



AK4414

High Performance 120dB 32-Bit 4ch DAC

GENERAL DESCRIPTION

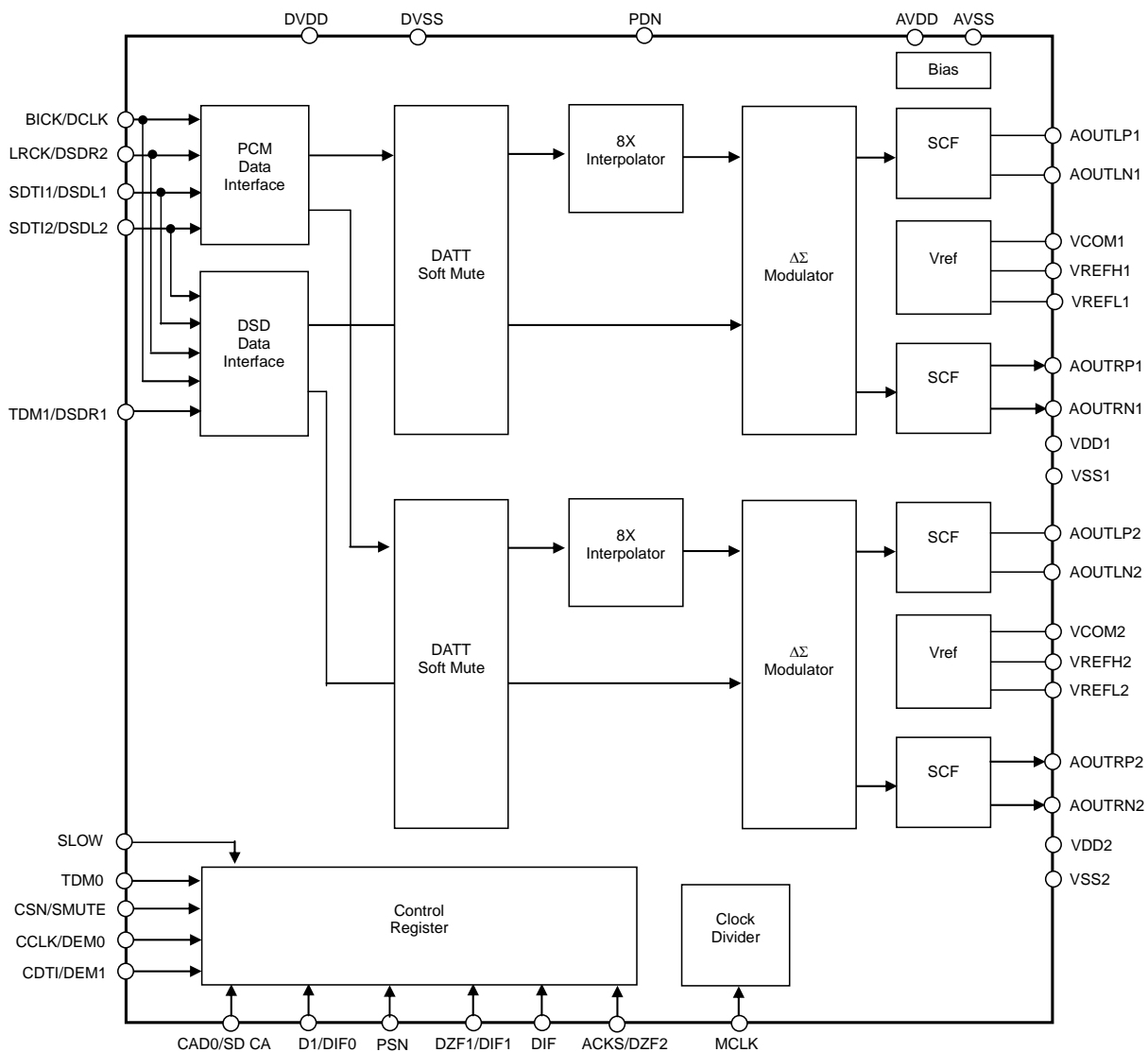
AK4414 is a 32-bit DAC, which corresponds to BD systems. An internal circuit includes newly developed 32bit Digital Filter for better sound quality achieving low distortion characteristics and wide dynamic range. The AK4414 has full differential SCF outputs, removing the need for AC coupling capacitors and increasing performance for systems with excessive clock jitter. The AK4414 accepts 216kHz PCM data and 1-bit DSD data, ideal for a wide range of applications including DVD-Audio and SACD.

FEATURES

- 128x Over sampling
- Sampling Rate: 30kHz ~ 216kHz
- 32Bit 8x Digital Filter
 - Ripple: ± 0.005 dB, Attenuation: 80dB
 - High Quality Sound Short Delay Option; GD=7/fs and GD=5.5/fs
 - Sharp Roll-Off Filter
 - Slow Roll-Off Filter
- High Tolerance to Clock Jitter
- Low Distortion Differential Output
- DSD data input
- Digital De-emphasis for 32, 44.1, 48kHz sampling
- Soft Mute
- Digital Attenuator (255 levels and 0.5dB step)
- Stereo Mode
- THD+N: -107dB
- DR, S/N: 120dB (Stereo mode: 123dB)
- I/F Format: 24/32bit MSB justified, 16/20/24/32bit LSB justified, I²S, DSD, TDM
- Master Clock:
 - 30kHz ~ 32kHz: 1152fs
 - 30kHz ~ 54kHz: 512fs or 768fs
 - 30kHz ~ 108kHz: 256fs or 384fs
 - 108kHz ~ 216kHz: 128fs or 192fs
- Power Supply: DVDD=AVDD=2.7 ~ 3.6V, VDD1/2=4.75 ~ 5.25V
- Digital Input Level: CMOS
- Package: 44pin LQFP



■ Block Diagram

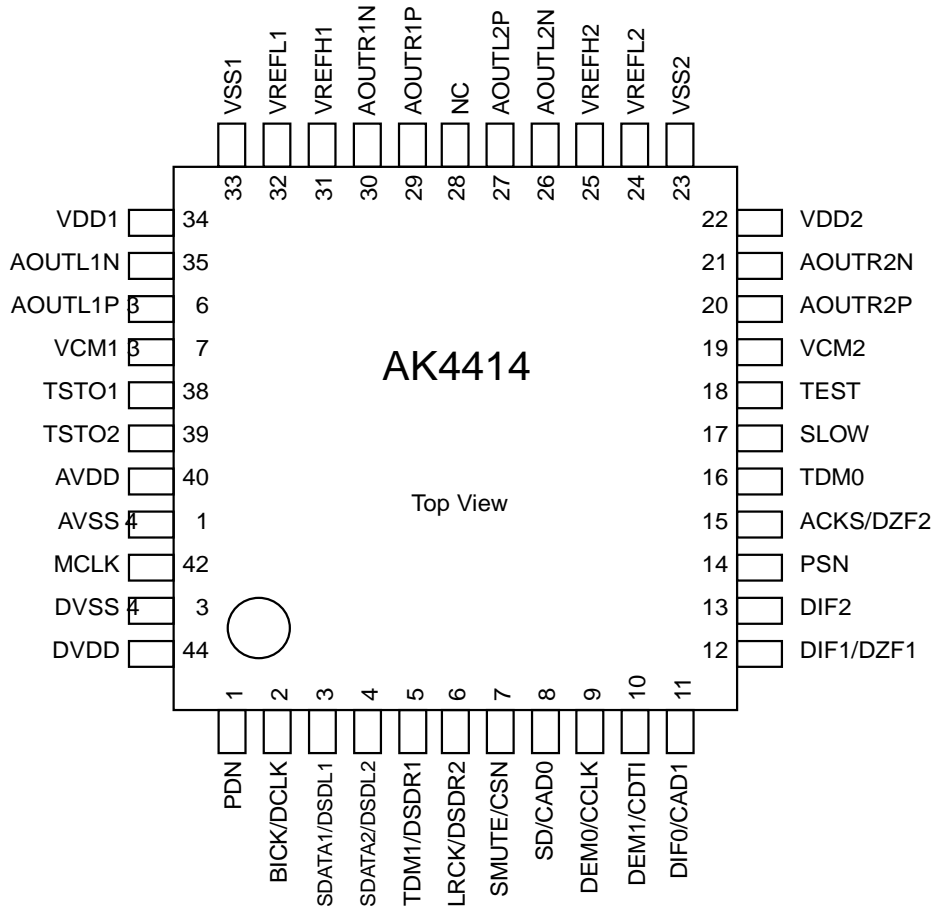


Block Diagram

■ Ordering Guide

AK4414EQ -10 ~ +70°C 44 pin LQFP (0.8mm pitch)
 AKD4414 Ev Evaluation Board for AK4414

■ Pin Layout



| PIN/FUNCTION | | | |
|--------------|-----------------|-----|--|
| No. | Pin Name | I/O | Function |
| 1 | PDN | I | Power-Down Mode When at "L", the AK4414 is in power-down mode and is held in reset. The AK4414 should always be reset upon power-up. |
| 2 | BICK DCLK | I | Audio Serial Data Clock in PCM Mode DSD Clock Pin in DSD mode |
| 3 | SDATA1 DSDL1 | I | Audio Serial Data Input in PCM Mode Audio Serial Data Input in DSD Mode |
| 4 | SDATA2 DSDL2 | I | Audio Serial Data Input in PCM Mode Audio Serial Data Input in DSD Mode |
| 5 | TDM1 DSDR1 | I | TDM I/F Format Mode in PCM Mode Audio Serial Data Input in DSD Mode |
| 6 | LRCK DSDR2 | I | L/R Clock in PCM Mode Audio Serial Data Input in DSD Mode |
| 7 | SMUTE CSN | I | Soft Mute in Parallel Control Mode When this pin goes to "H", soft mute cycle is initiated. When returning to "L", the output mute releases. Chip Select in Serial Control Mode |
| 8 | SD CAD0 | I | Digital Filter setting pin in Parallel Control mode Chip Address 0 in Serial Control Mode (Internal pull-down pin) |
| 9 | DEM0 CCLK | I | De-emphasis Enable 0 in Parallel Control Mode Control Data Clock in Serial Control Mode |
| 10 | DEM1 CDTI | I | De-emphasis Enable 1 in Parallel Control Mode Control Data Input in Serial Control Mode |
| 11 | DIF0 CAD1 | I | Digital Input Format 0 in PCM Mode Chip Address 1 in Serial Control Mode |
| 12 | DIF1 DZF1 | I | Digital Input Format 1 in PCM Mode Zero Input Detect in Serial Control Mode |
| 13 | DIF2 | I | Digital Input Format 2 in PCM Mode |
| 14 | PSN | I | Parallel/Serial Select (Internal pull-up pin) "L": Serial Control Mode, "H": Parallel Control Mode |
| 15 | ACKS I DZF2 | O | Auto Clock Setting Mode in Parallel Control mode "L": Manual Setting Mode, "H": Auto Setting Mode Zero Input Detect in Serial Control Mode |
| 16 | TDM0 | I | TDM I/F Format Mode in Parallel Control mode |
| 17 | SLOW | I | Digital filter setting pin |
| 18 | TEST | - | No internal bonding. Connect to DVSS. |
| 19 | VC M2 | - | Common Voltage 2 Normally connected to VSS with a 10uF electrolytic cap. |
| 20 | AOUTR2P | O | Right Channel Positive Analog Output 2 |
| 21 | AOUTR2N | O | Right Channel Negative Analog Output 2 |
| 22 | VDD2 | - | Analog Power Supply, 4.75 to 5.25V |
| 23 | VSS2 | - | Ground (connected to DVSS, AVSS, VSS1 ground) |
| 24 | VREFL2 | I | Low Level Voltage Reference Input 2 |
| 25 | VREFH2 | I | High Level Voltage Reference Input 2 |
| 26 | AOUTL2N | O | Left Channel Negative Analog Output 2 |
| 27 | AOUTL2P | O | Left Channel Positive Analog Output 2 |
| 28 | NC | - | No internal bonding. Connect to GND. |

| No. | Pin Name | I/O | Function |
|-----|----------|-----|---|
| 29 | AOUTR1P | O | Right Channel Positive Analog Output 1 |
| 30 | AOUTR1N | O | Right Channel Negative Analog Output 1 |
| 31 | VREFH1 | I | High Level Voltage Reference Input 1 |
| 32 | VREFL1 | I | Low Level Voltage Reference Input 1 |
| 33 | VSS1 | - | Connected to DVSS, AVSS, VSS2 Ground |
| 34 | VD D1 | - | Analog Power Supply Pin, 4.75 ~ 5.25V |
| 35 | AOUTL1N | O | Left Channel Negative Analog Output 1 |
| 36 | AOUTL1P | O | Left Channel Positive Analog Output 1 |
| 37 | VC M1 | - | Common Voltage 1 Normally connected to VSS with a 10uF electrolytic cap. |
| 38 | TSTO 1 | I | Test Output pin. "Hi-Z" at Normal Operation. Connect to AVSS. |
| 39 | TSTO 2 | I | Test Output pin. "Hi-Z" at Normal Operation. Connect to AVSS. |
| 40 | AVDD | - | Analog Power Supply, 2.7 to 3.6V |
| 41 | AVSS | - | Analog Ground Pin |
| 42 | MCLK | I | Master Clock Input |
| 43 | DVSS | - | Digital Ground Pin |
| 44 | DV DD | - | Digital Power Supply, 3.0 ~ 3.6V |

Note: All input pins except internal pull-up/down pins should not be left floating.

■ Handling of Unused Pin

The unused I/O pins should be processed appropriately as below.

(1) Parallel Mode (PCM Mode only)

| Classification | Pin Name | Setting |
|----------------|------------------|------------------------------------|
| Analog | AOUTL1P, AOUTL1N | These pins must be open. |
| | AOUTR1P, AOUTR1N | These pins must be open. |
| | AOUTL2P, AOUTL2N | These pins must be open. |
| | AOUTR2P, AOUTR2N | These pins must be open. |
| Analog | TSTO1, TSTO2 | This pin must be connected to AVSS |
| Digital | TEST | This pin must be connected to DVSS |

(2) Serial Mode

1. PCM Mode

| Classification | Pin Name | Setting |
|----------------|-----------------------------|------------------------------------|
| Analog | AOUTL1P, AOUTL1N | These pins must be open. |
| | AOUTR1P, AOUTR1N | These pins must be open. |
| | AOUTL2P, AOUTL2N | These pins must be open. |
| | AOUTR2P, AOUTR2N | These pins must be open. |
| Analog | TSTO1, TSTO2 | This pin must be connected to AVSS |
| Digital | DIF2, PSN, TDM0, SLOW, TEST | This pin must be connected to DVSS |
| | DZF1, DZF2 | These pins must be open. |

2. DSD Mode

| Classification | Pin name | Setting |
|----------------|-----------------------------|------------------------------------|
| Analog | AOUTL1P, AOUTL1N | These pins must be open. |
| | AOUTR1P, AOUTR1N | These pins must be open. |
| | AOUTL2P, AOUTL2N | These pins must be open. |
| | AOUTR2P, AOUTR2N | These pins must be open. |
| Analog | TSTO1, TSTO2 | This pin must be connected to AVSS |
| Digital | DIF2, PSN, TDM0, SLOW, TEST | This pin must be connected to DVSS |
| | DZF1, DZF2 | These pins must be open. |

| |
|---------------------------------|
| ABSOLUTE MAXIMUM RATINGS |
|---------------------------------|

(VSS1-2=AVSS =DVSS =0V; Note 1)

| Parameter | Symbol | min | max | Unit | |
|--|-------------|--------|----------|------|---|
| Power Supplies: | Analog | AVDD | -0.3 | 4.6 | V |
| | Analog | VDD1/2 | -0.3 | 6.0 | V |
| | Digital | DVDD | -0.3 | 4.6 | V |
| | AVSS – DVSS | ΔGND | - | 0.3 | V |
| Input Current, Any Pin Except Supplies | IIN | - | ±10 | mA | |
| Digital Input Voltage | VIND | -0.3 | DVDD+0.3 | V | |
| Ambient Temperature (Power applied) | Ta | -10 | 70 | °C | |
| Storage Temperature | Tstg | -65 | 150 | °C | |

Note 1. All voltages with respect to ground.

Note 2. AVSS, VSS1/2, DVSS must be connected to the same analog ground plane.

WARNING: Operation at or beyond these limits may result in permanent damage to the device.
Normal operation is not guaranteed at these extremes.

| |
|---|
| RECOMMENDED OPERATING CONDITIONS |
|---|

(VSS1-2=AVSS =DVSS =; Note 1)

| Parameter Sym | | bol | min | typ | max | Unit |
|----------------------------------|-----------------------|--------|----------|------|------|------|
| Power Supplies (Note 3) | Analog | AVDD | 2.7 | 3.0 | 3.6 | V |
| | Analog | VDD1/2 | 4.75 | 5.0 | 5.25 | V |
| | Digital | DVDD | 2.7 | 3.0 | 3.6 | V |
| Voltage Reference (Note 4) | “H” voltage reference | VREFH1 | VDD1-0.5 | - | VDD1 | V |
| | “H” voltage reference | VREFH2 | VDD2-0.5 | - | VDD2 | V |
| | “L” voltage reference | VREFL1 | - | AVSS | - | V |
| | “L” voltage reference | VREFL2 | - | AVSS | - | V |

Note 1. All voltages with respect to ground.

Note 3. The power up sequence between AVDD, VDD1/2 and DVDD is not critical.

Note 4. The analog output voltage scales with the voltage of (VREFH1/2 – VREFL1/2).

Connect a resistor of 20ohm or less and a capacitor of 100uF or more to the VREFH1/2 pin. (Figure 24)

 $AOUT (typ.@0dB) = (AOUT+) - (AOUT-) = \pm 2.8V_{pp} \times (VREFH1/2 - VREFL1/2)/5.$

* AKM assumes no responsibility for the usage beyond the conditions in this data sheet.

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|-------------------------------|
| ANALOG CHARACTERISTICS |
|-------------------------------|

(Ta=25°C; AVDD=DVDD=3.0V, VDD1/2=5.0V; AVSS=VSS1/2=DVSS=0V; VREFH1/2=VDD1/2, VREFL1/2=AVSS; Input data = 24bit; R_L ≥ 1kΩ; BICK=64fs; Signal Frequency = 1kHz; Sampling Frequency = 44.1kHz; Measurement bandwidth = 20Hz ~ 20kHz; External Circuit: [Figure 27](#); unless otherwise specified.)

| Parameter | min | | typ | max | Unit | |
|---|----------------------------|-------------|-----------|------|---------|--------|
| Resolution | - | | - | 24 | Bits | |
| Dynamic Characteristics (Note 5) | | | | | | |
| THD+N | fs=44.1kHz | 0dBFS | - | -107 | -98 | dB |
| | BW=20kHz | -60dBFS | - | -57 | - | dB |
| | fs=96kHz | 0dBFS | - | -104 | - | dB |
| | BW=40kHz | -60dBFS | - | -54 | - | dB |
| | fs=192kHz | 0dBFS | | -104 | - | dB |
| | BW=40kHz | -60dBFS | | -54 | - | dB |
| | BW=80kHz | -60dBFS | | -51 | - | dB |
| Dynamic Range (-60dBFS with A-weighted) | | (Note 6) 11 | 3 | 120 | | dB |
| S/N (A-weighted) | | (Note 7) 11 | 3 | 120 | | dB |
| Interchannel Isolation (1kHz) | | | 100 | 110 | | dB |
| DC Accuracy | | | | | | |
| Interchannel Gain Mismatch | | | - | 0 | 0.3 | dB |
| Gain Drift | | (Note 8) | - 20 - | | | ppm/°C |
| Output Voltage | | (Note 9) | ±2.65 | ±2.8 | ±2.95 V | pp |
| Load Capacitance | | | - | - | 10 | pF |
| Load Resistance | | (Note 10) | 1 - | | - | kΩ |
| Power Supplies | | | | | | |
| Power Supply Current | | | | | | |
| Normal operation (PDN pin = "H") | VDD1+VDD2 | | - | 41 | 60 | mA |
| | AVDD | | - | 1 | 1.5 | mA |
| | DVDD (fs ≤ 44.1kHz) | | - | 7 | 11 | mA |
| | DVDD (fs=96kHz) | | - | 12 | 18 | mA |
| | DVDD (fs = 192kHz) | | - | 18 | 27 | mA |
| | Power down (PDN pin = "L") | | (Note 11) | | | |
| AVDD+VDD1/2+DVDD | | | - | 10 | 100 | μA |

Note 5. Measured by Audio Precision, System Two. Averaging mode. Refer to the evaluation board manual.

Note 6. [Figure 27](#) External LPF Circuit Example 2. 100dB for 16-bit data.

Note 7. [Figure 27](#) External LPF Circuit Example 2. S/N does not depend on input data size.

Note 8. The voltage on (VREFH1/2 – VREFL1/2) is held +5V externally.

Note 9. Full scale voltage (0dB). Output voltage scales with the voltage of (VREFH1/2 – VREFL1/2).

$$AOUT (typ.@0dB) = (AOUT+) - (AOUT-) = \pm 2.8V_{pp} \times (VREFH1/2 - VREFL1/2)/5.$$

Note 10. Regarding Load Resistance, AC load is 1kΩ (min) with a DC cut capacitor ([Figure 27](#)). DC load is 1.5 kΩ (min) without a DC cut capacitor ([Figure 26](#)). The load resistance value is with respect to ground. Analog characteristics are sensitive to capacitive load that is connected to the output pin. Therefore the capacitive load must be minimized.

Note 11. In the power down mode. The PSN pin = DVDD, and all other digital input pins including clock pins (MCLK, BICK and LRCK) are held DVSS.

SHARP ROLL-OFF FILTER CHARACTERISTICS (fs = 44.1kHz)

(Ta=25°C; VDD1/2=4.75 ~ 5.25V, AVDD=DVDD=2.7 ~ 3.6V; Normal Speed Mode; DEM=OFF; SLOW bit = "0", SD bit="0")

| Parameter | Symbol | min | typ | max | Unit | |
|---------------------------------|-------------------|---------|-----|--------|------|-----|
| Digital Filter | | | | | | |
| Passband (Note 12) | ±0.01dB -6.0dB | PB | 0 | - | 20.0 | kHz |
| | | | - | 22.05 | - | kHz |
| Stopband (Note 12) | SB | 24.1 | - | - | kHz | |
| Passband Ripple | PR | -0.0032 | - | 0.0032 | dB | |
| Stopband Attenuation | SA | 80 | - | - | dB | |
| Group Delay (Note 13) | GD | - | 29 | - | 1/fs | |
| Digital Filter + SCF | | | | | | |
| Frequency Response: 0 ~ 20.0kHz | | -0.2 | - | 0.2 | dB | |

SHARP ROLL-OFF FILTER CHARACTERISTICS (fs = 96kHz)

(Ta=25°C; VDD1/2=4.75 ~ 5.25V, AVDD=DVDD=2.7 ~ 3.6V; Double Speed Mode; DEM=OFF; SLOW bit = "0", SD bit="0")

| Parameter | Symbol | min | typ | max | Unit | |
|---------------------------------|-------------------|---------|-----|--------|------|-----|
| Digital Filter | | | | | | |
| Passband (Note 12) | ±0.01dB -6.0dB | PB | 0 | - | 43.5 | kHz |
| | | | - | 48.0 | - | kHz |
| Stopband (Note 12) | SB | 52.5 | - | - | kHz | |
| Passband Ripple | PR | -0.0032 | - | 0.0032 | dB | |
| Stopband Attenuation | SA | 80 | - | - | dB | |
| Group Delay (Note 13) | GD | - | 29 | - | 1/fs | |
| Digital Filter + SCF | | | | | | |
| Frequency Response: 0 ~ 40.0kHz | | -0.3 | - | 0.3 | dB | |

SHARP ROLL-OFF FILTER CHARACTERISTICS (fs = 192kHz)

(Ta=25°C; VDD1/2=4.75 ~ 5.25V, AVDD=DVDD=2.7 ~ 3.6V; Quad Speed Mode; DEM=OFF; SLOW bit = "0", SD bit="0")

| Parameter Sym | bol | min | typ | max | Unit | |
|---------------------------------|-------------------|---------|-----|--------|------|-----|
| Digital Filter | | | | | | |
| Passband (Note 12) | ±0.01dB -6.0dB | PB | 0 | - | 87.0 | kHz |
| | | | - | 96.0 | - | kHz |
| Stopband (Note 12) | SB | 105 | - | - | kHz | |
| Passband Ripple | PR | -0.0032 | - | 0.0032 | dB | |
| Stopband Attenuation | SA | 80 | - | - | dB | |
| Group Delay (Note 13) | GD | - | 29 | - | 1/fs | |
| Digital Filter + SCF | | | | | | |
| Frequency Response: 0 ~ 80.0kHz | | -1 | - | 0.1 | dB | |

Note 12. The passband and stopband frequencies scale with fs. For example, PB=0.4535×fs, SB=0.546×fs.

Note 13. The calculating delay time which occurred by digital filtering. This time is from setting the 16/20/24/32bit data of both channels to input register to the output of analog signal.

SLOW ROLL-OFF FILTER CHARACTERISTICS (fs = 44.1kHz)

(Ta=25°C; VDD1/2=4.75 ~ 5.25V, AVDD=DVDD=2.7 ~ 3.6V; Normal Speed Mode; DEM=OFF; SLOW bit="1", SD bit = "0")

| Parameter | Symbol | min | typ | max | Unit | |
|---------------------------------|-------------------|--------|-----|-------|------|-----|
| Digital Filter | | | | | | |
| Passband (Note 14) | ±0.04dB -3.0dB | PB | 0 | - | 8.1 | kHz |
| | | | - | 18.2 | - | kHz |
| Stopband (Note 14) | SB | 39.2 | - | - | kHz | |
| Passband Ripple | PR | -0.043 | - | 0.043 | dB | |
| Stopband Attenuation | SA | 73 | - | - | dB | |
| Group Delay (Note 13) | GD | - | 6 | - | 1/fs | |
| Digital Filter + SCF | | | | | | |
| Frequency Response: 0 ~ 20.0kHz | | -5 | - | 0.1 | dB | |

SLOW ROLL-OFF FILTER CHARACTERISTICS (fs = 96kHz)

(Ta=25°C; VDD1/2=4.75 ~ 5.25V, AVDD=DVDD=2.7 ~ 3.6V; Double Speed Mode DEM=OFF; SLOW bit="1", SD bit = "0")

| Parameter | Symbol | min | typ | max | Unit | |
|---------------------------------|-------------------|--------|-----|-------|------|-----|
| Digital Filter | | | | | | |
| Passband (Note 14) | ±0.04dB -3.0dB | PB | 0 | - | 17.7 | kHz |
| | | | - | 39.6 | - | kHz |
| Stopband (Note 14) | SB | 85.3 | - | - | kHz | |
| Passband Ripple | PR | -0.043 | - | 0.043 | dB | |
| Stopband Attenuation | SA | 73 | - | - | dB | |
| Group Delay (Note 13) | GD | - | 6 | - | 1/fs | |
| Digital Filter + SCF | | | | | | |
| Frequency Response: 0 ~ 40.0kHz | | -4 | - | 0.1 | dB | |

SLOW ROLL-OFF FILTER CHARACTERISTICS (fs = 192kHz)

(Ta=25°C; VDD1/2=4.75 ~ 5.25V, AVDD=DVDD=2.7 ~ 3.6V; Quad Speed Mode; DEM=OFF; SLOW bit="1", SD bit = "0")

| Parameter Sym | bol | min | typ | max | Unit | |
|---------------------------------|-------------------|--------|-----|-------|------|-----|
| Digital Filter | | | | | | |
| Passband (Note 14) | ±0.04dB -3.0dB | PB | 0 | - | 35.5 | kHz |
| | | | - | 79.1 | - | kHz |
| Stopband (Note 14) | SB | 171 | - | - | kHz | |
| Passband Ripple | PR | -0.043 | - | 0.043 | dB | |
| Stopband Attenuation | SA | 73 | - | - | dB | |
| Group Delay (Note 13) | GD | - | 6 | - | 1/fs | |
| Digital Filter + SCF | | | | | | |
| Frequency Response: 0 ~ 80.0kHz | | -5 | - | 0.1 | dB | |

Note 14. The passband and stopband frequencies scale with fs. For example, PB=0.185×fs, SB=0.888×fs.

SHORT DELAY SHARP ROLL-OFF FILTER CHARACTERISTICS (fs = 44.1kHz)

(Ta=25°C; VDD1/2=4.75 ~ 5.25V, AVDD=DVDD=2.7 ~ 3.6V; Normal Speed Mode; DEM=OFF; SLOW bit = "0", SD bit="1")

| Parameter | Symbol | min | typ | max | Unit | |
|----------------------------------|-------------------|---------|-----|--------|------|-----|
| Digital Filter | | | | | | |
| Passband (Note 12) | ±0.01dB -6.0dB | PB | 0 | - | 20.0 | kHz |
| | | | - | 22.05 | - | kHz |
| Stopband (Note 12) | SB | 24.1 | - | - | kHz | |
| Passband Ripple | PR | -0.0031 | - | 0.0031 | dB | |
| Stopband Attenuation | SA | 80 | - | - | dB | |
| Group Delay (Note 13) | GD | - | 7 | - | 1/fs | |
| Digital Filter + SCF | | | | | | |
| Frequency Response : 0 ~ 20.0kHz | | -0.2 | - | 0.2 | dB | |

SHORT DELAY SHARP ROLL-OFF FILTER CHARACTERISTICS (fs = 96kHz)

(Ta=25°C; VDD1/2=4.75 ~ 5.25V, AVDD=DVDD=2.7 ~ 3.6V; Double Speed Mode; DEM=OFF; SLOW bit = "0", SD bit="1")

| Parameter | Symbol | min | typ | max | Unit | |
|----------------------------------|-------------------|---------|-----|--------|------|-----|
| Digital Filter | | | | | | |
| Passband (Note 12) | ±0.01dB -6.0dB | PB | 0 | - | 43.5 | kHz |
| | | | - | 48.0 | - | kHz |
| Stopband (Note 12) | SB | 52.5 | - | - | kHz | |
| Passband Ripple | PR | -0.0031 | - | 0.0031 | dB | |
| Stopband Attenuation | SA | 80 | - | - | dB | |
| Group Delay (Note 13) | GD | - | 7 | - | 1/fs | |
| Digital Filter + SCF | | | | | | |
| Frequency Response : 0 ~ 40.0kHz | | -0.3 | - | 0.3 | dB | |

SHORT DELAY SHARP ROLL-OFF FILTER CHARACTERISTICS (fs = 192kHz)

(Ta=25°C; VDD1/2=4.75 ~ 5.25V, AVDD=DVDD=2.7 ~ 3.6V; Quad Speed Mode; DEM=OFF; SLOW bit = "0", SD bit="1")

| Parameter Sym | bol | min | typ | max | Unit | |
|----------------------------------|-------------------|---------|-----|--------|------|-----|
| Digital Filter | | | | | | |
| Passband (Note 12) | ±0.01dB -6.0dB | PB | 0 | - | 87.0 | kHz |
| | | | - | 96.0 | - | kHz |
| Stopband (Note 12) | SB | 105 | - | - | kHz | |
| Passband Ripple | PR | -0.0031 | - | 0.0031 | dB | |
| Stopband Attenuation | SA | 80 | - | - | dB | |
| Group Delay (Note 13) | GD | - | 7 | - | 1/fs | |
| Digital Filter + SCF | | | | | | |
| Frequency Response : 0 ~ 80.0kHz | | -1 | - | 0.1 | dB | |

SHORT DELAY SLOW ROLL-OFF FILTER CHARACTERISTICS (fs = 44.1kHz)

(Ta=25°C; VDD1/2=4.75 ~ 5.25V, AVDD=DVDD=2.7 ~ 3.6V; Normal Speed Mode; DEM=OFF; SLOW bit = "1", SD bit="1")

| Parameter | Symbol | min | typ | max | Unit | |
|----------------------------------|-------------------|-------|-----|------|------|-----|
| Digital Filter | | | | | | |
| Passband (Note 12) | ±0.01dB -6.0dB | PB | 0 | - | 11.1 | kHz |
| | | | - | 22.3 | - | kHz |
| Stopband (Note 12) | SB | 38.1 | - | - | kHz | |
| Passband Ripple | PR | -0.05 | - | 0.05 | dB | |
| Stopband Attenuation | SA | 82 | - | - | dB | |
| Group Delay (Note 13) | GD | - 5. | 5 - | | 1/fs | |
| Digital Filter + SCF | | | | | | |
| Frequency Response : 0 ~ 20.0kHz | | -5 | - | 0.1 | dB | |

SHORT DELAY SLOW ROLL-OFF FILTER CHARACTERISTICS (fs = 96kHz)

(Ta=25°C; VDD1/2=4.75 ~ 5.25V, AVDD=DVDD=2.7 ~ 3.6V; Double Speed Mode; DEM=OFF; SLOW bit = "1", SD bit="1")

| Parameter | Symbol | min | typ | max | Unit | |
|----------------------------------|-------------------|-------|-----|------|------|-----|
| Digital Filter | | | | | | |
| Passband (Note 12) | ±0.01dB -6.0dB | PB | 0 | - | 24.2 | kHz |
| | | | - | 44.6 | - | kHz |
| Stopband (Note 12) | SB | 83.0 | - | - | kHz | |
| Passband Ripple | PR | -0.05 | - | 0.05 | dB | |
| Stopband Attenuation | SA | 82 | - | - | dB | |
| Group Delay (Note 13) | GD | - 5. | 5 - | | 1/fs | |
| Digital Filter + SCF | | | | | | |
| Frequency Response : 0 ~ 40.0kHz | | -5 | - | 0.1 | dB | |

SHORT DELAY SLOW ROLL-OFF FILTER CHARACTERISTICS (fs = 192kHz)

(Ta=25°C; VDD1/2=4.75 ~ 5.25V, AVDD=DVDD=2.7 ~ 3.6V; Quad Speed Mode; DEM=OFF; SLOW bit = "1", SD bit="1")

| Parameter Sym | bol | min | typ | max | Unit | |
|----------------------------------|-------------------|-------|-----|------|------|-----|
| Digital Filter | | | | | | |
| Passband (Note 12) | ±0.01dB -6.0dB | PB | 0 | - | 48.4 | kHz |
| | | | - | 89.2 | - | kHz |
| Stopband (Note 12) | SB | 165.9 | - | - | kHz | |
| Passband Ripple | PR | -0.05 | - | 0.05 | dB | |
| Stopband Attenuation | SA | 82 | - | - | dB | |
| Group Delay (Note 13) | GD | - 5. | 5 - | | 1/fs | |
| Digital Filter + SCF | | | | | | |
| Frequency Response : 0 ~ 80.0kHz | | -5 | - | 0.1 | dB | |

| |
|---------------------------|
| DC CHARACTERISTICS |
|---------------------------|

(Ta=25°C; VDD1/2=4.75 ~ 5.25V, AVDD=DVDD=2.7 ~ 3.6V)

| Parameter | Symbol | min | typ | max | Unit |
|---|--------|----------|-----|---------|------|
| High-Level Input Voltage | VIH | 70%DVDD | - | - | V |
| Low-Level Input Voltage | VIL | - | - | 30%DVDD | V |
| High-Level Output Voltage (Iout=-100μA) | VOH | DVDD-0.5 | - | - | V |
| Low-Level Output Voltage (Iout=100μA) | VOL | - | - | 0.5 | V |
| Input Leakage Current (Note 15) | Iin - | | - | ±10 | μA |

Note 15. The PSN pin has an internal pull-up device nominally 100kΩ. Therefore the PSN pin is not included.

SWITCHING CHARACTERISTICS

(Ta=25°C; VDD1/2=4.75 ~ 5.25V, AVDD=DVDD=2.7 ~ 3.6V)

| Parameter Sym | bol | min | typ | max | Unit |
|---|-------|----------|-----|--------|------|
| Master Clock Timing | | | | | |
| Frequency | fCLK | 2.048 | | 41.472 | MHz |
| Duty Cycle | dCLK | 40 | | 60 | % |
| LRCK Frequency (Note 16) | | | | | |
| Normal Mode (TDM0= "L", TDM1= "L") | | | | | |
| 1152fs, 512fs or 768fs | fsn | 8 | | 54 | kHz |
| 256fs or 384fs | fsd | 54 | | 108 | kHz |
| 128fs or 192fs | fsq | 108 | | 216 | kHz |
| Duty Cycle | Duty | 45 | | 55 | % |
| TDM256 mode (TDM0= "H", TDM1= "L") | | | | | |
| Normal Speed Mode High time | fsn | 8 | | 54 | kHz |
| Low time | tLRH | 1/256fs | | | ns |
| | tLRL | 1/256fs | | | ns |
| TDM128 mode (TDM0= "H", TDM1= "H") | | | | | |
| Normal Speed Mode | fsn | 8 | | 54 | kHz |
| Double Speed Mode | fsd | 54 | | 108 | kHz |
| Quad Speed Mode | fsq | 108 | | 216 | kHz |
| High time | tLRH | 1/128fs | | | ns |
| Low time | tLRL | 1/128fs | | | ns |
| PCM Audio Interface Timing | | | | | |
| Normal Mode (TDM0= "L", TDM1= "L") | | | | | |
| BICK Period | | | | | |
| 1152fs, 512fs or 768fs | tBCK | 1/128fsn | | | ns |
| 256fs or 384fs | tBCK | 1/64fsd | | | ns |
| 128fs or 192fs | tBCK | 1/64fsq | | | ns |
| BICK Pulse Width Low | tBCKL | 14 | | | ns |
| BICK Pulse Width High | tBCKH | 14 | | | ns |
| BICK "↑" to LRCK Edge (Note 17) | tBLR | 14 | | | ns |
| LRCK Edge to BICK "↑" (Note 17) | tLRB | 14 | | | ns |
| SDATA Hold Time | tSDH | 5 | | | ns |
| SDATA Setup Time | tSDS | 5 | | | ns |
| TDM256 mode (TDM0= "H", TDM1= "L") | | | | | |
| BICK Period | | | | | |
| Normal Speed Mode | tBCK | 1/256fsn | | | ns |
| BICK Pulse Width Low | tBCKL | 14 | | | ns |
| BICK Pulse Width High | tBCKH | 14 | | | ns |
| BICK "↑" to LRCK Edge (Note 17) | tBLR | 14 | | | ns |
| LRCK Edge to BICK "↑" (Note 17) | tLRB | 14 | | | ns |
| SDATA1/2 Hold Time | tSDH | 5 | | | ns |
| SDATA1/2 Setup Time | tSDS | 5 | | | ns |

| | | | | | | |
|---|-------|----------|--------|----|--|----|
| TDM128 mode (TDM0= “H”, TDM1= “H”) | | | | | | |
| BICK Period | | | | | | |
| Normal Speed Mode | tBCK | 1/128fsn | | | | ns |
| Double Speed Mode | tBCK | 1/128fsd | | | | ns |
| Quad Speed Mode | tBCK | 1/128fsq | | | | ns |
| BICK Pulse Width Low | tBCKL | 14 | | | | ns |
| BICK Pulse Width High | tBCKH | 14 | | | | ns |
| BICK “↑” to LRCK Edge (Note 17) | tBLR | 14 | | | | ns |
| LRCK Edge to BICK “↑” (Note 17) | tLRB | 14 | | | | ns |
| SDATA1/2 Hold Time | tSDH | 5 | | | | ns |
| SDATA1/2 Setup Time | tSDS | 5 | | | | ns |
| DSD Audio Interface Timing | | | | | | |
| DCLK Period | tDCK | - | 1/64fs | - | | ns |
| DCLK Pulse Width Low | tDCKL | 160 | | | | ns |
| DCLK Pulse Width High | tDCKH | 160 | | | | ns |
| DCLK Edge to DSDL1/R1/L2/R2 (Note 18) | tDDD | -20 | | 20 | | ns |
| Control Interface Timing | | | | | | |
| CCLK Period | tCCK | 200 | | | | ns |
| CCLK Pulse Width Low | tCCKL | 80 | | | | ns |
| Pulse Width High | tCCKH | 80 | | | | ns |
| CDTI Setup Time | tCDS | 50 | | | | ns |
| CDTI Hold Time | tCDH | 50 | | | | ns |
| CSN High Time | tCSW | 150 | | | | ns |
| CSN “↓” to CCLK “↑” | tCSS | 50 | | | | ns |
| CCLK “↑” to CSN “↑” | tCSH | 50 | | | | ns |
| Reset Timing | | | | | | |
| PDN Pulse Width (Note 19) | tPD | 150 | | | | ns |

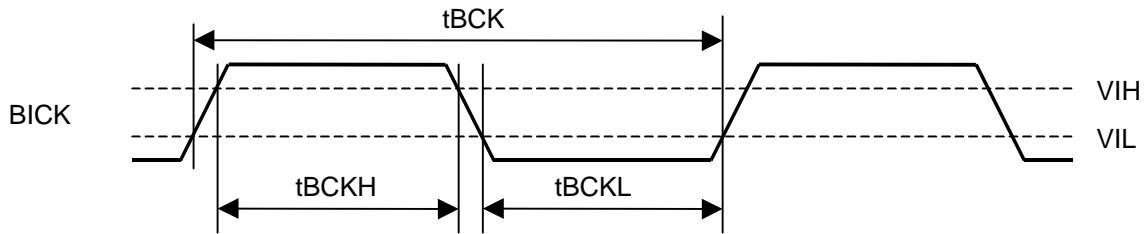
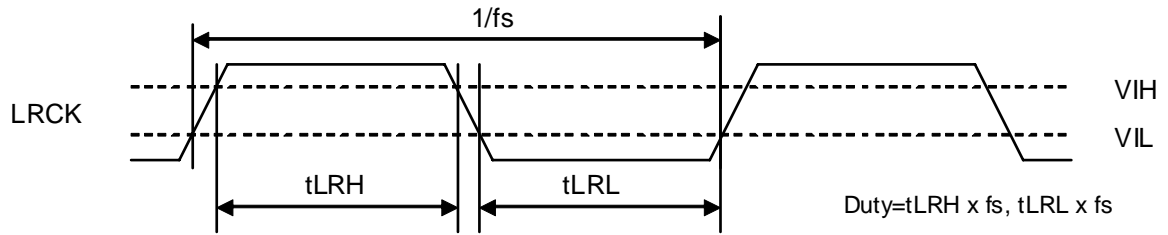
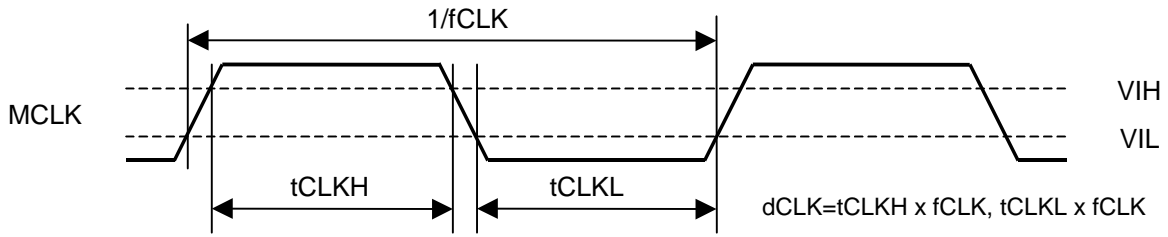
Note 16. When the 1152fs, 512fs or 768fs /256fs or 384fs /128fs or 192fs are switched, the AK4414 should be reset by the PDN pin or RSTN bit.

Note 17. BICK rising edge must not occur at the same time as LRCK edge.

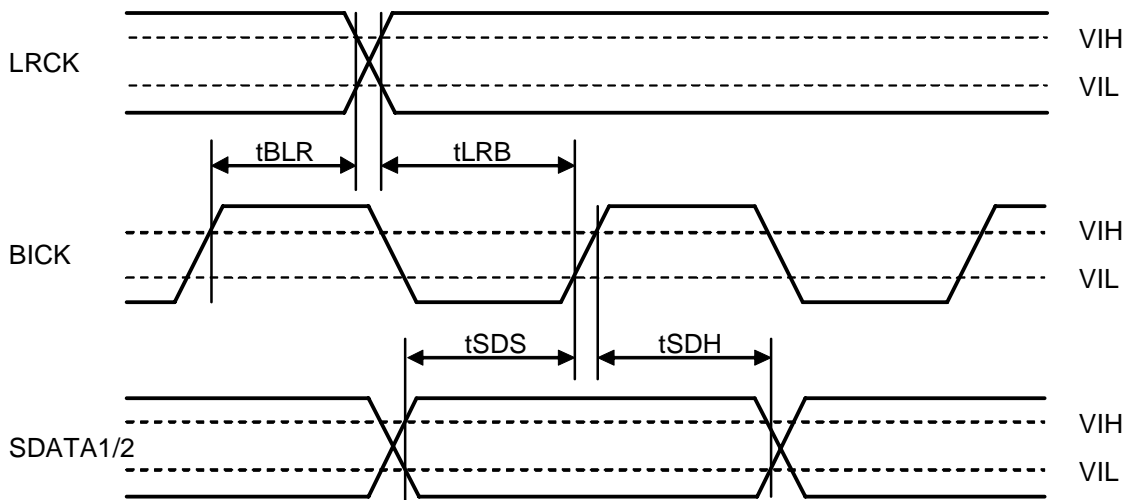
Note 18. DSD data transmitting device must meet this time.

Note 19. The AK4414 can be reset by bringing the PDN pin “L” to “H” upon power-up.

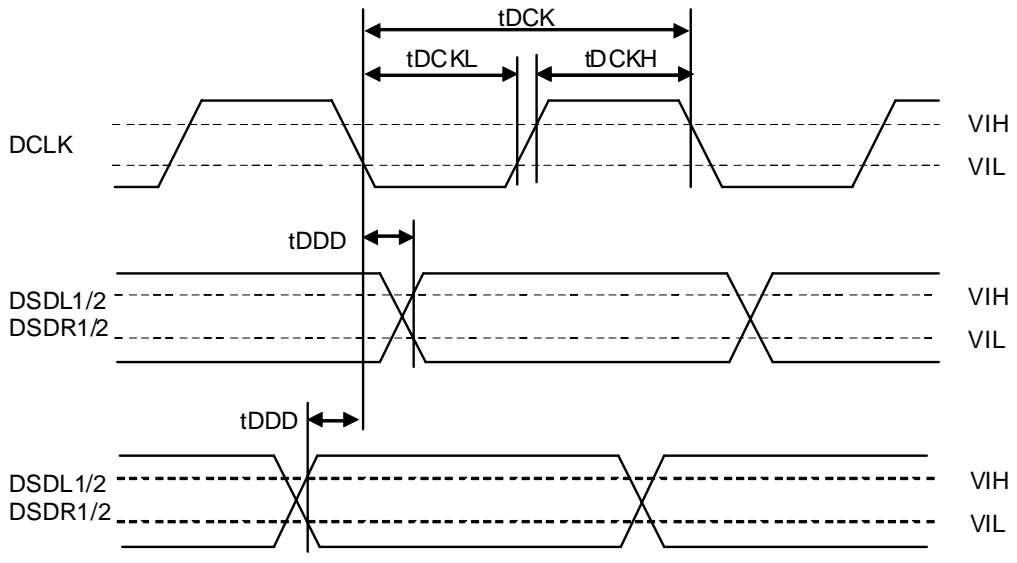
■ Timing Diagram



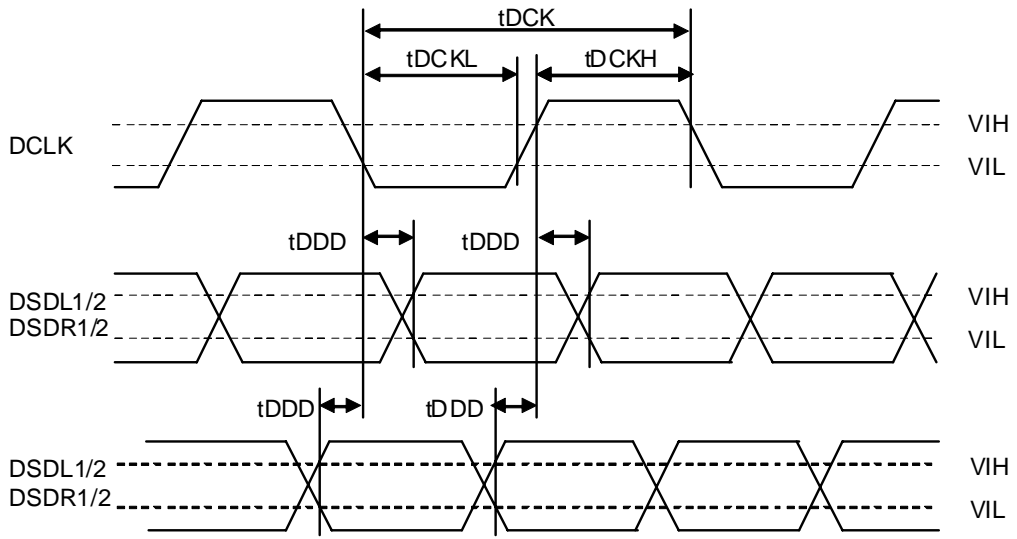
Clock Timing



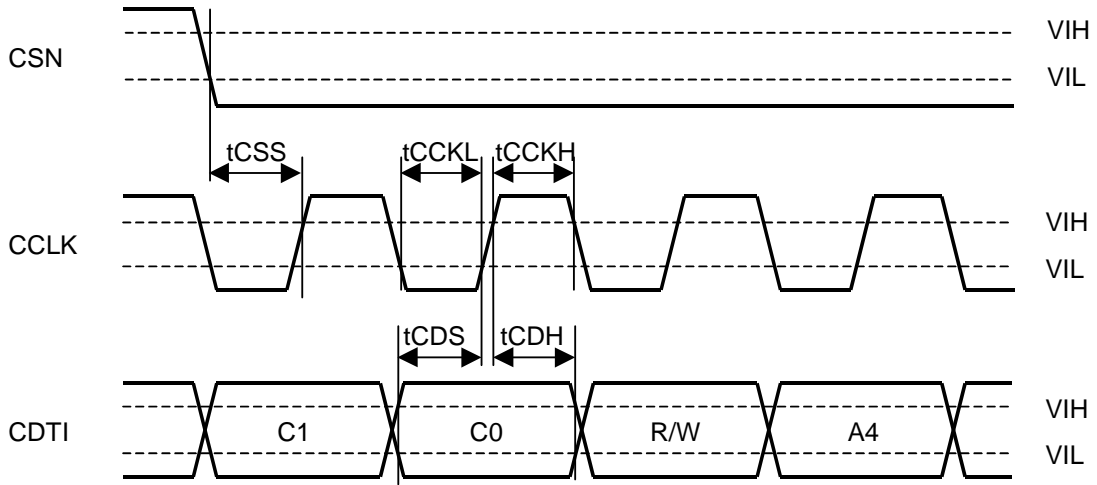
Audio Interface Timing (PCM Mode)



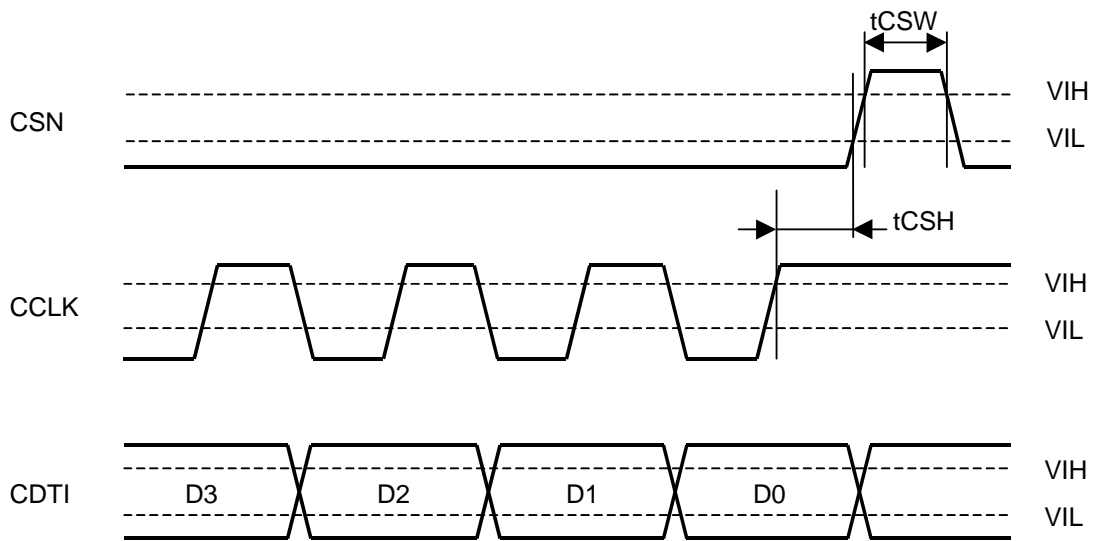
Audio Serial Interface Timing (DSD Normal Mode, DCKB bit = "0")



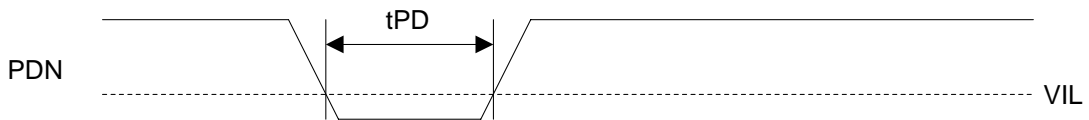
Audio Serial Interface Timing (DSD Phase Modulation Mode, DCKB bit = "0")



WRITE Command Input Timing



WRITE Data Input Timing



Power Down & Reset Timing

| |
|---------------------------|
| OPERATION OVERVIEW |
|---------------------------|

■ D/A Conversion Mode

In serial mode, the AK4414 can perform D/A conversion for either PCM data or DSD data. The D/P bit controls PCM/DSD mode. When DSD mode, DSD data can be input from DCLK, DSDL and DSDR pins. When PCM mode, PCM data can be input from BICK, LRCK and SDATA pins. When PCM/DSD mode is changed by D/P bit, the AK4414 should be reset by RSTN bit. It takes about 2/fs to 3/fs to change the mode. In parallel mode, the AK4414 performs for only PCM data.

| DP bit | Interface |
|--------|-----------|
| 0 | PCM |
| 1 | DSD |

Table 1. PCM/DSD Mode Control

■ System Clock

[1] PCM Mode

The external clocks, which are required to operate the AK4414, are MCLK, BICK and LRCK. MCLK should be synchronized with LRCK but the phase is not critical. The MCLK is used to operate the digital interpolation filter and the delta-sigma modulator.

The AK4414 is automatically placed in reset state when MCLK and LRCK are stopped during a normal operation (PDN pin = "H"), and the analog output becomes AVDD/2 (typ). When MCLK and LRCK are input again, the AK4414 exit reset state and starts the operation. After exiting system reset (PDN pin = "L" → "H") at power-up and other situations, the AK4414 is in power-down mode until MCLK and LRCK are supplied.

(1) Parallel Mode (PSN pin = "H")

1. Manual Setting Mode

In manual setting mode (ACKS pin = "L") only Normal Speed mode is supported with the sample rate range shown in [Table 2](#). The AK4414 automatically configures itself to operate with the supported MCLK frequencies which are required to be provided as input and are shown in [Table 3](#).

| Sampling Rate (fs) | |
|--------------------|--------------|
| Normal Speed Mode | 8kHz ~ 54kHz |

Table 2. Sampling Speed (Manual Setting Mode @Parallel Mode)

| LRCK fs | MCLK (MHz) | | | | | | BICK 64fs | |
|------------|------------|--------|------------|------------|------------|------------|--------------|-----------|
| | 128fs 1 | 92fs 2 | 56fs | 384fs 5 | 12fs | 768fs | | 1152fs |
| 32.0kHz | N/A | N/A | 8.1920 | 12.2880 16 | .3840 | 24.5760 36 | .8640 | 2.0480MHz |
| 44.1kHz | N/A | N/A | 11.2896 16 | .9344 | 22.5792 33 | .8688 | N/A | 2.8224MHz |
| 48.0kHz | N/A | N/A | 12.2880 18 | .4320 | 24.5760 36 | .8640 | N/A | 3.0720MHz |

Table 3. System Clock Example (Manual Setting Mode @Parallel Mode), (N/A: Not available)

2. Auto Setting Mode (ACKS pin = “H”)

In this mode, sampling speed and MCLK frequency are detected automatically (Table 4). The MCLK must be supplied at correct frequency according to the Table 5.

| MCLK Sampling Speed | | Sampling Speed |
|---------------------|-------|-------------------|
| 1152fs | | Normal (fs≤32kHz) |
| 512fs | 768fs | Normal |
| 256fs | 384fs | Double |
| 128fs | 192fs | Quad |

Table 4. Sampling Speed (Auto Setting Mode @Parallel Mode)

| LRCK MCLK fs | MCLK (MHz) | | | | | | | Sampling Speed |
|--------------|------------|---------|------------|------------|-----------|----------|--------|----------------------|
| | 128fs 1 | 92fs 2 | 56fs 3 | 84fs | 512fs 7 | 68fs | 1152fs | |
| 32.0kHz | N/A | N/A | (8.1920*) | (12.2880*) | 16.3840 2 | 4.5760 3 | 6.8640 | Normal/ (Double*) |
| 44.1kHz | N/A | N/A | (11.2896*) | (16.9344*) | 22.5792 | 33.8688 | N/A | |
| 48.0kHz | N/A | N/A | (12.2880*) | (18.4320*) | 24.5760 | 36.8640 | N/A | |
| 88.2kHz | N/A | N/A | 22.5792 | 33.8688 | N/A | N/A | N/A | Double |
| 96.0kHz | N/A | N/A | 24.5760 | 36.8640 | N/A | N/A | N/A | |
| 176.4kHz | 22.5792 | 33.8688 | N/A | N/A | N/A | N/A | N/A | Quad |
| 192.0kHz | 24.5760 | 36.8640 | N/A | N/A | N/A | N/A | N/A | |

Table 5. System Clock Example (Auto Setting Mode @Parallel Mode), (N/A: Not available)

MCLK= 256fs/384fs supports sampling rate of 32kHz~96kHz (Table 6). However, when the sampling rate is 32kHz~48kHz, DR and S/N will degrade by approximately 3dB as compared to when MCLK= 512fs/768fs.

| ACKS pin | MCLK | DR,S/N |
|----------|-------------------------|--------|
| L | 256fs/384fs/512fs/768fs | 120dB |
| H | 256fs/384fs | 117dB |
| H | 512fs/768fs | 120dB |

Table 6. Relationship between MCLK frequency and DR, S/N (fs= 44.1kHz)

3. Digital Filter Setting

| SD pin | SLOW pin | Mode |
|--------|----------|----------------------------|
| 0 | 0 | Sharp roll-off filter |
| 0 | 1 | Slow roll-off filter |
| 1 | 0 | Short delay sharp roll-off |
| 1 | 1 | Short delay slow roll-off |

Table 7. Digital Filter Setting (Parallel Mode)

(2) Serial Mode (PSN pin = “L”)

1. Manual Setting Mode (ACKS bit = “0”)

MCLK frequency is detected automatically and the sampling rate is set by DFS1-0 bits (Table 8). The MCLK frequency corresponding to each sampling speed should be provided externally (Table 9). The AK4414 is set to Manual Setting Mode at power-up (PDN pin = “L” → “H”). When DFS1-0 bits are changed, the AK4414 should be reset by RSTN bit.

| DFS1 bit | DFS0 bit | Sampling Rate (fs) | |
|----------|----------|--------------------|-------------------------|
| 0 0 | | Normal Speed Mode | 30kHz ~ 54kHz (default) |
| 0 1 | | Double Speed Mode | 54kHz ~ 108kHz |
| 1 0 | | Quad Speed Mode | 120kHz ~ 216kHz |

Table 8. Sampling Speed (Manual Setting Mode @Serial Mode)

| LRCK MCLK fs | MCLK (MHz) | | | | | | | BICK 64fs |
|-----------------|------------|---------|------------|------------|------------|------------|--------|--------------|
| | 128fs 1 | 92fs 2 | 56fs | 384fs 5 | 12fs | 768fs | 1152fs | |
| 32.0kHz | N/A | N/A | 8.1920 | 12.2880 16 | 3840 | 24.5760 36 | 8640 | 2.0480MHz |
| 44.1kHz | N/A | N/A | 11.2896 16 | 9344 | 22.5792 33 | 8688 | N/A | 2.8224MHz |
| 48.0kHz | N/A | N/A | 12.2880 18 | 4320 | 24.5760 36 | 8640 | N/A | 3.0720MHz |
| 88.2kHz | 11.2896 16 | 9344 22 | .5792 | 33.8688 | N/A | N/A | N/A | 5.6448MHz |
| 96.0kHz | 12.2880 18 | 4320 24 | .5760 | 36.8640 | N/A | N/A | N/A | 6.1440MHz |
| 176.4kHz 22 | .5792 | 33.8688 | N/A N/A | | N/A N/A | | N/A | 11.2896MHz |
| 192.0kHz 24 | .5760 | 36.8640 | N/A N/A | | N/A N/A | | N/A | 12.2880MHz |

Table 9. System Clock Example (Manual Setting Mode @Serial Mode)

2. Auto Setting Mode (ACKS bit = “1”)

MCLK frequency and the sampling speed are detected automatically (Table 10) and DFS1-0 bits are ignored. The MCLK frequency corresponding to each sampling speed should be provided externally (Table 11).

| MCLK Sam | | pling Speed |
|----------|------|-------------------|
| 1152fs | | Normal (fs≤32kHz) |
| 512fs 7 | 68fs | Normal |
| 256fs 3 | 84fs | Double |
| 128fs 1 | 92fs | Quad |

Table 10. Sampling Speed (Auto Setting Mode @Serial Mode)

| LRCK MCLK fs | MCLK (MHz) | | | | | | | Sampling Speed |
|-----------------|------------|---------|------------|------------|-----------|----------|--------|----------------------|
| | 128fs 1 | 92fs 2 | 56fs 3 | 84fs | 512fs 7 | 68fs | 1152fs | |
| 32.0kHz | N/A | N/A | (8.1920*) | (12.2880*) | 16.3840 2 | 4.5760 3 | 6.8640 | Normal/ (Double*) |
| 44.1kHz N | /A | N/A | (11.2896*) | (16.9344*) | 22.5792 | 33.8688 | N/A | |
| 48.0kHz N | /A | N/A | (12.2880*) | (18.4320*) | 24.5760 | 36.8640 | N/A | |
| 88.2kHz N | A | N/A | 22.5792 | 33.8688 | N/A N/A | N/A | | Double |
| 96.0kHz N | A | N/A | 24.5760 | 36.8640 | N/A N/A | N/A | | |
| 176.4kHz 22 | .5792 | 33.8688 | N/A N/A | | N/A N/A | N/A | | Quad |
| 192.0kHz 24 | .5760 | 36.8640 | N/A N/A | | N/A N/A | N/A | | |

Table 11. System Clock Example (Auto Setting Mode @Serial Mode)

MCLK= 256fs/384fs supports sampling rate of 32kHz~96kHz (Table 12). However, when the sampling rate is 32kHz~48kHz, DR and S/N will degrade by approximately 3dB as compared to when MCLK= 512fs/768fs.

| ACKS pin | MCLK | DR,S/N |
|----------|------------------------|--------|
| L 2 | 56fs/384fs/512fs/768fs | 120dB |
| H 2 | 56fs/384fs | 117dB |
| H 5 | 12fs/768fs | 120dB |

Table 12. Relationship between MCLK frequency and DR, S/N (fs= 44.1kHz)

3. Digital Filter Setting

| SD bit | SLOW bit | Mode |
|--------|----------|----------------------------|
| 0 | 0 | Sharp roll-off filter |
| 0 | 1 | Slow roll-off filter |
| 1 | 0 | Short delay sharp roll-off |
| 1 | 1 | Short delay slow roll-off |

(default)

Table 13. Digital Filter Setting (Serial Mode)

[2] DSD Mode

The external clocks, which are required to operate the AK4414, are MCLK and DCLK. MCLK should be synchronized with DCLK but the phase is not critical. The frequency of MCLK is set by DCKS bit.

The AK4414 is automatically placed in reset state when MCLK is stopped during a normal operation (PDN pin =“H”), and the analog output becomes AVDD/2 voltage (typ).

| DCKS bit | MCLK Frequency | DCLK Frequency |
|----------|----------------|----------------|
| 0 51 | 2fs | 64fs |
| 1 76 | 8fs | 64fs |

(default)

Table 14. System Clock (DSD Mode)

■ Audio Interface Format

[1] PCM Mode

(1) Parallel Control Mode (PSN pin = “H”)

Twenty formats are selectable by DIF1-0 and TDM2-0 pins (Table 15). In this mode, register settings are ignored. In all formats the serial data is MSB-first, 2's complement format and is latched on the rising edge of BICK. Mode 2 can be used for 20 and 16 MSB justified formats by zeroing the unused LSBs.

If TDM1-0 pins = “LH” the audio interface is TDM256 mode (Table 15) and all eight channels of DAC data are input to the SDTI1 pin. The input data to the SDTI2 pin is ignored. BICK is fixed to 256fs, “H” time and “L” time of LRCK should be 1/256fs at least. The data format is MSB first, 2's complement and the SDTI1 is latched on the rising edge of BICK. Only the first four channels of DAC data may be selected to be converted into four channels of DAC analog output.

If TDM1-0 pins = “HH” the audio interface is TDM128 mode (Table 15) and the serial data of DAC (four channels: L1, R1, L2, R2) is input to the SDTI1 pin.

| Mode TDM | 1 | TDM0 | DIF2 | DIF1 | DIF0 | SDTI Format | LRCK | BICK | |
|----------|------|------|------|------|------|------------------------------------|----------------------|-------|-------|
| Normal | 0 | - | 0 | 0 | 0 | 0 | 16-bit LSB justified | H/L | ≥32fs |
| | 1 0 | | | 0 | 1 | 20-bit LSB justified | H/L | ≥40fs | |
| | 2 | | | 0 | 1 | 0 | 24-bit MSB justified | H/L | ≥48fs |
| | 3 0 | | | 1 | 1 | 24-bit I ² S compatible | L/H | ≥48fs | |
| | 4 1 | | | 0 | 0 | 24-bit LSB justified | H/L | ≥48fs | |
| | 5 1 | | | 0 | 1 | 32-bit LSB justified | H/L | ≥64fs | |
| | 6 | | | 1 | 1 | 0 | 32-bit MSB justified | H/L | ≥64fs |
| | 7 | | | 1 1 | 1 | 32-bit I ² S compatible | L/H | ≥64fs | |
| TDM256 | 0 | 0 | 1 | | 0 | 0 | N/A | | |
| | 0 | | | 0 | 1 | N/A | | | |
| | 8 | | | 0 | 1 | 0 | 24-bit MSB justified | ↑ | 256fs |
| | 9 0 | | | 1 | 1 | 24-bit I ² S compatible | ↓ | 256fs | |
| | 10 1 | | | 0 | 0 | 24-bit LSB justified | ↑ | 256fs | |
| | 11 1 | | | 0 | 1 | 32-bit LSB justified | ↑ | 256fs | |
| | 12 | | | 1 | 1 | 0 | 32-bit MSB justified | ↑ | 256fs |
| | 13 | | | 1 1 | 1 | 32-bit I ² S compatible | ↓ | 256fs | |
| TDM128 | 0 | 1 | 1 | | 0 | 0 | N/A | | |
| | 0 | | | 0 | 1 | N/A | | | |
| | 14 | | | 0 | 1 | 0 | 24-bit MSB justified | ↑ | 128fs |
| | 15 0 | | | 1 | 1 | 24-bit I ² S compatible | ↓ | 128fs | |
| | 16 1 | | | 0 | 0 | 24-bit LSB justified | ↑ | 128fs | |
| | 17 1 | | | 0 | 1 | 32-bit LSB justified | ↑ | 128fs | |
| | 18 | | | 1 | 1 | 0 | 32-bit MSB justified | ↑ | 128fs |
| | 19 | | | 1 1 | 1 | 32-bit I ² S compatible | ↓ | 128fs | |

Table 15. Audio Interface Format (Parallel mode)

(2) Serial Control Mode (PSN pin = “L”)

Twenty formats are selected by setting DIF2-0 and TDM1-0 bits (Table 16). The initial setting of DIF2-0 bits is “010”. In this mode, the DIF1 pin setting is ignored.

The audio I/F format is TDM256 mode (Table 16) and all the serial data of eight DAC channels are input to the SDTI1 pin (Figure 15). The input data to the SDTI2 pin is ignored. BICK is fixed to 256fs, high and low amplitude of LRCK is 1/256fs (min). The data format is MSB first, 2’s complement and the SDTI1 is latched on the rising edge of BICK. The eight channels of DAC data may be mapped to two pieces of AK4414 (Table 17).

In TDM128 mode, the serial data of DAC (four channels: L1, R1, L2, R2) is input to the SDTI1 pin and other serial data of DAC (four channels: L3, R3, L4, R4) are input to the SDTI2 pin (Figure 14). BICK is fixed to 128fs. The data format is MSB first and 2’s complement and the input data to SDTI1-2 pins are latched on the rising edge of BICK. The eight channels of DAC data may be mapped to two pieces of AK4414 (Table 17).

| Mode | TDM | 1 | TDM0 | DIF2 | DIF1 | DIF0 | SDTI Format | LRCK | BICK |
|--------|------|-----|------|------|------|------|------------------------------------|------|-------|
| Normal | 0 0 | - | 0 | | 0 | 0 | 16-bit LSB justified | H/L | ≥32fs |
| | 1 0 | | | | 0 | 1 | 20-bit LSB justified | H/L | ≥40fs |
| | 2 | | | 0 | 1 | 0 | 24-bit MSB justified | H/L | ≥48fs |
| | 3 0 | | | | 1 | 1 | 24-bit I ² S compatible | L/H | ≥48fs |
| | 4 1 | | | | 0 | 0 | 24-bit LSB justified | H/L | ≥48fs |
| | 5 1 | | | | 0 | 1 | 32-bit LSB justified | H/L | ≥64fs |
| | 6 | | | 1 | 1 | 0 | 32-bit MSB justified | H/L | ≥64fs |
| | 7 | | | 1 1 | | 1 | 32-bit I ² S compatible | L/H | ≥64fs |
| TDM256 | 0 | 0 1 | | | 0 | 0 | N/A | | |
| | 0 | | | | 0 | 1 | N/A | | |
| | 8 | | | 0 | 1 | 0 | 24-bit MSB justified | ↑ | 256fs |
| | 9 0 | | | | 1 | 1 | 24-bit I ² S compatible | ↓ | 256fs |
| | 10 1 | | | | 0 | 0 | 24-bit LSB justified | ↑ | 256fs |
| | 11 1 | | | | 0 | 1 | 32-bit LSB justified | ↑ | 256fs |
| | 12 | | | 1 | 1 | 0 | 32-bit MSB justified | ↑ | 256fs |
| | 13 | | | 1 1 | | 1 | 32-bit I ² S compatible | ↓ | 256fs |
| TDM128 | 0 | 1 1 | | | 0 | 0 | N/A | | |
| | 0 | | | | 0 | 1 | N/A | | |
| | 14 | | | 0 | 1 | 0 | 24-bit MSB justified | ↑ | 128fs |
| | 15 0 | | | | 1 | 1 | 24-bit I ² S compatible | ↓ | 128fs |
| | 16 1 | | | | 0 | 0 | 24-bit LSB justified | ↑ | 128fs |
| | 17 1 | | | | 0 | 1 | 32-bit LSB justified | ↑ | 128fs |
| | 18 | | | 1 | 1 | 0 | 32-bit MSB justified | ↑ | 128fs |
| | 19 | | | 1 1 | | 1 | 32-bit I ² S compatible | ↓ | 128fs |

Table 16. Audio Interface Format (Serial mode)

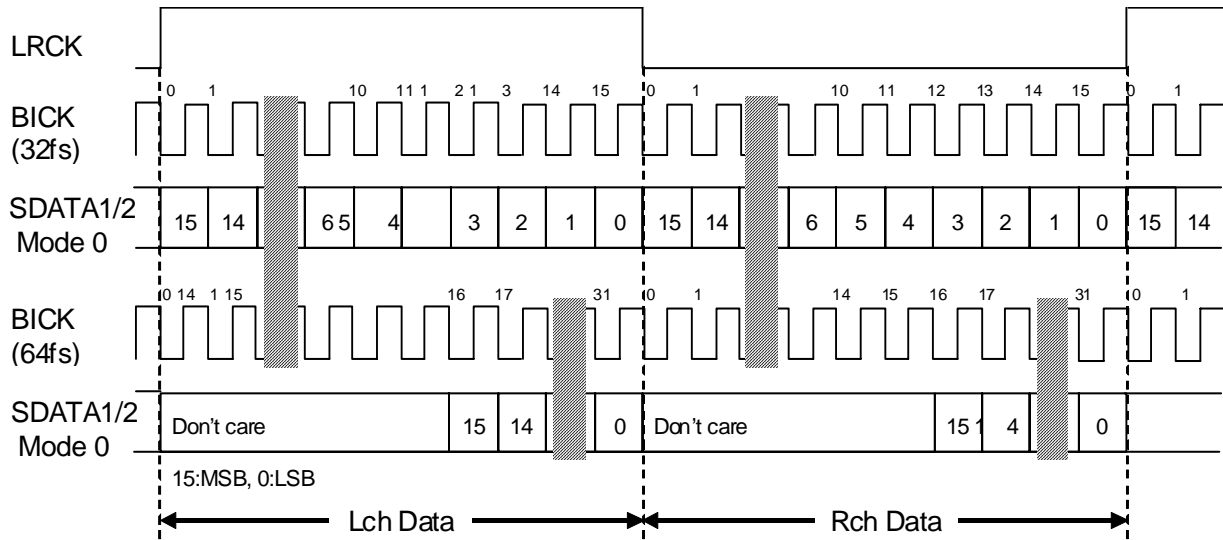


Figure 1. Mode 0 Timing

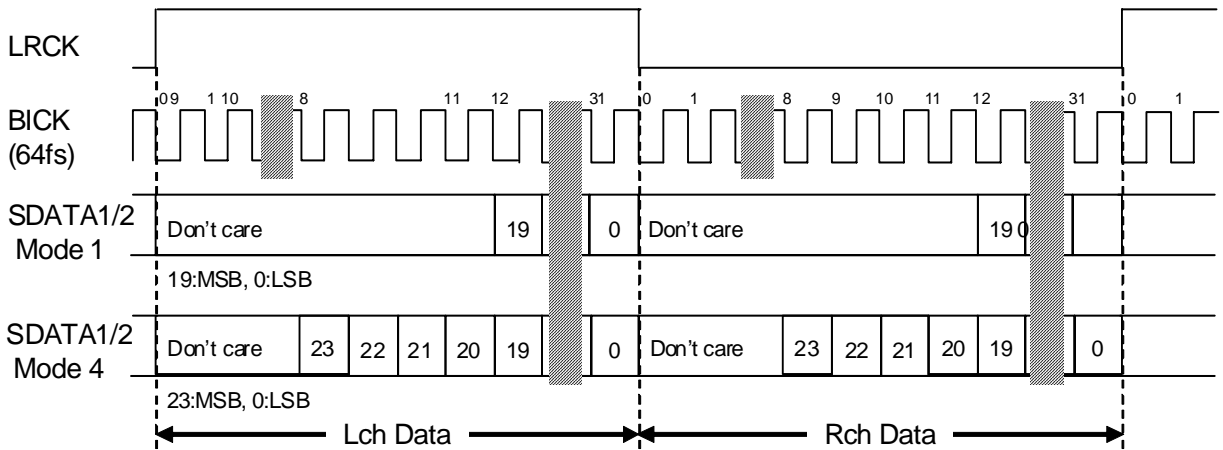


Figure 2. Mode 1/4 Timing

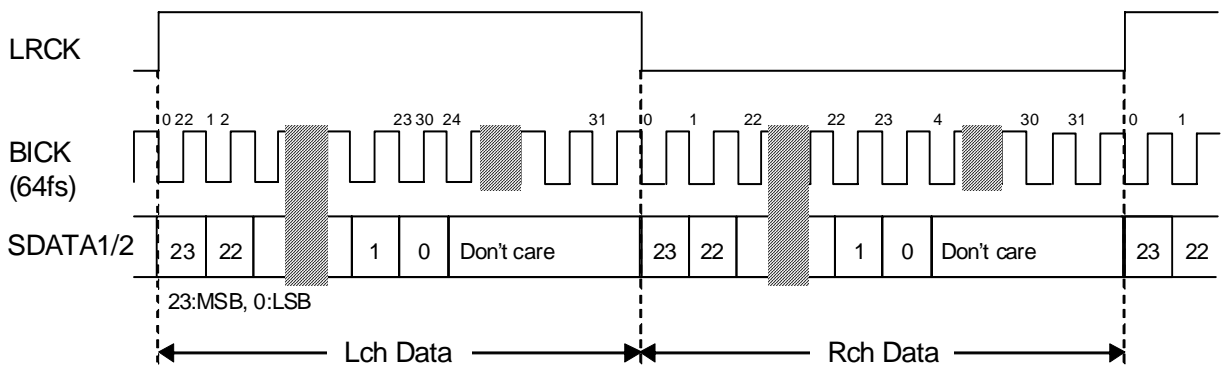


Figure 3. Mode 2 Timing

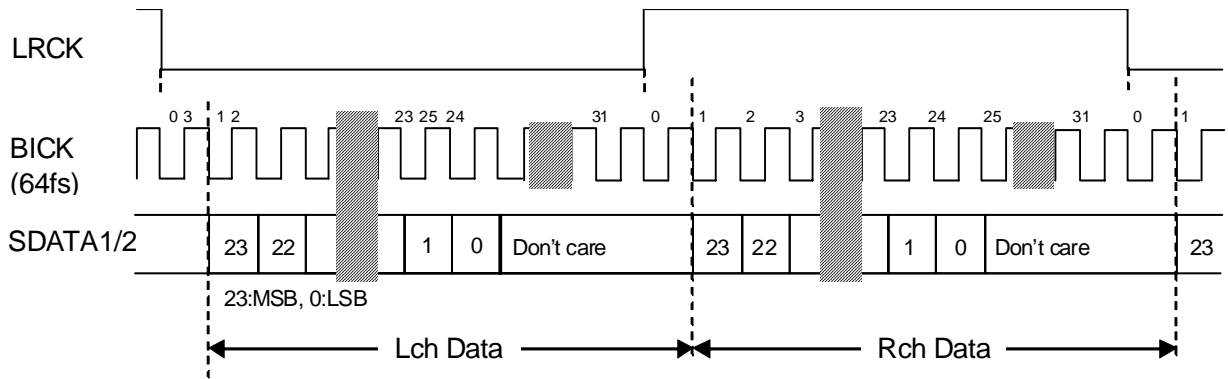


Figure 4. Mode 3 Timing

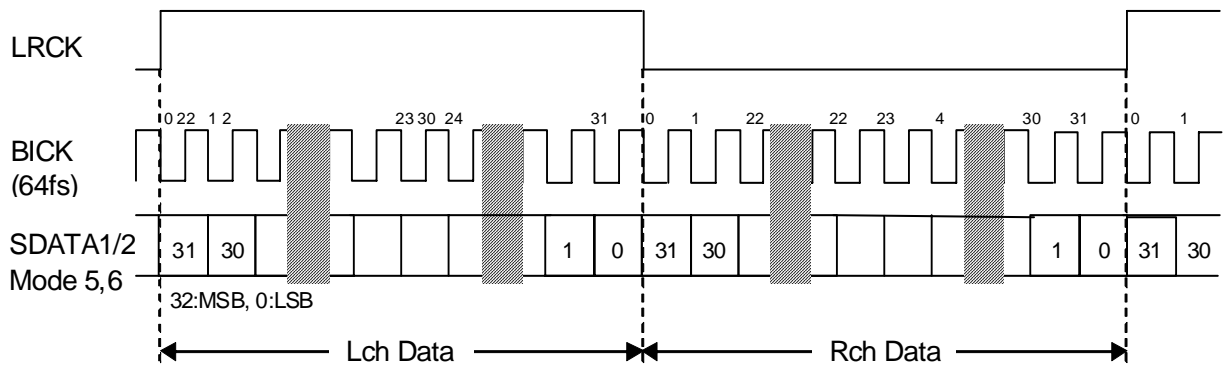


Figure 5. Mode 5/6 Timing

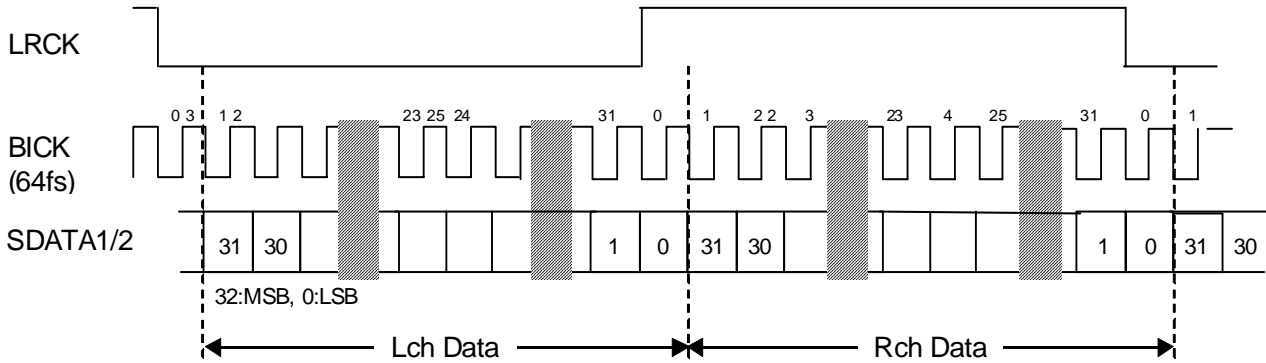


Figure 6. Mode 7 Timing

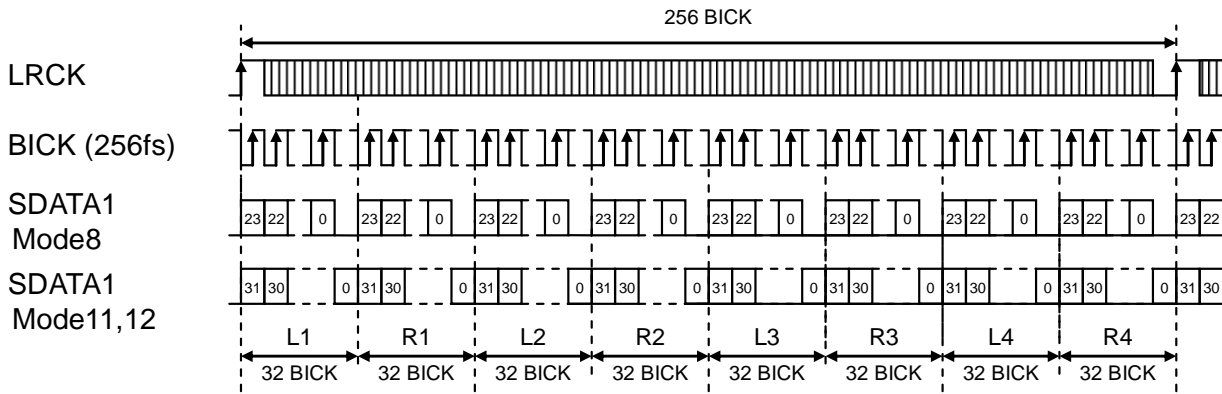


Figure 7. Mode 8/11/12 Timing

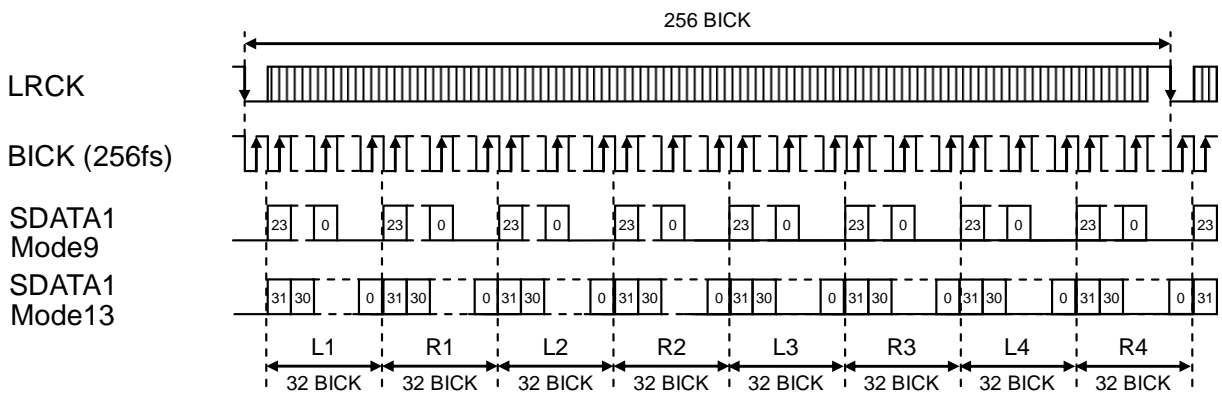


Figure 8. Mode 9/13 Timing

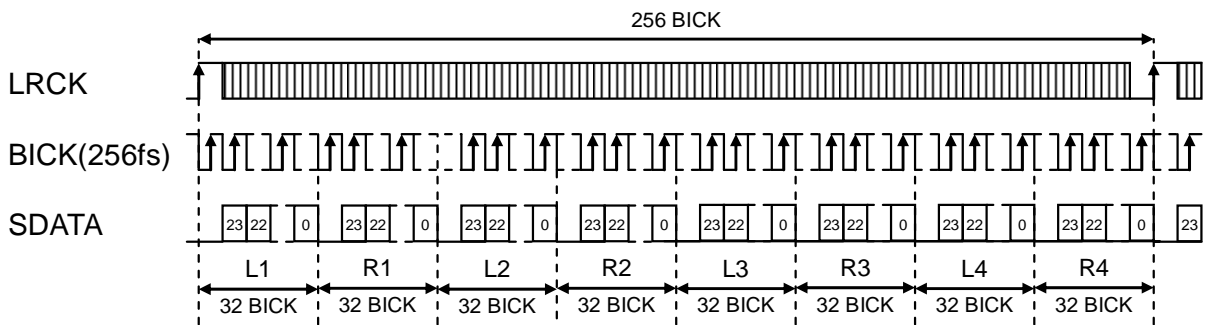


Figure 9. Mode 10 Timing

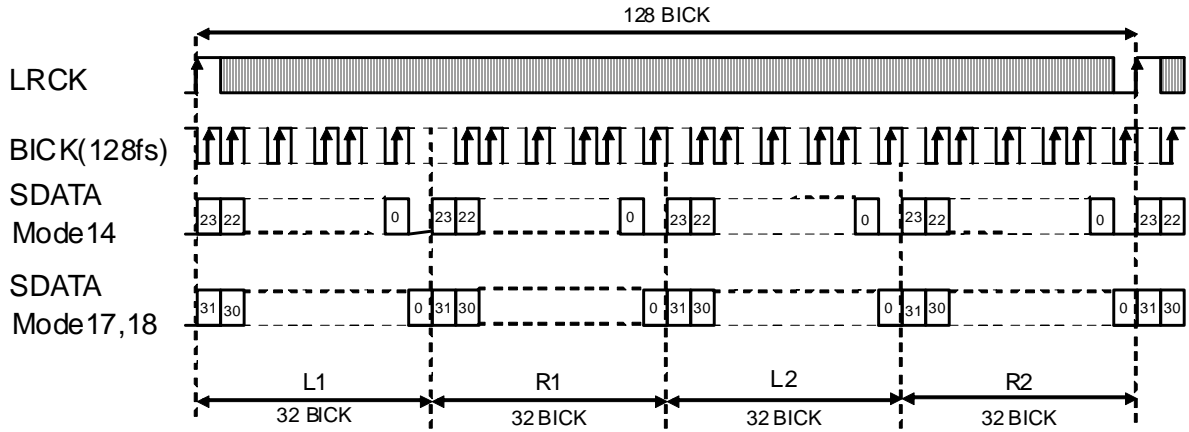


Figure 10. Mode 14/17/18 Timing

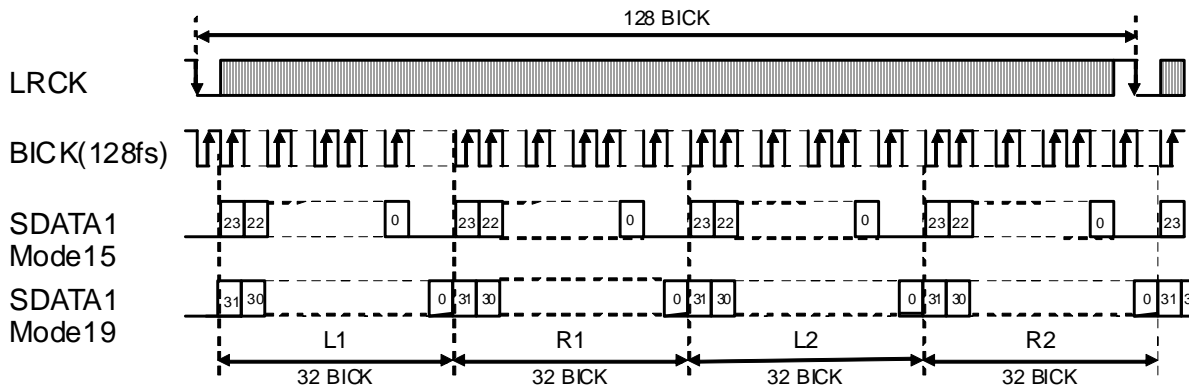


Figure 11. Mode 15/19 Timing

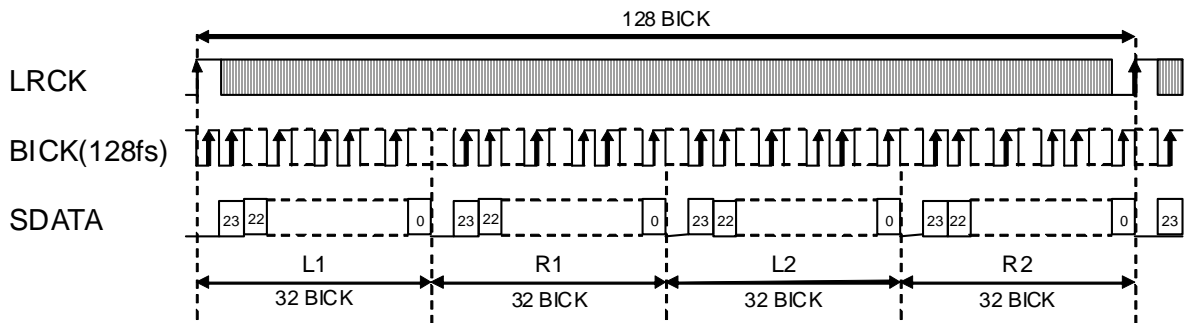


Figure 12. Mode 16 Timing

One data cycle of SDATA1 and SDATA2 for each format are defined as below. SDS2-1 bits control playback channel of each DAC.

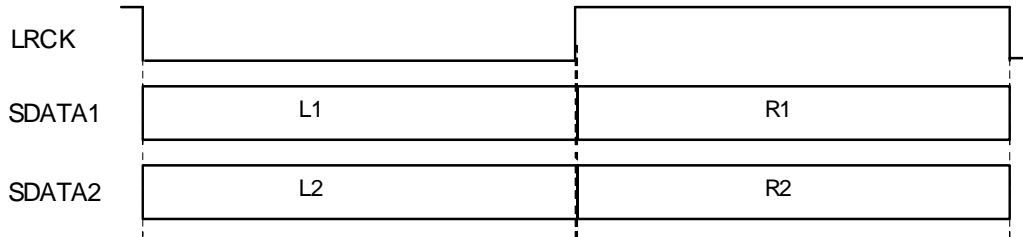


Figure 13. Data Slot in Normal Mode

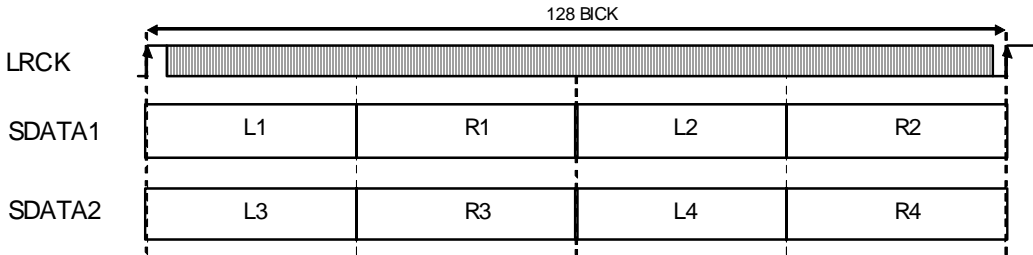


Figure 14. Data Slot in TDM128 Mode

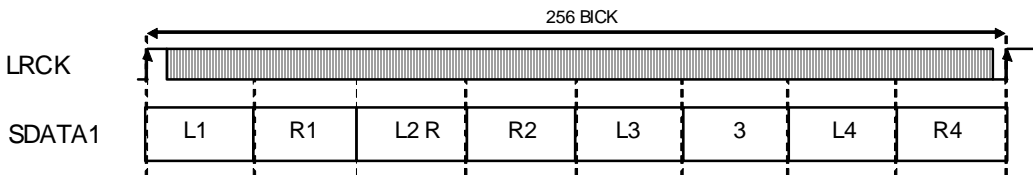


Figure 15. Data Slot in TDM256 Mode

AK4414 Data Select

| SDS | 1 | SDS2 | DAC1 DAC | | 2 | |
|--------|-----|------|----------|----|-----|-----|
| | | | Lch R | ch | Lch | Rch |
| Normal | 0 0 | | L1 | R1 | L2 | R2 |
| | 0 1 | | L1 | R1 | L1 | R1 |
| | 1 0 | | L2 | R2 | L2 | R2 |
| | 1 1 | | L2 | R2 | L1 | R1 |
| TDM128 | 0 0 | | L1 | R1 | L2 | R2 |
| | 0 1 | | L1 | R1 | L4 | R4 |
| | 1 0 | | L3 | R3 | L2 | R2 |
| | 1 1 | | L3 | R3 | L4 | R4 |
| TDM256 | 0 0 | | L1 | R1 | L2 | R2 |
| | 0 1 | | L1 | R1 | L4 | R4 |
| | 1 0 | | L3 | R3 | L2 | R2 |
| | 1 1 | | L3 | R3 | L4 | R4 |

Table 17. Data Select

[2] DSD Mode

In case of DSD mode, DIF2-0 pins and DIF2-0 bits are ignored. The frequency of DCLK is fixed to 64fs. DCKB bit can invert the polarity of DCLK.

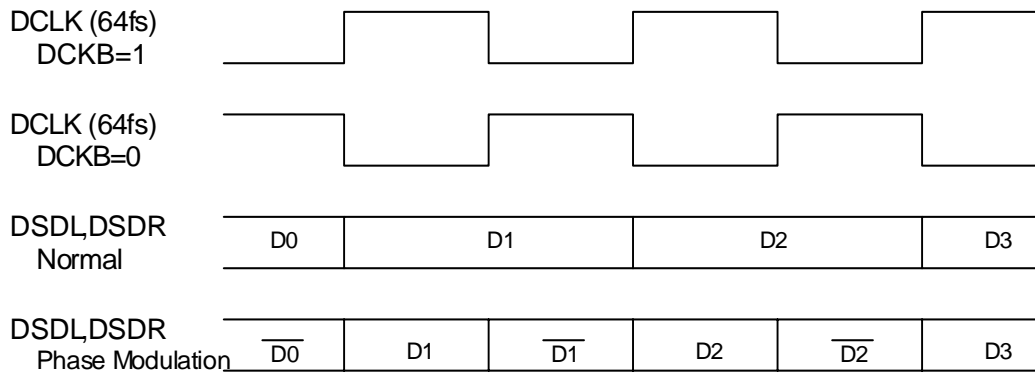


Figure 16. DSD Mode Timing

■ D/A Conversion Mode Switching Timing

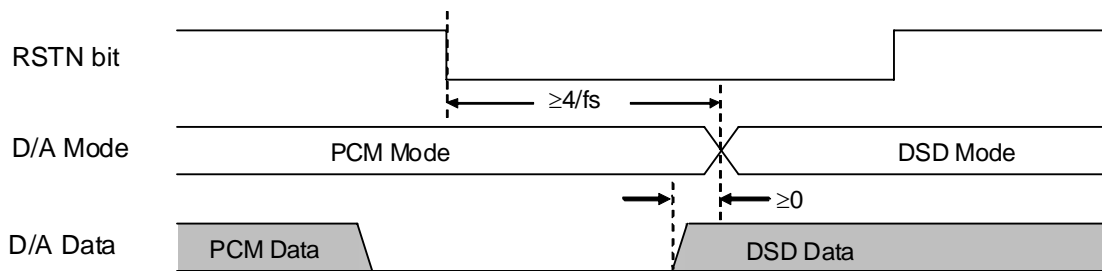


Figure 17. D/A Mode Switching Timing (PCM to DSD)

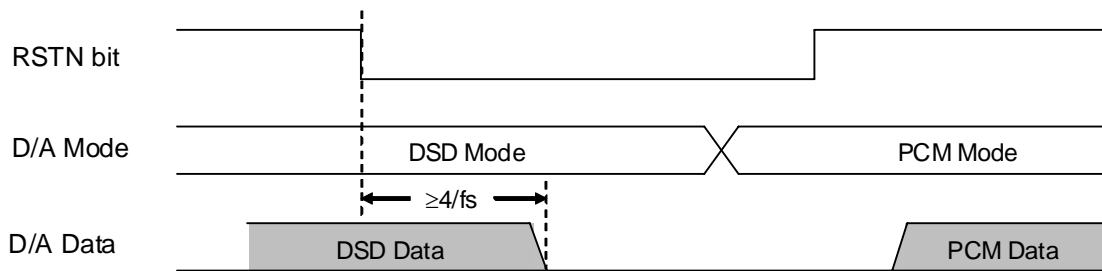


Figure 18. D/A Mode Switching Timing (DSD to PCM)

Note. The signal range is identified as 25% ~ 75% duty ratios in DSD mode. DSD signal must not go beyond this duty range at the SACD format book (Scarlet Book).

■ De-emphasis Filter

A digital de-emphasis filter is available for 32kHz, 44.1kHz or 48kHz sampling rates ($t_c = 50/15\mu s$) and is enabled or disabled with DEM1-0 pins or DEM1-0 bits. In case of 256fs/384fs and 128fs/192fs, the digital de-emphasis filter is always off. When DSD mode, DEM1-0 bits are ignored. The setting value is held even if PCM mode and DSD mode are switched.

[1] Parallel Mode

The DEM1 and DEM0 pins control de-emphasis mode of DAC1 and DAC2. This setting is common for both of DAC's. In parallel mode, the filter setting cannot be applied independently.

| DEM1 D | EM0 | Mode |
|--------|-----|---------|
| L L | | 44.1kHz |
| L H | | OFF |
| H L | | 48kHz |
| H H | | 32kHz |

(default)

Table 18. De-emphasis Control (Parallel Mode)

[2] Serial Mode

DEM1-0 bits and DEM3-2 bits control de-emphasis mode of DAC1 and DAC2, respectively. DEM3-0 bits settings are invalid in DSD mode. The register settings are maintained when switching the mode between PCM and DSD modes.

| DEM1 D | EM0 | Mode |
|--------|-----|---------|
| 0 0 | | 44.1kHz |
| 0 1 | | OFF |
| 1 0 | | 48kHz |
| 1 1 | | 32kHz |

(default)

Table 19. DAC1 De-emphasis Control (Serial Mode)

| DEM3 D | EM2 | Mode |
|--------|-----|---------|
| 0 0 | | 44.1kHz |
| 0 1 | | OFF |
| 1 0 | | 48kHz |
| 1 1 | | 32kHz |

(default)

Table 20. DAC2 De-emphasis Control (Serial Mode)

■ Output Volume

The AK4414 includes channel independent digital output volumes (ATT) with 255 levels at 0.5dB step including MUTE. This volume control is in front of the DAC and it can attenuate the input data from 0dB to -127dB and mute. When changing output levels, transitions are executed in soft change; thus no switching noise occurs during these transitions. It takes 7424/fs from FFH (0dB) to 00H (Mute). The attenuation level is reset to FFH (0dB) by initial reset. By RSTN bit = "0", the attenuation level is initialized to FFH, and the attenuation level returns to the setting value by RSTN bit = "1".

| Sampling Speed | Transition Time |
|----------------|-----------------|
| | 0dB to MUTE |
| fs=44.1kHz | 168.3ms |
| fs=96kHz | 77.3ms |
| fs=192kHz | 38.6ms |

Table 21. ATT Transition Time

■ Zero Detection (PCM mode, DSD mode)

The AK4414 has channel-independent zeros detect function. When the input data at each channel is continuously zeros for 8192 LRCK cycles, the DZF pin of each channel goes to “H”. The DZF pin of each channel immediately returns to “L” if the input data of each channel is not zero. If the RSTN bit is “0”, the DZF pins of both channels go to “H”. The DZF pins of both channels go to “L” after 4 ~ 5/fs when RSTN bit returns to “1”. The DZFB bit can invert the polarity of the DZF pin. In parallel control mode, the zero detect function is disabled.

| Pin C | omment |
|-------|---|
| DZF1 | Zero Detection flag output of the channels set by register 08H. |
| DZF2 | Zero Detection flag output of the channels set by register 09H. |

Table 22. DZF pin function

■ Mono Output

Input and output signal combination of the AK4414 can be set by MONO bit and SELLR bit. Monaural output mode is enabled when MONO bit = “1”. The output signal phase of DAC is controlled by INVL and INVL R bits. These settings are available for any audio format.

(L1/2 is the output signal of the AOUTL1N/2N and AOUTL1P/2P pins. R1/2 is the output signal of AOUTR1N/2N and AOUTR1P/2P pins)

| MONO bit | SELLR1 bit | INVL1 bit | INVR1 bit | L1 (AOUTL1N, AOUTL1P pins) | R1 (AOUTR1N, AOUTR1P pins) |
|----------|------------|-----------|-----------|-------------------------------|-------------------------------|
| 0 0 | | 0 | 0 | L1 | R1 |
| | | 1 0 | | L1 Invert | R1 |
| | | 0 1 | | L1 | R1 Invert |
| | | 1 | 1 | L1 Invert | R1 Invert |
| 0 1 | | 0 0 | | R1 | L1 |
| | | 1 0 | | R1 Invert | L1 |
| | | 0 1 | | R1 | L1 Invert |
| | | 1 | 1 | R1 Invert | L1 Invert |
| 1 0 | | 0 0 | | L1 | L1 |
| | | 1 0 | | L1 Invert | L1 |
| | | 0 | 1 | L1 | L1ch In Invert |
| | | 1 | 1 | L1 Invert | L1 Invert |
| 1 1 | | 0 0 | | R1 | R1 |
| | | 1 0 | | R1 Invert | R1 |
| | | 0 1 | | R1 | R1 Invert |
| | | 1 | 1 | R1 Invert | R1 Invert |

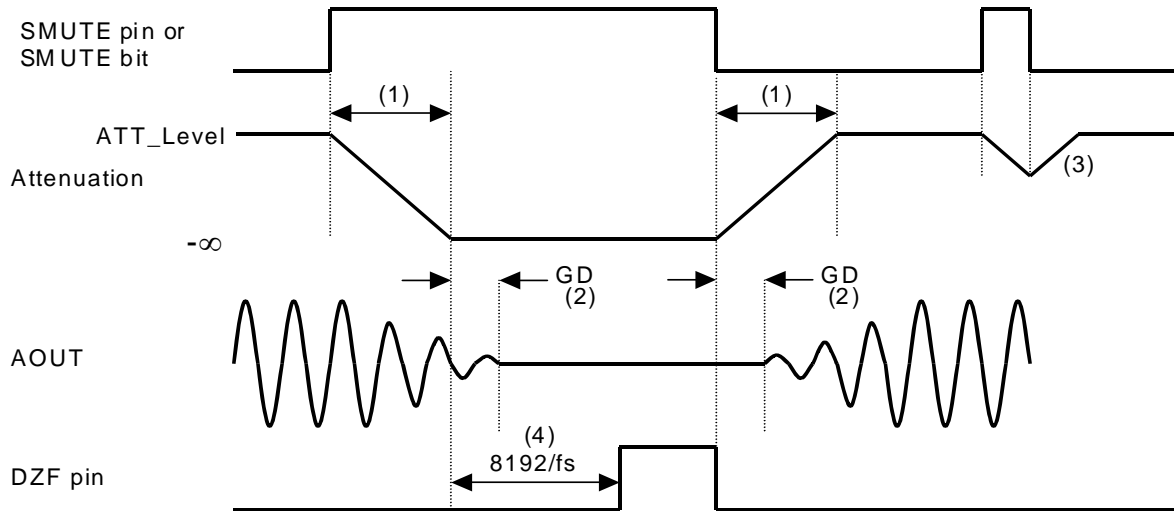
Table 23. Output Select for DAC1

| MONO bit | SELLR2 bit | INVL2 bit | INVR2 bit | L2 (AOURL2N, AOURL2P pins) | R2 (AOUR2N, AOUR2P pins) |
|----------|------------|-----------|-----------|-------------------------------|-----------------------------|
| 0 | 0 | 0 | 0 | L2 | R2 |
| | | 1 | 0 | L2 Invert | R2 |
| | | 0 1 | | L2 | R2 Invert |
| | | 1 | 1 | L2 Invert | R2 Invert |
| 0 | 1 | 0 0 | | R2 | L2 |
| | | 1 0 | | R2 Invert | L2 |
| | | 0 1 | | R2 | L2 Invert |
| | | 1 | 1 | R2 Invert | L2 Invert |
| 1 | 0 | 0 0 | | L2 | L2 |
| | | 1 0 | | L2 Invert | L2 |
| | | 0 1 | | L2 | L2 Invert |
| | | 1 | 1 | L2 Invert | L2 Invert |
| 1 | 1 | 0 0 | | R2 | R2 |
| | | 1 0 | | R2 Invert | R2 |
| | | 0 1 | | R2 | R2 Invert |
| | | 1 | 1 | R2 Invert | R2 Invert |

Table 24. Output Select for DAC2

■ Soft Mute Operation

The soft mute operation is performed at digital domain. When the SMUTE pin goes to “H” or the SMUTE bit set to “1”, the output signal is attenuated by $-\infty$ during $ATT_DATA \times ATT$ transition time from the current ATT level. When the SMUTE pin is returned to “L” or the SMUTE bit is returned to “0”, the mute is cancelled and the output attenuation gradually changes to the ATT level during $ATT_DATA \times ATT$ transition time. If the soft mute is cancelled before attenuating $-\infty$, the attenuation is discontinued and returned to ATT level by the same cycle. The soft mute is effective for changing the signal source without stopping the signal transmission.



Notes:

- (1) $ATT_DATA \times ATT$ transition time. For example, this time is 1020LRCK cycles (1020/fs) at $ATT_DATA=255$ in Normal Speed Mode.
- (2) The analog output corresponding to the digital input has group delay (GD).
- (3) If the soft mute is cancelled before attenuating $-\infty$ after starting the operation, the attenuation is discontinued and returned to ATT level by the same cycle.
- (4) When the input data for each channel is continuously zeros for 8192 LRCK cycles, the DZF pin for each channel goes to “H”. The DZF pin immediately returns to “L” if input data are not zero.

Figure 19. Soft Mute Function

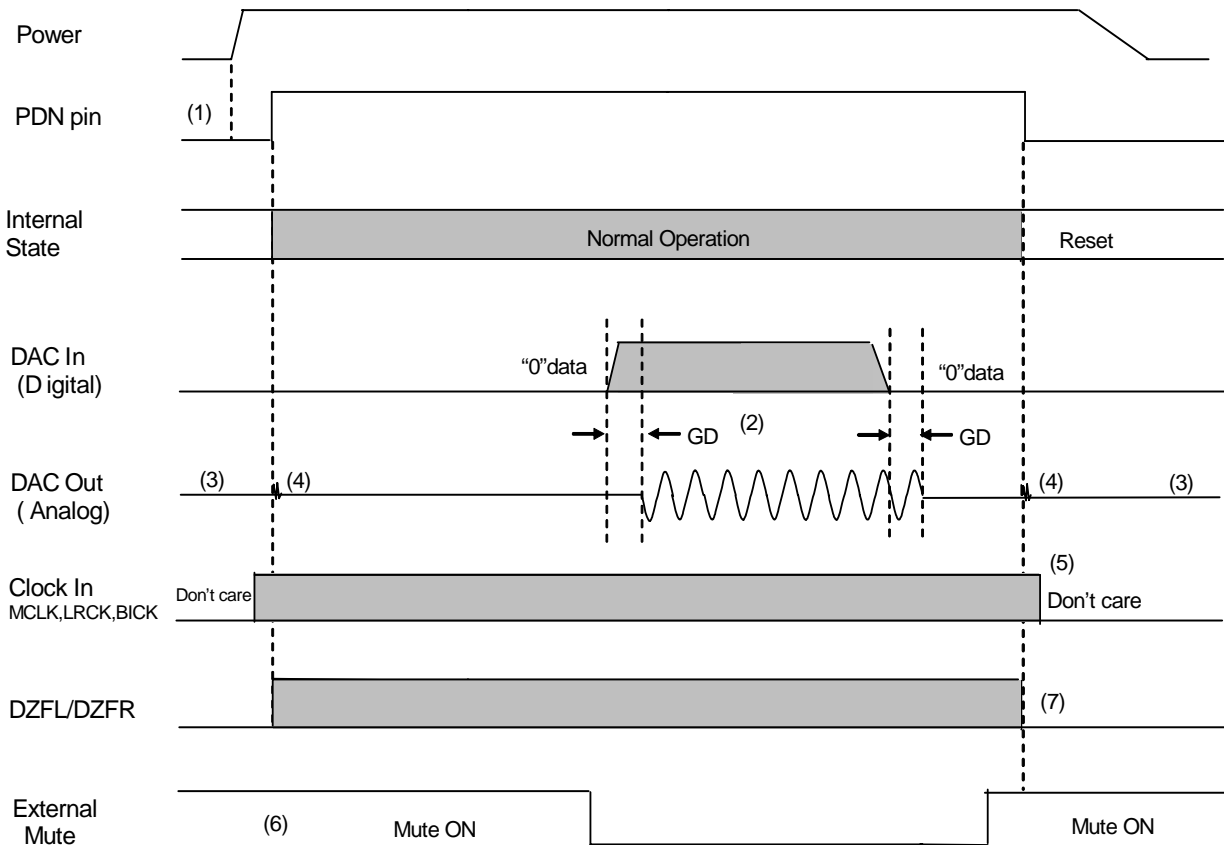
■ System Reset

The AK4414 should be reset once by bringing the PDN pin = “L” upon power-up. It initializes register settings of the device. The AK4414 exits this system reset (power-down mode) by MCLK after the PDN pin = “H”, and the analog block exits power-down mode. The digital block exits power-down mode after the internal counter counts MCLK for 4/fs.

■ Power ON/OFF timing

The AK4414 is placed in the power-down mode by bringing the PDN pin “L” and the registers are initialized. The analog outputs are floating (Hi-Z). Since a click noise occurs at the edge of the PDN pin signal, the analog output should be muted externally if the click noise influences system application.

The DAC can be reset by setting RSTN bit to “0”. In this case, the registers are not initialized and the corresponding analog outputs go to VCM1/2. Since a click noise occurs at the edge of RSTN signal, the analog output should be muted externally if click noise adversely affect system performance.



Notes:

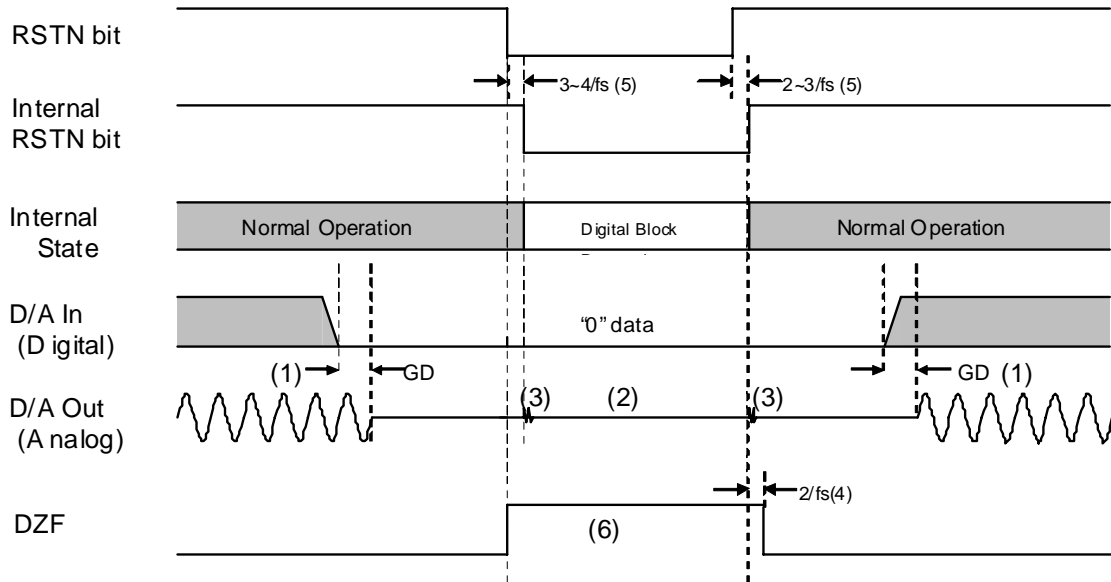
- (1) After AVDD and DVDD are powered-up, the PDN pin should be “L” for 150ns.
- (2) The analog output corresponding to digital input has group delay (GD).
- (3) Analog outputs are floating (Hi-Z) in power-down mode.
- (4) Click noise occurs at the edge of PDN signal. This noise is output even if “0” data is input.
- (5) MCLK, BICK and LRCK clocks can be stopped in power-down mode (PDN pin= “L”).
- (6) Mute the analog output externally if click noise (3) adversely affect system performance
The timing example is shown in this figure.
- (7) DZF1/2 pins are “L” in the power-down mode (PDN pin = “L”).

Figure 20. Power-down/up Sequence Example

Reset Function

(1) RESET by RSTN bit = "0"

When the RSTN bit = "0", the AK4414's digital block is powered down, but the internal register values are not initialized. In this time, the analog outputs go to VCM1/2 voltage and DZF1/2 pins are "H". Figure 21 shows an example of reset by RSTN bit.



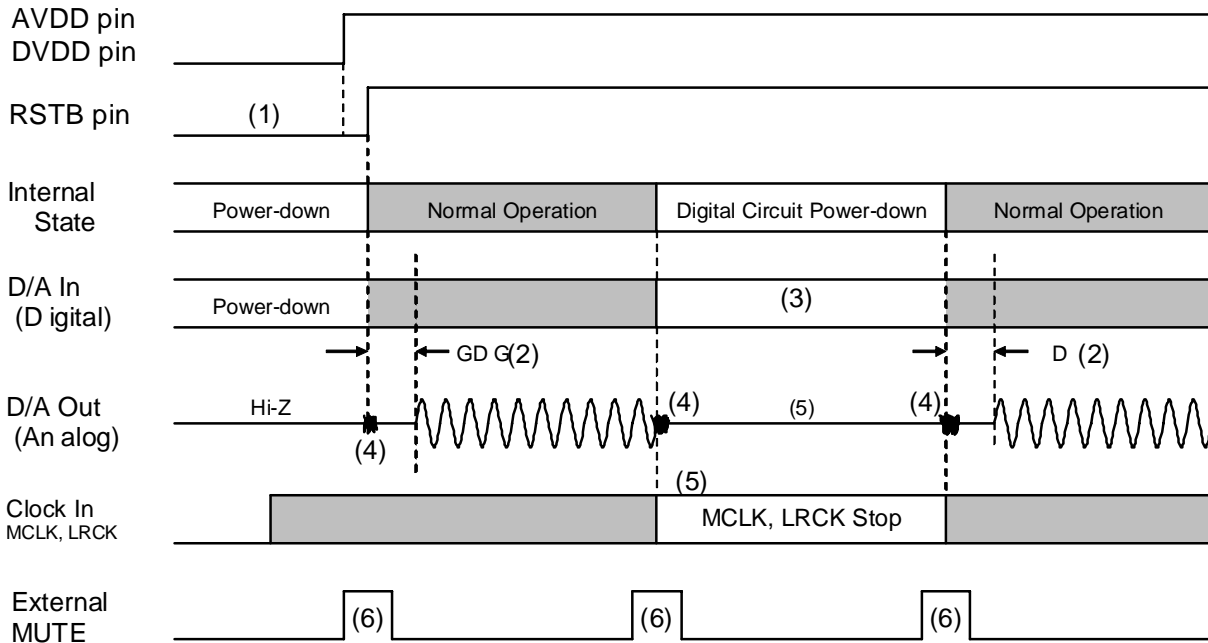
Notes:

- (1) The analog output corresponding to digital input has group delay (GD).
- (2) Analog outputs settle to VCOM voltage.
- (3) Small pop noise occurs at the edges ("↑ ↓") of the internal timing of RSTN bit. This noise is output even if "0" data is input.
- (4) The DZF pins change to "H" when the RSTN bit becomes "0", and return to "L" at $2/f_s$ after RSTN bit becomes "1".
- (5) There is a delay, $3\sim 4/f_s$ from RSTN bit "0" to the internal RSTN bit "0", and $2\sim 3/f_s$ from RSTN bit "1" to the internal RSTN bit "1".
- (6) Mute the analog output externally if click noise (3) and Hi-Z (2) adversely affect system performance

Figure 21. Reset Sequence Example 1

(2) RESET by MCLK or LRCK Stop

The AK4414 is automatically placed in reset state when MCLK or LRCK is stopped during PCM mode (RSTN pin = "H"), and the analog outputs are floating (Hi-Z). When MCLK and LRCK are input again, the AK4414 exits reset state and starts the operation. Zero detect function is disabled when MCLK or LRCK is stopped. In DSD mode the AK4414 is in reset state when MCLK is stopped.



Notes:

- (1) After AVDD and DVDD are powered-up, the PDN pin should be "L" for 150ns.
- (2) The analog output corresponding to digital input has group delay (GD).
- (3) The digital data can be stopped. Click noise after MCLK and LRCK are input again can be reduced by inputting "0" data during this period.
- (4) Click noise occurs within 3 ~ 4LRCK cycles from the rising edge ("↑") of the PDN pin or MCLK inputs. This noise occurs even when "0" data is input.
- (5) Clocks (MCLK, BICK, LRCK) can be stopped in the reset state (MCLK or LRCK is stopped).
- (6) Mute the analog output externally if click noise (4) influences system applications. The timing example is shown in this figure.

Figure 22. Reset Sequence Example 2

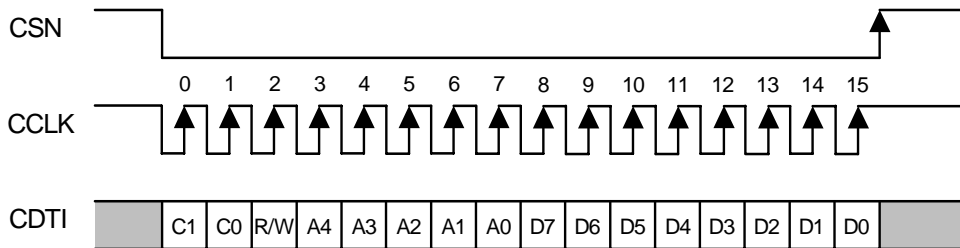
■ Register Control Interface

Pins (parallel control mode) or registers (serial control mode) can control the functions of the AK4414. In parallel control mode, the register setting is ignored, and in serial control mode the pin settings are ORed if the pin is not repurposed. When the state of the PSN pin is changed, the AK4414 should be reset by the PDN pin. The serial control interface is enabled by the PSN pin = “L”. In this mode, pin settings must be all “L”. Internal registers may be written to through 3-wire μ P interface pins: CSN, CCLK and CDTI. The data on this interface consists of Chip address (2-bits, C1/0), Read/Write (1-bit; fixed to “1”), Register address (MSB first, 5-bits) and Control data (MSB first, 8-bits). The AK4414 latches the data on the rising edge of CCLK, so data should be clocked in on the falling edge. The writing of data is valid when CSN “ \uparrow ”. The clock speed of CCLK is 5MHz (max).

| Function | Parallel mode | Serial mode |
|-----------------------|---------------|-------------|
| Auto Setting Mode | Y | Y |
| Manual Setting Mode | Y | Y |
| Audio Format | Y | Y |
| De-emphasis Y | | Y |
| SMUTE Y | | Y |
| TDM Mode | Y (4-ch only) | Y |
| Digital Filter Option | Y | Y |
| DSD Mode | - | Y |
| Zero Detection | - | Y |
| Digital Attenuator | - | Y |

Table 25. Function List1 (Y: Available, -: Not available)

Setting the PDN pin to “L” resets the registers to their default values. In serial control mode, the internal timing circuit is reset by the RSTN bit, but the registers are not initialized.



C1-C0: Chip Address (C1 bit =CAD1 pin, C0 bit =CAD0 pin)
 R/W: READ/WRITE (Fixed to “1”, Write only)
 A4-A0: Register Address
 D7-D0: Control Data

Figure 23. Control I/F Timing

- * The AK4414 does not support the read command.
- * When the AK4414 is in power down mode (PDN pin = “L”) or the MCLK is not provided, a writing into the control registers is prohibited.
- * The control data can not be written when the CCLK rising edge is 15 times or less or 17 times or more during CSN is “L”.

Function List

| Function Defau | lt | Address | Bit | PCM | DSD |
|---|-----------------------|--------------------------|----------------|-----|-----|
| Attenuation Level | 0dB | 03H 04H 06H 07H | ATT7-0 Y | | Y |
| Audio Data Interface Modes | 24bit MSB Justified | 00H | DIF2-0 | Y | - |
| Data Zero Detect Enable | Disable | 08H 09H | L1/R1/L2/R2 Y | | Y |
| Minimum delay Filter Enable | Sharp roll-off filter | 01H | SD | Y | - |
| Slow Rolloff Filter Enable | | 02H | SLOW | Y | - |
| Short delay Filter Enable | | | | Y - | |
| De-emphasis Response | OFF | 01H 0AH | DEM3-0 Y | | - |
| Soft Mute Enable | Normal Operation | 01H | SMUTE | Y | Y |
| DSD/PCM Mode Select | PCM mode | 02H | D/P | Y | Y |
| Master C lock Frequency Sel ect at DSD mode | 512fs 02 | H | DCKS | - | Y |
| MONO mode Stereo mode select | Stereo | 02H | MONO | Y | Y |
| Inverting Enable of DZF | “H” active | 02H | DZFB | Y | Y |
| The data selection of L channel and R channel | R channel | 02H 05H | SELLR1/2 Y | | Y |
| The dat a sel ection of DAC 1 and DAC2 | Normal 0A | H | SDS1/2 | Y | - |
| Data Invert Mode | OFF | 05H | INVL1/L2/R1/R2 | Y | Y |

Table 26. Function List2 (Y: Available, -: Not available)

■ Register Map

| Addr | Register Name | D7 | D6 D5 | D4 D3 D2 D1 | | | | D0 | |
|------|---------------|-------------|-------|-------------|-----------|--------|------|--------|-------|
| 00H | Control 1 | ACKS | 0 0 0 | | | DIF2 | DIF1 | DIF0 | RSTN |
| 01H | Control 2 | 0 | 0 | SD | DFS1 | DFS0 | DEM1 | DEM0 | SMUTE |
| 02H | Control 3 | DP | 0 | DCKS | DCKB | MONO | DZFB | SELLR1 | SLOW |
| 03H | L1ch ATT | ATT7 ATT6 | ATT5 | | ATT4 ATT3 | ATT2 | ATT1 | | ATT0 |
| 04H | R1ch ATT | ATT7 ATT6 | ATT5 | | ATT4 ATT3 | ATT2 | ATT1 | | ATT0 |
| 05H | Control 4 | INVL1 INVR1 | | INVL2 INVR2 | | SELLR2 | 0 | 0 | 0 |
| 06H | L2ch ATT | ATT7 ATT6 | ATT5 | | ATT4 ATT3 | ATT2 | ATT1 | | ATT0 |
| 07H | R2ch ATT | ATT7 ATT6 | ATT5 | | ATT4 ATT3 | ATT2 | ATT1 | | ATT0 |
| 08H | DZF1 Control | L1 R1 | L2 R2 | | | 0 | 0 | 0 | 0 |
| 09H | DZF2 Control | L1 R1 | L2 R2 | | | 0 | 0 | 0 | 0 |
| 0AH | Control 5 | TDM1 | TDM0 | SDS1 | SDS2 | PW2 | PW1 | DEM3 | DEM2 |

Notes:

Data must not be written into addresses from 0BH to 1FH.

When the PDN pin goes to “L”, the registers are initialized to their default values.

When RSTN bit is set to “0”, only the internal timing is reset, and the registers are not initialized to their default values.

When the state of the PSN pin is changed, the AK4414 should be reset by the PDN pin.

■ Register Definitions

| Addr | Register Name | D7 | D6 D5 | D4 D3 D2 D1 | | | | D0 | |
|------|---------------|-------|-------|-------------|--|------|------|------|------|
| 00H | Control 1 | ACKS | 0 0 0 | | | DIF2 | DIF1 | DIF0 | RSTN |
| | Default | 0 0 0 | 0 1 0 | | | | | | 1 |

RSTN: Internal Timing Reset

0: Reset. All registers are not initialized.

1: Normal Operation (default)

Internal clock timings are reset but registers are not reset.

DIF2-0: Audio Data Interface Modes (Table 16)

Initial value is “010” (Mode 2: 24-bit MSB justified).

ACKS: Master Clock Frequency Auto Setting Mode Enable (PCM only)

0: Disable : Manual Setting Mode (default)

1: Enable : Auto Setting Mode

When ACKS bit = “1”, the sampling frequency and MCLK frequency are detected automatically.

| Addr | Register Name | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | | |
|------|---------------|----|----|----|----|----|------|------|------|------|-------|
| 01H | Control 2 | 0 | 0 | | SD | | DFS1 | DFS0 | DEM1 | DEM0 | SMUTE |
| | Default | 0 | 0 | 1 | 0 | 0 | 1 | | | | 0 |

SMUTE: Soft Mute Enable

- 0: Normal Operation (default)
- 1: DAC outputs soft-muted.

DEM1-0: DAC1 De-emphasis Response ([Table 19](#))

Initial value is "01" (OFF).

SD: Short delay Filter Enable. This setting is ORed with the pin setting.

- 0 : Sharp roll-off filter
- 1 : Short delay filter (default)

| SD SLOW | | Mode |
|---------|---|----------------------------|
| 0 | 0 | Sharp roll-off filter |
| 0 | 1 | Slow roll-off filter |
| 1 | 0 | Short delay sharp roll-off |
| 1 | 1 | Short delay slow roll-off |

(default)

Table 27. Digital Filter setting

DFS1-0: Sampling Speed Control ([Table 8](#))

The default values are "00". A click noise occurs when changing DFS1-0 bits.

| Addr | Register Name | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|------|---------------|----|----|------|------|------|------|--------|------|
| 02H | Control 3 | DP | 0 | DCKS | DCKB | MONO | DZFB | SELLR1 | SLOW |
| | Default | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

SLOW: Slow Roll-off Filter Enable. This setting is ORed with the pin setting.

0 : (default)

1 : Slow roll-off filter

| SD | SLOW | Mode |
|----|------|----------------------------|
| 0 | 0 | Sharp roll-off filter |
| 0 | 1 | Slow roll-off filter |
| 1 | 0 | Short delay sharp roll-off |
| 1 | 1 | Short delay slow roll-off |

(default)

Table 28. Digital Filter setting

SELLR1: The data selection of L channel and R channel, when MONO mode

0: All channel output L channel data, when MONO mode. (default)

1: All channel output R channel data, when MONO mode.

It is enabled when MONO bit is "1", and outputs Lch data to both channels when "0", outputs Rch data to both channels when "1".

DZFB: Inverting Enable of DZF

0: DZF pin goes "H" at Zero Detection (default)

1: DZF pin goes "L" at Zero Detection

MONO: MONO mode Stereo mode select

0: Stereo mode (default)

1 : MONO mode

When MONO bit is "1", MONO mode is enabled.

DCKB: Polarity of DCLK (DSD Only)

0: DSD data is output from DCLK falling edge. (default)

1: DSD data is output from DCLK rising edge.

DCKS: Master Clock Frequency Select at DSD mode (DSD only)

0: 512fs (default)

1: 768fs

DP: DSD/PCM Mode Select

0: PCM Mode (default)

1 : DSD Mode

When D/P bit is changed, the AK4414 should be reset by RSTN bit.

| Addr | Register Name | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | | | | | | | | | |
|------|---------------|------|------|------|----|----|----|------|------|------|------|--|--|--|--|--|--|------|
| 03H | L1ch ATT | ATT7 | ATT6 | ATT5 | | | | ATT4 | ATT3 | ATT2 | ATT1 | | | | | | | ATT0 |
| 04H | R1ch ATT | ATT7 | ATT6 | ATT5 | | | | ATT4 | ATT3 | ATT2 | ATT1 | | | | | | | ATT0 |
| | Default | 1 | 1 | 1 | | | | 1 | 1 | 1 | 1 | | | | | | | 1 |

ATT7-0: Attenuation Level

25 5 levels, 0.5dB step

| Data | Attenuation |
|------|--------------------|
| FFH | 0dB |
| FEH | -0.5dB |
| FDH | -1.0dB |
| : | : |
| : | : |
| 02H | -126.5dB |
| 01H | -127.0dB |
| 00H | MUTE ($-\infty$) |

The transition between set values is soft transition of 7425 levels. It takes $7424/fs$ ($168ms@fs=44.1kHz$) from FFH (0dB) to 00H (MUTE). If the PDN pin goes to "L", the ATTs are initialized to FFH. The ATTs are FFH when RSTN bit="0". When RSTN return to "1", the ATTs fade to their current value. This digital attenuator is independent of soft mute function.

| Addr | Register Name | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
|------|---------------|-------|-------|-------|-------|----|--------|----|----|---|
| 05H | Control 4 | INVL1 | INVR1 | INVL2 | INVR2 | | SELLR2 | 0 | 0 | 0 |
| | Default | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 |

SELLR2: The data selection of AOUTL2-R2, when MONO mode

0: AOUTL2-R2 output L channel data, when MONO mode. (default)

1: AOUTL2-R2 output R channel data, when MONO mode.

When MONO bit is set to "1", Lch data is output by SELLR2 bit = "0" and Rch data is output by SELLR2 bit = "1".

INVR2: AOUTR2 output phase invert bit

0: Disable (default)

1 : Enable

INVL2: AOUTL2 output phase invert bit

0: Disable (default)

1 : Enable

INVR1: AOUTR1 output phase invert bit

0: Disable (default)

1 : Enable

INVL1: AOUTL1 output phase invert bit

0: Disable (default)

1 : Enable

| Addr | Register Name | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
|------|---------------|-----------|------|------|------|------|------|-----------|-----------|------|
| 06H | L2ch ATT | ATT7 ATT6 | ATT5 | | | | | ATT4 ATT3 | ATT2 ATT1 | ATT0 |
| 07H | R2ch ATT | ATT7 | ATT6 | ATT5 | ATT4 | ATT3 | ATT2 | ATT1 | ATT0 | |
| | Default | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |

ATT7-0: Attenuation Level

25 5 levels, 0.5dB step

| Data | Attenuation |
|------|-------------|
| FFH | 0dB |
| FEH | -0.5dB |
| FDH | -1.0dB |
| : | : |
| : | : |
| 02H | -126.5dB |
| 01H | -127.0dB |
| 00H | MUTE (-∞) |

The transition between set values is soft transition of 7425 levels. It takes 7424/fs (168ms@fs=44.1kHz) from FFH (0dB) to 00H (MUTE). If the PDN pin goes to “L”, the ATTs are initialized to FFH. The ATTs are FFH when RSTN bit= “0”. When RSTN return to “1”, the ATTs fade to their current value. This digital attenuator is independent of soft mute function.

| Addr | Register Name | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|------|---------------|-------|-------|----|----|----|----|----|----|
| 08H | DZF1 Control | L1 R1 | L2 R2 | | | | | 0 | 0 |
| 09H | DZF2 Control | L1 R1 | L2 R2 | | | | | 0 | 0 |
| | Default | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

L1-2, R1-2: Zero Detect Flag Enable Bit for the DZF1-2 pins

0: Disable

1: Enable

| Addr | Register Name | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|------|---------------|------|------|------|------|-----|-----|------|------|
| 0AH | Control 5 | TDM1 | TDM0 | SDS1 | SDS2 | PW2 | PW1 | DEM3 | DEM2 |
| | Default | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |

DEM3-2: DAC2 De-emphasis Response (Table 20)

Initial value is “01” (OFF).

PW2-1: Power Down control for DAC

PW2: Power management for DAC2

0: DAC2 power OFF

1: DAC2 power ON (default)

PW1: Power management for DAC1

0: DAC1 power OFF

1: DAC1 power ON (default)

SDS1-2: DAC1 and DAC2 data select

0: Normal Operation

1: Outputs other slot data

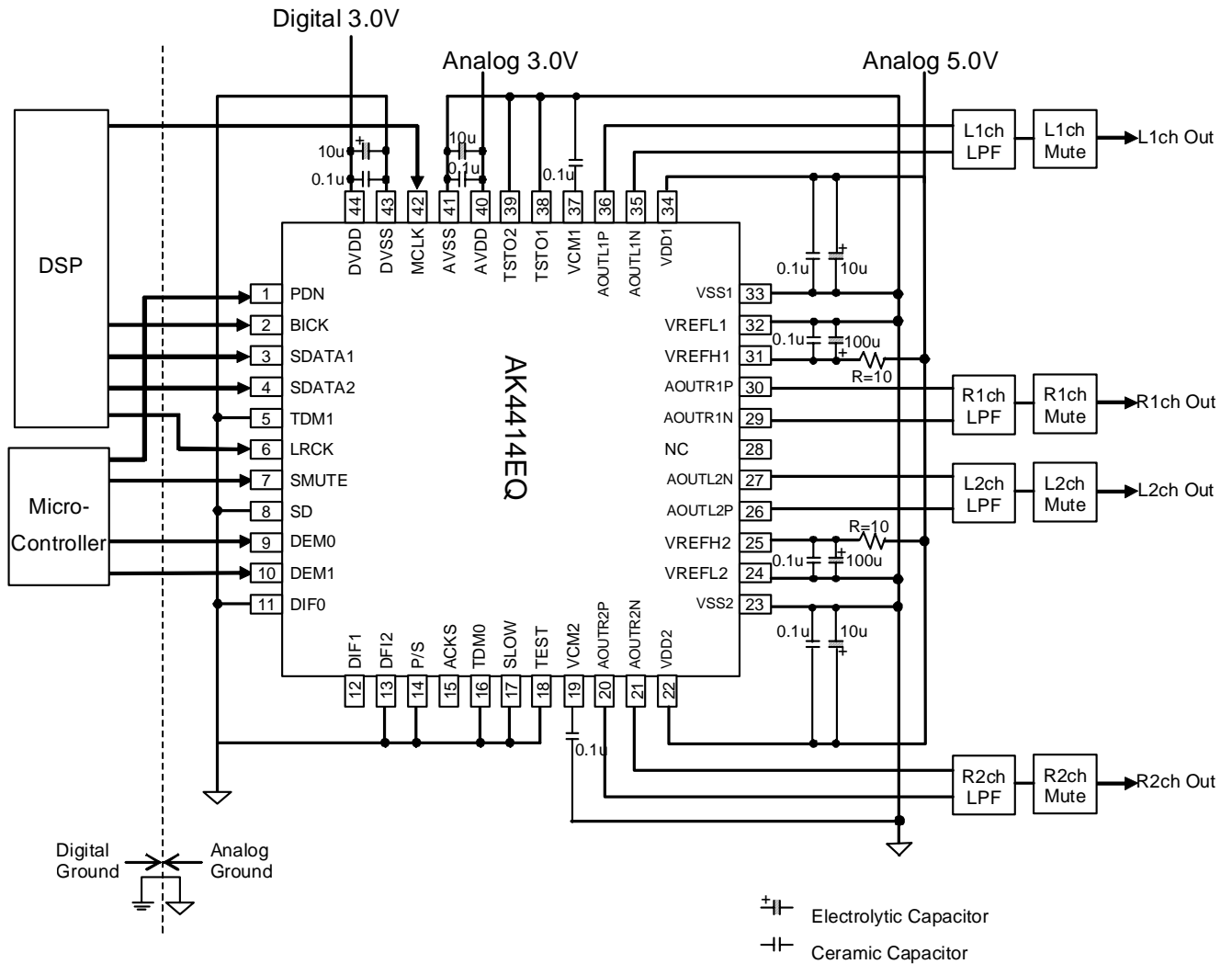
Refer to Table 17 for details.

TDM0-1: TDM Mode Select

| Mode | TDM | M | 1 | TDM0 | BICK | SDTI | Sampling Speed |
|--------|-----|---|---|------|-------------|------|----------------------------|
| Normal | 0 | | | 0 | 32fs~ | 1-2 | Normal, Double, Quad Speed |
| TDM256 | 0 | | | 1 | 256fs fixed | 1 | Normal Speed |
| TDM128 | 1 | | | 1 | 128fs fixed | 1-2 | Normal, Double, Quad Speed |

SYSTEM DESIGN

Figure 24 shows the system connection diagram. Figure 26, Figure 27 and Figure 28 show the analog output circuit examples. The evaluation board (AKD4414) demonstrates the optimum layout, power supply arrangements and measurement results.



Notes:

- Power lines of AVDD and DVDD should be distributed separately from the point with low impedance of regulator etc.
- VSS1-2, DVSS and AVSS must be connected to the same analog ground plane.
- When AOUT drives a capacitive load, some resistance should be added in series between AOUT and the capacitive load.
- All input pins except pull-down/pull-up pins should not be allowed to float.

Figure 24. Typical Connection Diagram (AVDD=3.0V, VDD1/2=5V, DVDD=3.0V, Serial Control Mode)

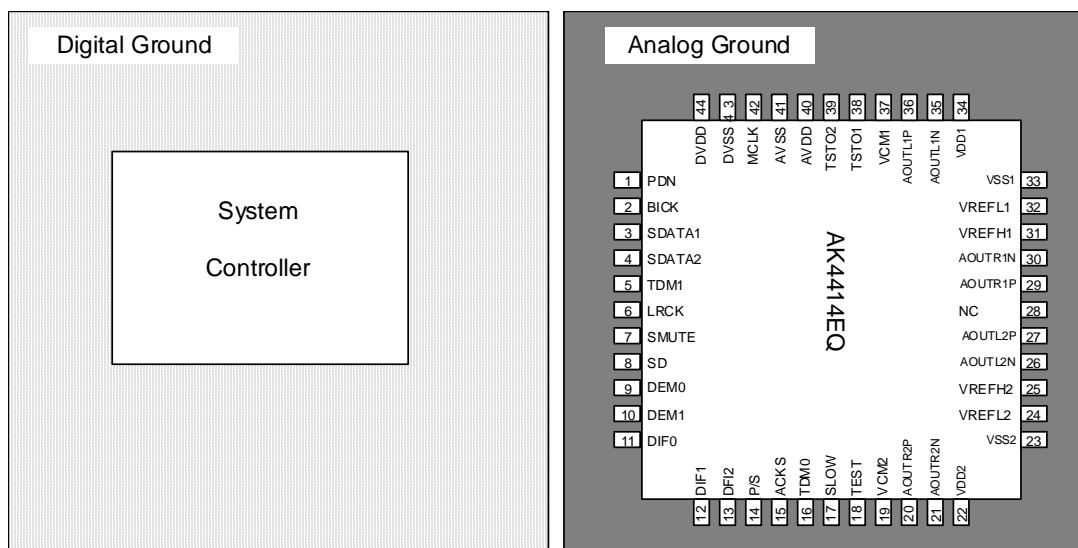


Figure 25. Ground Layout

1. Grounding and Power Supply Decoupling

To minimize coupling by digital noise, decoupling capacitors should be connected to AVDD, VDD1/2 and DVDD respectively. AVDD and VDD1/2 are supplied from analog supply in system and DVDD is supplied from digital supply in system. Power lines of AVDD, VDD1/2 and DVDD should be distributed separately from the point with low impedance of regulator etc. The power up sequence between AVDD, VDD1/2 and DVDD is not critical. **VSS1-2, DVSS and AVSS must be connected to the same analog ground plane.** Decoupling capacitors for high frequency should be placed as near as possible to the supply pin.

2. Voltage Reference

The differential voltage between VREFH1/2 and VREFL1/2 sets the analog output range. The VREFH1/2 pin is normally connected to AVDD, and the VREFL1/2 pin is normally connected to VSS1/VSS2/AVSS. VREFH1/2 and VREFL1/2 should be connected with a 0.1 μ F ceramic capacitor as near as possible to the pin to eliminate the effects of high frequency noise. No load current may be drawn from VCM1/2 pin. All signals, especially clocks, should be kept away from the VREFH1/2 and VREFL1/2 pins in order to avoid unwanted noise coupling into the AK4414.

3. Analog Outputs

The analog outputs are full differential outputs and 2.8V_{pp} (typ, VREFH1/2 – VREFL1/2 = 5V) centered around AVDD/2. The differential outputs are summed externally, $V_{AOUT} = (AOUT+) - (AOUT-)$ between AOUT+ and AOUT-. If the summing gain is 1, the output range is 5.6V_{pp} (typ, VREFH1/2 – VREFL1/2 = 5V). The bias voltage of the external summing circuit is supplied externally. The input data format is 2's complement. The output voltage (V_{AOUT}) is a positive full scale for 7FFFFFFH (@24bit) and a negative full scale for 800000H (@24bit). The ideal V_{AOUT} is 0V for 000000H (@24bit).

The internal switched-capacitor filters attenuate the noise generated by the delta-sigma modulator beyond the audio passband.

Figure 26 shows an example of external LPF circuit summing the differential outputs by an op-amp.

Figure 27 shows an example of differential outputs and LPF circuit example by three op-amps.

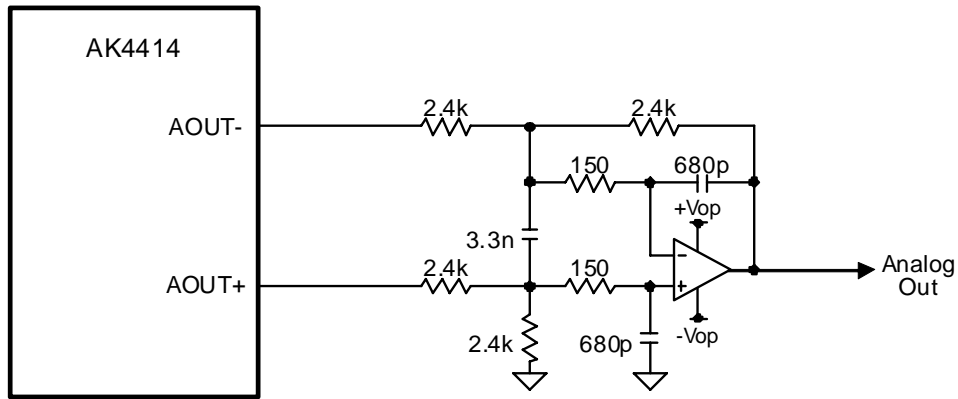


Figure 26. External LPF Circuit Example 1 for PCM ($f_c = 125\text{kHz}$, $Q=0.692$)

| Frequency Response | Gain |
|--------------------|----------|
| 20kHz | -0.036dB |
| 40kHz | -0.225dB |
| 80kHz | -1.855dB |

Table 29. Frequency Response of External LPF Circuit Example 1 for PCM

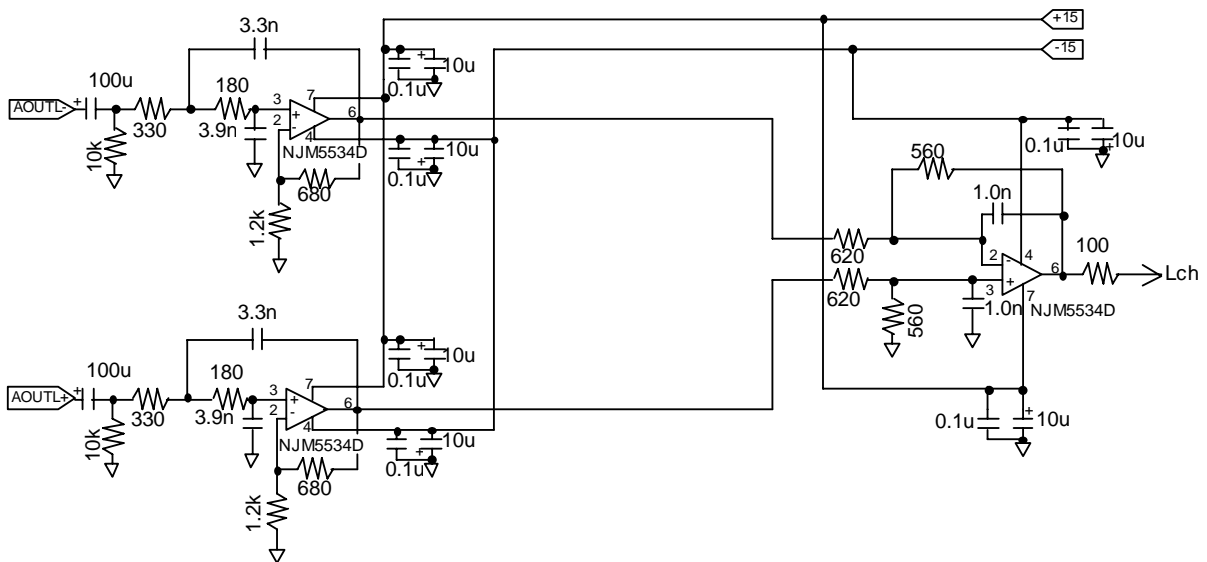


Figure 27. External LPF Circuit Example 2 for PCM

| 1 | | 1 st Stage | 2 nd Stage | Total |
|--------------------|-------|-----------------------|-----------------------|----------|
| Cut-off Frequency | | 182kHz | 284kHz | - |
| Q | | 0.637 | - | - |
| Gain | | +3.9dB | -0.88dB | +3.02dB |
| Frequency Response | 20kHz | -0.025 | -0.021 | -0.046dB |
| | 40kHz | -0.106 | 0.085 | -0.191dB |
| | 80kHz | -0.517 | -0.331 | -0.848dB |

Table 30. Frequency Response of External LPF Circuit Example 2 for PCM

It is recommended for SACD format book (Scarlet Book) that the filter response at SACD playback is an analog low pass filter with a cut-off frequency of maximum 50kHz and a slope of minimum 30dB/Oct. The AK4414 can achieve this filter response by combination of the internal filter (Table 31) and an external filter (Figure 28).

| Frequency Gain | n |
|----------------|---------|
| 20kHz | -0.4dB |
| 50kHz | -2.8dB |
| 100kHz | -15.5dB |

Table 31. Internal Filter Response at DSD Mode

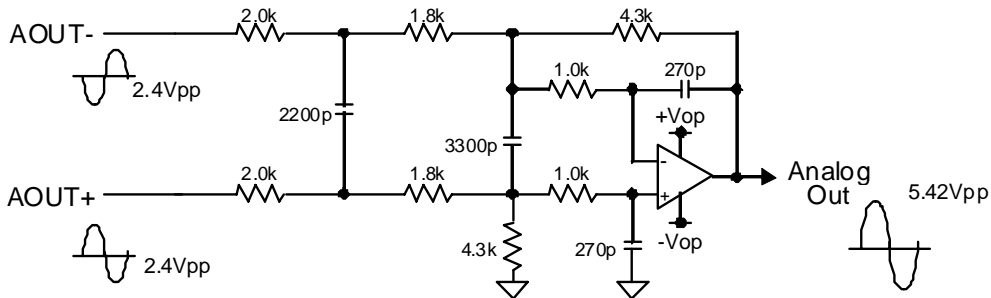


Figure 28. External 3rd Order LPF Circuit Example for DSD

| Frequency Gain | n |
|----------------|---------|
| 20kHz | -0.05dB |
| 50kHz | -0.51dB |
| 100kHz | -16.8dB |

DC gain = 1.07dB

Table 32. 3rd Order LPF (Figure 28) Response

4. Measurement Example

Figure 29 shows the relationship between THD+N and Frequency.

Measurement condition

Ta=25°C; AVDD=DVDD=3.3V, VDD1/2=5.0V; AVSS=VSS1/2=DVSS=0V; VREFH1/2=VDD1/2, VREFL1/2= AVSS; Mono bit = "1"; Signal Frequency = 1kHz; Sampling Frequency = 44.1kHz; Measurement bandwidth = 20Hz ~ 20kHz Measured by Audio Precision System Two.

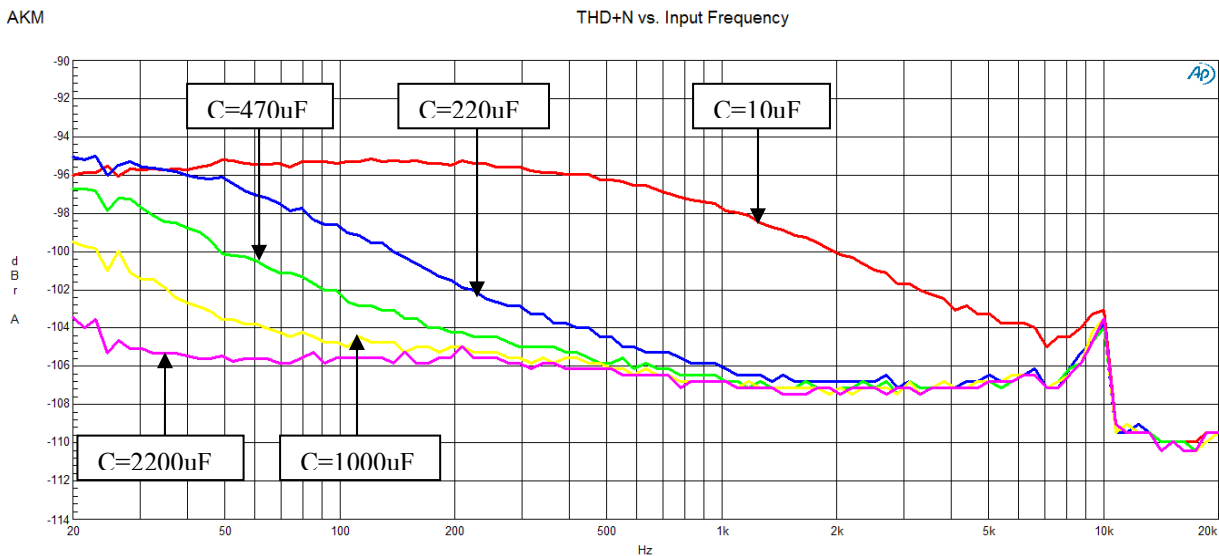
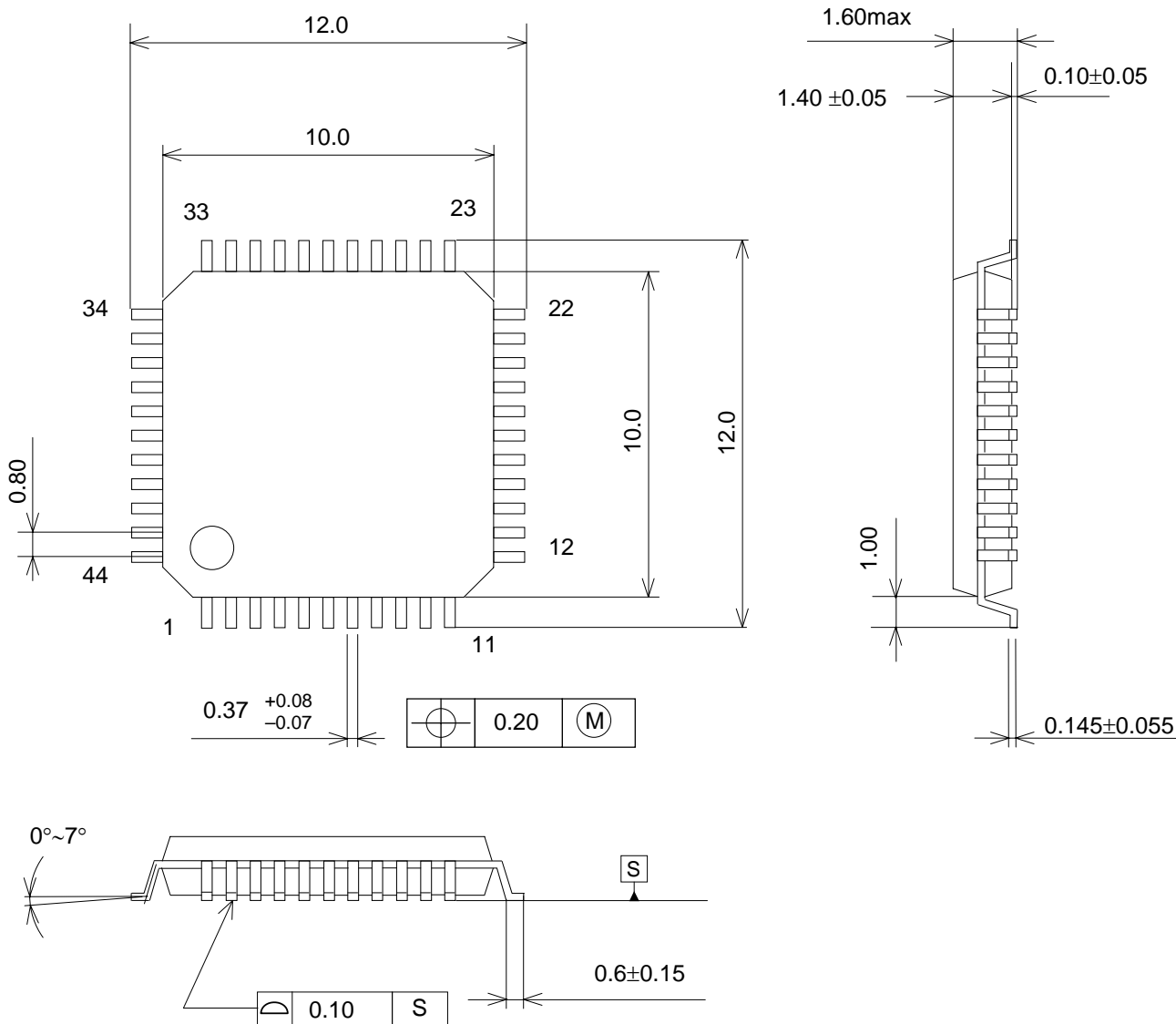


Figure 29. THD+N vs. Frequency

PACKAGE

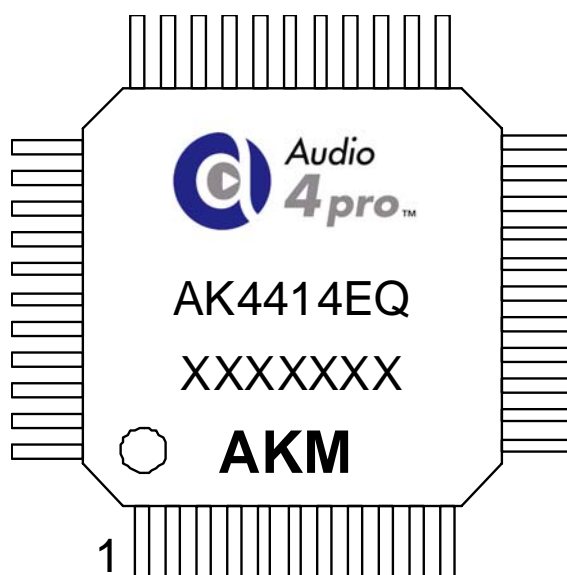
44pin LQFP (Unit: mm)



Material & Lead finish

- Package molding compound: Epoxy, Halogen (bromine and chlorine) free
- Lead frame material: Cu
- Lead frame surface treatment: Solde r (Pb free) plate

| |
|----------------|
| MARKING |
|----------------|



- 1) Pin #1 indication
- 2) AKM Logo
- 3) Date Code: XXXXXXXX(7 digits)
- 4) Marking Code: AK4414
- 5) Audio 4 pro Logo

| |
|-------------------------|
| REVISION HISTORY |
|-------------------------|

| Date (Y/M/D) | Revision | Reason | Page | Contents |
|--------------|----------|------------------|------|---|
| 12/11/16 00 | | First Edition | | |
| 13/01/15 01 | | Error Correction | 41 | <ul style="list-style-type: none"> ■ Register Definitions DEM1-0: The table number was corrected. |
| | | | 44 | A0H, Control 5 D3: The default value was changed. (0 → 1) D0: The default value was changed. (0 → 1) DEM3-2: Description was changed. PW2-1: Description was added. |
| | | | 48 | SYSTEM DESIGN 4. Measurement Example Measurement Condition was changed. |

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