BURR-BROWN®



PCM1733

SoundPLUS™ Stereo Audio DIGITAL-TO-ANALOG CONVERTER 18 Bits, 96kHz Sampling

FEATURES

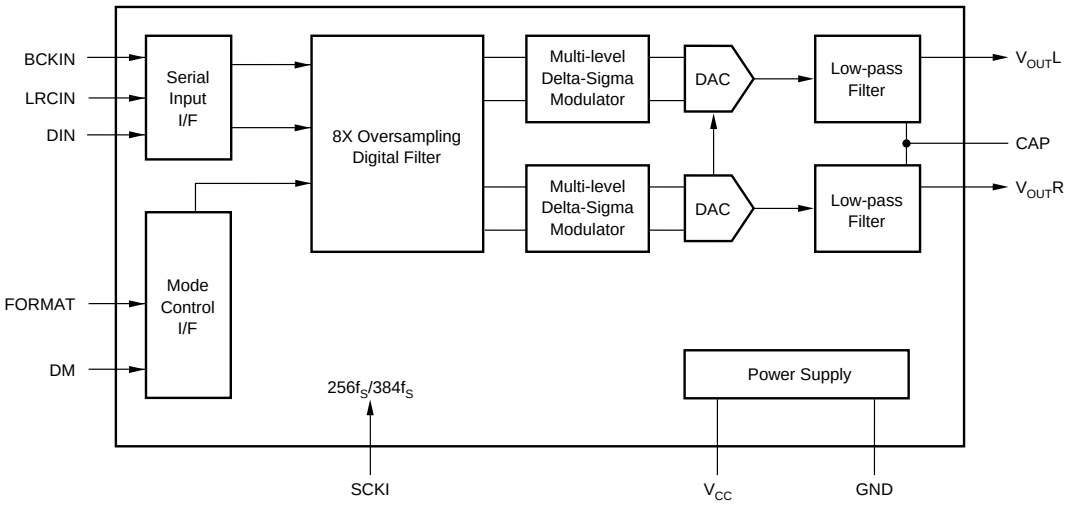
- **COMPLETE STEREO DAC: Includes Digital Filter and Output Amp**
- **DYNAMIC RANGE: 95dB**
- **MULTIPLE SAMPLING FREQUENCIES: 16kHz to 96kHz**
- **8X OVERSAMPLING DIGITAL FILTER**
- **SYSTEM CLOCK: $256f_S/384f_S$**
- **NORMAL OR I²S DATA INPUT FORMATS**
- **SMALL 14-PIN SOIC PACKAGE**

DESCRIPTION

The PCM1733 is a complete low cost stereo audio digital-to-analog converter (DAC), operating off of a $256f_S$ or $384f_S$ system clock. The DAC contains a 3rd-order ΔΣ modulator, a digital interpolation filter, and an analog output amplifier. The PCM1733 accepts 18-bit input data in either normal or I²S formats.

The digital filter performs an 8X interpolation function and includes de-emphasis at 44.1kHz. The PCM1733 can accept digital audio sampling frequencies from 16kHz to 96kHz, always at 8X oversampling.

The PCM1733 is ideal for low-cost, CD-quality consumer audio applications.



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SPECIFICATIONS

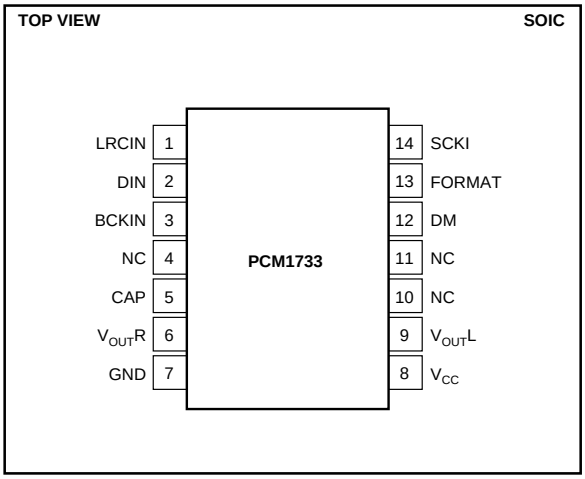
All specifications at +25°C, $+V_{CC}$ = +5V, f_S = 44.1kHz, and 18-bit input data, SYSCLK = $384f_S$, unless otherwise noted.

PARAMETER	CONDITIONS	PCM1733 MIN	PCM1733 TYP	PCM1733 MAX	UNITS
RESOLUTION			18		Bits
DATA FORMAT					
Audio Data Interface Format			Standard/I²S		
Audio Data Format			Two's Binary Complement		
Sampling Frequency (f_S)		16		96	kHz
Internal System Clock Frequency			$256f_S/384f_S$		
DIGITAL INPUT/OUTPUT					
Logic Level			TTL		
Input Logic Level					
V_{IH}(1)		2.0			VDC
V_{IL}(1)				0.8	VDC
Input Logic Current: I_{IN}(1)				±0.8	µA
DYNAMIC PERFORMANCE(2)	f = 991kHz				
THD+N at FS (0dB)			–83	–78	dB
THD+N at –60dB			–32		dB
Dynamic Range	EIAJ, A-weighted	90	95		dB
Signal-to-Noise Ratio	EIAJ, A-weighted	90	97		dB
Channel Separation		88	95		dB
DC ACCURACY					
Gain Error			±1.0	±5.0	% of FSR
Gain Mismatch, Channel-to-Channel			±1.0	±5.0	% of FSR
Bipolar Zero Error	$V_{OUT} = V_{CC}/2$ at BPZ		±20	±50	mV
ANALOG OUTPUT					
Output Voltage	Full Scale (0dB)		0.62 x V_{CC}		Vp-p
Center Voltage			$V_{CC}/2$		VDC
Load Impedance	AC Load	10			kΩ
DIGITAL FILTER PERFORMANCE					
Passband				0.445	f_S
Stopband		0.555			f_S
Passband Ripple				±0.17	dB
Stopband Attenuation		–35			dB
Delay Time			$11.125/f_S$		sec
INTERNAL ANALOG FILTER					
–3dB Bandwidth			100		kHz
Passband Response	f = 20kHz		–0.16		dB
POWER SUPPLY REQUIREMENTS					
Voltage Range		4.5	5	5.5	VDC
Supply Current			13	18	mA
Power Dissipation			65	90	mW
TEMPERATURE RANGE					
Operation		–25		+85	°C
Storage		–55		+125	°C

NOTES: (1) Pins 1, 2, 3, 12, 13, 14: LRCIN, DIN, BCKIN, DM, FORMAT, SCKI. (2) Dynamic performance specs are tested with 20kHz low pass filter and THD+N specs are tested with 30kHz LPF, 400Hz HPF, Average-Mode.

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PIN CONFIGURATION



PACKAGE INFORMATION

PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER(1)
PCM1733U	14 Pin SOIC	235

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
$+V_{CC}$ to $+V_{DD}$ Difference	±0.1V
Input Logic Voltage	–0.3V to (V_{DD} + 0.3V)
Power Dissipation	290mW
Operating Temperature Range	–25°C to +85°C
Storage Temperature	–55°C to +125°C
Lead Temperature (soldering, 5s)	+260°C
Thermal Resistance, θ_{JA}	+90°C/W

PIN ASSIGNMENTS

PIN	NAME	I/O	FUNCTION
1(1)	LRCIN	IN	Sample Rate Clock Input
2(1)	DIN	IN	Audio Data Input
3(1)	BCKIN	IN	Bit Clock Input for Audio Data.
4	NC	—	No Connection
5	CAP	—	Common Pin of Analog Output Amp
6	$V_{OUT}R$	OUT	Right-Channel Analog Output
7	GND	—	Ground
8	V_{CC}	—	Power Supply
9	$V_{OUT}L$	OUT	Left-Channel Analog Output
10	NC	—	No Connection
11	NC	—	No Connection
12(2)	DM	IN	De-emphasis Control HIGH: De-emphasis ON LOW: De-emphasis OFF
13(2)	FORMAT	IN	Audio Data Format Select HIGH: I^2S Data Format LOW: Standard Data Format
14	SCKI	IN	System Clock Input ($256f_S$ or $384f_S$)

NOTES: (1) Schmitt Trigger input. (2) Schmitt Trigger input with internal pull-up.

ELECTROSTATIC DISCHARGE SENSITIVITY

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

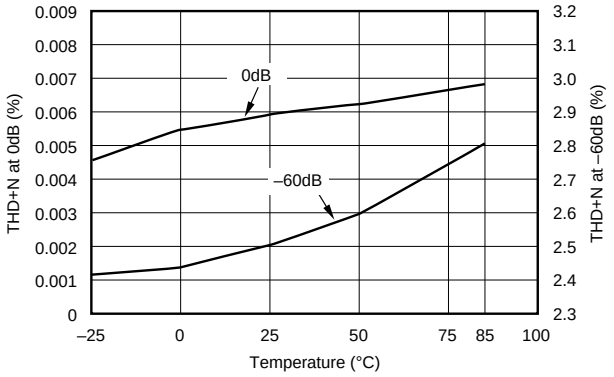
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

TYPICAL PERFORMANCE CURVES

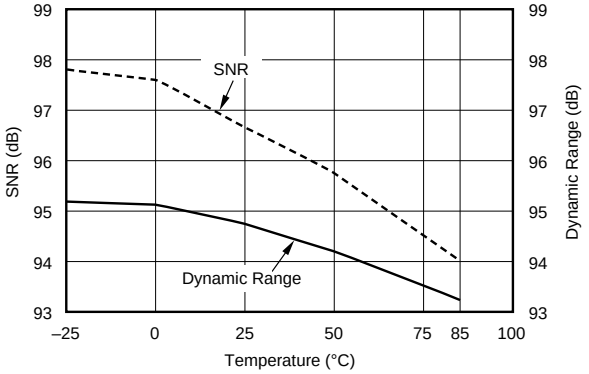
At T_A = +25°C, $+V_{CC}$ = +5V, f_S = 44.1kHz, SYSCLK = 256f_S, unless otherwise noted.

DYNAMIC PERFORMANCE

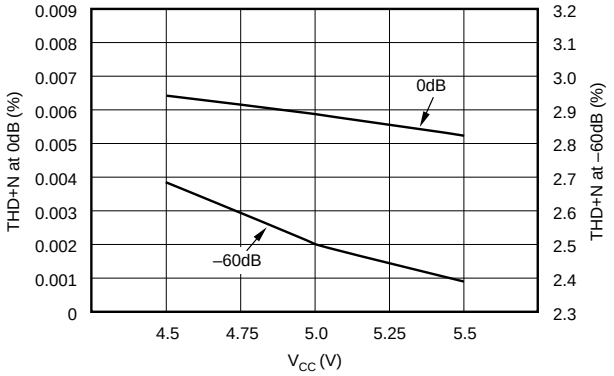
THD+N vs TEMPERATURE



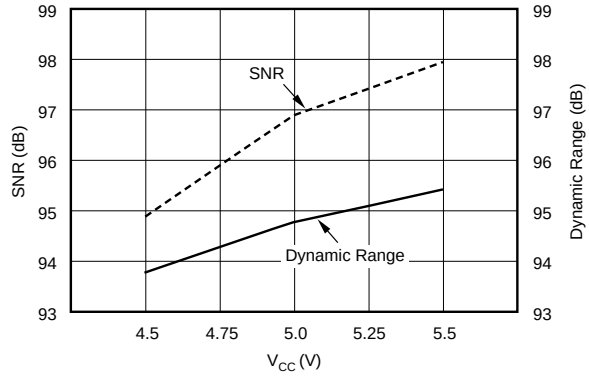
SNR, DYNAMIC RANGE vs TEMPERATURE



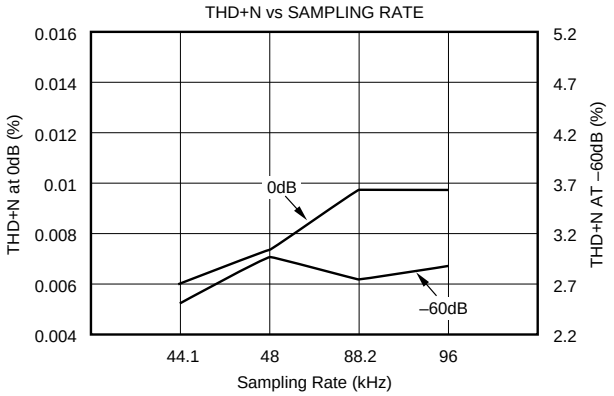
THD+N vs POWER SUPPLY



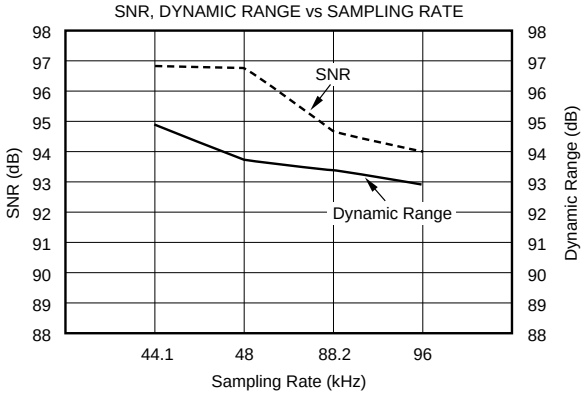
SNR, DYNAMIC RANGE vs POWER SUPPLY



THD+N vs SAMPLING RATE



SNR, DYNAMIC RANGE vs SAMPLING RATE

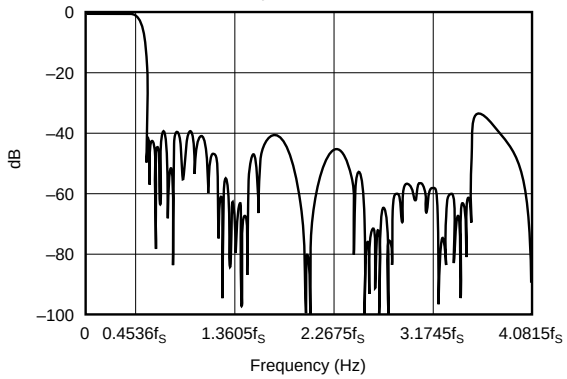


TYPICAL PERFORMANCE CURVES

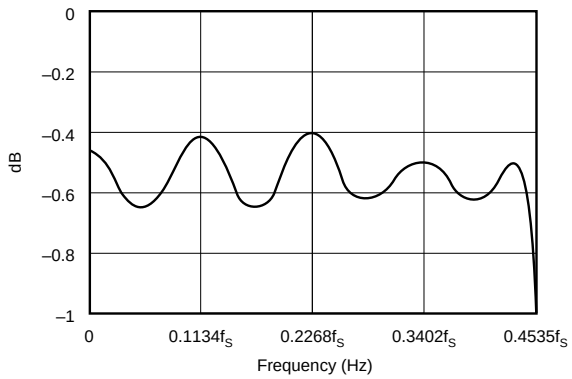
At T_A = +25°C, $+V_{CC}$ = $+V_{DD}$ = +5V, f_S = 44.1kHz, and 18-bit input data, SYSCLK = 384f_S, unless otherwise noted.

DIGITAL FILTER

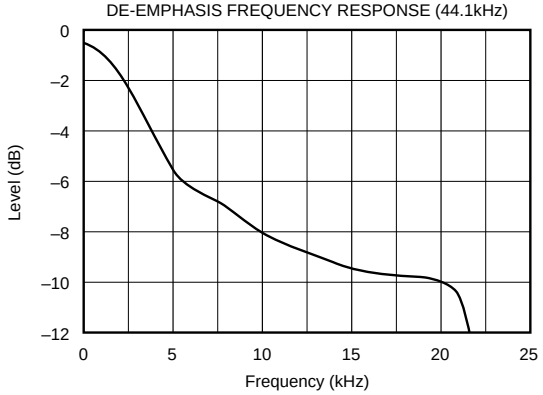
OVERALL FREQUENCY CHARACTERISTIC



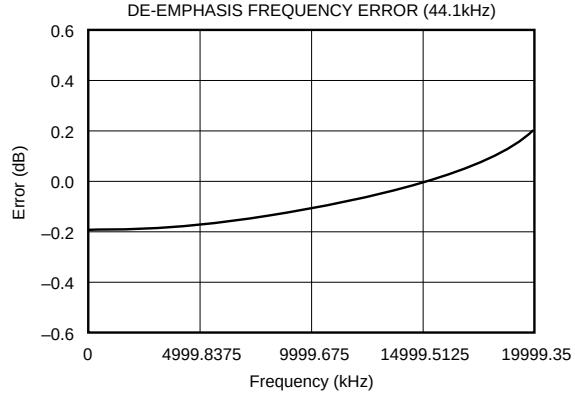
PASSBAND RIPPLE CHARACTERISTIC



DE-EMPHASIS FREQUENCY RESPONSE (44.1kHz)



DE-EMPHASIS FREQUENCY ERROR (44.1kHz)



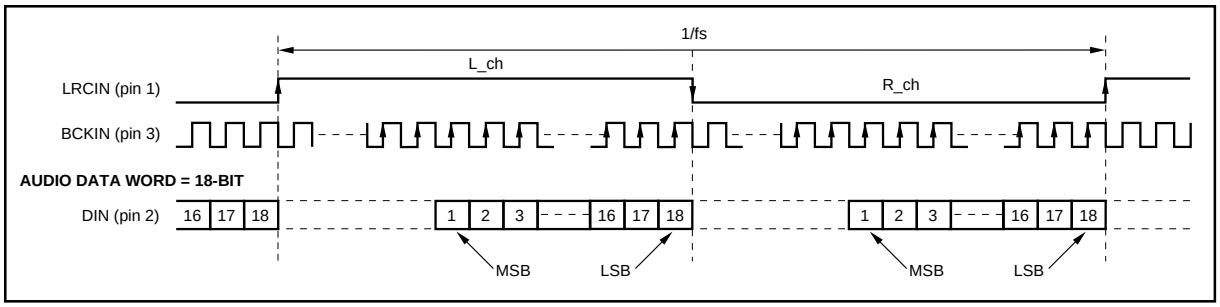


FIGURE 1. “Normal” Data Input Timing.

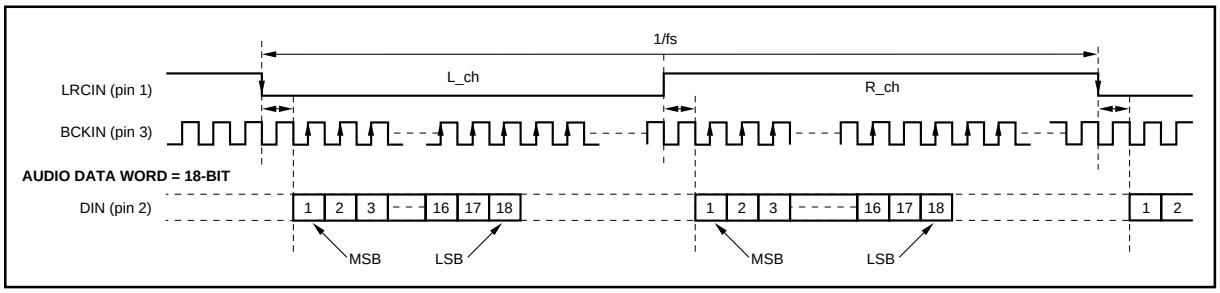
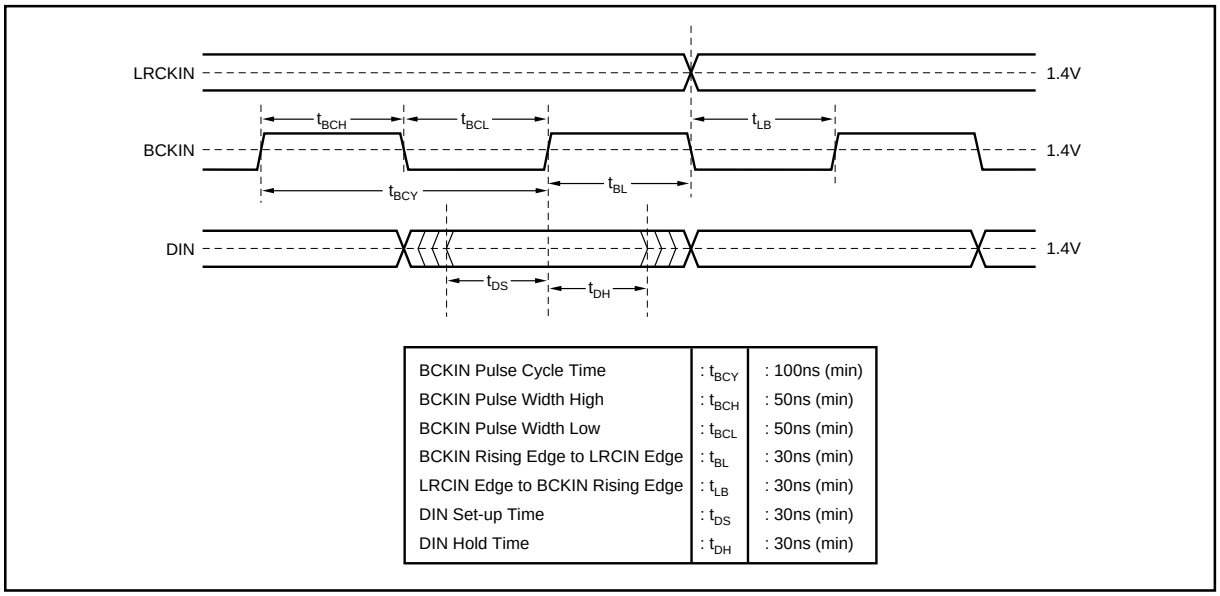
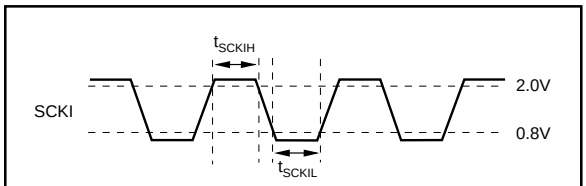


FIGURE 2. “I²S” Data Input Timing.



BCKIN Pulse Cycle Time	: t_{BCY}	: 100ns (min)
BCKIN Pulse Width High	: t_{BCH}	: 50ns (min)
BCKIN Pulse Width Low	: t_{BCL}	: 50ns (min)
BCKIN Rising Edge to LRCIN Edge	: t_{BL}	: 30ns (min)
LRCIN Edge to BCKIN Rising Edge	: t_{LB}	: 30ns (min)
DIN Set-up Time	: t_{DS}	: 30ns (min)
DIN Hold Time	: t_{DH}	: 30ns (min)

FIGURE 3. Audio Data Input Timing.



System Clock Pulse Width High	t_{SCKIH}	13ns (min)
System Clock Pulse Width Low	t_{SCKIL}	13ns (min)

FIGURE 4. System Clock Timing Requirements.

SYSTEM CLOCK

The system clock for PCM1733 must be either $256f_S$ or $384f_S$, where f_S is the audio sampling frequency (LRCIN), typically 32kHz, 44.1kHz or 48kHz. The system clock is used to operate the digital filter and the noise shaper. The system clock input (SCKI) is at pin 14. Timing conditions for SCKI are shown in Figure 4.

PCM1733 has a system clock detection circuit which automatically detects the frequency, either $256f_S$ or $384f_S$. The system clock should be synchronized with LRCIN (pin 1), but PCM1733 can compensate for phase differences. If the phase difference between LRCIN and system clock is greater than ±6 bit clocks (BCKIN), the synchronization is performed automatically. The analog outputs are forced to a bipolar zero state ($V_{CC}/2$) during the synchronization function. Table I shows the typical system clock frequency inputs for the PCM1733.

SAMPLING RATE (LRCIN)	SYSTEM CLOCK FREQUENCY (MHz)	
	$256f_S$	$384f_S$
32kHz	8.192	12.288
44.1kHz	11.2896	16.9340
48kHz	12.288	18.432

TABLE I. System Clock Frequencies vs Sampling Rate.

TYPICAL CONNECTION DIAGRAM

Figure 5 illustrates the typical connection diagram for PCM1733 used in a stand-alone application.

INPUT DATA FORMAT

PCM1733 can accept input data in either normal (MSB-first, right-justified) or I^2S formats. When pin 13 (FORMAT) is LOW, normal data format is selected; a HIGH on pin 13 selects I^2S format.

FORMAT	
0	Normal Format (MSB-first, right-justified)
1	I^2S Format (Philips serial data protocol)

TABLE II. Input Format Selection.

RESET

PCM1733 has an internal power-on reset circuit. The internal power-on reset initializes (resets) when the supply voltage V_{CC} > 2.2V (typ). The power-on reset has an initialization period equal to 1024 system clock periods after V_{CC} > 2.2V. During the initialization period, the outputs of the DAC are invalid, and the analog outputs are forced to $V_{CC}/2$. Figure 6 illustrates the power-on reset and reset-pin reset timing.

DE-EMPHASIS CONTROL

Pin 12 (DM) enables PCM1733's de-emphasis function. De-emphasis operates only at 44.1kHz.

DM	
0	De-emphasis OFF
1	De-emphasis ON (44.1kHz)

TABLE III. De-emphasis Control Selection.

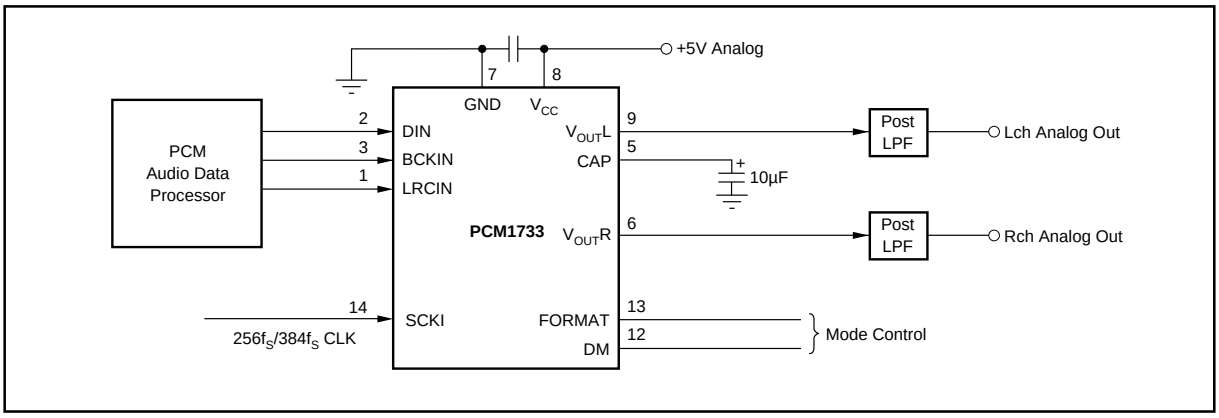


FIGURE 5. Typical Connection Diagram.

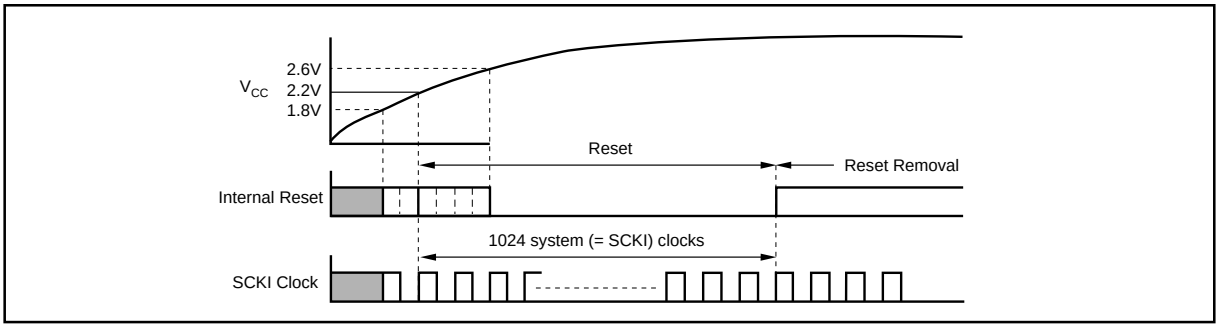


FIGURE 6. Internal Power-On Reset Timing.

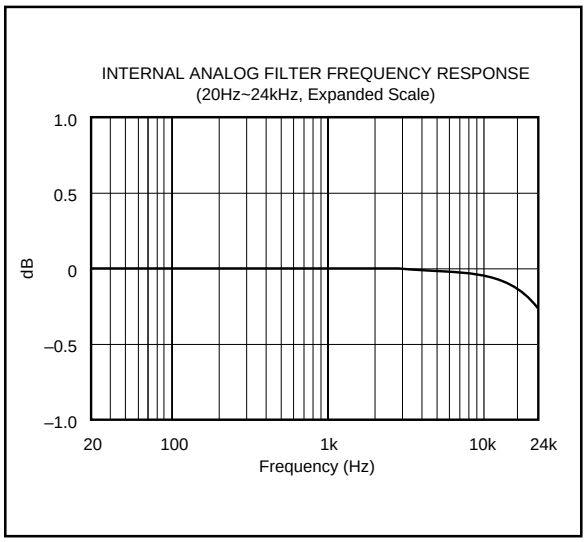


FIGURE 7. Low Pass Filter Frequency Response.

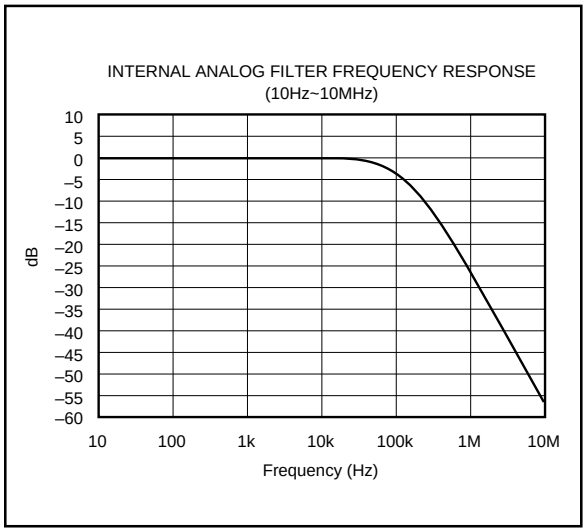


FIGURE 8. Low Pass Filter Wideband Frequency Response.

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 PCM1733:

$$T_D = 11.125 \times 1/f_S$$

For f_S = 44.1kHz, T_D = 11.125/44.1kHz = 251.4µs

Applications using data from a disc or tape source, such as CD audio, CD-Interactive, 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 PCM1733 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 24kHz is shown in Figure 7. The higher frequency rolloff of the filter is shown in Figure 8. If the user's application has the PCM1733 driving a wideband amplifier, it is recommended to use an external low pass filter. A simple 3rd-order filter is shown in Figure 9. For some applications, a passive RC filter or 2nd-order filter may be adequate.

BYPASSING POWER SUPPLIES

The power supplies should be bypassed as close as possible to the unit. It is also recommended to include a 0.1µF ceramic capacitor in parallel with the 10µF tantalum bypass capacitor.

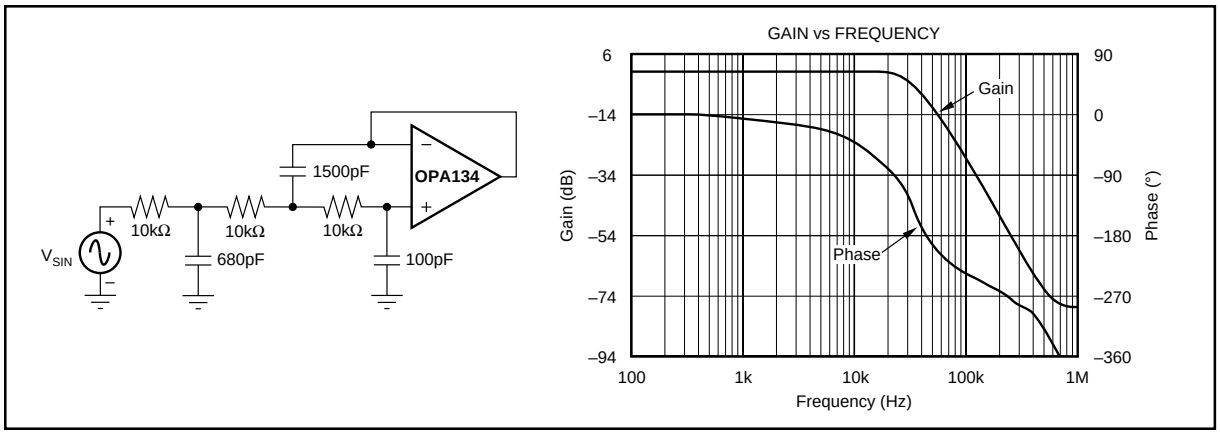


FIGURE 9. 3rd-Order LPF.

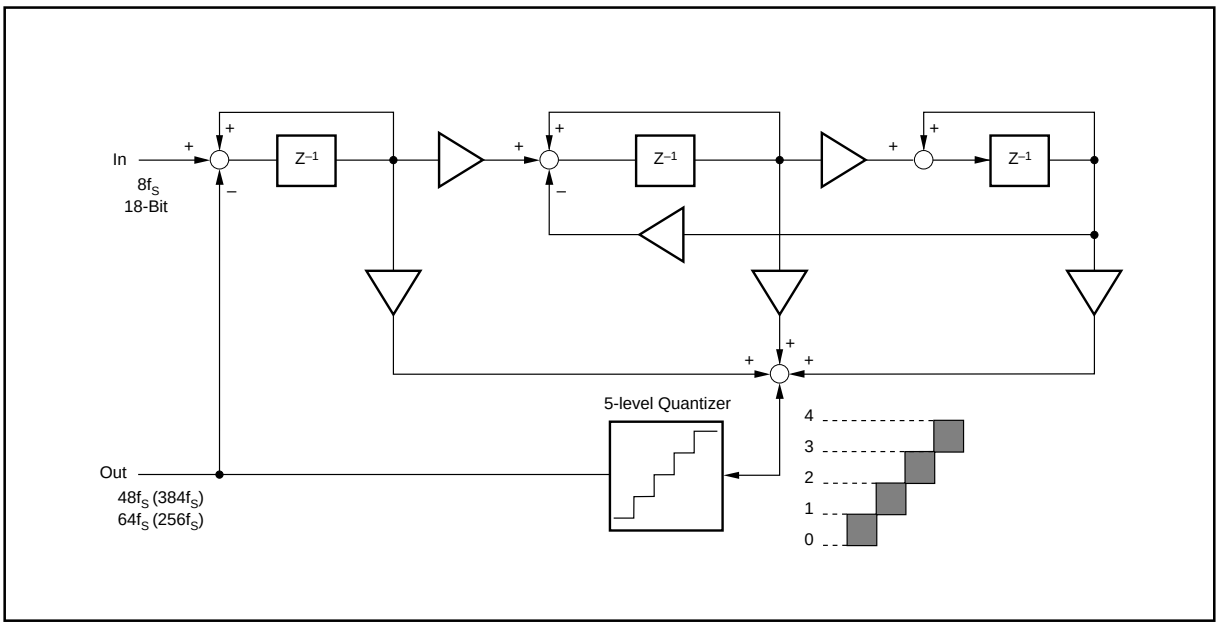


FIGURE 10. 5-Level ΔΣ Modulator Block Diagram.

THEORY OF OPERATION

The delta-sigma section of PCM1733 is based on a 5-level amplitude quantizer and a 3rd-order noise shaper. This section converts the oversampled input data to 5-level delta-sigma format. A block diagram of the 5-level delta-sigma modulator is shown in Figure 10. This 5-level delta-sigma modulator has the advantage of stability and clock jitter over the typical one-bit (2-level) delta-sigma modulator.

The combined oversampling rate of the delta-sigma modulator and the internal 8X interpolation filter is 96f$_S$ for a 384f$_S$ system clock, and 64f$_S$ for a 256f$_S$ system clock. The theoretical quantization noise performance of the 5-level delta-sigma modulator is shown in Figure 11.

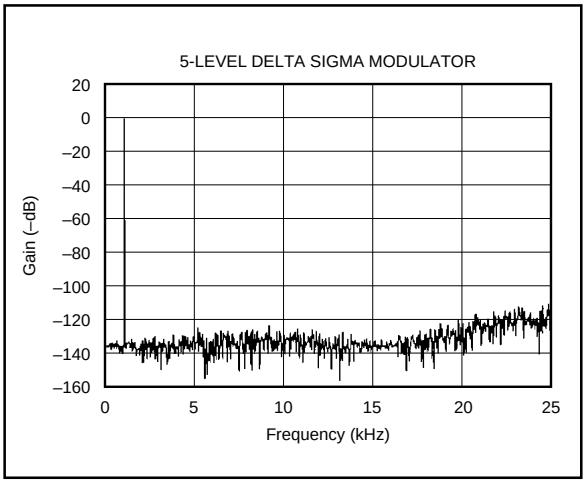


FIGURE 11. Quantization Noise Spectrum.

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
PCM1733U	Last Time Buy	Production	SOIC (D) | 14	50 | TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	-	PCM1733U
PCM1733U.B	Last Time Buy	Production	SOIC (D) | 14	50 | TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	See PCM1733U	PCM1733U

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

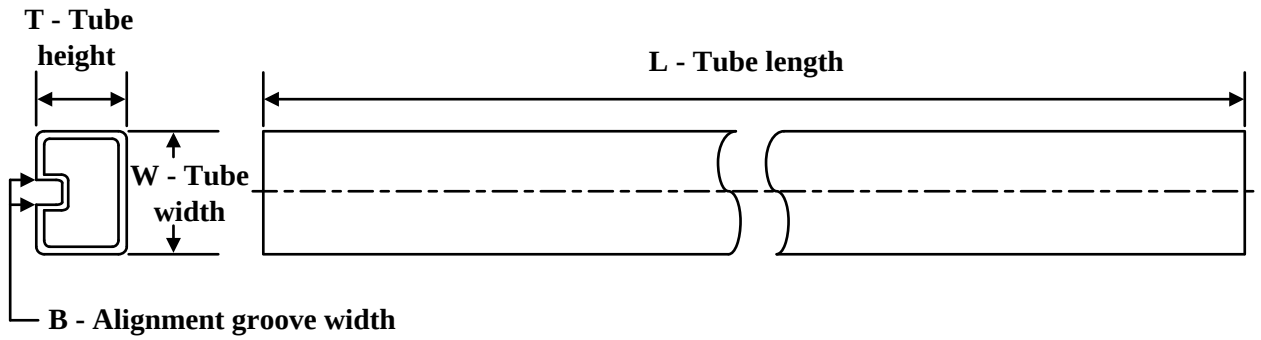
(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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TUBE



*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
PCM1733U	D	SOIC	14	50	506.6	8	3940	4.32
PCM1733U.B	D	SOIC	14	50	506.6	8	3940	4.32

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