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## ***Ultra Low-Power Codec for Portable Audio Applications***

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### **DESCRIPTION**

The WM8904 is a high performance ultra-low power stereo CODEC optimised for portable audio applications.

The device features stereo ground-referenced headphone amplifiers using the Wolfson 'Class-W' amplifier techniques - incorporating an innovative dual-mode charge pump architecture - to optimise efficiency and power consumption during playback. The ground-referenced headphone and line outputs eliminate AC coupling capacitors, and both outputs include common mode feedback paths to reject ground noise.

Control sequences for audio path setup can be pre-loaded and executed by an integrated control write sequencer to reduce software driver development and minimise pops and clicks via SilentSwitch™ technology.

The analogue input stage can be configured for single ended or differential inputs. Up to 3 stereo microphone or line inputs may be connected. The input impedance is constant with PGA gain setting.

A stereo digital microphone interface is provided, with a choice of two inputs.

A dynamic range controller provides compression and level control to support a wide range of portable recording applications. Anti-clip and quick release features offer good performance in the presence of loud impulsive noises.

ReTune™ Mobile 5-band parametric equaliser with fully programmable coefficients is integrated for optimization of speaker characteristics. Programmable dynamic range control is also available for maximizing loudness, protecting speakers from clipping and preventing premature shutdown due to battery droop.

Common audio sampling frequencies are supported from a wide range of external clocks, either directly or generated via the FLL.

The WM8904 can operate directly from a single 1.8V switched supply. For optimal power consumption, the digital core can be operated from a 1.0V supply.

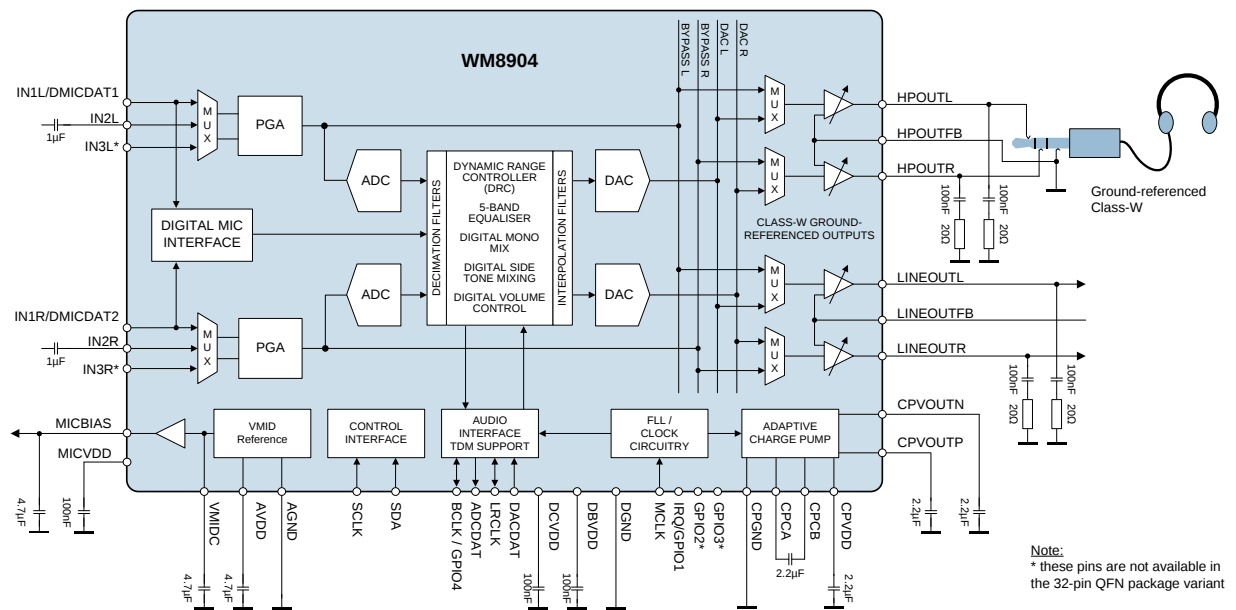
### **FEATURES**

- 3.0mW quiescent power consumption for DAC to headphone playback
- DAC SNR 96dB typical, THD -86dB typical
- ADC SNR 91dB typical, THD -80dB typical
- 2.4mW quiescent power consumption for analogue bypass playback
- Control write sequencer for pop minimised start-up and shutdown
- Single register write for default start-up sequence
- Integrated FLL provides all necessary clocks
  - Self-clocking modes allow processor to sleep
  - All standard sample rates from 8kHz to 96kHz
- Stereo digital microphone input
- 3 single ended inputs per stereo channel
- 1 fully differential mic / line input per stereo channel
- Digital Dynamic Range Controller (compressor / limiter)
- Digital sidetone mixing
- Ground-referenced headphone driver
- Ground-referenced line outputs
- 32-pin QFN package (4 x 4mm, 0.4mm pitch)
- 36-ball WLCSP package (2.6 x 2.5mm, 6 x 6 ball grid, 0.4mm pitch)

### **APPLICATIONS**

- Portable multimedia players
- Multimedia handsets
- Handheld gaming
- Wireless headsets
- Mobile internet devices
- Netbooks

## BLOCK DIAGRAM



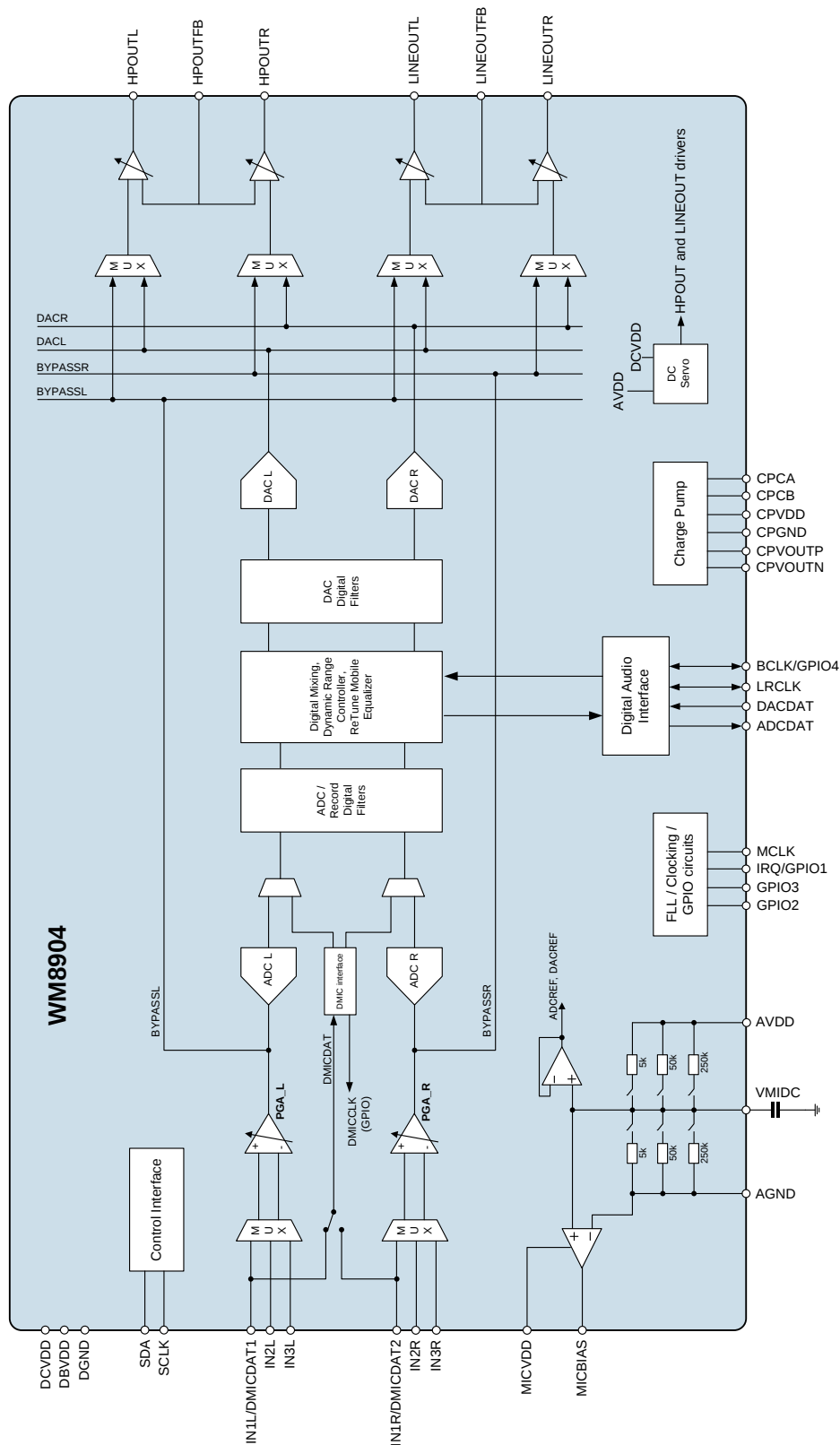
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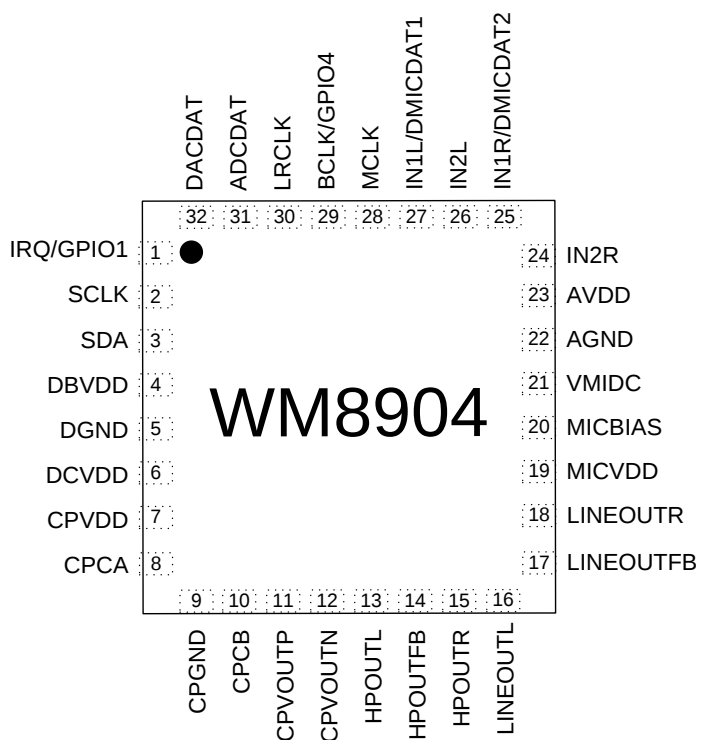
## AUDIO SIGNAL PATHS DIAGRAM



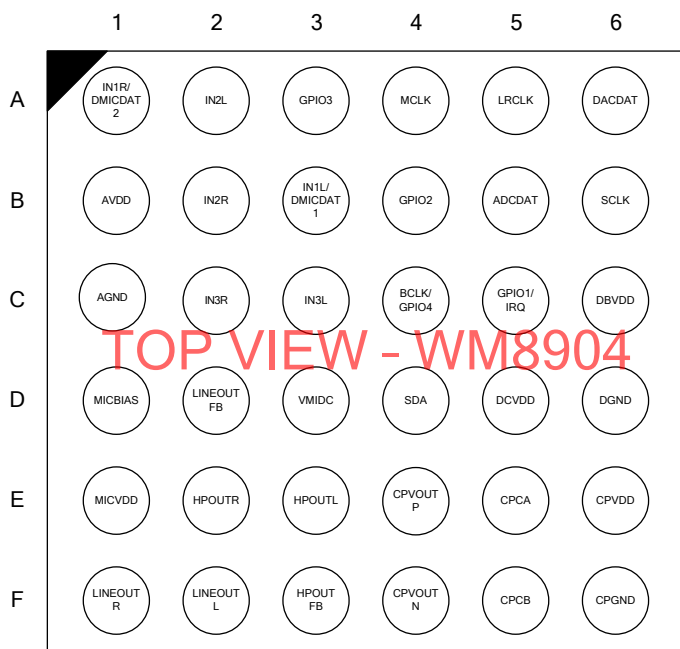
## PIN CONFIGURATION

The WM8904 is supplied in a 32-pin QFN package or in a 36-ball CSP format.

The diagram below shows the 32-pin QFN configuration.



The following diagram shows the 36-ball CSP configuration.



**ORDERING INFORMATION**

| DEVICE         | TEMPERATURE RANGE | PACKAGE                                                                                      | MOISTURE SENSITIVITY LEVEL | PEAK SOLDERING TEMPERATURE |
|----------------|-------------------|----------------------------------------------------------------------------------------------|----------------------------|----------------------------|
| WM8904CGEFL/V  | -40°C to +85°C    | 32-lead QFN<br>(4 x 4 x 0.75mm, 0.4mm pitch, lead-free)                                      | MSL3                       | 260°C                      |
| WM8904CGEFL/RV | -40°C to +85°C    | 32-lead QFN<br>(4 x 4 x 0.75mm, 0.4mm pitch, lead-free, tape and reel)                       | MSL3                       | 260°C                      |
| WM8904ECS/R    | -40°C to +85°C    | 36-ball W-CSP<br>(2.6 x 2.5 x 0.5mm, 6 x 6 ball grid, 0.4mm pitch, lead-free, tape and reel) | MSL1                       | 260°C                      |

**Note:**

QFN Reel quantity = 3,500

W-CSP Reel quantity = 3,500

**PIN DESCRIPTION**

| NAME            | WLCSP 6×6 | QFN-32 | TYPE                     | DESCRIPTION                                                          |
|-----------------|-----------|--------|--------------------------|----------------------------------------------------------------------|
| IN1L / DMICDAT1 | B3        | 27     | Analogue / Digital Input | Left channel input 1 / Digital microphone data input 1               |
| IN2L            | A2        | 26     | Analogue Input           | Left channel input 2                                                 |
| IN3L            | C3        | n/a    | Analogue Input           | Left channel input 3                                                 |
| IN1R / DMICDAT2 | A1        | 25     | Analogue / Digital Input | Right channel input 1 / Digital microphone data input 2              |
| IN2R            | B2        | 24     | Analogue Input           | Right channel input 2                                                |
| IN3R            | C2        | n/a    | Analogue Input           | Right channel input 3                                                |
| MICBIAS         | D1        | 20     | Analogue Output          | Microphone bias                                                      |
| MICVDD          | E1        | 19     | Supply                   | Microphone bias amp supply                                           |
| HPOUTL          | E3        | 13     | Analogue Output          | Left headphone output (line or headphone output)                     |
| HPOUTR          | E2        | 15     | Analogue Output          | Right headphone output (line or headphone output)                    |
| HPOUTFB         | F3        | 14     | Analogue Input           | Headphone output ground loop noise rejection feedback                |
| LINEOUTL        | F2        | 16     | Analogue Output          | Left line output 1 (line output)                                     |
| LINEOUTR        | F1        | 18     | Analogue Output          | Right line output 1 (line output)                                    |
| LINEOUTFB       | D2        | 17     | Analogue Input           | Line output ground loop noise rejection feedback                     |
| CPVDD           | E6        | 7      | Supply                   | Charge pump power supply                                             |
| CPGND           | F6        | 9      | Supply                   | Charge pump ground                                                   |
| CPCA            | E5        | 8      | Analogue Output          | Charge pump flyback capacitor pin                                    |
| CPCB            | F5        | 10     | Analogue Output          | Charge pump flyback capacitor pin                                    |
| CPVOUTP         | E4        | 11     | Analogue Output          | Charge pump positive supply decoupling (powers HPOUTL/R, LINEOUTL/R) |
| CPVOUTN         | F4        | 12     | Analogue Output          | Charge pump negative supply decoupling (powers HPOUTL/R, LINEOUTL/R) |
| AVDD            | B1        | 23     | Supply                   | Analogue power supply (powers analogue inputs, reference, ADC, DAC)  |
| AGND            | C1        | 22     | Supply                   | Analogue power return                                                |
| VMIDC           | D3        | 21     |                          | Midrail voltage decoupling capacitor                                 |
| DCVDD           | D5        | 6      | Supply                   | Digital core supply                                                  |
| DBVDD           | C6        | 4      | Supply                   | Digital buffer supply (powers audio interface and control interface) |
| DGND            | D6        | 5      | Supply                   | Digital ground (return path for DCVDD and DBVDD)                     |
| MCLK            | A4        | 28     | Digital Input            | Master clock for CODEC                                               |
| BCLK / GPIO4    | C4        | 29     | Digital Input / Output   | Audio interface bit clock / GPIO4                                    |
| LRCLK           | A5        | 30     | Digital Input / Output   | Audio interface left / right clock (common for ADC and DAC)          |
| DACDAT          | A6        | 32     | Digital Input            | DAC digital audio data                                               |
| ADCDAT          | B5        | 31     | Digital Output           | ADC digital audio data                                               |
| SCLK            | B6        | 2      | Digital Input            | Control interface clock input                                        |
| SDA             | D4        | 3      | Digital Input / Output   | Control interface data input / output                                |
| GPIO1 / IRQ     | C5        | 1      | Digital Input / Output   | GPIO1 / Interrupt                                                    |
| GPIO2           | B4        | n/a    | Digital Input / Output   | GPIO2                                                                |
| GPIO3           | A3        | n/a    | Digital Input / Output   | GPIO3                                                                |
| GND_PADDLE      | n/a       | 33     |                          | Die Paddle                                                           |

**Note:**

1. It is recommended that the QFN ground paddle is connected to analogue ground on the application PCB.

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

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

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

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

The Moisture Sensitivity Level for each package type is specified in Ordering Information.

| CONDITION                           | MIN                 | MAX          |
|-------------------------------------|---------------------|--------------|
| AVDD, DCVDD                         | -0.3V               | +2.5V        |
| DBVDD,                              | -0.3V               | +4.5V        |
| MICVDD                              | -0.3V               | +4.5V        |
| CPVDD                               | -0.3V               | +2.2V        |
| HPOUTL, HPOUTR, LINEOUTL, LINEOUTR  | (CPVDD + 0.3V) * -1 | CPVDD + 0.3V |
| Voltage range digital inputs        | DGND -0.3V          | DBVDD +0.3V  |
| Voltage range analogue inputs       | AGND -0.3V          | AVDD +0.3V   |
| Temperature range, T <sub>A</sub>   | -40°C               | +85°C        |
| Storage temperature after soldering | -65°C               | +150°C       |

### Notes:

1. Analogue and digital grounds must always be within 0.3V of each other.
2. All digital and analogue supplies are completely independent from each other; there is no restriction on power supply sequencing.
3. HPOUTL, HPOUTR, LINEOUTL, LINEOUTR are outputs, and should not normally become connected to DC levels. However, if the limits above are exceeded, then damage to the WM8904 may occur.

## RECOMMENDED OPERATING CONDITIONS

| PARAMETER                       | SYMBOL            | MIN  | TYP | MAX  | UNIT |
|---------------------------------|-------------------|------|-----|------|------|
| Digital supply range (Core)     | DCVDD             | 0.95 | 1.0 | 1.98 | V    |
| Digital supply range (Buffer)   | DBVDD             | 1.42 | 1.8 | 3.6  | V    |
| Analogue supplies range         | AVDD              | 1.71 | 1.8 | 2.0  | V    |
| Charge pump supply range        | CPVDD             | 1.71 | 1.8 | 2.0  | V    |
| Microphone bias                 | MICVDD            | 1.71 | 2.5 | 3.6  | V    |
| Ground                          | DGND, AGND, CPGND |      | 0   |      | V    |
| Operating Temperature (ambient) | T <sub>A</sub>    | -40  | +25 | +85  | °C   |

## ELECTRICAL CHARACTERISTICS

### TERMINOLOGY

1. Signal-to-Noise Ratio (dB) – SNR is the difference in level between a full scale output signal and the device output noise with no signal applied, measured over a bandwidth of 20Hz to 20kHz. This ratio is also called idle channel noise. (No Auto-zero or Automute function is employed).
2. Total Harmonic Distortion (dB) – THD is the difference in level between a 1kHz full scale sinewave output signal and the first seven harmonics of the output signal. The amplitude of the fundamental frequency of the output signal is compared to the RMS value of the next seven harmonics and expressed as a ratio.
3. Total Harmonic Distortion + Noise (dB) – THD+N is the difference in level between a 1kHz full scale sine wave output signal and all noise and distortion products in the audio band. The amplitude of the fundamental reference frequency of the output signal is compared to the RMS value of all other noise and distortion products and expressed as a ratio.
4. Channel Separation (dB) – is a measure of the coupling between left and right channels. A full scale signal is applied to the left channel only, the right channel amplitude is measured. Then a full scale signal is applied to the right channel only and the left channel amplitude is measured. The worst case channel separation is quoted as a ratio.
5. Multi-Path Crosstalk (dB) – is the measured signal level in the idle path at the test signal frequency relative to the signal level at the output of the active path. The active path is configured and supplied with an appropriate input signal to drive a full scale output, with signal measured at the output of the specified idle path.
6. Channel Level Matching (dB) – measures the difference in gain between the left and the right channels.
7. Power Supply Rejection Ratio (dB) – PSRR is a measure of ripple attenuation between the power supply pin and an output path. With the signal path idle, a small signal sine wave is summed onto the power supply rail, The amplitude of the sine wave is measured at the output port and expressed as a ratio.
8. All performance measurements carried out with 20kHz AES17 low pass filter for distortion measurements, and an A-weighted filter for noise measurement. Failure to use such a filter will result in higher THD and lower SNR and Dynamic Range readings than are found in the Electrical Characteristics. The low pass filter removes out of band noise; although it is not audible it may affect dynamic specification values.

### COMMON TEST CONDITIONS

Unless otherwise stated, the following test conditions apply throughout the following sections:

- DCVDD = 1.0V
- DBVDD = 1.8V
- AVDD = CPVDD = 1.8V
- Ambient temperature = +25°C
- Audio signal: 1kHz sine wave, sampled at 48kHz with 24-bit data resolution
- SYSCLK\_SRC = 0 (system clock comes direct from MCLK, not from FLL).

Additional, specific test conditions are given within the relevant sections below.

**INPUT SIGNAL PATH**

**Single-ended Stereo Line Record** - IN1L+IN1R pins to ADC output

**Test conditions:**

L\_MODE = R\_MODE = 00b (Single ended)

LIN\_VOL = RIN\_VOL = 00101b (0dB)

Total signal path gain = 6dB, incorporating 6dB single-ended to differential conversion gain

| PARAMETER                                      | SYMBOL          | TEST CONDITIONS                                                              | MIN | TYP                | MAX | UNIT                  |
|------------------------------------------------|-----------------|------------------------------------------------------------------------------|-----|--------------------|-----|-----------------------|
| Full Scale Input Signal Level (for ADC 0dBFS). |                 |                                                                              |     | 0.50<br>-6<br>1.41 |     | Vrms<br>dBV<br>Vpk-pk |
| Input Resistance                               | R <sub>in</sub> |                                                                              | 9   | 12                 |     | kΩ                    |
| Input Capacitance                              | C <sub>in</sub> |                                                                              |     | 10                 |     | pF                    |
| Signal to Noise Ratio                          | SNR             | A-weighted<br>ADC_OSR128 = 0<br>ADC_128_OSR_TST_MODE = 1<br>ADC_BIASx1P5 = 1 |     | 80                 |     | dB                    |
|                                                |                 | A-weighted<br>ADC_OSR128 = 1<br>ADC_128_OSR_TST_MODE = 0<br>ADC_BIASx1P5 = 0 | 80  | 90                 |     |                       |
| Total Harmonic Distortion + Noise              | THD+N           | -7dBV input                                                                  |     | -78                | -66 | dB                    |
| Channel Separation                             |                 | 1kHz signal, -7dBV                                                           |     | 85                 |     | dB                    |
|                                                |                 | 10kHz signal, -7dBV                                                          |     | 80                 |     |                       |
| Channel Level Matching                         |                 | 1kHz signal, -7dBV                                                           |     | +/-1               |     | dB                    |
| Power Supply Rejection Ratio                   | PSRR            | 217Hz, 100mVpk-pk                                                            |     | 45                 |     | dB                    |
|                                                |                 | 1kHz, 100mV pk-pk                                                            |     | 55                 |     |                       |

**Differential Stereo Line Record - IN2L+IN3L / IN2R+IN3R pins to ADC output**
**Test conditions:**

L\_MODE = R\_MODE = 01b (Differential Line)

LIN\_VOL = RIN\_VOL = 00101b (0dB)

Total signal path gain = 0dB

| PARAMETER                                                                         | SYMBOL          | TEST CONDITIONS                                                                                         | MIN | TYP               | MAX | UNIT                  |
|-----------------------------------------------------------------------------------|-----------------|---------------------------------------------------------------------------------------------------------|-----|-------------------|-----|-----------------------|
| Line Input Full Scale Signal Level applied to IN2L or IN2R (for ADC 0dBFS output) |                 |                                                                                                         |     | 1.00<br>0<br>2.83 |     | Vrms<br>dBV<br>Vpk-pk |
| IN3L, IN3R input range                                                            |                 |                                                                                                         |     |                   |     | mV                    |
| Input Resistance                                                                  | R <sub>in</sub> |                                                                                                         | 9   | 12                |     | kΩ                    |
| Input Capacitance                                                                 | C <sub>in</sub> |                                                                                                         |     | 10                |     | pF                    |
| Signal to Noise Ratio                                                             | SNR             | A-weighted<br>ADC_OSR128 = 0<br>ADC_128_OSR_TST_MODE = 1<br>ADC_BIASx1P5 = 1                            |     | 80                |     | dB                    |
|                                                                                   |                 | A-weighted<br>Best performance mode::<br>ADC_OSR128 = 1<br>ADC_128_OSR_TST_MODE = 0<br>ADC_BIASx1P5 = 0 | 81  | 91                |     |                       |
| Total Harmonic Distortion + Noise                                                 | THD+N           | -1dBV input                                                                                             |     | -78               | -66 | dB                    |
| Common Mode Rejection Ratio                                                       | CMRR            | 1kHz, 100mV pk-pk                                                                                       |     | 60                |     | dB                    |
| Channel Separation                                                                |                 | 1kHz signal, -1dBV                                                                                      |     | 85                |     | dB                    |
|                                                                                   |                 | 10kHz signal, -1dBV                                                                                     |     | 80                |     |                       |
| Channel Level Matching                                                            |                 | 1kHz signal, -1dBV                                                                                      |     | +/-1              |     | dB                    |
| Power Supply Rejection Ratio                                                      | PSRR            | 217Hz, 100mVpk-pk                                                                                       |     | 55                |     | dB                    |
|                                                                                   |                 | 1kHz, 100mV pk-pk                                                                                       |     | 55                |     |                       |

**Single-ended Stereo Record from Analogue Microphones - IN2L / IN2R pins to ADC output**
**Test conditions:**

L\_MODE = R\_MODE = 00b (Single ended)

LIN\_VOL = RIN\_VOL = 11111b (+28.3dB)

Total signal path gain = +34.3dB, incorporating 6dB single-ended to differential conversion gain

| PARAMETER                                                             | SYMBOL          | TEST CONDITIONS                                                                                         | MIN | TYP                     | MAX | UNIT                  |
|-----------------------------------------------------------------------|-----------------|---------------------------------------------------------------------------------------------------------|-----|-------------------------|-----|-----------------------|
| Single-ended mic input full-scale Signal Level (for ADC 0dBFS output) |                 |                                                                                                         |     | 0.019<br>-34.3<br>0.055 |     | Vrms<br>dBV<br>Vpk-pk |
| Input Resistance                                                      | R <sub>in</sub> |                                                                                                         | 9   | 12                      |     | kΩ                    |
| Input Capacitance                                                     | C <sub>in</sub> |                                                                                                         |     | 10                      |     | pF                    |
| Signal to Noise Ratio                                                 | SNR             | A-weighted<br>ADC_OSR128 = 0<br>ADC_128_OSR_TST_MODE = 1<br>ADC_BIASx1P5 = 1                            |     | 65                      |     | dB                    |
|                                                                       |                 | A-weighted<br>Best performance mode::<br>ADC_OSR128 = 1<br>ADC_128_OSR_TST_MODE = 0<br>ADC_BIASx1P5 = 0 |     | 73                      |     |                       |
| Total Harmonic Distortion + Noise                                     | THD+N           | -35.3dBV input                                                                                          |     | -69                     |     | dB                    |
| Channel Level Matching                                                |                 | 1kHz signal, -35.3dBV                                                                                   |     | +/-3                    |     | dB                    |
| Power Supply Rejection Ratio                                          | PSRR            | 217Hz, 100mVpk-pk                                                                                       |     | 45                      |     | dB                    |
|                                                                       |                 | 1kHz, 100mV pk-pk                                                                                       |     | 55                      |     |                       |

**Differential Stereo Record from Analogue Microphones - IN1L+IN2L / IN1R+IN2R pins to ADC output**
**Test conditions:**

L\_MODE = R\_MODE = 10b (Differential mic)

LIN\_VOL = RIN\_VOL = 00111b (+30dB)

Total signal path gain = +30dB

| PARAMETER                                                                                      | SYMBOL | TEST CONDITIONS                                                                                         | MIN | TYP                   | MAX | UNIT                  |
|------------------------------------------------------------------------------------------------|--------|---------------------------------------------------------------------------------------------------------|-----|-----------------------|-----|-----------------------|
| Differential Mic Input Full Scale Signal Level<br>IN1L-IN2L / IN1R-IN2R (for ADC 0dBFS output) |        |                                                                                                         |     | 0.032<br>-30<br>0.089 |     | Vrms<br>dBV<br>Vpk-pk |
| Input Resistance                                                                               | Rin    |                                                                                                         | 100 | 120                   |     | kΩ                    |
| Input Capacitance                                                                              | Cin    |                                                                                                         |     | 10                    |     | pF                    |
| Signal to Noise Ratio                                                                          | SNR    | A-weighted<br>ADC_OSR128 = 0<br>ADC_128_OSR_TST_MODE = 1<br>ADC_BIASx1P5 = 1                            |     | 68                    |     | dB                    |
|                                                                                                |        | A-weighted<br>Best performance mode::<br>ADC_OSR128 = 1<br>ADC_128_OSR_TST_MODE = 0<br>ADC_BIASx1P5 = 0 | 67  | 77                    |     |                       |
| Total Harmonic Distortion + Noise                                                              | THD+N  | -31dBV input                                                                                            |     | -75                   | -65 | dB                    |
| Common Mode Rejection Ratio                                                                    | CMRR   | 1kHz, 100mVpk-pk                                                                                        |     | 60                    |     | dB                    |
| Channel Separation                                                                             |        | 1kHz signal, -31dBV                                                                                     |     | 85                    |     | dB                    |
|                                                                                                |        | 10kHz signal, -31dBV                                                                                    |     | 80                    |     |                       |
| Channel Level Matching                                                                         |        | 1kHz signal, -31dBV                                                                                     |     | +/-1                  |     | dB                    |
| PSRR (Referred to Input)                                                                       | PSRR   | 217Hz, 100mVpk-pk                                                                                       |     | 50                    |     | dB                    |
|                                                                                                |        | 1kHz, 100mV pk-pk                                                                                       |     | 50                    |     |                       |

**PGA and Microphone Boost**

| PARAMETER                                    | TEST CONDITIONS                            | MIN  | TYP    | MAX  | UNIT   |
|----------------------------------------------|--------------------------------------------|------|--------|------|--------|
| Minimum PGA gain setting                     | L_MODE/R_MODE= 00b or 01b                  |      | -1.55  |      | dB     |
|                                              | L_MODE/R_MODE= 10b                         |      | +12    |      |        |
| Maximum PGA gain setting                     | L_MODE/R_MODE= 00b or 01b                  |      | +28.28 |      | dB     |
|                                              | L_MODE/R_MODE= 10b                         |      | +30    |      |        |
| Single-ended to differential conversion gain | L_MODE/R_MODE= 00b                         |      | +6     |      | dB     |
| PGA gain accuracy                            | L_MODE/R_MODE= 00b<br>Gain -1.5 to +6.7dB  | -1   |        | +1   | dB     |
|                                              | L_MODE/R_MODE= 00b<br>Gain +7.5 to +28.3dB | -1.5 |        | +1.5 |        |
|                                              | L_MODE/R_MODE= 1X<br>Gain +12 to +24dB     | -1   |        | +1   |        |
|                                              | L_MODE/R_MODE= 1X<br>Gain +27 to +30dB     | -1.5 |        | +1.5 |        |
| Mute attenuation                             | all modes of operation                     |      | 100    |      | dB     |
| Equivalent input noise                       | L_MODE/R_MODE= 00b or 01b                  |      | 30     |      | μVrms  |
|                                              |                                            |      | 214    |      | nV/√Hz |

**OUTPUT SIGNAL PATH**

**High Performance Stereo Playback to Headphones** - DAC input to HPOUTL+HPOUTR pins with 15Ω load

**Test conditions:**

HPOUTL\_VOL = HPOUTR\_VOL = 111001b (0dB)

Low Power Playback mode disabled. (See Table 49 for details; note that Low Power Playback mode is disabled by default.)

| PARAMETER                         | SYMBOL         | TEST CONDITIONS                            | MIN  | TYP                 | MAX  | UNIT              |
|-----------------------------------|----------------|--------------------------------------------|------|---------------------|------|-------------------|
| Output Power (per Channel)        | P <sub>o</sub> | 1% THD<br>R <sub>Load</sub> = 30Ω          |      | 28<br>0.92<br>-0.76 |      | mW<br>Vrms<br>dBV |
|                                   |                | 1% THD<br>R <sub>Load</sub> = 15Ω          |      | 32<br>0.69<br>-3.19 |      | mW<br>Vrms<br>dBV |
| DC Offset                         |                | DC servo enabled,<br>calibration complete. | -1.5 |                     | +1.5 | mV                |
| Signal to Noise Ratio             | SNR            | A-weighted                                 | 90   | 96                  |      | dB                |
| Total Harmonic Distortion + Noise | THD+N          | R <sub>L</sub> =30Ω; P <sub>o</sub> =2mW   |      | -91                 |      | dB                |
|                                   |                | R <sub>L</sub> =30Ω; P <sub>o</sub> =20mW  |      | -84                 |      |                   |
|                                   |                | R <sub>L</sub> =15Ω; P <sub>o</sub> =2mW   |      | -87                 | -80  |                   |
|                                   |                | R <sub>L</sub> =15Ω; P <sub>o</sub> =20mW  |      | -85                 |      |                   |
| Channel Separation                |                | 1kHz signal, 0dBFS                         |      | 100                 |      | dB                |
|                                   |                | 10kHz signal, 0dBFS                        |      | 90                  |      |                   |
| Channel Level Matching            |                | 1kHz signal, 0dBFS                         |      | +/-1                |      | dB                |
| Power Supply Rejection Ratio      | PSRR           | 217Hz, 100mVpk-pk                          |      | 75                  |      | dB                |
|                                   |                | 1kHz, 100mV pk-pk                          |      | 70                  |      |                   |

**Low Power Stereo Playback to Headphones** - DAC input to HPOUTL+HPOUTR pins with 15Ω load

**Test conditions:**

HPOUTL\_VOL = HPOUTR\_VOL = 111001b (0dB)

Low Power Playback Mode enabled (see Table 48 for details)

| PARAMETER                         | SYMBOL         | TEST CONDITIONS                           | MIN | TYP                 | MAX | UNIT              |
|-----------------------------------|----------------|-------------------------------------------|-----|---------------------|-----|-------------------|
| Output Power (per Channel)        | P <sub>o</sub> | 1% THD<br>R <sub>Load</sub> = 30Ω         |     | 27<br>0.90<br>-0.92 |     | mW<br>Vrms<br>dBV |
|                                   |                | 1% THD<br>R <sub>Load</sub> = 15Ω         |     | 30<br>0.67<br>-3.5  |     | mW<br>Vrms<br>dBV |
| Signal to Noise Ratio             | SNR            | A-weighted                                |     | 95                  |     | dB                |
| Total Harmonic Distortion + Noise | THD+N          | R <sub>L</sub> =30Ω; P <sub>o</sub> =2mW  |     | -91                 |     | dB                |
|                                   |                | R <sub>L</sub> =30Ω; P <sub>o</sub> =20mW |     | -83                 |     |                   |
|                                   |                | R <sub>L</sub> =15Ω; P <sub>o</sub> =2mW  |     | -87                 |     |                   |
|                                   |                | R <sub>L</sub> =15Ω; P <sub>o</sub> =20mW |     | -80                 |     |                   |

**High Performance Stereo Playback to Line-out - DAC input to LINEOUTL+LINEOUTR pins with 10k $\Omega$  / 50pF load**
**Test conditions:**

LINEOUTL\_VOL = LINEOUTR\_VOL = 111001b (0dB)

Low Power Playback mode disabled. (See Table 49 for details; note that Low Power Playback mode is disabled by default.)

| PARAMETER                         | SYMBOL | TEST CONDITIONS                            | MIN  | TYP              | MAX  | UNIT                  |
|-----------------------------------|--------|--------------------------------------------|------|------------------|------|-----------------------|
| Full Scale Output Signal Level    |        | DAC 0dBFS output at 0dB volume             |      | 1.0<br>0<br>2.83 |      | Vrms<br>dBV<br>Vpk-pk |
| DC offset                         |        | DC servo enabled.<br>Calibration complete. | -1.5 |                  | +1.5 | mV                    |
| Signal to Noise Ratio             | SNR    | A-weighted                                 | 90   | 96               |      | dB                    |
| Total Harmonic Distortion + Noise | THD+N  | 10k $\Omega$ load                          |      | -85              | -70  | dB                    |
| Channel Separation                |        | 1kHz signal, 0dBFS                         |      | 100              |      | dB                    |
|                                   |        | 10kHz signal, 0dBFS                        |      | 90               |      |                       |
| Channel Level Matching            |        | 1kHz signal, 0dBFS                         |      | +/-1             |      | dB                    |
| Power Supply Rejection Ratio      | PSRR   | 217Hz, 100mVpk-pk                          |      | 62               |      | dB                    |
|                                   |        | 1kHz, 100mV pk-pk                          |      | 62               |      |                       |

**Low Power Stereo Playback to Line-out - DAC input to LINEOUTL+LINEOUTR pins with 10k $\Omega$  / 50pF load**
**Test conditions:**

LINEOUTL\_VOL = LINEOUTR\_VOL = 111001b (0dB),

Low Power Playback Mode enabled (see Table 48 for details)

| PARAMETER                         | SYMBOL | TEST CONDITIONS                | MIN | TYP              | MAX | UNIT                  |
|-----------------------------------|--------|--------------------------------|-----|------------------|-----|-----------------------|
| Full Scale Output Signal Level    |        | DAC 0dBFS output at 0dB volume |     | 1.0<br>0<br>2.83 |     | Vrms<br>dBV<br>Vpk-pk |
| Signal to Noise Ratio             | SNR    | A-weighted                     |     | 95               |     | dB                    |
| Total Harmonic Distortion + Noise | THD+N  | 10k $\Omega$ load              |     | -82              |     | dB                    |

**Output PGAs (HP, LINE)**

| PARAMETER                | TEST CONDITIONS | MIN  | TYP | MAX  | UNIT |
|--------------------------|-----------------|------|-----|------|------|
| Minimum PGA gain setting |                 |      | -57 |      | dB   |
| Maximum PGA gain setting |                 |      | 6   |      | dB   |
| PGA Gain Step Size       |                 |      | 1   |      | dB   |
| PGA gain accuracy        | +6dB to -40dB   | -1.5 |     | +1.5 | dB   |
| PGA gain accuracy        | -40dB to -57dB  | -1   |     | +1   | dB   |
| Mute attenuation         | HPOUTL/R        |      | 85  |      | dB   |
|                          | LINEOUTL/R      |      | 85  |      | dB   |

## BYPASS PATH

**Differential Stereo Line Input to Stereo Line Output-** IN2L-IN3L / IN2R-IN3R pins to LINEOUTL+LINEOUTR pins with 10k $\Omega$  / 50pF load

**Test conditions:**

L\_MODE = R\_MODE = 01b (Differential Line)

LIN\_VOL = RIN\_VOL = 00101b (0dB)

LINEOUTL\_VOL = LINEOUTR\_VOL = 111001b (0dB)

Total signal path gain = 0dB

| PARAMETER                         | SYMBOL | TEST CONDITIONS     | MIN | TYP              | MAX | UNIT                  |
|-----------------------------------|--------|---------------------|-----|------------------|-----|-----------------------|
| Full Scale Output Signal Level    |        |                     |     | 1.0<br>0<br>2.83 |     | Vrms<br>dBV<br>Vpk-pk |
| Signal to Noise Ratio             | SNR    | A-weighted          | 90  | 100              |     | dBV                   |
| Total Harmonic Distortion + Noise | THD+N  | -1dBV input         |     | -92              | -85 | dBV                   |
| Channel Separation                |        | 1kHz signal, -1dBV  |     | 90               |     | dB                    |
|                                   |        | 10kHz signal, -1dBV |     | 80               |     |                       |
| Channel Level Matching            |        | 1kHz signal, -1dBV  |     | +/-1             |     | dB                    |
| Power Supply Rejection Ratio      | PSRR   | 217Hz, 100mV pk-pk  |     | 45               |     | dB                    |

## CHARGE PUMP

| PARAMETER                                                   | TEST CONDITIONS | MIN | TYP      | MAX | UNIT    |
|-------------------------------------------------------------|-----------------|-----|----------|-----|---------|
| Start-up Time                                               |                 |     | 260      |     | $\mu$ s |
| CPCA                                                        | Normal mode     |     | CPVDD    |     | V       |
|                                                             | Low power mode  |     | CPVDD/2  |     | V       |
| CPCB                                                        | Normal mode     |     | -CPVDD   |     | V       |
|                                                             | Low power mode  |     | -CPVDD/2 |     | V       |
| <b>External component requirements</b>                      |                 |     |          |     |         |
| To achieve specified headphone output power and performance |                 |     |          |     |         |
| Flyback Capacitor<br>(between CPCA and CPCB)                | at 2V           | 1   | 2.2      |     | $\mu$ F |
| CPVOUTN Capacitor                                           | at 2V           | 2   | 2.2      |     | $\mu$ F |
| CPVOUTP Capacitor                                           | at 2V           | 2   | 2.2      |     | $\mu$ F |

## FLL

| PARAMETER                            | SYMBOL           | TEST CONDITIONS              | MIN   | TYP   | MAX  | UNIT    |
|--------------------------------------|------------------|------------------------------|-------|-------|------|---------|
| Input Frequency                      | F <sub>REF</sub> | FLL_CLK_REF_DIV = 00         | 0.032 |       | 13.5 | MHz     |
|                                      |                  | FLL_CLK_REF_DIV = 01         | 0.064 |       | 27   | MHz     |
| Lock time                            |                  |                              |       | 2     |      | ms      |
| Free-running mode start-up time      |                  | VMID enabled                 |       | 100   |      | $\mu$ s |
| Free-running mode frequency accuracy |                  | Reference supplied initially |       | +/-10 |      | %       |
|                                      |                  | No reference provided        |       | +/-30 |      | %       |

**OTHER PARAMETERS**

| VMID Reference                                           |                          |     |        |     |      |
|----------------------------------------------------------|--------------------------|-----|--------|-----|------|
| PARAMETER                                                | TEST CONDITIONS          | MIN | TYP    | MAX | UNIT |
| Midrail Reference Voltage (VMIDC pin)                    |                          | -3% | AVDD/2 | +3% | V    |
| Charge up time (from fully discharged to 10% below VMID) | External capacitor 4.7µF |     | 890    |     | µs   |

| Microphone Bias (for analogue electret condenser microphones)                                                                      |                      |                                                         |      |             |      |        |
|------------------------------------------------------------------------------------------------------------------------------------|----------------------|---------------------------------------------------------|------|-------------|------|--------|
| Additional test conditions: MICBIAS_ENA=1, all parameters measured at the MICBIAS pin                                              |                      |                                                         |      |             |      |        |
| PARAMETER                                                                                                                          | SYMBOL               | TEST CONDITIONS                                         | MIN  | TYP         | MAX  | UNIT   |
| Bias Voltage.<br>Note: 7/6 and 9/10 are available only if MICVDD > AVDD.<br>Note: 3/2 and 4/3 are available only if MICVDD ≥ 2.5V. | V <sub>MICBIAS</sub> | MICVDD = 2.5V<br>3mA load current,<br>MICBIAS_SEL = 1xx | -10% | 3/2 x AVDD  | +10% | V      |
|                                                                                                                                    |                      | MICBIAS_SEL = 011                                       | -10% | 4/3 x AVDD  | +10% |        |
|                                                                                                                                    |                      | MICBIAS_SEL = 010                                       | -10% | 7/6 x AVDD  | +10% |        |
|                                                                                                                                    |                      | MICBIAS_SEL = 001                                       | -10% | 10/9 x AVDD | +10% |        |
|                                                                                                                                    |                      | MICBIAS_SEL = 000                                       | -10% | 9/10 xAVDD  | +10% |        |
| Drop out voltage between MICVDD and MICBIAS                                                                                        |                      |                                                         |      | 200         |      | mV     |
| Maximum source current                                                                                                             | I <sub>MICBIAS</sub> |                                                         |      | 4           |      | mA     |
| Noise spectral density                                                                                                             |                      | At 1kHz                                                 |      | 19          |      | nV/√Hz |
| Power Supply Rejection Ratio MICVDD to MICBIAS                                                                                     | PSRR                 | 1kHz, 100mV pk-pk<br>MICVDD = 1.71 V                    |      | 67          |      | dB     |
|                                                                                                                                    |                      | 20kHz, 100mV pk-pk<br>MICVDD = 1.71 V                   |      | 76          |      |        |
|                                                                                                                                    |                      | 1kHz, 100mV pk-pk<br>MICVDD = 2.5 V                     |      | 88          |      |        |
|                                                                                                                                    |                      | 20kHz, 100mV pk-pk<br>MICVDD = 2.5 V                    |      | 84          |      |        |
|                                                                                                                                    |                      | 1kHz, 100mV pk-pk<br>MICVDD = 3.6 V                     |      | 61          |      |        |
|                                                                                                                                    |                      | 20kHz, 100mV pk-pk<br>MICVDD = 3.6 V                    |      | 70          |      |        |
| Power Supply Rejection Ratio MICVDD and AVDD to MICBIAS                                                                            | PSRR                 | 1kHz, 100mV pk-pk<br>AVDD = MICVDD = 1.8 V              |      | 54          |      | dB     |
|                                                                                                                                    |                      | 20kHz, 100mV pk-pk<br>AVDD = MICVDD = 1.8 V             |      | 79          |      |        |
| MICBIAS Current Detect Function (See Note 1)                                                                                       |                      |                                                         |      |             |      |        |
| Current Detect Threshold (Microphone insertion)                                                                                    |                      | MICDET_THR = 00                                         |      |             | 80   | μA     |
| Current Detect Threshold (Microphone removal)                                                                                      |                      |                                                         | 60   |             |      |        |
| Delay Time for Current Detect Interrupt                                                                                            | t <sub>DET</sub>     |                                                         |      | 3.2         |      | ms     |
| MICBIAS Short Circuit (Hook Switch) Detect Function (See Note 1)                                                                   |                      |                                                         |      |             |      |        |
| Short Circuit Detect Threshold (Button press)                                                                                      |                      | MICSHORT_THR = 00                                       |      |             | 600  | μA     |
| Short Circuit Detect Threshold (Button release)                                                                                    |                      |                                                         | 400  |             |      |        |
| Minimum Delay Time for Short Circuit Detect Interrupt                                                                              | t <sub>SHORT</sub>   |                                                         |      | 47          |      | ms     |

**Note 1 :** If AVDD ≠ 1.8, current threshold values should be multiplied by (AVDD/1.8)

| <b>Digital Inputs / Outputs</b>                |          |                 |                    |     |                    |      |
|------------------------------------------------|----------|-----------------|--------------------|-----|--------------------|------|
| PARAMETER                                      | SYMBOL   | TEST CONDITIONS | MIN                | TYP | MAX                | UNIT |
| Input HIGH Level<br>(Digital Input)            | $V_{IH}$ |                 | $0.7 \times DBVDD$ |     |                    | V    |
| Input LOW Level<br>(Digital Input)             | $V_{IL}$ |                 |                    |     | $0.3 \times DBVDD$ | V    |
| Input HIGH Level<br>(Analogue / Digital Input) | $V_{IH}$ |                 | $0.7 \times AVDD$  |     |                    | V    |
| Input LOW Level<br>(Analogue / Digital Input)  | $V_{IL}$ |                 |                    |     | $0.3 \times AVDD$  | V    |
| Output HIGH Level                              | $V_{OH}$ | $I_{OH} = +1mA$ | $0.9 \times DBVDD$ |     |                    | V    |
| Output LOW Level                               | $V_{OL}$ | $I_{OL} = -1mA$ |                    |     | $0.1 \times DBVDD$ | V    |

**Multi-Path Crosstalk**
**Test Conditions:**

Input Path = IN1L/IN1R to ADC, 0dB gain

Output Path = DAC to HPOUTL/HPOUTR, 0dB gain

Fs = 48kHz

| PARAMETER            | SYMBOL | TEST CONDITIONS    | MIN | TYP | MAX | UNIT |
|----------------------|--------|--------------------|-----|-----|-----|------|
| DAC to ADC Crosstalk |        | 1kHz signal, 0dBFS |     | -45 |     | dB   |
| ADC to DAC Crosstalk |        | 1kHz signal, -7dBV |     | -60 |     | dB   |

## POWER CONSUMPTION

The WM8904 power consumption is dependent on many parameters. Most significantly, it depends on supply voltages, sample rates, mode of operation, and output loading.

The power consumption on each supply rail varies approximately with the square of the voltage. Power consumption is greater at fast sample rates than at slower ones. When the digital audio interface is operating in Master mode, the DBVDD current is significantly greater than in Slave mode. (Note also that power savings can be made by using MCLK as the BCLK source in Slave mode.) The output load conditions (impedance, capacitance and inductance) can also impact significantly on the device power consumption.

## COMMON TEST CONDITIONS

Unless otherwise stated, the following test conditions apply throughout the following sections:

- Ambient temperature = +25°C
- Audio signal = quiescent (zero amplitude)
- Sample rate = 48kHz
- MCLK = 12.288MHz
- Audio interface mode = Slave (LRCLK\_DIR=0, BCLK\_DIR=0)
- SYSCLK\_SRC = 0 (system clock comes direct from MCLK, not from FLL)

Additional, variant test conditions are quoted within the relevant sections below. Where applicable, power dissipated in the headphone or line loads is included.

## POWER CONSUMPTION MEASUREMENTS

| <b>Single-ended Stereo Line Record - IN1L/R, IN2L/R or IN3L/R pins to ADC output.</b><br><b>Test conditions:</b><br>L_MODE = R_MODE = 00b (Single ended)<br>LIN_VOL = RIN_VOL = 00101 = +0.0 dB<br>ADC_OSR128 = 0 (64*fs), ADC_128_OSR_TST_MODE = 1, ADC_BIASx1P5 = 1<br>MICBIAS = disabled |      |      |       |      |       |      |       |      |        |      |       |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|-------|------|-------|------|-------|------|--------|------|-------|
| Variant test conditions                                                                                                                                                                                                                                                                     | AVDD |      | DCVDD |      | DBVDD |      | CPVDD |      | MICVDD |      | TOTAL |
|                                                                                                                                                                                                                                                                                             | V    | mA   | V     | mA   | V     | mA   | V     | mA   | V      | mA   | mW    |
| 48kHz sample rate                                                                                                                                                                                                                                                                           | 1.80 | 4.38 | 1.00  | 0.80 | 1.80  | 0.02 | 1.80  | 0.01 | 1.80   | 0.01 | 8.72  |
| 8kHz sample rate                                                                                                                                                                                                                                                                            | 1.80 | 4.25 | 1.00  | 0.14 | 1.80  | 0.00 | 1.80  | 0.01 | 1.80   | 0.01 | 7.81  |
| 48kHz -6dBV sine wave                                                                                                                                                                                                                                                                       | 1.80 | 4.41 | 1.00  | 0.80 | 1.80  | 0.03 | 1.80  | 0.01 | 1.80   | 0.01 | 8.81  |

| <b>Differential Stereo Record from Analogue Microphones - IN1L/R, IN2L/R or IN3L/R pins to ADC out.</b><br><b>Test conditions:</b><br>L_MODE = R_MODE = 10b (Differential mic)<br>LIN_VOL = RIN_VOL = 00111 = +30.0 dB<br>ADC_OSR128 = 0 (64*fs), ADC_128_OSR_TST_MODE = 1, ADC_BIASx1P5 = 1<br>MICBIAS_ENA = 1, MICBIAS_SEL = 000, No load connected to MICBIAS |      |      |       |      |       |      |       |      |        |      |       |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|-------|------|-------|------|-------|------|--------|------|-------|
| Variant test conditions                                                                                                                                                                                                                                                                                                                                          | AVDD |      | DCVDD |      | DBVDD |      | CPVDD |      | MICVDD |      | TOTAL |
|                                                                                                                                                                                                                                                                                                                                                                  | V    | mA   | V     | mA   | V     | mA   | V     | mA   | V      | mA   | mW    |
| 48kHz sample rate                                                                                                                                                                                                                                                                                                                                                | 1.80 | 4.38 | 1.00  | 0.80 | 1.80  | 0.02 | 1.80  | 0.01 | 1.80   | 0.01 | 8.73  |
| 8kHz sample rate                                                                                                                                                                                                                                                                                                                                                 | 1.80 | 4.25 | 1.00  | 0.14 | 1.80  | 0.00 | 1.80  | 0.01 | 1.80   | 0.01 | 7.81  |
| 48kHz -30dBV sine wave                                                                                                                                                                                                                                                                                                                                           | 1.80 | 4.39 | 1.00  | 0.81 | 1.80  | 0.03 | 1.80  | 0.01 | 1.80   | 0.01 | 8.78  |

**High Performance Stereo Playback to Headphones - DAC input to HPOUTL+HPOUTR pins with 30Ω load.**
**Test conditions:**

VMID\_RES = 01 (for normal operation)

CP\_DYN\_PWR = 1 (Class-W, Charge pump controlled by real-time audio level)

Low Power Playback mode disabled. (See Table 49 for details; note that Low Power Playback mode is disabled by default.)

| Variant test conditions                                                               | AVDD |      | DCVDD |      | DBVDD |      | CPVDD |      | MICVDD |      | TOTAL |
|---------------------------------------------------------------------------------------|------|------|-------|------|-------|------|-------|------|--------|------|-------|
|                                                                                       | V    | mA   | V     | mA   | V     | mA   | V     | mA   | V      | mA   | mW    |
| 48kHz sample rate                                                                     | 1.80 | 1.69 | 1.00  | 0.76 | 1.80  | 0.00 | 1.80  | 0.31 | 2.50   | 0.01 | 4.38  |
| 8kHz sample rate                                                                      | 1.80 | 1.69 | 1.00  | 0.18 | 1.80  | 0.00 | 1.80  | 0.31 | 2.50   | 0.01 | 3.80  |
| 48kHz, Po = 0.1mW/channel<br>1kHz sine wave 0dBFS<br>HPOUT_VOL= -25dB<br>DAC_VOL= 0dB | 1.80 | 1.71 | 1.00  | 0.77 | 1.80  | 0.00 | 1.80  | 1.99 | 2.50   | 0.01 | 7.45  |
| 48kHz, Po = 1mW/channel<br>1kHz sine wave 0dBFS<br>HPOUT_VOL= -15dB<br>DAC_VOL= 0dB   | 1.80 | 1.73 | 1.00  | 0.77 | 1.80  | 0.00 | 1.80  | 5.61 | 2.50   | 0.01 | 13.99 |
| 48kHz sample rate, Master mode,<br>FLL enabled, MCLK input<br>frequency = 13MHz       | 1.80 | 1.82 | 1.00  | 1.05 | 1.80  | 0.73 | 1.80  | 0.30 | 2.50   | 0.01 | 6.18  |
| 48kHz sample rate, Master mode,<br>FLL enabled, MCLK input<br>frequency = 32.768kHz   | 1.80 | 1.83 | 1.00  | 0.94 | 1.80  | 0.76 | 1.80  | 0.29 | 2.50   | 0.01 | 6.14  |

**Low Power Stereo Playback to Headphones - DAC input to HPOUTL+HPOUTR pins with 30Ω load.**
**Test conditions:**

VMID\_RES = 01 (for normal operation)

CP\_DYN\_PWR = 1 (Class-W, Charge pump controlled by real-time audio level)

Low Power Playback Mode enabled (See Table 48 for details)

SYSCLK = 6.144MHz, CLK\_SYS\_RATE = 0001b (for 128 fs clocking)

| Variant test conditions                                                               | AVDD |      | DCVDD |      | DBVDD |      | CPVDD |      | MICVDD |      | TOTAL |
|---------------------------------------------------------------------------------------|------|------|-------|------|-------|------|-------|------|--------|------|-------|
|                                                                                       | V    | mA   | V     | mA   | V     | mA   | V     | mA   | V      | mA   | mW    |
| 48kHz sample rate                                                                     | 1.80 | 0.99 | 1.00  | 0.61 | 1.80  | 0.00 | 1.80  | 0.31 | 2.50   | 0.01 | 2.98  |
| 48kHz, Po = 0.1mW/channel<br>1kHz sine wave 0dBFS<br>HPOUT_VOL= -25dB<br>DAC_VOL= 0dB | 1.80 | 1.02 | 1.00  | 0.62 | 1.80  | 0.00 | 1.80  | 1.68 | 2.50   | 0.01 | 5.51  |
| 48kHz, Po = 1mW/channel<br>1kHz sine wave 0dBFS<br>HPOUT_VOL= -15dB<br>DAC_VOL= 0dB   | 1.80 | 1.04 | 1.00  | 0.62 | 1.80  | 0.00 | 1.80  | 5.23 | 2.50   | 0.01 | 11.93 |

**High Performance Stereo Playback to Line-out** - DAC input to LINEOUTL+LINEOUTR or HPOUTL+HPOUTR pins with 10k $\Omega$  / 50pF load

**Test conditions:**

VMID\_RES = 01 (for normal operation)

CP\_DYN\_PWR = 1 (Class-W, Charge pump controlled by real-time audio level)

Low Power Playback mode disabled. (See Table 49 for details; note that Low Power Playback mode is disabled by default.)

| Variant test conditions          | AVDD |      | DCVDD |      | DBVDD |      | CPVDD |      | MICVDD |      | TOTAL |
|----------------------------------|------|------|-------|------|-------|------|-------|------|--------|------|-------|
|                                  | V    | mA   | V     | mA   | V     | mA   | V     | mA   | V      | mA   | mW    |
| 48kHz sample rate                | 1.80 | 1.67 | 1.00  | 0.76 | 1.80  | 0.00 | 1.80  | 0.36 | 2.50   | 0.01 | 4.43  |
| 8kHz sample rate                 | 1.80 | 1.67 | 1.00  | 0.18 | 1.80  | 0.00 | 1.80  | 0.36 | 2.50   | 0.01 | 3.86  |
| 48kHz, Po = 0dBFS 1kHz sine wave | 1.80 | 1.78 | 1.00  | 0.77 | 1.80  | 0.00 | 1.80  | 2.27 | 2.50   | 0.01 | 8.09  |

**Low Power Stereo Playback to Line-out** - DAC input to LINEOUTL+LINEOUTR or HPOUTL+HPOUTR pins with 10k $\Omega$  / 50pF load

**Test conditions:**

VMID\_RES = 01 (for normal operation)

CP\_DYN\_PWR = 1 (Class-W, Charge pump controlled by real-time audio level)

Low Power Playback Mode enabled (see Table 48 for details)

SYSCLK = 6.144MHz, CLK\_SYS\_RATE = 0001b (for 128 fs clocking)

| Variant test conditions          | AVDD |      | DCVDD |      | DBVDD |      | CPVDD |      | MICVDD |      | TOTAL |
|----------------------------------|------|------|-------|------|-------|------|-------|------|--------|------|-------|
|                                  | V    | mA   | V     | mA   | V     | mA   | V     | mA   | V      | mA   | mW    |
| 48kHz sample rate                | 1.80 | 0.99 | 1.00  | 0.61 | 1.80  | 0.00 | 1.80  | 0.22 | 2.50   | 0.01 | 2.81  |
| 48kHz, Po = 0dBFS 1kHz sine wave | 1.80 | 1.04 | 1.00  | 0.62 | 1.80  | 0.00 | 1.80  | 1.77 | 2.50   | 0.01 | 5.70  |

**Stereo analogue bypass to headphones** - IN1L/R, IN2L/R or IN3L/R pins to HPOUTL+HPOUTR pins with 30Ω load.

**Test conditions:**

LIN\_VOL = RIN\_VOL = 00101 = +0.0 dB

MCLK = 11.2896MHz

Digital audio interface disabled

Note that the Analogue bypass configuration does not benefit from the Class W dynamic control.

| Variant test conditions                                        | AVDD |      | DCVDD |      | DBVDD |      | CPVDD |      | MICVDD |      | TOTAL |
|----------------------------------------------------------------|------|------|-------|------|-------|------|-------|------|--------|------|-------|
|                                                                | V    | mA   | V     | mA   | V     | mA   | V     | mA   | V      | mA   | mW    |
| Quiescent<br>HPOUTVOL = 000000 (-57dB)                         | 1.8  | 1.24 | 1     | 0.11 | 1.8   | 0.00 | 1.8   | 0.26 | 2.5    | 0.01 | 2.82  |
| Po = 0.1mW/channel 1kHz sine wave<br>HPOUTVOL = 100000 (-25dB) | 1.8  | 1.29 | 1     | 0.11 | 1.8   | 0.00 | 1.8   | 2.05 | 2.5    | 0.01 | 6.13  |
| Po = 1mW/channel 1kHz sine wave<br>HPOUTVOL = 101010 (-15dB)   | 1.8  | 1.30 | 1     | 0.11 | 1.8   | 0.00 | 1.8   | 5.86 | 2.5    | 0.01 | 13.02 |

**Stereo analogue bypass to Line-out** - IN1L/R, IN2L/R or IN3L/R pins to LINEOUTL+LINEOUTR pins with 30Ω load.

**Test conditions:**

LIN\_VOL = RIN\_VOL = 00101 = +0.0 dB

MCLK = 11.2896MHz

Digital audio interface disabled

Note that the Analogue bypass configuration does not benefit from the Class W dynamic control.

| Variant test conditions                  | AVDD |      | DCVDD |      | DBVDD |      | CPVDD |      | MICVDD |      | TOTAL |
|------------------------------------------|------|------|-------|------|-------|------|-------|------|--------|------|-------|
|                                          | V    | mA   | V     | mA   | V     | mA   | V     | mA   | V      | mA   | mW    |
| Quiescent<br>LINEOUTVOL = 000000 (-57dB) | 1.8  | 1.04 | 1.0   | 0.15 | 1.8   | 0.00 | 1.8   | 0.21 | 1.8    | 0.01 | 2.41  |
| Quiescent<br>LINEOUTVOL = 101011 (-14dB) | 1.8  | 1.04 | 1.0   | 0.15 | 1.8   | 0.00 | 1.8   | 0.63 | 1.8    | 0.01 | 3.18  |
| Quiescent<br>LINEOUTVOL = 111001 (0dB)   | 1.8  | 1.04 | 1.0   | 0.15 | 1.8   | 0.00 | 1.8   | 1.25 | 1.8    | 0.01 | 4.28  |

**Off**

**Note:** DC servo calibration is retained in this state as long as DCVDD is supplied. This allows fast, pop suppressed start-up from the off state.

| Variant test conditions                                         | AVDD |      | DCVDD |      | DBVDD |      | CPVDD |      | MICVDD |      | TOTAL |
|-----------------------------------------------------------------|------|------|-------|------|-------|------|-------|------|--------|------|-------|
|                                                                 | V    | mA   | V     | mA   | V     | mA   | V     | mA   | V      | mA   | mW    |
| Off (default settings)<br>No Clocks applied                     | 1.8  | 0.01 | 1     | 0.00 | 1.8   | 0.00 | 1.8   | 0.01 | 2.5    | 0.01 | 0.04  |
| Off (default settings)<br>DACDAT, MCLK, BCLK, and LRCLK applied | 1.8  | 0.01 | 1     | 0.02 | 1.8   | 0.00 | 1.8   | 0.01 | 2.5    | 0.01 | 0.06  |

## SIGNAL TIMING REQUIREMENTS

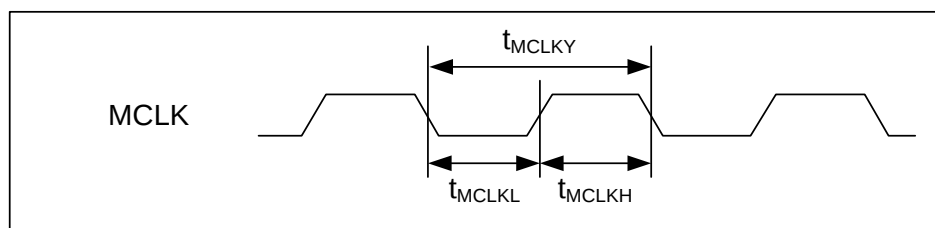
### COMMON TEST CONDITIONS

Unless otherwise stated, the following test conditions apply throughout the following sections:

- Ambient temperature = +25°C
- DCVDD = 1.0V
- DBVDD = AVDD = CPVDD = 1.8V
- DGND = AGND = CPGND = 0V

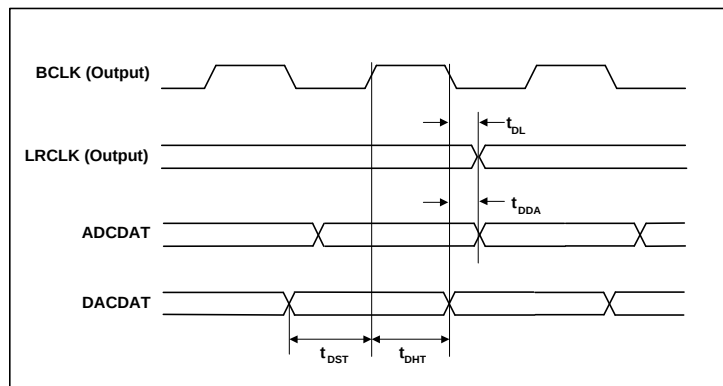
Additional, specific test conditions are given within the relevant sections below.

### MASTER CLOCK



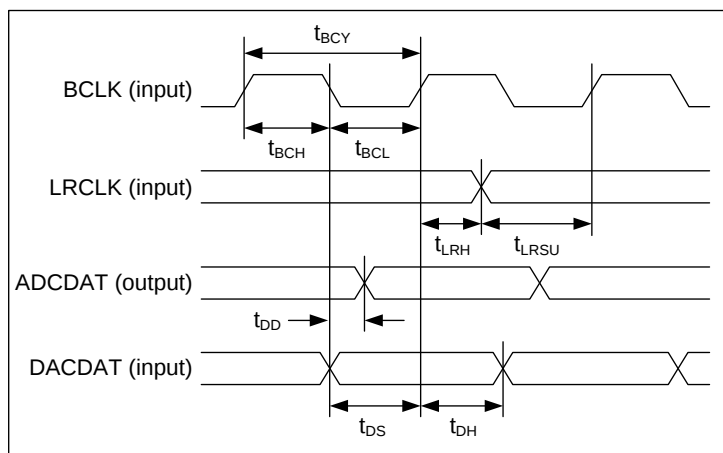
**Figure 1 Master Clock Timing**

| Master Clock Timing |              |                 |       |     |       |      |
|---------------------|--------------|-----------------|-------|-----|-------|------|
| PARAMETER           | SYMBOL       | TEST CONDITIONS | MIN   | TYP | MAX   | UNIT |
| MCLK cycle time     | $T_{MCLKY}$  | MCLK_DIV=1      | 40    |     |       | ns   |
|                     |              | MCLK_DIV=0      | 80    |     |       | ns   |
| MCLK duty cycle     | $T_{MCLKDS}$ |                 | 60:40 |     | 40:60 |      |

**AUDIO INTERFACE TIMING**
**MASTER MODE**

**Figure 2 Audio Interface Timing – Master Mode**
**Test Conditions**

DCVDD = 1.0V, AVDD = DBVDD = CPVDD = 1.8V, DGND=AGND=CPGND =0V,  $T_A = +25^{\circ}\text{C}$ , Master Mode,  $f_s=48\text{kHz}$ , MCLK=256fs, 24-bit data, unless otherwise stated.

| PARAMETER                                       | SYMBOL    | MIN | TYP | MAX | UNIT |
|-------------------------------------------------|-----------|-----|-----|-----|------|
| <b>Audio Interface Timing - Master Mode</b>     |           |     |     |     |      |
| LRCLK propagation delay from BCLK falling edge  | $t_{DL}$  |     |     | 20  | ns   |
| ADCDAT propagation delay from BCLK falling edge | $t_{DDA}$ |     |     | 20  | ns   |
| DACDAT setup time to BCLK rising edge           | $t_{DST}$ | 20  |     |     | ns   |
| DACDAT hold time from BCLK rising edge          | $t_{DHT}$ | 10  |     |     | ns   |

**SLAVE MODE**

**Figure 3 Audio Interface Timing – Slave Mode**
**Test Conditions**

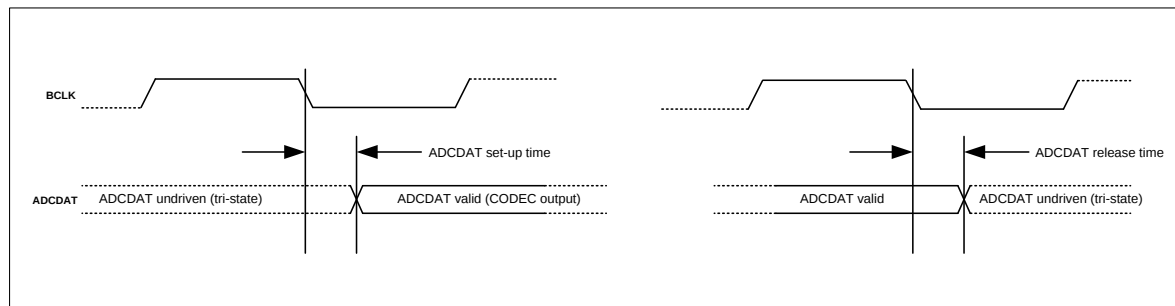
DCVDD = 1.0V, AVDD = DBVDD = CPVDD = 1.8V, DGND=AGND=CPGND =0V, T<sub>A</sub> = +25°C, Slave Mode, fs=48kHz, MCLK=256fs, 24-bit data, unless otherwise stated.

| PARAMETER                                       | SYMBOL            | MIN | TYP | MAX | UNIT |
|-------------------------------------------------|-------------------|-----|-----|-----|------|
| <b>Audio Interface Timing - Slave Mode</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   |
| LRCLK set-up time to BCLK rising edge           | t <sub>LRSU</sub> | 20  |     |     | ns   |
| LRCLK 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   |
| ADCDAT propagation delay from BCLK falling edge | t <sub>DD</sub>   |     |     | 20  | ns   |
| DACDAT set-up time to BCLK rising edge          | t <sub>DS</sub>   | 20  |     |     | ns   |

**Note:** BCLK period must always be greater than or equal to MCLK period.

## TDM MODE

In TDM mode, it is important that two ADC devices do not attempt to drive the ADCDAT pin simultaneously. The timing of the WM8904 ADCDAT tri-stating at the start and end of the data transmission is described below.

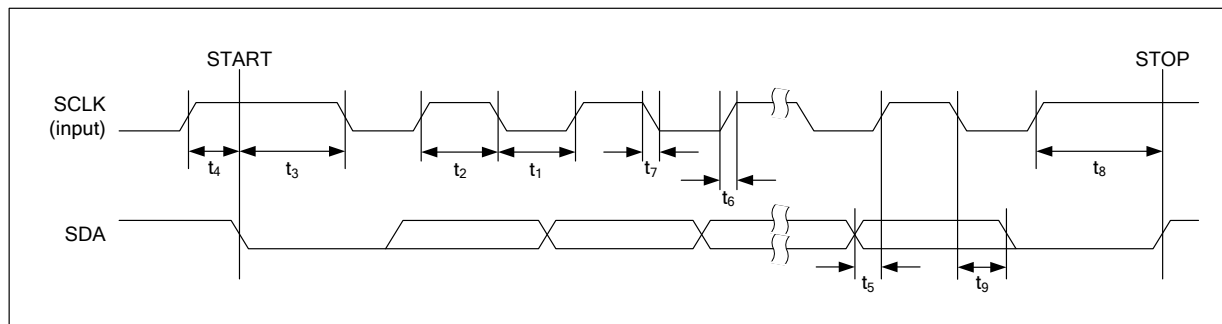


**Figure 4 Audio Interface Timing - TDM Mode**

### Test Conditions

AVDD = CPVDD = 1.8V , DGND=AGND=CPGND= 0V,  $T_A = +25^{\circ}\text{C}$ , Master Mode,  $f_s=48\text{kHz}$ , MCLK=256fs, 24-bit data, unless otherwise stated.

| PARAMETER                                  | CONDITIONS                     | MIN | TYP | MAX | UNIT |
|--------------------------------------------|--------------------------------|-----|-----|-----|------|
| <b>Audio Data Timing Information</b>       |                                |     |     |     |      |
| ADCDAT setup time from BCLK falling edge   | DCVDD =2.0V<br>DBVDD = 3.6V    |     | 5   |     | ns   |
|                                            | DCVDD = 1.08V<br>DBVDD = 1.62V |     | 15  |     | ns   |
| ADCDAT release time from BCLK falling edge | DCVDD = 2.0V<br>DBVDD = 3.6V   |     | 5   |     | ns   |
|                                            | DCVDD = 1.08V<br>DBVDD = 1.62V |     | 15  |     | ns   |

**CONTROL INTERFACE TIMING**

**Figure 5 Control Interface Timing**
**Test Conditions**

DCVDD = 1.0V, AVDD = DBVDD = CPVDD = 1.8V, DGND=AGND=CPGND =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 |
|-----------------------------------------------|-----------------|------|-----|-----|------|
| SCLK Frequency                                |                 |      |     | 400 | kHz  |
| SCLK Low Pulse-Width                          | t <sub>1</sub>  | 1300 |     |     | ns   |
| 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   |
| SDA, SCLK Rise Time                           | t <sub>6</sub>  |      |     | 300 | ns   |
| SDA, 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   |

## DIGITAL FILTER CHARACTERISTICS

| PARAMETER                          | TEST CONDITIONS | MIN      | TYP    | MAX      | UNIT |
|------------------------------------|-----------------|----------|--------|----------|------|
| <b>ADC Filter</b>                  |                 |          |        |          |      |
| Passband                           | +/- 0.05dB      | 0        |        | 0.454 fs |      |
|                                    | -6dB            |          | 0.5 fs |          |      |
| Passband Ripple                    |                 |          |        | +/- 0.05 | dB   |
| Stopband                           |                 | 0.546s   |        |          |      |
| Stopband Attenuation               | f > 0.546 fs    | -60      |        |          | dB   |
| <b>DAC Normal Filter</b>           |                 |          |        |          |      |
| Passband                           | +/- 0.05dB      | 0        |        | 0.454 fs |      |
|                                    | -6dB            |          | 0.5 fs |          |      |
| Passband Ripple                    | 0.454 fs        |          |        | +/- 0.03 | dB   |
| Stopband                           |                 | 0.546 fs |        |          |      |
| Stopband Attenuation               | F > 0.546 fs    | -50      |        |          | dB   |
| <b>DAC Sloping Stopband Filter</b> |                 |          |        |          |      |
| Passband                           | +/- 0.03dB      | 0        |        | 0.25 fs  |      |
|                                    | +/- 1dB         | 0.25 fs  |        | 0.454 fs |      |
|                                    | -6dB            |          | 0.5 fs |          |      |
| Passband Ripple                    | 0.25 fs         |          |        | +/- 0.03 | dB   |
| Stopband 1                         |                 | 0.546 fs |        | 0.7 fs   |      |
| Stopband 1 Attenuation             | f > 0.546 fs    | -60      |        |          | dB   |
| Stopband 2                         |                 | 0.7 fs   |        | 1.4 fs   |      |
| Stopband 2 Attenuation             | f > 0.7 fs      | -85      |        |          | dB   |
| Stopband 3                         |                 | 1.4 fs   |        |          |      |
| Stopband 3 Attenuation             | F > 1.4 fs      | -55      |        |          | dB   |

| DAC FILTERS      |             | ADC FILTERS |             |
|------------------|-------------|-------------|-------------|
| Mode             | Group Delay | Mode        | Group Delay |
| Normal           | 16.5 / fs   | Normal      | 16.5 / fs   |
| Sloping Stopband | 18 / fs     |             |             |

### 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

## ADC FILTER RESPONSES

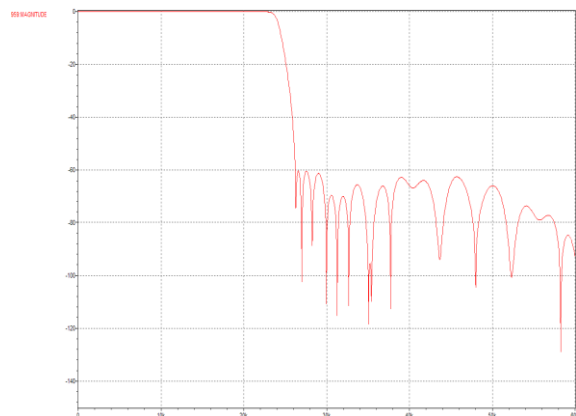


Figure 6 ADC Digital Filter Frequency Response

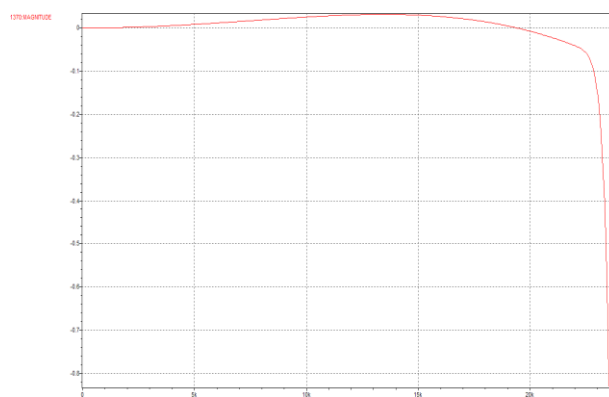


Figure 7 ADC Digital Filter Ripple

## ADC HIGH PASS FILTER RESPONSES

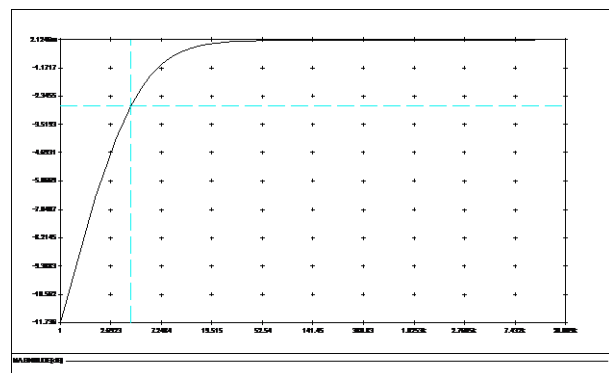


Figure 8 ADC Digital High Pass Filter Frequency Response (48kHz, Hi-Fi Mode, ADC\_HPF\_CUT[1:0]=00)

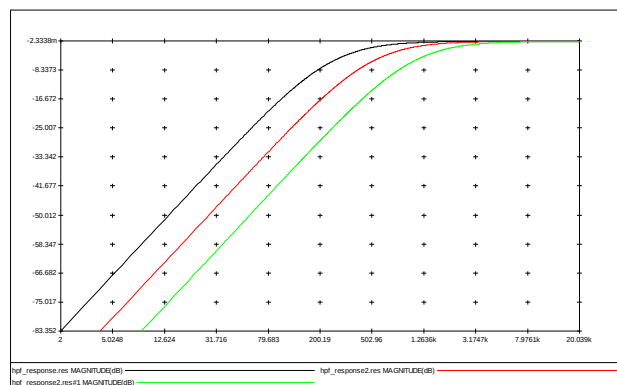
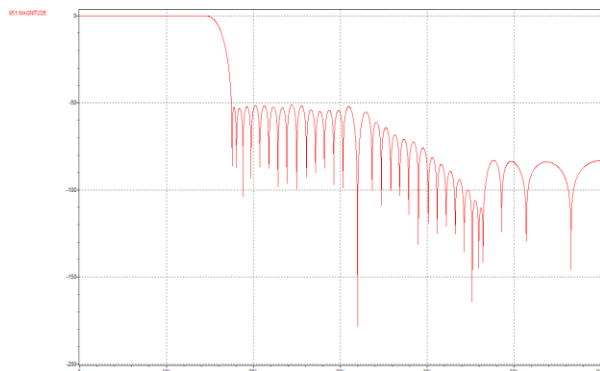
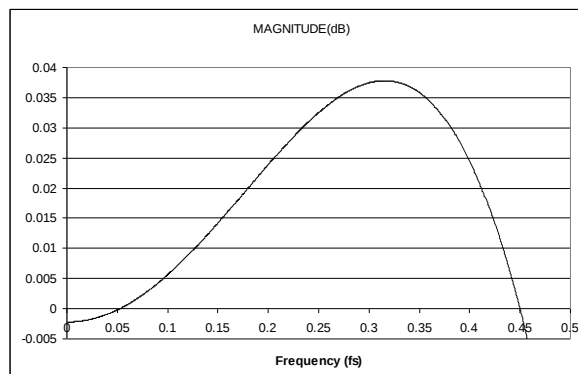


Figure 9 ADC Digital High Pass Filter Ripple (48kHz, Voice Mode, ADC\_HPF\_CUT=01, 10 and 11)

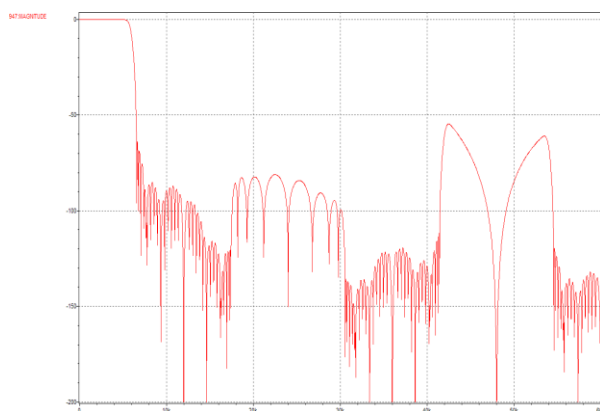
## DAC FILTER RESPONSES



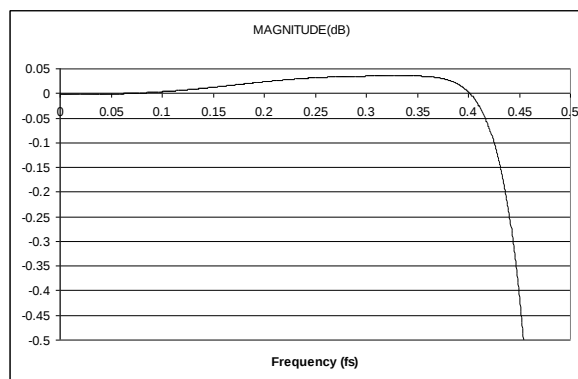
**Figure 10 DAC Digital Filter Frequency Response; (Normal Mode); Sample Rate > 24kHz**



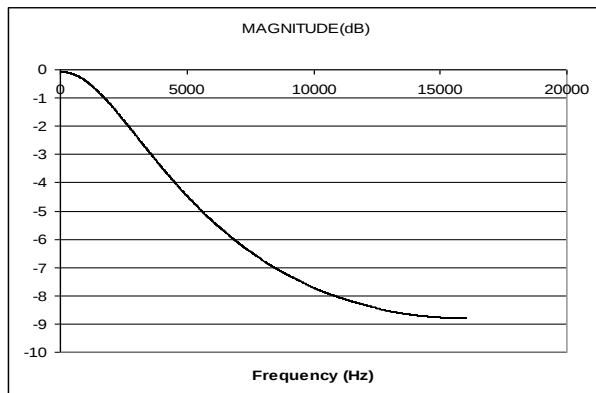
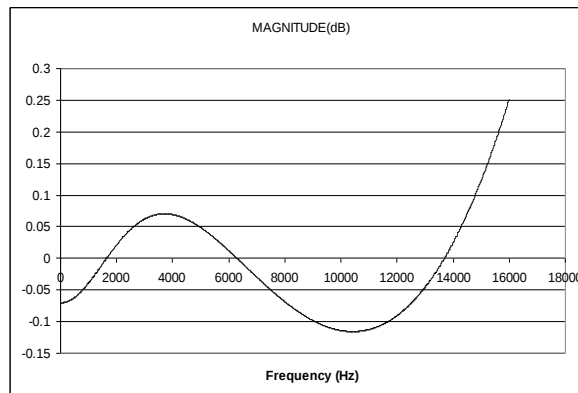
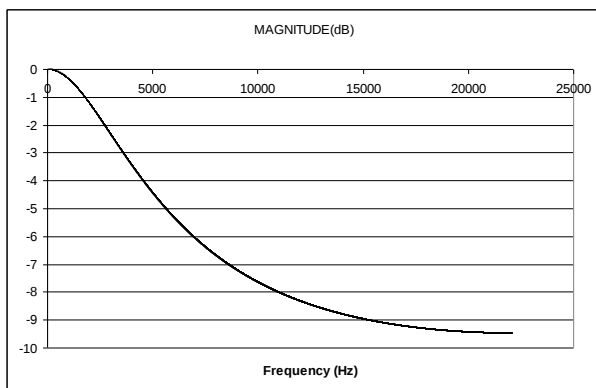
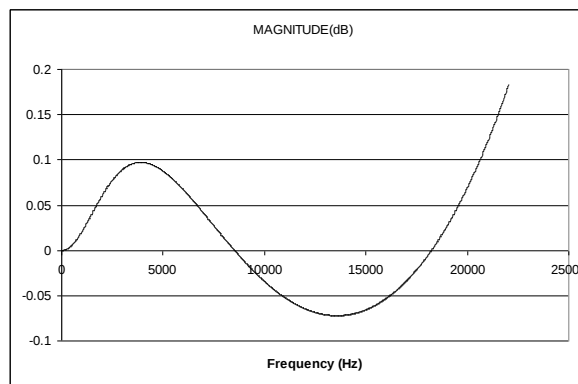
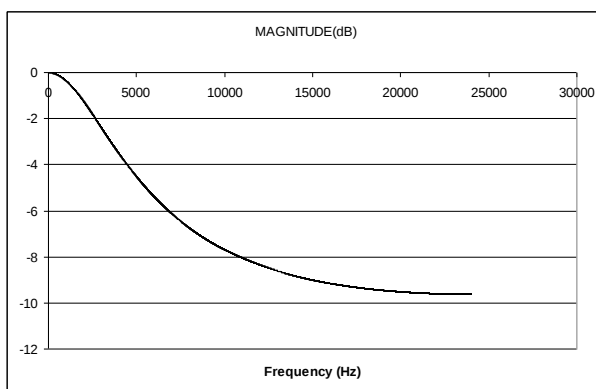
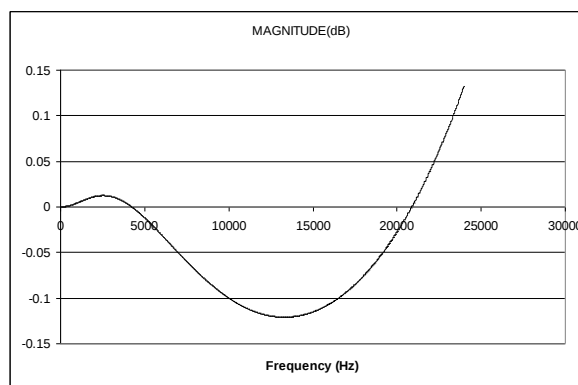
**Figure 11 DAC Digital Filter Ripple (Normal Mode)**



**Figure 12 DAC Digital Filter Frequency Response; (Sloping Stopband Mode); Sample Rate <= 24kHz**



**Figure 13 DAC Digital Filter Ripple (Sloping Stopband Mode)**

**DE-EMPHASIS FILTER RESPONSES**

**Figure 14 De-Emphasis Digital Filter Response (32kHz)**

**Figure 15 De-Emphasis Error (32kHz)**

**Figure 16 De-Emphasis Digital Filter Response (44.1kHz)**

**Figure 17 De-Emphasis Error (44.1kHz)**

**Figure 18 De-Emphasis Digital Filter Response (48kHz)**

**Figure 19 De-Emphasis Error (48kHz)**

## DEVICE DESCRIPTION

### INTRODUCTION

The WM8904 is a high performance ultra-low power stereo CODEC optimised for portable audio applications. Flexible analogue interfaces and powerful digital signal processing (DSP) make it ideal for small portable devices.

The WM8904 supports up to 6 analogue audio inputs. One pair of single-ended or differential microphone/line inputs is selected as the ADC input source. An integrated bias reference is provided to power standard electret microphones.

A two-channel digital microphone interface is also supported, with direct input to the DSP core bypassing the ADCs.

One pair of ground-reference Class-W headphone outputs is provided; these are powered from an integrated Charge Pump, enabling high quality, power efficient headphone playback without any requirement for DC blocking capacitors. A DC Servo circuit is available for DC offset correction, thereby suppressing pops and reducing power consumption. Two line outputs are provided; these are also capable of driving ear speakers and stereo headsets. Ground loop feedback is available on the headphone outputs and the line outputs, providing rejection of noise on the ground connections. All outputs use SilentSwitch technology for pop and click suppression.

The stereo ADCs and DACs are of hi-fi quality, using a 24-bit low-order oversampling architecture to deliver optimum performance. A flexible clocking arrangement supports mixed ADC and DAC sample rates, whilst an integrated ultra-low power FLL provides additional flexibility. A high pass filter is available in the ADC path for removing DC offsets and suppressing low frequency noise such as mechanical vibration and wind noise. A digital mixing path from the ADC to the DAC provides a sidetone of enhanced quality during voice calls. DAC soft mute and un-mute is available for pop-free music playback.

The integrated Dynamic Range Controller (DRC) and ReTune™ Mobile 5-band parametric equaliser (EQ) provide further processing capability of the digital audio paths. The DRC provides compression and signal level control to improve the handling of unpredictable signal levels. 'Anti-clip' and 'quick release' algorithms improve intelligibility in the presence of transients and impulsive noises. The EQ provides the capability to tailor the audio path according to the frequency characteristics of an earpiece or loudspeaker, and/or according to user preferences.

The WM8904 has a highly flexible digital audio interface, supporting a number of protocols, including I2S, DSP, MSB-first left/right justified, and can operate in master or slave modes. PCM operation is supported in the DSP mode. A-law and  $\mu$ -law companding are also supported. Time division multiplexing (TDM) is available to allow multiple devices to stream data simultaneously on the same bus, saving space and power.

The system clock SYSCLK provides clocking for the ADCs, DACs, DSP core, digital audio interface and other circuits. SYSCLK can be derived directly from the MCLK pin or via an integrated FLL, providing flexibility to support a wide range of clocking schemes. Typical portable system MCLK frequencies, and sample rates from 8kHz to 48kHz are all supported. The clocking circuits are configured automatically from the sample rate (fs) and from the SYSCLK / fs ratio.

The integrated FLL can be used to generate SYSCLK from a wide variety of different reference sources and frequencies. The FLL can accept a wide range of reference frequencies, which may be high frequency (e.g. 13MHz) or low frequency (eg. 32.768kHz). The FLL is tolerant of jitter and may be used to generate a stable SYSCLK from a less stable input signal. The integrated FLL can be used as a free-running oscillator, enabling autonomous clocking of the Charge Pump and DC Servo if required.

The WM8904 uses a standard 2-wire control interface, providing full software control of all features, together with device register readback. An integrated Control Write Sequencer enables automatic scheduling of control sequences; commonly-used signal configurations may be selected using ready-programmed sequences, including time-optimised control of the WM8904 pop suppression features. It is an ideal partner for a wide range of industry standard microprocessors, controllers and DSPs. Unused circuitry can be disabled under software control, in order to save power; low leakage currents enable extended standby/off time in portable battery-powered applications.

Up to 4 GPIO pins may be configured for miscellaneous input/output functions such as button/accessory detect inputs, or for clock, system status, or programmable logic level output for

control of additional external circuitry. Interrupt logic, status readback and de-bouncing options are supported within this functionality.

## ANALOGUE INPUT SIGNAL PATH

The WM8904 has six analogue input pins, which may be used to support connections to multiple microphone or line input sources. The input multiplexer on the Left and Right channels can be used to select different configurations for each of the input sources. The analogue input paths can support line and microphone inputs, in single-ended and differential modes. The input stage can also provide common mode noise rejection in some configurations.

Two of the six analogue input pins have dual functionality and can be used as digital microphone inputs. (See the “Digital Microphone Interface” section for details.)

The Left and Right analogue input channels are routed to the Analogue to Digital converters (ADCs). There is also a bypass path for each channel, enabling the signal to be routed directly to the output multiplexers and PGAs.

The WM8904 input signal paths and control registers are illustrated in Figure 20.

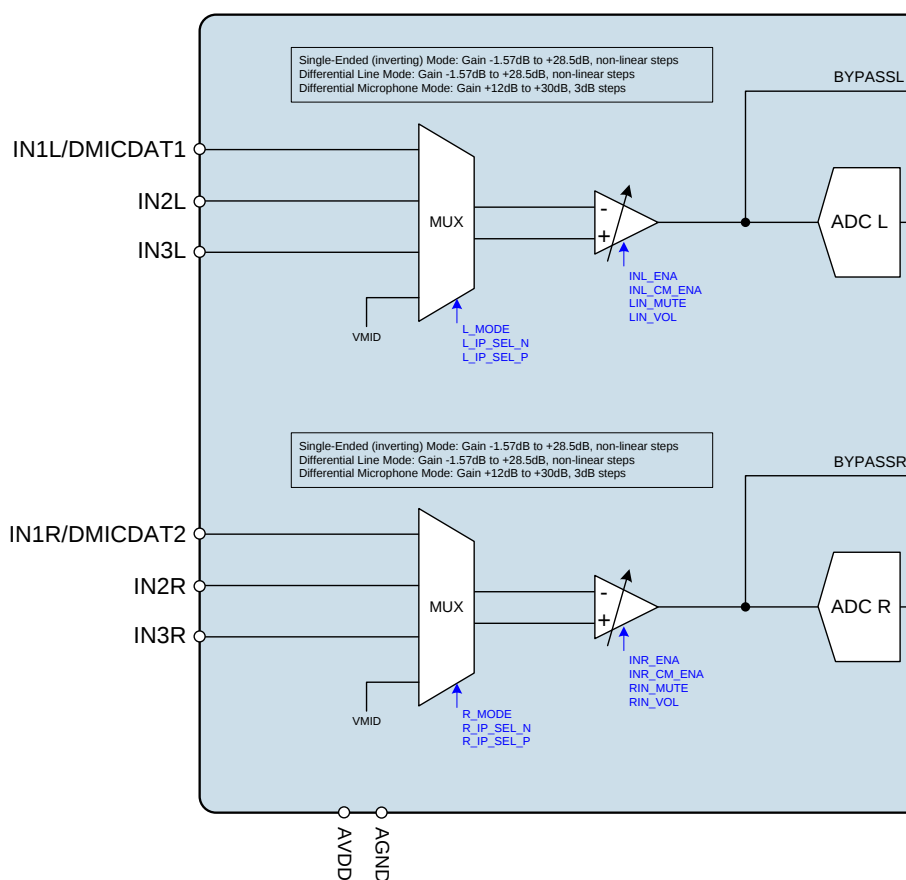


Figure 20 Block Diagram for Input Signal Path

## INPUT PGA ENABLE

The input PGAs (Programmable Gain Amplifiers) and Multiplexers are enabled using register bits INL\_ENA and INR\_ENA, as shown in Table 1.

| REGISTER ADDRESS                   | BIT | LABEL   | DEFAULT | DESCRIPTION                                           |
|------------------------------------|-----|---------|---------|-------------------------------------------------------|
| R12 (0Ch)<br>Power Management<br>0 | 1   | INL_ENA | 0       | Left Input PGA Enable<br>0 = disabled<br>1 = enabled  |
|                                    | 0   | INR_ENA | 0       | Right Input PGA Enable<br>0 = disabled<br>1 = enabled |

**Table 1 Input PGA Enable**

To enable the input PGAs, the reference voltage VMID and the bias current must also be enabled. See Reference Voltages and Master Bias for details of the associated controls VMID\_RES and BIAS\_ENA.

## INPUT PGA CONFIGURATION

The analogue input channels can each be configured in three different modes, which are as follows:

- Single-Ended Mode (Inverting)
- Differential Line Mode
- Differential Mic Mode

The mode is selected by the L\_MODE and R\_MODE fields for the Left and Right channels respectively. The input pins are selected using the L\_IP\_SEL\_N and L\_IP\_SEL\_P fields for the Left channel and the R\_IP\_SEL\_N and R\_IP\_SEL\_P for the Right channel. In Single-Ended mode, L\_IP\_SEL\_N alone determines the Left Input pin, and the R\_IP\_SEL\_N determines the Right Input pin.

The three modes are illustrated in Figure 21, Figure 22 and Figure 23. It should be noted that the available gain and input impedance varies between configurations (see also "Electrical Characteristics"). The input impedance is constant with PGA gain setting.

The Input PGA modes are selected and configured using the register fields described in Table 2 below.

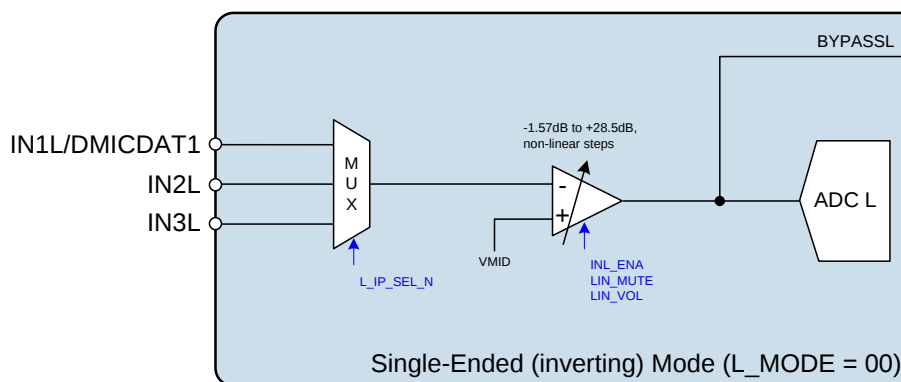
| REGISTER ADDRESS                       | BIT | LABEL            | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                   |
|----------------------------------------|-----|------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R46 (2Eh)<br>Analogue<br>Left Input 1  | 5:4 | L_IP_SEL_N [1:0] | 00      | In Single-Ended or Differential Line Modes, this field selects the input pin for the inverting side of the left input path.<br><br>In Differential Mic Mode, this field selects the input pin for the non-inverting side of the left input path.<br><br>00 = IN1L<br>01 = IN2L<br>1X = IN3L   |
|                                        | 3:2 | L_IP_SEL_P [1:0] | 01      | In Single-Ended or Differential Line Modes, this field selects the input pin for the non-inverting side of the left input path.<br><br>In Differential Mic Mode, this field selects the input pin for the inverting side of the left input path.<br><br>00 = IN1L<br>01 = IN2L<br>1X = IN3L   |
|                                        | 1:0 | L_MODE [1:0]     | 00      | Sets the mode for the left analogue input:<br><br>00 = Single-Ended<br>01 = Differential Line<br>10 = Differential MIC<br>11 = Reserved                                                                                                                                                       |
| R47 (2Fh)<br>Analogue<br>Right Input 1 | 5:4 | R_IP_SEL_N [1:0] | 00      | In Single-Ended or Differential Line Modes, this field selects the input pin for the inverting side of the right input path.<br><br>In Differential Mic Mode, this field selects the input pin for the non-inverting side of the right input path.<br><br>00 = IN1R<br>01 = IN2R<br>1X = IN3R |
|                                        | 3:2 | R_IP_SEL_P [1:0] | 01      | In Single-Ended or Differential Line Modes, this field selects the input pin for the non-inverting side of the right input path.<br><br>In Differential Mic Mode, this field selects the input pin for the inverting side of the right input path.<br><br>00 = IN1R<br>01 = IN2R<br>1X = IN3R |
|                                        | 1:0 | R_MODE [1:0]     | 00      | Sets the mode for the right analogue input:<br><br>00 = Single-Ended<br>01 = Differential Line<br>10 = Differential MIC<br>11 = Reserved                                                                                                                                                      |

**Table 2 Input PGA Mode Selection**

### SINGLE-ENDED INPUT

The Single-Ended PGA configuration is illustrated in Figure 21 for the Left channel. The available gain in this mode is from -1.57dB to +28.5dB in non-linear steps. The input to the ADC is phase inverted with respect to the selected input pin. Different input pins can be selected in the same mode by altering the L\_IP\_SEL\_N field.

The equivalent configuration is also available on the Right channel; this can be selected independently of the Left channel mode.



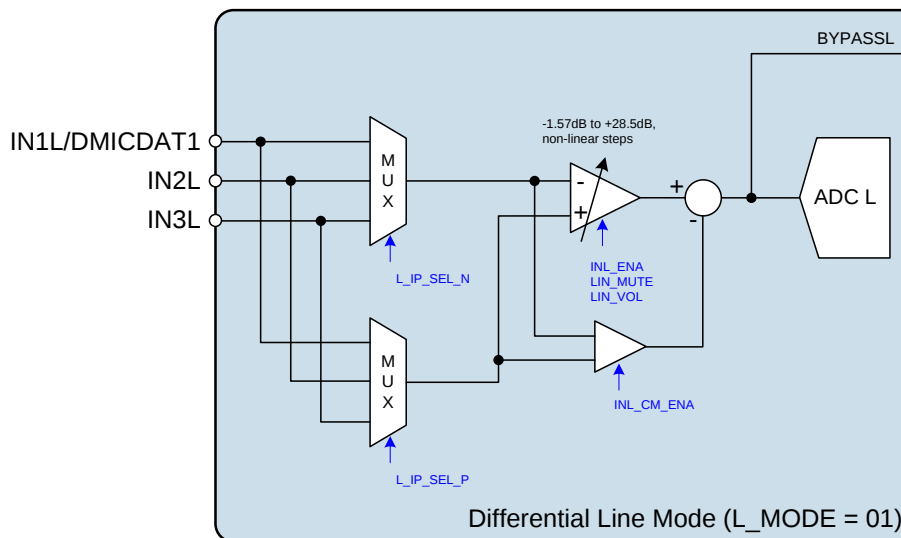
**Figure 21 Single Ended Mode**

### DIFFERENTIAL LINE INPUT

The Differential Line PGA configuration is illustrated in Figure 22 for the Left channel. The available gain in this mode is from -1.57dB to +28.5dB in non-linear steps. The input to the ADC is in phase with the input pin selected by L\_IP\_SEL\_P. The input to the ADC is phase inverted with respect to the input pin selected by L\_IP\_SEL\_N.

As an option, common mode noise rejection can be provided in this PGA configuration, as illustrated in Figure 22. This is enabled using the register bits defined in Table 5.

The equivalent configuration is also available on the Right channel; this can be selected independently of the Left channel mode.



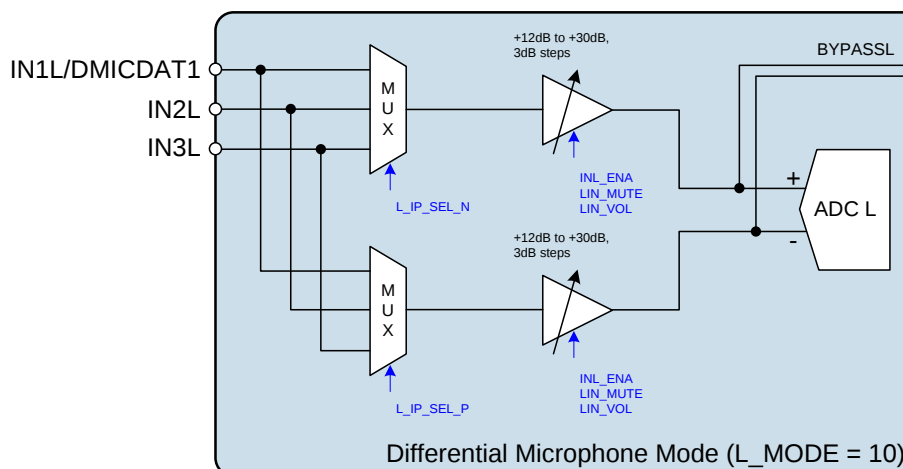
**Figure 22 Differential Line Mode**

## DIFFERENTIAL MICROPHONE INPUT

The Differential Mic PGA configuration is illustrated in Figure 23 for the Left channel. The available gain in this mode is from +12dB to +30dB in 3dB linear steps. The input to the ADC is in phase with the input pin selected by L\_IP\_SEL\_N. The input to the ADC is phase inverted with respect to the input pin selected by L\_IP\_SEL\_P.

Note that the inverting input pin is selected using L\_IP\_SEL\_P and the non-inverting input pin is selected using L\_IP\_SEL\_N. This is not the same as for the Differential Line mode.

The equivalent configuration is also available on the Right channel; this can be selected independently of the Left channel mode.



**Figure 23 Differential Microphone Mode**

## INPUT PGA GAIN CONTROL

The volume control gain for the Left and Right channels be independently controlled using the LIN\_VOL and RIN\_VOL register fields as described in Table 3. The available gain range varies according to the selected PGA Mode as detailed in Table 4. Note that the value '00000' must not be used in Differential Mic Mode, as the PGA will not function correctly under this setting. In single-ended mode (L\_MODE / R\_MODE = 00b), the conversion from single-ended to differential within the WM8904 adds a further 6dB of gain to the signal path.

Each input channel can be independently muted using LINMUTE and RINMUTE.

It is recommended to not adjust the gain dynamically whilst the signal path is enabled; the signal should be muted at the input or output stage prior to adjusting the volume control.

| REGISTER ADDRESS                       | BIT | LABEL         | DEFAULT | DESCRIPTION                                              |
|----------------------------------------|-----|---------------|---------|----------------------------------------------------------|
| R44 (2Ch)<br>Analogue Left<br>Input 0  | 7   | LINMUTE       | 1       | Left Input PGA Mute<br>0 = not muted<br>1 = muted        |
|                                        | 4:0 | LIN_VOL [4:0] | 00101   | Left Input PGA Volume<br>(See Table 4 for volume range)  |
| R45 (2Dh)<br>Analogue<br>Right Input 0 | 7   | RINMUTE       | 1       | Right Input PGA Mute<br>0 = not muted<br>1 = muted       |
|                                        | 4:0 | RIN_VOL [4:0] | 00101   | Right Input PGA Volume<br>(See Table 4 for volume range) |

**Table 3 Input PGA Volume Control**

| LIN_VOL [4:0],<br>RIN_VOL [4:0] | GAIN –<br>SINGLE-ENDED MODE /<br>DIFFERENTIAL LINE MODE | GAIN –<br>DIFFERENTIAL MIC MODE |
|---------------------------------|---------------------------------------------------------|---------------------------------|
| 00000                           | -1.5 dB                                                 | Not valid                       |
| 00001                           | -1.3 dB                                                 | +12 dB                          |
| 00010                           | -1.0 dB                                                 | +15 dB                          |
| 00011                           | -0.7 dB                                                 | +18 dB                          |
| 00100                           | -0.3 dB                                                 | +21 dB                          |
| 00101                           | 0.0 dB                                                  | +24 dB                          |
| 00110                           | +0.3 dB                                                 | +27 dB                          |
| 00111                           | +0.7 dB                                                 | +30 dB                          |
| 01000                           | +1.0 dB                                                 | +30 dB                          |
| 01001                           | +1.4 dB                                                 | +30 dB                          |
| 01010                           | +1.8 dB                                                 | +30 dB                          |
| 01011                           | +2.3 dB                                                 | +30 dB                          |
| 01100                           | +2.7 dB                                                 | +30 dB                          |
| 01101                           | +3.2 dB                                                 | +30 dB                          |
| 01110                           | +3.7 dB                                                 | +30 dB                          |
| 01111                           | +4.2 dB                                                 | +30 dB                          |
| 10000                           | +4.8 dB                                                 | +30 dB                          |
| 10001                           | +5.4 dB                                                 | +30 dB                          |
| 10010                           | +6.0 dB                                                 | +30 dB                          |
| 10011                           | +6.7 dB                                                 | +30 dB                          |
| 10100                           | +7.5 dB                                                 | +30 dB                          |
| 10101                           | +8.3 dB                                                 | +30 dB                          |
| 10110                           | +9.2 dB                                                 | +30 dB                          |
| 10111                           | +10.2 dB                                                | +30 dB                          |
| 11000                           | +11.4 dB                                                | +30 dB                          |
| 11001                           | +12.7 dB                                                | +30 dB                          |
| 11010                           | +14.3 dB                                                | +30 dB                          |
| 11011                           | +16.2 dB                                                | +30 dB                          |
| 11100                           | +19.2 dB                                                | +30 dB                          |
| 11101                           | +22.3 dB                                                | +30 dB                          |
| 11110                           | +25.2 dB                                                | +30 dB                          |
| 11111                           | +28.3 dB                                                | +30 dB                          |

**Table 4 Input PGA Volume Range**

### INPUT PGA COMMON MODE AMPLIFIER

In Differential Line Mode only, a Common Mode amplifier can be enabled as part of the input PGA circuit. This feature provides approximately 20dB reduction in common mode noise on the differential input, which can reduce problematic interference. Since the ADC has differential signal inputs, it has an inherent immunity to common mode noise (see “Electrical Characteristics”) However, the presence of Common Mode noise can limit the usable signal range of the ADC path; enabling the Common Mode amplifier can solve this issue.

It should be noted that the Common Mode amplifier consumes additional power and can also add its own noise to the input signal. For these reasons, it is recommended that the Common Mode Amplifier is only enabled if there is a known source of Common Mode interference.

The Common Mode amplifier is controlled by the INL\_CM\_ENA and INR\_CM\_ENA fields as described in Table 5. Although the Common Mode amplifier may be enabled regardless of the input PGA mode, its function is only effective in the Differential Line Mode configuration.

| REGISTER ADDRESS                    | BIT | LABEL      | DEFAULT | DESCRIPTION                                                                                                                       |
|-------------------------------------|-----|------------|---------|-----------------------------------------------------------------------------------------------------------------------------------|
| R46 (2Eh)<br>Analogue Left Input 1  | 6   | INL_CM_ENA | 1       | Left Input PGA Common Mode Rejection enable<br>0 = Disabled<br>1 = Enabled<br>(only available for L_MODE=01 – Differential Line)  |
| R47 (2Fh)<br>Analogue Right Input 1 | 6   | INR_CM_ENA | 1       | Right Input PGA Common Mode Rejection enable<br>0 = Disabled<br>1 = Enabled<br>(only available for R_MODE=01 – Differential Line) |

**Table 5 Common Mode Amplifier Enable**

## ELECTRET CONDENSER MICROPHONE INTERFACE

Electret Condenser microphones may be connected as single-ended or differential inputs to the Input PGAs described in the “Analogue Input Signal Path” section. The WM8904 provides a low-noise reference voltage (MICBIAS) suitable for biasing electret condenser microphones.

### MICBIAS CONTROL

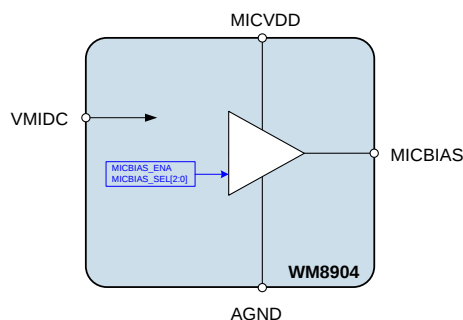
The MICBIAS reference is provided on the MICBIAS pin. This reference voltage is enabled by setting the MICBIAS\_ENA register bit.

The MICBIAS output voltage is selected using the MICBIAS\_SEL register. This register selects the output voltage as a ratio of AVDD; the actual output voltage scales with AVDD.

The MICBIAS output is powered from the MICVDD supply pin, and uses VMID (ie. AVDD/2) as a reference, as illustrated in Figure 24. In all cases, MICVDD must be at least 200mV greater than the required MICBIAS output voltage.

Under the default setting of MICBIAS\_SEL, the MICVDD supply may be connected directly to AVDD. For other settings of MICBIAS\_SEL, (ie. for higher MICBIAS voltages), the MICVDD supply must be greater than AVDD.

The MICBIAS generator is illustrated in in Figure 24. The associated control registers are defined in Table 6.



**Figure 24 MICBIAS Generator**

| REGISTER ADDRESS               | BIT | LABEL             | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                               |
|--------------------------------|-----|-------------------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R6 (06h)<br>Mic Bias Control 0 | 0   | MICBIAS_ENA       | 0       | MICBIAS Enable<br>0 = disabled<br>1 = enabled                                                                                                                                                                                                                             |
| R7 (07h)<br>Mic Bias Control 1 | 2:0 | MICBIAS_SEL [2:0] | 000     | Selects MICBIAS voltage<br>000 = 9/10 x AVDD (1.6V)<br>001 = 10/9 x AVDD (2.0V)<br>010 = 7/6 x AVDD (2.1V)<br>011 = 4/3 x AVDD (2.4V)<br>100 to 111 = 3/2 x AVDD (2.7V)<br>Note that the voltage scales with AVDD. The value quoted in brackets is correct for AVDD=1.8V. |

**Table 6 MICBIAS Control**

## MICBIAS CURRENT DETECT

A MICBIAS Current Detect function is provided for external accessory detection. This is provided in order to detect the insertion/removal of a microphone or the pressing/releasing of the microphone 'hook' switch; these events will cause a significant change in MICBIAS current flow, which can be detected and used to generate a signal to the host processor.

The MICBIAS current detect function is enabled by setting the MICDET\_ENA register bit. When this function is enabled, two current thresholds can be defined, using the MICDET\_THR and MICSHORT\_THR registers. When a change in MICBIAS current which crosses either threshold is detected, then an interrupt event can be generated. In a typical application, accessory insertion would be detected when the MICBIAS current exceeds MICDET\_THR, and microphone hookswitch operation would be detected when the MICBIAS current exceeds MICSHORT\_THR.

The current detect threshold functions are both inputs to the Interrupt control circuit and can be used to trigger an Interrupt event when either threshold is crossed. Both events can also be indicated as an output on a GPIO pin - see "General Purpose Input/Output (GPIO)".

The current detect thresholds are enabled and controlled using the registers described in Table 7. Performance parameters for this circuit block can be found in the "Electrical Characteristics" section.

Hysteresis and filtering is also provided in the both current detect circuits to improve reliability in conditions where AC current spikes are present due to ambient noise conditions. These features are described in the following section. Further guidance on the usage of the MICBIAS current monitoring features is also described in the following pages.

| REGISTER ADDRESS               | BIT | LABEL              | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                |
|--------------------------------|-----|--------------------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R6 (06h)<br>Mic Bias Control 0 | 6:4 | MICDET_THR [2:0]   | 000     | MICBIAS Current Detect Threshold (AVDD = 1.8V)<br>000 = 0.070mA<br>001 = 0.260mA<br>010 = 0.450mA<br>011 = 0.640mA<br>100 = 0.830mA<br>101 = 1.020mA<br>110 = 1.210mA<br>111 = 1.400mA<br>Note that the value scales with AVDD. The value quoted is correct for AVDD=1.8V. |
|                                | 3:2 | MICSHORT_THR [1:0] | 00      | MICBIAS Short Circuit Threshold (AVDD = 1.8V)<br>00 = 0.520mA<br>01 = 0.880mA<br>10 = 1.240mA<br>11 = 1.600mA<br>Note that the value scales with AVDD. The value quoted is correct for AVDD=1.8V.                                                                          |
|                                | 1   | MICDET_ENA         | 0       | MICBIAS Current and Short Circuit Detect Enable<br>0 = disabled<br>1 = enabled                                                                                                                                                                                             |

**Table 7 MICBIAS Current Detect**

## MICBIAS CURRENT DETECT FILTERING

The function of the filtering is to ensure that AC current spikes caused by ambient noise conditions near the microphone do not lead to incorrect signalling of the microphone insertion/removal status or the microphone hookswitch status.

Hysteresis on the current thresholds is provided; this means that a different current threshold is used to detect microphone insertion and microphone removal. Similarly, a different current threshold is used to detect hookswitch press and hookswitch release.

Digital filtering of the hookswitch status ensures that the MICBIAS Short Circuit detection event is only signalled if the MICSHORT\_THR threshold condition has been met for 10 consecutive measurements.

In a typical application, microphone insertion would be detected when the MICBIAS current exceeds the Current Detect threshold set by MICDET\_THR.

When the MIC\_DET\_EINT\_POL interrupt polarity bit is set to 0, then microphone insertion detection will cause the MIC\_DET\_EINT interrupt status register to be set.

For detection of microphone removal, the MIC\_DET\_EINT\_POL bit should be set to 1. When the MIC\_DET\_EINT\_POL interrupt polarity bit is set to 1, then microphone removal detection will cause the MIC\_DET\_EINT interrupt status register to be set.

The detection of these events is bandwidth limited for best noise rejection, and is subject to detection delay time  $t_{DET}$ , as specified in the "Electrical Characteristics". Provided that the MICDET\_THR field has been set appropriately, each insertion or removal event is guaranteed to be detected within the delay time  $t_{DET}$ .

It is likely that the microphone socket contacts will have mechanical "bounce" when a microphone is inserted or removed, and hence the resultant control signal will not be a clean logic level transition. Since  $t_{DET}$  has a range of values, it is possible that the interrupt will be generated before the mechanical "bounce" has ceased. Hence after a mic insertion or removal has been detected, a time delay should be applied before re-configuring the MIC\_DET\_EINT\_POL bit. The maximum possible mechanical bounce times for mic insertion and removal must be understood by the software programmer.

Utilising a GPIO pin to monitor the steady state of the microphone detection function does not change the timing of the detection mechanism, so there will also be a delay  $t_{DET}$  before the signal changes state. It may be desirable to implement de-bounce in the host processor when monitoring the state of the GPIO signal.

Microphone hook switch operation is detected when the MICBIAS current exceeds the Short Circuit Detect threshold set by MICSHORT\_THR. Using the digital filtering, the hook switch detection event is only signalled if the MICSHORT\_THR threshold condition has been met for 10 consecutive measurements.

When the MIC\_SHRT\_EINT\_POL interrupt polarity bit is set to 0, then hook switch operation will cause the MIC\_SHRT\_EINT interrupt status register to be set.

For detection of microphone removal, the MIC\_SHRT\_EINT\_POL bit should be set to 1. When the MIC\_SHRT\_EINT\_POL interrupt polarity bit is set to 1, then hook switch release will cause the MIC\_SHRT\_EINT interrupt status register to be set.

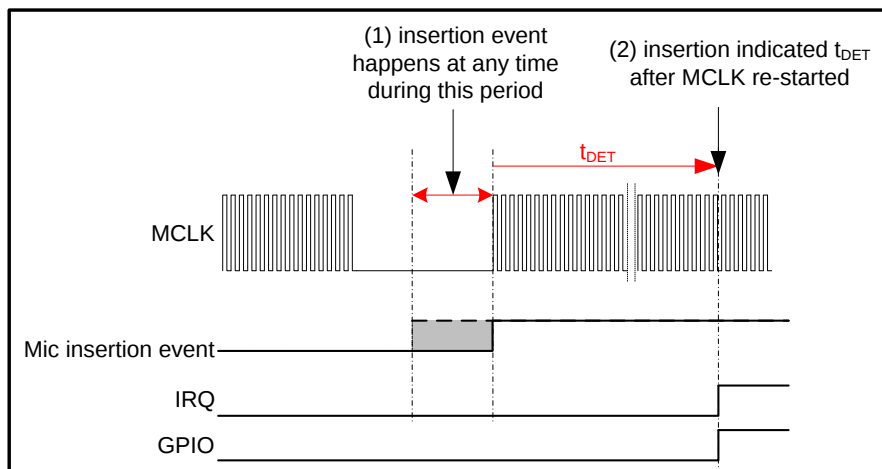
The hook switch detection measurement frequency and the detection delay time  $t_{SHORT}$  are detailed in the "Electrical Characteristics" section.

The WM8904 Interrupt function is described in the "Interrupts" section. Example control sequences for configuring the Interrupts functions for MICBIAS current detection events are described in the "Applications Information" section.

A clock is required for the digital filtering function, and the DC Servo must also be running. This requires:

- MCLK is present or the FLL is selected as the SYSCLK source in free-running mode
- CLK\_SYS\_ENA = 1
- DCS\_ENA\_CHAN\_n is enabled (where n = 0, 1, 2 or 3)

Any MICBIAS Current Detect event (accessory insertion/removal or hookswitch press/release) which happens while one or more of the clocking criteria is not satisfied (for example during a low power mode where the CPU has disabled MCLK) will still be detected, but only after the clocking conditions are met. An example is illustrated in Figure 25, where the mic is inserted while MCLK is stopped.



**Figure 25 MICBIAS Detection events without MCLK**

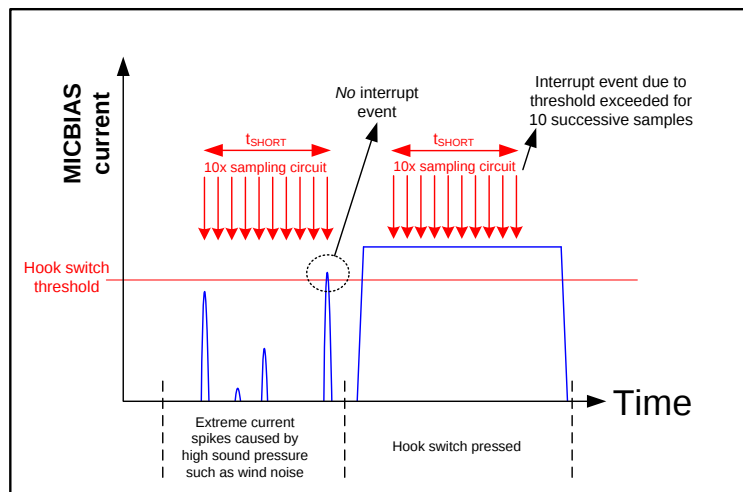
### MICROPHONE HOOK SWITCH DETECTION

The possibility of spurious hook switch interrupts due to ambient noise conditions can be removed by careful understanding of microphone behaviour under extremely high sound pressure levels or during mechanical shock, and by correct selection of the MICBIAS resistor value; these factors will affect the level of the MICBIAS AC current spikes.

In applications where the Current Detect threshold is close to the level of the current spikes, the probability of false detections is reduced by the hysteresis and digital filtering described above.

Note that the filtering algorithm provides only limited rejection of very high current spikes at frequencies less than or equal to the hook switch detect measurement frequency, or at frequencies equal to harmonics of the hook switch detect measurement frequency.

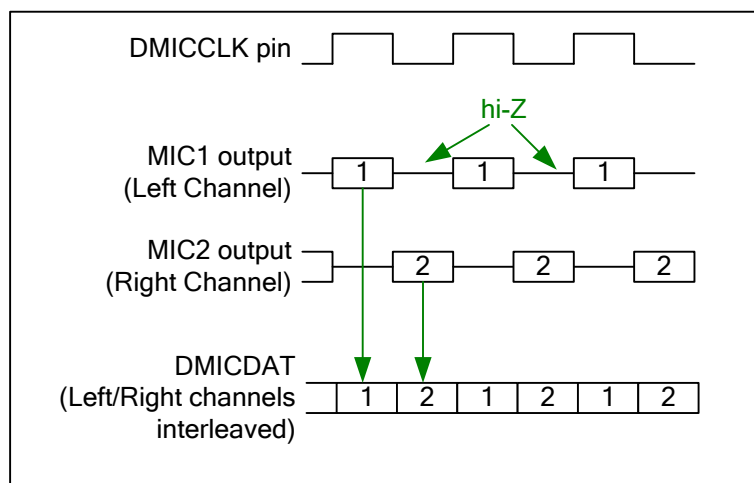
The MICBIAS Hook Switch detection filtering is illustrated in Figure 26. Example control sequences for configuring the Interrupts functions for MICBIAS current detection events are described in the "Applications Information" section.



**Figure 26 MICBIAS Hook Switch Detection Filtering**



the digital microphone data in the middle of each DMICCLK clock phase. Each microphone must tri-state its data output when the other microphone is transmitting.



**Figure 28 Digital Microphone Interface Timing**

The digital microphone interface control fields are described in Table 8.

| REGISTER ADDRESS                  | BIT | LABEL    | DEFAULT | DESCRIPTION                                                                                                                                                                                              |
|-----------------------------------|-----|----------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R39 (27h)<br>Digital Microphone 0 | 12  | DMIC_ENA | 0       | Enables Digital Microphone mode<br>0 = Audio DSP input is from ADC<br>1 = Audio DSP input is from digital microphone interface<br>When DMIC_ENA = 0, the Digital microphone clock (DMICCLK) is held low. |
|                                   | 11  | DMIC_SRC | 0       | Selects Digital Microphone Data Input pin<br>0 = IN1L/DMICDAT1<br>1 = IN1R/DMICDAT2                                                                                                                      |

**Table 8 Digital Microphone Interface Control**

## ANALOGUE-TO-DIGITAL CONVERTER (ADC)

The WM8904 uses stereo 24-bit, 128x oversampled sigma-delta ADCs. The use of multi-bit feedback and high oversampling rates reduces the effects of jitter and high frequency noise. An oversample rate of 64x can also be supported - see "Clocking and Sample Rates" for details. The ADC full scale input level is proportional to AVDD - see "Electrical Characteristics". Any input signal greater than full scale may overload the ADC and cause distortion.

The ADCs are enabled by the ADCL\_ENA and ADCR\_ENA register bits.

| REGISTER ADDRESS                  | BIT | LABEL    | DEFAULT | DESCRIPTION                                             |
|-----------------------------------|-----|----------|---------|---------------------------------------------------------|
| R18 (12h)<br>Power Management (6) | 1   | ADCL_ENA | 0       | Left ADC Enable<br>0 = ADC disabled<br>1 = ADC enabled  |
|                                   | 0   | ADCR_ENA | 0       | Right ADC Enable<br>0 = ADC disabled<br>1 = ADC enabled |

**Table 9 ADC Enable Control**

### ADC DIGITAL VOLUME CONTROL

The output of the ADCs can be digitally amplified or attenuated over a range from -71.625dB to +17.625dB in 0.375dB steps. The volume of each channel can be controlled separately. The gain for a given eight-bit code is detailed in Table 11.

The ADC\_VU bit controls the loading of digital volume control data. When ADC\_VU is set to 0, the ADCL\_VOL or ADCR\_VOL control data will be loaded into the respective control register, but will not actually change the digital gain setting. Both left and right gain settings are updated when a 1 is written to ADC\_VU. This makes it possible to update the gain of both channels simultaneously.

| REGISTER ADDRESS                      | BIT | LABEL          | DEFAULT         | DESCRIPTION                                                                                                                                                                                          |
|---------------------------------------|-----|----------------|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R36 (24h)<br>ADC Digital Volume Left  | 8   | ADC_VU         | 0               | ADC Volume Update<br>Writing a 1 to this bit will cause left and right ADC volume to be updated simultaneously                                                                                       |
|                                       | 7:0 | ADCL_VOL [7:0] | 1100_0000 (0dB) | Left ADC Digital Volume<br>00h = Mute<br>01h = -71.625dB<br>02h = -71.250dB<br>... (0.375dB steps)<br>C0h = 0dB<br>... (0.375dB steps)<br>EFh to FFh = +17.625dB<br>(See Table 11 for volume range)  |
| R37 (25h)<br>ADC Digital Volume Right | 8   | ADC_VU         | 0               | ADC Volume Update<br>Writing a 1 to this bit will cause left and right ADC volume to be updated simultaneously                                                                                       |
|                                       | 7:0 | ADCR_VOL [7:0] | 1100_0000 (0dB) | Right ADC Digital Volume<br>00h = Mute<br>01h = -71.625dB<br>02h = -71.250dB<br>... (0.375dB steps)<br>C0h = 0dB<br>... (0.375dB steps)<br>EFh to FFh = +17.625dB<br>(See Table 11 for volume range) |

**Table 10 ADC Digital Volume Control**

| ADCL_VOL or<br>ADCR_VOL | Volume (dB) | ADCL_VOL or<br>ADCR_VOL | Volume (dB) | ADCL_VOL or<br>ADCR_VOL | Volume (dB) | ADCL_VOL or<br>ADCR_VOL | Volume (dB) |
|-------------------------|-------------|-------------------------|-------------|-------------------------|-------------|-------------------------|-------------|
| 0h                      | MUTE        | 40h                     | -48.000     | 80h                     | -24.000     | C0h                     | 0.000       |
| 1h                      | -71.625     | 41h                     | -47.625     | 81h                     | -23.625     | C1h                     | 0.375       |
| 2h                      | -71.250     | 42h                     | -47.250     | 82h                     | -23.250     | C2h                     | 0.750       |
| 3h                      | -70.875     | 43h                     | -46.875     | 83h                     | -22.875     | C3h                     | 1.125       |
| 4h                      | -70.500     | 44h                     | -46.500     | 84h                     | -22.500     | C4h                     | 1.500       |
| 5h                      | -70.125     | 45h                     | -46.125     | 85h                     | -22.125     | C5h                     | 1.875       |
| 6h                      | -69.750     | 46h                     | -45.750     | 86h                     | -21.750     | C6h                     | 2.250       |
| 7h                      | -69.375     | 47h                     | -45.375     | 87h                     | -21.375     | C7h                     | 2.625       |
| 8h                      | -69.000     | 48h                     | -45.000     | 88h                     | -21.000     | C8h                     | 3.000       |
| 9h                      | -68.625     | 49h                     | -44.625     | 89h                     | -20.625     | C9h                     | 3.375       |
| Ah                      | -68.250     | 4Ah                     | -44.250     | 8Ah                     | -20.250     | CAh                     | 3.750       |
| Bh                      | -67.875     | 4Bh                     | -43.875     | 8Bh                     | -19.875     | CBh                     | 4.125       |
| Ch                      | -67.500     | 4Ch                     | -43.500     | 8Ch                     | -19.500     | CCh                     | 4.500       |
| Dh                      | -67.125     | 4Dh                     | -43.125     | 8Dh                     | -19.125     | CDh                     | 4.875       |
| Eh                      | -66.750     | 4Eh                     | -42.750     | 8Eh                     | -18.750     | CEh                     | 5.250       |
| Fh                      | -66.375     | 4Fh                     | -42.375     | 8Fh                     | -18.375     | CFh                     | 5.625       |
| 10h                     | -66.000     | 50h                     | -42.000     | 90h                     | -18.000     | D0h                     | 6.000       |
| 11h                     | -65.625     | 51h                     | -41.625     | 91h                     | -17.625     | D1h                     | 6.375       |
| 12h                     | -65.250     | 52h                     | -41.250     | 92h                     | -17.250     | D2h                     | 6.750       |
| 13h                     | -64.875     | 53h                     | -40.875     | 93h                     | -16.875     | D3h                     | 7.125       |
| 14h                     | -64.500     | 54h                     | -40.500     | 94h                     | -16.500     | D4h                     | 7.500       |
| 15h                     | -64.125     | 55h                     | -40.125     | 95h                     | -16.125     | D5h                     | 7.875       |
| 16h                     | -63.750     | 56h                     | -39.750     | 96h                     | -15.750     | D6h                     | 8.250       |
| 17h                     | -63.375     | 57h                     | -39.375     | 97h                     | -15.375     | D7h                     | 8.625       |
| 18h                     | -63.000     | 58h                     | -39.000     | 98h                     | -15.000     | D8h                     | 9.000       |
| 19h                     | -62.625     | 59h                     | -38.625     | 99h                     | -14.625     | D9h                     | 9.375       |
| 1Ah                     | -62.250     | 5Ah                     | -38.250     | 9Ah                     | -14.250     | DAh                     | 9.750       |
| 1Bh                     | -61.875     | 5Bh                     | -37.875     | 9Bh                     | -13.875     | DBh                     | 10.125      |
| 1Ch                     | -61.500     | 5Ch                     | -37.500     | 9Ch                     | -13.500     | DCh                     | 10.500      |
| 1Dh                     | -61.125     | 5Dh                     | -37.125     | 9Dh                     | -13.125     | DDh                     | 10.875      |
| 1Eh                     | -60.750     | 5Eh                     | -36.750     | 9Eh                     | -12.750     | DEh                     | 11.250      |
| 1Fh                     | -60.375     | 5Fh                     | -36.375     | 9Fh                     | -12.375     | DFh                     | 11.625      |
| 20h                     | -60.000     | 60h                     | -36.000     | A0h                     | -12.000     | E0h                     | 12.000      |
| 21h                     | -59.625     | 61h                     | -35.625     | A1h                     | -11.625     | E1h                     | 12.375      |
| 22h                     | -59.250     | 62h                     | -35.250     | A2h                     | -11.250     | E2h                     | 12.750      |
| 23h                     | -58.875     | 63h                     | -34.875     | A3h                     | -10.875     | E3h                     | 13.125      |
| 24h                     | -58.500     | 64h                     | -34.500     | A4h                     | -10.500     | E4h                     | 13.500      |
| 25h                     | -58.125     | 65h                     | -34.125     | A5h                     | -10.125     | E5h                     | 13.875      |
| 26h                     | -57.750     | 66h                     | -33.750     | A6h                     | -9.750      | E6h                     | 14.250      |
| 27h                     | -57.375     | 67h                     | -33.375     | A7h                     | -9.375      | E7h                     | 14.625      |
| 28h                     | -57.000     | 68h                     | -33.000     | A8h                     | -9.000      | E8h                     | 15.000      |
| 29h                     | -56.625     | 69h                     | -32.625     | A9h                     | -8.625      | E9h                     | 15.375      |
| 2Ah                     | -56.250     | 6Ah                     | -32.250     | AAh                     | -8.250      | EAh                     | 15.750      |
| 2Bh                     | -55.875     | 6Bh                     | -31.875     | ABh                     | -7.875      | EBh                     | 16.125      |
| 2Ch                     | -55.500     | 6Ch                     | -31.500     | ACH                     | -7.500      | ECh                     | 16.500      |
| 2Dh                     | -55.125     | 6Dh                     | -31.125     | ADh                     | -7.125      | EDh                     | 16.875      |
| 2Eh                     | -54.750     | 6Eh                     | -30.750     | AEdh                    | -6.750      | EEh                     | 17.250      |
| 2Fh                     | -54.375     | 6Fh                     | -30.375     | AFh                     | -6.375      | EFh                     | 17.625      |
| 30h                     | -54.000     | 70h                     | -30.000     | B0h                     | -6.000      | F0h                     | 17.625      |
| 31h                     | -53.625     | 71h                     | -29.625     | B1h                     | -5.625      | F1h                     | 17.625      |
| 32h                     | -53.250     | 72h                     | -29.250     | B2h                     | -5.250      | F2h                     | 17.625      |
| 33h                     | -52.875     | 73h                     | -28.875     | B3h                     | -4.875      | F3h                     | 17.625      |
| 34h                     | -52.500     | 74h                     | -28.500     | B4h                     | -4.500      | F4h                     | 17.625      |
| 35h                     | -52.125     | 75h                     | -28.125     | B5h                     | -4.125      | F5h                     | 17.625      |
| 36h                     | -51.750     | 76h                     | -27.750     | B6h                     | -3.750      | F6h                     | 17.625      |
| 37h                     | -51.375     | 77h                     | -27.375     | B7h                     | -3.375      | F7h                     | 17.625      |
| 38h                     | -51.000     | 78h                     | -27.000     | B8h                     | -3.000      | F8h                     | 17.625      |
| 39h                     | -50.625     | 79h                     | -26.625     | B9h                     | -2.625      | F9h                     | 17.625      |
| 3Ah                     | -50.250     | 7Ah                     | -26.250     | BAh                     | -2.250      | FAh                     | 17.625      |
| 3Bh                     | -49.875     | 7Bh                     | -25.875     | BBh                     | -1.875      | FBh                     | 17.625      |
| 3Ch                     | -49.500     | 7Ch                     | -25.500     | BCh                     | -1.500      | FCh                     | 17.625      |
| 3Dh                     | -49.125     | 7Dh                     | -25.125     | BDh                     | -1.125      | FDh                     | 17.625      |
| 3Eh                     | -48.750     | 7Eh                     | -24.750     | BEh                     | -0.750      | FEh                     | 17.625      |
| 3Fh                     | -48.375     | 7Fh                     | -24.375     | BFh                     | -0.375      | FFh                     | 17.625      |

**Table 11 ADC Digital Volume Range**

## HIGH PASS FILTER

A digital high pass filter is applied by default to the ADC path to remove DC offsets. This filter can also be programmed to remove low frequency noise in voice applications (e.g. wind noise or mechanical vibration). This filter is controlled using the ADC\_HPF and ADC\_HPF\_CUT register bits.

In hi-fi mode the high pass filter is optimised for removing DC offsets without degrading the bass response and has a cut-off frequency of 3.7Hz at fs=44.1kHz.

In voice mode the high pass filter is optimised for voice communication and it is recommended to program the cut-off frequency below 300Hz (e.g. ADC\_HPF\_CUT=11 at fs=8kHz or ADC\_HPF\_CUT=10 at fs=16kHz).

| REGISTER ADDRESS           | BIT | LABEL             | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                                                             |
|----------------------------|-----|-------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R38 (26h)<br>ADC Digital 0 | 6:5 | ADC_HPF_CUT [1:0] | 00      | ADC Digital High Pass Filter Cut-Off Frequency (fc)<br>00 = Hi-fi mode (fc=4Hz at fs=48kHz)<br>01 = Voice mode 1 (fc=127Hz at fs=16kHz)<br>10 = Voice mode 2 (fc=130Hz at fs=8kHz)<br>11 = Voice mode 3 (fc=267Hz at fs=8kHz)<br>(Note: fc scales with sample rate. See Table 13 for cut-off frequencies at all supported sample rates) |
|                            | 4   | ADC_HPF           | 1       | ADC Digital High Pass Filter Enable<br>0 = disabled<br>1 = enabled                                                                                                                                                                                                                                                                      |

**Table 12 ADC Digital 0 Register**

| Sample Frequency (kHz) | CUT-OFF FREQUENCY (Hz) |                 |                 |                 |
|------------------------|------------------------|-----------------|-----------------|-----------------|
|                        | ADC_HPF_CUT =00        | ADC_HPF_CUT =01 | ADC_HPF_CUT =10 | ADC_HPF_CUT =11 |
| 8.000                  | 0.7                    | 64              | 130             | 267             |
| 11.025                 | 0.9                    | 88              | 178             | 367             |
| 16.000                 | 1.3                    | 127             | 258             | 532             |
| 22.050                 | 1.9                    | 175             | 354             | 733             |
| 24.000                 | 2.0                    | 190             | 386             | 798             |
| 32.000                 | 2.7                    | 253             | 514             | 1063            |
| 44.100                 | 3.7                    | 348             | 707             | 1464            |
| 48.000                 | 4.0                    | 379             | 770             | 1594            |

**Table 13 ADC High Pass Filter Cut-Off Frequencies**

The high pass filter characteristics are shown in the “Digital Filter Characteristics” section.

### ADC OVERSAMPLING RATIO (OSR)

The ADC oversampling rate is programmable to allow power consumption versus audio performance trade-offs. The default oversampling rate is high for best performance; using the lower OSR setting reduces ADC power consumption.

To ensure specified ADC performance, the ADC Bias Control bits in register R198 must be set correctly, depending on the ADC\_OSR128 value, as described in Table 14.

| REGISTER ADDRESS            | BIT | LABEL                | DEFAULT | DESCRIPTION                                                                                                                           |
|-----------------------------|-----|----------------------|---------|---------------------------------------------------------------------------------------------------------------------------------------|
| R10 (0Ah)<br>Analogue ADC 0 | 0   | ADC_OSR128           | 1       | ADC Oversampling Ratio<br>0 = Low Power (64 x fs)<br>1 = High Performance (128 x fs)                                                  |
| R198 (C6h)<br>ADC Test 0    | 2   | ADC_128_OSR_TST_MODE | 0       | ADC Bias Control (1)<br>Set this bit to 1 in ADC 64fs mode (ADC_OSR128 = 0).<br>Set this bit to 0 in ADC 128fs mode (ADC_OSR128 = 1). |
|                             | 0   | ADC_BIASX1P5         | 0       | ADC Bias Control (2)<br>Set this bit to 1 in ADC 64fs mode (ADC_OSR128 = 0).<br>Set this bit to 0 in ADC 128fs mode (ADC_OSR128 = 1). |

**Table 14** ADC Oversampling Ratio

### DYNAMIC RANGE CONTROL (DRC)

The dynamic range controller (DRC) is a circuit which can be enabled in the digital data path of either the ADCs or the DACs. The function of the DRC is to adjust the signal gain in conditions where the input amplitude is unknown or varies over a wide range, e.g. when recording from microphones built into a handheld system. The DRC can apply Compression and Automatic Level Control to the signal path. It incorporates 'anti-clip' and 'quick release' features for handling transients in order to improve intelligibility in the presence of loud impulsive noises.

The DRC is enabled by DRC\_ENA, as shown in Table 15. It can be enabled in the ADC digital path or in the DAC digital path, under the control of the DRC\_DAC\_PATH register bit. Note that the DRC can be active in only one of these paths at any time.

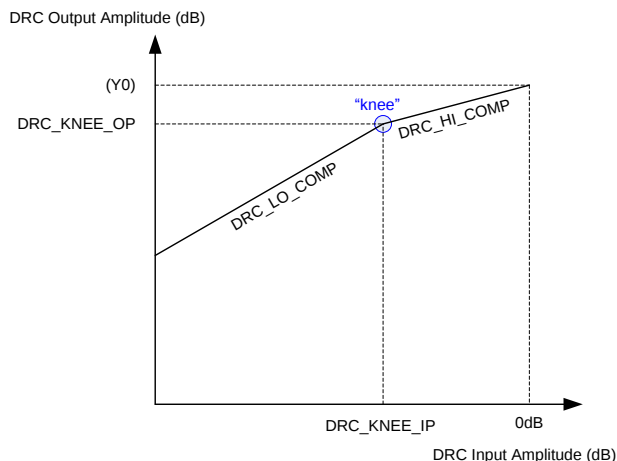
| REGISTER ADDRESS           | BIT | LABEL        | DEFAULT | DESCRIPTION                                     |
|----------------------------|-----|--------------|---------|-------------------------------------------------|
| R40 (28h)<br>DRC Control 0 | 15  | DRC_ENA      | 0       | DRC enable<br>0 = disabled<br>1 = enabled       |
|                            | 14  | DRC_DAC_PATH | 0       | DRC path select<br>0 = ADC path<br>1 = DAC path |

**Table 15** DRC Enable

## COMPRESSION/LIMITING CAPABILITIES

The DRC supports two different compression regions, separated by a “knee” at input amplitude T. For signals above the knee, the compression slope DRC\_HI\_COMP applies; for signals below the knee, the compression slope DRC\_LO\_COMP applies.

The overall DRC compression characteristic in “steady state” (i.e. where the input amplitude is near-constant) is illustrated in Figure 29.



**Figure 29 DRC Compression Characteristic**

The slope of the DRC response is determined by register fields DRC\_HI\_COMP and DRC\_LO\_COMP respectively. A slope of 1 indicates constant gain in this region. A slope less than 1 represents compression (i.e. a change in input amplitude produces only a smaller change in output amplitude). A slope of 0 indicates that the target output amplitude is the same across a range of input amplitudes; this is infinite compression.

The “knee” in Figure 29 is represented by register fields DRC\_KNEE\_IP and DRC\_KNEE\_OP.

Parameter Y0, the output level for a 0dB input, is not specified directly, but can be calculated from the other parameters, using the equation

$$Y0 = DRC\_KNEE\_OP - (DRC\_KNEE\_IP * DRC\_HI\_COMP)$$

The DRC Compression parameters are defined in Table 16.

| REGISTER ADDRESS           | BIT  | LABEL                | DEFAULT | DESCRIPTION                                                                                                                                                           |
|----------------------------|------|----------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R43 (2Bh)<br>DRC Control 3 | 10:5 | DRC_KNEE_IP<br>[5:0] | 00_0000 | Input signal at the Compressor 'knee'.<br>000000 = 0dB<br>000001 = -0.75dB<br>000010 = -1.5dB<br>... (-0.75dB steps)<br>111100 = -45dB<br>111101 to 111111 = Reserved |
|                            | 4:0  | DRC_KNEE_OP<br>[4:0] | 0_0000  | Output signal at the Compressor 'knee'.<br>00000 = 0dB<br>00001 = -0.75dB<br>00010 = -1.5dB<br>... (-0.75dB steps)<br>11110 = -22.5dB<br>11111 = Reserved             |

| REGISTER ADDRESS           | BIT | LABEL             | DEFAULT | DESCRIPTION                                                                                                                                          |
|----------------------------|-----|-------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| R42 (2Ah)<br>DRC Control 2 | 5:3 | DRC_HI_COMP [2:0] | 000     | Compressor slope (upper region)<br>000 = 1 (no compression)<br>001 = 1/2<br>010 = 1/4<br>011 = 1/8<br>100 = 1/16<br>101 = 0<br>110 to 111 = Reserved |
|                            | 2:0 | DRC_LO_COMP [2:0] | 000     | Compressor slope (lower region)<br>000 = 1 (no compression)<br>001 = 1/2<br>010 = 1/4<br>011 = 1/8<br>100 = 0<br>101 to 111 = Reserved               |

**Table 16 DRC Compression Control**

#### GAIN LIMITS

The minimum and maximum gain applied by the DRC is set by register fields DRC\_MINGAIN and DRC\_MAXGAIN. These limits can be used to alter the DRC response from that illustrated in Figure 29. If the range between maximum and minimum gain is reduced, then the extent of the dynamic range control is reduced. The maximum gain prevents quiet signals (or silence) from being excessively amplified.

| REGISTER ADDRESS           | BIT | LABEL             | DEFAULT | DESCRIPTION                                                                                                            |
|----------------------------|-----|-------------------|---------|------------------------------------------------------------------------------------------------------------------------|
| R41 (29h)<br>DRC Control 1 | 3:2 | DRC_MINGAIN [1:0] | 10      | Minimum gain the DRC can use to attenuate audio signals<br>00 = 0dB (default)<br>01 = -6dB<br>10 = -12dB<br>11 = -18dB |
|                            | 1:0 | DRC_MAXGAIN [1:0] | 00      | Maximum gain the DRC can use to boost audio signals<br>00 = 12dB<br>01 = 18dB (default)<br>10 = 24dB<br>11 = 36dB      |

**Table 17 DRC Gain Limits**

## DYNAMIC CHARACTERISTICS

The dynamic behaviour determines how quickly the DRC responds to changing signal levels. Note that the DRC responds to the average (RMS) signal amplitude over a period of time.

DRC\_ATK determines how quickly the DRC gain decreases when the signal amplitude is high. DRC\_DCY determines how quickly the DRC gain increases when the signal amplitude is low.

These register fields are described in Table 18. Note that the register defaults are suitable for general purpose microphone use.

| REGISTER ADDRESS           | BIT   | LABEL         | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                              |
|----------------------------|-------|---------------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R41 (29h)<br>DRC Control 1 | 15:12 | DRC_ATK [3:0] | 0011    | Gain attack rate (seconds/6dB)<br>0000 = Reserved<br>0001 = 182µs<br>0010 = 363µs<br>0011 = 726µs (default)<br>0100 = 1.45ms<br>0101 = 2.9ms<br>0110 = 5.8ms<br>0111 = 11.6ms<br>1000 = 23.2ms<br>1001 = 46.4ms<br>1010 = 92.8ms<br>1011-1111 = Reserved |
|                            | 11:8  | DRC_DCY [3:0] | 0010    | Gain decay rate (seconds/6dB)<br>0000 = 186ms<br>0001 = 372ms<br>0010 = 743ms (default)<br>0011 = 1.49s<br>0100 = 2.97s<br>0101 = 5.94s<br>0110 = 11.89s<br>0111 = 23.78s<br>1000 = 47.56s<br>1001-1111 = Reserved                                       |

**Table 18 DRC Attack and Decay Rates**

### Note:

For detailed information about DRC attack and decay rates, please see Application Note WAN0247.

## ANTI-CLIP CONTROL

The DRC includes an Anti-Clip feature to avoid signal clipping when the input amplitude rises very quickly. This feature uses a feed-forward technique for early detection of a rising signal level. Signal clipping is avoided by dynamically increasing the gain attack rate when required. The Anti-Clip feature is enabled using the DRC\_ANTICLIP bit.

Note that the feed-forward processing increases the latency in the input signal path. For low-latency applications (e.g. telephony), it may be desirable to reduce the delay, although this will also reduce the effectiveness of the anti-clip feature. The latency is determined by the DRC\_FF\_DELAY bit. If necessary, the latency can be minimised by disabling the anti-clip feature altogether.

The DRC Anti-Clip control bits are described in Table 19.

| REGISTER ADDRESS           | BIT | LABEL        | DEFAULT | DESCRIPTION                                                                                                                                                        |
|----------------------------|-----|--------------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R40 (28h)<br>DRC Control 0 | 5   | DRC_FF_DELAY | 1       | Feed-forward delay for anti-clip feature<br>0 = 5 samples<br>1 = 9 samples<br>Time delay can be calculated as $5/f_s$ or $9/f_s$ , where $f_s$ is the sample rate. |
|                            | 1   | DRC_ANTICLIP | 1       | Anti-clip enable<br>0 = disabled<br>1 = enabled                                                                                                                    |

**Table 19 DRC Anti-Clip Control**

Note that the Anti-Clip feature operates entirely in the digital domain. It cannot be used to prevent signal clipping in the analogue domain nor in the source signal. Analogue clipping can only be prevented by reducing the analogue signal gain or by adjusting the source signal.

### QUICK RELEASE CONTROL

The DRC includes a Quick-Release feature to handle short transient peaks that are not related to the intended source signal. For example, in handheld microphone recording, transient signal peaks sometimes occur due to user handling, key presses or accidental tapping against the microphone. The Quick Release feature ensures that these transients do not cause the intended signal to be masked by the longer time constants of DRC\_DCY.

The Quick-Release feature is enabled by setting the DRC\_QR bit. When this bit is enabled, the DRC measures the crest factor (peak to RMS ratio) of the input signal. A high crest factor is indicative of a transient peak that may not be related to the intended source signal. If the crest factor exceeds the level set by DRC\_QR\_THR, then the normal decay rate (DRC\_DCY) is ignored and a faster decay rate (DRC\_QR\_DCY) is used instead.

The DRC Quick-Release control bits are described in Table 20.

| REGISTER ADDRESS           | BIT | LABEL               | DEFAULT | DESCRIPTION                                                                                                    |
|----------------------------|-----|---------------------|---------|----------------------------------------------------------------------------------------------------------------|
| R40 (28h)<br>DRC Control 0 | 2   | DRC_QR              | 1       | Quick release enable<br>0 = disabled<br>1 = enabled                                                            |
| R41 (29h)<br>DRC Control 1 | 7:6 | DRC_QR_THR<br>[1:0] | 01      | Quick release crest factor threshold<br>00 = 12dB<br>01 = 18dB (default)<br>10 = 24dB<br>11 = 30dB             |
|                            | 5:4 | DRC_QR_DCY<br>[1:0] | 00      | Quick release decay rate (seconds/6dB)<br>00 = 0.725ms (default)<br>01 = 1.45ms<br>10 = 5.8ms<br>11 = Reserved |

**Table 20 DRC Quick-Release Control**

## GAIN SMOOTHING

The DRC includes a gain smoothing filter in order to prevent gain ripples. A programmable level of hysteresis is also used to control the DRC gain. This improves the handling of very low frequency input signals whose period is close to the DRC attack/decay time. DRC Gain Smoothing is enabled by default and it is recommended to use the default register settings.

The extent of the gain smoothing filter may be adjusted or disabled using the control fields described in Table 21.

| REGISTER ADDRESS           | BIT   | LABEL                 | DEFAULT | DESCRIPTION                                                                                                |
|----------------------------|-------|-----------------------|---------|------------------------------------------------------------------------------------------------------------|
| R40 (28h)<br>DRC Control 0 | 12:11 | DRC_GS_HYST_LVL [1:0] | 00      | Gain smoothing hysteresis threshold<br>00 = Low<br>01 = Medium (recommended)<br>10 = High<br>11 = Reserved |
|                            | 3     | DRC_GS_ENA            | 1       | Gain smoothing enable<br>0 = disabled<br>1 = enabled                                                       |
|                            | 0     | DRC_GS_HYST           | 1       | Gain smoothing hysteresis enable<br>0 = disabled<br>1 = enabled                                            |

**Table 21 DRC Gain Smoothing**

## INITIALISATION

When the DRC is initialised, the gain is set to the level determined by the DRC\_STARTUP\_GAIN register field. The default setting is 0dB, but values from -3dB to +6dB are available, as described in Table 22.

| REGISTER ADDRESS           | BIT  | LABEL                  | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                              |
|----------------------------|------|------------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R40 (28h)<br>DRC Control 0 | 10:6 | DRC_STARTUP_GAIN [4:0] | 00110   | Initial gain at DRC start-up<br>00000 = -3dB<br>00001 = -2.5dB<br>00010 = -2dB<br>00011 = -1.5dB<br>00100 = -1dB<br>00101 = -0.5dB<br>00110 = 0dB (default)<br>00111 = 0.5dB<br>01000 = 1dB<br>01001 = 1.5dB<br>01010 = 2dB<br>01011 = 2.5dB<br>01100 = 3dB<br>01101 = 3.5dB<br>01110 = 4dB<br>01111 = 4.5dB<br>10000 = 5dB<br>10001 = 5.5dB<br>10010 = 6dB<br>10011 to 11111 = Reserved |

**Table 22 DRC Initialisation**

## RETUNE™ MOBILE PARAMETRIC EQUALIZER (EQ)

The ReTune™ Mobile Parametric Equaliser is a circuit that can be enabled in the DAC path. The function of the EQ is to adjust the frequency characteristic of the output to compensate for unwanted frequency characteristics in the loudspeaker (or other output transducer). It can also be used to tailor the response according to user preferences, for example to accentuate or attenuate specific frequency bands to emulate different sound profiles or environments such as concert hall, rock etc. The EQ is enabled using the EQ\_ENA bit as shown in Table 23.

| REGISTER ADDRESS  | BIT | LABEL  | DEFAULT | DESCRIPTION                                    |
|-------------------|-----|--------|---------|------------------------------------------------|
| R134 (86h)<br>EQ1 | 0   | EQ_ENA | 0       | EQ enable<br>0 = EQ disabled<br>1 = EQ enabled |

**Table 23 ReTune™ Mobile Parametric EQ Enable**

The EQ can be configured to operate in two modes - "Default" mode or "ReTune™ Mobile" mode.

### DEFAULT MODE (5-BAND PARAMETRIC EQ)

In default mode, the cut-off / centre frequencies are fixed as per Table 24. The filter bandwidths are also fixed in default mode. The gain of the individual bands (-12dB to +12dB) can be controlled as described in Table 25.

Note that the cut-off / centre frequencies noted in Table 24 are applicable to a DAC Sample Rate of 48kHz. When using other sample rates, these frequencies will be scaled in proportion to the selected sample rate.

| EQ BAND | CUT-OFF/CENTRE FREQUENCY |
|---------|--------------------------|
| 1       | 100 Hz                   |
| 2       | 300 Hz                   |
| 3       | 875 Hz                   |
| 4       | 2400 Hz                  |
| 5       | 6900 Hz                  |

**Table 24 EQ Band Cut-off / Centre Frequencies**

| REGISTER ADDRESS  | BIT | LABEL            | DEFAULT         | DESCRIPTION                                     |
|-------------------|-----|------------------|-----------------|-------------------------------------------------|
| R135 (87h)<br>EQ2 | 4:0 | EQ_B1_GAIN [4:0] | 01100b<br>(0dB) | EQ Band 1 Gain<br>(see Table 26 for gain range) |
| R136 (88h)<br>EQ3 | 4:0 | EQ_B2_GAIN [4:0] | 01100b<br>(0dB) | EQ Band 2 Gain<br>(see Table 26 for gain range) |
| R137 (89h)<br>EQ4 | 4:0 | EQ_B3_GAIN [4:0] | 01100b<br>(0dB) | EQ Band 3 Gain<br>(see Table 26 for gain range) |
| R138 (8Ah)<br>EQ5 | 4:0 | EQ_B4_GAIN [4:0] | 01100b<br>(0dB) | EQ Band 4 Gain<br>(see Table 26 for gain range) |
| R139 (8Bh)<br>EQ6 | 4:0 | EQ_B5_GAIN [4:0] | 01100b<br>(0dB) | EQ Band 5 Gain<br>(see Table 26 for gain range) |

**Table 25 EQ Band Gain Control**

| EQ GAIN SETTING | GAIN (DB) |
|-----------------|-----------|
| 00000           | -12       |
| 00001           | -11       |
| 00010           | -10       |
| 00011           | -9        |
| 00100           | -8        |
| 00101           | -7        |
| 00110           | -6        |
| 00111           | -5        |
| 01000           | -4        |
| 01001           | -3        |
| 01010           | -2        |
| 01011           | -1        |
| 01100           | 0         |
| 01101           | +1        |
| 01110           | +2        |
| 01111           | +3        |
| 10000           | +4        |
| 10001           | +5        |
| 10010           | +6        |
| 10011           | +7        |
| 10100           | +8        |
| 10101           | +9        |
| 10110           | +10       |
| 10111           | +11       |
| 11000           | +12       |
| 11001 to 11111  | Reserved  |

**Table 26 EQ Gain Control**

### RETUNE™ MOBILE MODE

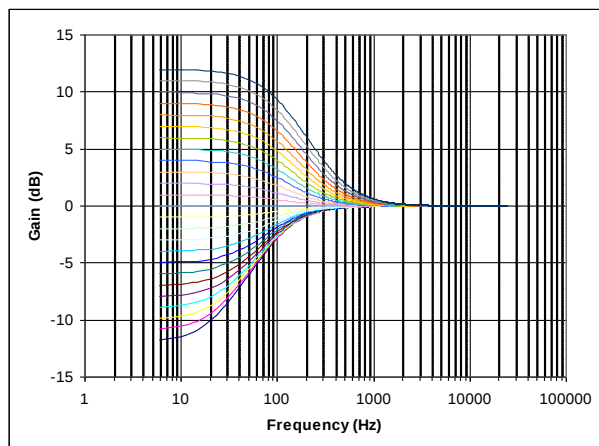
ReTune™ Mobile mode provides a comprehensive facility for the user to define the cut-off/centre frequencies and filter bandwidth for each EQ band, in addition to the gain controls already described. This enables the EQ to be accurately customised for a specific transducer characteristic or desired sound profile.

The EQ enable and EQ gain controls are the same as defined for the default mode. The additional coefficients used in ReTune™ Mobile mode are held in registers R140 to R157. These coefficients are derived using tools provided in the WISCE™ evaluation board control software.

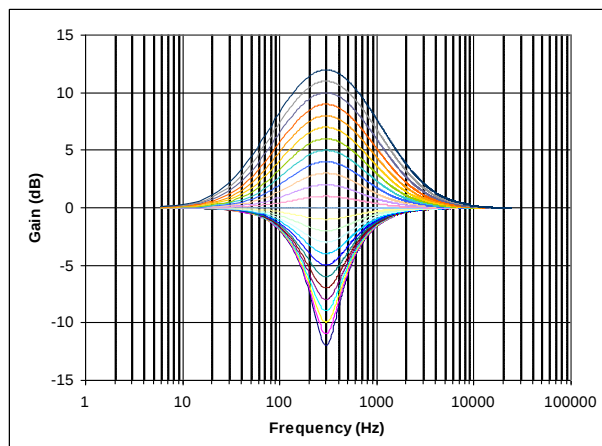
Please contact your local Cirrus Logic representative for more details.

### EQ FILTER CHARACTERISTICS

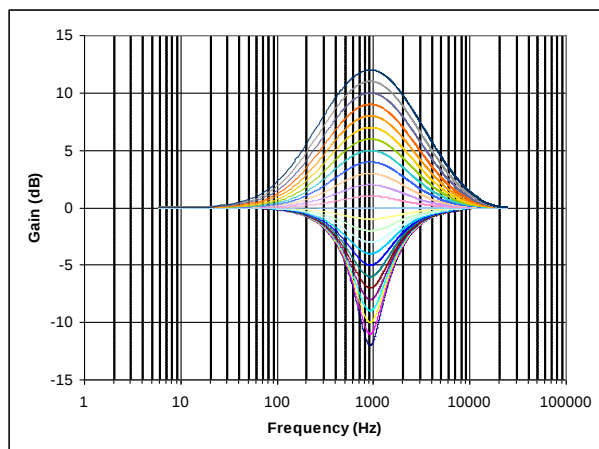
The filter characteristics for each frequency band are shown in Figure 30 to Figure 34. These figures show the frequency response for all available gain settings, using default cut-off/centre frequencies and bandwidth.



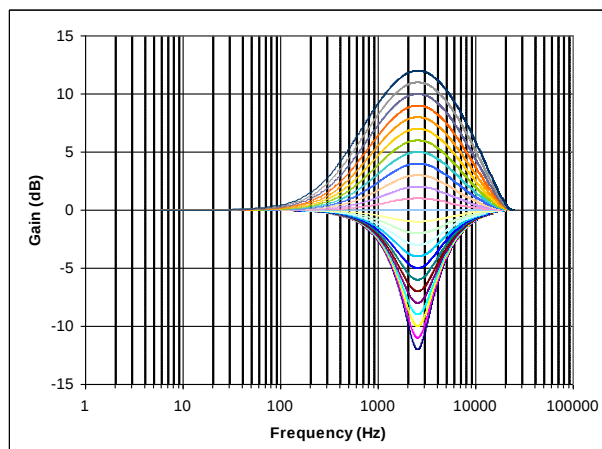
**Figure 30 EQ Band 1 – Low Freq Shelf Filter Response**



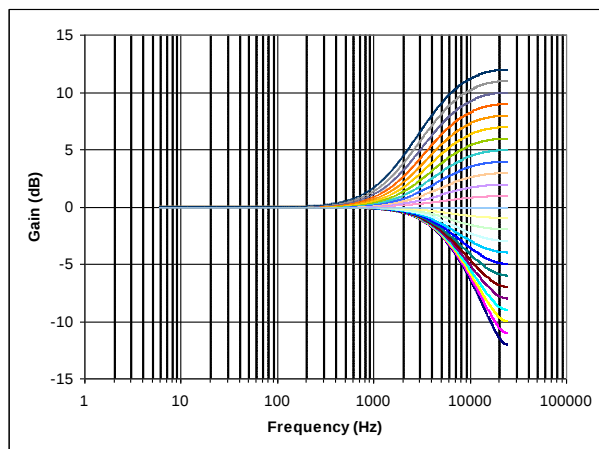
**Figure 31 EQ Band 2 – Peak Filter Response**



**Figure 32 EQ Band 3 – Peak Filter Response**



**Figure 33 EQ Band 4 – Peak Filter Response**



**Figure 34 EQ Band 5 – High Freq Shelf Filter Response**

## DIGITAL MIXING

The ADC and DAC data can be combined in various ways to support a range of different usage modes.

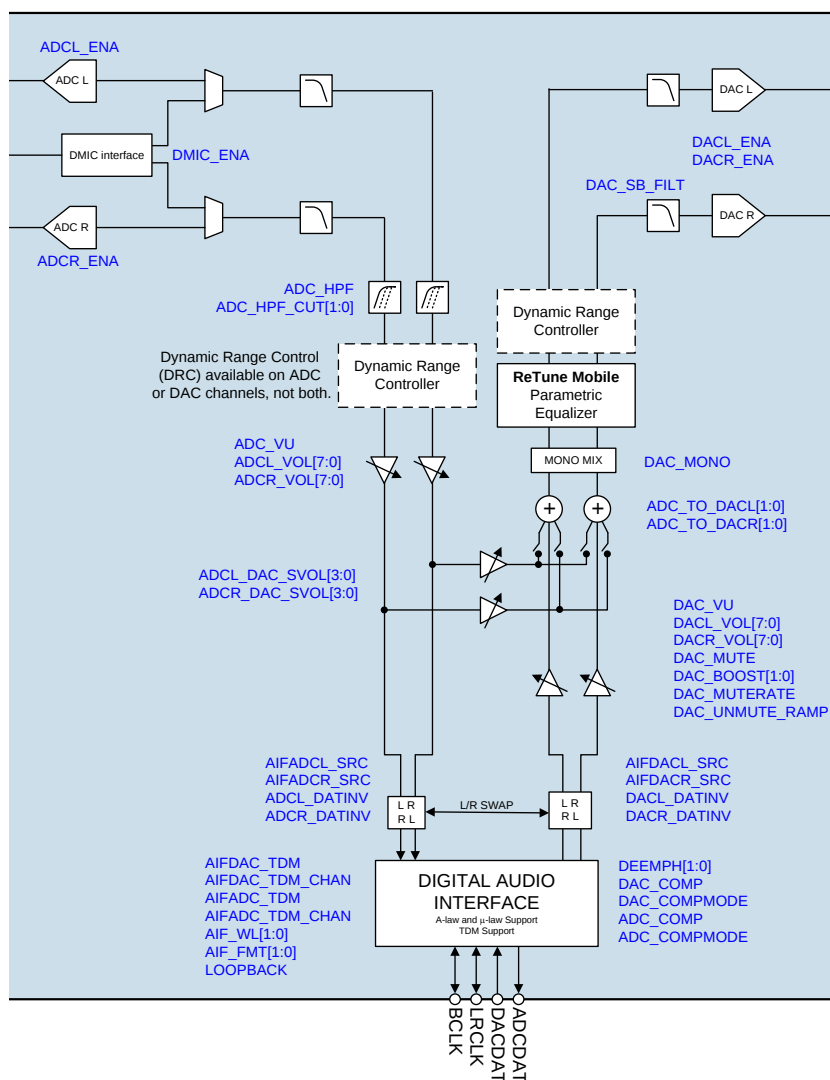
Data from either of the two ADCs can be routed to either the left or the right channel of the digital audio interface. In addition, data from either of the digital audio interface channels can be routed to either the left or the right DAC. See "Digital Audio Interface" for more information on the audio interface.

The WM8904 provides a Dynamic Range Control (DRC) feature, which can apply compression and gain adjustment in the digital domain to either the ADC or DAC signal path. This is effective in controlling signal levels under conditions where input amplitude is unknown or varies over a wide range.

The DACs can be configured as a mono mix of the two audio channels. Digital sidetone from the ADCs can also be selectively mixed into the DAC output path.

## DIGITAL MIXING PATHS

Figure 35 shows the digital mixing paths available in the WM8904 digital core.



**Figure 35 Digital Mixing Paths**

The polarity of each ADC output signal can be changed under software control using the ADCL\_DATINV and ADCR\_DATINV register bits. The AIFADCL\_SRC and AIFADCR\_SRC register bits may be used to select which ADC is used for the left and right digital audio interface data. These register bits are described in Table 27.

| REGISTER ADDRESS               | BIT | LABEL       | DEFAULT | DESCRIPTION                                                                                                                           |
|--------------------------------|-----|-------------|---------|---------------------------------------------------------------------------------------------------------------------------------------|
| R24 (18h)<br>Audio Interface 0 | 7   | AIFADCL_SRC | 0       | Left Digital Audio interface source<br>0 = Left ADC data is output on left channel<br>1 = Right ADC data is output on left channel    |
|                                | 6   | AIFADCR_SRC | 1       | Right Digital Audio interface source<br>0 = Left ADC data is output on right channel<br>1 = Right ADC data is output on right channel |
| R38 (26h)<br>ADC Digital 0     | 1   | ADCL_DATINV | 0       | Left ADC Invert<br>0 = Left ADC output not inverted<br>1 = Left ADC output inverted                                                   |
|                                | 0   | ADCR_DATINV | 0       | Right ADC Invert<br>0 = Right ADC output not inverted<br>1 = Right ADC output inverted                                                |

**Table 27 ADC Routing and Control**

The input data source for each DAC can be changed under software control using register bits AIFDACL\_SRC and AIFDACR\_SRC. The polarity of each DAC input may also be modified using register bits DACL\_DATINV and DACR\_DATINV. These register bits are described in Table 28.

| REGISTER ADDRESS               | BIT | LABEL       | DEFAULT | DESCRIPTION                                                                                                             |
|--------------------------------|-----|-------------|---------|-------------------------------------------------------------------------------------------------------------------------|
| R24 (18h)<br>Audio Interface 0 | 12  | DACL_DATINV | 0       | Left DAC Invert<br>0 = Left DAC output not inverted<br>1 = Left DAC output inverted                                     |
|                                | 11  | DACR_DATINV | 0       | Right DAC Invert<br>0 = Right DAC output not inverted<br>1 = Right DAC output inverted                                  |
|                                | 5   | AIFDACL_SRC | 0       | Left DAC Data Source Select<br>0 = Left DAC outputs left interface data<br>1 = Left DAC outputs right interface data    |
|                                | 4   | AIFDACR_SRC | 1       | Right DAC Data Source Select<br>0 = Right DAC outputs left interface data<br>1 = Right DAC outputs right interface data |

**Table 28 DAC Routing and Control**

### DAC INTERFACE VOLUME BOOST

A digital gain function is available at the audio interface to boost the DAC volume when a small signal is received on DACDAT. This is controlled using register bits DAC\_BOOST [1:0]. To prevent clipping at the DAC input, this function should not be used when the boosted DAC data is expected to be greater than 0dBFS.

The digital interface volume is controlled as shown in Table 29.

| REGISTER ADDRESS               | BIT  | LABEL           | DEFAULT | DESCRIPTION                                                                                                                                                                               |
|--------------------------------|------|-----------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R24 (18h)<br>Audio Interface 0 | 10:9 | DAC_BOOST [1:0] | 00      | DAC Input Volume Boost<br>00 = 0dB<br>01 = +6dB (Input data must not exceed -6dBFS)<br>10 = +12dB (Input data must not exceed -12dBFS)<br>11 = +18dB (Input data must not exceed -18dBFS) |

**Table 29** DAC Interface Volume Boost

### DIGITAL SIDETONE

A digital sidetone is available when ADCs and DACs are operating at the same sample rate. Digital data from either left or right ADC can be mixed with the audio interface data on the left and right DAC channels. Sidetone data is taken from the ADC high pass filter output, to reduce low frequency noise in the sidetone (e.g. wind noise or mechanical vibration).

When using the digital sidetone, it is recommended that the ADCs are enabled before un-muting the DACs to prevent pop noise. The DAC volumes and sidetone volumes should be set to an appropriate level to avoid clipping at the DAC input.

When digital sidetone is used, it is recommended that the Charge Pump operates in Register Control mode only (CP\_DYN\_PWR = 0). See "Charge Pump" for details.

The digital sidetone is controlled as shown in Table 30.

| REGISTER ADDRESS           | BIT  | LABEL               | DEFAULT | DESCRIPTION                                                                                               |
|----------------------------|------|---------------------|---------|-----------------------------------------------------------------------------------------------------------|
| R32 (20h)<br>DAC Digital 0 | 11:8 | ADCL_DAC_SVOL [3:0] | 0000    | Left Digital Sidetone Volume<br>(See Table 31 for volume range)                                           |
|                            | 7:4  | ADCR_DAC_SVOL [3:0] | 0000    | Right Digital Sidetone Volume<br>(See Table 31 for volume range)                                          |
|                            | 3:2  | ADC_TO_DACL [1:0]   | 00      | Left DAC Digital Sidetone Source<br>00 = No sidetone<br>01 = Left ADC<br>10 = Right ADC<br>11 = Reserved  |
|                            | 1:0  | ADC_TO_DACR [1:0]   | 00      | Right DAC Digital Sidetone Source<br>00 = No sidetone<br>01 = Left ADC<br>10 = Right ADC<br>11 = Reserved |

**Table 30** Digital Sidetone Control

The digital sidetone volume settings are shown in Table 31.

| <b>ADCL_DAC_SVOL<br/>OR<br/>ADCR_DAC_SVOL</b> | <b>SIDETONE VOLUME</b> |
|-----------------------------------------------|------------------------|
| 0000                                          | -36                    |
| 0001                                          | -33                    |
| 0010                                          | -30                    |
| 0011                                          | -27                    |
| 0100                                          | -24                    |
| 0101                                          | -21                    |
| 0110                                          | -18                    |
| 0111                                          | -15                    |
| 1000                                          | -12                    |
| 1001                                          | -9                     |
| 1010                                          | -6                     |
| 1011                                          | -3                     |
| 1100                                          | 0                      |
| 1101                                          | 0                      |
| 1110                                          | 0                      |
| 1111                                          | 0                      |

**Table 31 Digital Sidetone Volume**

## DIGITAL-TO-ANALOGUE CONVERTER (DAC)

The WM8904 DACs receive digital input data from the DACDAT pin and via the digital sidetone path (see “Digital Mixing” section). The digital audio data is converted to oversampled bit streams in the on-chip, true 24-bit digital interpolation filters. The bitstream data enters two multi-bit, sigma-delta DACs, which convert them to high quality analogue audio signals. The Wolfson SmartDAC™ architecture offers reduced power consumption, whilst also delivering a reduction in high frequency noise and sensitivity to clock jitter. It also uses a Dynamic Element Matching technique for high linearity and low distortion.

The analogue outputs from the DACs are sent directly to the output PGAs (see “Output Signal Path”).

The DACs are enabled by the DACL\_ENA and DACR\_ENA register bits.

| REGISTER ADDRESS                | BIT | LABEL    | DEFAULT | DESCRIPTION                                             |
|---------------------------------|-----|----------|---------|---------------------------------------------------------|
| R18 (12h)<br>Power Management 6 | 3   | DACL_ENA | 0       | Left DAC Enable<br>0 = DAC disabled<br>1 = DAC enabled  |
|                                 | 2   | DACR_ENA | 0       | Right DAC Enable<br>0 = DAC disabled<br>1 = DAC enabled |

**Table 32 DAC Enable Control**

## DAC DIGITAL VOLUME CONTROL

The output level of each DAC can be controlled digitally over a range from -71.625dB to 0dB in 0.375dB steps. The level of attenuation for an eight-bit code is detailed in Table 34.

The DAC\_VU bit controls the loading of digital volume control data. When DAC\_VU is set to 0, the DACL\_VOL or DACR\_VOL control data is loaded into the respective control register, but does not actually change the digital gain setting. Both left and right gain settings are updated when a 1 is written to DAC\_VU. This makes it possible to update the gain of both channels simultaneously.

| REGISTER ADDRESS                      | BIT | LABEL          | DEFAULT         | DESCRIPTION                                                                                                                                                |
|---------------------------------------|-----|----------------|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R30 (1Eh)<br>DAC Digital Volume Left  | 8   | DAC_VU         | N/A             | DAC Volume Update<br>Writing a 1 to this bit causes left and right DAC volume to be updated simultaneously                                                 |
|                                       | 7:0 | DACL_VOL [7:0] | 1100_0000 (0dB) | Left DAC Digital Volume<br>00h = Mute<br>01h = -71.625dB<br>02h = -71.250dB<br>... (0.375dB steps)<br>C0h to FFh = 0dB<br>(See Table 34 for volume range)  |
| R31 (1Fh)<br>DAC Digital Volume Right | 8   | DAC_VU         | N/A             | DAC Volume Update<br>Writing a 1 to this bit causes left and right DAC volume to be updated simultaneously                                                 |
|                                       | 7:0 | DACR_VOL [7:0] | 1100_0000 (0dB) | Right DAC Digital Volume<br>00h = Mute<br>01h = -71.625dB<br>02h = -71.250dB<br>... (0.375dB steps)<br>C0h to FFh = 0dB<br>(See Table 34 for volume range) |

**Table 33 DAC Digital Volume Control**

| DACL_VOL or<br>DACR_VOL | Volume (dB) | DACL_VOL or<br>DACR_VOL | Volume (dB) | DACL_VOL or<br>DACR_VOL | Volume (dB) | DACL_VOL or<br>DACR_VOL | Volume (dB) |
|-------------------------|-------------|-------------------------|-------------|-------------------------|-------------|-------------------------|-------------|
| 0h                      | MUTE        | 40h                     | -48.000     | 80h                     | -24.000     | C0h                     | 0.000       |
| 1h                      | -71.625     | 41h                     | -47.625     | 81h                     | -23.625     | C1h                     | 0.000       |
| 2h                      | -71.250     | 42h                     | -47.250     | 82h                     | -23.250     | C2h                     | 0.000       |
| 3h                      | -70.875     | 43h                     | -46.875     | 83h                     | -22.875     | C3h                     | 0.000       |
| 4h                      | -70.500     | 44h                     | -46.500     | 84h                     | -22.500     | C4h                     | 0.000       |
| 5h                      | -70.125     | 45h                     | -46.125     | 85h                     | -22.125     | C5h                     | 0.000       |
| 6h                      | -69.750     | 46h                     | -45.750     | 86h                     | -21.750     | C6h                     | 0.000       |
| 7h                      | -69.375     | 47h                     | -45.375     | 87h                     | -21.375     | C7h                     | 0.000       |
| 8h                      | -69.000     | 48h                     | -45.000     | 88h                     | -21.000     | C8h                     | 0.000       |
| 9h                      | -68.625     | 49h                     | -44.625     | 89h                     | -20.625     | C9h                     | 0.000       |
| Ah                      | -68.250     | 4Ah                     | -44.250     | 8Ah                     | -20.250     | CAh                     | 0.000       |
| Bh                      | -67.875     | 4Bh                     | -43.875     | 8Bh                     | -19.875     | CBh                     | 0.000       |
| Ch                      | -67.500     | 4Ch                     | -43.500     | 8Ch                     | -19.500     | CCh                     | 0.000       |
| Dh                      | -67.125     | 4Dh                     | -43.125     | 8Dh                     | -19.125     | CDh                     | 0.000       |
| Eh                      | -66.750     | 4Eh                     | -42.750     | 8Eh                     | -18.750     | CEh                     | 0.000       |
| Fh                      | -66.375     | 4Fh                     | -42.375     | 8Fh                     | -18.375     | CFh                     | 0.000       |
| 10h                     | -66.000     | 50h                     | -42.000     | 90h                     | -18.000     | D0h                     | 0.000       |
| 11h                     | -65.625     | 51h                     | -41.625     | 91h                     | -17.625     | D1h                     | 0.000       |
| 12h                     | -65.250     | 52h                     | -41.250     | 92h                     | -17.250     | D2h                     | 0.000       |
| 13h                     | -64.875     | 53h                     | -40.875     | 93h                     | -16.875     | D3h                     | 0.000       |
| 14h                     | -64.500     | 54h                     | -40.500     | 94h                     | -16.500     | D4h                     | 0.000       |
| 15h                     | -64.125     | 55h                     | -40.125     | 95h                     | -16.125     | D5h                     | 0.000       |
| 16h                     | -63.750     | 56h                     | -39.750     | 96h                     | -15.750     | D6h                     | 0.000       |
| 17h                     | -63.375     | 57h                     | -39.375     | 97h                     | -15.375     | D7h                     | 0.000       |
| 18h                     | -63.000     | 58h                     | -39.000     | 98h                     | -15.000     | D8h                     | 0.000       |
| 19h                     | -62.625     | 59h                     | -38.625     | 99h                     | -14.625     | D9h                     | 0.000       |
| 1Ah                     | -62.250     | 5Ah                     | -38.250     | 9Ah                     | -14.250     | DAh                     | 0.000       |
| 1Bh                     | -61.875     | 5Bh                     | -37.875     | 9Bh                     | -13.875     | DBh                     | 0.000       |
| 1Ch                     | -61.500     | 5Ch                     | -37.500     | 9Ch                     | -13.500     | DCh                     | 0.000       |
| 1Dh                     | -61.125     | 5Dh                     | -37.125     | 9Dh                     | -13.125     | DDh                     | 0.000       |
| 1Eh                     | -60.750     | 5Eh                     | -36.750     | 9Eh                     | -12.750     | DEh                     | 0.000       |
| 1Fh                     | -60.375     | 5Fh                     | -36.375     | 9Fh                     | -12.375     | DFh                     | 0.000       |
| 20h                     | -60.000     | 60h                     | -36.000     | A0h                     | -12.000     | E0h                     | 0.000       |
| 21h                     | -59.625     | 61h                     | -35.625     | A1h                     | -11.625     | E1h                     | 0.000       |
| 22h                     | -59.250     | 62h                     | -35.250     | A2h                     | -11.250     | E2h                     | 0.000       |
| 23h                     | -58.875     | 63h                     | -34.875     | A3h                     | -10.875     | E3h                     | 0.000       |
| 24h                     | -58.500     | 64h                     | -34.500     | A4h                     | -10.500     | E4h                     | 0.000       |
| 25h                     | -58.125     | 65h                     | -34.125     | A5h                     | -10.125     | E5h                     | 0.000       |
| 26h                     | -57.750     | 66h                     | -33.750     | A6h                     | -9.750      | E6h                     | 0.000       |
| 27h                     | -57.375     | 67h                     | -33.375     | A7h                     | -9.375      | E7h                     | 0.000       |
| 28h                     | -57.000     | 68h                     | -33.000     | A8h                     | -9.000      | E8h                     | 0.000       |
| 29h                     | -56.625     | 69h                     | -32.625     | A9h                     | -8.625      | E9h                     | 0.000       |
| 2Ah                     | -56.250     | 6Ah                     | -32.250     | AAh                     | -8.250      | EAh                     | 0.000       |
| 2Bh                     | -55.875     | 6Bh                     | -31.875     | ABh                     | -7.875      | EBh                     | 0.000       |
| 2Ch                     | -55.500     | 6Ch                     | -31.500     | ACH                     | -7.500      | ECh                     | 0.000       |
| 2Dh                     | -55.125     | 6Dh                     | -31.125     | ADh                     | -7.125      | EDh                     | 0.000       |
| 2Eh                     | -54.750     | 6Eh                     | -30.750     | AEh                     | -6.750      | EEh                     | 0.000       |
| 2Fh                     | -54.375     | 6Fh                     | -30.375     | AFh                     | -6.375      | EFh                     | 0.000       |
| 30h                     | -54.000     | 70h                     | -30.000     | B0h                     | -6.000      | F0h                     | 0.000       |
| 31h                     | -53.625     | 71h                     | -29.625     | B1h                     | -5.625      | F1h                     | 0.000       |
| 32h                     | -53.250     | 72h                     | -29.250     | B2h                     | -5.250      | F2h                     | 0.000       |
| 33h                     | -52.875     | 73h                     | -28.875     | B3h                     | -4.875      | F3h                     | 0.000       |
| 34h                     | -52.500     | 74h                     | -28.500     | B4h                     | -4.500      | F4h                     | 0.000       |
| 35h                     | -52.125     | 75h                     | -28.125     | B5h                     | -4.125      | F5h                     | 0.000       |
| 36h                     | -51.750     | 76h                     | -27.750     | B6h                     | -3.750      | F6h                     | 0.000       |
| 37h                     | -51.375     | 77h                     | -27.375     | B7h                     | -3.375      | F7h                     | 0.000       |
| 38h                     | -51.000     | 78h                     | -27.000     | B8h                     | -3.000      | F8h                     | 0.000       |
| 39h                     | -50.625     | 79h                     | -26.625     | B9h                     | -2.625      | F9h                     | 0.000       |
| 3Ah                     | -50.250     | 7Ah                     | -26.250     | BAh                     | -2.250      | FAh                     | 0.000       |
| 3Bh                     | -49.875     | 7Bh                     | -25.875     | BBh                     | -1.875      | FBh                     | 0.000       |
| 3Ch                     | -49.500     | 7Ch                     | -25.500     | BCh                     | -1.500      | FCh                     | 0.000       |
| 3Dh                     | -49.125     | 7Dh                     | -25.125     | BDh                     | -1.125      | FDh                     | 0.000       |
| 3Eh                     | -48.750     | 7Eh                     | -24.750     | BEh                     | -0.750      | FEh                     | 0.000       |
| 3Fh                     | -48.375     | 7Fh                     | -24.375     | BFh                     | -0.375      | FFh                     | 0.000       |

**Table 34 DAC Digital Volume Range**

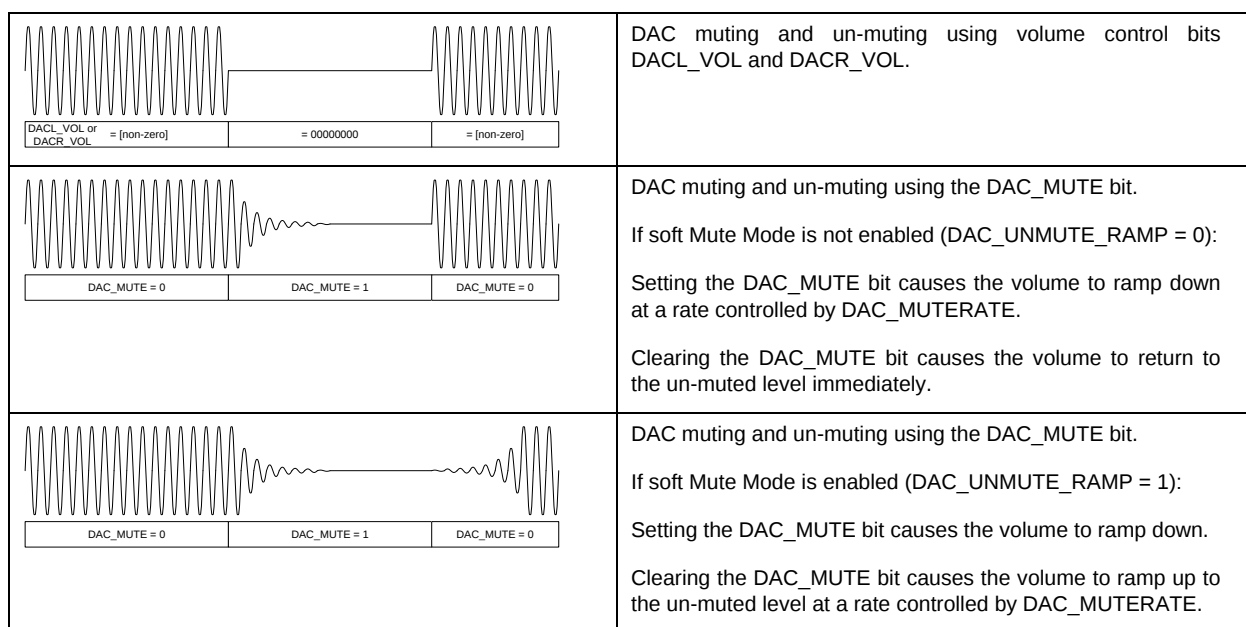
## DAC SOFT MUTE AND SOFT UN-MUTE

The WM8904 has a soft mute function. When enabled, this gradually attenuates the volume of the DAC output. When soft mute is disabled, the gain will either gradually ramp back up to the digital gain setting, or return instantly to the digital gain setting, depending on the DAC\_UNMUTE\_RAMP register bit.

To mute the DAC, this function must be enabled by setting DAC\_MUTE to 1.

Soft Mute Mode would typically be enabled (DAC\_UNMUTE\_RAMP = 1) when using DAC\_MUTE during playback of audio data so that when DAC\_MUTE is subsequently disabled, the sudden volume increase will not create pop noise by jumping immediately to the previous volume level (e.g. resuming playback after pausing during a track).

Soft Mute Mode would typically be disabled (DAC\_UNMUTE\_RAMP = 0) when un-muting at the start of a music file, in order that the first part of the track is not attenuated (e.g. when starting playback of a new track, or resuming playback after pausing between tracks).



**Figure 36 DAC Mute Control**

The volume ramp rate during soft mute and un-mute is controlled by the DAC\_MUTERATE bit. Ramp rates of fs/32 and fs/2 can be selected, as shown in Table 35. The ramp rate determines the rate at which the volume is increased or decreased. The actual ramp time depends on the extent of the difference between the muted and un-muted volume settings.

| REGISTER ADDRESS           | BIT | LABEL           | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                   |
|----------------------------|-----|-----------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R33 (21h)<br>DAC Digital 1 | 10  | DAC_MUTERATE    | 0       | DAC Soft Mute Ramp Rate<br>0 = Fast ramp (fs/2, maximum ramp time is 10.7ms at fs=48k)<br>1 = Slow ramp (fs/32, maximum ramp time is 171ms at fs=48k)                                                                                                                         |
|                            | 9   | DAC_UNMUTE_RAMP | 0       | DAC Soft Mute Mode<br>0 = Disabling soft-mute (DAC_MUTE=0) will cause the DAC volume to change immediately to DACL_VOL and DACR_VOL settings<br><br>1 = Disabling soft-mute (DAC_MUTE=0) will cause the DAC volume to ramp up gradually to the DACL_VOL and DACR_VOL settings |
|                            | 3   | DAC_MUTE        | 1       | DAC Soft Mute Control<br>0 = DAC Un-mute<br>1 = DAC Mute                                                                                                                                                                                                                      |

**Table 35 DAC Soft-Mute Control**

### DAC MONO MIX

A DAC digital mono-mix mode can be enabled using the DAC\_MONO register bit. This mono mix will be output on whichever DAC is enabled. To prevent clipping, a -6dB attenuation is automatically applied to the mono mix.

The mono mix is only supported when one or other DAC is disabled. When the mono mix is selected, then the mono mix is output on the enabled DAC only; there is no output from the disabled DAC. If DACL\_ENA and DACR\_ENA are both set, then stereo operation applies.

| REGISTER ADDRESS           | BIT | LABEL    | DEFAULT | DESCRIPTION                                                             |
|----------------------------|-----|----------|---------|-------------------------------------------------------------------------|
| R33 (21h)<br>DAC Digital 1 | 12  | DAC_MONO | 0       | DAC Mono Mix<br>0 = Stereo<br>1 = Mono (Mono mix output on enabled DAC) |

**Table 36 DAC Mono Mix**

### DAC DE-EMPHASIS

Digital de-emphasis can be applied to the DAC playback data (e.g. when the data comes from a CD with pre-emphasis used in the recording). De-emphasis filtering is available for sample rates of 48kHz, 44.1kHz and 32kHz. See "Digital Filter Characteristics" for details of de-emphasis filter characteristics.

| REGISTER ADDRESS           | BIT | LABEL        | DEFAULT | DESCRIPTION                                                                                                                    |
|----------------------------|-----|--------------|---------|--------------------------------------------------------------------------------------------------------------------------------|
| R33 (21h)<br>DAC Digital 1 | 2:1 | DEEMPH [1:0] | 00      | DAC De-Emphasis Control<br>00 = No de-emphasis<br>01 = 32kHz sample rate<br>10 = 44.1kHz sample rate<br>11 = 48kHz sample rate |

**Table 37 DAC De-Emphasis Control**

### DAC SLOPING STOPBAND FILTER

Two DAC filter types are available, selected by the register bit DAC\_SB\_FILT. When operating at sample rates  $\leq 24\text{kHz}$  (eg. during voice communication) it is recommended that the sloping stopband filter type is selected (DAC\_SB\_FILT=1) to reduce out-of-band noise which can be audible at low DAC sample rates. See "Digital Filter Characteristics" for details of DAC filter characteristics.

| REGISTER ADDRESS           | BIT | LABEL       | DEFAULT | DESCRIPTION                                                                                                                       |
|----------------------------|-----|-------------|---------|-----------------------------------------------------------------------------------------------------------------------------------|
| R33 (21h)<br>DAC Digital 1 | 11  | DAC_SB_FILT | 0       | Selects DAC filter characteristics<br>0 = Normal mode<br>1 = Sloping stopband mode<br>(recommended when $f_s \leq 24\text{kHz}$ ) |

**Table 38 DAC Sloping Stopband Filter**

### DAC OVERSAMPLING RATIO (OSR)

The DAC oversampling rate is programmable to allow power consumption versus audio performance trade-offs. The default oversampling rate is low for reduced power consumption; using the higher OSR setting improves the DAC signal-to-noise performance.

| REGISTER ADDRESS           | BIT | LABEL      | DEFAULT | DESCRIPTION                                                                                   |
|----------------------------|-----|------------|---------|-----------------------------------------------------------------------------------------------|
| R33 (21h)<br>DAC Digital 1 | 6   | DAC_OSR128 | 0       | DAC Oversample Rate Select<br>0 = Low power (normal OSR)<br>1 = High performance (double OSR) |

**Table 39 DAC Oversampling Control**

## OUTPUT SIGNAL PATH

The outputs HPOUTL and LINEOUTL are normally derived from the Left DAC output, whilst the outputs HPOUTR and LINEOUTR are normally derived from the Right DAC output, as illustrated in Figure 37. A multiplexer is provided on each output path to select the BYPASSL or BYPASSR analogue input signals in place of the DAC outputs.

A feedback path for common mode noise rejection is provided at HPOUTFB and LINEOUTFB for the Headphone and Line outputs respectively. This pin must be connected to ground for normal operation.

Each analogue output can be separately enabled; independent volume control is also provided for each output. The output signal paths and associated control registers are illustrated in Figure 37. See "Analogue Outputs" for details of the external connections to these outputs.

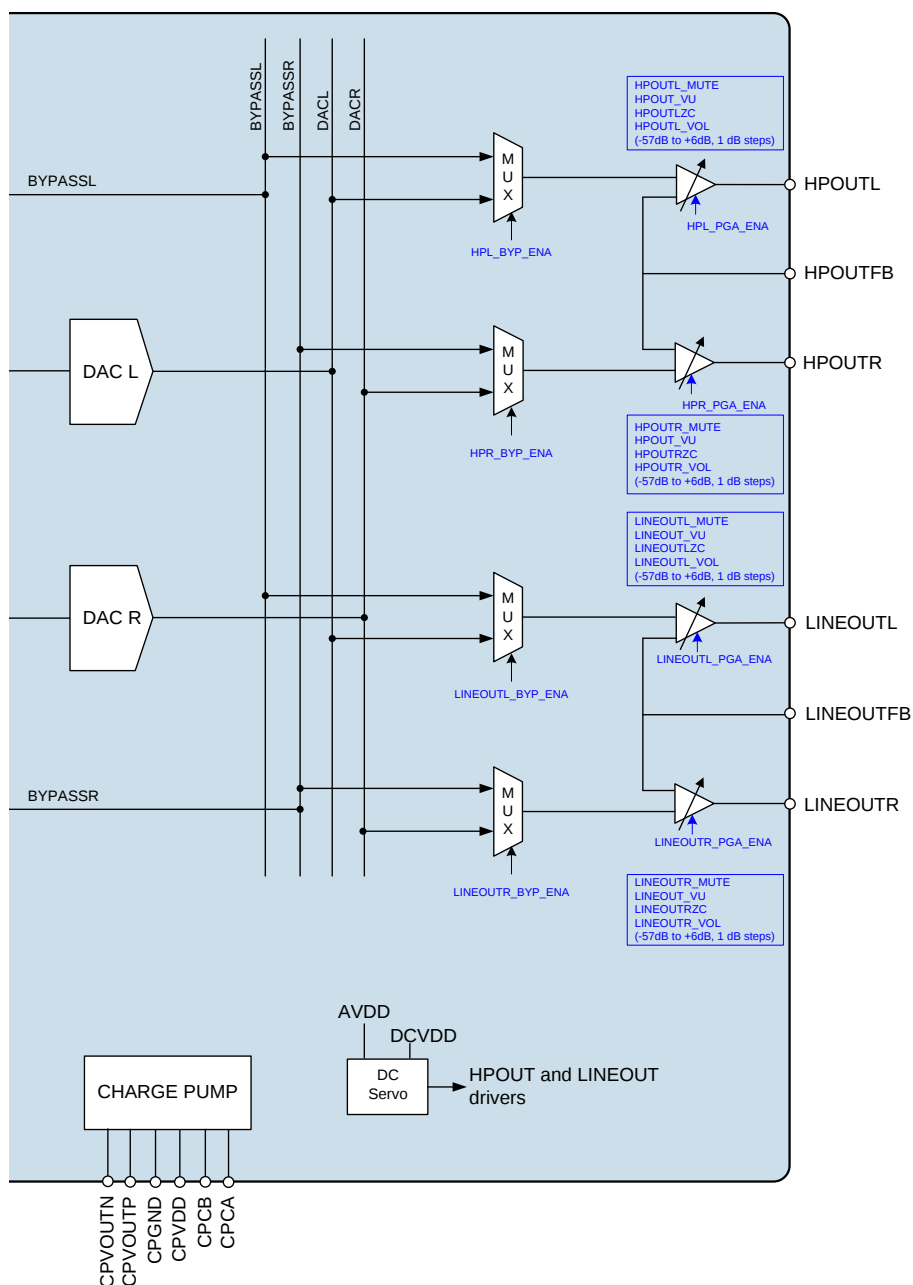


Figure 37 Output Signal Path and Control Registers

## OUTPUT SIGNAL PATHS ENABLE

The output PGAs for each analogue output pin can be enabled and disabled using the register bits described in Table 40.

Note that the Headphone Outputs and Line Outputs are also controlled by fields located within Register R90 and R94, which provide suppression of pops & clicks when enabling and disabling these signal paths. These registers are described in the following “Headphone / Line Output Signal Paths Enable” section.

Under recommended usage conditions, all the control bits associated with enabling the Headphone Outputs and the Line Outputs will be configured by scheduling the default Start-Up and Shutdown sequences as described in the “Control Write Sequencer” section. In these cases, the user does not need to set the register fields in R14, R15, R90 and R94 directly.

| REGISTER ADDRESS                | BIT | LABEL            | DEFAULT | DESCRIPTION                                                  |
|---------------------------------|-----|------------------|---------|--------------------------------------------------------------|
| R14 (0Eh)<br>Power Management 2 | 1   | HPL_PGA_ENA      | 0       | Left Headphone Output Enable<br>0 = disabled<br>1 = enabled  |
|                                 | 0   | HPR_PGA_ENA      | 0       | Right Headphone Output Enable<br>0 = disabled<br>1 = enabled |
| R15 (0Fh)<br>Power Management 3 | 1   | LINEOUTL_PGA_ENA | 0       | Left Line Output Enable<br>0 = disabled<br>1 = enabled       |
|                                 | 0   | LINEOUTR_PGA_ENA | 0       | Right Line Output Enable<br>0 = disabled<br>1 = enabled      |

**Table 40 Output Signal Paths Enable**

To enable the output PGAs and multiplexers, the reference voltage VMID and the bias current must also be enabled. See “Reference Voltages and Master Bias” for details of the associated controls VMID\_RES and BIAS\_ENA.

## HEADPHONE / LINE OUTPUT SIGNAL PATHS ENABLE

The output paths can be actively discharged to AGND through internal resistors if desired. This is desirable at start-up in order to achieve a known output stage condition prior to enabling the VMID reference voltage. This is also desirable in shutdown to prevent the external connections from being affected by the internal circuits. The ground-referenced Headphone outputs and Line outputs are shorted to AGND by default; the short circuit is removed on each of these paths by setting the applicable fields HPL\_RMV\_SHORT, HPR\_RMV\_SHORT, LINEOUTL\_RMV\_SHORT or LINEOUTR\_RMV\_SHORT.

The ground-referenced Headphone output and Line output drivers are designed to suppress pops and clicks when enabled or disabled. However, it is necessary to control the drivers in accordance with a defined sequence in start-up and shutdown to achieve the pop suppression. It is also necessary to schedule the DC Servo offset correction at the appropriate point in the sequence (see “DC Servo”). Table 41 and Table 42 describe the recommended sequences for enabling and disabling these output drivers.

| SEQUENCE | HEADPHONE ENABLE                       | LINEOUT ENABLE                                   |
|----------|----------------------------------------|--------------------------------------------------|
| Step 1   | HPL_ENA = 1<br>HPR_ENA = 1             | LINEOUTL_ENA = 1<br>LINEOUTR_ENA = 1             |
| Step 2   | HPL_ENA_DLY = 1<br>HPR_ENA_DLY = 1     | LINEOUTL_ENA_DLY = 1<br>LINEOUTR_ENA_DLY = 1     |
| Step 3   | DC offset correction                   | DC offset correction                             |
| Step 4   | HPL_ENA_OUTP = 1<br>HPR_ENA_OUTP = 1   | LINEOUTL_ENA_OUTP = 1<br>LINEOUTR_ENA_OUTP = 1   |
| Step 5   | HPL_RMV_SHORT = 1<br>HPR_RMV_SHORT = 1 | LINEOUTL_RMV_SHORT = 1<br>LINEOUTR_RMV_SHORT = 1 |

**Table 41 Headphone / Line Output Enable Sequence**

| SEQUENCE | HEADPHONE DISABLE                                                                                        | LINEOUT DISABLE                                                                                                                        |
|----------|----------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| Step 1   | HPL_RMV_SHORT = 0<br>HPR_RMV_SHORT = 0                                                                   | LINEOUTL_RMV_SHORT = 0<br>LINEOUTR_RMV_SHORT = 0                                                                                       |
| Step 2   | HPL_ENA = 0<br>HPL_ENA_DLY = 0<br>HPL_ENA_OUTP = 0<br>HPR_ENA = 0<br>HPR_ENA_DLY = 0<br>HPR_ENA_OUTP = 0 | LINEOUTL_ENA = 0<br>LINEOUTL_ENA_DLY = 0<br>LINEOUTL_ENA_OUTP = 0<br>LINEOUTR_ENA = 0<br>LINEOUTR_ENA_DLY = 0<br>LINEOUTR_ENA_OUTP = 0 |

**Table 42 Headphone / Line Output Disable Sequence**

The registers relating to Headphone / Line Output pop suppression control are defined in Table 43.

| REGISTER ADDRESS              | BIT | LABEL         | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                         |
|-------------------------------|-----|---------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R90 (5Ah)<br>Analogue<br>HP 0 | 7   | HPL_RMV_SHORT | 0       | Removes HPL short<br>0 = HPL short enabled<br>1 = HPL short removed<br>For normal operation, this bit should be set as the final step of the HPL Enable sequence.                                                                                                                   |
|                               | 6   | HPL_ENA_OUTP  | 0       | Enables HPL output stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set to 1 after the DC offset cancellation has been scheduled.                                                                                                                   |
|                               | 5   | HPL_ENA_DLY   | 0       | Enables HPL intermediate stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set to 1 after the output signal path has been configured, and before DC offset cancellation is scheduled. This bit should be set with at least 20us delay after HPL_ENA. |
|                               | 4   | HPL_ENA       | 0       | Enables HPL input stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set as the first step of the HPL Enable sequence.                                                                                                                                |

| REGISTER ADDRESS                | BIT | LABEL              | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                   |
|---------------------------------|-----|--------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                 | 3   | HPR_RMV_SHORT      | 0       | Removes HPR short<br>0 = HPR short enabled<br>1 = HPR short removed<br>For normal operation, this bit should be set as the final step of the HPR Enable sequence.                                                                                                                             |
|                                 | 2   | HPR_ENA_OUTP       | 0       | Enables HPR output stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set to 1 after the DC offset cancellation has been scheduled.                                                                                                                             |
|                                 | 1   | HPR_ENA_DLY        | 0       | Enables HPR intermediate stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set to 1 after the output signal path has been configured, and before DC offset cancellation is scheduled. This bit should be set with at least 20us delay after HPR_ENA.           |
|                                 | 0   | HPR_ENA            | 0       | Enables HPR input stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set as the first step of the HPR Enable sequence.                                                                                                                                          |
| R94 (5Eh)<br>Analogue Lineout 0 | 7   | LINEOUTL_RMV_SHORT | 0       | Removes LINEOUTL short<br>0 = LINEOUTL short enabled<br>1 = LINEOUTL short removed<br>For normal operation, this bit should be set as the final step of the LINEOUTL Enable sequence.                                                                                                         |
|                                 | 6   | LINEOUTL_ENA_OUTP  | 0       | Enables LINEOUTL output stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set to 1 after the DC offset cancellation has been scheduled.                                                                                                                        |
|                                 | 5   | LINEOUTL_ENA_DLY   | 0       | Enables LINEOUTL intermediate stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set to 1 after the output signal path has been configured, and before DC offset cancellation is scheduled. This bit should be set with at least 20us delay after LINEOUTL_ENA. |
|                                 | 4   | LINEOUTL_ENA       | 0       | Enables LINEOUTL input stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set as the first step of the LINEOUTL Enable sequence.                                                                                                                                |

| REGISTER ADDRESS | BIT | LABEL              | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                       |
|------------------|-----|--------------------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                  | 3   | LINEOUTR_RMV_SHORT | 0       | Removes LINEOUTR short<br>0 = LINEOUTR short enabled<br>1 = LINEOUTR short removed<br><br>For normal operation, this bit should be set as the final step of the LINEOUTR Enable sequence.                                                                                                         |
|                  | 2   | LINEOUTR_ENA_OUTP  | 0       | Enables LINEOUTR output stage<br>0 = Disabled<br>1 = Enabled<br><br>For normal operation, this bit should be set to 1 after the DC offset cancellation has been scheduled.                                                                                                                        |
|                  | 1   | LINEOUTR_ENA_DLY   | 0       | Enables LINEOUTR intermediate stage<br>0 = Disabled<br>1 = Enabled<br><br>For normal operation, this bit should be set to 1 after the output signal path has been configured, and before DC offset cancellation is scheduled. This bit should be set with at least 20us delay after LINEOUTR_ENA. |
|                  | 0   | LINEOUTR_ENA       | 0       | Enables LINEOUTR input stage<br>0 = Disabled<br>1 = Enabled<br><br>For normal operation, this bit should be set as the first step of the LINEOUTR Enable sequence.                                                                                                                                |

**Table 43 Headphone / Line Output Pop Suppression Control**

### OUTPUT MUX CONTROL

By default, the DAC outputs are routed directly to the respective output PGAs. A multiplexer (mux) is provided on each output path to select the BYPASSL or BYPASSR analogue signals from the Left/Right Input PGAs in place of the DAC outputs.

The output multiplexers are configured using the register bits described in Table 44.

| REGISTER ADDRESS                  | BIT | LABEL            | DEFAULT | DESCRIPTION                                                                                            |
|-----------------------------------|-----|------------------|---------|--------------------------------------------------------------------------------------------------------|
| R61 (3Dh)<br>Analogue<br>OUT12 ZC | 3   | HPL_BYP_ENA      | 0       | Selects input for left headphone output MUX<br>0 = Left DAC<br>1 = Left input PGA (Analogue bypass)    |
|                                   | 2   | HPR_BYP_ENA      | 0       | Selects input for right headphone output MUX<br>0 = Right DAC<br>1 = Right input PGA (Analogue bypass) |
|                                   | 1   | LINEOUTL_BYP_ENA | 0       | Selects input for left line output MUX<br>0 = Left DAC<br>1 = Left input PGA (Analogue bypass)         |

| REGISTER ADDRESS | BIT | LABEL            | DEFAULT | DESCRIPTION                                                                                       |
|------------------|-----|------------------|---------|---------------------------------------------------------------------------------------------------|
|                  | 0   | LINEOUTR_BYP_ENA | 0       | Selects input for right line output MUX<br>0 = Right DAC<br>1 = Right input PGA (Analogue bypass) |

**Table 44 Output Mux Control**

## OUTPUT VOLUME CONTROL

Each analogue output can be independently controlled. The headphone output control fields are described in Table 45. The line output control fields are described in Table 46. The output pins are described in more detail in "Analogue Outputs".

The volume and mute status of each output can be controlled individually using the bit fields shown in Table 45 and Table 46.

To prevent "zipper noise" when a volume adjustment is made, a zero-cross function is provided on all output paths. When this function is enabled, volume updates will not take place until a zero-crossing is detected. In the event of a long period without zero-crossings, a timeout will apply. The timeout must be enabled by setting the TOCLK\_ENA bit, as defined in "Clocking and Sample Rates".

The volume update bits control the loading of the output driver volume data. For example, when HPOUT\_VU is set to 0, the headphone volume data can be loaded into the respective control register, but will not actually change the gain setting. The Left and Right headphone volume settings are updated when a 1 is written to HPOUT\_VU. This makes it possible to update the gain of a Left/Right pair of output paths simultaneously.

| REGISTER ADDRESS                   | BIT | LABEL            | DEFAULT | DESCRIPTION                                                                                                                                              |
|------------------------------------|-----|------------------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| R57 (39h)<br>Analogue<br>OUT1 Left | 8   | HPOUTL_MUTE      | 0       | Left Headphone Output Mute<br>0 = Un-mute<br>1 = Mute                                                                                                    |
|                                    | 7   | HPOUT_VU         | 0       | Headphone Output Volume Update<br>Writing a 1 to this bit will update HPOUTL and HPOUTR volumes simultaneously.                                          |
|                                    | 6   | HPOUTLZC         | 0       | Left Headphone Output Zero Cross Enable<br>0 = disabled<br>1 = enabled                                                                                   |
|                                    | 5:0 | HPOUTL_VOL [5:0] | 10_1101 | Left Headphone Output Volume<br>000000 = -57dB<br>000001 = -56dB<br>(... 1dB steps)<br>111001 = 0dB<br>(... 1dB steps)<br>111110 = +5dB<br>111111 = +6dB |

| REGISTER ADDRESS                    | BIT | LABEL               | DEFAULT | DESCRIPTION                                                                                                                                               |
|-------------------------------------|-----|---------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| R58 (3Ah)<br>Analogue<br>OUT1 Right | 8   | HPOUTR_MUTE         | 0       | Right Headphone Output Mute<br>0 = Un-mute<br>1 = Mute                                                                                                    |
|                                     | 7   | HPOUT_VU            | 0       | Headphone Output Volume Update<br>Writing a 1 to this bit will update<br>HPOUTL and HPOUTR volumes<br>simultaneously.                                     |
|                                     | 6   | HPOUTRZC            | 0       | Right Headphone Output Zero Cross<br>Enable<br>0 = disabled<br>1 = enabled                                                                                |
|                                     | 5:0 | HPOUTR_VOL<br>[5:0] | 10_1101 | Right Headphone Output Volume<br>000000 = -57dB<br>000001 = -56dB<br>(... 1dB steps)<br>111001 = 0dB<br>(... 1dB steps)<br>111110 = +5dB<br>111111 = +6dB |

**Table 45 Volume Control for HPOUTL and HPOUTR**

| REGISTER ADDRESS                    | BIT | LABEL                 | DEFAULT | DESCRIPTION                                                                                                                                         |
|-------------------------------------|-----|-----------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| R59 (3Bh)<br>Analogue<br>OUT2 Left  | 8   | LINEOUTL_MUTE         | 0       | Left Line Output Mute<br>0 = Un-mute<br>1 = Mute                                                                                                    |
|                                     | 7   | LINEOUT_VU            | 0       | Line Output Volume Update<br>Writing a 1 to this bit will update<br>LINEOUTL and LINEOUTR volumes<br>simultaneously.                                |
|                                     | 6   | LINEOUTLZC            | 0       | Left Line Output Zero Cross Enable<br>0 = disabled<br>1 = enabled                                                                                   |
|                                     | 5:0 | LINEOUTL_VOL<br>[5:0] | 11_1001 | Left Line Output Volume<br>000000 = -57dB<br>000001 = -56dB<br>(... 1dB steps)<br>111001 = 0dB<br>(... 1dB steps)<br>111110 = +5dB<br>111111 = +6dB |
| R60 (3Ch)<br>Analogue<br>OUT2 Right | 8   | LINEOUTR_MUTE         | 0       | Right Line Output Mute<br>0 = Un-mute<br>1 = Mute                                                                                                   |
|                                     | 7   | LINEOUT_VU            | 0       | Line Output Volume Update<br>Writing a 1 to this bit will update<br>LINEOUTL and LINEOUTR volumes<br>simultaneously.                                |
|                                     | 6   | LINEOUTRZC            | 0       | Right Line Output Zero Cross<br>Enable<br>0 = disabled<br>1 = enabled                                                                               |

| REGISTER ADDRESS | BIT | LABEL                 | DEFAULT | DESCRIPTION                                                                                                                                          |
|------------------|-----|-----------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------|
|                  | 5:0 | LINEOUTR_VOL<br>[5:0] | 11_1001 | Right Line Output Volume<br>000000 = -57dB<br>000001 = -56dB<br>(... 1dB steps)<br>111001 = 0dB<br>(... 1dB steps)<br>111110 = +5dB<br>111111 = +6dB |

**Table 46 Volume Control for LINEOUTL and LINEOUTR**

## ANALOGUE OUTPUTS

The WM8904 has four analogue output pins:

- Headphone outputs, HPOUTL and HPOUTR, with feedback HPOUTFB
- Line outputs, LINEOUTL and LINEOUTR, with feedback LINEOUTFB

The output signal paths and associated control registers are illustrated in Figure 37.

### HEADPHONE OUTPUTS – HPOUTL AND HPOUTR

The headphone outputs are designed to drive 16Ω or 32Ω headphones. These outputs are ground-referenced, i.e. no series capacitor is required between the pins and the headphone load. They are powered by an on-chip charge pump (see “Charge Pump” section). Signal volume at the headphone outputs is controlled as shown in Table 45.

The ground-referenced outputs incorporates a common mode, or ground loop, feedback path which provides rejection of system-related ground noise. The return path for the HPOUTL and HPOUTR outputs is via HPOUTFB. This pin must be connected to ground for normal operation of the headphone output. No register configuration is required.

### LINE OUTPUTS – LINEOUTL AND LINEOUTR

The line outputs are identical to the headphone outputs in design. They are ground-referenced and powered by the on-chip charge pump. Signal volume at the line outputs is controlled as shown in Table 46.

Note that these outputs are intended for driving line loads, as the charge pump powering both the Headphone and Line outputs can only provide sufficient power to drive one set of headphones at any given time.

The ground-referenced outputs incorporates a common mode, or ground loop, feedback path which provides rejection of system-related ground noise. The return path for the LINEOUTL and LINEOUTR outputs is via LINEOUTFB. This pin must be connected to ground for normal operation of the line output. No register configuration is required.

## EXTERNAL COMPONENTS FOR GROUND REFERENCED OUTPUTS

It is recommended to connect a zobel network to the ground-referenced outputs HPOUTL, HPOUTR, LINEOUTL and LINEOUTR in order to ensure best audio performance in all applications. The components of the zobel network have the effect of dampening high frequency oscillations or instabilities that can arise outside the audio band under certain conditions. Possible sources of these instabilities include the inductive load of a headphone coil or an active load in the form of an external line amplifier. The capacitance of lengthy cables or PCB tracks can also lead to amplifier instability. The zobel network should comprise a  $20\Omega$  resistor and  $100\text{nF}$  capacitor in series with each other, as illustrated in Figure 38.

Note that the zobel network is recommended for best audio quality and amplifier stability in all cases.

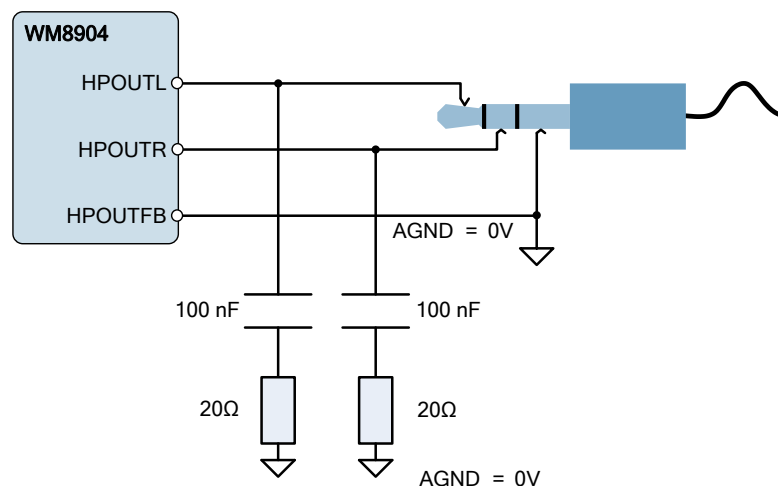


Figure 38 Zobel Network Components for HPOUTL, HPOUTR, LINEOUTL and LINEOUTR

## REFERENCE VOLTAGES AND MASTER BIAS

This section describes the analogue reference voltage and bias current controls. Note that, under the recommended usage conditions of the WM8904, these features will be configured by scheduling the default Start-Up and Shutdown sequences as described in the "Control Write Sequencer" section. In these cases, the user does not need to set these register fields directly.

### ANALOGUE REFERENCE AND MASTER BIAS

The analogue circuits in the WM8904 require a mid-rail analogue reference voltage, VMID. This reference is generated from AVDD via a programmable resistor chain.

VMID is enabled by setting the VMID\_ENA register bit. The programmable resistor chain is configured by VMID\_RES [1:0], and can be used to optimise the reference for normal operation, low power standby or for fast start-up as described in Table 47. For normal operation, the VMID\_RES field should be set to 01.

The VMID\_BUF\_ENA bit allows the buffered VMID reference to be connected to unused inputs/outputs.

The analogue circuits in the WM8904 require a bias current. The bias current is enabled by setting BIAS\_ENA. Note that the bias current source requires VMID to be enabled also.

The Bias current is controlled using the ISEL register field. Note that the ISEL register should only be changed as part of the 'Low Power Mode Enable' sequence described in Table 48. In all other cases, it is recommended that the ISEL register is not changed from the default setting.

| REGISTER ADDRESS             | BIT | LABEL          | DEFAULT | DESCRIPTION                                                                                                                                                                                                                        |
|------------------------------|-----|----------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R5 (05h)<br>VMID Control (0) | 6   | VMID_BUF_ENA   | 0       | Enable VMID buffer to unused Inputs/Outputs<br>0 = Disabled<br>1 = Enabled                                                                                                                                                         |
|                              | 2:1 | VMID_RES [1:0] | 00      | VMID Divider Enable and Select<br>00 = VMID disabled (for OFF mode)<br>01 = 2 x 50k divider (for normal operation)<br>10 = 2 x 250k divider (for low power standby)<br>11 = 2 x 5k divider (for fast start-up)                     |
|                              | 0   | VMID_ENA       | 0       | Enable VMID master bias current source<br>0 = Disabled<br>1 = Enabled                                                                                                                                                              |
| R4 (04h)<br>Bias Control (0) | 3:2 | ISEL [1:0]     | 10      | Master Bias Control<br>00 = Low power bias<br>01 = Reserved<br>10 = High performance bias (default)<br>11 = Reserved<br>Note that the ISEL register should only be changed as part of the Low Power Mode Enable/Disable sequences. |
|                              | 0   | BIAS_ENA       | 0       | Enables the Normal bias current generator (for all analogue functions)<br>0 = Disabled<br>1 = Enabled                                                                                                                              |

**Table 47 Reference Voltages and Master Bias Enable**

## LOW POWER PLAYBACK MODE

The analogue circuits of the WM8904 require a bias current. The default bias configuration is suitable for typical applications, and does not require any user adjustment.

For lowest power consumption in headphone or line output playback mode, the WM8904 bias settings must be configured using the register sequence described in Table 48.

Note that the low power playback bias settings are recommended for DAC / Playback modes only; they are not suitable for ADC / Record Path modes.

| REGISTER ADDRESS | VALUE |
|------------------|-------|
| 04h              | 0011h |
| 08h              | 0019h |
| CCh              | 0030h |
| 5Bh              | 0002h |
| 63h              | 2425h |
| 64h              | 2B23h |
| A1h              | 0002h |
| 65h              | 00C0h |
| A1h              | 0000h |

**Table 48 Low Power Playback Mode Enable Sequence**

The low power mode disable sequence is described in Table 49.

Note that the low power playback bias settings are not suitable for ADC / Record Path modes; the low power configuration must be disabled for these modes.

| REGISTER ADDRESS | VALUE |
|------------------|-------|
| 04h              | 0019h |
| 08h              | 0001h |
| CCh              | 0000h |
| 5Bh              | 0000h |
| 63h              | 1F25h |
| 64h              | 2B19h |
| A1h              | 0002h |
| 65h              | 01C0h |
| A1h              | 0000h |

**Table 49 Low Power Playback Mode Disable Sequence**

## POP SUPPRESSION CONTROL

The WM8904 incorporates SilentSwitch technology which enables pops normally associated with Start-Up, Shutdown or signal path control to be suppressed. To achieve maximum benefit from these features, careful attention is required to the sequence and timing of these controls. Note that, under the recommended usage conditions of the WM8904, these features will be configured by running the default Start-Up and Shutdown sequences as described in the “Control Write Sequencer” section. In these cases, the user does not need to set these register fields directly.

The Pop Suppression controls relating to the Headphone / Line Output drivers are described in the “Output Signal Path” section.

## DISABLED INPUT CONTROL

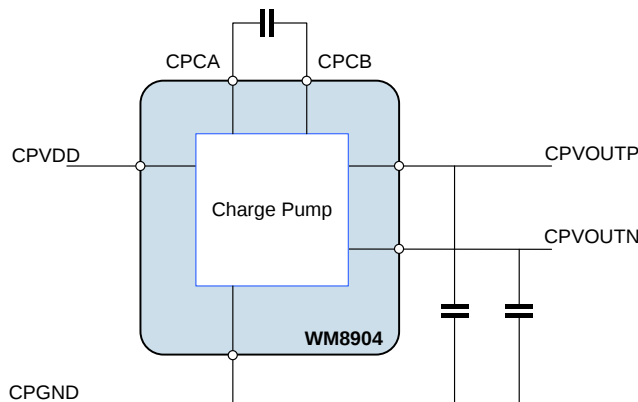
The analogue inputs to the WM8904 are biased to VMID in normal operation. In order to avoid audible pops caused by a disabled signal path dropping to AGND, the WM8904 can maintain these connections at VMID when the relevant input stage is disabled. This is achieved by connecting a buffered VMID reference to the input. The buffered VMID reference is enabled by setting VMID\_BUF\_ENA; when the buffered VMID reference is enabled, it is connected to any unused input pins.

| REGISTER ADDRESS              | BIT | LABEL        | DEFAULT | DESCRIPTION                                                         |
|-------------------------------|-----|--------------|---------|---------------------------------------------------------------------|
| R5 (05h)<br>VMID<br>Control 0 | 6   | VMID_BUF_ENA | 0       | VMID buffer to unused Inputs/Outputs<br>0 = Disabled<br>1 = Enabled |
|                               | 0   | VMID_ENA     | 0       | VMID Buffer Enable<br>0 = Disabled<br>1 = Enabled                   |

**Table 50 Disabled Line Input Control**

## CHARGE PUMP

The WM8904 incorporates a dual-mode Charge Pump which generates the supply rails for the headphone and line output drivers, HPOUTL, HPOUTR, and LINEOUTL and LINEOUTR. The Charge Pump has a single supply input, CPVDD, and generates split rails CPVOUTP and CPVOUTN according to the selected mode of operation. The Charge Pump connections are illustrated in Figure 39 (see the “Electrical Characteristics” section for external component values). An input decoupling capacitor may also be required at CPVDD, depending upon the system configuration.



**Figure 39 Charge Pump External Connections**

The Charge Pump is enabled by setting the CP\_ENA bit. When enabled, the charge pump adjusts the output voltages (CPVOUTP and CPVOUTN) as well as the switching frequency in order to optimise the power consumption according to the operating conditions. This can take two forms, which are selected using the CP\_DYN\_PWR register bit.

- Register control (CP\_DYN\_PWR = 0)
- Dynamic control (CP\_DYN\_PWR = 1)

Under Register control, the HPOUTL\_VOL, HPOUTR\_VOL, LINEOUTL\_VOL and LINEOUTR\_VOL register settings are used to control the charge pump mode of operation.

Under Dynamic control, the audio signal level in the DAC is used to control the charge pump mode of operation. This is the Wolfson 'Class W' mode, which allows the power consumption to be optimised in real time, but can only be used if the DAC is the only signal source. This mode should not be used if any of the bypass paths are used to feed analogue inputs into the output signal path.

Under the recommended usage conditions of the WM8904, the Charge Pump will be enabled by running the default headphone Start-Up sequence as described in the "Control Write Sequencer" section. (Similarly, it will be disabled by running the Shutdown sequence.) In these cases, the user does not need to write to the CP\_ENA bit. The Charge Pump operating mode defaults to Register control; Dynamic control may be selected by setting the CP\_DYN\_PWR register bit, if appropriate.

When digital sidetone is used (see "Digital Mixing"), it is recommended that the Charge Pump operates in Register Control mode only (CP\_DYN\_PWR = 0). This is because the Dynamic Control mode (Class W) does not measure the sidetone signal level and hence the Charge Pump configuration cannot be optimised for all signal conditions when digital sidetone is enabled; this could lead to signal clipping.

Note that the charge pump clock is derived from internal clock SYSCLK; this may be derived from MCLK directly or else using the FLL output, as determined by the SYSCLK\_SRC bit. Under normal circumstances an external clock signal must be present for the charge pump to function. However, the FLL has a free-running mode that does not require an external clock but will generate an internal clock suitable for running the charge pump. The clock division from SYSCLK is handled transparently by the WM8904 without user intervention, as long as SYSCLK and sample rates are set correctly. Refer to the "Clocking and Sample Rates" section for more detail on the FLL and clocking configuration.

The Charge Pump control fields are described in Table 51.

| REGISTER ADDRESS           | BIT | LABEL      | DEFAULT | DESCRIPTION                                                                                                                                                                                                                              |
|----------------------------|-----|------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R98 (62h)<br>Charge Pump 0 | 0   | CP_ENA     | 0       | Enable charge-pump digits<br>0 = disable<br>1 = enable                                                                                                                                                                                   |
| R104 (68h)<br>Class W (0)  | 0   | CP_DYN_PWR | 0       | Enable dynamic charge pump power control<br>0 = Charge pump controlled by volume register settings (Class G)<br>1 = Charge pump controlled by real-time audio level (Class W)<br><br>Class W is recommended for lowest power consumption |

**Table 51 Charge Pump Control**

## DC SERVO

The WM8904 provides four DC servo circuits, two on the headphone outputs HPOUTL and HPOUTR and two on the line outputs LINEOUTL and LINEOUTR, to remove DC offset from these ground-referenced outputs. When enabled, the DC servos ensure that the DC level of these outputs remains within 1mV of ground. Removal of the DC offset is important because any deviation from GND at the output pin will cause current to flow through the load under quiescent conditions, resulting in increased power consumption. Additionally, the presence of DC offsets can result in audible pops and clicks at power up and power down.

The recommended usage of the DC Servo is initialised by running the default Start-Up sequence as described in the "Control Write Sequencer" section. The default Start-Up sequence executes a series of DC offset corrections, after which the measured offset correction is maintained on the headphone output channels. If a different usage is required, e.g. if a periodic DC offset correction is required, then the default Start-Up sequence may be modified according to specific requirements. The relevant control fields are described in the following paragraphs and are defined in Table 52.

### DC SERVO ENABLE AND START-UP

The DC Servo circuits are enabled on HPOUTL and HPOUTR by setting DCS\_ENA\_CHAN\_0 and DCS\_ENA\_CHAN\_1 respectively. Similarly, the DC Servo circuits are enabled on LINEOUTL and LINEOUTR by setting DCS\_ENA\_CHAN\_2 and DCS\_ENA\_CHAN\_3 respectively. When the DC Servo is enabled, the DC offset correction can be commanded in a number of different ways, including single-shot and periodically recurring events.

Writing a logic 1 to DCS\_TRIG\_STARTUP\_n initiates a series of DC offset measurements and applies the necessary correction to the associated output; ('n' = 3 for LINEOUTR channel, 2 for LINEOUTL channel, 1 for HPOUTR channel, 0 for HPOUTL channel). On completion, the output will be within 1mV of AGND. This is the DC Servo mode selected by the default Start-Up sequence. Completion of the DC offset correction triggered in this way is indicated by the DCS\_STARTUP\_COMPLETE field, as described in Table 52. Typically, this operation takes 86ms per channel.

Writing a logic 1 to DCS\_TRIG\_DAC\_WR\_n causes the DC offset correction to be set to the value contained in the DCS\_DAC\_WR\_VAL\_n fields in Registers R73 to R76. This mode is useful if the required offset correction has already been determined and stored; it is faster than the DCS\_TRIG\_STARTUP\_n mode, but relies on the accuracy of the stored settings. Completion of the DC offset correction triggered in this way is indicated by the DCS\_DAC\_WR\_COMPLETE field, as described in Table 52. Typically, this operation takes 2ms per channel.

When using either of the DC Servo options above, the status of the DC offset correction process is indicated by the DCS\_CAL\_COMPLETE field; this is the logical OR of the DCS\_STARTUP\_COMPLETE and DCS\_DAC\_WR\_COMPLETE fields.

The DC Servo control fields associated with start-up operation are described in Table 52. It is important to note that, to minimise audible pops/clicks, the Start-Up and DAC Write modes of DC Servo operation should be commanded as part of a control sequence which includes muting and shorting of the headphone outputs; a suitable sequence is defined in the default Start-Up sequence.

| REGISTER ADDRESS        | BIT | LABEL              | DEFAULT | DESCRIPTION                                                                                                                                                     |
|-------------------------|-----|--------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R68 (44h)<br>DC Servo 1 | 7   | DCS_TRIG_STARTUP_3 | 0       | Writing 1 to this bit selects Start-Up DC Servo mode for LINEOUTR.<br>In readback, a value of 1 indicates that the DC Servo Start-Up correction is in progress. |
|                         | 6   | DCS_TRIG_STARTUP_2 | 0       | Writing 1 to this bit selects Start-Up DC Servo mode for LINEOUTL.<br>In readback, a value of 1 indicates that the DC Servo Start-Up correction is in progress. |
|                         | 5   | DCS_TRIG_STARTUP_1 | 0       | Writing 1 to this bit selects Start-Up DC Servo mode for HPOUTR.<br>In readback, a value of 1 indicates that the DC Servo Start-Up correction is in progress.   |

| REGISTER ADDRESS        | BIT | LABEL                  | DEFAULT   | DESCRIPTION                                                                                                                                                                                                                                       |
|-------------------------|-----|------------------------|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                         | 4   | DCS_TRIG_STAR_TUP_0    | 0         | Writing 1 to this bit selects Start-Up DC Servo mode for HPOUTL.<br>In readback, a value of 1 indicates that the DC Servo Start-Up correction is in progress.                                                                                     |
|                         | 3   | DCS_TRIG_DAC_WR_3      | 0         | Writing 1 to this bit selects DAC Write DC Servo mode for LINEOUTR.<br>In readback, a value of 1 indicates that the DC Servo DAC Write correction is in progress.                                                                                 |
|                         | 2   | DCS_TRIG_DAC_WR_2      | 0         | Writing 1 to this bit selects DAC Write DC Servo mode for LINEOUTL.<br>In readback, a value of 1 indicates that the DC Servo DAC Write correction is in progress.                                                                                 |
|                         | 1   | DCS_TRIG_DAC_WR_1      | 0         | Writing 1 to this bit selects DAC Write DC Servo mode for HPOUTR.<br>In readback, a value of 1 indicates that the DC Servo DAC Write correction is in progress.                                                                                   |
|                         | 0   | DCS_TRIG_DAC_WR_0      | 0         | Writing 1 to this bit selects DAC Write DC Servo mode for HPOUTL.<br>In readback, a value of 1 indicates that the DC Servo DAC Write correction is in progress.                                                                                   |
| R67 (43h)<br>DC Servo 0 | 3   | DCS_ENA_CHAN_3         | 0         | DC Servo enable for LINEOUTR<br>0 = disabled<br>1 = enabled                                                                                                                                                                                       |
|                         | 2   | DCS_ENA_CHAN_2         | 0         | DC Servo enable for LINEOUTL<br>0 = disabled<br>1 = enabled                                                                                                                                                                                       |
|                         | 1   | DCS_ENA_CHAN_1         | 0         | DC Servo enable for HPOUTR<br>0 = disabled<br>1 = enabled                                                                                                                                                                                         |
|                         | 0   | DCS_ENA_CHAN_0         | 0         | DC Servo enable for HPOUTL<br>0 = disabled<br>1 = enabled                                                                                                                                                                                         |
| R73 (49h)<br>DC Servo 6 | 7:0 | DCS_DAC_WR_VAL_3 [7:0] | 0000 0000 | DC Offset value for LINEOUTR in DAC Write DC Servo mode in two's complement format.<br><br>In readback, the current DC offset value is returned in two's complement format.<br><br>Two's complement format:<br>LSB is 0.25mV.<br>Range is +/-32mV |

| REGISTER ADDRESS                 | BIT  | LABEL                      | DEFAULT   | DESCRIPTION                                                                                                                                                                                                                                                |
|----------------------------------|------|----------------------------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R74 (4Ah)<br>DC Servo 7          | 7:0  | DCS_DAC_WR_V<br>AL_2 [7:0] | 0000 0000 | <p>DC Offset value for LINEOUTL in DAC Write DC Servo mode in two's complement format.</p> <p>In readback, the current DC offset value is returned in two's complement format.</p> <p>Two's complement format:<br/>LSB is 0.25mV.<br/>Range is +/-32mV</p> |
| R75 (4Bh)<br>DC Servo 8          | 7:0  | DCS_DAC_WR_V<br>AL1 [7:0]  | 0000 0000 | <p>DC Offset value for HPOUTR in DAC Write DC Servo mode in two's complement format.</p> <p>In readback, the current DC offset value is returned in two's complement format.</p> <p>Two's complement format:<br/>LSB is 0.25mV.<br/>Range is +/-32mV</p>   |
| R76 (4Ch)<br>DC Servo 9          | 7:0  | DCS_DAC_WR_V<br>AL0 [7:0]  | 0000 0000 | <p>DC Offset value for HPOUTL in DAC Write DC Servo mode in two's complement format.</p> <p>In readback, the current DC offset value is returned in two's complement format.</p> <p>Two's complement format:<br/>LSB is 0.25mV.<br/>Range is +/-32mV</p>   |
| R77 (4Dh)<br>DC Servo Readback 0 | 11:8 | DCS_CAL_COMPLETE [3:0]     | 0000      | <p>DC Servo Complete status</p> <p>[3] - LINEOUTR<br/>[2] - LINEOUTL<br/>[1] - HPOUTR<br/>[0] - HPOUTL</p> <p>0 = DAC Write or Start-Up DC Servo mode not completed.<br/>1 = DAC Write or Start-Up DC Servo mode complete.</p>                             |
|                                  | 7:4  | DCS_DAC_WR_COMPLETE [3:0]  | 0000      | <p>DC Servo DAC Write status</p> <p>[3] - LINEOUTR<br/>[2] - LINEOUTL<br/>[1] - HPOUTR<br/>[0] - HPOUTL</p> <p>0 = DAC Write DC Servo mode not completed.<br/>1 = DAC Write DC Servo mode complete.</p>                                                    |

| REGISTER ADDRESS | BIT | LABEL                      | DEFAULT | DESCRIPTION                                                                                                                                                                            |
|------------------|-----|----------------------------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                  | 3:0 | DCS_STARTUP_COMPLETE [3:0] | 0000    | DC Servo Start-Up status<br>[3] - LINEOUTR<br>[2] - LINEOUTL<br>[1] - HPOUTR<br>[0] - HPOUTL<br><br>0 = Start-Up DC Servo mode not completed..<br>1 = Start-Up DC Servo mode complete. |

**Table 52 DC Servo Enable and Start-Up Modes**

### DC SERVO ACTIVE MODES

The DC Servo modes described above are suitable for initialising the DC offset correction circuit on the Line and Headphone outputs as part of a controlled start-up sequence which is executed before the signal path is fully enabled. Additional modes are available for use whilst the signal path is active; these modes may be of benefit following a large change in signal gain, which can lead to a change in DC offset level. Periodic updates may also be desirable to remove slow drifts in DC offset caused by changes in parameters such as device temperature.

The DC Servo circuit is enabled on HPOUTR and HPOUTL by setting DCS\_ENA\_CHAN\_1 and DCS\_ENA\_CHAN\_0 respectively, as described earlier in Table 52. Similarly, the DC Servo circuit is enabled on LINEOUTR and LINEOUTL by setting DCS\_ENA\_CHAN\_3 and DCS\_ENA\_CHAN\_2 respectively.

Writing a logic 1 to DCS\_TRIG\_SINGLE\_*n* initiates a single DC offset measurement and adjustment to the associated output; ('n' = 3 for LINEOUTR channel, 2 for LINEOUTL channel, 1 for HPOUTR channel, 0 for HPOUTL channel). This will adjust the DC offset correction on the selected channel by no more than 1LSB (0.25mV).

Setting DCS\_TIMER\_PERIOD\_01 or DCS\_TIMER\_PERIOD\_23 to a non-zero value will cause a single DC offset measurement and adjustment to be scheduled on a periodic basis. Periodic rates ranging from every 0.52s to in excess of 2 hours can be selected.

Writing a logic 1 to DCS\_TRIG\_SERIES\_*n* initiates a series of DC offset measurements and applies the necessary correction to the associated output. The number of DC Servo operations performed is determined by DCS\_SERIES\_NO\_01 or DCS\_SERIES\_NO\_23. A maximum of 128 operations may be selected, though a much lower value will be sufficient in most applications.

The DC Servo control fields associated with active modes (suitable for use on a signal path that is in active use) are described in Table 53.

| REGISTER ADDRESS        | BIT | LABEL                 | DEFAULT | DESCRIPTION                                                                                                                                                          |
|-------------------------|-----|-----------------------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R68 (44h)<br>DC Servo 1 | 15  | DCS_TRIG_SING<br>LE_3 | 0       | Writing 1 to this bit selects a single DC offset correction for LINEOUTR.<br>In readback, a value of 1 indicates that the DC Servo single correction is in progress. |
|                         | 14  | DCS_TRIG_SING<br>LE_2 | 0       | Writing 1 to this bit selects a single DC offset correction for LINEOUTL.<br>In readback, a value of 1 indicates that the DC Servo single correction is in progress. |
|                         | 13  | DCS_TRIG_SING<br>LE_1 | 0       | Writing 1 to this bit selects a single DC offset correction for HPOUTR.<br>In readback, a value of 1 indicates that the DC Servo single correction is in progress.   |

| REGISTER ADDRESS        | BIT  | LABEL                         | DEFAULT  | DESCRIPTION                                                                                                                                                                                      |
|-------------------------|------|-------------------------------|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                         | 12   | DCS_TRIG_SING<br>LE_0         | 0        | Writing 1 to this bit selects a single DC offset correction for HPOUTL.<br>In readback, a value of 1 indicates that the DC Servo single correction is in progress.                               |
|                         | 11   | DCS_TRIG_SERI<br>ES_3         | 0        | Writing 1 to this bit selects a series of DC offset corrections for LINEOUTR.<br>In readback, a value of 1 indicates that the DC Servo DAC Write correction is in progress.                      |
|                         | 10   | DCS_TRIG_SERI<br>ES_2         | 0        | Writing 1 to this bit selects a series of DC offset corrections for LINEOUTL.<br>In readback, a value of 1 indicates that the DC Servo DAC Write correction is in progress.                      |
|                         | 9    | DCS_TRIG_SERI<br>ES_1         | 0        | Writing 1 to this bit selects a series of DC offset corrections for HPOUTR.<br>In readback, a value of 1 indicates that the DC Servo DAC Write correction is in progress.                        |
|                         | 8    | DCS_TRIG_SERI<br>ES_0         | 0        | Writing 1 to this bit selects a series of DC offset corrections for HPOUTL.<br>In readback, a value of 1 indicates that the DC Servo DAC Write correction is in progress.                        |
| R71 (47h)<br>DC Servo 4 | 6:0  | DCS_SERIES_N<br>O_23 [6:0]    | 010_1010 | Number of DC Servo updates to perform in a series event for LINEOUTL/LINEOUTR.<br>0 = 1 updates<br>1 = 2 updates<br>...<br>127 = 128 updates                                                     |
| R72 (48h)<br>DC Servo 5 | 6:0  | DCS_SERIES_N<br>O_01 [6:0]    | 010 1010 | Number of DC Servo updates to perform in a series event for HPOUTL/HPOUTR.<br>0 = 1 updates<br>1 = 2 updates<br>...<br>127 = 128 updates                                                         |
| R69 (45h)<br>DC Servo 2 | 11:8 | DCS_TIMER_PE<br>RIOD_23 [3:0] | 1010     | Time between periodic updates for LINEOUTL/LINEOUTR. Time is calculated as $0.256s \times (2^{\text{PERIOD}})$<br>0000 = Off<br>0001 = 0.52s<br>1010 = 266s (4min 26s)<br>1111 = 8519s (2hr 22s) |
|                         | 3:0  | DCS_TIMER_PE<br>RIOD_01 [3:0] | 1010     | Time between periodic updates for HPOUTL/HPOUTR. Time is calculated as $0.256s \times (2^{\text{PERIOD}})$<br>0000 = Off<br>0001 = 0.52s<br>1010 = 266s (4min 26s)<br>1111 = 8519s (2hr 22s)     |

**Table 53 DC Servo Active Modes**

## DC SERVO READBACK

The current DC offset value for each Line and Headphone output channel can be read in two's complement format from the DCS\_DAC\_WR\_VAL\_n [7:0] bit fields in Registers R73, R74, R75 and R76. Note that these values may form the basis of settings that are subsequently used by the DC Servo in DAC Write mode.

## DIGITAL AUDIO INTERFACE

The digital audio interface is used for inputting DAC data to the WM8904 and outputting ADC data from it. The digital audio interface uses four pins:

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

The clock signals BCLK and LRCLK can be outputs when the WM8904 operates as a master, or inputs when it is a slave (see "Master and Slave Mode Operation", below).

Four different audio data formats are supported:

- Left justified
- Right justified
- I2S
- DSP mode

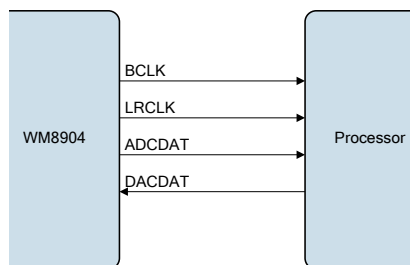
All four of these modes are MSB first. They are described in "Audio Data Formats (Normal Mode)", below. Refer to the "Signal Timing Requirements" section for timing information.

Time Division Multiplexing (TDM) is available in all four data format modes. The WM8904 can be programmed to send and receive data in one of two time slots.

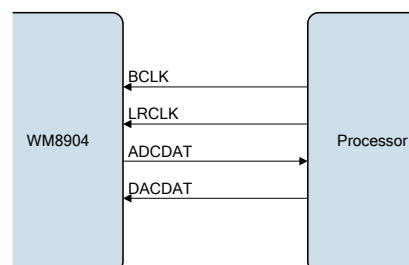
PCM operation is supported using the DSP mode.

## MASTER AND SLAVE MODE OPERATION

The WM8904 digital audio interface can operate in master or slave mode, as shown in Figure 40 and Figure 41.



**Figure 40 Master Mode**



**Figure 41 Slave Mode**

In master mode, BCLK is derived from SYSCCLK via a programmable division set by BCLK\_DIV.

In master mode, LRCLK is derived from BCLK via a programmable division set by LRCLK\_RATE. The BCLK input to this divider may be internal or external, allowing mixed master and slave modes.

The direction of these signals and the clock frequencies are controlled as described in the “Digital Audio Interface Control” section.

BCLK and LRCLK can be enabled as outputs in Slave mode, allowing mixed Master/Slave operation - see “Digital Audio Interface Control”.

## OPERATION WITH TDM

Time division multiplexing (TDM) allows multiple devices to transfer data simultaneously on the same bus. The WM8904 ADCs and DACs support TDM in master and slave modes for all data formats and word lengths. TDM is enabled and configured using register bits defined in the “Digital Audio Interface Control” section.

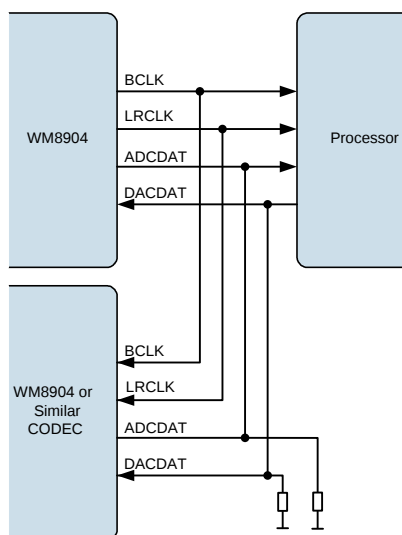


Figure 42 TDM with WM8904 as Master

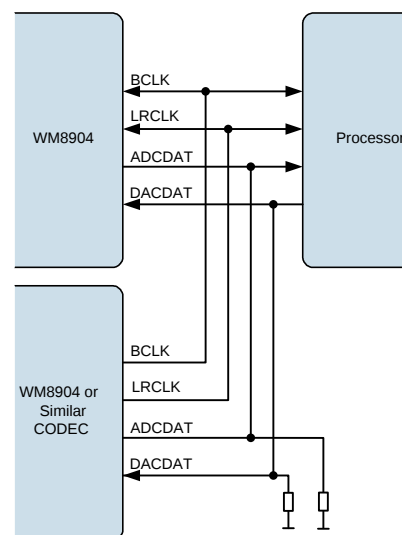


Figure 43 TDM with Other CODEC as Master

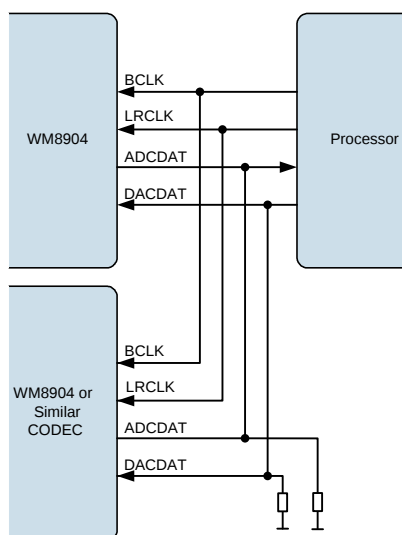


Figure 44 TDM with Processor as Master

**Note:** The WM8904 is a 24-bit device. If the user operates the WM8904 in 32-bit mode then the 8 LSBs will be ignored on the receiving side and not driven on the transmitting side. It is therefore

recommended to add a pull-down resistor if necessary to the DACDAT line and the ADCDAT line in TDM mode.

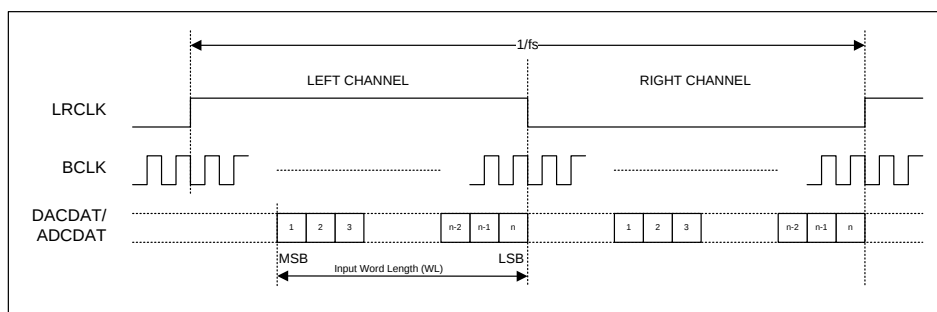
### BCLK FREQUENCY

The BCLK frequency is controlled relative to SYSCLK by the BCLK\_DIV divider. Internal clock divide and phase control mechanisms ensure that the BCLK and LRCLK edges will occur in a predictable and repeatable position relative to each other and relative to the data for a given combination of DAC/ADC sample rate and BCLK\_DIV settings.

BCLK\_DIV is defined in the “Digital Audio Interface Control” section. See also the “Clocking and Sample Rates” section for more information.

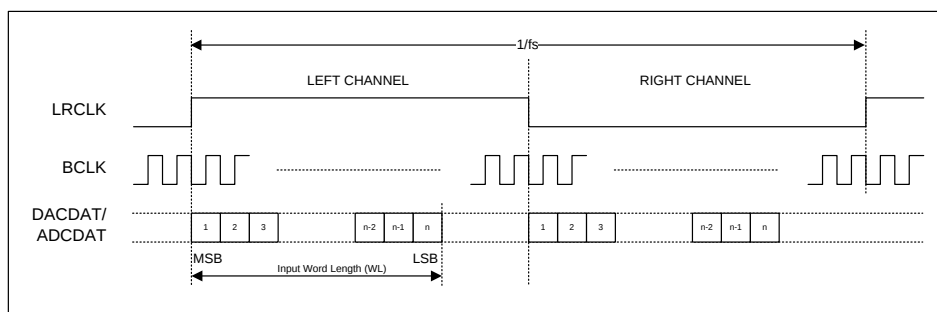
### AUDIO DATA FORMATS (NORMAL MODE)

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



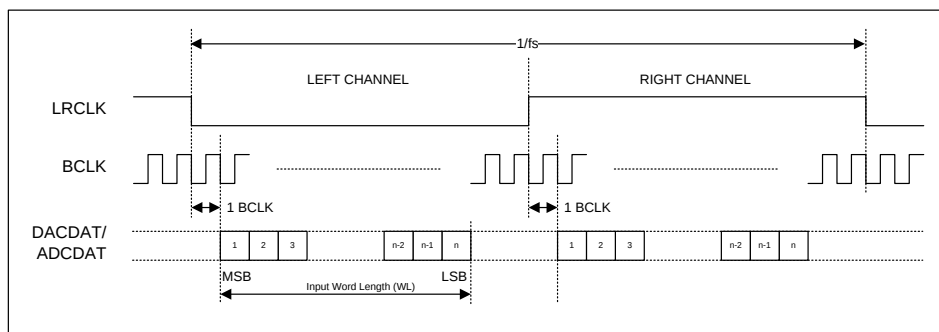
**Figure 45 Right Justified Audio Interface (assuming n-bit word length)**

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



**Figure 46 Left Justified Audio Interface (assuming n-bit word length)**

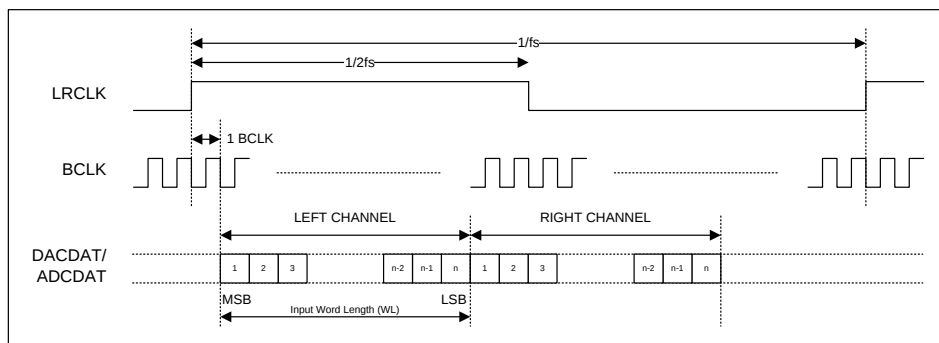
In I<sup>2</sup>S mode, the MSB is available on the second rising edge of BCLK following a LRCLK transition. The other bits up to the LSB are then transmitted in order. Depending on word length, BCLK frequency and sample rate, there may be unused BCLK cycles between the LSB of one sample and the MSB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



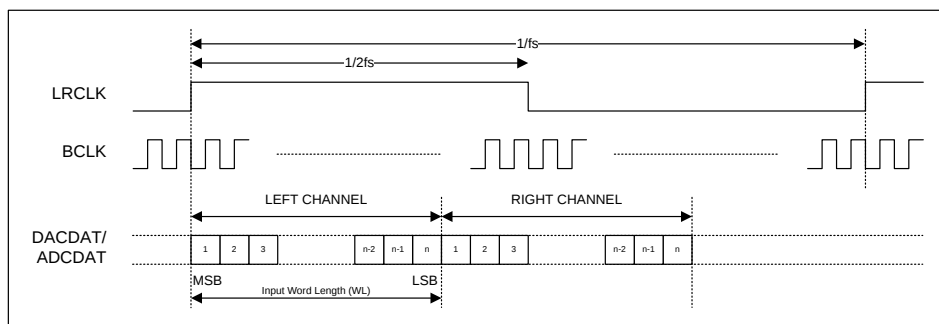
**Figure 47 I2S Justified Audio Interface (assuming n-bit word length)**

In DSP 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 AIF\_LRCLK\_INV) following a rising edge of LRCLK. 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.

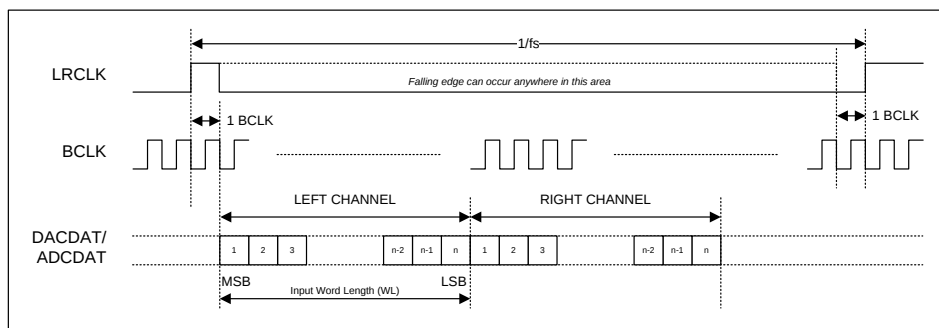
In device master mode, the LRCLK output will resemble the frame pulse shown in Figure 48 and Figure 49. In device slave mode, Figure 50 and Figure 51, it is possible to use any length of frame pulse less than  $1/f_s$ , providing the falling edge of the frame pulse occurs greater than one BCLK period before the rising edge of the next frame pulse.



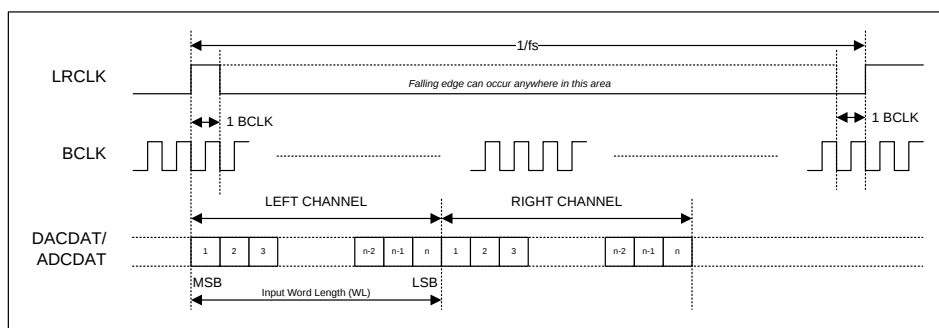
**Figure 48 DSP Mode Audio Interface (mode A, AIF\_LRCLK\_INV=0, Master)**



**Figure 49 DSP Mode Audio Interface (mode B, AIF\_LRCLK\_INV=1, Master)**



**Figure 50 DSP Mode Audio Interface (mode A, AIF\_LRCLK\_INV=0, Slave)**



**Figure 51 DSP Mode Audio Interface (mode B, AIF\_LRCLK\_INV=1, Slave)**

PCM operation is supported in DSP interface mode. WM8904 ADC data that is output on the Left Channel will be read as mono PCM data by the receiving equipment. Mono PCM data received by the WM8904 will be treated as Left Channel data. This data may be routed to the Left/Right DACs as described in the “Digital Mixing” section.

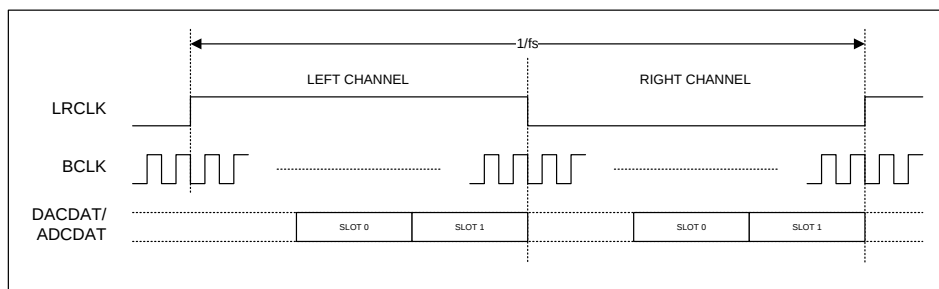
### AUDIO DATA FORMATS (TDM MODE)

TDM is supported in master and slave mode and is enabled by register bits AIFADC\_TDM and AIFDAC\_TDM. All audio interface data formats support time division multiplexing (TDM) for ADC and DAC data.

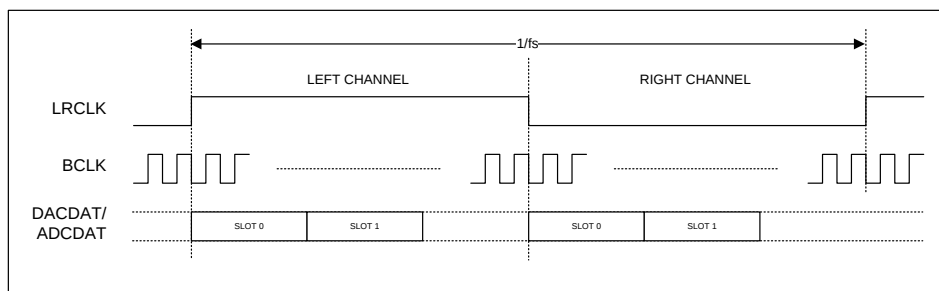
Two time slots are available (Slot 0 and Slot 1), selected by register bits AIFADC\_TDM\_CHAN and AIFDAC\_TDM\_CHAN which control time slots for the ADC data and the DAC data.

When TDM is enabled, the ADCDAT pin will be tri-stated immediately before and immediately after data transmission, to allow another audio device to drive this signal line for the remainder of the sample period. It is important that two audio devices do not attempt to drive the data pin simultaneously, as this could result in a short circuit. See “Audio Interface Timing” for details of the ADCDAT output relative to BCLK signal. Note that it is possible to ensure a gap exists between transmissions by setting the transmitted word length to a value higher than the actual length of the data. For example, if 32-bit word length is selected where only 24-bit data is available, then the WM8904 interface will tri-state after transmission of the 24-bit data; this creates an 8-bit gap after the WM8904’s TDM transmission slot.

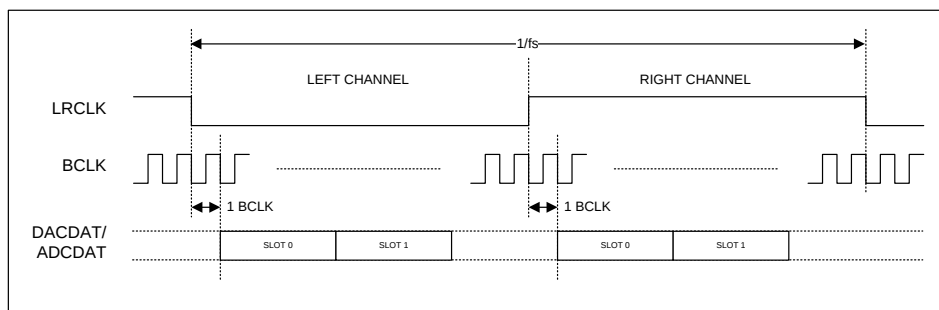
When TDM is enabled, BCLK frequency must be high enough to allow data from both time slots to be transferred. The relative timing of Slot 0 and Slot 1 depends upon the selected data format as shown in Figure 52 to Figure 56.



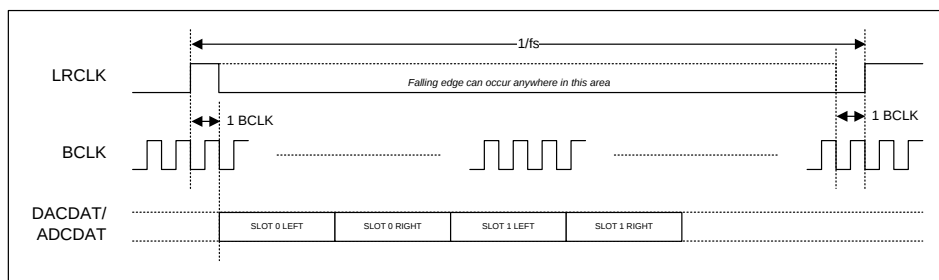
**Figure 52 TDM in Right-Justified Mode**



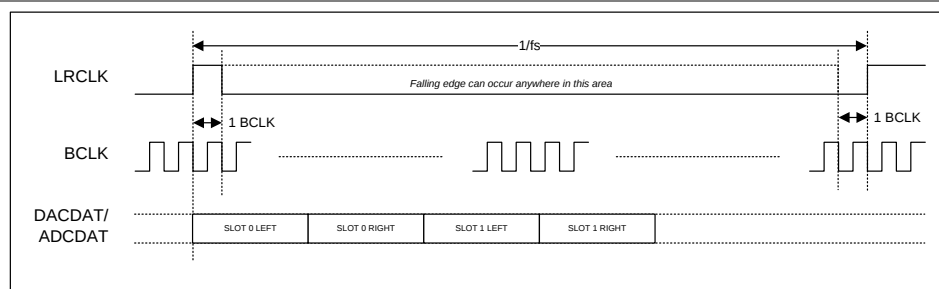
**Figure 53 TDM in Left-Justified Mode**



**Figure 54 TDM in I<sup>2</sup>S Mode**



**Figure 55 TDM in DSP Mode A**



**Figure 56 TDM in DSP Mode B**

## DIGITAL AUDIO INTERFACE CONTROL

The register bits controlling audio data format, word length, left/right channel data source and TDM are summarised in Table 54.

| REGISTER ADDRESS               | BIT | LABEL           | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                                     |
|--------------------------------|-----|-----------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R24 (18h)<br>Audio Interface 0 | 7   | AIFADCL_SRC     | 0       | Left Digital Audio channel source<br>0 = Left ADC data is output on left channel<br>1 = Right ADC data is output on left channel                                                                                                                                                                                |
|                                | 6   | AIFADCR_SRC     | 1       | Right Digital Audio channel source<br>0 = Left ADC data is output on right channel<br>1 = Right ADC data is output on right channel                                                                                                                                                                             |
|                                | 5   | AIFDACL_SRC     | 0       | Left DAC Data Source Select<br>0 = Left DAC outputs left channel data<br>1 = Left DAC outputs right channel data                                                                                                                                                                                                |
|                                | 4   | AIFDACR_SRC     | 1       | Right DAC Data Source Select<br>0 = Right DAC outputs left channel data<br>1 = Right DAC outputs right channel data                                                                                                                                                                                             |
| R25 (19h)<br>Audio Interface 1 | 13  | AIFDAC_TDM      | 0       | DAC TDM Enable<br>0 = Normal DACDAT operation<br>1 = TDM enabled on DACDAT                                                                                                                                                                                                                                      |
|                                | 12  | AIFDAC_TDM_CHAN | 0       | DACDAT TDM Channel Select<br>0 = DACDAT data input on slot 0<br>1 = DACDAT data input on slot 1                                                                                                                                                                                                                 |
|                                | 11  | AIFADC_TDM      | 0       | ADC TDM Enable<br>0 = Normal ADCDAT operation<br>1 = TDM enabled on ADCDAT                                                                                                                                                                                                                                      |
|                                | 10  | AIFADC_TDM_CHAN | 0       | ADCDAT TDM Channel Select<br>0 = ADCDAT outputs data on slot 0<br>1 = ADCDAT output data on slot 1                                                                                                                                                                                                              |
|                                | 7   | AIF_BCLK_INV    | 0       | BCLK Invert<br>0 = BCLK not inverted<br>1 = BCLK inverted                                                                                                                                                                                                                                                       |
|                                | 4   | AIF_LRCLK_INV   | 0       | LRC Polarity / DSP Mode A-B select.<br>Right, left and I2S modes – LRC polarity<br>0 = Not Inverted<br>1 = Inverted<br>DSP Mode – Mode A-B select<br>0 = MSB is available on 2nd BCLK rising edge after LRC rising edge (mode A)<br>1 = MSB is available on 1st BCLK rising edge after LRC rising edge (mode B) |

| REGISTER ADDRESS | BIT | LABEL         | DEFAULT | DESCRIPTION                                                                                           |
|------------------|-----|---------------|---------|-------------------------------------------------------------------------------------------------------|
|                  | 3:2 | AIF_WL [1:0]  | 10      | Digital Audio Interface Word Length<br>00 = 16 bits<br>01 = 20 bits<br>10 = 24 bits<br>11 = 32 bits   |
|                  | 1:0 | AIF_FMT [1:0] | 10      | Digital Audio Interface Format<br>00 = Right Justified<br>01 = Left Justified<br>10 = I2S<br>11 = DSP |

**Table 54 Digital Audio Interface Data Control**

Note that the WM8904 is a 24-bit device. In 32-bit mode (AIF\_WL=11), the 8 LSBs are ignored on the receiving side and not driven on the transmitting side.

#### AUDIO INTERFACE OUTPUT TRI-STATE

Register bit AIF\_TRIS can be used to tri-state the audio interface pins as described in Table 55. All digital audio interface pins will be tri-stated by this function, regardless of the state of other registers which control these pin configurations.

| REGISTER ADDRESS               | BIT | LABEL    | DEFAULT | DESCRIPTION                                                                                                    |
|--------------------------------|-----|----------|---------|----------------------------------------------------------------------------------------------------------------|
| R25 (19h)<br>Audio Interface 1 | 8   | AIF_TRIS | 0       | Audio Interface Tristate<br>0 = Audio interface pins operate normally<br>1 = Tristate all audio interface pins |

**Table 55 Digital Audio Interface Tri-State Control**

#### BCLK AND LRCLK CONTROL

The audio interface can be programmed to operate in master mode or slave mode using the BCLK\_DIR and LRCLK\_DIR register bits. In master mode, the BCLK and LRCLK signals are generated by the WM8904 when any of the ADCs or DACs is enabled. In slave mode, the BCLK and LRCLK clock outputs are disabled by default to allow another digital audio interface to drive these pins.

It is also possible to force the BCLK or LRCLK signals to be output using BCLK\_DIR and LRCLK\_DIR, allowing mixed master and slave modes. The BCLK\_DIR and LRCLK\_DIR fields are defined in Table 56.

| REGISTER ADDRESS               | BIT | LABEL    | DEFAULT | DESCRIPTION                                                               |
|--------------------------------|-----|----------|---------|---------------------------------------------------------------------------|
| R25 (19h)<br>Audio Interface 1 | 6   | BCLK_DIR | 0       | Audio Interface BCLK Direction<br>0 = BCLK is input<br>1 = BCLK is output |

| REGISTER ADDRESS               | BIT  | LABEL                | DEFAULT           | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|--------------------------------|------|----------------------|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R26 (1Ah)<br>Audio Interface 2 | 4:0  | BCLK_DIV<br>[4:0]    | 0_0100            | BCLK Frequency (Master Mode)<br>00000 = SYSCLK<br>00001 = SYSCLK / 1.5<br>00010 = SYSCLK / 2<br>00011 = SYSCLK / 3<br>00100 = SYSCLK / 4 (default)<br>00101 = SYSCLK / 5<br>00110 = SYSCLK / 5.5<br>00111 = SYSCLK / 6<br>01000 = SYSCLK / 8<br>01001 = SYSCLK / 10<br>01010 = SYSCLK / 11<br>01011 = SYSCLK / 12<br>01100 = SYSCLK / 16<br>01101 = SYSCLK / 20<br>01110 = SYSCLK / 22<br>01111 = SYSCLK / 24<br>10000 = SYSCLK / 25<br>10001 = SYSCLK / 30<br>10010 = SYSCLK / 32<br>10011 = SYSCLK / 44<br>10100 = SYSCLK / 48 |
| R27 (1Bh)<br>Audio Interface 3 | 11   | LRCLK_DIR            | 0                 | Audio Interface LRC Direction<br>0 = LRC is input<br>1 = LRC is output                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|                                | 10:0 | LRCLK_RATE<br>[10:0] | 000_0100<br>_0000 | LRC Rate (Master Mode)<br>LRC clock output = BCLK / LRCLK_RATE<br>Integer (LSB = 1)<br>Valid range: 8 to 2047                                                                                                                                                                                                                                                                                                                                                                                                                    |

**Table 56 Digital Audio Interface Clock Control**

### COMPANDING

The WM8904 supports A-law and  $\mu$ -law companding on both transmit (ADC) and receive (DAC) sides as shown in Table 57.

| REGISTER ADDRESS               | BIT | LABEL        | DEFAULT | DESCRIPTION                                          |
|--------------------------------|-----|--------------|---------|------------------------------------------------------|
| R24 (18h)<br>Audio Interface 0 | 3   | ADC_COMP     | 0       | ADC Companding Enable<br>0 = disabled<br>1 = enabled |
|                                | 2   | ADC_COMPMODE | 0       | ADC Companding Type<br>0 = $\mu$ -law<br>1 = A-law   |
|                                | 1   | DAC_COMP     | 0       | DAC Companding Enable<br>0 = disabled<br>1 = enabled |
|                                | 0   | DAC_COMPMODE | 0       | DAC Companding Type<br>0 = $\mu$ -law<br>1 = A-law   |

**Table 57 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):

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

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

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 MSBs of data.

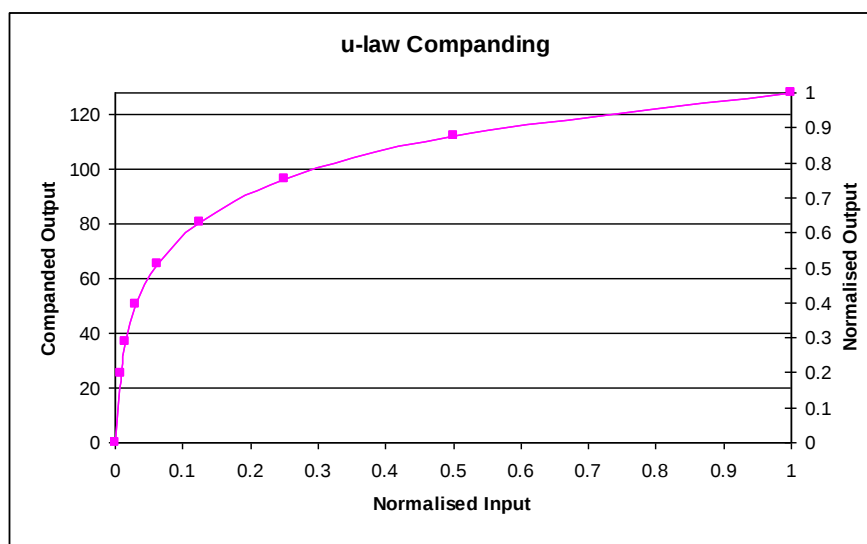
Companding converts 13 bits ( $\mu$ -law) or 12 bits (A-law) to 8 bits using non-linear quantization. This provides greater precision for low amplitude signals than for high amplitude signals, resulting in a greater usable dynamic range than 8 bit linear quantization. The companded signal is an 8-bit word comprising sign (1 bit), exponent (3 bits) and mantissa (4 bits).

8-bit mode is selected whenever  $DAC\_COMP=1$  or  $ADC\_COMP=1$ . The use of 8-bit data allows samples to be passed using as few as 8 BCLK cycles per LRCLK frame. When using DSP mode B, 8-bit data words may be transferred consecutively every 8 BCLK cycles.

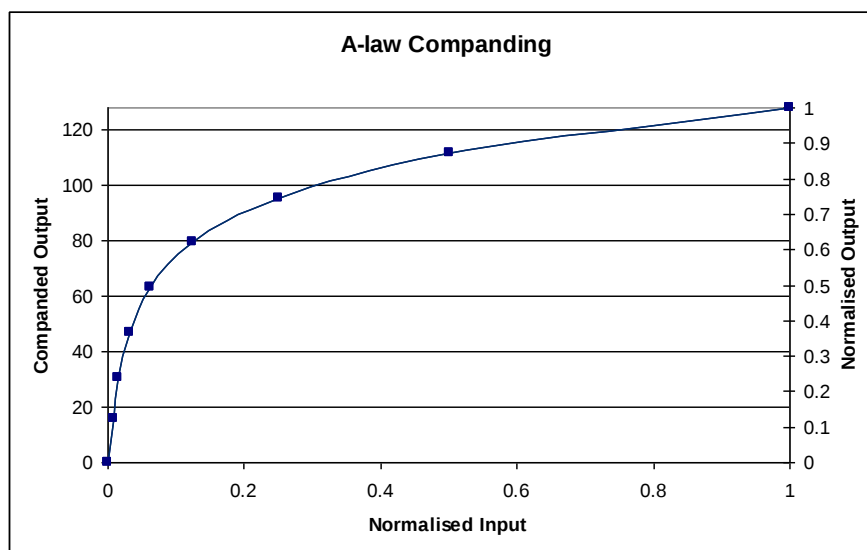
8-bit mode (without Companding) may be enabled by setting  $DAC\_COMPMODE=1$  or  $ADC\_COMPMODE=1$ , when  $DAC\_COMP=0$  and  $ADC\_COMP=0$ .

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

**Table 58 8-bit Companded Word Composition**



**Figure 57  $\mu$ -Law Companding**



**Figure 58 A-Law Comping**

### LOOPBACK

Setting the LOOPBACK register bit enables digital loopback. When this bit is set, the ADC digital data output is routed to the DAC digital data input path. The digital audio interface input (DACDAT) is not used when LOOPBACK is enabled.

| REGISTER ADDRESS               | BIT | LABEL    | DEFAULT | DESCRIPTION                                                                                                                 |
|--------------------------------|-----|----------|---------|-----------------------------------------------------------------------------------------------------------------------------|
| R24 (18h)<br>Audio Interface 0 | 8   | LOOPBACK | 0       | Digital Loopback Function<br>0 = No loopback<br>1 = Loopback enabled (ADC data output is directly input to DAC data input). |

**Table 59 Loopback Control**

**Note:** When the digital sidetone is enabled, ADC data will also be added to DAC digital data input path within the Digital Mixing circuit. This applies regardless of whether LOOPBACK is enabled.

### DIGITAL PULL-UP AND PULL-DOWN

The WM8904 provides integrated pull-up and pull-down resistors on each of the MCLK, DACDAT, LRCLK and BCLK pins. This provides a flexible capability for interfacing with other devices. Each of the pull-up and pull-down resistors can be configured independently using the register bits described in Table 60.

| REGISTER ADDRESS            | BIT | LABEL     | DEFAULT | DESCRIPTION                                                                       |
|-----------------------------|-----|-----------|---------|-----------------------------------------------------------------------------------|
| R126 (7Eh)<br>Digital Pulls | 7   | MCLK_PU   | 0       | MCLK pull-up resistor enable<br>0 = pull-up disabled<br>1 = pull-up enabled       |
|                             | 6   | MCLK_PD   | 0       | MCLK pull-down resistor enable<br>0 = pull-down disabled<br>1 = pull-down enabled |
|                             | 5   | DACDAT_PU | 0       | DACDAT pull-up resistor enable<br>0 = pull-up disabled<br>1 = pull-up enabled     |

| REGISTER ADDRESS | BIT | LABEL     | DEFAULT | DESCRIPTION                                                                         |
|------------------|-----|-----------|---------|-------------------------------------------------------------------------------------|
|                  | 4   | DACDAT_PD | 0       | DACDAT pull-down resistor enable<br>0 = pull-down disabled<br>1 = pull-down enabled |
|                  | 3   | LRCLK_PU  | 0       | LRCLK pull-up resistor enable<br>0 = pull-up disabled<br>1 = pull-up enabled        |
|                  | 2   | LRCLK_PD  | 0       | LRCLK pull-down resistor enable<br>0 = pull-down disabled<br>1 = pull-down enabled  |
|                  | 1   | BCLK_PU   | 0       | BCLK pull-up resistor enable<br>0 = pull-up disabled<br>1 = pull-up enabled         |
|                  | 0   | BCLK_PD   | 0       | BCLK pull-down resistor enable<br>0 = pull-down disabled<br>1 = pull-down enabled   |

**Table 60 Digital Audio Interface Pull-Up and Pull-Down Control**

## CLOCKING AND SAMPLE RATES

The internal clocks for the WM8904 are all derived from a common internal clock source, SYSCLK. This clock is the reference for the ADCs, DACs, DSP core functions, digital audio interface, DC servo control and other internal functions.

SYSCLK can either be derived directly from MCLK, or may be generated from a Frequency Locked Loop (FLL) using MCLK, BCLK or LRCLK as a reference. Many commonly-used audio sample rates can be derived directly from typical MCLK frequencies; the FLL provides additional flexibility for a wide range of MCLK frequencies. To avoid audible glitches, all clock configurations must be set up before enabling playback. The FLL can be used to generate a free-running clock in the absence of an external reference source; see "Frequency Locked Loop (FLL)" for further details.

The WM8904 supports automatic clocking configuration. The programmable dividers associated with the ADCs, DACs, DSP core functions and DC servo are configured automatically, with values determined from the CLK\_SYS\_RATE and SAMPLE\_RATE fields. The user must also configure the OPCLK (if required), the TOCLK (if required) and the Digital Audio Interface.

Oversample rates of 64fs or 128fs are supported (based on a 48kHz sample rate).

A 256kHz clock, supporting a number of internal functions, is derived from SYSCLK.

The DC servo control is clocked from SYSCLK.

A GPIO Clock, OPCLK, can be derived from SYSCLK and output on a GPIO pin to provide clocking to other devices. This clock is enabled by OPCLK\_ENA and controlled by OPCLK\_DIV.

A slow clock, TOCLK, is used to de-bounce the button/accessory detect inputs, and to set the timeout period for volume updates when zero-cross detect is used. This clock is enabled by TOCLK\_ENA and controlled by TOCLK\_RATE, TOCLK\_RATE\_X4 and TOCLK\_RATE\_DIV16.

In master mode, BCLK is derived from SYSCLK via a programmable divider set by BCLK\_DIV. In master mode, the LRCLK is derived from BCLK via a programmable divider LRCLK\_RATE. The LRCLK can be derived from an internal or external BCLK source, allowing mixed master/slave operation.

The control registers associated with Clocking and Sample Rates are shown in Table 61 to Table 65.

The overall clocking scheme for the WM8904 is illustrated in Figure 59.

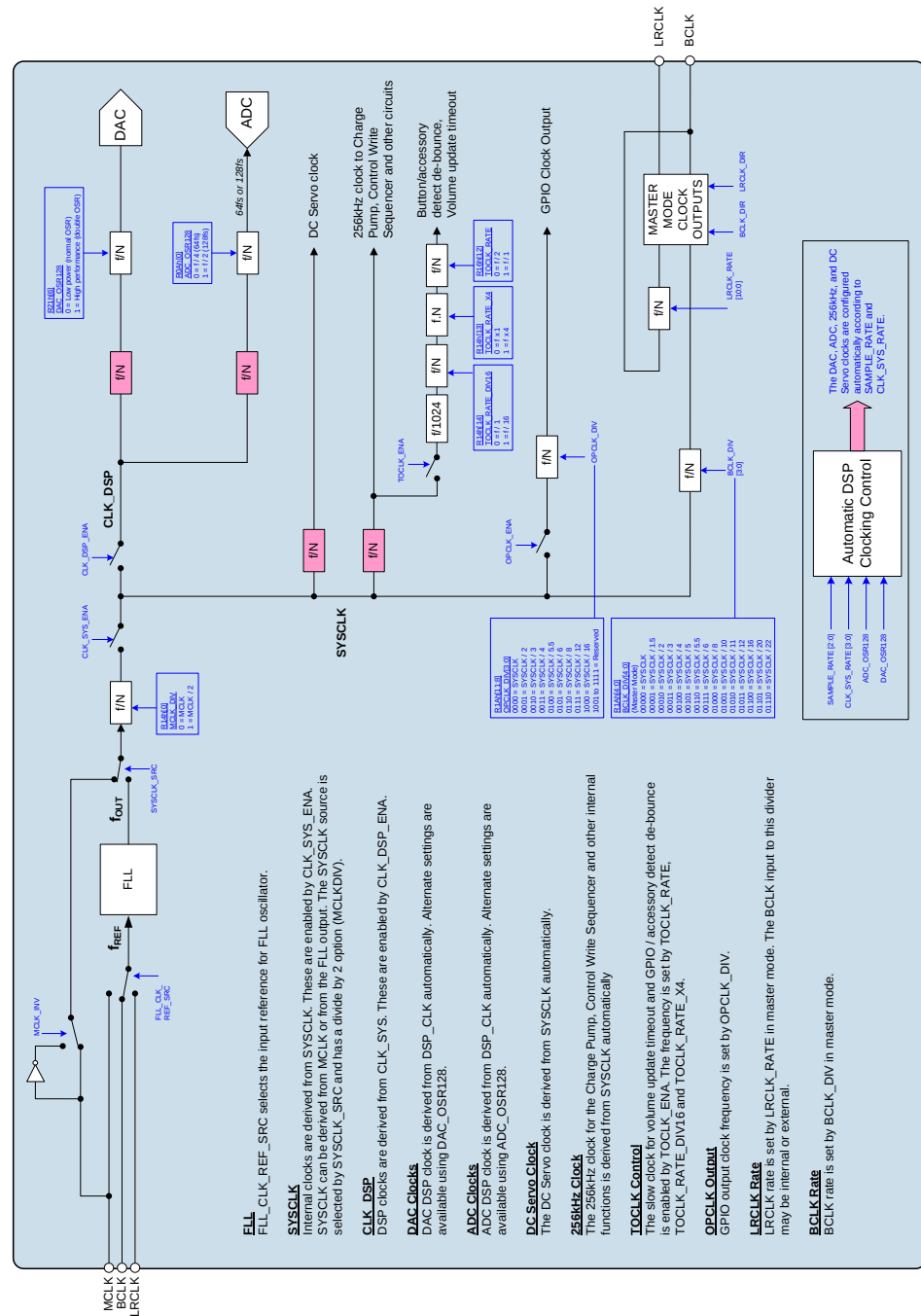


Figure 59 Clocking Overview

## SYSCLK CONTROL

The SYSCLK\_SRC bit is used to select the source for SYSCLK. The source may be either the MCLK input or the FLL output. The MCLK input can be inverted or non-inverted, as selected by the MCLK\_INV bit. The selected source may also be adjusted by the MCLK\_DIV divider to generate SYSCLK. These register fields are described in Table 61. See “Frequency Locked Loop (FLL)” for more details of the Frequency Locked Loop clock generator.

The SYSCLK signal is enabled by register bit CLK\_SYS\_ENA. This bit should be set to 0 when reconfiguring clock sources. It is not recommended to change SYSCLK\_SRC while the CLK\_SYS\_ENA bit is set.

The following operating frequency limits must be observed when configuring SYSCLK. Failure to observe these limits will result in degraded noise performance and/or incorrect ADC/DAC functionality.

- $\text{SYSCLK} \geq 3\text{MHz}$
- If  $\text{DAC\_OSR128} = 1$  then  $\text{SYSCLK} \geq 6\text{MHz}$
- If  $\text{DAC\_MONO} = 1$ , then  $\text{SYSCLK} \geq 64 \times f_s$
- If  $\text{DAC\_MONO} = 0$ , then  $\text{SYSCLK} \geq 128 \times f_s$
- If  $\text{ADCL\_ENA} = 1$  or  $\text{ADCR\_ENA} = 1$  then  $\text{SYSCLK} \geq 256 \times f_s$

Note that DAC Mono mode ( $\text{DAC\_MONO} = 1$ ) is only valid when one or other DAC is disabled. If both DACs are enabled, then the minimum SYSCLK for clocking the DACs is  $128 \times f_s$ .

The SYSCLK control register fields are defined in Table 61.

| REGISTER ADDRESS              | BIT | LABEL       | DEFAULT | DESCRIPTION                                                                                               |
|-------------------------------|-----|-------------|---------|-----------------------------------------------------------------------------------------------------------|
| R22 (16h)<br>Clock Rates<br>2 | 15  | MCLK_INV    | 0       | MCLK Invert<br>0 = MCLK not inverted<br>1 = MCLK inverted                                                 |
|                               | 14  | SYSCLK_SRC  | 0       | SYSCLK Source Select<br>0 = MCLK<br>1 = FLL output                                                        |
|                               | 2   | CLK_SYS_ENA | 0       | System Clock enable<br>0 = Disabled<br>1 = Enabled                                                        |
| R20 (14h)<br>Clock Rates<br>0 | 0   | MCLK_DIV    | 0       | Enables divide by 2 on MCLK<br>0 = $\text{SYSCLK} = \text{MCLK}$<br>1 = $\text{SYSCLK} = \text{MCLK} / 2$ |

**Table 61 MCLK and SYSCLK Control**

## CONTROL INTERFACE CLOCKING

Register map access is possible with or without a Master Clock (MCLK). However, if CLK\_SYS\_ENA has been set to 1, then a Master Clock must be present for control register Read/Write operations. If  $\text{CLK\_SYS\_ENA} = 1$  and MCLK is not present, then register access will be unsuccessful. (Note that read/write access to register R22, containing CLK\_SYS\_ENA, is always possible.)

If it cannot be assured that MCLK is present when accessing the register map, then it is required to set  $\text{CLK\_SYS\_ENA} = 0$  to ensure correct operation.

It is possible to use the WM8904 analogue bypass paths to the differential line outputs (LON/LOP and RON/ROP) without MCLK. Note that MCLK is always required when using HPOUTL, HPOUTR, LINEOUTL or LINEOUTR.

## CLOCKING CONFIGURATION

The WM8904 supports a wide range of standard audio sample rates from 8kHz to 48kHz. The Automatic Clocking Configuration simplifies the configuration of the clock dividers in the WM8904 by deriving most of the necessary parameters from a minimum number of user registers.

The SAMPLE\_RATE field selects the sample rate, fs, of the ADC and DAC. Note that the same sample rate always applies to the ADC and DAC.

The CLK\_SYS\_RATE field must be set according to the ratio of SYSCLK to fs. When these fields are set correctly, the Sample Rate Decoder circuit automatically determines the clocking configuration for all other circuits within the WM8904.

A high performance mode of DAC operation can be selected by setting the DAC\_OSR128 bit; in 48kHz sample mode, the DAC\_OSR128 feature results in 128x oversampling. Audio performance is improved, but power consumption is also increased.

| REGISTER ADDRESS           | BIT   | LABEL              | DEFAULT | DESCRIPTION                                                                                                                                                                  |
|----------------------------|-------|--------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R33 (21h)<br>DAC Digital 1 | 6     | DAC_OSR128         | 0       | DAC Oversample Rate Select<br>0 = Low power (normal OSR)<br>1 = High performance (double OSR)                                                                                |
| R21 (15h)<br>Clock Rates 1 | 13:10 | CLK_SYS_RATE [3:0] | 0011    | Selects the SYSCLK / fs ratio<br>0000 = 64<br>0001 = 128<br>0010 = 192<br>0011 = 256<br>0100 = 384<br>0101 = 512<br>0110 = 768<br>0111 = 1024<br>1000 = 1408<br>1001 = 1536  |
|                            | 2:0   | SAMPLE_RATE [2:0]  | 101     | Selects the Sample Rate (fs)<br>000 = 8kHz<br>001 = 11.025kHz, 12kHz<br>010 = 16kHz<br>011 = 22.05kHz, 24kHz<br>100 = 32kHz<br>101 = 44.1kHz, 48kHz<br>110 to 111 = Reserved |

**Table 62 Automatic Clocking Configuration Control**

### ADC / DAC CLOCK CONTROL

The clocking of the ADC and DAC circuits is derived from CLK\_DSP, which is enabled by CLK\_DSP\_ENA. CLK\_DSP is generated from SYSCLK which is separately enabled, using the register bit CLK\_SYS\_ENA.

Two modes of ADC operation can be selected using the ADC\_OSR128 bit; in 48kHz sample mode, setting the ADC\_OSR128 bit results in 128x oversampling. This bit is enabled by default, giving best audio performance. Deselecting this bit gives 64x oversampling in 48kHz mode, resulting in decreased power consumption.

Higher performance DAC operation can be achieved by increasing the DAC oversample rate - see Table 62.

The ADC / DAC Clock Control registers are defined in Table 63.

| REGISTER ADDRESS           | BIT | LABEL       | DEFAULT | DESCRIPTION                                                                          |
|----------------------------|-----|-------------|---------|--------------------------------------------------------------------------------------|
| R10 (0Ah)<br>Analog ADC 0  | 0   | ADC_OSR128  | 1       | ADC Oversampling Ratio<br>0 = Low Power (64 x fs)<br>1 = High Performance (128 x fs) |
| R22 (16h)<br>Clock Rates 2 | 1   | CLK_DSP_ENA | 0       | DSP Clock enable<br>0 = Disabled<br>1 = Enabled                                      |

**Table 63 ADC / DAC Clock Control**

### OPCLK CONTROL

A clock output (OPCLK) derived from SYSCLK may be output on a GPIO pin. This clock is enabled by register bit OPCLK\_ENA, and its frequency is controlled by OPCLK\_DIV.

This output of this clock is also dependent upon the GPIO register settings described under "General Purpose Input/Output (GPIO)".

| REGISTER ADDRESS               | BIT  | LABEL           | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                       |
|--------------------------------|------|-----------------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R22 (16h)<br>Clock Rates 2     | 3    | OPCLK_ENA       | 0       | GPIO Clock Output Enable<br>0 = disabled<br>1 = enabled                                                                                                                                                                                           |
| R26 (1Ah)<br>Audio Interface 2 | 11:8 | OPCLK_DIV [3:0] | 0000    | GPIO Output Clock Divider<br>0000 = SYSCLK<br>0001 = SYSCLK / 2<br>0010 = SYSCLK / 3<br>0011 = SYSCLK / 4<br>0100 = SYSCLK / 5.5<br>0101 = SYSCLK / 6<br>0110 = SYSCLK / 8<br>0111 = SYSCLK / 12<br>1000 = SYSCLK / 16<br>1001 to 1111 = Reserved |

**Table 64 OPCLK Control**

## TOCLK CONTROL

A slow clock (TOCLK) is derived from the internally generated 256kHz clock to enable input de-bouncing and volume update timeout functions. This clock is enabled by register bit TOCLK\_ENA, and its frequency is controlled by TOCLK\_RATE and TOCLK\_RATE\_X4, as described in Table 65.

| REGISTER ADDRESS           | BIT | LABEL            | DEFAULT | DESCRIPTION                                              |
|----------------------------|-----|------------------|---------|----------------------------------------------------------|
| R22 (16h)<br>Clock Rates 2 | 12  | TOCLK_RATE       | 0       | TOCLK Rate Divider (/2)<br>0 = f / 2<br>1 = f / 1        |
|                            | 0   | TOCLK_ENA        | 0       | Zero Cross timeout enable<br>0 = Disabled<br>1 = Enabled |
| R20 (14h)<br>Clock Rates 0 | 14  | TOCLK_RATE_DIV16 | 0       | TOCLK Rate Divider (/16)<br>0 = f / 1<br>1 = f / 16      |
|                            | 13  | TOCLK_RATE_X4    | 0       | TOCLK Rate Multiplier<br>0 = f x 1<br>1 = f x 4          |

**Table 65 TOCLK Control**

A list of possible TOCLK rates is provided in Table 66.

| TOCLK_RATE | TOCLK_RATE_X4 | TOCLK_RATE_DIV16 | TOCLK     |             |
|------------|---------------|------------------|-----------|-------------|
|            |               |                  | FREQ (Hz) | PERIOD (ms) |
| 1          | 1             | 0                | 1000      | 1           |
| 0          | 1             | 0                | 500       | 2           |
| 1          | 0             | 0                | 250       | 4           |
| 0          | 0             | 0                | 125       | 8           |
| 1          | 1             | 1                | 62.5      | 16          |
| 0          | 1             | 1                | 31.25     | 32          |
| 1          | 0             | 1                | 15.625    | 64          |
| 0          | 0             | 1                | 7.8125    | 128         |

**Table 66 TOCLK Rates**

## ADC / DAC OPERATION AT 88.2K / 96K

The WM8904 supports ADC or DAC operation at 88.2kHz and 96kHz sample rates. This section details specific conditions applicable to these operating modes. Note that simultaneous ADC and DAC operation at 88.2kHz or 96kHz is not possible.

For DAC operation at 88.2kHz or 96kHz sample rates, the available clocking configurations are detailed in Table 67. DAC operation at these sample rates is achieved by setting the SAMPLE\_RATE field to half the required sample rate (eg. select 48kHz for 96kHz mode).

For DAC operation at 88.2kHz or 96kHz sample rates, the ADCs must both be disabled (ADCL\_ENA = 0 and ADCR\_ENA = 0). Also, the DAC\_OSR128 register must be set to 0. ReTune™ Mobile can not be used during 88.2kHz or 96kHz operation, so EQ\_ENA must be set to 0.

The SYSCLK frequency is derived from MCLK. The maximum MCLK frequency is defined in the "Signal Timing Requirements" section.

| SAMPLE RATE | REGISTER CONFIGURATION                                                                                | CLOCKING RATIO    |
|-------------|-------------------------------------------------------------------------------------------------------|-------------------|
| 88.2kHz     | SAMPLE_RATE = 101<br>CLK_SYS_RATE = 0001 (SYSCLK / fs = 128)<br>BCLK_DIV = 00010<br>LRCLK_RATE = 040h | SYSCLK = 128 x fs |
| 96kHz       | SAMPLE_RATE = 101<br>CLK_SYS_RATE = 0001 (SYSCLK / fs = 128)<br>BCLK_DIV = 00010<br>LRCLK_RATE = 040h | SYSCLK = 128 x fs |

**Table 67 DAC Operation at 88.2kHz and 96kHz Sample Rates**

For ADC operation at 88.2kHz or 96kHz sample rates, the available clocking configurations are detailed in Table 68.

ADC operation at these sample rates is achieved by setting the SAMPLE\_RATE field to half the required sample rate (eg. select 48kHz for 96kHz mode). For ADC operation at 88.2kHz or 96kHz sample rates, the DACs must both be disabled (DACL\_ENA = 0 and DACR\_ENA = 0). Note that ADC\_OSR128, ADC\_128\_OSR\_TST\_MODE, and ADC\_BIASX1P5 must be configured according to Table 68.

The SYSCLK frequency is derived from MCLK. The maximum MCLK frequency is defined in the "Signal Timing Requirements" section.

| SAMPLE RATE | REGISTER CONFIGURATION                                                                                                                                                  | CLOCKING RATIO    |
|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 88.2kHz     | SAMPLE_RATE = 101<br>CLK_SYS_RATE = 0001 (SYSCLK / fs = 128)<br>BCLK_DIV = 00010<br>LRCLK_RATE = 040h<br>ADC_OSR128 = 0<br>ADC_128_OSR_TST_MODE = 0<br>ADC_BIASX1P5 = 0 | SYSCLK = 128 x fs |
| 96kHz       | SAMPLE_RATE = 101<br>CLK_SYS_RATE = 0001 (SYSCLK / fs = 128)<br>BCLK_DIV = 00010<br>LRCLK_RATE = 040h<br>ADC_OSR128 = 0<br>ADC_128_OSR_TST_MODE = 0<br>ADC_BIASX1P5 = 0 | SYSCLK = 128 x fs |

**Table 68 ADC Operation at 88.2kHz and 96kHz Sample Rates**

## FREQUENCY LOCKED LOOP (FLL)

The integrated FLL can be used to generate SYSCLK from a wide variety of different reference sources and frequencies. The FLL can use either MCLK, BCLK or LRCLK as its reference, which may be a high frequency (eg. 12.288MHz) or low frequency (eg. 32,768kHz) reference. The FLL is tolerant of jitter and may be used to generate a stable SYSCLK from a less stable input signal. The FLL characteristics are summarised in "Electrical Characteristics".

Note that the FLL can be used to generate a free-running clock in the absence of an external reference source. This is described in the "Free-Running FLL Clock" section below.

The FLL is enabled using the FLL\_ENA register bit. Note that, when changing FLL settings, it is recommended that the digital circuit be disabled via FLL\_ENA and then re-enabled after the other register settings have been updated. When changing the input reference frequency  $F_{REF}$ , it is recommended the FLL be reset by setting FLL\_ENA to 0.

The FLL\_CLK\_REF\_SRC field allows MCLK, BCLK or LRCLK to be selected as the input reference clock.

The field FLL\_CLK\_REF\_DIV provides the option to divide the input reference (MCLK, BCLK or LRCLK) by 1, 2, 4 or 8. This field should be set to bring the reference down to 13.5MHz or below. For best performance, it is recommended that the highest possible frequency - within the 13.5MHz limit - should be selected.

The field FLL\_CTRL\_RATE controls internal functions within the FLL; it is recommended that only the default setting be used for this parameter. FLL\_GAIN controls the internal loop gain and should be set to the recommended value quoted in Table 71.

The FLL output frequency is directly determined from FLL\_FRATIO, FLL\_OUTDIV and the real number represented by FLL\_N and FLL\_K. The field FLL\_N is an integer (LSB = 1); FLL\_K is the fractional portion of the number (MSB = 0.5). The fractional portion is only valid in Fractional Mode when enabled by the field FLL\_FRACN\_ENA.

It is recommended that FLL\_FRACN\_ENA is enabled at all times. Power consumption in the FLL is reduced in integer mode; however, the performance may also be reduced, with increased noise or jitter on the output.

If low power consumption is required, then FLL settings must be chosen when N.K is an integer (ie. FLL\_K = 0). In this case, the fractional mode can be disabled by setting FLL\_FRACN\_ENA = 0.

For best FLL performance, a non-integer value of N.K is required. In this case, the fractional mode must be enabled by setting FLL\_FRACN\_ENA = 1. The FLL settings must be adjusted, if necessary, to produce a non-integer value of N.K.

The FLL output frequency is generated according to the following equation:

$$F_{OUT} = (F_{VCO} / FLL\_OUTDIV)$$

The FLL operating frequency,  $F_{VCO}$  is set according to the following equation:

$$F_{VCO} = (F_{REF} \times N.K \times FLL\_FRATIO)$$

See Table 71 for the coding of the FLL\_OUTDIV and FLL\_FRATIO fields.

$F_{REF}$  is the input frequency, as determined by FLL\_CLK\_REF\_DIV.

$F_{VCO}$  must be in the range 90-100 MHz. Frequencies outside this range cannot be supported.

Note that the output frequencies that do not lie within the ranges quoted above cannot be guaranteed across the full range of device operating temperatures.

In order to follow the above requirements for  $F_{VCO}$ , the value of FLL\_OUTDIV should be selected according to the desired output  $F_{OUT}$ . The divider, FLL\_OUTDIV, must be set so that  $F_{VCO}$  is in the range 90-100MHz. The available divisions are integers from 4 to 64. Some typical settings of FLL\_OUTDIV are noted in Table 69.

| OUTPUT FREQUENCY $F_{OUT}$ | FLL_OUTDIV            |
|----------------------------|-----------------------|
| 2.8125 MHz - 3.125 MHz     | 011111 (divide by 32) |
| 3.75 MHz - 4.1667 MHz      | 011000 (divide by 24) |
| 5.625 MHz - 6.25 MHz       | 001111 (divide by 16) |
| 11.25 MHz - 12.5 MHz       | 000111 (divide by 8)  |
| 18 MHz - 20 MHz            | 000100 (divide by 5)  |
| 22.5 MHz - 25 MHz          | 000011 (divide by 4)  |

**Table 69 Selection of FLL\_OUTDIV**

The value of FLL\_FRATIO should be selected as described in Table 70.

| REFERENCE FREQUENCY $F_{REF}$ | FLL_FRATIO        |
|-------------------------------|-------------------|
| 1MHz - 13.5MHz                | 0h (divide by 1)  |
| 256kHz - 1MHz                 | 1h (divide by 2)  |
| 128kHz - 256kHz               | 2h (divide by 4)  |
| 64kHz - 128kHz                | 3h (divide by 8)  |
| Less than 64kHz               | 4h (divide by 16) |

**Table 70 Selection of FLL\_FRATIO**

In order to determine the remaining FLL parameters, the FLL operating frequency,  $F_{VCO}$ , must be calculated, as given by the following equation:

$$F_{VCO} = (F_{OUT} \times FLL\_OUTDIV)$$

The value of FLL\_N and FLL\_K can then be determined as follows:

$$N.K = F_{VCO} / (FLL\_FRATIO \times F_{REF})$$

See Table 71 for the coding of the FLL\_OUTDIV and FLL\_FRATIO fields.

Note that  $F_{REF}$  is the input frequency, after division by FLL\_CLK\_REF\_DIV, where applicable.

In FLL Fractional Mode, the fractional portion of the N.K multiplier is held in the FLL\_K register field. This field is coded as a fixed point quantity, where the MSB has a weighting of 0.5. Note that, if desired, the value of this field may be calculated by multiplying K by  $2^{16}$  and treating FLL\_K as an integer value, as illustrated in the following example:

If  $N.K = 8.192$ , then  $K = 0.192$

Multiplying K by  $2^{16}$  gives  $0.192 \times 65536 = 12582.912$  (decimal)

Apply rounding to the nearest integer = 12583 (decimal) = 3127 (hex)

For best performance, FLL Fractional Mode should always be used. Therefore, if the calculations yield an integer value of N.K, then it is recommended to adjust FLL\_OUTDIV in order to obtain a non-integer value of N.K. Care must always be taken to ensure that the FLL operating frequency,  $F_{VCO}$ , is within its recommended limits of 90-100 MHz.

The register fields that control the FLL are described in Table 71. Example settings for a variety of reference frequencies and output frequencies are shown in Table 73.

| REGISTER ADDRESS            | BIT  | LABEL               | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                        |
|-----------------------------|------|---------------------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R116 (74h)<br>FLL Control 1 | 2    | FLL_FRACN_ENA       | 0       | FLL Fractional enable<br>0 = Integer Mode<br>1 = Fractional Mode<br><br>Fractional Mode (FLL_FRACN_ENA=1) is recommended in all cases                                                                                                                              |
|                             | 1    | FLL_OSC_ENA         | 0       | FLL Oscillator enable<br>0 = Disabled<br>1 = Enabled<br><br>FLL_OSC_ENA must be enabled before enabling FLL_ENA.<br><br>Note that this field is required for free-running FLL modes only.                                                                          |
|                             | 0    | FLL_ENA             | 0       | FLL Enable<br>0 = Disabled<br>1 = Enabled<br><br>FLL_OSC_ENA must be enabled before enabling FLL_ENA.                                                                                                                                                              |
| R117 (75h)<br>FLL Control 2 | 13:8 | FLL_OUTDIV [5:0]    | 00_0000 | FLL FOUT clock divider<br>00_0000 = Reserved<br>00_0001 = Reserved<br>00_0010 = Reserved<br>00_0011 = 4<br>00_0100 = 5<br>00_0101 = 6<br>...<br>11_1110 = 63<br>11_1111 = 64<br>(FOUT = FVCO / FLL_OUTDIV)                                                         |
|                             | 6:4  | FLL_CTRL_RATE [2:0] | 000     | Frequency of the FLL control block<br>000 = FVCO / 1 (Recommended value)<br>001 = FVCO / 2<br>010 = FVCO / 3<br>011 = FVCO / 4<br>100 = FVCO / 5<br>101 = FVCO / 6<br>110 = FVCO / 7<br>111 = FVCO / 8<br><br>Recommended that these are not changed from default. |

| REGISTER ADDRESS            | BIT  | LABEL                 | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                               |
|-----------------------------|------|-----------------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                             | 2:0  | FLL_FRATIO [2:0]      | 111     | <p>F<sub>VCO</sub> clock divider</p> <p>000 = divide by 1<br/> 001 = divide by 2<br/> 010 = divide by 4<br/> 011 = divide by 8<br/> 1XX = divide by 16</p> <p>000 recommended for F<sub>REF</sub> &gt; 1MHz<br/> 100 recommended for F<sub>REF</sub> &lt; 64kHz</p>                       |
| R118 (76h)<br>FLL Control 3 | 15:0 | FLL_K [15:0]          | 0000h   | Fractional multiply for F <sub>REF</sub><br>(MSB = 0.5)                                                                                                                                                                                                                                   |
| R119 (77h)<br>FLL Control 4 | 14:5 | FLL_N [9:0]           | 177h    | Integer multiply for F <sub>REF</sub><br>(LSB = 1)                                                                                                                                                                                                                                        |
|                             | 3:0  | FLL_GAIN [3:0]        | 0h      | <p>Gain applied to error</p> <p>0000 = x 1 (Recommended value)<br/> 0001 = x 2<br/> 0010 = x 4<br/> 0011 = x 8<br/> 0100 = x 16<br/> 0101 = x 32<br/> 0110 = x 64<br/> 0111 = x 128<br/> 1000 = x 256</p> <p>Recommended that these are not changed from default.</p>                     |
| R120 (78h)<br>FLL Control 5 | 4:3  | FLL_CLK_REF_DIV [1:0] | 00      | <p>FLL Clock Reference Divider</p> <p>00 = MCLK / 1<br/> 01 = MCLK / 2<br/> 10 = MCLK / 4<br/> 11 = MCLK / 8</p> <p>MCLK (or other input reference) must be divided down to &lt;=13.5MHz.<br/> For lower power operation, the reference clock can be divided down further if desired.</p> |
|                             | 1:0  | FLL_CLK_REF_SRC [1:0] | 00      | <p>FLL Clock source</p> <p>00 = MCLK<br/> 01 = BCLK<br/> 10 = LRCLK<br/> 11 = Reserved</p>                                                                                                                                                                                                |

**Table 71 FLL Register Map**

## FREE-RUNNING FLL CLOCK

The FLL can generate a clock signal even when no external reference is available. However, it should be noted that the accuracy of this clock is reduced, and a reference source should always be used where possible. Note that, in free-running mode, the FLL is not sufficiently accurate for hi-fi ADC or DAC applications. However, the free-running mode is suitable for clocking most other functions, including the Write Sequencer, Charge Pump, DC Servo and Class W output driver.

If an accurate reference clock is available at FLL start-up, then the FLL should be configured as described above. The FLL will continue to generate a stable output clock after the reference input is stopped or disconnected.

If no reference clock is available at the time of starting up the FLL, then an internal clock frequency of approximately 12MHz can be generated by enabling the FLL Analogue Oscillator using the FLL\_OSC\_ENA register bit, and setting F<sub>OUT</sub> clock divider to divide by 8 (FLL\_OUTDIV = 07h), as defined in Table 71. Under recommended operating conditions, the FLL output may be forced to approximately 12MHz by then enabling the FLL\_FRC\_NCO bit and setting FLL\_FRC\_NCO\_VAL to 19h (see Table 72). The resultant SYSCLK delivers the required clock frequencies for the Class W output driver, DC Servo, Charge Pump and other functions. Note that the value of FLL\_FRC\_NCO\_VAL may be adjusted to control F<sub>OUT</sub>, but care should be taken to maintain the correct relationship between SYSCLK and the aforementioned functional blocks.

| REGISTER ADDRESS             | BIT | LABEL                 | DEFAULT | DESCRIPTION                                                                                                                                                           |
|------------------------------|-----|-----------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R248 (F8h)<br>FLL NCO Test 1 | 5:0 | FLL_FRC_NCO_VAL [5:0] | 01_1001 | FLL Forced oscillator value<br>Valid range is 000000 to 111111<br>0x19h (011001) = 12MHz approx<br>(Note that this field is required for free-running FLL modes only) |
| R247 (F7h)<br>FLL NCO Test 0 | 0   | FLL_FRC_NCO           | 0       | FLL Forced control select<br>0 = Normal<br>1 = FLL oscillator controlled by FLL_FRC_NCO_VAL<br>(Note that this field is required for free-running FLL modes only)     |

**Table 72 FLL Free-Running Mode**

In both cases described above, the FLL must be selected as the SYSCLK source by setting SYSCLK\_SRC (see Table 61). Note that, in the absence of any reference clock, the FLL output is subject to a very wide tolerance. See “Electrical Characteristics” for details of the FLL accuracy.

## GPIO OUTPUTS FROM FLL

The WM8904 has an internal signal which indicates whether the FLL Lock has been achieved. The FLL Lock status is an input to the Interrupt control circuit and can be used to trigger an Interrupt event - see “Interrupts”.

The FLL Lock signal can be output directly on a GPIO pin as an external indication of FLL Lock. See “General Purpose Input/Output (GPIO)” for details of how to configure a GPIO pin to output the FLL Lock signal.

The FLL Clock can be output directly on a GPIO pin as a clock signal for other circuits. Note that the FLL Clock may be output even if the FLL is not selected as the WM8904 SYSCLK source. The clocking configuration is illustrated in Figure 59. See “General Purpose Input/Output (GPIO)” for details of how to configure a GPIO pin to output the FLL Clock.

**EXAMPLE FLL CALCULATION**

To generate 12.288 MHz output ( $F_{OUT}$ ) from a 12.000 MHz reference clock ( $F_{REF}$ ):

- Set FLL\_CLK\_REF\_DIV in order to generate  $F_{REF} \leq 13.5\text{MHz}$ :  
 $FLL\_CLK\_REF\_DIV = 00$  (divide by 1)
- Set FLL\_CTRL\_RATE to the recommended setting:  
 $FLL\_CTRL\_RATE = 000$  (divide by 1)
- Set FLL\_GAIN to the recommended setting:  
 $FLL\_GAIN = 0000$  (multiply by 1)
- Set FLL\_OUTDIV for the required output frequency as shown in Table 69:-  
 $F_{OUT} = 12.288\text{ MHz}$ , therefore  $FLL\_OUTDIV = 07h$  (divide by 8)
- Set FLL\_FRATIO for the given reference frequency as shown in Table 70:  
 $F_{REF} = 12\text{MHz}$ , therefore  $FLL\_FRATIO = 0h$  (divide by 1)
- Calculate  $F_{VCO}$  as given by  $F_{VCO} = F_{OUT} \times FLL\_OUTDIV$ :-  
 $F_{VCO} = 12.288 \times 8 = 98.304\text{MHz}$
- Calculate N.K as given by  $N.K = F_{VCO} / (FLL\_FRATIO \times F_{REF})$ :  
 $N.K = 98.304 / (1 \times 12) = 8.192$
- Determine FLL\_N and FLL\_K from the integer and fractional portions of N.K:-  
FLL\_N is 8. FLL\_K is 0.192
- Confirm that N.K is a fractional quantity and set FLL\_FRACN\_ENA:  
N.K is fractional. Set  $FLL\_FRACN\_ENA = 1$ .  
Note that, if N.K is an integer, then an alternative value of FLL\_FRATIO should be selected in order to produce a fractional value of N.K.

## EXAMPLE FLL SETTINGS

Table 73 provides example FLL settings for generating common SYSCLK frequencies from a variety of low and high frequency reference inputs.

| F <sub>REF</sub> | F <sub>OUT</sub> | FLL_CLK_REF_DIV     | F <sub>VCO</sub> | FLL_N         | FLL_K               | FLL_FRATIO | FLL_OUTDIV | FLL_FRACN_ENA |
|------------------|------------------|---------------------|------------------|---------------|---------------------|------------|------------|---------------|
| 32.768 kHz       | 12.288 MHz       | Divide by 1<br>(0h) | 98.304<br>MHz    | 187<br>(0BBh) | 0.5<br>(8000h)      | 16<br>(4h) | 8<br>(7h)  | 1             |
| 32.768 kHz       | 11.288576<br>MHz | Divide by 1<br>(0h) | 90.308608<br>MHz | 344<br>(158h) | 0.5<br>(8000h)      | 8<br>(3h)  | 8<br>(7h)  | 1             |
| 32.768 kHz       | 11.2896<br>MHz   | Divide by 1<br>(0h) | 90.3168<br>MHz   | 344<br>(158h) | 0.53125<br>(8800h)  | 8<br>(3h)  | 8<br>(7h)  | 1             |
| 48 kHz           | 12.288 MHz       | Divide by 1<br>(0h) | 98.304<br>MHz    | 256<br>(100h) | 0<br>(0000h)        | 8<br>(3h)  | 8<br>(7h)  | 0             |
| 12.000 MHz       | 12.288 MHz       | Divide by 1<br>(0h) | 98.3040<br>MHz   | 8<br>(008h)   | 0.192<br>(3127h)    | 1<br>(0h)  | 8<br>(7h)  | 1             |
| 12.000 MHz       | 11.289597<br>MHz | Divide by 1<br>(0h) | 90.3168<br>MHz   | 7<br>(007h)   | 0.526398<br>(86C2h) | 1<br>(0h)  | 8<br>(7h)  | 1             |
| 12.288 MHz       | 12.288 MHz       | Divide by 1<br>(0h) | 98.304<br>MHz    | 8<br>(008h)   | 0<br>(0000h)        | 1<br>(0h)  | 8<br>(7h)  | 0             |
| 12.288 MHz       | 11.2896<br>MHz   | Divide by 1<br>(0h) | 90.3168<br>MHz   | 7<br>(007h)   | 0.35<br>(599Ah)     | 1<br>(0h)  | 8<br>(7h)  | 1             |
| 13.000 MHz       | 12.287990<br>MHz | Divide by 1<br>(0h) | 98.3040<br>MHz   | 7<br>(007h)   | 0.56184<br>(8FD5h)  | 1<br>(0h)  | 8<br>(7h)  | 1             |
| 13.000 MHz       | 11.289606<br>MHz | Divide by 1<br>(0h) | 90.3168<br>MHz   | 6<br>(006h)   | 0.94745<br>(F28Ch)  | 1<br>(0h)  | 8<br>(7h)  | 1             |
| 19.200 MHz       | 12.287988<br>MHz | Divide by 2<br>(1h) | 98.3039<br>MHz   | 5<br>(005h)   | 0.119995<br>(1EB8h) | 1<br>(0h)  | 8<br>(7h)  | 1             |
| 19.200 MHz       | 11.289588<br>MHz | Divide by 2<br>(1h) | 90.3168<br>MHz   | 4<br>(004h)   | 0.703995<br>(B439h) | 1<br>(0h)  | 8<br>(7h)  | 1             |

**Table 73 Example FLL Settings**

## GENERAL PURPOSE INPUT/OUTPUT (GPIO)

The WM8904 provides four multifunction pins that can be configured to provide a number of different functions. These are digital input/output pins on the DBVDD power domain. The GPIO pins are:

- IRQ/GPIO1
- GPIO2
- GPIO3
- BCLK/GPIO4

Each general purpose I/O pin can be configured to be a GPIO input or configured as one of a number of output functions. Signal de-bouncing can be selected on GPIO input pins for use with jack/button detect applications. Table 74 lists the functions that are available on each of the GPIO pins.

| GPIO Pin Function                                   | GPIO PINS   |       |       |              |
|-----------------------------------------------------|-------------|-------|-------|--------------|
|                                                     | IRQ / GPIO1 | GPIO2 | GPIO3 | BCLK / GPIO4 |
| GPIO input<br>(including jack/button detect)        | Yes         | Yes   | Yes   | Yes          |
| GPIO output                                         | Yes         | Yes   | Yes   | Yes          |
| BCLK                                                | No          | No    | No    | Yes          |
| Interrupt (IRQ)                                     | Yes         | Yes   | Yes   | Yes          |
| MICBIAS current detect                              | Yes         | Yes   | Yes   | Yes          |
| MICBIAS short-circuit detect                        | Yes         | Yes   | Yes   | Yes          |
| Digital microphone interface<br>(DMIC clock output) | Yes         | Yes   | Yes   | Yes          |
| FLL Lock output                                     | Yes         | Yes   | Yes   | Yes          |
| FLL Clock output                                    | Yes         | Yes   | Yes   | Yes          |

**Table 74 GPIO Functions Available**

### IRQ/GPIO1

The IRQ/GPIO1 pin is configured using the register bits described in Table 75. By default, this pin is IRQ output with pull-down resistor enabled.

| REGISTER ADDRESS             | BIT | LABEL           | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                        |
|------------------------------|-----|-----------------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R121 (79h)<br>GPIO Control 1 | 5   | GPIO1_PU        | 0       | GPIO1 pull-up resistor enable<br>0 = pull-up disabled<br>1 = pull-up enabled                                                                                                                                                                                                                       |
|                              | 4   | GPIO1_PD        | 1       | GPIO1 pull-down resistor enable<br>0 = pull-down disabled<br>1 = pull-down enabled                                                                                                                                                                                                                 |
|                              | 3:0 | GPIO1_SEL [3:0] | 0100    | GPIO1 Function Select<br>0000 = Input pin<br>0001 = Clock output<br>(f=SYSCLK/OPCLKDIV)<br>0010 = Logic '0'<br>0011 = Logic '1'<br>0100 = IRQ (default)<br>0101 = FLL Lock<br>0110 = Mic Detect<br>0111 = Mic Short<br>1000 = DMIC clock out<br>1001 = FLL Clock Output<br>1010 to 1111 = Reserved |

**Table 75 IRQ/GPIO1 Control**

## GPIO2

The GPIO2 pin is configured using the register bits described in Table 76. By default, this pin is GPIO input with pull-down resistor enabled.

| REGISTER ADDRESS                | BIT | LABEL           | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                        |
|---------------------------------|-----|-----------------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R122 (7Ah)<br>GPIO<br>Control 2 | 5   | GPIO2_PU        | 0       | GPIO2 pull-up resistor enable<br>0 = pull-up disabled<br>1 = pull-up enabled                                                                                                                                                                                                                       |
|                                 | 4   | GPIO2_PD        | 1       | GPIO2 pull-down resistor enable<br>0 = pull-down disabled<br>1 = pull-down enabled                                                                                                                                                                                                                 |
|                                 | 3:0 | GPIO2_SEL [3:0] | 0000    | GPIO2 Function Select<br>0000 = Input pin (default)<br>0001 = Clock output<br>(f=SYSCLK/OPCLKDIV)<br>0010 = Logic '0'<br>0011 = Logic '1'<br>0100 = IRQ<br>0101 = FLL Lock<br>0110 = Mic Detect<br>0111 = Mic Short<br>1000 = DMIC clock out<br>1001 = FLL Clock Output<br>1010 to 1111 = Reserved |

**Table 76 GPIO2 Control**

## GPIO3

The GPIO3 pin is configured using the register bits described in Table 77. By default, this pin is GPIO input with pull-down resistor enabled.

| REGISTER ADDRESS                | BIT | LABEL           | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                        |
|---------------------------------|-----|-----------------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R123 (7Bh)<br>GPIO<br>Control 3 | 5   | GPIO3_PU        | 0       | GPIO3 pull-up resistor enable<br>0 = pull-up disabled<br>1 = pull-up enabled                                                                                                                                                                                                                       |
|                                 | 4   | GPIO3_PD        | 1       | GPIO3 pull-down resistor enable<br>0 = pull-down disabled<br>1 = pull-down enabled                                                                                                                                                                                                                 |
|                                 | 3:0 | GPIO3_SEL [3:0] | 0000    | GPIO3 Function Select<br>0000 = Input pin (default)<br>0001 = Clock output<br>(f=SYSCLK/OPCLKDIV)<br>0010 = Logic '0'<br>0011 = Logic '1'<br>0100 = IRQ<br>0101 = FLL Lock<br>0110 = Mic Detect<br>0111 = Mic Short<br>1000 = DMIC clock out<br>1001 = FLL Clock Output<br>1010 to 1111 = Reserved |

**Table 77 GPIO3 Control**

### BCLK/GPIO4

The BCLK/GPIO4 pin is configured using the register bits described in Table 78. By default, this pin provides the BCLK function associated with the Digital Audio Interface. The BCLK function can operate in slave mode (BCLK input) or in master mode (BCLK output), depending on the BCLK\_DIR register bit as described in the "Digital Audio Interface" section.

It is possible to configure the BCLK/GPIO4 pin to provide various GPIO functions; in this case, the BCLK function is provided using the MCLK pin. Note that the BCLK function is always in slave mode (BCLK input) in this mode.

To select the GPIO4 functions, it is required to set BCLK\_DIR = 0 (see Table 56) and to set GPIO\_BCLK\_MODE\_ENA = 1 (see Table 78 below). In this configuration, the MCLK input is used as the bit-clock (BCLK) for the Digital Audio Interface.

When the BCLK/GPIO4 pin is configured as GPIO4, then the pin function is determined by the GPIO\_BCLK\_SEL register field.

| REGISTER ADDRESS             | BIT | LABEL               | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                          |
|------------------------------|-----|---------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R124 (7Ch)<br>GPIO Control 4 | 7   | GPIO_BCLK_MODE_ENA  | 0       | Selects BCLK/GPIO4 pin function<br>0 = BCLK/GPIO4 is used as BCLK<br>1 = BCLK/GPIO4 is used as GPIO.<br>MCLK provides the BCLK in the AIF in this mode.                                                                                                                                              |
|                              | 3:0 | GPIO_BCLK_SEL [3:0] | 0000    | GPIO_BCLK function select:<br>0000 = Input Pin (default)<br>0001 = Clock output (f=SYSCLK/OPCLKDIV)<br>0010 = Logic '0'<br>0011 = Logic '1'<br>0100 = IRQ<br>0101 = FLL Lock<br>0110 = Mic Detect<br>0111 = Mic Short<br>1000 = DMIC clock out<br>1001 = FLL Clock Output<br>1010 to 1111 = Reserved |

**Table 78 BCLK/GPIO4 Control**

## INTERRUPTS

The Interrupt Controller has multiple inputs; these include the GPIO input pins and the MICBIAS current detection circuits. Any combination of these inputs can be used to trigger an Interrupt (IRQ) event.

WM8904 interrupt events may be triggered in response to external GPIO inputs, FLL Lock status, MICBIAS status or Write Sequencer status. Note that the GPIO inputs (including GPI7 and GPI8) are only supported as interrupt events when the respective pin is configured as a GPIO input.

There is an Interrupt Status field associated with each of the IRQ inputs. These are contained in the Interrupt Status Register (R127), as described in Table 79. The status of the IRQ inputs can be read from this register at any time, or in response to the Interrupt Output being signalled via a GPIO pin.

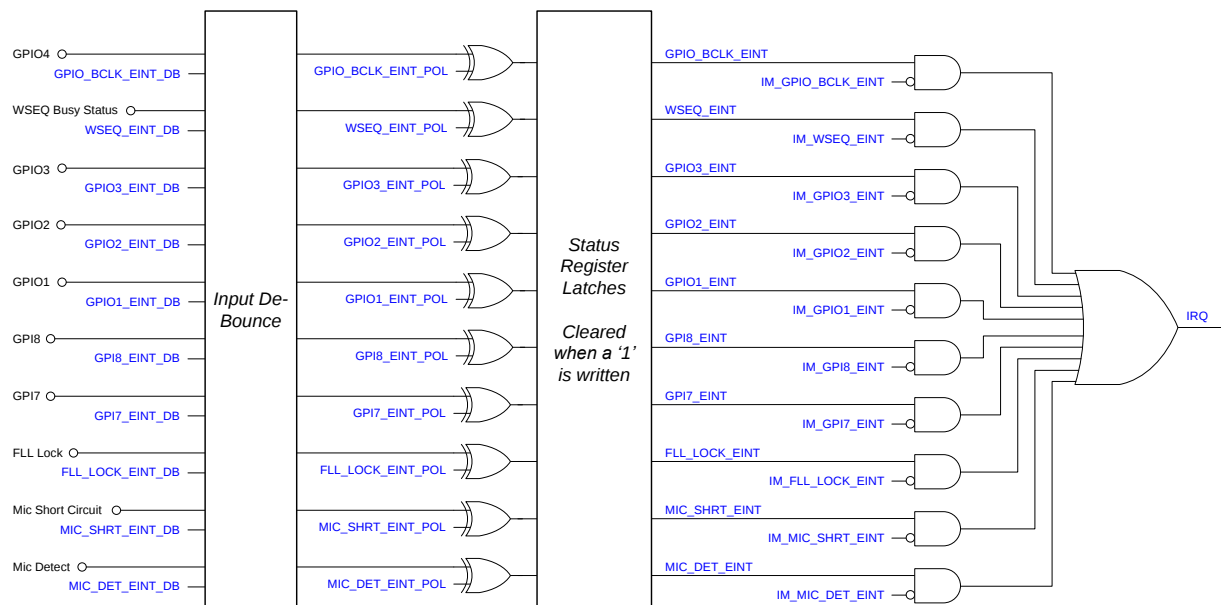
Individual mask bits can select or deselect different functions from the Interrupt controller. These are listed within the Interrupt Status Mask register (R128), as described in Table 80. Note that the Interrupt Status fields remain valid, even when masked, but the masked bits will not cause the Interrupt (IRQ) output to be asserted.

The Interrupt (IRQ) output represents the logical 'OR' of all unmasked IRQ inputs. The bits within the Interrupt Status register (R127) are latching fields and, once set, are not reset until a '1' is written to the respective register bit in the Interrupt Status Register. The Interrupt (IRQ) output is not reset until each of the unmasked IRQ inputs has been reset.

Each of the IRQ inputs can be individually inverted in the Interrupt function, enabling either active high or active low behaviour on each IRQ input. The polarity inversion is controlled using the bits contained in the Interrupt Polarity register (R129).

Each of the IRQ inputs can be debounced to ensure that spikes and transient glitches do not assert the Interrupt Output. This is selected using the bits contained in the Interrupt Debounce Register (R130).

The WM8904 Interrupt Controller circuit is illustrated in Figure 60. The associated control fields are described in Table 79 through to Table 82.



**Figure 60** Interrupt Controller

| REGISTER ADDRESS               | BIT | LABEL          | DEFAULT | DESCRIPTION                                                                                                                                                                                          |
|--------------------------------|-----|----------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R127 (7Fh)<br>Interrupt Status | 10  | IRQ            | 0       | Logical OR of all other interrupt flags                                                                                                                                                              |
|                                | 9   | GPIO_BCLK_EINT | 0       | GPIO4 interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written                                                                                                    |
|                                | 8   | WSEQ_EINT      | 0       | Write Sequence interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written.<br>Note that the read value of WSEQ_EINT is not valid whilst the Write Sequencer is Busy |
|                                | 7   | GPIO3_EINT     | 0       | GPIO3 interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written                                                                                                    |
|                                | 6   | GPIO2_EINT     | 0       | GPIO2 interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written                                                                                                    |
|                                | 5   | GPIO1_EINT     | 0       | GPIO1 interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written                                                                                                    |
|                                | 4   | GPI8_EINT      | 0       | GPI8 interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written                                                                                                     |
|                                | 3   | GPI7_EINT      | 0       | GPI7 interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written                                                                                                     |
|                                | 2   | FLL_LOCK_EINT  | 0       | FLL Lock interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written                                                                                                 |
|                                | 1   | MIC_SHRT_EINT  | 0       | MICBIAS short circuit interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written                                                                                    |
|                                | 0   | MIC_DET_EINT   | 0       | MICBIAS current detect interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written                                                                                   |

**Table 79 Interrupt Status Registers**

| REGISTER ADDRESS                    | BIT | LABEL             | DEFAULT | DESCRIPTION                                                                              |
|-------------------------------------|-----|-------------------|---------|------------------------------------------------------------------------------------------|
| R128 (80h)<br>Interrupt Status Mask | 9   | IM_GPIO_BCLK_EINT | 1       | GPIO4 interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt                  |
|                                     | 8   | IM_WSEQ_EINT      | 1       | Write sequencer interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt        |
|                                     | 7   | IM_GPIO3_EINT     | 1       | GPIO3 interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt                  |
|                                     | 6   | IM_GPIO2_EINT     | 1       | GPIO2 interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt                  |
|                                     | 5   | IM_GPIO1_EINT     | 1       | GPIO1 interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt                  |
|                                     | 4   | IM_GPI8_EINT      | 1       | GPI8 interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt                   |
|                                     | 3   | IM_GPI7_EINT      | 1       | GPI7 interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt                   |
|                                     | 2   | IM_FLL_LOCK_EINT  | 1       | FLL Lock interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt               |
|                                     | 1   | IM_MIC_SHRT_EINT  | 1       | MICBIAS short circuit interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt  |
|                                     | 0   | IM_MIC_DET_EINT   | 1       | MICBIAS current detect interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt |

**Table 80 Interrupt Mask Registers**

| REGISTER ADDRESS                 | BIT | LABEL              | DEFAULT | DESCRIPTION                                                                                                                                                   |
|----------------------------------|-----|--------------------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R129 (81h)<br>Interrupt Polarity | 9   | GPIO_BCLK_EINT_POL | 0       | GPIO4 interrupt polarity<br>0 = active high<br>1 = active low                                                                                                 |
|                                  | 8   | WSEQ_EINT_POL      | 0       | Write Sequencer interrupt polarity<br>0 = active high (interrupt is triggered when WSEQ is busy)<br>1 = active low (interrupt is triggered when WSEQ is idle) |
|                                  | 7   | GPIO3_EINT_POL     | 0       | GPIO3 interrupt polarity<br>0 = active high<br>1 = active low                                                                                                 |
|                                  | 6   | GPIO2_EINT_POL     | 0       | GPIO2 interrupt polarity<br>0 = active high<br>1 = active low                                                                                                 |

| REGISTER ADDRESS | BIT | LABEL             | DEFAULT | DESCRIPTION                                                                                                                                                        |
|------------------|-----|-------------------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                  | 5   | GPIO1_EINT_POL    | 0       | GPIO1 interrupt polarity<br>0 = active high<br>1 = active low                                                                                                      |
|                  | 4   | GPI8_EINT_POL     | 0       | GPI8 interrupt polarity<br>0 = active high<br>1 = active low                                                                                                       |
|                  | 3   | GPI7_EINT_POL     | 0       | GPI7 interrupt polarity<br>0 = active high<br>1 = active low                                                                                                       |
|                  | 2   | FLL_LOCK_EINT_POL | 0       | FLL Lock interrupt polarity<br>0 = active high (interrupt is triggered when FLL Lock is reached)<br>1 = active low (interrupt is triggered when FLL is not locked) |
|                  | 1   | MIC_SHRT_EINT_POL | 0       | MICBIAS short circuit interrupt polarity<br>0 = active high<br>1 = active low                                                                                      |
|                  | 0   | MIC_DET_EINT_POL  | 0       | MICBIAS current detect interrupt polarity<br>0 = active high<br>1 = active low                                                                                     |

**Table 81 Interrupt Polarity Registers**

| REGISTER ADDRESS                 | BIT | LABEL             | DEFAULT | DESCRIPTION                                                              |
|----------------------------------|-----|-------------------|---------|--------------------------------------------------------------------------|
| R130 (82h)<br>Interrupt Debounce | 9   | GPIO_BCLK_EINT_DB | 0       | GPIO4 interrupt debounce<br>0 = disabled<br>1 = enabled                  |
|                                  | 8   | WSEQ_EINT_DB      | 0       | Write Sequencer interrupt debounce enable<br>0 = disabled<br>1 = enabled |
|                                  | 7   | GPIO3_EINT_DB     | 0       | GPIO3 input debounce<br>0 = disabled<br>1 = enabled                      |
|                                  | 6   | GPIO2_EINT_DB     | 0       | GPIO2 input debounce<br>0 = disabled<br>1 = enabled                      |
|                                  | 5   | GPIO1_EINT_DB     | 0       | GPIO1 input debounce<br>0 = disabled<br>1 = enabled                      |
|                                  | 4   | GPI8_EINT_DB      | 0       | GPI8 input debounce<br>0 = disabled<br>1 = enabled                       |
|                                  | 3   | GPI7_EINT_DB      | 0       | GPI7 input debounce<br>0 = disabled<br>1 = enabled                       |
|                                  | 2   | FLL_LOCK_EINT_DB  | 0       | FLL Lock debounce<br>0 = disabled<br>1 = enabled                         |

| REGISTER ADDRESS | BIT | LABEL            | DEFAULT | DESCRIPTION                                                              |
|------------------|-----|------------------|---------|--------------------------------------------------------------------------|
|                  | 1   | MIC_SHRT_EINT_DB | 0       | MICBIAS short circuit interrupt debounce<br>0 = disabled<br>1 = enabled  |
|                  | 0   | MIC_DET_EINT_DB  | 0       | MICBIAS current detect interrupt debounce<br>0 = disabled<br>1 = enabled |

**Table 82 Interrupt Debounce Registers**

### USING IN1L AND IN1R AS INTERRUPT INPUTS

IN1L pin has three input functions.

- Analogue audio input
- Digital microphone input (DMICDAT1)
- Digital interrupt input (GPI7)

IN1R pin has three input functions.

- Analogue audio input
- Digital microphone input (DMICDAT2)
- Digital interrupt input (GPI8)

To use these pins as digital interrupt inputs, they must be enabled using the GPI7\_ENA and GPI8\_ENA bits as described in Table 83.

| REGISTER ADDRESS             | BIT | LABEL    | DEFAULT | DESCRIPTION                                      |
|------------------------------|-----|----------|---------|--------------------------------------------------|
| R124 (7Ch)<br>GPIO Control 4 | 9   | GPI7_ENA | 0       | GPI7 input enable<br>0 = disabled<br>1 = enabled |
|                              | 8   | GPI8_ENA | 0       | GPI8 input enable<br>0 = disabled<br>1 = enabled |

**Table 83 Enabling IN1L and IN1R as Interrupts GPI7 and GPI8**

## CONTROL INTERFACE

The WM8904 is controlled by writing to registers through a 2-wire serial control interface. Readback is available for all registers, including Chip ID, power management status and GPIO status.

Note that, if it cannot be assured that MCLK is present when accessing the register map, then it is required to set CLK\_SYS\_ENA = 0 to ensure correct operation. See “Clocking and Sample Rates” for details of CLK\_SYS\_ENA.

The WM8904 is a slave device on the control interface; SCLK is a clock input, while SDA is a bi-directional data pin. To allow arbitration of multiple slaves (and/or multiple masters) on the same interface, the WM8904 transmits logic 1 by tri-stating the SDA pin, rather than pulling it high. An external pull-up resistor is required to pull the SDA line high so that the logic 1 can be recognised by the master.

In order to allow many devices to share a single 2-wire control bus, every device on the bus has a unique 8-bit device ID (this is not the same as the 8-bit address of each register in the WM8904). The WM8904 device ID is 0011 0100 (34h). The LSB of the device ID is the Read/Write bit; this bit is set to logic 1 for “Read” and logic 0 for “Write”.

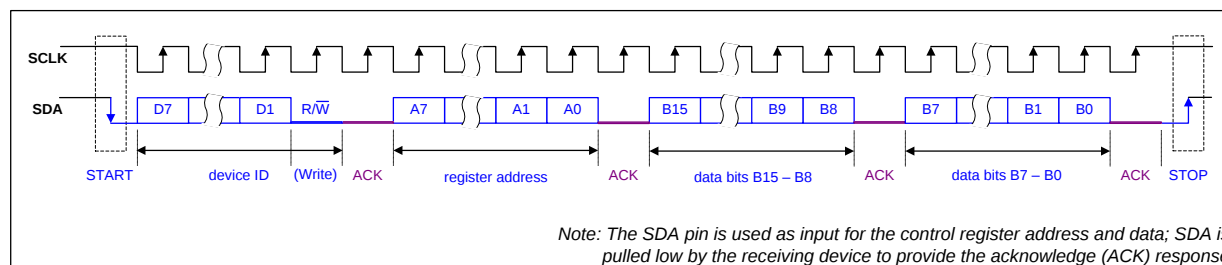
The WM8904 operates as a slave device only. The controller indicates the start of data transfer with a high to low transition on SDA while SCLK remains high. This indicates that a device ID, register address and data will follow. The WM8904 responds to the start condition and shifts in the next eight bits on SDA (8-bit device ID including Read/Write bit, MSB first). If the device ID received matches the device ID of the WM8904, then the WM8904 responds by pulling SDA low on the next clock pulse (ACK). If the device ID is not recognised or the R/W bit is ‘1’ when operating in write only mode, the WM8904 returns to the idle condition and waits for a new start condition and valid address.

If the device ID matches the device ID of the WM8904, the data transfer continues as described below. The controller indicates the end of data transfer with a low to high transition on SDA while SCLK remains high. After receiving a complete address and data sequence the WM8904 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. SDA changes while SCLK is high), the device returns to the idle condition.

The WM8904 supports the following read and write operations:

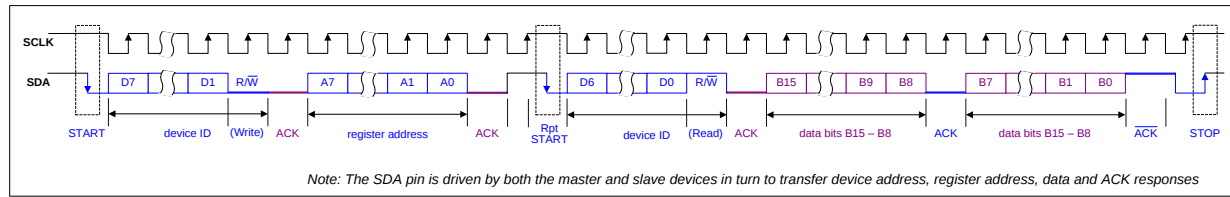
- Single write
- Single read
- Multiple write using auto-increment
- Multiple read using auto-increment

The sequence of signals associated with a single register write operation is illustrated in Figure 61.



**Figure 61 Control Interface Register Write**

The sequence of signals associated with a single register read operation is illustrated in Figure 62.



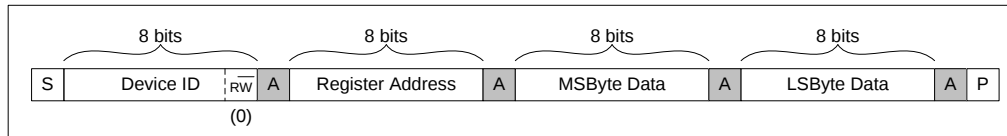
**Figure 62 Control Interface Register Read**

The Control Interface also supports other register operations, as listed above. The interface protocol for these operations is summarised below. The terminology used in the following figures is detailed in Table 84.

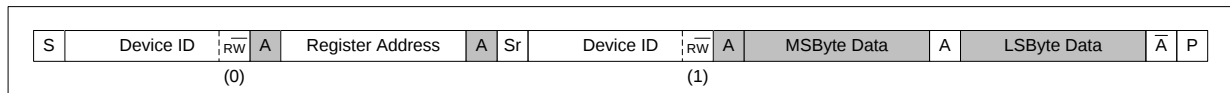
Note that multiple write and multiple read operations are supported using the auto-increment mode. This feature enables the host processor to access sequential blocks of the data in the WM8904 register map faster than is possible with single register operations.

| TERMINOLOGY   |              | DESCRIPTION                         |
|---------------|--------------|-------------------------------------|
| S             |              | Start Condition                     |
| Sr            |              | Repeated start                      |
| A             |              | Acknowledge (SDA Low)               |
| $\bar{A}$     |              | Not Acknowledge (SDA High)          |
| P             |              | Stop Condition                      |
| R/W           | ReadNotWrite | 0 = Write<br>1 = Read               |
| [White field] |              | Data flow from bus master to WM8904 |
| [Grey field]  |              | Data flow from WM8904 to bus master |

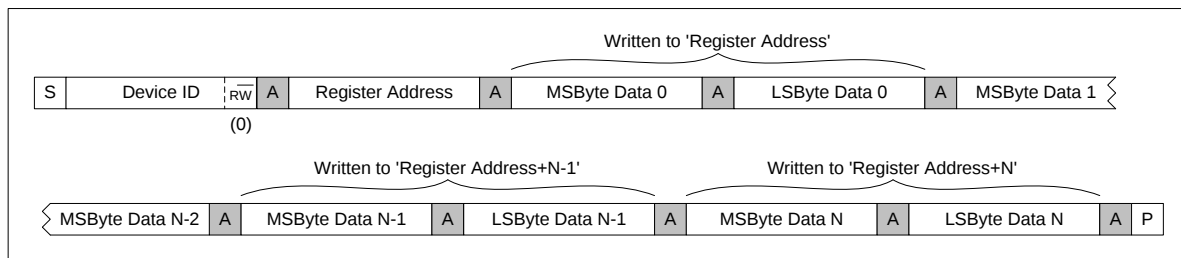
**Table 84 Control Interface Terminology**



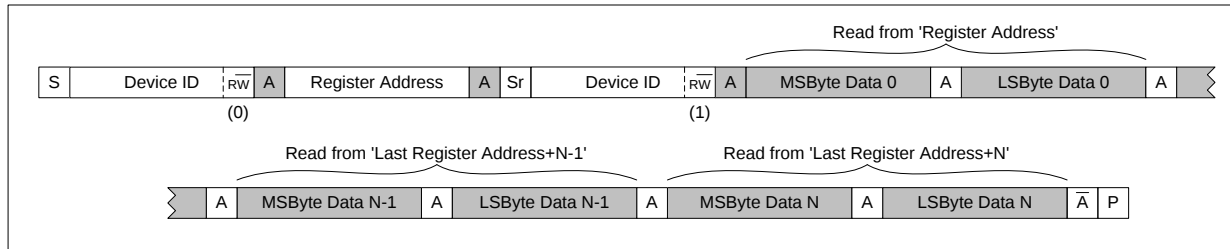
**Figure 63 Single Register Write to Specified Address**



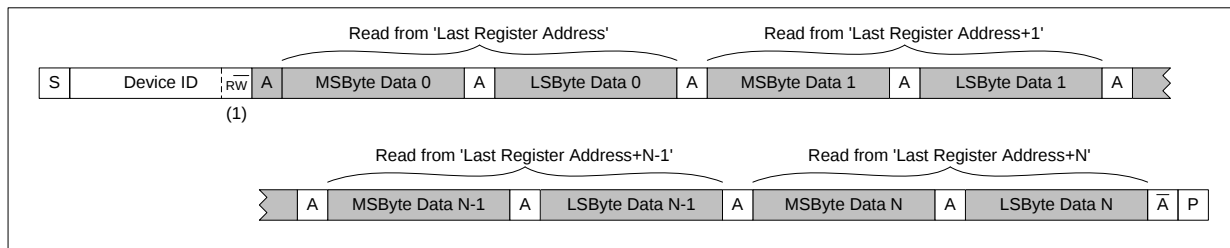
**Figure 64 Single Register Read from Specified Address**



**Figure 65 Multiple Register Write to Specified Address using Auto-increment**



**Figure 66 Multiple Register Read from Specified Address using Auto-increment**



**Figure 67 Multiple Register Read from Last Address using Auto-increment**

## CONTROL WRITE SEQUENCER

The Control Write Sequencer is a programmable unit that forms part of the WM8904 control interface logic. It provides the ability to perform a sequence of register write operations with the minimum of demands on the host processor - the sequence may be initiated by a single operation from the host processor and then left to execute independently.

Default sequences for Start-Up and Shutdown are provided (see “Default Sequences” section). It is recommended that these default sequences are used unless changes become necessary.

When a sequence is initiated, the sequencer performs a series of pre-defined register writes. The host processor informs the sequencer of the start index of the required sequence within the sequencer's memory. At each step of the sequence, the contents of the selected register fields are read from the sequencer's memory and copied into the WM8904 control registers. This continues sequentially through the sequencer's memory until an “End of Sequence” bit is encountered; at this point, the sequencer stops and an Interrupt status flag is asserted. For cases where the timing of the write sequence is important, a programmable delay can be set for specific steps within the sequence.

Note that the Control Write Sequencer's internal clock is derived from the internal clock SYSCLK. An external MCLK signal must be present when using the Control Write Sequencer, and SYSCLK must be enabled by setting CLK\_SYS\_ENA (see “Clocking and Sample Rates”). The clock division from MCLK is handled transparently by the WM8904 without user intervention, as long as MCLK and sample rates are set correctly.

### INITIATING A SEQUENCE

The Register fields associated with running the Control Write Sequencer are described in Table 85.

The Write Sequencer Clock is enabled by setting the WSEQ\_ENA bit. Note that the operation of the Control Write Sequencer also requires the internal clock SYSCLK to be enabled via the CLK\_SYS\_ENA (see “Clocking and Sample Rates”).

The start index of the required sequence must be written to the WSEQ\_START\_INDEX field. Setting the WSEQ\_START bit initiates the sequencer at the given start index.

The Write Sequencer can be interrupted by writing a logic 1 to the WSEQ\_ABORT bit.

The current status of the Write Sequencer can be read using two further register fields - when the WSEQ\_BUSY bit is asserted, this indicates that the Write Sequencer is busy. Note that, whilst the Control Write Sequencer is running a sequence (indicated by the WSEQ\_BUSY bit), normal read/write operations to the Control Registers cannot be supported. (The Write Sequencer registers and the Software Reset register can still be accessed when the Sequencer is busy.) The index of the current step in the Write Sequencer can be read from the WSEQ\_CURRENT\_INDEX field; this is an indicator of the sequencer's progress. On completion of a sequence, this field holds the index of the last step within the last commanded sequence.

When the Write Sequencer reaches the end of a sequence, it asserts the WSEQ\_EINT flag in Register R127 (see Table 79 within the "Interrupts" section). This flag can be used to generate an Interrupt Event on completion of the sequence. Note that the WSEQ\_EINT flag is asserted to indicate that the WSEQ is NOT Busy.

| REGISTER ADDRESS                | BIT | LABEL                    | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                      |
|---------------------------------|-----|--------------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R108 (6Ch)<br>Write Sequencer 0 | 8   | WSEQ_ENA                 | 0       | Write Sequencer Enable.<br>0 = Disabled<br>1 = Enabled                                                                                                                                                                                                           |
| R111 (6Fh)<br>Write Sequencer 3 | 9   | WSEQ_ABORT               | 0       | Writing a 1 to this bit aborts the current sequence and returns control of the device back to the serial control interface.                                                                                                                                      |
|                                 | 8   | WSEQ_START               | 0       | Writing a 1 to this bit starts the write sequencer at the memory location indicated by the WSEQ_START_INDEX field. The sequence continues until it reaches an "End of sequence" flag. At the end of the sequence, this bit will be reset by the Write Sequencer. |
|                                 | 5:0 | WSEQ_START_INDEX [5:0]   | 00_0000 | Sequence Start Index. This is the memory location of the first command in the selected sequence.<br>0 to 31 = RAM addresses<br>32 to 48 = ROM addresses<br>49 to 63 = Reserved                                                                                   |
| R112 (70h)<br>Write Sequencer 4 | 9:4 | WSEQ_CURRENT_INDEX [5:0] | 00_0000 | Sequence Current Index (read only):<br>This is the location of the most recently accessed command in the write sequencer memory.                                                                                                                                 |
|                                 | 0   | WSEQ_BUSY                | 0       | Sequencer Busy flag (read only):<br>0 = Sequencer idle<br>1 = Sequencer busy<br>Note: it is not possible to write to control registers via the control interface while the Sequencer is Busy.                                                                    |

**Table 85 Write Sequencer Control - Initiating a Sequence**

## PROGRAMMING A SEQUENCE

A sequence consists of write operations to data bits (or groups of bits) within the control registers. The register fields associated with programming the Control Write Sequencer are described in Table 86.

For each step of the sequence being programmed, the Sequencer Index must be written to the WSEQ\_WRITE\_INDEX field. The values 0 to 31 correspond to all the available RAM addresses within the Write Sequencer memory. (Note that memory addresses 32 to 48 also exist, but these are ROM addresses, which are not programmable.)

Having set the Index as described above, Register R109 must be written to (containing the Control Register Address, the Start Bit Position and the Field Width applicable to this step of the sequence).

Also, Register R110 must be written to (containing the Register Data, the End of Sequence flag and the Delay time required after this step is executed). After writing to these two registers, the next step in the sequence may be programmed by updating WSEQ\_WRITE\_INDEX and repeating the procedure.

WSEQ\_ADDR is an 8-bit field containing the Control Register Address in which the data should be written.

WSEQ\_DATA\_START is a 4-bit field which identifies the LSB position within the selected Control Register to which the data should be written. Setting WSEQ\_DATA\_START = 0100 will cause 1-bit data to be written to bit 4. With this setting, 4-bit data would be written to bits 7:4 and so on.

WSEQ\_DATA\_WIDTH is a 3-bit field which identifies the width of the data block to be written. This enables selected portions of a Control Register to be updated without any concern for other bits within the same register, eliminating the need for read-modify-write procedures. Values of 0 to 7 correspond to data widths of 1 to 8 respectively. For example, setting WSEQ\_DATA\_WIDTH = 010 will cause a 3-bit data block to be written. Note that the maximum value of this field corresponds to an 8-bit data block; writing to register fields greater than 8 bits wide must be performed using two separate operations of the Control Write Sequencer.

WSEQ\_DATA is an 8-bit field which contains the data to be written to the selected Control Register. The WSEQ\_DATA\_WIDTH field determines how many of these bits are written to the selected register; the most significant bits (above the number indicated by WSEQ\_DATA\_WIDTH) are ignored.

WSEQ\_DELAY is a 4-bit field which controls the waiting time between the current step and the next step in the sequence. The total delay time per step (including execution) is given by:

$$T = k \times (2^{WSEQ\_DELAY} + 8)$$

where  $k = 62.5\mu s$  (under recommended operating conditions)

This gives a useful range of execution/delay times from  $562\mu s$  up to 2.048s per step.

WSEQ\_EOS is a 1-bit field which indicates the End of Sequence. If this bit is set, then the Control Write Sequencer will automatically stop after this step has been executed.

| REGISTER ADDRESS                | BIT   | LABEL                  | DEFAULT   | DESCRIPTION                                                                                                                                                                           |
|---------------------------------|-------|------------------------|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R108 (6Ch)<br>Write Sequencer 0 | 4:0   | WSEQ_WRITE_INDEX [4:0] | 0_0000    | Sequence Write Index. This is the memory location to which any updates to R109 and R110 will be copied.<br>0 to 31 = RAM addresses                                                    |
| R109 (6Dh)<br>Write Sequencer 1 | 14:12 | WSEQ_DATA_WIDTH [2:0]  | 000       | Width of the data block written in this sequence step.<br>000 = 1 bit<br>001 = 2 bits<br>010 = 3 bits<br>011 = 4 bits<br>100 = 5 bits<br>101 = 6 bits<br>110 = 7 bits<br>111 = 8 bits |
|                                 | 11:8  | WSEQ_DATA_START [3:0]  | 0000      | Bit position of the LSB of the data block written in this sequence step.<br>0000 = Bit 0<br>...<br>1111 = Bit 15                                                                      |
|                                 | 7:0   | WSEQ_ADDR [7:0]        | 0000_0000 | Control Register Address to be written to in this sequence step.                                                                                                                      |

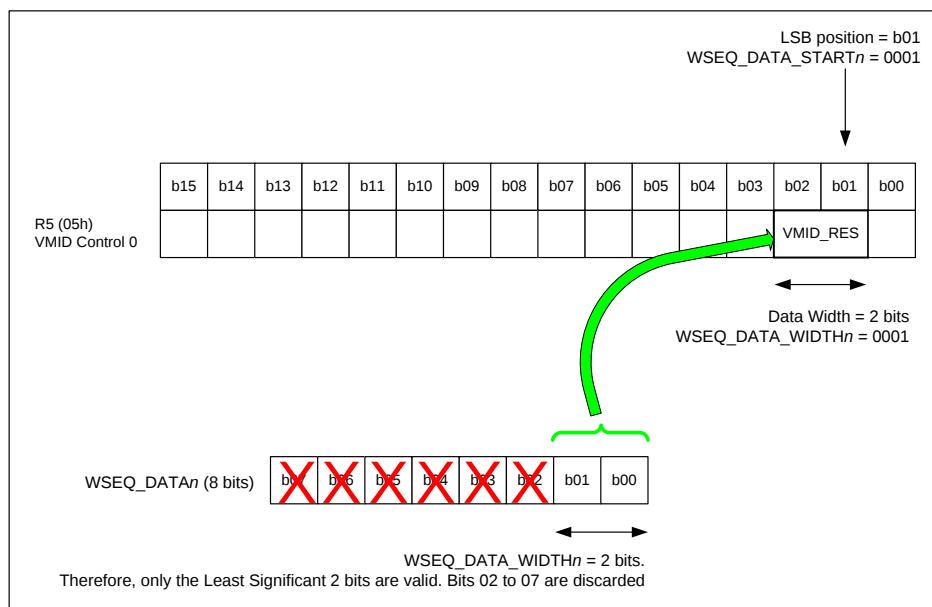
| REGISTER ADDRESS                | BIT  | LABEL            | DEFAULT   | DESCRIPTION                                                                                                                                                                                                 |
|---------------------------------|------|------------------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R110 (6Eh)<br>Write Sequencer 2 | 14   | WSEQ_EOS         | 0         | End of Sequence flag. This bit indicates whether the Control Write Sequencer should stop after executing this step.<br>0 = Not end of sequence<br>1 = End of sequence (Stop the sequencer after this step). |
|                                 | 11:8 | WSEQ_DELAY [3:0] | 0000      | Time delay after executing this step.<br>Total delay time per step (including execution)=<br>$62.5\mu s \times (2^{WSEQ\_DELAY} + 8)$                                                                       |
|                                 | 7:0  | WSEQ_DATA [7:0]  | 0000_0000 | Data to be written in this sequence step. When the data width is less than 8 bits, then one or more of the MSBs of WSEQ_DATA are ignored. It is recommended that unused bits be set to 0.                   |

**Table 86 Write Sequencer Control - Programming a Sequence**

Note that a 'Dummy' write can be inserted into a control sequence by commanding the sequencer to write a value of 0 to bit 0 of Register R255 (FFh). This is effectively a write to a non-existent register location. This can be used in order to create placeholders ready for easy adaptation of the sequence. For example, a sequence could be defined to power-up a mono signal path from DACL to headphone, with a 'dummy' write included to leave space for easy modification to a stereo signal path configuration. Dummy writes can also be used in order to implement additional time delays between register writes. Dummy writes are included in the default start-up sequence – see Table 88.

In summary, the Control Register to be written is set by the WSEQ\_ADDR field. The data bits that are written are determined by a combination of WSEQ\_DATA\_START, WSEQ\_DATA\_WIDTH and WSEQ\_DATA. This is illustrated below for an example case of writing to the VMID\_RES field within Register R5 (05h).

In this example, the Start Position is bit 01 (WSEQ\_DATA\_START = 0001b) and the Data width is 2 bits (WSEQ\_DATA\_WIDTH = 0001b). With these settings, the Control Write Sequencer would update the Control Register R5 [2:1] with the contents of WSEQ\_DATA [1:0].


**Figure 68 Control Write Sequencer Example**

## DEFAULT SEQUENCES

When the WM8904 is powered up, two Control Write Sequences are available through default settings in both RAM and ROM memory locations. The purpose of these sequences, and the register write required to initiate them, is summarised in Table 87. In both cases, a single register write will initiate the sequence.

| WSEQ START INDEX | WSEQ FINISH INDEX | PURPOSE           | TO INITIATE                        |
|------------------|-------------------|-------------------|------------------------------------|
| 0 (00h)          | 22 (16h)          | Start-Up sequence | Write 0100h to Register R111 (6Fh) |
| 25 (19h)         | 39 (27h)          | Shutdown sequence | Write 0119h to Register R111 (6Fh) |

**Table 87 Write Sequencer Default Sequences**

Note on Shutdown sequence: The instruction at Index Address 25 (19h) shorts the outputs LINEOUTL and LINEOUTR. If the Line outputs are not in use at the time the sequence is run, then the sequence could, instead, be started at Index Address 26.

Index addresses 0 to 31 may be programmed to users' own settings at any time, as described in "Programming a Sequence". Users' own settings remain in memory and are not affected by software resets (i.e. writing to Register R0). However, any non-default sequences are lost when the device is powered down.

## START-UP SEQUENCE

The Start-up sequence is initiated by writing 0100h to Register R111 (6Fh). This single operation starts the Control Write Sequencer at Index Address 0 (00h) and executes the sequence defined in Table 88.

For typical clocking configurations with MCLK=12.288MHz, this sequence takes approximately 300ms to run.

Note that, for fast startup, step 18 may be overwritten with dummy data in order to achieve startup within 50ms (see "Quick Start-Up and Shutdown").

| WSEQ INDEX | REGISTER ADDRESS | WIDTH  | START | DATA | DELAY | EOS | DESCRIPTION                                                                |
|------------|------------------|--------|-------|------|-------|-----|----------------------------------------------------------------------------|
| 0 (00h)    | R4 (04h)         | 5 bits | Bit 0 | 1Ah  | 0h    | 0b  | ISEL = 10b<br>BIAS_ENA = 0<br>(delay = 0.5625ms)                           |
| 1 (01h)    | R5 (05h)         | 8 bits | Bit 0 | 47h  | 6h    | 0b  | VMID_BUF_ENA = 1<br>VMID_RES[1:0] = 11b<br>VMID_ENA = 1<br>(delay = 4.5ms) |
| 2 (02h)    | R5 (05h)         | 2 bits | Bit 1 | 01h  | 0h    | 0b  | VMID_RES[1:0] = 01b<br>(delay = 0.5625ms)                                  |
| 3 (03h)    | R4 (04h)         | 1 bit  | Bit 0 | 01h  | 0h    | 0b  | BIAS_ENA = 1<br>(delay = 0.5625ms)                                         |
| 4 (04h)    | R14 (0Eh)        | 2 bits | Bit 0 | 03h  | 0h    | 0b  | HPL_PGA_ENA = 1<br>HPR_PGA_ENA = 1<br>(delay = 0.5625ms)                   |
| 5 (05h)    | R15 (0Fh)        | 2 bits | Bit 0 | 03h  | 0h    | 0b  | LINEOUTL_PGA_ENA = 1<br>LINEOUTR_PGA_ENA = 1<br>(delay = 0.5625ms)         |
| 6 (06h)    | R22 (16h)        | 1 bit  | Bit 1 | 01h  | 0h    | 0b  | CLK_DSP_ENA = 1<br>(delay = 0.5625ms)                                      |

| WSEQ INDEX | REGISTER ADDRESS | WIDTH  | START | DATA | DELAY | EOS | DESCRIPTION                                                                                                               |
|------------|------------------|--------|-------|------|-------|-----|---------------------------------------------------------------------------------------------------------------------------|
| 7 (07h)    | R18 (12h)        | 2 bits | Bit 2 | 03h  | 5h    | 0b  | DACL_ENA = 1<br>DACR_ENA = 1<br>(delay = 2.5ms)                                                                           |
| 8 (08h)    | R255 (FFh)       | 1 bit  | Bit 0 | 00h  | 0h    | 0b  | Dummy Write for expansion<br>(delay = 0.5625ms)                                                                           |
| 9 (09h)    | R4 (04h)         | 1 bit  | Bit 4 | 00h  | 0h    | 0b  | (delay = 0.5625ms)                                                                                                        |
| 10 (0Ah)   | R98 (62h)        | 1 bit  | Bit 0 | 01h  | 6h    | 0b  | CP_ENA = 1<br>(delay = 4.5ms)                                                                                             |
| 11 (0Bh)   | R255 (FFh)       | 1 bit  | Bit 0 | 00h  | 0h    | 0b  | Dummy Write for expansion<br>(delay = 0.5625ms)                                                                           |
| 12 (0Ch)   | R90 (5Ah)        | 8 bits | Bit 0 | 11h  | 0h    | 0b  | HPL_ENA = 1<br>HPR_ENA = 1<br>(delay = 0.5625ms)                                                                          |
| 13 (0Dh)   | R94 (5Eh)        | 8 bits | Bit 0 | 11h  | 0h    | 0b  | LINEOUTL_ENA = 1<br>LINEOUTR_ENA = 1<br>(delay = 0.5625ms)                                                                |
| 14 (0Eh)   | R90 (5Ah)        | 8 bits | Bit 0 | 33h  | 0h    | 0b  | HPL_ENA_DLY = 1<br>HPR_ENA_DLY = 1<br>(delay = 0.5625ms)                                                                  |
| 15 (0Fh)   | R94 (5Eh)        | 8 bits | Bit 0 | 33h  | 0h    | 0b  | LINEOUTL_ENA_DLY = 1<br>LINEOUTR_ENA_DLY = 1<br>(delay = 0.5625ms)                                                        |
| 16 (10h)   | R67 (43h)        | 4 bits | Bit 0 | 0Fh  | Ch    | 0b  | DCS_ENA_CHAN_0 = 1<br>DCS_ENA_CHAN_1 = 1<br>DCS_ENA_CHAN_2 = 1<br>DCS_ENA_CHAN_3 = 1<br>(delay = 0.5625ms)                |
| 17 (11h)   | R68 (44h)        | 8 bits | Bit 0 | F0h  | 0h    | 0b  | DCS_TRIG_STARTUP_0 = 1<br>DCS_TRIG_STARTUP_1 = 1<br>DCS_TRIG_STARTUP_2 = 1<br>DCS_TRIG_STARTUP_3 = 1<br>(delay = 256.5ms) |
| 18 (12h)   | R255 (FFh)       | 1 bit  | Bit 0 | 00h  | 0h    | 0b  | Dummy Write for expansion<br>(delay = 0.5625ms)                                                                           |
| 19 (13h)   | R90 (5Ah)        | 8 bits | Bit 0 | 77h  | 0h    | 0b  | HPL_ENA_OUTP = 1<br>HPR_ENA_OUTP = 1<br>(delay = 0.5625ms)                                                                |
| 20 (14h)   | R94 (5Eh)        | 8 bits | Bit 0 | 77h  | 0h    | 0b  | LINEOUTL_ENA_OUTP = 1<br>LINEOUTR_ENA_OUTP = 1<br>(delay = 0.5625ms)                                                      |
| 21 (15h)   | R90 (5Ah)        | 8 bits | Bit 0 | FFh  | 0h    | 0b  | HPL_RMV_SHORT = 1<br>HPR_RMV_SHORT = 1<br>(delay = 0.5625ms)                                                              |
| 22 (16h)   | R94 (5Eh)        | 8 bits | Bit 0 | FFh  | 0h    | 1b  | LINEOUTL_RMV_SHORT = 1<br>LINEOUTR_RMV_SHORT = 1<br>End of Sequence                                                       |
| 23 (17h)   | R255 (FFh)       | 1 bit  | Bit 0 | 00h  | 0h    | 0b  | Spare                                                                                                                     |
| 24 (18h)   | R255 (FFh)       | 1 bit  | Bit 0 | 00h  | 0h    | 0b  | Spare                                                                                                                     |

**Table 88 Start-up Sequence**

### SHUTDOWN SEQUENCE

The Shutdown sequence is initiated by writing 0119h to Register R111 (6Fh). This single operation starts the Control Write Sequencer at Index Address 25 (19h) and executes the sequence defined in Table 89.

For typical clocking configurations with MCLK=12.288MHz, this sequence takes approximately 350ms.

| WSEQ INDEX | REGISTER ADDRESS | WIDTH  | START | DATA | DELAY | EOS | DESCRIPTION                                                                                                                                                  |
|------------|------------------|--------|-------|------|-------|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 25 (19h)   | R94 (5Eh)        | 8 bits | Bit 0 | 77h  | 0h    | 0b  | LINEOUTL_RMV_SHORT = 0<br>LINEOUTR_RMV_SHORT = 0<br>(delay = 0.5625ms)                                                                                       |
| 26 (1Ah)   | R90 (5Ah)        | 8 bits | Bit 0 | 77h  | 0h    | 0b  | HPL_RMV_SHORT = 0<br>HPR_RMV_SHORT = 0<br>(delay = 0.5625ms)                                                                                                 |
| 27 (1Bh)   | R90 (5Ah)        | 8 bits | Bit 0 | 00h  | 0h    | 0b  | HPL_ENA_OUTP = 0<br>HPL_ENA_DLY = 0<br>HPL_ENA = 0<br>HPR_ENA_OUTP = 0<br>HPR_ENA_DLY = 0<br>HPR_ENA = 0<br>(delay = 0.5625ms)                               |
| 28 (1Ch)   | R94 (5Eh)        | 8 bits | Bit 0 | 00h  | 0h    | 0b  | LINEOUTL_ENA_OUTP = 0<br>LINEOUTL_ENA_DLY = 0<br>LINEOUTL_ENA = 0<br>LINEOUTR_ENA_OUTP = 0<br>LINEOUTR_ENA_DLY = 0<br>LINEOUTR_ENA = 0<br>(delay = 0.5625ms) |
| 29 (1Dh)   | R67 (43h)        | 4 bits | Bit 0 | 00h  | 0h    | 0b  | DCS_ENA_CHAN_0 = 0<br>DCS_ENA_CHAN_1 = 0<br>DCS_ENA_CHAN_2 = 0<br>DCS_ENA_CHAN_3 = 0<br>(delay = 0.5625ms)                                                   |
| 30 (1Eh)   | R98 (62h)        | 1 bit  | Bit 0 | 00h  | 0h    | 0b  | CP_ENA = 0<br>(delay = 0.5625ms)                                                                                                                             |
| 31 (1Fh)   | R18 (12h)        | 2 bits | Bit 2 | 00h  | 0h    | 0b  | DACL_ENA = 0<br>DACR_ENA = 0<br>(delay = 0.5625ms)                                                                                                           |
| 32 (20h)   | R22 (16h)        | 1 bit  | Bit 1 | 00h  | 0h    | 0b  | CLK_DSP_ENA = 0<br>(delay = 0.5625ms)                                                                                                                        |
| 33 (21h)   | R14 (0Eh)        | 2 bits | Bit 0 | 00h  | 0h    | 0b  | HPL_PGA_ENA = 0<br>HPR_PGA_ENA = 0<br>(delay = 0.5625ms)                                                                                                     |
| 34 (22h)   | R15 (0Fh)        | 2 bits | Bit 0 | 00h  | 0h    | 0b  | LINEOUTL_PGA_ENA = 0<br>LINEOUTR_PGA_ENA = 0<br>(delay = 0.5625ms)                                                                                           |
| 35 (23h)   | R4 (04h)         | 1 bit  | Bit 0 | 00h  | 0h    | 0b  | BIAS_ENA = 0<br>(delay = 0.5625ms)                                                                                                                           |
| 36 (24h)   | R5 (05h)         | 1 bit  | Bit 0 | 00h  | Ch    | 0b  | VMID_ENA = 0<br>(delay = 256.5ms)                                                                                                                            |
| 37 (25h)   | R5 (05h)         | 1 bit  | Bit 0 | 00h  | 9h    | 0b  | VMID_ENA = 0<br>(delay = 32.5ms)                                                                                                                             |
| 38 (26h)   | R5 (05h)         | 8 bits | Bit 0 | 00h  | 0h    | 0b  | VMID_BUF_ENA = 0<br>VMID_RES[1:0] = 00<br>VMID_ENA = 0                                                                                                       |

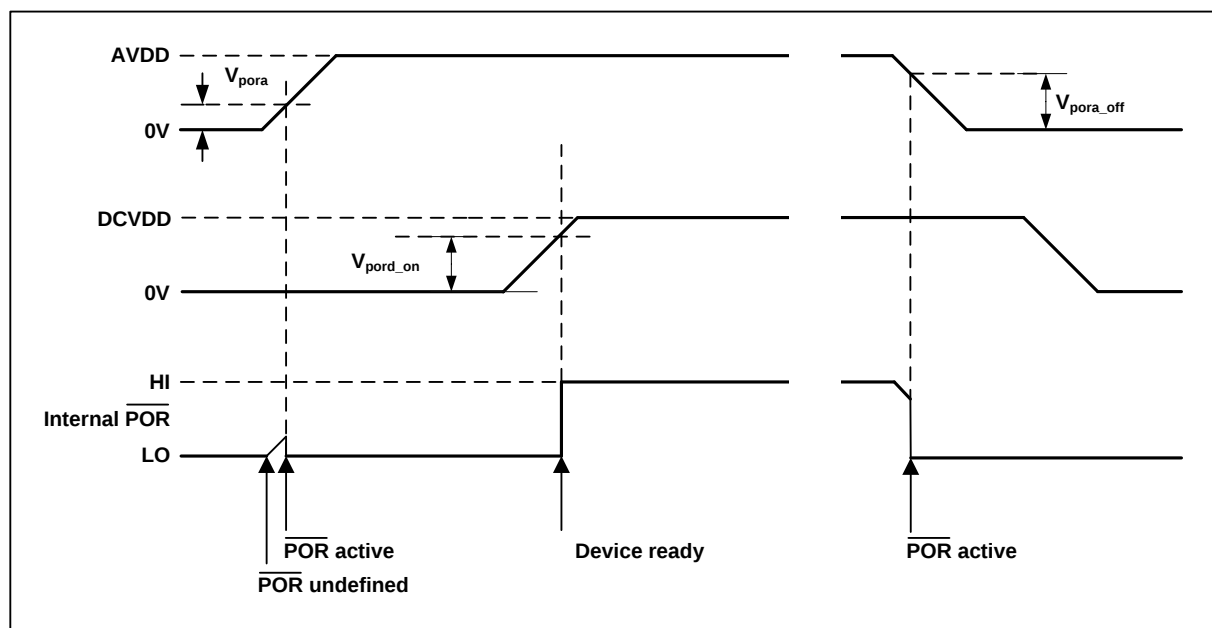
| WSEQ INDEX | REGISTER ADDRESS | WIDTH  | START | DATA | DELAY | EOS | DESCRIPTION                     |
|------------|------------------|--------|-------|------|-------|-----|---------------------------------|
|            |                  |        |       |      |       |     | (delay = 0.5625ms)              |
| 39 (27h)   | R4 (04h)         | 2 bits | Bit 0 | 00h  | 0h    | 1b  | BIAS_ENA = 0<br>End of Sequence |

**Table 89 Shutdown Sequence**

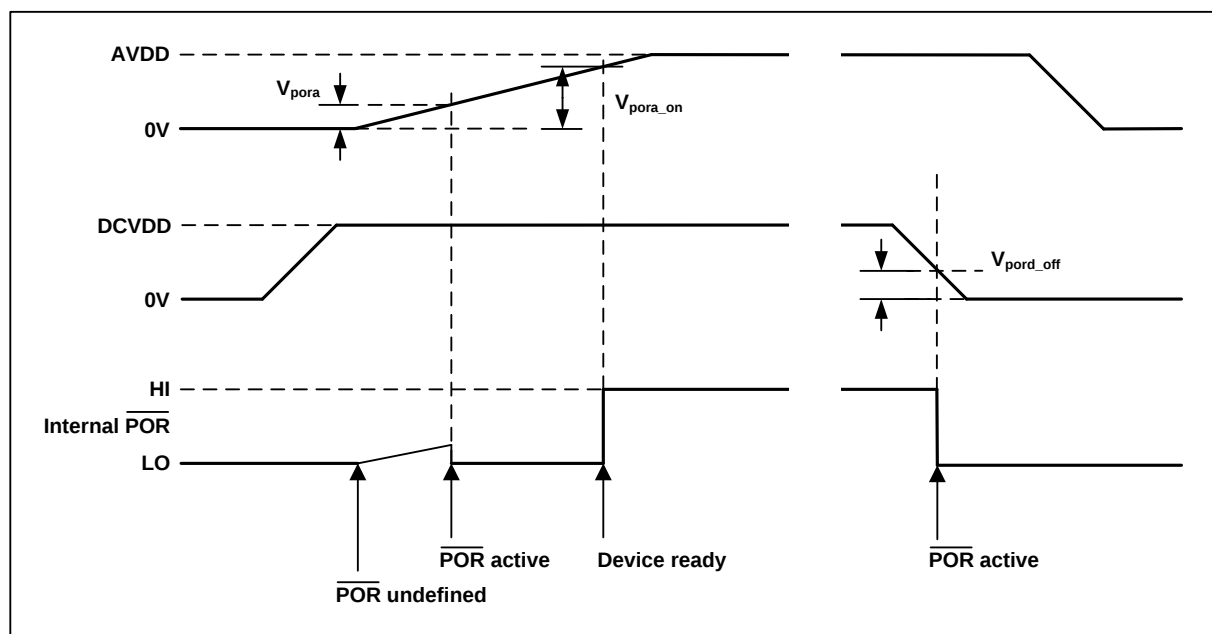
## POWER-ON RESET

The WM8904 includes an internal Power-On-Reset (POR) circuit, which is used to reset the digital logic into a default state after power up. The POR circuit is powered from AVDD and monitors DCVDD. The internal POR signal is asserted low when AVDD or DCVDD are below minimum thresholds.

The specific behaviour of the circuit will vary, depending on the relative timing of the supply voltages. Typical scenarios are illustrated in Figure 69 and Figure 70.



**Figure 69 Power On Reset timing - AVDD enabled first**



**Figure 70** Power On Reset timing - DCVDD enabled first

The  $\overline{POR}$  signal is undefined until AVDD has exceeded the minimum threshold,  $V_{pora}$ . Once this threshold has been exceeded,  $\overline{POR}$  is asserted low and the chip is held in reset. In this condition, all writes to the control interface are ignored. Once AVDD and DCVDD have reached their respective power on thresholds,  $\overline{POR}$  is released high, all registers are in their default state, and writes to the control interface may take place.

Note that a minimum power-on reset period,  $T_{POR}$ , applies even if AVDD and DCVDD have zero rise time. (This specification is guaranteed by design rather than test.)

On power down,  $\overline{POR}$  is asserted low when any of AVDD or DCVDD falls below their respective power-down thresholds.

Typical Power-On Reset parameters for the WM8904 are defined in Table 90.

| SYMBOL          | DESCRIPTION                                              | TYP  | UNIT    |
|-----------------|----------------------------------------------------------|------|---------|
| $V_{pora}$      | AVDD threshold below which $\overline{POR}$ is undefined | 0.25 | V       |
| $V_{pora\_on}$  | Power-On threshold (AVDD)                                | 1.15 | V       |
| $V_{pora\_off}$ | Power-Off threshold (AVDD)                               | 1.12 | V       |
| $V_{pord\_on}$  | Power-On threshold (DCVDD)                               | 0.57 | V       |
| $V_{pord\_off}$ | Power-Off threshold (DCVDD)                              | 0.55 | V       |
| $T_{POR}$       | Minimum Power-On Reset period                            | 9.5  | $\mu$ s |

**Table 90** Typical Power-On Reset parameters

**Notes:**

1. If AVDD 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 does not reset and resumes normal operation when the voltage is back to the recommended level again.
2. The chip enters reset at power down when AVDD 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 AVDD have zero rise time. This specification is guaranteed by design rather than test.

## QUICK START-UP AND SHUTDOWN

The WM8904 has the capability to perform a quick start-up and shutdown with a minimum number of register operations. This is achieved using the Control Write Sequencer, which is configured with default start-up settings that set up the device for DAC playback via Headphone and Line output. Assuming a 12.288MHz external clock, the start-up sequence configures the device for 48kHz playback mode.

The default start-up sequence requires three register write operations. The default shutdown sequence requires just a single register write. The minimum procedure for executing the quick start-up and shutdown sequences is described below. See "Control Write Sequencer" for more details.

After the default start-up sequence has been performed, the DC offset correction values will be held in memory, provided that power is maintained and a software reset is not performed. Fast start-up using the stored values of DC offset correction is also possible, as described below.

### QUICK START-UP (DEFAULT SEQUENCE)

An external clock must be applied to MCLK. Assuming 12.288MHz input clock, the start-up sequence will take approximately 300ms to complete.

The following register operations will initiate the quick start-up sequence.

| REGISTER ADDRESS                | VALUE | DESCRIPTION                                                                                                                                           |
|---------------------------------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| R108 (6Ch)<br>Write Sequencer 0 | 0100h | WSEQ_ENA = 1<br>WSEQ_WRITE_INDEX = 00h<br>This enables the Write Sequencer                                                                            |
| R111 (6Fh)<br>Write Sequencer 3 | 0100h | WSEQ_ABORT = 0<br>WSEQ_START = 1<br>WSEQ_START_INDEX = 00h<br>This starts the Write Sequencer at Index address 0 (00h)                                |
| R33 (21h)<br>DAC Digital 1      | 0000h | DAC_MONO = 0<br>DAC_SB_FILT = 0<br>DAC_MUTERATE = 0<br>DAC_UNMUTE_RAMP = 0<br>DAC_OSR128 = 0<br>DAC_MUTE = 0<br>DEEMPH = 00<br>This un-mutes the DACs |

**Table 91 Quick Start-up Control**

The WSEQ\_BUSY bit (in Register R112, see Table 85) will be set to 1 while the sequence runs. When this bit returns to 0, the device has been set up and is ready for DAC playback operation.

### FAST START-UP FROM STANDBY

The default start-up sequence runs the DC Servo to remove DC offsets from the outputs. The offset for this path selection is then stored in memory. Provided that power is maintained to the chip, and a software reset is not performed, then the DC offset correction will be held in memory on the WM8904. This allows the DC Servo calibrations to be omitted from the start-up sequence if the offset correction has already been performed. By omitting this part of the start-up sequence, a fast start-up time of less than 50ms can be achieved.

The register write sequence described in Table 92 replaces the default DC Servo operation with dummy operations, allowing a fast start-up to be achieved, assuming the device is initially in a standby condition with DC offset correction previously performed.

Note that, if power is removed from the WM8904 or if a software reset is performed, then the default sequence will be restored, and the DC offset correction will be necessary on the output paths once more.

| REGISTER ADDRESS                | VALUE | DESCRIPTION                                                                                                                                           |
|---------------------------------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| R108 (6Ch)<br>Write Sequencer 0 | 0111h | WSEQ_ENA = 1<br>WSEQ_WRITE_INDEX = 11h<br>This enables the Write Sequencer and selects WSEQ Index 17 (11h) for modification                           |
| R109 (6Dh)<br>Write Sequencer 1 | 00FFh | WSEQ_DATA_WIDTH = 000<br>WSEQ_DATA_START = 0000<br>WSEQ_ADDR = FFh<br>This modifies WSEQ Index 17 (11h) with Dummy step                               |
| R110 (6Eh)<br>Write Sequencer 2 | 0000h | WSEQ_EOS = 0<br>WSEQ_DELAY = 0000<br>WSEQ_DATA = 00h<br>This modifies WSEQ Index 17 (11h) with Dummy step                                             |
| R111 (6Fh)<br>Write Sequencer 3 | 0100h | WSEQ_ABORT = 0<br>WSEQ_START = 1<br>WSEQ_START_INDEX = 00h<br>This starts the Write Sequencer at Index address 0 (00h)                                |
| R33 (21h)<br>DAC Digital 1      | 0000h | DAC_MONO = 0<br>DAC_SB_FILT = 0<br>DAC_MUTERATE = 0<br>DAC_UNMUTE_RAMP = 0<br>DAC_OSR128 = 0<br>DAC_MUTE = 0<br>DEEMPH = 00<br>This un-mutes the DACs |

**Table 92 Fast Start-up from Standby Control**

The WSEQ\_BUSY bit (in Register R112, see Table 85) will be set to 1 while the sequence runs. When this bit returns to 0, the device has been set up and is ready for DAC playback operation.

### QUICK SHUTDOWN (DEFAULT SEQUENCE)

The default shutdown sequence assumes the initial device conditions are as configured by the default start-up sequence. Assuming 12.288MHz input clock, the shutdown sequence will take approximately 350ms to complete.

The following register operation will initiate the default shutdown sequence.

| REGISTER ADDRESS                | VALUE | DESCRIPTION                                                                                                             |
|---------------------------------|-------|-------------------------------------------------------------------------------------------------------------------------|
| R111 (6Fh)<br>Write Sequencer 3 | 0119h | WSEQ_ABORT = 0<br>WSEQ_START = 1<br>WSEQ_START_INDEX = 19h<br>This starts the Write Sequencer at Index address 25 (19h) |

**Table 93 Quick Shutdown Control**

The WSEQ\_BUSY bit (in Register R112, see Table 85) will be set to 1 while the sequence runs. When this bit returns to 0, the system clock can be disabled (CLK\_SYS\_ENA=0) and MCLK can be stopped.

### SOFTWARE RESET AND CHIP ID

A Software Reset can be commanded by writing to Register R0. This is a read-only register field and the contents will not be affected by writing to this Register.

The Chip ID can be read back from Register R0.

| REGISTER ADDRESS            | BIT  | LABEL                     | DEFAULT | DESCRIPTION                                                                                                                        |
|-----------------------------|------|---------------------------|---------|------------------------------------------------------------------------------------------------------------------------------------|
| R0 (00h)<br>SW Reset and ID | 15:0 | SW_RST_DE<br>V_ID1 [15:0] | 8904h   | Writing to this register resets all registers to their default state.<br>Reading from this register will indicate Device ID 8904h. |

**Table 94 Software Reset and Chip ID**

## REGISTER MAP

| Dec Addr | Hex Addr | Name                    | 15              | 14              | 13            | 12 | 11           | 10 | 9            | 8 | 7            | 6               | 5            | 4               | 3            | 2               | 1            | 0        | Bin Default         |                     |
|----------|----------|-------------------------|-----------------|-----------------|---------------|----|--------------|----|--------------|---|--------------|-----------------|--------------|-----------------|--------------|-----------------|--------------|----------|---------------------|---------------------|
| 0        | 00       | SW Reset and ID         | SW_RST_DRV_CFG0 |                 |               |    |              |    |              |   |              |                 |              |                 |              |                 |              |          |                     |                     |
| 4        | 04       | Bias Control 0          | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 1               | ISBL[10]     |                 | 0            | BIAS_BNA | 0001_0000_0000_0000 |                     |
| 5        | 05       | VREF Control 0          | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | VREF_BUF_BNA    |              | 0               | 0            | VREF_REF[10]    |              | 0        | BIAS_BNA            | 0000_0000_0000_0000 |
| 6        | 06       | Mic Bias Control 0      | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | MICBIAS_THR[20] |              | MICBIAS_THR[20] |              | MICBIAS_THR[20] |              | 0        | MICBIAS_BNA         | 0000_0000_0000_0000 |
| 7        | 07       | Mic Bias Control 1      | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | MICBIAS_SEL[20] |              | 0        | MICBIAS_BNA         | 0000_0000_0000_0000 |
| 8        | 08       | Antenna ADC 0           | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | ADC_OSR[18]         | 0000_0000_0000_0000 |
| 9        | 09       | Power Management 0      | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 10       | 0A       | Power Management 1      | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 11       | 0B       | Power Management 2      | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 12       | 0C       | Power Management 3      | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 13       | 0D       | Power Management 4      | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 14       | 0E       | Power Management 5      | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 15       | 0F       | Power Management 6      | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 16       | 10       | Power Management 7      | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 17       | 11       | Power Management 8      | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 18       | 12       | Power Management 9      | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 19       | 13       | Power Management 10     | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 20       | 14       | TOCLK_RATE_DIV4         | 1               | TOCLK_RATE_DIV4 | TOCLK_RATE_X4 | 0  | 0            | 1  | 0            | 0 | 0            | 1               | 0            | 1               | 1            | 1               | 1            | 0        | 0                   | 0000_0000_0000_0000 |
| 21       | 15       | Clock Rates 1           | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 22       | 16       | Clock Rates 2           | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 23       | 17       | Clock Rates 3           | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 24       | 18       | Audio Interface 0       | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 25       | 19       | Audio Interface 1       | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 26       | 1A       | Audio Interface 2       | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 27       | 1B       | Audio Interface 3       | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | 0               | 0            | 0               | 0            | 0               | 0            | 0        | 0                   | 0000_0000_0000_0000 |
| 30       | 1E       | DAC Digital VolumeLeft  | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | DAC_VOL[10]     |              | DAC_VOL[10]     |              | DAC_VOL[10]     |              | 0        | 0                   | 0000_0000_0000_0000 |
| 31       | 1F       | DAC Digital VolumeRight | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | DAC_VOL[10]     |              | DAC_VOL[10]     |              | DAC_VOL[10]     |              | 0        | 0                   | 0000_0000_0000_0000 |
| 32       | 20       | DAC Digital 0           | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | DAC_VOL[10]     |              | DAC_VOL[10]     |              | DAC_VOL[10]     |              | 0        | 0                   | 0000_0000_0000_0000 |
| 33       | 21       | DAC Digital 1           | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | DAC_VOL[10]     |              | DAC_VOL[10]     |              | DAC_VOL[10]     |              | 0        | 0                   | 0000_0000_0000_0000 |
| 36       | 24       | ADC Digital VolumeLeft  | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | ADC_VOL[10]     |              | ADC_VOL[10]     |              | ADC_VOL[10]     |              | 0        | 0                   | 0000_0000_0000_0000 |
| 37       | 25       | ADC Digital VolumeRight | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | ADC_VOL[10]     |              | ADC_VOL[10]     |              | ADC_VOL[10]     |              | 0        | 0                   | 0000_0000_0000_0000 |
| 38       | 26       | ADC Digital 0           | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | ADC_VOL[10]     |              | ADC_VOL[10]     |              | ADC_VOL[10]     |              | 0        | 0                   | 0000_0000_0000_0000 |
| 39       | 27       | Digital Microphone0     | 0               | 0               | 0             | 0  | 0            | 0  | 0            | 0 | 0            | ADC_VOL[10]     |              | ADC_VOL[10]     |              | ADC_VOL[10]     |              | 0        | 0                   | 0000_0000_0000_0000 |
| 40       | 28       | DAC0                    | DRC_DAC_PATH    | 0               | DRC_DAC_PATH  | 0  | DRC_DAC_PATH | 0  | DRC_DAC_PATH | 0 | DRC_DAC_PATH | 0               | DRC_DAC_PATH | 0               | DRC_DAC_PATH | 0               | DRC_DAC_PATH | 0        | DRC_DAC_PATH        | 0000_0000_0000_0000 |
| 41       | 29       | DAC1                    | DRC1            | 0               | DRC1          | 0  | DRC1         | 0  | DRC1         | 0 | DRC1         | 0               | DRC1         | 0               | DRC1         | 0               | DRC1         | 0        | DRC1                | 0000_0000_0000_0000 |
| 42       | 2A       | DAC2                    | DRC2            | 0               | DRC2          | 0  | DRC2         | 0  | DRC2         | 0 | DRC2         | 0               | DRC2         | 0               | DRC2         | 0               | DRC2         | 0        | DRC2                | 0000_0000_0000_0000 |
| 43       | 2B       | DAC3                    | DRC3            | 0               | DRC3          | 0  | DRC3         | 0  | DRC3         | 0 | DRC3         | 0               | DRC3         | 0               | DRC3         | 0               | DRC3         | 0        | DRC3                | 0000_0000_0000_0000 |

| Dec Addr | Hex Addr | Name                   | 15                              | 14                              | 13                              | 12                  | 11                  | 10                      | 9                   | 8                        | 7                        | 6                        | 5                        | 4                        | 3                        | 2                         | 1                        | 0                        | Bin Default         |                     |                     |
|----------|----------|------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------|---------------------|-------------------------|---------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|---------------------------|--------------------------|--------------------------|---------------------|---------------------|---------------------|
| 44       | 2C       | Analogue Left input 0  | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | 0                        | LIMUTE                   | 0                        | 0                        | LIN_VOL[4:0]             |                          |                           |                          | 0                        | 0000_0000_1000_0101 |                     |                     |
| 45       | 2D       | Analogue Right input 0 | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | 0                        | RIMUTE                   | 0                        | 0                        | RIN_VOL[4:0]             |                          |                           |                          | 0                        | 0000_0000_1000_0101 |                     |                     |
| 46       | 2E       | Analogue Left input 1  | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | 0                        | 0                        | INL_CM_ENA               | L_P_SEL_N[1:0]           | L_P_SEL_P[1:0]           |                          | L_MODEL[1:0]              |                          | 0                        | 0000_0000_0100_0100 |                     |                     |
| 47       | 2F       | Analogue Right input 1 | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | 0                        | 0                        | INR_CM_ENA               | R_P_SEL_N[1:0]           | R_P_SEL_P[1:0]           |                          | R_MODEL[0]                |                          | 0                        | 0000_0000_0100_0100 |                     |                     |
| 57       | 39       | Analogue OUT1 Left     | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | HPOUT1_MUTE              | HPOUT1_VU                | HPOUT1_ZC                | HPOUT1_VOL[5:0]          |                          |                          |                           |                          |                          | 0                   | 0000_0000_P010_1101 |                     |
| 58       | 3A       | Analogue OUT1 Right    | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | HPOUT1_MUTE              | HPOUT1_VU                | HPOUT1_ZC                | HPOUT1_VOL[5:0]          |                          |                          |                           |                          |                          | 0                   | 0000_0000_P010_1101 |                     |
| 59       | 3B       | Analogue OUT2 Left     | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | LINEOUT1_MUTE            | LINEOUT1_VU              | LINEOUT1_ZC              | LINEOUT1_VOL[5:0]        |                          |                          |                           |                          |                          | 0                   | 0000_0000_P011_1001 |                     |
| 60       | 3C       | Analogue OUT2 Right    | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | LINEOUT1_MUTE            | LINEOUT1_VU              | LINEOUT1_ZC              | LINEOUT1_VOL[5:0]        |                          |                          |                           |                          |                          | 0                   | 0000_0000_P011_1001 |                     |
| 61       | 3D       | Analogue OUT12 ZC      | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | 0                        | 0                        | 0                        | 0                        | 0                        | HPL_BYP_ENA              | HPR_BYP_ENA               | LINEOUT1_BYP_ENA         | LINEOUT1_BYP_ENA         | 0000_0000_0000_0000 |                     |                     |
| 67       | 43       | DC Servo 0             | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | 0                        | 0                        | 0                        | 0                        | 0                        | DCS_BNA_CHAN_2           | DCS_BNA_CHAN_3            | DCS_BNA_CHAN_4           | DCS_BNA_CHAN_5           | 0000_0000_0000_0000 |                     |                     |
| 68       | 44       | DC Servo 1             | DCS_TRIG_SNR[DCS_TRIG_SNR_ES_3] | DCS_TRIG_SNR[DCS_TRIG_SNR_ES_2] | DCS_TRIG_SNR[DCS_TRIG_SNR_ES_1] | DCS_TRIG_STA_RTUP_3 | DCS_TRIG_STA_RTUP_2 | DCS_TRIG_STA_RTUP_1     | DCS_TRIG_STA_RTUP_0 | DCS_TIMER_PERIOD_0[13:0] | DCS_TIMER_PERIOD_0[13:0] | DCS_TIMER_PERIOD_0[13:0] | DCS_TIMER_PERIOD_0[13:0] | DCS_TIMER_PERIOD_0[13:0] | DCS_TIMER_PERIOD_0[13:0] | DCS_TIMER_PERIOD_0[13:0]  | DCS_TIMER_PERIOD_0[13:0] | DCS_TIMER_PERIOD_0[13:0] | PPPP_PPPP_PPPP_PPPP |                     |                     |
| 69       | 45       | DC Servo 2             | 0                               | 0                               | 0                               | 0                   | 0                   | DCS_TIMER_PERIOD_2[3:0] |                     |                          |                          | 0                        | 0                        | 0                        | 0                        | DCS_TIMER_PERIOD_0[13:0]  |                          |                          |                     | 1010_1010_1010_1010 |                     |
| 71       | 47       | DC Servo 4             | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | 0                        | 0                        | DCS_SERIES_NO_2[6:0]     |                          |                          |                          |                           |                          |                          |                     | 0                   | 1010_1010_1010_1010 |
| 72       | 48       | DC Servo 5             | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | 0                        | 0                        | DCS_SERIES_NO_0[6:0]     |                          |                          |                          |                           |                          |                          |                     | 0                   | 1010_1010_1010_1010 |
| 73       | 49       | DC Servo 6             | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | 0                        | DCS_DAC_WR_VAL_3[7:0]    |                          |                          |                          |                          |                           |                          |                          | 0                   | 0000_0000_0000_0000 |                     |
| 74       | 4A       | DC Servo 7             | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | 0                        | DCS_DAC_WR_VAL_2[7:0]    |                          |                          |                          |                          |                           |                          |                          | 0                   | 0000_0000_0000_0000 |                     |
| 75       | 4B       | DC Servo 8             | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | 0                        | DCS_DAC_WR_VAL_1[7:0]    |                          |                          |                          |                          |                           |                          |                          | 0                   | 0000_0000_0000_0000 |                     |
| 76       | 4C       | DC Servo 9             | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | 0                        | DCS_DAC_WR_VAL_0[7:0]    |                          |                          |                          |                          |                           |                          |                          | 0                   | 0000_0000_0000_0000 |                     |
| 77       | 4D       | DC Servo Feedback 0    | 0                               | 0                               | 0                               | 0                   | 0                   | DCS_CAL_COMPLETE[0]     |                     |                          |                          | DCS_DAC_WR_COMPLETE[0]   |                          |                          |                          | DCS_STARTUP_COMPLETE[3:0] |                          |                          |                     | 0                   | 0000_0000_0000_0000 |
| 90       | 5A       | Analogue HP 0          | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | 0                        | HP_L_BNA_SHORT           | HP_L_ENA_OUTP            | HP_L_ENA_DLY             | HP_L_ENA                 | HP_R_BNA_SHORT           | HP_R_ENA_OUTP             | HP_R_ENA_DLY             | HP_R_ENA                 | 0000_0000_0000_0000 |                     |                     |
| 94       | 5E       | Analogue Lineout 0     | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | 0                        | LINEOUT1_BNA_SHORT       | LINEOUT1_ENA_OUTP        | LINEOUT1_ENA_DLY         | LINEOUT1_ENA             | LINEOUT1_BNA_SHORT       | LINEOUT1_ENA_OUTP         | LINEOUT1_ENA_DLY         | LINEOUT1_ENA             | 0000_0000_0000_0000 |                     |                     |
| 98       | 62       | Charge Pump 0          | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | 0                        | 0                        | 0                        | 0                        | 0                        | 0                        | 0                         | 0                        | 0                        | 0000_0000_0000_0000 |                     |                     |
| 104      | 68       | Class W 0              | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | 0                        | 0                        | 0                        | 0                        | 0                        | 0                        | 0                         | 0                        | 0                        | 0000_0000_0000_0100 |                     |                     |
| 108      | 6C       | Write Sequencer 0      | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | 0                        | 0                        | 0                        | 0                        | WSEQ_WRITE_INDEX[4:0]    |                          |                           |                          |                          |                     | 0                   | 0000_0000_0000_0000 |
| 109      | 6D       | Write Sequencer 1      | 0                               | WSEQ_DATA_START[5:0]            |                                 |                     |                     | WSEQ_DATA_START[5:0]    |                     |                          |                          | WSEQ_ADDR[7:0]           |                          |                          |                          | WSEQ_DATA[7:0]            |                          |                          |                     | 0                   | 0000_0000_0000_0000 |
| 110      | 6E       | Write Sequencer 2      | 0                               | WSEQ_EOS                        |                                 |                     |                     | WSEQ_DELAYS[0]          |                     |                          |                          | WSEQ_DATA[7:0]           |                          |                          |                          | WSEQ_DATA[7:0]            |                          |                          |                     | 0                   | 0000_0000_0000_0000 |
| 111      | 6F       | Write Sequencer 3      | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | WSEQ_ABORT               | WSEQ_START               | 0                        | 0                        | WSEQ_START_INDEX[6:0]    |                          |                           |                          | 0                        | 0000_0000_0000_0000 |                     |                     |
| 112      | 70       | Write Sequencer 4      | 0                               | 0                               | 0                               | 0                   | 0                   | 0                       | 0                   | WSEQ_CURRENT_INDEX[5:0]  |                          |                          |                          | 0                        | 0                        | 0                         | 0                        | 0                        | 0                   | 0000_0000_0000_0000 |                     |

| Dec Addr | Hex Addr | Name                  | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2            | 1           | 0           | Bin Default         |
|----------|----------|-----------------------|----|----|----|----|----|----|---|---|---|---|---|---|---|--------------|-------------|-------------|---------------------|
| 116      | 74       | PLL Control 1         | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | PLL_FRAC_ENA | PLL_OSC_ENA | PLL_ENA     | 0000_0000_0000_0000 |
| 117      | 75       | PLL Control 2         | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | PLL_REF1020 | PLL_REF1020 | 0000_0000_0000_0111 |
| 118      | 76       | PLL Control 3         | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0000_0000_0000 |
| 119      | 77       | PLL Control 4         | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0010_1110_1110_0000 |
| 120      | 78       | PLL Control 5         | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0000_0000_0100 |
| 121      | 79       | GPI0 Control 1        | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0000_0001_0100 |
| 122      | 7A       | GPI0 Control 2        | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0000_0001_0000 |
| 123      | 7B       | GPI0 Control 3        | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0000_0001_0000 |
| 124      | 7C       | GPI0 Control 4        | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0000_0001_0000 |
| 126      | 7E       | Digital Pulls         | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0000_0000_0000 |
| 127      | 7F       | Interrupt Status      | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0000_0000_0000 |
| 128      | 80       | Interrupt Status Mask | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | XXXX_XPPP_PPPP_PPPP |
| 129      | 81       | Interrupt Polarity    | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 1111_1111_1111_1111 |
| 130      | 82       | Interrupt Debounce    | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0000_0000_0000 |
| 134      | 86       | EQ1                   | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0000_0000_0000 |
| 135      | 87       | EQ2                   | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0000_0000_1100 |
| 136      | 88       | EQ3                   | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0000_0000_1100 |
| 137      | 89       | EQ4                   | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0000_0000_1100 |
| 138      | 8A       | EQ5                   | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0000_0000_1100 |
| 139      | 8B       | EQ6                   | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0000_0000_1100 |
| 140      | 8C       | EQ7                   | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_1111_1100_1010 |
| 141      | 8D       | EQ8                   | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0100_0000_0000 |
| 142      | 8E       | EQ9                   | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0000_1101_1000 |
| 143      | 8F       | EQ10                  | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0001_1110_1011_0001 |
| 144      | 90       | EQ11                  | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 1111_0001_0100_0001 |
| 145      | 91       | EQ12                  | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_1001_0111_0001 |
| 146      | 92       | EQ13                  | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0000_1100_0001 |
| 147      | 93       | EQ14                  | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0001_1100_0101_1000 |
| 148      | 94       | EQ15                  | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 1111_0001_0111_0001 |
| 149      | 95       | EQ16                  | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_1001_0101_0000 |
| 150      | 96       | EQ17                  | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0000_0001_0101_1000 |
| 151      | 97       | EQ18                  | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0            | 0           | 0           | 0001_0110_1000_1110 |

| Dec Addr | Hex Addr | Name           | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7              | 6 | 5 | 4 | 3                      | 2                       | 1 | 0 | Bin Default         |
|----------|----------|----------------|----|----|----|----|----|----|---|---|----------------|---|---|---|------------------------|-------------------------|---|---|---------------------|
| 152      | 98       | EQ19           |    |    |    |    |    |    |   |   | EQ_B4_B[15:0]  |   |   |   |                        |                         |   |   | 1111_0000_0010_1001 |
| 153      | 99       | EQ20           |    |    |    |    |    |    |   |   | EQ_B4_G[15:0]  |   |   |   |                        |                         |   |   | 0000_0111_1010_1101 |
| 154      | 9A       | EQ21           |    |    |    |    |    |    |   |   | EQ_B4_FQ[15:0] |   |   |   |                        |                         |   |   | 0001_0000_0000_0011 |
| 155      | 9B       | EQ22           |    |    |    |    |    |    |   |   | EQ_B5_A[15:0]  |   |   |   |                        |                         |   |   | 0000_0101_0110_0100 |
| 156      | 9C       | EQ23           |    |    |    |    |    |    |   |   | EQ_B5_B[15:0]  |   |   |   |                        |                         |   |   | 0000_0101_0101_1001 |
| 157      | 9D       | EQ24           |    |    |    |    |    |    |   |   | EQ_B5_FQ[15:0] |   |   |   |                        |                         |   |   | 0100_0000_0000_0000 |
| 198      | C8       | ADC Test 0     | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0              | 0 | 0 | 0 | 0                      | ADC_128_CSR<br>TST_MODE | 0 | 0 | 0000_0000_0000_0000 |
| 247      | F7       | PLL NCO Test 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0              | 0 | 0 | 0 | 0                      | 0                       | 0 | 0 | 0000_0000_0000_0000 |
| 248      | F8       | PLL NCO Test 1 | 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 | 0              | 0 | 0 | 0 | FULL_PRC_NCO_VALUES[0] |                         |   |   | 0000_0000_0001_1001 |

## REGISTER BITS BY ADDRESS

| REGISTER ADDRESS         | BIT  | LABEL                 | DEFAULT             | DESCRIPTION                                                                                                                        | REFER TO                   |
|--------------------------|------|-----------------------|---------------------|------------------------------------------------------------------------------------------------------------------------------------|----------------------------|
| R0 (00h) SW Reset and ID | 15:0 | SW_RST_DEV_ID1 [15:0] | 1000_1001_0000_0100 | Writing to this register resets all registers to their default state.<br>Reading from this register will indicate Device ID 8904h. | Software Reset and Chip ID |

### Register 00h SW Reset and ID

| REGISTER ADDRESS        | BIT | LABEL      | DEFAULT | DESCRIPTION                                                                                                                                                                                                                        | REFER TO                           |
|-------------------------|-----|------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|
| R4 (04h) Bias Control 0 | 3:2 | ISEL [1:0] | 10      | Master Bias Control<br>00 = Low power bias<br>01 = Reserved<br>10 = High performance bias (default)<br>11 = Reserved<br>Note that the ISEL register should only be changed as part of the Low Power Mode Enable/Disable sequences. | Reference Voltages and Master Bias |
|                         | 0   | BIAS_ENA   | 0       | Enables the Normal bias current generator (for all analogue functions)<br>0 = Disabled<br>1 = Enabled                                                                                                                              | Reference Voltages and Master Bias |

### Register 04h Bias Control 0

| REGISTER ADDRESS        | BIT | LABEL          | DEFAULT | DESCRIPTION                                                                                                                                                                                                    | REFER TO         |
|-------------------------|-----|----------------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| R5 (05h) VMID Control 0 | 6   | VMID_BUF_ENA   | 0       | Enable VMID buffer to unused Inputs/Outputs<br>0 = Disabled<br>1 = Enabled                                                                                                                                     | Analogue Outputs |
|                         | 2:1 | VMID_RES [1:0] | 00      | VMID Divider Enable and Select<br>00 = VMID disabled (for OFF mode)<br>01 = 2 x 50k divider (for normal operation)<br>10 = 2 x 250k divider (for low power standby)<br>11 = 2 x 5k divider (for fast start-up) | Analogue Outputs |
|                         | 0   | VMID_ENA       | 0       | VMID Buffer Enable<br>0 = Disabled<br>1 = Enabled                                                                                                                                                              | Analogue Outputs |

### Register 05h VMID Control 0

| REGISTER ADDRESS            | BIT | LABEL              | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                | REFER TO                                |
|-----------------------------|-----|--------------------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|
| R6 (06h) Mic Bias Control 0 | 6:4 | MICDET_THR [2:0]   | 000     | MICBIAS Current Detect Threshold (AVDD = 1.8V)<br>000 = 0.070mA<br>001 = 0.260mA<br>010 = 0.450mA<br>011 = 0.640mA<br>100 = 0.830mA<br>101 = 1.020mA<br>110 = 1.210mA<br>111 = 1.400mA<br>Note that the value scales with AVDD. The value quoted is correct for AVDD=1.8V. | Electret Condenser Microphone Interface |
|                             | 3:2 | MICSHORT_THR [1:0] | 00      | MICBIAS Short Circuit Threshold (AVDD = 1.8V)<br>00 = 0.520mA<br>01 = 0.880mA<br>10 = 1.240mA<br>11 = 1.600mA<br>Note that the value scales with AVDD. The value quoted is correct for AVDD=1.8V.                                                                          | Electret Condenser Microphone Interface |
|                             | 1   | MICDET_ENA         | 0       | MICBIAS Current and Short Circuit Detect Enable<br>0 = disabled<br>1 = enabled                                                                                                                                                                                             | Electret Condenser Microphone Interface |
|                             | 0   | MICBIAS_ENA        | 0       | MICBIAS Enable<br>0 = disabled<br>1 = enabled                                                                                                                                                                                                                              | Electret Condenser Microphone Interface |

**Register 06h Mic Bias Control 0**

| REGISTER ADDRESS            | BIT | LABEL             | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                                                                     | REFER TO                                |
|-----------------------------|-----|-------------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|
| R7 (07h) Mic Bias Control 1 | 2:0 | MICBIAS_SEL [2:0] | 000     | Selects MICBIAS voltage<br>000 = $9/10 \times \text{AVDD}$ (1.6V)<br>001 = $10/9 \times \text{AVDD}$ (2.0V)<br>010 = $7/6 \times \text{AVDD}$ (2.1V)<br>011 = $4/3 \times \text{AVDD}$ (2.4V)<br>100 to 111 = $3/2 \times \text{AVDD}$ (2.7V)<br>Note that the voltage scales with AVDD. The value quoted in brackets is correct for AVDD=1.8V. | Electret Condenser Microphone Interface |

**Register 07h Mic Bias Control 1**

| REGISTER ADDRESS               | BIT | LABEL      | DEFAULT | DESCRIPTION                                                                          | REFER TO                     |
|--------------------------------|-----|------------|---------|--------------------------------------------------------------------------------------|------------------------------|
| R10 (0Ah)<br>Analogue<br>ADC 0 | 0   | ADC_OSR128 | 1       | ADC Oversampling Ratio<br>0 = Low Power (64 x fs)<br>1 = High Performance (128 x fs) | ADC Oversampling Ratio (OSR) |

**Register 0Ah Analogue ADC 0**

| REGISTER ADDRESS                      | BIT | LABEL   | DEFAULT | DESCRIPTION                                           | REFER TO         |
|---------------------------------------|-----|---------|---------|-------------------------------------------------------|------------------|
| R12 (0Ch)<br>Power<br>Management<br>0 | 1   | INL_ENA | 0       | Left Input PGA Enable<br>0 = disabled<br>1 = enabled  | Input PGA Enable |
|                                       | 0   | INR_ENA | 0       | Right Input PGA Enable<br>0 = disabled<br>1 = enabled | Input PGA Enable |

**Register 0Ch Power Management 0**

| REGISTER ADDRESS                      | BIT | LABEL       | DEFAULT | DESCRIPTION                                                  | REFER TO                   |
|---------------------------------------|-----|-------------|---------|--------------------------------------------------------------|----------------------------|
| R14 (0Eh)<br>Power<br>Management<br>2 | 1   | HPL_PGA_ENA | 0       | Left Headphone Output Enable<br>0 = disabled<br>1 = enabled  | Output Signal Paths Enable |
|                                       | 0   | HPR_PGA_ENA | 0       | Right Headphone Output Enable<br>0 = disabled<br>1 = enabled | Output Signal Paths Enable |

**Register 0Eh Power Management 2**

| REGISTER ADDRESS                      | BIT | LABEL            | DEFAULT | DESCRIPTION                                             | REFER TO                   |
|---------------------------------------|-----|------------------|---------|---------------------------------------------------------|----------------------------|
| R15 (0Fh)<br>Power<br>Management<br>3 | 1   | LINEOUTL_PGA_ENA | 0       | Left Line Output Enable<br>0 = disabled<br>1 = enabled  | Output Signal Paths Enable |
|                                       | 0   | LINEOUTR_PGA_ENA | 0       | Right Line Output Enable<br>0 = disabled<br>1 = enabled | Output Signal Paths Enable |

**Register 0Fh Power Management 3**

| REGISTER ADDRESS                      | BIT | LABEL    | DEFAULT | DESCRIPTION                                             | REFER TO                            |
|---------------------------------------|-----|----------|---------|---------------------------------------------------------|-------------------------------------|
| R18 (12h)<br>Power<br>Management<br>6 | 3   | DACL_ENA | 0       | Left DAC Enable<br>0 = DAC disabled<br>1 = DAC enabled  | Digital-to-Analogue Converter (DAC) |
|                                       | 2   | DACR_ENA | 0       | Right DAC Enable<br>0 = DAC disabled<br>1 = DAC enabled | Digital-to-Analogue Converter (DAC) |
|                                       | 1   | ADCL_ENA | 0       | Left ADC Enable<br>0 = disabled<br>1 = enabled          | Digital-to-Analogue Converter (DAC) |
|                                       | 0   | ADCR_ENA | 0       | Right ADC Enable<br>0 = disabled<br>1 = enabled         | Digital-to-Analogue Converter (DAC) |

**Register 12h Power Management 6**

| REGISTER ADDRESS              | BIT | LABEL            | DEFAULT | DESCRIPTION                                                               | REFER TO                  |
|-------------------------------|-----|------------------|---------|---------------------------------------------------------------------------|---------------------------|
| R20 (14h)<br>Clock Rates<br>0 | 14  | TOCLK_RATE_DIV16 | 0       | TOCLK Rate Divider (/16)<br>0 = f / 1<br>1 = f / 16                       | Clocking and Sample Rates |
|                               | 13  | TOCLK_RATE_X4    | 0       | TOCLK Rate Multiplier<br>0 = f x 1<br>1 = f x 4                           | Clocking and Sample Rates |
|                               | 0   | MCLK_DIV         | 0       | Enables divide by 2 on MCLK<br>0 = SYSCLK = MCLK<br>1 = SYSCLK = MCLK / 2 | Clocking and Sample Rates |

**Register 14h Clock Rates 0**

| REGISTER ADDRESS              | BIT   | LABEL              | DEFAULT | DESCRIPTION                                                                                                                                                                  | REFER TO                  |
|-------------------------------|-------|--------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|
| R21 (15h)<br>Clock Rates<br>1 | 13:10 | CLK_SYS_RATE [3:0] | 0011    | Selects the SYSCLK / fs ratio<br>0000 = 64<br>0001 = 128<br>0010 = 192<br>0011 = 256<br>0100 = 384<br>0101 = 512<br>0110 = 768<br>0111 = 1024<br>1000 = 1408<br>1001 = 1536  | Clocking and Sample Rates |
|                               | 2:0   | SAMPLE_RATE [2:0]  | 101     | Selects the Sample Rate (fs)<br>000 = 8kHz<br>001 = 11.025kHz, 12kHz<br>010 = 16kHz<br>011 = 22.05kHz, 24kHz<br>100 = 32kHz<br>101 = 44.1kHz, 48kHz<br>110 to 111 = Reserved | Clocking and Sample Rates |

**Register 15h Clock Rates 1**

| REGISTER ADDRESS              | BIT | LABEL       | DEFAULT | DESCRIPTION                                               | REFER TO                  |
|-------------------------------|-----|-------------|---------|-----------------------------------------------------------|---------------------------|
| R22 (16h)<br>Clock Rates<br>2 | 15  | MCLK_INV    | 0       | MCLK Invert<br>0 = MCLK not inverted<br>1 = MCLK inverted | Clocking and Sample Rates |
|                               | 14  | SYSCLK_SRC  | 0       | SYSCLK Source Select<br>0 = MCLK<br>1 = FLL output        | Clocking and Sample Rates |
|                               | 12  | TOCLK_RATE  | 0       | TOCLK Rate Divider (/2)<br>0 = f / 2<br>1 = f / 1         | Clocking and Sample Rates |
|                               | 3   | OPCLK_ENA   | 0       | GPIO Clock Output Enable<br>0 = disabled<br>1 = enabled   | Clocking and Sample Rates |
|                               | 2   | CLK_SYS_ENA | 0       | System Clock enable<br>0 = Disabled<br>1 = Enabled        | Clocking and Sample Rates |

| REGISTER ADDRESS | BIT | LABEL       | DEFAULT | DESCRIPTION                                              | REFER TO                  |
|------------------|-----|-------------|---------|----------------------------------------------------------|---------------------------|
|                  | 1   | CLK_DSP_ENA | 0       | DSP Clock enable<br>0 = Disabled<br>1 = Enabled          | Clocking and Sample Rates |
|                  | 0   | TOCLK_ENA   | 0       | Zero Cross timeout enable<br>0 = Disabled<br>1 = Enabled | Clocking and Sample Rates |

**Register 16h Clock Rates 2**

| REGISTER ADDRESS               | BIT  | LABEL           | DEFAULT | DESCRIPTION                                                                                                                                                                                       | REFER TO                        |
|--------------------------------|------|-----------------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|
| R24 (18h)<br>Audio Interface 0 | 12   | DACL_DATINV     | 0       | Left DAC Invert<br>0 = Left DAC output not inverted<br>1 = Left DAC output inverted                                                                                                               | Digital Mixing                  |
|                                | 11   | DACR_DATINV     | 0       | Right DAC Invert<br>0 = Right DAC output not inverted<br>1 = Right DAC output inverted                                                                                                            | Digital Mixing                  |
|                                | 10:9 | DAC_BOOST [1:0] | 00      | DAC Digital Input Volume Boost<br>00 = 0dB<br>01 = +6dB (Input data must not exceed -6dBFS)<br>10 = +12dB (Input data must not exceed -12dBFS)<br>11 = +18dB (Input data must not exceed -18dBFS) | Digital Mixing                  |
|                                | 8    | LOOPBACK        | 0       | Digital Loopback Function<br>0 = No loopback<br>1 = Loopback enabled (ADC data output is directly input to DAC data input)                                                                        | Digital Audio Interface Control |
|                                | 7    | AIFADCL_SRC     | 0       | Left Digital Audio channel source<br>0 = Left ADC data is output on left channel<br>1 = Right ADC data is output on left channel                                                                  | Digital Audio Interface Control |
|                                | 6    | AIFADCR_SRC     | 1       | Right Digital Audio channel source<br>0 = Left ADC data is output on right channel<br>1 = Right ADC data is output on right channel                                                               | Digital Audio Interface Control |
|                                | 5    | AIFDACL_SRC     | 0       | Left DAC Data Source Select<br>0 = Left DAC outputs left channel data<br>1 = Left DAC outputs right channel data                                                                                  | Digital Audio Interface Control |
|                                | 4    | AIFDACR_SRC     | 1       | Right DAC Data Source Select<br>0 = Right DAC outputs left channel data<br>1 = Right DAC outputs right channel data                                                                               | Digital Audio Interface Control |
|                                | 3    | ADC_COMP        | 0       | ADC Companding Enable<br>0 = disabled<br>1 = enabled                                                                                                                                              | Digital Audio Interface Control |
|                                | 2    | ADC_COMPMODE    | 0       | ADC Companding Type<br>0 = $\mu$ -law<br>1 = A-law                                                                                                                                                | Digital Audio Interface Control |
|                                | 1    | DAC_COMP        | 0       | DAC Companding Enable<br>0 = disabled<br>1 = enabled                                                                                                                                              | Digital Audio Interface Control |
|                                | 0    | DAC_COMPMODE    | 0       | DAC Companding Type<br>0 = $\mu$ -law<br>1 = A-law                                                                                                                                                | Digital Audio Interface Control |

**Register 18h Audio Interface 0**

| REGISTER ADDRESS               | BIT | LABEL           | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                                             | REFER TO                        |
|--------------------------------|-----|-----------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|
| R25 (19h)<br>Audio Interface 1 | 13  | AIFDAC_TDM      | 0       | DAC TDM Enable<br>0 = Normal DACDAT operation<br>1 = TDM enabled on DACDAT                                                                                                                                                                                                                                              | Digital Audio Interface Control |
|                                | 12  | AIFDAC_TDM_CHAN | 0       | DACDAT TDM Channel Select<br>0 = DACDAT data input on slot 0<br>1 = DACDAT data input on slot 1                                                                                                                                                                                                                         | Digital Audio Interface Control |
|                                | 11  | AIFADC_TDM      | 0       | ADC TDM Enable<br>0 = Normal ADCDAT operation<br>1 = TDM enabled on ADCDAT                                                                                                                                                                                                                                              | Digital Audio Interface Control |
|                                | 10  | AIFADC_TDM_CHAN | 0       | ADCDAT TDM Channel Select<br>0 = ADCDAT outputs data on slot 0<br>1 = ADCDAT output data on slot 1                                                                                                                                                                                                                      | Digital Audio Interface Control |
|                                | 8   | AIF_TRIS        | 0       | Audio Interface Tristate<br>0 = Audio interface pins operate normally<br>1 = Tristate all audio interface pins                                                                                                                                                                                                          | Digital Audio Interface Control |
|                                | 7   | AIF_BCLK_INV    | 0       | BCLK Invert<br>0 = BCLK not inverted<br>1 = BCLK inverted                                                                                                                                                                                                                                                               | Digital Audio Interface Control |
|                                | 6   | BCLK_DIR        | 0       | Audio Interface BCLK Direction<br>0 = BCLK is input<br>1 = BCLK is output                                                                                                                                                                                                                                               | Digital Audio Interface Control |
|                                | 4   | AIF_LRCLK_INV   | 0       | LRC Polarity / DSP Mode A-B select.<br><br>Right, left and I2S modes – LRC polarity<br>0 = Not Inverted<br>1 = Inverted<br><br>DSP Mode – Mode A-B select<br>0 = MSB is available on 2nd BCLK rising edge after LRC rising edge (mode A)<br>1 = MSB is available on 1st BCLK rising edge after LRC rising edge (mode B) | Digital Audio Interface Control |
|                                | 3:2 | AIF_WL [1:0]    | 10      | Digital Audio Interface Word Length<br>00 = 16 bits<br>01 = 20 bits<br>10 = 24 bits<br>11 = 32 bits                                                                                                                                                                                                                     | Digital Audio Interface Control |
|                                | 1:0 | AIF_FMT [1:0]   | 10      | Digital Audio Interface Format<br>00 = Right Justified<br>01 = Left Justified<br>10 = I2S<br>11 = DSP                                                                                                                                                                                                                   | Digital Audio Interface Control |

**Register 19h Audio Interface 1**

| REGISTER ADDRESS               | BIT  | LABEL           | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | REFER TO                        |
|--------------------------------|------|-----------------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|
| R26 (1Ah)<br>Audio Interface 2 | 11:8 | OPCLK_DIV [3:0] | 0000    | GPIO Output Clock Divider<br>0000 = SYSCLK<br>0001 = SYSCLK / 2<br>0010 = SYSCLK / 3<br>0011 = SYSCLK / 4<br>0100 = SYSCLK / 5.5<br>0101 = SYSCLK / 6<br>0110 = SYSCLK / 8<br>0111 = SYSCLK / 12<br>1000 = SYSCLK / 16<br>1001 to 1111 = Reserved                                                                                                                                                                                                                                                                                | Digital Audio Interface Control |
|                                | 4:0  | BCLK_DIV [4:0]  | 0_0100  | BCLK Frequency (Master Mode)<br>00000 = SYSCLK<br>00001 = SYSCLK / 1.5<br>00010 = SYSCLK / 2<br>00011 = SYSCLK / 3<br>00100 = SYSCLK / 4 (default)<br>00101 = SYSCLK / 5<br>00110 = SYSCLK / 5.5<br>00111 = SYSCLK / 6<br>01000 = SYSCLK / 8<br>01001 = SYSCLK / 10<br>01010 = SYSCLK / 11<br>01011 = SYSCLK / 12<br>01100 = SYSCLK / 16<br>01101 = SYSCLK / 20<br>01110 = SYSCLK / 22<br>01111 = SYSCLK / 24<br>10000 = SYSCLK / 25<br>10001 = SYSCLK / 30<br>10010 = SYSCLK / 32<br>10011 = SYSCLK / 44<br>10100 = SYSCLK / 48 | Digital Audio Interface Control |

**Register 1Ah Audio Interface 2**

| REGISTER ADDRESS               | BIT  | LABEL             | DEFAULT       | DESCRIPTION                                                                                                   | REFER TO                        |
|--------------------------------|------|-------------------|---------------|---------------------------------------------------------------------------------------------------------------|---------------------------------|
| R27 (1Bh)<br>Audio Interface 3 | 11   | LRCLK_DIR         | 0             | Audio Interface LRC Direction<br>0 = LRC is input<br>1 = LRC is output                                        | Digital Audio Interface Control |
|                                | 10:0 | LRCLK_RATE [10:0] | 000_0100_0000 | LRC Rate (Master Mode)<br>LRC clock output = BCLK / LRCLK_RATE<br>Integer (LSB = 1)<br>Valid range: 8 to 2047 | Digital Audio Interface Control |

**Register 1Bh Audio Interface 3**

| REGISTER ADDRESS                     | BIT | LABEL          | DEFAULT   | DESCRIPTION                                                                                                            | REFER TO                   |
|--------------------------------------|-----|----------------|-----------|------------------------------------------------------------------------------------------------------------------------|----------------------------|
| R30 (1Eh)<br>DAC Digital Volume Left | 8   | DAC_VU         | 0         | DAC Volume Update<br>Writing a 1 to this bit causes left and right DAC volume to be updated simultaneously             | DAC Digital Volume Control |
|                                      | 7:0 | DACL_VOL [7:0] | 1100_0000 | Left DAC Digital Volume<br>00h = Mute<br>01h = -71.625dB<br>02h = -71.250dB<br>... (0.375dB steps)<br>C0h to FFh = 0dB | DAC Digital Volume Control |

**Register 1Eh DAC Digital Volume Left**

| REGISTER ADDRESS                      | BIT | LABEL          | DEFAULT   | DESCRIPTION                                                                                                             | REFER TO                   |
|---------------------------------------|-----|----------------|-----------|-------------------------------------------------------------------------------------------------------------------------|----------------------------|
| R31 (1Fh)<br>DAC Digital Volume Right | 8   | DAC_VU         | 0         | DAC Volume Update<br>Writing a 1 to this bit causes left and right DAC volume to be updated simultaneously              | DAC Digital Volume Control |
|                                       | 7:0 | DACR_VOL [7:0] | 1100_0000 | Right DAC Digital Volume<br>00h = Mute<br>01h = -71.625dB<br>02h = -71.250dB<br>... (0.375dB steps)<br>C0h to FFh = 0dB | DAC Digital Volume Control |

**Register 1Fh DAC Digital Volume Right**

| REGISTER ADDRESS           | BIT  | LABEL               | DEFAULT | DESCRIPTION                                                                                                   | REFER TO       |
|----------------------------|------|---------------------|---------|---------------------------------------------------------------------------------------------------------------|----------------|
| R32 (20h)<br>DAC Digital 0 | 11:8 | ADCL_DAC_SVOL [3:0] | 0000    | Left Digital Sidetone Volume<br>0000 = -36dB<br>0001 = -33dB<br>(... 3dB steps)<br>1011 = -3dB<br>11XX = 0dB  | Digital Mixing |
|                            | 7:4  | ADCR_DAC_SVOL [3:0] | 0000    | Right Digital Sidetone Volume<br>0000 = -36dB<br>0001 = -33dB<br>(... 3dB steps)<br>1011 = -3dB<br>11XX = 0dB | Digital Mixing |
|                            | 3:2  | ADC_TO_DACL [1:0]   | 00      | Left DAC Digital Sidetone Source<br>00 = No sidetone<br>01 = Left ADC<br>10 = Right ADC<br>11 = Reserved      | Digital Mixing |
|                            | 1:0  | ADC_TO_DACR [1:0]   | 00      | Right DAC Digital Sidetone Source<br>00 = No sidetone<br>01 = Left ADC<br>10 = Right ADC<br>11 = Reserved     | Digital Mixing |

**Register 20h DAC Digital 0**

| REGISTER ADDRESS           | BIT | LABEL           | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                   | REFER TO                       |
|----------------------------|-----|-----------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|
| R33 (21h)<br>DAC Digital 1 | 12  | DAC_MONO        | 0       | DAC Mono Mix<br>0 = Stereo<br>1 = Mono (Mono mix output on enabled DAC)                                                                                                                                                                                                       | DAC Mono Mix                   |
|                            | 11  | DAC_SB_FILT     | 0       | Selects DAC filter characteristics<br>0 = Normal mode<br>1 = Sloping stopband mode (recommended when fs ≤ 24kHz)                                                                                                                                                              | DAC Sloping Stopband Filter    |
|                            | 10  | DAC_MUTERATE    | 0       | DAC Soft Mute Ramp Rate<br>0 = Fast ramp (fs/2, maximum ramp time is 10.7ms at fs=48k)<br>1 = Slow ramp (fs/32, maximum ramp time is 171ms at fs=48k)                                                                                                                         | DAC Soft Mute and Soft Un-Mute |
|                            | 9   | DAC_UNMUTE_RAMP | 0       | DAC Soft Mute Mode<br>0 = Disabling soft-mute (DAC_MUTE=0) will cause the DAC volume to change immediately to DACL_VOL and DACR_VOL settings<br><br>1 = Disabling soft-mute (DAC_MUTE=0) will cause the DAC volume to ramp up gradually to the DACL_VOL and DACR_VOL settings | DAC Soft Mute and Soft Un-Mute |
|                            | 6   | DAC_OSR128      | 0       | DAC Oversample Rate Select<br>0 = Low power (normal OSR)<br>1 = High performance (double OSR)                                                                                                                                                                                 | DAC Oversampling Ratio (OSR)   |
|                            | 3   | DAC_MUTE        | 1       | DAC Soft Mute Control<br>0 = DAC Un-mute<br>1 = DAC Mute                                                                                                                                                                                                                      | DAC Soft Mute and Soft Un-Mute |
|                            | 2:1 | DEEMPH [1:0]    | 00      | DAC De-Emphasis Control<br>00 = No de-emphasis<br>01 = 32kHz sample rate<br>10 = 44.1kHz sample rate<br>11 = 48kHz sample rate                                                                                                                                                | DAC De-Emphasis                |

**Register 21h DAC Digital 1**

| REGISTER ADDRESS                     | BIT | LABEL          | DEFAULT   | DESCRIPTION                                                                                                                                                      | REFER TO                            |
|--------------------------------------|-----|----------------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|
| R36 (24h)<br>ADC Digital Volume Left | 8   | ADC_VU         | 0         | ADC Volume Update<br>Writing a 1 to this bit causes left and right ADC volume to be updated simultaneously                                                       | Analogue-to-Digital Converter (ADC) |
|                                      | 7:0 | ADCL_VOL [7:0] | 1100_0000 | Left ADC Digital Volume<br>00h = Mute<br>01h = -71.625dB<br>02h = -71.250dB<br>... (0.375dB steps)<br>C0h = 0dB<br>... (0.375dB steps)<br>EFh to FFh = +17.625dB | Analogue-to-Digital Converter (ADC) |

**Register 24h ADC Digital Volume Left**

| REGISTER ADDRESS                      | BIT | LABEL          | DEFAULT   | DESCRIPTION                                                                                                                                                       | REFER TO                            |
|---------------------------------------|-----|----------------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|
| R37 (25h)<br>ADC Digital Volume Right | 8   | ADC_VU         | 0         | ADC Volume Update<br>Writing a 1 to this bit causes left and right ADC volume to be updated simultaneously                                                        | Analogue-to-Digital Converter (ADC) |
|                                       | 7:0 | ADCR_VOL [7:0] | 1100_0000 | Right ADC Digital Volume<br>00h = Mute<br>01h = -71.625dB<br>02h = -71.250dB<br>... (0.375dB steps)<br>C0h = 0dB<br>... (0.375dB steps)<br>EFh to FFh = +17.625dB | Analogue-to-Digital Converter (ADC) |

**Register 25h ADC Digital Volume Right**

| REGISTER ADDRESS           | BIT | LABEL             | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                             | REFER TO                            |
|----------------------------|-----|-------------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|
| R38 (26h)<br>ADC Digital 0 | 6:5 | ADC_HPF_CUT [1:0] | 00      | ADC Digital High Pass Filter Cut-Off Frequency (fc)<br>00 = Hi-fi mode (fc=4Hz at fs=48kHz)<br>01 = Voice mode 1 (fc=127Hz at fs=16kHz)<br>10 = Voice mode 2 (fc=130Hz at fs=8kHz)<br>11 = Voice mode 3 (fc=267Hz at fs=8kHz)<br>(Note: fc scales with sample rate fs.) | Analogue-to-Digital Converter (ADC) |
|                            | 4   | ADC_HPF           | 1       | ADC Digital High Pass Filter Enable<br>0 = disabled<br>1 = enabled                                                                                                                                                                                                      | Analogue-to-Digital Converter (ADC) |
|                            | 1   | ADCL_DATINV       | 0       | Left ADC Invert<br>0 = Left ADC output not inverted<br>1 = Left ADC output inverted                                                                                                                                                                                     | Analogue-to-Digital Converter (ADC) |
|                            | 0   | ADCR_DATINV       | 0       | Right ADC Invert<br>0 = Right ADC output not inverted<br>1 = Right ADC output inverted                                                                                                                                                                                  | Analogue-to-Digital Converter (ADC) |

**Register 26h ADC Digital 0**

| REGISTER ADDRESS                  | BIT | LABEL    | DEFAULT | DESCRIPTION                                                                                                                                                                                              | REFER TO                     |
|-----------------------------------|-----|----------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|
| R39 (27h)<br>Digital Microphone 0 | 12  | DMIC_ENA | 0       | Enables Digital Microphone mode<br>0 = Audio DSP input is from ADC<br>1 = Audio DSP input is from digital microphone interface<br>When DMIC_ENA = 0, the Digital microphone clock (DMICCLK) is held low. | Digital Microphone Interface |
|                                   | 11  | DMIC_SRC | 0       | Selects Digital Microphone Data Input pin<br>0 = IN1L/DMICDAT1<br>1 = IN1R/DMICDAT2                                                                                                                      | Digital Microphone Interface |

**Register 27h Digital Microphone 0**

| REGISTER ADDRESS   | BIT   | LABEL                  | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                             | REFER TO                    |
|--------------------|-------|------------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| R40 (28h)<br>DRC 0 | 15    | DRC_ENA                | 0       | DRC enable<br>1 = enabled<br>0 = disabled                                                                                                                                                                                                                                                                                                                                               | Dynamic Range Control (DRC) |
|                    | 14    | DRC_DAC_PATH           | 0       | DRC path select<br>0 = ADC path<br>1 = DAC path                                                                                                                                                                                                                                                                                                                                         | Dynamic Range Control (DRC) |
|                    | 12:11 | DRC_GS_HYST_LVL [1:0]  | 00      | Gain smoothing hysteresis threshold<br>00 = Low<br>01 = Medium (recommended)<br>10 = High<br>11 = Reserved                                                                                                                                                                                                                                                                              | Dynamic Range Control (DRC) |
|                    | 10:6  | DRC_STARTUP_GAIN [4:0] | 0_0110  | Initial gain at DRC startup<br>00000 = -3dB<br>00001 = -2.5dB<br>00010 = -2dB<br>00011 = -1.5dB<br>00100 = -1dB<br>00101 = -0.5dB<br>00110 = 0dB (default)<br>00111 = 0.5dB<br>01000 = 1dB<br>01001 = 1.5dB<br>01010 = 2dB<br>01011 = 2.5dB<br>01100 = 3dB<br>01101 = 3.5dB<br>01110 = 4dB<br>01111 = 4.5dB<br>10000 = 5dB<br>10001 = 5.5dB<br>10010 = 6dB<br>10011 to 11111 = Reserved | Dynamic Range Control (DRC) |
|                    | 5     | DRC_FF_DELAY           | 1       | Feed-forward delay for anti-clip feature<br>0 = 5 samples<br>1 = 9 samples<br>Time delay can be calculated as $5/f_s$ or $9/f_s$ , where $f_s$ is the sample rate.                                                                                                                                                                                                                      | Dynamic Range Control (DRC) |
|                    | 3     | DRC_GS_ENA             | 1       | Gain smoothing enable<br>0 = disabled<br>1 = enabled                                                                                                                                                                                                                                                                                                                                    | Dynamic Range Control (DRC) |
|                    | 2     | DRC_QR                 | 1       | Quick release enable<br>0 = disabled<br>1 = enabled                                                                                                                                                                                                                                                                                                                                     | Dynamic Range Control (DRC) |
|                    | 1     | DRC_ANTICLIP           | 1       | Anti-clip enable<br>0 = disabled<br>1 = enabled                                                                                                                                                                                                                                                                                                                                         | Dynamic Range Control (DRC) |
|                    | 0     | DRC_GS_HYST            | 1       | Gain smoothing hysteresis enable<br>0 = disabled<br>1 = enabled                                                                                                                                                                                                                                                                                                                         | Dynamic Range Control (DRC) |

**Register 28h DRC 0**

| REGISTER ADDRESS   | BIT   | LABEL             | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                              | REFER TO                    |
|--------------------|-------|-------------------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| R41 (29h)<br>DRC 1 | 15:12 | DRC_ATK [3:0]     | 0011    | Gain attack rate (seconds/6dB)<br>0000 = Reserved<br>0001 = 182μs<br>0010 = 363μs<br>0011 = 726μs (default)<br>0100 = 1.45ms<br>0101 = 2.9ms<br>0110 = 5.8ms<br>0111 = 11.6ms<br>1000 = 23.2ms<br>1001 = 46.4ms<br>1010 = 92.8ms<br>1011-1111 = Reserved | Dynamic Range Control (DRC) |
|                    | 11:8  | DRC_DCY [3:0]     | 0010    | Gain decay rate (seconds/6dB)<br>0000 = 186ms<br>0001 = 372ms<br>0010 = 743ms (default)<br>0011 = 1.49s<br>0100 = 2.97s<br>0101 = 5.94s<br>0110 = 11.89s<br>0111 = 23.78s<br>1000 = 47.56s<br>1001-1111 = Reserved                                       | Dynamic Range Control (DRC) |
|                    | 7:6   | DRC_QR_THR [1:0]  | 01      | Quick release crest factor threshold<br>00 = 12dB<br>01 = 18dB (default)<br>10 = 24dB<br>11 = 30dB                                                                                                                                                       | Dynamic Range Control (DRC) |
|                    | 5:4   | DRC_QR_DCY [1:0]  | 00      | Quick release decay rate (seconds/6dB)<br>00 = 0.725ms (default)<br>01 = 1.45ms<br>10 = 5.8ms<br>11 = Reserved                                                                                                                                           | Dynamic Range Control (DRC) |
|                    | 3:2   | DRC_MINGAIN [1:0] | 10      | Minimum gain the DRC can use to attenuate audio signals<br>00 = 0dB (default)<br>01 = -6dB<br>10 = -12dB<br>11 = -18dB                                                                                                                                   | Dynamic Range Control (DRC) |
|                    | 1:0   | DRC_MAXGAIN [1:0] | 00      | Maximum gain the DRC can use to boost audio signals<br>00 = 12dB<br>01 = 18dB (default)<br>10 = 24dB<br>11 = 36dB                                                                                                                                        | Dynamic Range Control (DRC) |

**Register 29h DRC 1**

| REGISTER ADDRESS   | BIT | LABEL                  | DEFAULT | DESCRIPTION                                                                                                                                          | REFER TO                    |
|--------------------|-----|------------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| R42 (2Ah)<br>DRC 2 | 5:3 | DRC_HI_COMP<br>[2:0]   | 000     | Compressor slope (upper region)<br>000 = 1 (no compression)<br>001 = 1/2<br>010 = 1/4<br>011 = 1/8<br>100 = 1/16<br>101 = 0<br>110 to 111 = Reserved | Dynamic Range Control (DRC) |
|                    | 2:0 | DRC_LO_COMP<br>P [2:0] | 000     | Compressor slope (lower region)<br>000 = 1 (no compression)<br>001 = 1/2<br>010 = 1/4<br>011 = 1/8<br>100 = 0<br>101 to 111 = Reserved               | Dynamic Range Control (DRC) |

**Register 2Ah DRC 2**

| REGISTER ADDRESS   | BIT  | LABEL                | DEFAULT | DESCRIPTION                                                                                                                                                           | REFER TO                    |
|--------------------|------|----------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| R43 (2Bh)<br>DRC 3 | 10:5 | DRC_KNEE_IP<br>[5:0] | 00_0000 | Input signal at the Compressor 'knee'.<br>000000 = 0dB<br>000001 = -0.75dB<br>000010 = -1.5dB<br>... (-0.75dB steps)<br>111100 = -45dB<br>111101 to 111111 = Reserved | Dynamic Range Control (DRC) |
|                    | 4:0  | DRC_KNEE_OP<br>[4:0] | 0_0000  | Output signal at the Compressor 'knee'.<br>00000 = 0dB<br>00001 = -0.75dB<br>00010 = -1.5dB<br>... (-0.75dB steps)<br>11110 = -22.5dB<br>11111 = Reserved             | Dynamic Range Control (DRC) |

**Register 2Bh DRC 3**

| REGISTER ADDRESS                      | BIT | LABEL         | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | REFER TO                  |
|---------------------------------------|-----|---------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|
| R44 (2Ch)<br>Analogue Left<br>Input 0 | 7   | LINMUTE       | 1       | Left Input PGA Mute<br>0 = not muted<br>1 = muted                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Input PGA Gain<br>Control |
|                                       | 4:0 | LIN_VOL [4:0] | 0_0101  | Left Input PGA Volume<br><br>If L_MODE = 00 (Single ended)<br>OR L_MODE = 01 (Differential Line)<br>00000 = -1.5 dB<br>00001 = -1.3 dB<br>00010 = -1.0 dB<br>00011 = -0.7 dB<br>00100 = -0.3 dB<br>00101 = +0.0 dB (default)<br>00110 = +0.3 dB<br>00111 = +0.7 dB<br>01000 = +1.0 dB<br>01001 = +1.4 dB<br>01010 = +1.8 dB<br>01011 = +2.3 dB<br>01100 = +2.7 dB<br>01101 = +3.2 dB<br>01110 = +3.7 dB<br>01111 = +4.2 dB<br>10000 = +4.8 dB<br>10001 = +5.4 dB<br>10010 = +6.0 dB<br>10011 = +6.7 dB<br>10100 = +7.5 dB<br>10101 = +8.3 dB<br>10110 = +9.2 dB<br>10111 = +10.2 dB<br>11000 = +11.4 dB<br>11001 = +12.7 dB<br>11010 = +14.3 dB<br>11011 = +16.2 dB<br>11100 = +19.2 dB<br>11101 = +22.3 dB<br>11110 = +25.2 dB<br>11111 = +28.3 dB<br><br>If L_MODE = 10 (Differential MIC)<br>00000 = Reserved<br>00001 = +12 dB<br>00010 = +15 dB<br>00011 = +18 dB<br>00100 = +21 dB<br>00101 = +24 dB (default)<br>00110 = +27 dB<br>00111 to 11111 = +30 dB | Input PGA Gain<br>Control |

**Register 2Ch Analogue Left Input 0**

| REGISTER ADDRESS                       | BIT | LABEL         | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | REFER TO               |
|----------------------------------------|-----|---------------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|
| R45 (2Dh)<br>Analogue<br>Right Input 0 | 7   | RINMUTE       | 1       | Right Input PGA Mute<br>0 = not muted<br>1 = muted                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Input PGA Gain Control |
|                                        | 4:0 | RIN_VOL [4:0] | 0_0101  | Right Input PGA Volume<br><br>If R_MODE = 00 (Single ended)<br>OR R_MODE = 01 (Differential Line)<br>00000 = -1.5 dB<br>00001 = -1.3 dB<br>00010 = -1.0 dB<br>00011 = -0.7 dB<br>00100 = -0.3 dB<br>00101 = +0.0 dB (default)<br>00110 = +0.3 dB<br>00111 = +0.7 dB<br>01000 = +1.0 dB<br>01001 = +1.4 dB<br>01010 = +1.8 dB<br>01011 = +2.3 dB<br>01100 = +2.7 dB<br>01101 = +3.2 dB<br>01110 = +3.7 dB<br>01111 = +4.2 dB<br>10000 = +4.8 dB<br>10001 = +5.4 dB<br>10010 = +6.0 dB<br>10011 = +6.7 dB<br>10100 = +7.5 dB<br>10101 = +8.3 dB<br>10110 = +9.2 dB<br>10111 = +10.2 dB<br>11000 = +11.4 dB<br>11001 = +12.7 dB<br>11010 = +14.3 dB<br>11011 = +16.2 dB<br>11100 = +19.2 dB<br>11101 = +22.3 dB<br>11110 = +25.2 dB<br>11111 = +28.3 dB<br><br>If R_MODE = 10 (Differential MIC)<br>00000 = Reserved<br>00001 = +12 dB<br>00010 = +15 dB<br>00011 = +18 dB<br>00100 = +21 dB<br>00101 = +24 dB (default)<br>00110 = +27 dB<br>00111 to 11111 = +30 dB | Input PGA Gain Control |

**Register 2Dh Analogue Right Input 0**

| REGISTER ADDRESS                   | BIT | LABEL            | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                         | REFER TO                        |
|------------------------------------|-----|------------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|
| R46 (2Eh)<br>Analogue Left Input 1 | 6   | INL_CM_ENA       | 1       | Left Input PGA Common Mode Rejection enable<br>0 = Disabled<br>1 = Enabled<br>(only available for L_MODE=01 – Differential Line)                                                                                                                                                    | Input PGA Common Mode Amplifier |
|                                    | 5:4 | L_IP_SEL_N [1:0] | 00      | In Single-Ended or Differential Line Modes, this field selects the input pin for the inverting side of the left input path.<br>In Differential Mic Mode, this field selects the input pin for the non-inverting side of the left input path.<br>00 = IN1L<br>01 = IN2L<br>1X = IN3L | Analogue Input Signal Path      |
|                                    | 3:2 | L_IP_SEL_P [1:0] | 01      | In Single-Ended or Differential Line Modes, this field selects the input pin for the non-inverting side of the left input path.<br>In Differential Mic Mode, this field selects the input pin for the inverting side of the left input path.<br>00 = IN1L<br>01 = IN2L<br>1X = IN3L | Analogue Input Signal Path      |
|                                    | 1:0 | L_MODE [1:0]     | 00      | Sets the mode for the left analogue input:<br>00 = Single-Ended<br>01 = Differential Line<br>10 = Differential MIC<br>11 = Reserved                                                                                                                                                 | Analogue Input Signal Path      |

**Register 2Eh Analogue Left Input 1**

| REGISTER ADDRESS                    | BIT | LABEL            | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                           | REFER TO                        |
|-------------------------------------|-----|------------------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|
| R47 (2Fh)<br>Analogue Right Input 1 | 6   | INR_CM_ENA       | 1       | Right Input PGA Common Mode Rejection enable<br>0 = Disabled<br>1 = Enabled<br>(only available for R_MODE=01 – Differential Line)                                                                                                                                                     | Input PGA Common Mode Amplifier |
|                                     | 5:4 | R_IP_SEL_N [1:0] | 00      | In Single-Ended or Differential Line Modes, this field selects the input pin for the inverting side of the right input path.<br>In Differential Mic Mode, this field selects the input pin for the non-inverting side of the right input path.<br>00 = IN1R<br>01 = IN2R<br>1X = IN3R | Analogue Input Signal Path      |
|                                     | 3:2 | R_IP_SEL_P [1:0] | 01      | In Single-Ended or Differential Line Modes, this field selects the input pin for the non-inverting side of the right input path.<br>In Differential Mic Mode, this field selects the input pin for the inverting side of the right input path.<br>00 = IN1R<br>01 = IN2R<br>1X = IN3R | Analogue Input Signal Path      |
|                                     | 1:0 | R_MODE [1:0]     | 00      | Sets the mode for the right analogue input:<br>00 = Single-Ended<br>01 = Differential Line<br>10 = Differential MIC<br>11 = Reserved                                                                                                                                                  | Analogue Input Signal Path      |

**Register 2Fh Analogue Right Input 1**

| REGISTER ADDRESS                   | BIT | LABEL            | DEFAULT | DESCRIPTION                                                                                                                                              | REFER TO              |
|------------------------------------|-----|------------------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| R57 (39h)<br>Analogue<br>OUT1 Left | 8   | HPOUTL_MUTE      | 0       | Left Headphone Output Mute<br>0 = Un-mute<br>1 = Mute                                                                                                    | Output Volume Control |
|                                    | 7   | HPOUT_VU         | 0       | Headphone Output Volume Update<br>Writing a 1 to this bit will update HPOUTL and HPOUTR volumes simultaneously.                                          | Output Volume Control |
|                                    | 6   | HPOUTLZC         | 0       | Left Headphone Output Zero Cross Enable<br>0 = disabled<br>1 = enabled                                                                                   | Output Volume Control |
|                                    | 5:0 | HPOUTL_VOL [5:0] | 10_1101 | Left Headphone Output Volume<br>000000 = -57dB<br>000001 = -56dB<br>(... 1dB steps)<br>111001 = 0dB<br>(... 1dB steps)<br>111110 = +5dB<br>111111 = +6dB | Output Volume Control |

**Register 39h Analogue OUT1 Left**

| REGISTER ADDRESS                    | BIT | LABEL            | DEFAULT | DESCRIPTION                                                                                                                                               | REFER TO              |
|-------------------------------------|-----|------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| R58 (3Ah)<br>Analogue<br>OUT1 Right | 8   | HPOUTR_MUTE      | 0       | Right Headphone Output Mute<br>0 = Un-mute<br>1 = Mute                                                                                                    | Output Volume Control |
|                                     | 7   | HPOUT_VU         | 0       | Headphone Output Volume Update<br>Writing a 1 to this bit will update HPOUTL and HPOUTR volumes simultaneously.                                           | Output Volume Control |
|                                     | 6   | HPOUTRZC         | 0       | Right Headphone Output Zero Cross Enable<br>0 = disabled<br>1 = enabled                                                                                   | Output Volume Control |
|                                     | 5:0 | HPOUTR_VOL [5:0] | 10_1101 | Right Headphone Output Volume<br>000000 = -57dB<br>000001 = -56dB<br>(... 1dB steps)<br>111001 = 0dB<br>(... 1dB steps)<br>111110 = +5dB<br>111111 = +6dB | Output Volume Control |

**Register 3Ah Analogue OUT1 Right**

| REGISTER ADDRESS                   | BIT | LABEL              | DEFAULT | DESCRIPTION                                                                                                                                         | REFER TO              |
|------------------------------------|-----|--------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| R59 (3Bh)<br>Analogue<br>OUT2 Left | 8   | LINEOUTL_MUTE      | 0       | Left Line Output Mute<br>0 = Un-mute<br>1 = Mute                                                                                                    | Output Volume Control |
|                                    | 7   | LINEOUT_VU         | 0       | Line Output Volume Update<br>Writing a 1 to this bit will update LINEOUTL and LINEOUTR volumes simultaneously.                                      | Output Volume Control |
|                                    | 6   | LINEOUTLZC         | 0       | Left Line Output Zero Cross Enable<br>0 = disabled<br>1 = enabled                                                                                   | Output Volume Control |
|                                    | 5:0 | LINEOUTL_VOL [5:0] | 11_1001 | Left Line Output Volume<br>000000 = -57dB<br>000001 = -56dB<br>(... 1dB steps)<br>111001 = 0dB<br>(... 1dB steps)<br>111110 = +5dB<br>111111 = +6dB | Output Volume Control |

**Register 3Bh Analogue OUT2 Left**

| REGISTER ADDRESS                    | BIT | LABEL              | DEFAULT | DESCRIPTION                                                                                                                                          | REFER TO              |
|-------------------------------------|-----|--------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| R60 (3Ch)<br>Analogue<br>OUT2 Right | 8   | LINEOUTR_MUTE      | 0       | Right Line Output Mute<br>0 = Un-mute<br>1 = Mute                                                                                                    | Output Volume Control |
|                                     | 7   | LINEOUT_VU         | 0       | Line Output Volume Update<br>Writing a 1 to this bit will update LINEOUTL and LINEOUTR volumes simultaneously.                                       | Output Volume Control |
|                                     | 6   | LINEOUTRZC         | 0       | Right Line Output Zero Cross Enable<br>0 = disabled<br>1 = enabled                                                                                   | Output Volume Control |
|                                     | 5:0 | LINEOUTR_VOL [5:0] | 11_1001 | Right Line Output Volume<br>000000 = -57dB<br>000001 = -56dB<br>(... 1dB steps)<br>111001 = 0dB<br>(... 1dB steps)<br>111110 = +5dB<br>111111 = +6dB | Output Volume Control |

**Register 3Ch Analogue OUT2 Right**

| REGISTER ADDRESS            | BIT | LABEL             | DEFAULT | DESCRIPTION                                                                                            | REFER TO                   |
|-----------------------------|-----|-------------------|---------|--------------------------------------------------------------------------------------------------------|----------------------------|
| R61 (3Dh) Analogue OUT12 ZC | 3   | HPL_BYP_ENA       | 0       | Selects input for left headphone output MUX<br>0 = Left DAC<br>1 = Left input PGA (Analogue bypass)    | Output Signal Paths Enable |
|                             | 2   | HPR_BYP_ENA       | 0       | Selects input for right headphone output MUX<br>0 = Right DAC<br>1 = Right input PGA (Analogue bypass) | Output Signal Paths Enable |
|                             | 1   | LINEOUTL_BYP_ENA  | 0       | Selects input for left line output MUX<br>0 = Left DAC<br>1 = Left input PGA (Analogue bypass)         | Output Signal Paths Enable |
|                             | 0   | LINEOUTR_BY_P_ENA | 0       | Selects input for right line output MUX<br>0 = Right DAC<br>1 = Right input PGA (Analogue bypass)      | Output Signal Paths Enable |

**Register 3Dh Analogue OUT12 ZC**

| REGISTER ADDRESS     | BIT | LABEL           | DEFAULT | DESCRIPTION                                                 | REFER TO |
|----------------------|-----|-----------------|---------|-------------------------------------------------------------|----------|
| R67 (43h) DC Servo 0 | 3   | DCS_ENA_CHA_N_3 | 0       | DC Servo enable for LINEOUTR<br>0 = disabled<br>1 = enabled | DC Servo |
|                      | 2   | DCS_ENA_CHA_N_2 | 0       | DC Servo enable for LINEOUTL<br>0 = disabled<br>1 = enabled | DC Servo |
|                      | 1   | DCS_ENA_CHA_N_1 | 0       | DC Servo enable for HPOUTR<br>0 = disabled<br>1 = enabled   | DC Servo |
|                      | 0   | DCS_ENA_CHA_N_0 | 0       | DC Servo enable for HPOUTL<br>0 = disabled<br>1 = enabled   | DC Servo |

**Register 43h DC Servo 0**

| REGISTER ADDRESS     | BIT | LABEL              | DEFAULT | DESCRIPTION                                                                                                                                                                 | REFER TO |
|----------------------|-----|--------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| R68 (44h) DC Servo 1 | 15  | DCS_TRIG_SIN_GLE_3 | 0       | Writing 1 to this bit selects a single DC offset correction for LINEOUTR.<br>In readback, a value of 1 indicates that the DC Servo single correction is in progress.        | DC Servo |
|                      | 14  | DCS_TRIG_SIN_GLE_2 | 0       | Writing 1 to this bit selects a single DC offset correction for LINEOUTL.<br>In readback, a value of 1 indicates that the DC Servo single correction is in progress.        | DC Servo |
|                      | 13  | DCS_TRIG_SIN_GLE_1 | 0       | Writing 1 to this bit selects a single DC offset correction for HPOUTR.<br>In readback, a value of 1 indicates that the DC Servo single correction is in progress.          | DC Servo |
|                      | 12  | DCS_TRIG_SIN_GLE_0 | 0       | Writing 1 to this bit selects a single DC offset correction for HPOUTL.<br>In readback, a value of 1 indicates that the DC Servo single correction is in progress.          | DC Servo |
|                      | 11  | DCS_TRIG_SERIES_3  | 0       | Writing 1 to this bit selects a series of DC offset corrections for LINEOUTR.<br>In readback, a value of 1 indicates that the DC Servo DAC Write correction is in progress. | DC Servo |

| REGISTER ADDRESS | BIT | LABEL              | DEFAULT | DESCRIPTION                                                                                                                                                                 | REFER TO |
|------------------|-----|--------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
|                  | 10  | DCS_TRIG_SERIES_2  | 0       | Writing 1 to this bit selects a series of DC offset corrections for LINEOUTL.<br>In readback, a value of 1 indicates that the DC Servo DAC Write correction is in progress. | DC Servo |
|                  | 9   | DCS_TRIG_SERIES_1  | 0       | Writing 1 to this bit selects a series of DC offset corrections for HPOUTR.<br>In readback, a value of 1 indicates that the DC Servo DAC Write correction is in progress.   | DC Servo |
|                  | 8   | DCS_TRIG_SERIES_0  | 0       | Writing 1 to this bit selects a series of DC offset corrections for HPOUTL.<br>In readback, a value of 1 indicates that the DC Servo DAC Write correction is in progress.   | DC Servo |
|                  | 7   | DCS_TRIG_STARTUP_3 | 0       | Writing 1 to this bit selects Start-Up DC Servo mode for LINEOUTR.<br>In readback, a value of 1 indicates that the DC Servo Start-Up correction is in progress.             | DC Servo |
|                  | 6   | DCS_TRIG_STARTUP_2 | 0       | Writing 1 to this bit selects Start-Up DC Servo mode for LINEOUTL.<br>In readback, a value of 1 indicates that the DC Servo Start-Up correction is in progress.             | DC Servo |
|                  | 5   | DCS_TRIG_STARTUP_1 | 0       | Writing 1 to this bit selects Start-Up DC Servo mode for HPOUTR.<br>In readback, a value of 1 indicates that the DC Servo Start-Up correction is in progress.               | DC Servo |
|                  | 4   | DCS_TRIG_STARTUP_0 | 0       | Writing 1 to this bit selects Start-Up DC Servo mode for HPOUTL.<br>In readback, a value of 1 indicates that the DC Servo Start-Up correction is in progress.               | DC Servo |
|                  | 3   | DCS_TRIG_DAC_WR_3  | 0       | Writing 1 to this bit selects DAC Write DC Servo mode for LINEOUTR.<br>In readback, a value of 1 indicates that the DC Servo DAC Write correction is in progress.           | DC Servo |
|                  | 2   | DCS_TRIG_DAC_WR_2  | 0       | Writing 1 to this bit selects DAC Write DC Servo mode for LINEOUTL.<br>In readback, a value of 1 indicates that the DC Servo DAC Write correction is in progress.           | DC Servo |
|                  | 1   | DCS_TRIG_DAC_WR_1  | 0       | Writing 1 to this bit selects DAC Write DC Servo mode for HPOUTR.<br>In readback, a value of 1 indicates that the DC Servo DAC Write correction is in progress.             | DC Servo |
|                  | 0   | DCS_TRIG_DAC_WR_0  | 0       | Writing 1 to this bit selects DAC Write DC Servo mode for HPOUTL.<br>In readback, a value of 1 indicates that the DC Servo DAC Write correction is in progress.             | DC Servo |

**Register 44h DC Servo 1**

| REGISTER ADDRESS     | BIT  | LABEL                         | DEFAULT | DESCRIPTION                                                                                                                                                                                      | REFER TO |
|----------------------|------|-------------------------------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| R69 (45h) DC Servo 2 | 11:8 | DCS_TIMER_PE<br>RIOD_23 [3:0] | 1010    | Time between periodic updates for LINEOUTL/LINEOUTR. Time is calculated as $0.256s \times (2^{\text{PERIOD}})$<br>0000 = Off<br>0001 = 0.52s<br>1010 = 266s (4min 26s)<br>1111 = 8519s (2hr 22s) | DC Servo |
|                      | 3:0  | DCS_TIMER_PE<br>RIOD_01 [3:0] | 1010    | Time between periodic updates for HPOUTL/HPOUTR. Time is calculated as $0.256s \times (2^{\text{PERIOD}})$<br>0000 = Off<br>0001 = 0.52s<br>1010 = 266s (4min 26s)<br>1111 = 8519s (2hr 22s)     | DC Servo |

**Register 45h DC Servo 2**

| REGISTER ADDRESS     | BIT | LABEL                      | DEFAULT  | DESCRIPTION                                                                                                                                  | REFER TO |
|----------------------|-----|----------------------------|----------|----------------------------------------------------------------------------------------------------------------------------------------------|----------|
| R71 (47h) DC Servo 4 | 6:0 | DCS_SERIES_N<br>O_23 [6:0] | 010_1010 | Number of DC Servo updates to perform in a series event for LINEOUTL/LINEOUTR.<br>0 = 1 updates<br>1 = 2 updates<br>...<br>127 = 128 updates | DC Servo |

**Register 47h DC Servo 4**

| REGISTER ADDRESS     | BIT | LABEL                      | DEFAULT  | DESCRIPTION                                                                                                                              | REFER TO |
|----------------------|-----|----------------------------|----------|------------------------------------------------------------------------------------------------------------------------------------------|----------|
| R72 (48h) DC Servo 5 | 6:0 | DCS_SERIES_N<br>O_01 [6:0] | 010_1010 | Number of DC Servo updates to perform in a series event for HPOUTL/HPOUTR.<br>0 = 1 updates<br>1 = 2 updates<br>...<br>127 = 128 updates | DC Servo |

**Register 48h DC Servo 5**

| REGISTER ADDRESS     | BIT | LABEL                      | DEFAULT   | DESCRIPTION                                                                                                                                                                                                                                       | REFER TO |
|----------------------|-----|----------------------------|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| R73 (49h) DC Servo 6 | 7:0 | DCS_DAC_WR_<br>VAL_3 [7:0] | 0000_0000 | DC Offset value for LINEOUTR in DAC Write DC Servo mode in two's complement format.<br><br>In readback, the current DC offset value is returned in two's complement format.<br><br>Two's complement format:<br>LSB is 0.25mV.<br>Range is +/-32mV | DC Servo |

**Register 49h DC Servo 6**

| REGISTER ADDRESS        | BIT | LABEL                  | DEFAULT   | DESCRIPTION                                                                                                                                                                                                                                                | REFER TO |
|-------------------------|-----|------------------------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| R74 (4Ah)<br>DC Servo 7 | 7:0 | DCS_DAC_WR_VAL_2 [7:0] | 0000_0000 | <p>DC Offset value for LINEOUTL in DAC Write DC Servo mode in two's complement format.</p> <p>In readback, the current DC offset value is returned in two's complement format.</p> <p>Two's complement format:<br/>LSB is 0.25mV.<br/>Range is +/-32mV</p> | DC Servo |

**Register 4Ah DC Servo 7**

| REGISTER ADDRESS        | BIT | LABEL                  | DEFAULT   | DESCRIPTION                                                                                                                                                                                                                                              | REFER TO |
|-------------------------|-----|------------------------|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| R75 (4Bh)<br>DC Servo 8 | 7:0 | DCS_DAC_WR_VAL_1 [7:0] | 0000_0000 | <p>DC Offset value for HPOUTR in DAC Write DC Servo mode in two's complement format.</p> <p>In readback, the current DC offset value is returned in two's complement format.</p> <p>Two's complement format:<br/>LSB is 0.25mV.<br/>Range is +/-32mV</p> | DC Servo |

**Register 4Bh DC Servo 8**

| REGISTER ADDRESS        | BIT | LABEL                  | DEFAULT   | DESCRIPTION                                                                                                                                                                                                                                              | REFER TO |
|-------------------------|-----|------------------------|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| R76 (4Ch)<br>DC Servo 9 | 7:0 | DCS_DAC_WR_VAL_0 [7:0] | 0000_0000 | <p>DC Offset value for HPOUTL in DAC Write DC Servo mode in two's complement format.</p> <p>In readback, the current DC offset value is returned in two's complement format.</p> <p>Two's complement format:<br/>LSB is 0.25mV.<br/>Range is +/-32mV</p> | DC Servo |

**Register 4Ch DC Servo 9**

| REGISTER ADDRESS                 | BIT  | LABEL                 | DEFAULT | DESCRIPTION                                                                                                                                                                                                                    | REFER TO |
|----------------------------------|------|-----------------------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| R77 (4Dh)<br>DC Servo Readback 0 | 11:8 | DCS_CAL_COMPLET [3:0] | 0000    | <p>DC Servo Complete status</p> <p>[3] - LINEOUTR<br/>[2] - LINEOUTL<br/>[1] - HPOUTR<br/>[0] - HPOUTL</p> <p>0 = DAC Write or Start-Up DC Servo mode not completed.<br/>1 = DAC Write or Start-Up DC Servo mode complete.</p> | DC Servo |

| REGISTER ADDRESS | BIT | LABEL                      | DEFAULT | DESCRIPTION                                                                                                                                                                              | REFER TO |
|------------------|-----|----------------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
|                  | 7:4 | DCS_DAC_WR_COMPLETE [3:0]  | 0000    | DC Servo DAC Write status<br>[3] - LINEOUTR<br>[2] - LINEOUTL<br>[1] - HPOUTR<br>[0] - HPOUTL<br><br>0 = DAC Write DC Servo mode not completed.<br>1 = DAC Write DC Servo mode complete. | DC Servo |
|                  | 3:0 | DCS_STARTUP_COMPLETE [3:0] | 0000    | DC Servo Start-Up status<br>[3] - LINEOUTR<br>[2] - LINEOUTL<br>[1] - HPOUTR<br>[0] - HPOUTL<br><br>0 = Start-Up DC Servo mode not completed..<br>1 = Start-Up DC Servo mode complete.   | DC Servo |

**Register 4Dh DC Servo Readback 0**

| REGISTER ADDRESS              | BIT | LABEL         | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                            | REFER TO                |
|-------------------------------|-----|---------------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| R90 (5Ah)<br>Analogue HP<br>0 | 7   | HPL_RMV_SHORT | 0       | Removes HPOUTL short<br>0 = HPOUTL short enabled<br>1 = HPOUTL short removed<br>For normal operation, this bit should be set as the final step of the HPL Enable sequence.                                                                                                             | Pop Suppression Control |
|                               | 6   | HPL_ENA_OUTP  | 0       | Enables HPOUTL output stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set to 1 after the DC offset cancellation has been scheduled.                                                                                                                   | Pop Suppression Control |
|                               | 5   | HPL_ENA_DLY   | 0       | Enables HPOUTL intermediate stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set to 1 after the output signal path has been configured, and before DC offset cancellation is scheduled. This bit should be set with at least 20us delay after HPL_ENA. | Pop Suppression Control |
|                               | 4   | HPL_ENA       | 0       | Enables HPOUTL input stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set as the first step of the HPL Enable sequence.                                                                                                                                | Pop Suppression Control |
|                               | 3   | HPR_RMV_SHORT | 0       | Removes HPOUTR short<br>0 = HPOUTR short enabled<br>1 = HPOUTR short removed<br>For normal operation, this bit should be set as the final step of the HPR Enable sequence.                                                                                                             | Pop Suppression Control |
|                               | 2   | HPR_ENA_OUTP  | 0       | Enables HPOUTR output stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set to 1 after the DC offset cancellation has been scheduled.                                                                                                                   | Pop Suppression Control |

| REGISTER ADDRESS | BIT | LABEL       | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                | REFER TO                |
|------------------|-----|-------------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
|                  | 1   | HPR_ENA_DLY | 0       | Enables HPOUTR intermediate stage<br>0 = Disabled<br>1 = Enabled<br><br>For normal operation, this bit should be set to 1 after the output signal path has been configured, and before DC offset cancellation is scheduled. This bit should be set with at least 20us delay after HPR_ENA. | Pop Suppression Control |
|                  | 0   | HPR_ENA     | 0       | Enables HPOUTR input stage<br>0 = Disabled<br>1 = Enabled<br><br>For normal operation, this bit should be set as the first step of the HPR Enable sequence.                                                                                                                                | Pop Suppression Control |

**Register 5Ah Analogue HP 0**

| REGISTER ADDRESS                | BIT | LABEL              | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                   | REFER TO                |
|---------------------------------|-----|--------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| R94 (5Eh)<br>Analogue Lineout 0 | 7   | LINEOUTL_RMV_SHORT | 0       | Removes LINEOUTL short<br>0 = LINEOUTL short enabled<br>1 = LINEOUTL short removed<br>For normal operation, this bit should be set as the final step of the LINEOUTL Enable sequence.                                                                                                         | Pop Suppression Control |
|                                 | 6   | LINEOUTL_ENA_OUTP  | 0       | Enables LINEOUTL output stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set to 1 after the DC offset cancellation has been scheduled.                                                                                                                        | Pop Suppression Control |
|                                 | 5   | LINEOUTL_ENA_DLY   | 0       | Enables LINEOUTL intermediate stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set to 1 after the output signal path has been configured, and before DC offset cancellation is scheduled. This bit should be set with at least 20us delay after LINEOUTL_ENA. | Pop Suppression Control |
|                                 | 4   | LINEOUTL_ENA       | 0       | Enables LINEOUTL input stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set as the first step of the LINEOUTL Enable sequence.                                                                                                                                | Pop Suppression Control |
|                                 | 3   | LINEOUTR_RMV_SHORT | 0       | Removes LINEOUTR short<br>0 = LINEOUTR short enabled<br>1 = LINEOUTR short removed<br>For normal operation, this bit should be set as the final step of the LINEOUTR Enable sequence.                                                                                                         | Pop Suppression Control |
|                                 | 2   | LINEOUTR_ENA_OUTP  | 0       | Enables LINEOUTR output stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set to 1 after the DC offset cancellation has been scheduled.                                                                                                                        | Pop Suppression Control |
|                                 | 1   | LINEOUTR_ENA_DLY   | 0       | Enables LINEOUTR intermediate stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set to 1 after the output signal path has been configured, and before DC offset cancellation is scheduled. This bit should be set with at least 20us delay after LINEOUTR_ENA. | Pop Suppression Control |
|                                 | 0   | LINEOUTR_ENA       | 0       | Enables LINEOUTR input stage<br>0 = Disabled<br>1 = Enabled<br>For normal operation, this bit should be set as the first step of the LINEOUTR Enable sequence.                                                                                                                                | Pop Suppression Control |

**Register 5Eh Analogue Lineout 0**

| REGISTER ADDRESS           | BIT | LABEL  | DEFAULT | DESCRIPTION                                            | REFER TO    |
|----------------------------|-----|--------|---------|--------------------------------------------------------|-------------|
| R98 (62h)<br>Charge Pump 0 | 0   | CP_ENA | 0       | Enable charge-pump digits<br>0 = disable<br>1 = enable | Charge Pump |

**Register 62h Charge Pump 0**

| REGISTER ADDRESS      | BIT | LABEL      | DEFAULT | DESCRIPTION                                                                                                                                                                                                                               | REFER TO    |
|-----------------------|-----|------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| R104 (68h)<br>Class W | 0   | CP_DYN_PWR | 0       | Enable dynamic charge pump power control<br>0 = Charge pump controlled by volume register settings (Class G)<br>1 = Charge pump controlled by real-time audio level (Class W)<br><br>Class W is recommended for lowest power consumption. | Charge Pump |

**Register 68h Class W**

| REGISTER ADDRESS                | BIT | LABEL                  | DEFAULT | DESCRIPTION                                                                                                                        | REFER TO                |
|---------------------------------|-----|------------------------|---------|------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| R108 (6Ch)<br>Write Sequencer 0 | 8   | WSEQ_ENA               | 0       | Write Sequencer Enable.<br>0 = Disabled<br>1 = Enabled                                                                             | Control Write Sequencer |
|                                 | 4:0 | WSEQ_WRITE_INDEX [4:0] | 0_0000  | Sequence Write Index. This is the memory location to which any updates to R109 and R110 will be copied.<br>0 to 31 = RAM addresses | Control Write Sequencer |

**Register 6Ch Write Sequencer 0**

| REGISTER ADDRESS                | BIT   | LABEL                 | DEFAULT   | DESCRIPTION                                                                                                                                                                           | REFER TO                |
|---------------------------------|-------|-----------------------|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| R109 (6Dh)<br>Write Sequencer 1 | 14:12 | WSEQ_DATA_WIDTH [2:0] | 000       | Width of the data block written in this sequence step.<br>000 = 1 bit<br>001 = 2 bits<br>010 = 3 bits<br>011 = 4 bits<br>100 = 5 bits<br>101 = 6 bits<br>110 = 7 bits<br>111 = 8 bits | Control Write Sequencer |
|                                 | 11:8  | WSEQ_DATA_START [3:0] | 0000      | Bit position of the LSB of the data block written in this sequence step.<br>0000 = Bit 0<br>...<br>1111 = Bit 15                                                                      | Control Write Sequencer |
|                                 | 7:0   | WSEQ_ADDR [7:0]       | 0000_0000 | Control Register Address to be written to in this sequence step.                                                                                                                      | Control Write Sequencer |

**Register 6Dh Write Sequencer 1**

| REGISTER ADDRESS                | BIT  | LABEL            | DEFAULT   | DESCRIPTION                                                                                                                                                                                                 | REFER TO                |
|---------------------------------|------|------------------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| R110 (6Eh)<br>Write Sequencer 2 | 14   | WSEQ_EOS         | 0         | End of Sequence flag. This bit indicates whether the Control Write Sequencer should stop after executing this step.<br>0 = Not end of sequence<br>1 = End of sequence (Stop the sequencer after this step). | Control Write Sequencer |
|                                 | 11:8 | WSEQ_DELAY [3:0] | 0000      | Time delay after executing this step.<br>Total delay time per step (including execution)=<br>$62.5\mu s \times (2^{\text{WSEQ\_DELAY}} + 8)$                                                                | Control Write Sequencer |
|                                 | 7:0  | WSEQ_DATA [7:0]  | 0000_0000 | Data to be written in this sequence step. When the data width is less than 8 bits, then one or more of the MSBs of WSEQ_DATA are ignored. It is recommended that unused bits be set to 0.                   | Control Write Sequencer |

**Register 6Eh Write Sequencer 2**

| REGISTER ADDRESS                | BIT | LABEL                  | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                      | REFER TO                |
|---------------------------------|-----|------------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| R111 (6Fh)<br>Write Sequencer 3 | 9   | WSEQ_ABORT             | 0       | Writing a 1 to this bit aborts the current sequence and returns control of the device back to the serial control interface.                                                                                                                                      | Control Write Sequencer |
|                                 | 8   | WSEQ_START             | 0       | Writing a 1 to this bit starts the write sequencer at the memory location indicated by the WSEQ_START_INDEX field. The sequence continues until it reaches an "End of sequence" flag. At the end of the sequence, this bit will be reset by the Write Sequencer. | Control Write Sequencer |
|                                 | 5:0 | WSEQ_START_INDEX [5:0] | 00_0000 | Sequence Start Index. This is the memory location of the first command in the selected sequence.<br>0 to 31 = RAM addresses<br>32 to 48 = ROM addresses<br>49 to 63 = Reserved                                                                                   | Control Write Sequencer |

**Register 6Fh Write Sequencer 3**

| REGISTER ADDRESS                | BIT | LABEL                    | DEFAULT | DESCRIPTION                                                                                                                                                                                   | REFER TO                |
|---------------------------------|-----|--------------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| R112 (70h)<br>Write Sequencer 4 | 9:4 | WSEQ_CURRENT_INDEX [5:0] | 00_0000 | Sequence Current Index (read only):<br>This is the location of the most recently accessed command in the write sequencer memory.                                                              | Control Write Sequencer |
|                                 | 0   | WSEQ_BUSY                | 0       | Sequencer Busy flag (read only):<br>0 = Sequencer idle<br>1 = Sequencer busy<br>Note: it is not possible to write to control registers via the control interface while the Sequencer is Busy. | Control Write Sequencer |

**Register 70h Write Sequencer 4**

| REGISTER ADDRESS            | BIT | LABEL         | DEFAULT | DESCRIPTION                                                                                                                                                                               | REFER TO                    |
|-----------------------------|-----|---------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| R116 (74h)<br>FLL Control 1 | 2   | FLL_FRACN_ENA | 0       | FLL Fractional enable<br>0 = Integer Mode<br>1 = Fractional Mode<br><br>Fractional Mode (FLL_FRACN_ENA=1) is recommended in all cases                                                     | Frequency Locked Loop (FLL) |
|                             | 1   | FLL_OSC_ENA   | 0       | FLL Oscillator enable<br>0 = Disabled<br>1 = Enabled<br><br>FLL_OSC_ENA must be enabled before enabling FLL_ENA.<br><br>Note that this field is required for free-running FLL modes only. | Frequency Locked Loop (FLL) |
|                             | 0   | FLL_ENA       | 0       | FLL Enable<br>0 = Disabled<br>1 = Enabled<br><br>FLL_OSC_ENA must be enabled before enabling FLL_ENA.                                                                                     | Frequency Locked Loop (FLL) |

**Register 74h FLL Control 1**

| REGISTER ADDRESS            | BIT  | LABEL               | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                        | REFER TO                    |
|-----------------------------|------|---------------------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| R117 (75h)<br>FLL Control 2 | 13:8 | FLL_OUTDIV [5:0]    | 00_0000 | FLL FOUT clock divider<br>00_0000 = Reserved<br>00_0001 = Reserved<br>00_0010 = Reserved<br>00_0011 = 4<br>00_0100 = 5<br>00_0101 = 6<br>...<br>11_1110 = 63<br>11_1111 = 64<br>(FOUT = FVCO / FLL_OUTDIV)                                                         | Frequency Locked Loop (FLL) |
|                             | 6:4  | FLL_CTRL_RATE [2:0] | 000     | Frequency of the FLL control block<br>000 = FVCO / 1 (Recommended value)<br>001 = FVCO / 2<br>010 = FVCO / 3<br>011 = FVCO / 4<br>100 = FVCO / 5<br>101 = FVCO / 6<br>110 = FVCO / 7<br>111 = FVCO / 8<br><br>Recommended that these are not changed from default. | Frequency Locked Loop (FLL) |
|                             | 2:0  | FLL_FRATIO [2:0]    | 111     | F <sub>VCO</sub> clock divider<br>000 = divide by 1<br>001 = divide by 2<br>010 = divide by 4<br>011 = divide by 8<br>1XX = divide by 16                                                                                                                           | Frequency Locked Loop (FLL) |

| REGISTER ADDRESS | BIT | LABEL | DEFAULT | DESCRIPTION                                                                                 | REFER TO |
|------------------|-----|-------|---------|---------------------------------------------------------------------------------------------|----------|
|                  |     |       |         | 000 recommended for $F_{REF} > 1\text{MHz}$<br>100 recommended for $F_{REF} < 64\text{kHz}$ |          |

**Register 75h FLL Control 2**

| REGISTER ADDRESS            | BIT  | LABEL        | DEFAULT                 | DESCRIPTION                                 | REFER TO                    |
|-----------------------------|------|--------------|-------------------------|---------------------------------------------|-----------------------------|
| R118 (76h)<br>FLL Control 3 | 15:0 | FLL_K [15:0] | 0000_0000_00<br>00_0000 | Fractional multiply for FREF<br>(MSB = 0.5) | Frequency Locked Loop (FLL) |

**Register 76h FLL Control 3**

| REGISTER ADDRESS            | BIT  | LABEL          | DEFAULT          | DESCRIPTION                                                                                                                                                                                                                                    | REFER TO                    |
|-----------------------------|------|----------------|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| R119 (77h)<br>FLL Control 4 | 14:5 | FLL_N [9:0]    | 01_0111_01<br>11 | Integer multiply for FREF<br>(LSB = 1)                                                                                                                                                                                                         | Frequency Locked Loop (FLL) |
|                             | 3:0  | FLL_GAIN [3:0] | 0000             | FLL Gain applied to error<br>0000 = x 1 (Recommended value)<br>0001 = x 2<br>0010 = x 4<br>0011 = x 8<br>0100 = x 16<br>0101 = x 32<br>0110 = x 64<br>0111 = x 128<br>1000 = x 256<br><br>Recommended that these are not changed from default. | Frequency Locked Loop (FLL) |

**Register 77h FLL Control 4**

| REGISTER ADDRESS            | BIT | LABEL                    | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                      | REFER TO                    |
|-----------------------------|-----|--------------------------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| R120 (78h)<br>FLL Control 5 | 4:3 | FLL_CLK_REF_DIV [1:0]    | 00      | FLL Clock Reference Divider<br>00 = MCLK / 1<br>01 = MCLK / 2<br>10 = MCLK / 4<br>11 = MCLK / 8<br><br>MCLK (or other input reference) must be divided down to $\leq 13.5\text{MHz}$ .<br>For lower power operation, the reference clock can be divided down further if desired. | Frequency Locked Loop (FLL) |
|                             | 1:0 | FLL_CLK_REF_SOURCE [1:0] | 00      | FLL Clock source<br>00 = MCLK<br>01 = BCLK<br>10 = LRCLK<br>11 = Reserved                                                                                                                                                                                                        | Frequency Locked Loop (FLL) |

**Register 78h FLL Control 5**

| REGISTER ADDRESS             | BIT | LABEL           | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                     | REFER TO                            |
|------------------------------|-----|-----------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|
| R121 (79h)<br>GPIO Control 1 | 5   | GPIO1_PU        | 0       | GPIO1 pull-up resistor enable<br>0 = pull-up disabled<br>1 = pull-up enabled                                                                                                                                                                                                                    | General Purpose Input/Output (GPIO) |
|                              | 4   | GPIO1_PD        | 1       | GPIO1 pull-down resistor enable<br>0 = pull-down disabled<br>1 = pull-down enabled                                                                                                                                                                                                              | General Purpose Input/Output (GPIO) |
|                              | 3:0 | GPIO1_SEL [3:0] | 0100    | GPIO1 Function Select<br>0000 = Input pin<br>0001 = Clock output (f=SYSCLK/OPCLKDIV)<br>0010 = Logic '0'<br>0011 = Logic '1'<br>0100 = IRQ (default)<br>0101 = FLL Lock<br>0110 = Mic Detect<br>0111 = Mic Short<br>1000 = DMIC clock out<br>1001 = FLL Clock Output<br>1010 to 1111 = Reserved | General Purpose Input/Output (GPIO) |

**Register 79h GPIO Control 1**

| REGISTER ADDRESS             | BIT | LABEL           | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                     | REFER TO                            |
|------------------------------|-----|-----------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|
| R122 (7Ah)<br>GPIO Control 2 | 5   | GPIO2_PU        | 0       | GPIO2 pull-up resistor enable<br>0 = pull-up disabled<br>1 = pull-up enabled                                                                                                                                                                                                                    | General Purpose Input/Output (GPIO) |
|                              | 4   | GPIO2_PD        | 1       | GPIO2 pull-down resistor enable<br>0 = pull-down disabled<br>1 = pull-down enabled                                                                                                                                                                                                              | General Purpose Input/Output (GPIO) |
|                              | 3:0 | GPIO2_SEL [3:0] | 0000    | GPIO2 Function Select<br>0000 = Input pin (default)<br>0001 = Clock output (f=SYSCLK/OPCLKDIV)<br>0010 = Logic '0'<br>0011 = Logic '1'<br>0100 = IRQ<br>0101 = FLL Lock<br>0110 = Mic Detect<br>0111 = Mic Short<br>1000 = DMIC clock out<br>1001 = FLL Clock Output<br>1010 to 1111 = Reserved | General Purpose Input/Output (GPIO) |

**Register 7Ah GPIO Control 2**

| REGISTER ADDRESS             | BIT | LABEL           | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                     | REFER TO                            |
|------------------------------|-----|-----------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|
| R123 (7Bh)<br>GPIO Control 3 | 5   | GPIO3_PU        | 0       | GPIO3 pull-up resistor enable<br>0 = pull-up disabled<br>1 = pull-up enabled                                                                                                                                                                                                                    | General Purpose Input/Output (GPIO) |
|                              | 4   | GPIO3_PD        | 1       | GPIO3 pull-down resistor enable<br>0 = pull-down disabled<br>1 = pull-down enabled                                                                                                                                                                                                              | General Purpose Input/Output (GPIO) |
|                              | 3:0 | GPIO3_SEL [3:0] | 0000    | GPIO3 Function Select<br>0000 = Input pin (default)<br>0001 = Clock output (f=SYSCLK/OPCLKDIV)<br>0010 = Logic '0'<br>0011 = Logic '1'<br>0100 = IRQ<br>0101 = FLL Lock<br>0110 = Mic Detect<br>0111 = Mic Short<br>1000 = DMIC clock out<br>1001 = FLL Clock Output<br>1010 to 1111 = Reserved | General Purpose Input/Output (GPIO) |

**Register 7Bh GPIO Control 3**

| REGISTER ADDRESS             | BIT | LABEL               | DEFAULT | DESCRIPTION                                                                                                                                                                                                                                                                                          | REFER TO                            |
|------------------------------|-----|---------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|
| R124 (7Ch)<br>GPIO Control 4 | 9   | GPI7_ENA            | 0       | GPI7 input enable<br>0 = disabled<br>1 = enabled                                                                                                                                                                                                                                                     | General Purpose Input/Output (GPIO) |
|                              | 8   | GPI8_ENA            | 0       | GPI8 input enable<br>0 = disabled<br>1 = enabled                                                                                                                                                                                                                                                     | General Purpose Input/Output (GPIO) |
|                              | 7   | GPIO_BCLK_MODE_ENA  | 0       | Selects BCLK/GPIO4 pin function<br>0 = BCLK/GPIO4 is used as BCLK<br>1 = BCLK/GPIO4 is used as GPIO. MCLK provides the BCLK in the AIF in this mode.                                                                                                                                                 | General Purpose Input/Output (GPIO) |
|                              | 3:0 | GPIO_BCLK_SEL [3:0] | 0000    | GPIO_BCLK function select:<br>0000 = Input Pin (default)<br>0001 = Clock output (f=SYSCLK/OPCLKDIV)<br>0010 = Logic '0'<br>0011 = Logic '1'<br>0100 = IRQ<br>0101 = FLL Lock<br>0110 = Mic Detect<br>0111 = Mic Short<br>1000 = DMIC clock out<br>1001 = FLL Clock Output<br>1010 to 1111 = Reserved | General Purpose Input/Output (GPIO) |

**Register 7Ch GPIO Control 4**

| REGISTER ADDRESS            | BIT | LABEL     | DEFAULT | DESCRIPTION                                                                         | REFER TO                        |
|-----------------------------|-----|-----------|---------|-------------------------------------------------------------------------------------|---------------------------------|
| R126 (7Eh)<br>Digital Pulls | 7   | MCLK_PU   | 0       | MCLK pull-up resistor enable<br>0 = pull-up disabled<br>1 = pull-up enabled         | Digital Audio Interface Control |
|                             | 6   | MCLK_PD   | 0       | MCLK pull-down resistor enable<br>0 = pull-down disabled<br>1 = pull-down enabled   | Digital Audio Interface Control |
|                             | 5   | DACDAT_PU | 0       | DACDAT pull-up resistor enable<br>0 = pull-up disabled<br>1 = pull-up enabled       | Digital Audio Interface Control |
|                             | 4   | DACDAT_PD | 0       | DACDAT pull-down resistor enable<br>0 = pull-down disabled<br>1 = pull-down enabled | Digital Audio Interface Control |
|                             | 3   | LRCLK_PU  | 0       | LRCLK pull-up resistor enable<br>0 = pull-up disabled<br>1 = pull-up enabled        | Digital Audio Interface Control |
|                             | 2   | LRCLK_PD  | 0       | LRCLK pull-down resistor enable<br>0 = pull-down disabled<br>1 = pull-down enabled  | Digital Audio Interface Control |
|                             | 1   | BCLK_PU   | 0       | BCLK pull-up resistor enable<br>0 = pull-up disabled<br>1 = pull-up enabled         | Digital Audio Interface Control |
|                             | 0   | BCLK_PD   | 0       | BCLK pull-down resistor enable<br>0 = pull-down disabled<br>1 = pull-down enabled   | Digital Audio Interface Control |

**Register 7Eh Digital Pulls**

| REGISTER ADDRESS               | BIT | LABEL          | DEFAULT | DESCRIPTION                                                                                                                                                                                          | REFER TO   |
|--------------------------------|-----|----------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| R127 (7Fh)<br>Interrupt Status | 10  | IRQ            | 0       | Logical OR of all other interrupt flags                                                                                                                                                              | Interrupts |
|                                | 9   | GPIO_BCLK_EINT | 0       | GPIO4 interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written                                                                                                    | Interrupts |
|                                | 8   | WSEQ_EINT      | 0       | Write Sequence interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written.<br>Note that the read value of WSEQ_EINT is not valid whilst the Write Sequencer is Busy | Interrupts |
|                                | 7   | GPIO3_EINT     | 0       | GPIO3 interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written                                                                                                    | Interrupts |
|                                | 6   | GPIO2_EINT     | 0       | GPIO2 interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written                                                                                                    | Interrupts |
|                                | 5   | GPIO1_EINT     | 0       | GPIO1 interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written                                                                                                    | Interrupts |

| REGISTER ADDRESS | BIT | LABEL         | DEFAULT | DESCRIPTION                                                                                                        | REFER TO   |
|------------------|-----|---------------|---------|--------------------------------------------------------------------------------------------------------------------|------------|
|                  | 4   | GPI8_EINT     | 0       | GPI8 interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written                   | Interrupts |
|                  | 3   | GPI7_EINT     | 0       | GPI7 interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written                   | Interrupts |
|                  | 2   | FLL_LOCK_EINT | 0       | FLL Lock interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written               | Interrupts |
|                  | 1   | MIC_SHRT_EINT | 0       | MICBIAS short circuit interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written  | Interrupts |
|                  | 0   | MIC_DET_EINT  | 0       | MICBIAS current detect interrupt<br>0 = interrupt not set<br>1 = interrupt is set<br>Cleared when a '1' is written | Interrupts |

**Register 7Fh Interrupt Status**

| REGISTER ADDRESS                       | BIT | LABEL             | DEFAULT | DESCRIPTION                                                                             | REFER TO   |
|----------------------------------------|-----|-------------------|---------|-----------------------------------------------------------------------------------------|------------|
| R128 (80h)<br>Interrupt<br>Status Mask | 9   | IM_GPIO_BCLK_EINT | 1       | GPIO4 interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt                 | Interrupts |
|                                        | 8   | IM_WSEQ_EINT      | 1       | Write sequencer interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt       | Interrupts |
|                                        | 7   | IM_GPIO3_EINT     | 1       | GPIO3 interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt                 | Interrupts |
|                                        | 6   | IM_GPIO2_EINT     | 1       | GPIO2 interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt                 | Interrupts |
|                                        | 5   | IM_GPIO1_EINT     | 1       | GPIO1 interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt                 | Interrupts |
|                                        | 4   | IM_GPI8_EINT      | 1       | GPI8 interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt                  | Interrupts |
|                                        | 3   | IM_GPI7_EINT      | 1       | GPI7 interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt                  | Interrupts |
|                                        | 2   | IM_FLL_LOCK_EINT  | 1       | FLL Lock interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt              | Interrupts |
|                                        | 1   | IM_MIC_SHRT_EINT  | 1       | MICBIAS short circuit interrupt mask<br>0 = do not mask interrupt<br>1 = mask interrupt | Interrupts |
|                                        | 0   | IM_MIC_DET_EINT   | 1       | MICBIAS current detect interrupt mask                                                   | Interrupts |

| REGISTER ADDRESS | BIT | LABEL | DEFAULT | DESCRIPTION                                     | REFER TO |
|------------------|-----|-------|---------|-------------------------------------------------|----------|
|                  |     |       |         | 0 = do not mask interrupt<br>1 = mask interrupt |          |

**Register 80h Interrupt Status Mask**

| REGISTER ADDRESS                 | BIT | LABEL              | DEFAULT | DESCRIPTION                                                                                                                                                        | REFER TO   |
|----------------------------------|-----|--------------------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| R129 (81h)<br>Interrupt Polarity | 9   | GPIO_BCLK_EINT_POL | 0       | GPIO4 interrupt polarity<br>0 = active high<br>1 = active low                                                                                                      | Interrupts |
|                                  | 8   | WSEQ_EINT_POL      | 0       | Write Sequencer interrupt polarity<br>0 = active high (interrupt is triggered when WSEQ is busy)<br>1 = active low (interrupt is triggered when WSEQ is idle)      | Interrupts |
|                                  | 7   | GPIO3_EINT_POL     | 0       | GPIO3 interrupt polarity<br>0 = active high<br>1 = active low                                                                                                      | Interrupts |
|                                  | 6   | GPIO2_EINT_POL     | 0       | GPIO2 interrupt polarity<br>0 = active high<br>1 = active low                                                                                                      | Interrupts |
|                                  | 5   | GPIO1_EINT_POL     | 0       | GPIO1 interrupt polarity<br>0 = active high<br>1 = active low                                                                                                      | Interrupts |
|                                  | 4   | GPI8_EINT_POL      | 0       | GPI8 interrupt polarity<br>0 = active high<br>1 = active low                                                                                                       | Interrupts |
|                                  | 3   | GPI7_EINT_POL      | 0       | GPI7 interrupt polarity<br>0 = active high<br>1 = active low                                                                                                       | Interrupts |
|                                  | 2   | FLL_LOCK_EINT_POL  | 0       | FLL Lock interrupt polarity<br>0 = active high (interrupt is triggered when FLL Lock is reached)<br>1 = active low (interrupt is triggered when FLL is not locked) | Interrupts |
|                                  | 1   | MIC_SHRT_EINT_POL  | 0       | MICBIAS short circuit interrupt polarity<br>0 = active high<br>1 = active low                                                                                      | Interrupts |
|                                  | 0   | MIC_DET_EINT_POL   | 0       | MICBIAS current detect interrupt polarity<br>0 = active high<br>1 = active low                                                                                     | Interrupts |

**Register 81h Interrupt Polarity**

| REGISTER ADDRESS                 | BIT | LABEL             | DEFAULT | DESCRIPTION                                                              | REFER TO   |
|----------------------------------|-----|-------------------|---------|--------------------------------------------------------------------------|------------|
| R130 (82h)<br>Interrupt Debounce | 9   | GPIO_BCLK_EINT_DB | 0       | GPIO4 interrupt debounce<br>0 = disabled<br>1 = enabled                  | Interrupts |
|                                  | 8   | WSEQ_EINT_DB      | 0       | Write Sequencer interrupt debounce enable<br>0 = disabled<br>1 = enabled | Interrupts |
|                                  | 7   | GPIO3_EINT_DB     | 0       | GPIO3 input debounce<br>0 = disabled<br>1 = enabled                      | Interrupts |
|                                  | 6   | GPIO2_EINT_DB     | 0       | GPIO2 input debounce<br>0 = disabled<br>1 = enabled                      | Interrupts |
|                                  | 5   | GPIO1_EINT_DB     | 0       | GPIO1 input debounce<br>0 = disabled<br>1 = enabled                      | Interrupts |
|                                  | 4   | GPI8_EINT_DB      | 0       | GPI8 input debounce<br>0 = disabled<br>1 = enabled                       | Interrupts |
|                                  | 3   | GPI7_EINT_DB      | 0       | GPI7 input debounce<br>0 = disabled<br>1 = enabled                       | Interrupts |
|                                  | 2   | FLL_LOCK_EINT_DB  | 0       | FLL Lock debounce<br>0 = disabled<br>1 = enabled                         | Interrupts |
|                                  | 1   | MIC_SHRT_EINT_DB  | 0       | MICBIAS short circuit interrupt debounce<br>0 = disabled<br>1 = enabled  | Interrupts |
|                                  | 0   | MIC_DET_EINT_DB   | 0       | MICBIAS current detect interrupt debounce<br>0 = disabled<br>1 = enabled | Interrupts |

**Register 82h Interrupt Debounce**

| REGISTER ADDRESS  | BIT | LABEL  | DEFAULT | DESCRIPTION                                    | REFER TO                                       |
|-------------------|-----|--------|---------|------------------------------------------------|------------------------------------------------|
| R134 (86h)<br>EQ1 | 0   | EQ_ENA | 0       | EQ enable<br>0 = EQ disabled<br>1 = EQ enabled | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

**Register 86h EQ1**

| REGISTER ADDRESS  | BIT | LABEL               | DEFAULT | DESCRIPTION                                                                                                                                             | REFER TO                                       |
|-------------------|-----|---------------------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|
| R135 (87h)<br>EQ2 | 4:0 | EQ_B1_GAIN<br>[4:0] | 0_1100  | Gain for EQ band 1<br>00000 = -12dB<br>00001 = -11dB<br>(... 1dB steps)<br>01100 = 0dB<br>(... 1dB steps)<br>11000 = +12dB<br>11001 to 11111 = reserved | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

**Register 87h EQ2**

| REGISTER ADDRESS  | BIT | LABEL               | DEFAULT | DESCRIPTION                                                                                                                                             | REFER TO                                       |
|-------------------|-----|---------------------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|
| R136 (88h)<br>EQ3 | 4:0 | EQ_B2_GAIN<br>[4:0] | 0_1100  | Gain for EQ band 2<br>00000 = -12dB<br>00001 = -11dB<br>(... 1dB steps)<br>01100 = 0dB<br>(... 1dB steps)<br>11000 = +12dB<br>11001 to 11111 = reserved | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

Register 88h EQ3

| REGISTER ADDRESS  | BIT | LABEL               | DEFAULT | DESCRIPTION                                                                                                                                             | REFER TO                                       |
|-------------------|-----|---------------------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|
| R137 (89h)<br>EQ4 | 4:0 | EQ_B3_GAIN<br>[4:0] | 0_1100  | Gain for EQ band 3<br>00000 = -12dB<br>00001 = -11dB<br>(... 1dB steps)<br>01100 = 0dB<br>(... 1dB steps)<br>11000 = +12dB<br>11001 to 11111 = reserved | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

Register 89h EQ4

| REGISTER ADDRESS  | BIT | LABEL               | DEFAULT | DESCRIPTION                                                                                                                                             | REFER TO                                       |
|-------------------|-----|---------------------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|
| R138 (8Ah)<br>EQ5 | 4:0 | EQ_B4_GAIN<br>[4:0] | 0_1100  | Gain for EQ band 4<br>00000 = -12dB<br>00001 = -11dB<br>(... 1dB steps)<br>01100 = 0dB<br>(... 1dB steps)<br>11000 = +12dB<br>11001 to 11111 = reserved | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

Register 8Ah EQ5

| REGISTER ADDRESS  | BIT | LABEL               | DEFAULT | DESCRIPTION                                                                                                                                            | REFER TO                                       |
|-------------------|-----|---------------------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|
| R139 (8Bh)<br>EQ6 | 4:0 | EQ_B5_GAIN<br>[4:0] | 0_1100  | Gain for EQ band5<br>00000 = -12dB<br>00001 = -11dB<br>(... 1dB steps)<br>01100 = 0dB<br>(... 1dB steps)<br>11000 = +12dB<br>11001 to 11111 = reserved | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

Register 8Bh EQ6

| REGISTER ADDRESS  | BIT  | LABEL          | DEFAULT                 | DESCRIPTION             | REFER TO                                       |
|-------------------|------|----------------|-------------------------|-------------------------|------------------------------------------------|
| R140 (8Ch)<br>EQ7 | 15:0 | EQ_B1_A [15:0] | 0000_1111_11<br>00_1010 | EQ Band 1 Coefficient A | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

## Register 8Ch EQ7

| REGISTER ADDRESS  | BIT  | LABEL          | DEFAULT                 | DESCRIPTION             | REFER TO                                       |
|-------------------|------|----------------|-------------------------|-------------------------|------------------------------------------------|
| R141 (8Dh)<br>EQ8 | 15:0 | EQ_B1_B [15:0] | 0000_0100_<br>0000_0000 | EQ Band 1 Coefficient B | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

## Register 8Dh EQ8

| REGISTER ADDRESS  | BIT  | LABEL           | DEFAULT                 | DESCRIPTION              | REFER TO                                       |
|-------------------|------|-----------------|-------------------------|--------------------------|------------------------------------------------|
| R142 (8Eh)<br>EQ9 | 15:0 | EQ_B1_PG [15:0] | 0000_0000_11<br>01_1000 | EQ Band 1 Coefficient PG | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

## Register 8Eh EQ9

| REGISTER ADDRESS   | BIT  | LABEL          | DEFAULT                 | DESCRIPTION             | REFER TO                                       |
|--------------------|------|----------------|-------------------------|-------------------------|------------------------------------------------|
| R143 (8Fh)<br>EQ10 | 15:0 | EQ_B2_A [15:0] | 0001_1110_10<br>11_0101 | EQ Band 2 Coefficient A | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

## Register 8Fh EQ10

| REGISTER ADDRESS   | BIT  | LABEL          | DEFAULT                 | DESCRIPTION             | REFER TO                                       |
|--------------------|------|----------------|-------------------------|-------------------------|------------------------------------------------|
| R144 (90h)<br>EQ11 | 15:0 | EQ_B2_B [15:0] | 1111_0001_01<br>00_0101 | EQ Band 2 Coefficient B | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

## Register 90h EQ11

| REGISTER ADDRESS   | BIT  | LABEL          | DEFAULT                 | DESCRIPTION             | REFER TO                                       |
|--------------------|------|----------------|-------------------------|-------------------------|------------------------------------------------|
| R145 (91h)<br>EQ12 | 15:0 | EQ_B2_C [15:0] | 0000_1011_01<br>11_0101 | EQ Band 2 Coefficient C | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

## Register 91h EQ12

| REGISTER ADDRESS   | BIT  | LABEL           | DEFAULT                 | DESCRIPTION              | REFER TO                                       |
|--------------------|------|-----------------|-------------------------|--------------------------|------------------------------------------------|
| R146 (92h)<br>EQ13 | 15:0 | EQ_B2_PG [15:0] | 0000_0001_11<br>00_0101 | EQ Band 2 Coefficient PG | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

## Register 92h EQ13

| REGISTER ADDRESS   | BIT  | LABEL          | DEFAULT                 | DESCRIPTION             | REFER TO                                       |
|--------------------|------|----------------|-------------------------|-------------------------|------------------------------------------------|
| R147 (93h)<br>EQ14 | 15:0 | EQ_B3_A [15:0] | 0001_1100_01<br>01_1000 | EQ Band 3 Coefficient A | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

## Register 93h EQ14

| REGISTER ADDRESS   | BIT  | LABEL          | DEFAULT                 | DESCRIPTION             | REFER TO                                       |
|--------------------|------|----------------|-------------------------|-------------------------|------------------------------------------------|
| R148 (94h)<br>EQ15 | 15:0 | EQ_B3_B [15:0] | 1111_0011_01<br>11_0011 | EQ Band 3 Coefficient B | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

## Register 94h EQ15

| REGISTER ADDRESS   | BIT  | LABEL          | DEFAULT                 | DESCRIPTION             | REFER TO                                       |
|--------------------|------|----------------|-------------------------|-------------------------|------------------------------------------------|
| R149 (95h)<br>EQ16 | 15:0 | EQ_B3_C [15:0] | 0000_1010_01<br>01_0100 | EQ Band 3 Coefficient C | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

## Register 95h EQ16

| REGISTER ADDRESS   | BIT  | LABEL           | DEFAULT                 | DESCRIPTION              | REFER TO                                       |
|--------------------|------|-----------------|-------------------------|--------------------------|------------------------------------------------|
| R150 (96h)<br>EQ17 | 15:0 | EQ_B3_PG [15:0] | 0000_0101_01<br>01_1000 | EQ Band 3 Coefficient PG | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

## Register 96h EQ17

| REGISTER ADDRESS   | BIT  | LABEL          | DEFAULT                 | DESCRIPTION             | REFER TO                                       |
|--------------------|------|----------------|-------------------------|-------------------------|------------------------------------------------|
| R151 (97h)<br>EQ18 | 15:0 | EQ_B4_A [15:0] | 0001_0110_10<br>00_1110 | EQ Band 4 Coefficient A | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

## Register 97h EQ18

| REGISTER ADDRESS   | BIT  | LABEL          | DEFAULT                 | DESCRIPTION             | REFER TO                                       |
|--------------------|------|----------------|-------------------------|-------------------------|------------------------------------------------|
| R152 (98h)<br>EQ19 | 15:0 | EQ_B4_B [15:0] | 1111_1000_00<br>10_1001 | EQ Band 4 Coefficient B | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

## Register 98h EQ19

| REGISTER ADDRESS   | BIT  | LABEL          | DEFAULT                 | DESCRIPTION             | REFER TO                                       |
|--------------------|------|----------------|-------------------------|-------------------------|------------------------------------------------|
| R153 (99h)<br>EQ20 | 15:0 | EQ_B4_C [15:0] | 0000_0111_10<br>10_1101 | EQ Band 4 Coefficient C | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

## Register 99h EQ20

| REGISTER ADDRESS   | BIT  | LABEL           | DEFAULT                 | DESCRIPTION              | REFER TO                                       |
|--------------------|------|-----------------|-------------------------|--------------------------|------------------------------------------------|
| R154 (9Ah)<br>EQ21 | 15:0 | EQ_B4_PG [15:0] | 0001_0001_00<br>00_0011 | EQ Band 4 Coefficient PG | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

## Register 9Ah EQ21

| REGISTER ADDRESS   | BIT  | LABEL          | DEFAULT                 | DESCRIPTION             | REFER TO                                       |
|--------------------|------|----------------|-------------------------|-------------------------|------------------------------------------------|
| R155 (9Bh)<br>EQ22 | 15:0 | EQ_B5_A [15:0] | 0000_0101_01<br>10_0100 | EQ Band 5 Coefficient A | ReTune™ Mobile<br>Parametric<br>Equalizer (EQ) |

## Register 9Bh EQ22

| REGISTER ADDRESS   | BIT  | LABEL          | DEFAULT                 | DESCRIPTION             | REFER TO                                 |
|--------------------|------|----------------|-------------------------|-------------------------|------------------------------------------|
| R156 (9Ch)<br>EQ23 | 15:0 | EQ_B5_B [15:0] | 0000_0101_01<br>01_1001 | EQ Band 1 Coefficient B | ReTune™ Mobile Parametric Equalizer (EQ) |

## Register 9Ch EQ23

| REGISTER ADDRESS   | BIT  | LABEL           | DEFAULT                 | DESCRIPTION              | REFER TO                                 |
|--------------------|------|-----------------|-------------------------|--------------------------|------------------------------------------|
| R157 (9Dh)<br>EQ24 | 15:0 | EQ_B5_PG [15:0] | 0100_0000_00<br>00_0000 | EQ Band 5 Coefficient PG | ReTune™ Mobile Parametric Equalizer (EQ) |

## Register 9Dh EQ24

| REGISTER ADDRESS         | BIT | LABEL                | DEFAULT | DESCRIPTION                                                                                                                           | REFER TO                     |
|--------------------------|-----|----------------------|---------|---------------------------------------------------------------------------------------------------------------------------------------|------------------------------|
| R198 (C6h)<br>ADC Test 0 | 2   | ADC_128_OSR_TST_MODE | 0       | ADC Bias Control (1)<br>Set this bit to 1 in ADC 64fs mode (ADC_OSR128 = 0).<br>Set this bit to 0 in ADC 128fs mode (ADC_OSR128 = 1). | ADC Oversampling Ratio (OSR) |
|                          | 0   | ADC_BIASX1P5         | 0       | ADC Bias Control (2)<br>Set this bit to 1 in ADC 64fs mode (ADC_OSR128 = 0).<br>Set this bit to 0 in ADC 128fs mode (ADC_OSR128 = 1). | ADC Oversampling Ratio (OSR) |

## Register C6h ADC Test 0

| REGISTER ADDRESS             | BIT | LABEL       | DEFAULT | DESCRIPTION                                                                                                                                                       | REFER TO                    |
|------------------------------|-----|-------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| R247 (F7h)<br>FLL NCO Test 0 | 0   | FLL_FRC_NCO | 0       | FLL Forced control select<br>0 = Normal<br>1 = FLL oscillator controlled by FLL_FRC_NCO_VAL<br>(Note that this field is required for free-running FLL modes only) | Frequency Locked Loop (FLL) |

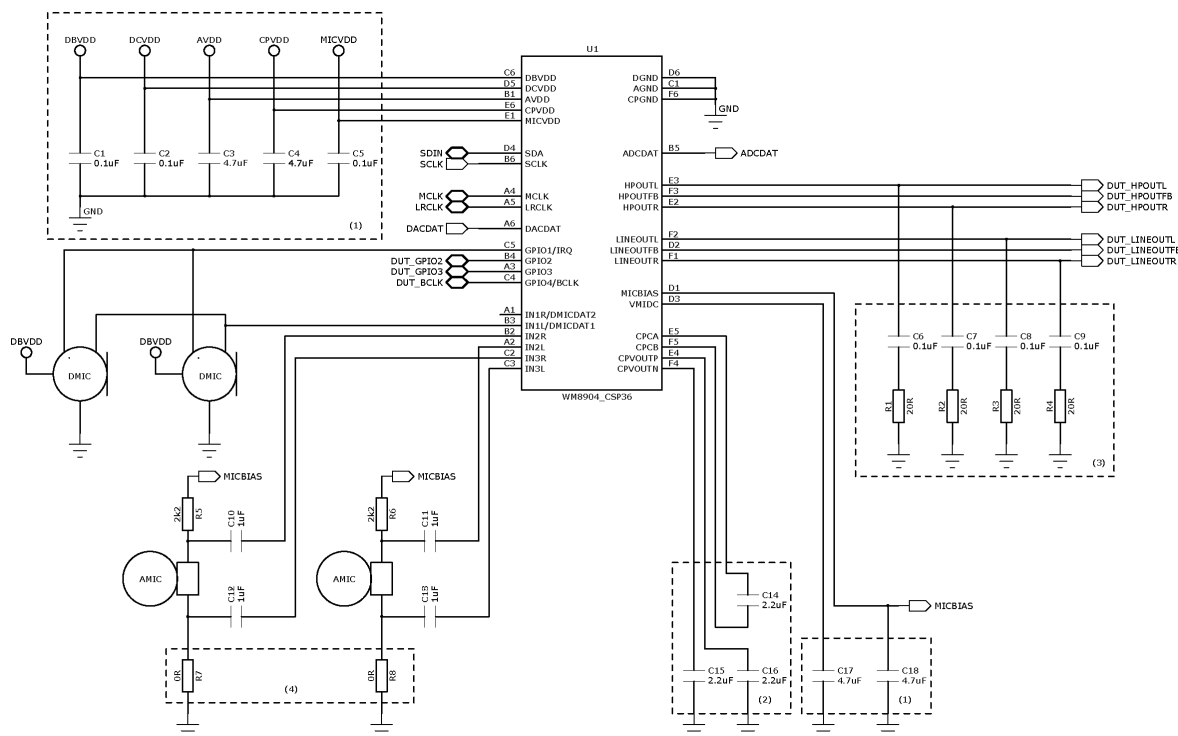
## Register F7h FLL NCO Test 0

| REGISTER ADDRESS             | BIT | LABEL                 | DEFAULT | DESCRIPTION                                                                                                                                                           | REFER TO                    |
|------------------------------|-----|-----------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| R248 (F8h)<br>FLL NCO Test 1 | 5:0 | FLL_FRC_NCO_VAL [5:0] | 01_1001 | FLL Forced oscillator value<br>Valid range is 000000 to 111111<br>0x19h (011001) = 12MHz approx<br>(Note that this field is required for free-running FLL modes only) | Frequency Locked Loop (FLL) |

## Register F8h FLL NCO Test 1

## APPLICATIONS INFORMATION

### RECOMMENDED EXTERNAL COMPONENTS



**Figure 71 Recommended External Components**

#### Notes:

##### 1. Decoupling Capacitors

X5R ceramic capacitor is recommended for capacitors C1, C2, C3, C4, C5, C15, C16, C17 and C18.

The positioning of C17 and C18 is very important - these should be as close to the WM8904 as possible.

Capacitors C15 and C16 should also be positioned as close to the WM8904 as possible.

##### 2. Charge Pump Capacitors

Specific recommendations for C14, C15 and C16 are provided in Table 95. Note that two different recommendations are provided for C15 and C16; either of these components is suitable, depending upon size requirements and availability.

The positioning of C14 is very important - this should be as close to the WM8904 as possible.

It is important to select a suitable capacitor type for the Charge Pump. Note that the capacitance may vary with DC voltage; care is required to ensure that required capacitance is achieved at the applicable operating voltage, as specified in Table 95. The capacitor datasheet should be consulted for this information.

| COMPONENT      | REQUIRED CAPACITANCE        | VALUE             | PART NUMBER               | VOLTAGE | TYPE | SIZE |
|----------------|-----------------------------|-------------------|---------------------------|---------|------|------|
| C14 (CPA-CPCB) | $\geq 1\mu\text{F}$ at 2VDC | 2.2 $\mu\text{F}$ | Kemet C0402C225M9PAC      | 6.3v    | X5R  | 0402 |
| C15 (CPVOUTN)  | $\geq 2\mu\text{F}$ at 2VDC | 2.2 $\mu\text{F}$ | MuRata GRM188R61A225KE34D | 10v     | X5R  | 0603 |
| C16 (CPVOUTP)  |                             | 4.7 $\mu\text{F}$ | MuRata GRM155R60J475M_EIA | 6.3v    | X5R  | 0402 |

**Table 95 Charge Pump Capacitors**

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**3. Zobel Networks**

The Zobel network shown in Figure 71 is required on HPOUTL, HPOUTR, LINEOUTL and LINEOUTR whenever that output is enabled. Stability of these ground-referenced outputs across all process corners cannot be guaranteed without the Zobel network components. (Note that, if any ground-referenced output pin is not required, the zobel network components can be omitted from the output pin, and the pin can be left floating.) The Zobel network requirement is detailed further in the applications note WAN\_0212 "Class W Headphone Impedance Compensation".

Zobel networks (C6, C7, C8, C9, R1, R2, R3, R4) should be positioned reasonably close to the WM8904.

**4. Microphone Grounding**

R7 and R8 can be populated with other values to remove common mode noise on the microphone if required.

## MIC DETECTION SEQUENCE USING MICBIAS CURRENT

This section details an example sequence which summarises how the host processor can configure and detect the events supported by the MICBIAS current detect function (see “Electret Condenser Microphone Interface”):

- Mic insertion/removal
- Hook switch press/release

Figure 72 shows an example of how the MICBIAS current flow varies versus time, during mic insertion and hook switch events. The Y axis is annotated with the Mic detection thresholds, and the X axis is annotated with the stages of an example sequence as detailed in Table 96, to illustrate how the host processor can implement mic insertion and hook switch detection.

The sequence assumes that the microphone insertion and hook switch detection functions are monitored by polling the interrupt flags using the control interface. Note that the maximum mechanical bounce times for mic insertion and removal must be fully understood by the software programmer.

A GPIO pin could be used as an alternative mechanism to monitor the MICBIAS detection functions. This enables the host processor to detect mechanical bounce at any time.

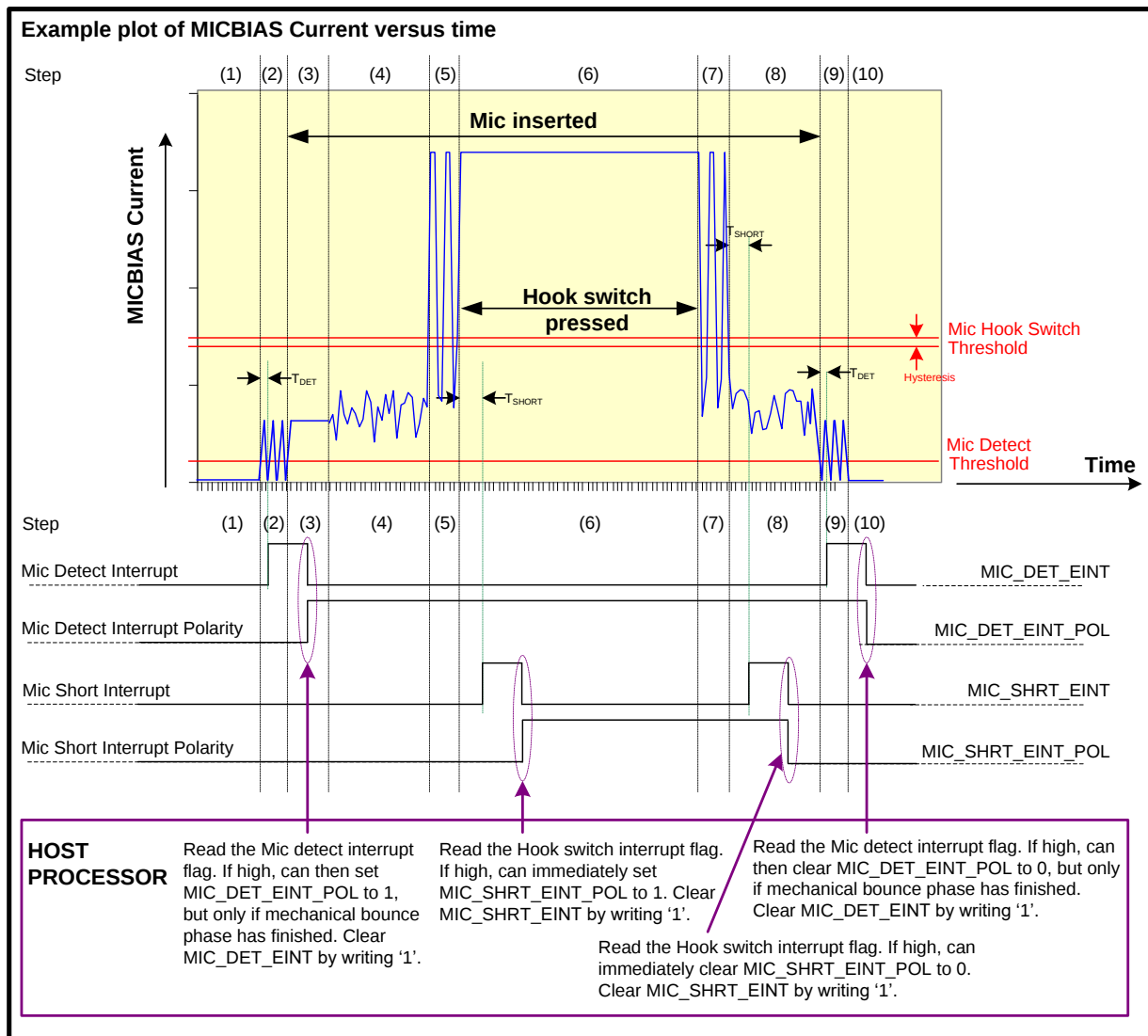


Figure 72 Mic Insert and Hook Switch Detect: Example MICBIAS Current Plot

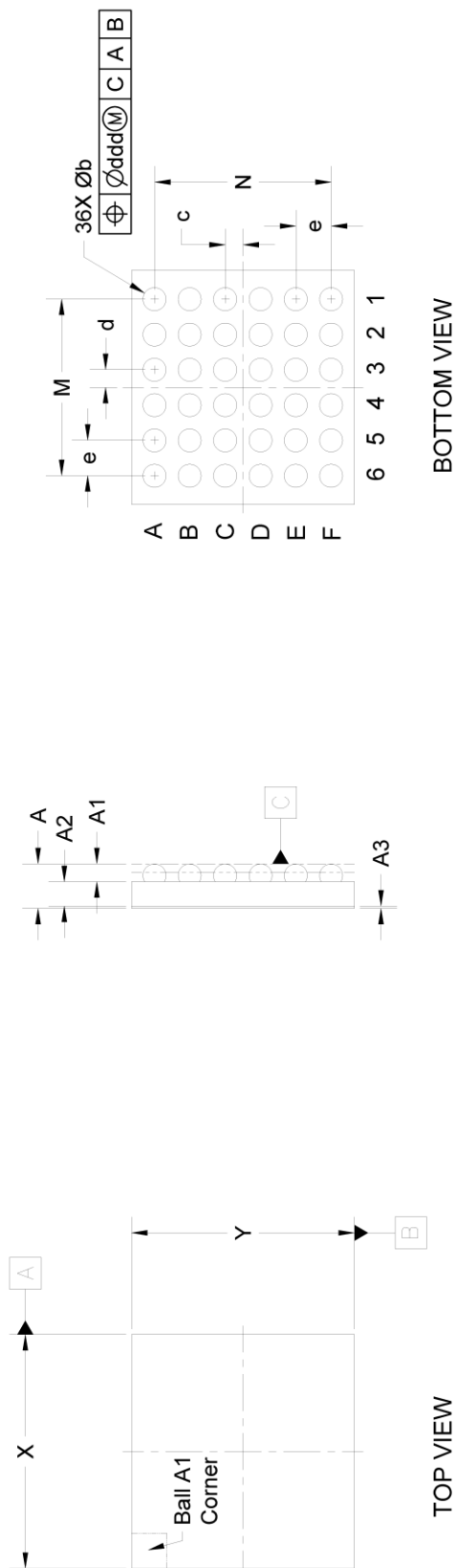
| STEP | DETAILS                                                                                                                                                                                                                                                                                                                                                                                     |
|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1    | Mic not inserted. To detect mic insertion, Host processor must initialise interrupts and clear MIC_DET_EINT_POL = 0. At every step, the host processor should poll the interrupt status register.<br>Note that Mic Insertion de-bounce circuitry can be enabled by setting MIC_DET_EINT_DB = 1.                                                                                             |
| 2    | Mechanical bounce of jack socket during Mic insertion. Host processor may already detect a mic insertion interrupt (MIC_DET_EINT) during this step. Once detected, the host processor can set MIC_DET_EINT_POL = 1 and then clear the interrupt, unless mechanical bounce can last longer than the shortest possible $T_{DET}$ , in which case the host processor should wait until step 3. |
| 3    | Mic fully inserted. If not already set, the host processor must now set MIC_DET_EINT_POL = 1. If not already cleared, the host processor must now clear the MIC_DET_EINT interrupt. To detect Hook switch press, the host processor must clear MIC_SHRT_EINT_POL = 0. At this step, the diagram shows no AC current swing, due to a very low ambient noise level.                           |
| 4    | Mic fully inserted. Diagram shows AC current swing due to high levels of background noise (such as wind).                                                                                                                                                                                                                                                                                   |
| 5    | Mechanical bounce during hook switch press. The hook switch interrupt is unlikely to be set during this step, because 10 successive samples of the MICBIAS current exceeding the hook switch threshold have not yet been sampled.<br>Note that Hook Switch de-bounce circuitry can be enabled by setting MIC_SHRT_EINT_DB = 1.                                                              |
| 6    | Hook switch is fully pressed down. After $T_{SHORT}$ , 10 successive samples of the MICBIAS current exceeding the hook switch threshold have been detected, hence a hook switch interrupt (MIC_SHRT_EINT) will be generated. Once detected, the host processor can immediately set MIC_SHRT_EINT_POL = 1 and then clear the MIC_SHRT_EINT interrupt.                                        |
| 7    | Mechanical bounce during hook switch release. The hook switch interrupt is unlikely to be set during this step, because 10 successive samples of the MICBIAS current lower than the hook switch threshold have not yet been sampled.                                                                                                                                                        |
| 8    | Hook switch fully released. After $T_{SHORT}$ , 10 successive samples of the MICBIAS current lower than the hook switch threshold have been detected, hence a hook switch interrupt (MIC_SHRT_EINT) will be generated. Once detected, the host processor can immediately clear MIC_SHRT_EINT_POL = 0 and then clear the MIC_SHRT_EINT interrupt.                                            |
| 9    | Mechanical bounce of jack socket during Mic removal. Host processor may already detect a mic removal interrupt (MIC_DET_EINT) during this step. Once detected, the host processor can clear MIC_DET_EINT_POL = 0 and then clear the interrupt, unless mechanical bounce can last longer than the shortest possible $T_{DET}$ , in which case the host processor should wait until step 10.  |
| 10   | Mic fully removed. If not already cleared, the host processor must now clear MIC_DET_EINT_POL = 0. If not already cleared, the host processor must now clear the MIC_DET_EINT interrupt.                                                                                                                                                                                                    |

**Table 96 Mic Insert and Hook Switch Detect: Example Sequence**

Alternatively, utilising a GPIO pin to monitor the MICBIAS current detect functionality permits the host processor to monitor the steady state of microphone detection or hook switch press functions. Because the GPIO shows the steady state condition, software de-bounce may be easier to implement in the host processor, dependant on the processor performance characteristics, hence use of the GPIO is likely to simplify the rejection of mechanical bounce. Changes of state in the GPIO pin are also subject to the time delays  $t_{DET}$  and  $t_{SHORT}$ .

## PACKAGE DIMENSIONS

The 36-ball W-CSP package drawing is shown below (POD 128.A):

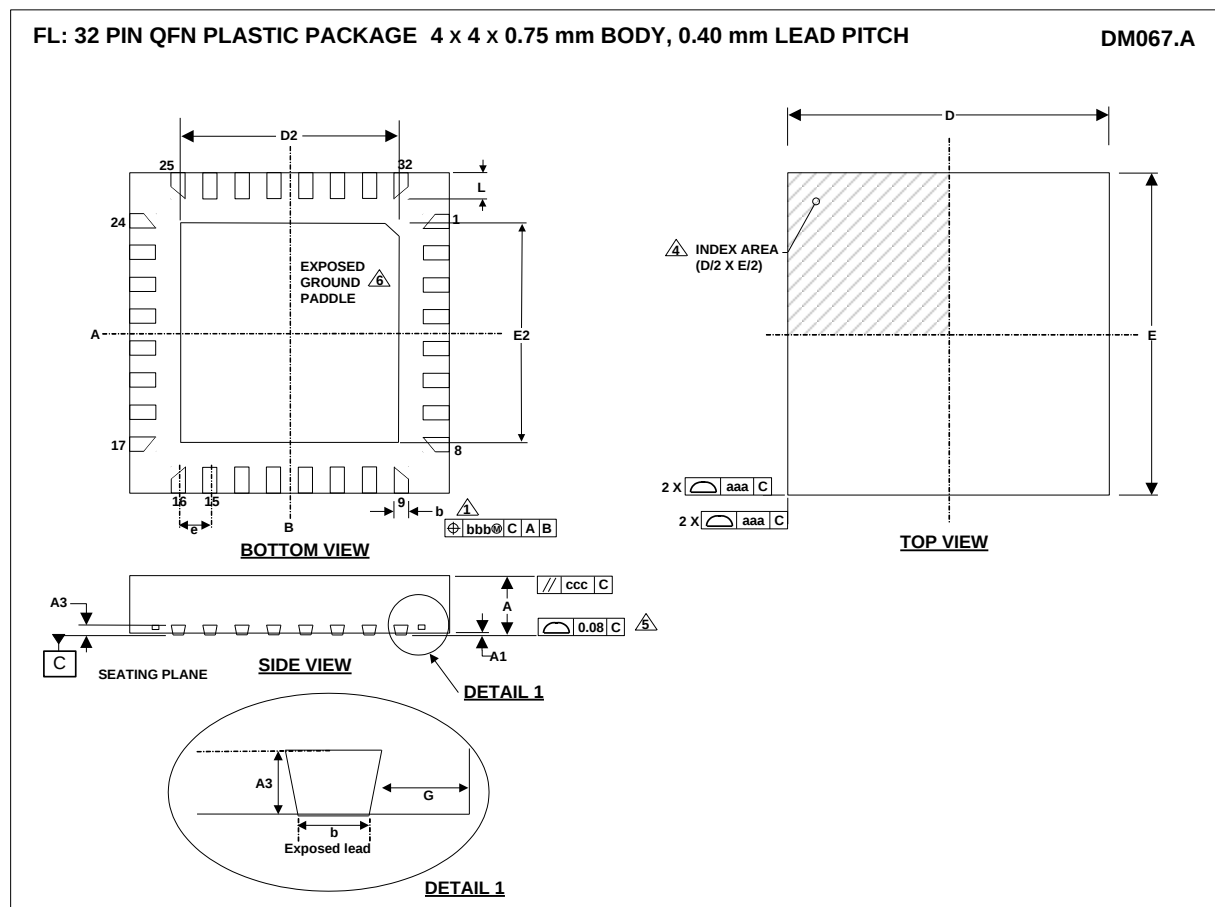


| Dimension | Millimeters |         |         |
|-----------|-------------|---------|---------|
|           | Minimum     | Nominal | Maximum |
| A         | 0.474       | 0.504   | 0.534   |
| A1        | 0.187       | 0.202   | 0.217   |
| A2        | 0.262       | 0.277   | 0.292   |
| A3        | REF         | 0.025   | REF     |
| b         | 0.232       | 0.262   | 0.292   |
| c         | 0.1925      | 0.2     | 0.2075  |
| d         | 0.1925      | 0.2     | 0.2075  |
| e         | BSC         | 0.4     | BSC     |
| M         | BSC         | 2       | BSC     |
| N         | BSC         | 2       | BSC     |
| X         | 2.626       | 2.651   | 2.676   |
| Y         | 2.5         | 2.525   | 2.55    |
| ddd=0.015 |             |         |         |

**Notes:** Controlling dimension is millimeters.

Dimensioning and tolerances per ASME Y 14.5-2009. The Ball A1 position indicator is for illustration purposes only. Dimension "b" applies to the solder sphere diameter and is measured at the maximum solder sphere diameter, parallel to primary Datum C. X/Y Tolerances can apply to an individual edge increasing or decreasing by 25µm.

The 32-pin QFN package drawing is shown below (DM 67.A):



| Symbols                                | Dimensions (mm) |           |      |      |
|----------------------------------------|-----------------|-----------|------|------|
|                                        | MIN             | NOM       | MAX  | NOTE |
| <b>A</b>                               | 0.70            | 0.75      | 0.8  |      |
| <b>A1</b>                              | 0               | 0.035     | 0.05 |      |
| <b>A3</b>                              |                 | 0.203 REF |      |      |
| <b>b</b>                               | 0.15            | 0.2       | 0.25 | 1    |
| <b>D</b>                               |                 | 4.00 BSC  |      |      |
| <b>D2</b>                              | 2.65            | 2.7       | 2.75 | 2    |
| <b>E</b>                               |                 | 4.00 BSC  |      |      |
| <b>E2</b>                              | 2.65            | 2.7       | 2.75 | 2    |
| <b>e</b>                               |                 | 0.40 BSC  |      |      |
| <b>G</b>                               |                 | 0.5       |      |      |
| <b>L</b>                               | 0.35            | 0.40      | 0.45 |      |
| <b>Tolerances of Form and Position</b> |                 |           |      |      |
| <b>aaa</b>                             |                 | 0.05      |      |      |
| <b>bbb</b>                             |                 | 0.10      |      |      |
| <b>ccc</b>                             |                 | 0.10      |      |      |
| <b>REF:</b>                            |                 |           |      |      |

**NOTES:**

1. DIMENSION **b** APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.15 mm AND 0.25 mm FROM TERMINAL TIP.
2. ALL DIMENSIONS ARE IN MILLIMETRES.
3. THE TERMINAL #1 IDENTIFIER AND TERMINAL NUMBERING CONVENTION SHALL CONFORM TO JEDEC 95-1 SPP-002.
4. COPLANARITY APPLIES TO THE EXPOSED HEAT SINK SLUG AS WELL AS THE TERMINALS.
5. REFER TO APPLICATION NOTE WAN\_0118 FOR FURTHER INFORMATION REGARDING PCB FOOTPRINTS AND QFN PACKAGE SOLDERING.
6. 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                                                                              | PAGE                | CHANGED BY |
|----------|-----|-----------------------------------------------------------------------------------------------------|---------------------|------------|
| 05/08/11 | 3.3 | Low Power Playback mode definition and characteristics added.<br>ISEL (bias control) register added | 22,23,81,<br>82,142 | PH         |
| 10/01/12 | 3.3 | Order codes updated to WM8904CGEFL/V and WM8904CGEFL/RV<br>to reflect change to copper wire bonding | 8                   | JMacD      |
| 24/08/12 | 3.3 | 36 Ball package diagram updated to DM066.C                                                          | 185                 | JMacD      |
| 27/08/12 | 3.3 | Headline DAC to headphone playback power consumption updated<br>to 3.0mW.                           | 1                   | ssaunders  |
| 03/09/12 | 3.3 | W-CSP reel quantity changed to 5,000                                                                | 8                   | JMacD      |
| 24/06/14 | 3.4 | W-CSP reel quantity changed to 3,500                                                                | 8                   | JMacD      |
| 11/11/16 | 3.5 | 36-ball package drawing updated to DM066.D                                                          | 181                 | PH         |
| 21/12/16 | 4.0 | Revision status updated                                                                             |                     | PH         |
| 04/07/18 | 4.1 | 36-ball WLCSP package drawing updated to POD 00128.A                                                | 181                 | PH         |