National Semiconductor

ADVANCE INFORMATION
September 2004

ADC08D1000
High Performance, Low Power, Dual 8-Bit, 1 GSPS A/D Converter

General Description

NOTE: This product is currently in development. – ALL specifications are design targets and are subject to change.

The ADC08D1000 is a dual, low power, high performance CMOS analog-to-digital converter that digitizes signals to 8 bits resolution at sampling rates up to 1.6 GSPS. Consuming a typical 1.6 Watts at 1 GSPS from a single 1.9 Volt supply, this device is guaranteed to have no missing codes over the full operating temperature range. The unique folding and interpolating architecture, the fully differential comparator design, the innovative design of the internal sample-and-hold amplifier and the self-calibration scheme enable a very flat response of all dynamic parameters beyond Nyquist, producing a high 7.5 ENOB with a 500 MHz input signal and a 1 GHz sample rate while providing a 10^{-18} B.E.R. Output formatting is offset binary and the LVDS digital outputs are compliant with IEEE 1596.3-1996, with the exception of a reduced common mode voltage of 0.8V.

Each converter has a 1:2 demultiplexer that feeds two LVDS buses and reduces the output data rate on each bus to half the sampling rate. The two converters can be interleaved and used as a single 2 GSPS ADC.

The converter typically consumes less than 20 mW in the Power Down Mode and is available in a 128-lead, thermally enhanced exposed pad LQFP and operates over the industrial (-40˚C ≤ T_A ≤ +85˚C) temperature range.

Features

- Internal Sample-and-Hold
- Single +1.9V ±0.1V Operation
- Choice of SDR or DDR output clocking
- Interleave Mode for 2x Sampling Rate
- Multiple ADC Synchronization Capability
- Guaranteed No Missing Codes
- Serial Interface for Extended Control
- Fine Adjustment of Input Full-Scale Range and Offset

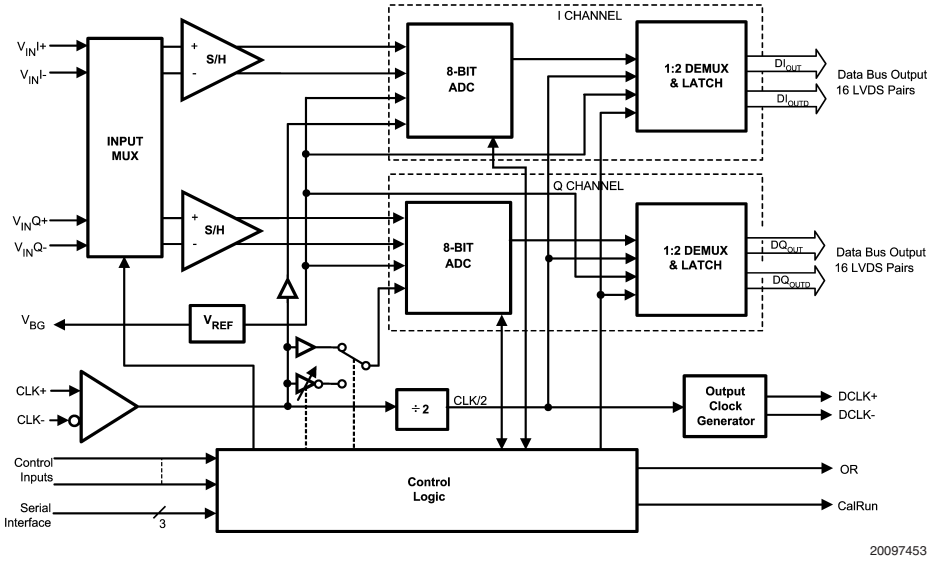
Key Specifications

■ Resolution	8 Bits
■ Max Conversion Rate	1 GSPS (min)
■ Bit Error Rate	10^{-18} (typ)
■ ENOB @ 500 MHz Input	7.5 Bits (typ)
■ DNL	±0.25 LSB (typ)
■ Power Consumption	
— Operating	1.6 W (typ)
— Power Down Mode	20 mW (typ)

Applications

- Direct RF Down Conversion
- Digital Oscilloscopes
- Satellite Set-top boxes
- Communications Systems
- Test Instrumentation

Block Diagram

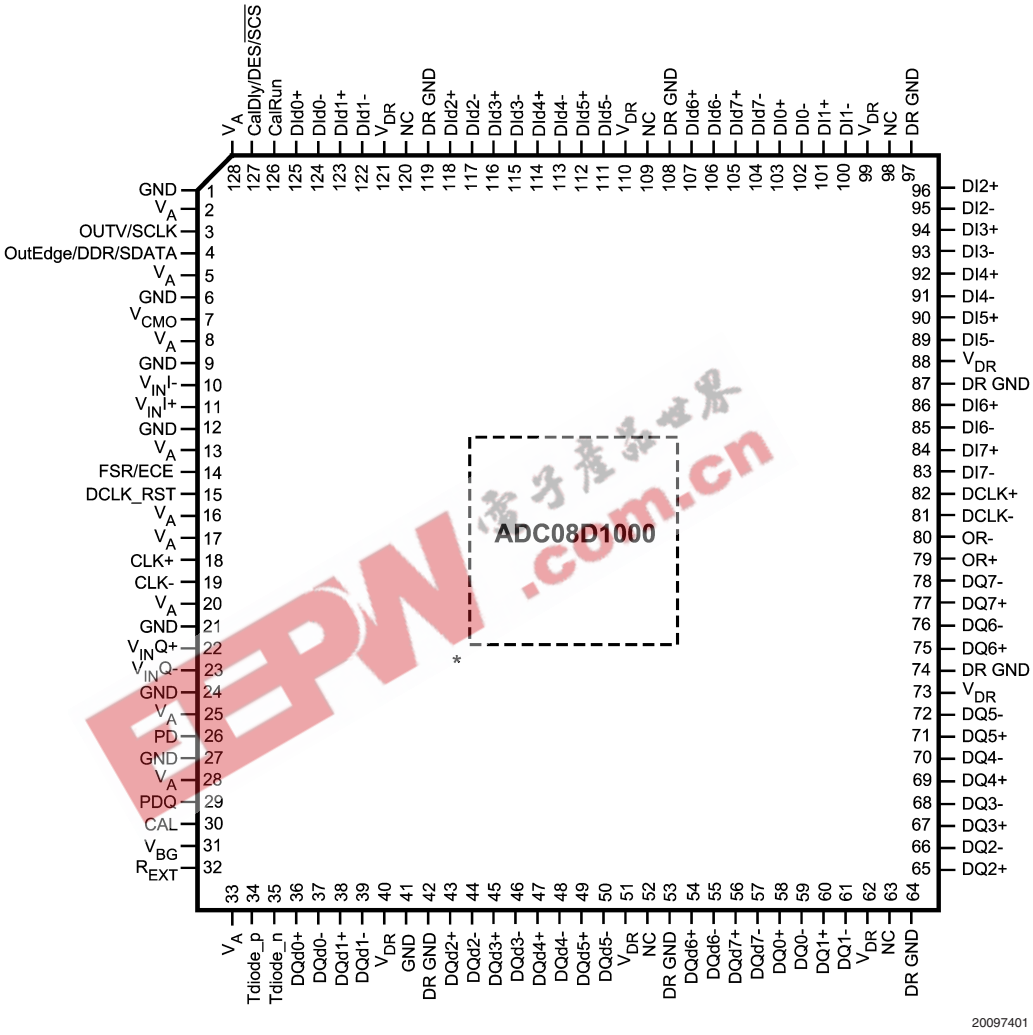


High Performance, Low Power, Dual 8-Bit, 1 GSPS A/D Converter

Ordering Information

Extended Commercial Temperature Range (-40˚C < T_A < +85˚C)	NS Package
ADC08D1000CIYB	128-Pin Exposed Pad LQFP
ADC08D1000EVAL	Evaluation Board

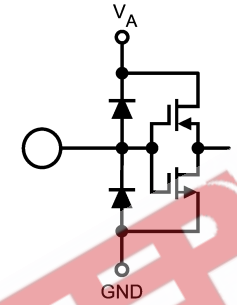
Pin Configuration



* Exposed pad on back of package must be soldered to ground plane to ensure rated performance.

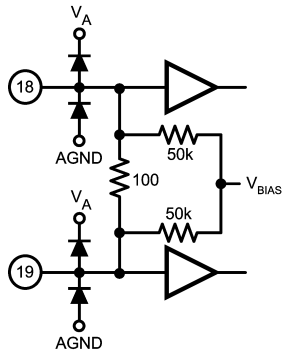
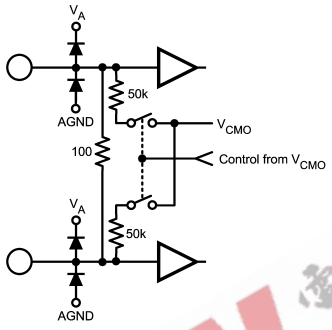
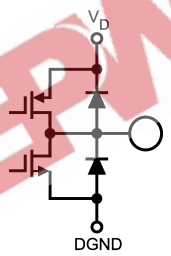
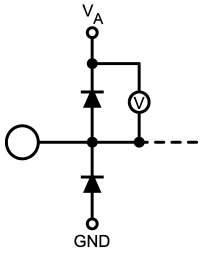
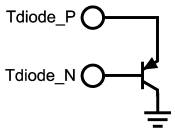
Pin Descriptions and Equivalent Circuits

Pin Functions

Pin No.	Symbol	Equivalent Circuit	Description
3	OutV / SCLK		Output Voltage Amplitude and Serial Interface Clock. Tie this pin high for normal differential DCLK and data amplitude. Ground this pin for a reduced differential output amplitude and reduced power consumption. See Section 1.1.6. When the extended control mode is enabled, this pin functions as the SCLK input which clocks in the serial data. See Section 1.3
4	OutEdge / DDR / SDATA		DCLK Edge Select, Double Data Rate Enable and Serial Data Input. This input sets the output edge of DCLK+ at which the output data transitions. (See Section 1.1.5.2). When this pin is floating or connected to 1/2 the supply voltage, DDR clocking is enabled. When the extended control mode is enabled, this pin functions as the (SDATA) input. See Section 1.2 for details on the extended control mode.
15	DCLK_RST		DCLK Reset. A positive pulse on this pin is used to reset and synchronize the DCLK outs of multiple converters. See Section 1.5 for detailed description.
26 29	PD PDQ		Power Down Pins. A logic high on the PD pin puts the entire device into the Power Down Mode. A logic high on the PDQ pin puts only the "Q" ADC into the Power Down mode.
30	CAL		Calibration Cycle Initiate. A minimum 10 input clock cycles logic low followed by a minimum of 10 input clock cycles high on this pin initiates the self calibration sequence. See Section 2.4.2.
14	FSR/ECE		Full Scale Range Select and Extended Control Enable. In non-extended control mode, a logic low on this pin sets the full-scale differential input range to 600 mV_{P-P}. A logic high on this pin sets the full-scale differential input range to 800 mV_{P-P}. See Section 1.1.4. To enable the extended control mode, whereby the serial interface and control registers are employed, allow this pin to float or connect it to a voltage equal to $V_A/2$. See Section 1.2 for information on the extended control mode.
127	CalDly / DES / $\overline{SCS}$		Calibration Delay, Dual Edge Sampling and Serial Interface Chip Select. With a logic high or low on pin 14, this pin functions as Calibration Delay and sets the number of input clock cycles after power up before calibration begins (See Section 1.1.1). With pin 14 floating, this pin acts as the enable pin for the serial interface input and the CalDly value becomes "0" (short delay with no provision for a long power-up calibration delay). When this pin is floating or connected to a voltage equal to $V_A/2$, DES (Dual Edge Sampling) mode is selected where the "I" input is sampled at twice the input clock rate and the "Q" input is ignored. See Section 1.1.5.1.

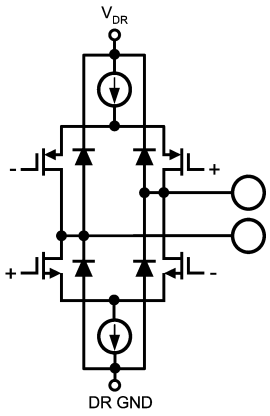
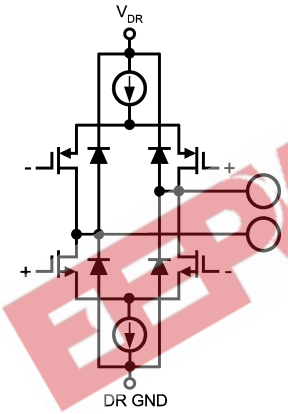
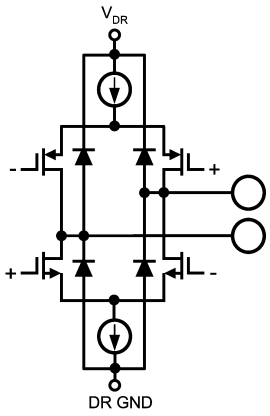
Pin Descriptions and Equivalent Circuits (Continued)

Pin Functions

Pin No.	Symbol	Equivalent Circuit	Description
18 19	CLK+ CLK-		LVDS Clock input pins for the ADC. The differential clock signal must be a.c. coupled to these pins. The input signal is sampled on the falling edge of CLK+. See Section 2.3.
11 10 . 22 23	V_{IN}I+ V_{IN}I− . V_{IN}Q+ V_{IN}Q−		Analog signal inputs to the ADC. The differential full-scale input range is 600 mV_{P-P} when the FSR pin is low, or 800 mV_{P-P} when the FSR pin is high.
7	V_{CMO}		Common Mode Voltage. The voltage output at this pin is required to be the common mode input voltage at V_{IN}+ and V_{IN}− when d.c. coupling is used. This pin should be grounded when a.c. coupling is used at the analog inputs. This pin is capable of sourcing or sinking 100µA. See Section 2.2.
31	V_{BG}		Bandgap output voltage capable of 100 µA source/sink.
126	CalRun		Calibration Running indication. This pin is at a logic high when calibration is running.
32	R_{EXT}		External bias resistor connection. Nominal value is 3.3k-Ohms (±0.1%) to ground. See Section 1.1.1.
34 35	Tdiode_P Tdiode_N		Temperature Diode Positive (Anode) and Negative (Cathode) for die temperature measurements. See Section 2.6.2.

Pin Descriptions and Equivalent Circuits (Continued)

Pin Functions

Pin No.	Symbol	Equivalent Circuit	Description
83 / 78 84 / 77 85 / 76 86 / 75 89 / 72 90 / 71 91 / 70 92 / 69 93 / 68 94 / 67 95 / 66 96 / 65 100 / 61 101 / 60 102 / 59 103 / 58	DI7– / DQ7– DI7+ / DQ7+ DI6– / DQ6– DI6+ / DQ6+ DI5– / DQ5– DI5+ / DQ5+ DI4– / DQ4– DI4+ / DQ4+ DI3– / DQ3– DI3+ / DQ3+ DI2– / DQ2– DI2+ / DQ2+ DI1– / DQ1– DI1+ / DQ1+ DI0– / DQ0– DI0+ / DQ0+		I and Q channel LVDS Data Outputs that are not delayed in the output demultiplexer. Compared with the DId and DQd outputs, these outputs represent the later time samples. These outputs should always be terminated with a 100Ω differential resistor.
104 / 57 105 / 56 106 / 55 107 / 54 111 / 50 112 / 49 113 / 48 114 / 47 115 / 46 116 / 45 117 / 44 118 / 43 122 / 39 123 / 38 124 / 37 125 / 36	DId7– / DQd7– DId7+ / DQd7+ DId6– / DQd6– DId6+ / DQd6+ DId5– / DQd5– DId5+ / DQd5+ DId4– / DQd4– DId4+ / DQd4+ DId3– / DQd3– DId3+ / DQd3+ DId2– / DQd2– DId2+ / DQd2+ DId1– / DQd1– DId1+ / DQd1+ DId0– / DQd0– DId0+ / DQd0+		I and Q channel LVDS Data Outputs that are delayed by one CLK cycle in the output demultiplexer. Compared with the DI/DQ outputs, these outputs represent the earlier time sample. These outputs should always be terminated with a 100Ω differential resistor.
79 80	OR+ OR-		Out Of Range output. A differential high at these pins indicates that the differential input is out of range (outside the range ±300 mV or ±400 mV as defined by the FSR pin).
82 81	DCLK+ DCLK-		Differential Clock outputs used to latch the output data. Delayed and non-delayed data outputs are supplied synchronous to this signal. This signal is at 1/2 the input clock rate in SDR mode and at 1/4 the input clock rate in the DDR mode.
2, 5, 8, 13, 16, 17, 20, 25, 28, 33, 128	V_A		Analog power supply pins. Bypass these pins to ground.

Pin Descriptions and Equivalent Circuits (Continued)

Pin Functions

Pin No.	Symbol	Equivalent Circuit	Description
40, 51 ,62, 73, 88, 99, 110, 121	V_{DR}		Output Driver power supply pins. Bypass these pins to DR GND.
1, 6, 9, 12, 21, 24, 27, 41	GND		Ground return for V_A.
42, 53, 64, 74, 87, 97, 108, 119	DR GND		Ground return for V_{DR}.
52, 63, 98, 109, 120	NC		No Connection. Make no connection to these pins.

Absolute Maximum Ratings

(Notes 1, 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage (V_A, V_{DR})	2.2V
Voltage on Any Input Pin	−0.15V to (V_A +0.15V)
Ground Difference |GND - DR GND|	0V to 100 mV
Input Current at Any Pin (Note 3)	±25 mA
Package Input Current (Note 3)	±50 mA
Power Dissipation at T_A = 25˚C	2.0 W
ESD Susceptibility (Note 4)	
Human Body Model	2500V
Machine Model	250V
Soldering Temperature, Infrared, 10 seconds (Note 5)	235˚C
Storage Temperature	−65˚C to +150˚C

Operating Ratings (Notes 1, 2)

Ambient Temperature Range	−40˚C ≤ T_A ≤ +85˚C
Supply Voltage (V_A)	+1.8V to +2.0V
Driver Supply Voltage (V_{DR})	+1.8V to V_A
Analog Input Common Mode Voltage	1.2V to 1.3V
V_{IN} Differential Voltage Range	$-V_{FS}/2$ to $+V_{FS}/2$
Ground Difference |GND - DR GND|	0V
CLK Pins Voltage Range	0V to V_A
Differential CLK Amplitude	$0.6V_{P-P}$ to $2.0V_{P-P}$

Package Thermal Resistance

Package	θ_{JC} (Top of Package)	$\theta_{J\text{-}PAD}$ (Thermal Pad)
128-Lead Exposed Pad LQFP	10˚C / W	2.8˚C / W

Converter Electrical Characteristics

[Note: This product is currently in development. As such, the parameters specified in this section are DESIGN TARGETS. The specifications in this section cannot be guaranteed until device characterization has taken place.]

The following specifications apply after calibration for V_A = V_{DR} = +1.9V_{DC}, OutV = 1.9V, V_{IN} FSR (a.c. coupled) = differential 800mV_{P-P}, C_L = 10 pF, Differential, a.c. coupled Sinewave Input Clock, f_{CLK} = 1 GHz at 0.5V_{P-P} with 50% duty cycle, Non-Extended Control Mode, R_{EXT} = 3300Ω ±0.1%, Analog Signal Source Impedance = 100Ω. **Boldface limits apply for T_A = T_{MIN} to T_{MAX}.** All other limits T_A = 25˚C, unless otherwise noted. (Notes 6, 7)

Symbol	Parameter	Conditions	Typical (Note 8)	Limits (Note 8)	Units (Limits)
STATIC CONVERTER CHARACTERISTICS					
INL	Integral Non-Linearity		±0.35	**±TBD**	LSB (max)
DNL	Differential Non-Linearity		±0.25	**±TBD**	LSB (max)
	Resolution with No Missing Codes			**8**	Bits
V_{OFF}	Offset Error		-0.45	**−TBD** **TBD**	LSB (min) LSB (max)
V_{OFF}_ADJ	Input Offset Adjustment Range	Extended Control Mode	±45		mV
TC V_{OFF}	Offset Error Tempco	−40˚C to +85˚C	−3		ppm/˚C
PFSE	Positive Full-Scale Error (Note 9)		−2.2	**±TBD**	mV (max)
NFSE	Negative Full-Scale Error (Note 9)		−1.1	**±TBD**	mV (max)
FS_ADJ	Full-Scale Adjustment Range	Extended Control Mode	±20	**±15**	%FS
TC PFSE	Positive Full-Scale Error Tempco	−40˚C to +85˚C	20		ppm/˚C
TC NFSE	Negative Full-Scale Error Tempco	−40˚C to +85˚C	13		ppm/˚C
Dynamic Converter Characteristics					
FPBW	Full Power Bandwidth	Normal (non DES) Mode	1.7		GHz
FPBW (DES)	Full Power Bandwidth	Dual Edge Sampling Mode	900		MHz
B.E.R.	Bit Error Rate		10^{-18}		Error/Bit
	Gain Flatness	d.c. to 500 MHz	±0.5		dBFS
		d.c. to 1 GHz	±1.0		dBFS
ENOB	Effective Number of Bits	f_{IN} = 100 MHz, V_{IN} = FSR − 0.5 dB	7.5		Bits
		f_{IN} = 248 MHz, V_{IN} = FSR − 0.5 dB	7.5	**TBD**	Bits (min)
		f_{IN} = 498 MHz, V_{IN} = FSR − 0.5 dB	7.5	**TBD**	Bits (min)

Converter Electrical Characteristics (Continued)

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The following specifications apply after calibration for $V_A = V_{DR} = +1.9V_{DC}$, OutV = 1.9V, V_{IN} FSR (a.c. coupled) = differential $800mV_{P-P}$, C_L = 10 pF, Differential, a.c. coupled Sinewave Input Clock, f_{CLK} = 1 GHz at $0.5V_{P-P}$ with 50% duty cycle, Non-Extended Control Mode, R_{EXT} = 3300Ω ±0.1%, Analog Signal Source Impedance = 100Ω. **Boldface limits apply for $T_A = T_{MIN}$ to T_{MAX}.** All other limits T_A = 25˚C, unless otherwise noted. (Notes 6, 7)

Symbol	Parameter	Conditions	Typical (Note 8)	Limits (Note 8)	Units (Limits)
STATIC CONVERTER CHARACTERISTICS					
SINAD	Signal-to-Noise Plus Distortion Ratio	f_{IN} = 100 MHz, V_{IN} = FSR – 0.5 dB	47		dB
		f_{IN} = 248 MHz, V_{IN} = FSR – 0.5 dB	47	**TBD**	dB (min)
		f_{IN} = 498 MHz, V_{IN} = FSR – 0.5 dB	47	**TBD**	dB (min)
SNR	Signal-to-Noise Ratio	f_{IN} = 100 MHz, V_{IN} = FSR – 0.5 dB	48		dB
		f_{IN} = 248 MHz, V_{IN} = FSR – 0.5 dB	48	**TBD**	dB (min)
		f_{IN} = 498 MHz, V_{IN} = FSR – 0.5 dB	48	**TBD**	dB (min)
THD	Total Harmonic Distortion	f_{IN} = 100 MHz, V_{IN} = FSR – 0.5 dB	-57		dB
		f_{IN} = 248 MHz, V_{IN} = FSR – 0.5 dB	-57	**–TBD**	dB (max)
		f_{IN} = 498 MHz, V_{IN} = FSR – 0.5 dB	-57	**–TBD**	dB (max)
2nd Harm	Second Harmonic Distortion	f_{IN} = 100 MHz, V_{IN} = FSR – 0.5 dB	–64		dB
		f_{IN} = 248 MHz, V_{IN} = FSR – 0.5 dB	–64		dB
		f_{IN} = 498 MHz, V_{IN} = FSR – 0.5 dB	–64		dB
3rd Harm	Third Harmonic Distortion	f_{IN} = 100 MHz, V_{IN} = FSR – 0.5 dB	–64		dB
		f_{IN} = 248 MHz, V_{IN} = FSR – 0.5 dB	–64	**–TBD**	dB
		f_{IN} = 498 MHz, V_{IN} = FSR – 0.5 dB	–64	**–TBD**	dB
SFDR	Spurious-Free dynamic Range	f_{IN} = 100 MHz, V_{IN} = FSR – 0.5 dB	58.5		dB
		f_{IN} = 248 MHz, V_{IN} = FSR – 0.5 dB	58.5	**TBD**	dB (min)
		f_{IN} = 498 MHz, V_{IN} = FSR – 0.5 dB	58.5	**TBD**	dB (min)
IMD	Intermodulation Distortion	f_{IN1} = 121 MHz, V_{IN} = FSR – 7 dB f_{IN2} = 126 MHz, V_{IN} = FSR – 7 dB	-51		dB
	Out of Range Output Code (In addition to OR Output high)	$(V_{IN}+) - (V_{IN}-) >$ + Full Scale		**255**	
		$(V_{IN}+) - (V_{IN}-) <$ – Full Scale		**0**	
ANALOG INPUT AND REFERENCE CHARACTERISTICS					
V_{IN}	Full Scale Analog Differential Input Range	FSR pin 14 Low	600	**550**	mV_{P-P} (min)
				650	mV_{P-P} (max)
		FSR pin 14 High	800	**750**	mV_{P-P} (min)
				850	mV_{P-P} (max)
V_{CMI}	Analog Input Common Mode Voltage		V_{CMO}	**V_{CMO} – 50** **V_{CMO} + 50**	mV (min) mV (max)
C_{IN}	Analog Input Capacitance, normal operation (Note 10)	Differential	0.02		pF
		Each input pin to ground	1.6		pF
	Analog Input Capacitance, DES Mode (Note 10)	Differential	0.8		pF
		Each input pin to ground	2.2		pF
R_{IN}	Differential Input Resistance		100	**94**	Ω (min)
				106	Ω (max)
ANALOG OUTPUT CHARACTERISTICS					
V_{CMO}	Common Mode Output Voltage		1.25	**0.95** **1.45**	V (min) V (max)
TC V_{CMO}	Common Mode Output Voltage Temperature Coefficient	T_A = –40˚C to +85˚C	118		ppm/˚C
C_{LOAD} V_{CMO}	Maximum VCMO load Capacitance			80	pF

Converter Electrical Characteristics (Continued)

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The following specifications apply after calibration for $V_A = V_{DR} = +1.9V_{DC}$, OutV = 1.9V, V_{IN} FSR (a.c. coupled) = differential $800mV_{P-P}$, C_L = 10 pF, Differential, a.c. coupled Sinewave Input Clock, f_{CLK} = 1 GHz at $0.5V_{P-P}$ with 50% duty cycle, Non-Extended Control Mode, R_{EXT} = 3300Ω ±0.1%, Analog Signal Source Impedance = 100Ω. **Boldface limits apply for $T_A = T_{MIN}$ to T_{MAX}.** All other limits T_A = 25˚C, unless otherwise noted. (Notes 6, 7)

Symbol	Parameter	Conditions	Typical (Note 8)	Limits (Note 8)	Units (Limits)
ANALOG OUTPUT CHARACTERISTICS					
V_{BG}	Bandgap Reference Output Voltage	I_{BG} = ±100 µA	1.26	**1.22** **1.33**	V (min) V (max)
TC V_{BG}	Bandgap Reference Voltage Temperature Coefficient	T_A = −40˚C to +85˚C, I_{BG} = ±100 µA	28		ppm/˚C
C_{LOAD} V_{BG}	Maximum Bandgap Reference load Capacitance			80	pF
TEMPERATURE DIODE CHARACTERISTICS					
	Temperature Diode Voltage	ΔI_{DIODE}, 100 µA vs. 10 µA, T_J = 25˚C	TBD		mV
		ΔI_{DIODE}, 100 µA vs. 10 µA, T_J = 85˚C	TBD		mV
CHANNEL-TO-CHANNEL CHARACTERISTICS					
	Offset Error Match		2	**TBD**	LSB (max)
	Positive Full-Scale Error Match	Zero offset selected in Control Register	6	**TBD**	mV (max)
	Negative Full-Scale Error Match	Zero offset selected in Control Register	6	**TBD**	mV (max)
X-TALK	Crosstalk	100 MHz input to Victim Channel 800 MHz to Interfering Channel	−77		dB
CLOCK INPUT CHARACTERISTICS					
V_{ID}	Differential Clock Input Level	Sine Wave Clock	0.6	**0.4** **2.0**	mV_{P-P} (min) mV_{P-P} (max)
		Square Wave Clock	0.6	**0.4** **2.0**	mV_{P-P} (min) mV_{P-P} (max)
I_I	Input Current	V_{IN} = 0 or V_{IN} = V_A	±1		µA
C_{IN}	Input Capacitance (Note 11)	Differential	0.02		pF
		Each input to ground	1.5		pF
DIGITAL CONTROL PIN CHARACTERISTICS					
V_{IH}	Logic High Input Voltage	(Note 12)		**1.4**	V (min)
V_{IL}	Logic Low Input Voltage	(Note 12)		**0.5**	V (max)
I_I	Input Current	V_{IN} = 0 or V_{IN} = V_A, Pins 4, 14, 127	±80		µA
		V_{IN} = 0 or V_{IN} = V_A, All Other Pins	±1		µA
C_{IN}	Input Capacitance (Note 11)	Each input to ground	1.2		pF
DIGITAL OUTPUT CHARACTERISTICS					
V_{OD}	LVDS Differential Output Voltage	OutV = V_A, measured single-ended	600	**400**	mV_{P-P} (min)
				900	mV_{P-P} (max)
		OutV = GND, measured single-ended	450	**280**	mV_{P-P} (min)
				680	mV_{P-P} (max)
$\Delta V_{O\ DIFF}$	Change in LVDS Output Swing Between Logic Levels		±1		mV
V_{OS}	Output Offset Voltage		800		mV
ΔV_{OS}	Output Offset Voltage Change Between Logic Levels		±1		mV

Converter Electrical Characteristics (Continued)

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Symbol	Parameter	Conditions	Typical (Note 8)	Limits (Note 8)	Units (Limits)
DIGITAL OUTPUT CHARACTERISTICS					
I_{OS}	Output Short Circuit Current	Output+ & Output- connected to 0.8V	−4		mA
Z_O	Differential Output Impedance		100		Ohms
POWER SUPPLY CHARACTERISTICS					
I_A	Analog Supply Current	PD = PDQ = Low PD = Low, PDQ = High PD = High	627 325 4.3	**690** **360**	mA (max) mA mA
I_{DR}	Output Driver Supply Current	PD = PDQ = Low PD = Low, PDQ = High PD = PDQ = High	202 116 1	**257** **135**	mA (max) mA (max) mA
P_D	Power Consumption	PD = PDQ = Low PD = Low, PDQ = High PD = PDQ = High	1.6 0.84 20	**1.8** **0.94**	W (max) W mW
PSRR1	D.C. Power Supply Rejection Ratio	Change in Full Scale Error with change in V_A from 1.8V to 2.0V	73		dB
PSRR2	A.C. Power Supply Rejection Ratio	248 MHz, $50mV_{P-P}$ riding on V_A	TBD		dB
AC ELECTRICAL CHARACTERISTICS					
f_{CLK1}	Maximum Conversion Rate	$T_A \le 85˚C$	1.1	**1.0**	GHz (min)
		$T_A \le 75˚C$	1.3		GHz
f_{CLK2}	Minimum Conversion Rate		200		MHz
	Input Clock Duty Cycle	200 MHz ≤ Input clock frequency ≤ 1 GHz	50	20 80	% (min) % (max)
t_{CL}	Input Clock Low Time	(Note 12)	500	**200**	ps (min)
t_{CH}	Input Clock High Time	(Note 12)	500	**200**	ps (min)
	DCLK Duty Cycle	(Note 12)	50	**45** **55**	% (min) % (max)
t_{RS}	Reset Setup Time	(Note 12)	150	**TBD**	ps (min)
t_{RH}	Reset Hold Time	(Note 12)	250	**TBD**	ps (min)
t_{RPW}	Reset Pulse Width			**4**	Clock Cycles (min)
t_{LHT}	Differential Low to High Transition Time	10% to 90%, C_L = 2.5 pF	250		ps
t_{HLT}	Differential High to Low Transition Time	10% to 90%, C_L = 2.5 pF	250		ps
t_{OSK}	DCLK to Data Output Skew	50% of DCLK transition to 50% of Data transition, SDR Mode and DDR Mode, 0˚ DCLK (Note 12)	±200	**±TBD**	ps (max)
t_{SU}	Data to DCLK Set-Up Time	DDR Mode, 180˚ DCLK (Note 12)	750	**TBD**	ps (min)
t_H	DCLK to Data Hold Time	DDR Mode, 180˚ DCLK (Note 12)	750	**TBD**	ps (min)
t_{AD}	Sampling (Aperture) Delay	Input CLK+ Fall to Acquisition of Data	1.3		ns
t_{AJ}	Aperture Jitter		0.4		ps rms
t_{OD}	Input Clock to Data Output Delay	50% of Input Clock transition to 50% of Data transition	3.1		ns

Converter Electrical Characteristics (Continued)

[Note: This product is currently in development. As such, the parameters specified in this section are DESIGN TARGETS. The specifications in this section cannot be guaranteed until device characterization has taken place.]

The following specifications apply after calibration for $V_A = V_{DR} = +1.9V_{DC}$, OutV = 1.9V, V_{IN} FSR (a.c. coupled) = differential $800mV_{P-P}$, C_L = 10 pF, Differential, a.c. coupled Sinewave Input Clock, f_{CLK} = 1 GHz at $0.5V_{P-P}$ with 50% duty cycle, Non-Extended Control Mode, R_{EXT} = 3300Ω ±0.1%, Analog Signal Source Impedance = 100Ω. **Boldface limits apply for $T_A = T_{MIN}$ to T_{MAX}.** All other limits T_A = 25˚C, unless otherwise noted. (Notes 6, 7)

Symbol	Parameter	Conditions		Typical (Note 8)	Limits (Note 8)	Units (Limits)
AC ELECTRICAL CHARACTERISTICS						
	Pipeline Delay (Latency) (Note 11)	DI Outputs			**13**	Input Clock Cycles
		DId Outputs			**14**	
		DQ Outputs	Normal Mode		**13**	
			Extended Control Mode		**13.5**	
		DQd Outputs	Normal Mode		**14**	
			Extended Control Mode		**14.5**	
	Over Range Recovery Time	Differential V_{IN} step from ±1.2V to 0V to get accurate conversion		TBD		ns
t_{WU}	PD low to Rated Accuracy Conversion (Wake-Up Time)			500		ns
f_{SCLK}	Maximum Serial Clock Frequency			100		MHz
t_{SSU}	Data to Serial Clock Setup Time	(Note 12)		2.5	**TBD**	ns (min)
t_{SH}	Data to Serial Clock Hold Time	(Note 12)		1	**TBD**	ns (min)
	Serial Clock Low Time				**4**	ns (min)
	Serial Clock High Time				**4**	ns (min)
t_{CAL}	Calibration Cycle Time			1.4×10^5		Clock Cycles

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. There is no guarantee of operation at the Absolute Maximum Ratings. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.

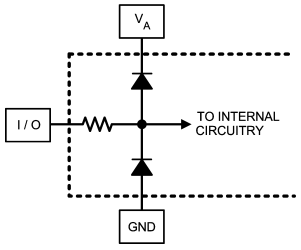
Note 2: All voltages are measured with respect to GND = DR GND = 0V, unless otherwise specified.

Note 3: When the input voltage at any pin exceeds the power supply limits (that is, less than GND or greater than V_A), the current at that pin should be limited to 25 mA. The 50 mA maximum package input current rating limits the number of pins that can safely exceed the power supplies with an input current of 25 mA to two. This limit is not placed upon the power, ground and digital output pins.

Note 4: Human body model is 100 pF capacitor discharged through a 1.5 kΩ resistor. Machine model is 220 pF discharged through ZERO Ohms.

Note 5: See AN-450, "Surface Mounting Methods and Their Effect on Product Reliability".

Note 6: The analog inputs are protected as shown below. Input voltage magnitudes beyond the Absolute Maximum Ratings may damage this device.



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Note 7: To guarantee accuracy, it is required that V_A and V_{DR} be well bypassed. Each supply pin must be decoupled with separate bypass capacitors. Additionally, achieving rated performance requires that the backside exposed pad be well grounded.

Note 8: Typical figures are at T_J = 25˚C, and represent most likely parametric norms. Test limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

Note 9: Calculation of Full-Scale Error for this device assumes that the actual reference voltage is exactly its nominal value. Full-Scale Error for this device, therefore, is a combination of Full-Scale Error and Reference Voltage Error. See *Figure 2*. For relationship between Gain Error and Full-Scale Error, see Specification Definitions for Gain Error.

Note 10: The analog and clock input capacitances are die capacitances only. Additional package capacitances of 0.65 pF differential and 0.95 pF each pin to ground are isolated from the die capacitances by lead and bond wire inductances.

Note 11: This parameter is guaranteed by design and is not tested in production.

Converter Electrical Characteristics (Continued)

Note 12: This parameter is guaranteed by design and/or characterization and is not tested in production.

Note 13: The digital control pin capacitances are die capacitances only. Additional package capacitance of 1.6 pF each pin to ground are isolated from the die capacitances by lead and bond wire inductances.

Note 14: Each of the two converters of the ADC08D1000 has two LVDS output buses, which each clock data out at one half the sample rate. The data at each bus is clocked out at one half the sample rate. The second bus (D0 through D7) has a pipeline latency that is one Input Clock cycle less than the latency of the first bus (Dd0 through Dd7).

Specification Definitions

APERTURE (SAMPLING) DELAY is that time required after the fall of the clock input for the sampling switch to open. The Sample/Hold circuit effectively stops capturing the input signal and goes into the "hold" mode the aperture delay time (t_{AD}) after the input clock goes low.

APERTURE JITTER (t_{AJ}) is the variation in aperture delay from sample to sample. Aperture jitter shows up as input noise.

Bit Error Rate (B.E.R.) is the probability of error and is defined as the probable number of errors per unit of time divided by the number of bits seen in that amount of time. A B.E.R. of 10^{-18} corresponds to a statistical error in one bit about every four (4) years.

CLOCK DUTY CYCLE is the ratio of the time that the clock wave form is at a logic high to the total time of one clock period.

DIFFERENTIAL NON-LINEARITY (DNL) is the measure of the maximum deviation from the ideal step size of 1 LSB. Measured at 1 GSPS with a ramp input.

EFFECTIVE NUMBER OF BITS (ENOB, or EFFECTIVE BITS) is another method of specifying Signal-to-Noise and Distortion Ratio, or SINAD. ENOB is defined as (SINAD – 1.76) / 6.02 and says that the converter is equivalent to a perfect ADC of this (ENOB) number of bits.

FULL POWER BANDWIDTH (FPBW) is a measure of the frequency at which the reconstructed output fundamental drops 3 dB below its low frequency value for a full scale input.

GAIN ERROR is the deviation from the ideal slope of the transfer function. It can be calculated from Offset and Full-Scale Errors:

Positive Gain Error = Offset Error – Positive Full-Scale Error

Negative Gain Error = –(Offset Error – Negative Full-Scale Error)

Gain Error = Negative Full-Scale Error – Positive Full-Scale Error = Positive Gain Error + Negative Gain Error

INTEGRAL NON-LINEARITY (INL) is a measure of the deviation of each individual code from a straight line through the input to output transfer function. The deviation of any given code from this straight line is measured from the center of that code value. The best fit method is used.

INTERMODULATION DISTORTION (IMD) is the creation of additional spectral components as a result of two sinusoidal frequencies being applied to the ADC input at the same time. it is defined as the ratio of the power in the second and third order intermodulation products to the power in one of the original frequencies. IMD is usually expressed in dBFS.

LSB (LEAST SIGNIFICANT BIT) is the bit that has the smallest value or weight of all bits. This value is

$$V_{FS} / 2^n$$

where V_{FS} is the differential full-scale amplitude of 600 mV or 800 mV as set by the FSR input and "n" is the ADC resolution in bits, which is 8 for the ADC08D1000.

LVDS DIFFERENTIAL OUTPUT VOLTAGE (V_{OD}) is the absolute value of the difference between the V_D+ & V_D- outputs; each measured with respect to Ground.

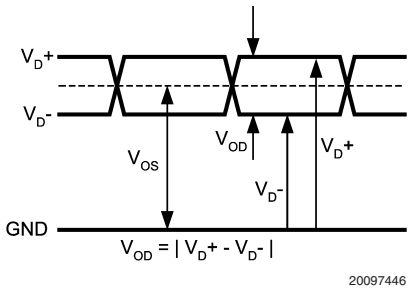


FIGURE 1.

LVDS OUTPUT OFFSET VOLTAGE (V_{OS}) is the midpoint between the D+ and D- pins output voltage; ie., [(V_D+) +(V_D-)]/2.

MISSING CODES are those output codes that are skipped and will never appear at the ADC outputs. These codes cannot be reached with any input value.

MSB (MOST SIGNIFICANT BIT) is the bit that has the largest value or weight. Its value is one half of full scale.

NEGATIVE FULL-SCALE ERROR (NFSE) is a measure of how far the last code transition is from the ideal 1/2 LSB above a differential –800 mV with the FSR pin high, or 1/2 LSB above a differential –600 mV with the FSR pin low. For the ADC08D1000 the reference voltage is assumed to be ideal, so this error is a combination of full-scale error and reference voltage error.

OFFSET ERROR (V_{OFF}) is a measure of how far the mid-scale point is from the ideal zero voltage differential input.

Offset Error = Actual Input causing average of 8k samples to result in an average code of 127.5.

OUTPUT DELAY (t_{OD}) is the time delay after the falling edge of DCLK before the data update is present at the output pins.

OVER-RANGE RECOVERY TIME is the time required after the differential input voltages goes from ±1.2V to 0V for the converter to recover and make a conversion with its rated accuracy.

PIPELINE DELAY (LATENCY) is the number of input clock cycles between initiation of conversion and when that data is presented to the output driver stage. New data is available at every clock cycle, but the data lags the conversion by the Pipeline Delay plus the t_{OD}.

POSITIVE FULL-SCALE ERROR (PFSE) is a measure of how far the last code transition is from the ideal 1-1/2 LSB below a differential +800 mV with the FSR pin high, or 1-1/2 LSB below a differential +600 mV with the FSR pin low. For the ADC08D1000 the reference voltage is assumed to be ideal, so this error is a combination of full-scale error and reference voltage error.

POWER SUPPLY REJECTION RATIO (PSRR) can be one of two specifications. PSRR1 (DC PSRR) is the ratio of the change in full-scale error that results from a power supply voltage change from 1.8V to 2.0V. PSRR2 (AC PSRR) is a measure of how well an a.c. signal riding upon the power supply is rejected from the output and is measured with a 248 MHz, 50 mV_{P-P} signal riding upon the power supply. It is the ratio of the output amplitude of that signal at the output to its amplitude on the power supply pin. PSRR is expressed in dB.

Specification Definitions (Continued)

SIGNAL TO NOISE RATIO (SNR) is the ratio, expressed in dB, of the rms value of the input signal at the output to the rms value of the sum of all other spectral components below one-half the sampling frequency, not including harmonics or d.c.

SIGNAL TO NOISE PLUS DISTORTION (S/(N+D) or SINAD) is the ratio, expressed in dB, of the rms value of the input signal at the output to the rms value of all of the other spectral components below half the input clock frequency, including harmonics but excluding d.c.

SPURIOUS-FREE DYNAMIC RANGE (SFDR) is the difference, expressed in dB, between the rms values of the input signal at the output and the peak spurious signal, where a spurious signal is any signal present in the output spectrum that is not present at the input, excluding d.c.

TOTAL HARMONIC DISTORTION (THD) is the ratio expressed in dB, of the rms total of the first nine harmonic levels at the output to the level of the fundamental at the output. THD is calculated as

$$THD = 20 \times \log \sqrt{\frac{A_{f2}^2 + \ldots + A_{f10}^2}{A_{f1}^2}}$$

where A_{f1} is the RMS power of the fundamental (output) frequency and A_{f2} through A_{f10} are the RMS power of the first 9 harmonic frequencies in the output spectrum.

– Second Harmonic Distortion (2nd Harm) is the difference, expressed in dB, between the RMS power in the input frequency seen at the output and the power in its 2nd harmonic level at the output.

– Third Harmonic Distortion (3rd Harm) is the difference expressed in dB between the RMS power in the input frequency seen at the output and the power in its 3rd harmonic level at the output.

Transfer Characteristic

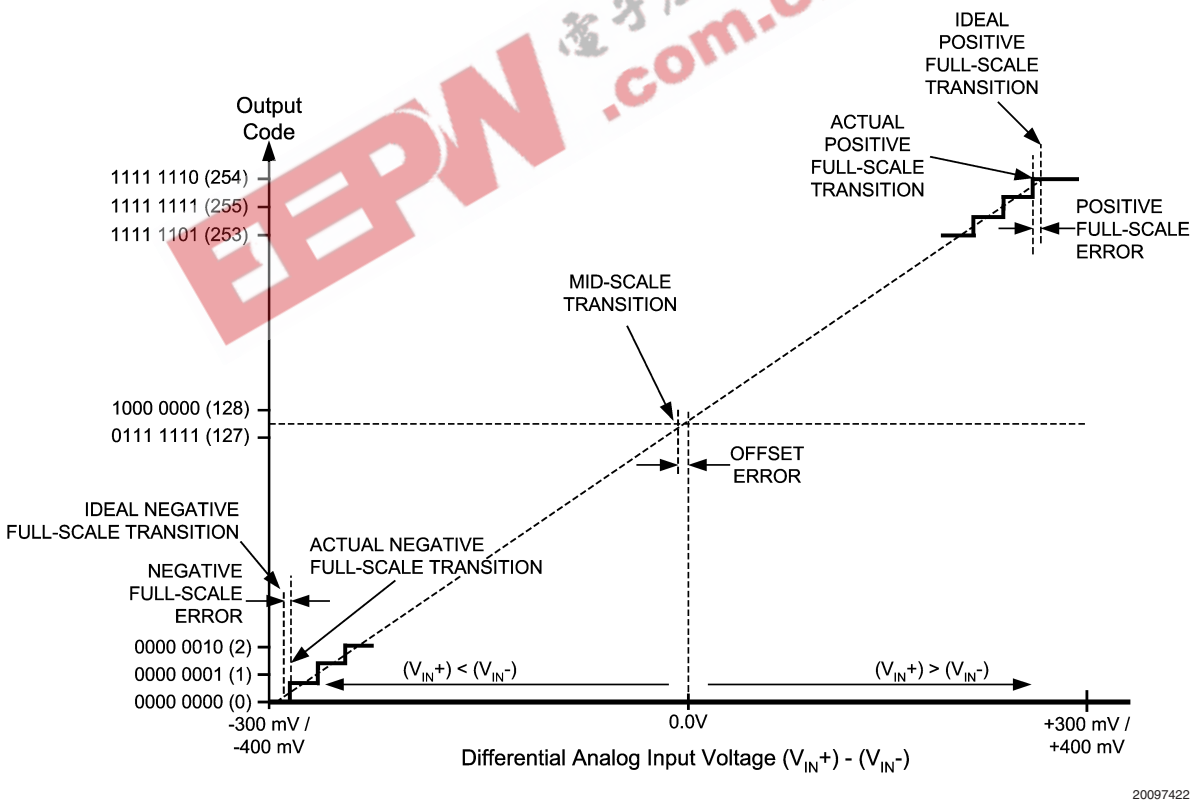


FIGURE 2. Input / Output Transfer Characteristic

Timing Diagrams

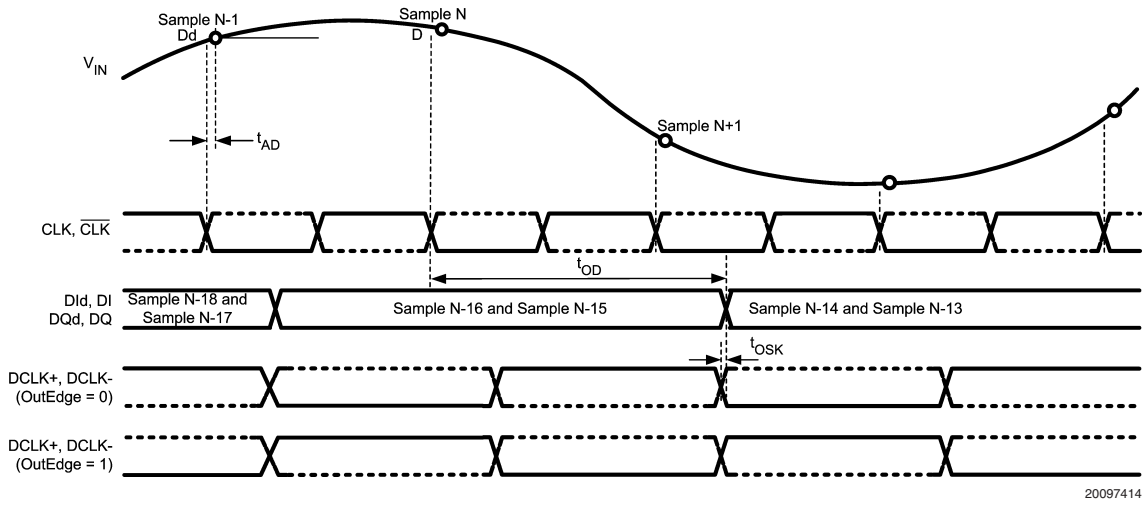


FIGURE 3. ADC08D1000 Timing — SDR Clocking

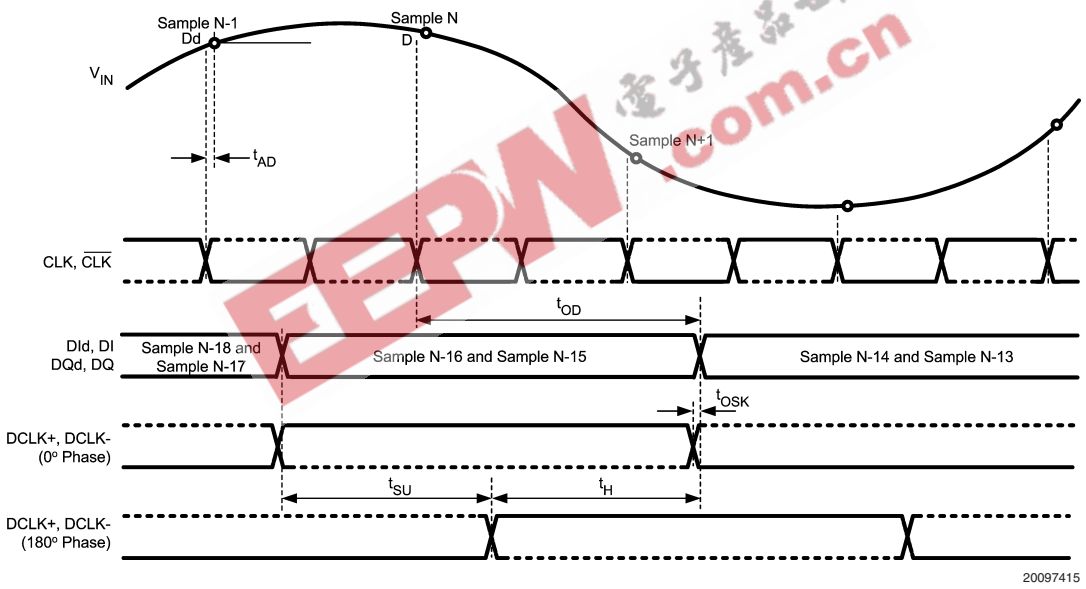


FIGURE 4. ADC08D1000 Timing — DDR Clocking

Timing Diagrams (Continued)

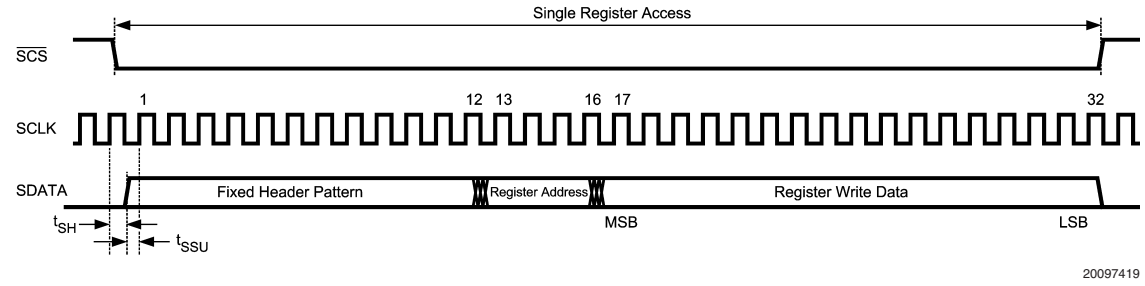


FIGURE 5. Serial Interface Timing

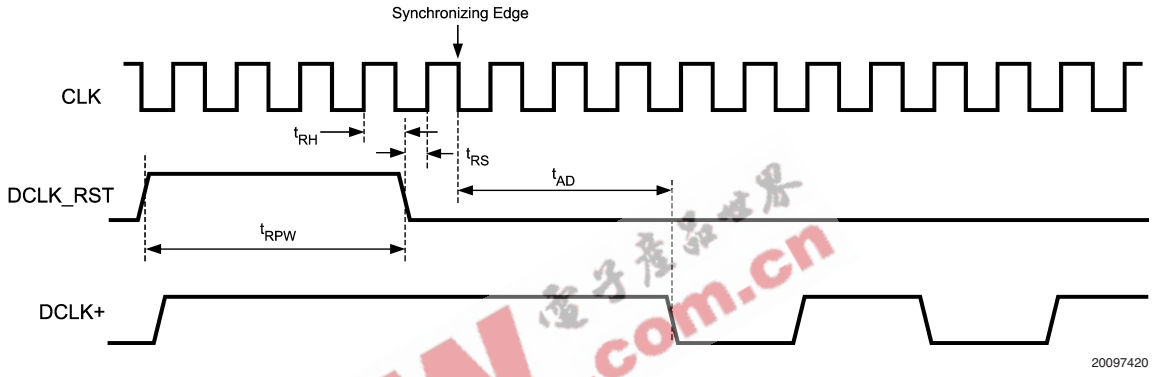


FIGURE 6. Clock Reset Timing in DDR Mode

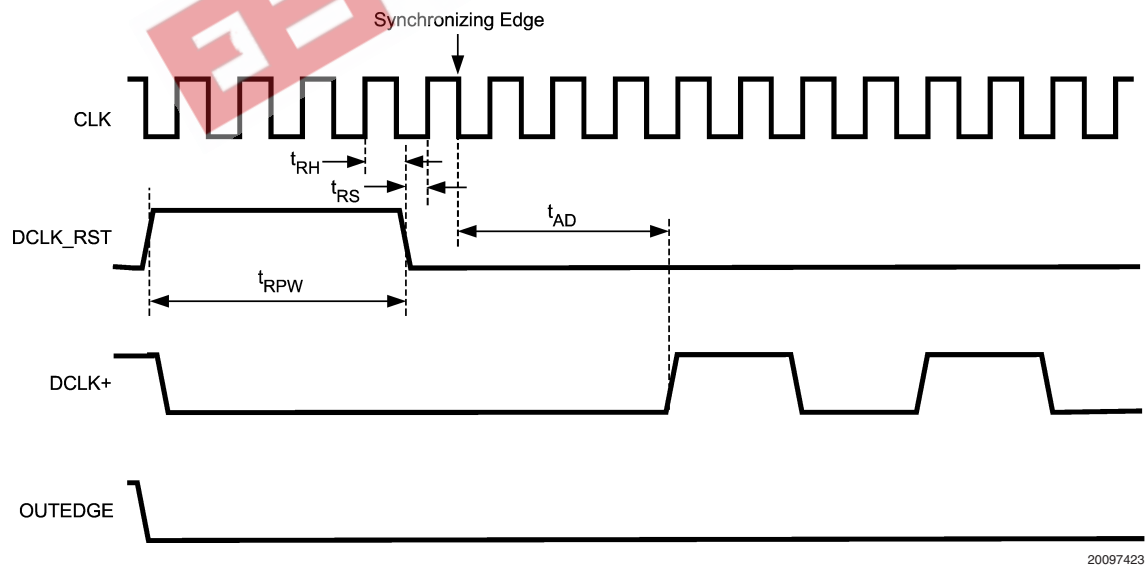


FIGURE 7. Clock Reset Timing in SDR Mode with OUTEDGE Low

Timing Diagrams (Continued)

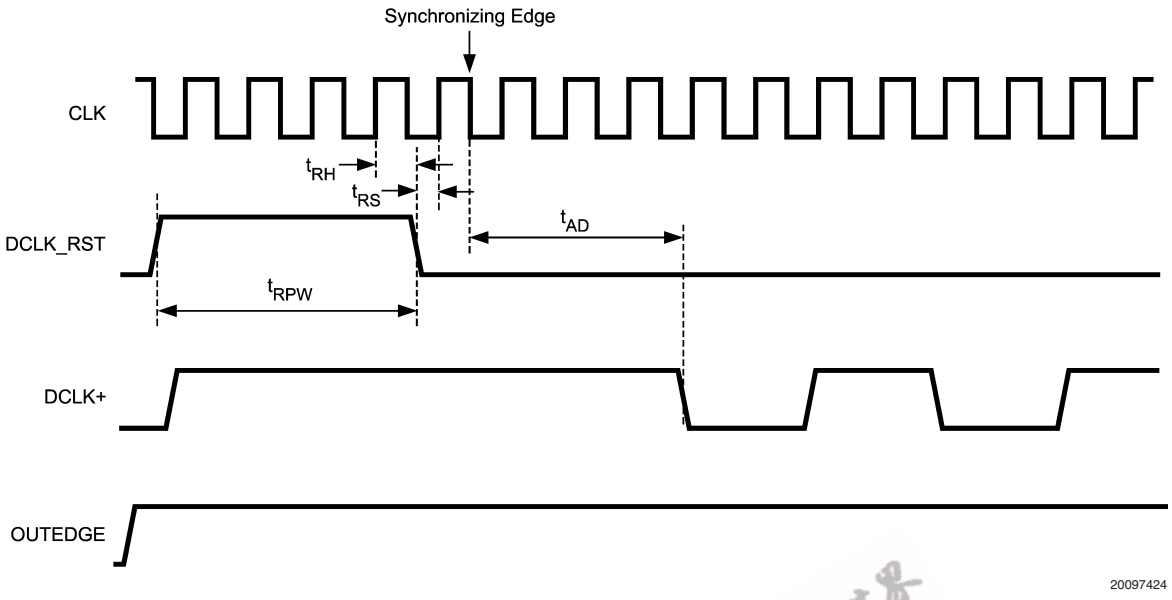


FIGURE 8. Clock Reset Timing in SDR Mode with OUTEDGE High

1.0 Functional Description

The ADC08D1000 is a versatile A/D Converter with an innovative architecture permitting very high speed operation. The controls available ease the application of the device to circuit solutions. Optimum performance requires adherence to the provisions discussed here and in the Applications Information Section.

While it is generally poor practice to allow an active pin to float, pins 4, 14 and 127 of the ADC08D1000 are designed to be left floating without jeopardy. In all discussions throughout this data sheet, whenever a function is called by allowing a pin to float, connecting that pin to a potential of one half the V_A supply voltage will have the same effect as allowing it to float.

1.1 OVERVIEW

The ADC08D1000 uses a calibrated folding and interpolating architecture that achieves over 7.5 effective bits. The use of folding amplifiers greatly reduces the number of comparators and power consumption. Interpolation reduces the number of front-end amplifiers required, minimizing the load on the input signal and further reducing power requirements. In addition to other things, on-chip calibration reduces the INL bow often seen with folding architectures. The result is an extremely fast, high performance, low power converter.

The analog input signal that is within the converter's input voltage range is digitized to eight bits at speeds of 200 MSPS to 1.6 GSPS, typical. Differential input voltages below negative full-scale will cause the output word to consist of all zeroes. Differential input voltages above positive full-scale will cause the output word to consist of all ones. Either of these conditions at either the "I" or "Q" input will cause the OR (Out of Range) output to be activated. This single OR output indicates when the output code from one or both of the channels is below negative full scale or above positive full scale.

Each of the two converters has a 1:2 demultiplexer that feeds two LVDS output buses. The data on these buses provide an output word rate on each bus at half the ADC sampling rate and must be interleaved by the user to provide output words at the full conversion rate.

The output levels may be selected to be normal or reduced. Using reduced levels saves power but could result in erroneous data capture of some or all of the bits, especially at higher sample rates and in marginally designed systems.

1.1.1 Self-Calibration

A self-calibration is performed upon power-up and can also be invoked by the user upon command. Calibration trims the 100Ω analog input differential termination resistor and minimizes full-scale error, offset error, DNL and INL, resulting in maximizing SNR, THD, SINAD (SNDR) and ENOB. Internal bias currents are also set with the calibration process. All of this is true whether the calibration is performed upon power up or is performed upon command. Running the self calibration is an important part of this chip's functionality and is required in order to obtain adequate performance. In addition to the requirement to be run at power-up, self calibration must be re-run whenever the sense of the FSR pin is changed. For best performance, we recommend that self calibration be run 20 seconds or more after application of power and whenever the operating ambient temperature changes more than 30˚C since calibration was last performed. See Section 2.4.2.2 for more information. Calibration can not be initiated or run while the device is in the power-down mode. See Section 1.1.7 for information on the interaction between Power Down and Calibration.

During the calibration process, the input termination resistor is trimmed to a value that is equal to R_{EXT} / 33. This external resistor is located between pin 32 and ground. R_{EXT} must be 3300 Ω ±0.1%. With this value, the input termination resistor is trimmed to be 100 Ω. Because R_{EXT} is also used to set the proper current for the Track and Hold amplifier, for the preamplifiers and for the comparators, other values of R_{EXT} should not be used. In normal operation, calibration is performed just after application of power and whenever a valid calibration command is given, which is holding the CAL pin low for at least 10 input clock cycles, then hold it high for at least another 10 input clock cycles. The time taken by the calibration procedure is specified in the A.C. Characteristics Table. Holding the CAL pin high upon power up will prevent the calibration process from running until the CAL pin experiences the above-mentioned 10 input clock cycles low followed by 10 cycles high.

CalDly (pin 127) is used to select one of two delay times after the application of power to the start of calibration. This calibration delay is 2^{25} input clock cycles (about 33.6 ms at 1 GSPS) with CalDly low, or 2^{31} input clock cycles (about 2.15 seconds at 1 GSPS) with CalDly high. These delay values allow the power supply to come up and stabilize before calibration takes place. If the PD pin is high upon power-up, the calibration delay counter will be disabled until the PD pin is brought low. Therefore, holding the PD pin high during power up will further delay the start of the power-up calibration cycle. The best setting of the CalDly pin depends upon the power-on settling time of the power supply.

The CalRun output is high whenever the calibration procedure is running. This is true whether the calibration is done at power-up or on-command.

1.1.2 Acquiring the Input

Data is acquired at the falling edge of CLK+ (pin 18) and the digital equivalent of that data is available at the digital outputs 13 input clock cycles later for the DI and DQ output buses and 14 input clock cycles later for the DId and DQd output buses. There is an additional internal delay called t_{OD} before the data is available at the outputs. See the Timing Diagram. The ADC08D1000 will convert as long as the input clock signal is present. The fully differential comparator design and the innovative design of the sample-and-hold amplifier, together with self calibration, enables a very flat SINAD/ENOB response beyond 1.0 GHz. The ADC08D1000 output data signaling is LVDS and the output format is offset binary.

1.1.3 Control Modes

Much of the user control can be accomplished with several control pins that are provided. Examples include initiation of the calibration cycle, power down mode and full scale range setting. However, the ADC08D1000 also provides an Extended Control mode whereby a serial interface is used to access register-based control of several advanced features. The Extended Control mode is not intended to be enabled and disabled dynamically. Rather, the user is expected to employ either the normal control mode or the Extended Control mode at all times. When the device is in the Extended Control mode, pin-based control of several features is replaced with register-based control and those pin-based

1.0 Functional Description (Continued)

controls are disabled. These pins are OutV (pin 3), OutEdge/DDR (pin 4), FSR (pin 14) and CalDly/DES (pin 127). See Section 1.2 for details on the Extended Control mode.

1.1.4 The Analog Inputs

The ADC08D1000 must be driven with a differential input signal. Operation with a single-ended signal is not recommended. It is important that the inputs either be a.c. coupled to the inputs with the V_{CMO} pin grounded or d.c. coupled with the V_{CMO} pin not grounded and an input common mode voltage equal to the V_{CMO} output.

Two full-scale range settings are provided with pin 14 (FSR). A high on pin 14 causes an input full-scale range setting of 800 mV_{P-P}, while grounding pin 14 causes an input full-scale range setting of 600 mV_{P-P}. The full-scale range setting operates equally on both ADCs.

In the Extended Control mode, the full-scale input range can be set to values between 560 mV_{P-P} and 840 mV_{P-P} through a serial interface. See Section 2.2

1.1.5 Clocking

The ADC08D1000 must be driven with an a.c. coupled, differential clock signal. Section 2.3 describes the use of the clock input pins. A differential LVDS output clock is available for use in latching the ADC output data into whatever device is used to receive the data.

The ADC08D1000 offers options for input and output clocking. These options include a choice of Dual Edge Sampling (DES) or interleaved mode where the ADC08D1000 performs as a single device converting at twice the input clock rate and a choice of which DCLK (DCLK) edge the output data transitions on and choice of Single Data Rate (SDR) or Double Data Rate (DDR) outputs.

The ADC08D1000 also has the option to use a duty cycle corrected clock receiver as part of the input clock circuit. This feature is enabled by default and provides improved ADC clocking especially in the Dual-Edge Sampling mode (DES).

1.1.5.1 Dual-Edge Sampling

The DES mode allows one of the ADC08D1000's inputs (I or Q Channel) to be sampled by both ADCs. One ADC samples the input on the positive edge of the input clock and the other ADC samples the same input on the other edge of the input clock. A single input is thus sampled twice per input clock cycle, resulting in an overall sample rate of twice the input clock frequency, or 2 GSPS with a 1 GHz input clock.

In this mode the outputs are interleaved such that the data is effectively demultiplexed 4:1. Since the sample rate is doubled, each of the 4 output buses have a 500 MSPS output rate with a 1 GHz input clock. All data is available in parallel. The four bytes of parallel data that is output with each clock is in the following sampling order, from the earliest to the latest: DQd, DId, DQ, DI. *Table 1* indicates what the outputs represent for the various sampling possibilities.

In the non-extended mode of operation only the "I" input can be sampled in the DES mode. In the extended mode of operation the user can select which input is sampled.

The ADC08D1000 also includes an automatic clock phase background calibration feature which can be used in DES mode to automatically and continuously adjust the clock phase of the I and Q channel. This feature removes the need to adjust the clock phase setting manually and provides optimal Dual-Edge Sampling ENOB performance.

TABLE 1. Input Channel Samples Produced at Data Outputs

Data Outputs (Always sourced with respect to fall of DCLK)	Normal Sampling Mode	Dual-Edge Sampling Mode	
		I-Channel Selected	Q-Channel Selected *
DI	"I" Input Sampled with Fall of CLK 13 cycles earlier.	"I" Input Sampled with Fall of CLK 13 cycles earlier.	"Q" Input Sampled with Fall of CLK 13 cycles earlier.
DId	"I" Input Sampled with Fall of CLK 14 cycles earlier.	"I" Input Sampled with Fall of CLK 14 cycles earlier.	"Q" Input Sampled with Fall of CLK 14 cycles earlier.
DQ	"Q" Input Sampled with Fall of CLK 13 cycles earlier.	"I" Input Sampled with Rise of CLK 13.5 cycles earlier.	"Q" Input Sampled with Rise of CLK 13.5 cycles earlier.
DQd	"Q" Input Sampled with Fall of CLK 14 14 CLK cycles after being sampled.	"I" Input Sampled with Rise of CLK 14.5 cycles earlier.	"Q" Input Sampled with Rise of CLK 14.5 cycles earlier.

* Note that, in the Dual-Edge Sampling (DES) mode, the "Q" channel input can only be selected for sampling in the Extended Control Mode.

1.1.5.2 OutEdge Setting

To help ease data capture in the SDR mode, the output data may be caused to transition on either the positive or the negative edge of the output data clock (DCLK). This is chosen with the OutEdge input (pin 4). A high on the OutEdge input causes the output data to transition on the rising edge of DCLK, while grounding this input causes the output to transition on the falling edge of DCLK. See Section 2.4.3.

1.1.5.3 Double Data Rate

A choice of single data rate (SDR) or double data rate (DDR) output is offered. With single data rate the output clock (DCLK) frequency is the same as the data rate of the two output buses. With double data rate the DCLK frequency is half the data rate and data is sent to the outputs on both input clock edges. DDR clocking is enabled by allowing pin 4 to float.

1.0 Functional Description (Continued)

1.1.6 The LVDS Outputs

The data outputs, the Out Of Range (OR) and DCLK, are LVDS. Output current sources provide 3 mA of output current to a differential 100 Ohm load when the OutV input (pin 14) is high or 2.2 mA when the OutV input is low. For short LVDS lines and low noise systems, satisfactory performance may be realized with the OutV input low, which results in lower power consumption. If the LVDS lines are long and/or the system in which the ADC08D1000 is used is noisy, it may be necessary to tie the OutV pin high.

1.1.7 Power Down

The ADC08D1000 is in the active state when the Power Down pin (PD) is low. When the PD pin is high, the device is in the power down mode, where the output pins hold the last conversion before the PD pin went high and the device power consumption is reduced to a minimual level. A high on the PDQ pin will power down the "Q" channel and leave the "I" channel active. There is no provision to power down the "I" channel independently of the "Q" channel. Upon return to normal operation, the pipeline will contain meaningless information.

If the PD input is brought high while a calibration is running, the device will not go into power down until the calibration sequence is complete. However, if power is applied and PD is already high, the device will not begin the calibration sequence until the PD input goes low. If a manual calibration is requested while the device is powered down, the calibration will not begin at all. That is, the manual calibration input is completely ignored in the power down state. Calibration will function with the "Q" channel powered down, but that channel will not be calibrated if PDQ is high. If the "Q" channel is subsequently to be used, it is necessary to perform a calibration after PDQ is brought low.

1.2 NORMAL/EXTENDED CONTROL

The ADC08D1000 may be operated in one of two modes. In the simpler "normal" control mode, the user affects available configuration and control of the device through several control pins. The "extended control mode" provides additional configuration and control options through a serial interface and a set of 8 registers. The two control modes are selected with pin 14 (FSR/ECE: Extended Control Enable). The choice of control modes is required to be a fixed selection and is not intended to be switched dynamically while the device is operational.

Table 2 shows how several of the device features are affected by the control mode chosen.

TABLE 2. Features and modes

Feature	Normal Control Mode	Extended Control Mode
SDR or DDR Clocking	Selected with pin 4	Selected with DE bit in the Configuration Register
DDR Clock Phase	Not Selectable (0˚ Phase Only)	Selected with DCP bit in the Configuration Register. See *Section 1.4 REGISTER DESCRIPTION*
SDR Data transitions with rising or falling DCLK edge	Selected with pin 4	Selected with the OE bit in the Configuration Register
LVDS output level	Selected with pin 3	Selected with the OV bit in the Configuration Register
Power-On Calibration Delay	Delay Selected with pin 127	Short delay only.
Full-Scale Range	Options (600 mV_{P-P} or 800 mV_{P-P}) selected with pin 14. Selected range applies to both channels.	Up to 512 step adjustments over a nominal range of 560 mV to 840 mV. Separate range selected for I- and Q-Channels. Selected using registers 3H and Bh
Input Offset Adjust	Not possible	Separate ±45 mV adjustments in 512 steps for each channel using registers 2h and Ah
Dual Edge Sampling Selection	Enabled with pin 127	Enabled through DES Enable Register
Dual Edge Sampling Input Channel Selection	Only I-Channel Input can be used	Either I- or Q-Channel input may be sampled by both ADCs
DES Sampling Clock Adjustment	The Clock Phase is adjusted automatically	Automatic Clock Phase control can be selected by setting bit 14 in the DES Enable register (Dh). The clock phase can also be adjusted manually through the Coarse & Fine registers (Eh and Fh)

1.0 Functional Description (Continued)

The default state of the Extended Control Mode is set upon power-on reset (internally performed by the device) and is shown in *Table 3*.

TABLE 3. Extended Control Mode Operation (Pin 14 Floating)

Feature	Extended Control Mode Default State
SDR or DDR Clocking	DDR Clocking
DDR Clock Phase	Data changes with DCLK edge (0˚ phase)
LVDS Output Amplitude	Normal amplitude (600 mV_{P-P})
Calibration Delay	Short Delay
Full-Scale Range	700 mV nominal for both channels
Input Offset Adjust	No adjustment for either channel
Dual Edge Sampling (DES)	Not enabled

1.3 THE SERIAL INTERFACE

The 3-pin serial interface is enabled only when the device is in the Extended Control mode. The pins of this interface are Serial Clock (SCLK), Serial Data (SDATA) and Serial Interface Chip Select ($\overline{SCS}$) Eight write only registers are accessible through this serial interface.

$\overline{SCS}$: This signal should be asserted low while accessing a register through the serial interface. Setup and hold times with respect to the SCLK must be observed.

SCLK: Serial data input is accepted with the rising edge of this signal.

SDATA: Each register access requires a specific 32-bit pattern at this input. This pattern consists of a header, register address and register value. The data is shifted in MSB first. Setup and hold times with respect to the SCLK must be observed. See the Timing Diagram.

Each Register access consists of 32 bits, as shown in *Figure 5* of the Timing Diagrams. The fixed header pattern is 0000 0000 0001 (eleven zeros followed by a 1). The loading sequence is such that a "0" is loaded first. These 12 bits form the header. The next 4 bits are the address of the register that is to be written to and the last 16 bits are the data written to the addressed register. The addresses of the various registers are indicated in *Table 4*.

Refer to the Register Description (Section 1.4) for information on the data to be written to the registers.

Subsequent register accesses may be performed immediately, starting with the 33rd SCLK. This means that the $\overline{SCS}$ input does not have to be deasserted and asserted again between register addresses. It is possible, although not recommended, to keep the $\overline{SCS}$ input permanently enabled (at a logic low) when using extended control.

TABLE 4. Register Addresses

4-Bit Address					
Loading Sequence: A3 loaded after H0, A0 loaded last					
A3	A2	A1	A0	Hex	Register Addressed
0	0	0	0	0h	Reserved
0	0	0	1	1h	Configuration
0	0	1	0	2h	"I" Ch Offset
0	0	1	1	3h	"I" Ch Full-Scale Voltage Adjust
0	1	0	0	4h	Reserved
0	1	0	1	5h	Reserved
0	1	1	0	6h	Reserved
0	1	1	1	7h	Reserved
1	0	0	0	8h	Reserved
1	0	0	1	9h	Reserved
1	0	1	0	Ah	"Q" Ch Offset
1	0	1	1	Bh	"Q" Ch Full-Scale Voltage Adjust
1	1	0	0	Ch	Reserved
1	1	0	1	Dh	DES Enable
1	1	1	0	Eh	DES Coarse Adjust
1	1	1	1	Fh	DES Fine Adjust

1.4 REGISTER DESCRIPTION

Eight write-only registers provide several control and configuration options in the Extended Control Mode. These registers have no effect when the device is in the Normal Control Mode. Each register description below also shows the Power-On Reset (POR) state of each control bit.

Configuration Register

Addr: 1h (0001b) **W only (0xB2FF)**

D15	D14	D13	D12	D11	D10	D9	D8
1	0	1	DCS	DCP	nDE	OV	OE
D7	D6	D5	D4	D3	D2	D1	D0
1	1	1	1	1	1	1	1

Bit 15 Must be set to "1"

Bit 14 Must be set to "0"

Bit 13 Must be set to "1"

Bit 12 DCS:Duty Cycle Stabilizer. When this bit is set to "1" , a duty cycle stabilzation circuit is applied to the clock input. When this bit is set to "0" the stabilzation circuit is disabled.

POR State: 1

Bit 11 DCP: DDR Clock Phase. This bit only has an effect in the DDR mode. When this bit is set to "0", the DCLK edges are time-aligned with the data bus edges ("0˚ Phase"). When this bit is set to a "1", the DCLK edges are placed in the middle of the data bit-cells ("180˚ Phase").

POR State: 0

1.0 Functional Description (Continued)

Bit 10 nDE: DDR Enable. When this bit is set to "0", data bus clocking follows the DDR (Dual Data Rate) mode whereby a data word is output with each rising and falling edge of DCLK. When this bit is set to a "1", data bus clocking follows the SDR (single data rate) mode whereby each data word is output with either the rising or falling edge of DCLK , as determined by the OutEdge bit.

POR State: 0

Bit 9 OV: Output Voltage. This bit determines the LVDS outputs' voltage amplitude and has the same function as the OutV pin that is used in the normal control mode. When this bit is set to "1", the "normal" output amplitude of 600 mV_{P-P} is used. When this bit is set to "0", the reduced output amplitude of 450mV_{P-P} is used.

POR State: 1

Bit 8 OE: Output Edge. This bit selects the DCLK edge with which the data words transition in the SDR mode and has the same effect as the OutEdge pin in the normal control mode. When this bit is "1", the data outputs change with the rising edge of DCLK+. When this bit is "0", the data output change with the falling edge of DCLK+.

POR State: 0

Bits 7:0 Must be set to "1".

I-Channel Offset

Addr: 2h (0010b) **W only (0x007F)**

D15	D14	D13	D12	D11	D10	D9	D8
(MSB)	Offset Value						(LSB)

D7	D6	D5	D4	D3	D2	D1	D0
Sign	1	1	1	1	1	1	1

Bits 15:8 Offset Value. The input offset of the I-Channel ADC is adjusted linearly and monotonically by the value in this field. 00h provides zero nominal offset, while FFh provides a nominal ±45 mV of offset. Thus, each code step provides 0.176 mV of offset.

POR State: 00h

Bit 7 Sign bit. "0" gives positive offset, "1" gives negative offset.

POR State: 0b

Bit 6:0 Must be set to "1"

I-Channel Full-Scale Voltage Adjust

Addr: 3h (0011b) **W only (0x807F)**

D15	D14	D13	D12	D11	D10	D9	D8
(MSB)	Adjust Value						

D7	D6	D5	D4	D3	D2	D1	D0
(LSB)	1	1	1	1	1	1	1

Bit 15:7 Full Scale Voltage Adjust Value. The input full-scale voltage or gain of the I-Channel ADC is adjusted linearly and monotonically with a 9 bit data value. The adjustment range is ±20% of the nominal 700 mV_{P-P} differential value.

0000 0000 0 560mV_{DIFF}

1000 0000 0 700mV_{DIFF} Default Value

1111 1111 1 840mV_{DIFF}

For best performance, it is recommended that the value in this field be limited to the range of 0110 0000 0b to 1110 0000 0b. i.e., limit the amount of adjustment to ±15%. The remaining ±5% headroom allows for the ADC's own full scale variation. A gain adjustment does not require ADC re-calibration.

POR State: 1 0000 0000b (no adjustment)

Bits 6:0 Must be set to "1"

Q-Channel Offset

Addr: Ah (1010b) **W only (0x007F)**

D15	D14	D13	D12	D11	D10	D9	D8
(MSB)	Offset Value						(LSB)

D7	D6	D5	D4	D3	D2	D1	D0
Sign	1	1	1	1	1	1	1

Bit 15:8 Offset Value. The input offset of the Q-Channel ADC is adjusted linearly and monotonically by the value in this field. 00h provides zero nominal offset, while FFh provides a nominal ±45 mV of offset. Thus, each code step provides about 0.176 mV of offset.

POR State: 00h

Bit 7 Sign bit. "0" gives positive offset, "1" gives negative offset.

POR State: 0b

Bit 6:0 Must be set to "1"

1.0 Functional Description (Continued)

Q-Channel Full-Scale Voltage Adjust

Addr: Bh (1011b) **W only (0x807F)**

D15	D14	D13	D12	D11	D10	D9	D8
(MSB)	Adjust Value						
D7	D6	D5	D4	D3	D2	D1	D0
(LSB)	1	1	1	1	1	1	1

Bit 15:7 Full Scale Voltage Adjust Value. The input full-scale voltage or gain of the I-Channel ADC is adjusted linearly and monotonically with a 9 bit data value. The adjustment range is ±20% of the nominal 700 mV_{P-P} differential value.

0000 0000 0 560mV_{P-P}

1000 0000 0 700mV_{P-P}

1111 1111 1 840mV_{P-P}

For best performance, it is recommended that the value in this field be limited to the range of 0110 0000 0b to 1110 0000 0b. i.e., limit the amount of adjustment to ±15%. The remaining ±5% headroom allows for the ADC's own full scale variation. A gain adjustment does not require ADC re-calibration.

POR State: 1 0000 0000b (no adjustment)

Bits 6:0 Must be set to "1"

DES Enable

Addr: Dh (1101b) **W only (0x3FFF)**

D15	D14	D13	D12	D11	D10	D9	D8
DEN	ACP	1	1	1	1	1	1
D7	D6	D5	D4	D3	D2	D1	D0
1	1	1	1	1	1	1	1

Bit 15 DES Enable. Setting this bit to "1" enables the Dual Edge Sampling mode. In this mode the ADCs in this device are used to sample and convert the same analog input in a time-interleaved manner, accomplishing a sampling rate of twice the input clock rate. When this bit is set to "0", the device operates in the normal dual channel mode.

POR State: 0b

Bit 14 Automatic Clock Phase Control. Setting this bit to "1" enables the Automatic Clock Phase Control. In this mode the DES Coarse and Fine manual controls are disabled. A phase detection circuit continually adjusts the I and Q sampling edges to be 180 degrees out of phase. When this bit is set to "0", the sample (input) clock delay between the I and Q channels is set manually using the DES Coarse and Fine Adjust registers. (See Section 2.4.5 for important application information)

POR State: 0b

Bits 13:0 Must be set to "1"

DES Coarse Adjust

Addr: Eh (1110b) **W only (0x07FF)**

D15	D14	D13	D12	D11	D10	D9	D8
IS	ADS	CAM			1	1	1
D7	D6	D5	D4	D3	D2	D1	D0
1	1	1	1	1	1	1	1

Bit 15 Input Select. When this bit is set to "0" the "I" input is operated upon by both ADCs. When this bit is set to "1" the "Q" input is operated on by both ADCs.

POR State: 0b

Bit 14 Adjust Direction Select. When this bit is set to "0", the "I" channel sample clock is delayed while the "Q" channel sample clock remains fixed. When this bit is set to "1", the "Q" channel sample clock is delayed while the "I" channel sample clock remains fixed.

POR State: 0b

Bits 13:11 Coarse Adjust Magnitude. Each code value in this field delays either the "I" channel or the "Q" channel sample clock (as determined by the ADS bit) by approximately 20 picoseconds. A value of 000b in this field causes zero adjustment.

POR State: 000b

Bits 10:0 Must be set to "1"

1.0 Functional Description (Continued)

DES Fine Adjust

Addr: Fh (1111b) **W only (0x007F)**

D15	D14	D13	D12	D11	D10	D9	D8
(MSB)	FAM						

D7	D6	D5	D4	D3	D2	D1	D0
(LSB)	1	1	1	1	1	1	1

Bits 15:7 Fine Adjust Magnitude. Each code value in this field delays either the "I" channel or the "Q" channel sample clock (as determined by the ADS bit of the DES Coarse Adjust Register) by approximately 0.1 ps. A value of 00h in this field causes zero adjustment. Note that the amount of adjustment achieved with each code will vary with the device conditions as well as with the Coarse Adjustment value chosen.

POR State: 00h

Bit 6:0 Must be set to "1"

1.5 MULTIPLE ADC SYNCHRONIZATION

The ADC08D1000 has the capability to precisely reset its sampling clock input to DCLK output relationship as determined by the user-supplied DCLK_RST pulse. This allows multiple ADCs in a system to have their DCLK (and data) outputs transition at the same time with respect to the shared CLK input that they all use for sampling.

The DCLK_RST signal must observe some timing requirements that are shown in *Figure 6*, *Figure 7* and *Figure 8* of the Timing Diagrams. The DCLK_RST pulse must be of a minimum width and its deassertion edge must observe setup and hold times with respect to the CLK input rising edge. These times are specified in the AC Electrical Characteristics Table.

The DCLK_RST signal can be asserted asynchronous to the input clock. If DCLK_RST is asserted, the DCLK output is immediately held in a designated state. The state in which DCLK is held during the reset period is determined by the mode of operation (SDR/DDR) and the setting of the Output Edge configuration pin or bit. (Refer to *Figure 6*, *Figure 7* and *Figure 8* for the DCLK reset state conditions). Therefore, depending upon when the DCLK_RST signal is asserted, there may be a narrow pulse on the DCLK line during this reset event. When the DCLK_RST signal is deasserted in synchronization with the CLK rising edge, the next CLK falling edge synchronizes the DCLK output with those of other ADC08D1000s in the system. The DCLK output is enabled again after a constant delay which is equal to the CLK input to DCLK output delay (t_{AD}). The device always exhibits this delay characteristic in normal operation.

The DCLK-RST pin should NOT be brought high while the calibration process is running (while CalRun is high). Doing so could cause a digital glitch in the digital circuitry, resulting in corruption and invalidation of the calibration.

2.0 Applications Information

2.1 THE REFERENCE VOLTAGE

The voltage reference for the ADC08D1000 is derived from a 1.254V bandgap reference which is made available at pin 31, V_{BG} for user convenience and has an output current capability of ±100 µA and should be buffered if more current than this is required.

The internal bandgap-derived reference voltage has a nominal value of 600 mV or 800 mV, as determined by the FSR pin and described in Section 1.1.4.

There is no provision for the use of an external reference voltage, but the full-scale input voltage can be adjusted through a Configuration Register in the Extended Control mode, as explained in Section 1.2.

Differential input signals up to the chosen full-scale level will be digitized to 8 bits. Signal excursions beyond the full-scale range will be clipped at the output. These large signal excursions will also activate the OR output for the time that the signal is out of range. See Section 2.2.2.

2.2 THE ANALOG INPUT

The analog input is a differential one to which the signal source may be a.c. coupled or d.c. coupled. The full-scale input range is selected with the FSR pin to be 600 mV_{P-P} or 800 mV_{P-P}, or can be adjusted to values between 560 mV_{P-P} and 840 mV_{P-P} in the Extended Control mode through the Serial Interface. For best performance, it is recommended that the full-scale range be kept between 595 mV_{P-P} and 805 mV_{P-P}.

Table 5 gives the input to output relationship with the FSR pin high and the normal (non-extended) mode is used. With the FSR pin grounded, the millivolt values in *Table 5* are reduced to 75% of the values indicated. In the Enhanced Control Mode, these values will be determined by the full scale range and offset settings in the Control Registers.

TABLE 5. DIFFERENTIAL INPUT TO OUTPUT RELATIONSHIP (Non-Extended Control Mode, FSR High)

V_{IN}+	V_{IN}−	Output Code
V_{CM} − 200 mV	V_{CM} + 200 mV	0000 0000
V_{CM} − 99 mV	V_{CM} + 99 mV	0100 0000
V_{CM}	V_{CM}	0111 1111 / 1000 0000
V_{CM} + 101 mV	V_{CM} − 101 mV	1100 0000
V_{CM} + 200mV	V_{CM} − 200 mV	1111 1111

The buffered analog inputs simplify the task of driving these inputs and the RC pole that is generally used at sampling ADC inputs is not required. If it is desired to use an amplifier circuit before the ADC, use care in choosing an amplifier with adequate noise and distortion performance and adequate gain at the frequencies used for the application.

Note that a precise d.c. common mode voltage must be present at the ADC inputs. This common mode voltage, V_{CMO}, is provided on-chip when a.c. input coupling is used and the input signal is a.c. coupled to the ADC.

When the inputs are a.c. coupled, the V_{CMO} output *must* be grounded, as shown in *Figure 9*. This causes the on-chip V_{CMO} voltage to be connected to the inputs through on-chip 50k-Ohm resistors.

2.0 Applications Information

(Continued)

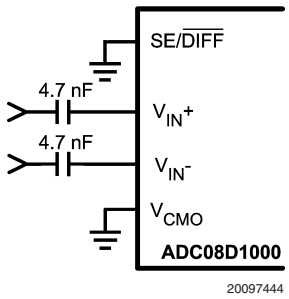


FIGURE 9. Differential Input Drive

When the d.c. coupled mode is used, a common mode voltage must be provided at the differential inputs. This common mode voltage should track the V_{CMO} output pin. Note that the V_{CMO} output potential will change with temperature. The common mode output of the driving device should track this change.

Full-scale distortion performance falls off rapidly as the input common mode voltage deviates from V_{CMO}. This is a direct result of using a very low supply voltage to minimize power. Keep the input common voltage within 50 mV of V_{CMO}.

Performance is as good in the d.c. coupled mode as it is in the a.c. coupled mode, provided the input common mode voltage at both analog inputs remain within 50 mV of V_{CMO}.

If d.c. coupling is used, it is best to servo the input common mode voltage, using the V_{CMO} pin, to maintain optimum performance. An example of this type of circuit is shown in *Figure 10*.

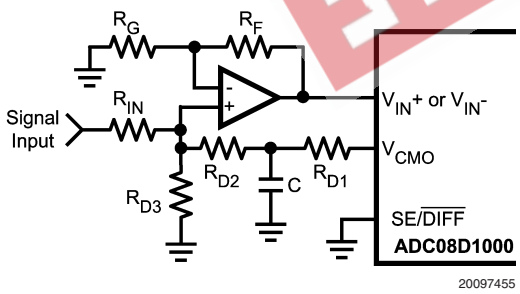


FIGURE 10. Example of Servoing the Analog Input with V_{CMO}

One such circuit should be used in front of the V_{IN}+ input and another in front of the V_{IN}– input. In that figure, R_{D1}, R_{D2} and R_{D3} are used to divide the V_{CMO} potential so that, after being gained up by the amplifier, the input common mode voltage is equal to V_{CMO} from the ADC. R_{D1} and R_{D2} are split to allow the bypass capacitor to isolate the input signal from V_{CMO}. R_{IN}, R_{D2} and R_{D3} will divide the input signal, if necessary. If there is no need to divide the input signal, R_{IN} is not needed. Capacitor "C" in *Figure 10* should be chosen to keep any component of the input signal from affecting V_{CMO}.

Be sure that the current drawn from the V_{CMO} output does not exceed 100 µA.

The Input impedance in the d.c. coupled mode (V_{CMO} pin not grounded) consists of a precision 100Ω resistor between V_{IN}+ and V_{IN}– and a capacitance from each of these inputs to ground. In the a.c. coupled mode the input appears the same except there is also a resistor of 50K between each analog input pin and the V_{CMO} potential.

Driving the inputs beyond full scale will result in a saturation or clipping of the reconstructed output.

2.2.1 Handling Single-Ended Input Signals

There is no provision for the ADC08D1000 to adequately process single-ended input signals. The best way to handle single-ended signals is to convert them to differential signals before presenting them to the ADC. The easiest way to accomplish single-ended to differential signal conversion is with an appropriate balun-connected transformer, as shown in *Figure 11*.

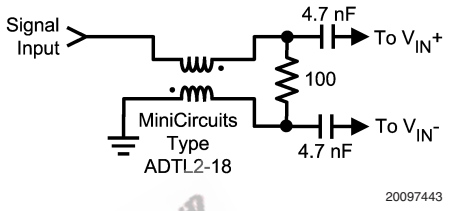


FIGURE 11. Single-Ended to Differential signal conversion with a balun-connected transformer

2.2.2 Out Of Range (OR) Indication

When the conversion result is clipped the Out of Range output is activated such that OR+ goes high and OR- goes low. This output is active as long as accurate data on either or both of the buses would be outside the range of 00h to FFh.

2.2.3 Full-Scale Input Range

As with all A/D Converters, the input range is determined by the value of the ADC's reference voltage. The reference voltage of the ADC08D1000 is derived from an internal band-gap reference. The FSR pin controls the effective reference voltage of the ADC08D1000 such that the differential full-scale input range at the analog inputs is 800 mV_{P-P} with the FSR pin high, or is 600 mV_{P-P} with FSR pin low. Best SNR is obtained with FSR high, but better distortion and SFDR are obtained with the FSR pin low.

2.3 THE CLOCK INPUTS

The ADC08D1000 has differential LVDS clock inputs, CLK+ and CLK-, which must be driven with an a.c. coupled, differential clock signal. Although the ADC08D1000 is tested and its performance is guaranteed with a differential 1.0 GHz clock, it typically will function well with input clock frequencies indicated in the Electrical Characteristics Table. The clock inputs are internally terminated and biased. The input clock signal must be capacitively coupled to the clock pins as indicated in *Figure 12*.

Operation up to the sample rates indicated in the Electrical Characteristics Table is typically possible if the maximum ambient temperatures indicated are not exceeded. Operating at higher sample rates than indicated for the given ambient temperature may result in reduced device reliability and product lifetime. This is because of the higher power consumption and die temperatures at high sample rates. Important also for reliability is proper thermal management . See Section 2.6.2.

2.0 Applications Information

(Continued)

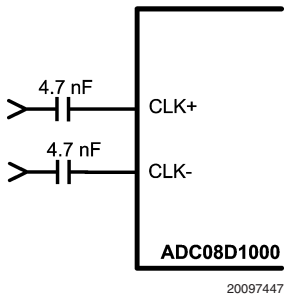


FIGURE 12. Differential (LVDS) Input Clock Connection

The differential input clock line pair should have a characteristic impedance of 100Ω and be terminated at the clock source in that (100Ω) characteristic impedance. The input clock line should be as short and as direct as possible. The ADC08D1000 clock input is internally terminated with an untrimmed 100Ω resistor.

Insufficient input clock levels will result in poor dynamic performance. Excessively high input clock levels could cause a change in the analog input offset voltage. To avoid these problems, keep the input clock level within the range specified in the Electrical Characteristics Table.

The low and high times of the input clock signal can affect the performance of any A/D Converter. While it is specified and performance is guaranteed at 1.0 GSPS with a 50% input clock duty cycle, ADC08D1000 performance is typically maintained over temperature if the input clock high and low times are maintained within the range specified in the Electrical Characteristics Table.

High speed, high performance ADCs such as the ADC08D1000 require a very stable input clock signal with minimum phase noise or jitter. ADC jitter requirements are defined by the ADC resolution (number of bits), maximum ADC input frequency and the input signal amplitude relative to the ADC input full scale range. The maximum jitter (the sum of the jitter from all sources) allowed to prevent a jitter-induced reduction in SNR is found to be

$$t_{J(MAX)} = (V_{IN(P-P)}/V_{INFSR}) \times (1/(2^{(N+1)} \times \pi \times f_{IN}))$$

where $t_{J(MAX)}$ is the rms total of all jitter sources in seconds, $V_{IN(P-P)}$ is the peak-to-peak analog input signal, V_{INFSR} is the full-scale range of the ADC, "N" is the ADC resolution in bits and f_{IN} is the maximum input frequency, in Hertz, to the ADC analog input.

Note that the maximum jitter described above is the arithmetic sum of the jitter from all sources, including that in the ADC input clock, that added by the system to the ADC input clock and input signals and that added by the ADC itself. Since the effective jitter added by the ADC is beyond user control, the best the user can do is to keep the sum of the externally added input clock jitter and the jitter added by the analog circuitry to the analog signal to a minimum.

Input clock amplitudes above those specified in the Electrical Characteristics Table may result in increased input offset voltage. This would cause the converter to produce an output code other than the expected 127/128 when both input pins are at the same potential.

2.4 CONTROL PINS

Six control pins (without the use of the serial interface) provide a wide range of possibilities in the operation of the ADC08D1000 and facilitate its use. These control pins provide Full-Scale Input Range setting, Self Calibration, Calibration Delay, Output Edge Synchronization choice, LVDS Output Level choice and a Power Down feature.

2.4.1 Full-Scale Input Range Setting

The input full-scale range can be selected to be either 600 mV_{P-P} or 800 mV_{P-P}, as selected with the FSR control input (pin 14) in the Normal Mode of operation. In the Extended Control Mode, the input full-scale range may be set to be anywhere from 560 mV_{P-P} to 840 mV_{P-P}. See Section 2.2 for more information.

2.4.2 Self Calibration

The ADC08D1000 self-calibration must be run to achieve specified performance. The calibration procedure is run upon power-up and can be run any time on command. The calibration procedure is exactly the same whether there is an input clock present upon power up or if the clock begins some time after application of power. The CalRun output indicator is high while a calibration is in progress.

2.4.2.1 Power-On Calibration

Power-on calibration begins after a time delay following the application of power. This time delay is determined by the setting of CalDly, as described in the Calibration Delay Section, below.

The calibration process will be not be performed if the CAL pin is high at power up. In this case, the calibration cycle will not begin until the on-command calibration conditions are met. The ADC08D1000 will function with the CAL pin held high at power up, but no calibration will be done and performance will be impaired. A manual calibration, however, may be performed after powering up with the CAL pin high. See On-Command Calibration Section 2.4.2.2.

The internal power-on calibration circuitry comes up in a random state. If the input clock is not running at power up and the power on calibration circuitry is active, it will hold the analog circuitry in power down and the power consumption will typically be less than 200 mW. The power consumption will be normal after the clock starts.

2.4.2.2 On-Command Calibration

Calibration may be run at any time by bringing the CAL pin high for a minimum of 10 input clock cycles after it has been low for a minimum of 10 input clock cycles. Holding the CAL pin high upon power up will prevent execution of power-on calibration until the CAL pin is low for a minimum of 10 input clock cycles, then brought high for a minimum of another 10 input clock cycles. The calibration cycle will begin 10 input clock cycles after the CAL pin is thus brought high.

The minimum 10 input clock cycle sequences are required to ensure that random noise does not cause a calibration to begin when it is not desired. As mentioned in section 1.1 for best performance, a self calibration should be performed 20 seconds or more after power up and repeated when the ambient temperature changes more than 30˚C since the last self calibration was run. SINAD drops about 1.5 dB for every 30˚C change in die temperature and ENOB drops about 0.25 bit for every 30˚C change in die temperature.

2.0 Applications Information

(Continued)

2.4.2.3 Calibration Delay

The CalDly input (pin 127) is used to select one of two delay times after the application of power to the start of calibration, as described in Section 1.1.1. The calibration delay values allow the power supply to come up and stabilize before calibration takes place. With no delay or insufficient delay, calibration would begin before the power supply is stabilized at its operating value and result in non-optimal calibration coefficients. If the PD pin is high upon power-up, the calibration delay counter will be disabled until the PD pin is brought low. Therefore, holding the PD pin high during power up will further delay the start of the power-up calibration cycle. The best setting of the CalDly pin depends upon the power-on settling time of the power supply.

Note that the calibration delay selection is not possible in the Extended Control mode and the short delay time is used.

2.4.3 Output Edge Synchronization

DCLK signals are available to help latch the converter output data into external circuitry. The output data can be synchronized with either edge of these DCLK signals. That is, the output data transition can be set to occur with either the rising edge or the falling edge of the DCLK signal, so that either edge of that DCLK signal can be used to latch the output data into the receiving circuit.

When OutEdge (pin 4) is high, the output data is synchronized with (changes with) the rising edge of the DCLK+ (pin 82). When OutEdge is low, the output data is synchronized with the falling edge of DCLK+.

At the very high speeds of which the ADC08D1000 is capable, slight differences in the lengths of the DCLK and data lines can mean the difference between successful and erroneous data capture. The OutEdge pin is used to capture data on the DCLK edge that best suits the application circuit and layout.

2.4.4 LVDS Output Level Control

The output level can be set to one of two levels with OutV (pin3). The strength of the output drivers is greater with OutV high. With OutV low there is less power consumption in the output drivers, but the lower output level means decreased noise immunity.

For short LVDS lines and low noise systems, satisfactory performance may be realized with the FSR input low. If the LVDS lines are long and/or the system in which the ADC08D1000 is used is noisy, it may be necessary to tie the FSR pin high.

2.4.5 Dual Edge Sampling

The Dual Edge Sampling (DES) feature causes one of the two input pairs to be routed to both ADCs. The other input pair is deactivated. One of the ADCs samples the input signal on one input clock edge, the other samples the input signal on the other input clock edge. The result is a 4:1 demultiplexed output with a sample rate that is twice the input clock frequency.

To use this feature in the non-enhanced control mode, allow pin 127 to float and the signal at the "I" channel input will be sampled by both converters. The Calibration Delay will then only be a short delay.

In the enhanced control mode, either input may be used for dual edge sampling. See Section 1.1.5.1.

IMPORTANT NOTE :

When using the Automatic Clock Phase Control feature in dual edge sampling mode, it is important that the automatic phase control is disabled (set bit 14 of DES Enable register Dh to 0) before the ADC is powered down. Not doing so may cause the device not to wakeup from the powerdown state. The automatic phase control should also be disabled if the input clock is intrerrupted for any reason, or a large abrupt change in the clock frequency occurs.

Also when the ADC08D1000 is powered up and DES mode is required, ensure that pin 127 (CalDly/DES/notSCS) is initially pulled low during or after the power up sequence. The pin can then be allowed to float or be tied to VCC/2 to enter the DES mode. This will ensure that the part enters the DES mode correctly.

2.4.6 Power Down Feature

The Power Down pins (PD and PDQ) allow the ADC08D1000 to be entirely powered down (PD) or the "Q" channel to be powered down and the "I" channel to remain active. See Section 1.1.7 for details on the power down feature.

The digital output pins retain the last conversion output code when either the input clock is stopped or the PD pin is high. However, upon return to normal operation, the pipeline will contain meaningless information and must be flushed.

If the PD input is brought high while a calibration is running, the device will not go into power down until the calibration sequence is complete. However, if power is applied and PD is already high, the device will not begin the calibration sequence until the PD input goes low. If a manual calibration is requested while the device is powered down, the calibration will not begin at all. That is, the manual calibration input is completely ignored in the power down state.

2.5 THE DIGITAL OUTPUTS

The ADC08D1000 demultiplexes the output data of each of the two ADCs on the die onto two LVDS output buses (total of four buses, two for each ADC). For each of the two converters, the results of successive conversions started on the odd falling edges of the CLK+ pin are available on one of the two LVDS buses, while the results of conversions started on the even falling edges of the CLK+ pin are available on the other LVDS bus. This means that, in the SDR mode, the word rate at each LVDS bus is 1/2 the ADC08D1000 input clock rate and the two buses must be multiplexed to obtain the entire 1 GSPS conversion result.

DDR (Double Data Rate) clocking can also be used. In this mode a word of data is presented with each edge of DCLK, reducing the DCLK frequency to 1/4 the input clock frequency. See the Timing Diagram section for details.

Since the minimum recommended input clock rate for this device is 200 MSPS, the effective rate can be reduced to as low as 100 MSPS by using the results available on just one of the the two LVDS buses and a 200 MHz input clock, decimating the 200 MSPS data by two.

There is one LVDS output clock pair (DCLK) available for use to latch the LVDS outputs on all buses. Whether the data is sent at the rising or falling edge of DCLK is determined by the sense of the OutEdge pin, as described in Section 2.4.3.

The OutV pin is used to set the LVDS differential output levels. See Section 2.4.4.

The output format is Offset Binary. Accordingly, a full-scale input level with V_{IN}+ positive with respect to V_{IN}– will produce an output code of all ones, a full-scale input level with

2.0 Applications Information

(Continued)

$V_{IN}-$ positive with respect to $V_{IN}+$ will produce an output code of all zeros and when $V_{IN}+$ and $V_{IN}-$ are equal, the output code will vary between codes 127 and 128.

2.6 POWER CONSIDERATIONS

A/D converters draw sufficient transient current to corrupt their own power supplies if not adequately bypassed. A 33 µF capacitor should be placed within an inch (2.5 cm) of the A/D converter power pins. A 0.1 µF capacitor should be placed as close as possible to each V_A pin, preferably within one-half centimeter. Leadless chip capacitors are preferred because they have low lead inductance.

The V_A and V_{DR} supply pins should be isolated from each other to prevent any digital noise from being coupled into the analog portions of the ADC. A ferrite choke, such as the JW Miller FB20009-3B, is recommended between these supply lines when a common source is used for them.

As is the case with all high speed converters, the ADC08D1000 should be assumed to have little power supply noise rejection. Any power supply used for digital circuitry in a syatem where a lot of digital power is being consumed should not be used to supply power to the ADC08D1000. The ADC supplies should be the same supply used for other analog circuitry, if not a dedicated supply.

2.6.1 Supply Voltage

The ADC08D1000 is specified to operate with a supply voltage of 1.9V ±0.1V. It is very important to note that, while this device will function with slightly higher supply voltages, these higher supply voltages may reduce product lifetime.

No pin should ever have a voltage on it that is in excess of the supply voltage or below ground by more than 150 mV, not even on a transient basis. This can be a problem upon application of power and power shut-down. Be sure that the supplies to circuits driving any of the input pins, analog or digital, do not come up any faster than does the voltage at the ADC08D1000 power pins.

The Absolute Maximum Ratings should be strictly observed, even during power up and power down. A power supply that produces a voltage spike at turn-on and/or turn-off of power can destroy the ADC08D1000. The circuit of *Figure 13* will provide supply overshoot protection.

Many linear regulators will produce output spiking at power-on unless there is a minimum load provided. Active devices draw very little current until their supply voltages reach a few hundred millivolts. The result can be a turn-on spike that can destroy the ADC08D1000, unless a minimum load is provided for the supply. The 100Ω resistor at the regulator output provides a minimum output current during power-up to ensure there is no turn-on spiking.

In the circuit of *Figure 13*, an LM317 linear regulator is satisfactory if its input supply voltage is 4V to 5V . If a 3.3V supply is used, an LM1086 linear regulator is recommended.

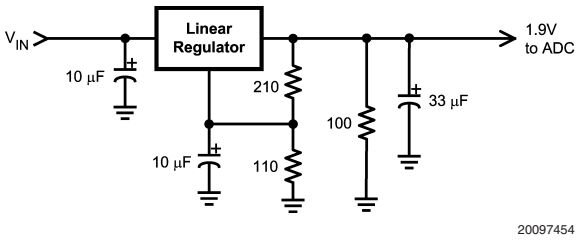


FIGURE 13. Non-Spiking Power Supply

The output drivers should have a supply voltage, V_{DR}, that is within the range specified in the Operating Ratings table. This voltage should not exceed the V_A supply voltage.

If the power is applied to the device without an input clock signal present, the current drawn by the device might be below 200 mA. This is because the ADC08D1000 gets reset through clocked logic and its initial state is random. If the reset logic comes up in the "on" state, it will cause most of the analog circuitry to be powered down, resulting in less than 100 mA of current draw. This current is greater than the power down current because not all of the ADC is powered down. The device current will be normal after the input clock is established.

2.6.2 Thermal Management

The ADC08D1000 is capable of impressive speeds and performance at very low power levels for its speed. However, the power consumption is still high enough to require attention to thermal management. For reliability reasons, the die temperature should be kept to a maximum of 130˚C. That is, t_A (ambient temperature) plus ADC power consumption times θ_{JA} (junction to ambient thermal resistance) should not exceed 130˚C. This is not a problem if the ambient temperature is kept to a maximum of +85˚C with the requisite amount of airflow as specified in the Operating Ratings section.

Please note that the following are general recommendations for mounting exposed pad devices onto a PCB. This should be considered the starting point in PCB and assembly process development. It is recommended that the process be developed based upon past experience in package mounting.

The package of the ADC08D1000 has an exposed pad on its back that provides the primary heat removal path as well as excellent electrical grounding to the printed circuit board. The land pattern design for lead attachment to the PCB should be the same as for a conventional LQFP, but the exposed pad must be attached to the board to remove the maximum amount of heat from the package, as well as to ensure best product parametric performance.

To maximize the removal of heat from the package, a thermal land pattern must be incorporated on the PC board within the footprint of the package. The exposed pad of the device must be soldered down to ensure adequate heat conduction out of the package. The land pattern for this exposed pad should be at least as large as the 5 x 5 mm of the exposed pad of the package and be located such that the exposed pad of the device is entirely over that thermal land pattern. This thermal land pattern should be electrically connected to ground. A clearance of at least 0.5 mm should separate this land pattern from the mounting pads for the package pins.

2.0 Applications Information

(Continued)

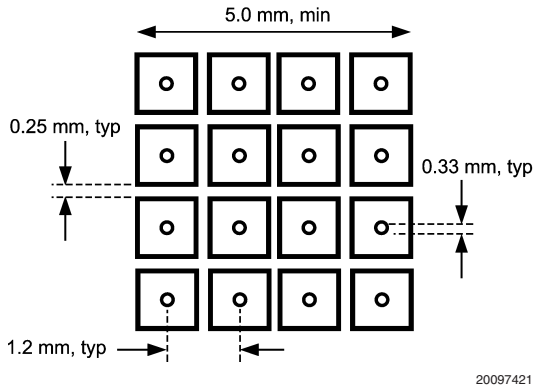


FIGURE 14. Recommended Package Land Pattern

Since a large aperture opening may result in poor release, the aperture opening should be subdivided into an array of smaller openings, similar to the land pattern of *Figure 14*.

To minimize junction temperature, it is recommended that a simple heat sink be built into the PCB. This is done by including a copper area of about 2 square inches (6.5 square cm) on the opposite side of the PCB. This copper area may be plated or solder coated to prevent corrosion, but should not have a conformal coating, which could provide some thermal insulation. Thermal vias should be used to connect these top and bottom copper areas. These thermal vias act as "heat pipes" to carry the thermal energy from the device side of the board to the opposite side of the board where it can be more effectively dissipated. The use of 9 to 16 thermal vias is recommended.

The thermal vias should be placed on a 1.2 mm grid spacing and have a diameter of 0.30 to 0.33 mm. These vias should be barrel plated to avoid solder wicking into the vias during the soldering process as this wicking could cause voids in the solder between the package exposed pad and the thermal land on the PCB. Such voids could increase the thermal resistance between the device and the thermal land on the board, which would cause the device to run hotter.

If it is desired to monitor die temperature, a temperature sensor may be mounted on the heat sink area of the board near the thermal vias. .Allow for a thermal gradient between the temperature sensor and the ADC08D1000 die of θ_{Jc} times typical power consumption = 2.8 x 1.6 = 4.5˚C. Allowing for a 5.5˚C (including an extra 1˚C) temperature drop from the die to the temperature sensor, then, would mean that maintaining a maximum pad temperature reading of 124.5˚C will ensure that the die temperature does not exceed 130˚C, assuming that the exposed pad of the ADC08D1000 is properly soldered down and the thermal vias are adequate. (The inaccuracy of the temperature sensor is addtional to the above calculation).

2.7 LAYOUT AND GROUNDING

Proper grounding and proper routing of all signals are essential to ensure accurate conversion. A single ground plane should be used, as apposed to splitting the ground plane into analog and digital areas.

Since digital switching transients are composed largely of high frequency components, the skin effect tells us that total ground plane copper weight will have little effect upon the logic-generated noise. Total surface area is more important than is total ground plane volume. Coupling between the typically noisy digital circuitry and the sensitive analog circuitry can lead to poor performance that may seem impossible to isolate and remedy. The solution is to keep the analog circuitry well separated from the digital circuitry.

High power digital components should not be located on or near any linear component or power supply trace or plane that services analog or mixed signal components as the resulting common return current path could cause fluctuation in the analog input “ground” return of the ADC, causing excessive noise in the conversion result.

Generally, we assume that analog and digital lines should cross each other at 90˚ to avoid getting digital noise into the analog path. In high frequency systems, however, avoid crossing analog and digital lines altogether. The input clock lines should be isolated from ALL other lines, analog AND digital. The generally accepted 90˚ crossing should be avoided as even a little coupling can cause problems at high frequencies. Best performance at high frequencies is obtained with a straight signal path.

The analog input should be isolated from noisy signal traces to avoid coupling of spurious signals into the input. This is especially important with the low level drive required of the ADC08D1000. Any external component (e.g., a filter capacitor) connected between the converter’s input and ground should be connected to a very clean point in the analog ground plane. All analog circuitry (input amplifiers, filters, etc.) should be separated from any digital components.

2.8 DYNAMIC PERFORMANCE

The ADC08D1000 is a.c. tested and its dynamic performance is guaranteed. To meet the published specifications and avoid jitter-induced noise, the clock source driving the CLK input must exhibit low rms jitter. The allowable jitter is a function of the input frequency and the input signal level, as described in Section 2.3.

It is good practice to keep the ADC input clock line as short as possible, to keep it well away from any other signals and to treat it as a transmission line. Other signals can introduce jitter into the input clock signal. The clock signal can also introduce noise into the analog path if not isolated from that path.

Best dynamic performance is obtained when the exposed pad at the back of the package has a good connection to ground. This is because this path from the die to ground is a lower impedance than offered by the package pins.

2.9 USING THE SERIAL INTERFACE

The ADC08D1000 may be operated in the non-extended control (non-Serial Interface) mode or in the extended control mode. *Table 6* and *Table 7* describe the functions of pins 3, 4, 14 and 127 in the non-extended control mode and the extended control mode, respectively.

2.9.1 Non-Extended Control Mode Operation

Non-extended control mode operation means that the Serial Interface is not active and all controllable functions are controlled with various pin settings. That is, the full-scale range, single-ended or differential input and input coupling (a.c. or d.c.) are all controlled with pin settings. The non-extended control mode is used by setting pin 14 high or low, as opposed to letting it float. *Table 6* indicates the pin functions of the ADC08D1000 in the non-extended control mode.

2.0 Applications Information

(Continued)

TABLE 6. Non-Extended Control Mode Operation (Pin 14 High or Low)

Pin	Low	High	Floating
3	0.44V_{P-P} Output	0.6V_{P-P} Output	n/a
4	OutEdge = Neg	OutEdge = Pos	DDR
127	CalDly Low	CalDly High	DES
14	600 mV_{P-P} input range	800 mV_{P-P} input range	Extended Control Mode

Pin 3 can be either high or low in the non-extended control mode. Pin 14 must not be left floating to select this mode. See Section 1.2 for more information.

Pin 4 can be high or low or can be left floating in the non-extended control mode. In the non-extended control mode, pin 4 high or low defines the edge at which the output data transitions. See Section 2.4.3 for more information. If this pin is floating, the output clock (DCLK) is a DDR (Double Data Rate) clock (see Section 1.1.5.3) and the output edge synchronization is irrelevant since data is clocked out on both DCLK edges.

Pin 127, if it is high or low in the non-extended control mode, sets the calibration delay. If pin 127 is floating, the calibration delay is the same as it would be with this pin low and the converter performs dual edge sampling (DES).

TABLE 7. Extended Control Mode Operation (Pin 14 Floating)

Pin	Function
3	SCLK (Serial Clock)
4	SDATA (Serial Data)
127	$\overline{SCS}$ (Serial Interface Chip Select)

2.10 COMMON APPLICATION PITFALLS

Driving the inputs (analog or digital) beyond the power supply rails. For device reliability, no input should not go more than 150 mV below the ground pins or 150 mV above the supply pins. Exceeding these limits on even a transient basis may not only cause faulty or erratic operation, but may impair device reliability. It is not uncommon for high speed digital circuits to exhibit undershoot that goes more than a volt below ground. Controlling the impedance of high speed lines and terminating these lines in their characteristic impedance should control overshoot.

Care should be taken not to overdrive the inputs of the ADC08D1000. Such practice may lead to conversion inaccuracies and even to device damage.

Incorrect analog input common mode voltage in the d.c. coupled mode. As discussed in section 1.3 and 3.0, the Input common mode voltage must remain within 50 mV of the V_{CMO} output , which has a variability with temperature that must also be tracked. Distortion performance will be degraded if the input common mode voltages more than 50 mV from V_{CMO} .

Using an inadequate amplifier to drive the analog input. Use care when choosing a high frequency amplifier to drive the ADC08D1000 as many high speed amplifiers will have higher distortion than will the ADC08D1000, resulting in overall system performance degradation.

Driving the V_{BG} pin to change the reference voltage. As mentioned in Section 2.1, the reference voltage is intended to be fixed to provide one of two different full-scale values (600 mV_{P-P} and 800 mV_{P-P}). Over driving this pin will not change the full scale value, but can otherwise upset operation.

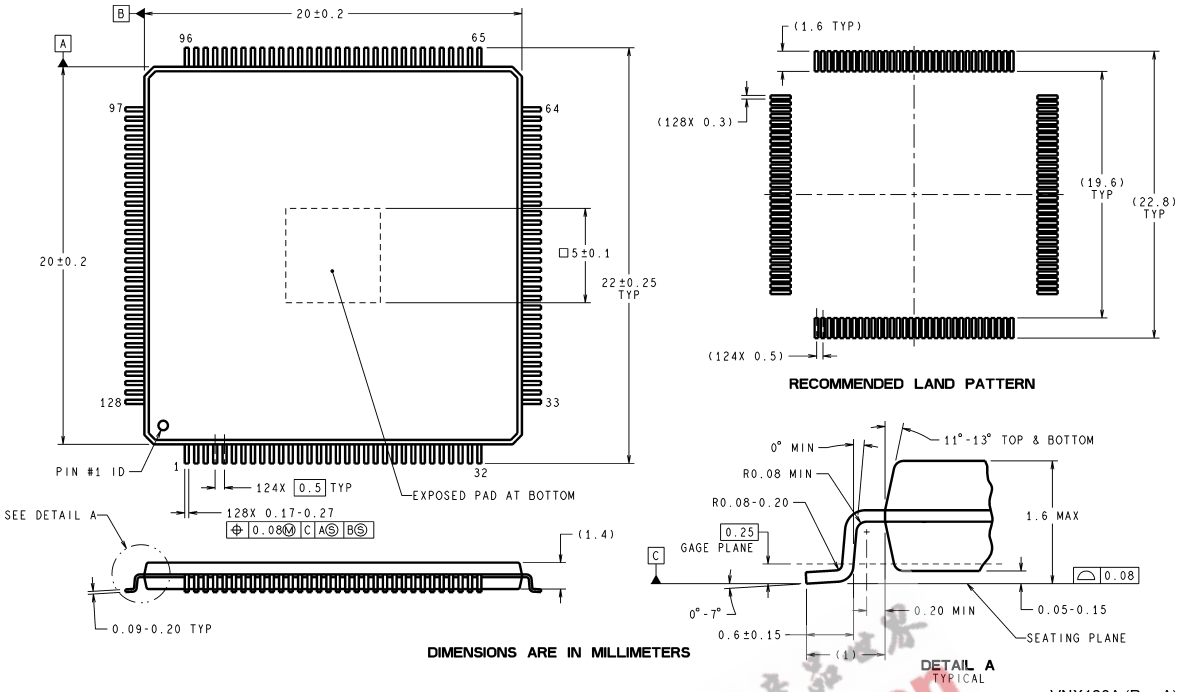
Driving the clock input with an excessively high level signal. The ADC input clock level should not exceed the level described in the Operating Ratings Table or the input offset could change.

Inadequate input clock levels. As described in Section 2.3, insufficient input clock levels can result in poor performance. Excessive input clock levels could result in the introduction of an input offset.

Using a clock source with excessive jitter, using an excessively long input clock signal trace, or having other signals coupled to the input clock signal trace. This will cause the sampling interval to vary, causing excessive output noise and a reduction in SNR performance.

Failure to provide adequate heat removal. As described in Section 2.6.2, it is important to provide adequate heat removal to ensure device reliability. This can either be done with adequate air flow or the use of a simple heat sink built into the board. The backside pad should be grounded for best performance.

Physical Dimensions inches (millimeters) unless otherwise noted



VNX128A (Rev A)

NOTES: UNLESS OTHERWISE SPECIFIED

REFERENCE JEDEC REGISTRATION MS-026, VARIATION BFB.

128-Lead Exposed Pad LQFP
Order Number ADC08D1000CIYB
NS Package Number VNX128A

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