

Stereo Audio Codec With Embedded miniDSP

 Check for Samples: [PCM3070](#)

FEATURES

- Stereo Audio DAC with 100dB SNR
- Stereo Audio ADC with 93dB SNR
- Extensive Signal Processing Options
- Embedded miniDSP
- Six Single-Ended or 3 Fully-Differential Analog Inputs
- Stereo Headphone Outputs
- Stereo Line Outputs
- Very Low-Noise PGA
- Analog Bypass Mode
- Programmable PLL
- Integrated LDO
- 5mm x 5mm 32-pin QFN Package

APPLICATIONS

- Soundbar
- Flat Panel Television
- MP3 Docking stations
- Cell Phone Docking Stations
- Other Stereo or 2.1 Home Audio systems

DESCRIPTION

The PCM3070 is a flexible stereo audio codec with programmable inputs and outputs, fully-programmable miniDSP, fixed predefined and parameterizable signal processing blocks, integrated PLL, integrated LDOs and flexible digital interfaces.

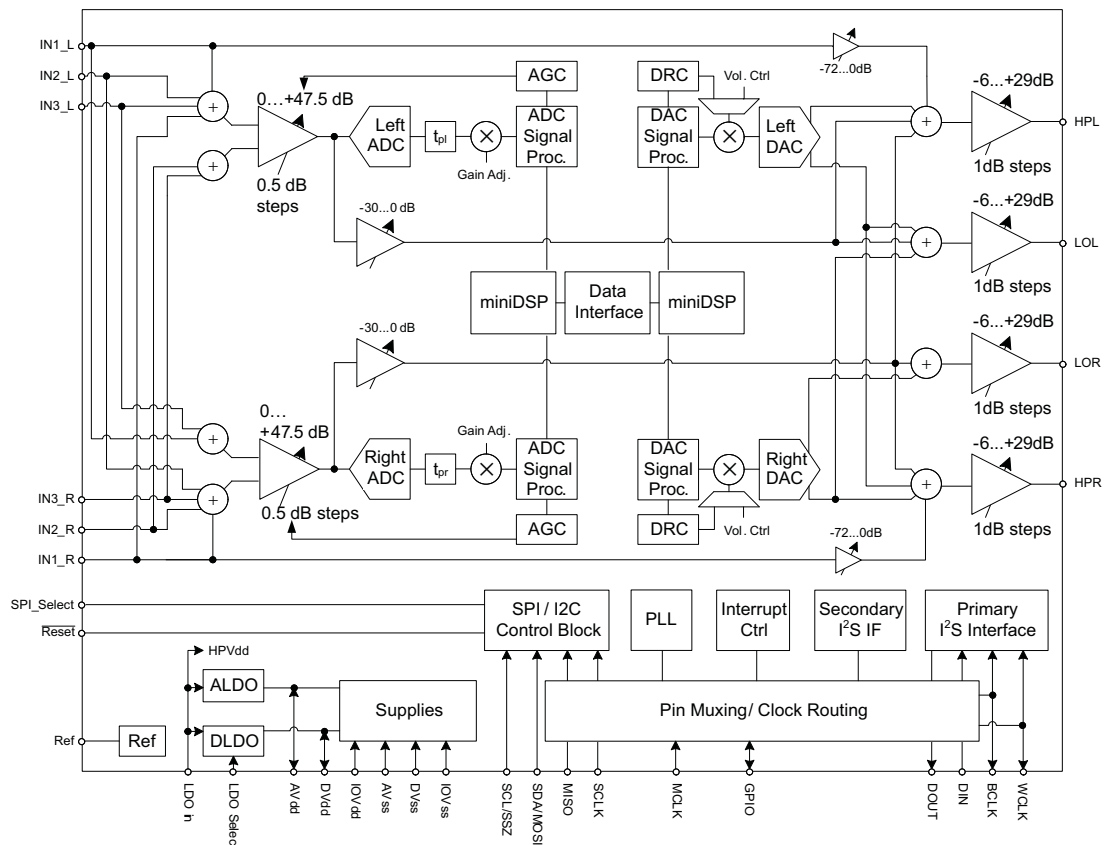


Figure 1. Simplified Block Diagram



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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.

DESCRIPTION (CONTINUED)

The PCM3070 features two fully-programmable miniDSP cores that support application-specific algorithms in the record and/or the playback path of the device. The miniDSP cores are fully software controlled. Target algorithms, like speaker EQ, Crossovers, Dynamic Range Controls, Intelligent volume controls and other post-processing algorithms are loaded into the device after power-up.

Extensive register-based control of input/output channel configuration, gains, effects, pin-multiplexing and clocks is included, allowing the device to be precisely targeted to its application.

The record path of the PCM3070 covers operations from 8kHz mono to 192kHz stereo recording, and contains programmable input channel configurations covering single-ended and differential setups, as well as floating or mixed input signals.

The playback path offers signal-processing blocks for filtering and effects, and supports flexible mixing of DAC and analog input signals as well as programmable volume controls. The playback path contains two high-power output drivers as well as two fully-differential outputs. The high-power outputs can be configured in multiple ways, including stereo and mono BTL.

The voltage supply range for the PCM3070 for analog is 1.5V–1.95V, and for digital it is 1.26V–1.95V. To ease system-level design, LDOs are integrated to generate the appropriate analog or digital supply from input voltages ranging from 1.8V to 3.6V. Digital I/O voltages are supported in the range of 1.5V–3.6V.

The required internal clock of the PCM3070 can be derived from multiple sources, including the MCLK pin, the BCLK pin, the GPIO pin or the output of the internal PLL, where the input to the PLL again can be derived from the MCLK pin, the BCLK or GPIO pins. The PLL is highly programmable and can accept available input clocks in the range of 512kHz to 50MHz.

The device is available in the 5mm × 5mm, 32-pin QFN package.

Package and Signal Descriptions

Packaging/Ordering Information

PRODUCT	PACKAGE	PACKAGE DESIGNATOR	OPERATING TEMPERATURE RANGE	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
PCM3070	QFN	RHB	-40°C to 85°C	PCM3070RHBT	Tape and Reel, 250
				PCM3070RHBR	Tape and Reel, 3000

Pin Assignments

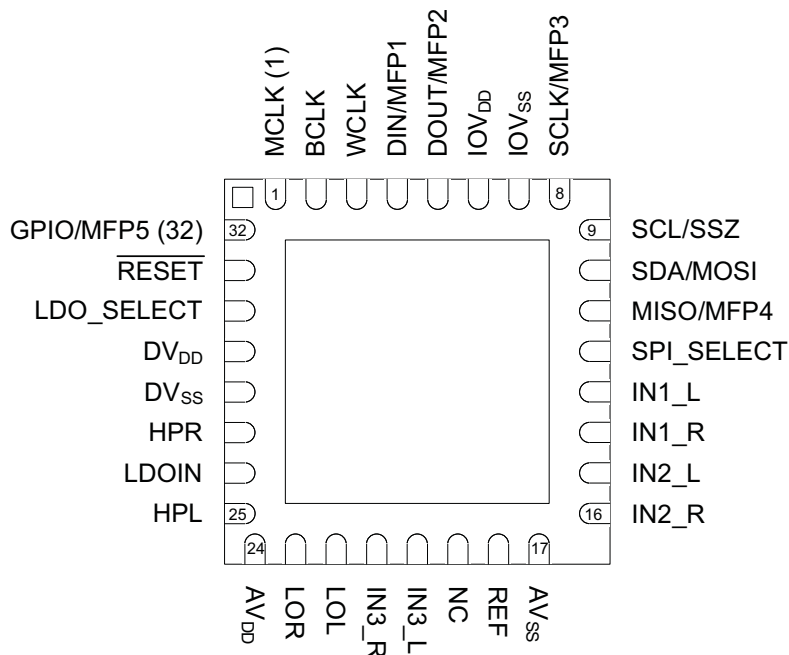


Figure 2. QFN (RHB) Package, Bottom View

Table 1. Terminal Functions

TERMINAL	NAME	TYPE	DESCRIPTION
1	MCLK	I	Master Clock Input
2	BCLK	IO	Audio serial data bus (primary) bit clock
3	WCLK	IO	Audio serial data bus (primary) word clock
4	DIN MFP1	I	Primary function Audio serial data bus data input Secondary function Audio serial data bus (secondary) bit clock input Audio serial data bus (secondary) word clock input Clock Input General Purpose Input
5	DOUT MFP2	O	Primary Audio serial data bus data output Secondary General Purpose Output Clock Output INT1 Output INT2 Output Audio serial data bus (secondary) bit clock output Audio serial data bus (secondary) word clock output
6	IOVDD	Power	I/O voltage supply 1.1V – 3.6V
7	IOVSS	Ground	I/O ground supply
8	SCLK MFP3	I	Primary (SPI_Select = 1) SPI serial clock Secondary: (SPI_Select = 0) Audio serial data bus (secondary) bit clock input Audio serial data bus (secondary) DAC/common word clock input Audio serial data bus (secondary) ADC word clock input Audio serial data bus (secondary) data input General Purpose Input
9	SCL/ SSZ	I	I ² C interface serial clock (SPI_Select = 0) SPI interface mode chip-select signal (SPI_Select = 1)
10	SDA/ MOSI	I	I ² C interface mode serial data input (SPI_Select = 0) SPI interface mode serial data input (SPI_Select = 1)
11	MISO MFP4	O	Primary (SPI_Select = 1) Serial data output Secondary (SPI_Select = 0) General purpose output CLKOUT output INT1 output INT2 output Audio serial data bus (primary) ADC word clock output Audio serial data bus (secondary) data output Audio serial data bus (secondary) bit clock output Audio serial data bus (secondary) word clock output
12	SPI_SELECT	I	Control mode select pin (1 = SPI, 0 = I ² C)

Table 1. Terminal Functions (continued)

TERMINAL	NAME	TYPE	DESCRIPTION
13	IN1_L	I	Multifunction Analog Input, or Single-ended configuration: Line 1 left or Differential configuration: Line right, negative
14	IN1_R	I	Multifunction Analog Input, or Single-ended configuration: or Line 1 right or Differential configuration: Line right, positive
15	IN2_L	I	Multifunction Analog Input, or Single-ended configuration: Line 2 right or Differential configuration: Line left, positive
16	IN2_R	I	Multifunction Analog Input, or Single-ended configuration: Line 2 right or Differential configuration: Line left, negative
17	AVss	Ground	Analog ground supply
18	REF	O	Reference voltage output for filtering
19	NC	-	NC, do not connect
20	IN3_L	I	Multifunction Analog Input, or Single-ended configuration: Line 3 left, or Differential configuration: Line left, positive, or Differential configuration: Line right, negative
21	IN3_R	I	Multifunction Analog Input, or Single-ended configuration: Line 3 right, or Differential configuration: Line left, negative, or Differential configuration: Line right, positive
24	AVdd	Power	Analog voltage supply 1.5V–1.95V Input when A-LDO disabled, Filtering output when A-LDO enabled
25	HPL	O	Left high power output driver
26	LDOIN/ HPVDD	Power	LDO Input supply and Headphone Power supply 1.9V– 3.6V
27	HPR	O	Right high power output driver
28	DVss	Ground	Digital Ground and Chip-substrate
29	DVdd	Power	If LDO_SELECT Pin = 0 (D-LDO disabled) Digital voltage supply 1.26V – 1.95V If LDO_SELECT Pin = 1 (D-LDO enabled) Digital voltage supply filtering output
30	LDO_SELECT	I	connect to DVss.
31	$\overline{\text{RESET}}$	I	Reset (active low)
32	GPIO MFP5	I	Primary General Purpose digital IO Secondary CLKOUT Output INT1 Output INT2 Output Audio serial data bus ADC word clock output Audio serial data bus (secondary) bit clock output Audio serial data bus (secondary) word clock output

Electrical Characteristics

Absolute Maximum Ratings

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

		VALUE	UNIT
AVdd to AVss		–0.3 to 2.2	V
DVdd to DVss		–0.3 to 2.2	V
IOVDD to IOVSS		–0.3 to 3.9	V
LDOIN to AVss		–0.3 to 3.9	V
Digital Input voltage		to IOVDD + 0.3	V
Analog input voltage		to AVdd + 0.3	V
Operating temperature range		–40 to 85	°C
Storage temperature range			°C
Junction temperature (T _J Max)		105	°C
QFN package (RHB)	Power dissipation	(T _J Max – TA) / θ _{JA}	W
	θ _{JA} Thermal impedance	35	C/W

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

Recommended Operating Conditions

			MIN	NOM	MAX	UNIT
LDOIN	Power Supply Voltage Range	Referenced to AVss ⁽¹⁾	1.9			V
AVdd			1.5	1.8	1.95	
IOVDD		Referenced to IOVSS ⁽¹⁾	1.5		3.6	
DVdd ⁽²⁾			Referenced to DVss ⁽¹⁾		1.8	
PLL Input Frequency		Clock divider uses fractional divide (D > 0), P=1, D _{Vdd} ≥ 1.65V		10	20	MHz
		Clock divider uses integer divide (D = 0), P=1, D _{Vdd} ≥ 1.65V		0.512	20	MHz
MCLK	Master Clock Frequency	MCLK; Master Clock Frequency; D _{Vdd} ≥ 1.65V			50	MHz
		MCLK; Master Clock Frequency; D _{Vdd} ≥ 1.26V			25	
SCL	SCL Clock Frequency				400	kHz
C _{Lout}	Digital output load capacitance				10	pF
TOPR	Operating Temperature Range			–40	85	°C

- (1) All grounds on board are tied together, so they should not differ in voltage by more than 0.2V max, for any combination of ground signals.
- (2) At DVdd values lower than 1.65V, the PLL does not function. Please see the *Maximum PCM3070 Clock Frequencies* table in the *PCM3070 Application Reference Guide* (SLAU332) for details on maximum clock frequencies.

Electrical Characteristics, ADC

At 25°C, AVdd, DVdd, IOVDD = 1.8V, LDO_in = 3.3V, AVdd LDO disabled, f_s (Audio) = 48kHz, Cref = 10 μ F on REF PIN, PLL disabled unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
AUDIO ADC						
	Input signal level (0dB)	Single-ended, CM = 0.9V		0.5		V _{RMS}
	Device Setup	1kHz sine wave input Single-ended Configuration IN1R to Right ADC and IN1L to Left ADC, $R_{in} = 20K$, $f_s = 48kHz$, AOSR = 128, MCLK = $256 \cdot f_s$, PLL Disabled; AGC = OFF, Channel Gain = 0dB, Processing Block = PRB_R1,				
SNR	Signal-to-noise ratio, A-weighted ^{(1) (2)}	Inputs ac-shortened to ground	80	93		dB
		IN2R, IN3R routed to Right ADC and ac-shortened to ground IN2L, IN3L routed to Left ADC and ac-shortened to ground		93		
DR	Dynamic range A-weighted ^{(1) (2)}	–60dB full-scale, 1-kHz input signal		92		dB
THD+N	Total Harmonic Distortion plus Noise	–3 dB full-scale, 1-kHz input signal		–85	–70	dB
		IN2R, IN3R routed to Right ADC IN2L, IN3L routed to Left ADC –3dB full-scale, 1-kHz input signal		–85		
AUDIO ADC						
	Input signal level (0dB)	Single-ended, CM=0.75V, AVdd = 1.5V		0.375		V _{RMS}
	Device Setup	1kHz sine wave input Single-ended Configuration IN1R, IN2R, IN3R routed to Right ADC IN1L, IN2L, IN3L routed to Left ADC $R_{in} = 20K$, $f_s = 48kHz$, AOSR=128, MCLK = $256 \cdot f_s$, PLL Disabled, AGC = OFF, Channel Gain = 0dB, Processing Block = PRB_R1				
SNR	Signal-to-noise ratio, A-weighted ^{(1) (2)}	Inputs ac-shortened to ground		91		dB
DR	Dynamic range A-weighted ^{(1) (2)}	–60dB full-scale, 1-kHz input signal		90		dB
THD+N	Total Harmonic Distortion plus Noise	–3dB full-scale, 1-kHz input signal		–80		dB

- (1) Ratio of output level with 1kHz full-scale sine wave input, to the output level with the inputs short circuited, measured A-weighted over a 20Hz to 20kHz bandwidth using an audio analyzer.
- (2) All performance measurements done with 20kHz low-pass filter and, where noted, A-weighted filter. Failure to use such a filter may result in higher THD+N and lower SNR and dynamic range readings than shown in the Electrical Characteristics. The low-pass filter removes out-of-band noise, which, although not audible, may affect dynamic specification values

Electrical Characteristics, ADC (continued)

At 25°C, AVdd, DVdd, IOVDD = 1.8V, LDO_in = 3.3V, AVdd LDO disabled, f_s (Audio) = 48kHz, Cref = 10 μ F on REF PIN, PLL disabled unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
AUDIO ADC					
Input signal level (0dB)	Differential Input, CM=0.9V		10		mV
Device Setup	1kHz sine wave input Differential configuration IN1L and IN1R routed to Right ADC IN2L and IN2R routed to Left ADC $R_{in} = 10K$, $f_s = 48kHz$, AOSR=128 MCLK = $256 * f_s$ PLL Disabled AGC = OFF, Channel Gain=40dB Processing Block = PRB_R1,				
ICN Idle-Channel Noise, A-weighted ⁽³⁾ ⁽⁴⁾	Inputs ac-shortened to ground, input referred noise		2		μ V _{RMS}
AUDIO ADC					
Gain Error	1kHz sine wave input Single-ended configuration $R_{in} = 20K$ $f_s = 48kHz$, AOSR=128, MCLK = $256 * f_s$, PLL Disabled AGC = OFF, Channel Gain=0dB Processing Block = PRB_R1,		-0.05		dB
Input Channel Separation	1kHz sine wave input at -3dBFS Single-ended configuration IN1L routed to Left ADC IN1R routed to Right ADC, $R_{in} = 20K$ AGC = OFF, AOSR = 128, Channel Gain=0dB, CM=0.9V		108		dB
Input Pin Crosstalk	1kHz sine wave input at -3dBFS on IN2L, IN2L internally not routed. IN1L routed to Left ADC ac-coupled to ground 1kHz sine wave input at -3dBFS on IN2R, IN2R internally not routed. IN1R routed to Right ADC ac-coupled to ground Single-ended configuration $R_{in} = 20K$, AOSR=128 Channel, Gain=0dB, CM=0.9V		115		dB
PSRR	217Hz, 100mVpp signal on AVdd, Single-ended configuration, $R_{in} = 20K$, Channel Gain=0dB; CM=0.9V		55		dB
ADC programmable gain amplifier gain	Single-Ended, $R_{in} = 10K$, PGA gain set to 0dB		0		dB
	Single-Ended, $R_{in} = 10K$, PGA gain set to 47.5dB		47.5		dB
	Single-Ended, $R_{in} = 20K$, PGA gain set to 0dB		-6		dB
	Single-Ended, $R_{in} = 20K$, PGA gain set to 47.5dB		41.5		dB
	Single-Ended, $R_{in} = 40K$, PGA gain set to 0dB		-12		dB
	Single-Ended, $R_{in} = 40K$, PGA gain set to 47.5dB		35.5		dB

(3) Ratio of output level with 1kHz full-scale sine wave input, to the output level with the inputs short circuited, measured A-weighted over a 20Hz to 20kHz bandwidth using an audio analyzer.

(4) All performance measurements done with 20kHz low-pass filter and, where noted, A-weighted filter. Failure to use such a filter may result in higher THD+N and lower SNR and dynamic range readings than shown in the Electrical Characteristics. The low-pass filter removes out-of-band noise, which, although not audible, may affect dynamic specification values

Electrical Characteristics, ADC (continued)

At 25°C, AVdd, DVdd, IOVDD = 1.8V, LDO_in = 3.3V, AVdd LDO disabled, f_s (Audio) = 48kHz, Cref = 10 μF on REF PIN, PLL disabled unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
ADC programmable gain amplifier step size	1-kHz tone		0.5		dB

Electrical Characteristics, Bypass Outputs

At 25°C, AVdd, DVdd, IOVDD = 1.8V, LDO_in = 3.3V, AVdd LDO disabled, f_s (Audio) = 48kHz, Cref = 10 μF on REF PIN, PLL disabled unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
ANALOG BYPASS TO HEADPHONE AMPLIFIER, DIRECT MODE					
Device Setup	Load = 16Ω (single-ended), 50pF; Input and Output CM=0.9V; Headphone Output on LDOIN Supply; IN1L routed to HPL and IN1R routed to HPR; Channel Gain=0dB				
Gain Error			-0.8		dB
Noise, A-weighted ⁽¹⁾	Idle Channel, IN1L and IN1R ac-shortened to ground		3		μV _{RMS}
THD Total Harmonic Distortion	446mV _{rms} , 1kHz input signal		-89		dB
ANALOG BYPASS TO LINE-OUT AMPLIFIER, PGA MODE					
Device Setup	Load = 10kΩ (single-ended), 56pF; Input and Output CM=0.9V; LINE Output on LDOIN Supply; IN1L routed to ADCPGA_L and IN1R routed to ADCPGA_R; Rin = 20kΩ ADCPGA_L routed to LOL and ADCPGA_R routed to LOR; Channel Gain = 0dB				
Gain Error			0.6		dB
Noise, A-weighted ⁽¹⁾	Idle Channel, IN1L and IN1R ac-shortened to ground		7		μV _{RMS}
	Channel Gain=40dB, Input Signal (0dB) = 5mV _{rms} Inputs ac-shortened to ground, Input Referred		3.4		μV _{RMS}

- (1) All performance measurements done with 20kHz low-pass filter and, where noted, A-weighted filter. Failure to use such a filter may result in higher THD+N and lower SNR and dynamic range readings than shown in the Electrical Characteristics. The low-pass filter removes out-of-band noise, which, although not audible, may affect dynamic specification values

Electrical Characteristics, Audio DAC Outputs

At 25°C, AVdd, DVdd, IOVDD = 1.8V, LDO_in = 3.3V, AVdd LDO disabled, f_s (Audio) = 48kHz, Cref = 10μF on REF PIN, PLL disabled unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
AUDIO DAC – STEREO SINGLE-ENDED LINE OUTPUT					
Device Setup	Load = 10kΩ (single-ended), 56pF Line Output on AVdd Supply Input & Output CM=0.9V DOSR = 128, MCLK=256* f _s , Channel Gain = 0dB, word length = 16 bits, Processing Block = PRB_P1,				
Full scale output voltage (0dB)			0.5		V _{RMS}
SNR	Signal-to-noise ratio A-weighted ^{(1) (2)}	87	100		dB
DR	Dynamic range, A-weighted ^{(1) (2)}		100		dB
THD+N	Total Harmonic Distortion plus Noise		-83	-70	dB
	DAC Gain Error		0.3		dB
	DAC Mute Attenuation		119		dB
	DAC channel separation		113		dB
	DAC PSRR		73		dB
			77		dB
AUDIO DAC – STEREO SINGLE-ENDED LINE OUTPUT					
Device Setup	Load = 10kΩ (single-ended), 56pF Line Output on AVdd Supply Input & Output CM=0.75V; AVdd=1.5V DOSR = 128 MCLK=256* f _s Channel Gain = -2dB word length = 20 bits Processing Block = PRB_P1				
Full scale output voltage (0dB)			0.375		V _{RMS}
SNR	Signal-to-noise ratio, A-weighted ^{(1) (2)}		99		dB
DR	Dynamic range, A-weighted ^{(1) (2)}		97		dB
THD+N	Total Harmonic Distortion plus Noise		-85		dB
AUDIO DAC – STEREO SINGLE-ENDED HEADPHONE OUTPUT					
Device Setup	Load = 16Ω (single-ended), 50pF Headphone Output on AVdd Supply, Input & Output CM=0.9V, DOSR = 128, MCLK=256* f _s , Channel Gain=0dB word length = 16 bits; Processing Block = PRB_P1				
Full scale output voltage (0dB)			0.5		V _{RMS}
SNR	Signal-to-noise ratio, A-weighted ^{(1) (2)}	87	100		dB
DR	Dynamic range, A-weighted ^{(1) (2)}		99		dB
THD+N	Total Harmonic Distortion plus Noise		-83	-70	dB
	DAC Gain Error		-0.3		dB
	DAC Mute Attenuation		122		dB
	DAC channel separation		110		dB

- (1) Ratio of output level with 1kHz full-scale sine wave input, to the output level with the inputs short circuited, measured A-weighted over a 20Hz to 20kHz bandwidth using an audio analyzer.
- (2) All performance measurements done with 20kHz low-pass filter and, where noted, A-weighted filter. Failure to use such a filter may result in higher THD+N and lower SNR and dynamic range readings than shown in the Electrical Characteristics. The low-pass filter removes out-of-band noise, which, although not audible, may affect dynamic specification values

Electrical Characteristics, Audio DAC Outputs (continued)

At 25°C, AVdd, DVdd, IOVDD = 1.8V, LDO_in = 3.3V, AVdd LDO disabled, f_s (Audio) = 48kHz, Cref = 10µF on REF PIN, PLL disabled unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
DAC PSRR	100mVpp, 1kHz signal applied to AVdd		73		dB
	100mVpp, 217Hz signal applied to AVdd		78		dB
Power Delivered	R _L =16Ω, Output Stage on AVdd = 1.8V THDN < 1%, Input CM=0.9V, Output CM=0.9V		15		mW
	R _L =16Ω Output Stage on LDOIN = 3.3V, THDN < 1% Input CM=0.9V, Output CM=1.65V		64		
AUDIO DAC – STEREO SINGLE-ENDED HEADPHONE OUTPUT					
Device Setup	Load = 16Ω (single-ended), 50pF, Headphone Output on AVdd Supply, Input & Output CM=0.75V; AVdd=1.5V, DOSR = 128, MCLK=256* f _s , Channel Gain = -2dB, word length=20-bits; Processing Block = PRB_P1,				
Full scale output voltage (0dB)			0.375		V _{RMS}
SNR	Signal-to-noise ratio, A-weighted ^{(1) (2)}	All zeros fed to DAC input	99		dB
DR	Dynamic range, A-weighted ^{(3) (4)}	-60dB 1kHz input full-scale signal	98		dB
THD+N	Total Harmonic Distortion plus Noise	-1dB full-scale, 1kHz input signal	-83		dB
AUDIO DAC – MONO DIFFERENTIAL HEADPHONE OUTPUT					
Device Setup	Load = 32Ω (differential), 50pF, Headphone Output on LDOIN Supply Input CM = 0.75V, Output CM=1.5V, AVdd=1.8V, LDOIN=3.0V, DOSR = 128 MCLK=256* f _s , Channel (headphone driver) Gain = 5dB for full scale output signal, word length=16-bits, Processing Block = PRB_P1,				
Full scale output voltage (0dB)			1778		mV _{RMS}
SNR	Signal-to-noise ratio, A-weighted ^{(3) (4)}	All zeros fed to DAC input	98		dB
DR	Dynamic range, A-weighted ^{(3) (4)}	-60dB 1kHz input full-scale signal	96		dB
THD	Total Harmonic Distortion	-3dB full-scale, 1kHz input signal	-82		dB
Power Delivered	R _L =32Ω, Output Stage on LDOIN = 3.3V, THDN < 1%, Input CM=0.9V, Output CM=1.65V		136		mW
	R _L =32Ω Output Stage on LDOIN = 3.0V, THDN < 1% Input CM=0.9V, Output CM=1.5V		114		mW

(3) Ratio of output level with 1kHz full-scale sine wave input, to the output level with the inputs short circuited, measured A-weighted over a 20Hz to 20kHz bandwidth using an audio analyzer.

(4) All performance measurements done with 20kHz low-pass filter and, where noted, A-weighted filter. Failure to use such a filter may result in higher THD+N and lower SNR and dynamic range readings than shown in the Electrical Characteristics. The low-pass filter removes out-of-band noise, which, although not audible, may affect dynamic specification values

Electrical Characteristics, LDO

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
LOW DROPOUT REGULATOR (AVdd)					
Output Voltage	LDOmode = 1, LDOin > 1.95V		1.67		V
	LDOmode = 0, LDOin > 2.0V		1.72		
	LDOmode = 2, LDOin > 2.05V		1.77		
Output Voltage Accuracy			±2		%
Load Regulation	Load current range 0 to 50mA		15		mV
Line Regulation	Input Supply Range 1.9V to 3.6V		5		mV
Decoupling Capacitor		1			μF
Bias Current			60		μA

Electrical Characteristics, Misc.

At 25°C, AVdd, DVdd, IOVDD = 1.8V, LDO_in = 3.3V, AVdd LDO disabled, f_s (Audio) = 48kHz, C_{ref} = 10 μF on REF PIN, PLL disabled unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
REFERENCE					
Reference Voltage Settings	CMMode = 0 (0.9V)		0.9		V
	CMMode = 1 (0.75V)		0.75		
Reference Noise	CM=0.9V, A-weighted, 20Hz to 20kHz bandwidth, C _{ref} = 10μF		1		μV _{RtMS}
Decoupling Capacitor		1	10		μF
miniDSP⁽¹⁾					
Maximum miniDSP clock frequency - ADC	DVdd = 1.65V		55.3		MHz
Maximum miniDSP clock frequency - DAC	DVdd = 1.65V		55.3		MHz
Shutdown Current					
Device Setup	Coarse AVdd supply turned off, LDO_select held at ground, No external digital input is toggled				
I(DVdd)			0.9		μA
I(IOVDD)			13		nA

(1) docato-extra-info-title miniDSP miniDSP Processing-block clock speed is specified by design and not tested in production.

Electrical Characteristics, Logic Levels

At 25°C, AVdd, DVdd, IOVDD = 1.8V

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
LOGIC FAMILY					
CMOS					
V _{IH} Logic Level	I _{IH} = 5 μA, IOVDD > 1.6V	0.7 × IOVDD			V
	I _{IH} = 5μA, 1.2V ≤ IOVDD <1.6V	0.9 × IOVDD			V
	I _{IH} = 5μA, IOVDD < 1.2V	IOVDD			V
V _{IL}	I _{IL} = 5 μA, IOVDD > 1.6V	-0.3	0.3 × IOVDD		V
	I _{IL} = 5μA, 1.2V ≤ IOVDD <1.6V		0.1 × IOVDD		V
	I _{IL} = 5μA, IOVDD < 1.2V		0		V
V _{OH}	I _{OH} = 2 TTL loads	0.8 × IOVDD			V
V _{OL}	I _{OL} = 2 TTL loads		0.1 × IOVDD		V
Capacitive Load			10		pF

Interface Timing

Typical Timing Characteristics — Audio Data Serial Interface Timing (I²S)

All specifications at 25°C, DV_{DD} = 1.8V

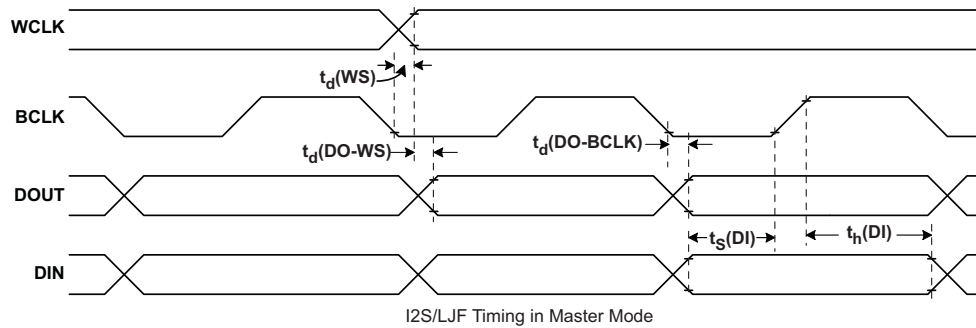


Figure 3. I²S/LJF/RJF Timing in Master Mode

Table 2. I²S/LJF/RJF Timing in Master Mode (see Figure 3)

PARAMETER		IOVDD=1.8V		IOVDD=3.3V		UNITS
		MIN	MAX	MIN	MAX	
$t_d(WS)$	WCLK delay		30		20	ns
$t_d(DO-WS)$	WCLK to DOUT delay (For LJF Mode only)		20		20	ns
$t_d(DO-BCLK)$	BCLK to DOUT delay		22		20	ns
$t_s(DI)$	DIN setup	8		8		ns
$t_h(DI)$	DIN hold	8		8		ns
t_r	Rise time		24		12	ns
t_f	Fall time		24		12	ns

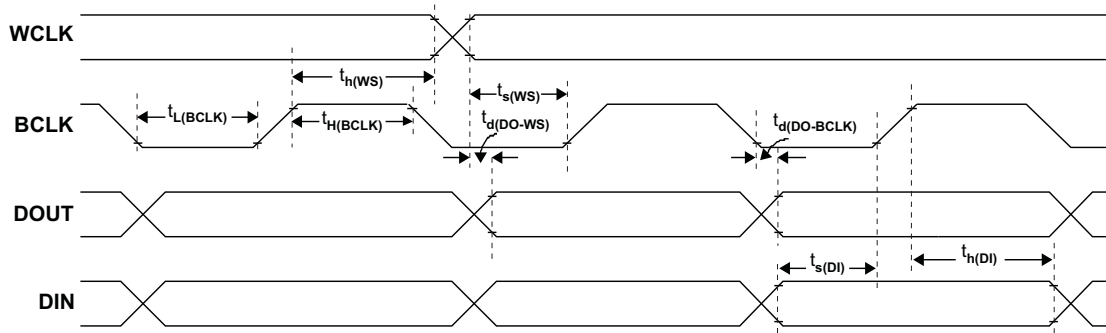


Figure 4. I²S/LJF/RJF Timing in Slave Mode

Table 3. I²S/LJF/RJF Timing in Slave Mode (see Figure 4)

PARAMETER		IOVDD=1.8V		IOVDD=3.3V		UNITS
		MIN	MAX	MIN	MAX	
t _H (BCLK)	BCLK high period	35		35		ns
t _L (BCLK)	BCLK low period	35		35		
t _s (WS)	WCLK setup	8		8		
t _h (WS)	WCLK hold	8		8		
t _d (DO-WS)	WCLK to DOUT delay (For LJF mode only)		20		20	
t _d (DO-BCLK)	BCLK to DOUT delay		22		22	
t _s (DI)	DIN setup	8		8		
t _h (DI)	DIN hold	8		8		
t _r	Rise time		4		4	
t _f	Fall time		4		4	

Typical DSP Timing Characteristics

All specifications at 25°C, DVdd = 1.8V

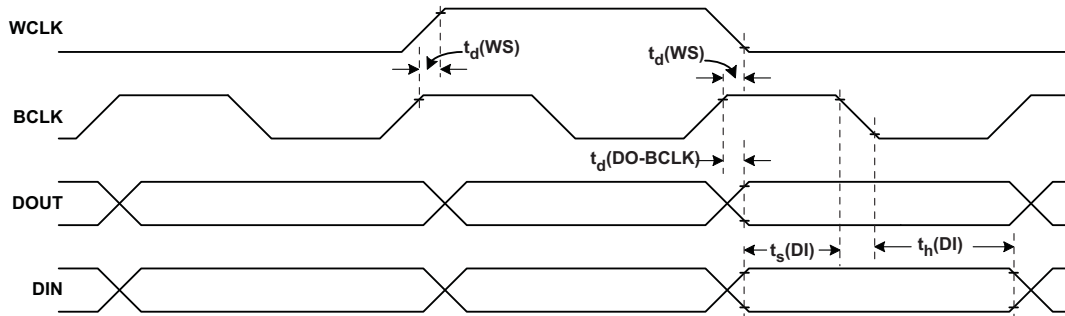


Figure 5. DSP Timing in Master Mode

Table 4. DSP Timing in Master Mode (see Figure 5)

PARAMETER		IOVDD=1.8V		IOVDD=3.3V		UNITS
		MIN	MAX	MIN	MAX	
$t_d(WS)$	WCLK delay		30		20	ns
$t_d(DO-BCLK)$	BCLK to DOUT delay		22		20	ns
$t_s(DI)$	DIN setup	8		8		ns
$t_h(DI)$	DIN hold	8		8		ns
t_r	Rise time		24		12	ns
t_f	Fall time		24		12	ns

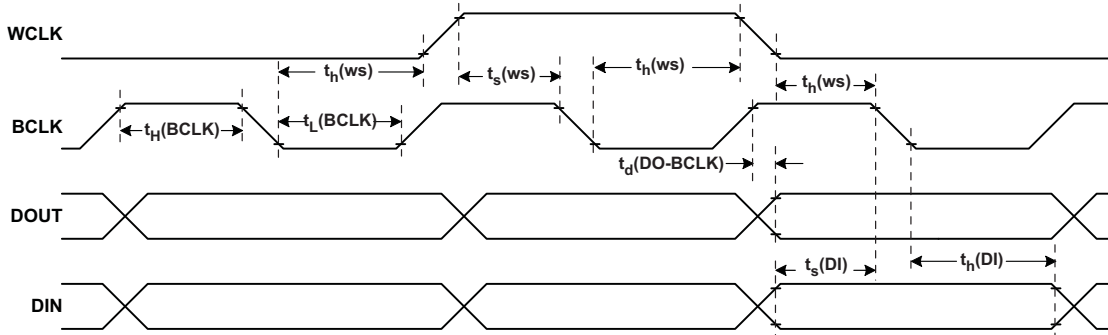


Figure 6. DSP Timing in Slave Mode

Table 5. DSP Timing in Slave Mode (see Figure 6)

PARAMETER		IOVDD=1.8V		IOVDD=3.3V		UNITS
		MIN	MAX	MIN	MAX	
$t_H(BCLK)$	BCLK high period	35		35		ns
$t_L(BCLK)$	BCLK low period	35		35		ns
$t_s(WS)$	WCLK setup	8		8		ns
$t_h(WS)$	WCLK hold	8		8		ns
$t_d(DO-BCLK)$	BCLK to DOUT delay		22		22	ns
$t_s(DI)$	DIN setup	8		8		ns
$t_h(DI)$	DIN hold	8		8		ns
t_r	Rise time		4		4	ns
t_f	Fall time		4		4	ns

I²C Interface Timing

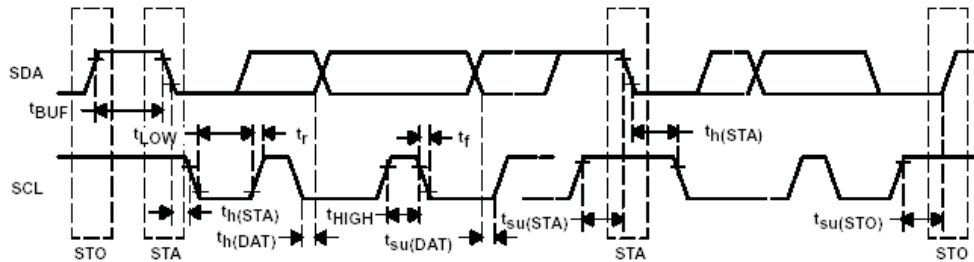


Figure 7. I²C Interface Timing

Table 6. I²C Interface Timing

PARAMETER	TEST CONDITION	Standard-Mode			Fast-Mode			UNITS			
		MIN	TYP	MAX	MIN	TYP	MAX				
f _{SCL}	SCL clock frequency			0		100		0		400	kHz
t _{HD;STA}	Hold time (repeated) START condition. After this period, the first clock pulse is generated.	4.0			0.8						μs
t _{LOW}	LOW period of the SCL clock	4.7			1.3						μs
t _{HIGH}	HIGH period of the SCL clock	4.0			0.6						μs
t _{SU;STA}	Setup time for a repeated START condition	4.7			0.8						μs
t _{HD;DAT}	Data hold time: For I2C bus devices	0		3.45	0		0.9				μs
t _{SU;DAT}	Data set-up time	250			100						ns
t _r	SDA and SCL Rise Time			1000	20+0.1C _b		300				ns
t _f	SDA and SCL Fall Time			300	20+0.1C _b		300				ns
t _{SU;STO}	Set-up time for STOP condition	4.0			0.8						μs
t _{BUF}	Bus free time between a STOP and START condition	4.7			1.3						μs
C _b	Capacitive load for each bus line			400			400				pF

SPI Interface Timing

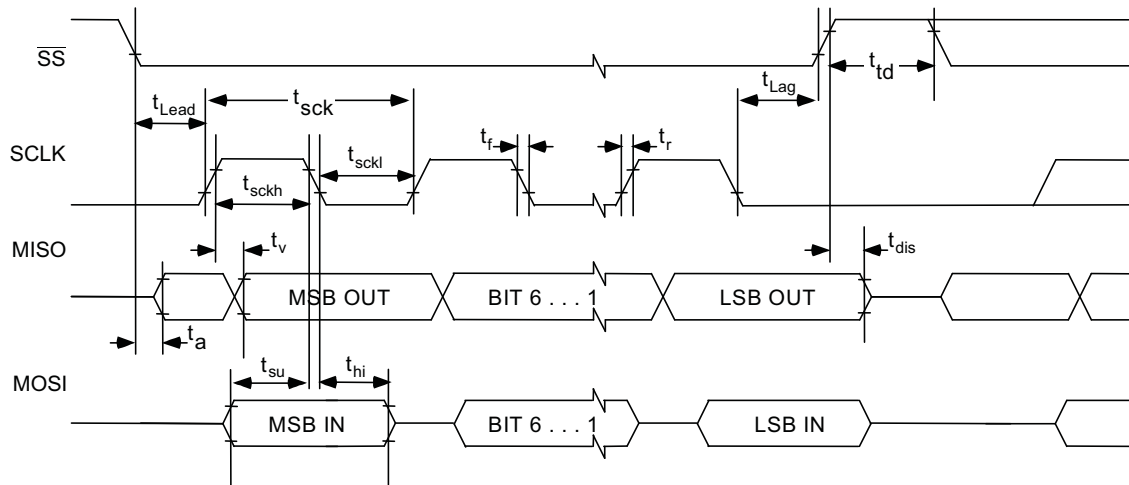


Figure 8. SPI Interface Timing Diagram

Timing Requirements (See Figure 8)

At 25°C, DVdd = 1.8V

Table 7. SPI Interface Timing

PARAMETER	TEST CONDITION	IOVDD=1.8V			IOVDD=3.3V			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
t _{sck}	SCLK Period ⁽¹⁾	100			50			ns
t _{sckh}	SCLK Pulse width High	50			25			ns
t _{sckl}	SCLK Pulse width Low	50			25			ns
t _{lead}	Enable Lead Time	30			20			ns
t _{trail}	Enable Trail Time	30			20			ns
t _{d;seqxfr}	Sequential Transfer Delay	40			20			ns
t _a	Slave DOUT access time			40			20	ns
t _{dis}	Slave DOUT disable time			40			20	ns
t _{su}	DIN data setup time	15			10			ns
t _{h;DIN}	DIN data hold time	15			10			ns
t _{v;DOUT}	DOUT data valid time			25			18	ns
t _r	SCLK Rise Time			4			4	ns
t _f	SCLK Fall Time			4			4	ns

(1) These parameters are based on characterization and are not tested in production.

Typical Characteristics

Typical Performance

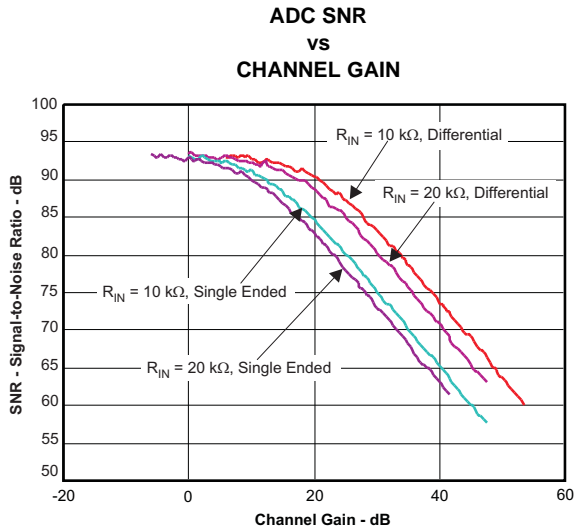


Figure 9.

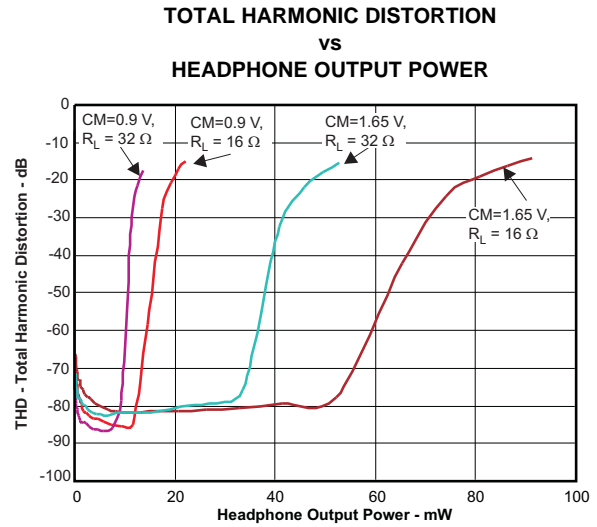


Figure 10.

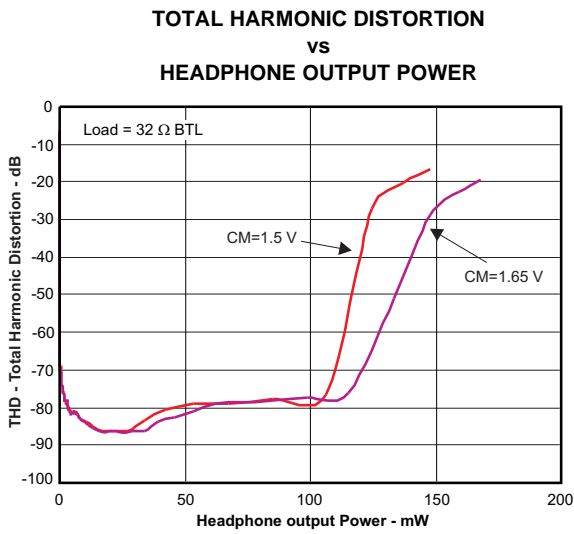


Figure 11.

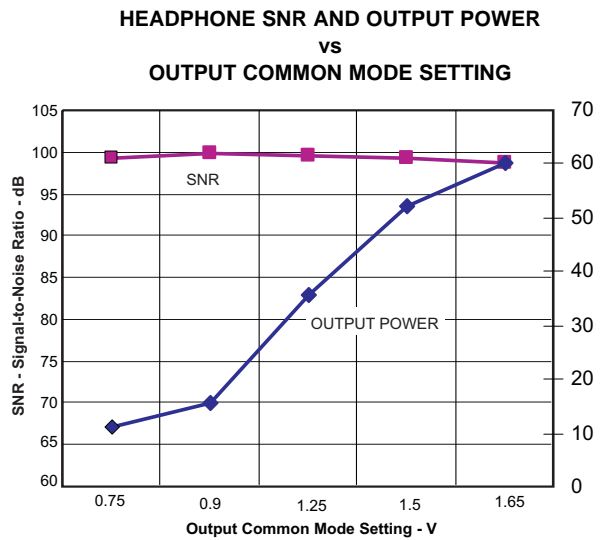


Figure 12.

**LDO DROPOUT VOLTAGE
vs
LOAD CURRENT**

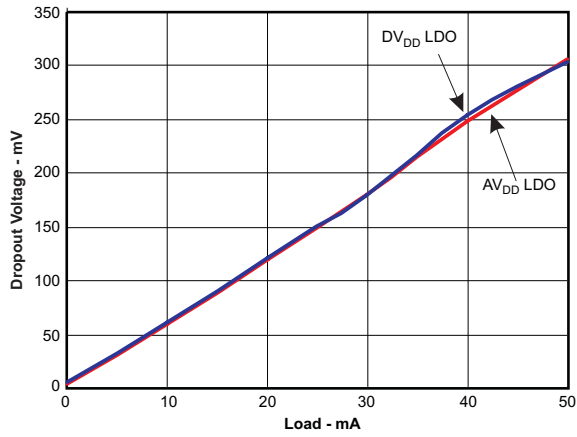


Figure 13.

LDO LOAD RESPONSE

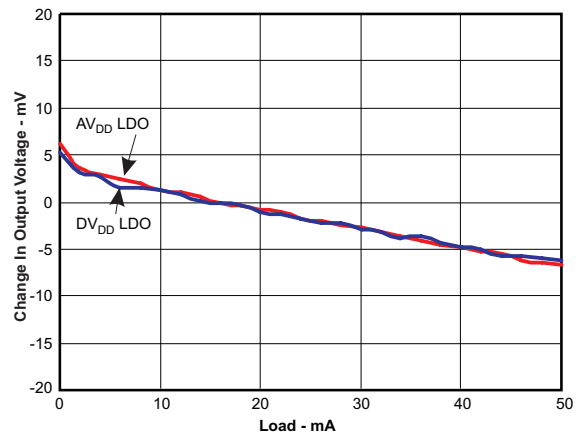


Figure 14.

FFT

**SINGLE ENDED LINE INPUT TO ADC FFT @ -1dB_r
vs
FREQUENCY**

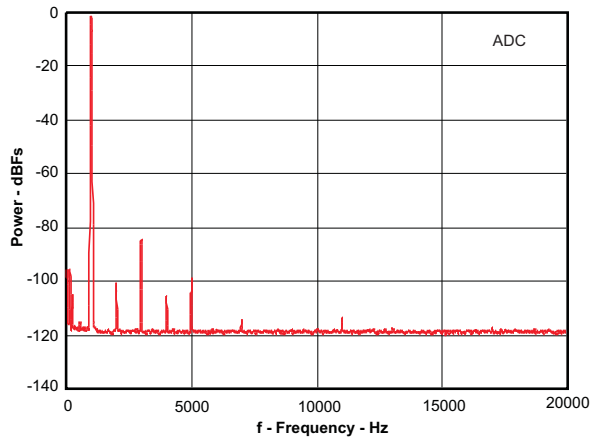


Figure 15.

**PLAYBACK TO HEADPHONE FFT @ -1dB_r
vs
FREQUENCY**

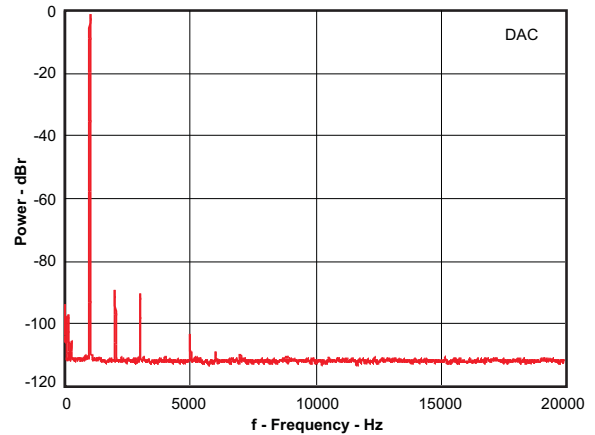


Figure 16.

**DAC PLAYBACK TO LINE-OUT FFT @ -1dBFS
vs
FREQUENCY**

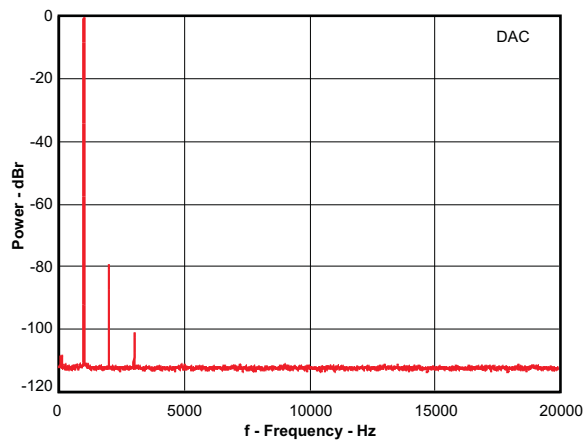


Figure 17.

**LINE INPUT TO HEADPHONE FFT @ 446mVrms
vs
FREQUENCY**

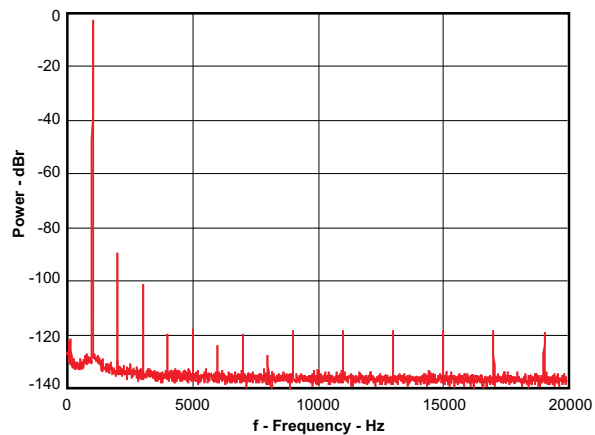


Figure 18.

**LINE INPUT TO LINE-OUT FFT @ 446mVrms
vs
FREQUENCY**

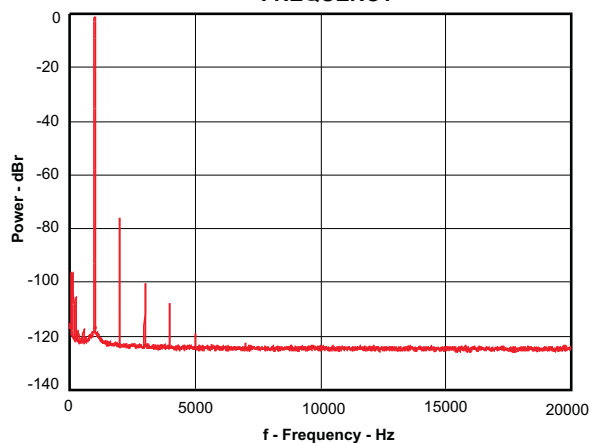


Figure 19.

Typical Circuit Configuration

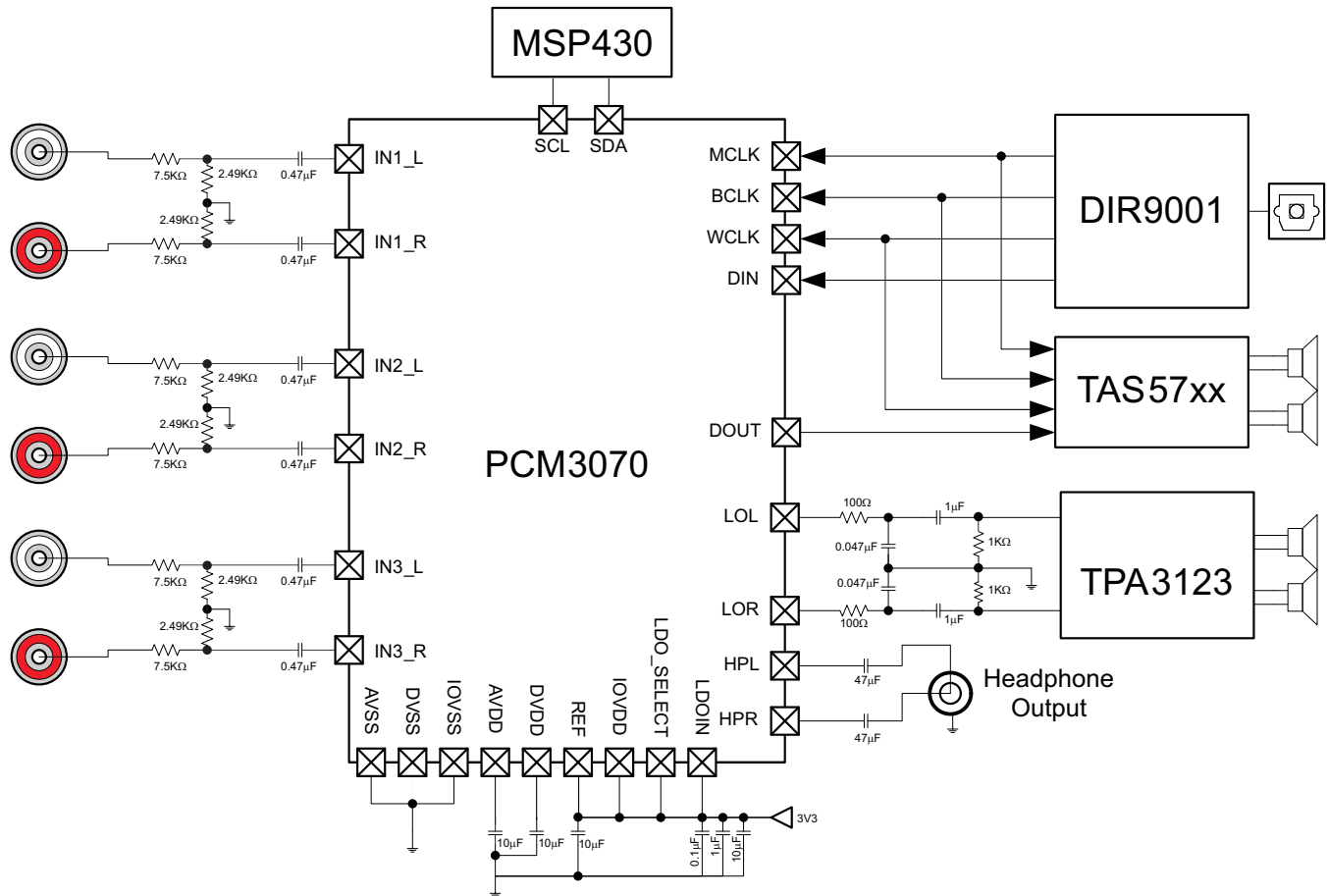


Figure 20. Typical Circuit Configuration

Application Overview

The PCM3070 offers a wide range of configuration options. [Figure 1](#) shows the basic functional blocks of the device.

Device Connections

Digital Pins

Only a small number of digital pins are dedicated to a single function; whenever possible, the digital pins have a default function, and also can be reprogrammed to cover alternative functions for various applications.

The fixed-function pins are Reset and the `SPI_Select` pin, which are HW control pins. Depending on the state of `SPI_Select`, the two control-bus pins `SCL/SS` and `SDA/MOSI` are configured for either I²C or SPI protocol.

Other digital IO pins can be configured for various functions via register control. An overview of available functionality is given in [Multifunction Pins](#).

Analog Pins

Analog functions can also be configured to a large degree. Analog blocks are powered down by default. The blocks can be powered up with fine granularity according to the application needs.

Multifunction Pins

Table 8 shows the possible allocation of pins for specific functions. The PLL input, for example, can be programmed to be any of 4 pins (MCLK, BCLK, DIN, GPIO).

Table 8. Multifunction Pin Assignments

		1	2	3	4	5	6	7	8
	Pin Function	MCLK	BCLK	WCLK	DIN MFP1	DOUT MFP2	MFP3/ SCLK	MFP4/ MISO	GPIO MFP5
A	PLL Input	S ⁽¹⁾	S ⁽²⁾		E				S ⁽³⁾
B	Codec Clock Input	S ⁽¹⁾ , D ⁽⁴⁾	S ⁽²⁾						S ⁽³⁾
C	I ² S BCLK input		S ⁽²⁾ , D						
D	I ² S BCLK output		E ⁽⁵⁾						
E	I ² S WCLK input			E, D					
F	I ² S WCLK output			E					
G	I ² S ADC word clock input						E		E
H	I ² S ADC WCLK out							E	E
I	I ² S DIN				E, D				
J	I ² S DOUT					E, D			
K	General Purpose Output I					E			
K	General Purpose Output II							E	
K	General Purpose Output III								E
L	General Purpose Input I				E				
L	General Purpose Input II						E		
L	General Purpose Input III								E
M	INT1 output					E		E	E
N	INT2 output					E		E	E
Q	Secondary I ² S BCLK input						E		E
R	Secondary I ² S WCLK in						E		E
S	Secondary I ² S DIN						E		E
T	Secondary I ² S DOUT							E	
U	Secondary I ² S BCLK OUT					E		E	E
V	Secondary I ² S WCLK OUT					E		E	E
W	Reserved								
X	Aux Clock Output					E		E	E

(1) S⁽¹⁾: The MCLK pin can be used to drive the PLL and Codec Clock inputs **simultaneously**

(2) S⁽²⁾: The BCLK pin can be used to drive the PLL and Codec Clock and audio interface bit clock inputs **simultaneously**

(3) S⁽³⁾: The GPIO/MFP5 pin can be used to drive the PLL and Codec Clock inputs **simultaneously**

(4) D: Default Function

(5) E: The pin is **exclusively** used for this function, no other function can be implemented with the same pin (e.g. if GPIO/MFP5 has been allocated for General Purpose Output, it cannot be used as the INT1 output at the same time)

Analog Audio I/O

The analog I/O path of the PCM3070 features a large set of options for signal conditioning as well as signal routing:

- 6 analog inputs which can be mixed and/or multiplexed in single-ended and/or differential configuration
- 2 programmable gain amplifiers (PGA) with a range of 0 to +47.5dB
- 2 mixer amplifiers for analog bypass
- 2 low power analog bypass channels
- Mute function
- Automatic gain control (AGC)
- Channel-to-channel phase adjustment

- Fast charge of ac-coupling capacitors
- Anti thump

Analog Bypass

The PCM3070 offers two analog-bypass modes. In either of the modes, an analog input signal can be routed from an analog input pin to an amplifier driving an analog output pin. Neither the ADC nor the DAC resources are required for such operation.

In analog low-power bypass mode, line-level signals can be routed directly from the analog inputs INL to the left headphone amplifier (HPL) and INR to HPR.

ADC Bypass Using Mixer Amplifiers

In addition to the analog bypass mode, there is a bypass mode that uses the programmable gain amplifiers of the input stage in conjunction with a mixer amplifier. With this mode, low-level signals can be amplified and routed to the line or headphone outputs, fully bypassing the ADC and DAC.

To enable this mode, the mixer amplifiers are powered on via software command.

Headphone Outputs

The stereo headphone drivers on pins HPL and HPR can drive loads with impedances down to 16Ω in single-ended AC-coupled headphone configurations, or loads down to 32Ω in differential mode, where a speaker is connected between HPL and HPR. In single-ended drive configuration these drivers can drive up to 15mW power into each headphone channel while operating from 1.8V analog supplies. While running from the AVdd supply, the output common-mode of the headphone driver is set by the common-mode setting of analog inputs in Page 1 / Register 10, Bit D6, to allow maximum utilization of the analog supply range while simultaneously providing a higher output-voltage swing. In cases when higher output-voltage swing is required, the headphone amplifiers can run directly from the higher supply voltage on LDOIN input (up to 3.6V). To use the higher supply voltage for higher output signal swing, the output common-mode can be adjusted to either 1.25V, 1.5V or 1.65V by configuring Page 1 / Register 10, Bits D5-D4. When the common-mode voltage is configured at 1.65V and LDOIN supply is 3.3V, the headphones can each deliver up to 40mW power into a 16Ω load.

The headphone drivers are capable of driving a mixed combination of DAC signal and bypass from analog input INL and INR by configuring Page 1 / Register 12 and Page 1 / Register 13 respectively. The analog input signals can be attenuated up to 72dB before routing by configuring Page 1 / Register 22 and 23. The level of the DAC signal can be controlled using the digital volume control of the DAC in Page 0, Reg 65 and 66. To control the output-voltage swing of headphone drivers, the digital volume control provides a range of -6.0dB to $+29.0\text{dB}^{(6)}$ in steps of 1dB. These can be configured by programming Page 1 / Register 16 and 17. These level controls are not meant to be used as dynamic volume control, but more to set output levels during initial device configuration. Refer to for recommendations for using headphone volume control for achieving 0dB gain through the DAC channel with various configurations.

Line Outputs

The stereo line level drivers on LOL and LOR pins can drive a wide range of line level resistive impedances in the range of 600Ω to $10\text{k}\Omega$. The output common modes of line level drivers can be configured to equal either the analog input common-mode setting or to 1.65V. With output common-mode setting of 1.65V and DRVdd_HP supply at 3.3V the line-level drivers can drive up to 1Vrms output signal. The line-level drivers can drive out a mixed combination of DAC signal and attenuated ADC PGA signal. Signal mixing is register-programmable.

ADC

The PCM3070 includes a stereo audio ADC, which uses a delta-sigma modulator with a programmable oversampling ratio, followed by a digital decimation filter. The stereo recording path can be powered up one channel at a time, to support the case where only mono record capability is required.

The ADC path of the PCM3070 features a large set of options for signal conditioning as well as signal routing:

- 2 ADCs
- 6 analog inputs which can be mixed and/or multiplexed in single-ended and/or differential configuration

(6) If the device must be placed into 'mute' from the -6.0dB setting, set the device at a gain of -5.0dB first, then place the device into mute.

- 2 programmable gain amplifiers (PGA) with a range of 0 to +47.5dB
- 2 mixer amplifiers for analog bypass
- 2 analog bypass channels
- Fine gain adjust of digital channels with 0.1 dB step size
- Digital volume control with a range of -12 to +20dB
- Mute function
- Automatic gain control (AGC)

In addition to the standard set of ADC features the PCM3070 also offers the following special functions:

- Channel-to-channel phase adjustment
- Fast charge of ac-coupling capacitors
- Anti thump
- Adaptive filter mode

ADC Processing

The PCM3070 ADC channel includes a built-in digital decimation filter to process the oversampled data from the sigma-delta modulator to generate digital data at Nyquist sampling rate with high dynamic range. The decimation filter can be chosen from three different types, depending on the required frequency response, group delay and sampling rate.

ADC Processing Blocks

The PCM3070 offers a range of processing blocks which implement various signal processing capabilities along with decimation filtering. These processing blocks give users the choice of how much and what type of signal processing they may use and which decimation filter is applied.

[Table 9](#) gives an overview of the available processing blocks of the ADC channel and their properties.

The signal processing blocks available are:

- First-order IIR
- Scalable number of biquad filters
- Variable-tap FIR filter
- AGC

The processing blocks are tuned for common cases and can achieve high anti-alias filtering or low-group delay in combination with various signal processing effects such as audio effects and frequency shaping. The available first order IIR, BiQuad and FIR filters have fully user-programmable coefficients. The Resource Class Column (RC) gives an approximate indication of power consumption.

Table 9. ADC Processing Blocks

Processing Blocks	Channel	Decimation Filter	1st Order IIR Available	Number BiQuads	FIR	Required AOSR Value	Resource Class
PRB_R1 ⁽¹⁾	Stereo	A	Yes	0	No	128,64	6
PRB_R2	Stereo	A	Yes	5	No	128,64	8
PRB_R3	Stereo	A	Yes	0	25-Tap	128,64	8
PRB_R4	Right	A	Yes	0	No	128,64	3
PRB_R5	Right	A	Yes	5	No	128,64	4
PRB_R6	Right	A	Yes	0	25-Tap	128,64	4
PRB_R7	Stereo	B	Yes	0	No	64	3
PRB_R8	Stereo	B	Yes	3	No	64	4
PRB_R9	Stereo	B	Yes	0	20-Tap	64	4
PRB_R10	Right	B	Yes	0	No	64	2
PRB_R11	Right	B	Yes	3	No	64	2

(1) Default

Table 9. ADC Processing Blocks (continued)

Processing Blocks	Channel	Decimation Filter	1st Order IIR Available	Number BiQuads	FIR	Required AOSR Value	Resource Class
PRB_R12	Right	B	Yes	0	20-Tap	64	2
PRB_R13	Stereo	C	Yes	0	No	32	3
PRB_R14	Stereo	C	Yes	5	No	32	4
PRB_R15	Stereo	C	Yes	0	25-Tap	32	4
PRB_R16	Right	C	Yes	0	No	32	2
PRB_R17	Right	C	Yes	5	No	32	2
PRB_R18	Right	C	Yes	0	25-Tap	32	2

For more detailed information see the *PCM3070 Application Reference Guide*, SLAU332.

DAC

The PCM3070 includes a stereo audio DAC supporting data rates from 8kHz to 192kHz. Each channel of the stereo audio DAC consists of a signal-processing engine with fixed processing blocks, a programmable miniDSP, a digital interpolation filter, multi-bit digital delta-sigma modulator, and an analog reconstruction filter. The DAC is designed to provide enhanced performance at low sampling rates through increased oversampling and image filtering, thereby keeping quantization noise generated within the delta-sigma modulator and signal images strongly suppressed within the audio band to beyond 20kHz. To handle multiple input rates and optimize performance, the PCM3070 allows the system designer to program the oversampling rates over a wide range from 1 to 1024. The system designer can choose higher oversampling ratios for lower input data rates and lower oversampling ratios for higher input data rates.

The PCM3070 DAC channel includes a built-in digital interpolation filter to generate oversampled data for the sigma-delta modulator. The interpolation filter can be chosen from three different types depending on required frequency response, group delay and sampling rate.

The DAC path of the PCM3070 features many options for signal conditioning and signal routing:

- 2 headphone amplifiers
 - Usable in single-ended or differential mode
 - Analog volume setting with a range of -6 to +29 dB
- 2 line-out amplifiers
 - Usable in single-ended or differential mode
 - Analog volume setting with a range of -6 to +29 dB
- Digital volume control with a range of -63.5 to +24dB
- Mute function
- Dynamic range compression (DRC)

In addition to the standard set of DAC features the PCM3070 also offers the following special features:

- Built in sine wave generation (beep generator)
- Digital auto mute
- Adaptive filter mode

DAC Processing Blocks — Overview

The PCM3070 implements signal processing capabilities and interpolation filtering via processing blocks. These fixed processing blocks give users the choice of how much and what type of signal processing they may use and which interpolation filter is applied.

[Table 10](#) gives an overview over all available processing blocks of the DAC channel and their properties. The Resource Class Column (RC) gives an approximate indication of power consumption.

The signal processing blocks available are:

- First-order IIR
- Scalable number of biquad filters
- 3D – Effect
- Beep Generator

The processing blocks are tuned for typical cases and can achieve high image rejection or low group delay in combination with various signal processing effects such as audio effects and frequency shaping. The available first-order IIR and biquad filters have fully user-programmable coefficients. The Resource Class Column (RC) gives an approximate indication of power consumption.

Table 10. Overview – DAC Predefined Processing Blocks

Processing Block No.	Interpolation Filter	Channel	1st Order IIR Available	Num. of Biquads	DRC	3D	Beep Generator	Resource Class
PRB_P1 ⁽¹⁾	A	Stereo	No	3	No	No	No	8
PRB_P2	A	Stereo	Yes	6	Yes	No	No	12

(1) Default

Table 10. Overview – DAC Predefined Processing Blocks (continued)

Processing Block No.	Interpolation Filter	Channel	1st Order IIR Available	Num. of Biquads	DRC	3D	Beep Generator	Resource Class
PRB_P3	A	Stereo	Yes	6	No	No	No	10
PRB_P4	A	Left	No	3	No	No	No	4
PRB_P5	A	Left	Yes	6	Yes	No	No	6
PRB_P6	A	Left	Yes	6	No	No	No	6
PRB_P7	B	Stereo	Yes	0	No	No	No	6
PRB_P8	B	Stereo	No	4	Yes	No	No	8
PRB_P9	B	Stereo	No	4	No	No	No	8
PRB_P10	B	Stereo	Yes	6	Yes	No	No	10
PRB_P11	B	Stereo	Yes	6	No	No	No	8
PRB_P12	B	Left	Yes	0	No	No	No	3
PRB_P13	B	Left	No	4	Yes	No	No	4
PRB_P14	B	Left	No	4	No	No	No	4
PRB_P15	B	Left	Yes	6	Yes	No	No	6
PRB_P16	B	Left	Yes	6	No	No	No	4
PRB_P17	C	Stereo	Yes	0	No	No	No	3
PRB_P18	C	Stereo	Yes	4	Yes	No	No	6
PRB_P19	C	Stereo	Yes	4	No	No	No	4
PRB_P20	C	Left	Yes	0	No	No	No	2
PRB_P21	C	Left	Yes	4	Yes	No	No	3
PRB_P22	C	Left	Yes	4	No	No	No	2
PRB_P23	A	Stereo	No	2	No	Yes	No	8
PRB_P24	A	Stereo	Yes	5	Yes	Yes	No	12
PRB_P25	A	Stereo	Yes	5	Yes	Yes	Yes	12

For more detailed information see the *PCM3070 Application Reference Guide*, SLAU332.

Digital Audio I/O Interface

Audio data is transferred between the host processor and the PCM3070 via the digital audio data serial interface, or audio bus. The audio bus on this device is very flexible, including left or right-justified data options, support for I²S or PCM protocols, programmable data length options, a TDM mode for multichannel operation, very flexible master/slave configurability for each bus clock line, and the ability to communicate with multiple devices within a system directly.

The audio bus of the PCM3070 can be configured for left or right-justified, I²S, DSP, or TDM modes of operation, where communication with standard PCM interfaces is supported within the TDM mode. These modes are all MSB-first, with data width programmable as 16, 20, 24, or 32 bits by configuring Page 0, Register 27, D(5:4). In addition, the word clock and bit clock can be independently configured in either Master or Slave mode, for flexible connectivity to a wide variety of processors. The word clock is used to define the beginning of a frame, and may be programmed as either a pulse or a square-wave signal. The frequency of this clock corresponds to the maximum of the selected ADC and DAC sampling frequencies.

The bit clock is used to clock in and clock out the digital audio data across the serial bus. When in Master mode, this signal can be programmed to generate variable clock pulses by controlling the bit-clock divider in Page 0, Register 30. The number of bit-clock pulses in a frame may need adjustment to accommodate various word-lengths as well as to support the case when multiple PCM3070s may share the same audio bus.

The PCM3070 also includes a feature to offset the position of start of data transfer with respect to the word-clock. This offset can be controlled in terms of number of bit-clocks and can be programmed in Page 0, Register 28.

The PCM3070 also has the feature of inverting the polarity of the bit-clock used for transferring the audio data as compared to the default clock polarity used. This feature can be used independently of the mode of audio interface chosen. This can be configured via Page 0, Register 29, D(3).

The PCM3070 further includes programmability (Page 0, Register 27, D0) to place the DOUT line into a hi-Z (3-state) condition during all bit clocks when valid data is not being sent. By combining this capability with the ability to program at what bit clock in a frame the audio data begins, time-division multiplexing (TDM) can be accomplished, enabling the use of multiple codecs on a single audio serial data bus. When the audio serial data bus is powered down while configured in master mode, the pins associated with the interface are put into a hi-Z output condition.

By default when the word-clocks and bit-clocks are generated by the PCM3070, these clocks are active only when the codec (ADC, DAC or both) are powered up within the device. This is done to save power. However, it also supports a feature when both the word clocks and bit-clocks can be active even when the codec in the device is powered down. This is useful when using the TDM mode with multiple codecs on the same bus, or when word-clock or bit-clocks are used in the system as general-purpose clocks.

Clock Generation and PLL

The PCM3070 supports a wide range of options for generating clocks for the ADC and DAC sections as well as interface and other control blocks. The clocks for ADC and DAC require a source reference clock. This clock can be provided on variety of device pins such as MCLK, BCLK or GPI pins. The CODEC_CLKIN can then be routed through highly-flexible clock dividers to generate the various clocks required for ADC, DAC and the miniDSP sections. In the event that the desired audio or miniDSP clocks cannot be generated from the reference clocks on MCLK BCLK or GPIO, the PCM3070 also provides the option of using the on-chip PLL which supports a wide range of fractional multiplication values to generate the required clocks. Starting from CODEC_CLKIN the PCM3070 provides several programmable clock dividers to help achieve a variety of sampling rates for ADC, DAC and clocks for the miniDSP

For more detailed information see the *PCM3070 Application Reference Guide*, SLAU332.

Control Interfaces

The PCM3070 control interface supports SPI or I²C communication protocols, with the protocol selectable using the SPI_SELECT pin. For SPI, SPI_SELECT should be tied high; for I²C, SPI_SELECT should be tied low. It is not recommended to change the state of SPI_SELECT during device operation.

I²C Control

The PCM3070 supports the I²C control protocol, and will respond to the I²C address of 0011000. I²C is a two-wire, open-drain interface supporting multiple devices and masters on a single bus. Devices on the I²C bus only drive the bus lines LOW by connecting them to ground; they never drive the bus lines HIGH. Instead, the bus wires are pulled HIGH by pullup resistors, so the bus wires are HIGH when no device is driving them LOW. This way, two devices cannot conflict; if two devices drive the bus simultaneously, there is no driver contention.

SPI Control

In the SPI control mode, the PCM3070 uses the pins SCL/SS as SS, SCLK as SCLK, MISO as MISO, SDA/MOSI as MOSI; a standard SPI port with clock polarity setting of 0 (typical microprocessor SPI control bit CPOL = 0). The SPI port allows full-duplex, synchronous, serial communication between a host processor (the master) and peripheral devices (slaves). The SPI master (in this case, the host processor) generates the synchronizing clock (driven onto SCLK) and initiates transmissions. The SPI slave devices (such as the PCM3070) depend on a master to start and synchronize transmissions. A transmission begins when initiated by an SPI master. The byte from the SPI master begins shifting in on the slave MOSI pin under the control of the master serial clock (driven onto SCLK). As the byte shifts in on the MOSI pin, a byte shifts out on the MISO pin to the master shift register.

For more detailed information see the *PCM3070 Application Reference Guide*, SLAU332.

Power Supply

To power up the device, a 3.3V system rail (1.9V to 3.6V) can be used. The IO_{VDD} voltage can be in the range of 1.1V - 3.6V. Internal LDOs generate the appropriate digital core voltage of 1.65V and analog core voltage of 1.8V (minimum 1.5V). For maximum flexibility, the respective voltages can also be supplied externally, bypassing the built-in LDOs. To support high-output drive capabilities, the output stages of the output amplifiers can either be driven from the analog core voltage or the 1.9...3.6V rail used for the LDO inputs (LDO_in).

For more detailed information see the *PCM3070 Application Reference Guide*, SLAU332.

Device Special Functions

The following special functions are available to support advanced system requirements:

- Interrupt generation
- Flexible pin multiplexing

For more detailed information see the *PCM3070 Application Reference Guide*, SLAU332.

MiniDSP

The PCM3070 features two miniDSP cores. The first miniDSP core is tightly coupled to the ADC, the second miniDSP core is tightly coupled to the DAC. The fully programmable algorithms for the miniDSP must be loaded into the device after power up. The miniDSPs have direct access to the digital stereo audio stream on the ADC and on the DAC side, offering the possibility for advanced, very-low group delay DSP algorithms. Each miniDSP can run up to 1152 instructions on every audio sample at a 48kHz sample rate. The two cores can run fully synchronized and can exchange data.

Software

Software development for the PCM3070 is supported through TI's comprehensive PurePath Studio Development Environment; a powerful, easy-to-use tool designed specifically to simplify software development on the PCM3070 miniDSP audio platform. The Graphical Development Environment consists of a library of common audio functions that can be dragged-and-dropped into an audio signal flow and graphically connected together. The DSP code can then be assembled from the graphical signal flow with the click of a mouse.

Please visit the PCM3070 product folder on www.ti.com to learn more about PurePath Studio and the latest status on available, ready-to-use DSP algorithms.

Register Map Summary

Table 11. Summary of Register Map

Decimal		Hex		DESCRIPTION
PAGE NO.	REG. NO.	PAGE NO.	REG. NO.	
0	0	0x00	0x00	Page Select Register
0	1	0x00	0x01	Software Reset Register
0	2	0x00	0x02	Reserved Register
0	3	0x00	0x03	Reserved Register
0	4	0x00	0x04	Clock Setting Register 1, Multiplexers
0	5	0x00	0x05	Clock Setting Register 2, PLL P&R Values
0	6	0x00	0x06	Clock Setting Register 3, PLL J Values
0	7	0x00	0x07	Clock Setting Register 4, PLL D Values (MSB)
0	8	0x00	0x08	Clock Setting Register 5, PLL D Values (LSB)
0	9-10	0x00	0x09-0x0A	Reserved Register
0	11	0x00	0x0B	Clock Setting Register 6, NDAC Values
0	12	0x00	0x0C	Clock Setting Register 7, MDAC Values
0	13	0x00	0x0D	DAC OSR Setting Register 1, MSB Value
0	14	0x00	0x0E	DAC OSR Setting Register 2, LSB Value
0	15	0x00	0x0F	miniDSP_D Instruction Control Register 1
0	16	0x00	0x10	miniDSP_D Instruction Control Register 2
0	17	0x00	0x11	miniDSP_D Interpolation Factor Setting Register
0	18	0x00	0x12	Clock Setting Register 8, NADC Values
0	19	0x00	0x13	Clock Setting Register 9, MADC Values
0	20	0x00	0x14	ADC Oversampling (AOSR) Register
0	21	0x00	0x15	miniDSP_A Instruction Control Register 1

Table 11. Summary of Register Map (continued)

Decimal		Hex		DESCRIPTION
PAGE NO.	REG. NO.	PAGE NO.	REG. NO.	
0	22	0x00	0x16	miniDSP_A Instruction Control Register 2
0	23	0x00	0x17	miniDSP_A Decimation Factor Setting Register
0	24	0x00	0x18	Reserved Register
0	25	0x00	0x19	Clock Setting Register 10, Multiplexers
0	26	0x00	0x1A	Clock Setting Register 11, CLKOUT M divider value
0	27	0x00	0x1B	Audio Interface Setting Register 1
0	28	0x00	0x1C	Audio Interface Setting Register 2, Data offset setting
0	29	0x00	0x1D	Audio Interface Setting Register 3
0	30	0x00	0x1E	Clock Setting Register 12, BCLK N Divider
0	31	0x00	0x1F	Audio Interface Setting Register 4, Secondary Audio Interface
0	32	0x00	0x20	Audio Interface Setting Register 5
0	33	0x00	0x21	Audio Interface Setting Register 6
0	34	0x00	0x22	Digital Interface Misc. Setting Register
0	35	0x00	0x23	Reserved Register
0	36	0x00	0x24	ADC Flag Register
0	37	0x00	0x25	DAC Flag Register 1
0	38	0x00	0x26	DAC Flag Register 2
0	39-41	0x00	0x27-0x29	Reserved Register
0	42	0x00	0x2A	Sticky Flag Register 1
0	43	0x00	0x2B	Interrupt Flag Register 1
0	44	0x00	0x2C	Sticky Flag Register 2
0	45	0x00	0x2D	Sticky Flag Register 3
0	46	0x00	0x2E	Interrupt Flag Register 2
0	47	0x00	0x2F	Interrupt Flag Register 3
0	48	0x00	0x30	INT1 Interrupt Control Register
0	49	0x00	0x31	INT2 Interrupt Control Register
0	50-51	0x00	0x32-0x33	Reserved Register
0	52	0x00	0x34	GPIO/MFP5 Control Register
0	53	0x00	0x35	DOOUT/MFP2 Function Control Register
0	54	0x00	0x36	DIN/MFP1 Function Control Register
0	55	0x00	0x37	MISO/MFP4 Function Control Register
0	56	0x00	0x38	SCLK/MFP3 Function Control Register
0	57-59	0x00	0x39-0x3B	Reserved Registers
0	60	0x00	0x3C	DAC Signal Processing Block Control Register
0	61	0x00	0x3D	ADC Signal Processing Block Control Register
0	62	0x00	0x3E	miniDSP_A and miniDSP_D Configuration Register
0	63	0x00	0x3F	DAC Channel Setup Register 1
0	64	0x00	0x40	DAC Channel Setup Register 2
0	65	0x00	0x41	Left DAC Channel Digital Volume Control Register
0	66	0x00	0x42	Right DAC Channel Digital Volume Control Register
0	67	0x00	0x43	RESERVED
0	68	0x00	0x44	DRC Control Register 1
0	69	0x00	0x45	DRC Control Register 2
0	70	0x00	0x46	DRC Control Register 3
0	71	0x00	0x47	Beep Generator Register 1
0	72	0x00	0x48	Beep Generator Register 2

Table 11. Summary of Register Map (continued)

Decimal		Hex		DESCRIPTION
PAGE NO.	REG. NO.	PAGE NO.	REG. NO.	
0	73	0x00	0x49	Beep Generator Register 3
0	74	0x00	0x4A	Beep Generator Register 4
0	75	0x00	0x4B	Beep Generator Register 5
0	76	0x00	0x4C	Beep Generator Register 6
0	77	0x00	0x4D	Beep Generator Register 7
0	78	0x00	0x4E	Beep Generator Register 8
0	79	0x00	0x4F	Beep Generator Register 9
0	80	0x00	0x50	Reserved Register
0	81	0x00	0x51	ADC Channel Setup Register
0	82	0x00	0x52	ADC Fine Gain Adjust Register
0	83	0x00	0x53	Left ADC Channel Volume Control Register
0	84	0x00	0x54	Right ADC Channel Volume Control Register
0	85	0x00	0x55	ADC Phase Adjust Register
0	86	0x00	0x56	Left Channel AGC Control Register 1
0	87	0x00	0x57	Left Channel AGC Control Register 2
0	88	0x00	0x58	Left Channel AGC Control Register 3
0	89	0x00	0x59	Left Channel AGC Control Register 4
0	90	0x00	0x5A	Left Channel AGC Control Register 5
0	91	0x00	0x5B	Left Channel AGC Control Register 6
0	92	0x00	0x5C	Left Channel AGC Control Register 7
0	93	0x00	0x5D	Left Channel AGC Control Register 8
0	94	0x00	0x5E	Right Channel AGC Control Register 1
0	95	0x00	0x5F	Right Channel AGC Control Register 2
0	96	0x00	0x60	Right Channel AGC Control Register 3
0	97	0x00	0x61	Right Channel AGC Control Register 4
0	98	0x00	0x62	Right Channel AGC Control Register 5
0	99	0x00	0x63	Right Channel AGC Control Register 6
0	100	0x00	0x64	Right Channel AGC Control Register 7
0	101	0x00	0x65	Right Channel AGC Control Register 8
0	102	0x00	0x66	DC Measurement Register 1
0	103	0x00	0x67	DC Measurement Register 2
0	104	0x00	0x68	Left Channel DC Measurement Output Register 1
0	105	0x00	0x69	Left Channel DC Measurement Output Register 2
0	106	0x00	0x6A	Left Channel DC Measurement Output Register 3
0	107	0x00	0x6B	Right Channel DC Measurement Output Register 1
0	108	0x00	0x6C	Right Channel DC Measurement Output Register 2
0	109	0x00	0x6D	Right Channel DC Measurement Output Register 3
0	110-127	0x00	0x6E-0x7F	Reserved Register
1	0	0x01	0x00	Page Select Register
1	1	0x01	0x01	Power Configuration Register
1	2	0x01	0x02	LDO Control Register
1	3	0x01	0x03	Playback Configuration Register 1
1	4	0x01	0x04	Playback Configuration Register 2
1	5-8	0x01	0x05-0x08	Reserved Register
1	9	0x01	0x09	Output Driver Power Control Register
1	10	0x01	0x0A	Common Mode Control Register

Table 11. Summary of Register Map (continued)

Decimal		Hex		DESCRIPTION
PAGE NO.	REG. NO.	PAGE NO.	REG. NO.	
1	11	0x01	0x0B	Over Current Protection Configuration Register
1	12	0x01	0x0C	HPL Routing Selection Register
1	13	0x01	0x0D	HPR Routing Selection Register
1	14	0x01	0x0E	LOL Routing Selection Register
1	15	0x01	0x0F	LOR Routing Selection Register
1	16	0x01	0x10	HPL Driver Gain Setting Register
1	17	0x01	0x11	HPR Driver Gain Setting Register
1	18	0x01	0x12	LOL Driver Gain Setting Register
1	19	0x01	0x13	LOR Driver Gain Setting Register
1	20	0x01	0x14	Headphone Driver Startup Control Register
1	21	0x01	0x15	Reserved Register
1	22	0x01	0x16	IN1L to HPL Volume Control Register
1	23	0x01	0x17	IN1R to HPR Volume Control Register
1	24	0x01	0x18	Mixer Amplifier Left Volume Control Register
1	25	0x01	0x19	Mixer Amplifier Right Volume Control Register
1	26-50	0x01	0x1A-0x32	Reserved Register
1	51	0x01	0x33	Reserved. Do Not Use
1	52	0x01	0x34	Left PGA Positive Terminal Input Routing Configuration Register
1	53	0x01	0x35	Reserved Register
1	54	0x01	0x36	Left PGA Negative Terminal Input Routing Configuration Register
1	55	0x01	0x37	Right PGA Positive Terminal Input Routing Configuration Register
1	56	0x01	0x38	Reserved Register
1	57	0x01	0x39	Right PGA Negative Terminal Input Routing Configuration Register
1	58	0x01	0x3A	Floating Input Configuration Register
1	59	0x01	0x3B	Left PGA Volume Control Register
1	60	0x01	0x3C	Right PGA Volume Control Register
1	61	0x01	0x3D	Reserved. Do Not Use
1	62	0x01	0x3E	ADC Analog Volume Control Flag Register
1	63	0x01	0x3F	DAC Analog Gain Control Flag Register
1	64-70	0x01	0x40-0x46	Reserved Register
1	71	0x01	0x47	Analog Input Quick Charging Configuration Register
1	72-122	0x01	0x48-0x7A	Reserved Register
1	123	0x01	0x7B	Reference Power-up Configuration Register
1	124-127	0x01	0x7C-0x7F	Reserved Register
8	0	0x08	0x00	Page Select Register
8	1	0x08	0x01	ADC Adaptive Filter Configuration Register
8	2-7	0x08	0x02-0x07	Reserved
8	8-127	0x08	0x08-0x7F	ADC Coefficients Buffer-A C(0:29)
9-16	0	0x09-0x10	0x00	Page Select Register
9-16	1-7	0x09-0x10	0x01-0x07	Reserved
9-16	8-127	0x09-0x10	0x08-0x7F	ADC Coefficients Buffer-A C(30:255)
26-34	0	0x1A-0x22	0x00	Page Select Register
26-34	1-7	0x1A-0x22	0x01-0x07	Reserved.
26-34	8-127	0x1A-0x22	0x08-0x7F	ADC Coefficients Buffer-B C(0:255)
44	0	0x2C	0x00	Page Select Register
44	1	0x2C	0x01	DAC Adaptive Filter Configuration Register

Table 11. Summary of Register Map (continued)

Decimal		Hex		DESCRIPTION
PAGE NO.	REG. NO.	PAGE NO.	REG. NO.	
44	2-7	0x2C	0x02-0x07	Reserved
44	8-127	0x2C	0x08-0x7F	DAC Coefficients Buffer-A C(0:29)
45-52	0	0x2D-0x34	0x00	Page Select Register
45-52	1-7	0x2D-0x34	0x01-0x07	Reserved.
45-52	8-127	0x2D-0x34	0x08-0x7F	DAC Coefficients Buffer-A C(30:255)
62-70	0	0x3E-0x46	0x00	Page Select Register
62-70	1-7	0x3E-0x46	0x01-0x07	Reserved.
62-70	8-127	0x3E-0x46	0x08-0x7F	DAC Coefficients Buffer-B C(0:255)
80-114	0	0x50-0x72	0x00	Page Select Register
80-114	1-7	0x50-0x72	0x01-0x07	Reserved.
80-114	8-127	0x50-0x72	0x08-0x7F	miniDSP_A Instructions
152-186	0	0x98-0xBA	0x00	Page Select Register
152-186	1-7	0x98-0xBA	0x01-0x07	Reserved.
152-186	8-127	0x98-0xBA	0x08-0x7F	miniDSP_D Instructions

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)
PCM3070IRHBR	ACTIVE	QFN	RHB	32	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	
PCM3070IRHBT	ACTIVE	QFN	RHB	32	250	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.

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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
PCM3070IRHBR	QFN	RHB	32	3000	330.0	12.4	5.3	5.3	1.5	8.0	12.0	Q2
PCM3070IRHBT	QFN	RHB	32	250	180.0	12.4	5.3	5.3	1.5	8.0	12.0	Q2

TAPE AND REEL BOX DIMENSIONS



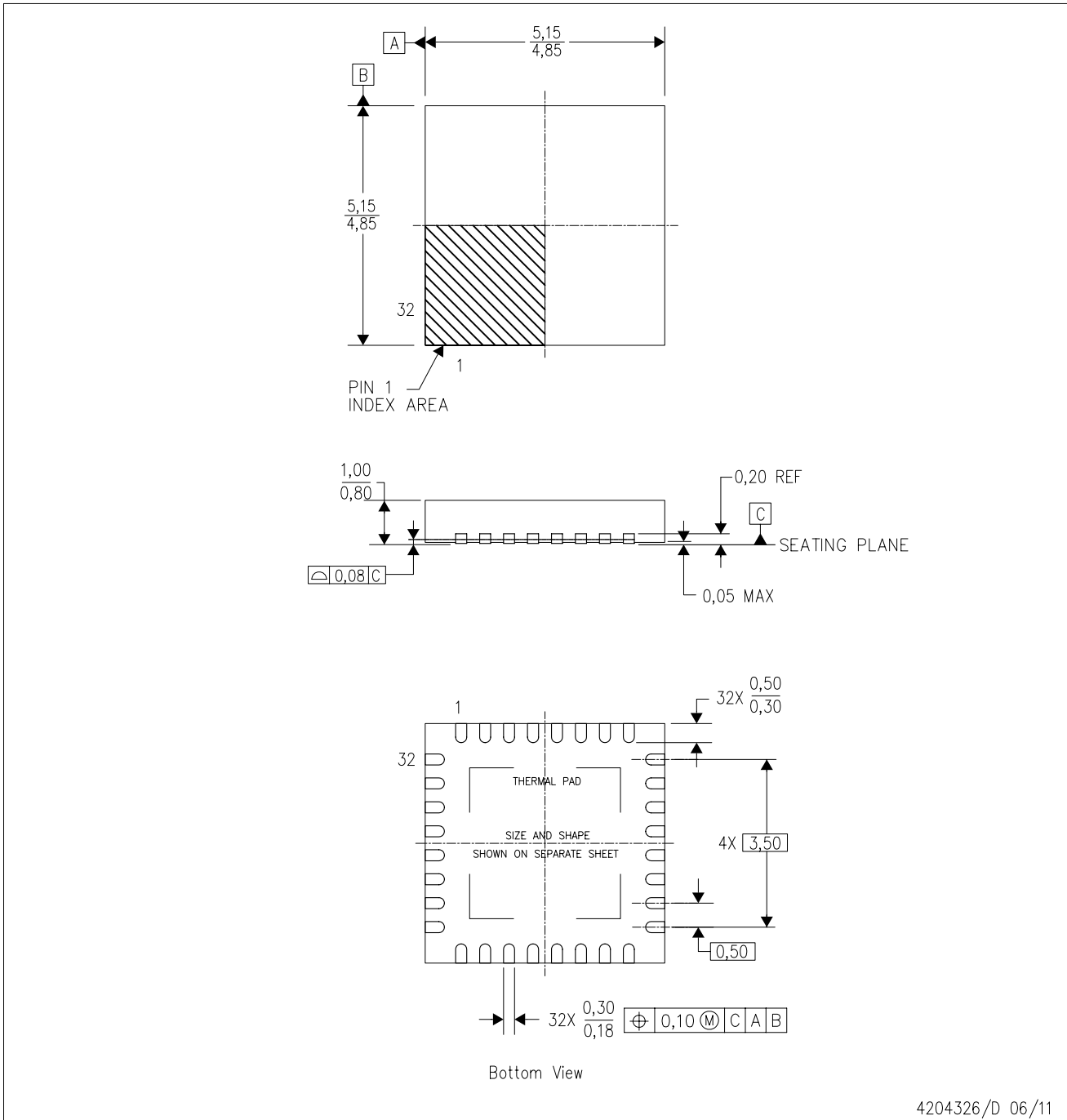
*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
PCM3070IRHBR	QFN	RHB	32	3000	367.0	367.0	35.0
PCM3070IRHBT	QFN	RHB	32	250	210.0	185.0	35.0

MECHANICAL DATA

RHB (S-PVQFN-N32)

PLASTIC QUAD FLATPACK NO-LEAD



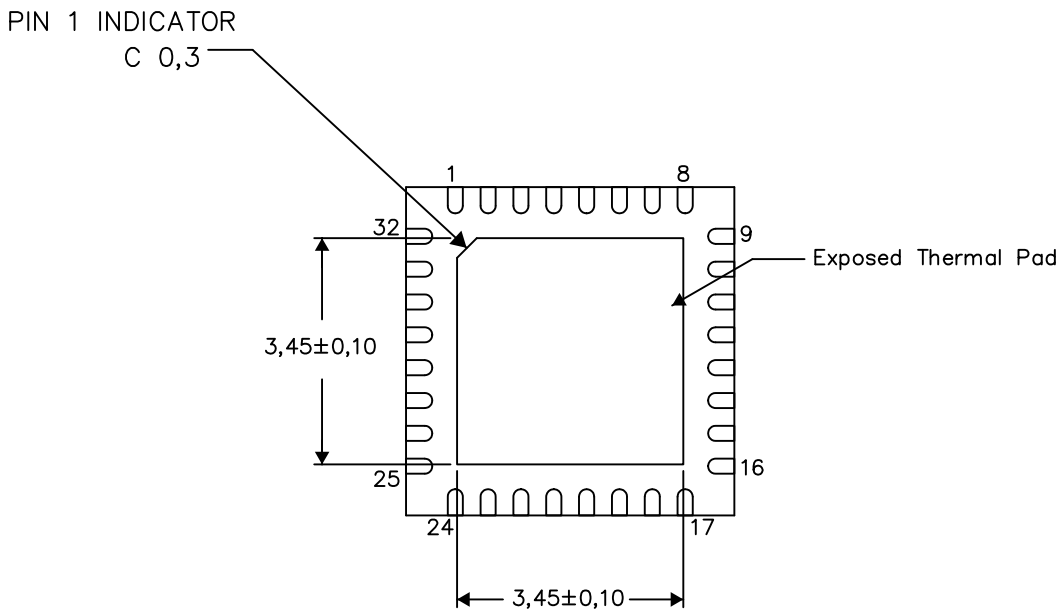
- NOTES:
- All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
 - This drawing is subject to change without notice.
 - QFN (Quad Flatpack No-Lead) Package configuration.
 - The package thermal pad must be soldered to the board for thermal and mechanical performance.
 - See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
 - Falls within JEDEC MO-220.

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No-Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



Bottom View

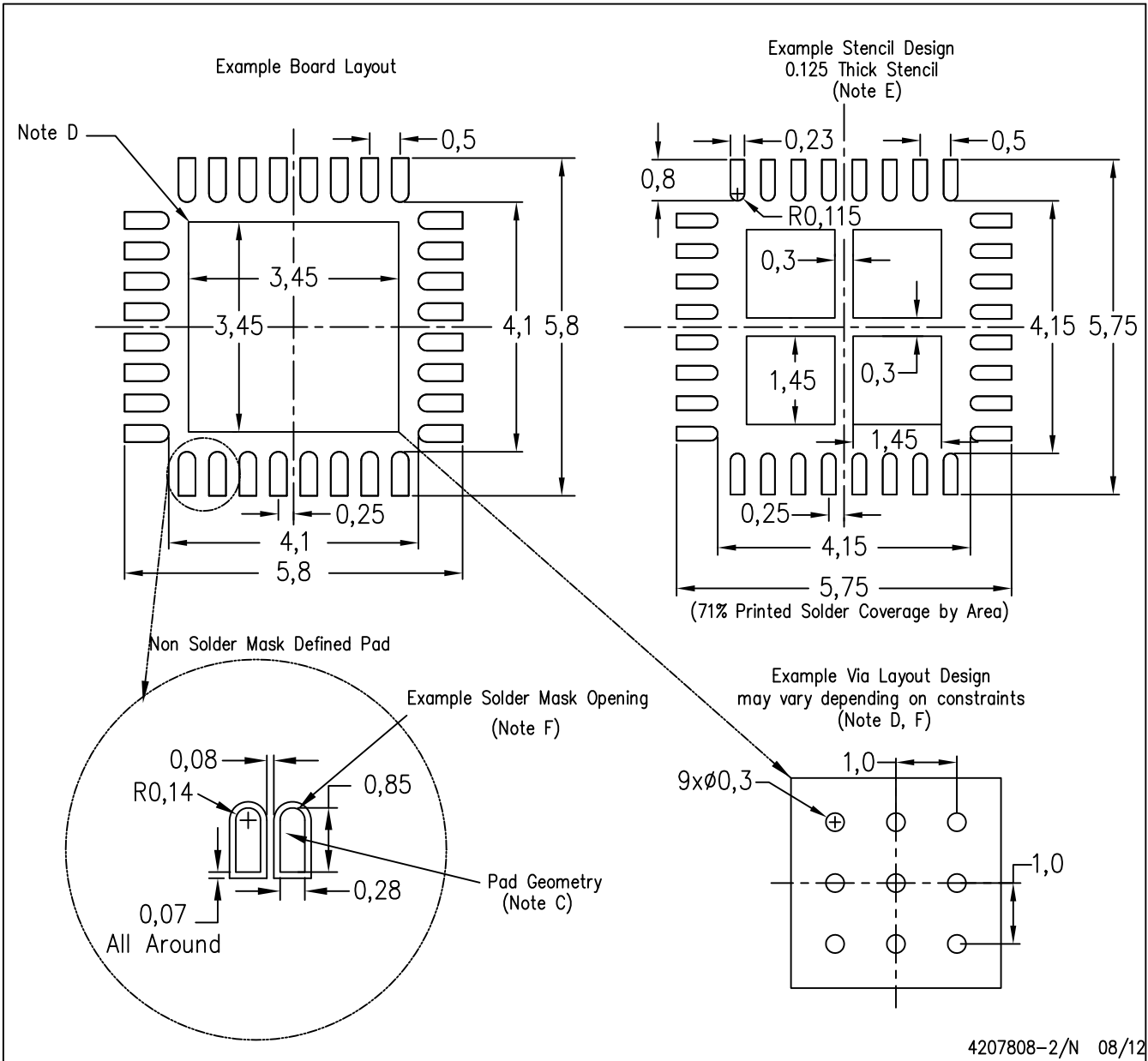
Exposed Thermal Pad Dimensions

4206356-2/W 09/12

NOTE: A. All linear dimensions are in millimeters

RHB (S-PVQFN-N32)

PLASTIC QUAD FLATPACK NO-LEAD



- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - Publication IPC-7351 is recommended for alternate designs.
 - This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat-Pack Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <<http://www.ti.com>>.
 - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
 - Customers should contact their board fabrication site for recommended solder mask tolerances and via tenting recommendations for vias placed in the thermal pad.

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