

24-BIT 192-KHz SAMPLING ENHANCED MULTI-LEVEL DELTA-SIGMA AUDIO DIGITAL-TO-ANALOG CONVERTER

Check for Samples: [PCM1754-Q1](#), [PCM1753-Q1](#)

FEATURES

- Qualified for Automotive Applications
- 24-Bit Resolution
- Analog Performance ($V_{CC} = 5\text{ V}$)
 - Dynamic Range: 106 dB
 - SNR: 106 dB, Typical
 - THD+N: 0.002%, Typical
 - Full-Scale Output: $4 V_{PP}$, Typical
- 4×/8× Oversampling Digital Filter
 - Stop-Band Attenuation: -50 dB
 - Pass-Band Ripple: $\pm 0.04\text{ dB}$
- Sampling Frequency: 5 kHz to 200 kHz
- System Clock: 128 f_S , 192 f_S , 256 f_S , 384 f_S , 512 f_S , 768 f_S , 1152 f_S with Auto Detect
- Hardware Control (PCM1754)
 - I²S and 16-Bit Word, Right-Justified
 - 44.1 kHz Digital De-Emphasis
 - Soft Mute
 - Zero Flag for L-, R-Channel Common Output
- Power Supply: 5-V Single Supply
- Small 16-Lead SSOP Package, Lead-Free

APPLICATIONS

- A/V Receivers
- DVD Movie Players
- DVD Add-On Cards for High-End PCs
- DVD Audio Players
- HDTV Receivers
- Car Audio Systems
- Other Applications Requiring 24-Bit Audio

DESCRIPTION

The PCM175x is a CMOS, monolithic, integrated circuit, which includes stereo digital-to-analog converters and support circuitry in a small 16-lead SSOP package. The data converters use TI's enhanced multilevel delta-sigma architecture, which employs 4th-order noise shaping and 8-level amplitude quantization to achieve excellent dynamic performance and improved tolerance to clock jitter. The PCM175x accepts industry standard audio data formats with 16- to 24-bit data, providing easy interfacing to audio DSP and decoder chips. Sampling rates up to 200 kHz are supported. A full set of user-programmable functions is accessible through a three-wire serial control port, which supports register write functions.

The PCM1753 is pin-compatible with the PCM1748, PCM1742, and PCM1741, except for pin 5.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

System Two, Audio Precision are trademarks of Audio Precision, Inc..



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⁽¹⁾

T _A	PACKAGE ⁽²⁾		ORDERABLE PART NUMBER	TOP-SIDE MARKING
			-40°C to 105°C	SSOP - DBQ
			PCM1753TDBQRQ1	P1753T

- (1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.
- (2) Package drawings, thermal data, and symbolization are available at www.ti.com/packaging.

ABSOLUTE MAXIMUM RATINGS⁽¹⁾

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

Supply voltage: V _{CC}	-0.3 V to 6.5 V
Ground voltage differences: AGND, DGND	±0.1 V
Input voltage	-0.3 V to 6.5 V
Input current (any pins except supplies)	±10 mA
Ambient temperature under bias	-40°C to 105°C
Storage temperature	-55°C to 150°C
Junction temperature	150°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 is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

All specifications at T_A = 25°C, V_{CC} = 5 V, f_S = 44.1 kHz, system clock = 384 f_S, and 24-bit data (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Resolution				24		Bits
DATA FORMAT						
Audio-data interface format PCM1753	PCM1753		I ² S, standard, left-justified			
	PCM1754		I ² S, standard			
Audio-data bit length	PCM1753		16-, 18-, 20-, 24-bit, selectable			
	PCM1754		16-24-bit (I ² S), 16-bit (standard)			
Audio data format			MSB first, 2s complement			
f _S	Sampling frequency		5		200	kHz
System clock frequency			128 f _S , 192 f _S , 256 f _S , 384 f _S , 512 f _S , 768 f _S , 1152 f _S			
DIGITAL INPUT/OUTPUT						
Logic family			TTL compatible			
V _{IH}	Input logic level		2			VDC
V _{IL}					0.8	
I _{IH} ⁽¹⁾	Input logic current	V _{IN} = V _{CC}			10	μA
I _{IL} ⁽¹⁾		V _{IN} = 0 V			-10	
I _{IH} ⁽²⁾		V _{IN} = V _{CC}	65		100	
I _{IL} ⁽²⁾		V _{IN} = 0 V			-10	

- (1) Pins 16, 1, 2, 3: SCK, BCK, DATA, LRCK
- (2) Pins 12-15: TEST, DEMP, MUTE, FMT

ELECTRICAL CHARACTERISTICS (continued)

 All specifications at $T_A = 25^\circ\text{C}$, $V_{CC} = 5\text{ V}$, $f_S = 44.1\text{ kHz}$, system clock = $384 f_S$, and 24-bit data (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{OH}^{(3)}$	Output logic level	$I_{OH} = -1\text{ mA}$	2.4			VDC
$V_{OL}^{(3)}$		$I_{OL} = 1\text{ mA}$			0.4	
DYNAMIC PERFORMANCE⁽⁴⁾⁽⁵⁾						
THD+N at $V_{OUT} = 0\text{ dB}$		$f_S = 44.1\text{ kHz}$		0.00%	0.01%	
		$f_S = 96\text{ kHz}$		0.00%		
		$f_S = 192\text{ kHz}$		0.00%		
THD+N at $V_{OUT} = -60\text{ dB}$		$f_S = 44.1\text{ kHz}$		0.65%		
		$f_S = 96\text{ kHz}$		0.80%		
		$f_S = 192\text{ kHz}$		0.95%		
Dynamic range		EIAJ, A-weighted, $f_S = 44.1\text{ kHz}$	100	106		dB
		A-weighted, $f_S = 96\text{ kHz}$		104		
		A-weighted, $f_S = 192\text{ kHz}$		102		
Signal-to-noise ratio		EIAJ, A-weighted, $f_S = 44.1\text{ kHz}$	100	106		dB
		A-weighted, $f_S = 96\text{ kHz}$		104		
		A-weighted, $f_S = 192\text{ kHz}$		102		
Channel separation		$f_S = 44.1\text{ kHz}$	97	103		dB
		$f_S = 96\text{ kHz}$		101		
		$f_S = 192\text{ kHz}$		100		
Level linearity error		$V_{OUT} = -90\text{ dB}$		± 0.5		dB
DC ACCURACY						
Gain error				± 1	± 6	% of FSR
Gain mismatch, channel-to-channel				± 1	± 3	% of FSR
Bipolar zero error		$V_{OUT} = 0.5 V_{CC}$ at BPZ		± 30	± 60	mV
ANALOG OUTPUT						
Output voltage		Full scale (0 dB)		80% of V_{CC}		V_{PP}
Center voltage				50% of V_{CC}		VDC
Load impedance		AC-coupled load		5		k Ω
DIGITAL FILTER PERFORMANCE						
FILTER CHARACTERISTICS (SHARP ROLLOFF)						
Pass band		$\pm 0.04\text{ dB}$			$0.454 f_S$	
Stop band				0.54 6 f_S		
Pass-band ripple				± 0.04		dB
Stop-band attenuation		Stop band = $0.546 f_S$		-50		dB

(3) Pin 11: ZEROA

(4) Analog performance specifications are measured using the System Two™ Cascade audio measurement system by Audio Precision™ in the averaging mode.

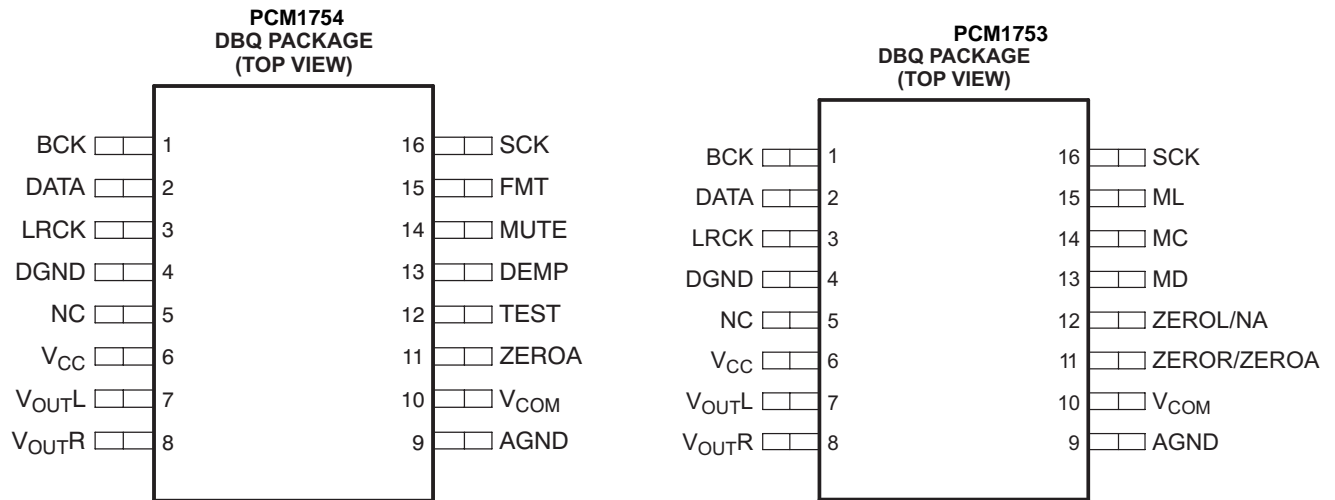
 (5) Conditions in 192-kHz operation are system clock = $128 f_S$ and oversampling rate = $64 f_S$ of register 18.

ELECTRICAL CHARACTERISTICS (continued)

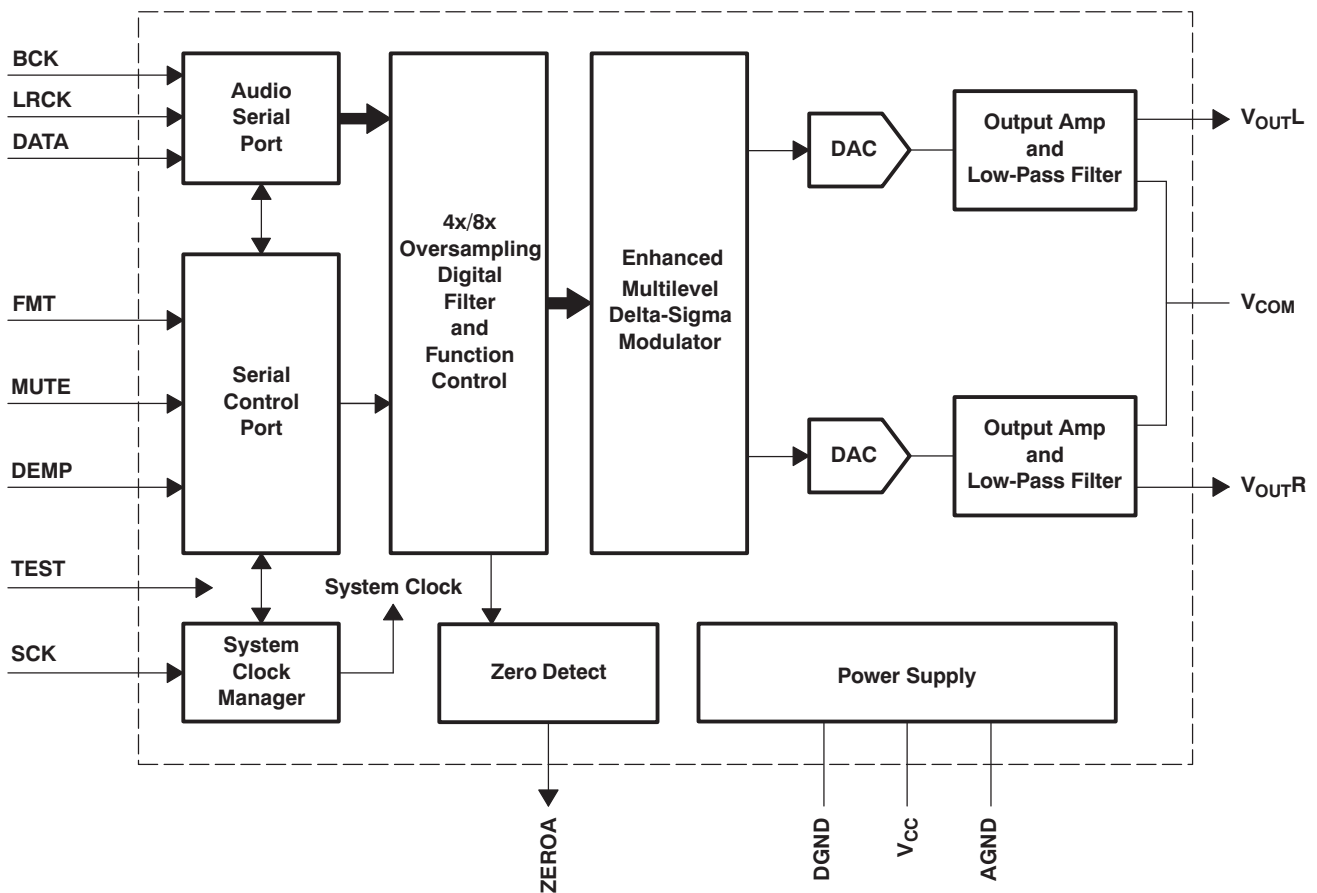
All specifications at $T_A = 25^\circ\text{C}$, $V_{CC} = 5\text{ V}$, $f_S = 44.1\text{ kHz}$, system clock = $384 f_S$, and 24-bit data (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
ANALOG FILTER PERFORMANCE					
Frequency response	At 20 kHz		-0.03		dB
	At 44 kHz		-0.20		
POWER SUPPLY REQUIREMENTS⁽⁶⁾					
V_{CC} Voltage range		4.5	5	5.5	VDC
I_{CC} Supply current	$f_S = 44.1\text{ kHz}$		16	21	mA
	$f_S = 96\text{ kHz}$		25		
	$f_S = 192\text{ kHz}$		30		
Power dissipation	$f_S = 44.1\text{ kHz}$		80	105	mW
	$f_S = 96\text{ kHz}$		125		
	$f_S = 192\text{ kHz}$		150		
TEMPERATURE RANGE					
Operation temperature		-40		105	$^\circ\text{C}$
θ_{JA} Thermal resistance	16-pin SSOP		115		$^\circ\text{C/W}$

(6) Conditions in 192-kHz operation are system clock = $128 f_S$ and oversampling rate = $64 f_S$ of register 18.



FUNCTIONAL BLOCK DIAGRAM



TERMINAL FUNCTIONS

NAME	NO.	I/O	DESCRIPTION
PCM1753			
AGND	9	–	Analog ground
BCK	1	I	Audio–data bit–clock input
DATA	2	I	Audio–data digital input
DGND	4	I	Digital ground
LRCK	3	–	L-channel and R-channel audio data latch enable input
MC	14	I	Mode control clock input ⁽¹⁾
MD	13	I	Mode control data input ⁽¹⁾
ML	15	I	Mode control latch input ⁽¹⁾
NC	5	–	No connection
SCK	16	I	System clock input
V _{CC}	6	I	Analog power supply, 5 V
V _{COM}	10	–	Common voltage decoupling
V _{OUTL}	7	–	Analog output for L-channel
V _{OUTR}	8	O	Analog output for R-channel
ZEROR/ZEROA	11	O	Zero flag output for R-channel/Zero flag output for L-/R-channels ⁽²⁾
ZEROL/NA	12	O	Zero flag output for L-channel/Not assigned ⁽²⁾
PCM1754			
AGND	9	–	Analog ground
BCK	1	I	Audio–data bit–clock input
DATA	2	I	Audio–data digital input
DEMP	13	I	De–emphasis control ⁽¹⁾
DGND	4	–	Digital ground
FMT	15	I	Data format select ⁽¹⁾
LRCK	3	I	L–channel and R–channel audio data latch enable input
MUTE	14	I	Analog mixing control ⁽¹⁾
NC	5	–	No connection
SCK	16	I	System clock input
TEST	12	I	Test pin. Ground or open ⁽¹⁾
V _{CC}	6	–	Analog power supply, 5 V
V _{COM}	10	–	Common voltage decoupling
V _{OUTL}	7	O	Analog output for L–channel
V _{OUTR}	8	O	Analog output for R–channel
ZEROA	11	O	Zero flag output for L/R channels

(1) Schmitt-trigger input with internal pulldown

(2) Open-drain output (PCM1755).

TYPICAL PERFORMANCE CURVES

All specifications at $T_A = 25^\circ\text{C}$, $V_{CC} = 5\text{ V}$, $f_S = 44.1\text{ kHz}$, system clock = $384 f_S$, and 24-bit data, (unless otherwise noted)

DIGITAL FILTER (DE-EMPHASIS OFF)

AMPLITUDE
vs
FREQUENCY

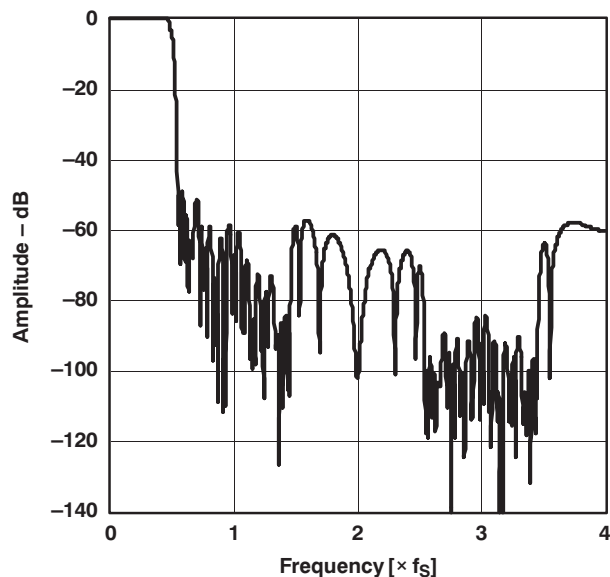


Figure 1. Frequency Response, Sharp Rolloff

AMPLITUDE
vs
FREQUENCY

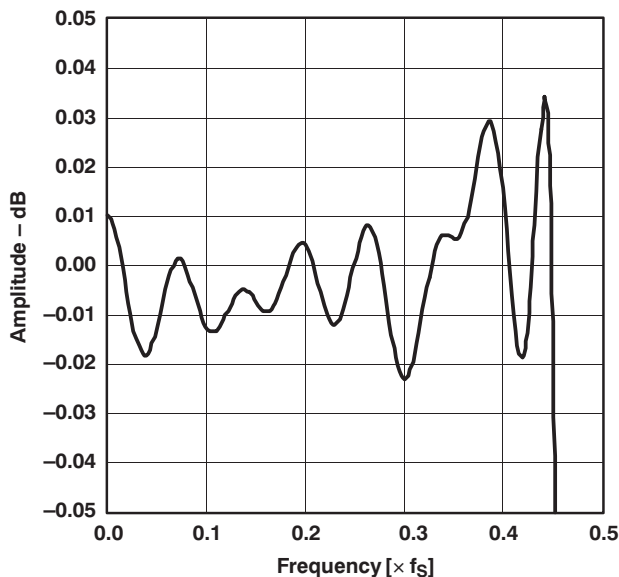


Figure 2. Pass-Band Ripple, Sharp Rolloff

AMPLITUDE
vs
FREQUENCY

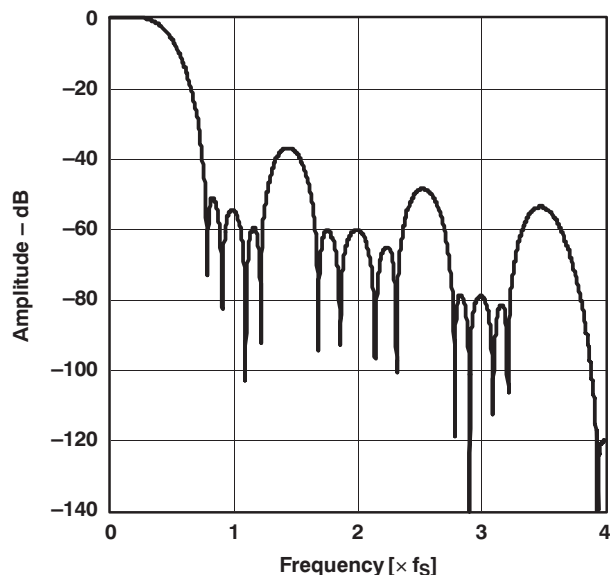


Figure 3. Frequency Response, Slow Rolloff

AMPLITUDE
vs
FREQUENCY

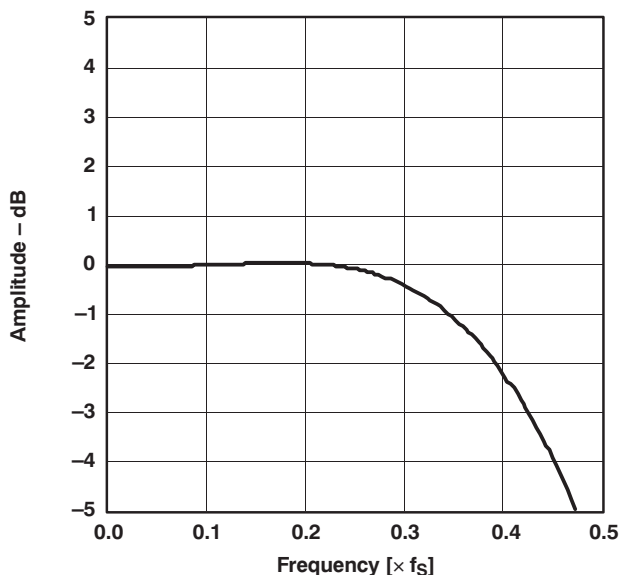


Figure 4. Transition Characteristics, Slow Rolloff

TYPICAL PERFORMANCE CURVES (continued)

All specifications at $T_A = 25^\circ\text{C}$, $V_{CC} = 5\text{ V}$, $f_S = 44.1\text{ kHz}$, system clock = $384 f_S$, and 24-bit data, (unless otherwise noted)

DE-EMPHASIS LEVEL

vs
FREQUENCY

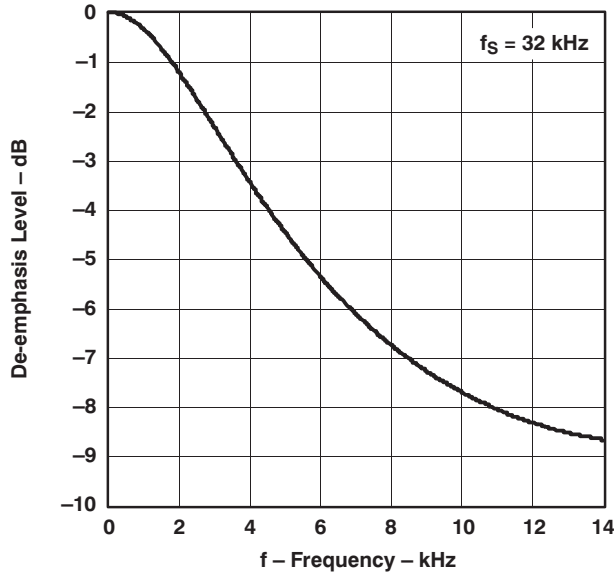


Figure 5.

DE-EMPHASIS ERROR

vs
FREQUENCY

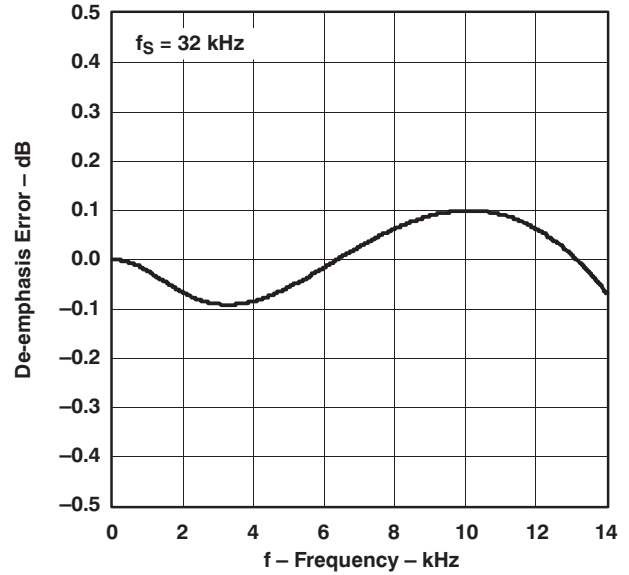


Figure 6.

DE-EMPHASIS LEVEL

vs
FREQUENCY

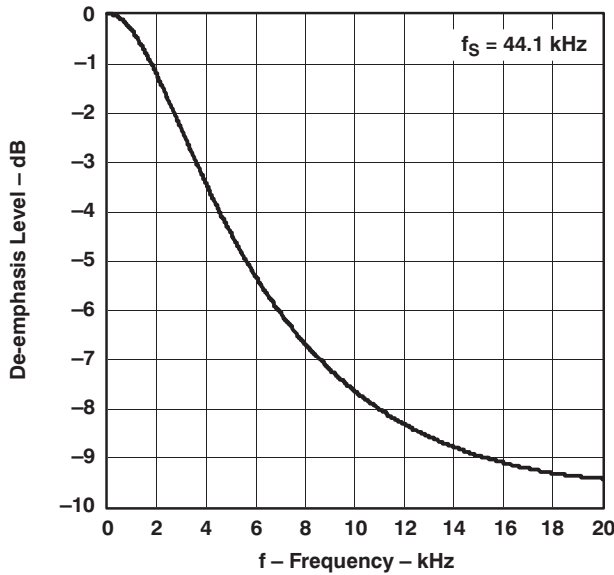


Figure 7.

DE-EMPHASIS ERROR

vs
FREQUENCY

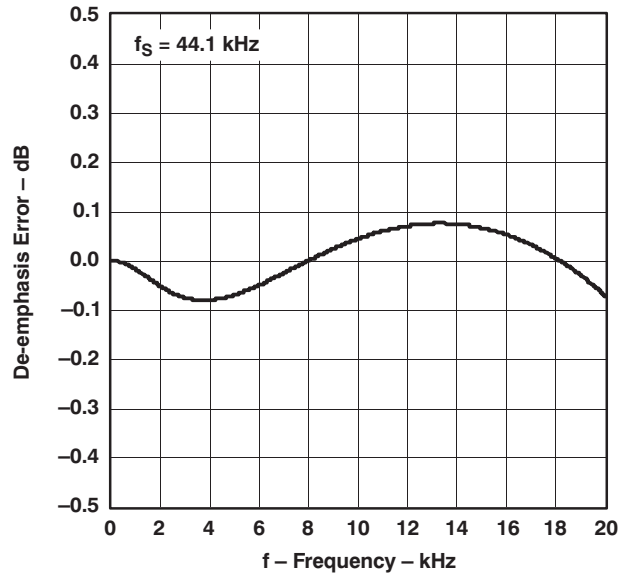


Figure 8.

TYPICAL PERFORMANCE CURVES (continued)

All specifications at $T_A = 25^\circ\text{C}$, $V_{CC} = 5\text{ V}$, $f_S = 44.1\text{ kHz}$, system clock = $384 f_S$, and 24-bit data, (unless otherwise noted)

DE-EMPHASIS LEVEL

vs
FREQUENCY

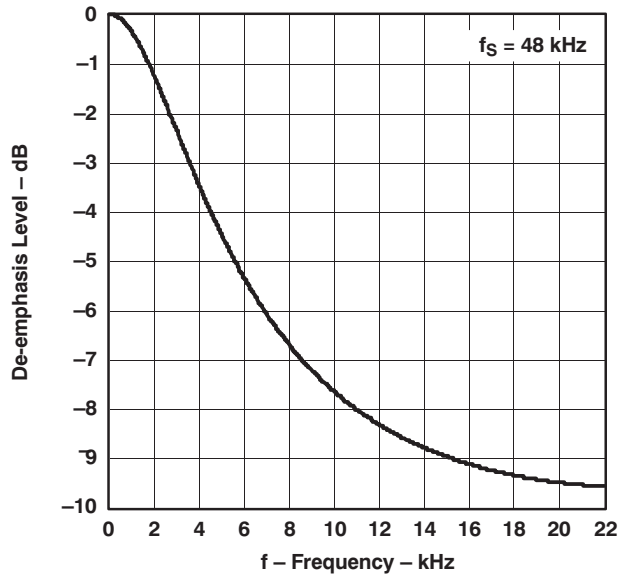


Figure 9.

DE-EMPHASIS ERROR

vs
FREQUENCY

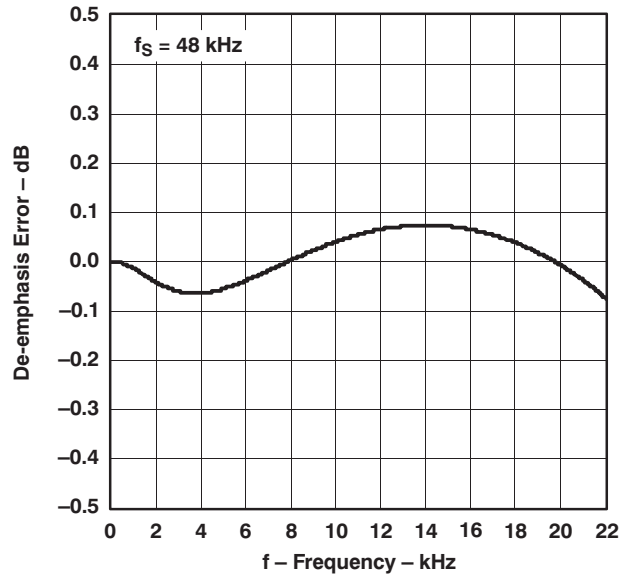


Figure 10.

TYPICAL PERFORMANCE CURVES (continued)

All specifications at $T_A = 25^\circ\text{C}$, $V_{CC} = 5\text{ V}$, $f_S = 44.1\text{ kHz}$, system clock = $384 f_S$, and 24-bit data, (unless otherwise noted)

ANALOG DYNAMIC PERFORMANCE (SUPPLY VOLTAGE CHARACTERISTICS)

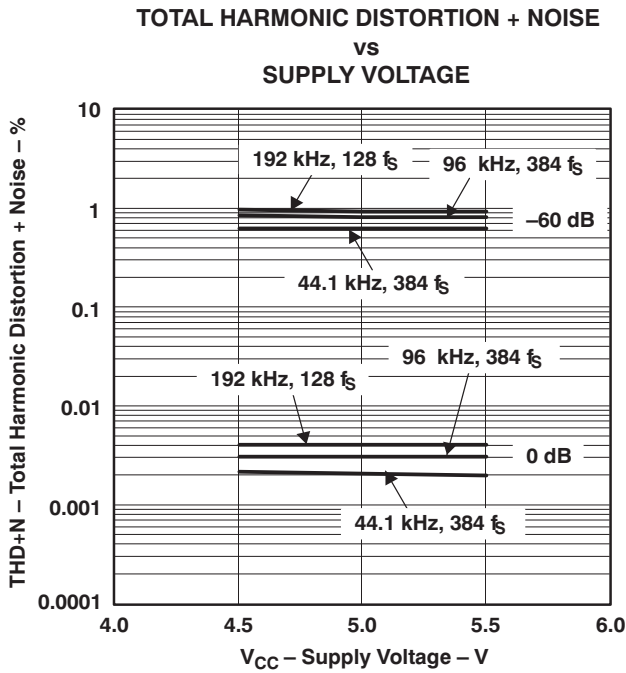


Figure 11.

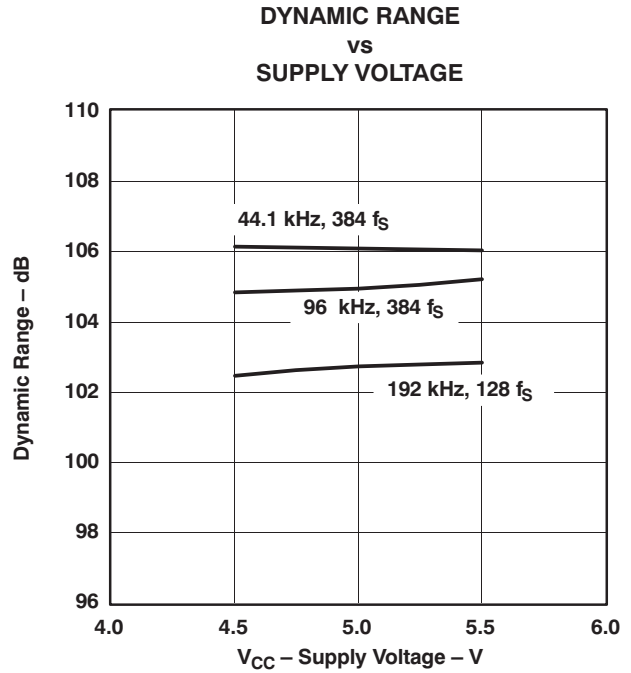


Figure 12.

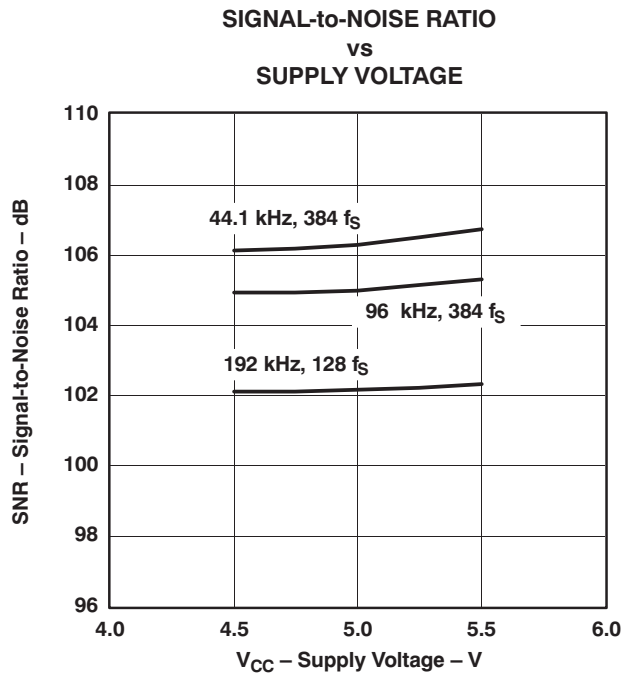


Figure 13.

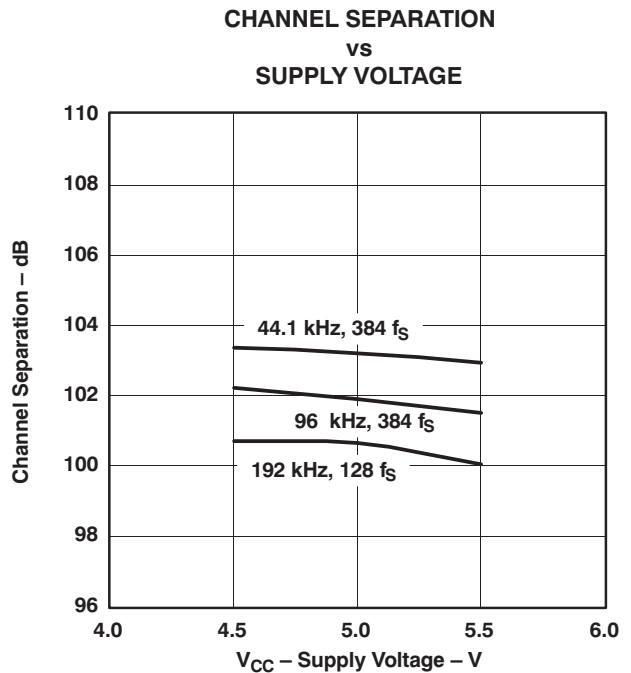


Figure 14.

TYPICAL PERFORMANCE CURVES (continued)

All specifications at $T_A = 25^\circ\text{C}$, $V_{CC} = 5\text{ V}$, $f_S = 44.1\text{ kHz}$, system clock = $384 f_S$, and 24-bit data, (unless otherwise noted)

ANALOG DYNAMIC PERFORMANCE (TEMPERATURE CHARACTERISTICS)

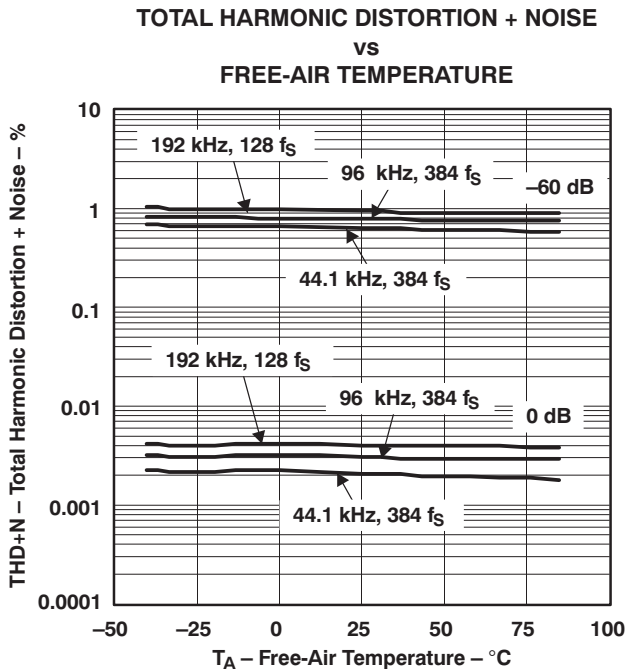


Figure 15.

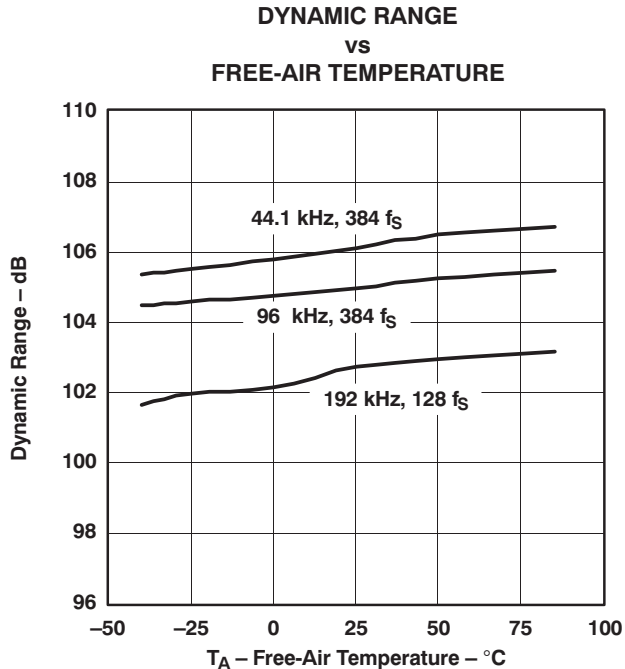


Figure 16.

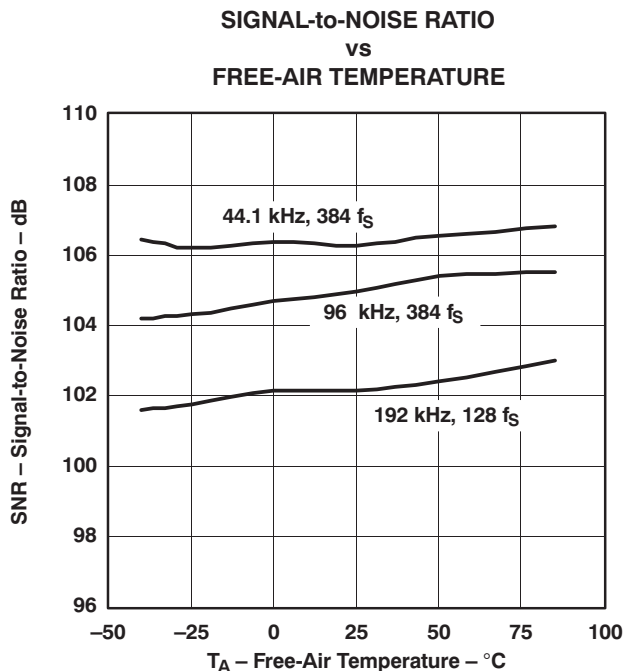


Figure 17.

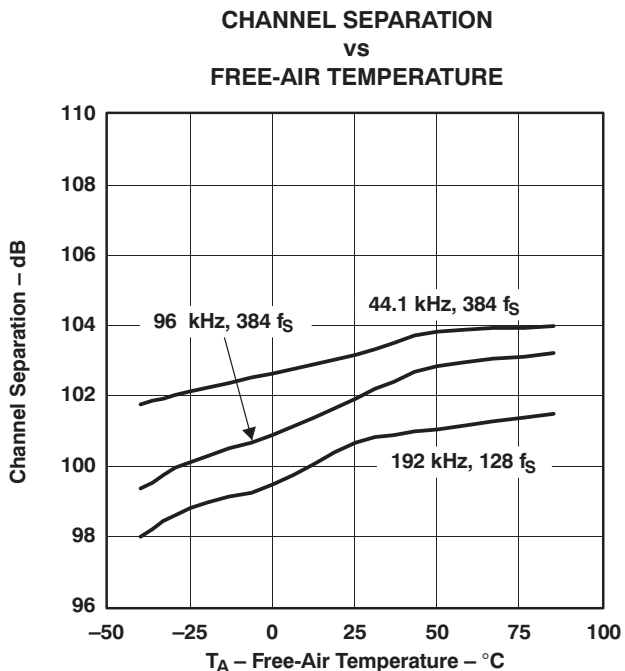


Figure 18.

SYSTEM CLOCK AND RESET FUNCTIONS

System Clock Input

The PCM175x requires a system clock for operating the digital interpolation filters and multilevel delta-sigma modulators. The system clock is applied at the SCK input (pin 16). Table 1 shows examples of system clock frequencies for common audio sampling rates.

Figure 19 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. TI's PLL170x family of multiclock generators is an excellent choice for providing the PCM175x system clock.

Table 1. System Clock Rates for Common Audio Sampling Frequencies

SAMPLING FREQUENCY	SYSTEM CLOCK FREQUENCY (f_{SCLK}) (MHz)						
	128 f_s	192 f_s	256 f_s	384 f_s	512 f_s	768 f_s	1152 f_s
8 kHz	1.024	1.536	2.048	3.072	4.096	6.144	9.216
16 kHz	2.048	3.072	4.096	6.144	8.192	12.288	18.432
32 kHz	4.096	6.144	8.192	12.288	16.384	24.576	36.864
44.1 kHz	5.6448	8.4672	11.2896	16.9344	22.5792	33.8688	(1)
48 kHz	6.144	9.216	12.288	18.432	24.576	36.864	(1)
88.2 kHz	11.2896	16.9344	22.5792	33.8688	45.1584	(1)	(1)
96 kHz	12.288	18.432	24.576	36.864	49.152	(1)	(1)
192 kHz	24.576	36.864	(1)	(1)	(1)	(1)	(1)

(1) This system clock rate is not supported for the given sampling frequency.

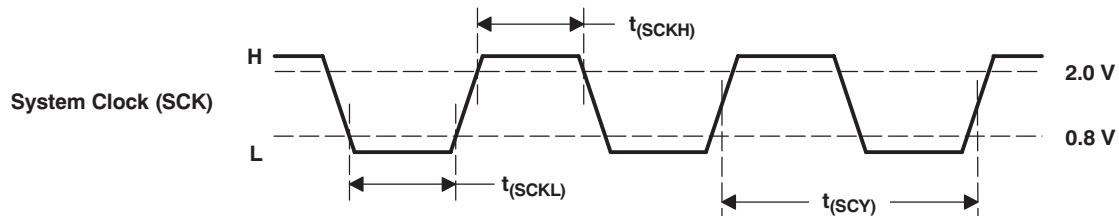


Figure 19. System Clock Input Timing

Table 2. System Clock Input Timing

PARAMETER	SYMBOL	MIN	TYP	MAX	UNIT
System clock pulse duration, high	$t_{(SCKH)}$	7			ns
System clock pulse duration, low	$t_{(SCKL)}$	7			ns
System clock pulse cycle time	$t_{(SCY)}$		(1)		ns

(1) 1/128 f_s , 1/256 f_s , 1/384 f_s , 1/512 f_s , 1/768 f_s , or 1/1152 f_s

Power-On Reset Functions

The PCM175x includes a power-on reset function. Figure 20 shows the operation of this function. With the system clock active and $V_{CC} > 3\text{ V}$ (typical, 2.2 V to 3.7 V), the power-on reset function is enabled. The initialization sequence requires 1024 system clocks from the time $V_{CC} > 3\text{ V}$ (typical, 2.2 V to 3.7 V).

During the reset period (1024 system clocks), the analog output is forced to the bipolar zero level, or $V_{CC}/2$. After the reset period, an internal register is initialized in the next $1/f_S$ period and if SCK, BCK, and LRCK are provided continuously, the PCM175x provides proper analog output with unit group delay against the input data.

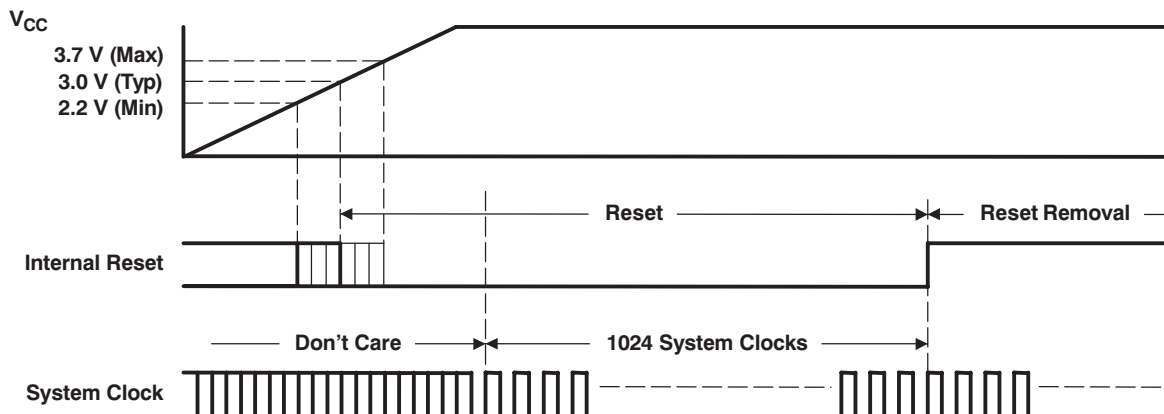


Figure 20. Power-On Reset Timing

AUDIO SERIAL INTERFACE

The audio serial interface for the PCM175x consists of a 3-wire synchronous serial port. It includes LRCK (pin 3), BCK (pin 1), and DATA (pin 2). 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 PCM175x on the rising edge of BCK. LRCK is the serial audio left/right word clock. It is used to latch serial data into the internal registers of the serial audio interface.

Both LRCK and BCK should be synchronous to the system clock. Ideally, it is recommended that LRCK and BCK be derived from the system clock input, SCK. LRCK is operated at the sampling frequency, f_S . BCK can be operated at 32, 48, or 64 times the sampling frequency for standard (right-justified) format, and 32 times the sampling frequency of BCK is limited to 16-bit right-justified format only. BCK can be operated at 48 or 64 times the sampling frequency for the I²S and left-justified formats. 48 times the sampling frequency of BCK is limited to $192/384/768 f_S$ SCKI.

Internal operation of the PCM175x is synchronized with LRCK. Accordingly, internal operation is held when the sampling rate clock of LRCK is changed or when SCK and/or BCK is interrupted for a 3-bit clock cycle or longer. If SCK, BCK, and LRCK are provided continuously after this held condition, the internal operation is re-synchronized automatically in a period of less than $3/f_S$. External resetting is not required.

Audio Data Formats and Timing

The PCM1753 supports industry-standard audio data formats, including right-justified, I2S, and left-justified. The PCM1754 supports I²S and 16-bit-word right-justified audio data formats. The data formats are shown in [Figure 22](#). Data formats are selected using the format bits, FMT[2:0], located in control register 20 of the PCM1753, and are selected using the FMT pin on the PCM1754. The default data format is 24-bit left-justified. All formats require binary 2s-complement MSB-first audio data. [Figure 21](#) shows a detailed timing diagram for the serial audio interface.

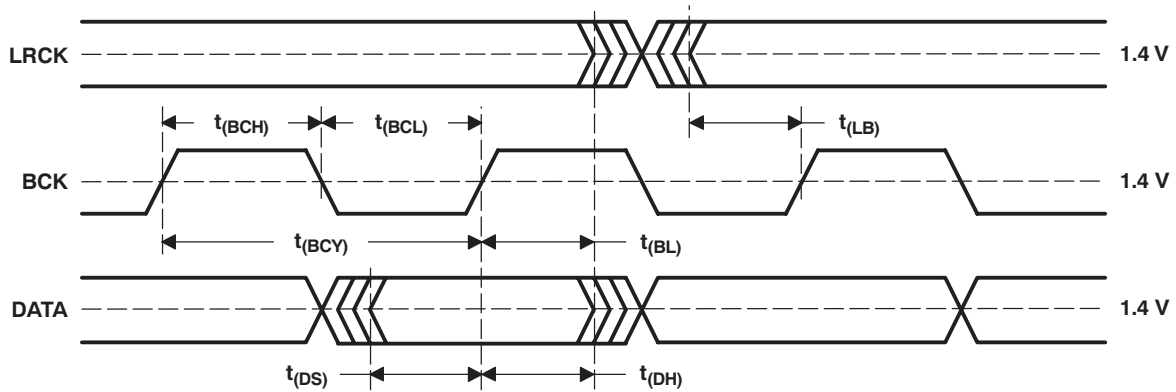


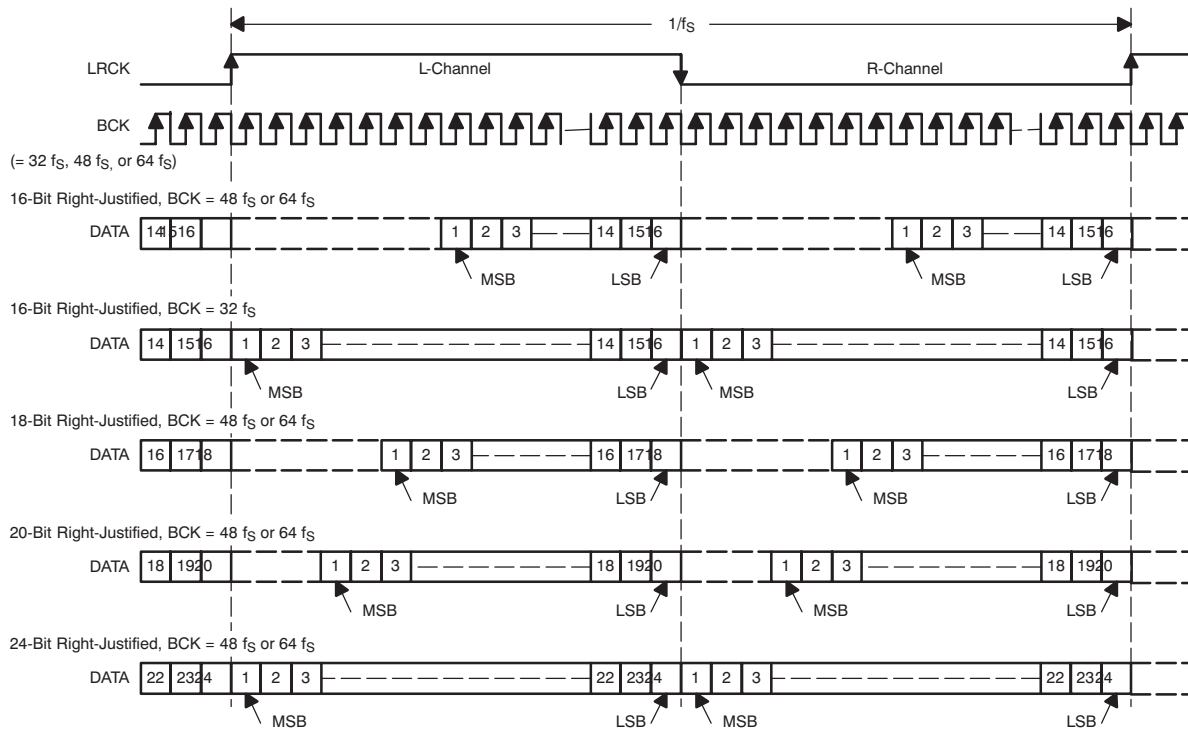
Figure 21. Audio Interface Timing

Table 3. Audio Interface Timing

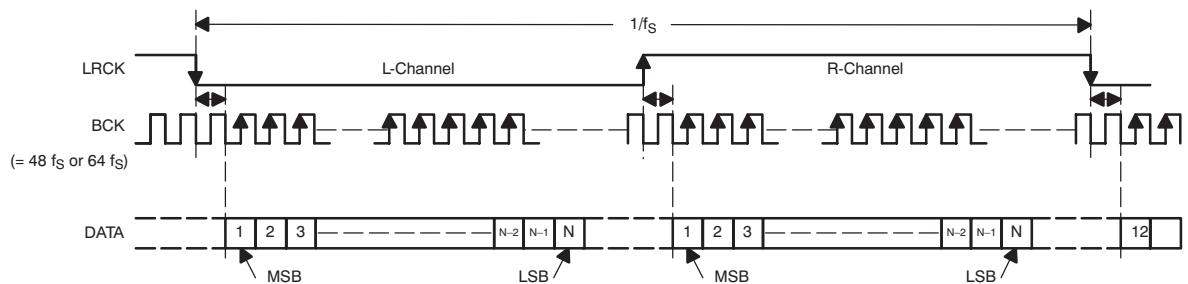
PARAMETER	SYMBOL	MIN	MAX	UNIT
BCK pulse cycle time	$t_{(BCY)}$	$1/(32 f_s)$, $1/(48 f_s)$, $1/(64 f_s)$ ⁽¹⁾		
BCK high-level time	$t_{(BCH)}$	35		ns
BCK low-level time	$t_{(BCL)}$	35		ns
BCK rising edge to LRCK edge	$t_{(BL)}$	10		ns
LRCK falling edge to BCK rising edge	$t_{(LB)}$	10		ns
DATA setup time	$t_{(DS)}$	10		ns
DATA hold time	$t_{(DH)}$	10		ns

(1) f_s is the sampling frequency (e.g., 44.1 kHz, 48 kHz, 96 kHz, etc.).

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



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



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

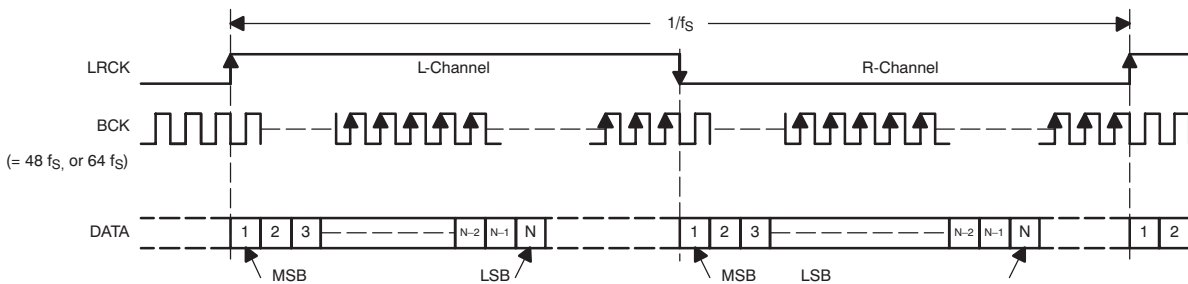


Figure 22. Audio Data Input Formats

ZERO FLAG (PCM1754)

The PCM1754 has a ZERO flag pin, ZEROA (pin 11). ZEROA is the L-channel and R-channel common zero flag pin. If the data for L-channel and R-channel remains at a 0 level for 1024 sampling periods (or LRCK clock periods), ZEROA is set to a logic 1 state.

ZERO FLAG (PCM1753)

Zero-Detect Condition

Zero detection for either output channel is independent from the other channel. If the data for a given channel remains at a 0 level for 1024 sample periods (or LRCK clock periods), a zero-detect condition exists for that channel.

Zero Flag Outputs

If a zero-detect condition exists for one or more channels, the zero flag pins for those channels are set to a logic 1 state. There are zero flag pins for each channel, ZEROL (pin 12) and ZEROR (pin 11). These pins can be used to operate external mute circuits, or used as status indicators for a microcontroller, audio signal processor, or other digitally controlled function. The active polarity of zero flag outputs can be inverted by setting the ZREV bit of control register 22 to 1. The reset default is active-high output, or ZREV = 0. The L-channel and R-channel common zero flag can be selected by setting the AZRO bit of control register 22 to 1. The reset default is independent zero flags for L-channel and R-channel, or AZRO = 0.

HARDWARE CONTROL (PCM1754)

The digital functions of the PCM1754 are capable of hardware control. [Table 4](#) shows selectable formats, [Table 5](#) shows de-emphasis control, and [Table 6](#) shows mute control.

Table 4. Data Format Select

FMT (PIN 15)	DATA FORMAT
LOW	16- to 24-bit, I ² S format
HIGH	16-bit right-justified

Table 5. De-Emphasis Control

DEMP (PIN 13)	DE-EMPHASIS FUNCTION
LOW	44.1 kHz de-emphasis OFF
HIGH	44.1 kHz de-emphasis ON

Table 6. Mute Control

MUTE (PIN 14)	MUTE
LOW	Mute OFF
HIGH	Mute ON

OVERSAMPLING RATE CONTROL(PCM1754)

The PCM1754 automatically controls the oversampling rate of the delta-sigma D/A converters with the system clock rate. The oversampling rate is set to 64× oversampling with every system clock and sampling frequency.

SOFTWARE CONTROL (PCM1753/55)

The PCM1753/55 has many programmable functions which can be controlled in the software control mode. The functions are controlled by programming the internal registers using ML, MC, and MD.

The serial control interface is a 3-wire serial port, which operates asynchronously to the audio serial interface. The serial control interface is used to program the on-chip mode registers. The control interface includes MD (pin 13), MC (pin 14), and ML (pin 15). MD is the serial data input, used to program the mode registers. MC is the serial bit clock, used to shift data into the control port. ML is the control port latch clock.

Register Write Operation

All write operations for the serial control port use 16-bit data words. Figure 23 shows the control data word format. The most significant bit must be a 0. There are seven bits, labeled IDX[6:0], that set the register index (or address) for the write operation. The least significant eight bits, D[7:0], contain the data to be written to the register specified by IDX[6:0].

Figure 24 shows the functional timing diagram for writing to the serial control port. ML is held at a logic 1 state until a register needs to be written. To start the register write cycle, ML is set to logic 0. Sixteen clocks are then provided on MC, corresponding to the 16 bits of the control data word on MD. After the sixteenth clock cycle has completed, ML is set to logic 1 to latch the data into the indexed mode control register.

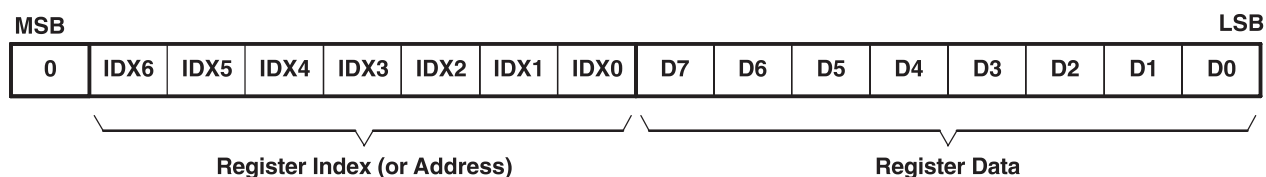


Figure 23. Control Data Word Format for MD

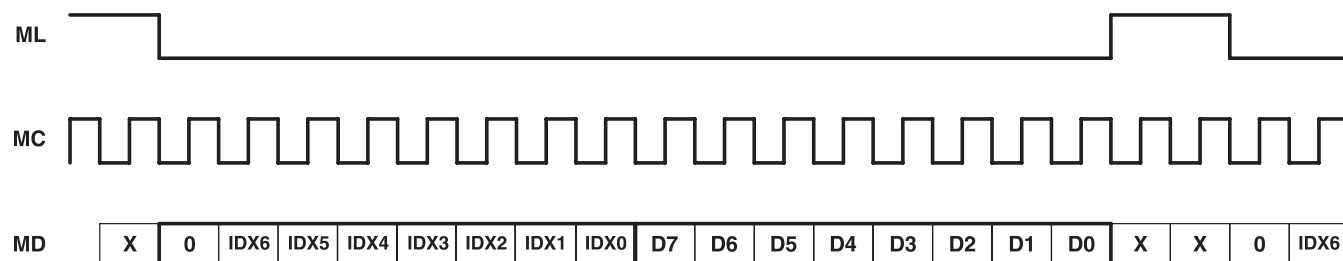
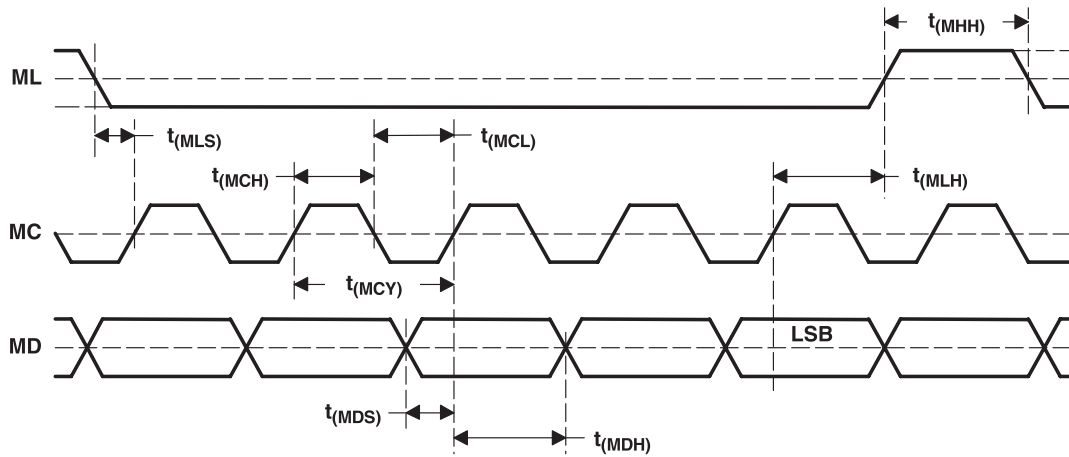


Figure 24. Register Write Operation

Control Interface Timing Requirements

Figure 25 shows a detailed timing diagram for the serial control interface. These timing parameters are critical for proper control port operation.



PARAMETERS	SYMBOL	MIN	TYP	MAX	UNITS
MC pulse cycle time	$t_{(MCY)}$	100			ns
MC low-level time	$t_{(MCL)}$	50			ns
MC high-level time	$t_{(MCH)}$	50			ns
ML high-level time	$t_{(MHH)}$	(2)			ns
ML falling edge to MC rising edge	$t_{(MLS)}$	20			ns
ML hold time ⁽¹⁾	$t_{(MLH)}$	20			ns
MD hold time	$t_{(MDH)}$	15			ns
MD setup time	$t_{(MDS)}$	20			ns

⁽¹⁾ MC rising edge for LSB to ML rising edge.

⁽²⁾ $\frac{3}{256 \times f_S}$ sec (min); f_S : sampling rate

Figure 25. Control Interface Timing

MODE CONTROL REGISTERS (PCM1753/55)

User-Programmable Mode Controls

The PCM1753/55 includes a number of user programmable functions, which are accessed via control registers. The registers are programmed using the serial control interface, which was previously discussed in this data sheet. [Table 7](#) lists the available mode control functions, along with their reset default conditions and associated register index.

Table 7. User-Programmable Mode Controls

FUNCTION	RESET DEFAULT	REGISTER	BIT(s)
Digital attenuation control, 0 dB to –63 dB in 0.5-dB steps	0 dB, no attenuation	16 and 17	AT1[7:0], AT2[7:0]
Soft mute control	Mute disabled	18	MUT[2:0]
Oversampling rate control (64 f _S or 128 f _S)	64 f _S oversampling	18	OVER
Soft reset control	Reset disabled	18	SRST
DAC operation control	DAC1 and DAC2 enabled	19	DAC[2:1]
De-emphasis function control	De-emphasis disabled	19	DM12
De-emphasis sample rate selection	44.1 kHz	19	DMF[1:0]
Audio data format control	24-bit left-justified	20	FMT[2:0]
Digital filter rolloff control	Sharp rolloff	20	FLT
Zero flag function select	L-, R-channel independent	22	AZRO
Output phase select	Normal phase	22	DREV
Zero flag polarity select	High	22	ZREV

Register Map

The mode control register map is shown in [Table 8](#). Each register includes an index (or address) indicated by the IDX[6:0] bits.

Table 8. Mode Control Register Map⁽¹⁾

IDX (B8–B 14)	REGISTER	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
10h	Register 16	0	IDX6	IDX5	IDX4	IDX3	IDX2	IDX1	IDX0	AT17	AT16	AT15	AT14	AT13	AT12	AT11	AT10
11h	Register 17	0	IDX6	IDX5	IDX4	IDX3	IDX2	IDX1	IDX0	AT27	AT26	AT25	AT24	AT23	AT22	AT21	AT20
12h	Register 18	0	IDX6	IDX5	IDX4	IDX3	IDX2	IDX1	IDX0	SRST	OVER	RSV	RSV	RSV	RSV	MUT2	MUT1
13h	Register 19	0	IDX6	IDX5	IDX4	IDX3	IDX2	IDX1	IDX0	RSV	DMF1	DMF0	DM12	RSV	RSV	DAC2	DAC1
14h	Register 20	0	IDX6	IDX5	IDX4	IDX3	IDX2	IDX1	IDX0	RSV	RSV	FLT	RSV	RSV	FMT2	FMT1	FMT0
16h	Register 22	0	IDX6	IDX5	IDX4	IDX3	IDX2	IDX1	IDX0	RSV	RSV	RSV	RSV	RSV	AZRO	ZREV	DREV

(1) RSV: Reserved for test operation. It should be set to 0 for regular operation.

Register Definitions

	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Register 16	0	IDX6	IDX5	IDX4	IDX3	IDX2	IDX1	IDX0	AT17	AT16	AT15	AT14	AT13	AT12	AT11	AT10

	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Register 17	0	IDX6	IDX5	IDX4	IDX3	IDX2	IDX1	IDX0	AT27	AT26	AT25	AT24	AT23	AT22	AT21	AT20

ATx[7:0]: Digital Attenuation Level Setting

Where x = 1 or 2, corresponding to the DAC output V_{OUTL} (x = 1) and V_{OUTR} (x = 2).

Default value: 1111 1111b

Each DAC channel (V_{OUTL} and V_{OUTR}) includes a digital attenuation function. The attenuation level can be set from 0 dB to –63 dB in 0.5-dB steps. Changes in attenuator levels are made by incrementing or decrementing one step (0.5 dB) for every 8/fS time interval until the programmed attenuator setting is reached. Alternatively, the attenuation level can be set to infinite attenuation (or mute).

The attenuation data for each channel can be set individually. The attenuation level is set using the following formula:

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

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

For ATx[7:0]_{DEC} = 0 through 128, attenuation is set to infinite attenuation.

The following table shows the 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
⋮	⋮	⋮
1000 0011b	131	–62.0 dB
1000 0010b	130	–62.5 dB
1000 0001b	129	–63.0 dB
1000 0000b	128	Mute
⋮	⋮	⋮
0000 0000 _B	0	Mute

	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Register 18	0	IDX6	IDX5	IDX4	IDX3	IDX2	IDX1	IDX0	SRST	OVER	RSV	RSV	RSV	RSV	MUT2	MUT1

MUTx: Soft Mute Control

where x = 1 or 2, corresponding to the DAC outputs V_{OUTL} (x = 1) and V_{OUTR} (x = 2).

Default value: 0

MUTx = 0	Mute disabled (default)
MUTx = 1	Mute enabled

The mute bits, MUT1 and MUT2, are used to enable or disable the soft mute function for the corresponding DAC outputs, V_{OUTL} and V_{OUTR}. The soft mute function is incorporated into the digital attenuators. When mute is disabled (MUTx = 0), the attenuator and DAC operate normally. When mute is enabled by setting MUTx = 1, the digital attenuator for the corresponding output is decreased from the current setting to infinite attenuation, one attenuator step (0.5 dB) for every 8/fS seconds. This provides pop-free muting of the DAC output.

By setting MUTx = 0, the attenuator is increased one step for every 8/f_S seconds to the previously programmed attenuation level.

OVER: Oversampling Rate Control

Default value: 0

System clock rate = 256 f_S, 384 f_S, 512 f_S, 768 f_S, or 1152 f_S:

OVER = 0	64· oversampling (default)
OVER = 1	128· oversampling

System clock rate = 128 f_S or 192 f_S:

OVER = 0	32· oversampling (default)
OVER = 1	64· oversampling

The OVER bit is used to control the oversampling rate of the delta-sigma D/A converters. The OVER = 1 setting is recommended when the sampling rate is 192 kHz (system clock rate is 128 f_S or 192 f_S).

SRST: Reset

Default value: 0

SRST = 0	Reset disabled (default)
SRST = 1	Reset enabled

The SRST bit is used to enable or disable the soft reset function. The operation is the same as power-on reset. All registers are initialized.

	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Register 19	0	IDX6	IDX5	IDX4	IDX3	IDX2	IDX1	IDX0	RSV	DMF1	DMF0	DM12	RSV	RSV	DAC2	DAC1

DACx: DAC Operation Control

Where x = 1 or 2, corresponding to the DAC output V_{OUTL} (x = 1) or V_{OUTR} (x = 2).

Default value: 0

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

The DAC operation controls are used to enable and disable the DAC outputs, V_{OUTL} and V_{OUTR}. When DACx = 0, the corresponding output generates the audio waveform dictated by the data present on the DATA pin. When DACx = 1, the corresponding output is set to the bipolar zero level, or 0.5 V_{CC}.

DM12: Digital De-Emphasis Function Control

Default value: 0

DM12 = 0	De-emphasis disabled (default)
DM12 = 1	De-emphasis enabled

The DM12 bit is used to enable or disable the digital de-emphasis function. See the plots shown in the *Typical Performance Curves* section of this data sheet.

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

Default value: 00

The DMF[1:0] bits are used to select the sampling frequency used for the digital de-emphasis function when it is enabled.

DMF[1:0]	De-Emphasis Sample Rate Selection
00	44.1 kHz (default)
01	48 kHz
10	32 kHz
11	Reserved

	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Register 20	0	IDX6	IDX5	IDX4	IDX3	IDX2	IDX1	IDX0	RSV	RSV	FLT	RSV	RSV	FMT2	FMT1	FMT0

FMT[2:0]: Audio Interface Data Format

Default value: 101

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

FMT[2:0]	Audio Data Format Selection
000	24-bit standard format, right-justified data
001	20-bit standard format, right-justified data
010	18-bit standard format, right-justified data
011	16-bit standard format, right-justified data
100	16- to 24-bit I ² S format
101	16- to 24-bit left-justified format (default)
110	Reserved
111	Reserved

FLT: Digital Filter Rolloff Control

Default value: 0

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

The FLT bit allows the user to select the digital filter rolloff that is best suited to the application. Two filter rolloff selections are available, sharp and slow. The filter responses for these selections are shown in the *Typical Performance Curves* section of this data sheet.

	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Register 22	0	IDX6	IDX5	IDX4	IDX3	IDX2	IDX1	IDX0	RSV	RSV	RSV	RSV	RSV	AZRO	ZREV	DREV

DREV: Output Phase Select

Default value: 0

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

The DREV bit is the output analog signal phase control.

ZREV: Zero Flag Polarity Select

Default value: 01h

ZREV = 0	High on zero flag pins indicates a zero detect (default)
ZREV = 1	Low on zero flag pins indicates a zero detect

The ZREV bit allows the user to select the polarity of zero flag pins.

AZRO: Zero Flag Function Select

Default value: 0

AZRO = 0	L-/R-channel independent zero flags (default)
AZRO = 1	L-/R-channel common zero flag

The AZRO bit allows the user to select the function of zero flag pins.

AZRO = 0:	Pin 11: ZEROR, zero flag output for R-channel
	Pin 12: ZEROL, zero flag output for L-channel
AZRO = 1:	Pin 11: ZEROA, zero flag output for L-/R-channels
	Pin 12: NA, not assigned

ANALOG OUTPUTS

The PCM1753 includes two independent output channels, V_{OUTL} and V_{OUTR} . These are unbalanced outputs, each capable of driving 4 V_{PP} typical into a 5-k Ω ac-coupled load. The internal output amplifiers for V_{OUTL} and V_{OUTR} are biased to the dc common-mode (or bipolar zero) voltage, equal to 0.5 V_{CC} .

The output amplifiers include an RC continuous-time filter, which helps to reduce the out-of-band noise energy present at the DAC outputs due to the noise shaping characteristics of the PCM1754 delta-sigma D/A converters. The frequency response of this filter is shown in [Figure 26](#). By itself, this filter is not enough to attenuate the out-of-band noise to an acceptable level for many applications. An external low-pass filter is required to provide sufficient out-of-band noise rejection. Further discussion of DAC post-filter circuits is provided in the Applications Information section of this data sheet.

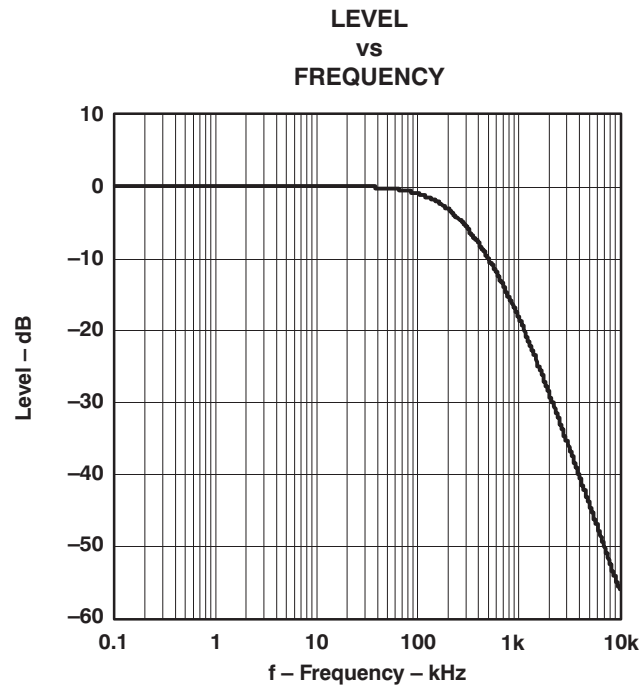
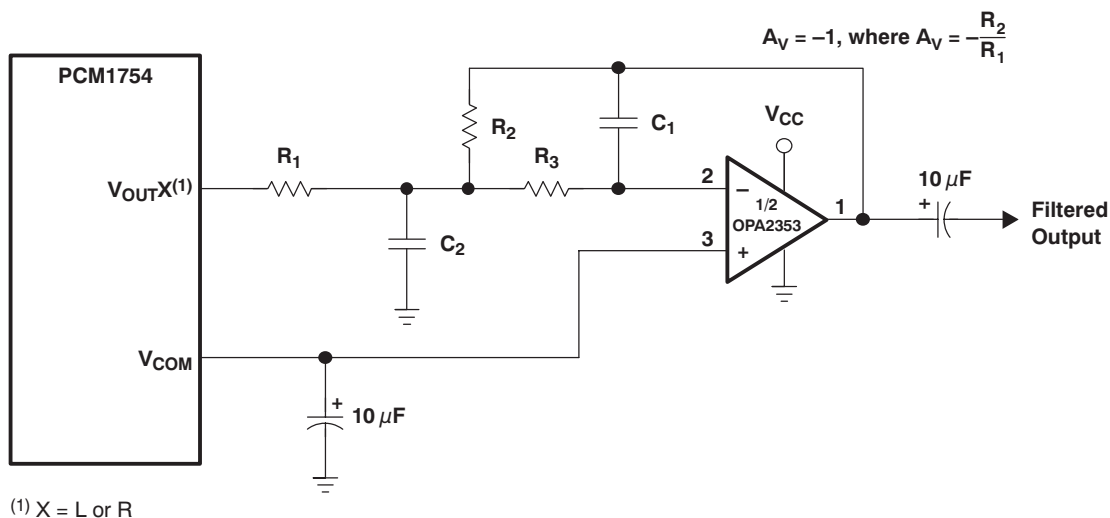


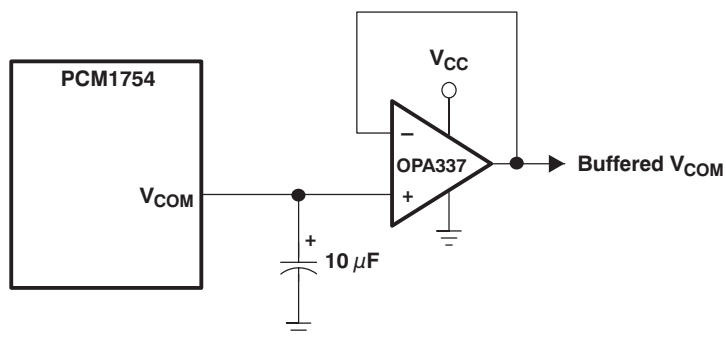
Figure 26. Output Filter Frequency Response

V_{COM} Output

One unbuffered common-mode voltage output pin, V_{COM} (pin 10) is brought out for decoupling purposes. This pin is nominally biased to a dc voltage level equal to 0.5 V_{CC}. This pin can be used to bias external circuits. Figure 27 shows an example of using the V_{COM} pin for external biasing applications.



(a) Using V_{COM} to Bias a Single-Supply Filter Stage



(b) Using a Voltage Follower to Buffer V_{COM} When Biasing Multiple Nodes

Figure 27. Biasing External Circuits Using the V_{COM} Pin

APPLICATION INFORMATION

CONNECTION DIAGRAMS

A basic connection diagram is shown in [Figure 28](#), with the necessary power supply bypassing and decoupling components. TI recommends using the component values shown in [Figure 28](#) for all designs.

The use of series resistors (22 Ω to 100 Ω) is recommended for the SCK, LRCK, BCK, and DATA inputs. The series resistor combines with the stray PCB and device input capacitance to form a low-pass filter, which reduces high-frequency noise emissions and helps to dampen glitches and ringing present on clock and data lines.

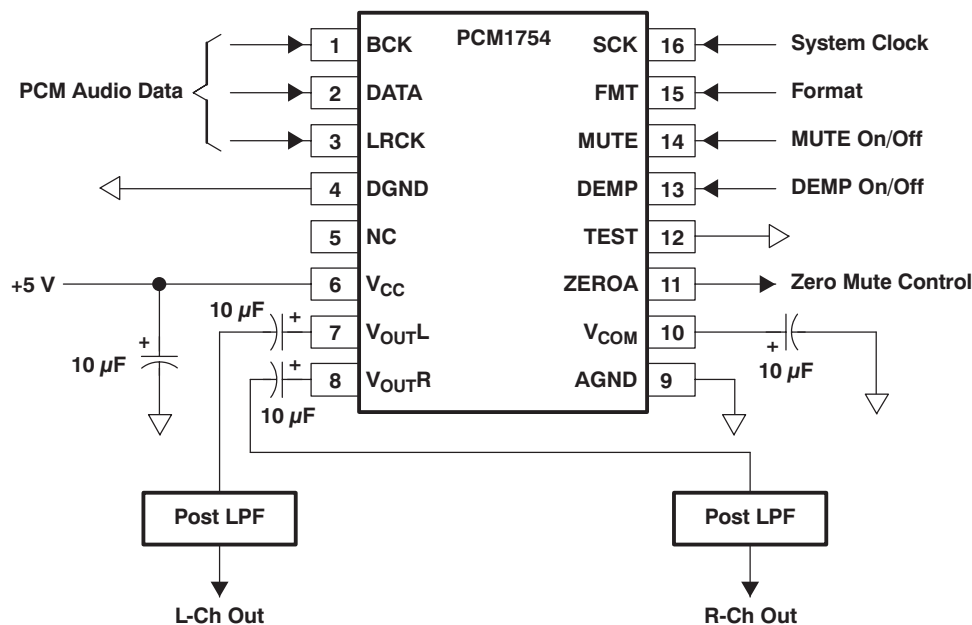


Figure 28. Basic Connection Diagram

POWER SUPPLIES AND GROUNDING

The PCM1754 requires 5 V for V_{CC} .

Proper power supply bypassing is shown in [Figure 28](#). The 10- μ F capacitors should be tantalum or aluminum electrolytic.

D/A OUTPUT FILTER CIRCUITS

Delta-sigma D/A converters use noise-shaping techniques to improve in-band signal-to-noise ratio (SNR) performance at the expense of generating increased out-of-band noise above the Nyquist frequency, or $f_s/2$. The out-of-band noise must be low-pass filtered in order to provide the optimal converter performance. This is accomplished by a combination of on-chip and external low-pass filtering.

[Figure 27\(a\)](#) and [Figure 29](#) show the recommended external low-pass active filter circuits for single- and dual-supply applications. These circuits are 2nd-order Butterworth filters using the multiple feedback (MFB) circuit arrangement, which reduces sensitivity to passive component variations over frequency and temperature. For more information regarding MFB active filter design, see Burr-Brown applications bulletin (SBAA055), available from the TI Web site at <http://www.ti.com>.

Because the overall system performance is defined by the quality of the D/A converters and their associated analog output circuitry, high-quality audio operational amplifiers are recommended for the active filters. TI's OPA2353 and OPA2134 dual operational amplifiers are shown in [Figure 27\(a\)](#) and [Figure 29](#), and are recommended for use with the PCM1754.

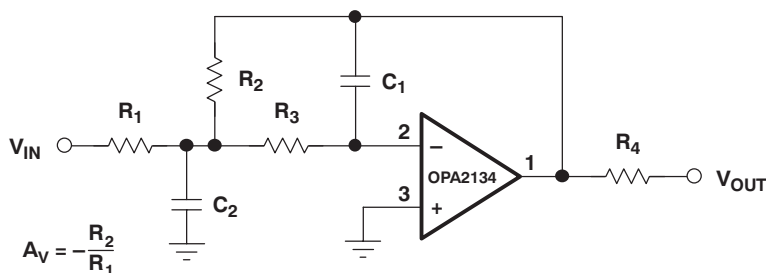


Figure 29. Dual-Supply Filter Circuit

PCB LAYOUT GUIDELINES

A typical PCB floor plan for the PCM175x is shown in Figure 30. A ground plane is recommended, with the analog and digital sections being isolated from one another using a split or cut in the circuit board. The PCM175x should be oriented with the digital I/O pins facing the ground plane split/cut to allow for short, direct connections to the digital audio interface and control signals originating from the digital section of the board.

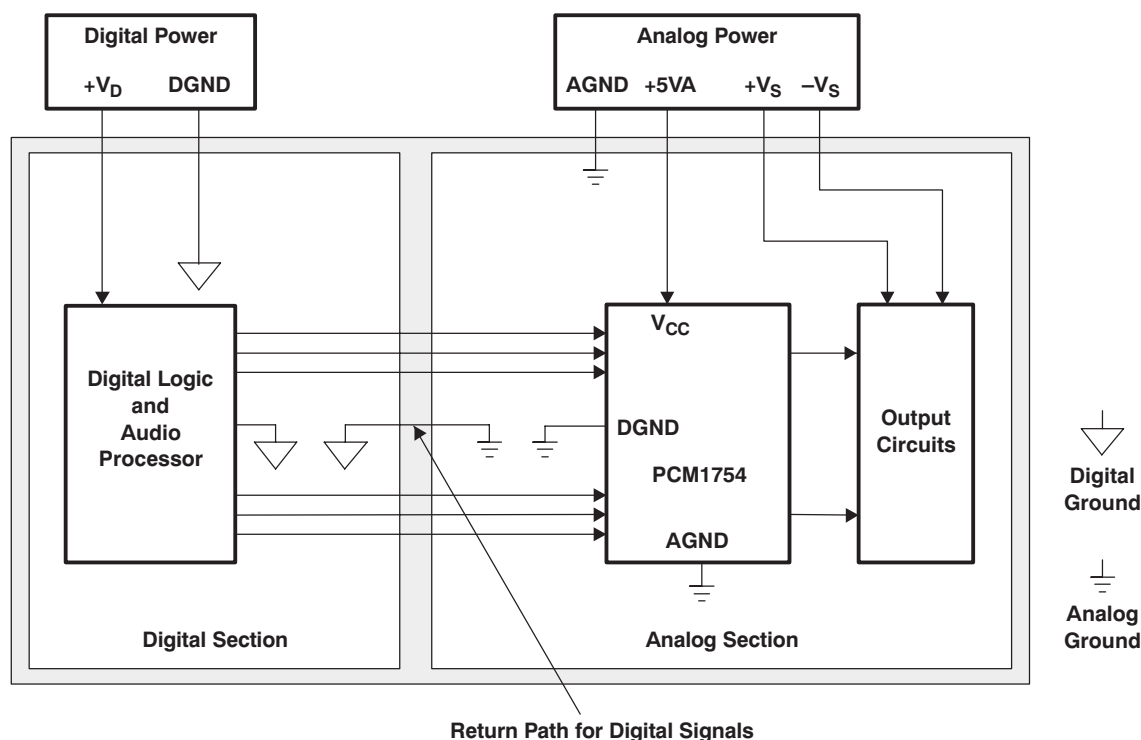


Figure 30. Recommended PCB Layout

Separate power supplies are recommended for the digital and analog sections of the board. This prevents the switching noise present on the digital supply from contaminating the analog power supply and degrading the dynamic performance of the PCM175x. In cases where a common 5-V supply must be used for the analog and digital sections, an inductance (RF choke, ferrite bead) should be placed between the analog and digital 5-V supply connections to avoid coupling of the digital switching noise into the analog circuitry. Figure 31 shows the recommended approach for single-supply applications.

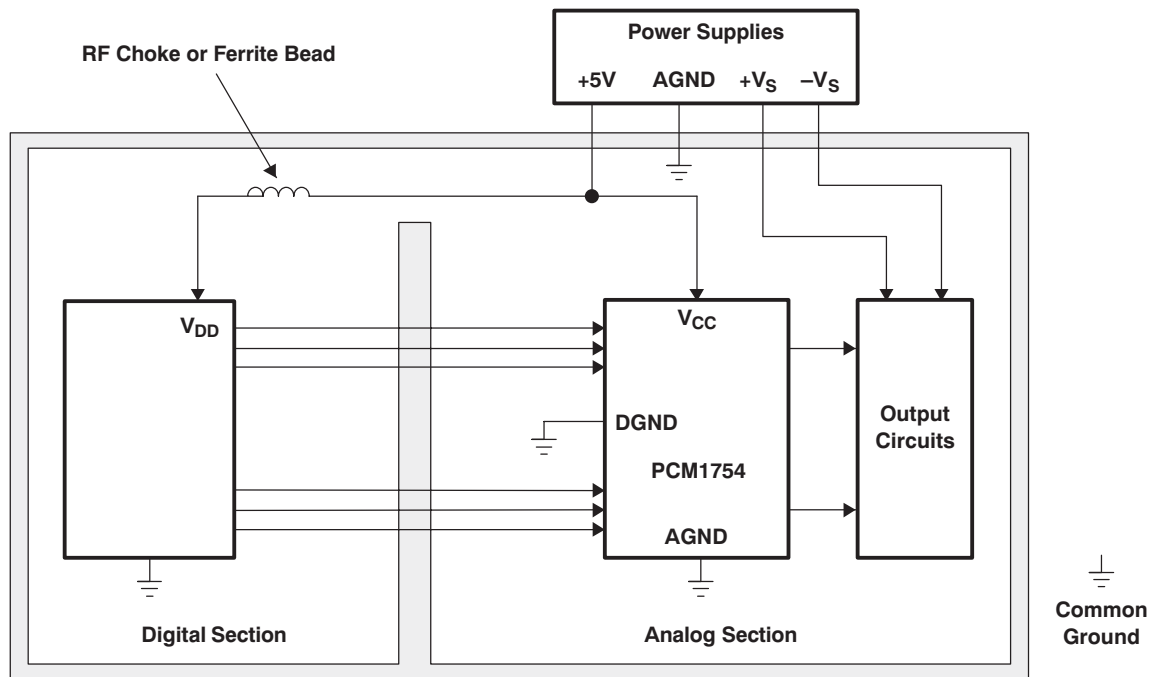


Figure 31. Single-Supply PCB Layout

THEORY OF OPERATION

The delta-sigma section of the PCM175x 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. A block diagram of the 8-level delta-sigma modulator is shown in [Figure 32](#). 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 interpolation filter is $64 f_s$.

The theoretical quantization noise performance of the 8-level delta-sigma modulator is shown in [Figure 33](#) and [Figure 34](#). The enhanced multilevel delta-sigma architecture also has advantages for input clock jitter sensitivity due to the multilevel quantizer, with the simulated jitter sensitivity shown in [Figure 35](#).

KEY PERFORMANCE PARAMETERS AND MEASUREMENT

This section provides information on how to measure key dynamic performance parameters for the PCM175x. In all cases, an Audio Precision System Two Cascade audio measurement system or equivalent is used to perform the testing.

Total Harmonic Distortion + Noise

Total harmonic distortion + noise (THD+N) is a significant figure of merit for audio D/A converters because it takes into account both harmonic distortion and all noise sources within a specified measurement bandwidth. The average value of the distortion and noise is referred to as THD+N.

For the PCM175x, THD+N is measured with a full-scale, 1-kHz digital sine wave as the test stimulus at the input of the DAC (see [Figure 36](#)). The digital generator is set to 24-bit audio word length and a sampling frequency of 44.1 kHz or 96 kHz. The digital generator output is taken from the unbalanced S/PDIF connector of the measurement system. The S/PDIF data is transmitted via a coaxial cable to the digital audio receiver on the DEM-DAI1753 demonstration board. The receiver is then configured to output 24-bit data in either I²S or left-justified data format. The DAC audio interface format is programmed to match the receiver output format. The analog output is then taken from the DAC post filter and connected to the analog analyzer input of the measurement system. The analog input is band limited using filters resident in the analyzer. The resulting THD+N is measured by the analyzer and displayed by the measurement system.

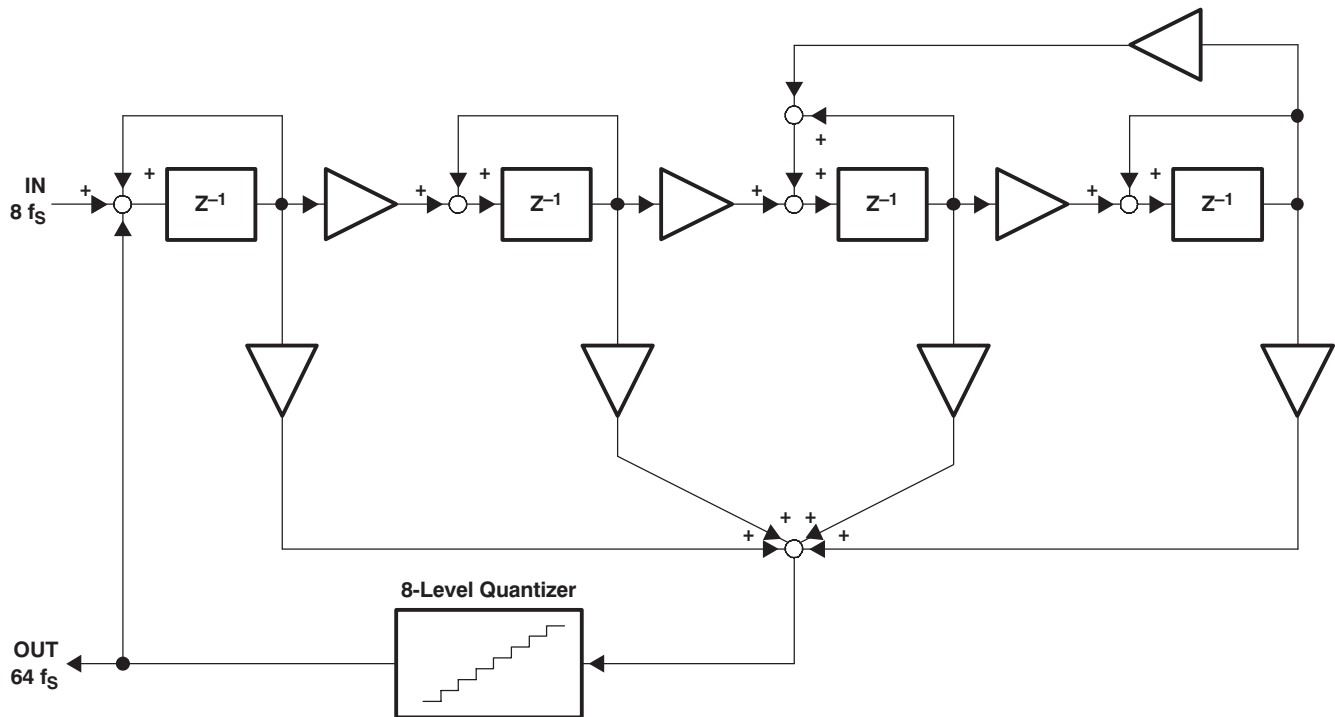


Figure 32. Eight-Level Delta-Sigma Modulator

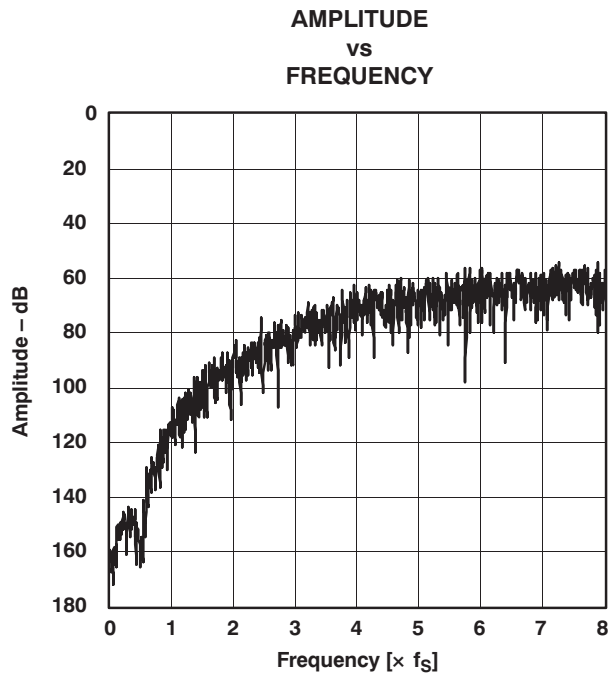


Figure 33. Quantization Noise Spectrum ($\times 64$ Oversampling)

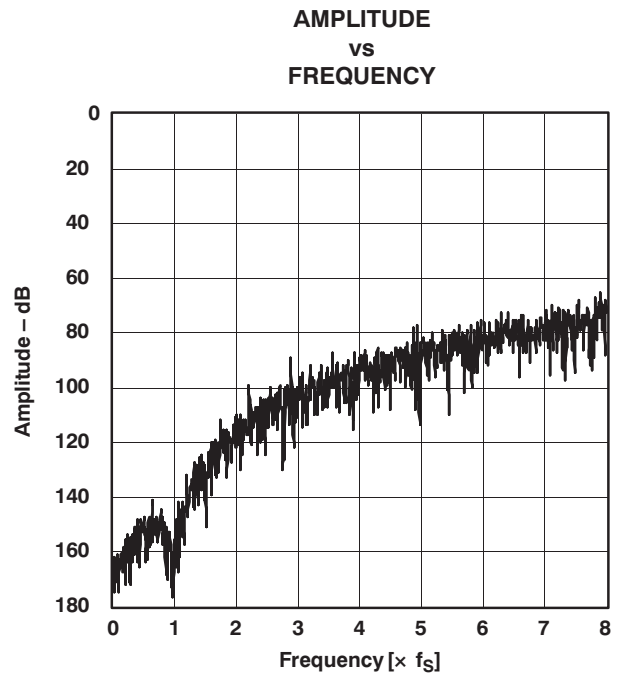


Figure 34. Quantization Noise Spectrum ($\times 128$ Oversampling)

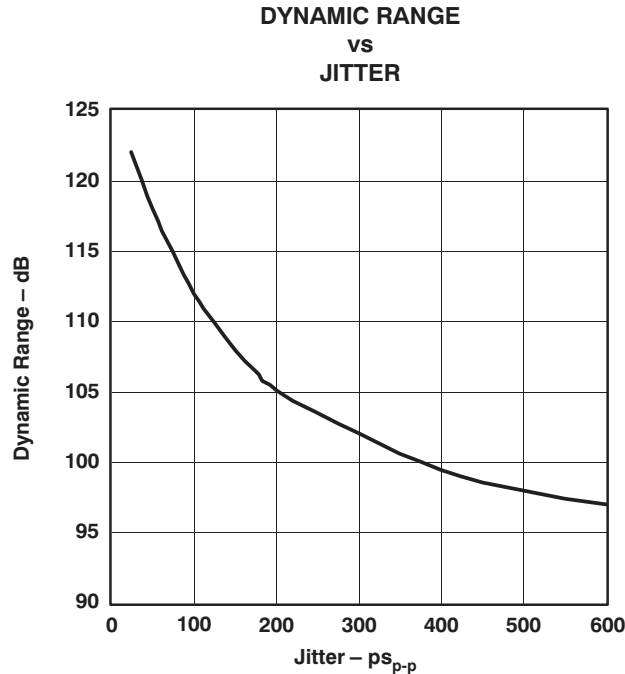


Figure 35. Jitter Dependence (×64 Oversampling)

Dynamic Range

Dynamic range is specified as A-weighted THD+N measured with a –60-dB full-scale, 1-kHz digital sine wave stimulus at the input of the D/A converter. This measurement is designed to give a good indicator of how the DAC performs given a low-level input signal.

The measurement setup for the dynamic range measurement is shown in Figure 37, and is similar to the THD+N test setup discussed previously. The differences include the band limit filter selection, the additional A-weighting filter, and the –60-dB full-scale input level.

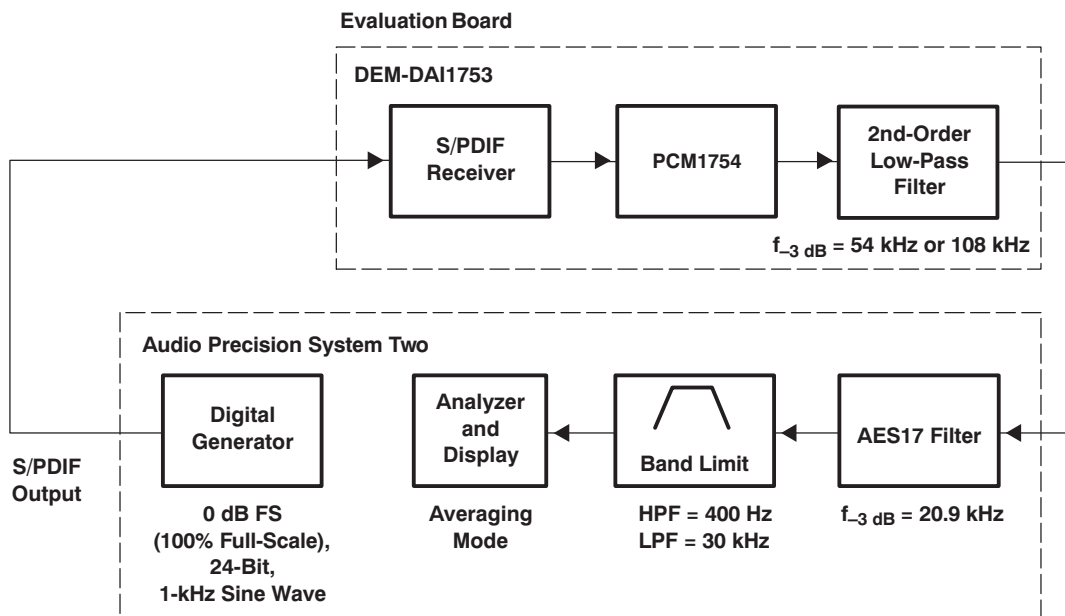


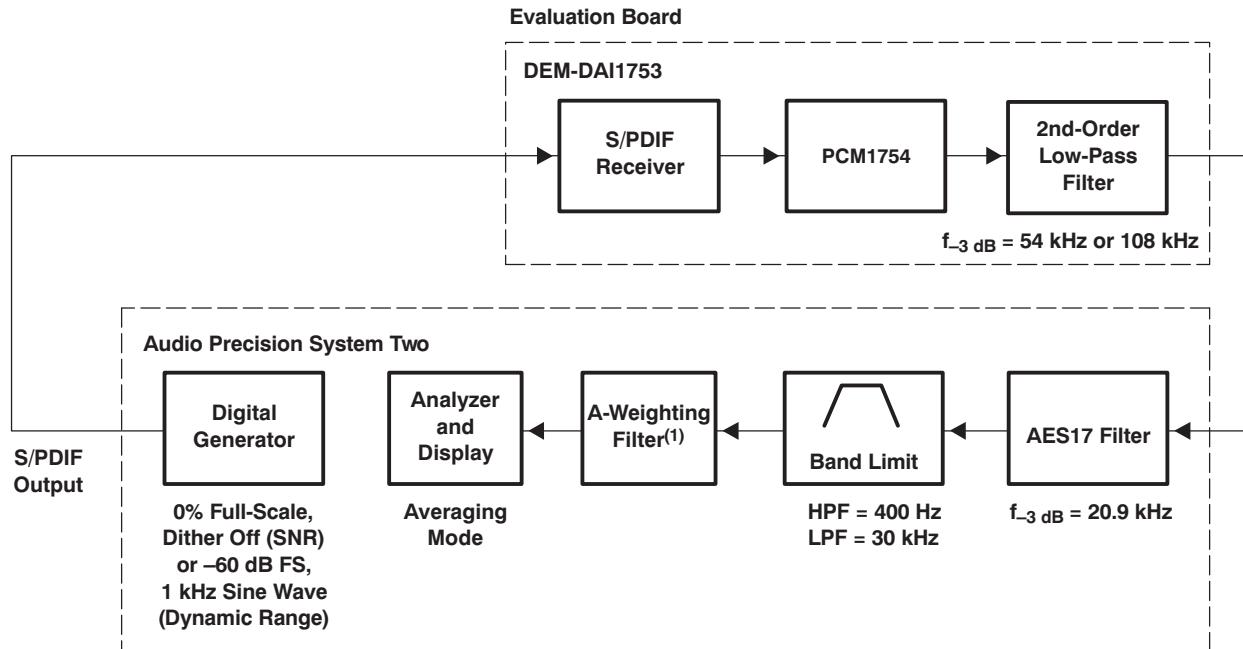
Figure 36. Test Setup for THD+N Measurement

Idle Channel Signal-to-Noise Ratio (SNR)

The SNR test provides a measure of the noise floor of the D/A converter. The input to the D/A is all-0s data, and the dither function of the digital generator must be disabled to ensure an all-0s data stream at the input of the D/A converter.

The measurement setup for SNR is identical to that used for dynamic range, with the exception of the input signal level.

(See the note provided in [Figure 37](#)).



⁽¹⁾ Results without A-Weighting are approximately 3 dB worse.

Figure 37. Test Setup for Dynamic Range and SNR Measurement

PACKAGING INFORMATION

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	Eco Plan ⁽²⁾	Lead/ Ball Finish	MSL Peak Temp ⁽³⁾	Samples (Requires Login)
PCM1753TDBQRQ1	ACTIVE	SSOP	DBQ	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	
PCM1754TDBQRQ1	ACTIVE	SSOP	DBQ	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	

⁽¹⁾ The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBsolete: TI has discontinued the production of the device.

⁽²⁾ Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

⁽³⁾ MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

OTHER QUALIFIED VERSIONS OF PCM1753-Q1, PCM1754-Q1 :

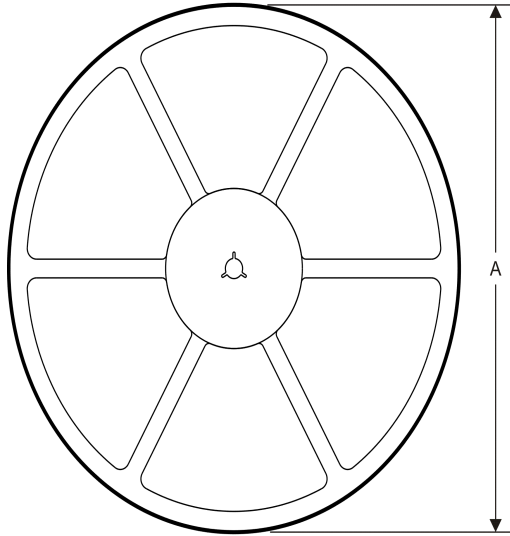
- Catalog: [PCM1753](#), [PCM1754](#)

NOTE: Qualified Version Definitions:

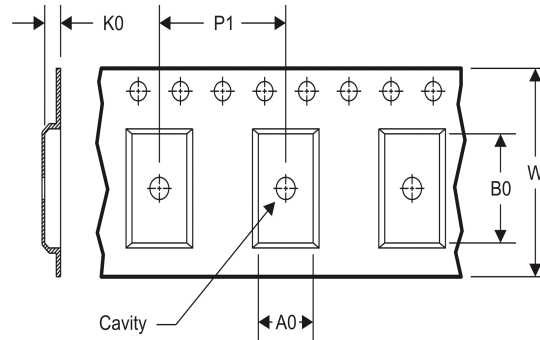
- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

TAPE AND REEL INFORMATION

*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
PCM1753TDBQRQ1	SSOP	DBQ	16	2000	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
PCM1754TDBQRQ1	SSOP	DBQ	16	2000	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS

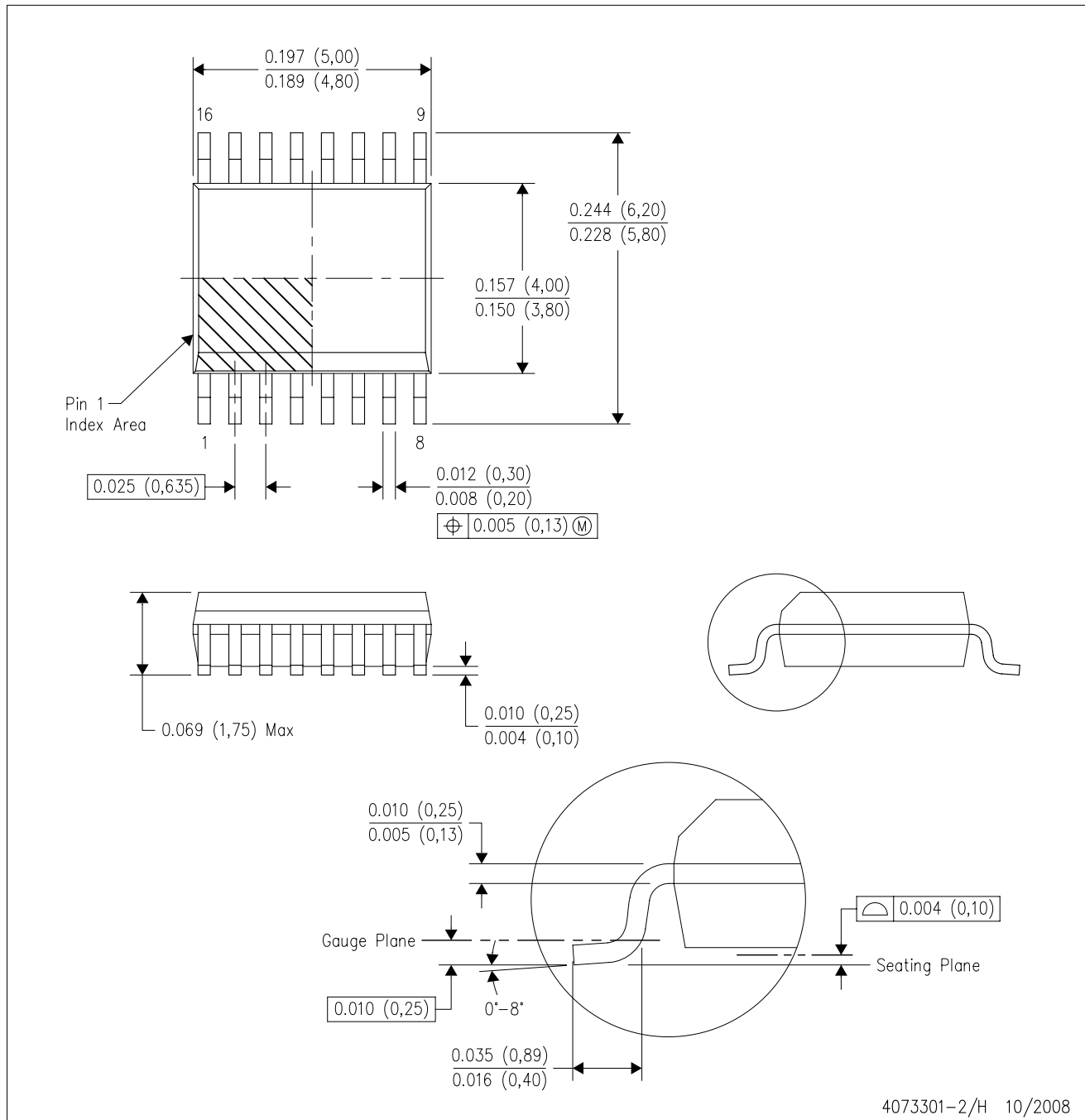


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
PCM1753TDBQRQ1	SSOP	DBQ	16	2000	367.0	367.0	35.0
PCM1754TDBQRQ1	SSOP	DBQ	16	2000	367.0	367.0	35.0

DBQ (R-PDSO-G16)

PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15) per side.
 - D. Falls within JEDEC MO-137 variation AB.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46C and to discontinue any product or service per JESD48B. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components which meet ISO/TS16949 requirements, mainly for automotive use. Components which have not been so designated are neither designed nor intended for automotive use; and TI will not be responsible for any failure of such components to meet such requirements.

Products

Audio	www.ti.com/audio
Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DLP® Products	www.dlp.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
OMAP Mobile Processors	www.ti.com/omap
Wireless Connectivity	www.ti.com/wirelessconnectivity

Applications

Automotive and Transportation	www.ti.com/automotive
Communications and Telecom	www.ti.com/communications
Computers and Peripherals	www.ti.com/computers
Consumer Electronics	www.ti.com/consumer-apps
Energy and Lighting	www.ti.com/energy
Industrial	www.ti.com/industrial
Medical	www.ti.com/medical
Security	www.ti.com/security
Space, Avionics and Defense	www.ti.com/space-avionics-defense
Video and Imaging	www.ti.com/video

TI E2E Community e2e.ti.com