Burr-Brown Products
from Texas Instruments

PCM1796

SLES100 − DECEMBER 2003

24-BIT, 192-kHz SAMPLING, ADVANCED SEGMENT, AUDIO STEREO DIGITAL-TO-ANALOG CONVERTER

FEATURES

- 24-Bit Resolution
- Analog Performance:
  - Dynamic Range: 123 dB
  - THD+N: 0.0005%
- Differential Current Output: 4 mA p-p
- 8× Oversampling Digital Filter:
  - Stop-Band Attenuation: –98 dB
  - Pass-Band Ripple: ±0.0002 dB
- Sampling Frequency: 10 kHz to 200 kHz
- System Clock: 128, 192, 256, 384, 512, or 768 f_S With Autodetect
- Accepts 16-, 20-, and 24-Bit Audio Data
- PCM Data Formats: Standard, I^2S, and Left-Justified
- DSD Format Interface Available
- Interface Available for Optional External Digital Filter or DSP
- TDMCA or Serial Port (SPI/I^2C)
- User-Programmable Mode Controls:
  - Digital Attenuation: 0 dB to –120 dB, 0.5 dB/Step
  - Digital De-Emphasis
  - Digital Filter Rolloff: Sharp or Slow
  - Soft Mute
  - Zero Flag for Each Output
- Compatible With PCM1792 (Pins and Mode Controls)
- Dual Supply Operation:
  - 5-V Analog, 3.3-V Digital
- 5-V Tolerant Digital Inputs
- Small 28-Lead SSOP Package, Lead-Free Product

APPLICATIONS

- A/V Receivers
- SACD Players
- DVD Players
- HDTV Receivers
- Car Audio Systems
- Digital Multitrack Recorders
- Other Applications Requiring 24-Bit Audio

DESCRIPTION

The PCM1796 is a monolithic CMOS integrated circuit that includes stereo digital-to-analog converters and support circuitry in a small 28-lead SSOP package. The data converters use TI's advanced segment DAC architecture to achieve excellent dynamic performance and improved tolerance to clock jitter. The PCM1796 provides balanced current outputs, allowing the user to optimize analog performance externally. The PCM1796 accepts PCM and DSD audio data formats, providing easy interfacing to audio DSP and decoder chips. The PCM1796 also interfaces with external digital filter devices (DF1704, DF1706, PMD200). Sampling rates up to 200 kHz are supported. A full set of user-programmable functions is accessible through an SPI or I^2C serial control port, which supports register write and readback functions. The PCM1796 also supports the time division multiplexed command and audio (TDMCA) data format.

This integrated circuit can be damaged by ESD. Texas Instruments 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.

ORDERING INFORMATION

PRODUCT	PACKAGE	PACKAGE CODE	OPERATION TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA
PCM1796DB	28-lead SSOP	28DB	−25°C to 85°C	PCM1796	PCM1796DB	Tube
					PCM1796DBR	Tape and reel

ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range unless otherwise noted(1)

		PCM1796
Supply voltage	$V_{CC}1$, $V_{CC}2L$, $V_{CC}2R$	−0.3 V to 6.5 V
	V_{DD}	−0.3 V to 4 V
Supply voltage differences: $V_{CC}1$, $V_{CC}2L$, $V_{CC}2R$		±0.1 V
Ground voltage differences: AGND1, AGND2, AGND3L, AGND3R, DGND		±0.1 V
Digital input voltage	LRCK, DATA, BCK, SCK, MSEL, $\overline{RST}$, $\overline{MS}$(2), MDI, MC, MDO(2), ZEROL(2), ZEROR(2)	–0.3 V to 6.5 V
	ZEROL(3), ZEROR(3), MDO(3), $\overline{MS}$(3)	–0.3 V to (V_{DD} + 0.3 V) < 4 V
Analog input voltage		–0.3 V to (V_{CC} + 0.3 V) < 6.5 V
Input current (any pins except supplies)		±10 mA
Ambient temperature under bias		–40°C to 125°C
Storage temperature		–55°C to 150°C
Junction temperature		150°C
Lead temperature (soldering)		260°C, 5 s
Package temperature (IR reflow, peak)		260°C

(1) Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) Input mode or I^2C mode
(3) Output mode except for I^2C mode

ELECTRICAL CHARACTERISTICS

all specifications at T_A = 25°C, $V_{CC}1 = V_{CC}2L = V_{CC}2R$ = 5 V, V_{DD} = 3.3 V, f_S = 44.1 kHz, system clock = 256 f_S, and 24-bit data unless otherwise noted

	PARAMETER	TEST CONDITIONS	PCM1796DB MIN	PCM1796DB TYP	PCM1796DB MAX	UNIT
RESOLUTION				24		Bits
DATA FORMAT (PCM Mode)						
	Audio data interface format			Standard, I^2S, left-justified		
	Audio data bit length			16-, 20-, 24-bit selectable		
	Audio data format			MSB first, twos complement		
f_S	Sampling frequency		10		200	kHz
	System clock frequency			128, 192, 256, 384, 512, 768 f_S		
DATA FORMAT (DSD Mode)						
	Audio data interface format			DSD (direct stream digital)		
	Audio data bit length			1 Bit		
f_S	Sampling frequency			2.8224		MHz
	System clock frequency		2.8224		11.2896	MHz

ELECTRICAL CHARACTERISTICS (Continued)

all specifications at T_A = 25°C, $V_{CC}1 = V_{CC}2L = V_{CC}2R$ = 5 V, V_{DD} = 3.3 V, f_S = 44.1 kHz, system clock = 256 f_S, and 24-bit data unless otherwise noted

PARAMETER		TEST CONDITIONS	PCM1796DB MIN	PCM1796DB TYP	PCM1796DB MAX	UNIT
DIGITAL INPUT/OUTPUT						
	Logic family			TTL compatible		
V_{IH}	Input logic level		2			VDC
V_{IL}	Input logic level				0.8	VDC
I_{IH}	Input logic current	$V_{IN} = V_{DD}$			10	µA
I_{IL}	Input logic current	V_{IN} = 0 V			–10	µA
V_{OH}	Output logic level	I_{OH} = −2 mA	2.4			VDC
V_{OL}	Output logic level	I_{OL} = 2 mA			0.4	VDC
DYNAMIC PERFORMANCE (PCM MODE) (1)(2)						
	THD+N at V_{OUT} = 0 dB	f_S = 44.1 kHz		0.0005%	0.001%	
		f_S = 96 kHz		0.001%		
		f_S = 192 kHz		0.0015%		
	Dynamic range	EIAJ, A-weighted, f_S = 44.1 kHz	120	123		dB
		EIAJ, A-weighted, f_S = 96 kHz		123		
		EIAJ, A-weighted, f_S = 192 kHz		123		
	Signal-to-noise ratio	EIAJ, A-weighted, f_S = 44.1 kHz	120	123		dB
		EIAJ, A-weighted, f_S = 96 kHz		123		
		EIAJ, A-weighted, f_S = 192 kHz		123		
	Channel separation	f_S = 44.1 kHz	116	119		dB
		f_S = 96 kHz		118		
		f_S = 192 kHz		117		
	Level Linearity Error	V_{OUT} = −120 dB		±1		dB
DYNAMIC PERFORMANCE (MONO MODE) (1)(2)(3)						
	THD+N at V_{OUT} = 0 dB	f_S = 44.1 kHz		0.0005%		
		f_S = 96 kHz		0.001%		
		f_S = 192 kHz		0.0015%		
	Dynamic range	EIAJ, A-weighted, f_S = 44.1 kHz		126		dB
		EIAJ, A-weighted, f_S = 96 kHz		126		
		EIAJ, A-weighted, f_S = 192 kHz		126		
	Signal-to-noise ratio	EIAJ, A-weighted, f_S = 44.1 kHz		126		dB
		EIAJ, A-weighted, f_S = 96 kHz		126		
		EIAJ, A-weighted, f_S = 192 kHz		126		

(1) Filter condition:
THD+N: 20-Hz HPF, 20-kHz AES17 LPF
Dynamic range: 20-Hz HPF, 20-kHz AES17 LPF, A-weighted
Signal-to-noise ratio: 20-Hz HPF, 20-kHz AES17 LPF, A-weighted
Channel separation: 20-Hz HPF, 20-kHz AES17 LPF
Analog performance specifications are measured using the System Two™ Cascade audio measurement system by Audio Precision™ in the averaging mode.

(2) Dynamic performance and dc accuracy are specified at the output of the postamplifier as shown in Figure 36.

(3) Dynamic performance and dc accuracy are specified at the output of the measurement circuit as shown in Figure 38.

ELECTRICAL CHARACTERISTICS (Continued)

all specifications at T_A = 25°C, $V_{CC}1 = V_{CC}2L = V_{CC}2R$ = 5 V, V_{DD} = 3.3 V, f_S = 44.1 kHz, system clock = 256 f_S, and 24-bit data unless otherwise noted

PARAMETER	TEST CONDITIONS	PCM1796DB			UNIT
		MIN	TYP	MAX	
DSD MODE DYNAMIC PERFORMANCE (1) (2) (44.1 KHZ, 64 f_S)					
THD+N at FS	2 V rms		0.0007%		
Dynamic range	–60 dB, EIAJ, A-weighted		122		dB
Signal-to-noise ratio	EIAJ, A-weighted		122		dB
ANALOG OUTPUT					
Gain error		–7	±2	7	% of FSR
Gain mismatch, channel-to-channel		–3	±0.5	3	% of FSR
Bipolar zero error	At BPZ	–2	±0.5	2	% of FSR
Output current	Full scale (0 dB)		4		mA p-p
Center current	At BPZ		–3.5		mA
DIGITAL FILTER PERFORMANCE					
De-emphasis error				±0.1	dB
FILTER CHARACTERISTICS–1: SHARP ROLLOFF					
Pass band	±0.0002 dB			0.454 f_S	
	–3 dB			0.49 f_S	
Stop band		0.546 f_S			
Pass-band ripple				±0.0002	dB
Stop-band attenuation	Stop band = 0.546 f_S	–98			dB
Delay time			38/f_S		s
FILTER CHARACTERISTICS–2: SLOW ROLLOFF					
Pass band	±0.001 dB			0.21 f_S	
	–3 dB			0.448 f_S	
Stop band		0.79 f_S			
Pass-band ripple				±0.001	dB
Stop-band attenuation	Stop band = 0.732 f_S	–80			dB
Delay time			38/f_S		s

(1) Filter condition:
THD+N: 20-Hz HPF, 20-kHz AES17 LPF
Dynamic range: 20-Hz HPF, 20-kHz AES17 LPF, A-weighted
Signal-to-noise ratio: 20-Hz HPF, 20-kHz AES17 LPF, A-weighted
Channel separation: 20-Hz HPF, 20-kHz AES17 LPF
Analog performance specifications are measured using the System Two Cascade audio measurement system by Audio Precision in the averaging mode.

(2) Dynamic performance and dc accuracy are specified at the output of the postamplifier as shown in Figure 37.

ELECTRICAL CHARACTERISTICS (Continued)

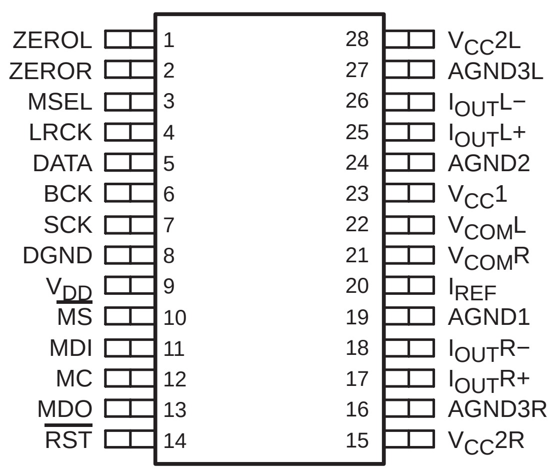
all specifications at T_A = 25°C, $V_{CC}1$ = $V_{CC}2L$ = $V_{CC}2R$ = 5 V, V_{DD} = 3.3 V, f_S = 44.1 kHz, system clock = 256 f_S, and 24-bit data unless otherwise noted

PARAMETER		TEST CONDITIONS	PCM1796DB			UNIT
			MIN	TYP	MAX	
POWER SUPPLY REQUIREMENTS						
V_{DD}	Voltage range		3	3.3	3.6	VDC
$V_{CC}1$ $V_{CC}2L$ $V_{CC}2R$	Voltage range		4.75	5	5.25	VDC
I_{DD}	Supply current (1)	f_S = 44.1 kHz		7	9	mA
		f_S = 96 kHz		13		
		f_S = 192 kHz		25		
I_{CC}		f_S = 44.1 kHz		18	23	mA
		f_S = 96 kHz		19		
		f_S = 192 kHz		20		
	Power dissipation (1)	f_S = 44.1 kHz		115	150	mW
		f_S = 96 kHz		140		
		f_S = 192 kHz		180		
TEMPERATURE RANGE						
	Operation temperature		–25		85	°C
θ_{JA}	Thermal resistance	28-pin SSOP		100		°C/W

(1) Input is BPZ data.

PIN ASSIGNMENTS

PCM1796
(TOP VIEW)

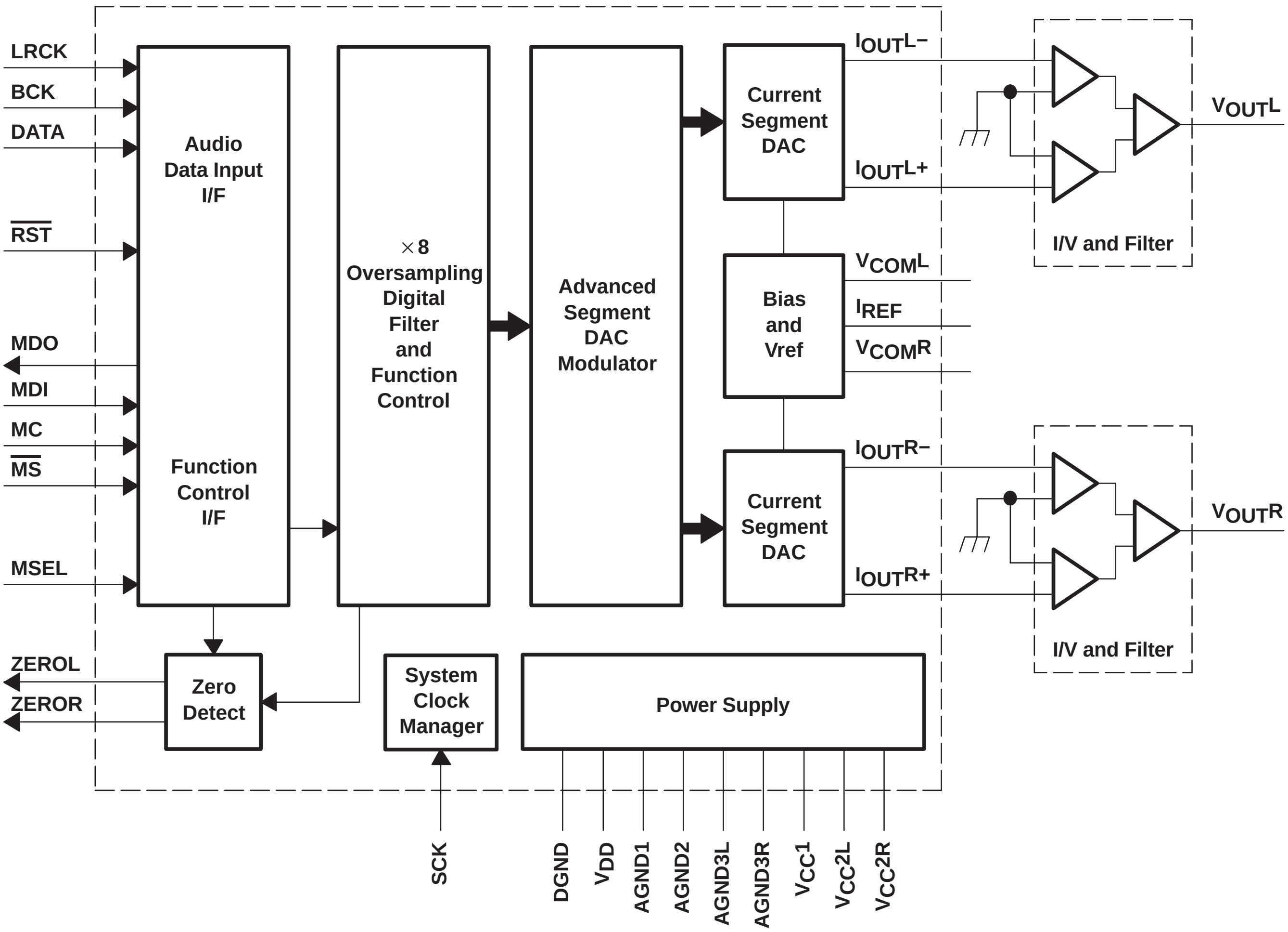


Terminal Functions

TERMINAL NAME	PIN	I/O	DESCRIPTIONS
AGND1	19	–	Analog ground (internal bias)
AGND2	24	–	Analog ground (internal bias)
AGND3L	27	–	Analog ground (L-channel DACFF)
AGND3R	16	–	Analog ground (R-channel DACFF)
BCK	6	I	Bit clock input(1)
DATA	5	I	Serial audio data input(1)
DGND	8	–	Digital ground
$I_{OUT}L+$	25	O	L-channel analog current output+
$I_{OUT}L–$	26	O	L-channel analog current output–
$I_{OUT}R+$	17	O	R-channel analog current output+
$I_{OUT}R–$	18	O	R-channel analog current output–
I_{REF}	20	–	Output current reference bias pin
LRCK	4	I	Left and right clock (f_S) input(1)
MC	12	I	Mode control clock input(1)
MDI	11	I	Mode control data input(1)
MDO	13	I/O	Mode control readback data output(3)
$\overline{MS}$	10	I/O	Mode control chip-select input(2)
MSEL	3	I	$I^2C/\overline{SPI}$ select(1)
$\overline{RST}$	14	I	Reset(1)
SCK	7	I	System clock input(1)
$V_{CC}1$	23	–	Analog power supply, 5 V
$V_{CC}2L$	28	–	Analog power supply (L-channel DACFF), 5 V
$V_{CC}2R$	15	–	Analog power supply (R-channel DACFF), 5 V
$V_{COM}L$	22	–	L-channel internal bias decoupling pin
$V_{COM}R$	21	–	R-channel internal bias decoupling pin
V_{DD}	9	–	Digital power supply, 3.3 V
ZEROL	1	I/O	Zero flag for L-channel(2)
ZEROR	2	I/O	Zero flag for R-channel(2)

(1) Schmitt-trigger input, 5-V tolerant
(2) Schmitt-trigger input and output. 5-V tolerant input and CMOS output
(3) Schmitt-trigger input and output. 5-V tolerant input. In I^2C mode, this pin becomes an open-drain 3-state output; otherwise, this pin is a CMOS output.

FUNCTIONAL BLOCK DIAGRAM



TYPICAL PERFORMANCE CURVES

DIGITAL FILTER

Digital Filter Response

AMPLITUDE
vs
FREQUENCY

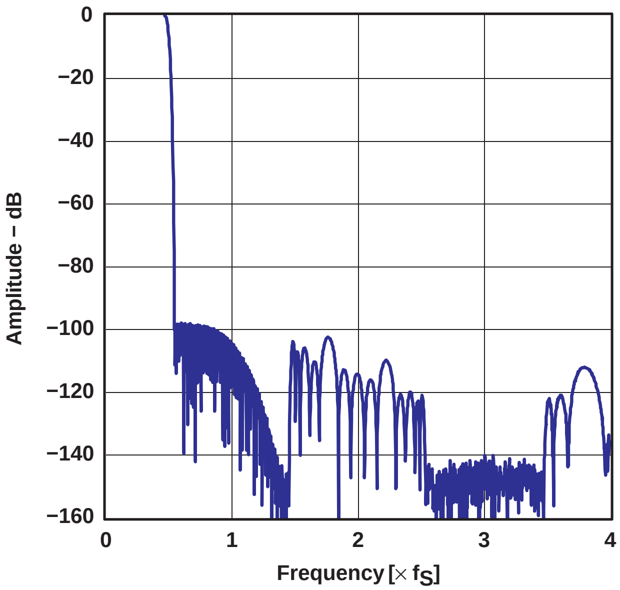


Figure 1. Frequency Response, Sharp Rolloff

AMPLITUDE
vs
FREQUENCY

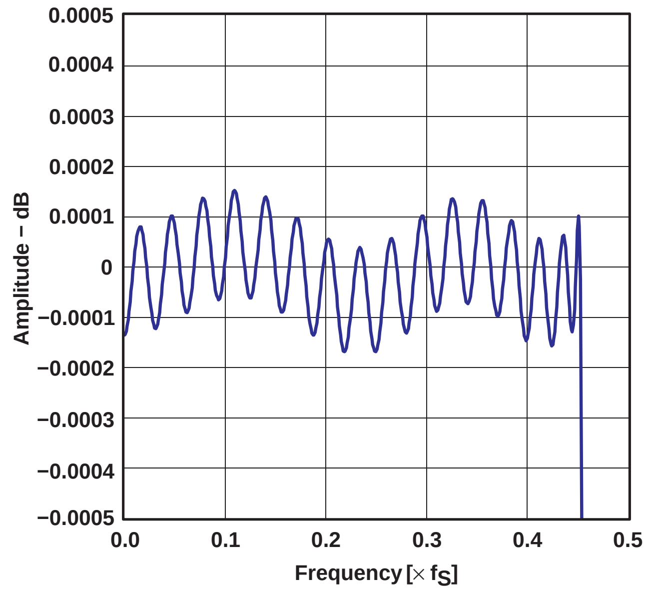


Figure 2. Pass-Band Ripple, Sharp Rolloff

AMPLITUDE
vs
FREQUENCY

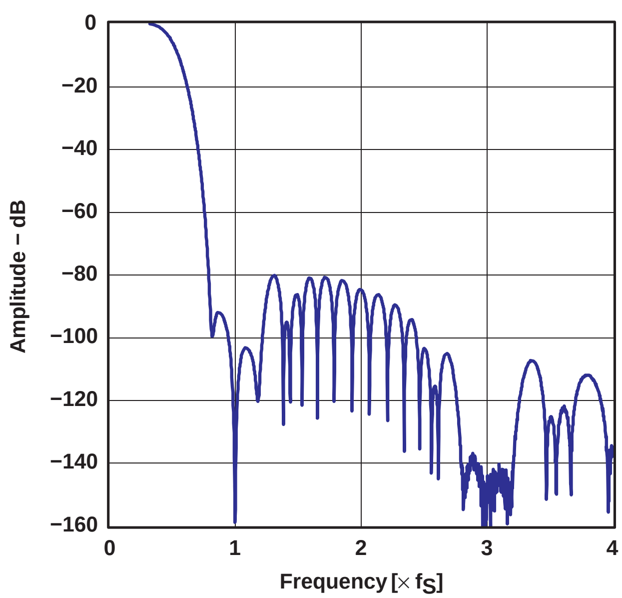


Figure 3. Frequency Response, Slow Rolloff

AMPLITUDE
vs
FREQUENCY

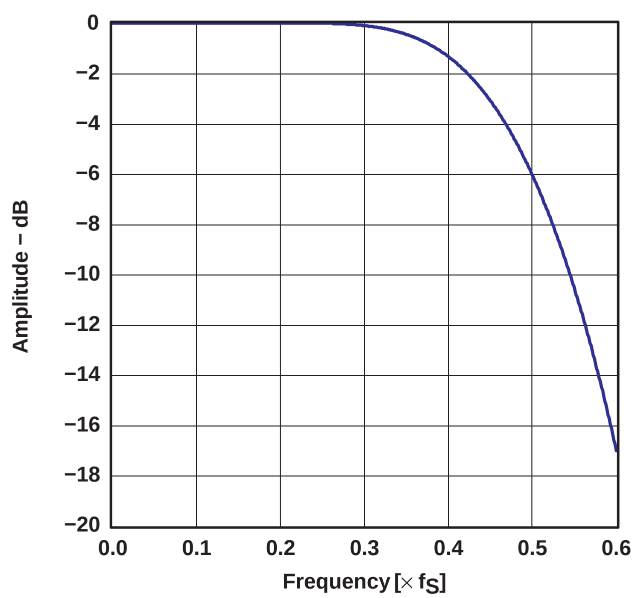


Figure 4. Transition Characteristics, Slow Rolloff

De-Emphasis Filter

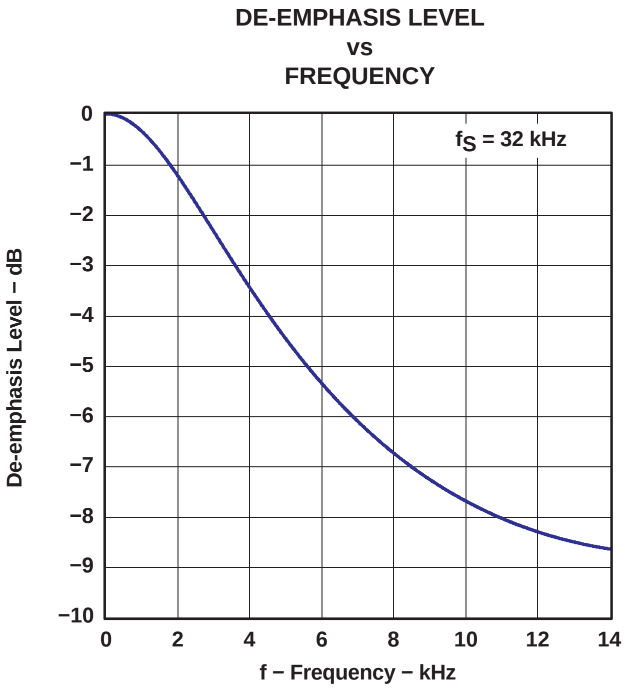


Figure 5

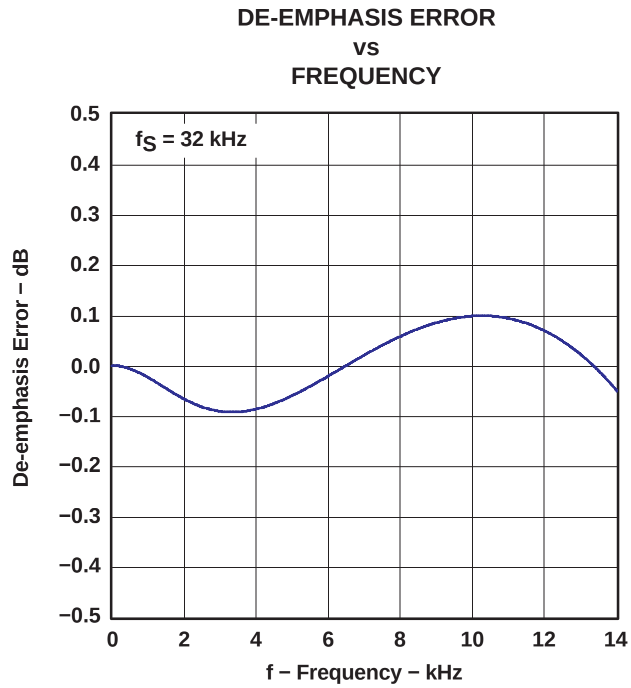


Figure 6

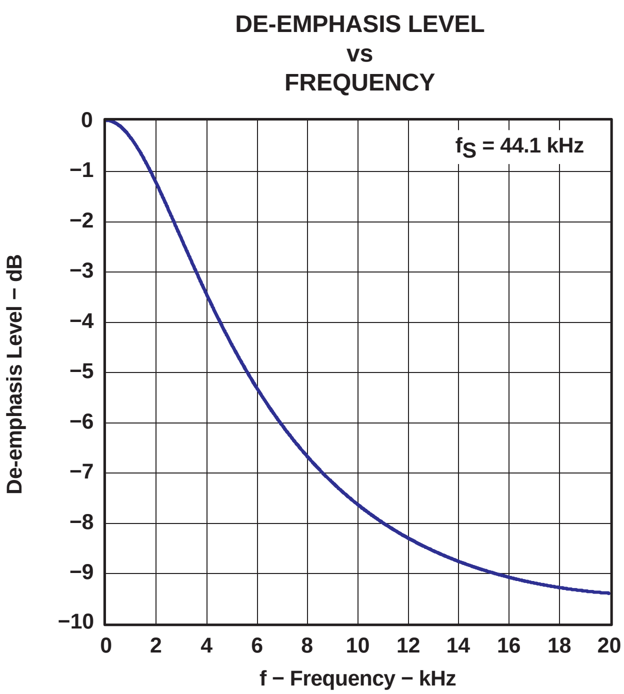


Figure 7

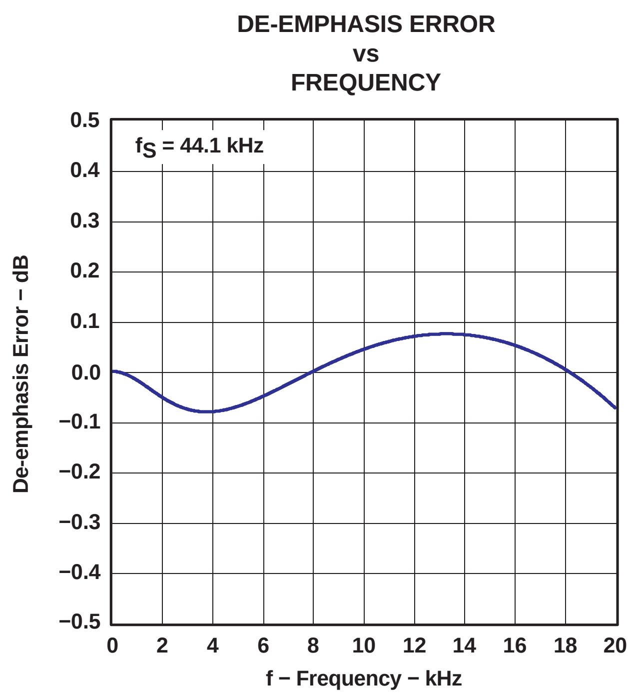


Figure 8

De-Emphasis Filter (Continued)

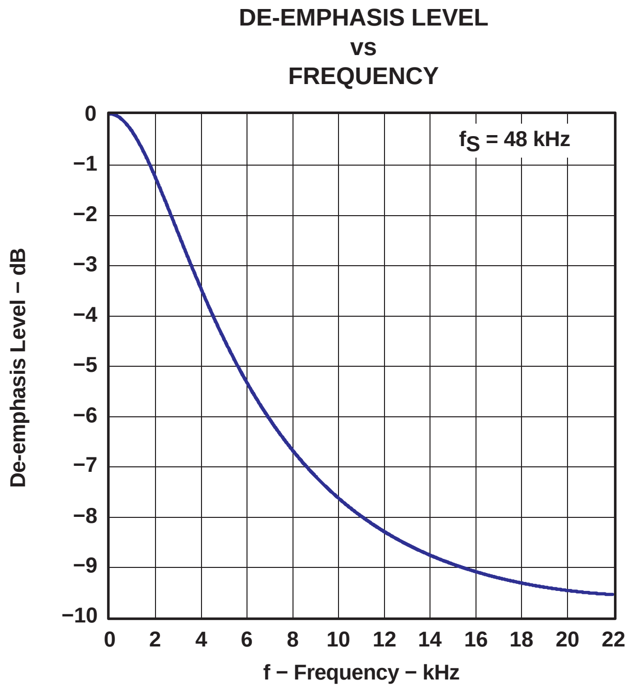


Figure 9

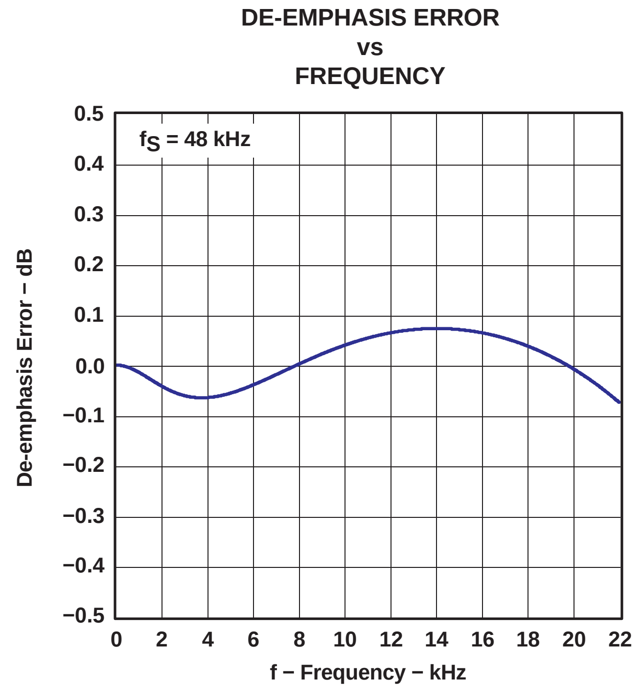


Figure 10

ANALOG DYNAMIC PERFORMANCE

Supply Voltage Characteristics

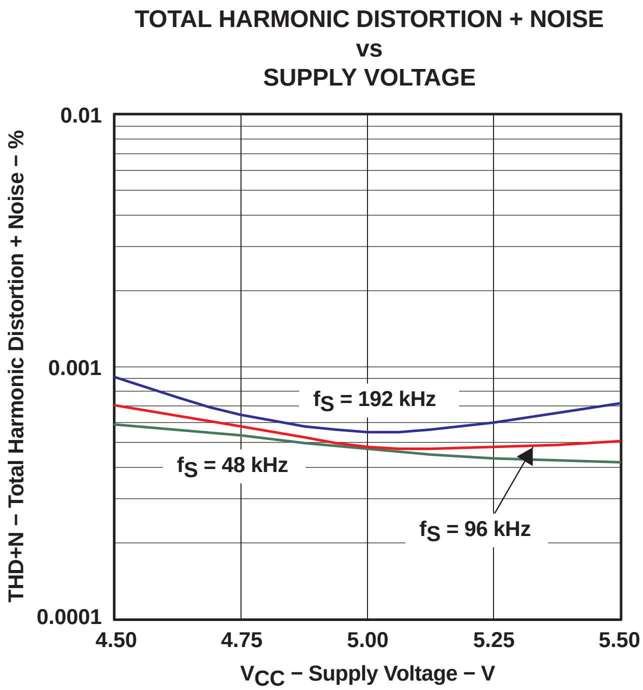


Figure 11

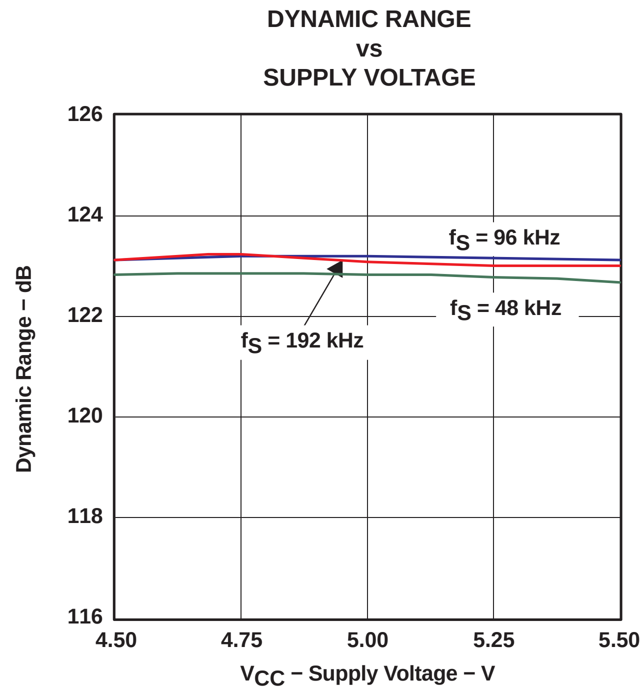


Figure 12

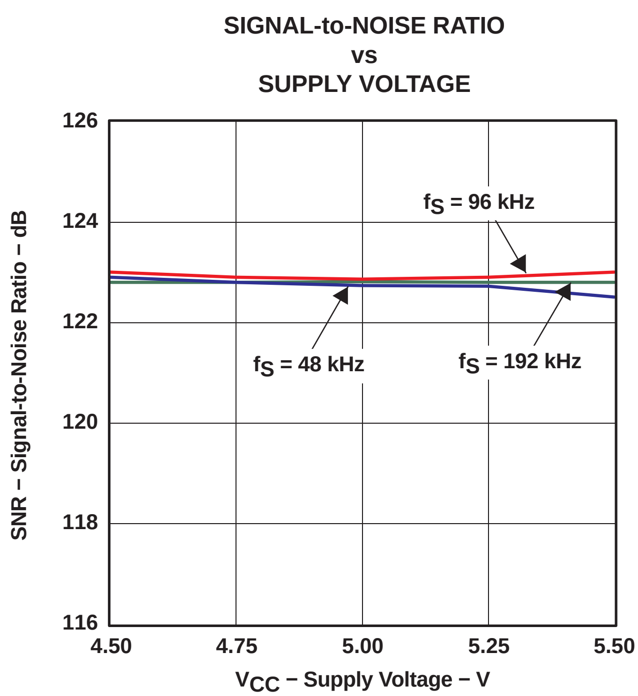


Figure 13

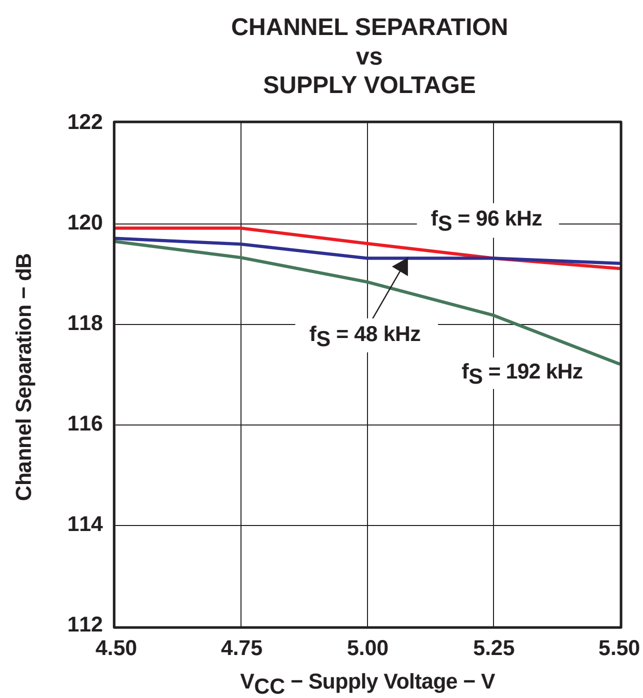


Figure 14

NOTE: PCM mode, T_A = 25°C, V_{DD} = 3.3 V, measurement circuit is Figure 36.

Temperature Characteristics

TOTAL HARMONIC DISTORTION + NOISE
vs
FREE-AIR TEMPERATURE

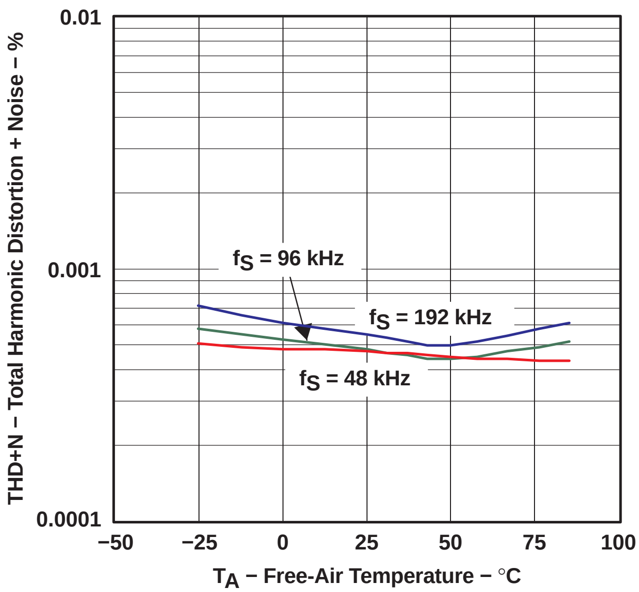


Figure 15

DYNAMIC RANGE
vs
FREE-AIR TEMPERATURE

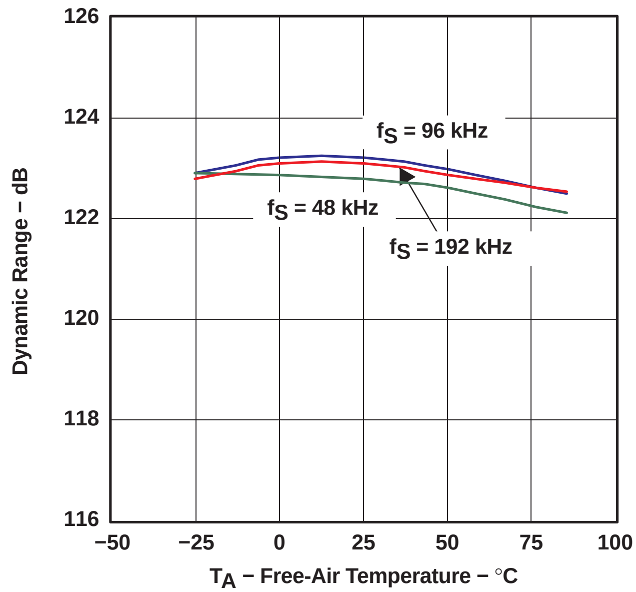


Figure 16

SIGNAL-to-NOISE RATIO
vs
FREE-AIR TEMPERATURE

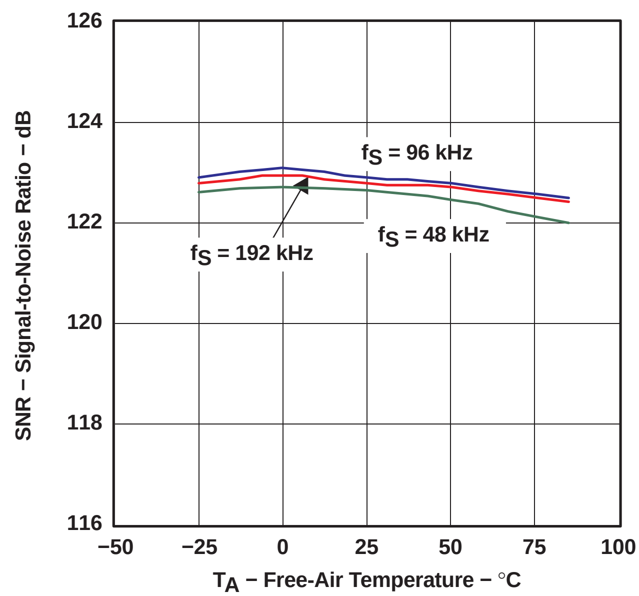


Figure 17

CHANNEL SEPARATION
vs
FREE-AIR TEMPERATURE

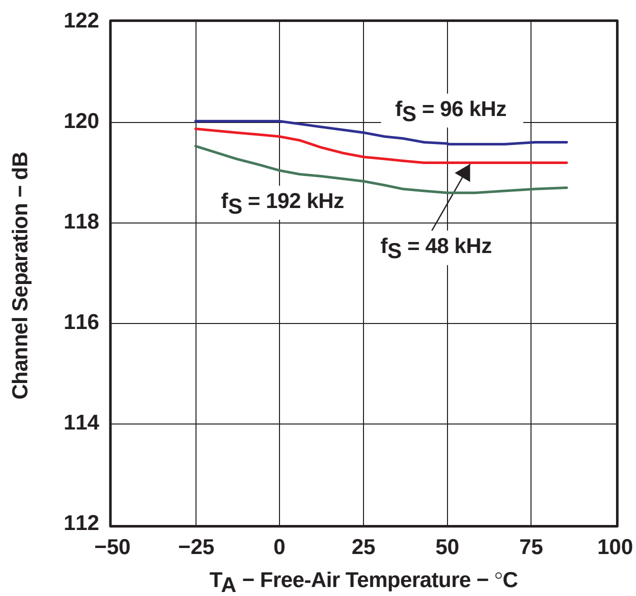
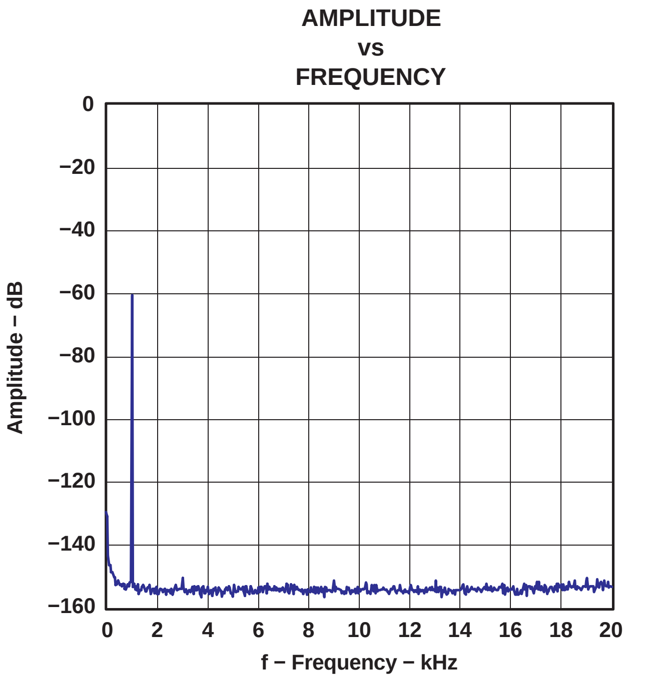


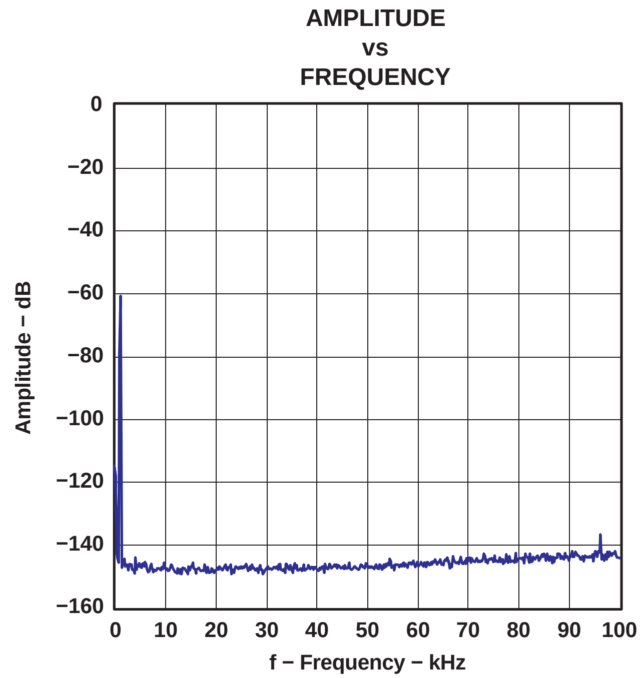
Figure 18

NOTE: PCM mode, V_{DD} = 3.3 V, V_{CC} = 5 V, measurement circuit is Figure 36.



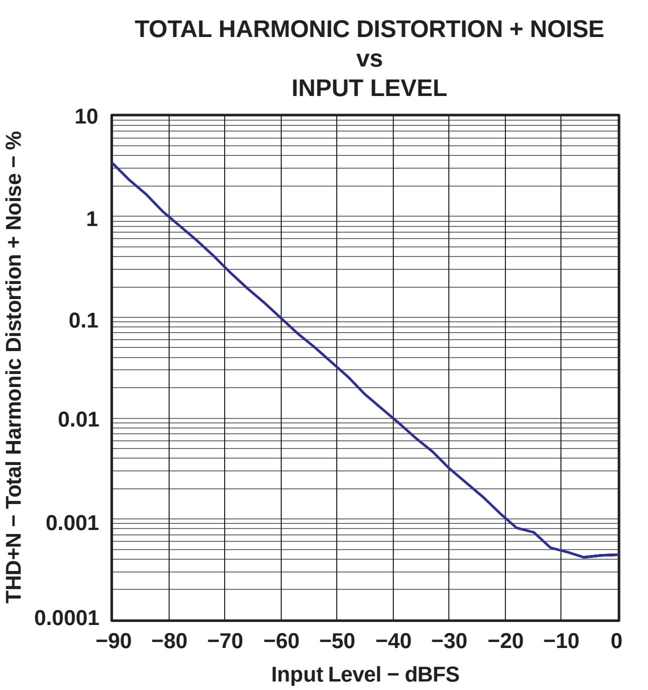
NOTE: PCM mode, f_S = 48 kHz, 32768 point 8 average, T_A = 25°C, V_{DD} = 3.3 V V_{CC} = 5 V, measurement circuit is Figure 36.

Figure 19. −60-dB Output Spectrum, BW = 20 kHz



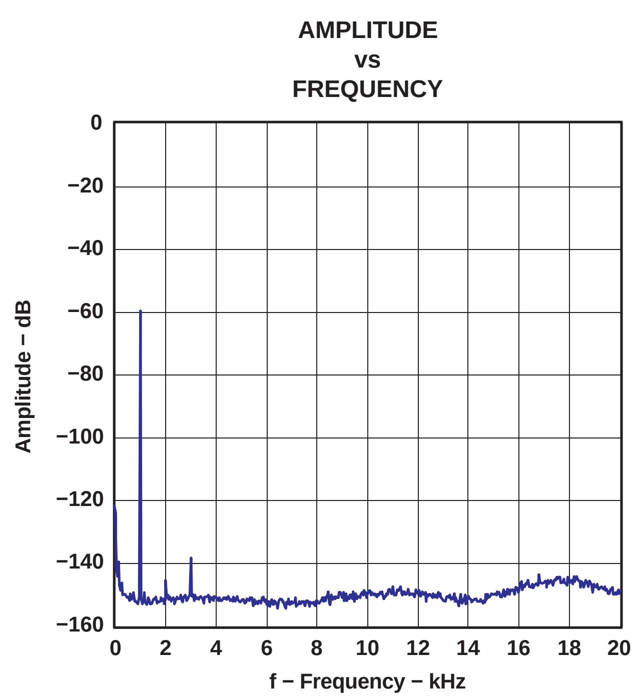
NOTE: PCM mode, f_S = 96 kHz, 32768 point 8 average, T_A = 25°C, V_{DD} = 3.3 V V_{CC} = 5 V, measurement circuit is Figure 36.

Figure 20. −60-dB Output Spectrum, BW = 100 kHz



NOTE: PCM mode, f_S = 48 kHz, T_A = 25°C, V_{DD} = 3.3 V, V_{CC} = 5 V, measurement circuit is Figure 36.

Figure 21. THD+N vs Input Level, PCM Mode



NOTE: DSD mode (FIR-2), 32768 point 8 average, T_A = 25°C, V_{DD} = 3.3 V, V_{CC} = 5 V, measurement circuit is Figure 37.

Figure 22. −60-dB Output Spectrum, DSD Mode

SYSTEM CLOCK AND RESET FUNCTIONS

System Clock Input

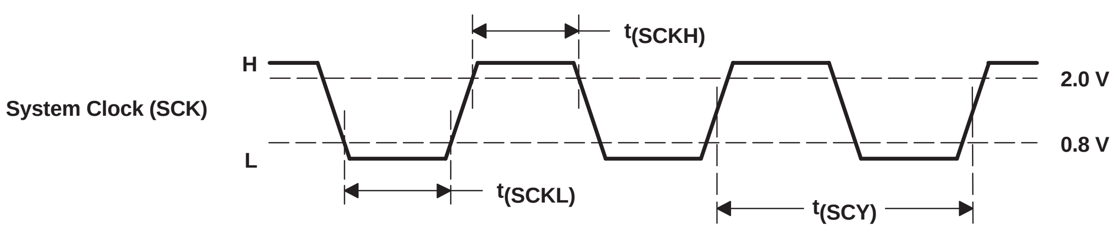
The PCM1796 requires a system clock for operating the digital interpolation filters and advanced segment DAC modulators. The system clock is applied at the SCK input (pin 7). The PCM1796 has a system clock detection circuit that automatically senses the frequency at which the system clock is operating. Table 1 shows examples of system clock frequencies for common audio sampling rates. If the oversampling rate of the delta-sigma modulator is selected as 128 f_S, the system clock frequency is required to be over 256 f_S.

Figure 23 shows the timing requirements for the system clock input. For optimal performance, it is important to use a clock source with low phase jitter and noise. One of the Texas Instruments PLL1700 family of multiclock generators is an excellent choice for providing the PCM1796 system clock.

Table 1. System Clock Rates for Common Audio Sampling Frequencies

SAMPLING FREQUENCY	SYSTEM CLOCK FREQUENCY (f_{SCK}) (MHz)					
	128 f_S	192 f_S	256 f_S	384 f_S	512 f_S	768 f_S
32 kHz	4.096(1)	6.144(1)	8.192	12.288	16.384	24.576
44.1 kHz	5.6488(1)	8.4672	11.2896	16.9344	22.5792	33.8688
48 kHz	6.144(1)	9.216	12.288	18.432	24.576	36.864
96 kHz	12.288	18.432	24.576	36.864	49.152(1)	73.728(1)
192 kHz	24.576	36.864	49.152(1)	73.728(1)	—(2)	—(2)

(1) This system clock rate is not supported in I²C fast mode.
(2) This system clock rate is not supported for the given sampling frequency.



PARAMETERS		MIN	MAX	UNITS
$t_{(SCY)}$	System clock pulse cycle time	13		ns
$t_{(SCKH)}$	System clock pulse duration, HIGH	$0.4t_{(SCY)}$		ns
$t_{(SCKL)}$	System clock pulse duration, LOW	$0.4t_{(SCY)}$		ns

Figure 23. System Clock Input Timing

Power-On and External Reset Functions

The PCM1796 includes a power-on reset function. Figure 24 shows the operation of this function. With V_{DD} > 2 V, the power-on reset function is enabled. The initialization sequence requires 1024 system clocks from the time V_{DD} > 2 V. After the initialization period, the PCM1796 is set to its default reset state, as described in the *MODE CONTROL REGISTERS* section of this data sheet.

The PCM1796 also includes an external reset capability using the $\overline{\text{RST}}$ input (pin 14). This allows an external controller or master reset circuit to force the PCM1796 to initialize to its default reset state.

Figure 25 shows the external reset operation and timing. The $\overline{\text{RST}}$ pin is set to logic 0 for a minimum of 20 ns. The $\overline{\text{RST}}$ pin is then set to a logic 1 state, thus starting the initialization sequence, which requires 1024 system clock periods. The external reset is especially useful in applications where there is a delay between the PCM1796 power up and system clock activation.

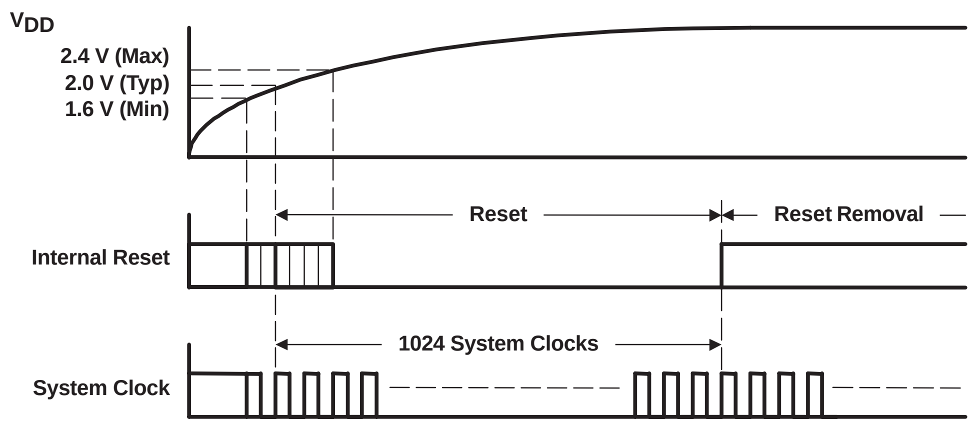
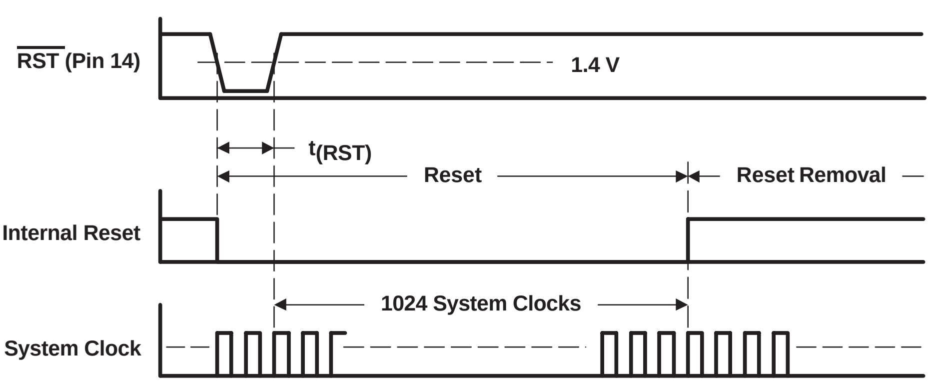


Figure 24. Power-On Reset Timing



PARAMETERS		MIN	MAX	UNITS
$t_{(RST)}$	Reset pulse duration, LOW	20		ns

Figure 25. External Reset Timing

AUDIO DATA INTERFACE

Audio Serial Interface

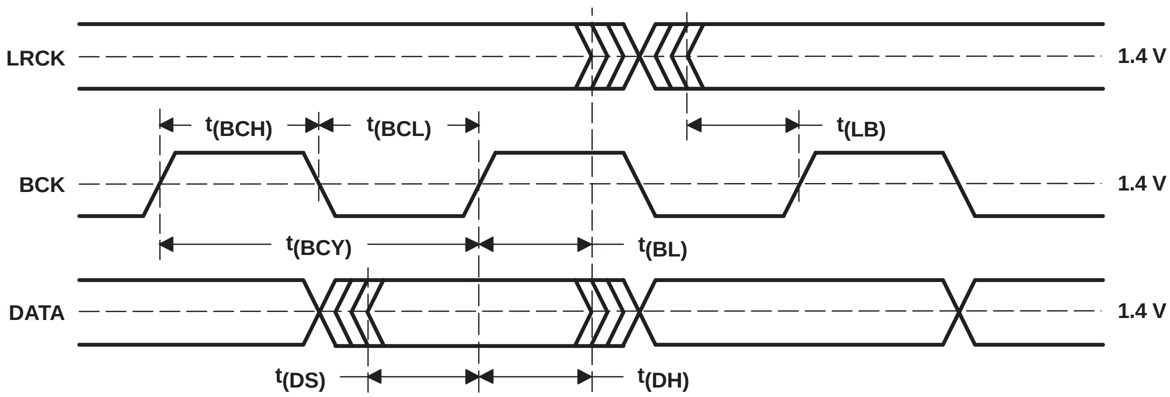
The audio interface port is a 3-wire serial port. It includes LRCK (pin 4), BCK (pin 6), and DATA (pin 5). BCK is the serial audio bit clock, and it is used to clock the serial data present on DATA into the serial shift register of the audio interface. Serial data is clocked into the PCM1796 on the rising edge of BCK. LRCK is the serial audio left/right word clock.

The PCM1796 requires the synchronization of LRCK and system clock, but does not need a specific phase relation between LRCK and system clock.

If the relationship between LRCK and system clock changes more than ±6 BCK, internal operation is initialized within $1/f_S$ and analog outputs are forced to the bipolar zero level until resynchronization between LRCK and system clock is completed.

PCM Audio Data Formats and Timing

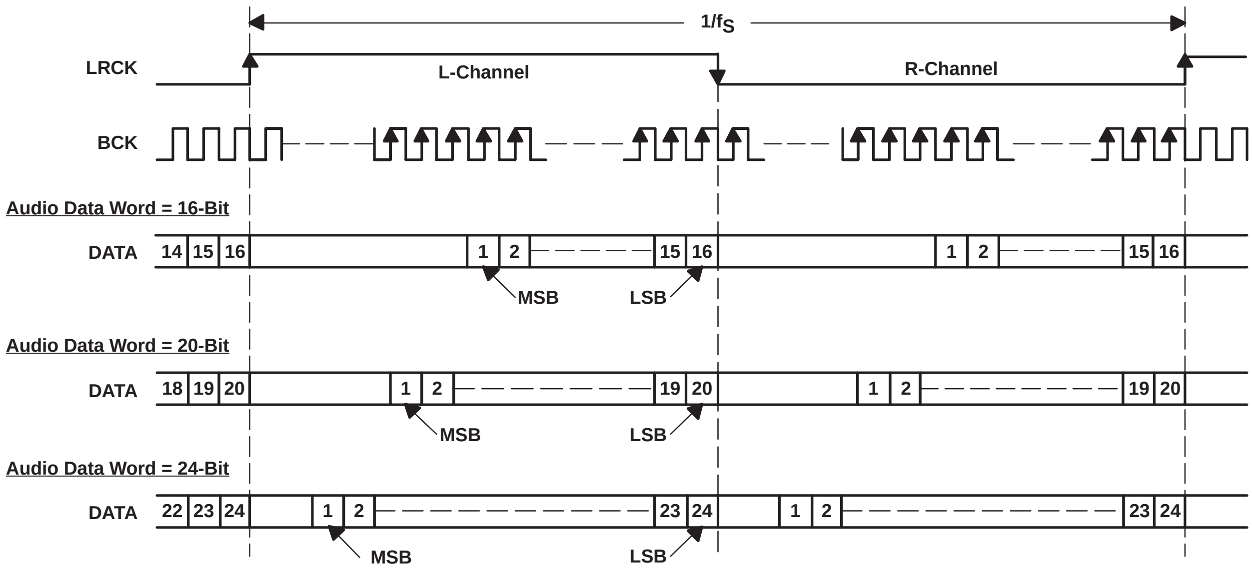
The PCM1796 supports industry-standard audio data formats, including standard right-justified, I^2S, and left-justified. The data formats are shown in Figure 27. Data formats are selected using the format bits, FMT[2:0], in control register 18. The default data format is 24-bit I^2S. All formats require binary 2s complement, MSB-first audio data. Figure 26 shows a detailed timing diagram for the serial audio interface.



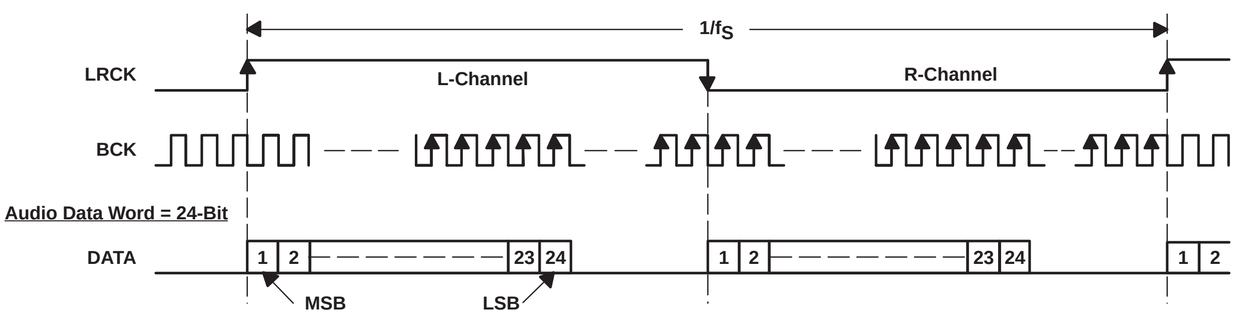
PARAMETERS		MIN	MAX	UNITS
$t_{(BCY)}$	BCK pulse cycle time	70		ns
$t_{(BCL)}$	BCK pulse duration, LOW	30		ns
$t_{(BCH)}$	BCK pulse duration, HIGH	30		ns
$t_{(BL)}$	BCK rising edge to LRCK edge	10		ns
$t_{(LB)}$	LRCK edge to BCK rising edge	10		ns
$t_{(DS)}$	DATA setup time	10		ns
$t_{(DH)}$	DATA hold time	10		ns
—	LRCK clock data	50% ± 2 bit clocks		

Figure 26. Timing of Audio Interface

(1) Standard Data Format (Right-Justified); L-Channel = HIGH, R-Channel = LOW



(2) Left-Justified Data Format; L-Channel = HIGH, R-Channel = LOW



(3) I2S Data Format; L-Channel = LOW, R-Channel = HIGH

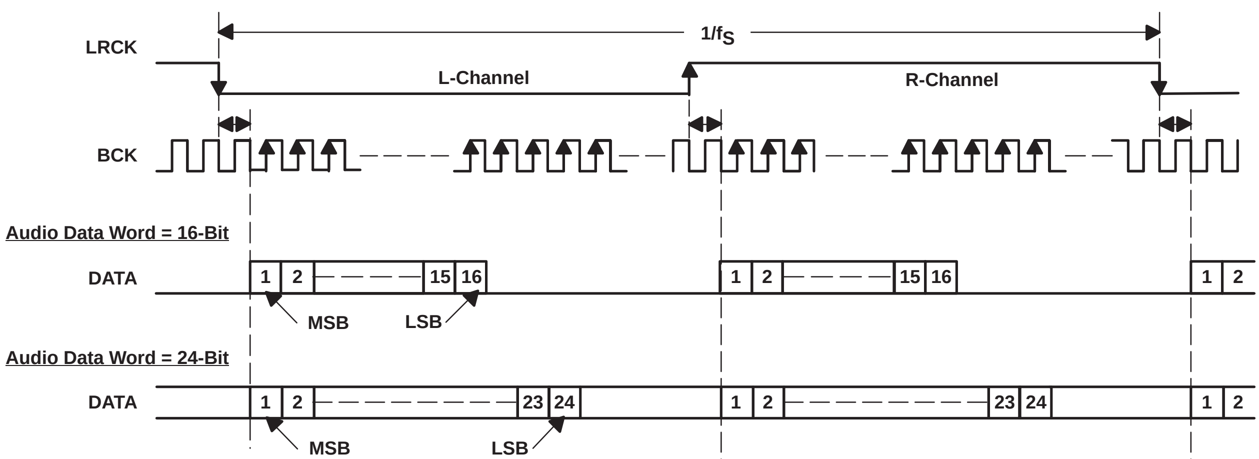


Figure 27. Audio Data Input Formats

External Digital Filter Interface and Timing

The PCM1796 supports an external digital filter interface comprising a 3- or 4-wire synchronous serial port, which allows the use of an external digital filter. External filters include the Texas Instruments' DF1704 and DF1706, the Pacific Microsonics PMD200, or a programmable digital signal processor.

In the external DF mode, LRCK (pin 4), BCK (pin 6) and DATA (pin 5) are defined as WDCK, the word clock; BCK, the bit clock; and DATA, the monaural data. The external digital filter interface is selected by using the DFTH bit of control register 20, which functions to bypass the internal digital filter of the PCM1796.

When the DFMS bit of control register 19 is set, the PCM1796 can process stereo data. In this case, ZEROL (pin 1) and ZEROR (pin 2) are defined as L-channel data and R-channel data input, respectively.

Detailed information for the external digital filter interface mode is provided in the *APPLICATION FOR EXTERNAL DIGITAL FILTER INTERFACE* section of this data sheet.

Direct Stream Digital (DSD) Format Interface and Timing

The PCM1796 supports the DSD format interface operation, which includes out-of-band noise filtering using an internal analog FIR filter. For DSD operation, SCK (pin 7) is redefined as BCK, DATA (pin 5) as DATAL (left channel audio data), and LRCK (pin 4) as DATAR (right channel audio data). BCK (pin 6) must be forced low in the DSD mode. The DSD format interface is activated by setting the DSD bit of control register 20.

Detailed information for the DSD mode is provided in the *APPLICATION FOR DSD FORMAT (DSD MODE) INTERFACE* section of this data sheet.

TDMCA Interface

The PCM1796 supports the time-division-multiplexed command and audio (TDMCA) data format to enable control of and communication with a number of external devices over a single serial interface.

Detailed information for the TDMCA format is provided in the *TDMCA INTERFACE FORMAT* section of this data sheet.

FUNCTION DESCRIPTIONS

Zero Detect

The PCM1796 has a zero-detect function. When the PCM1796 detects the zero conditions as shown in Table 2, the PCM1796 sets ZEROL (pin 1) and ZEROR (pin 2) to HIGH.

Table 2. Zero Conditions

MODE		DETECTING CONDITION AND TIME
PCM		DATA is continuously LOW for 1024 LRCKs.
External DF Mode		DATA is continuously LOW for 8 × 1024 WDCKs.
DSD	DZ0	There are an equal number of 1s and 0s in every 8 bits of DSD input data for 23 ms.
DSD	DZ1	The input data is 1001 0110 continuously for 23 ms.

SERIAL CONTROL INTERFACE

The PCM1796 supports SPI and I^2C that sets mode control registers as shown in Table 4. This serial control interface is selected by MSEL (pin 3), SPI is activated when MSEL is set to LOW, and I^2C is activated when MSEL is set to HIGH.

SPI Interface

The SPI interface is a 4-wire synchronous serial port that operates asynchronously to the serial audio interface and the system clock (SCK). The serial control interface is used to program and read the on-chip mode registers. The control interface includes MDO (pin 13), MDI (pin 11), MC (pin 12), and $\overline{MS}$ (pin 10). MDO is the serial data output, used to read back the values of the mode registers; MDI is the serial data input, used to program the mode registers; MC is the serial bit clock, used to shift data in and out of the control port, and $\overline{MS}$ is the mode control enable, used to enable the internal mode register access.

Register Read/Write Operation

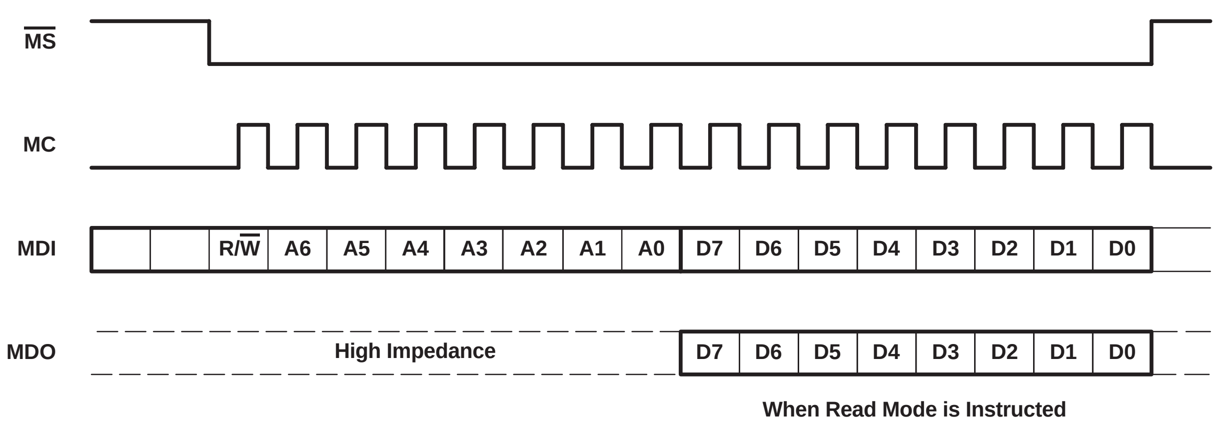
All read/write operations for the serial control port use 16-bit data words. Figure 28 shows the control data word format. The most significant bit is the read/write (R/$\overline{W}$) bit. For write operations, the R/$\overline{W}$ bit must be set to 0. For read operations, the R/$\overline{W}$ bit must be set to 1. There are seven bits, labeled IDX[6:0], that hold the register index (or address) for the read and write operations. The least significant eight bits, D[7:0], contain the data to be written to, or the data that was read from, the register specified by IDX[6:0].

Figure 29 shows the functional timing diagram for writing or reading the serial control port. $\overline{MS}$ is held at a logic 1 state until a register needs to be written or read. To start the register write or read cycle, $\overline{MS}$ is set to logic 0. Sixteen clocks are then provided on MC, corresponding to the 16 bits of the control data word on MDI and readback data on MDO. After the eighth clock cycle has completed, the data from the indexed-mode control register appears on MDO during the read operation. After the sixteenth clock cycle has completed, the data is latched into the indexed-mode control register during the write operation. To write or read subsequent data, $\overline{MS}$ must be set to 1 once.

MSB　　　　　　　　　　　　　　　　　　　　　　　　LSB

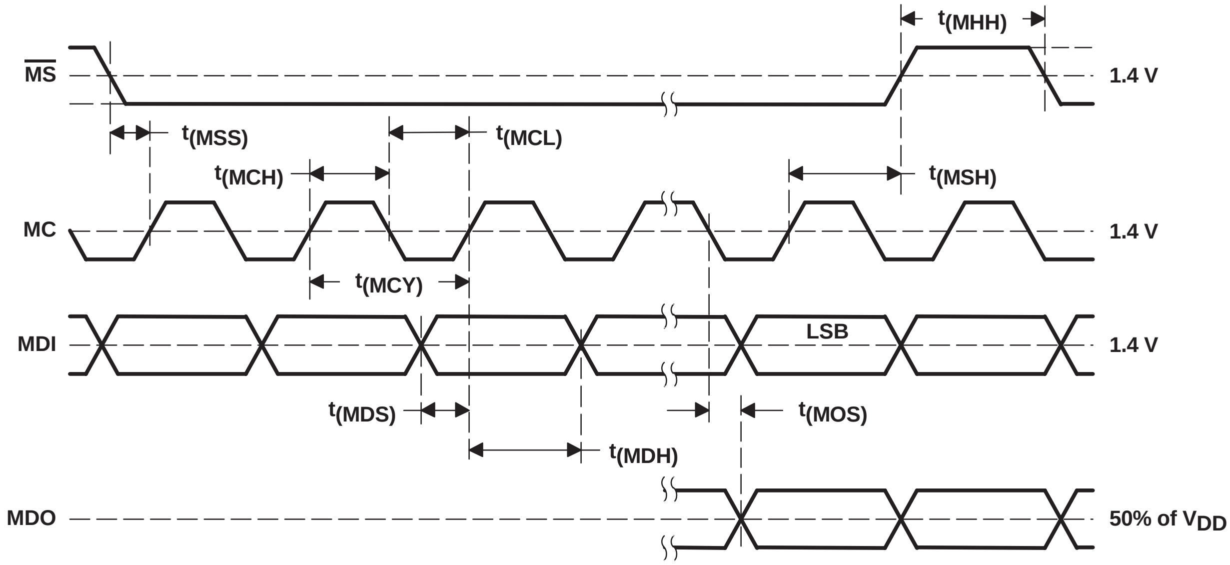
R/$\overline{W}$	IDX6	IDX5	IDX4	IDX3	IDX2	IDX1	IDX0	D7	D6	D5	D4	D3	D2	D1	D0
	Register Index (or Address)							Register Data							

Figure 28. Control Data Word Format for MDI



NOTE: Bit 15 is used for selection of write or read. Setting R/$\overline{W}$ = 0 indicates a write, while R/$\overline{W}$ = 1 indicates a read. Bits 14−8 are used for the register address. Bits 7–0 are used for register data.

Figure 29. Serial Control Format



PARAMETER		MIN	MAX	UNITS
$t_{(MCY)}$	MC pulse cycle time	100		ns
$t_{(MCL)}$	MC low-level time	40		ns
$t_{(MCH)}$	MC high-level time	40		ns
$t_{(MHH)}$	$\overline{MS}$ high-level time	80		ns
$t_{(MSS)}$	$\overline{MS}$ falling edge to MC rising edge	15		ns
$t_{(MSH)}$	$\overline{MS}$ hold time(1)	15		ns
$t_{(MDH)}$	MDI hold time	15		ns
$t_{(MDS)}$	MDI setup time	15		ns
$t_{(MOS)}$	MC falling edge to MDO stable		30	ns

(1) MC rising edge for LSB to $\overline{MS}$ rising edge

Figure 30. Control Interface Timing

I^2C INTERFACE

The PCM1796 supports the I^2C serial bus and the data transmission protocol for standard and fast mode as a slave device. This protocol is explained in I^2C specification 2.0.

In I^2C mode, the control terminals are changed as follows.

TERMINAL NAME	TDMCA NAME	PROPERTY	DESCRIPTION
$\overline{\text{MS}}$	ADR0	Input	I^2C address 0
MDI	ADR1	Input	I^2C address 1
MC	SCL	Input	I^2C clock
MDO	SDA	Input/output	I^2C data

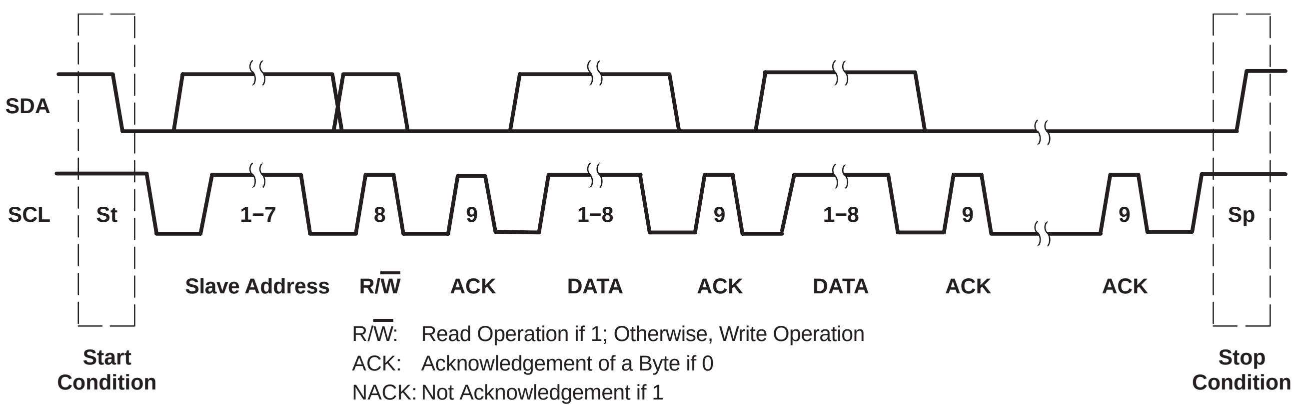
Slave Address

MSB							LSB
1	0	0	1	1	ADR1	ADR0	R/$\overline{\text{W}}$

The PCM1796 has 7 bits for its own slave address. The first five bits (MSBs) of the slave address are factory preset to 10011. The next two bits of the address byte are the device select bits which can be user-defined by the ADR1 and ADR0 terminals. A maximum of four PCM1796s can be connected on the same bus at one time. Each PCM1796 responds when it receives its own slave address.

Packet Protocol

A master device must control packet protocol, which consists of start condition, slave address, read/write bit, data if write or acknowledge if read, and stop condition. The PCM1796 supports only slave receivers and slave transmitters.



Write Operation

Transmitter	*M*	*M*	*M*	*S*	*M*	*S*	*M*	*S*		*S*	*M*
Data Type	St	Slave Address	$\overline{\text{W}}$	ACK	DATA	ACK	DATA	ACK		ACK	Sp

Read Operation

Transmitter	*M*	*M*	*M*	*S*	*S*	*M*	*S*	*M*		*M*	*M*
Data Type	St	Slave Address	R	ACK	DATA	ACK	DATA	ACK		NACK	Sp

M: Master Device *S: Slave Device*
St: Start Condition Sp: Stop Condition $\overline{\text{W}}$: Write R: Read ACK: Acknowledge
NACK: Not Acknowledge

Figure 31. Basic I^2C Framework

Write Register

A master can write to any PCM1796 registers using single or multiple accesses. The master sends a PCM1796 slave address with a write bit, a register address, and the data. If multiple access is required, the address is that of the starting register, followed by the data to be transferred. When the data are received properly, the index register is incremented by 1 automatically. When the index register reaches 0x7F, the next value is 0x00. When undefined registers are accessed, the PCM1796 does not send an acknowledgement. Figure 32 is a diagram of the write operation.

Transmitter	*M*	*M*	*M*	*S*	*M*	*S*	*M*	*S*	*M*	*S*		*S*	*M*
Data Type	St	Slave Address	$\overline{W}$	ACK	Reg Address	ACK	Write Data 1	ACK	Write Data 2	ACK		ACK	Sp

M: Master Device *S: Slave Device*

St: Start Condition Sp: Stop Condition ACK: Acknowledge $\overline{W}$: Write

Figure 32. Write Operation

Read Register

A master can read the PCM1796 register. The value of the register address is stored in an indirect index register in advance. The master sends a PCM1796 slave address with a read bit after storing the register address. Then the PCM1796 transfers the data which the index register points to. When the data are transferred during a multiple access, the index register is incremented by 1 automatically. (When first going into read mode immediately following a write, the index register is not incremented. The master can read the register that was previously written.) When the index register reaches 0x7F, the next value is 0x00. The PCM1796 outputs some data when the index register is 0x10 to 0x1F, even if it is not defined in Table 4. Figure 33 is a diagram of the read operation.

Transmitter	*M*	*M*	*M*	*S*	*M*	*S*	*M*	*M*	*M*	*S*	*S*	*M*		*M*	*M*
Data Type	St	Slave Address	$\overline{W}$	ACK	Reg Address	ACK	Sr	Slave Address	R	ACK	Data	ACK		NACK	Sp

M: Master Device *S: Slave Device*

St: Start Condition Sr: Repeated Start Condition Sp: Stop Condition ACK: Acknowledge NACK: Not Acknowledge

$\overline{W}$: Write R: Read

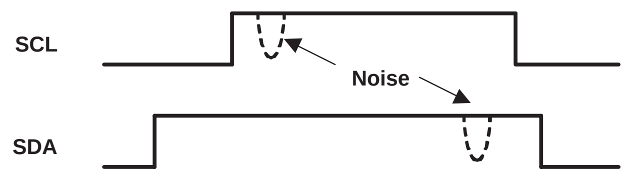
Figure 33. Read Operation

Noise Suppression

The PCM1796 incorporates noise suppression using the system clock (SCK). However, there must be no more than two noise spikes in 600 ns. The noise suppression works for SCK frequencies between 8 MHz and 40 MHz in fast mode. However, it works incorrectly in the following conditions.

Case 1:

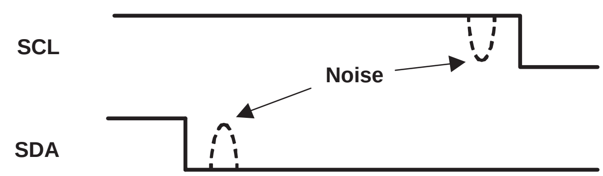
1. $t_{(SCK)}$ > 120 ns ($t_{(SCK)}$: period of SCK)
2. $t_{(HI)} + t_{(D-HD)} < t_{(SCK)} \times 5$
3. Spike noise exists on the first half of the SCL HIGH pulse.
4. Spike noise exists on the SDA HIGH pulse just before SDA goes LOW.



When these conditions occur at the same time, the data is recognized as LOW.

Case 2:

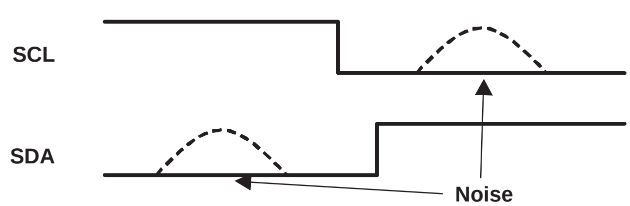
1. $t_{(SCK)}$ > 120 ns
2. $t_{(S-HD)}$ or $t_{(RS-HD)} < t_{(SCK)} \times 5$
3. Spike noise exists on both SCL and SDA during the hold time.



When these conditions occur at the same time, the PCM1796 fails to detect a start condition.

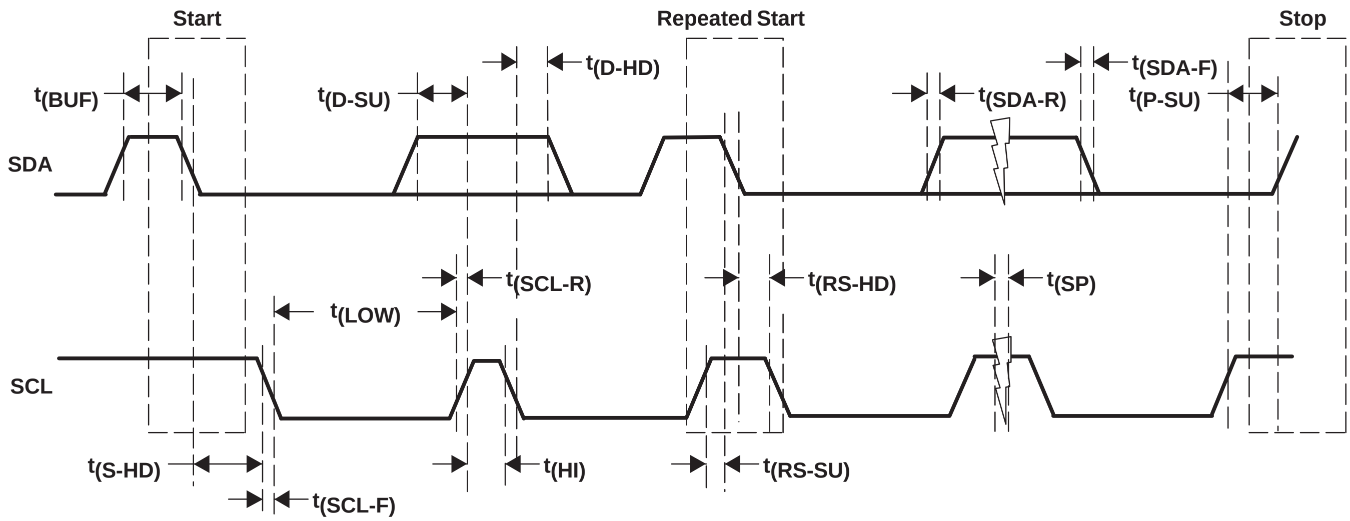
Case 3:

1. $t_{(SCK)}$ < 50 ns
2. $t_{(SP)} > t_{(SCK)}$
3. Spike noise exists on SCL just after SCL goes LOW.
4. Spike noise exists on SDA just before SCL goes LOW.



When these conditions occur at the same time, the PCM1796 erroneously detects a start or stop condition.

TIMING DIAGRAM



TIMING CHARACTERISTICS

PARAMETER		CONDITIONS	MIN	MAX	UNIT
$f_{(SCL)}$	SCL clock frequency	Standard		100	kHz
		Fast		400	
$t_{(BUF)}$	Bus free time between stop and start conditions	Standard	4.7		µs
		Fast	1.3		
$t_{(LOW)}$	Low period of the SCL clock	Standard	4.7		µs
		Fast	1.3		
$t_{(HI)}$	High period of the SCL clock	Standard	4		µs
		Fast	600		ns
$t_{(RS-SU)}$	Setup time for (repeated) start condition	Standard	4.7		µs
		Fast	600		ns
$t_{(S-HD)}$ $t_{(RS-HD)}$	Hold time for (repeated) start condition	Standard	4		µs
		Fast	600		ns
$t_{(D-SU)}$	Data setup time	Standard	250		ns
		Fast	100		
$t_{(D-HD)}$	Data hold time	Standard	0	900	ns
		Fast	0	900	
$t_{(SCL-R)}$	Rise time of SCL signal	Standard	$20 + 0.1\ C_B$	1000	ns
		Fast	$20 + 0.1\ C_B$	300	
$t_{(SCL-R1)}$	Rise time of SCL signal after a repeated start condition and after an acknowledge bit	Standard	$20 + 0.1\ C_B$	1000	ns
		Fast	$20 + 0.1\ C_B$	300	
$t_{(SCL-F)}$	Fall time of SCL signal	Standard	$20 + 0.1\ C_B$	1000	ns
		Fast	$20 + 0.1\ C_B$	300	
$t_{(SDA-R)}$	Rise time of SDA signal	Standard	$20 + 0.1\ C_B$	1000	ns
		Fast	$20 + 0.1\ C_B$	300	
$t_{(SDA-F)}$	Fall time of SDA signal	Standard	$20 + 0.1\ C_B$	1000	ns
		Fast	$20 + 0.1\ C_B$	300	
$t_{(P-SU)}$	Setup time for stop condition	Standard	4		µs
		Fast	600		ns
$C_{(B)}$	Capacitive load for SDA and SCL line			400	pF
$t_{(SP)}$	Pulse duration of suppressed spike	Fast		50	ns
V_{NH}	Noise margin at high level for each connected device (including hysteresis)		$0.2\ V_{DD}$		V

Figure 34. Timing Definition on the I^2C Bus

MODE CONTROL REGISTERS

User-Programmable Mode Controls

The PCM1796 includes a number of user-programmable functions which are accessed via mode control registers. The registers are programmed using the serial control interface, which is previously discussed in the *SPI Interface* and *I²C INTERFACE* sections of this data sheet. Table 3 lists the available mode-control functions, along with their default reset conditions and associated register index.

Table 3. User-Programmable Function Controls

FUNCTION	DEFAULT	REGISTER	BIT	PCM	DSD	DF BYPASS
Digital attenuation control 0 dB to –120 dB and mute, 0.5 dB step	0 dB	Register 16 Register 17	ATL[7:0] (for L-ch) ATR[7:0] (for R-ch)	yes		
Attenuation load control Disabled, enabled	Attenuation disabled	Register 18	ATLD	yes		
Input audio data format selection 16-, 20-, 24-bit standard (right-justified) format 24-bit MSB-first left-justified format 16-/24-bit I²S format	24-bit I²S format	Register 18	FMT[2:0]	yes		yes
Sampling rate selection for de-emphasis Disabled,44.1 kHz, 48 kHz, 32 kHz	De-emphasis disabled	Register 18	DMF[1:0]	yes	yes(1)	
De-emphasis control Disabled, enabled	De-emphasis disabled	Register 18	DME	yes		
Soft mute control Soft mute disabled, enabled	Mute disabled	Register 18	MUTE	yes		
Output phase reversal Normal, reverse	Normal	Register 19	REV	yes	yes	yes
Attenuation speed selection $\times 1 f_S$, $\times(1/2) f_S$, $\times(1/4) f_S$, $\times(1/8) f_S$	$\times 1\ f_S$	Register 19	ATS[1:0]	yes		
DAC operation control Enabled, disabled	DAC operation enabled	Register 19	OPE	yes	yes	yes
Stereo DF bypass mode select Monaural, stereo	Monaural	Register 19	DFMS			yes
Digital filter rolloff selection Sharp rolloff, slow rolloff	Sharp rolloff	Register 19	FLT	yes		
Infinite zero mute control Disabled, enabled	Disabled	Register 19	INZD	yes		yes
System reset control Reset operation , normal operation	Normal operation	Register 20	SRST	yes	yes	yes
DSD interface mode control DSD enabled, disabled	Disabled	Register 20	DSD	yes	yes	
Digital-filter bypass control DF enabled, DF bypass	DF enabled	Register 20	DFTH	yes		yes
Monaural mode selection Stereo, monaural	Stereo	Register 20	MONO	yes	yes	yes
Channel selection for monaural mode data L-channel, R-channel	L-channel	Register 20	CHSL	yes	yes	yes
Delta-sigma oversampling rate selection $\times 64\ f_S$, $\times 128\ f_S$, $\times 32\ f_S$	$\times 64\ f_S$	Register 20	OS[1:0]	yes	yes(2)	yes
PCM zero output enable	Enabled	Register 21	PCMZ	yes		yes
DSD zero output enable	Disabled	Register 21	DZ[1:0]		yes	
FUNCTION AVAILABLE ONLY FOR READ						
Zero detection flag Not zero, zero detected	Not zero = 0 Zero detected = 1	Register 22	ZFGL (for L-ch) ZFGR (for R-ch)	yes	yes	yes
Device ID (at TDMCA)	–	Register 23	ID[4:0]	yes		

(1) When in DSD mode, DMF[1:0] is defined as DSD filter (analog FIR) performance selection.
(2) When in DSD mode, OS[1:0] is defined as DSD filter (analog FIR) operation rate selection.

Register Map

The mode control register map is shown in Table 4. Registers 16–21 include an R/$\overline{W}$ bit, which determines whether a register read (R/$\overline{W}$ = 1) or write (R/$\overline{W}$ = 0) operation is performed. Registers 22 and 23 are read-only.

Table 4. Mode Control Register Map

	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Register 16	R/$\overline{W}$	0	0	1	0	0	0	0	ATL7	ATL6	ATL5	ATL4	ATL3	ATL2	ATL1	ATL0
Register 17	R/$\overline{W}$	0	0	1	0	0	0	1	ATR7	ATR6	ATR5	ATR4	ATR3	ATR2	ATR1	ATR0
Register 18	R/$\overline{W}$	0	0	1	0	0	1	0	ATLD	FMT2	FMT1	FMT0	DMF1	DMF0	DME	MUTE
Register 19	R/$\overline{W}$	0	0	1	0	0	1	1	REV	ATS1	ATS0	OPE	RSV	DFMS	FLT	INZD
Register 20	R/$\overline{W}$	0	0	1	0	1	0	0	RSV	SRST	DSD	DFTH	MONO	CHSL	OS1	OS0
Register 21	R/$\overline{W}$	0	0	1	0	1	0	1	RSV	RSV	RSV	RSV	RSV	DZ1	DZ0	PCMZ
Register 22	R	0	0	1	0	1	1	0	RSV	RSV	RSV	RSV	RSV	RSV	ZFGR	ZFGL
Register 23	R	0	0	1	0	1	1	1	RSV	RSV	RSV	ID4	ID3	ID2	ID1	ID0

Register Definitions

	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Register 16	R/$\overline{W}$	0	0	1	0	0	0	0	ATL7	ATL6	ATL5	ATL4	ATL3	ATL2	ATL1	ATL0
Register 17	R/$\overline{W}$	0	0	1	0	0	0	1	ATR7	ATR6	ATR5	ATR4	ATR3	ATR2	ATR1	ATR0

R/$\overline{W}$: Read/Write Mode Select

When R/$\overline{W}$ = 0, a write operation is performed.

When R/$\overline{W}$ = 1, a read operation is performed.

Default value: 0

ATx[7:0]: Digital Attenuation Level Setting

These bits are available for read and write.

Default value: 1111 1111b

Each DAC output has a digital attenuator associated with it. The attenuator can be set from 0 dB to –120 dB, in 0.5-dB steps. Alternatively, the attenuator can be set to infinite attenuation (or mute).

The attenuation data for each channel can be set individually. However, the data load control (the ATLD bit of control register 18) is common to both attenuators. ATLD must be set to 1 in order to change an attenuator setting. The attenuation level can be set using the following formula:

$$\text{Attenuation level (dB)} = 0.5\ \text{dB} \bullet (ATx[7:0]_{DEC} - 255)$$

where $ATx[7:0]_{DEC}$ = 0 through 255

For $ATx[7:0]_{DEC}$ = 0 through 14, the attenuator is set to infinite attenuation. The following table shows attenuation levels for various settings:

ATx[7:0]	Decimal Value	Attenuation Level Setting
1111 1111b	255	0 dB, no attenuation (default)
1111 1110b	254	–0.5 dB
1111 1101b	253	–1.0 dB
⋮	⋮	⋮
0001 0000b	16	–119.5 dB
0000 1111b	15	–120.0 dB
0000 1110b	14	Mute
⋮	⋮	⋮
0000 0000b	0	Mute

	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Register 18	R/$\overline{W}$	0	0	1	0	0	1	0	ATLD	FMT2	FMT1	FMT0	DMF1	DMF0	DME	MUTE

R/$\overline{W}$: Read/Write Mode Select

When R/$\overline{W}$ = 0, a write operation is performed.

When R/$\overline{W}$ = 1, a read operation is performed.

Default value: 0

ATLD: Attenuation Load Control

This bit is available for read and write.

Default value: 0

ATLD = 0	Attenuation control disabled (default)
ATLD = 1	Attenuation control enabled

The ATLD bit is used to enable loading of the attenuation data contained in registers 16 and 17. When ATLD = 0, the attenuation settings remain at the previously programmed levels, ignoring new data loaded from registers 16 and 17. When ATLD = 1, attenuation data written to registers 16 and 17 is loaded normally.

FMT[2:0]: Audio Interface Data Format

These bits are available for read and write.

Default value: 101

FMT[2:0]	Audio Data Format Selection
000	16-bit standard format, right-justified data
001	20-bit standard format, right-justified data
010	24-bit standard format, right-justified data
011	24-bit MSB-first, left-justified format data
100	16-bit I^2S format data
101	24-bit I^2S format data (default)
110	Reserved
111	Reserved

The FMT[2:0] bits are used to select the data format for the serial audio interface.

For the external digital filter interface mode (DFTH mode), this register is operated as shown in the *APPLICATION FOR EXTERNAL DIGITAL FILTER INTERFACE* section of this data sheet.

DMF[1:0]: Sampling Frequency Selection for the De-Emphasis Function

These bits are available for read and write.

Default value: 00

DMF[1:0]	De-Emphasis Sampling Frequency Selection
00	Disabled (default)
01	48 kHz
10	44.1 kHz
11	32 kHz

The DMF[1:0] bits are used to select the sampling frequency used by the digital de-emphasis function when it is enabled by setting the DME bit. The de-emphasis curves are shown in the *TYPICAL PERFORMANCE CURVES* section of this data sheet.

For the DSD mode, analog FIR filter performance can be selected using this register. A register map and filter response plots are shown in the *APPLICATION FOR DSD FORMAT (DSD MODE) INTERFACE* section of this data sheet.

DME: Digital De-Emphasis Control

This bit is available for read and write.

Default value: 0

DME = 0	De-emphasis disabled (default)
DME = 1	De-emphasis enabled

The DME bit is used to enable or disable the de-emphasis function for both channels.

MUTE: Soft Mute Control

This bit is available for read and write.

Default value: 0

MUTE = 0	Soft mute disabled (default)
MUTE = 1	Soft mute enabled

The MUTE bit is used to enable or disable the soft mute function for both channels.

Soft mute is operated as a 256-step attenuator. The speed for each step to −∞ dB (mute) is determined by the attenuation rate selected in the ATS register.

	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Register 19	R/$\overline{W}$	0	0	1	0	0	1	1	REV	ATS1	ATS0	OPE	RSV	DFMS	FLT	INZD

R/$\overline{W}$: Read/Write Mode Select

When R/$\overline{W}$ = 0, a write operation is performed.

When R/$\overline{W}$ = 1, a read operation is performed.

Default value: 0

REV: Output Phase Reversal

This bit is available for read and write.

Default value: 0

REV = 0	Normal output (default)
REV = 1	Inverted output

The REV bit is used to invert the output phase for both channels.

ATS[1:0]: Attenuation Rate Select

These bits are available for read and write.

Default value: 00

ATS[1:0]	Attenuation Rate Selection
00	Every LRCK (default)
01	LRCK/2
10	LRCK/4
11	LRCK/8

The ATS[1:0] bits are used to select the rate at which the attenuator is decremented/incremented during level transitions.

OPE: DAC Operation Control

This bit is available for read and write.

Default value: 0

OPE = 0	DAC operation enabled (default)
OPE = 1	DAC operation disabled

The OPE bit is used to enable or disable the analog output for both channels. Disabling the analog outputs forces them to the bipolar zero level (BPZ) even if audio data is present on the input.

DFMS: Stereo DF Bypass Mode Select

This bit is available for read and write.

Default value: 0

DFMS = 0	Monaural (default)
DFMS = 1	Stereo input enabled

The DFMS bit is used to enable stereo operation in DF bypass mode. In the DF bypass mode, when DFMS is set to 0, the pin for the input data is DATA (pin 5) only, therefore the PCM1796 operates as a monaural DAC. When DFMS is set to 1, the PCM1796 can operate as a stereo DAC with inputs of L-channel and R-channel data on ZEROL (pin 1) and ZEROR (pin 2), respectively.

FLT: Digital Filter Rolloff Control

This bit is available for read and write.

Default value: 0

FLT = 0	Sharp rolloff (default)
FLT = 1	Slow rolloff

The FLT bit is used to select the digital filter rolloff characteristic. The filter responses for these selections are shown in the *TYPICAL PERFORMANCE CURVES* section of this data sheet.

INZD: Infinite Zero Detect Mute Control

This bit is available for read and write.

Default value: 0

INZD = 0	Infinite zero detect mute disabled (default)
INZD = 1	Infinite zero detect mute enabled

The INZD bit is used to enable or disable the zero detect mute function. Setting INZD to 1 forces muted analog outputs to hold a bipolar zero level when the PCM1796 detects a zero condition in both channels. The infinite zero detect mute function is not available in the DSD mode.

	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Register 20	R/$\overline{W}$	0	0	1	0	1	0	0	RSV	SRST	DSD	DFTH	MONO	CHSL	OS1	OS0

R/$\overline{W}$: Read/Write Mode Select

When R/$\overline{W}$ = 0, a write operation is performed.

When R/$\overline{W}$ = 1, a read operation is performed.

Default value: 0

SRST: System Reset Control

This bit is available for write only.

Default value: 0

SRST = 0	Normal operation (default)
SRST = 1	System reset operation (generate one reset pulse)

The SRST bit is used to reset the PCM1796 to the initial system condition.

DSD: DSD Interface Mode Control

This bit is available for read and write.

Default value: 0

DSD = 0	DSD interface mode disabled (default)
DSD = 1	DSD interface mode enabled

The DSD bit is used to enable or disable the DSD interface mode.

DFTH: Digital Filter Bypass (or Through Mode) Control

This bit is available for read and write.

Default value: 0

DFTH = 0	Digital filter enabled (default)
DFTH = 1	Digital filter bypassed for external digital filter

The DFTH bit is used to enable or disable the external digital filter interface mode.

MONO: Monaural Mode Selection

This bit is available for read and write.

Default value: 0

MONO = 0	Stereo mode (default)
MONO = 1	Monaural mode

The MONO function is used to change operation mode from the normal stereo mode to the monaural mode. When the monaural mode is selected, both DACs operate in a balanced mode for one channel of audio input data. Channel selection is available for L-channel or R-channel data, determined by the CHSL bit as described immediately following.

CHSL: Channel Selection for Monaural Mode

This bit is available for read and write.

Default value: 0

CHSL = 0	L-channel selected (default)
CHSL = 1	R-channel selected

This bit is available when MONO = 1.

The CHSL bit selects L-channel or R-channel data to be used in monaural mode.

OS[1:0]: Delta-Sigma Oversampling Rate Selection

These bits are available for read and write.

Default value: 00

OS[1:0]	Operation Speed Select
00	64 times f_S (default)
01	32 times f_S
10	128 times f_S
11	Reserved

The OS bits are used to change the oversampling rate of delta-sigma modulation. Use of this function enables the designer to stabilize the conditions at the post low-pass filter for different sampling rates. As an application example, programming to set 128 times in 44.1-kHz operation, 64 times in 96-kHz operation, and 32 times in 192-kHz operation allows the use of only a single type (cutoff frequency) of post low-pass filter. The 128 f_S oversampling rate is not available at sampling rates above 100 kHz. If the 128-f_S oversampling rate is selected, a system clock of more than 256 f_S is required.

In DSD mode, these bits are used to select the speed of the bit clock for DSD data coming into the analog FIR filter.

	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Register 21	R/$\overline{W}$	0	0	1	0	1	0	1	RSV	RSV	RSV	RSV	RSV	DZ1	DZ0	PCMZ

R/$\overline{W}$: Read/Write Mode Select

When R/$\overline{W}$ = 0, a write operation is performed.

When R/$\overline{W}$ = 1, a read operation is performed.

Default value: 0

DZ[1:0]: DSD Zero Output Enable

These bits are available for read and write.

Default value: 00

DZ[1:0]	Zero Output Enable
00	Disabled (default)
01	Even pattern detect
1x	96h pattern detect

The DZ bits are used to enable or disable the output zero flags, and to select the zero pattern in the DSD mode.

PCMZ: PCM Zero Output Enable

These bits are available for read and write.

Default value: 1

PCMZ = 0	PCM zero output disabled
PCMZ = 1	PCM zero output enabled (default)

The PCMZ bit is used to enable or disable the output zero flags in the PCM mode and the external DF mode.

	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Register 22	R	0	0	1	0	1	1	0	RSV	RSV	RSV	RSV	RSV	RSV	ZFGR	ZFGL

R: Read Mode Select

Value is always 1, specifying the readback mode.

ZFGx: Zero-Detection Flag

Where x = L or R, corresponding to the DAC output channel. These bits are available only for readback.

Default value: 00

ZFGx = 0	Not zero
ZFGx = 1	Zero detected

These bits show zero conditions. Their status is the same as that of the zero flags at ZEROL (pin 1) and ZEROR (pin 2). See *Zero Detect* in the *FUNCTION DESCRIPTIONS* section.

	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Register 23	R	0	0	1	0	1	1	1	RSV	RSV	RSV	ID4	ID3	ID2	ID1	ID0

R: Read Mode Select

Value is always 1, specifying the readback mode.

ID[4:0]: Device ID

The ID[4:0] bits hold a device ID in the TDMCA mode.

APPLICATION INFORMATION

TYPICAL CONNECTION DIAGRAM IN PCM MODE

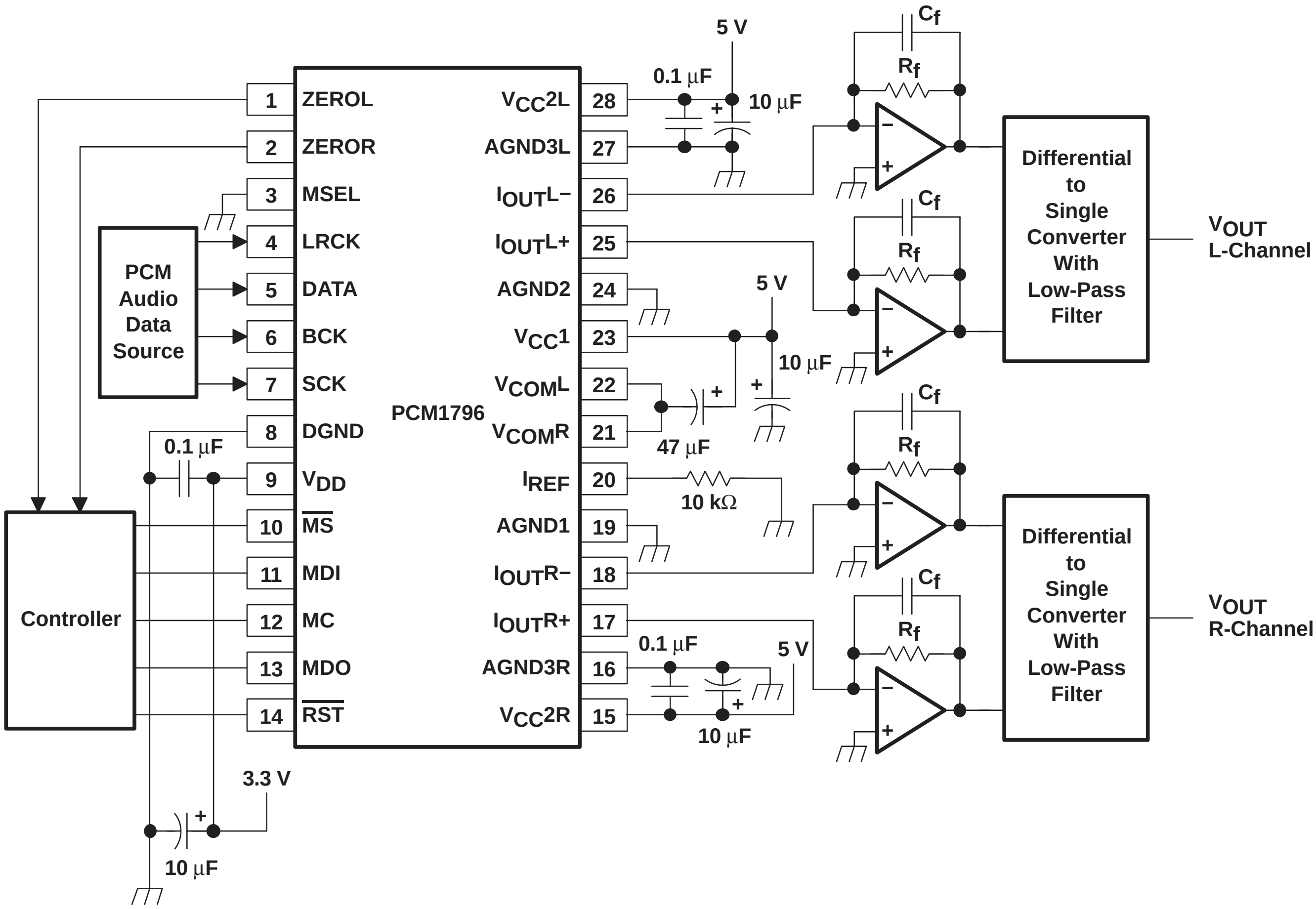


Figure 35. Typical Application Circuit for Standard PCM Audio Operation

APPLICATION CIRCUIT

The design of the application circuit is very important in order to actually realize the high S/N ratio of which the PCM1796 is capable. This is because noise and distortion that are generated in an application circuit are not negligible.

In the third-order LPF circuit of Figure 36, the output level is 2.1 V rms and 123 dB S/N is achieved.

Figure 37 shows a circuit for the DSD mode, which is a fourth-order LPF in order to reduce the out-of-band noise.

I/V Section

The current of the PCM1796 on each of the output pins ($I_{OUT}L+$, $I_{OUT}L-$, $I_{OUT}R+$, $I_{OUT}R-$) is 4 mA p-p at 0 dB (full scale). The voltage output level of the I/V converter (Vi) is given by following equation:

$$Vi = 4\text{ mA p−p} \times R_f \ (R_f : \text{feedback resistance of I/V converter})$$

An NE5534 op amp is recommended for the I/V circuit to obtain the specified performance. Dynamic performance such as the gain bandwidth, settling time, and slew rate of the op amp affects the audio dynamic performance of the I/V section.

Differential Section

The PCM1796 voltage outputs are followed by differential amplifier stages, which sum the differential signals for each channel, creating a single-ended I/V op-amp output. In addition, the differential amplifiers provide a low-pass filter function.

The op amp recommended for the differential circuit is the low-noise type.

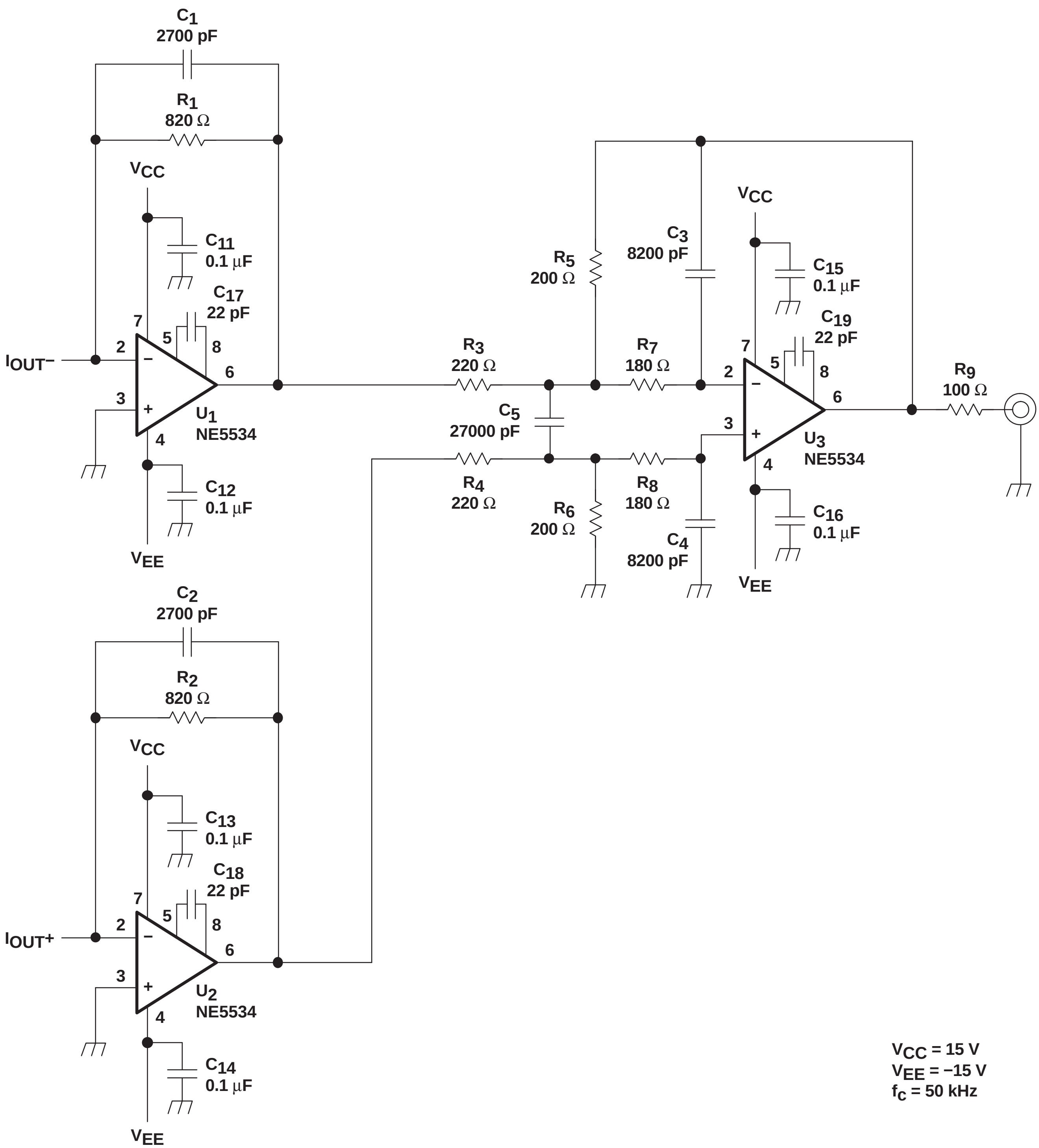


Figure 36. Measurement Circuit for PCM

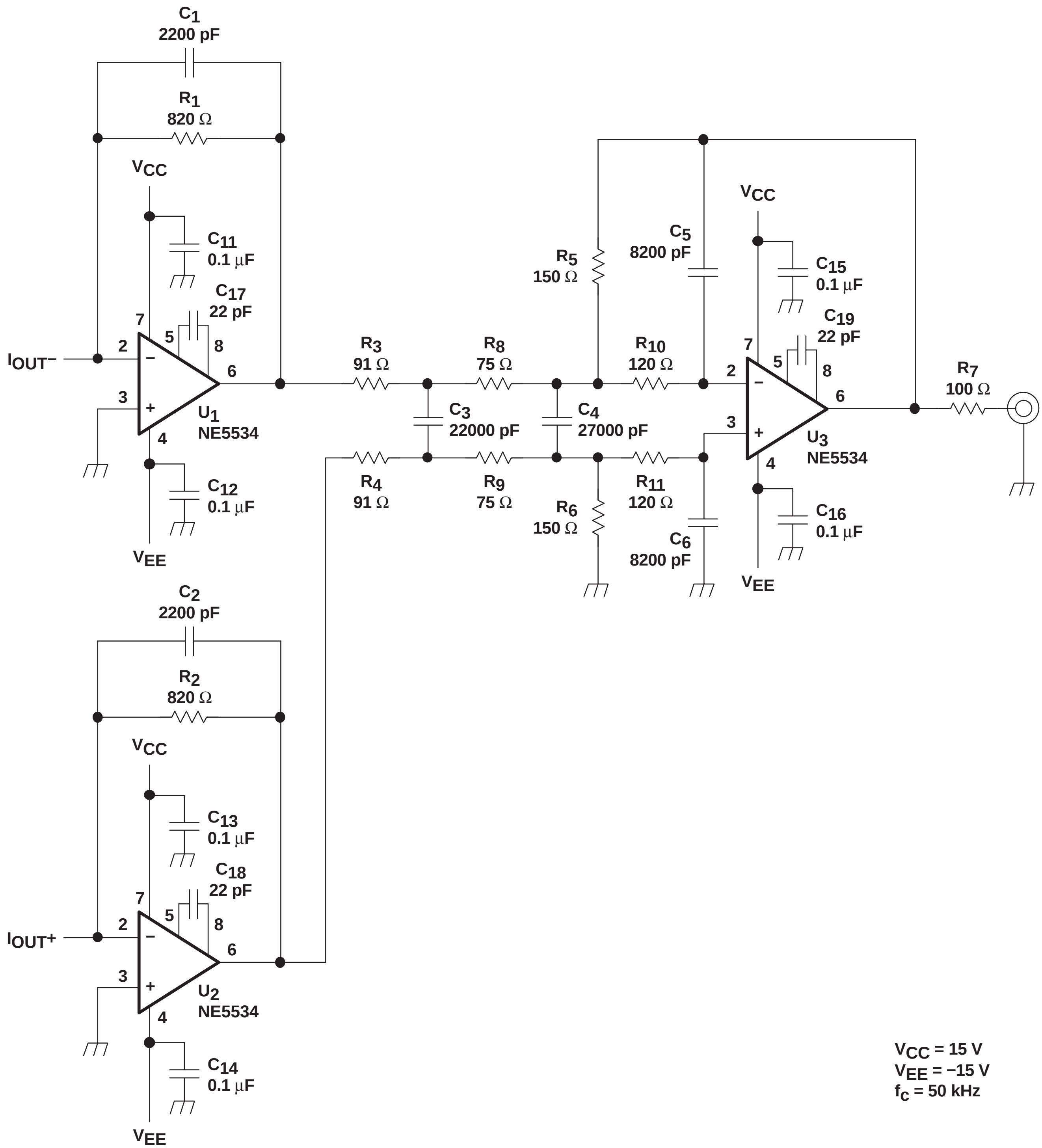


Figure 37. Measurement Circuit for DSD

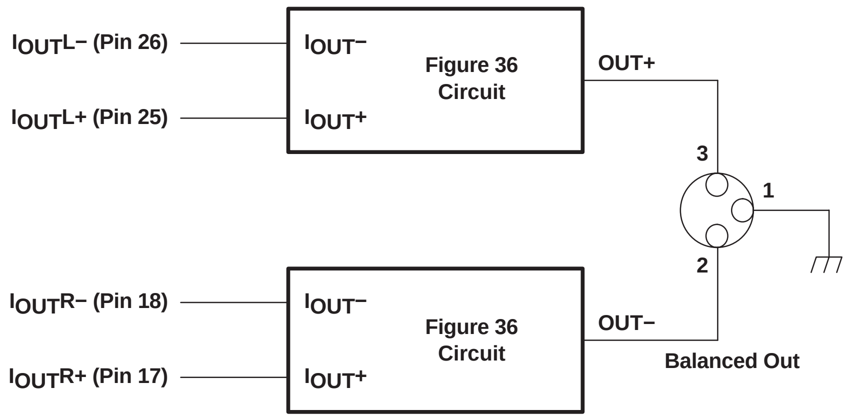


Figure 38. Measurement Circuit for Monaural Mode

APPLICATION FOR EXTERNAL DIGITAL FILTER INTERFACE

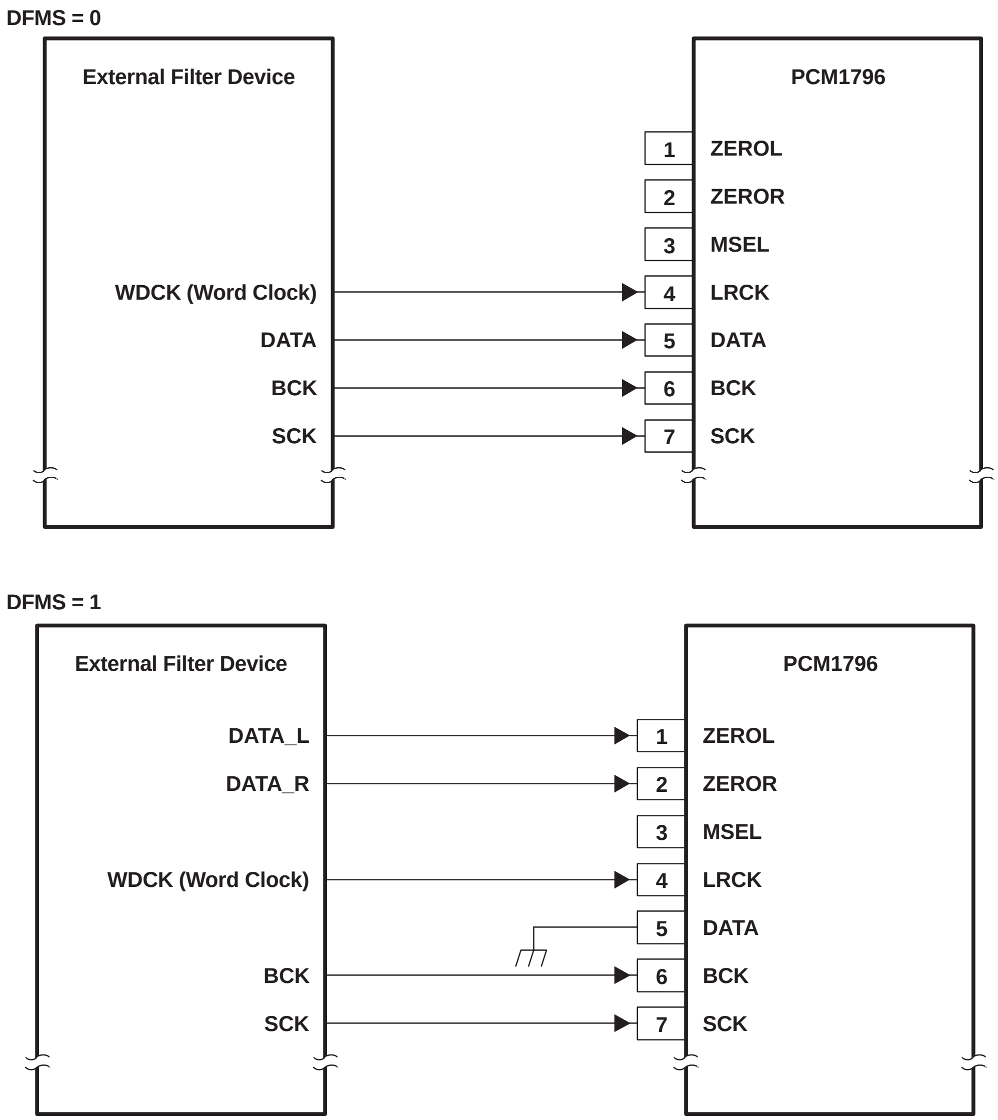


Figure 39. Connection Diagram for External DIgital Filter (Internal DF Bypass Mode) Application

Application for Interfacing With an External Digital Filter

For some applications, it may be desirable to use an external digital filter to perform the interpolation function, as it can provide improved stop-band attenuation when compared to the internal digital filter of the PCM1796.

The PCM1796 supports several external digital filters, including:

- Texas Instruments DF1704 and DF1706
- Pacific Microsonics PMD200 HDCD filter/decoder IC
- Programmable digital signal processors

The external digital filter application mode is accessed by programming the following bits in the corresponding control register:

- DFTH = 1 (register 20)

The pins used to provide the serial interface for the external digital filter are shown in the connection diagram of Figure 39. The word clock (WDCK) signal must be operated at 8× or 4× the desired sampling frequency, f_S.

Pin Assignment When Using the External Digital Filter Interface

- LRCK (pin 4): WDCK as word clock input
- BCK (pin 6): Bit clock for audio data
- DATA (pin 5): Monaural audio data input when the DFMS bit is not set to 1
- ZEROL (pin 1): DATAL as L-channel audio data input when the DFMS bit is set to 1
- ZEROR (pin 2): DATAR as R-channel audio data input when the DFMS bit is set to 1

Audio Format

The PCM1796 in the external digital filter interface mode supports right-justified audio formats including 16-bit, 20-bit, and 24-bit audio data, as shown in Figure 40. The audio format is selected by the FMT[2:0] bits of control register18.

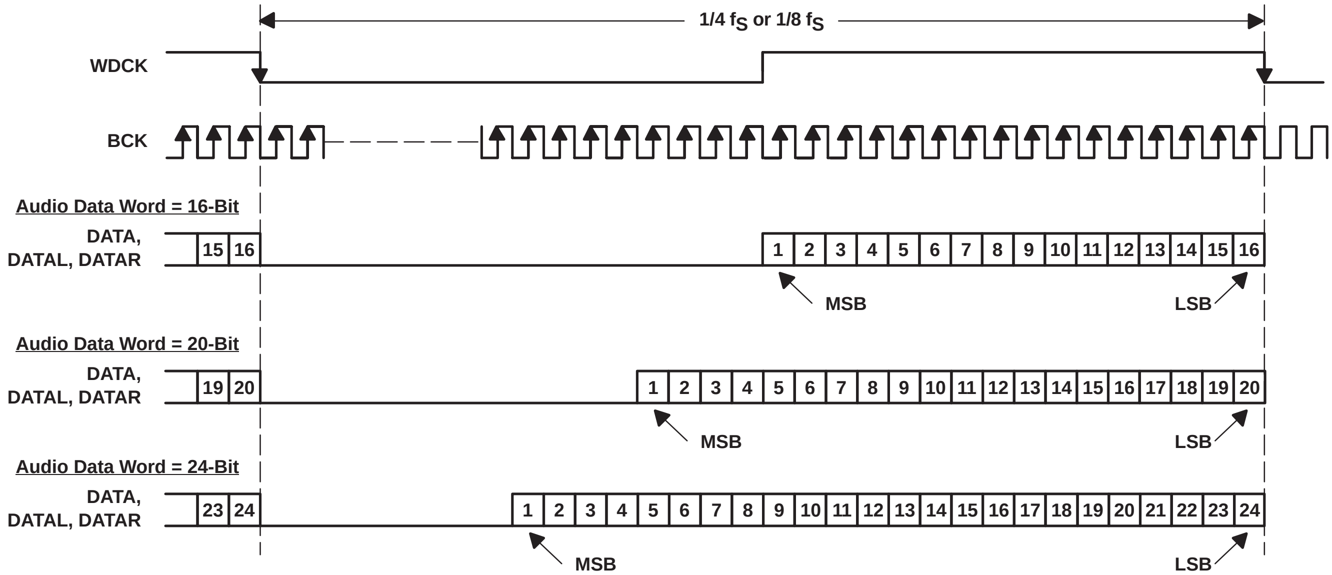
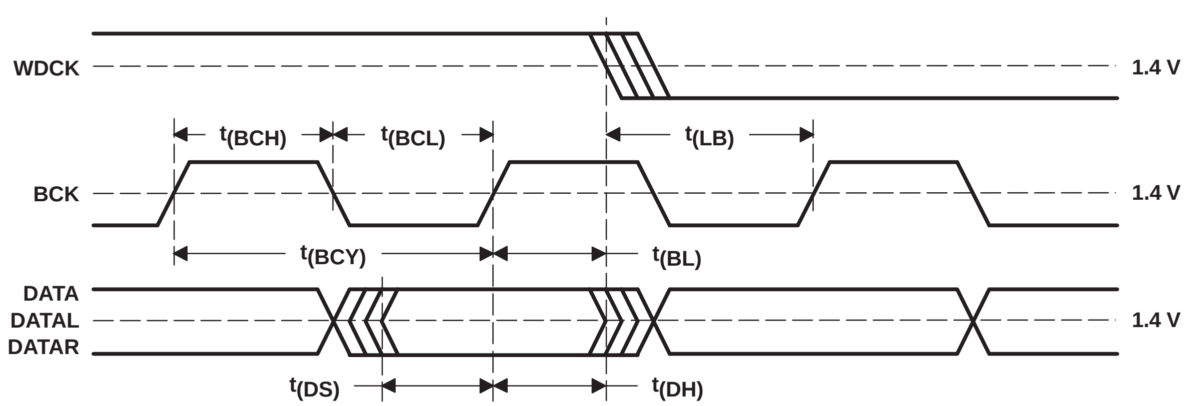


Figure 40. Audio Data Input Format for External Digital Filter (Internal DF Bypass Mode) Application

System Clock (SCK) and Interface Timing

The PCM1796 in an application using an external digital filter requires the synchronization of WDCK and the system clock. The system clock is phase-free with respect to WDCK. Interface timing among WDCK, BCK, DATA, DATAL, and DATAR is shown in Figure 41.



PARAMETER		MIN	MAX	UNITS
$t_{(BCY)}$	BCK pulse cycle time	20		ns
$t_{(BCL)}$	BCK pulse duration, LOW	7		ns
$t_{(BCH)}$	BCK pulse duration, HIGH	7		ns
$t_{(BL)}$	BCK rising edge to WDCK falling edge	5		ns
$t_{(LB)}$	WDCK falling edge to BCK rising edge	5		ns
$t_{(DS)}$	DATA, DATAL, DATAR setup time	5		ns
$t_{(DH)}$	DATA, DATAL, DATAR hold time	5		ns

Figure 41. Audio Interface Timing for External Digital Filter (Internal DF Bypass Mode) Application

FUNCTIONS AVAILABLE IN THE EXTERNAL DIGITAL FILTER MODE

The external digital filter mode is selected by setting DSD = 0 (register 20, B5) and DFTH = 1 (register 20. B4).

The external digital filter mode allows access to the majority of the PCM1796 mode control functions.

The following table shows the register mapping available when the external digital filter mode is selected, along with descriptions of functions which are modified when using this mode selection.

	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Register 16	R/$\overline{W}$	0	0	1	0	0	0	0	−	−	−	−	−	−	−	−
Register 17	R/$\overline{W}$	0	0	1	0	0	0	1	−	−	−	−	−	−	−	−
Register 18	R/$\overline{W}$	0	0	1	0	0	1	0	−	FMT2	FMT1	FMT0	−	−	−	−
Register 19	R/$\overline{W}$	0	0	1	0	0	1	1	REV	−	−	OPE	−	DFMS	−	INZD
Register 20	R/$\overline{W}$	0	0	1	0	1	0	0	−	SRST	0	1	MONO	CHSL	OS1	OS0
Register 21	R/$\overline{W}$	0	0	1	0	1	0	1	−	−	−	−	−	−	−	PCMZ
Register 22	R	0	0	1	0	1	1	0	−	−	−	−	−	−	ZFGR	ZFGL

NOTE: −: Function is disabled. No operation even if data bit is set

FMT[2:0]: Audio Data Format Selection

Default value: 000

FMT[2:0]	Audio Data Format Select
000	16-bit right-justified format (default)
001	20-bit right-justified format
010	24-bit right-justified format
Other	N/A

OS[1:0]: Delta-Sigma Modulator Oversampling Rate Selection

Default value: 00

OS[1:0]	Operation Speed Select
00	8 times WDCK (default)
01	4 times WDCK
10	16 times WDCK
11	Reserved

The effective oversampling rate is determined by the oversampling performed by both the external digital filter and the delta-sigma modulator. For example, if the external digital filter is 8× oversampling, and the user selects OS[1:0] = 00, then the delta-sigma modulator oversamples by 8×, resulting in an effective oversampling rate of 64×. The 16× WDCK oversampling rate is not available above a 100-kHz sampling rate. If the oversampling rate selected is 16× WDCK, the system clock frequency must be over 256 f_S.

APPLICATION FOR DSD FORMAT (DSD MODE) INTERFACE

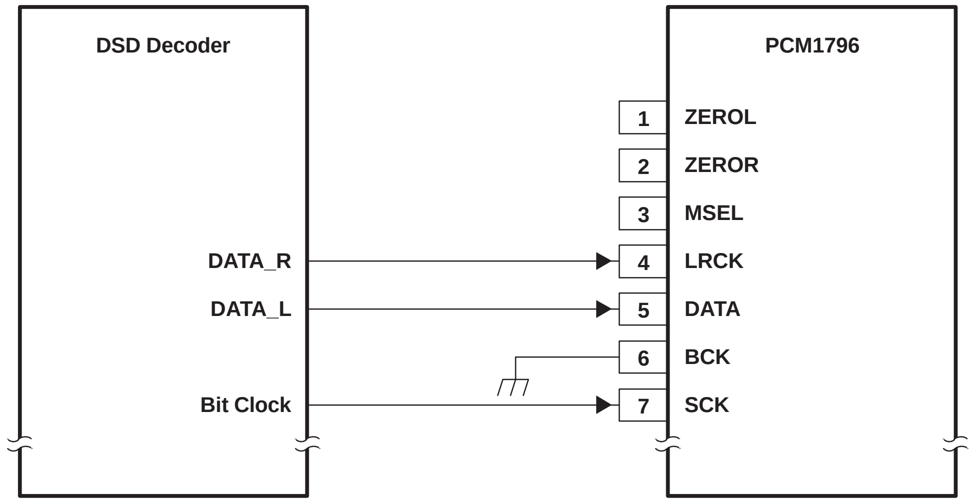


Figure 42. Connection Diagram in DSD Mode

Feature

This mode is used for interfacing directly to a DSD decoder, which is found in Super Audio CD™ (SACD) applications.

The DSD mode is accessed by programming the following bit in the corresponding control register.

DSD = 1 (register 20)

The DSD mode provides a low-pass filtering function. The filtering is provided using an analog FIR filter structure. Four FIR responses are available, and are selected by the DMF[1:0] bits of control register 18.

The DSD bit must be set before inputting DSD data; otherwise, the PCM1796 erroneously detects the TDMCA mode, and commands are not accepted through the serial control interface.

Pin Assignment When Using DSD Format Interface

Several pins are redefined for DSD mode operation. These include:

- DATA (pin 5): DSDL as L-channel DSD data input
- LRCK (pin 4): DSDR as R-channel DSD data input
- SCK (pin 7): DBCK as bit clock for DSD data
- BCK (pin 6): Set LOW (N/A)

Super Audio CD is a trademark of Sony Kabushiki Kaisha TA Sony Corporation, Japan.

Requirements for System Clock

For operation in the DSD mode, the bit clock (DBCK) is required on pin 7 of the PCM1796. The frequency of the bit clock can be N times the sampling frequency. Generally, N is 64 in DSD applications.

The interface timing between the bit clock and DSDL and DSDR is required to meet the setup and hold time specifications shown in Figure 44.

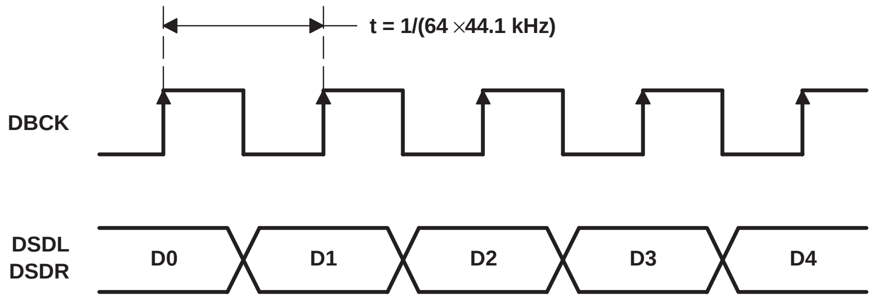
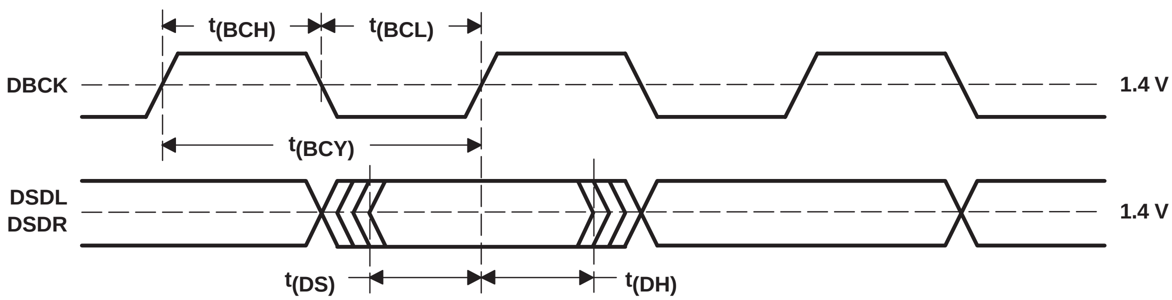


Figure 43. Normal Data Output Form From DSD Decoder



PARAMETER		MIN	MAX	UNITS
$t_{(BCY)}$	DBCK pulse cycle time	85(1)		ns
$t_{(BCH)}$	DBCK high-level time	30		ns
$t_{(BCL)}$	DBCK low-level time	30		ns
$t_{(DS)}$	DSDL, DSDR setup time	10		ns
$t_{(DH)}$	DSDL, DSDR hold time	10		ns

(1) 2.8224 MHz × 4. (2.8224 MHz = 64 × 44.1 kHz. This value is specified as a sampling rate of DSD.)

Figure 44. Timing for DSD Audio Interface

ANALOG FIR FILTER PERFORMANCE IN DSD MODE

GAIN
vs
FREQUENCY

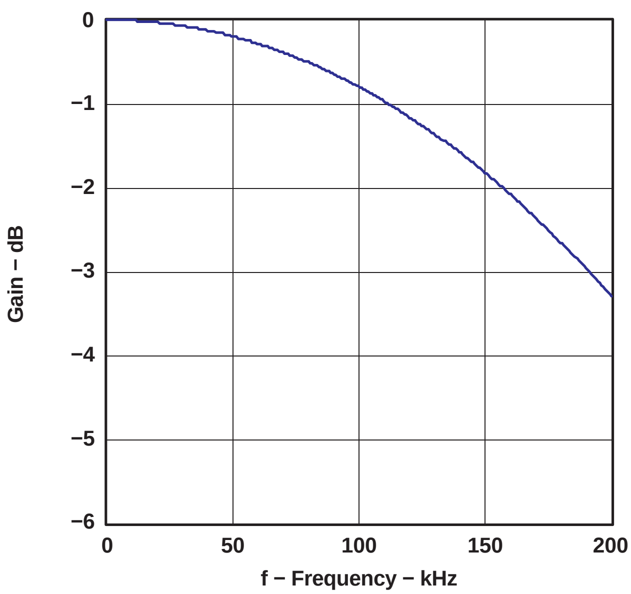


Figure 45. DSD Filter-1, Low BW

GAIN
vs
FREQUENCY

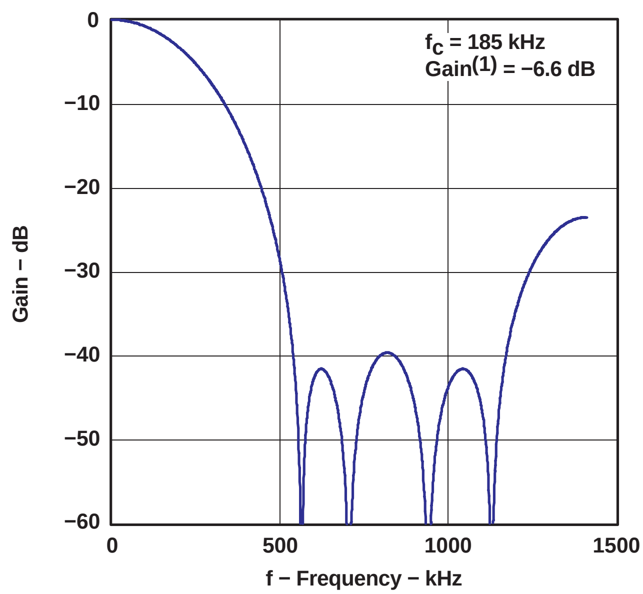


Figure 46. DSD Filter-1, High BW

GAIN
vs
FREQUENCY

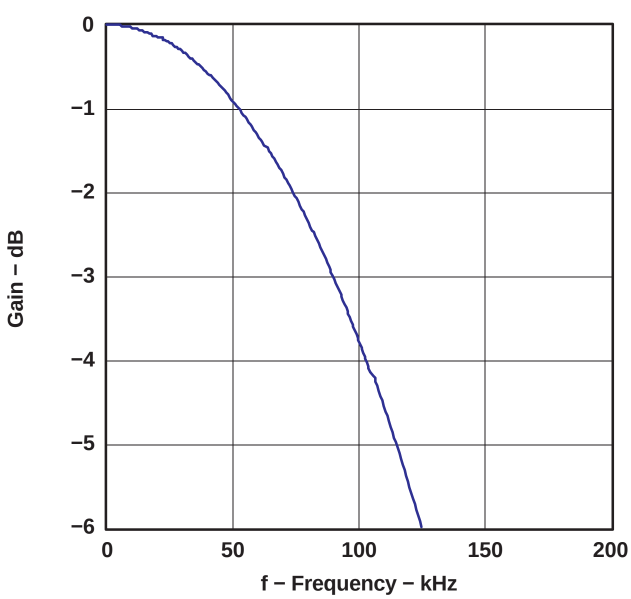


Figure 47. DSD Filter-2, Low BW

GAIN
vs
FREQUENCY

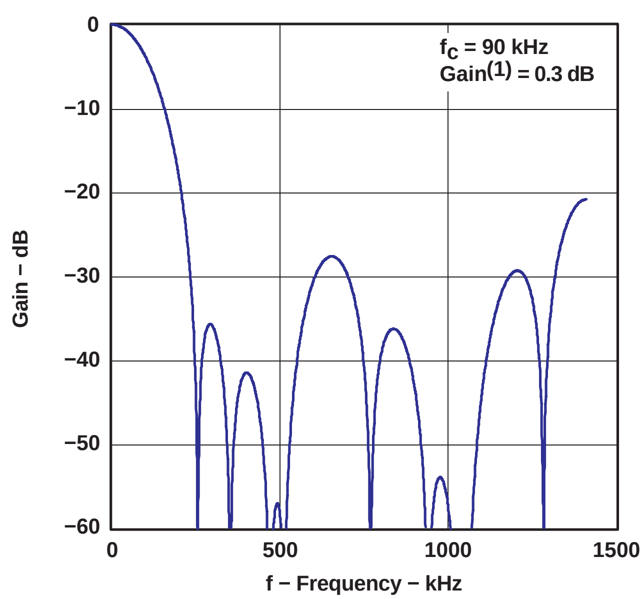


Figure 48. DSD Filter-2, High BW

(1) This gain is in comparison to PCM 0 dB, when the DSD input signal efficiency is 50%.

ANALOG FIR FILTER PERFORMANCE IN DSD MODE (CONTINUED)

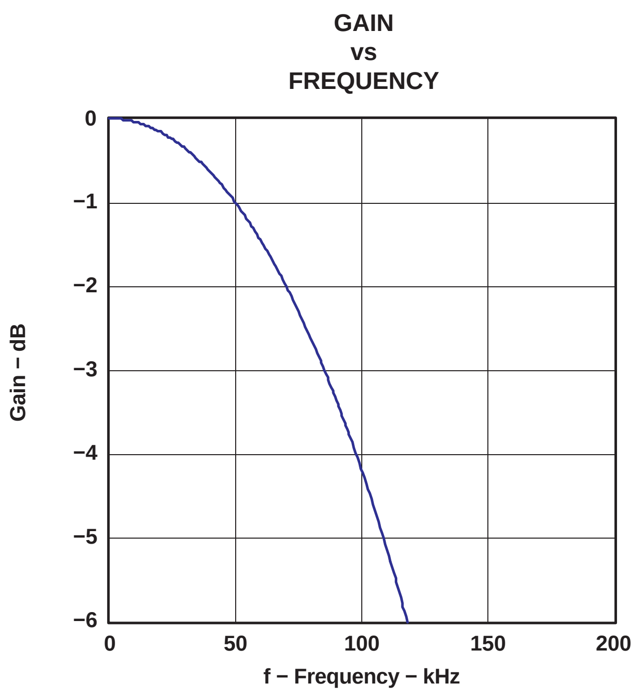


Figure 49. DSD Filter-3, Low BW

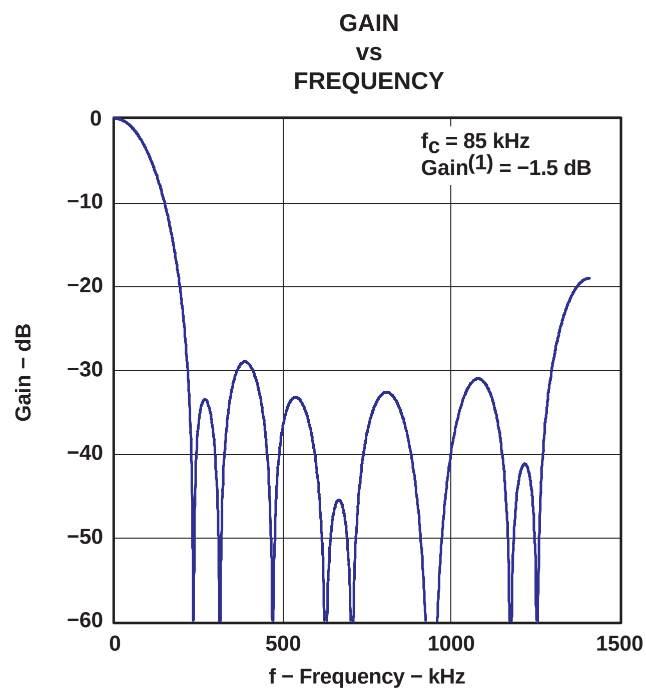


Figure 50. DSD Filter-3, High BW

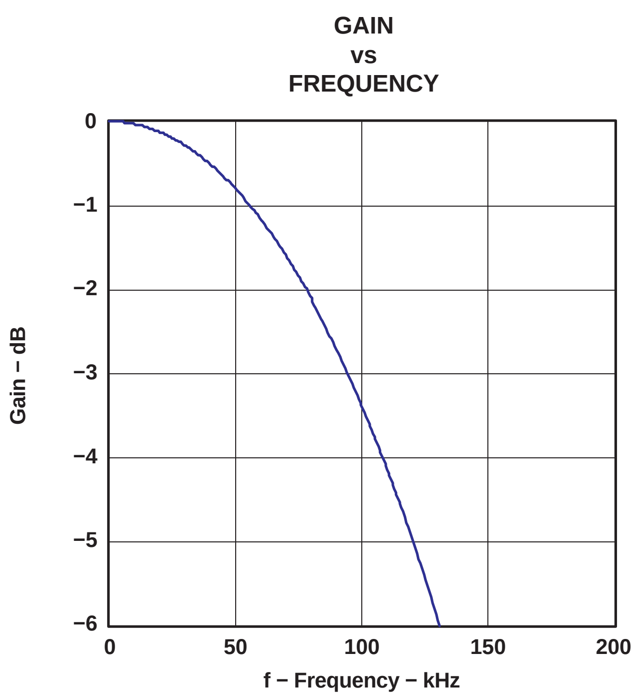


Figure 51. DSD Filter-4, Low BW

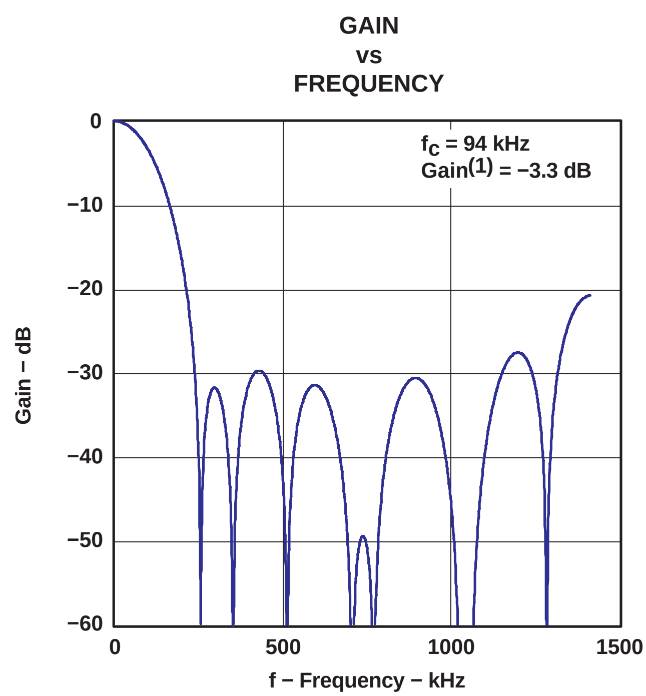


Figure 52. DSD Filter-4, High BW

(1) This gain is in comparison to PCM 0 dB, when the DSD input signal efficiency is 50%.

All specifications at DBCK = 2.8224 MHz (44.1 kHz × 64 f_S), and 50% modulation DSD data input, unless otherwise noted.

DSD MODE CONFIGURATION AND FUNCTION CONTROLS

Configuration for the DSD Interface Mode

The DSD interface mode is selected by setting DSD = 1 (register 20, B5).

	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Register 16	R/$\overline{W}$	0	0	1	0	0	0	0	−	−	−	−	−	−	−	−
Register 17	R/$\overline{W}$	0	0	1	0	0	0	1	−	−	−	−	−	−	−	−
Register 18	R/$\overline{W}$	0	0	1	0	0	1	0	−	−	−	−	DMF1	DMF0	−	−
Register 19	R/$\overline{W}$	0	0	1	0	0	1	1	REV	−	−	OPE	−	−	−	−
Register 20	R/$\overline{W}$	0	0	1	0	1	0	0	−	SRST	1	−	MONO	CHSL	OS1	OS0
Register 21	R	0	0	1	0	1	0	1	−	−	−	−	−	DZ1	DZ0	−
Register 22	R	0	0	1	0	1	1	0	−	−	−	−	−	−	ZFGR	ZFGL

NOTE: −: Function is disabled. No operation even if data bit is set

DMF[1:0]: Analog-FIR Performance Selection

Default value: 00

DMF[1:0]	Analog-FIR Performance Select
00	FIR-1 (default)
01	FIR-2
10	FIR-3
11	FIR-4

Plots for the four analog FIR filter responses are shown in the *ANALOG FIR FILTER PERFORMANCE IN DSD MODE* section of this data sheet.

OS[1:0]: Analog-FIR Operation-Speed Selection

Default value: 00

OS[1:0]	Operation-Speed Select
00	f_{DBCK} (default)
01	f_{DBCK} /2
10	Reserved
11	f_{DBCK}/4

The OS bit in the DSD mode is used to select the operating rate of the analog FIR. The OS bits must be set before setting the DSD bit to1.

TDMCA INTERFACE FORMAT

The PCM1796 supports the time-division-multiplexed command and audio (TDMCA) data format to simplify the host control serial interface. The TDMCA format is designed not only for the McBSP of TI DSPs but also for any programmable devices. The TDMCA format can transfer not only audio data but also command data, so that it can be used together with any kind of device that supports the TDMCA format. The TDMCA frame consists of a command field, extended command field, and some audio data fields. Those audio data are transported to IN devices (such as a DAC) and/or from OUT devices (such as an ADC). The PCM1796 is an IN device. LRCK and BCK are used with both IN and OUT devices so that the sample frequency of all devices in a system must be the same. The TDMCA mode supports a maximum of 30 device IDs. The maximum number of audio channels depends on the BCK frequency.

TDMCA Mode Determination

The PCM1796 recognizes the TDMCA mode automatically when it receives an LRCK signal with a pulse duration of two BCK clocks. If the TDMCA mode operation is not needed, the duty cycle of LRCK must be 50%. Figure 53 shows the LRCK and BCK timing that determines the TDMCA mode. The PCM1796 enters the TDMCA mode after two continuous TDMCA frames. Any TDMCA commands can be issued during the next TDMCA frame after the TDMCA mode is entered.

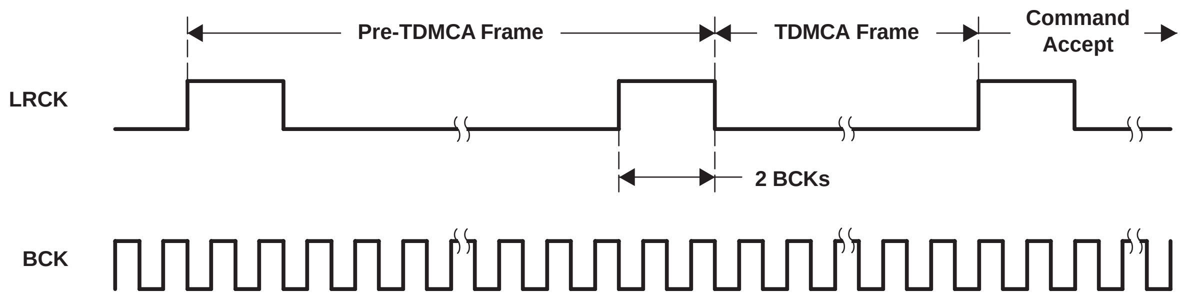


Figure 53. LRCK and BCK Timing for Determination of TDMCA Mode

TDMCA Terminals

TDMCA requires six signals, of which four signals are for command and audio data interface, and one pair for daisy chaining. Those signals can be shared as in the following table. The DO signal has a 3-state output so that it can be connected directly to other devices.

TERMINAL NAME	TDMCA NAME	PROPERTY	DESCRIPTION
LRCK	LRCK	input	TDMCA frame start signal. It must be the same as the sampling frequency.
BCK	BCK	input	TDMCA clock. Its frequency must be high enough to communicate a TDMCA frame within an LRCK cycle.
DATA	DI	input	TDMCA command and audio data input signal
MDO	DO	output	TDMCA command data 3-state output signal
MC	DCI	input	TDMCA daisy-chain input signal
$\overline{MS}$	DCO	output	TDMCA daisy-chain output signal

Device ID Determination

The TDMCA mode also supports a multichip implementation in one system. This means a host controller (DSP) can simultaneously support several TDMCA devices, which can be of the same type or different types, including PCM devices. The PCM devices are categorized as IN device, OUT device, IN/OUT device, and NO device. The IN device has an input port to receive audio data, the OUT device has an output port to supply audio data, the IN/OUT device has both input and output ports for audio data, and the NO device has no port for audio data but needs command data from the host. A DAC is an IN device, an ADC is an OUT device, a codec is an IN/OUT device, and a PLL is a NO device. The PCM1796 is an IN device. For the host controller to distinguish the devices, each device is assigned its own device ID by the daisy chain. The devices obtain their own device IDs automatically by connecting their DCI to the DCO of the preceding device and their DCO to the DCI of the following device in the daisy chain. The daisy chains are categorized as the IN chain and the OUT chain, which are completely independent and equivalent. Figure 54 shows an example daisy chain connection. If a system needs to chain the PCM1796 and a NO device in the same IN or OUT chain, the NO device must be chained at the back end of the chain because it does not require any audio data. Figure 55 shows an example of TDMCA system including an IN chain and an OUT chain with a TI DSP. For a device to get its own device ID, the DID signal must be set to 1 (see the *Command Field* section for details), and LRCK and BCK must be driven in the TDMCA mode for all PCM devices that are chained. The device at the top of the chain knows its device ID is 1 because its DCI is fixed HIGH. Other devices count the BCK pulses and observe their own DCI signal to determine their position and ID. Figure 56 shows the initialization of each device ID.

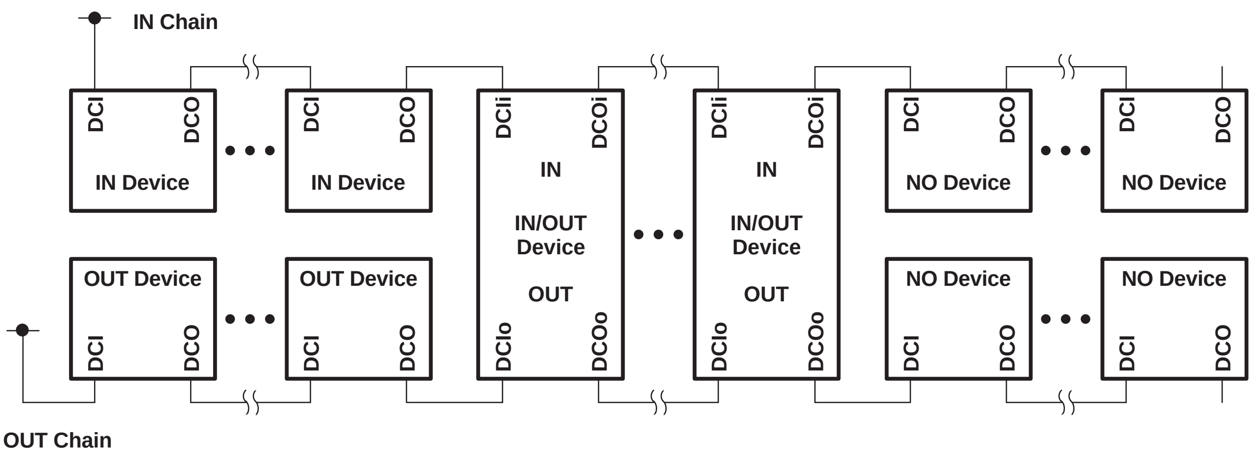


Figure 54. Daisy Chain Connection

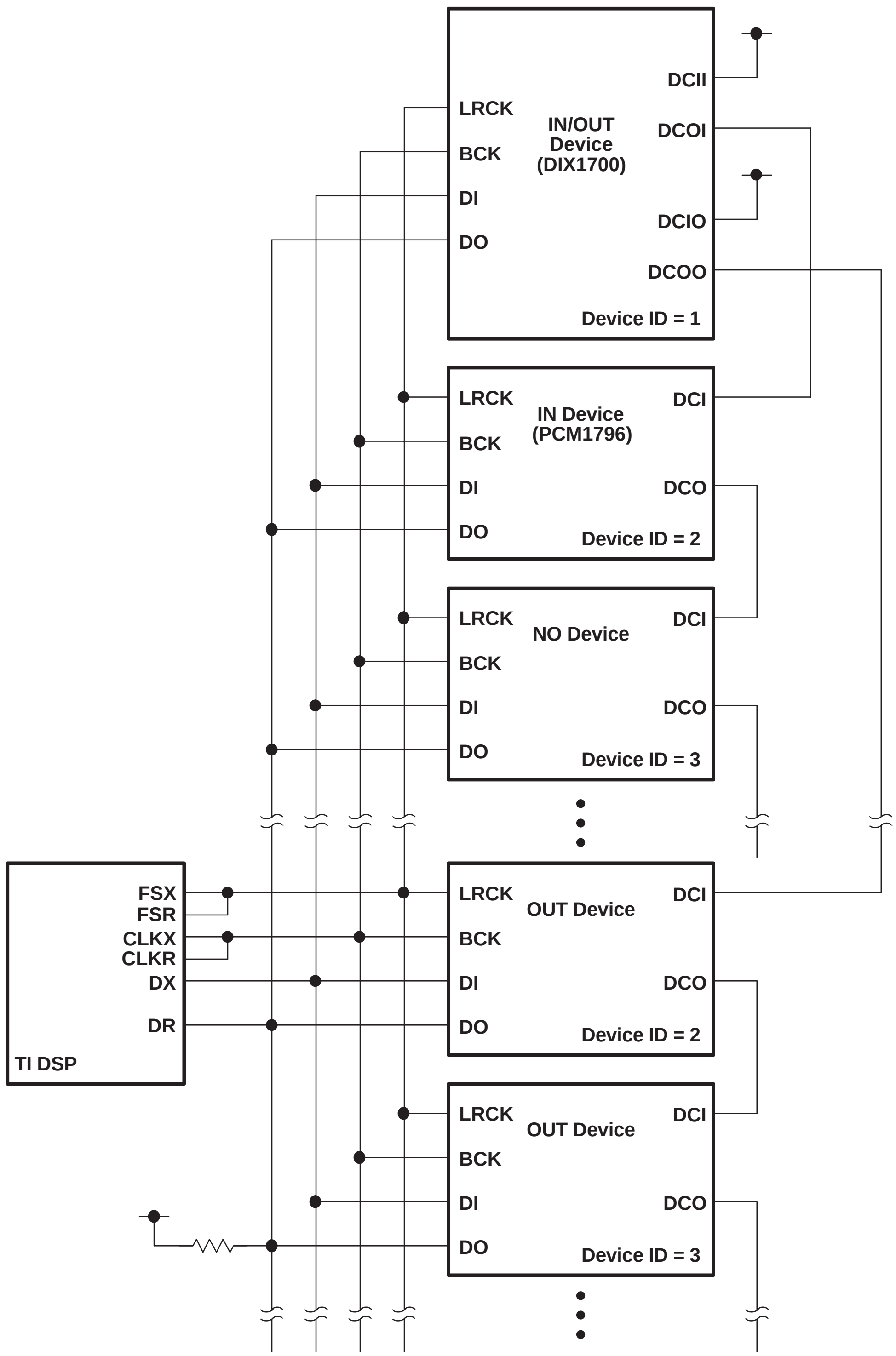


Figure 55. IN Daisy Chain and OUT Daisy Chain Connection for a Multichip System

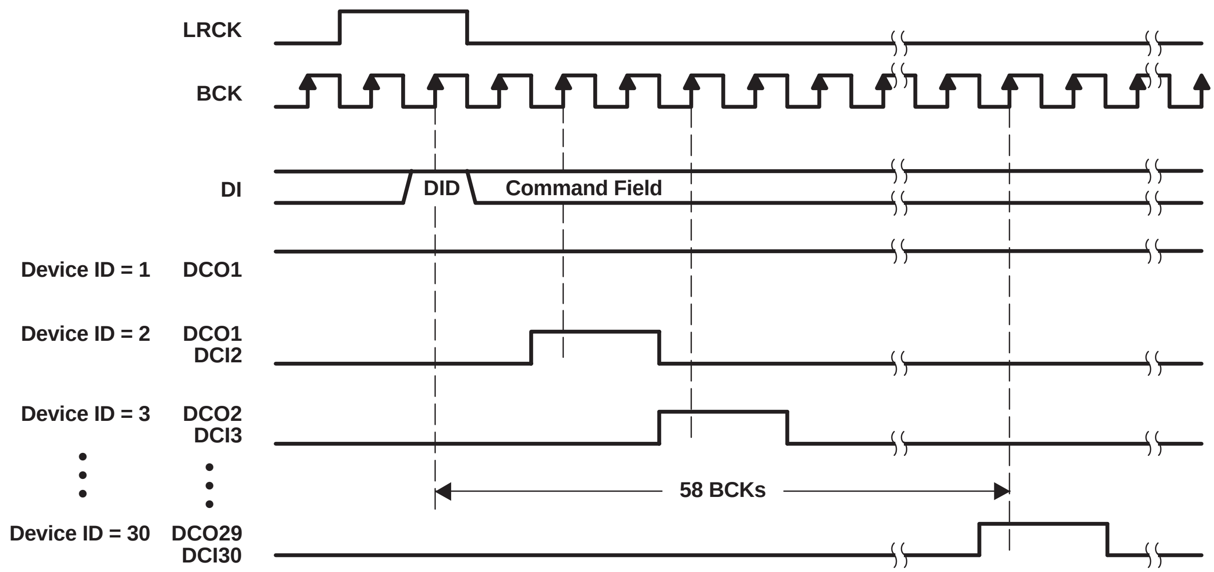


Figure 56. Device ID Determination Sequence

TDMCA Frame

In general, the TDMCA frame consists of the command field, extended command (EMD) field, and audio data fields. All of them are 32 bits in length, but the lowest byte has no meaning. The MSB is transferred first for each field. The command field is always transferred as the first packet of the frame. The EMD field is transferred if the EMD flag of the command field is HIGH. If any EMD packets are transferred, no audio data follows the EMD packets. This frame is for quick system initialization. All devices of a daisy chain should respond to the command field and extended command field. The PCM1796 has two audio channels that can be selected by OPE (register 19). If the OPE bit is not set to HIGH, those audio channels are transferred. Figure 57 shows the general TDMCA frame. If some DACs are enabled, but corresponding audio data packets are not transferred, the analog outputs are unpredictable.

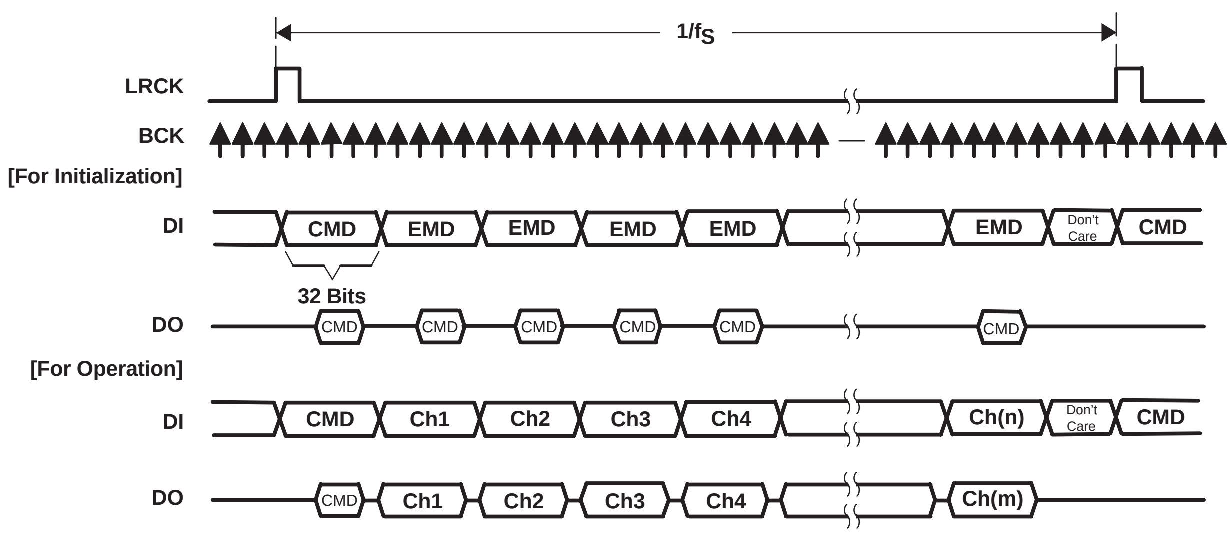


Figure 57. General TDMCA Frame

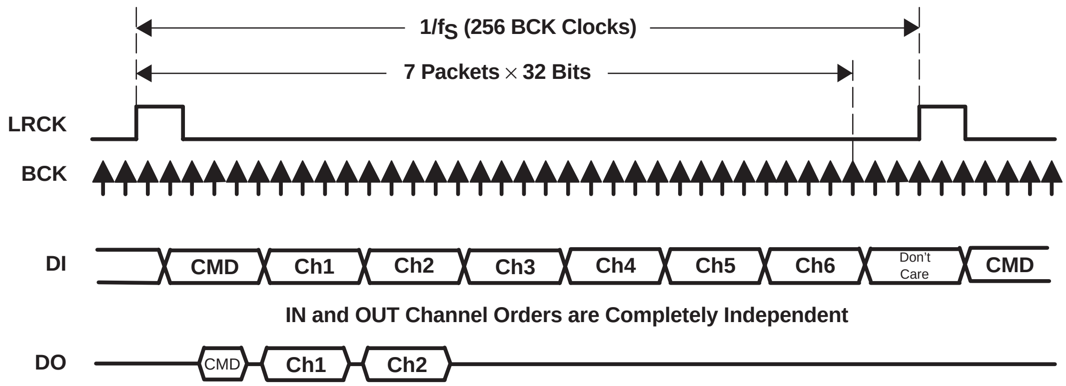


Figure 58. TDMCA Frame Example of 6-Ch DAC and 2-Ch ADC With Command Read

Command Field

The normal command field is defined as follows. When the DID bit (MSB) is 1, this frame is used only for device ID determination, and all remaining bits in the field are ignored.

	31	30	29	28 – 24	23	22 – 16	15 – 8	7 – 0
command	DID	EMD	DCS	device ID	R/$\overline{W}$	register ID	data	not used

Bit 31: Device ID enable flag

The PCM1796 operates to get its own device ID for TDMCA initialization if this bit is HIGH.

Bit 30: Extended command enable flag

The EMD packet is transferred if this bit is HIGH, otherwise skipped. Once this bit is HIGH, this frame does not contain any audio data. This is for system initialization.

Bit 29: Daisy chain selection flag

HIGH designates OUT-chain devices, LOW designates IN-chain devices. The PCM1796 is an IN device, so the DCS bit must be set to LOW.

Bits[28:24]: Device ID

The device ID is 5 bits length, and it can be defined. These bits identify the order of a device in the IN or OUT daisy chain. The top of the daisy chain defines device ID 1 and successive devices are numbered 2, 3, 4, etc. All devices for which the DCI is fixed HIGH are also defined as ID 1. The maximum device ID is 30 each in the IN and OUT chains. If a device ID of 0x1F is used, all devices are selected as broadcast when in the write mode. If a device ID of 0x00 is used, no device is selected.

Bit 23: Command Read/Write flag

If this bit is HIGH, the command is a read operation.

Bits[22:16]: Register ID

It is 7 bits in length.

Bits[15:8]: Command data

It is 8 bits in length. Any valid data can be chosen for each register.

Bits[7:0]: Not used

These bits are never transported when a read operation is performed.

Extended command field

The extended command field is the same as the command field, except that it does not have a DID flag.

	31	30	29	28 – 24	23	22 – 16	15 – 8	7 – 0
extended command	rsvd	EMD	DCS	device ID	R/$\overline{W}$	register ID	data	not used

Audio Fields

The audio field is 32 bits in length and the audio data is transferred MSB first, so the other fields must be stuffed with 0s as shown in the following example.

	31	16	12	8	7	4 3	0
audio data	MSB	24 bits		LSB	All 0s		

TDMCA Register Requirements

TDMCA mode requires device ID and audio channel information, previously described. The OPE bit in register 19 indicates audio channel availability and register 23 indicates the device ID. Register 23 is used only in the TDMCA mode. See the mode control register map (Table 4).

Register Write/Read Operation

The command supports register write and read operations. If the command requests to read one register, the read data is transferred on DO during the data phase of the timing cycle. The DI signal can be retrieved at the positive edge of BCK, and the DO signal is driven at the negative edge of BCK. DO is activated one BCK cycle early to compensate for the output delay caused by high impedance. Figure 59 shows the TDMCA write and read timing.

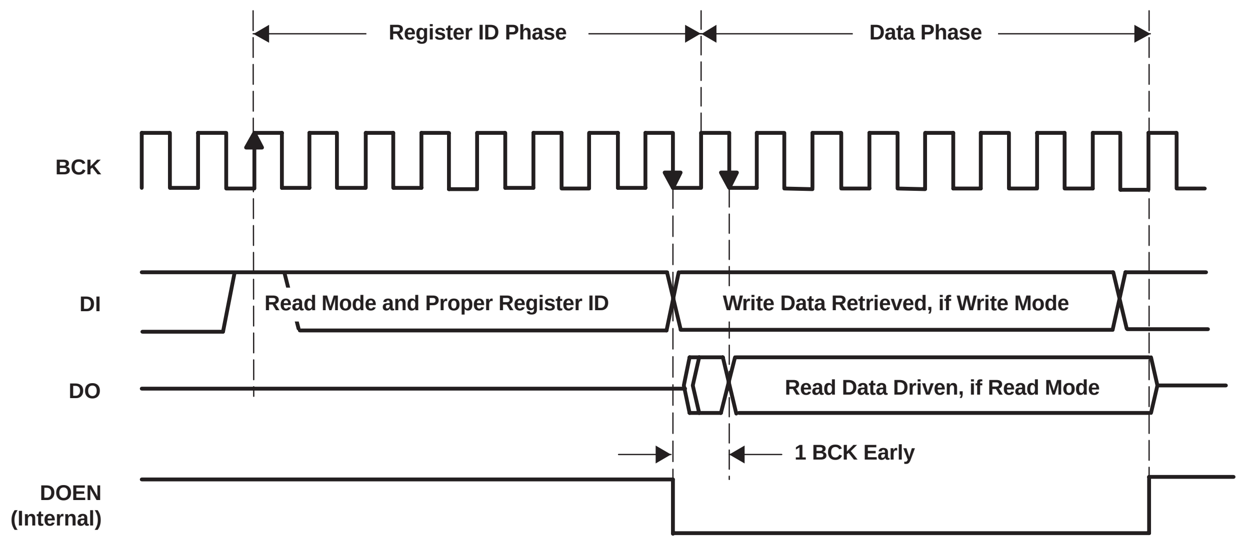


Figure 59. TDMCA Write and Read Operation Timing

TDMCA-Mode Operation

DCO specifies the owner of the next audio channel in TDMCA-mode operation. When a device retrieves its own audio channel data, DCO goes HIGH during the last audio channel period. Figure 60 shows the DCO output timing in TDMCA-mode operation. The host controller ignores the behavior of DCI and DCO. DCO indicates the last audio channel of each device. Therefore, DCI means the next audio channel is allocated.

If some devices are skipped due to no active audio channel, the skipped devices must notify the next device that the DCO will be passed through the next DCI. Figure 61 and Figure 62 show DCO timing with skip operation. Figure 63 shows the ac timing of the daisy chain signals.

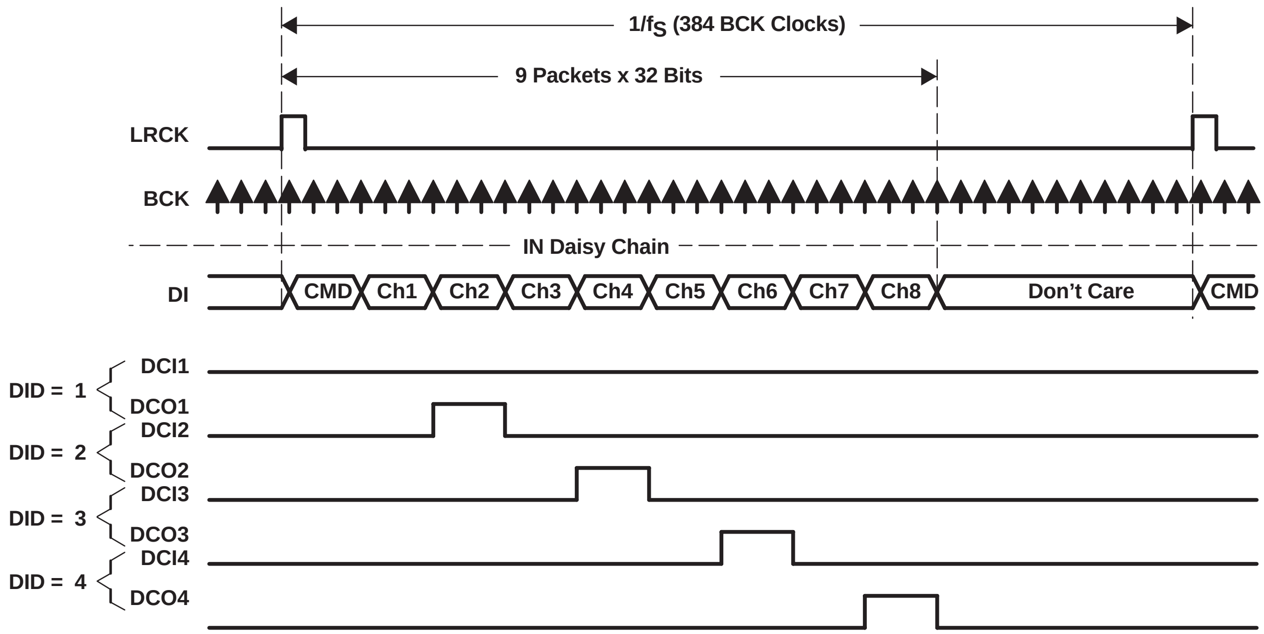


Figure 60. DCO Output Timing of TDMCA Mode Operation

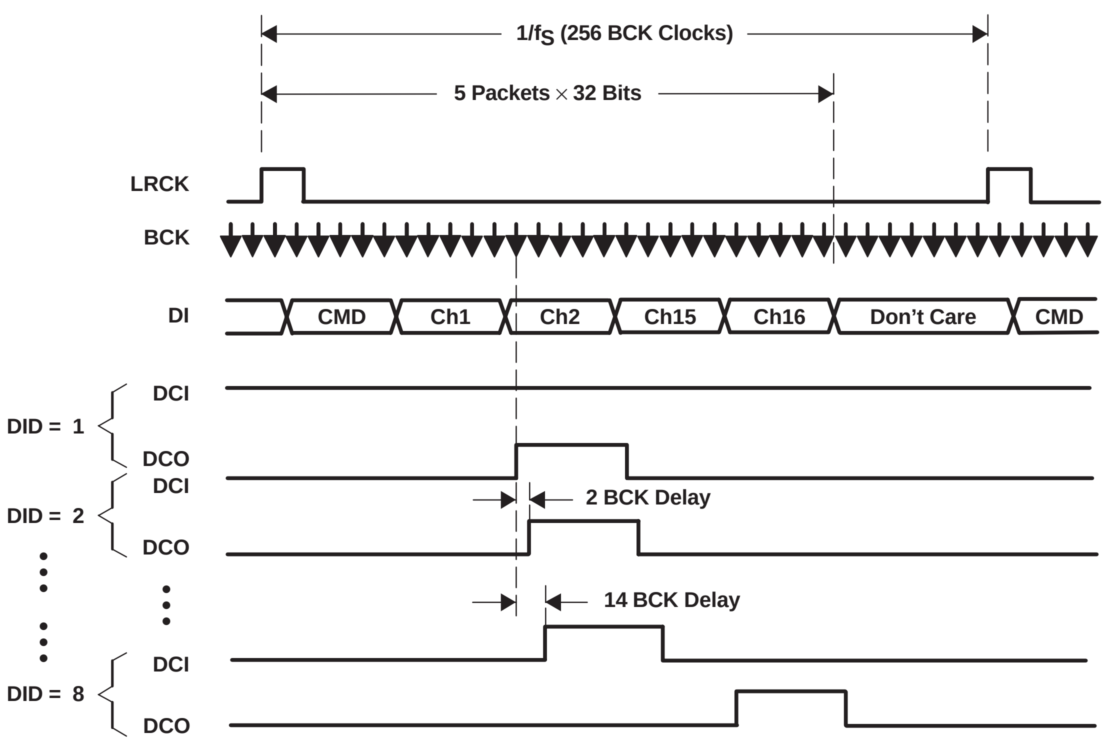


Figure 61. DCO Output Timing With Skip Operation

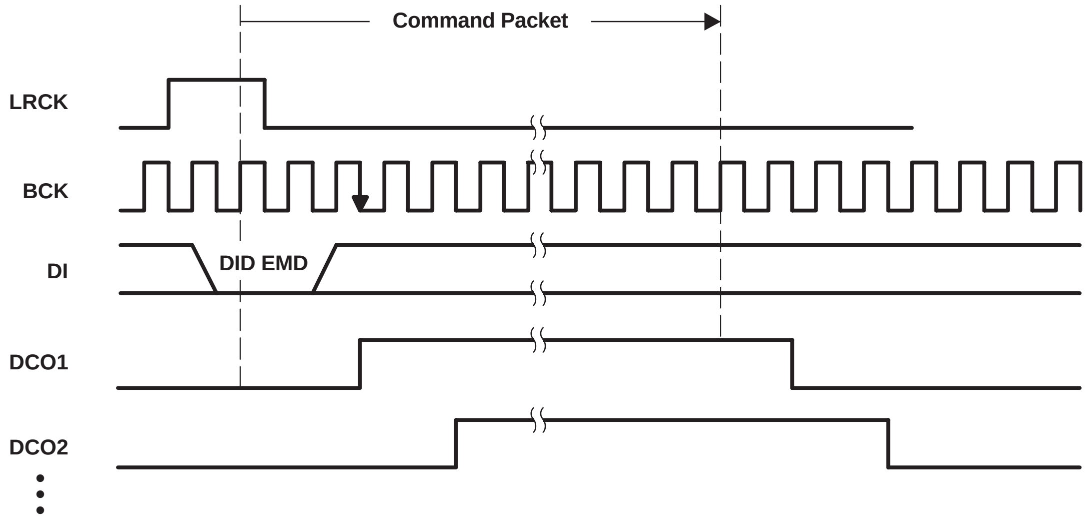
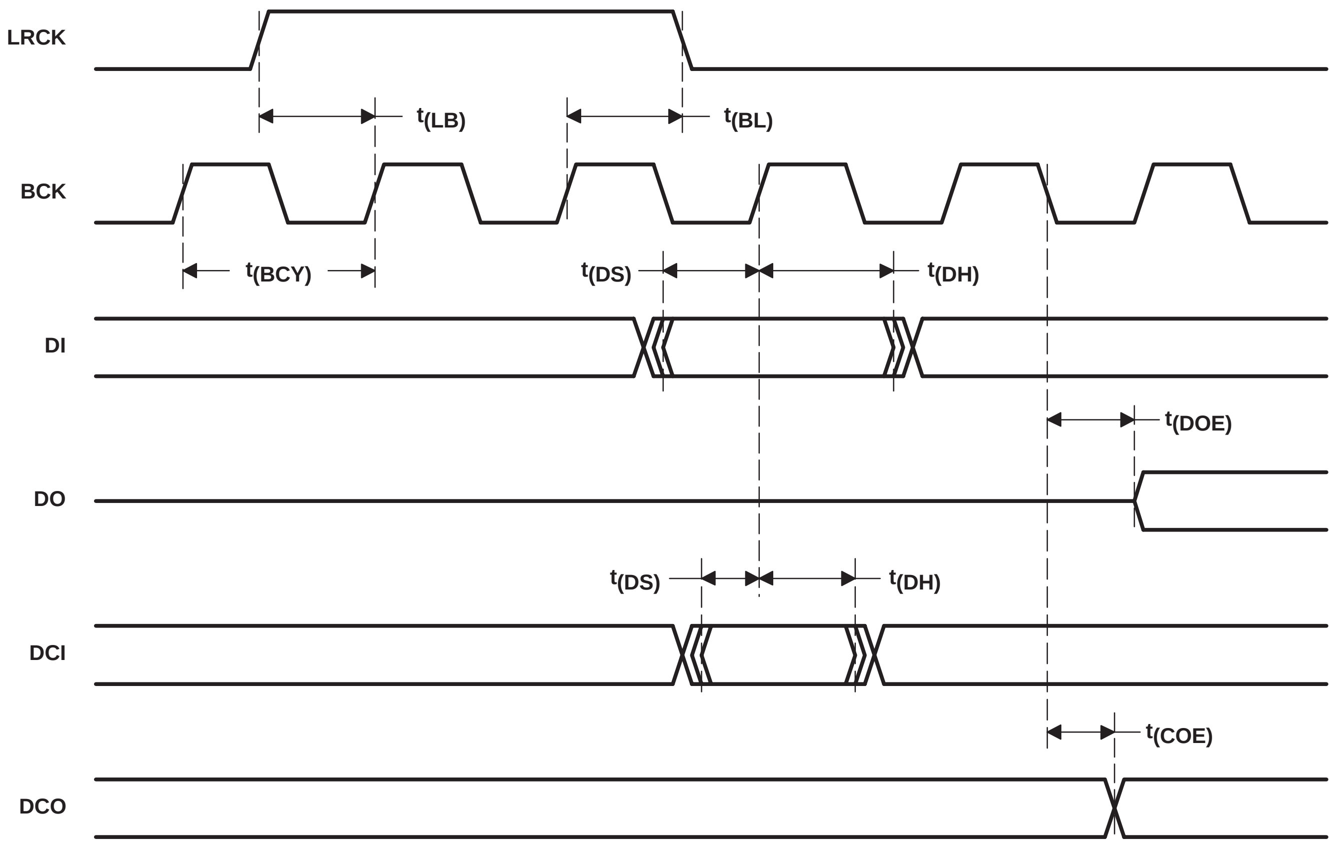


Figure 62. DCO Output Timing With Skip Operation (for Command Packet 1)



PARAMETER		MIN	MAX	UNITS
$t_{(BCY)}$	BCK pulse cycle time	20		ns
$t_{(LB)}$	LRCK setup time	0		ns
$t_{(BL)}$	LRCK hold time	3		ns
$t_{(DS)}$	DI setup time	0		ns
$t_{(DH)}$	DI hold time	3		ns
$t_{(DS)}$	DCI setup time	0		ns
$t_{(DH)}$	DCI hold time	3		ns
$t_{(DOE)}$	DO output delay(1)		8	ns
$t_{(COE)}$	DCO output delay(1)		6	ns

(1) Load capacitance is 10 pF.

Figure 63. AC Timing of Daisy Chain Signals

ANALOG OUTPUT

Table 5 and Figure 64 show the relationship between the digital input code and analog output.

Table 5. Analog Output Current and Voltage

	800000 (–FS)	000000 (BPZ)	7FFFFF (+FS)
$I_{OUT}N$ [mA]	–1.5	–3.5	–5.5
$I_{OUT}P$ [mA]	–5.5	–3.5	–1.5
$V_{OUT}N$ [V]	–1.23	–2.87	–4.51
$V_{OUT}P$ [V]	–4.51	–2.87	–1.23
V_{OUT} [V]	–2.98	0	2.98

NOTE: $V_{OUT}N$ is the output of U1, $V_{OUT}P$ is the output of U2, and V_{OUT} is the output of U3 in the measurement circuit of Figure 36.

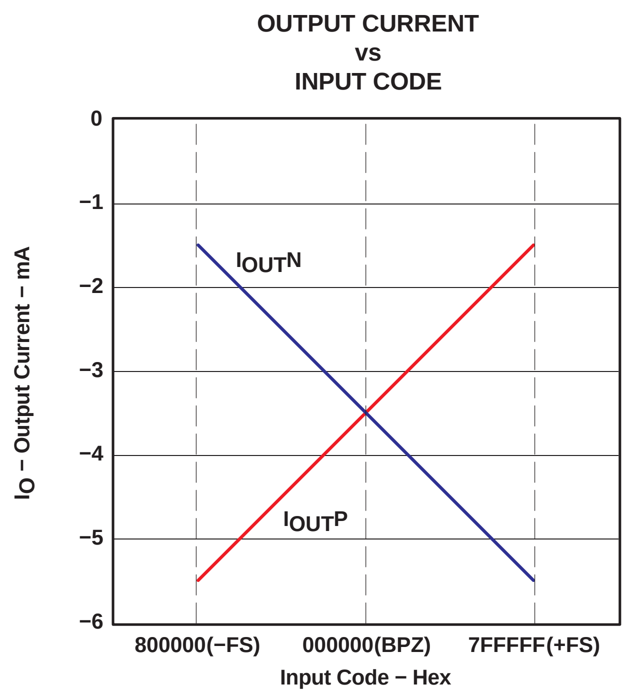
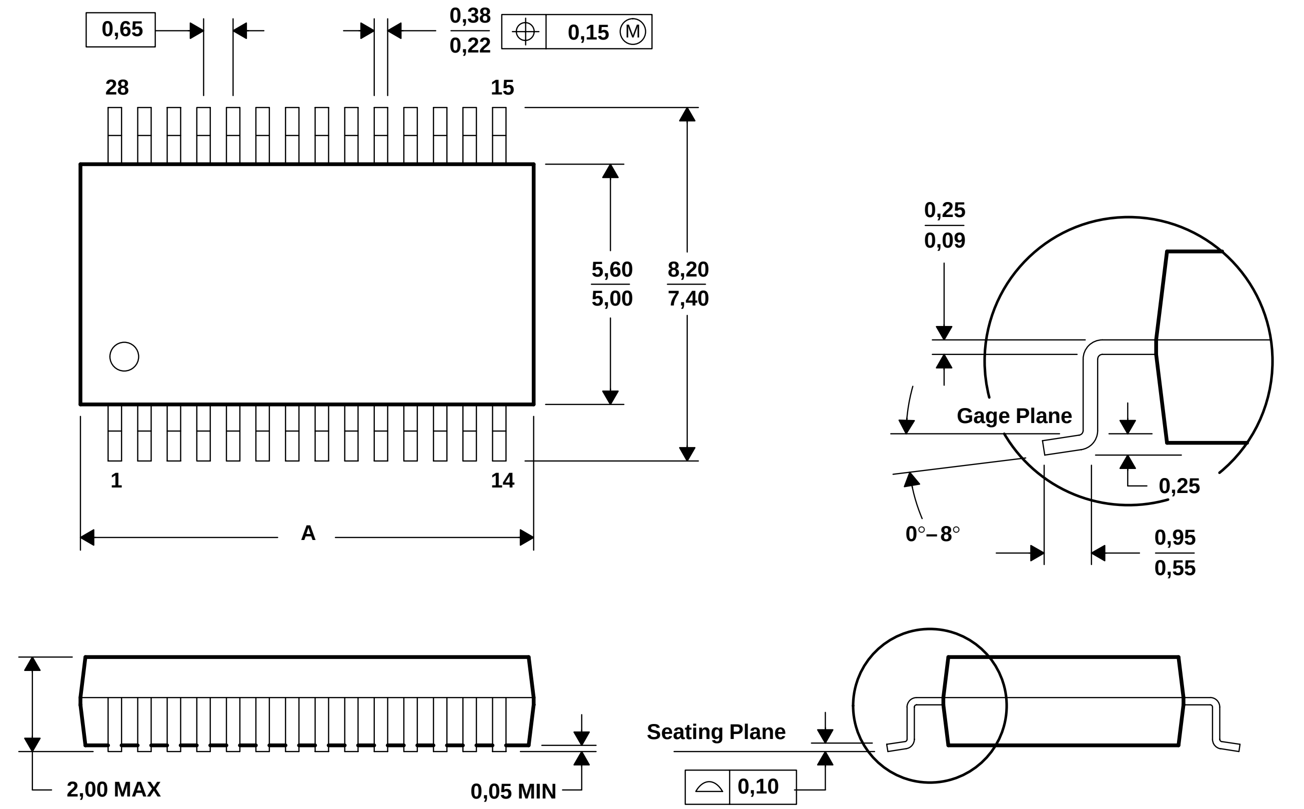


Figure 64. The Relationship Between Digital Input and Analog Output

DB (R-PDSO-G)** **PLASTIC SMALL-OUTLINE**

28 PINS SHOWN



PINS ** / DIM	14	16	20	24	28	30	38
A MAX	6,50	6,50	7,50	8,50	10,50	10,50	12,90
A MIN	5,90	5,90	6,90	7,90	9,90	9,90	12,30

4040065 /E 12/01

NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
D. Falls within JEDEC MO-150

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