



PCM1728

# SoundPLUS™ 24-Bit, 96kHz Sampling CMOS Delta-Sigma Stereo Audio DIGITAL-TO-ANALOG CONVERTER

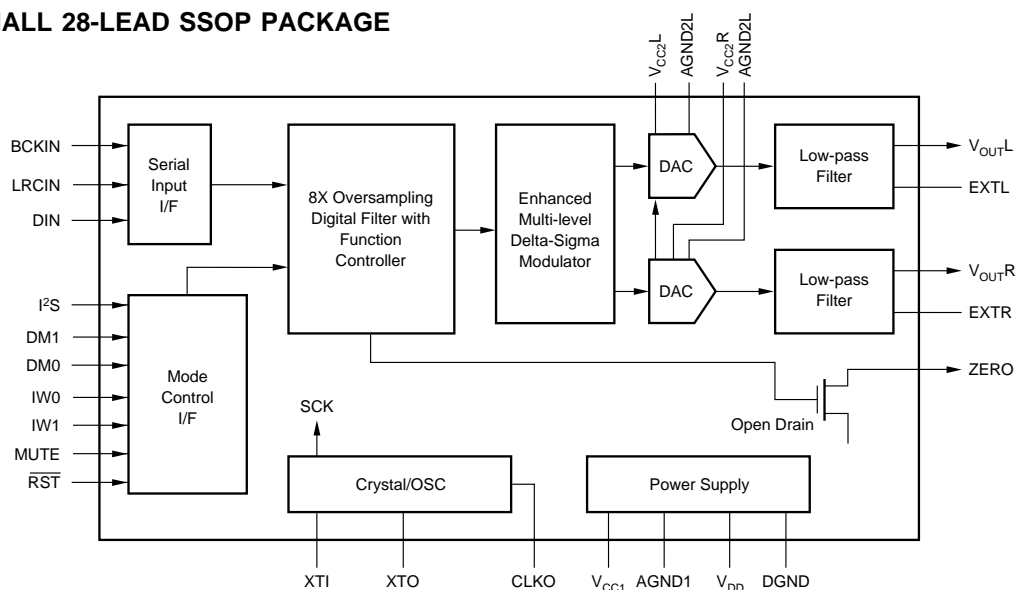
## FEATURES

- ENHANCED MULTI-LEVEL DELTA-SIGMA DAC
- SAMPLING FREQUENCY ( $f_s$ ): 16kHz - 96kHz
- INPUT AUDIO DATA WORD:  
16-, 20-, 24-Bit
- HIGH PERFORMANCE:  
THD+N: -96dB  
Dynamic Range: 106dB  
SNR: 106dB  
Analog Output Range:  $0.62 \times V_{CC}$  (Vp-p)
- 8x OVERSAMPLING DIGITAL FILTER:  
Stop Band Attenuation: -82dB  
Passband Ripple:  $\pm 0.002$ dB
- MULTI FUNCTIONS:  
Digital De-emphasis  
Soft Mute  
Zero Flag
- +5V SINGLE SUPPLY OPERATION
- SMALL 28-LEAD SSOP PACKAGE

## DESCRIPTION

The PCM1728 is designed for mid- to high-grade digital audio applications which achieve 96kHz sampling rates with 24-bit audio data. PCM1728 uses a newly developed, enhanced multi-level delta-sigma modulator architecture that improves audio dynamic performance and reduces jitter sensitivity in actual applications. The internal digital filter operates at 8X oversampling at a 96kHz sampling rate.

The PCM1728 has superior audio dynamic performance, 24-bit resolution, and 96kHz sampling, making it ideal for mid- to high-grade audio applications such as CD, DVD, and musical instruments.



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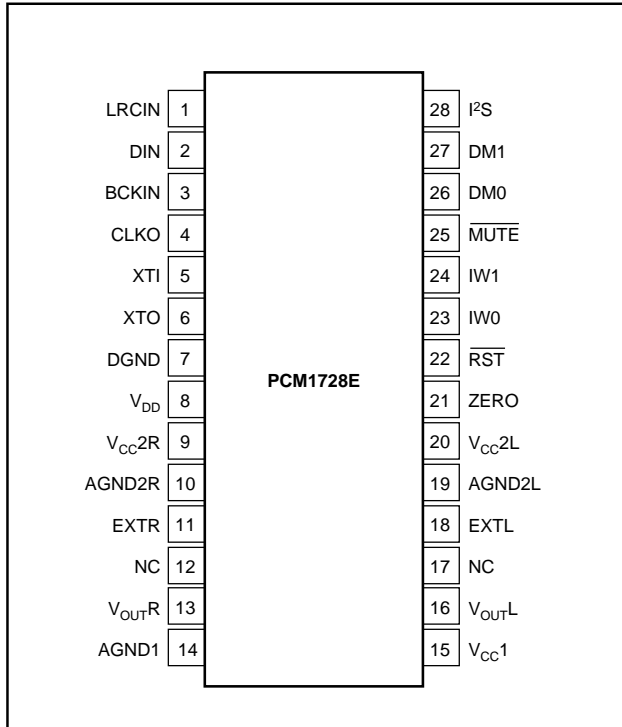
# SPECIFICATIONS

All specifications at +25°C, +V<sub>CC</sub> = +V<sub>DD</sub> = +5V, f<sub>S</sub> = 44.1kHz, and 24-bit input data, SYSCLK = 384f<sub>S</sub>, unless otherwise noted.

PARAMETER	CONDITIONS	PCM1728			UNITS
		MIN	TYP	MAX	
<b>RESOLUTION</b>		24			Bits
<b>DATA FORMAT</b> Audio Data Interface Format Data Bit Length Audio Data Format Sampling Frequency (f <sub>S</sub> ) System Clock Frequency <sup>(1)</sup>		Standard/I <sup>2</sup> S 16/20/24 Selectable MSB-First, Two's Binary Comp 16   96 256/384/512/768f <sub>S</sub>			kHz
<b>DIGITAL INPUT/OUTPUT LOGIC LEVEL</b> Input Logic Level Output Logic Level (CLKO)	$V_{IH}$ $V_{IL}$ $V_{OH}$ $V_{OL}$ $I_{OH} = 2mA$ $I_{OL} = 4mA$	2.0 4.5		0.8 0.5	V V V V
<b>CLKO PERFORMANCE<sup>(2)</sup></b> Output Rise Time Output Fall Time Output Duty Cycle	20 ~ 80% V <sub>DD</sub> , 10pF 80 ~ 20% V <sub>DD</sub> , 10pF 10pF Load		5.5 4 37		ns ns %
<b>DYNAMIC PERFORMANCE<sup>(3)</sup> (24-Bit Data)</b> THD+N Dynamic Range Signal-to-Noise Ratio Channel Separation	$V_O = 0dB$ $V_O = -60dB$ f <sub>S</sub> = 44.1kHz f <sub>S</sub> = 96kHz f <sub>S</sub> = 44.1kHz f <sub>S</sub> = 44.1kHz EIAJ A-weighted f <sub>S</sub> = 96kHz A-weighted f <sub>S</sub> = 44.1kHz EIAJ A-weighted f <sub>S</sub> = 96kHz A-weighted f <sub>S</sub> = 44.1kHz f <sub>S</sub> = 96kHz		-97 -94 -42 106 103 106 103 102 101	-90	dB dB dB dB dB dB dB dB
<b>DYNAMIC PERFORMANCE<sup>(3)</sup> (16-Bit Data)</b> THD+N Dynamic Range	$V_O = 0dB$ f <sub>S</sub> = 44.1kHz f <sub>S</sub> = 96kHz f <sub>S</sub> = 44.1kHz EIAJ A-weighted f <sub>S</sub> = 96kHz A-weighted		-94 -92 98 97		dB dB dB dB
<b>DC ACCURACY</b> Gain Error Gain Mismatch: Channel-to-Channel Bipolar Zero Error	$V_O = 0.5V_{CC}$ at Bipolar Zero		±1.0 ±1.0 ±30	±3.0 ±3.0 ±60	% of FSR % of FSR mV
<b>ANALOG OUTPUT</b> Output Voltage Center Voltage Load Impedance	Full Scale (0dB) AC Load		0.62 V <sub>CC</sub> 0.5 V <sub>CC</sub> 5		Vp-p V kΩ
<b>DIGITAL FILTER PERFORMANCE</b> Filter Characteristics Passband Stopband Passband Ripple Stopband Attenuation Delay Time De-emphasis Error	±0.002dB -3dB 0.546f <sub>S</sub> Stop Band = 0.546f <sub>S</sub> Stop Band = 0.567f <sub>S</sub>			0.454f <sub>S</sub> 0.490f <sub>S</sub> ±0.002 ±0.1	dB dB dB sec dB
<b>INTERNAL ANALOG FILTER</b> -3dB Bandwidth Passband Response	f = 20kHz		100 -0.16		kHz dB
<b>POWER SUPPLY REQUIREMENTS</b> Voltage Range Supply Current: I <sub>CC</sub> + I <sub>DD</sub> Power Dissipation	V <sub>DD</sub> , V <sub>CC</sub> f <sub>S</sub> = 44.1kHz f <sub>S</sub> = 96kHz f <sub>S</sub> = 44.1kHz f <sub>S</sub> = 96kHz	4.5	5 32 45 160 225	5.5 45 225	VDC mA mA mW mW
<b>TEMPERATURE RANGE</b> Operation Storage		-25 -55		+85 +100	°C °C

NOTES: (1) Refer section of system clock. (2) External buffer is recommended. (3) Dynamic performance specs are tested with 20kHz low pass filter and THD+N specs are tested with 30kHz LPF, 400Hz HPF, Average Mode.

## PIN CONFIGURATION



## PACKAGE INFORMATION

PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER <sup>(1)</sup>
PCM1728E	28-Pin SSOP	324

NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix C of Burr-Brown IC Data Book.

## ABSOLUTE MAXIMUM RATINGS

Power Supply Voltage	+6.5V
+V <sub>CC</sub> to +V <sub>DD</sub> Difference	±0.1V
Input Logic Voltage	-0.3V to (V <sub>DD</sub> + 0.3V)
Input Current (except power supply)	±10mA
Power Dissipation	400mW
Operating Temperature Range	-25°C to +85°C
Storage Temperature	-55°C to +125°C
Lead Temperature (soldering, 5s)	+260°C

## PIN ASSIGNMENTS

PIN	NAME	I/O	DESCRIPTION
1	LRCIN	IN	Left and Right Clock Input. This clock is equal to the sampling rate - f <sub>s</sub> . <sup>(1)</sup>
2	DIN	IN	Serial Audio Data Input <sup>(1)</sup>
3	BCKIN	IN	Bit Clock Input for Serial Audio Data. <sup>(1)</sup>
4	CLKO	OUT	Buffered Output of Oscillator. Equivalent to System Clock.
5	XTI	IN	Oscillator Input (External Clock Input)
6	XTO	OUT	Oscillator Output
7	DGND	—	Digital Ground
8	V <sub>DD</sub>	—	Digital Power +5V
9	V <sub>CC2R</sub>	—	Analog Power +5V
10	AGND2R	—	Analog Ground
11	EXTR	OUT	Rch, Common Pin of Analog Output Amp
12	NC	—	No Connection
13	V <sub>OUTR</sub>	OUT	Rch, Analog Voltage Output of Audio Signal
14	AGND1	—	Analog Ground
15	V <sub>CC1</sub>	—	Analog Power +5V
16	V <sub>OUTL</sub>	OUT	Lch, Analog Voltage Output of Audio Signal
17	NC	—	No Connection
18	EXTL	OUT	Lch, Common Pin of Analog Output Amp
19	AGND2L	—	Analog Ground
20	V <sub>CC2L</sub>	—	Analog Power +5V
21	ZERO	OUT	Zero Data Flag
22	RST	IN	Reset. When this pin is LOW, the DF and modulators are held in reset. <sup>(2)</sup>
23	IW0	IN	Input Format Selection <sup>(3)</sup>
24	IW1	IN	Input Format Selection <sup>(3)</sup>
25	MUTE	IN	Mute Control
26	DM0	IN	De-emphasis Selection 1 <sup>(2)</sup>
27	DM1	IN	De-emphasis Selection 2 <sup>(2)</sup>
28	I <sup>2</sup> S	IN	Input Format Selection <sup>(2)</sup>

NOTES: (1) Pins 1, 2, 3; Schmitt Trigger input. (2) Pins 22, 25, 26, 27, 28; Schmitt Trigger input with pull-up resistor. (3) Pins 23, 24; Schmitt Trigger input with pull-down resistor.



## ELECTROSTATIC DISCHARGE SENSITIVITY

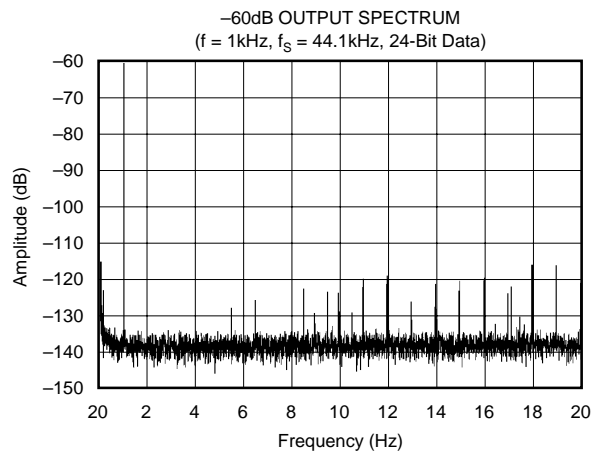
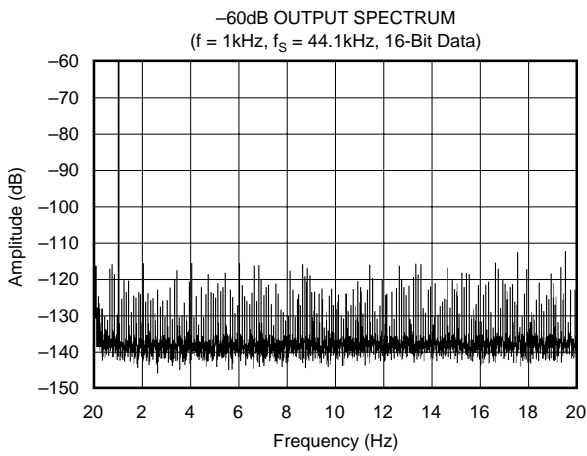
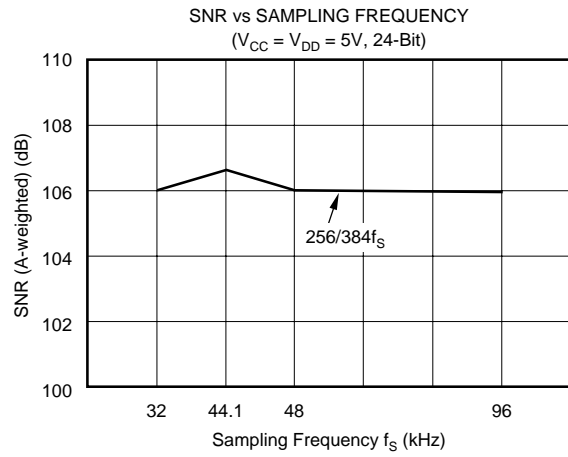
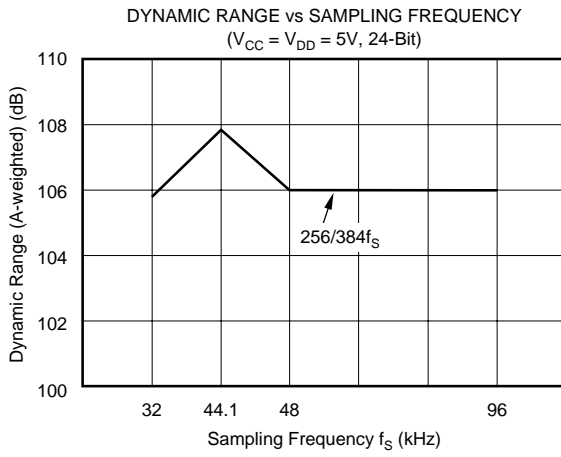
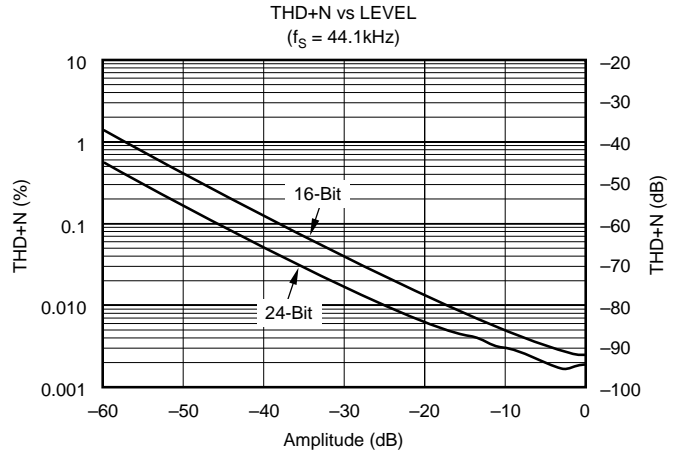
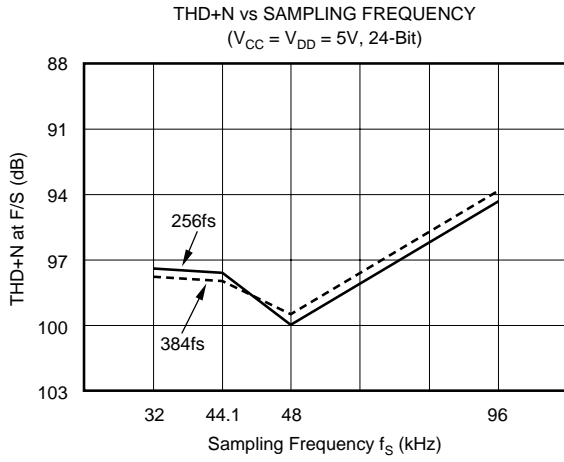
This integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

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.

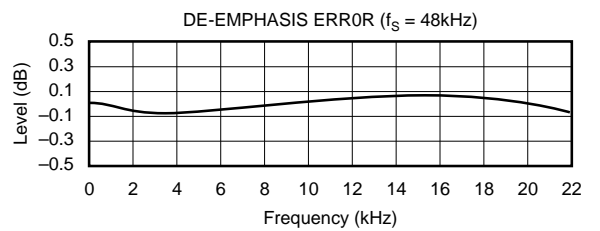
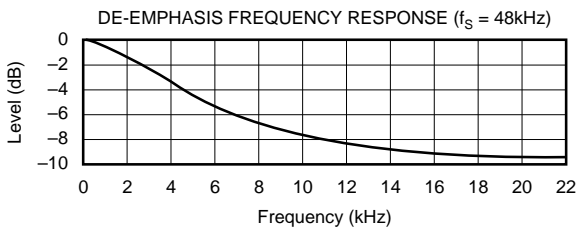
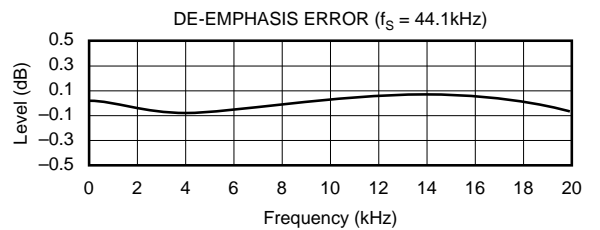
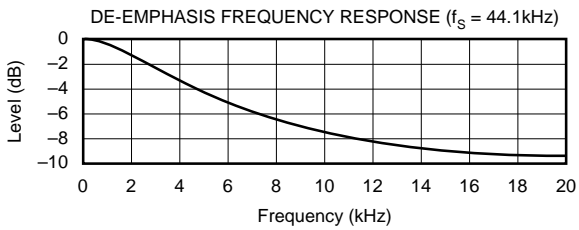
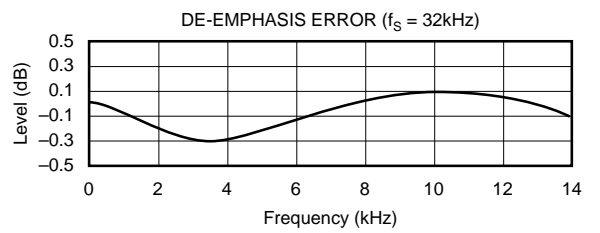
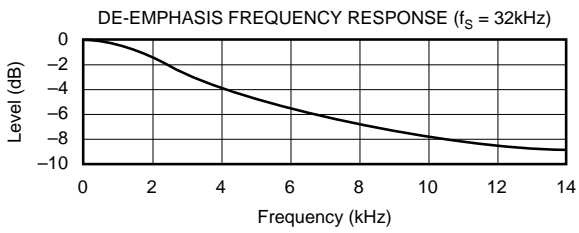
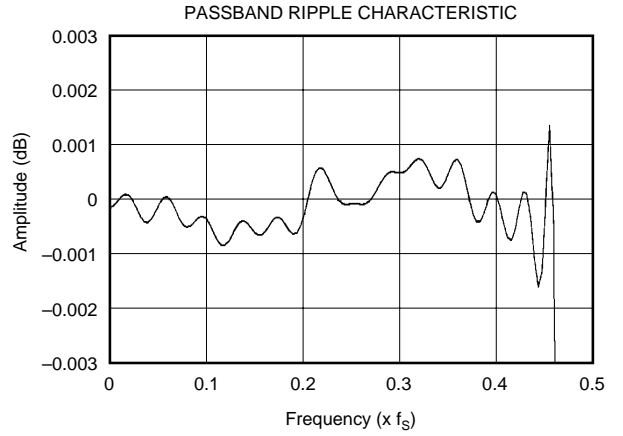
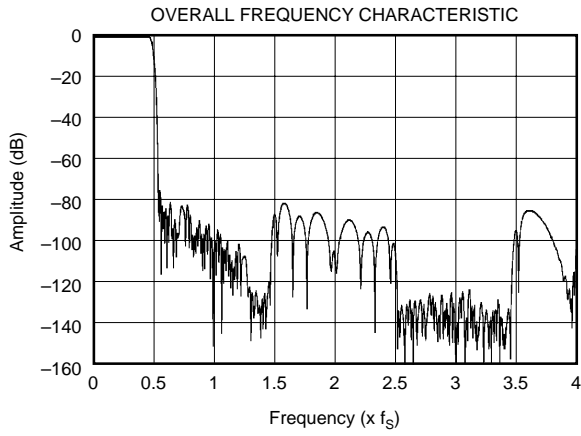
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# TYPICAL PERFORMANCE CURVES

All specifications at +25°C, +V<sub>CC</sub> = +V<sub>DD</sub> = +5V, f<sub>S</sub> = 44.1kHz, and 24-bit input data, SYSCLK = 384f<sub>S</sub>, unless otherwise noted.



# TYPICAL PERFORMANCE CURVES (CONT)



## SYSTEM CLOCK

The system clock for PCM1728 must be either  $256f_s$ ,  $384f_s$ ,  $512f_s$  or  $768f_s$ , where  $f_s$  is the audio sampling frequency (typically 32kHz, 44.1kHz, 48kHz, or 96kHz). But  $768f_s$  at 96kHz is not accepted.

The system clock can be either a crystal oscillator placed between XTI (pin 5) and XTO (pin 6), or an external clock input to XTI. If an external system clock is used, XTO is open (floating). Figure 1 illustrates the typical system clock connections.

PCM1728 has a system clock detection circuit which automatically senses if the system clock is operating at  $256f_s \sim 768f_s$ . The system clock should be synchronized with LRCIN (pin 1) clock. LRCIN (left-right clock) operates at the sampling frequency  $f_s$ . In the event these clocks are not synchronized, PCM1728 can compensate for the phase difference internally. If the phase difference between left-right and system clocks is greater than 6-bit clocks (BCKIN), the synchronization is performed internally. While the synchronization is processing, the analog output is forced to a DC level at bipolar zero. The synchronization typically occurs in less than 1 cycle of LRCIN.

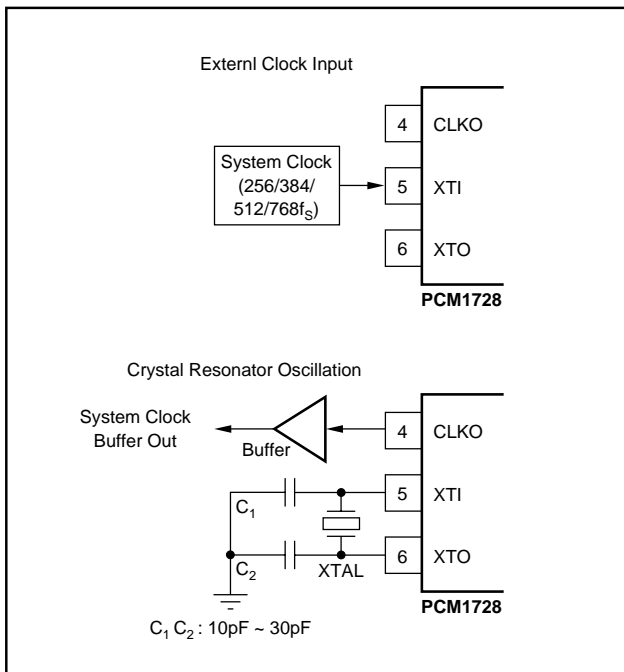


FIGURE 1. System Clock Connection.

Typical input system clock frequencies to the PCM1728 are shown in Table I, also, external input clock timing requirements are shown in Figure 2.

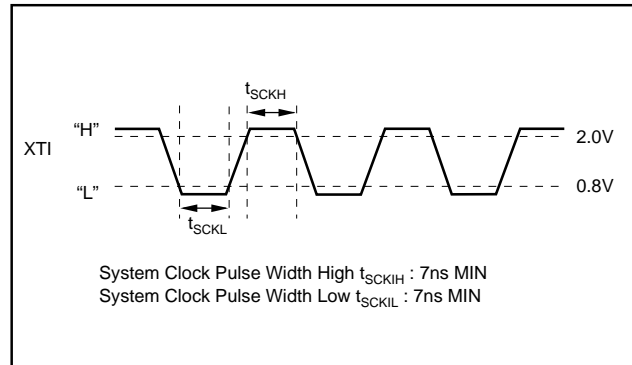


FIGURE 2. XTI Clock Timing.

## DATA INTERFACE FORMATS

Digital audio data is interfaced to PCM1728 on pins 1, 2, and 3, LRCIN (left-right clock), DIN (data input) and BCKIN (bit clock). PCM1728 can accept both standard, I<sup>2</sup>S, and left justified data formats.

Figure 3 illustrates acceptable input data formats. Figure 4 shows required timing specification for digital audio data.

## Reset

PCM1728 has both internal power-on reset circuit and the  $\overline{\text{RST}}$  pin (pin 22), which accepts an external forced reset by  $\overline{\text{RST}} = \text{LOW}$ . For internal power on reset, initialization is done automatically at power on  $V_{DD} > 2.2\text{V}$  (typ). During internal reset = LOW, the output of the DAC is invalid and the analog outputs are forced to  $V_{CC}/2$ . Figure 5 illustrates the timing of the internal power on reset.

PCM1728 accepts an external forced reset when  $\overline{\text{RST}} = \text{LOW}$ . When  $\overline{\text{RST}} = \text{LOW}$ , the output of the DAC is invalid and the analog outputs are forced to  $V_{CC}/2$  after internal initialization (1024 system clocks count after  $\overline{\text{RST}} = \text{HIGH}$ .) Figure 6 illustrates the timing of the  $\overline{\text{RST}}$  pin.

## Zero Out (pin 21)

If the input data is continuously zero for 65536 cycles of BCK, an internal FET is switched to "ON". The drain of the internal FET is the zero-pin, it will enable "wired-or" with external circuit.

SAMPLING RATE FREQUENCY ( $f_s$ ) - LRCIN	SYSTEM CLOCK FREQUENCY - MHz			
	$256f_s$	$384f_s$	$512f_s$	$768f_s$
32kHz	8.1920	12.2880	16.3840	24.5760
44.1kHz	11.2896	16.9340	22.5792	33.8688 <sup>(1)</sup>
48kHz	12.2880	18.4320	24.5760	36.8640 <sup>(1)</sup>
96kHz	24.5760	36.8640 <sup>(1)</sup>	49.1520 <sup>(1)</sup>	—

NOTE: (1) The internal crystal oscillator frequency cannot be larger than 24.576MHz.

TABLE I. Typical System Clock Frequency.

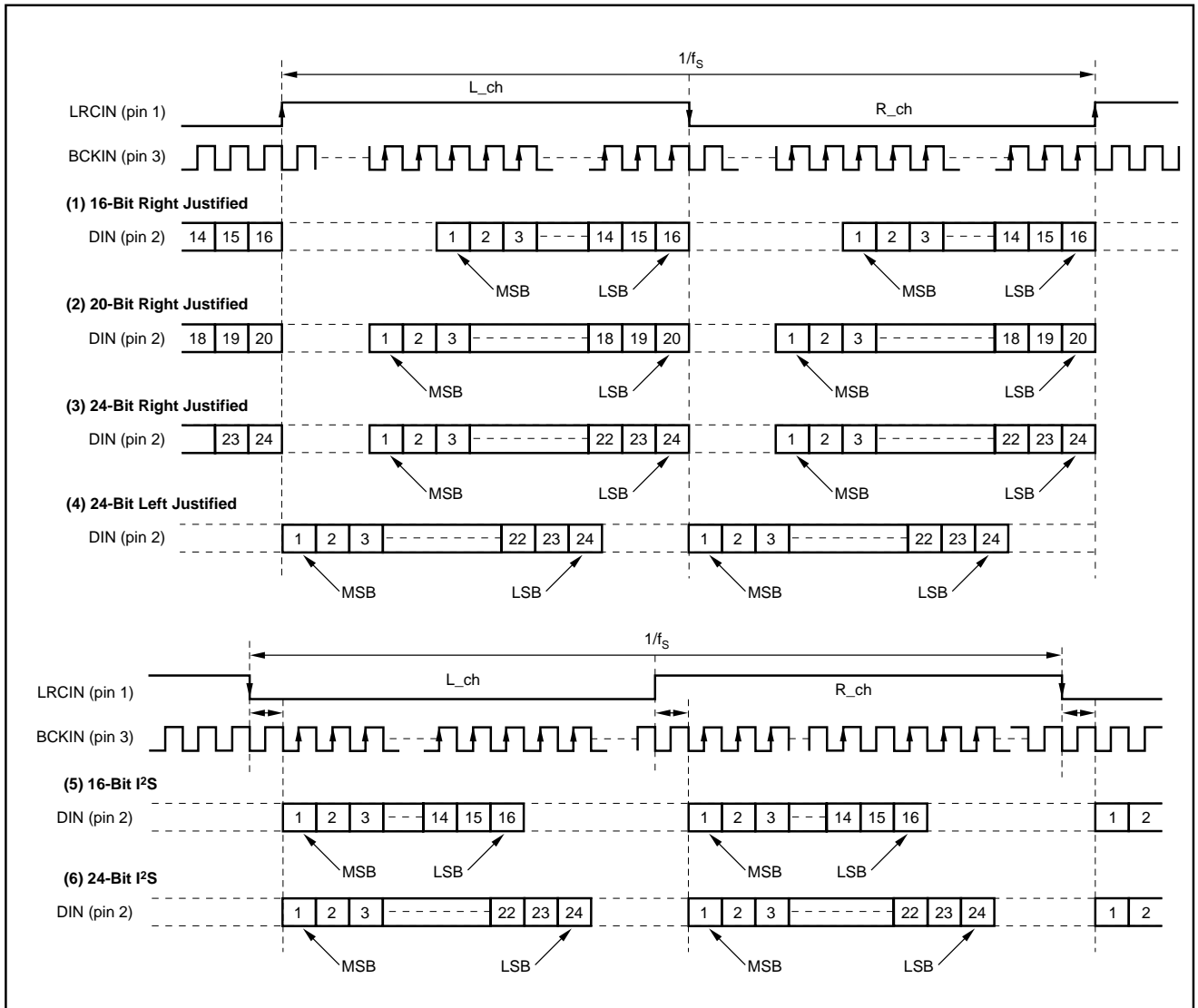


FIGURE 3. Audio Data Input Formats.

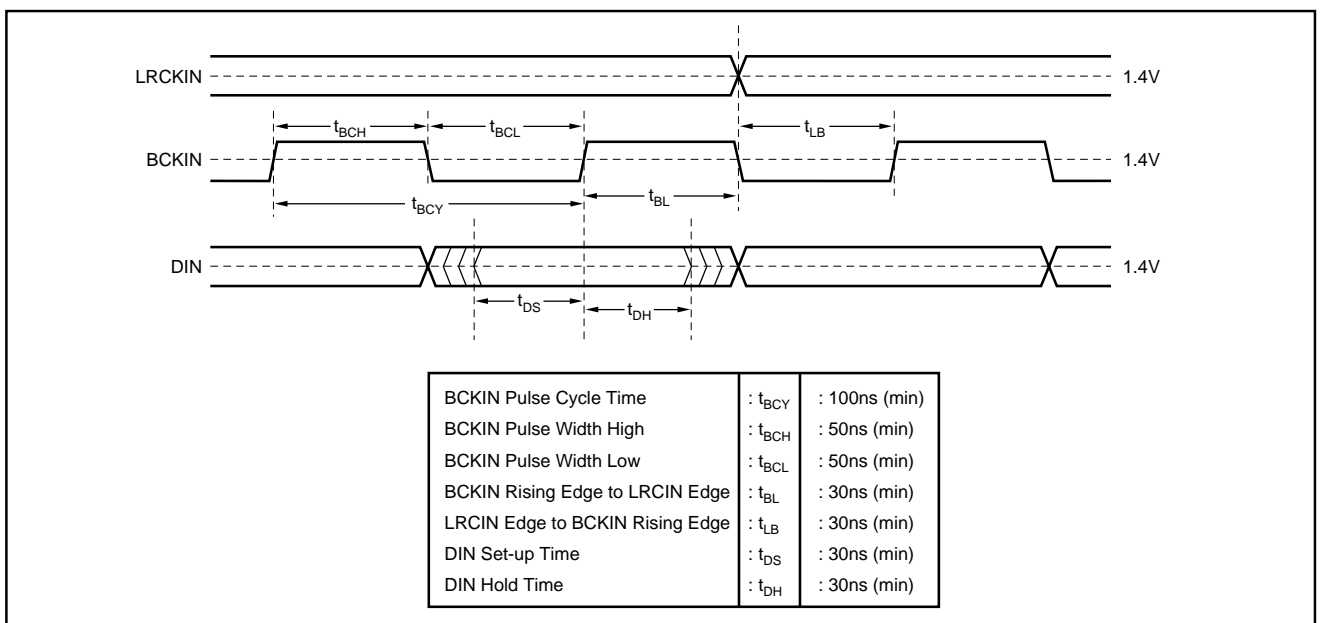


FIGURE 4. Audio Data Input Timing Specification.

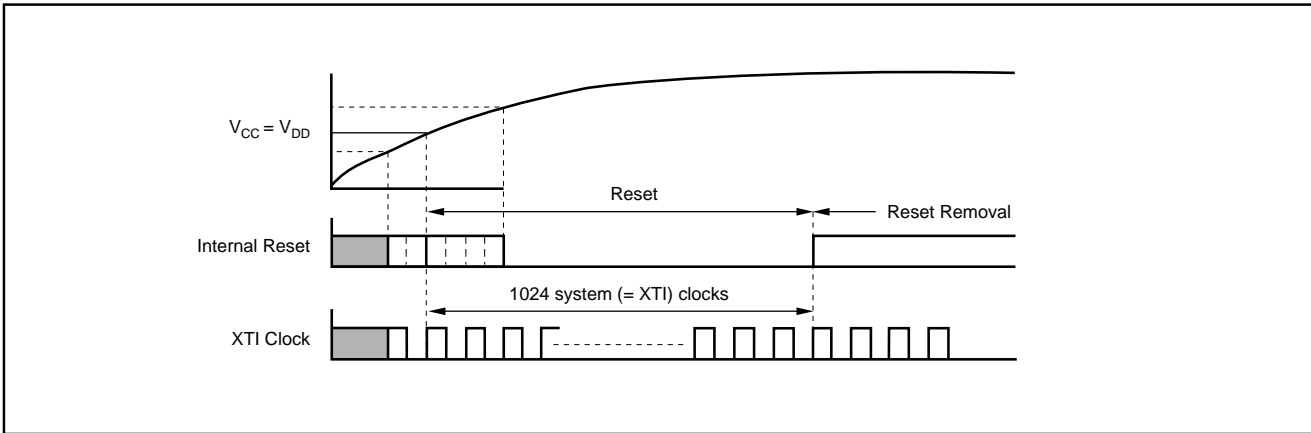


FIGURE 5. Internal Power-On Reset Timing.

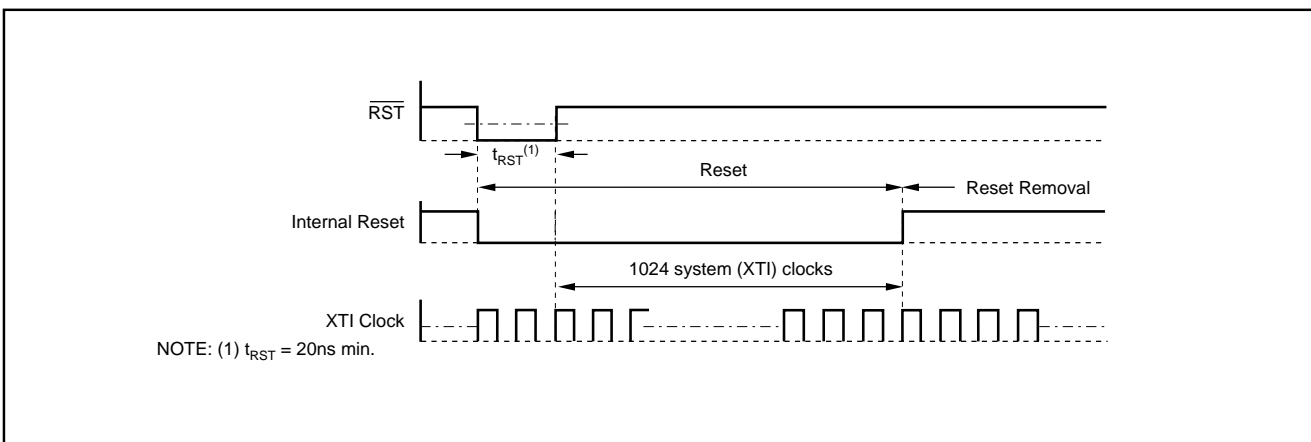


FIGURE 6. External Forced Reset Timing.

## FUNCTIONAL DESCRIPTION

PCM1728 has several built-in functions including digital input data format selection, soft mute, and digital de-emphasis. These functions are hardware controlled where static control signals are used on pin 28 (I<sup>2</sup>S), pin 27 (DM1), pin 26 (DM0), pin 25 (MUTE), pin 24 (IW1), and pin23 (IW0).

### DATA FORMAL SELECTION

PCM audio data format can be selected by pin 28 (I<sup>2</sup>S), pin 24 (IW1), and pin 23 (IW0), as shown in Table II.

IW1	IW0	I <sup>2</sup> S	AUDIO INTERFACE
0	0	0	16-Bit Standard, Right-Justified
0	1	0	20-Bit Standard, Right-Justified
1	0	0	24-Bit Standard, Right-Justified
1	1	0	24-Bit Left-Justified, MSB-First
0	0	1	16-Bit I <sup>2</sup> S
0	1	1	24-Bit I <sup>2</sup> S
1	0	1	Reserved
1	1	1	Reserved

TABLE II. Data Format Control.

### SOFT MUTE

Soft Mute function can be controlled by  $\overline{\text{MUTE}}$  (pin 25).

$\overline{\text{MUTE}}$ (Pin 25)	SOFT MUTE
L	Mute ON
H	Mute OFF (Normal Operation)

TABLE III. Soft Mute Control.

### DE-EMPHASIS CONTROL

De-emphasis control can be selected by DM1 (pin 27) and DM0 (pin 26).

DM1 (Pin 27)	DM0 (Pin 26)	DE-EMPHASIS
L	L	OFF
L	H	48kHz
H	L	44.1kHz
H	H	32kHz

TABLE IV. De-emphasis Control.



# THEORY OF OPERATION

The delta-sigma section of PCM1728 is based on an 8-level amplitude quantizer and a 4th-order noise shaper. This section converts the oversampled input data to 8-level delta-sigma format.

This newly developed, “Enhanced Multi-level Delta-Sigma” architecture achieves high-grade audio dynamic performance and sound quality.

A block diagram of the 8-level delta-sigma modulator is shown in Figure 7. This 8-level delta-sigma modulator has

the advantage of stability and clock jitter sensitivity over the typical one-bit (2-level) delta-sigma modulator.

The combined oversampling rate of the delta-sigma modulator and the internal 8-times interpolation filter is  $64f_s$  for all system clock ratios (256/384/512/768 $f_s$ ).

The theoretical quantization noise performance of the 8-level delta-sigma modulator is shown in Figure 8. This enhanced multi-level delta-sigma architecture also has advantages for input clock jitter sensitivity due to the multi-level quantizer, simulated jitter sensitivity is shown in Figure 9.

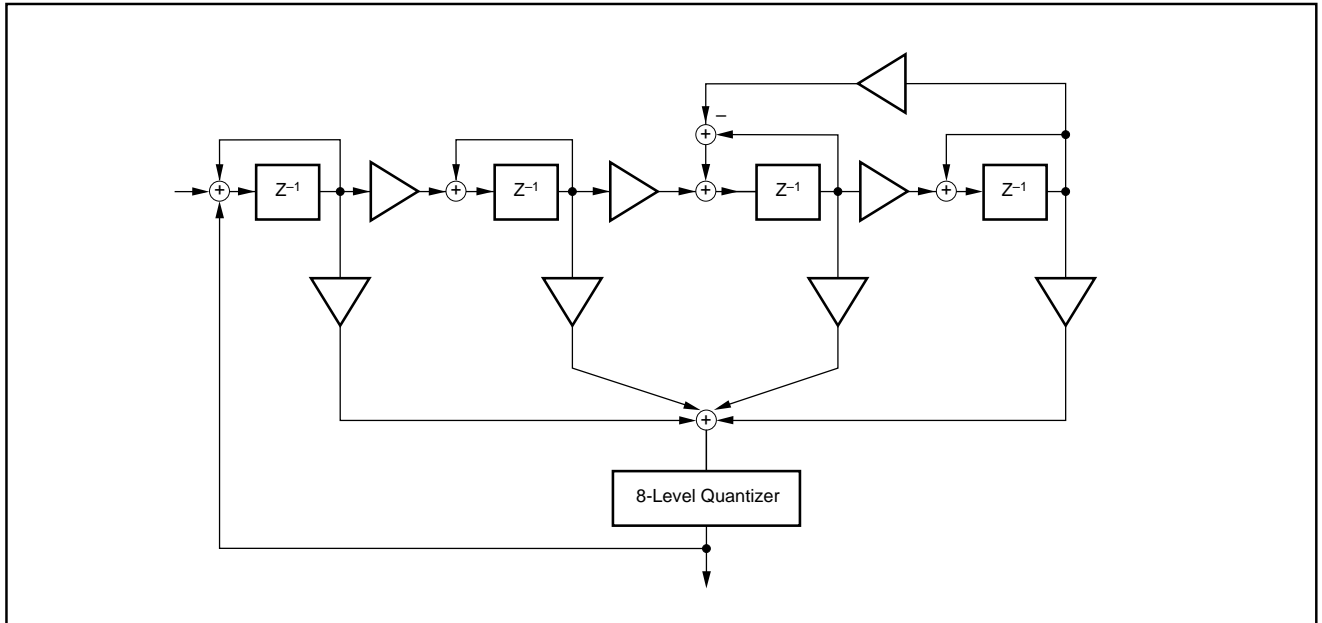


FIGURE 7. 8-Level Delta-Sigma Modulator.

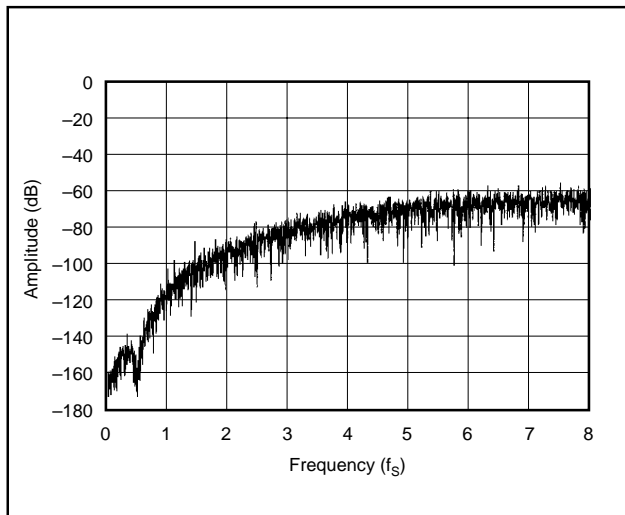


FIGURE 8. Quantization Noise Spectrum.

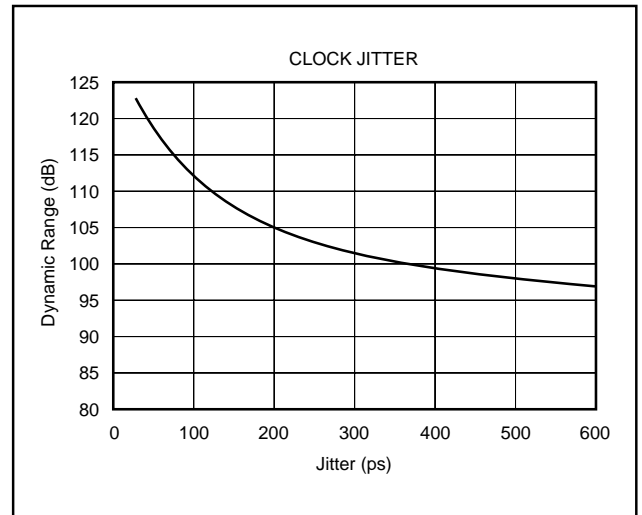


FIGURE 9. Jitter Sensitivity.

# APPLICATION CONSIDERATIONS

## DELAY TIME

There is a finite delay time in delta-sigma converters. In A/D converters, this is commonly referred to as latency. For a delta-sigma D/A converter, delay time is determined by the order number of the FIR filter stage, and the chosen sampling rate. The following equation expresses the delay time of PCM1728:

$$T_D = 30 \times 1/f_s$$

$$\text{For } f_s = 44.1\text{kHz, } T_D = 30/44.1\text{kHz} = 680\mu\text{s}$$

Applications using data from a disc or tape source, such as CD audio, DVD audio, Video CD, DAT, Minidisc, etc., generally are not affected by delay time. For some professional applications such as broadcast audio for studios, it is important for total delay time to be less than 2ms.

## OUTPUT FILTERING

For testing purposes all dynamic tests are done on the PCM1728 using a 20kHz low pass filter. This filter limits the measured bandwidth for THD+N, etc. to 20kHz. Failure to use such a filter will result in higher THD+N and lower SNR and Dynamic Range readings than are found in the specifications. The low pass filter removes out of band noise. Although it is not audible, it may affect dynamic specification numbers.

The performance of the internal low pass filter from DC to 40kHz is shown in Figure 10. The higher frequency roll-off of the filter is shown in Figure 11. If the user's application has the PCM1728 driving a wideband amplifier, it is recommended to use an external low pass filter.

## BYPASSING POWER SUPPLIES

The power supplies should be bypassed as close as possible to the unit. Refer to Figure 12 for optimal values of bypass capacitors.

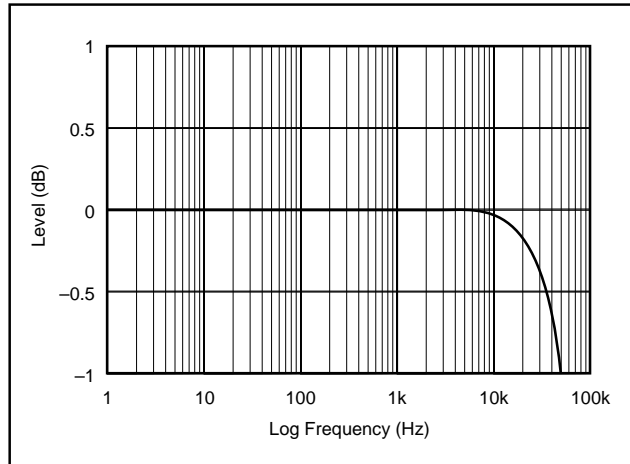


FIGURE 10. Low Pass Filter Response.

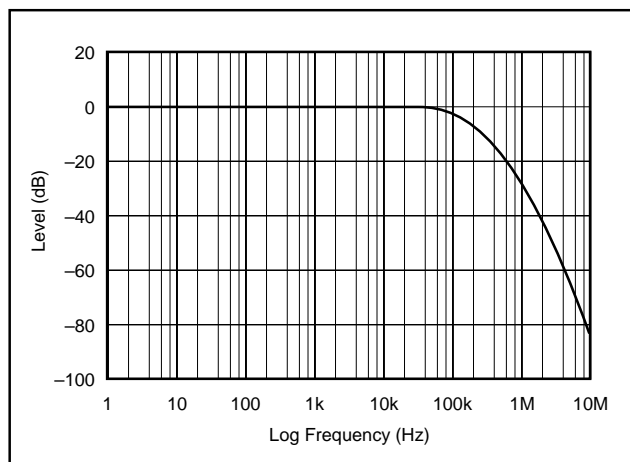


FIGURE 11. Low Pass Filter Response.

## POWER SUPPLY CONNECTIONS

PCM1728 has four power supply pins for digital ( $V_{DD}$ ), and analog ( $V_{CC}$ ). Each connection also has a separate ground. If the power supplies turn on at different times, there is a possibility of a latch-up condition. To avoid this condition, it is recommended to have a common connection between the digital and analog power supplies. If separate supplies are used without a common connection, the delta between the two supplies during ramp-up time must be less than 0.1V.

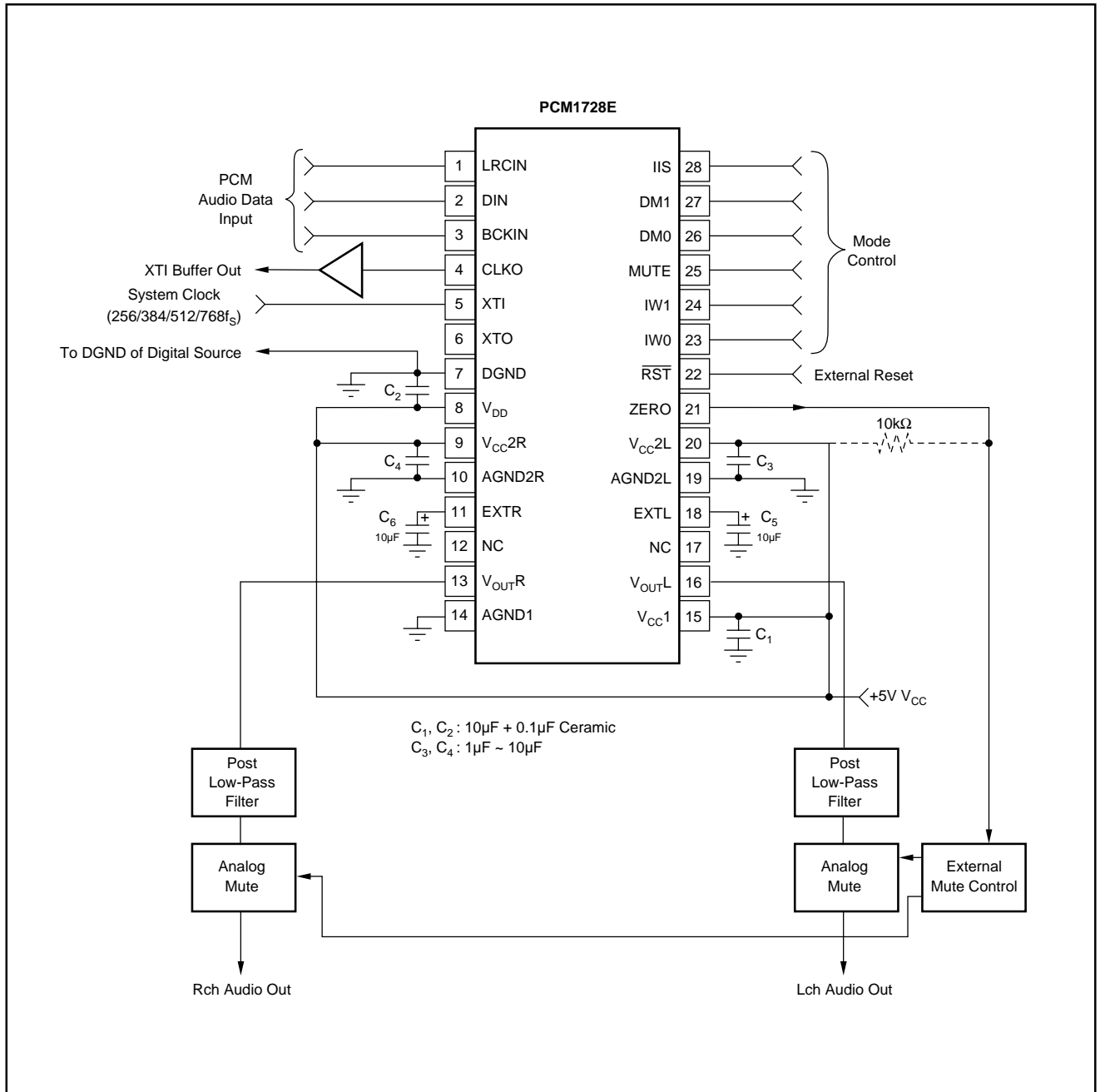


FIGURE 12. Typical Circuit Connection Diagram.