



## Stereo, 24-Bit, 192kHz 8x Oversampling Digital Interpolation Filter

### FEATURES

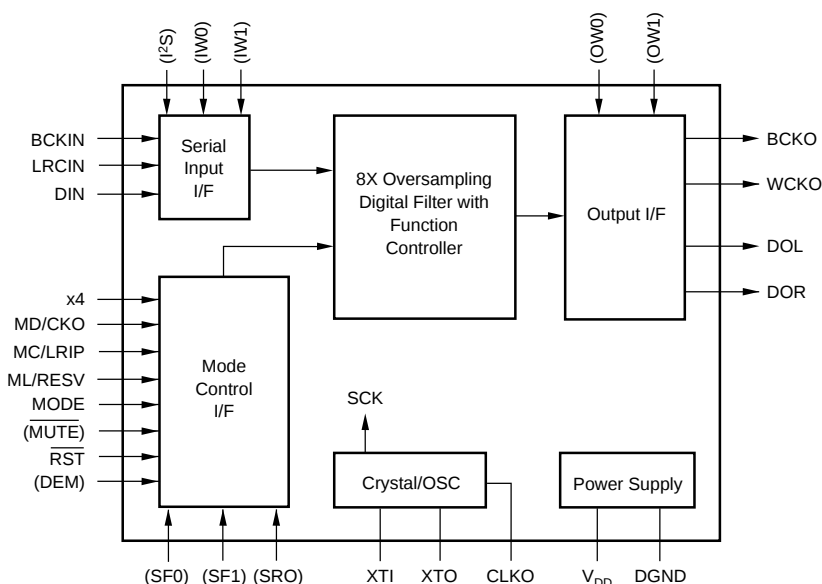
- COMPANION DIGITAL FILTER FOR THE PCM1704 24-BIT AUDIO DAC
- HIGH PERFORMANCE FILTER:  
Stopband Attenuation:  $-115\text{dB}$   
Passband Ripple:  $\pm 0.00005\text{dB}$
- AUDIO INTERFACE:  
Input Data Formats: Standard, Left-Justified, and  $I^2S$   
Input Word Length: 16, 20, or 24 Bits  
Output Word Length: 16, 18, 20, or 24 Bits  
Sampling Frequency: 32kHz to 192kHz
- SYSTEM CLOCK:  $128f_s$ ,  $192f_s$ ,  $256f_s$ ,  $384f_s$ ,  $512f_s$ ,  $768f_s$
- ON-CHIP CRYSTAL OSCILLATOR
- PROGRAMMABLE FUNCTIONS:  
Hardware or Software Control Modes  
Sharp or Slow Roll-Off Filter Response  
Soft Mute  
Digital De-Emphasis  
Independent Left/Right Digital Attenuation
- +3.3V SINGLE-SUPPLY OPERATION
- SMALL SSOP-28 PACKAGE

### DESCRIPTION

The DF1706 is a high performance, stereo, 8X oversampling digital interpolation filter designed for high-end consumer and professional audio applications. The DF1706 supports 24-bit, 192kHz operation and features user-programmable functions, including

selectable filter response, de-emphasis, attenuation, and input/output data formats.

The DF1706 is the ideal companion for Texas Instruments's PCM1704 24-bit audio Digital-to-Analog (D/A) converter. This combination allows for the construction of very high-performance audio systems and components.



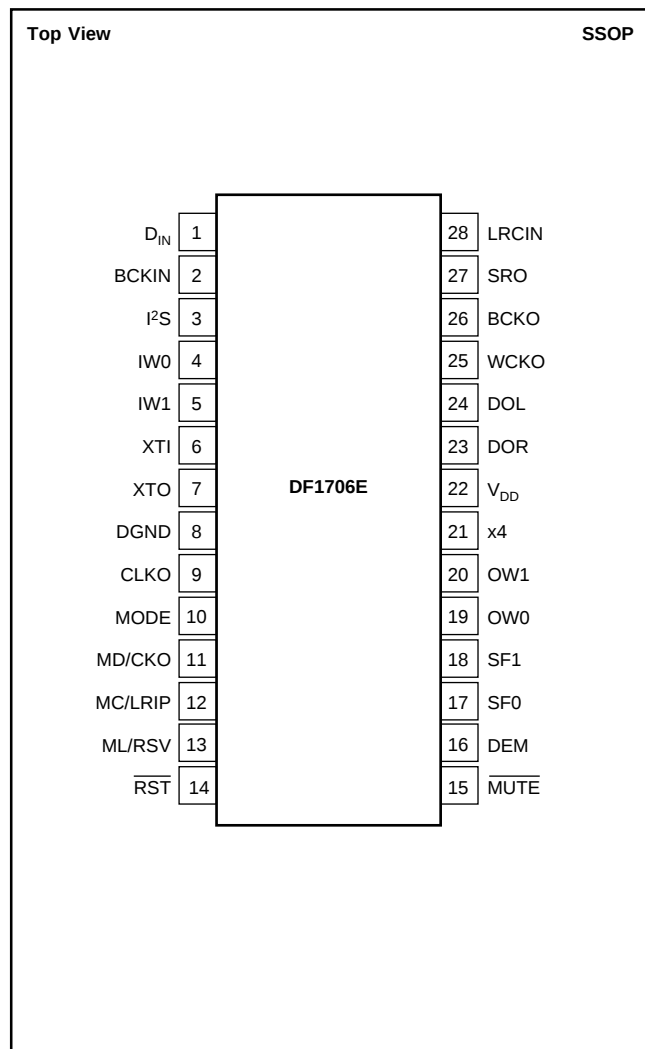
# SPECIFICATIONS

All specifications at  $T_A = +25^{\circ}\text{C}$ ,  $V_{DD} = 3.3\text{V}$ ,  $f_S = 44.1\text{kHz}$ , system clock =  $256f_S/384f_S$ , 16-bit data, unless otherwise noted.

| PARAMETER                                                                                                                                                                                                                                                                                                          | CONDITIONS                                                                                                                    | DF1706E                                                                                                                                          |                                                                           |                  | UNITS                                                                                         |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|------------------|-----------------------------------------------------------------------------------------------|
|                                                                                                                                                                                                                                                                                                                    |                                                                                                                               | MIN                                                                                                                                              | TYP                                                                       | MAX              |                                                                                               |
| <b>RESOLUTION</b>                                                                                                                                                                                                                                                                                                  |                                                                                                                               | 24                                                                                                                                               |                                                                           |                  | Bits                                                                                          |
| <b>INPUT DATA FORMAT</b><br>Audio Data Interface Format<br>Audio Data Bit Length<br>Audio Data Format<br>Sampling Frequency<br>System Clock Frequency <sup>(1)</sup>                                                                                                                                               | $f_S$                                                                                                                         | Standard, Left-Justified, I <sup>2</sup> S<br>16, 20, 24 Selectable<br>MSB First, Binary Two's Complement<br>32   192<br>128/192/256/384/512/768 |                                                                           |                  | kHz<br>$f_S$                                                                                  |
| <b>OUTPUT DATA FORMAT</b><br>Audio Data Interface Format<br>Audio Data Bit Length<br>Audio Data Format                                                                                                                                                                                                             |                                                                                                                               | Right-Justified<br>16, 20, 24 Selectable<br>MSB First, Binary Two's Complement                                                                   |                                                                           |                  |                                                                                               |
| <b>DIGITAL INPUT/OUTPUT</b><br>Input Logic Level: $V_{IH}$<br>$V_{IL}$<br>Output Logic Level: $V_{OH}$<br>$V_{OL}$                                                                                                                                                                                                 | $I_{OH} = 2\text{mA}$<br>$I_{OL} = 4\text{mA}$                                                                                | 0.7V <sub>DD</sub><br>2.4                                                                                                                        | CMOS Compatible<br>0.3V <sub>DD</sub><br>1.0                              |                  | V<br>V<br>V<br>V                                                                              |
| <b>CLKO AC CHARACTERISTICS</b> <sup>(2)</sup><br>Rise Time<br>Fall Time<br>Duty Cycle <sup>(2)</sup>                                                                                                                                                                                                               | $t_R$<br>$t_F$<br>20% to 80% V <sub>DD</sub> , 20pF<br>80% to 20% V <sub>DD</sub> , 20pF<br>20pF Load                         |                                                                                                                                                  | 4<br>3<br>50                                                              |                  | ns<br>ns<br>%                                                                                 |
| <b>DIGITAL FILTER PERFORMANCE</b><br>Filter Characteristics 1 (Sharp Roll-Off)<br>Passband<br><br>Stopband<br>Passband Ripple<br>Stopband Attenuation<br>Filter Characteristics 2 (Slow Roll-Off)<br>Passband Ripple<br><br>Stopband<br>Passband Ripple<br>Stopband Attenuation<br>Delay Time<br>De-Emphasis Error | $\pm 0.00005\text{dB}$<br>-3dB<br><br>Stopband = $0.546f_S$<br><br>$\pm 0.0001\text{dB}$<br>-3dB<br><br>Stopband = $0.748f_S$ | 0.546<br>-115<br><br>0.732<br>-100                                                                                                               | 45.125/ $f_S$<br><br>$\pm 0.00005$<br><br>$\pm 0.0001$<br><br>$\pm 0.004$ |                  | $f_S$<br>$f_S$<br>$f_S$<br>dB<br>$f_S$<br>$f_S$<br>$f_S$<br>dB<br>dB<br>dB<br>dB<br>sec<br>dB |
| <b>POWER-SUPPLY REQUIREMENTS</b><br>Voltage Range<br>Supply Current<br>Power Dissipation                                                                                                                                                                                                                           | $V_{DD}$<br>$V_{DD} = 3.3\text{V}$<br>$V_{DD} = 3.3\text{V}$                                                                  | 3.0                                                                                                                                              | 3.3<br>30<br>99                                                           | 3.6<br>45<br>149 | VDC<br>mA<br>mW                                                                               |
| <b>TEMPERATURE RANGE</b><br>Operation<br>Storage<br>Thermal Resistance, $\theta_{JA}$                                                                                                                                                                                                                              | SSOP-28                                                                                                                       | -25<br>-55                                                                                                                                       | 100                                                                       | +85<br>+125      | $^{\circ}\text{C}$<br>$^{\circ}\text{C}$<br>$^{\circ}\text{C}$                                |

NOTES: (1) Refer to Table I. (2) Crystal resonator used.

## PIN CONFIGURATION



## PIN ASSIGNMENTS

| PIN | NAME             | I/O | DESCRIPTION                                                                                     |
|-----|------------------|-----|-------------------------------------------------------------------------------------------------|
| 1   | D <sub>IN</sub>  | IN  | Serial Audio Data Input <sup>(1)</sup>                                                          |
| 2   | BCKIN            | IN  | Bit Clock Input for Serial Audio Data <sup>(1)</sup>                                            |
| 3   | I <sup>2</sup> S | IN  | Input Audio Data Format Select <sup>(2, 4)</sup>                                                |
| 4   | IW0              | IN  | Input Audio Data Word Select <sup>(2, 4)</sup>                                                  |
| 5   | IW1              | IN  | Input Audio Data Word Select <sup>(2, 4)</sup>                                                  |
| 6   | XTI              | IN  | Oscillator Input/External Clock Input                                                           |
| 7   | XTO              | OUT | Oscillator Output                                                                               |
| 8   | DGND             | —   | Digital Ground                                                                                  |
| 9   | CLKO             | OUT | Buffered System Clock Output                                                                    |
| 10  | MODE             | IN  | Mode Control Select (HIGH: Software Mode, LOW: Hardware Mode) <sup>(3)</sup>                    |
| 11  | MD/CKO           | IN  | Mode Control, Data/Half External Clock Frequency Select <sup>(3, 5)</sup>                       |
| 12  | MC/LRIP          | IN  | Mode Control, Clock/Polarity of LRCIN Select <sup>(3, 5)</sup>                                  |
| 13  | ML/RESV          | IN  | Mode Control, Latch Clock/Reserve <sup>(3, 5)</sup>                                             |
| 14  | RST              | IN  | Reset, Active LOW. When this pin is LOW the DF and modulators are held in reset. <sup>(3)</sup> |
| 15  | MUTE             | IN  | Mute Control, Active LOW <sup>(4)</sup>                                                         |
| 16  | DEM              | IN  | De-Emphasis Control <sup>(2, 4)</sup>                                                           |
| 17  | SF0              | IN  | Sampling Rate Select for De-emphasis <sup>(2, 4)</sup>                                          |
| 18  | SF1              | IN  | Sampling Rate Select for De-emphasis <sup>(2, 4)</sup>                                          |
| 19  | OW0              | IN  | Output Audio Data Word Select <sup>(2, 4)</sup>                                                 |
| 20  | OW1              | IN  | Output Audio Data Word Select <sup>(2, 4)</sup>                                                 |
| 21  | x4               | IN  | Oversampling Ratio Control. When this pin is set HIGH, the ratio is 4 times.                    |
| 22  | V <sub>DD</sub>  | —   | Digital Power, +3.3V                                                                            |
| 23  | DOR              | OUT | R-Channel, Serial Audio Data Output                                                             |
| 24  | DOL              | OUT | L-Channel, Serial Audio Data Output                                                             |
| 25  | WCKO             | OUT | Word Clock Output for Serial Audio Data Output                                                  |
| 26  | BCKO             | OUT | Bit Clock Output for Serial Audio Data Output                                                   |
| 27  | SRO              | IN  | Filter Response Select <sup>(2, 4)</sup>                                                        |
| 28  | LRCIN            | IN  | L/R Clock Input (f <sub>s</sub> ) <sup>(1)</sup>                                                |

NOTES: (1) Pins 1, 2, 28—Schmitt-Trigger input without pull-up and -down resistor. (2) Pins 3-5, 16-21, 27—Schmitt-Trigger input without pull-up and -down resistor. (3) Pins 10-15—Schmitt-Trigger input without pull-up and -down resistor. (4) Pins 3-5, 15-20, 27—these pins are invalid when MODE (pin 10) is HIGH. (5) Pins 11-13—these pins have different functions corresponding to MODE (pin 10) HIGH/LOW.

## ABSOLUTE MAXIMUM RATINGS

|                                                  |                 |
|--------------------------------------------------|-----------------|
| Supply Voltage .....                             | +4.0V           |
| Digital Input Voltage .....                      | –0.2V to 4.5V   |
| Input Current (any pins except supplies) .....   | ±10mA           |
| Operating Temperature Range .....                | –25°C to +85°C  |
| Ambient Storage Temperature .....                | –40°C to +125°C |
| Junction Temperature .....                       | +150°C          |
| Lead Temperature (soldering, 5s) .....           | +260°C          |
| Package Temperature (IR reflow, Peak, 10s) ..... | +235°C          |

## PACKAGE/ORDERING INFORMATION

| PRODUCT | PACKAGE | PACKAGE DRAWING NUMBER | SPECIFIED TEMPERATURE RANGE | PACKAGE MARKING | ORDERING NUMBER <sup>(1)</sup> | TRANSPORT MEDIA |
|---------|---------|------------------------|-----------------------------|-----------------|--------------------------------|-----------------|
| DF1706E | SSOP-28 | 324                    | –25°C to +85°C              | DF1706E         | DF1706E                        | Rails           |
| "       | "       | "                      | "                           | "               | DF1706E/2K                     | Tape and Reel   |

NOTE: (1) Models with a slash (/) are available only in Tape and Reel in the quantities indicated (e.g., /2K indicates 2000 devices per reel). Ordering 2000 pieces of "DF1706E/2K" will get a single 2000-piece Tape and Reel.



## ELECTROSTATIC DISCHARGE SENSITIVITY

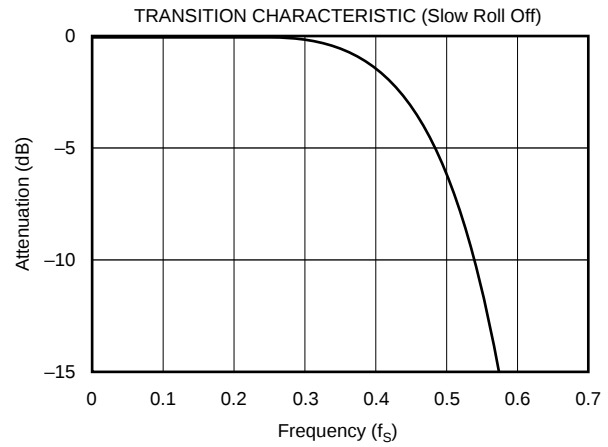
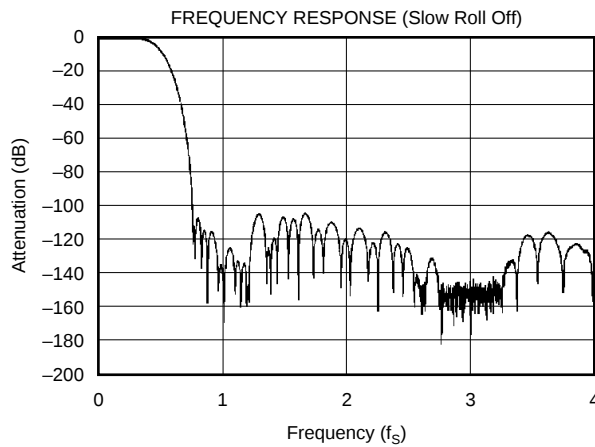
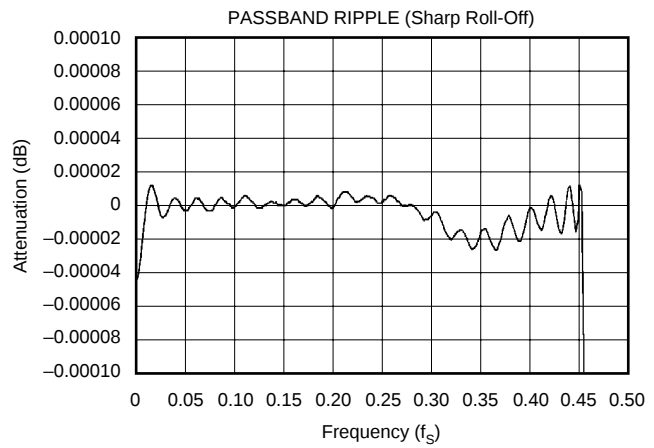
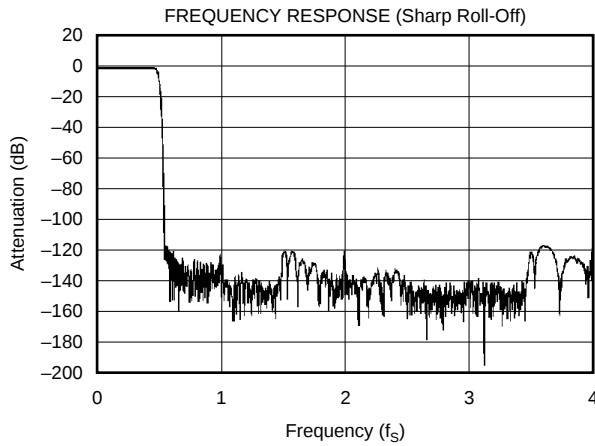
This integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

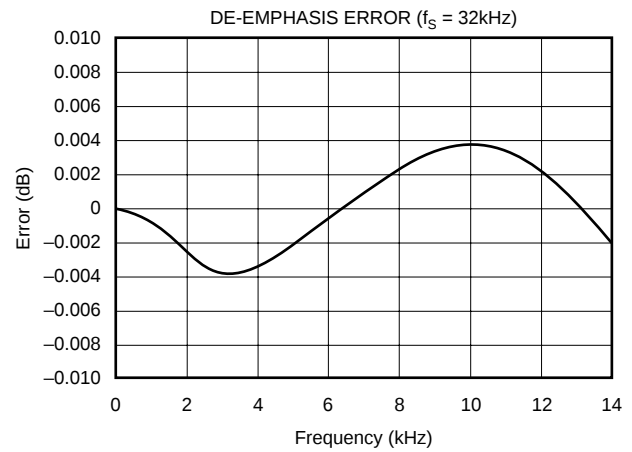
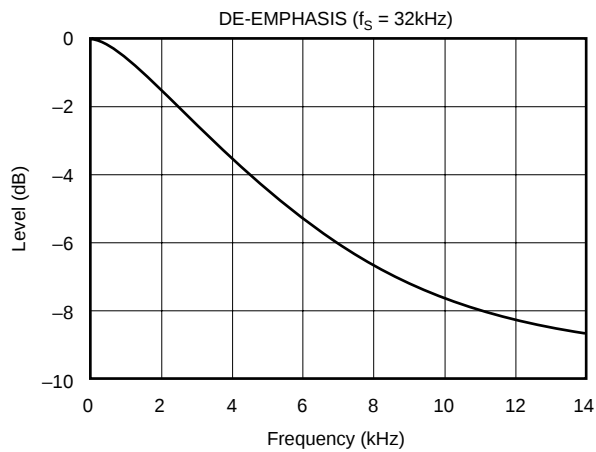
# TYPICAL PERFORMANCE CURVES

At  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = \pm 3.3\text{V}$ ,  $f_S = 44.1\text{kHz}$ , System Clock =  $256f_S/384f_S$ , 16-bit data, unless otherwise noted.

## DIGITAL FILTER (DE-EMPHASIS OFF, $f_S = 44.1\text{kHz}$ )

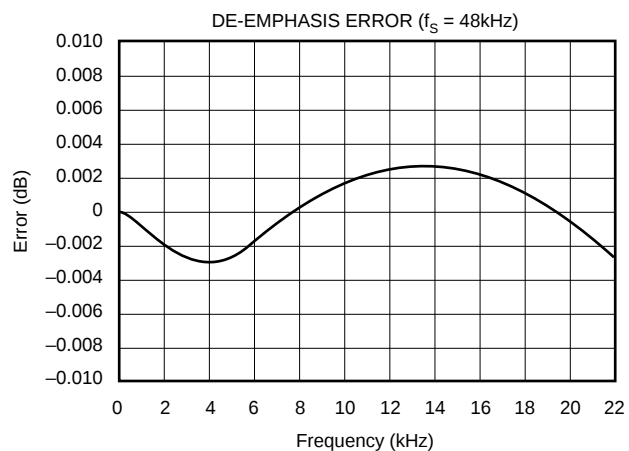
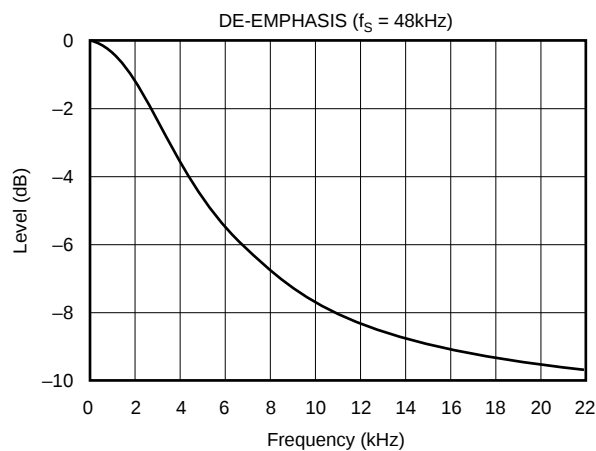
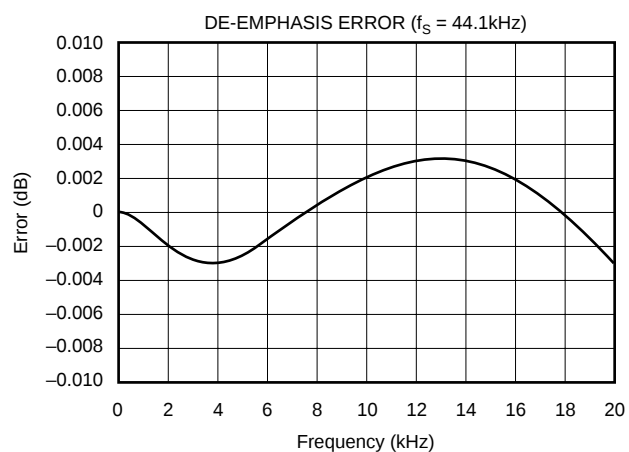
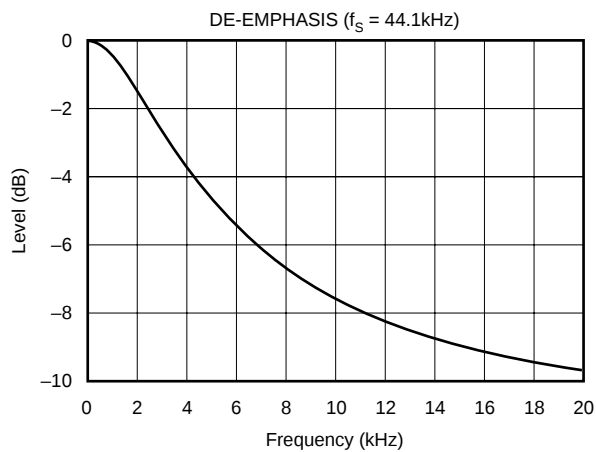


## DE-EMPHASIS AND DE-EMPHASIS ERROR



# TYPICAL PERFORMANCE CURVES (Cont.)

At  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = \pm 3.3\text{V}$ ,  $f_S = 44.1\text{kHz}$ , System Clock =  $256f_S/384f_S$ , 16-bit data, unless otherwise noted.



## SYSTEM CLOCK REQUIREMENTS

The system clock of the DF1706 can be supplied by either an external clock signal at XTI (pin 6), or by the on-chip crystal oscillator. The system clock rate must run at  $128f_s$ ,  $192f_s$ ,  $256f_s$ ,  $384f_s$ ,  $512f_s$ , or  $768f_s$ , where  $f_s$  is the audio sampling rate. When a  $128f_s$  or  $192f_s$  system clock is applied to DF1706, the Over-Sampling Ratio (OSR) of the DF1706's digital filter should be four times instead of eight times. The OSR can be selected by the x4 pin (pin 21) in hardware mode or x4 bit on MODE 2 register in software mode.

It should be noted that a  $768f_s$  system clock cannot be used when  $f_s$  is larger than 48kHz. Both  $128f_s$  and  $192f_s$  system clock can be used when  $f_s$  is larger than 96kHz. In addition, the on-chip crystal oscillator is limited to a maximum frequency of 24.0MHz. Table I shows the typical system clock frequencies for selected sample rates.

The DF1706 includes a system clock detection circuit that determines the system clock rate in use. The circuit compares the system clock input (XTI) frequency with the LRCIN input rate to determine the system clock multiplier. Ideally, LRCIN and BCKIN should be derived from the system clock to ensure proper synchronization. If the phase difference between the system clock and LRCIN is larger than  $\pm 4$  bit clock (BCKIN) periods, the synchronization of the system and LRCIN clocks will be performed automatically by the DF1706.

Timing requirements for the system clock input are shown in Figure 1.

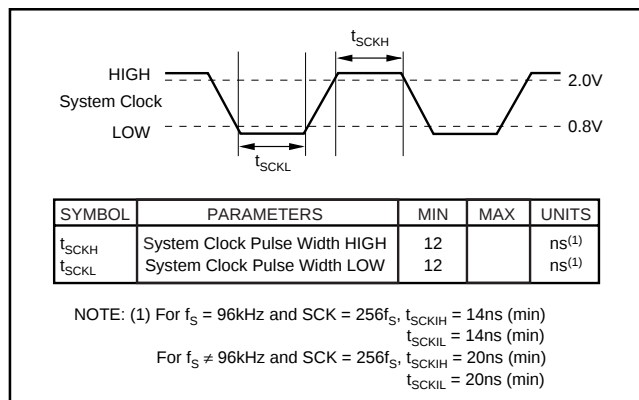


FIGURE 1. System Clock Timing.

## RESET

The DF1706 has both an internal power-on reset circuit and a reset pin,  $\overline{\text{RST}}$  (pin 14), for providing an external reset signal. The internal power-on reset is performed automatically when power is applied to the DF1706, as shown in Figure 2. The  $\overline{\text{RST}}$  pin can be used to synchronize the DF1706 with a system reset signal, as shown in Figure 3.

During the power-on reset period (1024 system clocks), the outputs of BCKO, DOL, and DOR are forced LOW and the output of WCKO is forced HIGH. For an external forced reset, the outputs of BCKO, DOL, and DOR are forced LOW and the output of WCKO is forced HIGH during the initialization period (1024 system clocks), which occurs after the LOW-to-HIGH transition of the  $\overline{\text{RST}}$  pin (see Figure 3).

| SAMPLING RATE FREQUENCY ( $f_s$ )/256 $f_s$ | SYSTEM CLOCK FREQUENCY (MHz) |                           |                        |                        |                       |                        |
|---------------------------------------------|------------------------------|---------------------------|------------------------|------------------------|-----------------------|------------------------|
|                                             | 128 $f_s$                    | 192 $f_s$                 | 256 $f_s$              | 384 $f_s$              | 512 $f_s$             | 768 $f_s$              |
| 32kHz                                       | N/A                          | N/A                       | 8.192                  | 12.288                 | 16.384                | 24.576 <sup>(1)</sup>  |
| 44.1kHz                                     | N/A                          | N/A                       | 11.2896                | 16.934                 | 22.5792               | 33.8688 <sup>(1)</sup> |
| 48kHz                                       | N/A                          | N/A                       | 12.288                 | 18.432                 | 24.576 <sup>(1)</sup> | 36.864 <sup>(1)</sup>  |
| 88.2kHz                                     | N/A                          | N/A                       | 22.5792 <sup>(1)</sup> | 33.8688 <sup>(1)</sup> | N/A                   | N/A                    |
| 96kHz                                       | N/A                          | N/A                       | 24.576                 | 36.864 <sup>(1)</sup>  | N/A                   | N/A                    |
| 176.4kHz                                    | 22.5792 <sup>(2)</sup>       | 33.8688 <sup>(1)(2)</sup> | N/A                    | N/A                    | N/A                   | N/A                    |
| 192kHz                                      | 24.576 <sup>(1)(2)</sup>     | 36.864 <sup>(1)(2)</sup>  | N/A                    | N/A                    | N/A                   | N/A                    |

NOTES: (1) Crystal oscillator frequency using internal oscillator is not covered at frequency larger than 24.0MHz. (2) x4 (pin 21) should be set to HIGH.

TABLE I. Typical System Clock Frequencies.

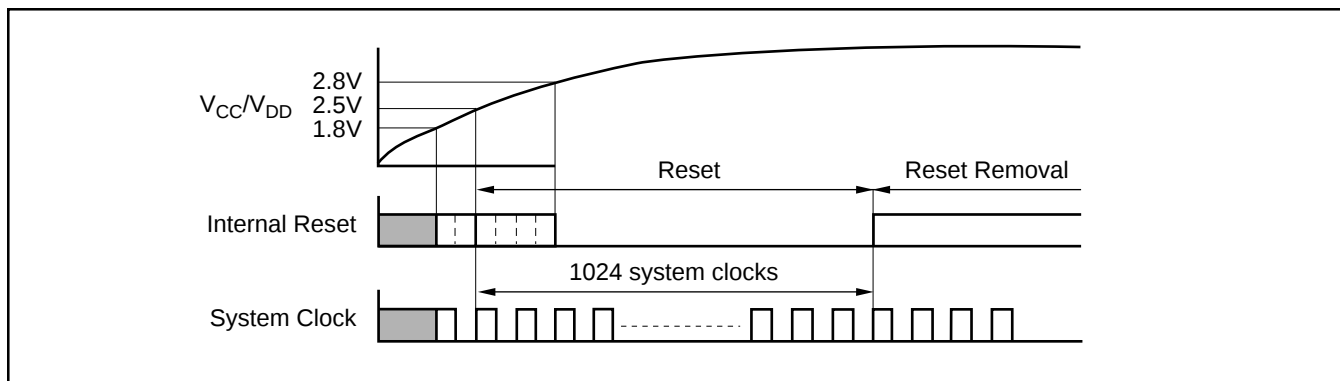


FIGURE 2. Internal Power-On Reset Timing.

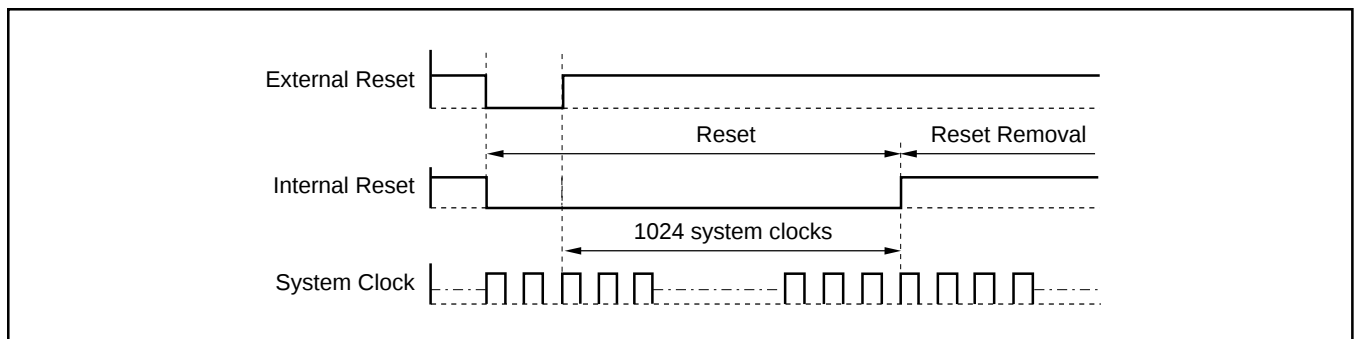


FIGURE 3. External Forces Reset Timing.

## AUDIO INPUT INTERFACE

The audio input interface is comprised of BCKIN (pin 2), LRCIN (pin 28), and DIN (pin 1). BCKIN is the input bit clock, which is used to clock data applied at  $D_{IN}$  into the DF1706's input serial interface. Input data at  $D_{IN}$  is clocked into the DF1706 on the rising edge of BCKIN. The left/right

clock, LRCIN, is used as a word latch for the audio input data. BCKIN can run at  $32f_s$ ,  $48f_s$ , or  $64f_s$ , where  $f_s$  is the audio sample frequency. LRCIN is run at the  $f_s$  rate. Figures 4 (a) through (c) show the input data formats, which are selected by hardware or software controls.

See Figure 5 for the audio input interface timing requirements.

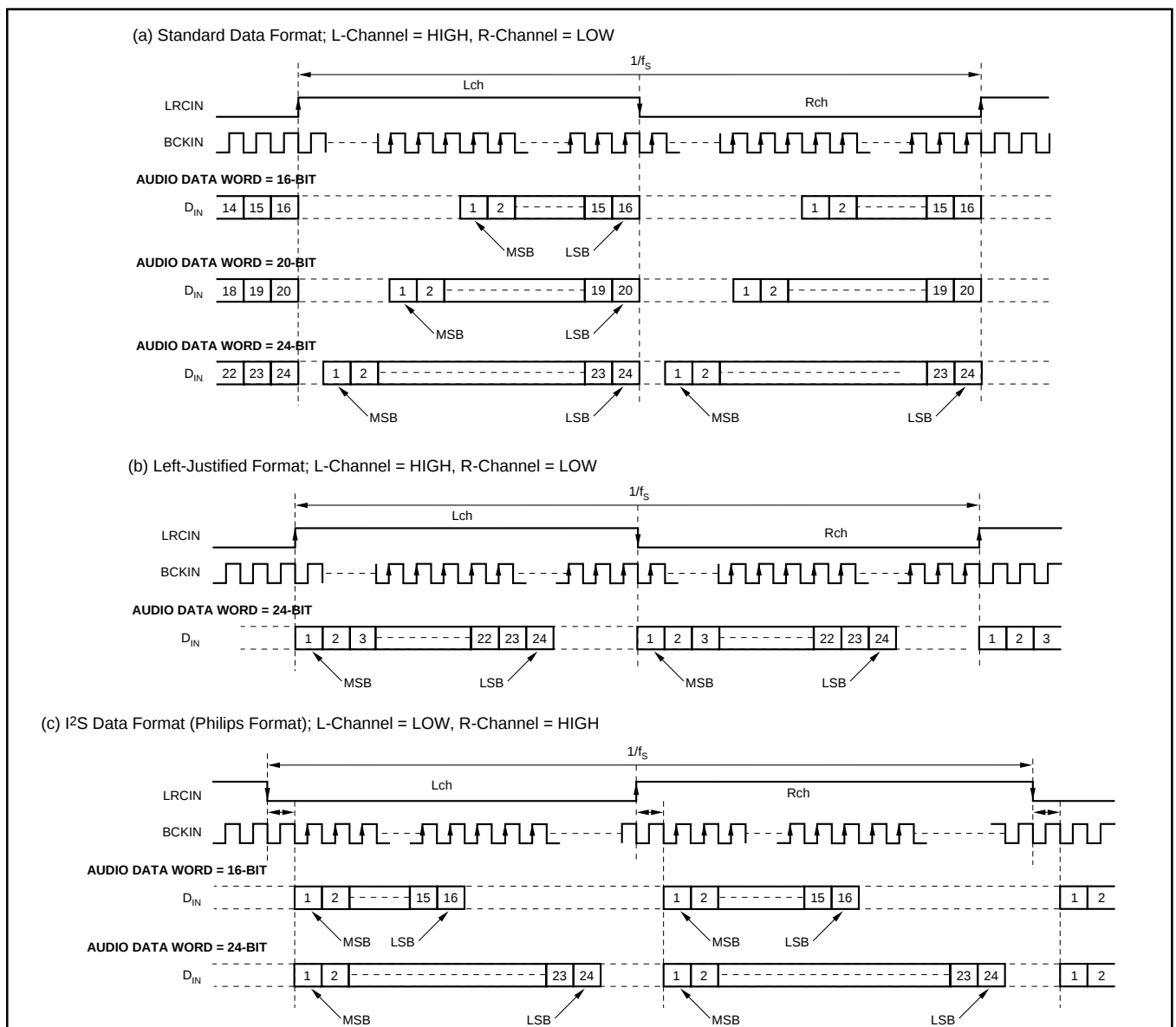


FIGURE 4. Audio Data Input Formats.

## AUDIO OUTPUT INTERFACE

The audio output interface includes BCKO (pin 26), WCKO (pin 25), DOL (pin 24), and DOR (pin 23).

BCKO is the output bit clock and is used to clock data into an audio D/A converter, such as the PCM1704. DOL and DOR are the left and right audio data outputs. WCKO is the output word clock and is used to latch audio data words into an audio D/A converter.

WCKO runs at a fixed rate of  $8f_s$  (8x oversampling) for all system clock rates.

BCKO is fixed at  $256f_s$  for system clock rates of  $256f_s$  or  $512f_s$ .

BCKO is fixed at  $192f_s$  for system clock rates of  $384f_s$  or  $768f_s$ .

The output data format used by the DF1706 for DOL and DOR is Binary Two's Complement, MSB-first, right-justified audio data. Figures 6(a), (b), (c), and (d) show the output data formats for the DF1706. See Figure 7 the audio output timing.

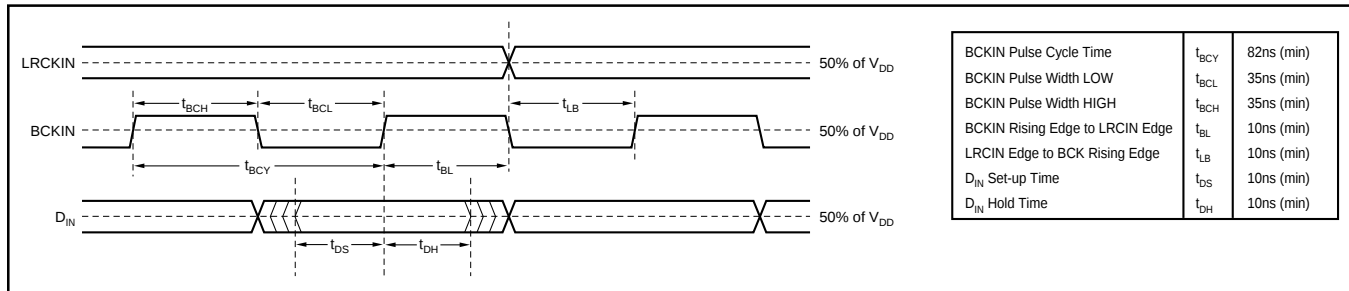


FIGURE 5. Audio Input Interface Timing.

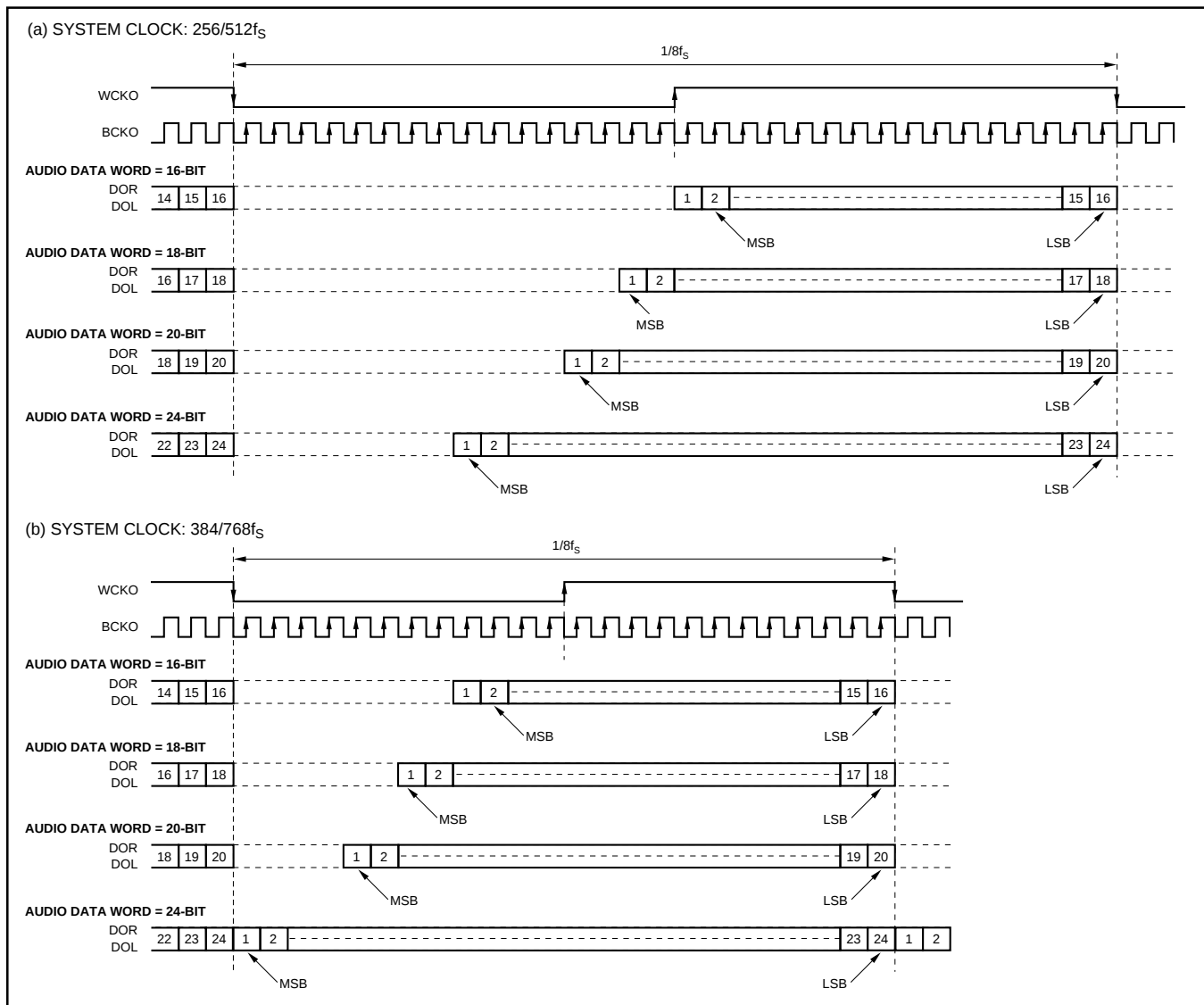
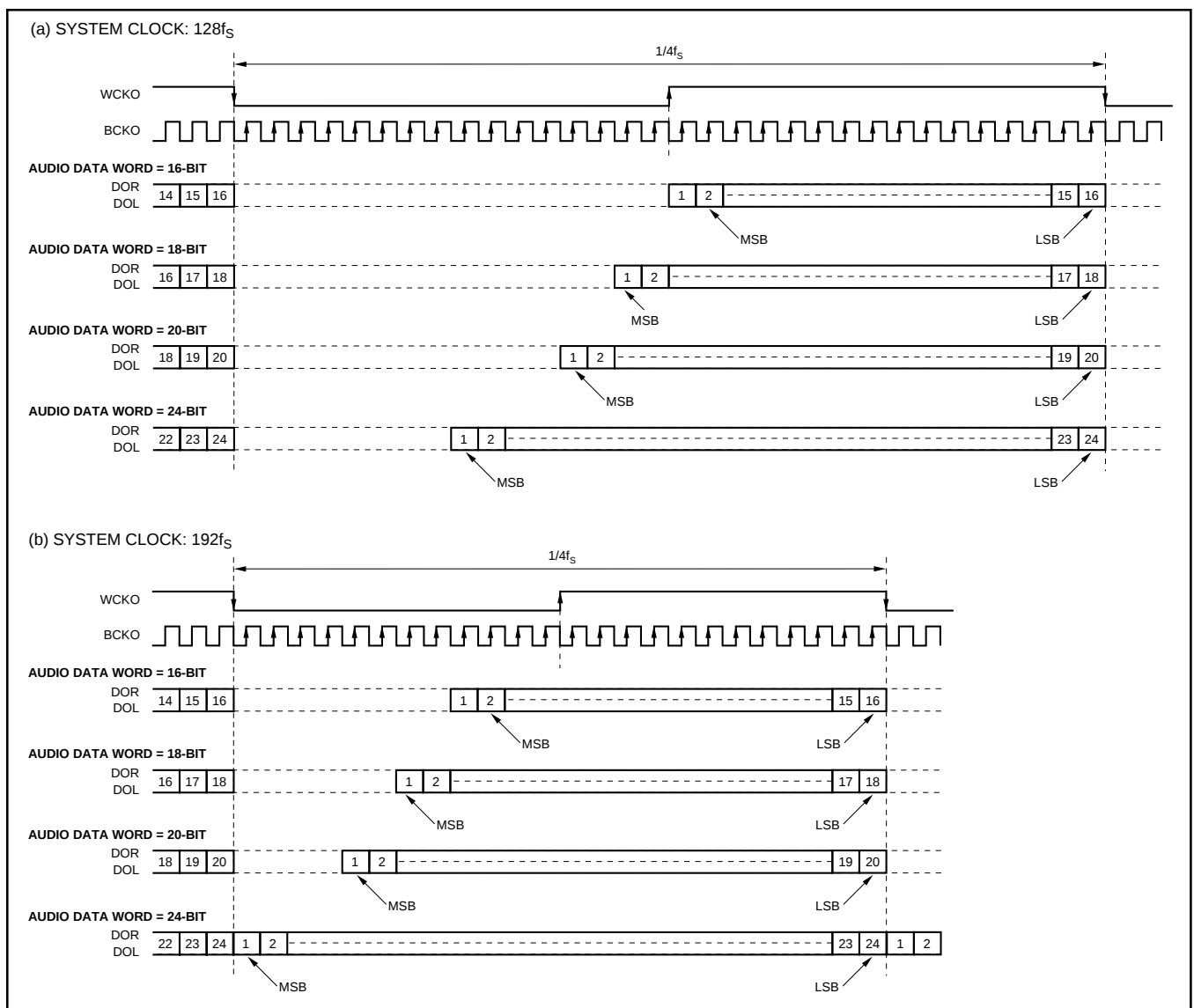


FIGURE 6. Audio Output Data Format.



(Cont.) FIGURE 6. Audio Output Data Format.

## MODE CONTROL

The DF1706 may be configured using either software or hardware control. The selection is made using the MODE input (pin 10). See Table II for MODE selection.

| MODE SETTING | MODE CONTROL SELECTION |
|--------------|------------------------|
| MODE = H     | Software Mode          |
| MODE = L     | Hardware Mode          |

TABLE II. MODE Selection.

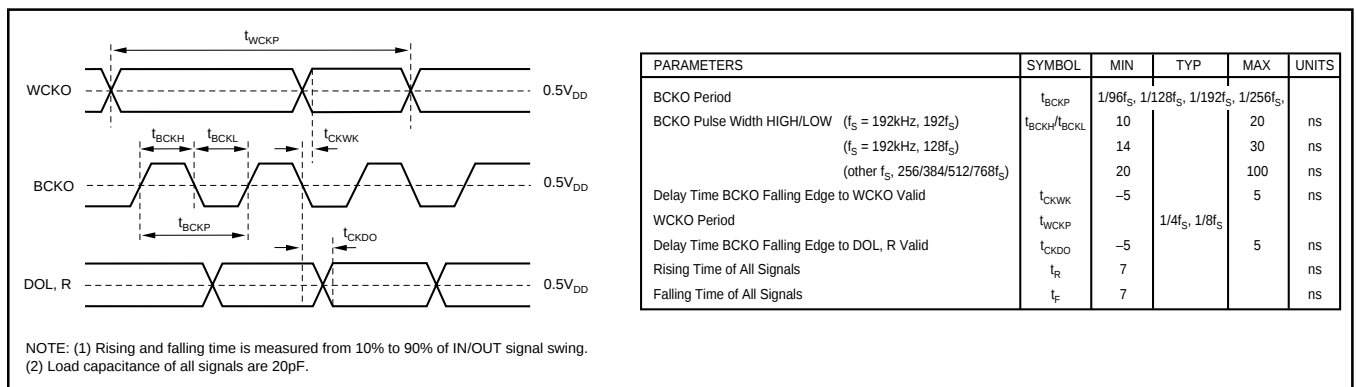


FIGURE 7. Audio Data Output Timing.

## Programmable Functions

The DF1706 includes a number of programmable features, with most being accessible from either Hardware or Software mode. Table III summarizes the user-programmable functions for both modes of operation.

| FUNCTION                                          | SOFTWARE<br>(MODE = H) | HARDWARE<br>(MODE = L) | RESET<br>DEFAULT<br>(Software Mode) |
|---------------------------------------------------|------------------------|------------------------|-------------------------------------|
| Input Data Format Selection                       | 0                      | 0                      | Standard Format                     |
| Input Word Length Selection                       | 0                      | 0                      | 16 Bits                             |
| Output Word Length Selection                      | 0                      | 0                      | 16 Bits                             |
| LRCIN Polarity Selection                          | 0                      | 0                      | Left/Right = High/Low               |
| Digital De-Emphasis                               | 0                      | 0                      | OFF                                 |
| Over Sample Ratio Control                         | 0                      | 0                      | 8x                                  |
| Soft Mute                                         | 0                      | 0                      | OFF                                 |
| Digital Attenuation                               | 0                      | X                      | 0dB, Independent L/R                |
| Sample Rate for<br>De-Emphasis Function           | 0                      | 0                      | 44.1 kHz                            |
| Filter Roll-Off Selection                         | 0                      | 0                      | Sharp Roll-Off Selected             |
| CLKO Output-Frequency Selection                   | 0                      | 0                      | Same As XTI Input                   |
| Legend: 0 = User Programmable, X = Not Available. |                        |                        |                                     |

TABLE III. User-Programmable Functions for Software and Hardware Mode.

## Hardware Mode Controls

With MODE = L, the DF1706 may be configured by utilizing several user-programmable pins. The following is a brief summary of the pin functions. Table IV provides more details on setting the hardware mode controls.

Pins I<sup>2</sup>S, IW0, and IW1 are used to select the audio data input format and word length.

Pins OW0 and OW1 are used to select the output data word length.

The DEM pin is used to enable and disable the digital de-emphasis function. De-emphasis is only available for 32kHz, 44.1kHz, and 48kHz sample rates.

Pins SF0 and SF1 are used to select the sample rate for the de-emphasis function.

The SRO pin is used to select the digital filter response, either sharp or slow roll-off. Generally, sharp roll-off filter is used.

The MUTE pin is used to enable or disable the soft mute function.

The CKO pin is used to select the clock frequency seen at the CLKO pin, either XTI or XTI ÷ 2.

The LRIP pin is used to select the polarity used for the audio input left/right clock, LRCIN.

The x4 pin is used to control the over sampling ratio of the internal digital filter, either a 8x or 4x. For instance, when fs is 192kHz or 176.4kHz, the over sampling ratio should be 4x.

| PIN NAME                       | PIN NUMBER  | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
|--------------------------------|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-----|---------------|--------------|---|-------------------|---|----------------------------------------------|--------------------|---|---|----------------------------------------------|---|---|-------------------|----------------------------------------------|---|---|---|-----------------------------------|---|---|---|--------------------------|---|---|---|--------------------------|
| RSV                            | 13          | Reserved, Not Used                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| LRIP                           | 12          | LRCIN Polarity<br>LRIP = H: LRCIN= H = Left Channel, LRCIN= L = Right Channel<br>LRIP = L: LRCIN= L = Left Channel, LRCIN = H = Right Channel                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| CKO                            | 11          | CLKO Output Frequency<br>CKO = H: CLKO Frequency = XTI/2<br>CKO = L: CLKO Frequency = XTI                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| MUTE                           | 15          | Soft Mute Control: H = Mute Off, L = Mute On                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| I <sup>2</sup> S<br>IW0<br>IW1 | 3<br>4<br>5 | Input Data Format Controls<br><br><table><tr><th>I<sup>2</sup>S</th><th>IW1</th><th>IW0</th><th>INPUT FORMAT</th></tr><tr><td>L</td><td>L</td><td>L</td><td>16-Bit, Standard, MSB-First, Right-Justified</td></tr><tr><td>L</td><td>L</td><td>H</td><td>20-Bit, Standard, MSB-First, Right-Justified</td></tr><tr><td>L</td><td>H</td><td>L</td><td>24-Bit, Standard, MSB-First, Right-Justified</td></tr><tr><td>L</td><td>H</td><td>H</td><td>24-Bit, MSB-First, Left-Justified</td></tr><tr><td>H</td><td>L</td><td>L</td><td>16-Bit, I<sup>2</sup>S</td></tr><tr><td>H</td><td>L</td><td>H</td><td>24-Bit, I<sup>2</sup>S</td></tr></table> | I <sup>2</sup> S                             | IW1 | IW0           | INPUT FORMAT | L | L                 | L | 16-Bit, Standard, MSB-First, Right-Justified | L                  | L | H | 20-Bit, Standard, MSB-First, Right-Justified | L | H | L                 | 24-Bit, Standard, MSB-First, Right-Justified | L | H | H | 24-Bit, MSB-First, Left-Justified | H | L | L | 16-Bit, I <sup>2</sup> S | H | L | H | 24-Bit, I <sup>2</sup> S |
| I <sup>2</sup> S               | IW1         | IW0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | INPUT FORMAT                                 |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| L                              | L           | L                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 16-Bit, Standard, MSB-First, Right-Justified |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| L                              | L           | H                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 20-Bit, Standard, MSB-First, Right-Justified |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| L                              | H           | L                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 24-Bit, Standard, MSB-First, Right-Justified |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| L                              | H           | H                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 24-Bit, MSB-First, Left-Justified            |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| H                              | L           | L                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 16-Bit, I <sup>2</sup> S                     |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| H                              | L           | H                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 24-Bit, I <sup>2</sup> S                     |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| SRO                            | 27          | Digital Filter Roll-Off: H = Slow, L = Sharp                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| OW0<br>OW1                     | 19<br>20    | Output Data Word Length Controls<br><br><table><tr><th>OW1</th><th>OW0</th><th>OUTPUT FORMAT</th></tr><tr><td>L</td><td>L</td><td>16-Bit, MSB-First</td></tr><tr><td>L</td><td>H</td><td>18-Bit, MSB-First</td></tr><tr><td>H</td><td>L</td><td>20-Bit, MSB-First</td></tr><tr><td>H</td><td>H</td><td>24-Bit, MSB-First</td></tr></table>                                                                                                                                                                                                                                                                                                      | OW1                                          | OW0 | OUTPUT FORMAT | L            | L | 16-Bit, MSB-First | L | H                                            | 18-Bit, MSB-First  | H | L | 20-Bit, MSB-First                            | H | H | 24-Bit, MSB-First |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| OW1                            | OW0         | OUTPUT FORMAT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| L                              | L           | 16-Bit, MSB-First                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| L                              | H           | 18-Bit, MSB-First                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| H                              | L           | 20-Bit, MSB-First                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| H                              | H           | 24-Bit, MSB-First                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| SF0<br>SF1                     | 17<br>18    | Sample Rate Selection for the Digital De-Emphasis Control<br><br><table><tr><th>SF1</th><th>SF0</th><th>SAMPLING RATE</th></tr><tr><td>L</td><td>L</td><td>44.1kHz</td></tr><tr><td>L</td><td>H</td><td>Reserved, Not Used</td></tr><tr><td>H</td><td>L</td><td>48kHz</td></tr><tr><td>H</td><td>H</td><td>32kHz</td></tr></table>                                                                                                                                                                                                                                                                                                              | SF1                                          | SF0 | SAMPLING RATE | L            | L | 44.1kHz           | L | H                                            | Reserved, Not Used | H | L | 48kHz                                        | H | H | 32kHz             |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| SF1                            | SF0         | SAMPLING RATE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| L                              | L           | 44.1kHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| L                              | H           | Reserved, Not Used                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| H                              | L           | 48kHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| H                              | H           | 32kHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| DEM                            | 16          | Digital De-Emphasis: H = On, L = Off                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |
| x4                             | 21          | Oversampling Rate Control: H = 4f <sub>s</sub> , L = 8f <sub>s</sub>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                              |     |               |              |   |                   |   |                                              |                    |   |   |                                              |   |   |                   |                                              |   |   |   |                                   |   |   |   |                          |   |   |   |                          |

TABLE IV. Hardware Mode Controls.

Finally, the RESV pin is not used by the current DF1706 design, but is reserved for future use.

## Software Mode Controls

With MODE = H, the DF1706 may be configured by programming four internal registers in software mode. ML (pin 13), MC (pin 12), and MD (pin 11) make up the 3-wire software control port, and may be controlled using DSP or microcontroller general purpose I/O pins, or a serial port. Table V provides an overview of the internal registers, labeled MODE0 through MODE3 (see Table V).

See Figures 8 through 10 for more details regarding the control port data format and timing requirements. The data format for the control port is 16-bit, MSB-first, with Bit B15 being the MSB.

## Register Addressing

A[1:0], bits B10 and B9 of the 16-bit control data word, are used to indicate the register address to be written to by the current control port write cycle. See Table VI for how to address the internal registers using bits A[1:0] of registers MODE0 through MODE3.

|       | B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8  | B7  | B6  | B5  | B4  | B3  | B2  | B1  | B0               |
|-------|-----|-----|-----|-----|-----|-----|----|-----|-----|-----|-----|-----|-----|-----|-----|------------------|
| MODE0 | res | res | res | res | res | A1  | A0 | LDL | AL7 | AL6 | AL5 | AL4 | AL3 | AL2 | AL1 | AL0              |
| MODE1 | res | res | res | res | res | A1  | A0 | LDR | AR7 | AR6 | AR5 | AR4 | AR3 | AR2 | AR1 | AR0              |
| MODE2 | res | res | res | res | res | A1  | A0 | res | res | OW1 | OW0 | IW1 | IW0 | x4  | DEM | MUT              |
| MODE3 | res | res | res | res | res | A1  | A0 | res | SF1 | SF0 | CKO | res | SRO | ATC | LRP | I <sup>2</sup> S |

FIGURE 8. Internal Mode Control Registers.

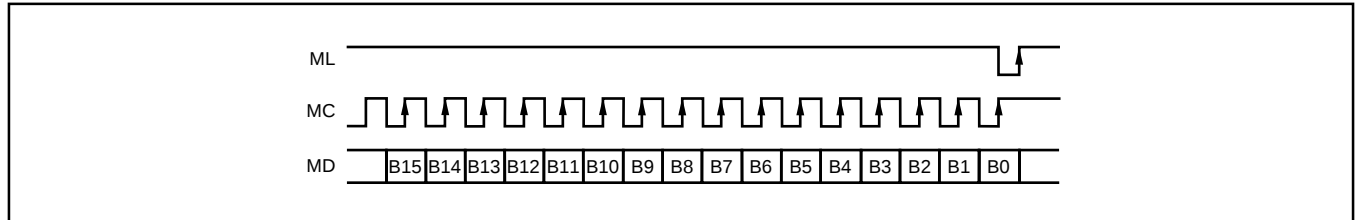


FIGURE 9. Software Interface Format.

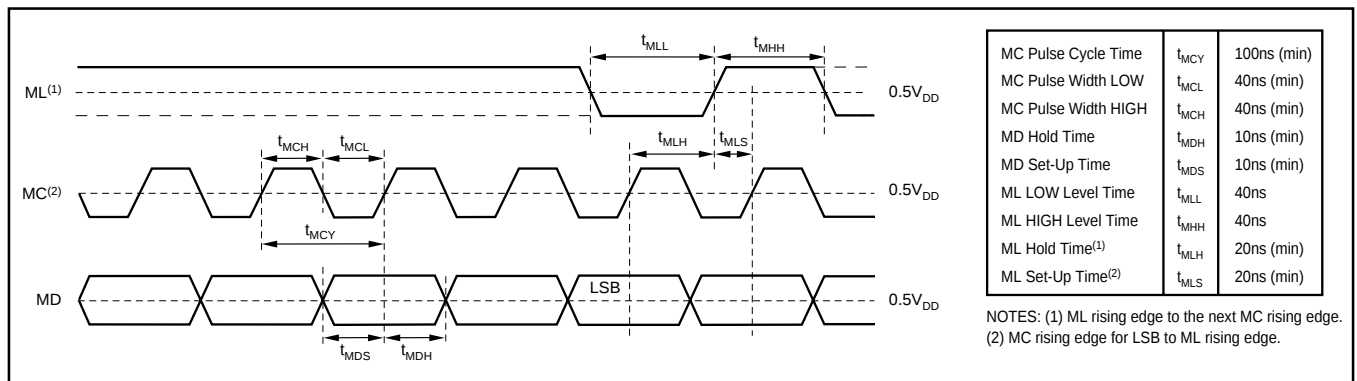


FIGURE 10. Software Interface Timing Requirements.

| REGISTER NAME | BIT NAME         | DESCRIPTION                                                     |
|---------------|------------------|-----------------------------------------------------------------|
| MODE0         | AL[7:0]          | Attenuation Data for the Left Channel                           |
|               | LDL              | Attenuation Load Control for the Left Channel                   |
|               | A[1:0]           | Register Address                                                |
|               | res              | Reserved                                                        |
| MODE1         | AR[7:0]          | Attenuation Data for the Right Channel                          |
|               | LDR              | Attenuation Load Control for the Right Channel                  |
|               | A[1:0]           | Register Address                                                |
|               | res              | Reserved                                                        |
| MODE2         | MUT              | Soft Mute Control                                               |
|               | DEM              | Digital De-Emphasis Control                                     |
|               | x4               | Oversampling Rate Control                                       |
|               | IW[1:0]          | Input Data Format and Word Length                               |
|               | OW[1:0]          | Output Data Word Length                                         |
|               | A[1:0]           | Register Address                                                |
| MODE3         | res              | Reserved                                                        |
|               | I <sup>2</sup> S | Input Data Format (I <sup>2</sup> S or Standard/Left-Justified) |
|               | LRP              | LRCIN Polarity                                                  |
|               | ATC              | Attenuator Control, Dependent or Independent                    |
|               | SRO              | Digital Filter Roll-Off Selection (sharp or slow)               |
|               | CKO              | CLKO Frequency Selection (XTI or XTI ÷ 2)                       |
|               | SF[1:0]          | Sample Rate Selection for De-Emphasis Function                  |
|               | A[1:0]           | Register Address                                                |
|               | res              | Reserved                                                        |

NOTE: All reserved bits should be programmed to 0.

TABLE V. Internal Register Mapping.

| A1 | A0 | REGISTER SELECTED |
|----|----|-------------------|
| 0  | 0  | MODE0             |
| 0  | 1  | MODE1             |
| 1  | 0  | MODE2             |
| 1  | 1  | MODE3             |

TABLE VI. Internal Register Addressing.

## MODE0 Register

The MODE0 register is used to set the attenuation data for the left output channel, or DOL (pin 24).

When ATC = 1 (Bit B2 of Register MODE3 = 1), the left channel attenuation data AL[7:0] is used for both the left and right channel attenuators.

When ATC = 0, (Bit B2 of Register MODE3 = 0), left channel attenuation data is taken from AL[7:0] of register MODE0, and right channel attenuation data is taken from AR[7:0] of register MODE1.

AL[7:0] Left Channel Attenuator Data, where AL7 is the MSB and AL0 is the LSB.

Attenuation Level is given by:

$$\text{ATTEN} = 0.5 \cdot (\text{DATA} - 255)\text{dB}$$

For DATA = FF<sub>H</sub>, ATTEN = -0dB

For DATA = FE<sub>H</sub>, ATTEN = -0.5dB

For DATA = 01<sub>H</sub>, ATTEN = -127.5dB

For DATA = 00<sub>H</sub>, ATTEN = infinity = Mute

LDL Left Channel Attenuation Data Load Control. This bit is used to simultaneously set attenuation levels of both the left and right channels.

When LDL = 1, the left channel output level is set by the data in AL[7:0]. The right channel output level is set by the data in AL[7:0], or the most recently programmed data in bits AR[7:0] of register MODE1.

When LDL = 0, the left channel output data remains at its previously programmed level.

## MODE1 Register

The MODE1 register is used to set the attenuation data for the right output channel, or DOR (pin 23).

When ATC = 1 (Bit B2 of Register MODE3 = 1), the left channel attenuation data AL[7:0] of register MODE0 is used for both the left and right channel attenuators.

When ATC = 0, (Bit B2 of Register MODE3 = 0), left channel attenuation data is taken from AL[7:0] of register MODE0, and right channel attenuation data is taken from AR[7:0] of register MODE1.

AR[7:0] Right Channel Attenuator Data, where AR7 is the MSB and AR0 is the LSB. Attenuation Level is given by:

$$\text{ATTEN} = 0.5 \cdot (\text{DATA} - 255)\text{dB}$$

For DATA = FF<sub>H</sub>, ATTEN = -0dB

For DATA = FE<sub>H</sub>, ATTEN = -0.5dB

For DATA = 01<sub>H</sub>, ATTEN = -127.5dB

For DATA = 00<sub>H</sub>, ATTEN = infinity = Mute

LDR Right Channel Attenuation Data Load Control. This bit is used to simultaneously set attenuation levels of both the left and right channels.

When LDR = 1, the right channel output level is set by the data in AR[7:0], or by the data in bits AL[7:0] of register MODE0. The left channel output level is set to the most recently

programmed data in bits AL[7:0] of register MODE0.

When LDR = 0, the right channel output data remains at its previously programmed level.

## MODE2 Register

The MODE2 register is used to program various functions:

MUT Soft Mute Function.

When MUT = 0, Soft Mute is ON for both left and right channels.

When MUT = 1, Soft Mute is OFF for both left and right channels.

DEM Digital De-Emphasis Function.

When DEM = 0, de-emphasis is OFF.

When DEM = 1, de-emphasis is ON.

x4 Oversampling Rate Selection

When x4 = 0, 8f<sub>s</sub> Sampling Rate Operation

When x4 = 1, 4f<sub>s</sub> Sampling Rate Operation

IW[1:0] Input Data Format and Word Length.

| I <sup>2</sup> S | IW1 | IW0 | Description                                               |
|------------------|-----|-----|-----------------------------------------------------------|
| 0                | 0   | 0   | 16-Bit Data, Standard Format (MSB-First, Right-Justified) |
| 0                | 0   | 1   | 20-Bit Data, Standard Format                              |
| 0                | 1   | 0   | 24-Bit Data, Standard Format                              |
| 0                | 1   | 1   | 24-Bit Data, MSB-First, Left-Justified                    |
| 1                | 0   | 0   | 16-Bit Data, I <sup>2</sup> S Format                      |
| 1                | 0   | 1   | 24-Bit Data, I <sup>2</sup> S format                      |
| 1                | 1   | 0   | Reserved                                                  |
| 1                | 1   | 1   | Reserved                                                  |

OW[1:0] Output Data Word Length.

| OW1 | OW0 | Description            |
|-----|-----|------------------------|
| 0   | 0   | 16-Bit Data, MSB-First |
| 0   | 1   | 18-Bit Data, MSB-First |
| 1   | 0   | 20-Bit Data, MSB-First |
| 1   | 1   | 24-Bit Data, MSB-First |

## MODE3 Register

The MODE3 register is used to program various functions.

I<sup>2</sup>S Input Data Format.

When I<sup>2</sup>S = 0, standard or left-justified formats are enabled.

When I<sup>2</sup>S = 1, the I<sup>2</sup>S formats are enabled.

LRP LRCIN Polarity Selection.

When LRP = 0, left channel is HIGH and right channel is LOW.

When LRP = 1, left channel is LOW and right channel is HIGH.

|         |                                                                                                                                                                                           |     |
|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| ATC     | Attenuator Control.                                                                                                                                                                       |     |
|         | This bit is used to determine whether the Left and Right channel attenuators operate with independent data, or use common data (the Left channel data in bits AL[7:0] of register MODE0). |     |
|         | When ATC = 0, the Left and Right channel attenuator data is independent.                                                                                                                  |     |
|         | When ATC = 1, the Left and Right channel attenuators use common data.                                                                                                                     |     |
| SRO     | Digital Filter Roll-Off Selection.                                                                                                                                                        |     |
|         | When SRO = 0, sharp roll-off is selected.                                                                                                                                                 |     |
|         | When SRO = 1, slow roll-off is selected.                                                                                                                                                  |     |
| CKO     | CLKO Output Frequency Selection.                                                                                                                                                          |     |
|         | When CKO = 0, the CLKO frequency is the same as the clock at the XTI input.                                                                                                               |     |
|         | When CKO = 1, the CLKO frequency is half of the XTI input clock frequency.                                                                                                                |     |
| SF[1:0] | Sampling Frequency Selection for the De-Emphasis Function.                                                                                                                                |     |
|         | SF1                                                                                                                                                                                       | SF0 |
|         | 0                                                                                                                                                                                         | 0   |
|         | 0                                                                                                                                                                                         | 1   |
|         | 1                                                                                                                                                                                         | 0   |
|         | 1                                                                                                                                                                                         | 1   |
|         | Description                                                                                                                                                                               |     |
|         | 44.1 kHz                                                                                                                                                                                  |     |
|         | Reserved                                                                                                                                                                                  |     |
|         | 48 kHz                                                                                                                                                                                    |     |
|         | 32 kHz                                                                                                                                                                                    |     |

## APPLICATIONS INFORMATION

### PCB LAYOUT GUIDELINES

In order to obtain the specified performance from the DF1706 and its associated D/A converters, proper printed circuit board layout is essential. Figure 11 shows two approaches for obtaining the best audio performance.

Figure 11(a) shows a standard, mixed signal layout scheme. The board is divided into digital and analog sections, each with its own ground. The ground areas should be put on a split-plane, separate from the routing and power layers. The DF1706 and all digital circuitry should be placed over the digital section, while the audio D/A converter(s) and analog circuitry should be located over the analog section of the board. A common connection between the digital and analog grounds is required and is done at a single point as shown.

For Figure 11(a), digital signals should be routed from the DF1706 to the audio D/A converter(s) using short, direct connections to reduce the amount of radiated high-frequency energy. If necessary, series resistors may be placed in the clock and data signal paths to reduce or eliminate any overshoot or undershoot present on these signals. A value of 50Ω to 100Ω is recommended as a starting point, but the designer should experiment with the resistor values in order to obtain the best results.

Figure 11(b) shows an improved method for high-performance, mixed signal board layout. This method adds digital isolation between the DF1706 and the audio D/A converter(s), and provides complete isolation between the digital and analog sections of the board. The ISO150 dual digital coupler provides excellent isolation, and operates at speeds up to 80Mbps.

### POWER SUPPLIES AND BYPASSING

The DF1706 requires a single +5V power supply for operation. The power supply should be bypassed by a 10μF and 0.1μF parallel capacitor combination. The capacitors should be placed as close as possible to V<sub>DD</sub> (pin 22). Aluminum electrolytics or tantalum capacitors can be used for the 10μF value, while ceramics may be used for the 0.1μF value.

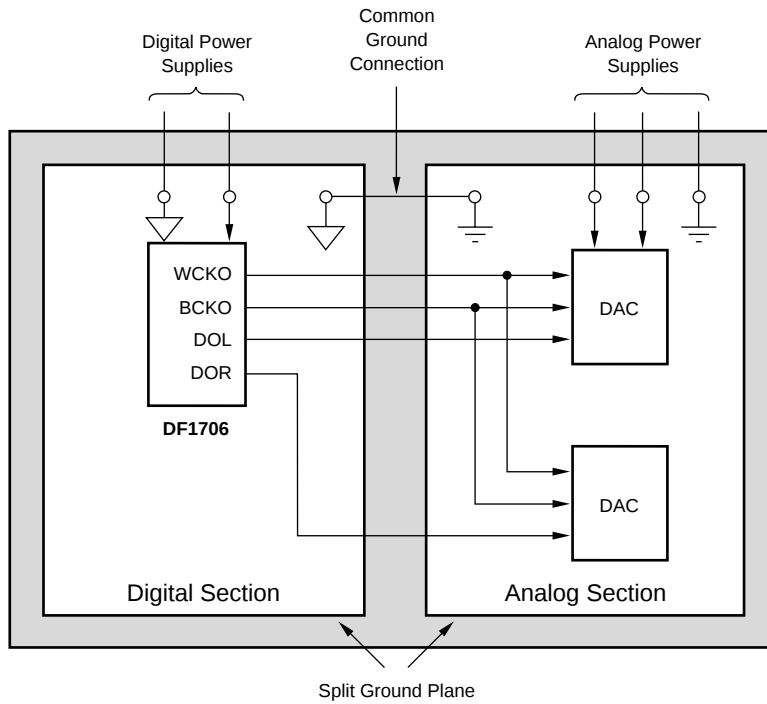
### BASIC CIRCUIT CONNECTIONS

See Figures 12 and 13 for basic circuit connections of the DF1706. Figure 12 shows connections for Hardware mode controls, while Figure 13 shows connections for Software mode controls. Notice the placement of C<sub>1</sub> and C<sub>2</sub> in both figures, as they are physically close to the DF1706.

### TYPICAL APPLICATIONS

The DF1706 will typically be used in high performance audio equipment, in conjunction with high performance audio D/A converters. Figure 14 shows a typical application circuit example, employing the DF1706, a digital audio receiver, and two PCM1704 24-bit, 192kHz audio D/A converter(s).

(a) Layout Without Isolation



(b) Layout With Isolation

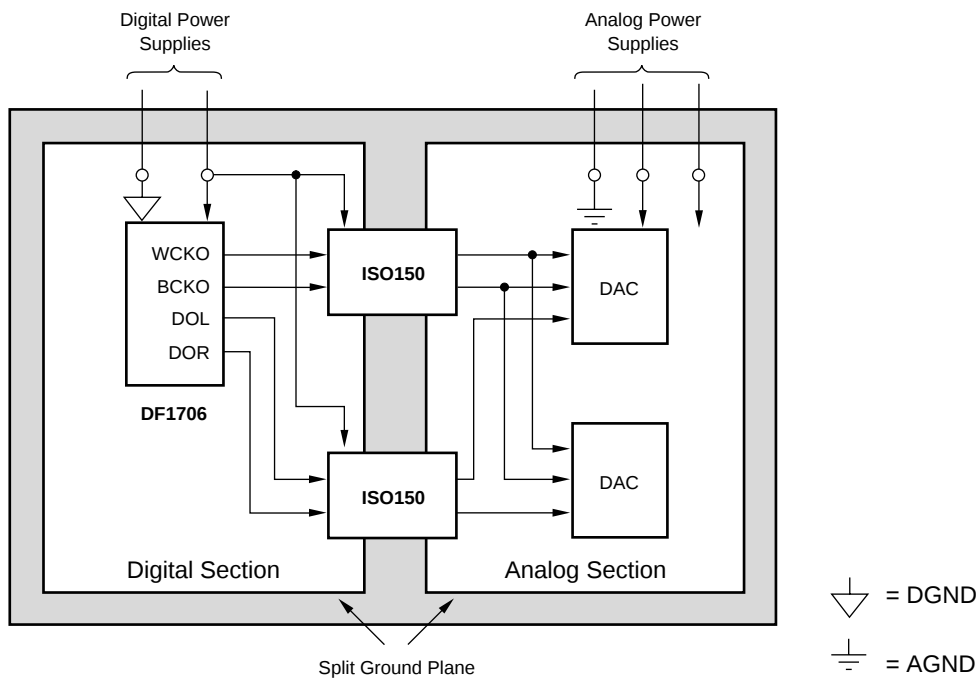


FIGURE 11. PCB Layout Model.

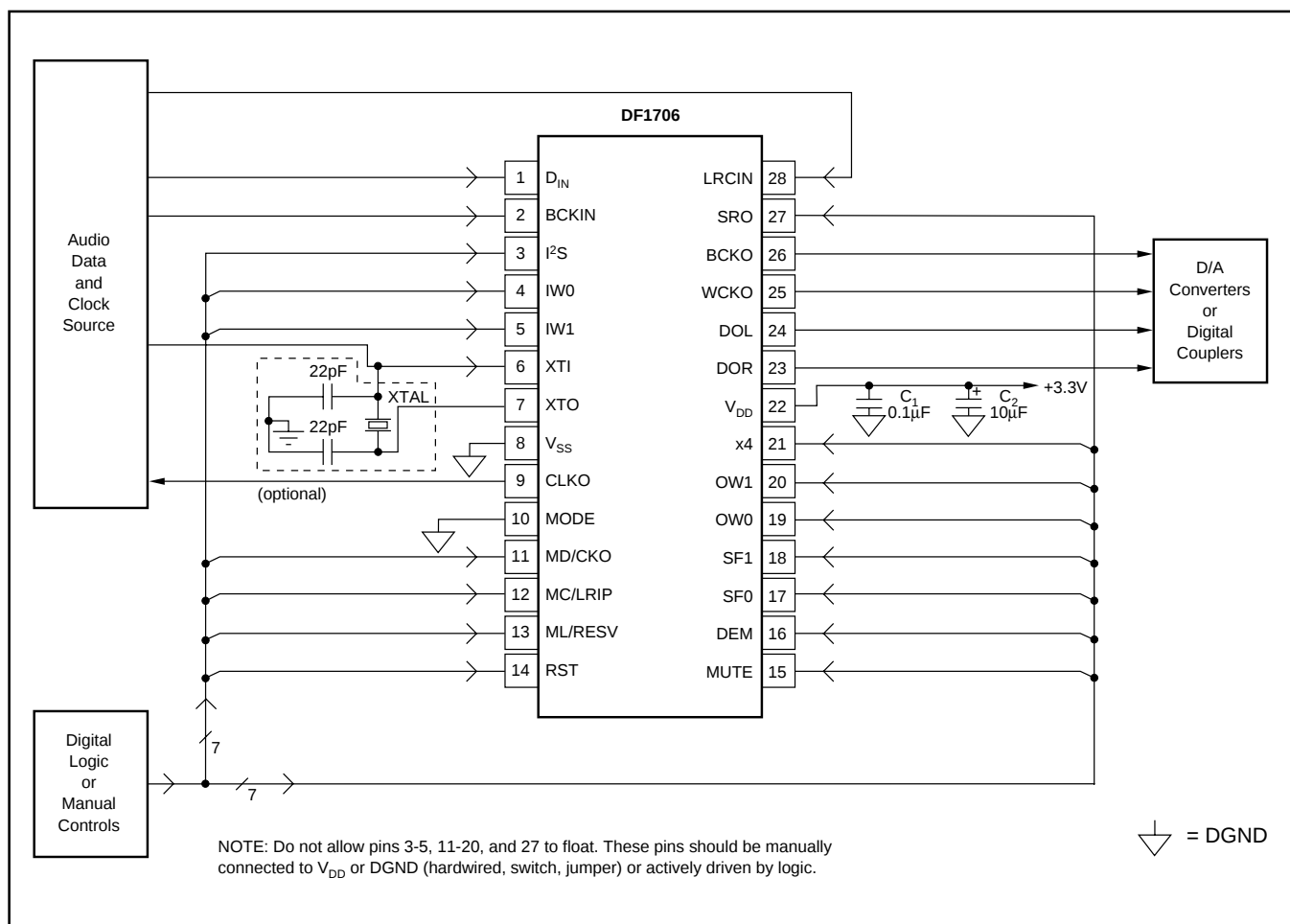


FIGURE 12. Basic Circuit Connections, Hardware Control.

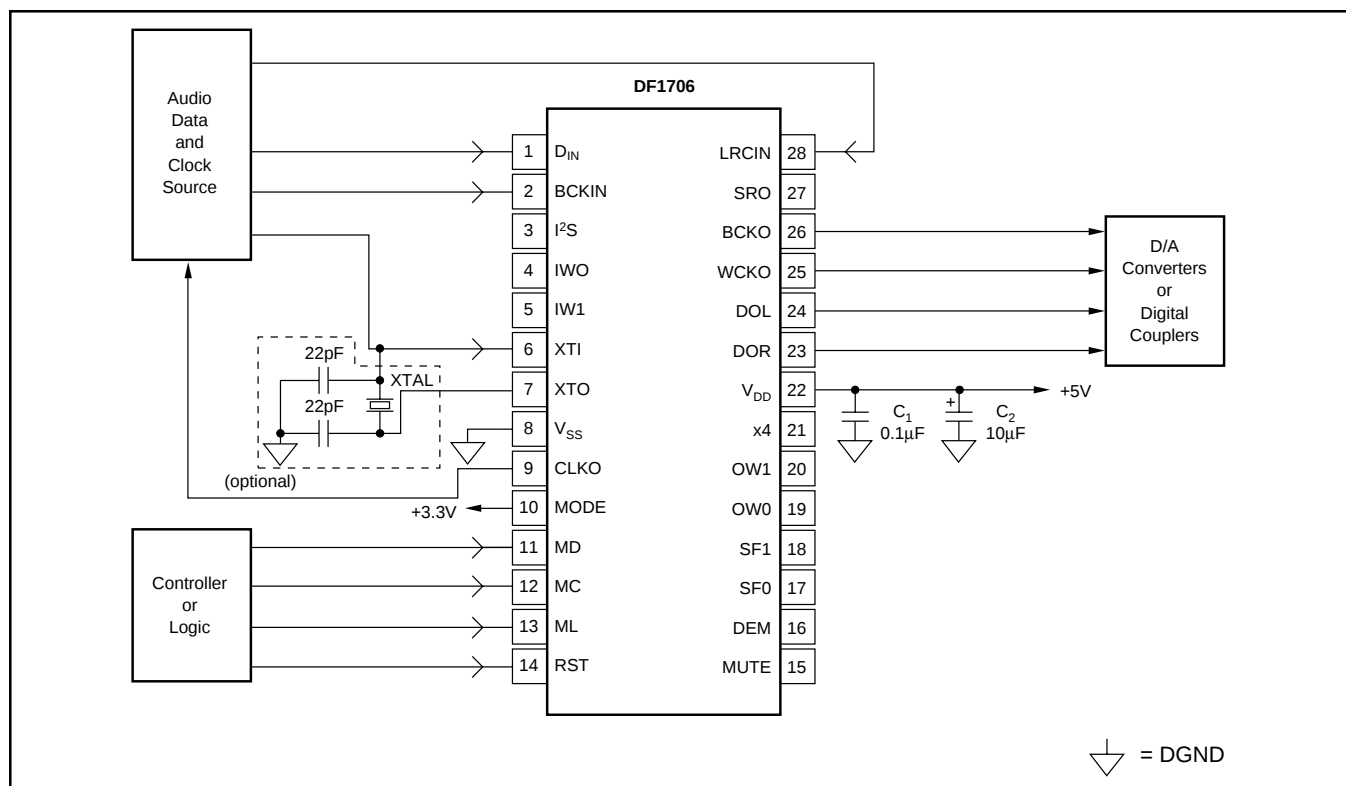


FIGURE 13. Basic Circuit Connection, Software Control.

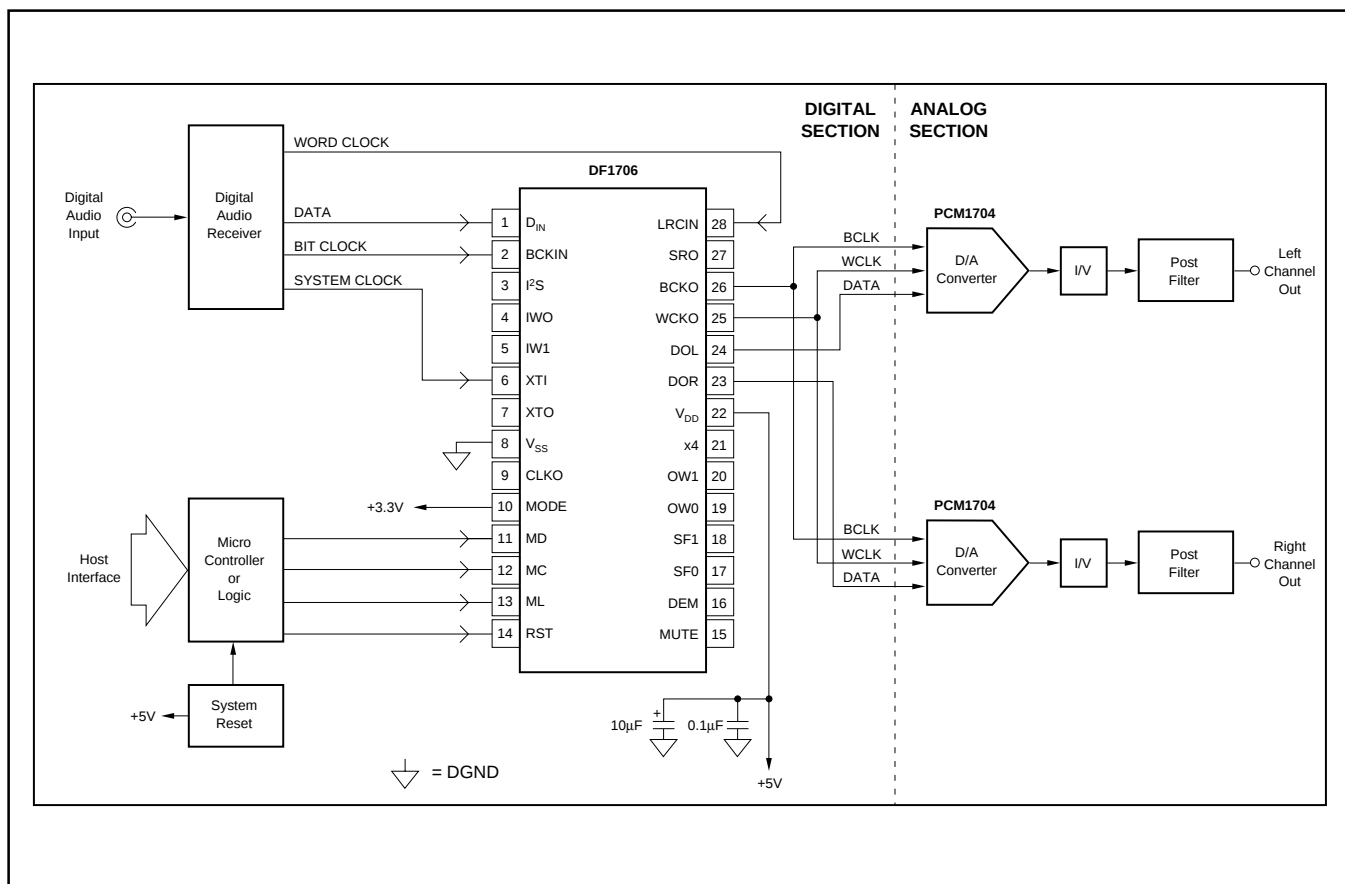


FIGURE 14. DF1706 Typical Application Circuit.

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|------------------|-----------|--------------|-----------------|------|-------------|
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| DF1706E/2K       | ACTIVE    | SSOP         | DB              | 28   | 2000        |

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Mailing Address: Texas Instruments  
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