



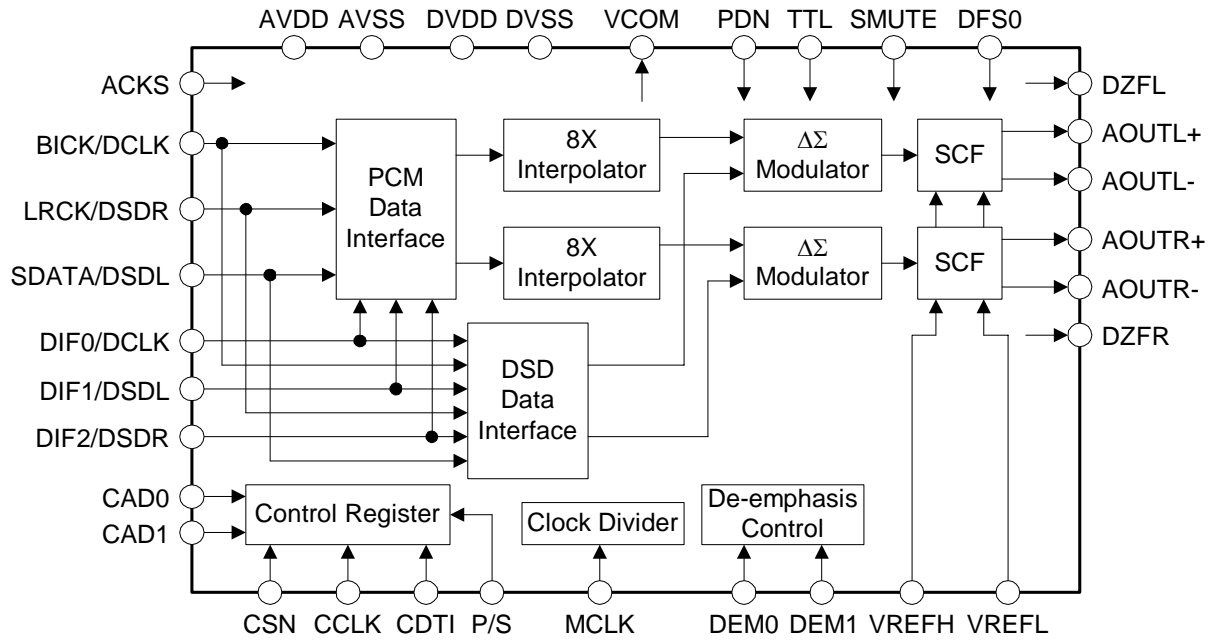
#### GENERAL DESCRIPTION

The AK4396 is a high performance stereo DAC for the 192kHz sampling mode of DVD-Audio including a 24bit digital filter. Using AKM's multi bit architecture for its modulator the AK4396 delivers a wide dynamic range while preserving linearity for improved THD+N performance. The AK4396 has full differential SCF outputs, removing the need for AC coupling capacitors and increasing performance for systems with excessive clock jitter. The AK4396 accepts 192kHz PCM data and 1-bit DSD data, ideal for a wide range of applications including DVD-Audio and SACD. The AK4396 has a fully functional compatibility with the AK4393/4/5 and lower power dissipation.

#### FEATURES

- **128x Oversampling**
- **Sampling Rate: 30kHz ~ 216kHz**
- **24Bit 8x Digital Filter (Slow-roll-off option)**  
     **Ripple:  $\pm 0.005$ dB, Attenuation: 75dB**
- **High Tolerance to Clock Jitter**
- **Low Distortion Differential Output**
- **DSD data input available**
- **Digital de-emphasis for 32, 44.1, 48kHz sampling**
- **Soft Mute**
- **Digital Attenuator (Linear 256 steps)**
- **THD+N: -100dB**
- **DR, S/N: 120dB**
- **I/F format : MSB justified, 16/20/24bit LSB justified, I<sup>2</sup>S**
- **Master Clock: Normal Speed: 256fs, 384fs, 512fs, 768fs or 1152fs**  
     **Double Speed: 128fs, 192fs, 256fs or 384fs**  
     **Quad Speed: 128fs or 192fs**  
     **DSD: 512fs or 768fs**
- **Power Supply: 5V  $\pm$  5% (Analog), 3.0 ~ 5.25V (Digital)**
- **CMOS or TTL Level Digital I/F**
- **Package: 28pin VSOP**
- **Pin Compatible with AK4393/4/5**

■ Block Diagram

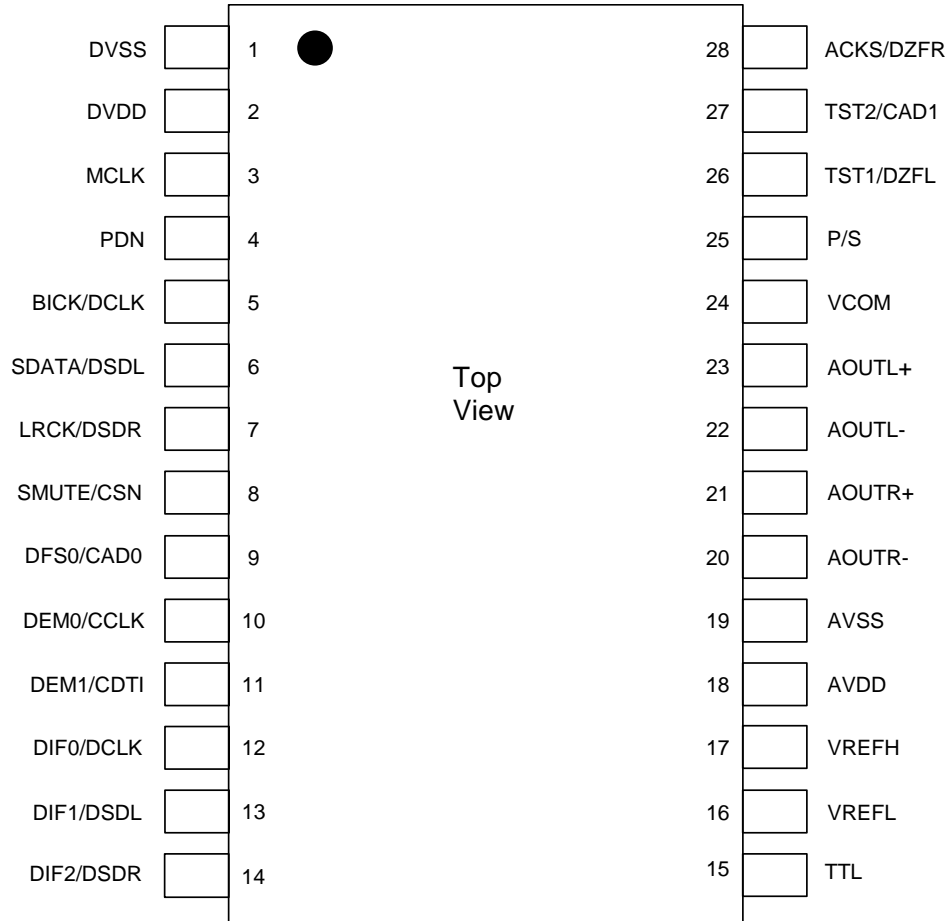


Block Diagram

■ Ordering Guide

|          |                             |                           |
|----------|-----------------------------|---------------------------|
| AK4396VF | -40 ~ +85°C                 | 28pin VSOP (0.65mm pitch) |
| AKD4396  | Evaluation Board for AK4396 |                           |

■ Pin Layout



## ■ Compatibility with AK4393/4/5

### 1. Function & Performance

|                         | AK4393               | AK4394               | AK4395               | AK4396                |
|-------------------------|----------------------|----------------------|----------------------|-----------------------|
| fs (max)                | 108kHz               | 216kHz               | 216kHz               | 216kHz                |
| DVDD                    | 3~5.25V              | 4.75~5.25V           | 4.75~5.25V           | 3~5.25V               |
| Power Dissipation       | 310mW                | 325mW                | 335mW                | 200mW                 |
| Digital Input Level     | CMOS                 | TTL                  | TTL                  | CMOS/TTL              |
| DF Stopband Attenuation | 75dB                 | 75dB                 | 110dB                | 75dB                  |
| Digital Volume          | Not available        | Not available        | 256 levels,<br>0.5dB | 256 levels,<br>Linear |
| μP I/F Address Pin      | Not available        | Not available        | CAD0/1               | CAD0/1                |
| De-emphasis Filter      | 32k, 44.1k, 48k, 96k | 32k, 44.1k, 48k, 96k | 32k, 44.1k, 48k      | 32k, 44.1k, 48k       |
| Optional DF             | Not available        | Slow Roll-off        | Slow Roll-off        | Slow Roll-off         |
| Zero Detection Pin      | Not available        | DZFL/R               | DZFL/R               | DZFL/R                |
| DSD Mode                | No                   | No                   | No                   | Yes                   |
| Pin #15                 | BVSS                 | BVSS                 | BVSS                 | TTL                   |
| Pin #26 (Serial mode)   | CKS0                 | DZFL                 | DZFL                 | DZFL                  |
| Pin #28 (Serial mode)   | CKS2                 | DZFR                 | DZFR                 | DZFR                  |

### 2. Pin Configuration

| Pin# | AK4393    | AK4394    | AK4395    | AK4396    |
|------|-----------|-----------|-----------|-----------|
| 1    | DVSS      | DVSS      | DVSS      | DVSS      |
| 2    | DVDD      | DVDD      | DVDD      | DVDD      |
| 3    | MCLK      | MCLK      | MCLK      | MCLK      |
| 4    | PDN       | PDN       | PDN       | PDN       |
| 5    | BICK      | BICK      | BICK      | BICK      |
| 6    | SDATA     | SDATA     | SDATA     | SDATA     |
| 7    | LRCK      | LRCK      | LRCK      | LRCK      |
| 8    | SMUTE/CSN | SMUTE/CSN | SMUTE/CSN | SMUTE/CSN |
| 9    | DFS0      | DFS0      | DFS0/CAD0 | DFS0/CAD0 |
| 10   | DEM0/CCLK | DEM0/CCLK | DEM0/CCLK | DEM0/CCLK |
| 11   | DEM1/CDTI | DEM1/CDTI | DEM1/CDTI | DEM1/CDTI |
| 12   | DIF0      | DIF0      | DIF0      | DIF0      |
| 13   | DIF1      | DIF1      | DIF1      | DIF1      |
| 14   | DIF2      | DIF2      | DIF2      | DIF2      |
| 15   | BVSS      | BVSS      | BVSS      | TTL       |
| 16   | VREFL     | VREFL     | VREFL     | VREFL     |
| 17   | VFEFH     | VFEFH     | VFEFH     | VFEFH     |
| 18   | AVDD      | AVDD      | AVDD      | AVDD      |
| 19   | AVSS      | AVSS      | AVSS      | AVSS      |
| 20   | AOUTR-    | AOUTR-    | AOUTR-    | AOUTR-    |
| 21   | AOUTR+    | AOUTR+    | AOUTR+    | AOUTR+    |
| 22   | AOUTL-    | AOUTL-    | AOUTL-    | AOUTL-    |
| 23   | AOUTL+    | AOUTL+    | AOUTL+    | AOUTL+    |
| 24   | VCOM      | VCOM      | VCOM      | VCOM      |
| 25   | P/S       | P/S       | P/S       | P/S       |
| 26   | CKS0      | CKS0/DZFL | CKS0/DZFL | TST1/DZFL |
| 27   | CKS1      | CKS1      | CKS1/CAD1 | TST2/CAD1 |
| 28   | CKS2      | CKS2/DZFR | ACKS/DZFR | ACKS/DZFR |

TST1-2: Don't care at parallel mode.

### 3. Compatibility of master clock select in parallel mode

| AK4393/4/5 |      |      |        |        | AK4396 |        |        |
|------------|------|------|--------|--------|--------|--------|--------|
| CKS2       | CKS1 | CKS0 | DFS0=0 | DFS0=1 | ACKS   | DFS0=0 | DFS0=1 |
| 0          | 0    | 0    | 256fs  | 128fs  | 0      | 256fs  | 128fs  |
| 0          | 0    | 1    | 256fs  | 256fs  | 0      | 256fs  | 256fs  |
| 0          | 1    | 0    | 384fs  | 192fs  | 0      | 384fs  | 192fs  |
| 0          | 1    | 1    | 384fs  | 384fs  | 0      | 384fs  | 384fs  |
| 1          | 0    | 0    | 512fs  | 256fs  | 1      | 512fs  | 256fs  |
| 1          | 0    | 1    | 512fs  | N/A    | 1      | 512fs  | N/A    |
| 1          | 1    | 0    | 768fs  | 384fs  | 1      | 768fs  | 384fs  |
| 1          | 1    | 1    | 768fs  | N/A    | 1      | 768fs  | N/A    |

: The setting of DFS0 is ignored.

### 4. Register map

| Addr | Register Name   | D7   | D6   | D5   | D4   | D3   | D2          | D1          | D0    |
|------|-----------------|------|------|------|------|------|-------------|-------------|-------|
| 00H  | Control 1       | ACKS | 0    | 0    | 0    | DIF2 | <i>DIF1</i> | DIF0        | RSTN  |
| 01H  | Control 2       | DZFE | DZFM | SLOW | DFS1 | DFS0 | DEM1        | <i>DEM0</i> | SMUTE |
| 02H  | Control 3       | D/P  | DSDM | DCKS | DCKB | 0    | DZFB        | 0           | 0     |
| 03H  | Lch ATT Control | ATT7 | ATT6 | ATT5 | ATT4 | ATT3 | ATT2        | ATT1        | ATT0  |
| 04H  | Rch ATT Control | ATT7 | ATT6 | ATT5 | ATT4 | ATT3 | ATT2        | ATT1        | ATT0  |

: Changing points from AK4393's register.

Italic means the default value differs from AK4393.

| Addr | Register Name   | D7   | D6   | D5   | D4   | D3   | D2          | D1          | D0    |
|------|-----------------|------|------|------|------|------|-------------|-------------|-------|
| 00H  | Control 1       | ACKS | 0    | 0    | 0    | DIF2 | <i>DIF1</i> | DIF0        | RSTN  |
| 01H  | Control 2       | DZFE | DZFM | SLOW | DFS1 | DFS0 | DEM1        | <i>DEM0</i> | SMUTE |
| 02H  | Control 3       | D/P  | DSDM | DCKS | DCKB | 0    | DZFB        | 0           | 0     |
| 03H  | Lch ATT Control | ATT7 | ATT6 | ATT5 | ATT4 | ATT3 | ATT2        | ATT1        | ATT0  |
| 04H  | Rch ATT Control | ATT7 | ATT6 | ATT5 | ATT4 | ATT3 | ATT2        | ATT1        | ATT0  |

: Changing points from AK4394's register.

Italic means the default value differs from AK4394.

| Addr | Register Name   | D7   | D6   | D5   | D4   | D3   | D2          | D1   | D0    |
|------|-----------------|------|------|------|------|------|-------------|------|-------|
| 00H  | Control 1       | ACKS | 0    | 0    | 0    | DIF2 | <i>DIF1</i> | DIF0 | RSTN  |
| 01H  | Control 2       | DZFE | DZFM | SLOW | DFS1 | DFS0 | DEM1        | DEM0 | SMUTE |
| 02H  | Control 3       | D/P  | DSDM | DCKS | DCKB | 0    | DZFB        | 0    | 0     |
| 03H  | Lch ATT Control | ATT7 | ATT6 | ATT5 | ATT4 | ATT3 | ATT2        | ATT1 | ATT0  |
| 04H  | Rch ATT Control | ATT7 | ATT6 | ATT5 | ATT4 | ATT3 | ATT2        | ATT1 | ATT0  |

: Changing points from AK4395's register.

Italic means the default value differs from AK4395.

| PIN/FUNCTION |          |     |  |
|--------------|----------|-----|--|
| No.          | Pin Name | I/O | Function   |
| 1            | DVSS     | -   | Digital Ground Pin   |
| 2            | DVDD     | -   | Digital Power Supply Pin, 3.3V or 5.0V   |
| 3            | MCLK     | I   | Master Clock Input Pin   |
| 4            | PDN      | I   | Power-Down Mode Pin<br>When at "L", the AK4396 is in power-down mode and is held in reset.<br>The AK4396 should always be reset upon power-up. |
| 5            | BICK     | I   | Audio Serial Data Clock Pin in PCM mode  |
|              | DCLK     | I   | DSD Clock Pin in DSD mode  |
| 6            | SDATA    | I   | Audio Serial Data Input Pin in PCM mode  |
|              | DSDL     | I   | DSD Lch Data Input Pin in DSD mode   |
| 7            | LRCK     | I   | L/R Clock Pin in PCM mode  |
|              | DSDR     | I   | DSD Rch Data Input Pin in DSD mode   |
| 8            | SMUTE    | I   | Soft Mute Pin in parallel mode<br>When this pin goes "H", soft mute cycle is initiated.<br>When returning "L", the output mute releases.       |
|              | CSN      | I   | Chip Select Pin in serial mode   |
| 9            | DFS0     | I   | Sampling Speed Mode Select Pin in parallel mode (Internal pull-down pin)   |
|              | CAD0     | I   | Chip Address 0 Pin in serial mode (Internal pull-down pin)   |
| 10           | DEM0     | I   | De-emphasis Enable 0 Pin in parallel mode  |
|              | CCLK     | I   | Control Data Clock Pin in serial mode  |
| 11           | DEM1     | I   | De-emphasis Enable 1 Pin in parallel mode  |
|              | CDTI     | I   | Control Data Input Pin in serial mode  |
| 12           | DIF0     | I   | Digital Input Format 0 Pin in PCM mode   |
|              | DCLK     | I   | DSD Clock Pin in DSD mode  |
| 13           | DIF1     | I   | Digital Input Format 1 Pin in PCM mode   |
|              | DSDL     | I   | DSD Lch Data Input Pin in DSD mode   |
| 14           | DIF2     | I   | Digital Input Format 2 Pin in PCM mode   |
|              | DSDR     | I   | DSD Rch Data Input Pin in DSD mode   |

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

|    |        |   |  |                          |
|----|--------|---|--|--------------------------|
| 15 | TTL    | I | CMOS/TTL Level Select Pin<br>“L” : CMOS Level, “H” : TTL Level     | (Internal pull-up pin)   |
| 16 | VREFL  | I | Low Level Voltage Reference Input Pin                              |                          |
| 17 | VREFH  | I | High Level Voltage Reference Input Pin                             |                          |
| 18 | AVDD   | - | Analog Power Supply Pin, 5.0V                                      |                          |
| 19 | AVSS   | - | Analog Ground Pin  |                          |
| 20 | AOUTR- | O | Rch Negative Analog Output Pin                                     |                          |
| 21 | AOUTR+ | O | Rch Positive Analog Output Pin                                     |                          |
| 22 | AOUTL- | O | Lch Negative Analog Output Pin                                     |                          |
| 23 | AOUTL+ | O | Lch Positive Analog Output Pin                                     |                          |
| 24 | VCOM   | O | Common Voltage Output Pin, AVDD/2                                  |                          |
| 25 | P/S    | I | Parallel/Serial Select Pin<br>“L”: Serial Mode, “H”: Parallel Mode | (Internal pull-up pin)   |
| 26 | TST1   | O | Test 1 Pin in parallel mode  | (Don't Care)             |
|    | DZFL   | O | Lch Zero Input Detect Pin in serial mode                           |                          |
| 27 | TST2   | I | Test 2 Pin in parallel mode  | (Internal pull-down pin) |
|    | CAD1   | I | Chip Address 1 Pin in serial mode                                  | (Internal pull-down pin) |
| 28 | ACKS   | I | Master Clock Auto Setting Mode Pin in parallel mode                |                          |
|    | DZFR   | O | Rch Zero Input Detect Pin in serial mode                           |                          |

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

Note: TST1 pin outputs Hi-Z in parallel mode.

## ■ 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         | AOUTL+, AOUTL- | These pins should be open.            |
|                | AOUTR+, AOUTR- | These pins should be open.            |
| Digital        | SMUTE          | This pin should be connected to DVSS. |
|                | TST1           | This pin should be open.              |
|                | TST2           | This pin should be connected to DVSS. |

### (2) Serial mode

#### 1. PCM mode

| Classification | Pin Name         | Setting                                 |
|----------------|------------------|---|
| Analog         | AOUTL+, AOUTL-   | These pins should be open.              |
|                | AOUTR+, AOUTR-   | These pins should be open.              |
| Digital        | DIF2, DIF1, DIF0 | These pins should be connected to DVSS. |
|                | DZFL, DZFR       | These pins should be open.              |

#### 2. DSD mode

- In case of using #5(DCLK), #6(DSDL) and #7(DSDR) pins

| Classification | Pin Name                        | Setting                                 |
|----------------|---------------------------------|---|
| Analog         | AOUTL+, AOUTL-                  | These pins should be open.              |
|                | AOUTR+, AOUTR-                  | These pins should be open.              |
| Digital        | DCLK(#12), DSDL(#13), DSDR(#14) | These pins should be connected to DVSS. |
|                | DZFL, DZFR                      | These pins should be open.              |

- In case of using #12(DCLK), #13(DSDL) and #14(DSDR) pins

| Classification | Pin Name                     | Setting                                 |
|----------------|------------------------------|---|
| Analog         | AOUTL+, AOUTL-               | These pins should be open.              |
|                | AOUTR+, AOUTR-               | These pins should be open.              |
| Digital        | DCLK(#5), DSDL(#6), DSDR(#7) | These pins should be connected to DVSS. |
|                | DZFL, DZFR                   | These pins should be open.              |



|                                 |
|---------------------------------|
| <b>ABSOLUTE MAXIMUM RATINGS</b> |
|---------------------------------|

(AVSS, DVSS = 0V; Note 1)

| Parameter                              |                          | Symbol       | min  | max      | Units |
|--|--------------------------|--------------|------|----------|-------|
| Power Supplies:                        | Analog                   | AVDD         | -0.3 | 6.0      | V     |
|  | Digital                  | DVDD         | -0.3 | 6.0      | V     |
|  | $ AVSS - DVSS $ (Note 2) | $\Delta$ GND | -    | 0.3      | V     |
| Input Current, Any pin Except Supplies |                          | IIN          | -    | $\pm 10$ | mA    |
| Input Voltage                          |                          | VIND         | -0.3 | DVDD+0.3 | V     |
| Ambient Operating Temperature          |                          | Ta           | -40  | 85       | °C    |
| Storage Temperature                    |                          | Tstg         | -65  | 150      | °C    |

Note 1. All voltages with respect to ground.

Note 2. AVSS and 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.

|   |
|---|
| <b>RECOMMENDED OPERATING CONDITIONS</b> |
|---|

(AVSS, DVSS=0V; Note 1)

| Parameter                     |                       | Symbol        | min      | typ | max  | Units |
|-------------------------------|-----------------------|---------------|----------|-----|------|-------|
| Power Supplies:<br>(Note 3)   | Analog                | AVDD          | 4.75     | 5.0 | 5.25 | V     |
|                               | Digital               | DVDD          | 3.0      | 5.0 | 5.25 | V     |
| Voltage Reference<br>(Note 4) | “H” voltage reference | VREFH         | AVDD-0.5 | -   | AVDD | V     |
|                               | “L” voltage reference | VREFL         | AVSS     | -   | -    | V     |
|                               | VREFH-VREFL           | $\Delta$ VREF | 3.0      | -   | AVDD | V     |

Note 1. All voltages with respect to ground.

Note 3. The power up sequence between AVDD and DVDD is not critical.

Note 4. Analog output voltage scales with the voltage of (VREFH – VREFL).

$$AOUT (\text{typ. @0dB}) = (AOUT+) - (AOUT-) = \pm 2.8V_{pp} \times (VREFH - VREFL) / 5.$$

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

|                               |
|-------------------------------|
| <b>ANALOG CHARACTERISTICS</b> |
|-------------------------------|

(Ta=25°C; AVDD=DVDD=5.0V; AVSS=DVSS=0V; VREFH=AVDD, VREFL=AVSS; Input data=24bit;  $R_L \geq 1k\Omega$ ; BICK=64fs; Input Signal Frequency = 1kHz; Sampling frequency = 44.1kHz; Measurement bandwidth = 20Hz ~ 20kHz; External Circuit: Figure 17; unless otherwise specified.)

| Parameter                               |            | min                | typ  | max   | Units  |    |
|---|------------|--------------------|------|-------|--------|----|
| Resolution                              |            |                    |      | 24    | Bits   |    |
| <b>Dynamic Characteristics</b> (Note 5) |            |                    |      |       |        |    |
| THD+N                                   | fs=44.1kHz | 0dBFS              |      | -100  | -90    | dB |
|   | BW=20kHz   | -60dBFS            |      | -57   | -      | dB |
|   | fs=96kHz   | 0dBFS              |      | -97   | -      | dB |
|   | BW=40kHz   | -60dBFS            |      | -54   | -      | dB |
|   | fs=192kHz  | 0dBFS              |      | -97   | -      | dB |
|   | BW=40kHz   | -60dBFS            |      | -54   | -      | dB |
|   | BW=80kHz   | -60dBFS            |      | -51   | -      | dB |
| Dynamic Range (-60dBFS with A-weighted) | (Note 6)   | 114                | 120  |       | dB     |    |
| S/N (A-weighted)                        | (Note 7)   | 114                | 120  |       | dB     |    |
| Interchannel Isolation (1kHz)           |            | 100                | 120  |       | dB     |    |
| <b>DC Accuracy</b>                      |            |                    |      |       |        |    |
| Interchannel Gain Mismatch              |            |                    | 0.15 | 0.3   | dB     |    |
| Gain Drift                              | (Note 8)   |                    | 20   | -     | ppm/°C |    |
| Output Voltage                          | (Note 9)   | ±2.65              | ±2.8 | ±2.95 | Vpp    |    |
| Load Capacitance                        |            |                    |      | 25    | pF     |    |
| Load Resistance                         | (Note 10)  | 1                  |      |       | kΩ     |    |
| <b>Power Supplies</b>                   |            |                    |      |       |        |    |
| Power Supply Current                    |            |                    |      |       |        |    |
| Normal operation (PDN pin = "H")        | (Note 11)  | AVDD               |      | 32    | 47     | mA |
|   |            | DVDD (fs ≤ 96kHz)  |      | 8     | -      | mA |
|   |            | DVDD (fs = 192kHz) |      | 13    | 19     | mA |
| Power down (PDN pin = "L")              | (Note 12)  |                    |      | 10    | 100    | μA |
|   |            |                    |      |       |        |    |
| Power Supply Rejection                  | (Note 13)  |                    |      | 50    |        | dB |

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

Note 6. By Figure 17. External LPF Circuit Example 2. 101dB at 16bit data and 118dB at 20bit data.

Note 7. By Figure 17. External LPF Circuit Example 2. S/N does not depend on input bit length.

Note 8. The voltage on (VREFH - VREFL) is held +5V externally.

Note 9. Full-scale voltage(0dB). Output voltage scales with the voltage of (VREFH - VREFL).

$$AOUT \text{ (typ. @0dB)} = (AOUT+) - (AOUT-) = \pm 2.8V_{pp} \times (VREFH - VREFL)/5.$$

Note 10. For AC-load. 1.5kΩ for DC-Load

Note 11. typ. 5mA (@ DVDD=3.3V, fs ≤ 96kHz), typ. 8mA (@ DVDD=3.3V, fs = 192kHz)

Note 12. In the power-down mode. P/S pin = TTL pin = DVDD, and all other digital input pins including clock pins (MCLK, BICK and LRCK) are held DVSS.

Note 13. PSR is applied to AVDD, DVDD with 1kHz, 100mVpp. VREFH pin is held +5V.

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

(Ta=25°C; AVDD=4.75 ~ 5.25V, DVDD=3.0 ~ 5.25V; Normal Speed Mode; DEM=OFF; SLOW bi =“0”)

| Parameter                        | Symbol            | min  | typ    | max    | Units       |
|----------------------------------|-------------------|------|--------|--------|-------------|
| <b>Digital Filter</b>            |                   |      |        |        |             |
| Passband (Note 15)               | ±0.01dB<br>-6.0dB | PB   | 0<br>- | 22.05  | 20.0<br>kHz |
| Stopband (Note 14)               | SB                | 24.1 |        |        | kHz         |
| Passband Ripple                  | PR                |      |        | ±0.005 | dB          |
| Stopband Attenuation             | SA                | 75   |        |        | dB          |
| Group Delay (Note 15)            | GD                | -    | 28     | -      | 1/fs        |
| <b>Digital Filter + SCF</b>      |                   |      |        |        |             |
| Frequency Response : 0 ~ 20.0kHz |                   | -    | ±0.2   | -      | dB          |

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

(Ta=25°C; AVDD=4.75 ~ 5.25V, DVDD=3.0 ~ 5.25V; Double Speed Mode; DEM=OFF; SLOW bit=“0”)

| Parameter                        | Symbol            | min  | typ    | max    | Units       |
|----------------------------------|-------------------|------|--------|--------|-------------|
| <b>Digital Filter</b>            |                   |      |        |        |             |
| Passband (Note 14)               | ±0.01dB<br>-6.0dB | PB   | 0<br>- | 48.0   | 43.5<br>kHz |
| Stopband (Note 14)               | SB                | 52.5 |        |        | kHz         |
| Passband Ripple                  | PR                |      |        | ±0.005 | dB          |
| Stopband Attenuation             | SA                | 75   |        |        | dB          |
| Group Delay (Note 15)            | GD                | -    | 28     | -      | 1/fs        |
| <b>Digital Filter + SCF</b>      |                   |      |        |        |             |
| Frequency Response : 0 ~ 40.0kHz |                   | -    | ±0.3   | -      | dB          |

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

(Ta=25°C; AVDD=4.75 ~ 5.25V, DVDD=3.0 ~ 5.25V; Quad Speed Mode; DEM=OFF; SLOW bit=“0”)

| Parameter                        | Symbol            | min | typ    | max    | Units       |
|----------------------------------|-------------------|-----|--------|--------|-------------|
| <b>Digital Filter</b>            |                   |     |        |        |             |
| Passband (Note 14)               | ±0.01dB<br>-6.0dB | PB  | 0<br>- | 96.0   | 87.0<br>kHz |
| Stopband (Note 14)               | SB                | 105 |        |        | kHz         |
| Passband Ripple                  | PR                |     |        | ±0.005 | dB          |
| Stopband Attenuation             | SA                | 75  |        |        | dB          |
| Group Delay (Note 15)            | GD                | -   | 28     | -      | 1/fs        |
| <b>Digital Filter + SCF</b>      |                   |     |        |        |             |
| Frequency Response : 0 ~ 80.0kHz |                   | -   | +0/-1  | -      | dB          |

Note 14. The passband and stopband frequencies scale with fs. For example, PB = 0.4535×fs (@±0.01dB), SB = 0.546×fs.

Note 15. The calculating delay time which occurred by digital filtering. This time is from setting the 16/20/24bit data of both channels to input register to the output of analog signal.

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

(Ta=25°C; AVDD=4.75 ~ 5.25V, DVDD=3.0 ~ 5.25V; Normal Speed Mode; DEM=OFF; SLOW bit="1")

| Parameter                       | Symbol            | min  | typ   | max    | Units |
|---------------------------------|-------------------|------|-------|--------|-------|
| <b>Digital Filter</b>           |                   |      |       |        |       |
| Passband (Note 16)              | ±0.04dB<br>-3.0dB | PB   | 0     | 8.1    | kHz   |
|                                 |                   |      | -     | 18.2   | kHz   |
| Stopband (Note 16)              | SB                | 39.2 |       |        | kHz   |
| Passband Ripple                 | PR                |      |       | ±0.005 | dB    |
| Stopband Attenuation            | SA                | 72   |       |        | dB    |
| Group Delay (Note 15)           | GD                | -    | 28    | -      | 1/fs  |
| <b>Digital Filter + SCF</b>     |                   |      |       |        |       |
| Frequency Response: 0 ~ 20.0kHz |                   | -    | +0/-5 | -      | dB    |

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

(Ta=25°C; AVDD=4.75 ~ 5.25V, DVDD=3.0 ~ 5.25V; DEM=OFF; SLOW bit="1")

| Parameter                       | Symbol            | min  | typ   | max    | Units |
|---------------------------------|-------------------|------|-------|--------|-------|
| <b>Digital Filter</b>           |                   |      |       |        |       |
| Passband (Note 16)              | ±0.04dB<br>-3.0dB | PB   | 0     | 17.7   | kHz   |
|                                 |                   |      | -     | 39.6   | kHz   |
| Stopband (Note 15)              | SB                | 85.3 |       |        | kHz   |
| Passband Ripple                 | PR                |      |       | ±0.005 | dB    |
| Stopband Attenuation            | SA                | 72   |       |        | dB    |
| Group Delay (Note 14)           | GD                | -    | 28    | -      | 1/fs  |
| <b>Digital Filter + SCF</b>     |                   |      |       |        |       |
| Frequency Response: 0 ~ 40.0kHz |                   | -    | +0/-4 | -      | dB    |

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

(Ta=25°C; AVDD=4.75 ~ 5.25V, DVDD=3.0 ~ 5.25V; Quad Speed Mode; DEM=OFF; SLOW bit="1")

| Parameter                       | Symbol            | min | typ   | max    | Units |
|---------------------------------|-------------------|-----|-------|--------|-------|
| <b>Digital Filter</b>           |                   |     |       |        |       |
| Passband (Note 16)              | ±0.04dB<br>-3.0dB | PB  | 0     | 35.5   | kHz   |
|                                 |                   |     | -     | 79.1   | kHz   |
| Stopband (Note 16)              | SB                | 171 |       |        | kHz   |
| Passband Ripple                 | PR                |     |       | ±0.005 | dB    |
| Stopband Attenuation            | SA                | 72  |       |        | dB    |
| Group Delay (Note 15)           | GD                | -   | 28    | -      | 1/fs  |
| <b>Digital Filter + SCF</b>     |                   |     |       |        |       |
| Frequency Response: 0 ~ 80.0kHz |                   | -   | +0/-5 | -      | dB    |

Note 16. The passband and stopband frequencies scale with fs. For example, PB = 0.185×fs (@±0.04dB), SB = 0.888×fs.

**DC CHARACTERISTICS (CMOS Level Mode)**

(Ta=25°C; AVDD=4.75 ~ 5.25V, DVDD=3.0 ~ 5.25V; TTL pin = "L")

| Parameter                                 | Symbol | min      | typ | max      | Units |
|---|--------|----------|-----|----------|-------|
| 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 17)           | Iin    | -        | -   | ±10      | μA    |

**DC CHARACTERISTICS (TTL Level Mode)**

(Ta=25°C; AVDD=4.75 ~ 5.25V, DVDD=4.75 ~ 5.25V; TTL pin = "H")

| Parameter                                 | Symbol | min      | typ | max      | Units |
|---|--------|----------|-----|----------|-------|
| High-Level Input Voltage (TTL pin)        | VIH    | 70% DVDD | -   | -        | V     |
| (All pins except TTL pin)                 | VIH    | 2.2      | -   | -        | V     |
| Low-Level Input Voltage (TTL pin)         | VIL    | -        | -   | 30% DVDD | V     |
| (All pins except TTL pin)                 | VIL    | -        | -   | 0.8      | 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 17)           | Iin    | -        | -   | ± 10     | μA    |

Note 17. DFS0, TTL, P/S and TST2 pins have internal pull-down or pull-up devices, nominally 100kΩ.

| SWITCHING CHARACTERISTICS                      |        |         |     |        |       |
|--|--------|---------|-----|--------|-------|
| (Ta=25°C; AVDD=4.75 ~ 5.25V, DVDD=3.0 ~ 5.25V) |        |         |     |        |       |
| Parameter                                      | Symbol | min     | typ | max    | Units |
| <b>Master Clock Timing</b>                     |        |         |     |        |       |
| Frequency                                      | fCLK   | 7.7     |     | 41.472 | MHz   |
| Duty Cycle                                     | dCLK   | 40      |     | 60     | %     |
| <b>LRCK Frequency</b> (Note 18)                |        |         |     |        |       |
| Normal Speed Mode                              | fsn    | 30      |     | 54     | kHz   |
| Double Speed Mode                              | fsd    | 54      |     | 108    | kHz   |
| Quad Speed Mode                                | fsq    | 108     |     | 216    | kHz   |
| Duty Cycle                                     | Duty   | 45      |     | 55     | %     |
| <b>PCM Audio Interface Timing</b>              |        |         |     |        |       |
| BICK Period                                    |        |         |     |        |       |
| Normal Speed Mode                              | tBCK   | 1/128fn |     |        | ns    |
| Double Speed Mode                              | tBCK   | 1/64fd  |     |        | ns    |
| Quad Speed Mode                                | tBCK   | 1/64fq  |     |        | ns    |
| BICK Pulse Width Low                           | tBCKL  | 30      |     |        | ns    |
| BICK Pulse Width High                          | tBCKH  | 30      |     |        | ns    |
| BICK “↑” to LRCK Edge                          | tBLR   | 20      |     |        | ns    |
| LRCK Edge to BICK “↑”                          | tLRB   | 20      |     |        | ns    |
| SDATA Hold Time                                | tSDH   | 20      |     |        | ns    |
| SDATA Setup Time                               | tSDS   | 20      |     |        | ns    |
| <b>DSD Audio Interface Timing</b>              |        |         |     |        |       |
| DCLK Period                                    | tDCK   | 1/64fs  |     |        | ns    |
| DCLK Pulse Width Low                           | tDCKL  | 160     |     |        | ns    |
| DCLK Pulse Width High                          | tDCKH  | 160     |     |        | ns    |
| DCLK Edge to DSDL/R                            | tDDD   | -20     |     | 20     | ns    |
| <b>Control Interface Timing</b>                |        |         |     |        |       |
| 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    |
| <b>Reset Timing</b>                            |        |         |     |        |       |
| PDN Pulse Width                                | tPD    | 150     |     |        | ns    |

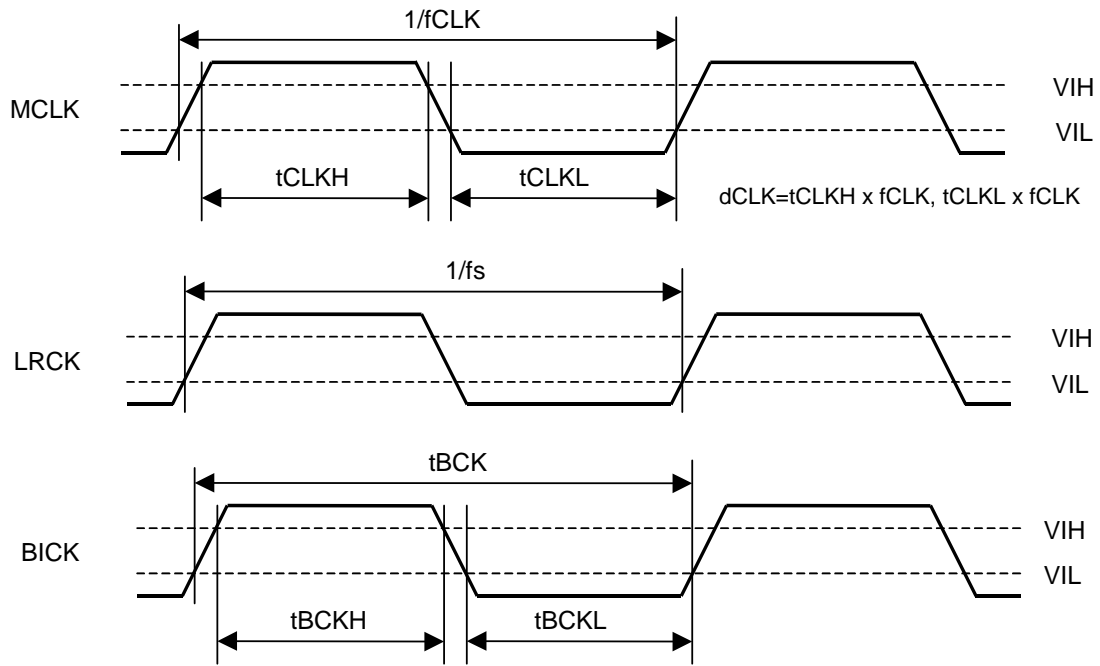
Note 18. When the normal/double/quad speed modes are switched, AK4396 should be reset by PDN pin or RSTN bit.

Note 19. BICK rising edge must not occur at the same time as LRCK edge.

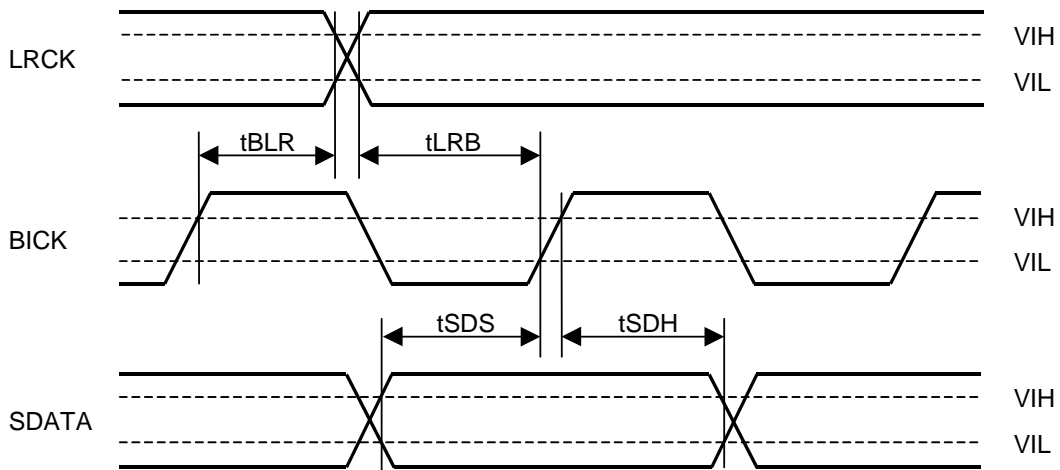
Note 20. DSD data transmitting device must meet this time.

Note 21. The AK4396 can be reset by bringing PDN pin “L” to “H”. When the states of or DFS1-0 bits change, the AK4396 should be reset by RSTN bit.

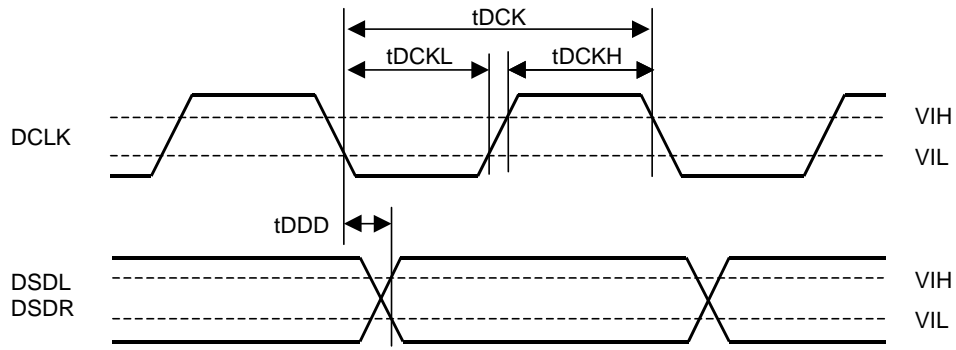
■ Timing Diagram



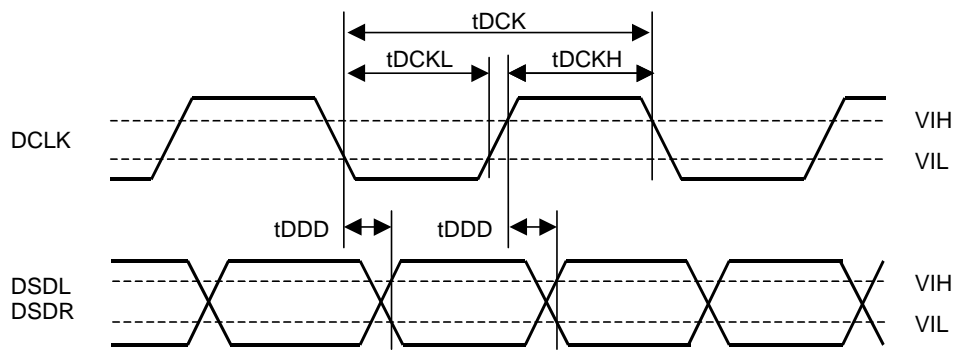
Clock Timing



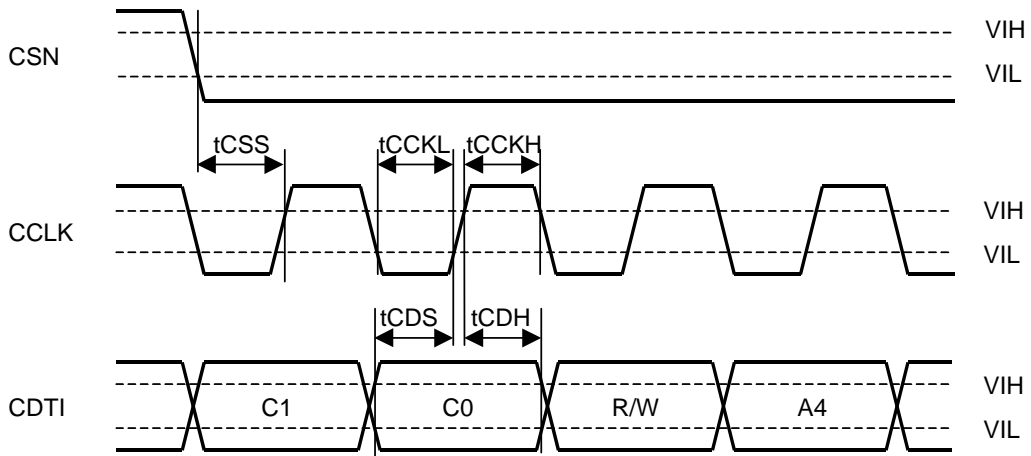
Audio Interface Timing (PCM Mode)



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

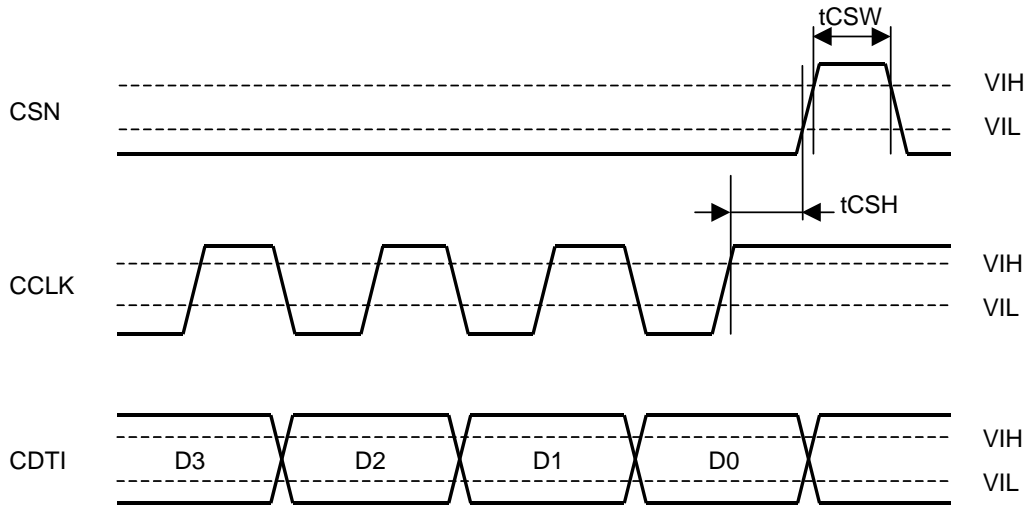


Audio Serial Interface Timing (DSD Phase Modulation Mode, DCKB bit = "0")

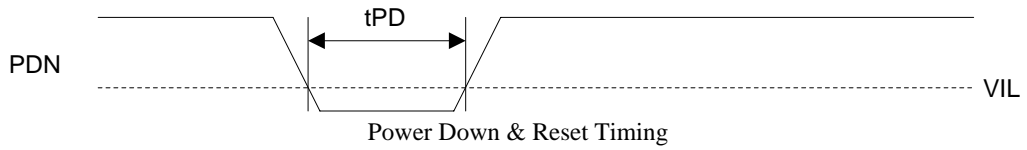


WRITE Command Input Timing





WRITE Data Input Timing



Power Down & Reset Timing

## OPERATION OVERVIEW

### ■ D/A Conversion Mode

In serial mode, the AK4396 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 changes by D/P bit, the AK4396 should be reset by RSTN bit. It takes about  $2/f_s$  to  $3/f_s$  to change the mode. In parallel mode, the AK4396 performs for only PCM data.

| D/P 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 AK4396, 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. When external clocks are changed, the AK4396 should be reset by PDN pin or RSTN bit.

All external clocks (MCLK, BICK and LRCK) should always be present whenever the AK4396 is in normal operation mode (PDN pin = "H"). If these clocks are not provided, the AK4396 may draw excess current because the device utilizes dynamic refreshed logic internally. If the external clocks are not present, the AK4396 should be in the power-down mode (PDN pin = "L") or in the reset mode (RSTN bit = "0"). After exiting reset (PDN pin = "L" → "H") at power-up etc., the AK4396 is in power-down mode until MCLK is supplied.

(1) Parallel Mode (P/S pin = "H")

1. Manual Setting Mode (ACKS pin = "L")

MCLK frequency is detected automatically and the sampling speed is set by DFS0 pin (Table 2). The MCLK frequency corresponding to each sampling speed should be provided (Table 3). DFS1 bit is fixed to "0". When DFS0 pin is changed, the AK4396 should be reset by PDN pin. Quad speed mode is not supported in this mode.

| DFS0 pin | Sampling Rate (fs) |                |
|----------|--------------------|----------------|
| L        | Normal Speed Mode  | 30kHz ~ 54kHz  |
| H        | Double Speed Mode  | 54kHz ~ 108kHz |

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

| LRCK<br>fs | MCLK (MHz) |         |         |         |         |         |         | BICK<br>64fs |
|------------|------------|---------|---------|---------|---------|---------|---------|--------------|
|            | 128fs      | 192fs   | 256fs   | 384fs   | 512fs   | 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    |

Table 3. System Clock Example (Manual Setting Mode @Parallel Mode)

## 2. Auto Setting Mode (ACKS pin = “H”)

MCLK frequency and the sampling speed are detected automatically (Table 4) and DFS0 pin is ignored. DFS0 pin should be fixed to DVSS or DVDD.

| MCLK   |       | 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<br>fs | MCLK (MHz) |         |         |         |         |         |         | Sampling<br>Speed |
|------------|------------|---------|---------|---------|---------|---------|---------|-------------------|
|            | 128fs      | 192fs   | 256fs   | 384fs   | 512fs   | 768fs   | 1152fs  |                   |
| 32.0kHz    | N/A        | N/A     | N/A     | N/A     | 16.3840 | 24.5760 | 36.8640 | Normal            |
| 44.1kHz    | N/A        | N/A     | N/A     | N/A     | 22.5792 | 33.8688 | N/A     |                   |
| 48.0kHz    | N/A        | N/A     | N/A     | N/A     | 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)

## (2) Serial Mode (P/S pin = “L”)

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

MCLK frequency is detected automatically and the sampling speed is set by DFS1-0 bits (Table 6). The MCLK frequency corresponding to each sampling speed should be provided (Table 7). The AK4396 is set to Manual Setting Mode at power-up (PDN pin = “L” → “H”). When DFS1-0 bits are changed, the AK4396 should be reset by RSTN bit.

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

Table 6. Sampling Speed (Manual Setting Mode @Serial Mode)

| LRCK<br>fs | MCLK (MHz) |         |         |         |         |         |         | BICK<br>64fs |
|------------|------------|---------|---------|---------|---------|---------|---------|--------------|
|            | 128fs      | 192fs   | 256fs   | 384fs   | 512fs   | 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 7. 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 8) and DFS1-0 bits are ignored. The MCLK frequency corresponding to each sampling speed should be provided (Table 9).

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

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

| LRCK<br>fs | MCLK (MHz) |         |         |         |         |         |         | Sampling<br>Speed |
|------------|------------|---------|---------|---------|---------|---------|---------|-------------------|
|            | 128fs      | 192fs   | 256fs   | 384fs   | 512fs   | 768fs   | 1152fs  |                   |
| 32.0kHz    | N/A        | N/A     | N/A     | N/A     | 16.3840 | 24.5760 | 36.8640 | Normal            |
| 44.1kHz    | N/A        | N/A     | N/A     | N/A     | 22.5792 | 33.8688 | N/A     |                   |
| 48.0kHz    | N/A        | N/A     | N/A     | N/A     | 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 9. System Clock Example (Auto Setting Mode @Serial Mode)

**[2] DSD Mode**

The external clocks, which are required to operate the AK4396, 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.

All external clocks (MCLK, DCLK) should always be present whenever the AK4396 is in the normal operation mode (PDN pin = "H"). If these clocks are not provided, the AK4396 may draw excess current because the device utilizes dynamic refreshed logic internally. The AK4396 should be reset by PDN pin = "L" after these clocks are provided. If the external clocks are not present, the AK4396 should be in the power-down mode (PDN pin = "L"). After exiting reset (PDN pin = "L" → "H") at power-up etc., the AK4396 is in the power-down mode until MCLK is input.

| DCKS bit | MCLK Frequency | DCLK Frequency | Default |
|----------|----------------|----------------|---------|
| 0        | 512fs          | 64fs           |         |
| 1        | 768fs          | 64fs           |         |

Table 10. System Clock (DSD Mode)

■ Audio Interface Format

[1] PCM Mode

Data is shifted in via the SDATA pin using BICK and LRCK inputs. Five data formats are supported and selected by the DIF2-0 pins (Parallel mode) or DIF2-0 bits (Serial mode) as shown in Table 11. In all formats the serial data is MSB-first, 2's compliment 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.

| Mode | DIF2 | DIF1 | DIF0 | Input Format                      | BICK   | Figure   |
|------|------|------|------|-----------------------------------|--------|----------|
| 0    | 0    | 0    | 0    | 16bit LSB justified               | ≥ 32fs | Figure 1 |
| 1    | 0    | 0    | 1    | 20bit LSB justified               | ≥ 48fs | Figure 2 |
| 2    | 0    | 1    | 0    | 24bit MSB justified               | ≥ 48fs | Figure 3 |
| 3    | 0    | 1    | 1    | 24bit I <sup>2</sup> S Compatible | ≥ 48fs | Figure 4 |
| 4    | 1    | 0    | 0    | 24bit LSB justified               | ≥ 48fs | Figure 2 |

Table 11. Audio Interface Format

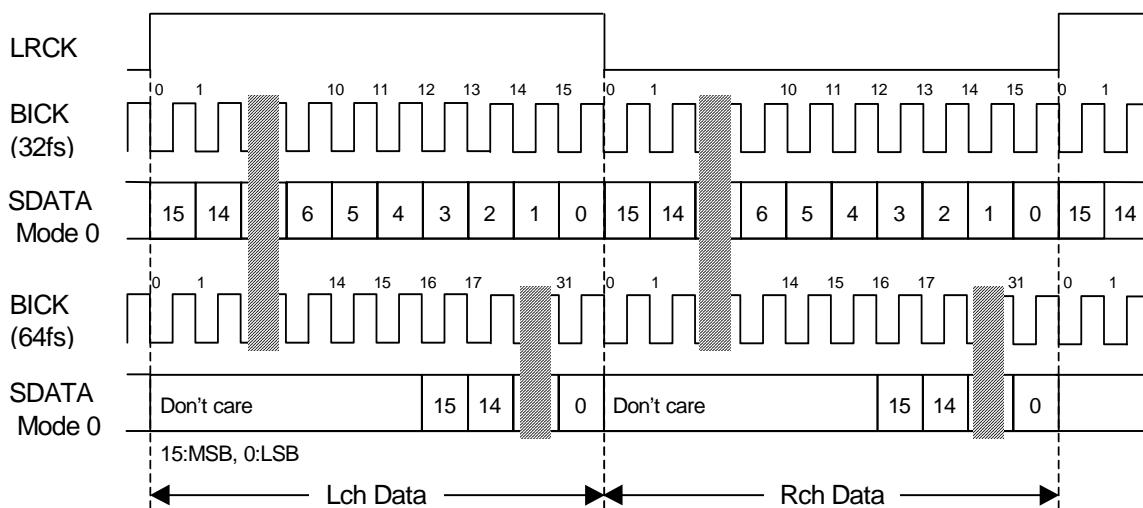


Figure 1. Mode 0 Timing

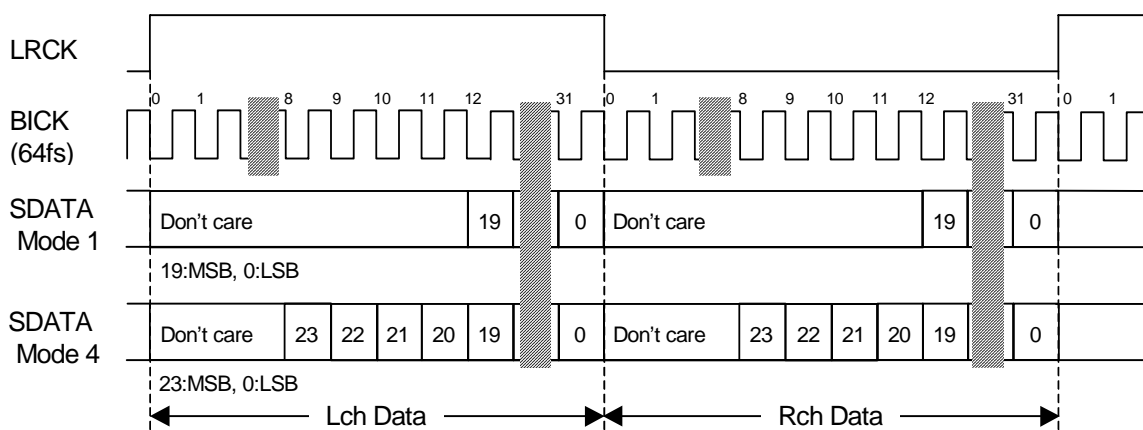


Figure 2. Mode 1, 4 Timing

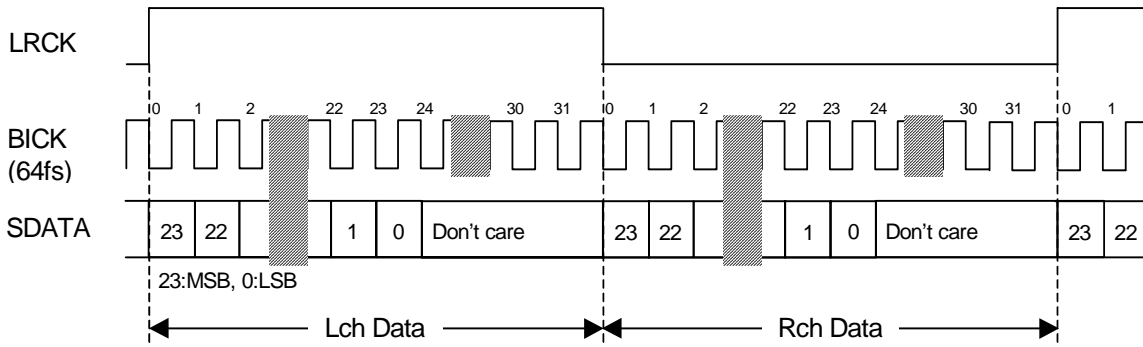


Figure 3. Mode 2 Timing

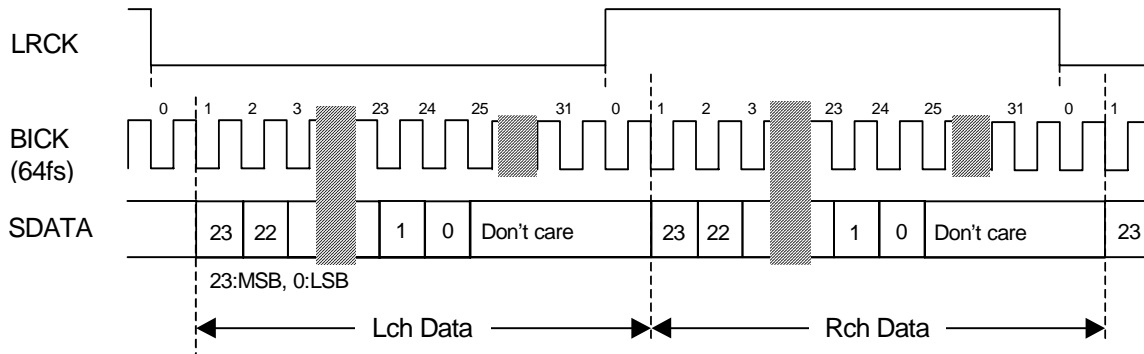


Figure 4. Mode 3 Timing

**[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.

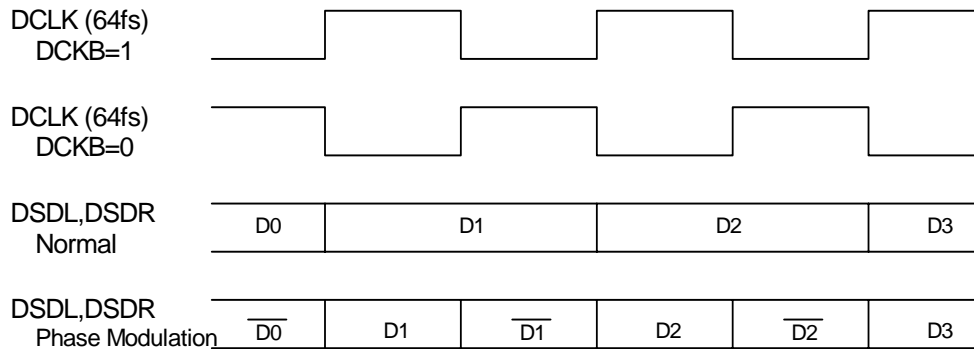


Figure 5. DSD Mode Timing

■ D/A conversion mode switching timing

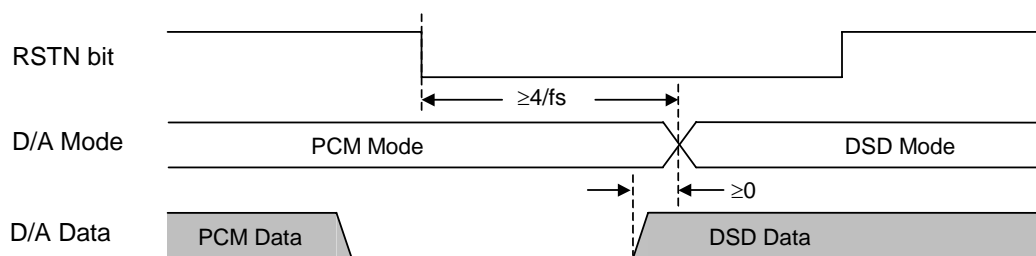


Figure 6. D/A Mode Switching Timing (PCM to DSD)

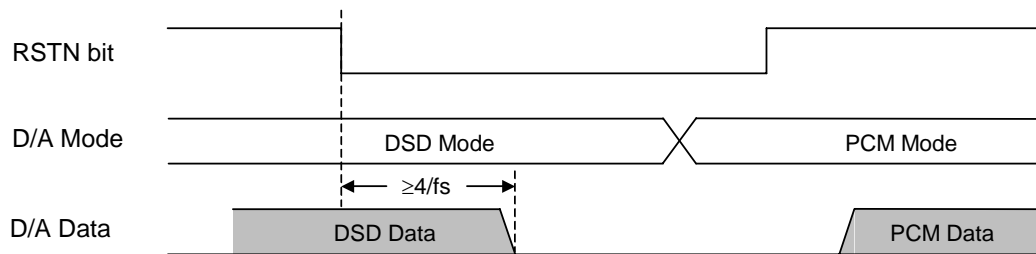


Figure 7. D/A Mode Switching Timing (DSD to PCM)

Caution: In DSD mode, the signal level is ranging from 25% to 75%. Peak levels of DSD signal above this duty are not recommended by 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 double speed and quad speed mode, 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.

| DEM1 | DEM0 | Mode    |
|------|------|---------|
| 0    | 0    | 44.1kHz |
| 0    | 1    | OFF     |
| 1    | 0    | 48kHz   |
| 1    | 1    | 32kHz   |

Default

Table 12. De-emphasis Control (Normal Speed Mode)

■ Output Volume

The AK4396 includes channel independent digital output volumes (ATT) with 256 levels at linear step including MUTE. These volumes are in front of the DAC and can attenuate the input data from 0dB to -48dB and mute. When changing levels, transitions are executed via soft changes; thus no switching noise occurs during these transitions. The transition time of 1 level and all 256 levels is shown in Table 13.

| Sampling Speed    | Transition Time |          |
|-------------------|-----------------|----------|
|                   | 1 Level         | 255 to 0 |
| Normal Speed Mode | 4LRCK           | 1020LRCK |
| Double Speed Mode | 8LRCK           | 2040LRCK |
| Quad Speed Mode   | 16LRCK          | 4080LRCK |

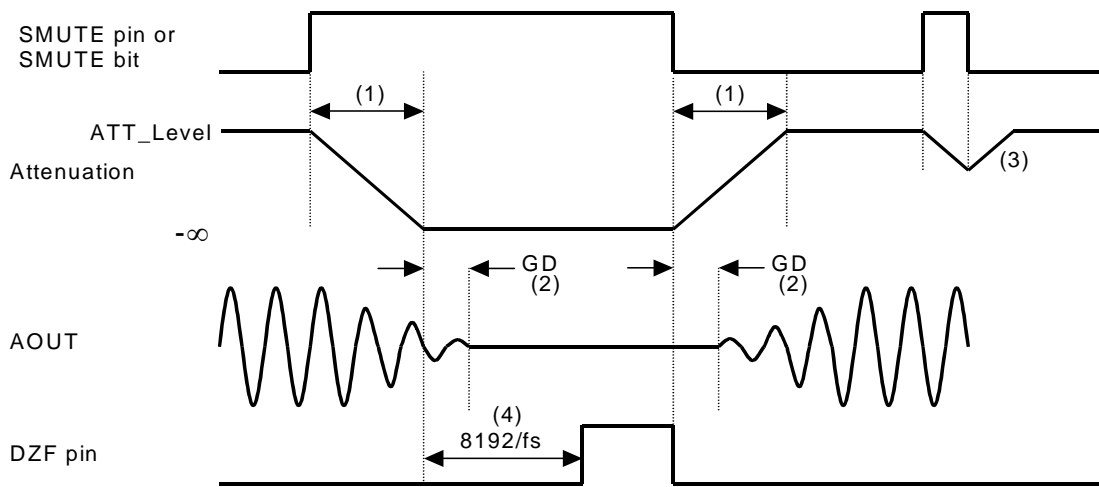
Table 13. ATT Transition Time

## ■ Zero Detection

The AK4396 has channel-independent zeros detect function. When the input data at each channel is continuously zeros for 8192 LRCK cycles, DZF pin of each channel goes to “H”. DZF pin of each channel immediately goes to “L” if input data of each channel is not zero after going DZF pin “H”. If RSTN bit is “0”, DZF pins of both channels go to “H”. DZF pins of both channels go to “L” at  $4 \sim 5/f_s$  after RSTN bit returns to “1”. If DZFM bit is set to “1”, DZF pins of both channels go to “H” only when the input data at both channels are continuously zeros for 8192 LRCK cycles. Zero detect function can be disabled by DZFE bit. In this case, DZF pins of both channels are always “L”. DZFB bit can invert the polarity of DZF pin.

## ■ Soft Mute operation

Soft mute operation is performed at digital domain. When SMUTE pin goes to “H” or SMUTE bit goes to “1”, the output signal is attenuated by  $-\infty$  during  $ATT\_DATA \times ATT$  transition time (Table 13) from the current ATT level. When SMUTE pin is returned to “L” or 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  $-\infty$  after starting the operation, 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 (Table 13). For example, this time is 1020LRCK cycles (1020/fs) at  $ATT\_DATA=255$  in Normal Speed Mode.
- (2) Analog output corresponding to digital input has the 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 at each channel is continuously zeros for 8192 LRCK cycles, DZF pin of each channel goes to “H”. DZF pin immediately goes to “L” if input data are not zero after going DZF pin “H”.

Figure 8. Soft Mute and Zero Detection

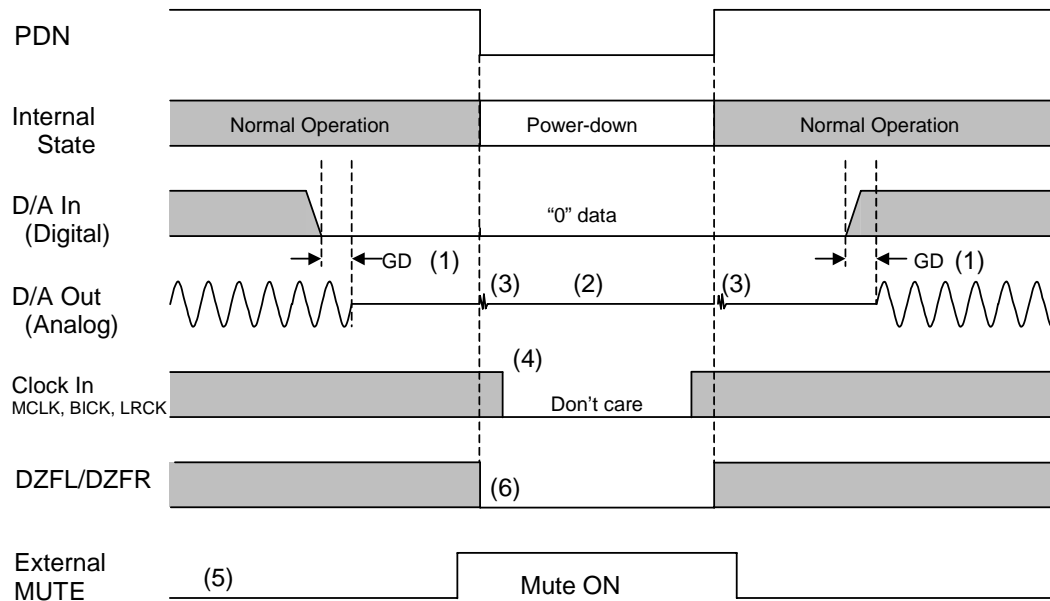
## ■ System Reset

The AK4396 should be reset once by bringing PDN pin = “L” upon power-up. The analog section exits power-down mode by MCLK input and then the digital section exits power-down mode after the internal counter counts MCLK during  $4/f_s$ .



## ■ Power-Down

The AK4396 is placed in the power-down mode by bringing PDN pin “L” and the analog outputs are floating (Hi-Z). Figure 9 shows an example of the system timing at the power-down and power-up.



### Notes:

- (1) The analog output corresponding to digital input has the group delay (GD).
- (2) Analog outputs are floating (Hi -Z) at the power-down mode.
- (3) Click noise occurs at the edge (“↑ ↓”) of PDN signal. This noise is output even if “0” data is input.
- (4) The external clocks (MCLK, BICK and LRCK) can be stopped in the power-down mode (PDN pin = “L”).
- (5) Please mute the analog output externally if the click noise (3) influences system application. The timing example is shown in this figure.
- (6) DZF pins are “L” in the power-down mode (PDN pin = “L”).

### Other:

After exiting power-down mode (PDN pin: “L” → “H”), AOUT pins go to VCOM voltage (VA/2). This time is set by a capacitor connected to VCOM pin and the internal resistor of VCOM pin.

E.g.  $C = 10\mu\text{F}$

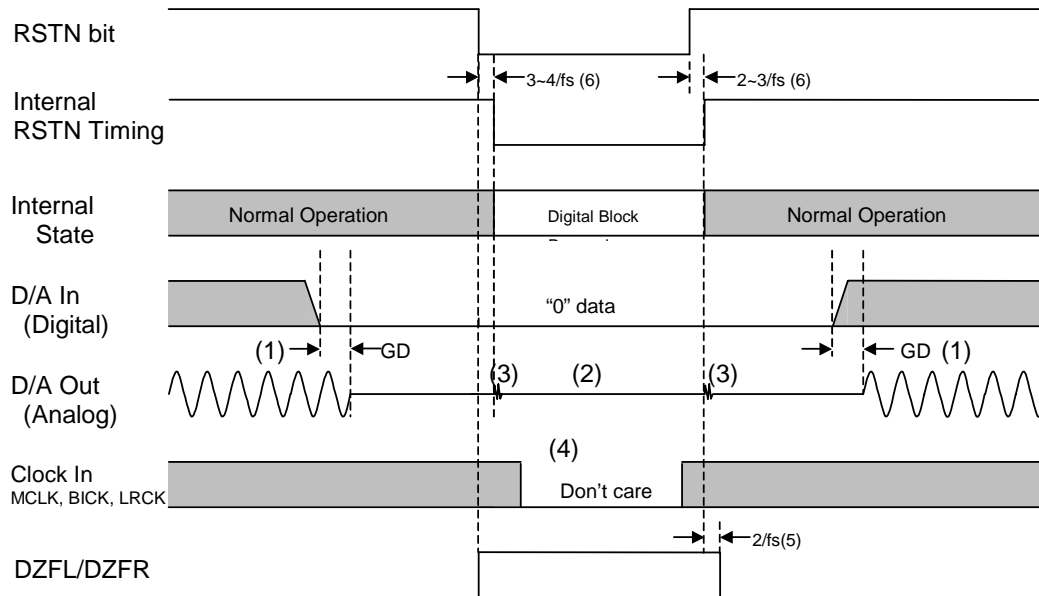
$$1\tau (\text{typ}) = 10\mu\text{F} \times 0.75\text{k}\Omega = 7.5\text{ms}, 5\tau (\text{typ}) = 37.5\text{ms}$$

$$1\tau (\text{max}) = 10\mu\text{F} \times 0.975\text{k}\Omega = 9.75\text{ms}, 5\tau (\text{max}) = 48.75\text{ms}$$

Figure 9. Power-down/up sequence example

## ■ Reset Function

When RSTN bit = "0", the AK4396's digital section is powered down but the internal register values are not initialized. The analog outputs go to VCOM voltage and DZF pins of both channels go to "H". Figure 10 shows the example of reset by RSTN bit.



### Notes:

- (1) The analog output corresponding to digital input has the group delay (GD).
- (2) Analog outputs go to VCOM voltage.
- (3) Click noise occurs at the edges ("↑↓") of the internal timing of RSTN bit.  
This noise is output even if "0" data is input.
- (4) The external clocks (MCLK, BICK and LRCK) can be stopped in the reset mode (RSTN bit = "L").
- (5) DZF pins go to "H" when the RSTN bit becomes "0", and go to "L" at  $2/f_s$  after RSTN bit becomes "1".
- (6) 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".

Figure 10. Reset sequence example

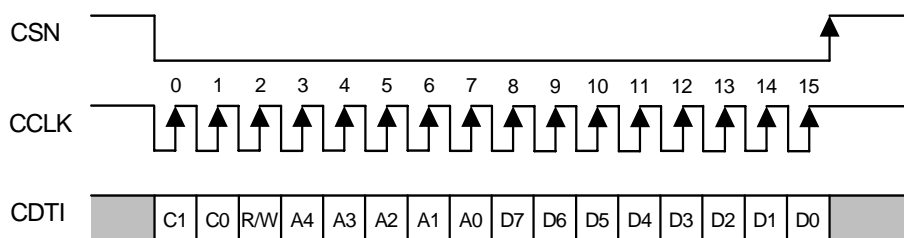
■ Register Control Interface

Pins (parallel control mode) or registers (serial control mode) can control each functions of the AK4396. In parallel mode, the register setting is ignored and the pin setting is ignored in serial mode. When the state of P/S pin is changed, the AK4396 should be reset by PDN pin. The serial control interface is enabled by the P/S pin = “L”. In this mode, pin setting must be all “L”. Internal registers may be written by 3-wire μP interface pins: CSN, CCLK and CDTI. The data on this interface consists of Chip address (2bits, CAD0/1), Read/Write (1bit; fixed to “1”), Register address (MSB first, 5bits) and Control data (MSB first, 8bits). The AK4396 latches the data on the rising edge of CCLK, so data should be clocked in on the falling edge. The writing of data becomes valid by CSN “↑”. The clock speed of CCLK is 5MHz (max).

| Function               | Parallel mode | Serial mode |
|------------------------|---------------|-------------|
| Auto Setting Mode      | O             | O           |
| Manual Setting Mode    | O             | O           |
| Audio Format           | O             | O           |
| De-emphasis            | O             | O           |
| SMUTE                  | O             | O           |
| DSD Mode               | X             | O           |
| Zero Detection         | X             | O           |
| Slow roll-off response | X             | O           |
| Digital Attenuator     | X             | O           |

Table 14. Function List (O: Available, X: Not available)

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



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

Figure 11. Control I/F Timing

- \* The AK4396 does not support the read command.
- \* When the AK4396 is in the power down mode (PDN pin = “L”) or the MCLK is not provided, writing into the control register is inhibited.
- \* The control data can not be written when the CCLK rising edge is 15times or less or 17times or more during CSN is “L”.

## ■ 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     | DZFE | DZFM | SLOW | DFS1 | DFS0 | DEM1 | DEM0 | SMUTE |
| 02H  | Control 3     | D/P  | DSDM | DCKS | DCKB | 0    | DZFB | 0    | 0     |
| 03H  | Lch ATT       | ATT7 | ATT6 | ATT5 | ATT4 | ATT3 | ATT2 | ATT1 | ATT0  |
| 04H  | Rch ATT       | ATT7 | ATT6 | ATT5 | ATT4 | ATT3 | ATT2 | ATT1 | ATT0  |

### Notes:

For addresses from 05H to 1FH, data must not be written.

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

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

When the state of P/S pin is changed, the AK4396 should be reset by 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  | 0    | 1    | 0    | 1    |

RSTN: Internal timing reset

0 : Reset. All registers are not initialized.

1 : Normal Operation (Default)

When the states of DFS1-0 bits change, the AK4396 should be reset by PDN pin or RSTN bit.

DIF2-0: Audio data interface modes (see Table 11)

Initial value is “010” (Mode 2: 24bit 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”, MCLK frequency and the sampling frequency are detected automatically.

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

SMUTE: Soft Mute Enable

0 : Normal operation (Default)

1 : DAC outputs soft-muted.

DEM1-0: De-emphasis response (Table 12)

Initial value is "01" (OFF).

DFS1-0: Sampling Speed Control (Table 6)

Initial value is "00" (Normal speed).

When changing between Normal/Double Speed Mode and Quad Speed Mode, some click noise occurs at that time.

SLOW: Slow Roll-off Filter Enable

0 : Sharp roll-off filter (Default)

1 : Slow roll-off filter

DZFM: Data Zero Detect Mode

0 : Channel separated mode (Default)

1 : Channel ANDed mode

If the DZFM bit is set to "1", the DZF pins of both channels go to "H" only when the input data at both channels are continuously zeros for 8192 LRCK cycles.

DZFE: Data Zero Detect Enable

0 : Disable (Default)

1 : Enable

Zero detect function can be disabled by DZFE bit "0". In this case, the DZF pins of both channels are always "L".

| Addr | Register Name | D7  | D6   | D5   | D4   | D3 | D2   | D1 | D0 |
|------|---------------|-----|------|------|------|----|------|----|----|
| 02H  | Control 3     | D/P | DSDM | DCKS | DCKB | 0  | DZFB | 0  | 0  |
|      | Default       | 0   | 0    | 0    | 0    | 0  | 0    | 0  | 0  |

DZFB: Inverting Enable of DZF

- 0 : DZF pin goes "H" at Zero Detection (Default)
- 1 : DZF pin goes "L" at Zero Detection

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

DSDM: DSD Input Select

- 0 : Input pin : No.5, 6, 7 (Default)
  - 1 : Input pin : No. 12, 13, 14
- When DSDM bit is changed, the AK4396 should be reset by RSTN bit.

D/P: DSD/PCM Mode Select

- 0 : PCM mode (Default)
  - 1 : DSD mode
- When D/P bit is changed, the AK4396 should be reset by RSTN bit.

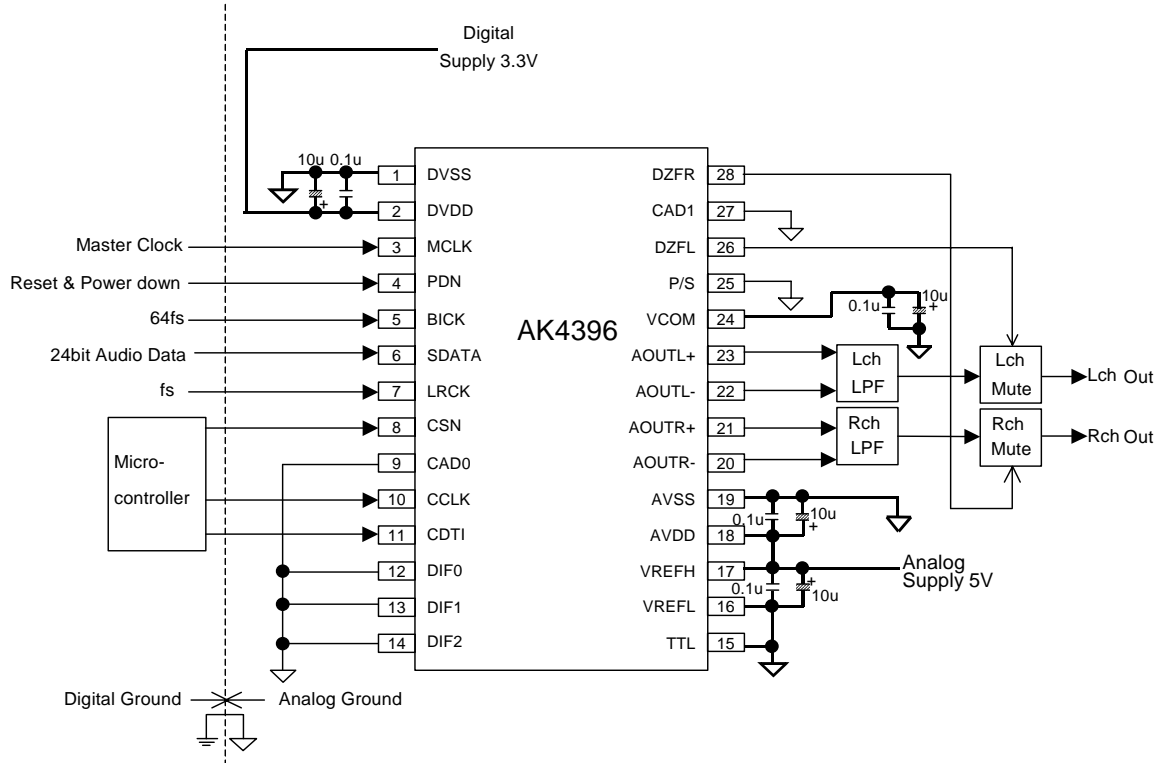
| Addr | Register Name | D7   | D6   | D5   | D4   | D3   | D2   | D1   | D0   |
|------|---------------|------|------|------|------|------|------|------|------|
| 03H  | Lch ATT       | ATT7 | ATT6 | ATT5 | ATT4 | ATT3 | ATT2 | ATT1 | ATT0 |
| 04H  | Rch ATT       | ATT7 | ATT6 | ATT5 | ATT4 | ATT3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

ATT7-0: Attenuation Level

- $ATT = 20 \log_{10}(ATT\_DATA / 255)$  [dB]
- FFH : 0dB (Default)
- 00H : Mute

**SYSTEM DESIGN**

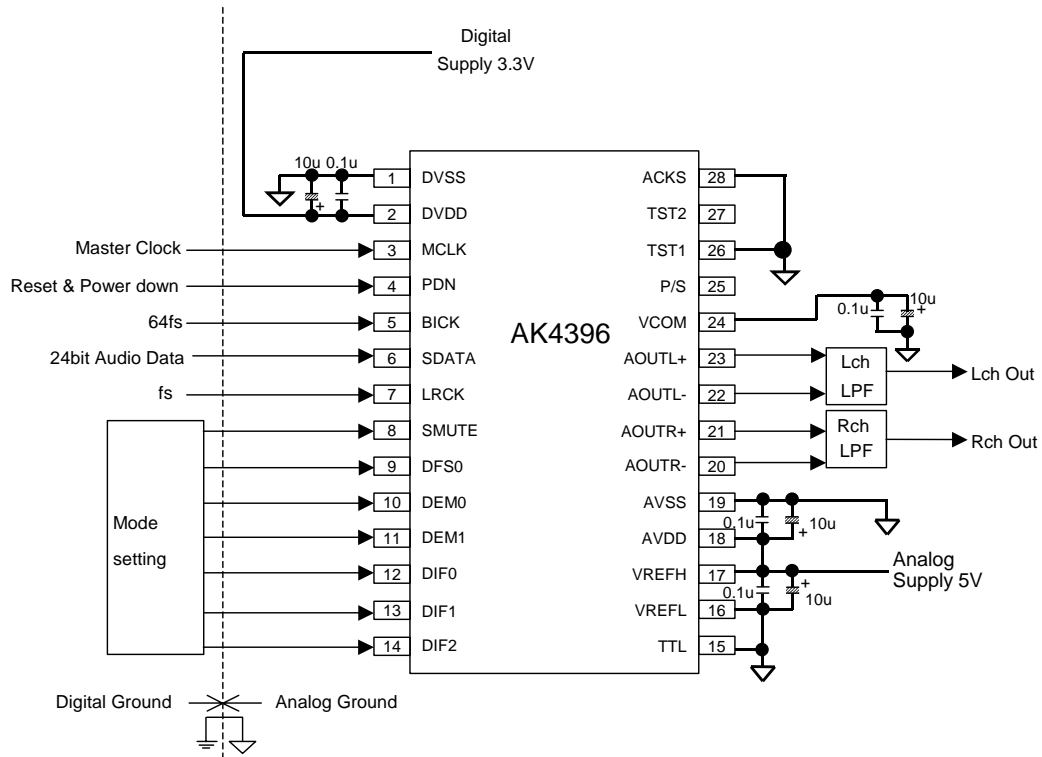
Figure 12, Figure 13 and Figure 14 show the system connection diagram. Figure 16 , Figure 17 and Figure 18 show the analog output circuit examples. An evaluation board (AKD4396) is available which demonstrates the optimum layout, power supply arrangements and measurement results.



Notes:

- Chip Address = "00". LRCK = fs, BICK = 64fs.
- Power lines of AVDD and DVDD should be distributed separately from the point with low impedance of regulator etc.
- AVSS and DVSS must be connected to the same analog ground plane.
- When AOUT drives some capacitive load, some resistor should be added in series between AOUT and capacitive load.
- All input pins except pull-down/pull-up pins should not be left floating.

Figure 12. Typical Connection Diagram (AVDD=5V, DVDD=3.3V, Serial mode)

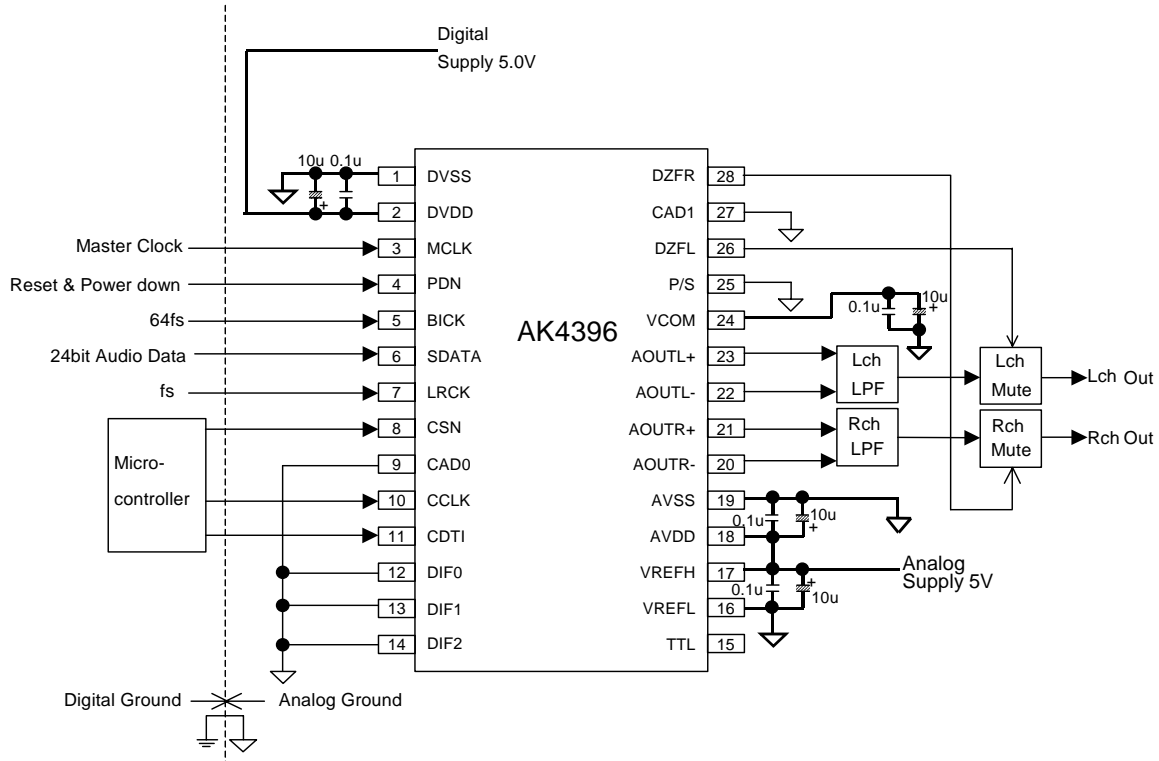


Notes:

- BICK = 64fs, LRCK = fs.
- Power lines of AVDD and DVDD should be distributed separately from the point with low impedance of regulator etc.
- AVSS and DVSS must be connected to the same analog ground plane.
- When AOUT drives some capacitive load, some resistor should be added in series between AOUT and capacitive load.
- All input pins except pull-down/pull-up pins should not be left floating.

Figure 13. Typical Connection Diagram (AVDD = 5V, DVDD = 3.3V, Parallel mode, AK4393 compatible)





Notes:

- TTL pin (BVSS pin in case of AK4394/5) should be open.
- Chip Address = "00", BICK = 64fs, LRCK = fs.
- Power lines of AVDD and DVDD should be distributed separately from the point with low impedance of regulator etc.
- AVSS and DVSS must be connected to the same analog ground plane.
- When AOUT drives some capacitive load, some resistor should be added in series between AOUT and capacitive load.
- All input pins except pull-down/pull-up pins should not be left floating.

Figure 14. Typical Connection Diagram (AVDD=5V, DVDD=5V, Serial mode, AK4394/5 compatible)

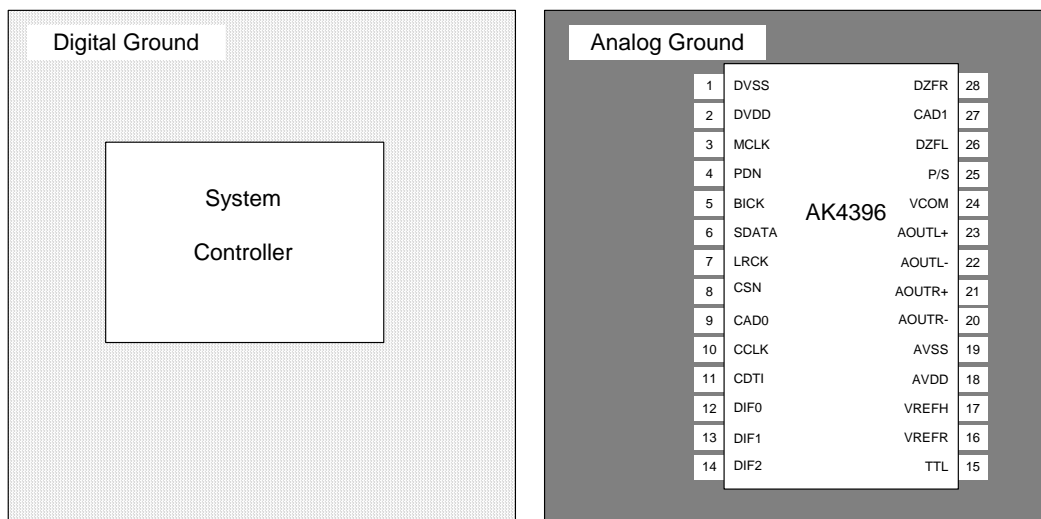


Figure 15. Ground Layout

### 1. Grounding and Power Supply Decoupling

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

### 2. Voltage Reference

The differential Voltage between VREFH and VREFL set the analog output range. VREFH pin is normally connected to AVDD and VREFL pin is normally connected to AVSS. VREFH and VREFL should be connected with a 0.1μF ceramic capacitor. VCOM is a signal ground of this chip. An electrolytic capacitor 10μF parallel with a 0.1μF ceramic capacitor attached to VCOM pin eliminates the effects of high frequency noise. No load current may be drawn from VCOM pin. All signals, especially clocks, should be kept away from the VREFH, VREFL and VCOM pins in order to avoid unwanted coupling into the AK4396.

### 3. Analog Outputs

The analog outputs are full differential outputs and 2.8Vpp (typ, VREFH – VREFL = 5V) centered around VCOM. The differential outputs are summed externally,  $V_{AOUT} = (AOUT+) - (AOUT-)$  between AOUT+ and AOUT-. If the summing gain is 1, the output range is 5.6Vpp (typ, VREFH – VREFL = 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 16 shows an example of external LPF circuit summing the differential outputs by an op-amp. Figure 17 shows an example of differential outputs and LPF circuit example by three op-amps.

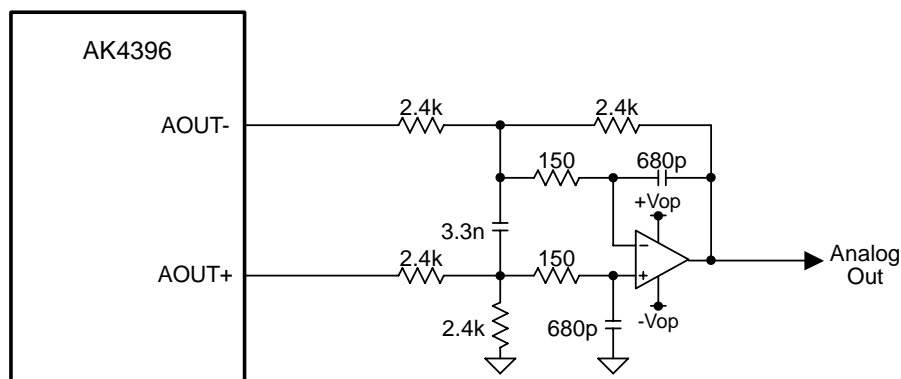


Figure 16. External LPF Circuit Example 1 for PCM ( $f_c = 125\text{kHz}$ ,  $Q=0.692$ )

| Frequency Response | Gain     |
|--------------------|----------|
| 20kHz              | -0.012dB |
| 40kHz              | -0.083dB |
| 80kHz              | -0.799dB |

Table 15. Filter Response of External LPF Circuit Example 1 for PCM

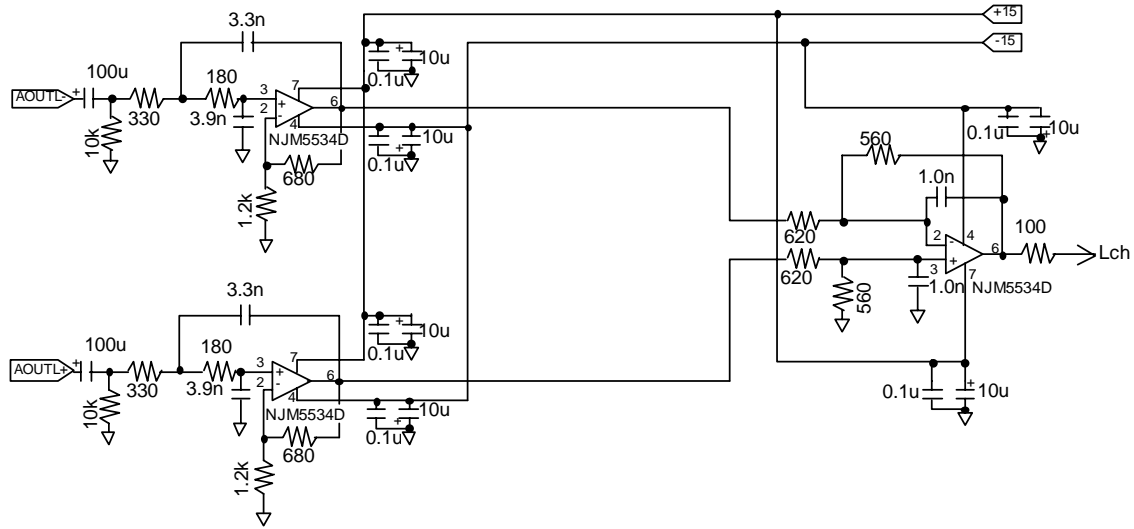


Figure 17. External LPF Circuit Example 2 for PCM

|                    |       | 1 <sup>st</sup> Stage | 2 <sup>nd</sup> 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 16. Filter Response of External LPF Circuit Example 2 for PCM

It is recommended by 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 AK4396 can achieve this filter response by combination of the internal filter (Table 17) and an external filter (Figure 18).

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

Table 17. Internal Filter Response at DSD mode

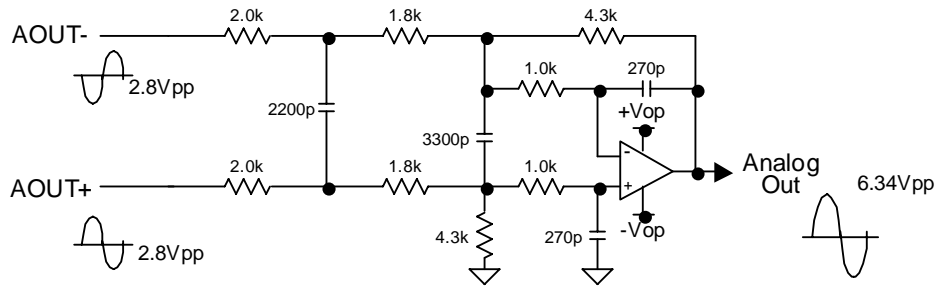


Figure 18. External 3rd order LPF Circuit Example for DSD

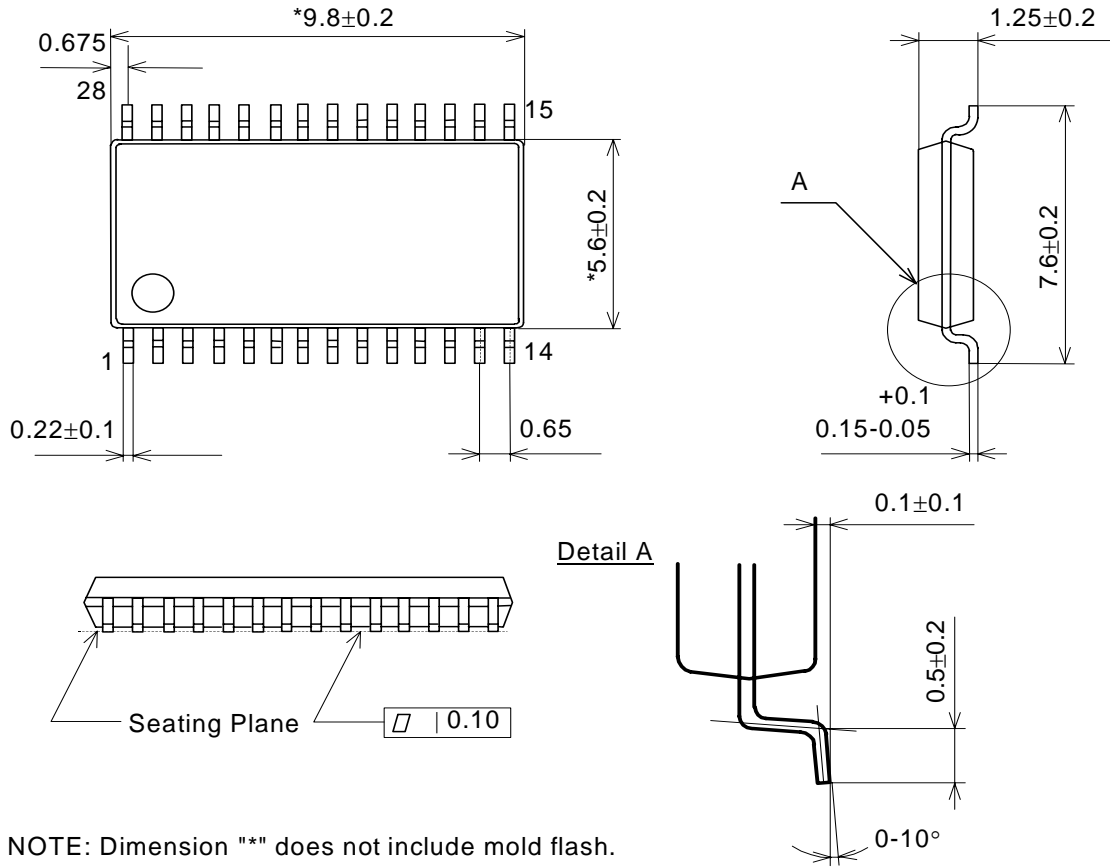
| Frequency | Gain    |
|-----------|---------|
| 20kHz     | -0.05dB |
| 50kHz     | -0.51dB |
| 100kHz    | -16.8dB |

DC gain = 1.07dB

Table 18. 3rd order LPF (Figure 18) Response

**PACKAGE**

**28pin VSOP (Unit: mm)**

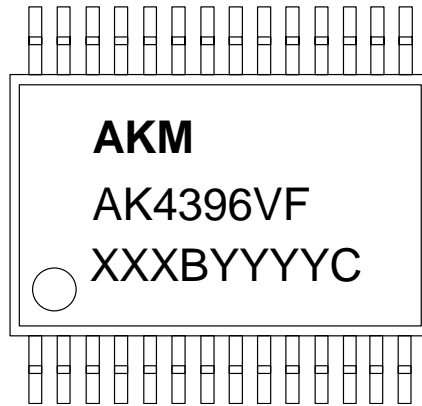


NOTE: Dimension "\*" does not include mold flash.

**Material & Lead finish**

- Package molding compound: Epoxy
- Lead frame material: Cu
- Lead frame surface treatment: Solder (Pb free) plate

**MARKING**



XXXXBYYYYC: Date code identifier

XXXB: Lot number (X : Digit number, B : Alpha character )  
 YYYYYC: Assembly date (Y : Digit number C : Alpha character)

**Revision History**

| Date (YY/MM/DD) | Revision | Reason        | Page | Contents |
|-----------------|----------|---------------|------|----------|
| 04/08/31        | 00       | First Edition |      |          |

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