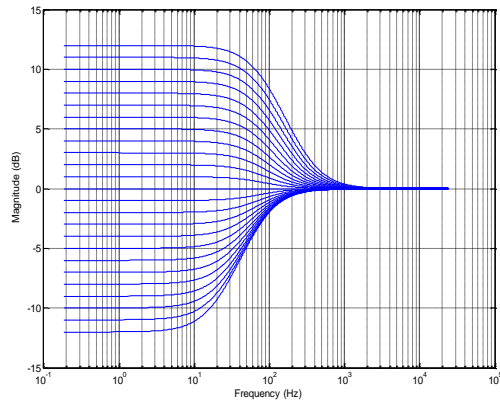
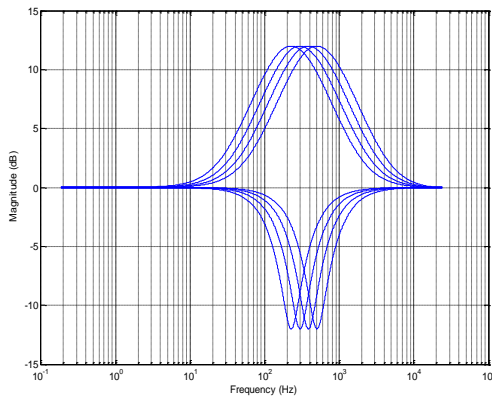
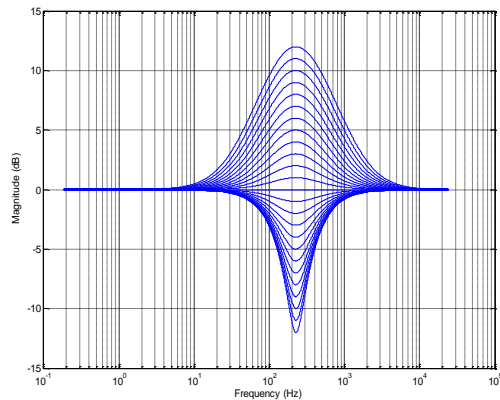
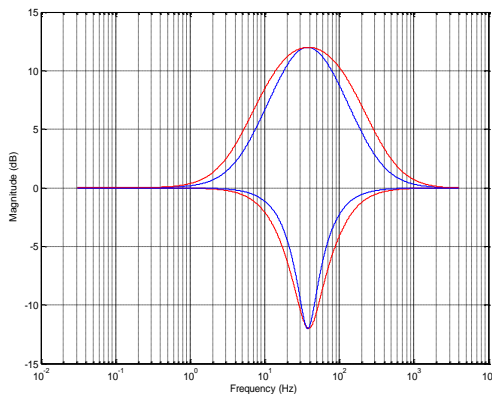
The WM8983 has a selectable digital highpass filter in the ADC filter path. This filter has two modes, audio and applications. In audio mode, the filter is a 1<sup>st</sup> order IIR with a cut-off of around 3.7Hz. In applications mode, the filter is a 2<sup>nd</sup> order high pass filter with a selectable cut-off frequency.

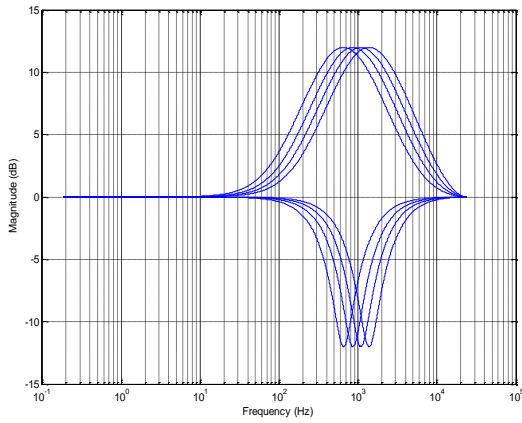

**Figure 60 ADC Highpass Filter Response, HPFAPP=0**

**Figure 61 ADC Highpass Filter Responses (48kHz), HPFAPP=1, all cut-off settings shown.**

**Figure 62 ADC Highpass Filter Responses (24kHz), HPFAPP=1, all cut-off settings shown.**

**Figure 63 ADC Highpass Filter Responses (12kHz), HPFAPP=1, all cut-off settings shown.**



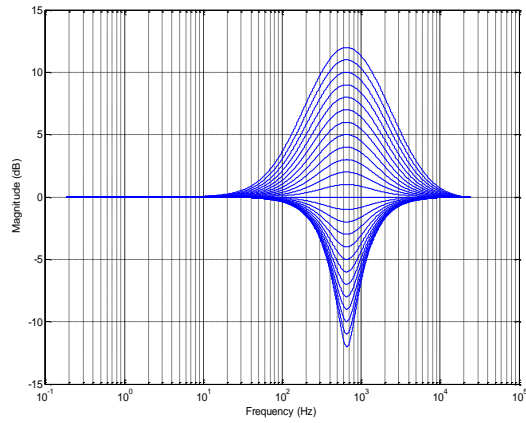
**5-BAND EQUALISER**

The WM8983 has a 5-band equaliser which can be applied to either the ADC path or the DAC path. The plots from Figure 64 to Figure 77 show the frequency responses of each filter with a sampling frequency of 48kHz, firstly showing the different cut-off/centre frequencies with a gain of  $\pm 12\text{dB}$ , and secondly a sweep of the gain from  $-12\text{dB}$  to  $+12\text{dB}$  for the lowest cut-off/centre frequency of each filter.

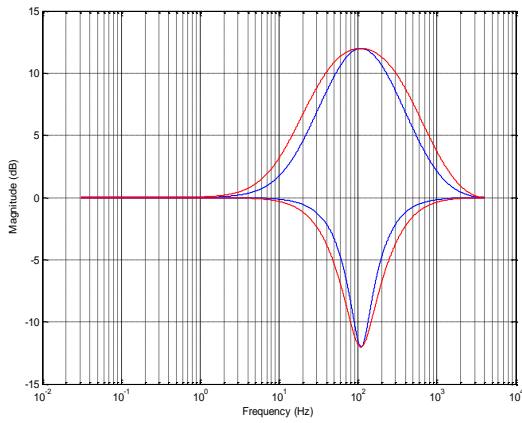

**Figure 64 EQ Band 1 Low Frequency Shelf Filter Cut-offs**

**Figure 65 EQ Band 1 Gains for Lowest Cut-off Frequency**

**Figure 66 EQ Band 2 – Peak Filter Centre Frequencies, EQ2BW=0**

**Figure 67 EQ Band 2 – Peak Filter Gains for Lowest Cut-off Frequency, EQ2BW=0**

**Figure 68 EQ Band 2 – EQ2BW=0, EQ2BW=1**



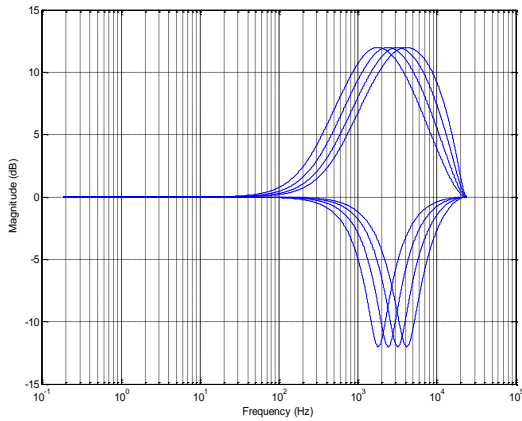
**Figure 69 EQ Band 3 – Peak Filter Centre Frequencies, EQ3BW=0**



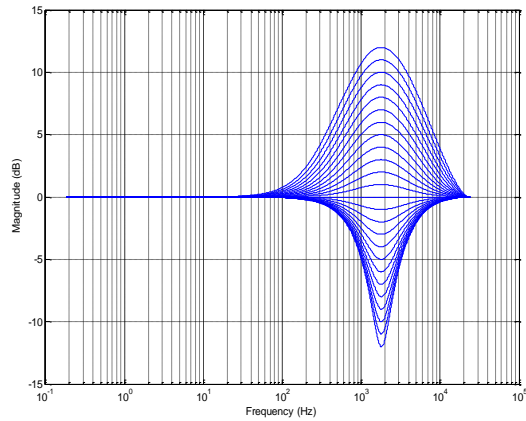
**Figure 70 EQ Band 3 – Peak Filter Gains for Lowest Cut-off Frequency, EQ3BW=0**



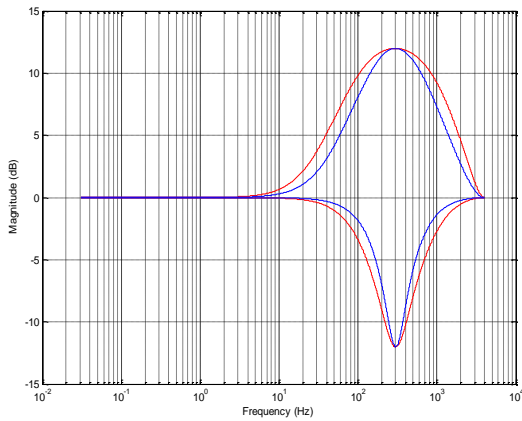
**Figure 71 EQ Band 3 – EQ3BW=0, EQ3BW=1**



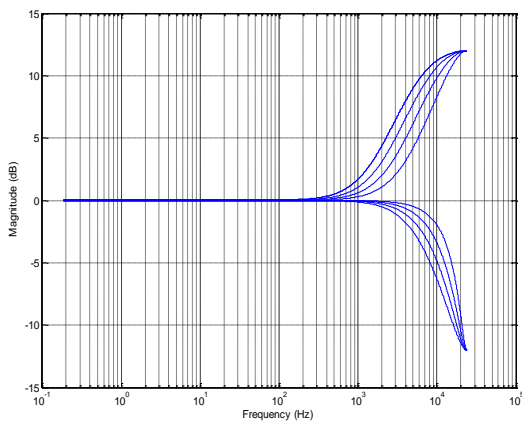
**Figure 72 EQ Band 4 – Peak Filter Centre Frequencies, EQ3BW=0**



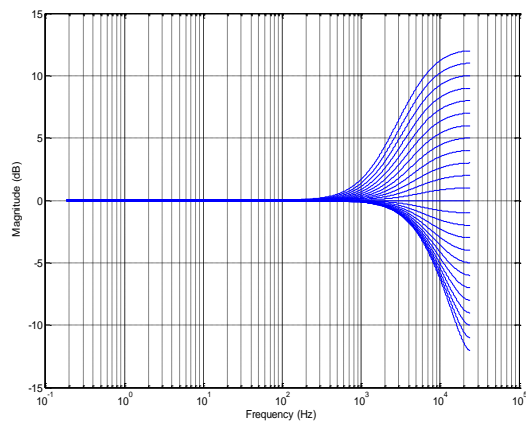
**Figure 73 EQ Band 4 – Peak Filter Gains for Lowest Cut-off Frequency, EQ4BW=0**



**Figure 74 EQ Band 4 – EQ3BW=0, EQ3BW=1**

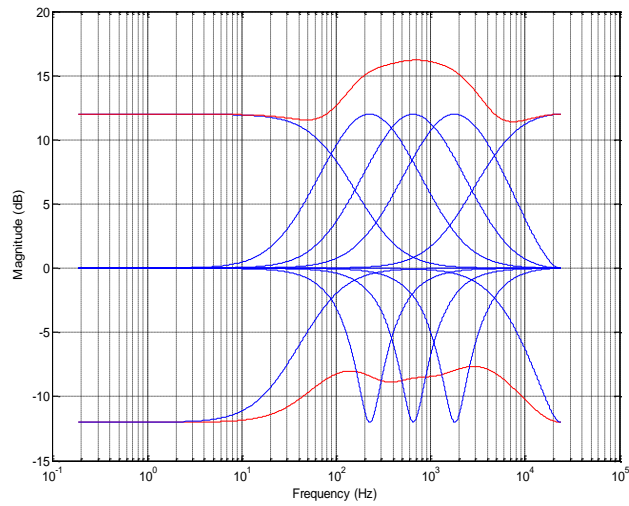


**Figure 75 EQ Band 5 High Frequency Shelf Filter Cut-offs**

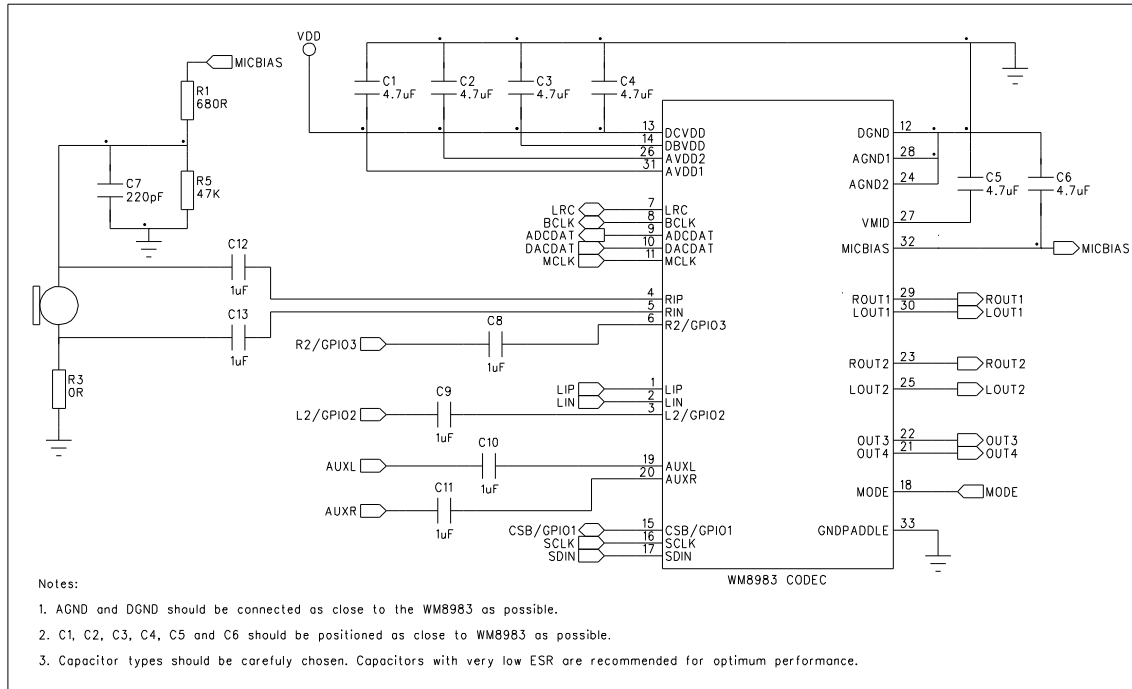


**Figure 76 EQ Band 5 Gains for Lowest Cut-off Frequency**

Figure 77 shows the result of having the gain set on more than one channel simultaneously. The blue traces show each band (lowest cut-off/centre frequency) with  $\pm 12\text{dB}$  gain. The red traces show the cumulative effect of all bands with  $+12\text{dB}$  gain and all bands  $-12\text{dB}$  gain, with EqxBW=0 for the peak filters.

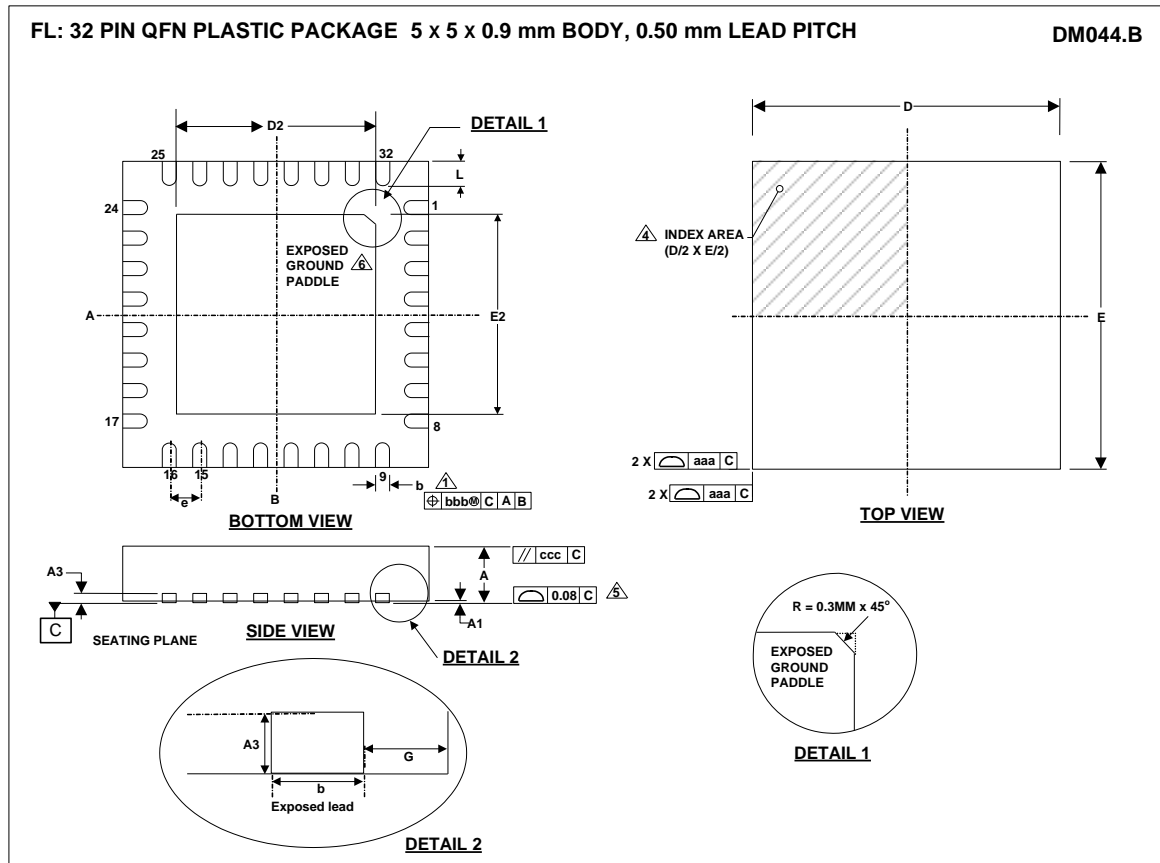


**Figure 77 Cumulative Frequency Boost/Cut**

**APPLICATIONS INFORMATION**
**RECOMMENDED EXTERNAL COMPONENTS**

**Figure 78 External Component Diagram**

## PACKAGE DIAGRAM

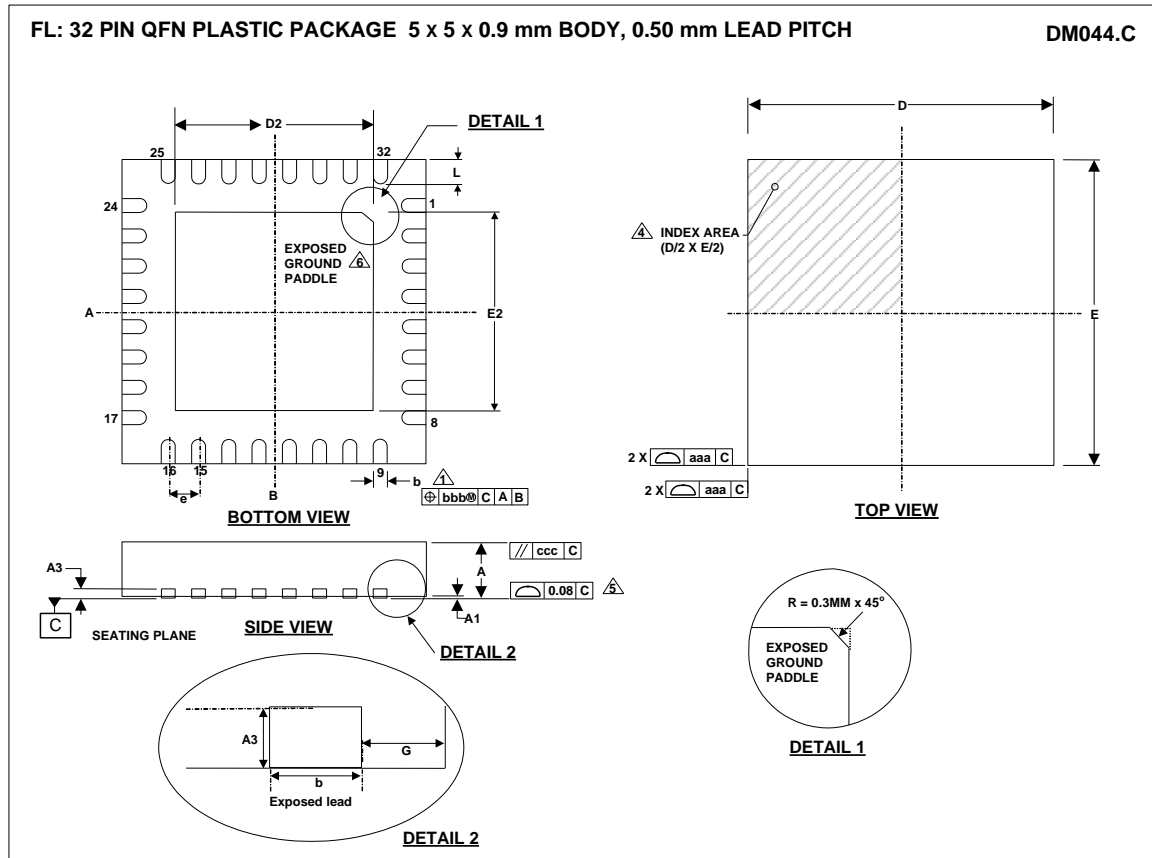
### PACKAGE DIAGRAM FOR DEVICES MARKED KF3 / LK8 / RFD



| Symbols                                | Dimensions (mm)                  |           |      | NOTE |
|--|----------------------------------|-----------|------|------|
|  | MIN                              | NOM       | MAX  |      |
| A                                      | 0.80                             | 0.85      | 0.90 |      |
| A1                                     | 0                                | 0.02      | 0.05 |      |
| A3                                     |                                  | 0.203 REF |      |      |
| b                                      | 0.20                             | 0.25      | 0.30 | 1    |
| D                                      |                                  | 5.00 BSC  |      |      |
| D2                                     | 3.05                             | 3.10      | 3.15 | 2    |
| E                                      |                                  | 5.00 BSC  |      |      |
| E2                                     | 3.05                             | 3.10      | 3.15 | 2    |
| e                                      |                                  | 0.50 BSC  |      |      |
| G                                      |                                  | 0.625     |      |      |
| L                                      | 0.35                             | 0.40      | 0.45 |      |
| <b>Tolerances of Form and Position</b> |                                  |           |      |      |
| aaa                                    |                                  | 0.15      |      |      |
| bbb                                    |                                  | 0.10      |      |      |
| ccc                                    |                                  | 0.10      |      |      |
| REF:                                   | JEDEC, MO-220, VARIATION VHHD-5. |           |      |      |

**NOTES:**

1. DIMENSION b APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.15 mm AND 0.30 mm FROM TERMINAL TIP.
2. FALLS WITHIN JEDEC, MO-220, VARIATION VHHD-5.
3. ALL DIMENSIONS ARE IN MILLIMETRES.
4. THE TERMINAL #1 IDENTIFIER AND TERMINAL NUMBERING CONVENTION SHALL CONFORM TO JEDEC 95-1 SPP-002.
5. COPLANARITY APPLIES TO THE EXPOSED HEAT SINK SLUG AS WELL AS THE TERMINALS.
6. REFER TO APPLICATION NOTE WAN\_0118 FOR FURTHER INFORMATION REGARDING PCB FOOTPRINTS AND QFN PACKAGE SOLDERING.
7. THIS DRAWING IS SUBJECT TO CHANGE WITHOUT NOTICE.

**PACKAGE DIAGRAM FOR DEVICES MARKED CT8**


| Symbols                                | Dimensions (mm)                  |           |      | NOTE |
|--|----------------------------------|-----------|------|------|
|  | MIN                              | NOM       | MAX  |      |
| A                                      | 0.80                             | 0.85      | 0.90 |      |
| A1                                     | 0                                | 0.035     | 0.05 |      |
| A3                                     |                                  | 0.203 REF |      |      |
| b                                      | 0.20                             | 0.25      | 0.30 | 1    |
| D                                      |                                  | 5.00 BSC  |      |      |
| D2                                     | 3.4                              | 3.5       | 3.6  | 2    |
| E                                      |                                  | 5.00 BSC  |      |      |
| E2                                     | 3.4                              | 3.5       | 3.6  | 2    |
| e                                      |                                  | 0.50 BSC  |      |      |
| G                                      |                                  | 0.625     |      |      |
| L                                      | 0.35                             | 0.40      | 0.45 |      |
| <b>Tolerances of Form and Position</b> |                                  |           |      |      |
| aaa                                    |                                  | 0.10      |      |      |
| bbb                                    |                                  | 0.10      |      |      |
| ccc                                    |                                  | 0.08      |      |      |
| REF:                                   | JEDEC, MO-220, VARIATION VHHD-5. |           |      |      |

- NOTES:
- DIMENSION b APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.15 mm AND 0.30 mm FROM TERMINAL TIP.
  - FALLS WITHIN JEDEC, MO-220, VARIATION VHHD-5.
  - ALL DIMENSIONS ARE IN MILLIMETRES.
  - THE TERMINAL #1 IDENTIFIER AND TERMINAL NUMBERING CONVENTION SHALL CONFORM TO JEDEC 95-1 SPP-002.
  - COPLANARITY APPLIES TO THE EXPOSED HEAT SINK SLUG AS WELL AS THE TERMINALS.
  - REFER TO APPLICATION NOTE WAN\_0118 FOR FURTHER INFORMATION REGARDING PCB FOOTPRINTS AND QFN PACKAGE SOLDERING.
  - THIS DRAWING IS SUBJECT TO CHANGE WITHOUT NOTICE.

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**IMPORTANT NOTICE**

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**REVISION HISTORY**

| DATE     | REV | DESCRIPTION OF CHANGES  | CHANGED BY |
|----------|-----|---|------------|
| 08/08/13 | 4.4 | Delete AUXR > ROUT2 signal path.<br>Miscellaneous formatting updates.       | PH         |
| 15/01/15 | 4.5 | Selectable ROUT2 inversion (INVROUT2) added in Audio Paths Overview diagram | PH         |
| 10/08/16 | 4.6 | New package drawing incorporated, for devices marked CT8                    | PH         |

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