FULL DIFFERENTIAL ANALOG INPUT 24-BIT, 192-kHz STEREO A/D CONVERTER

FEATURES

- **24-Bit Delta-Sigma Stereo A/D Converter**
- **High Performance:**
  - **Dynamic Range: 112 dB (Typical)**
  - **SNR: 111 dB (Typical)**
  - **THD+N: –102 dB (Typical)**
- **High-Performance Linear Phase Antialias Digital Filter:**
  - **Pass-Band Ripple: ±0.005 dB**
  - **Stop-Band Attenuation: –100 dB**
- **Fully Differential Analog Input: ±2.5 V**
- **Audio Interface: Master- or Slave-Mode Selectable**
- **Data Formats: Left-Justified, I^2S, Standard 24-Bit, and DSD**
- **Function:**
  - **Peak Detection**
  - **High-Pass Filter (HPF): –3 dB at 1 Hz, f_S = 48 kHz**
- **Sampling Rate up to 192 kHz**
- **System Clock: 128 f_S, 256 f_S, 384 f_S, 512 f_S, or 768 f_S**
- **Dual Power Supplies:**
  - **5 V for Analog**
  - **3.3 V for Digital**
- **Power Dissipation: 225 mW**
- **Small 28-Pin SSOP**
- **DSD Output: 1 Bit, 64 f_S**

APPLICATIONS

- **AV Amplifier**
- **MD Player**
- **Digital VTR**
- **Digital Mixer**
- **Digital Recorder**

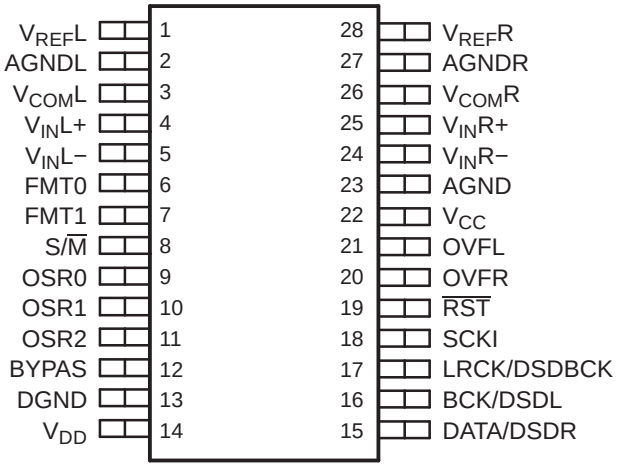
DESCRIPTION

The PCM1804 is a high-performance, single-chip stereo A/D converter with fully differential analog voltage input. The PCM1804 uses a precision delta-sigma modulator and includes a linear phase antialias digital filter and high-pass filter (HPF) that removes dc offset from the input signal. The PCM1804 is suitable for a wide variety of mid- to high-grade consumer and professional applications, where excellent performance and 5-V analog supply and 3.3-V digital power-supply operation are required. The PCM1804 can achieve both PCM audio and DSD format due to the precision delta-sigma modulator. The PCM1804 is fabricated using an advanced CMOS process and is available in a small 28-pin SSOP package.

This device contains circuits to protect its inputs and outputs against damage due to high static voltages or electrostatic fields. These circuits have been qualified to protect this device against electrostatic discharges (ESD) of up to 2 kV according to MIL-STD-883C, Method 3015; however, it is advised that precautions be taken to avoid application of any voltage higher than maximum-rated voltages to these high-impedance circuits. During storage or handling, the device leads should be shorted together or the device should be placed in conductive foam. In a circuit, unused inputs should always be connected to an appropriate logic voltage level, preferably either V_{CC} or ground. Specific guidelines for handling devices of this type are contained in the publication *Electrostatic Discharge (ESD)* (SSYA008), available from Texas Instruments.

PIN ASSIGNMENTS

PCM1804 PACKAGE
(TOP VIEW)



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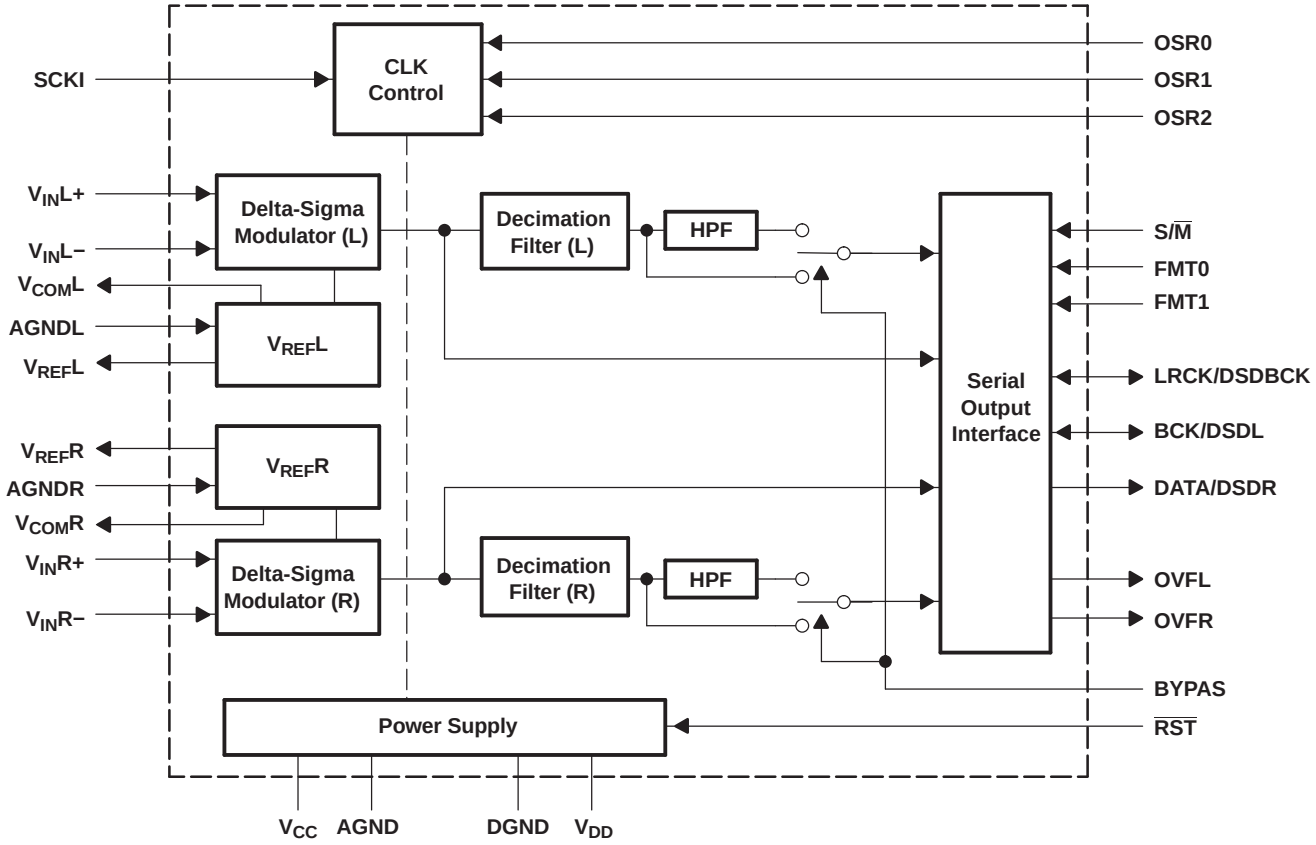
FUNCTIONAL BLOCK DIAGRAM



Terminal Functions

TERMINAL NAME	TERMINAL PIN	I/O	DESCRIPTIONS
AGND	23	–	Analog ground
AGNDL	2	–	Analog ground for $V_{REF}L$
AGNDR	27	–	Analog ground for $V_{REF}R$
BCK/DSDL	16	I/O	Bit clock input/output in PCM mode. L-channel audio data output in DSD mode. (1)
BYPAS	12	I	HPF bypass control. High: HPF disabled, Low: HPF enabled (1)
DATA/DSDR	15	O	L-channel and R-channel audio data output in PCM mode. R-channel audio data output in DSD mode. (DSD output, when in DSD mode)
DGND	13	–	Digital ground
FMT0	6	I	Audio data format 0. See Table 5. (2)
FMT1	7	I	Audio data format 1. See Table 5. (2)
LRCK/DSDBCK	17	I/O	Sampling clock input/output in PCM and DSD modes. (1)
OSR0	9	I	Oversampling ratio 0. See Table 1 and Table 2. (2)
OSR1	10	I	Oversampling ratio 1. See Table 1 and Table 2. (2)
OSR2	11	I	Oversampling ratio 2. See Table 1 and Table 2. (2)
OVFL	21	O	Overflow signal of L-channel in PCM mode. This is available in PCM mode only.
OVFR	20	O	Overflow signal of R-channel in PCM mode. This is available in PCM mode only.
$\overline{RST}$	19	I	Reset, power-down input, active-low (2)
SCKI	18	I	System clock input; 128 f_S, 256 f_S, 384 f_S, 512 f_S, or 768 f_S. (3)
S/$\overline{M}$	8	I	Slave/master mode selection. See Table 4. (2)
V_{CC}	22	–	Analog power supply
$V_{COM}L$	3	–	L-channel analog common-mode voltage (2.5 V)
$V_{COM}R$	26	–	R-channel analog common-mode voltage (2.5 V)
V_{DD}	14	–	Digital power supply
$V_{IN}L–$	5	I	L-channel analog input, negative pin
$V_{IN}L+$	4	I	L-channel analog input, positive pin
$V_{IN}R–$	24	I	R-channel analog input, negative pin
$V_{IN}R+$	25	I	R-channel analog input, positive pin
$V_{REF}L$	1	–	L-channel voltage reference output, requires capacitors for decoupling to AGND
$V_{REF}R$	28	–	R-channel voltage reference output, requires capacitors for decoupling to AGND

(1) Schmitt-trigger input
(2) Schmitt-trigger input with internal pulldown (51 kμ typically), 5-V tolerant.
(3) Schmitt-trigger input, 5-V tolerant.

ABSOLUTE MAXIMUM RATINGS

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

	Supply voltage	V_{CC}	–0.3 V to 6.5 V
		V_{DD}	–0.3 V to 4 V
	Ground voltage differences	AGND, AGNDL, AGNDR, DGND	±0.1 V
	Supply voltage difference	V_{CC}, V_{DD}	$V_{CC} - V_{DD} < 3$ V
	Digital input voltage	FMT0, FMT1, S/$\overline{M}$, OSR0, OSR1, OSR2, SCKI, $\overline{RST}$	–0.3 V to 6.5 V
		BYPAS, DATA/DSDR, BCK/DSDL, LRCK/DSDBCK, OVFL, OVFR	–0.3 V to (V_{DD} + 0.3 V)
	Analog input voltage	$V_{REF}L$, $V_{REF}R$, $V_{COM}L$, $V_{COM}R$, $V_{IN}L+$, $V_{IN}R+$, $V_{IN}L–$, $V_{IN}R–$	–0.3 V to (V_{CC} + 0.3 V)
	Input current (any pins except supplies)		±10 mA
T_A	Ambient temperature under bias		–40°C to 125°C
T_{stg}	Storage temperature		–55°C to 150°C
T_J	Junction temperature		150°C
	Lead temperature (soldering)		260°C, 5 s
	Package temperature (IR reflow, peak)		260°C

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

RECOMMENDED OPERATING CONDITIONS

over operating free-air temperature range

		MIN	NOM	MAX	UNIT
Analog supply voltage, V_{CC}		4.75	5	5.25	V
Digital supply voltage, V_{DD}		3	3.3	3.6	V
Analog input voltage, full-scale (–0 dB), differential input			5		Vp-p
Digital input logic family			TTL compatible		
Digital input clock frequency	System clock	8.192		36.864	MHz
	Sampling clock	32		192	kHz
Digital output load capacitance				10	pF
Operating free-air temperature, T_A		–10		70	°C

ELECTRICAL CHARACTERISTICS

All specifications at T_A = 25°C, V_{CC} = 5 V, V_{DD} = 3.3 V, master mode, single-speed mode, f_S = 48 kHz, system clock = 256 f_S, 24-bit data, unless otherwise noted.

PARAMETER		TEST CONDITIONS	PCM1804DB			UNIT
			MIN	TYP	MAX	
	Resolution			24		Bits
DATA FORMAT						
	Audio data interface format			Standard, I^2S, left-justified		
	Audio data bit length			24		Bits
	Audio data format			MSB first, 2s complement, DSD		
DIGITAL INPUT/OUTPUT						
	Logic family			TTL compatible		
V_{IH}	High-level input voltage	(1) (2)	2		5.5	Vdc
		(3)	2		V_{DD}	
V_{IL}	Low-level input voltage	(1) (2) (3)			0.8	Vdc
I_{IH}	High-level input current	$V_{IN} = V_{DD}$ (1)		65	100	μA
		$V_{IN} = V_{DD}$ (2)			±10	
		$V_{IN} = V_{DD}$ (3)			±100	
I_{IL}	Low-level input current	V_{IN} = 0 V (1) (2)			±10	μA
		V_{IN} = 0 V (3)			±50	
V_{OH}	High-level output voltage	I_{OH} = –1 mA (4)	2.4			Vdc
V_{OL}	Low-level output voltage	I_{OL} = 1 mA (4)			0.4	Vdc
CLOCK FREQUENCY						
f_S	Sampling frequency		32		192	kHz
	System clock frequency	256 f_S, single rate (5)		12.288		MHz
		384 f_S, single rate (5)		18.432		
		512 f_S, single rate (5)		24.576		
		768 f_S, single rate (5)		36.864		
		256 f_S, dual rate (6)		24.576		
		384 f_S, dual rate (6)		36.864		
		128 f_S, quad rate (7)		24.576		
		192 f_S, quad rate (7)		36.864		
DC ACCURACY						
	Gain mismatch, channel-to-channel				±3	% of FSR
	Gain error (V_{IN} = –0.5 dB)				±4	% of FSR
	Bipolar zero error	HPF bypass		±0.2		% of FSR

(1) Pins 6–11, 19: FMT0, FMT1, S/$\overline{M}$, OSR0, OSR1, OSR2, $\overline{RST}$ [Schmitt-trigger input with internal pulldown (51 kμ typically), 5-V tolerant]
(2) Pin 18: SCKI (Schmitt-trigger input, 5-V tolerant)
(3) Pins 12, 16–17: BYPAS, BCK/DSDL, LRCK/DSDBCK (in slave mode, Schmitt-trigger input)
(4) Pins 15–17, 20, and 21: DATA/DSDR, BCK/DSDL, LRCK/DSDBCK (in master mode), OVFR, OVFL
(5) Single rate, f_S = 48 kHz
(6) Dual rate, f_S = 96 kHz
(7) Quad rate, f_S = 192 kHz

ELECTRICAL CHARACTERISTICS (continued)

All specifications at T_A = 25°C, V_{CC} = 5 V, V_{DD} = 3.3 V, master mode, single-speed mode, f_S = 48 kHz, system clock = 256 f_S, 24-bit data, unless otherwise noted.

PARAMETER		TEST CONDITIONS		PCM1804DB			UNIT
				MIN	TYP	MAX	
DYNAMIC PERFORMANCE (8)							
THD+N	Total harmonic distortion plus noise	V_{IN} = –0.5 dB	f_S = 48 kHz, system clock = 256 f_S		–102	–95	dB
		V_{IN} = –60 dB			–49		
		V_{IN} = –0.5 dB	f_S = 96 kHz, system clock = 256 f_S		–101		
		V_{IN} = –60 dB			–47		
		V_{IN} = –0.5 dB	f_S = 192 kHz, system clock = 128 f_S		–101		
		V_{IN} = –60 dB			–47		
		V_{IN} = –0.5 dB	DSD mode		–100		
	Dynamic range (A-weighted)	V_{IN} = –60 dB	f_S = 48 kHz, system clock = 256 f_S	106	112		dB
			f_S = 96 kHz, system clock = 256 f_S		112		
			f_S = 192 kHz, system clock = 128 f_S		112		
		DSD mode			112		
	SNR (A-weighted)	f_S = 48 kHz, system clock = 256 f_S		105	111		dB
		f_S = 96 kHz, system clock = 256 f_S			111		
		f_S = 192 kHz, system clock = 128 f_S			111		
		DSD mode			111		
	Channel separation	f_S = 48 kHz, system clock = 256 f_S		97	109		dB
		f_S = 96 kHz, system clock = 256 f_S			107		
		f_S = 192 kHz, system clock = 128 f_S			107		
ANALOG INPUT							
	Input voltage	Differential input			±2.5		V
	Center voltage				2.5		Vdc
	Input impedance	Single-ended			10		kμ
DIGITAL FILTER PERFORMANCE							
	Pass-band edge	Single rate, dual rate				0.453 f_S	Hz
	Stop-band edge	Single rate, dual rate		0.547 f_S			Hz
	Pass-band ripple	Single rate, dual rate				±0.005	dB
	Stop-band attenuation	Single rate, dual rate		–100			dB
	Pass-band edge (–0.005 dB)	Quad rate				0.375 f_S	Hz
	Pass-band edge (–3 dB)	Quad rate				0.49 f_S	Hz
	Stop-band edge	Quad rate		0.77 f_S			Hz
	Pass-band ripple	Quad rate				±0.005	dB
	Stop-band attenuation	Quad rate		–135			dB
	Group delay	Single rate, dual rate			37/f_S		s
	Group delay	Quad rate			9.5/f_S		s
	HPF frequency response	–3 dB			f_S/48000		Hz

(8) f_{IN} = 1 kHz, using System Two™ audio measurement system by Audio Precision™ in RMS mode, with 20-kHz LPF and 400-Hz HPF in calculation for single rate, or with 40-kHz LPF in calculation for dual and quad rates.

ELECTRICAL CHARACTERISTICS (continued)

All specifications at T_A = 25°C, V_{CC} = 5 V, V_{DD} = 3.3 V, master mode, single-speed mode, f_S = 48 kHz, system clock = 256 f_S, 24-bit data, unless otherwise noted.

PARAMETER		TEST CONDITIONS	PCM1804DB			UNIT
			MIN	TYP	MAX	
POWER SUPPLY REQUIREMENTS						
V_{CC}	Supply voltage range		4.75	5	5.25	Vdc
V_{DD}			3	3.3	3.6	
I_{CC}	Supply current	V_{CC} = 5 V (9) (10) (11)		35	45	mA
I_{DD}		V_{DD} = 3.3 V (9) (12)		15	20	
		V_{DD} = 3.3 V (10) (12)		27		
		V_{DD} = 3.3 V (11) (12)		18		
P_D	Power dissipation	Operation, V_{CC} = 5 V, V_{DD} = 3.3 V (9) (12)		225	290	mW
		Operation, V_{CC} = 5 V, V_{DD} = 3.3 V (10) (12)		265		
		Operation, V_{CC} = 5 V, V_{DD} = 3.3 V (11) (12)		235		
		Power down, V_{CC} = 5 V, V_{DD} = 3.3 V		5		
TEMPERATURE RANGE						
	Operation temperature		–10		70	°C
θ_{JA}	Thermal resistance			100		°C/W

(9) Single rate, f_S = 48 kHz
(10) Dual rate, f_S = 96 kHz
(11) Quad rate, f_S = 192 kHz
(12) Minimum load on DATA/DSDR (pin 15)

TYPICAL PERFORMANCE CURVES - SINGLE RATE

All specifications at T_A = 25°C, V_{CC} = 3.3 V, V_{DD} = 5 V, master mode, f_S = 48 kHz, system clock = 256 f_S, 24-bit data, unless otherwise noted.

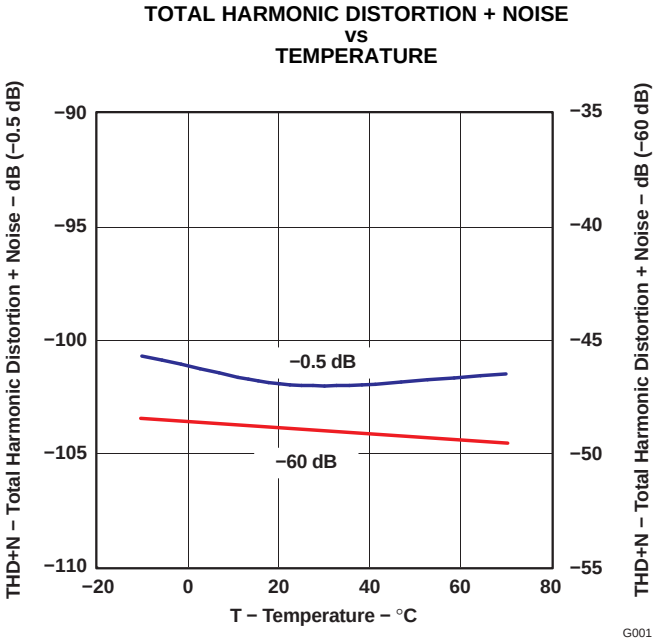


Figure 1.

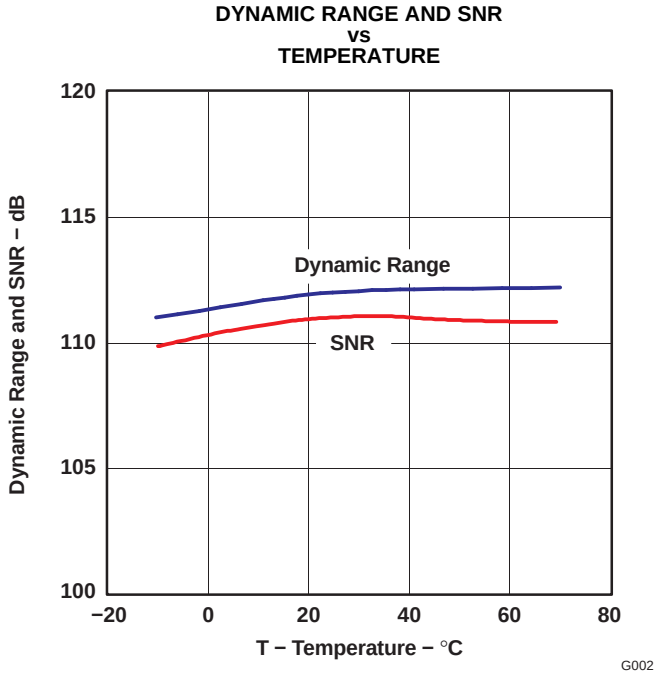


Figure 2.

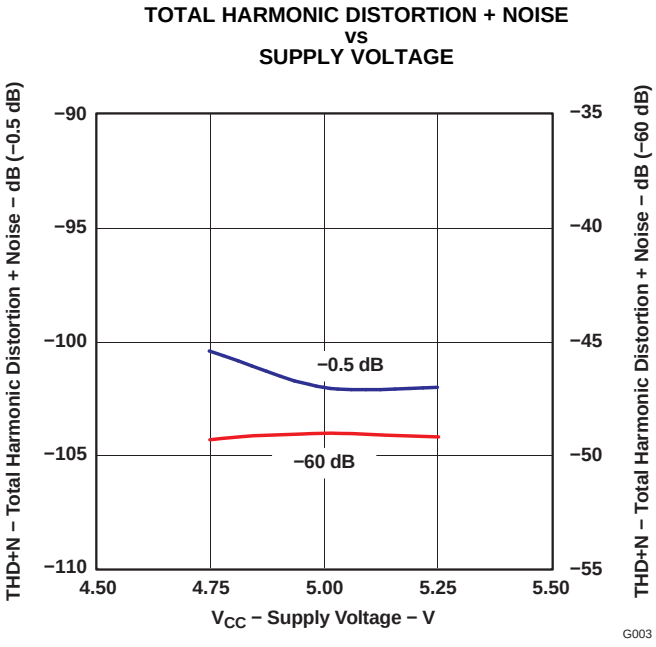


Figure 3.

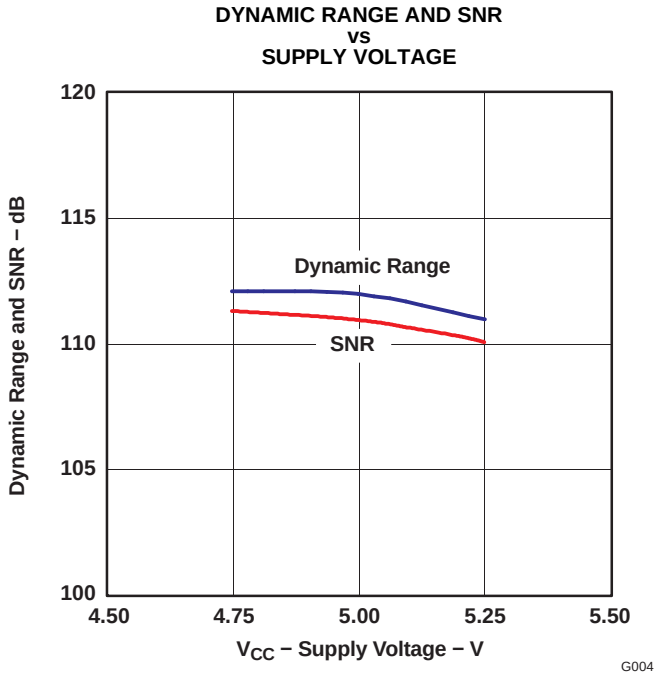


Figure 4.

TYPICAL PERFORMANCE CURVES - SINGLE RATE (continued)

All specifications at T_A = 25°C, V_{CC} = 3.3 V, V_{DD} = 5 V, master mode, f_S = 48 kHz, system clock = 256 f_S, 24-bit data, unless otherwise noted.

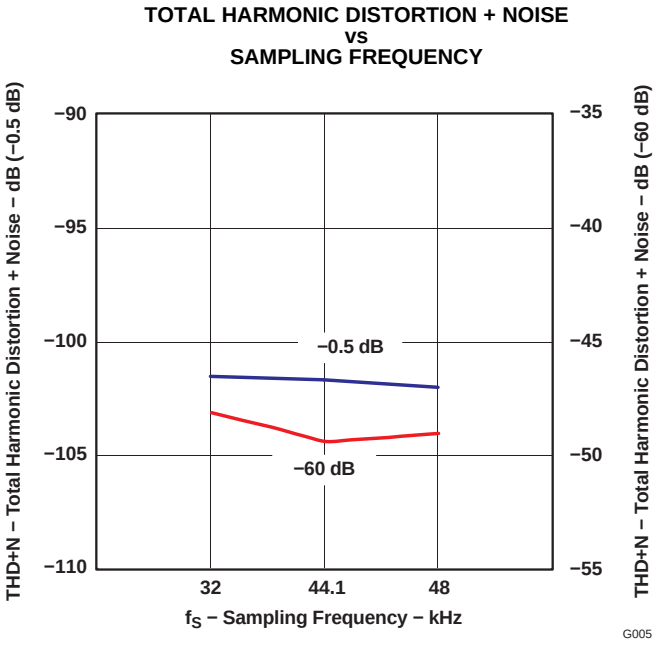


Figure 5.

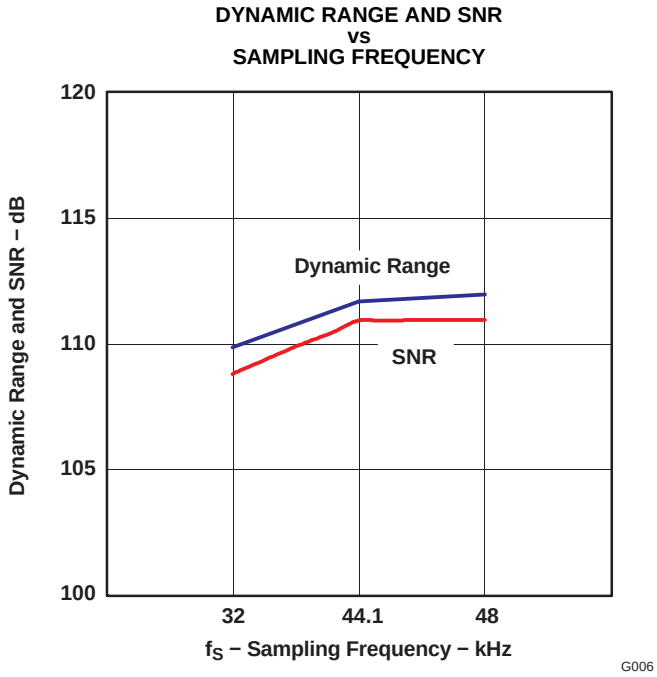


Figure 6.

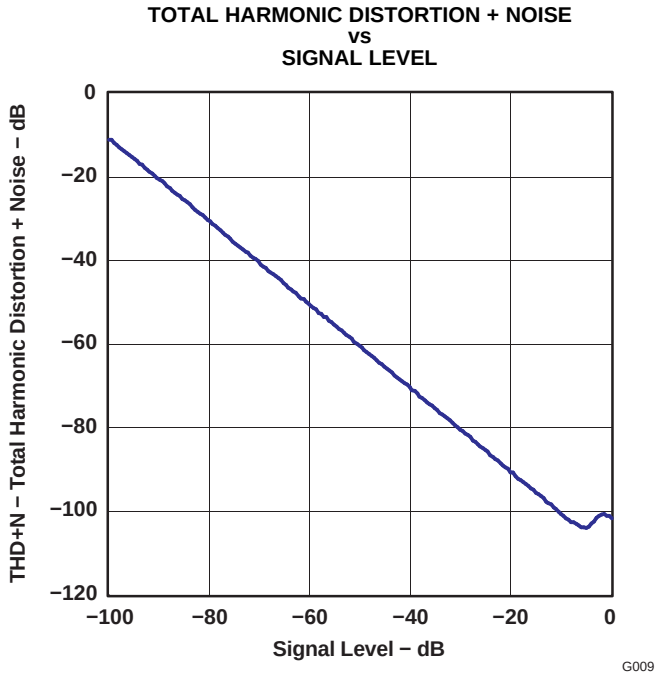


Figure 7.

TYPICAL PERFORMANCE CURVES - SINGLE RATE (continued)

All specifications at T_A = 25°C, V_{CC} = 3.3 V, V_{DD} = 5 V, master mode, f_S = 48 kHz, system clock = 256 f_S, 24-bit data, unless otherwise noted.

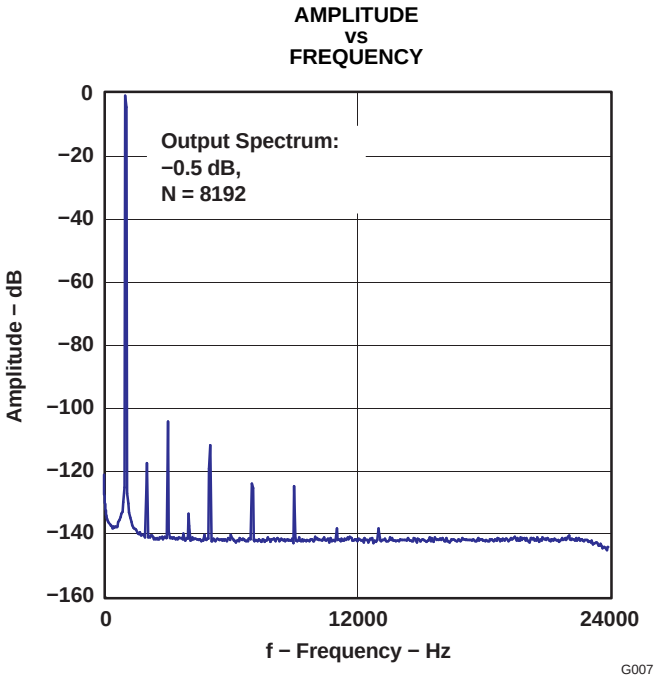


Figure 8.

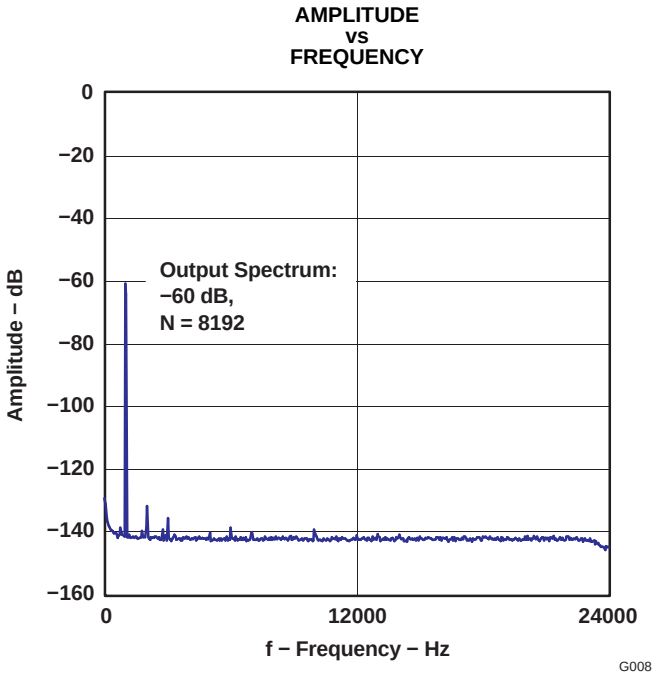


Figure 9.

TYPICAL PERFORMANCE CURVES - DUAL RATE

All specifications at T_A = 25°C, V_{CC} = 3.3 V, V_{DD} = 5 V, master mode, and 24-bit data, unless otherwise noted.

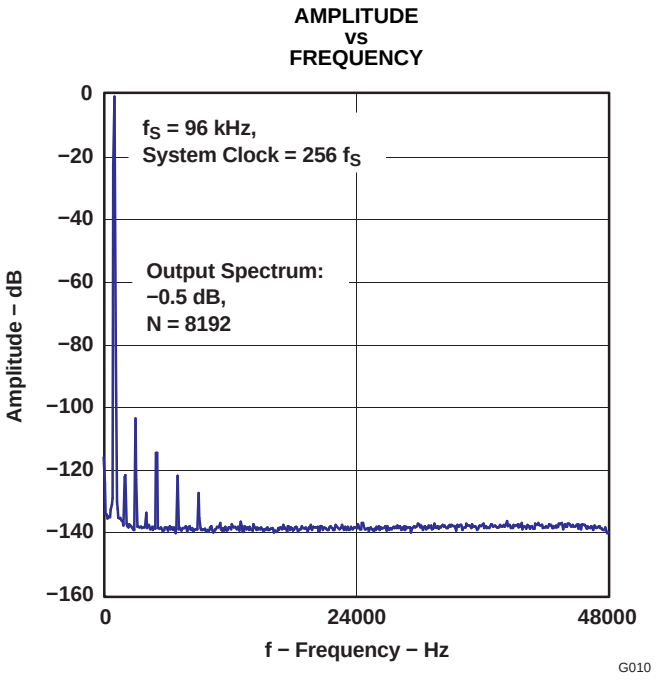


Figure 10.

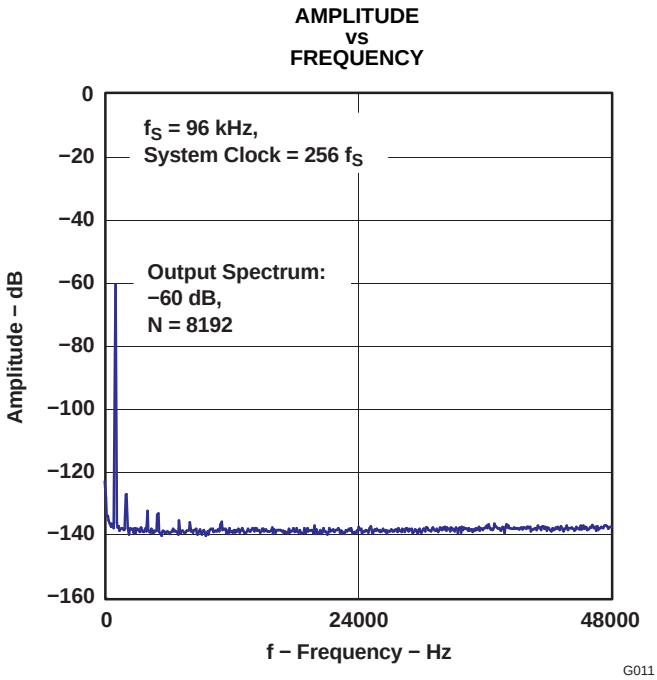


Figure 11.

TYPICAL PERFORMANCE CURVES - QUAD RATE

All specifications at T_A = 25°C, V_{CC} = 3.3 V, V_{DD} = 5 V, master mode, 24-bit data, unless otherwise noted.

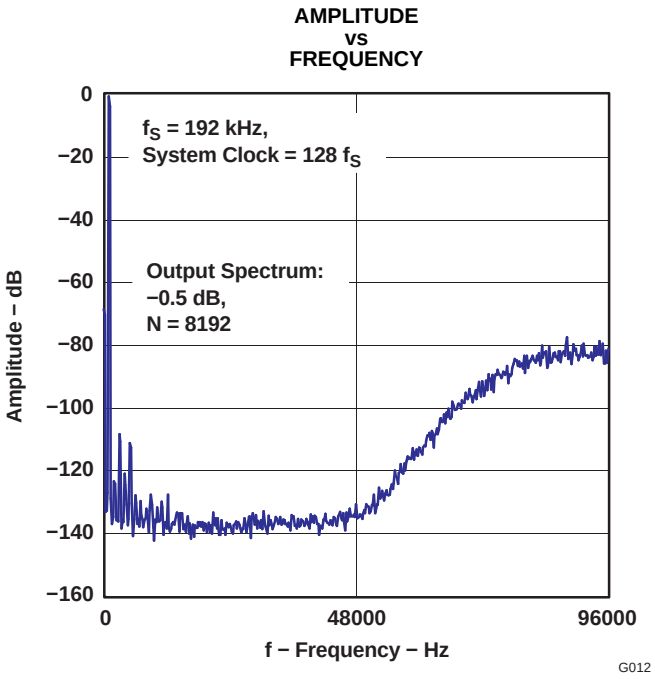


Figure 12.

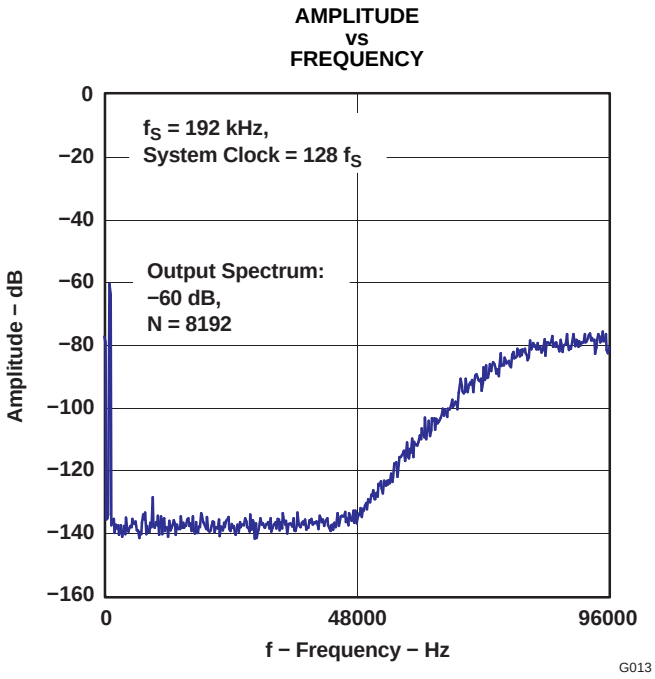


Figure 13.

TYPICAL PERFORMANCE CURVES - DSD MODE

All specifications at T_A = 25°C, V_{CC} = 3.3 V, V_{DD} = 5 V, master mode, f_S = 44.1 kHz, system clock = 16.9344 MHz, unless otherwise noted.

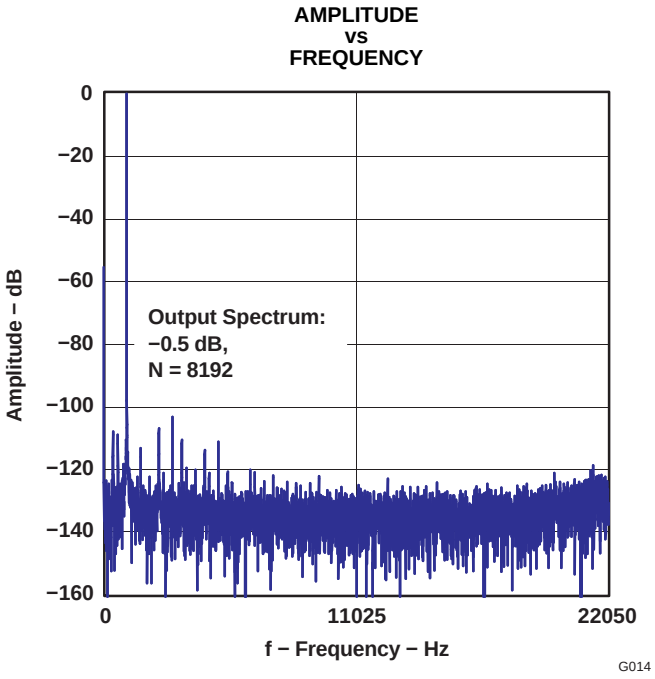


Figure 14.

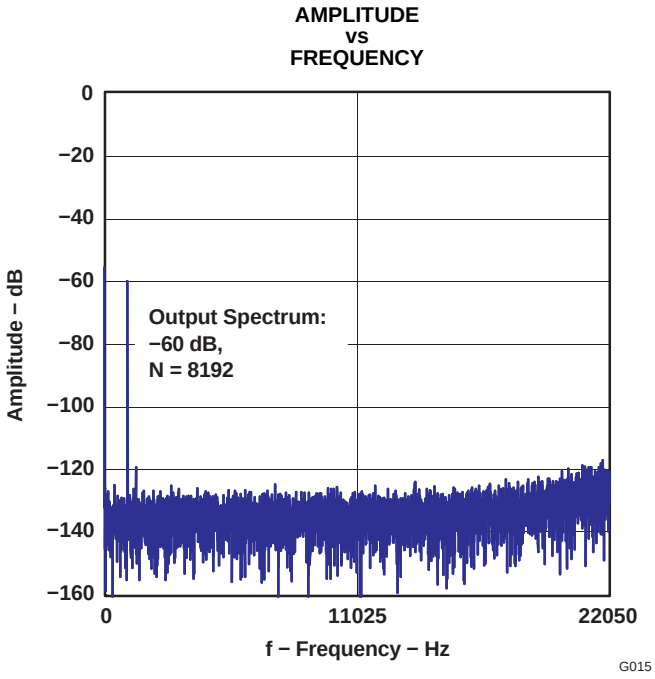


Figure 15.

TYPICAL PERFORMANCE CURVES OF INTERNAL FILTER

LINEAR PHASE ANTIALIAS DIGITAL FILTER FREQUENCY RESPONSE - Single-Rate

OVERALL CHARACTERISTICS FOR SINGLE-RATE FILTER

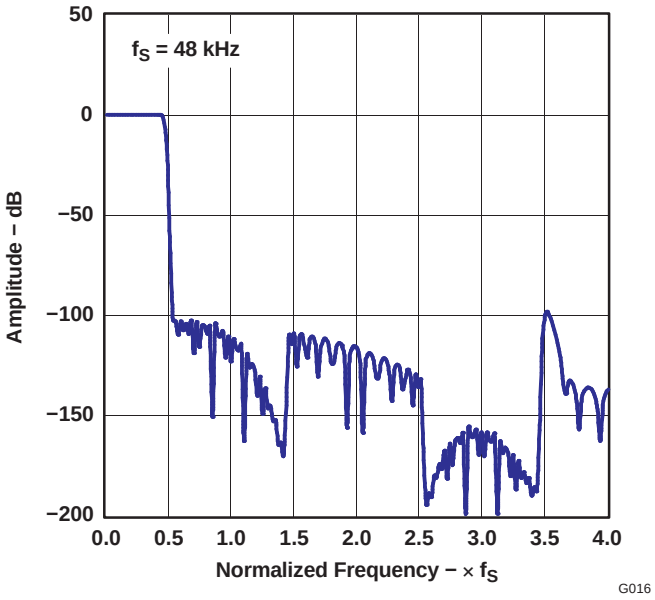


Figure 16.

STOP-BAND ATTENUATION CHARACTERISTICS FOR SINGLE-RATE FILTER

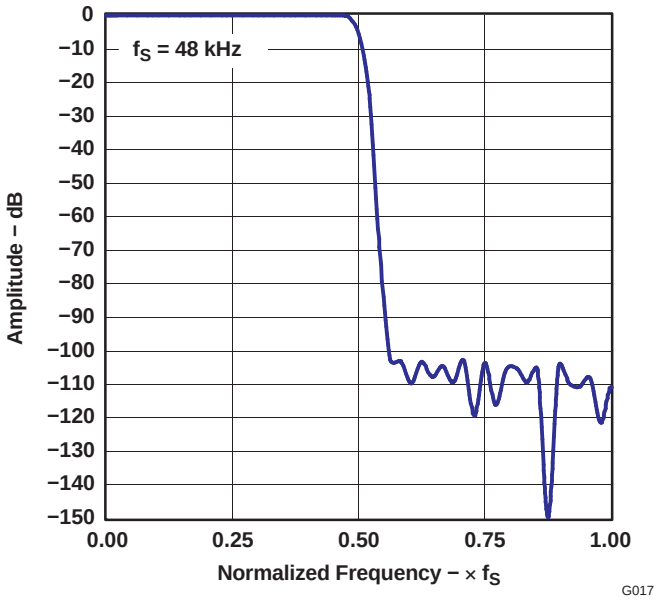


Figure 17.

PASS-BAND RIPPLE CHARACTERISTICS FOR SINGLE-RATE FILTER

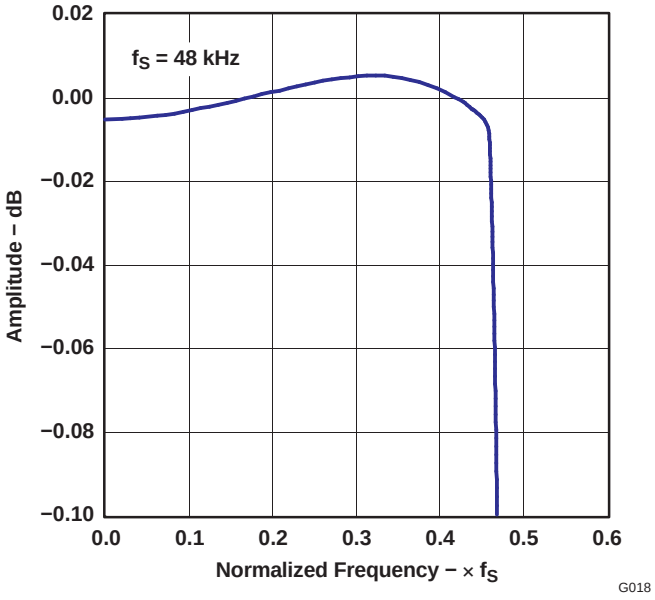


Figure 18.

TRANSIENT BAND CHARACTERISTICS FOR SINGLE-RATE FILTER

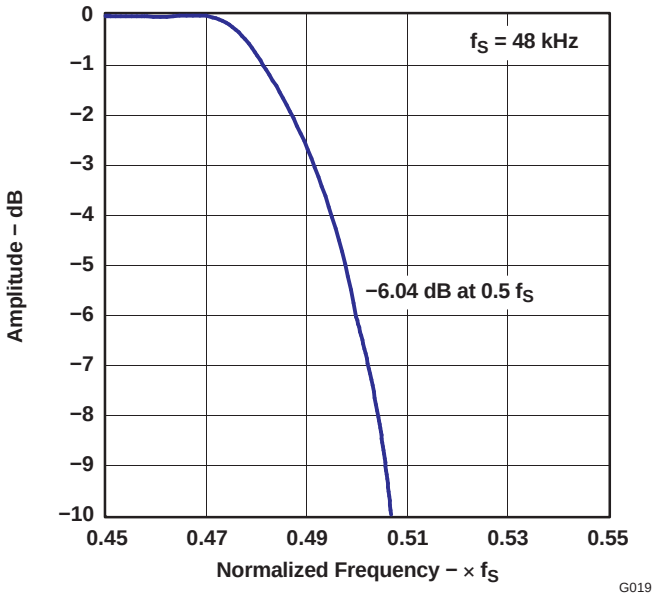


Figure 19.

TYPICAL PERFORMANCE CURVES OF INTERNAL FILTER (continued)

LINEAR PHASE ANTIALIAS DIGITAL FILTER FREQUENCY RESPONSE - Dual-Rate

OVERALL CHARACTERISTICS
FOR DUAL-RATE FILTER

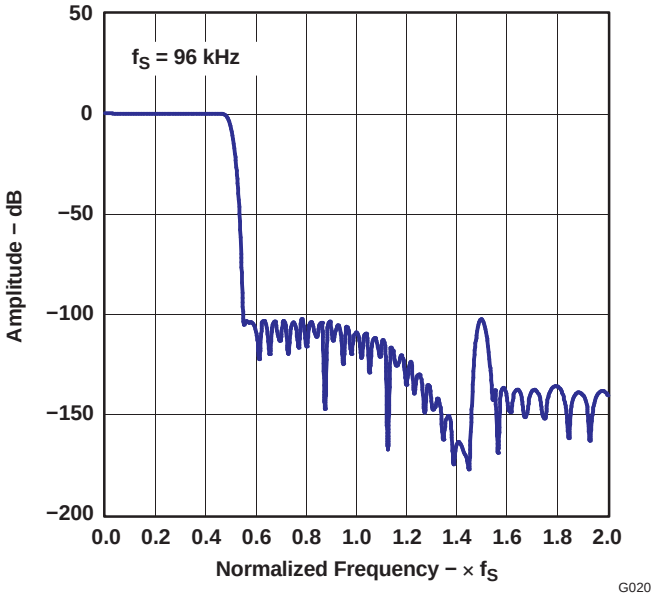


Figure 20.

STOP-BAND ATTENUATION CHARACTERISTICS
FOR DUAL-RATE FILTER

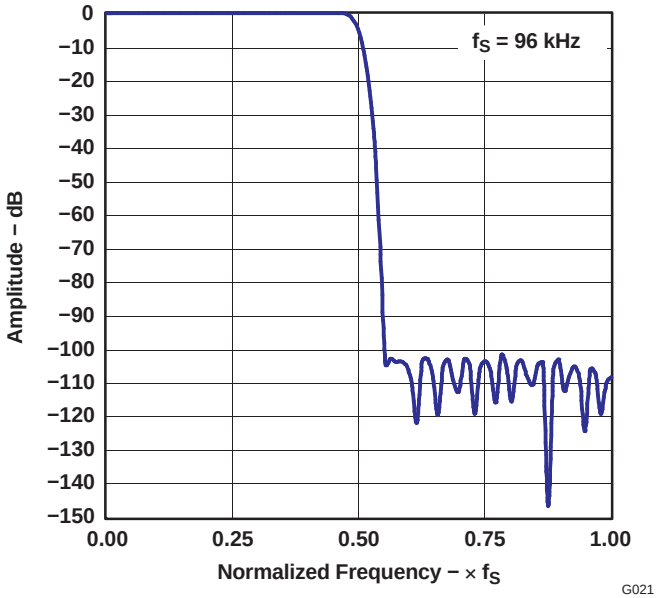


Figure 21.

PASS-BAND RIPPLE CHARACTERISTICS
FOR DUAL-RATE FILTER

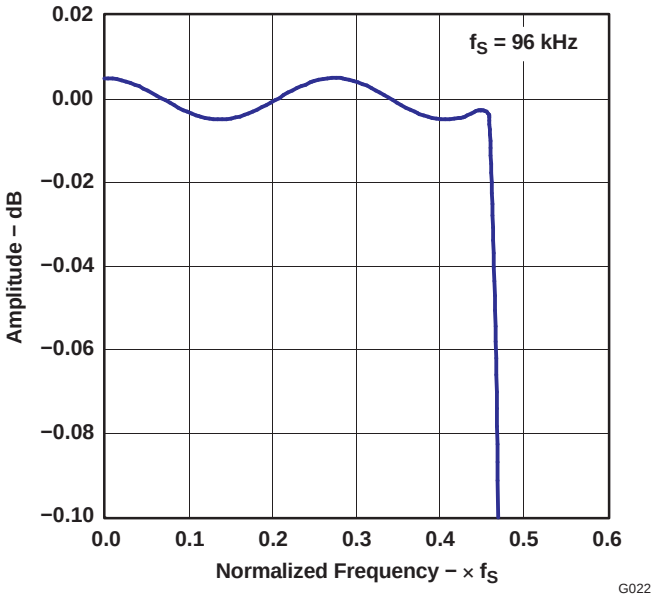


Figure 22.

TRANSIENT BAND CHARACTERISTICS
FOR DUAL-RATE FILTER

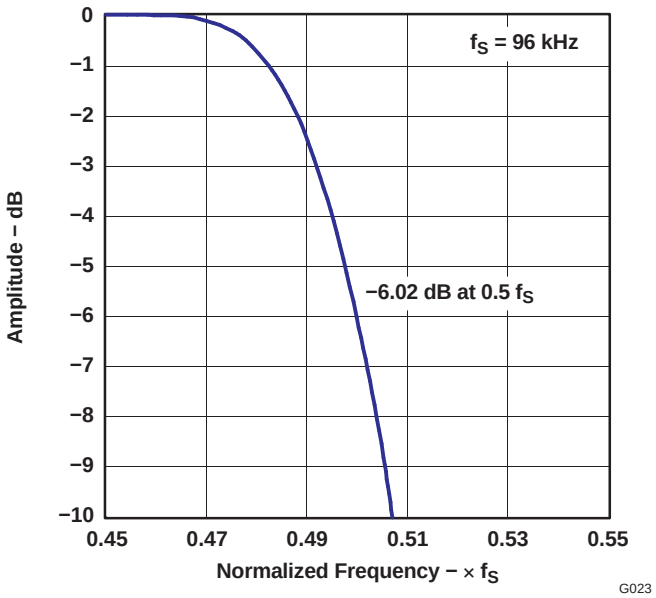


Figure 23.

TYPICAL PERFORMANCE CURVES OF INTERNAL FILTER (continued)

LINEAR PHASE ANTIALIAS DIGITAL FILTER FREQUENCY RESPONSE - Quad-Rate

OVERALL CHARACTERISTICS FOR QUAD-RATE FILTER

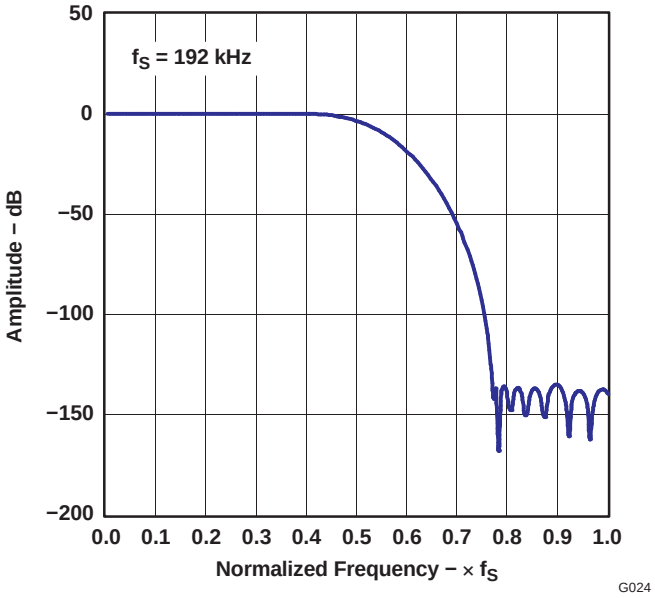


Figure 24.

STOP-BAND ATTENUATION CHARACTERISTICS FOR QUAD-RATE FILTER

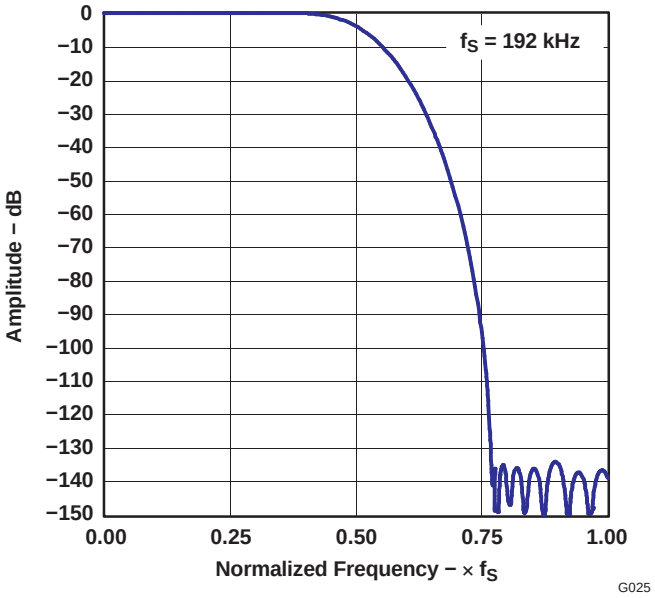


Figure 25.

PASS-BAND RIPPLE CHARACTERISTICS FOR QUAD-RATE FILTER

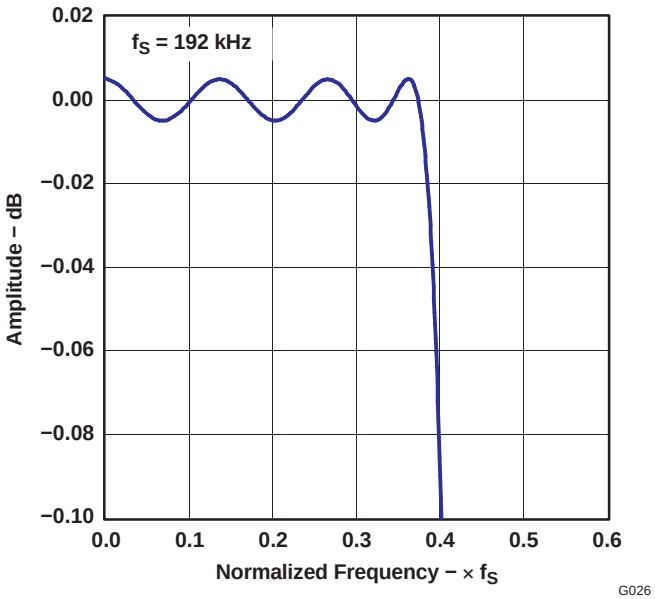


Figure 26.

TRANSIENT BAND CHARACTERISTICS FOR QUAD-RATE FILTER

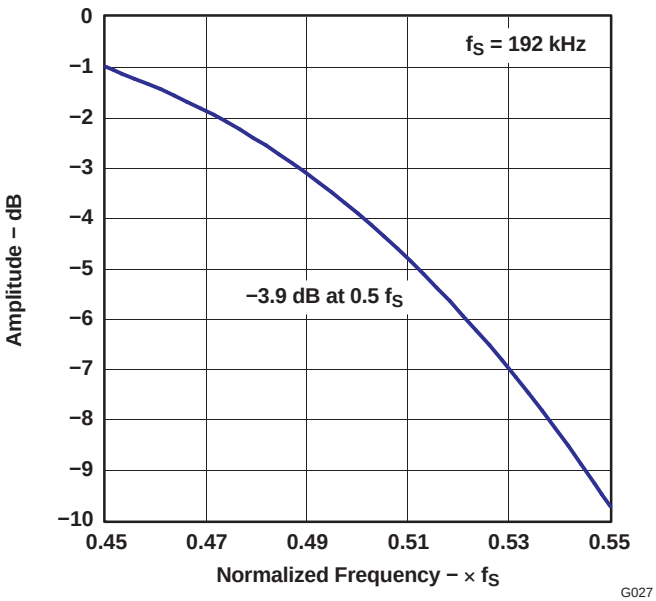


Figure 27.

TYPICAL PERFORMANCE CURVES OF INTERNAL FILTER (continued)

HIGH-PASS FILTER (HPF) FREQUENCY RESPONSE

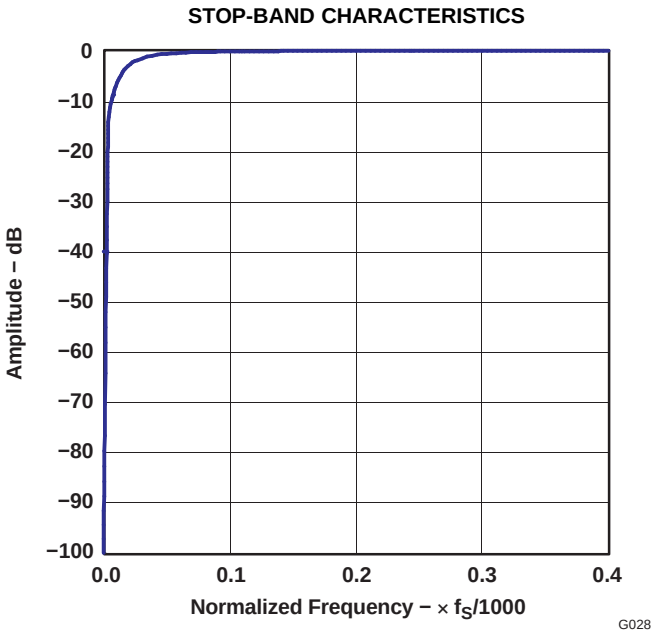


Figure 28.

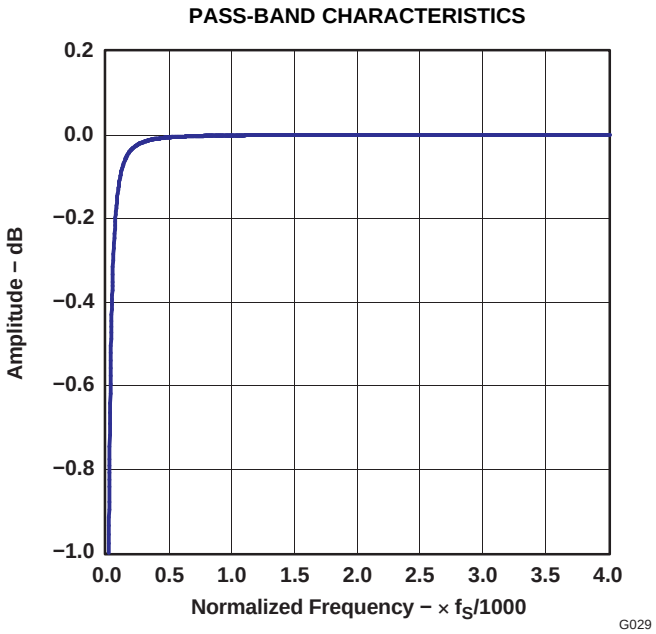


Figure 29.

PRINCIPLES OF OPERATION

THEORY OF OPERATION

The PCM1804 consists of a band-gap reference, a delta-sigma modulator with full-differential architecture for L-channel and R-channel, a decimation filter with a high-pass filter, and a serial interface circuit. Figure 30 illustrates the total architecture of the PCM1804. An on-chip, high-precision reference with 10-µF external capacitor(s) provides all the reference voltage needed in the PCM1804, and it defines the full-scale voltage range of both channels. Full-differential architecture provides a wide dynamic range and excellent power-supply rejection performance. The input signal is sampled at ×128, ×64, and ×32 oversampling rates according to the overasmpling ratio control, OSR[0:2]. The single rate, dual rate, and quad rate eliminate the external sample-hold amplifier. Figure 31 illustrates how for each oversampling ratio the PCM1804 decimates the modulator output down to PCM data when the modulator is running at 6.144 MHz. The delta-sigma modulation randomizes the modulator outputs and reduces the idle tone level. The oversampled data stream from the delta-sigma modulator is converted to a 1-f_S, 24-bit digital signal, while removing high-frequency noise components using a decimation filter. The dc components of the signal are removed by the HPF, and the HPF output is converted to a time-multiplexed serial signal through the serial interface, which provides flexible serial formats and master/slave modes. The PCM1804 also has a DSD output mode. The PCM1804 can output the signal directly from the modulators to DSDL (pin 16) and DSDR (pin 15).

PRINCIPLES OF OPERATION (continued)

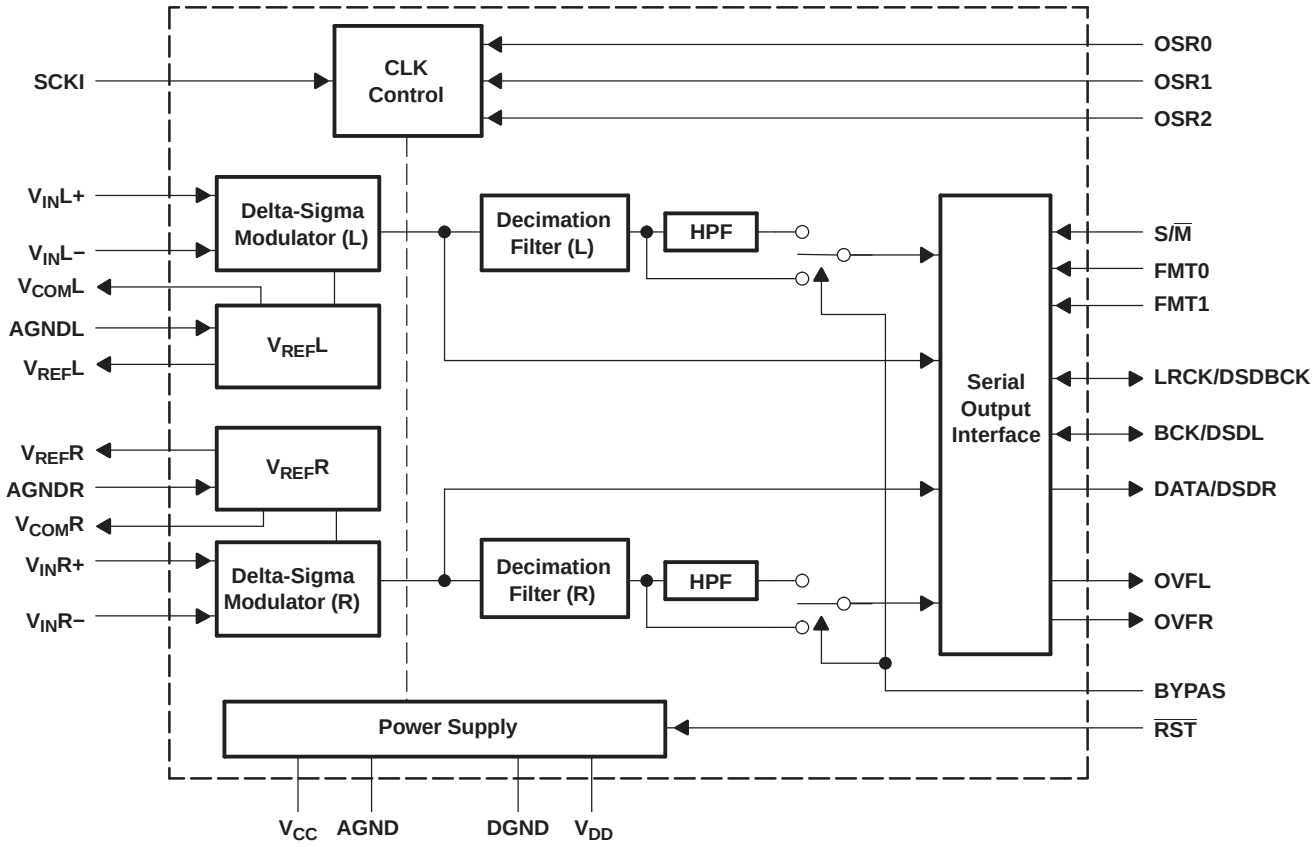


Figure 30. Total Block Diagram of PCM1804

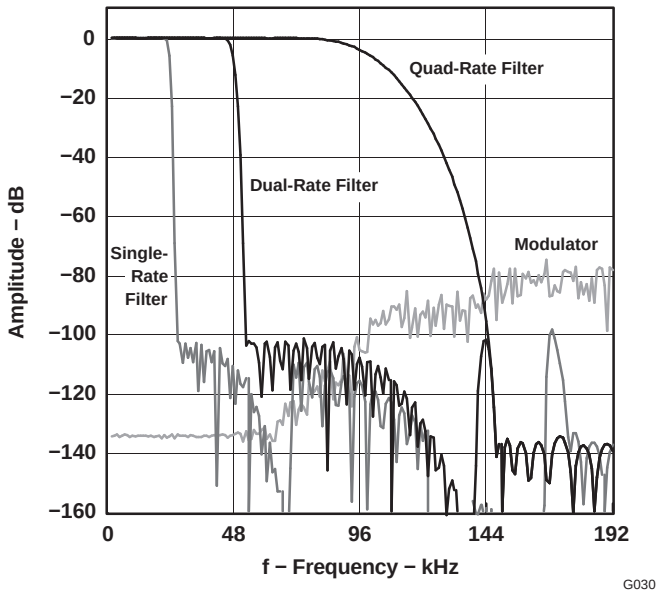
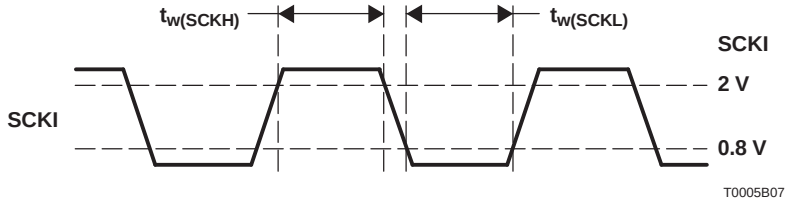


Figure 31. Spectrum of Modulator Output and Decimation Filter

PRINCIPLES OF OPERATION (continued)

SYSTEM CLOCK INPUT

The PCM1804 supports 128 f_S, 192 f_S (only in master mode at quad rate), 256 f_S, 384 f_S, 512 f_S, and 768 f_S as a system clock, where f_S is the audio sampling frequency. The system clock must be supplied on SCKI (pin 18). Table 3 shows the relationship of typical sampling frequency and the system clock frequency, and Figure 32 shows system clock timing. In master mode, the system clock rate is selected by OSR2 (pin 11), OSR1 (pin 10), and OSR0 (pin 9) as shown in Table 1. In slave mode, the system clock rate is automatically detected. In DSD mode, OSR2 (pin 11), OSR1 (pin 10), OSR0 (pin 9), and the system clock frequency are fixed as shown in Table 1 and Table 3.



PARAMETER		MIN	UNIT
$t_{w(SCKH)}$	System clock pulse duration, HIGH	11	ns
$t_{w(SCKL)}$	System clock pulse duration, LOW	11	ns

Figure 32. System Clock Input Timing

POWER-ON AND RESET FUNCTIONS

The PCM1804 has both an internal power-on-reset circuit and $\overline{RST}$ (pin 19). For internal power-on reset, initialization (reset) is performed automatically at the time when the power supply V_{DD} exceeds 2 V (typical) and V_{CC} exceeds 4 V (typical). $\overline{RST}$ accepts external forced reset, and a low level on $\overline{RST}$ initiates the reset sequence. Because an internal pulldown resistor terminates $\overline{RST}$, no connection of $\overline{RST}$ is equivalent to a low-level input. Because the system clock is used as a clock signal for the reset circuit, the system clock must be supplied as soon as power is supplied; more specifically, at least three system clocks are required prior to V_{DD} > 2 V, V_{CC} > 4 V, and $\overline{RST}$ = high. While V_{DD} < 2 V (typical), V_{CC} < 4 V (typical), or $\overline{RST}$ = low, and $1/f_S$ (maximum) count after V_{DD} > 2 V (typical),V_{CC} > 4 V (typical) and $\overline{RST}$ = high, the PCM1804 stays in the reset state and the digital output is forced to zero. The digital output is valid after the reset state is released and the time of $1116/f_S$ has passed. Figure 33 and Figure 34 illustrate the internal power-on-reset and external-reset timing, respectively. Figure 35 illustrates the digital output for power-on reset and $\overline{RST}$ control. The PCM1804 needs $\overline{RST}$ = low when control pins are changed or in slave mode when SCKI, LRCK, and BCK are changed.

POWER-DOWN FUNCTION

The PCM1804 has a power-down feature that is controlled by $\overline{RST}$ (pin 19). Entering the power-down mode is done by keeping the $\overline{RST}$ input level low for more than $65536/f_S$. In the master mode, the SCKI (pin 18) is used as the clock signal for the power-down counter. While in the slave mode, SCKI (pin 18) and LRCK (pin 17) are used as the clock signal. The clock(s) must be supplied until the power-down sequence completes. As soon as $\overline{RST}$ goes high, the PCM1804 starts the reset-release sequence described in the *Power-On and Reset Functions* section.

OVERSAMPLING RATIO

The oversampling ratio is selected by OSR2 (pin 11), OSR1 (pin 10), and OSR0 (pin 9) as shown in Table 1 and Table 2. The PCM1804 needs $\overline{RST}$ = low when logic levels on the OSR2, OSR1, and OSR0 pins are changed.

Table 1. Oversampling Ratio in Master Mode

OSR2	OSR1	OSR0	OVERSAMPLING RATIO	SYSTEM CLOCK RATE
Low	Low	Low	Single rate (× 128 f_S)	768 f_S
Low	Low	High	Single rate (× 128 f_S)	512 f_S
Low	High	Low	Single rate (× 128 f_S)	384 f_S
Low	High	High	Single rate (× 128 f_S)	256 f_S
High	Low	Low	Dual rate (× 64 f_S)	384 f_S
High	Low	High	Dual rate (× 64 f_S)	256 f_S
High	High	Low	Quad rate (× 32 f_S)	192 f_S
High	High	High	Quad rate (× 32 f_S)	128 f_S
High	Low	Low	DSD mode (× 64 f_S)	384 f_S
High	Low	High	DSD mode (× 64 f_S)	256 f_S

Table 2. Oversampling Ratio in Slave Mode

OSR2	OSR1	OSR0	OVERSAMPLING RATIO	SYSTEM CLOCK RATE
Low	Low	Low	Single rate (× 128 f_S)	Automatically detected
Low	Low	High	Dual rate (× 64 f_S)	Automatically detected
Low	High	Low	Quad rate (× 32 f_S)(1)	Automatically detected
Low	High	High	Reserved	–
High	Low	Low	Reserved	–
High	Low	High	Reserved	–
High	High	Low	Reserved	–
High	High	High	Reserved	–

(1) Only at the 128-f_S system clock rate

Table 3. Sampling Frequency and System Clock Frequency

OVERSAMPLING RATIO	SAMPLING FREQUENCY (kHz)	SYSTEM CLOCK FREQUENCY (MHz)					
		128 f_S	192 f_S(1)	256 f_S	384 f_S	512 f_S	768 f_S
Single rate(2)	32	–	–	8.192	12.288	16.384	24.576
	44.1	–	–	11.2896	16.9344	22.5792	33.8688
	48	–	–	12.288	18.432	24.576	36.864
Dual rate(3)	88.2	–	–	22.5792	33.8688	–	–
	96	–	–	24.576	36.864	–	–
Quad rate(4)	176.4	22.5792	33.8688	–	–	–	–
	192	24.576	36.864	–	–	–	–
DSD mode(3)	44.1	–	–	11. 2896	16.9344	–	–

(1) Only available in master mode at the quad rate
(2) Modulator is running at 128 f_S.
(3) Modulator is running at 64 f_S.
(4) Modulator is running at 32 f_S.

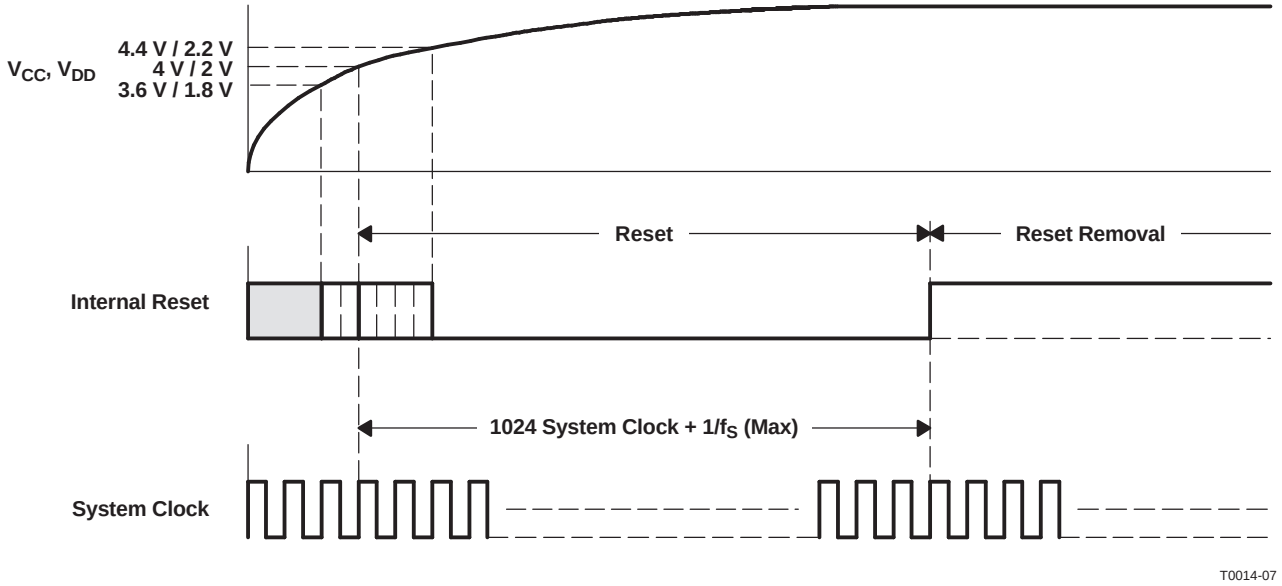


Figure 33. Internal Power-On-Reset Timing

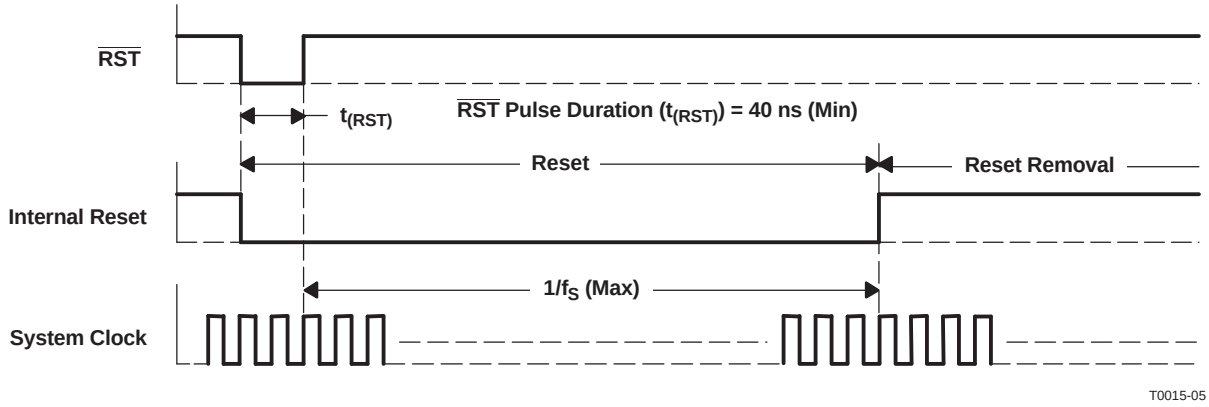
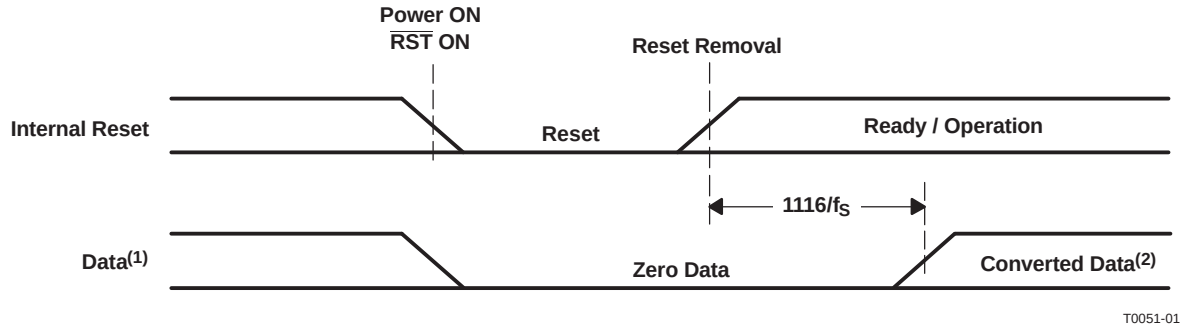


Figure 34. External Reset Timing



(1) In the DSD mode, DSDL is also controlled like DSDR.

(2) The HPF transient response appears initially.

Figure 35. ADC Digital Output for Power-On Reset and $\overline{RST}$ Control

AUDIO DATA INTERFACE

The PCM1804 interfaces the audio system through BCK/DSDL (pin 16), LRCK/DSDBCK (pin 17), and DATA/DSDR (pin 15). The PCM1804 needs $\overline{RST}$ = low when in the interface mode and/or the data format are changed.

INTERFACE MODE

The PCM1804 supports master mode and slave mode as interface modes, which are selected by S/$\overline{M}$ (pin 8) as shown in Table 4. In master mode, the PCM1804 provides the timing of the serial audio data communications between the PCM1804 and the digital audio processor or external circuit. While in slave mode, the PCM1804 receives the timing for data transfer from an external controller. Slave mode is not available for DSD.

Table 4. Interface Mode

S/$\overline{M}$	MODE
Low	Master mode
High	Slave mode

DATA FORMAT

The PCM1804 supports four audio data formats in both master and slave modes, and these data formats are selected by FMT0 (pin 6) and FMT1 (pin 7) as shown in Table 5.

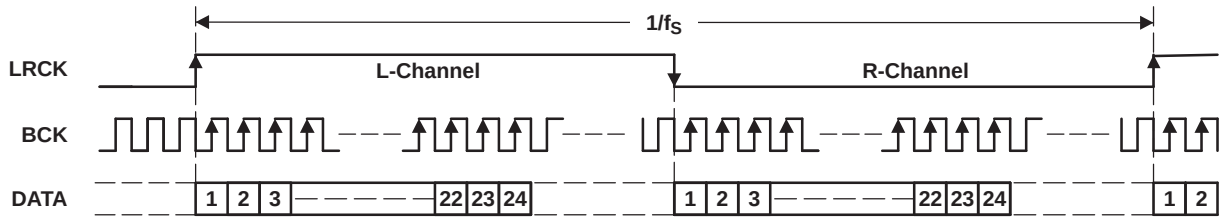
Table 5. Data Format

FMT1	FMT0	FORMAT	MASTER	SLAVE
Low	Low	PCM, left-justified, 24-bit	Yes	Yes
Low	High	PCM, I^2S, 24-bit	Yes	Yes
High	Low	PCM, standard, 24-bit	Yes	Yes
High	High	DSD	Yes	–

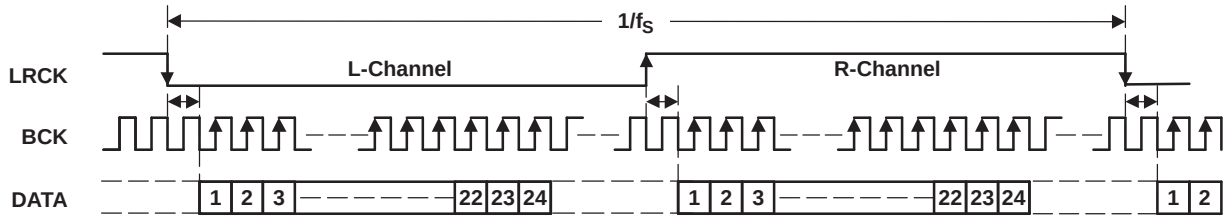
INTERFACE TIMING FOR PCM

Figure 36 through Figure 38 illustrate the interface timing for PCM.

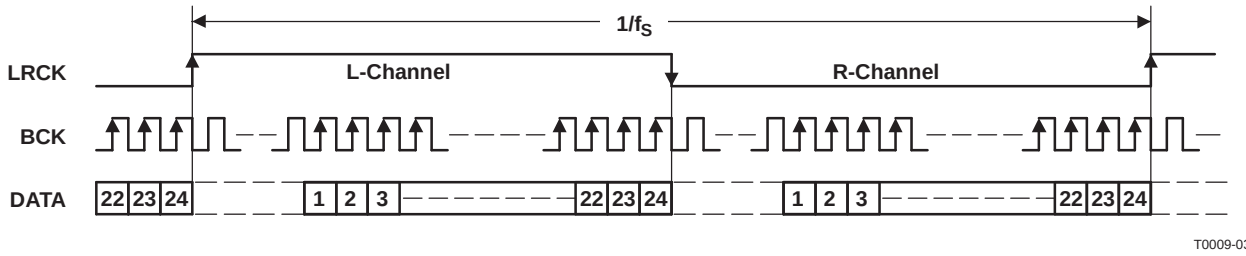
(1) Left-Justified Data Format; L-Channel = High, R-Channel = Low



(2) I²S Data Format; L-Channel = Low, R-Channel = High

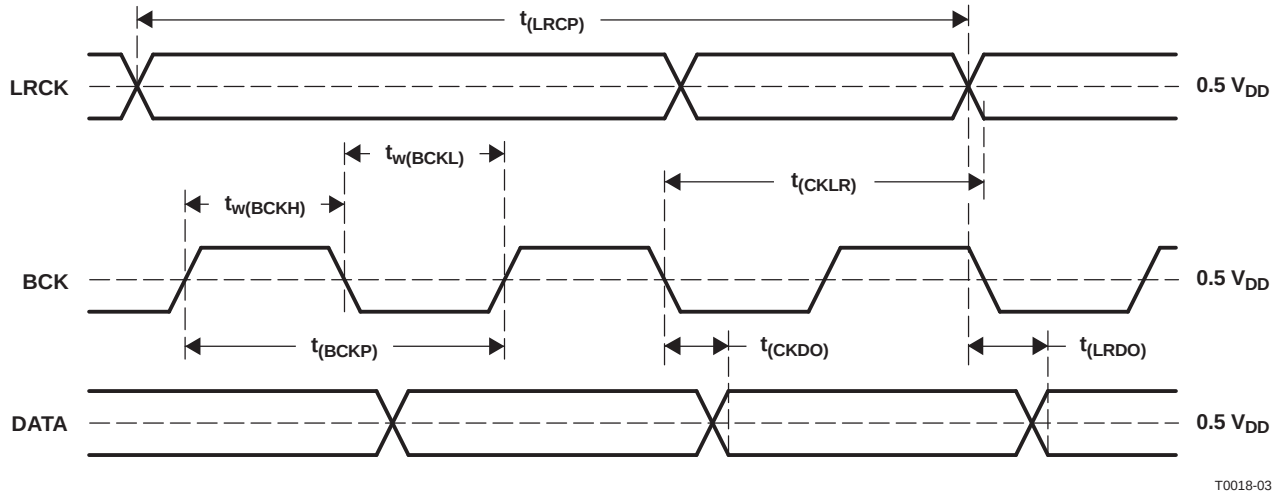


(3) Standard Data Format; L-Channel = High, R-Channel = Low



NOTE: LRCK and BCK work as outputs in master mode and as inputs in slave mode.

Figure 36. Audio Data Format for PCM



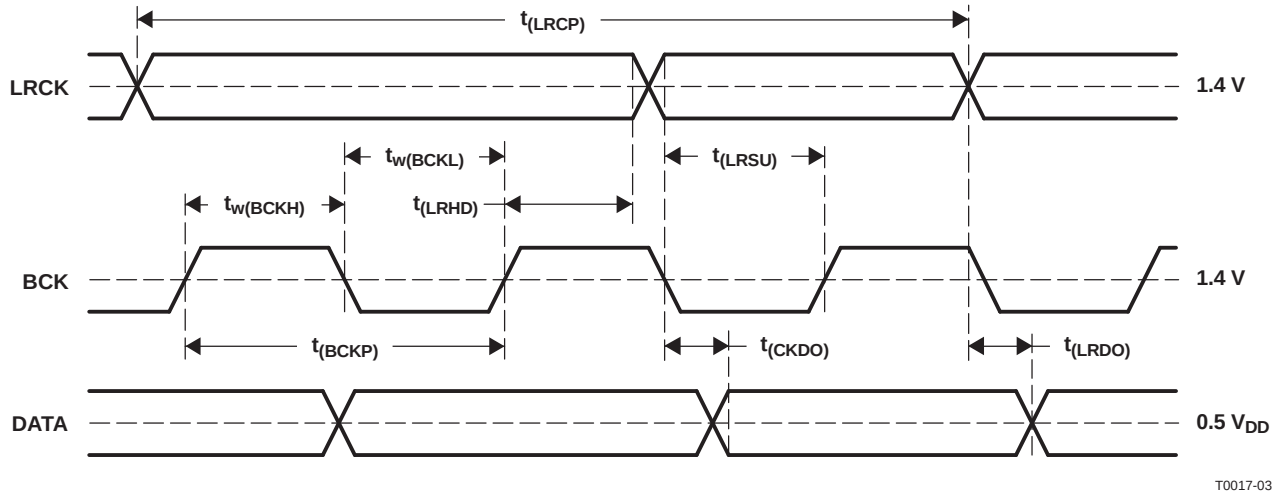
PARAMETERS		MIN	TYP	MAX	UNIT
$t_{(BCKP)}$	BCK period		1/(64 f_S)[3]		
$t_{w(BCKH)}$	BCK pulse duration, HIGH	32			ns
$t_{w(BCKL)}$	BCK pulse duration, LOW	32			ns
$t_{(CKLR)}$	Delay time, BCK falling edge to LRCK valid	–5		15	ns
$t_{(LRCP)}$	LRCK period		$1/f_S$		
$t_{(CKDO)}$	Delay time, BCK falling edge to DATA valid	–5		15	ns
$t_{(LRDO)}$	Delay time, LRCK edge to DATA valid	–5		15	ns
t_r	Rising time of all signals[1][2]			10	ns
t_f	Falling time of all signals[1][2]			10	ns

(1) Rising and falling times are measured from 10% to 90% of IN/OUT signal swing.

(2) Load capacitance of all signals is 10 pF.

(3) $t_{(BCKP)}$ is fixed at 1/(64 f_S) in case of master mode.

Figure 37. Audio Data Interface Timing for PCM (Master Mode: LRCK and BCK Work as Outputs)



PARAMETERS		MIN	TYP	MAX	UNIT
$t_{(BCKP)}$	BCK period	1/(64 f_S)		1/(48 f_S)	
$t_{w(BCKH)}$	BCK pulse duration, HIGH	32			ns
$t_{w(BCKL)}$	BCK pulse duration, LOW	32			ns
$t_{(LRSU)}$	LRCK setup time to BCK rising edge	12			ns
$t_{(LRHD)}$	LRCK hold time to BCK rising edge	12			ns
$t_{(LRCP)}$	LRCK period		1/f_S		
$t_{(CKDO)}$	Delay time, BCK falling edge to DATA valid	5		25	ns
$t_{(LRDO)}$	Delay time, LRCK edge to DATA valid	5		25	ns
t_r	Rising time of all signals(1)(2)			10	ns
t_f	Falling time of all signals(1)(2)			10	ns

(1) Rising and falling times are measured from 10% to 90% of IN/OUT signals swing.

(2) Load capacitance of DATA/DSDR signal is 10 pF.

Figure 38. Audio Data Interface Timing for PCM (Slave Mode: LRCK and BCK Work as Inputs)

INTERFACE TIMING FOR DSD

Figure 39 and Figure 40 illustrate the interface timing for DSD.

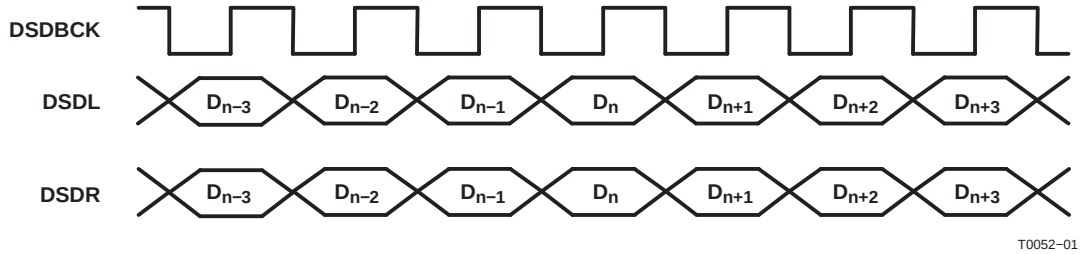
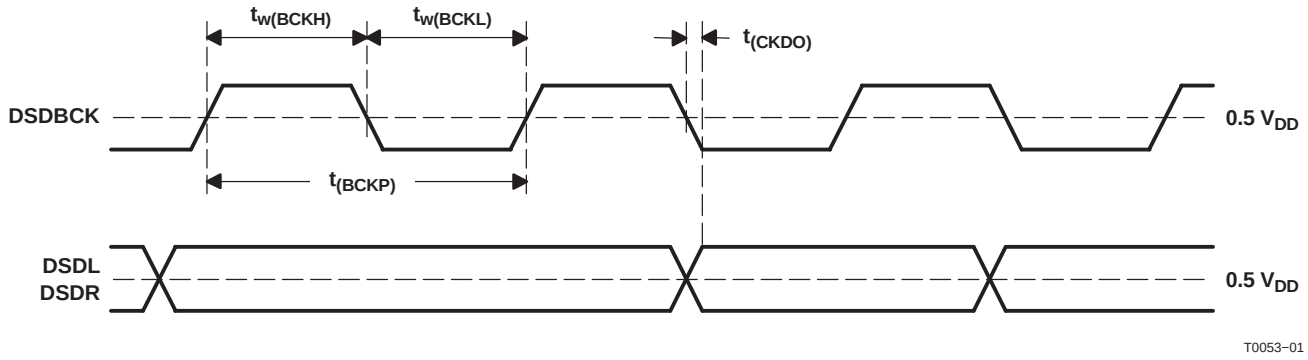


Figure 39. Audio Data Format



PARAMETERS		MIN	TYP	MAX	UNIT
$t_{(BCKP)}$	DSDBCK period		354		ns
$t_{w(BCKH)}$	DSDBCK pulse duration, HIGH		177		ns
$t_{w(BCKL)}$	DSDBCK pulse duration, LOW		177		ns
$t_{(CKDO)}$	Delay time DSDBCK falling edge to DSDL, DSDR valid	–5		15	ns
t_r	Rising time of all signals(1)(2)			10	ns
t_f	Falling time of all signals(1)(2)			10	ns

(1) Rising and falling times are measured from 10% to 90% of IN/OUT signal swing.

(2) Load capacitance of DSDBCK/DSDL/DSDR signal is 10 pF.

Figure 40. Audio Data Interface Timing for DSD (Master Mode Only)

SYNCHRONIZATION WITH DIGITAL AUDIO SYSTEM FOR PCM

In slave mode, the PCM1804 operates under LRCK synchronized with the system clock SCKI. The PCM1804 does not need a specific phase relationship between LRCK and SCKI, but does require the synchronization of LRCK and SCKI.

If the relationship between LRCK and SCKI changes more than ±6 BCK during one sample period due to LRCK or SCKI jitter, internal operation of the ADC halts within $1/f_S$ and digital output is forced into BPZ code until resynchronization between LRCK and SCKI is completed.

In case of changes less than ±5 BCK, resynchronization does not occur and the previously described digital output control and discontinuity do not occur.

Figure 41 illustrates ADC digital output for loss of synchronization and resynchronization. During undefined data, the PCM1804 may generate some noise in the audio signal. Also, the transitions of normal to undefined data and undefined or zero data to normal cause a discontinuity of data on the digital output. This can generate noise in the audio signal. In master mode, synchronization loss never occurs.

HIGH-PASS FILTER (HPF) BYPASS CONTROL FOR PCM

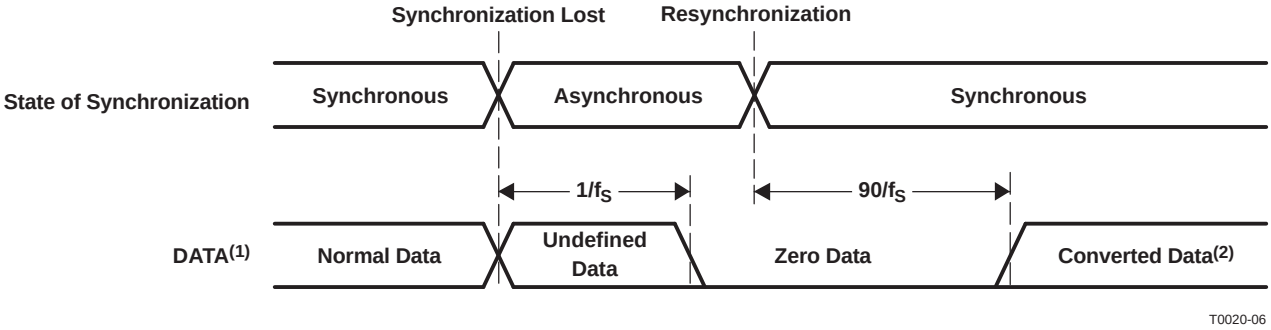
The built-in function for dc component rejection can be bypassed by BYPAS (pin 12) control. In bypass mode, the dc component of the input analog signal and the internal dc offset are also converted and output in the digital output data.

HPF Bypass Control

BYPAS PIN	HPF MODE
Low	Normal (high-pass) mode
High	Bypass (through) mode

OVERFLOW FLAG FOR PCM

The PCM1804 has two overflow flag pins, OVFR (pin 20) and OVFL (pin 21). The pins go to high as soon as the analog input goes across the full-scale range. The high level is held for 1.016 s at maximum, and returns to low if the analog input does not go across the full-scale range for the period.



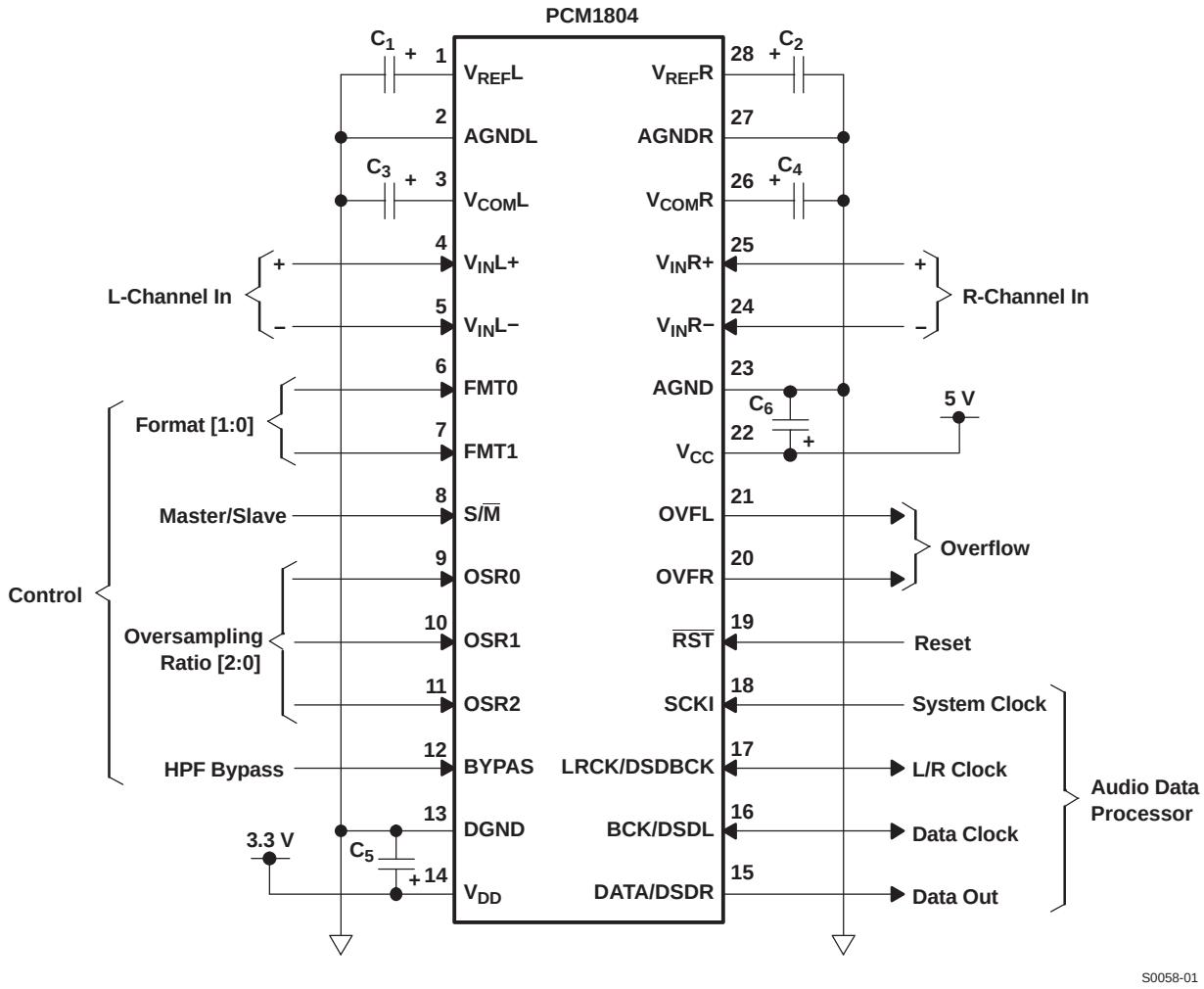
(1) Applies only for slave mode; the loss of synchronization never occurs in master mode.

(2) The HPF transient response appears initially.

Figure 41. ADC Digital Output for Loss of Synchronization and Resynchronization

TYPICAL CIRCUIT CONNECTION DIAGRAM

Figure 42 illustrates a typical circuit connection diagram in the PCM data format operation.

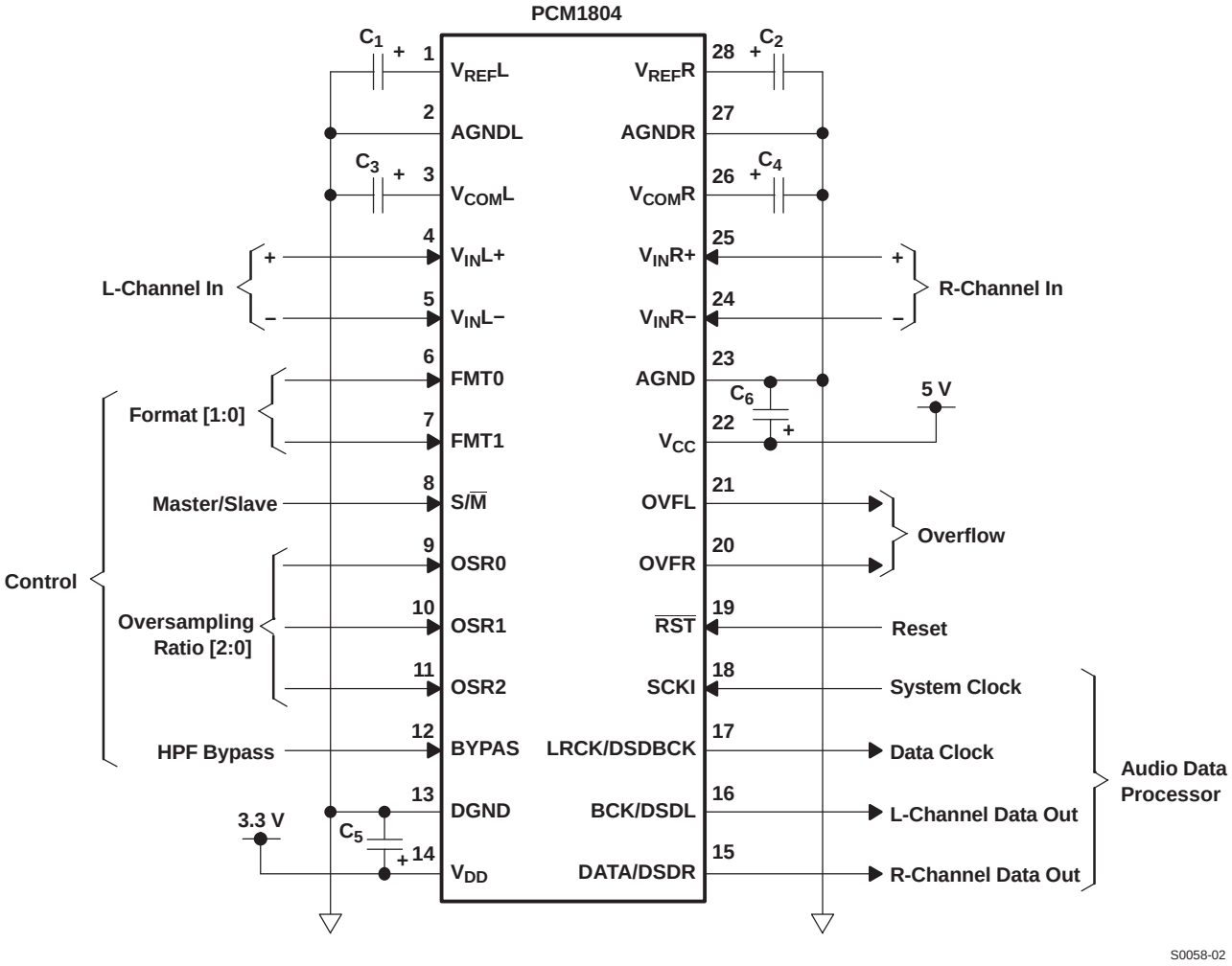


A. C1, C2, C5, and C6: Bypass capacitors, 0.1-μF ceramic and 10-μF tantalum, depending on layout and power supply

B. C3, C4: Bypass capacitor, 0.1-μF tantalum, depending on layout and power supply

Figure 42. Typical Circuit Connection Diagram for PCM

Figure 43 illustrates a typical circuit connection diagram in the DSD data format operation.



A. C1, C2, C5, and C6: Bypass capacitors, 0.1-μF ceramic and 10-μF tantalum, depending on layout and power supply

B. C3 and C4: Bypass capacitors, 0.1-μF tantalum, depending on layout and power supply

Figure 43. Typical Circuit Connection Diagram for DSD

APPLICATION INFORMATION

BOARD DESIGN AND LAYOUT CONSIDERATIONS

V_{CC}, V_{DD} Pins

The digital and analog power supply lines to the PCM1804 should be bypassed to the corresponding ground pins with 0.1-µF ceramic and 10-µF tantalum capacitors placed as close to the pins as possible to maximize the dynamic performance of the ADC. Although the PCM1804 has two power lines to maximize the potential of dynamic performance, using one common power supply is recommended to avoid unexpected power-supply trouble like latch-up or power-supply sequence.

V_{IN} Pins

Use of 0.01-µF film capacitors between $V_{IN}L+$ and $V_{IN}L-$ and between $V_{IN}R+$ and $V_{IN}R-$ is strongly recommended to remove higher-frequency noise from the delta-sigma input section.

$V_{REF}X$, $V_{COM}X$ Inputs

Use 0.1-µF ceramic and 10-µF tantalum capacitors between $V_{REF}L$, $V_{REF}R$, and corresponding AGNDx, to ensure low-source impedance at ADC references. Use 0.1-µF tantalum capacitors between $V_{COM}L$, $V_{COM}R$ and corresponding AGNDx to ensure low source impedance of common voltage. These capacitors should be located as close as possible to the $V_{REF}L$, $V_{REF}R$, $V_{COM}L$, and $V_{COM}R$ pins to reduce dynamic errors on references and common voltage. The dc voltage level of these pins is 2.5 V.

DATA/DSDR, BCK/DSDL, and LRCK/DSDBCK Pins

The DATA/DSDR, BCK/DSDL, and LRCK/DSDBCK pins in master mode have large load drive capability. Locating the buffer near the PCM1804 and minimizing the load capacitance, minimizes the digital-analog crosstalk and maximizes the dynamic performance of the ADC.

System Clock

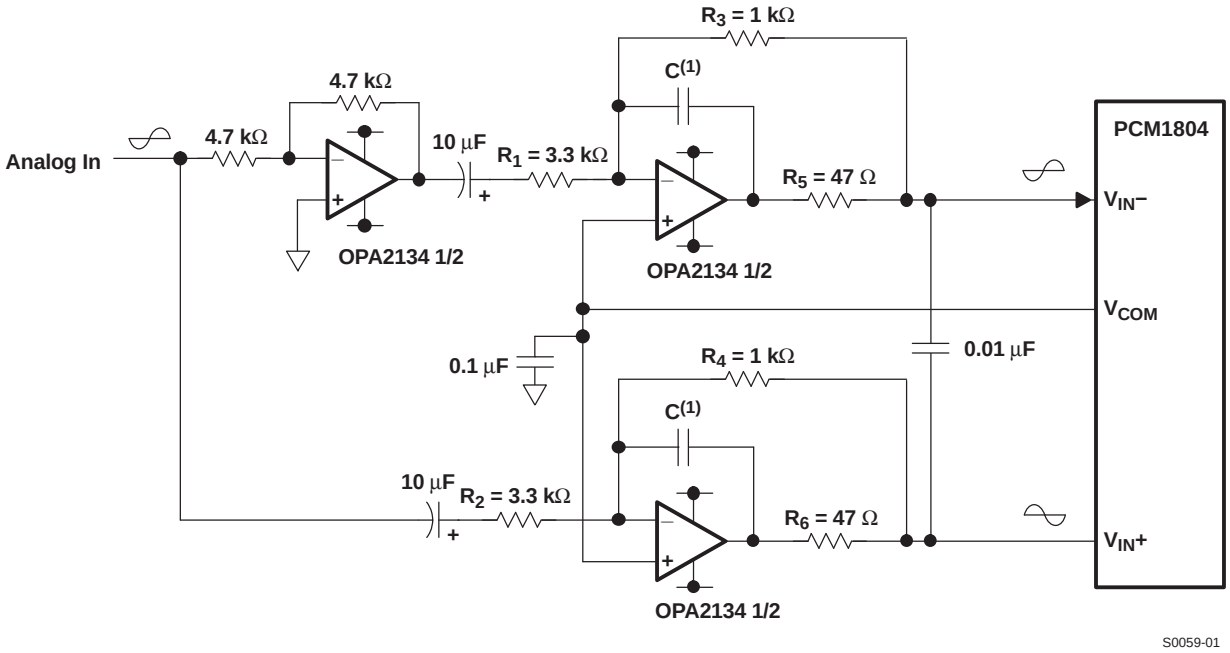
The quality of the system clock can influence dynamic performance, as the PCM1804 operates based on a system clock. Therefore, it might be necessary to consider the system clock duty, jitter, and the time difference between system clock transition and BCK/DSDL or LRCK/DSDBCK transition in slave mode.

Reset Control

If capacitors larger than 10 µF are used on $V_{REF}L$ and $V_{REF}R$, an external reset control with a delay time corresponding to the $V_{REF}L$ and $V_{REF}R$ response is required. Also, it works as a power-down control.

APPLICATION CIRCUIT FOR SINGLE-ENDED INPUT

An application diagram for a single-ended input circuit is shown in Figure 44. The maximum signal input voltage and differential gain of this circuit is designed as Vinmax = 8.28 Vpp, Ad = 0.3. Differential gain (Ad) is given by R3/R1(R4/R2) in a circuit configured as a normal inverted-gain amplifier. Resistor R5(R6) in the feedback loop gives low-impedance drive operation and noise filtering for the analog input of the PCM1804. The circuit technique using R5(R6) is recommended.



(1) A capacitor value of 1800 pF is recommended, unless an input signal greater than –6 dBFS at 100 kHz or higher is applied in the DSD mode. In that case, 3300 pF is recommended.

Figure 44. Application Circuit for Single-Ended Input Circuit (PCM)

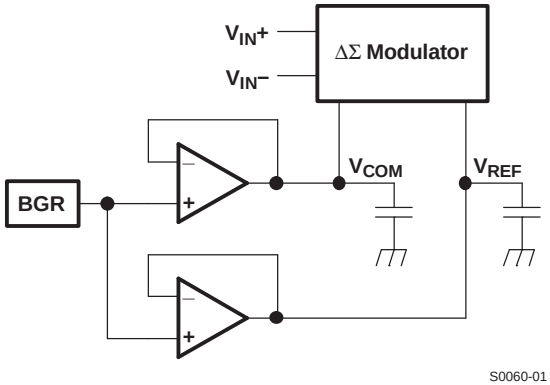


Figure 45. Equivalent Circuit of Internal Reference (V_{COM}, V_{REF})

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)
PCM1804DB	ACTIVE	SSOP	DB	28	47	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	
PCM1804DBG4	ACTIVE	SSOP	DB	28	47	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	
PCM1804DBR	ACTIVE	SSOP	DB	28	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	
PCM1804DBRG4	ACTIVE	SSOP	DB	28	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	

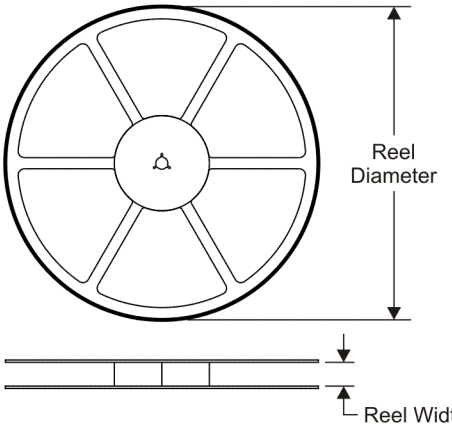
(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, 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)

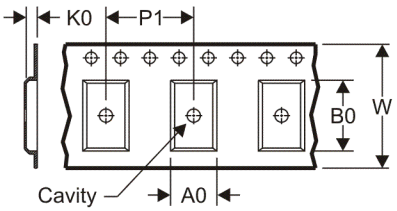
(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

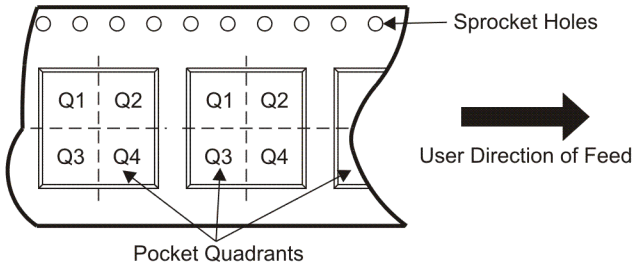


TAPE DIMENSIONS



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

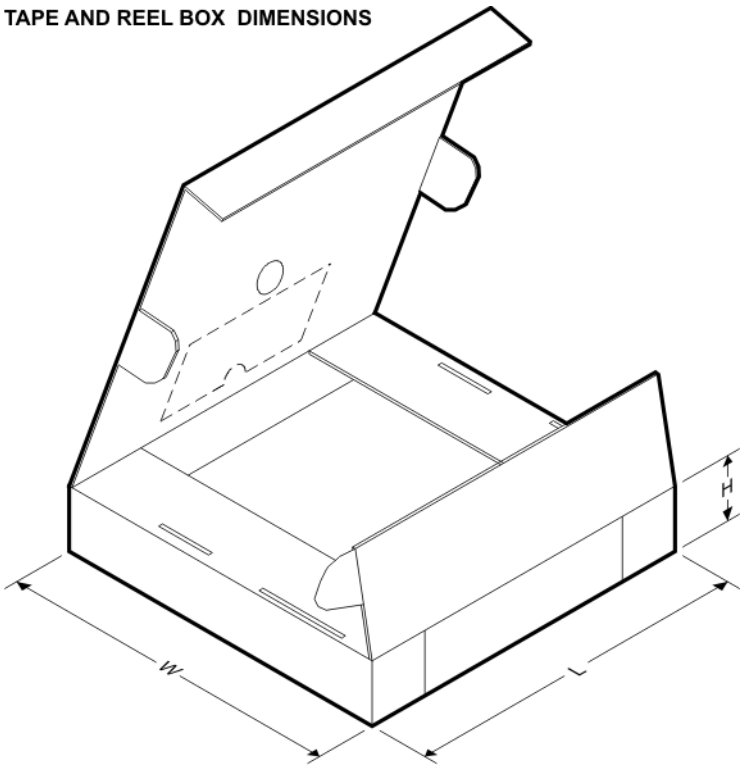
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
PCM1804DBR	SSOP	DB	28	2000	330.0	17.4	8.5	10.8	2.4	12.0	16.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
PCM1804DBR	SSOP	DB	28	2000	336.6	336.6	28.6

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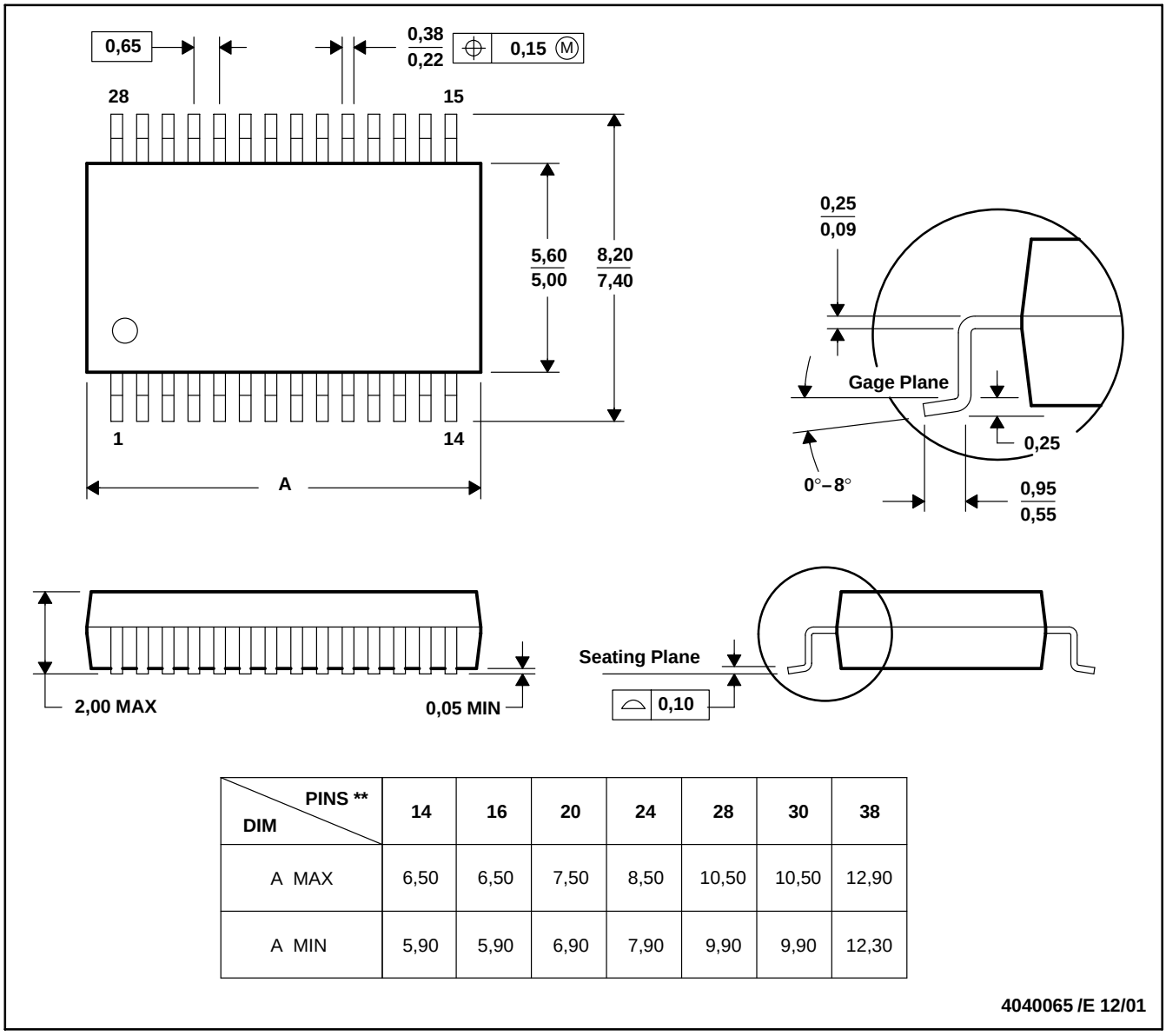
DB (R-PDSO-G)** **PLASTIC SMALL-OUTLINE**

28 PINS SHOWN



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

4040065 /E 12/01

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

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