Data Sheet

AD9209

12-Bit, 4 GSPS, JESD204B/JESD204C Quad ADC

FEATURES

- Flexible, reconfigurable common platform design
  - Supports single-, dual-, and quad-band
  - Datapaths and DSP blocks are fully bypassable
  - On-chip PLL with multichip synchronization
    - External RF clock input option for off-chip PLL
    - Supports clock input frequencies up to 12 GHz
- Maximum ADC sample rate up to 4 GSPS
  - Maximum data rate up to 4 GSPS using JESD204C
  - 8 GHz analog input bandwidth (−3 dB)
- ADC ac performance at 4 GSPS
  - Differential input voltage: 1.4 V p-p
  - Noise density: −151.5 dBFS/Hz
  - HD2: −69 dBFS at 2.7 GHz (A_{IN} at −1 dBFS)
  - HD3: −76 dBFS at 2.7 GHz (A_{IN} at −1 dBFS)
  - Worst other (excluding HD2 and HD3): −79 dBFS at 2.7 GHz
- Versatile digital features
  - Selectable decimation filters
  - Configurable DDCs
    - 8 fine complex DDCs and 4 coarse complex DDCs
    - 48-bit NCO per DDC
  - Programmable 192-tap PFIR filter for receive equalization
    - Supports 4 different profile settings loaded via GPIO
  - Programmable delay per datapath
  - Receive AGC support
    - Fast detect with low latency for fast AGC control
    - Signal monitor for slow AGC control
    - Dedicated AGC support pins
- Auxiliary features
  - Phase coherent fast frequency hopping
  - ADC clock driver with selectable divide ratios
  - On-chip temperature monitoring unit
  - Flexible GPIOx pins
- SERDES JESD204B/JESD204C interface, 8 lanes up to 24.75 Gbps
  - 8 lanes JESD204B/JESD204C Tx (JTx)
  - Supports real or complex digital data (8-, 12-, 16-, or 24-bit)
- 15 mm × 15 mm, 324-ball BGA_ED with 0.80 mm pitch

APPLICATIONS

- Wireless communications infrastructure
- Microwave point to point, E-band and 5G mmWave
- Broadband communications systems
- DOCSIS 3.1 and 4.0 CMTS
- Phased array radar and electronic warfare
- Electronic test and measurement systems

GENERAL DESCRIPTION

The AD9209 is a quad, 12-bit, 4 GSPS analog-to-digital converter (ADC). The ADC input features an on-chip wideband buffer with overload protection. This device is designed to support applications capable of direct sampling wideband signals up to 8 GHz. An on-chip, low phase noise, phase-locked loop (PLL) clock synthesizer is available to generate the ADC sampling clock, simplifying the printed circuit board (PCB) distribution of a high frequency clock signal. A clock output buffer is available to transmit the ADC sampling clock to other devices.

The quad ADC cores have code error rates (CER) better than 1×10^{-20}. Low latency fast detection and signal monitoring are available for automatic gain control (AGC) purposes. A flexible 192-tap programmable finite impulse response filter (PFIR) is available for digital filtering and/or equalization. Programmable integer and fractional delay blocks support compensation for analog delay mismatches.

The digital signal processing (DSP) block consisting of two coarse digital down converters (DDCs) and four fine DDCs per pair of ADCs. Each ADC can operate with one or two main DDC stages in support of multiband applications. The four additional fine DDC stages are available to support up to four bands per ADC The 48-bit numerically controlled oscillators (NCOs) associated with each DDC support fast frequency hopping (FFH) while maintaining synchronization with up to 16 unique frequency assignments selected via the general-purpose input and output (GPIOx) pins or the serial port interface (SPI).

The AD9209 supports one or two JTx links that can be configured for either JESD204B or JESD204C subclass operation, thus allowing for different datapath configurations for each ADC. Multidevice synchronization is supported through the SYSREF± input pins.

See the Outline Dimensions section and the Ordering Guide section for more information.

Rev. 0

DOCUMENT FEEDBACK

TECHNICAL SUPPORT

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TABLE OF CONTENTS

Features ... 1
Applications ... 1
General Description ... 1
Functional Block Diagram ... 3
Specifications ... 4
  Recommended Operating Conditions ... 4
  Power Consumption ... 4
  ADC DC Specifications ... 5
  Clock Inputs and Outputs ... 5
  Clock Input and Phase-Locked Loop (PLL) Frequency Specifications ... 6
  ADC Sample Rate Specifications ... 6
  JESD204B and JESD204C Interface Electrical and Speed Specifications ... 7
  CMOS Pin Specifications ... 8
  ADC AC Specifications ... 8
  Timing Specifications ... 10
Absolute Maximum Ratings ... 13
  Thermal Resistance ... 13
  ESD Caution ... 13
Pin Configuration and Function Descriptions ... 14
Typical Performance Characteristics ... 18
  ADC ... 18
Theory of Operation ... 25
Applications Information ... 26
Outline Dimensions ... 27
  Ordering Guide ... 27
  Evaluation Boards ... 27

REVISION HISTORY

6/2021—Revision 0: Initial Version

FUNCTIONAL BLOCK DIAGRAM

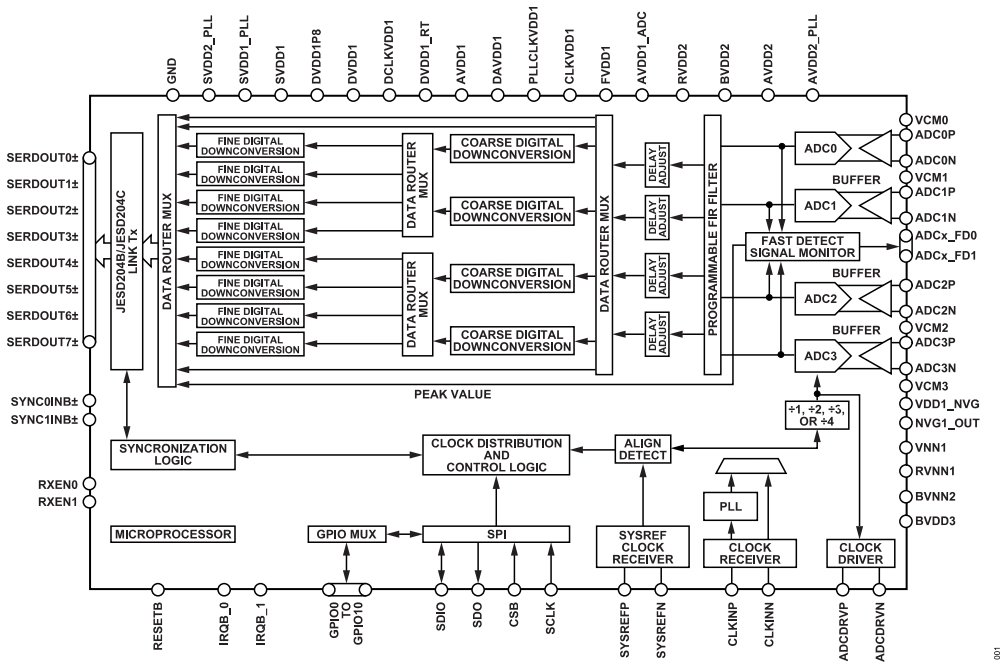

Figure 1. Functional Block Diagram

SPECIFICATIONS

RECOMMENDED OPERATING CONDITIONS

Refer to UG-1578 user guide for more information on device initialization.

Table 1.

Parameter	Min	Typ	Max	Unit
OPERATING JUNCTION TEMPERATURE (T_J)			120	°C
ANALOG SUPPLY VOLTAGE RANGE				
AVDD2, BVDD2, RVDD2	1.9	2.0	2.1	V
AVDD1, AVDD1_ADC, CLKVDD1, FVDD1, VDD1_NVG1	0.95	1.0	1.05	V
DIGITAL SUPPLY VOLTAGE RANGE				
DVDD1, DVDD1_RT, DCLKVDD1, DAVDD1	0.95	1.0	1.05	V
DVDD1P8	1.7	1.8	2.1	V
SERIALIZER AND DESERIALIZER (SERDES) SUPPLY VOLTAGE RANGE				
SVDD2_PLL	1.9	2.0	2.1	V
SVDD1, SVDD1_PLL	0.95	1.0	1.05	V

POWER CONSUMPTION

Typical at nominal supplies and maximum at 5% supplies. For the minimum and maximum values, T_J varies between −40°C and +120°C. For the typical values, T_A = 25°C, which corresponds to T_J = 80°C unless otherwise noted.

ADC datapath with DDCs bypassed (no decimation) and f_{ADC} of 4 GSPS. JESD204C mode of 27C (L = 8, M = 4, F = 3, S = 4, K = 256, E = 3, N = 12, NP = 12).

See the UG-1578 user guide for further information on the JESD204B and JESD204C mode configurations, and a detailed description of the settings referenced throughout this data sheet.

Table 2. Power Consumption

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
CURRENTS					
AVDD2 (I_{AVDD2})	2.0 V supply		10.1	20.7	mA
BVDD2 (I_{BVDD2}) + RVDD2 (I_{RVDD2})	2.0 V supply		292.5	347.6	mA
AVDD2_PLL (I_{AVDD2_PLL}) + SVDD2_PLL (I_{SVDD2_PLL})	2.0 V supply		45.6	54.8	mA
Power Dissipation for 2 V Supplies	2.0 V supply total power dissipation		0.70	0.85	W
PLLCLKVDD1 ($I_{PLLCLKVDD1}$)	1.0 V supply		6.6	12.1	mA
AVDD1 (I_{AVDD1}) + DCLKVDD1($I_{DCLKVDD1}$)	1.0 V supply		123.1	242.4	mA
AVDD1_ADC (I_{AVDD1_ADC})	1.0 V supply		1840.4	2157	mA
CLKVDD1 ($I_{CLKVDD1}$)	1.0 V supply		65.3	115.2	mA
FVDD1 (I_{FVDD1})	1.0 V supply		46.2	69.8	mA
VDD1_NVG (I_{VDD1_NVG})	1.0 V supply		279.2	342.4	mA
DAVDD1 (I_{DAVDD1})	1.0 V supply		55.1	149.9	mA
DVDD1 (I_{DVDD1})	1.0 V supply		860	1648.7	mA
DVDD1_RT (I_{DVDD1_RT})	1.0 V supply		560.7	690.7	mA
SVDD1 (I_{SVDD1}) + SVDD1_PLL (I_{SVDD1_PLL})	1.0 V supply		929.4	1334.9	mA
Power Dissipation for 1 V Supplies	1.0 V supply total power dissipation		4.77	6.77	W
DVDD1P8 ($I_{DVDD1P8}$)	1.8 V supply		1.9	3	mA
Total Power Dissipation	Total power dissipation of 2 V and 1 V supplies		5.47	7.61	W

SPECIFICATIONS

ADC DC SPECIFICATIONS

ADC setup in 4 GSPS, full bandwidth mode (all digital downconverters bypassed). For the minimum and maximum values, T_J = −40°C to +120°C, and for the typical values, T_A = 25°C, which corresponds to T_J = 80°C, unless otherwise noted.

Table 3. ADC DC Specifications

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
ADC RESOLUTION		12			Bit
ADC ACCURACY					
No Missing Codes			Guaranteed		
Offset Error			−0.20		% FSR
Offset Matching			0.05		% FSR
Gain Error			−0.71		% FSR
Gain Matching			1.2		% FSR
DNL			±1.9		LSB
INL			±0.5		LSB
ADC ANALOG INPUTS	ADCxP and ADCxN				
Differential Input Voltage			1.4		V p-p
Full-Scale Sine Wave Input Power	Input power level resulting 0 dBFS tone level on fast Fourier transform (FFT)		3.9		dBm
Common-Mode Input Voltage (VCM_{IN})	AC-coupled, equal to voltage at VCMx for the ADCxP or ADCxN input		1		V
Differential Input Resistance			100		Ω
Differential Input Capacitance			0.4		pF
Return Loss	<2.7 GHz		−4.3		dB
	2.7 GHz to 3.8 GHz		−3.6		dB
	3.8 GHz to 5.4 GHz		−2.9		dB

CLOCK INPUTS AND OUTPUTS

For the minimum and maximum values, T_J = −40°C to +120°C and ±5% of nominal supply, unless otherwise noted.

Table 4. Clock Inputs and Outputs

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
CLOCK INPUTS	CLKINP and CLKINN				
Differential Input Power	Direct RF clock				
Minimum				0	dBm
Maximum				6	dBm
Common-Mode Voltage	AC-coupled			0.5	V
Differential Input Resistance				100	Ω
Differential Input Capacitance				0.3	pF
CLOCK OUTPUTS (ADC CLOCK DRIVER)	ADCDRVP and ADCDRVN				
Differential Output Voltage Magnitude[1]	1.5 GHz			740	mV p-p
	2.0 GHz			690	mV p-p
	3.0 GHz			640	mV p-p
Differential Output Resistance				100	Ω
Common-Mode Voltage	AC-coupled			0.5	V

[1] Measured with differential 100 Ω load and less than 2 mm of PCB trace from package ball.

SPECIFICATIONS

CLOCK INPUT AND PHASE-LOCKED LOOP (PLL) FREQUENCY SPECIFICATIONS

For the minimum and maximum values, T_J = −40°C to +120°C and ±5% of nominal supply, unless otherwise noted.

Table 5.

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
CLOCK INPUTS (CLKINP, CLKINN) FREQUENCY RANGES		25		12000	MHz
PHASE FREQUENCY DETECTOR (PFD) INPUT FREQUENCY RANGES		25		750	MHz
FREQUENCY RANGES ACCORDING TO CLOCK PATH CONFIGURATION					
Direct Clock (PLL Off)		2900		12000	MHz
PLL Reference Clock (PLL On)	M divider set to divide by 1	25		750	MHz
	M divider set to divide by 2	50		1500	MHz
	M divider set to divide by 3	75		2250	MHz
	M divider set to divide by 4	100		3000	MHz
PLL VOLTAGE CONTROLLED OSCILLATOR (VCO) FREQUENCY RANGES					
VCO Output					
Divide by 1	D divider set to divide by 1	5.8		12	GHz
Divide by 2	D divider set to divide by 2	2.9		6	GHz
Divide by 3	D divider set to divide by 3	1.93333		4	GHz
Divide by 4	D divider set to divide by 4	1.45		3	GHz

ADC SAMPLE RATE SPECIFICATIONS

Nominal supplies. For the minimum and maximum values, T_J = −40°C to +120°C and ±5% of nominal supply. For the typical values, T_A = 25°C, which corresponds to T_J = 80°C, unless otherwise noted.

Table 6. ADC Sample Rate Specifications

Parameter	Min	Typ	Max	Unit
ADC SAMPLE RATE[1]				
Minimum			1.45	GSPS
Maximum	4			GSPS
Aperture Jitter[2]		65		fs rms

[1] Pertains to the update rate of the ADC core, independent of the datapath and JESD204 mode configuration.

[2] Measured using a signal-to-noise ratio (SNR) degradation method with the DAC disabled, clock divider = 1, ADC frequency (f_{ADC}) = 4 GSPS, and input frequency (f_{IN}) = 5.55 GHz.

SPECIFICATIONS

JESD204B AND JESD204C INTERFACE ELECTRICAL AND SPEED SPECIFICATIONS

Nominal supplies. For the minimum and maximum values, T_J = −40°C to +120°C and ±5% of nominal supply, and for the typical values, T_A = 25°C, which corresponds to T_J = 80°C, unless otherwise noted.

Table 7. Serial Interface Rate Specifications

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
JESD204B SERIAL INTERFACE RATE	Serial lane rate (bit repeat option disabled)	1.0		15.5	Gbps
Unit Interval		64.5		1000.0	ps
JESD204C SERIAL INTERFACE RATE	Serial lane rate (bit repeat option disabled)	6.0		24.75	Gbps
Unit Interval		40.4		166.67	ps

Table 8. JESD204 Transmitter (JTx) Electrical Specifications

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
JESD204x DATA OUTPUTS	SERDOUTx±, where x = 0 to 7				
Logic Compliance			JESD204B/JESD204C compliant		
Differential Output Voltage	Maximum strength		675		mV p-p
Differential Termination Impedance		80	108	120	Ω
Rise Time, t_R	20% to 80% into 100 Ω load		18		ps
Fall Time, t_F	20% to 80% into 100 Ω load		18		ps
SYNCxINB± INPUT[1]	Where x = 0 or 1				
Logic Compliance			LVDS[2]		
Differential Input Voltage		240	0.7	1900	mV p-p
Input Common-Mode Voltage	DC-coupled		0.675	2	V
R_{IN} (Differential)	18		18		kΩ
Input Capacitance (Differential)	1		1		pF
SYNCxINB+ INPUT	CMOS[3] input option		Refer to CMOS Pin Specifications		

[1] IEEE 1596.3 standard LVDS compatible.

[2] LVDS means low voltage differential signaling.

[3] CMOS means complementary metal-oxide semiconductor.

Table 9. SYSREF Electrical Specifications

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
SYSREFP AND SYSREFN INPUTS					
Logic Compliance			LVDS/LVPECL[1]		
Differential Input Voltage			0.7	1.9	V p-p
Input Common-Mode Voltage Range	DC-coupled		0.675	2	V
Input Reference, R_{IN} (Differential)			100		Ω
Input Capacitance (Differential)			1		pF

[1] LVPECL means low voltage positive/pseudo emitter-coupled logic.

SPECIFICATIONS

CMOS PIN SPECIFICATIONS

For the minimum and maximum values, T_J = −40°C to +120°C, 1.7 V ≤ DVDD1P8 ≤ 2.1 V, other supplies nominal, unless otherwise noted.

Table 10.

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
INPUTS		SDIO, SCLK, CSB, RESETB, RXEN0, RXEN1, SYNC0INB±, SYNC1INB±, and GPIOx				
Logic 1 Voltage	V_{IH}		0.70 × DVDD1P8			V
Logic 0 Voltage	V_{IL}				0.3 × DVDD1P8	V
Input Resistance			40			kΩ
OUTPUTS		SDIO, SDO, GPIOx, ADCx_FDx, ADCx_SMONx, 4 mA load				
Logic 1 Voltage	V_{OH}		DVDD1P8 − 0.45			V
Logic 0 Voltage	V_{OL}				0.45	V
INTERRUPT OUTPUTS		IRQB_0 and IRQB_1, pull-up resistor of 5 kΩ to DVDD1P8				
Logic 1 Voltage	V_{OH}		1.35			V
Logic 0 Voltage	V_{OL}				0.48	V

ADC AC SPECIFICATIONS

Nominal supplies with T_A = 25°C. Input amplitude (A_{IN}) = −1 dBFS, full bandwidth (no decimation) mode. For the minimum and maximum values, T_J = −40°C to +120°C. Specifications represent average of four ADC channels. See the AN-835 Application Note, Understanding High Speed ADC Testing and Evaluation, for definitions and for details on how these tests were completed.

Table 11.

Parameter	Min	Typ	Max	Unit
NOISE DENSITY[1]		−151.2		dBFS/Hz
NOISE FIGURE[2]		26.8		dB
CODE ERROR RATE (CER)		1×10^{-20}		Errors
SIGNAL-TO-NOISE RATIO (SNR)				
f_{IN} = 450 MHz		58.1		dBFS
f_{IN} = 900 MHz		57.8		dBFS
f_{IN} = 1800 MHz		58.1		dBFS
f_{IN} = 2700 MHz	53.5	55.9		dBFS
f_{IN} = 3600 MHz		54.9		dBFS
f_{IN} = 4500 MHz		53.5		dBFS
f_{IN} = 5400 MHz		52.9		dBFS
f_{IN} = 6300 MHz		52.9		dBFS
f_{IN} = 7200 MHz		50.8		dBFS
SIGNAL-TO-NOISE-AND-DISTORTION (SINAD)				
f_{IN} = 450 MHz		57.0		dBFS
f_{IN} = 900 MHz		57.4		dBFS
f_{IN} = 1800 MHz		56.3		dBFS
f_{IN} = 2700 MHz	52.4	54.5		dBFS
f_{IN} = 3600 MHz		52.9		dBFS
f_{IN} = 4500 MHz		51.2		dBFS
f_{IN} = 5400 MHz		49.3		dBFS
f_{IN} = 6300 MHz		47.5		dBFS
f_{IN} = 7200 MHz		45.8		dBFS

SPECIFICATIONS

Table 11.

Parameter	Min	Typ	Max	Unit
EFFECTIVE NUMBER OF BITS (ENOB)				
f_{IN} = 450 MHz		9.3		Bits
f_{IN} = 900 MHz		9.3		Bits
f_{IN} = 1800 MHz		9.1		Bits
f_{IN} = 2700 MHz	8.4	8.8		Bits
f_{IN} = 3600 MHz		8.5		Bits
f_{IN} = 4500 MHz		8.2		Bits
f_{IN} = 5400 MHz		7.9		Bits
f_{IN} = 6300 MHz		7.6		Bits
f_{IN} = 7200 MHz		7.3		Bits
SECOND-ORDER HARMONIC DISTORTION (HD2)				
f_{IN} = 450 MHz		−89		dBFS
f_{IN} = 900 MHz		−80		dBFS
f_{IN} = 1800 MHz		−76		dBFS
f_{IN} = 2700 MHz		−69	−54	dBFS
f_{IN} = 3600 MHz		−63		dBFS
f_{IN} = 4500 MHz		−57		dBFS
f_{IN} = 5400 MHz		−55		dBFS
f_{IN} = 6300 MHz		−49		dBFS
f_{IN} = 7200 MHz		−47		dBFS
THIRD-ORDER HARMONIC DISTORTION (HD3)				
f_{IN} = 450 MHz		−79		dBFS
f_{IN} = 900 MHz		−79		dBFS
f_{IN} = 1800 MHz		−78		dBFS
f_{IN} = 2700 MHz		−76	−62	dBFS
f_{IN} = 3600 MHz		−77		dBFS
f_{IN} = 4500 MHz		−65		dBFS
f_{IN} = 5400 MHz		−61		dBFS
f_{IN} = 6300 MHz		−59		dBFS
f_{IN} = 7200 MHz		−56		dBFS
WORST OTHER, EXCLUDING HD2, HD3, AND INTERLEAVING SPURS				
f_{IN} = 450 MHz		−86		dBFS
f_{IN} = 900 MHz		−85		dBFS
f_{IN} = 1800 MHz		−84		dBFS
f_{IN} = 2700 MHz		−83	−68	dBFS
f_{IN} = 3600 MHz		−81		dBFS
f_{IN} = 4500 MHz		−79		dBFS
f_{IN} = 5400 MHz		−78		dBFS
f_{IN} = 6300 MHz		−76		dBFS
f_{IN} = 7200 MHz		−75		dBFS
INTERLEAVING SPUR ($f_{IN} \pm f_S/2$)[3]				
f_{IN} = 450 MHz		−91		dBFS
f_{IN} = 900 MHz		−91		dBFS
f_{IN} = 1800 MHz		−88		dBFS
f_{IN} = 2700 MHz		−87		dBFS
f_{IN} = 3600 MHz		−86		dBFS
f_{IN} = 4500 MHz		−84		dBFS
f_{IN} = 5400 MHz		−81		dBFS

SPECIFICATIONS

Table 11.

Parameter	Min	Typ	Max	Unit
f_{IN} = 6300 MHz		−80		dBFS
f_{IN} = 7200 MHz		−80		dBFS
DIGITAL COUPLING SPUR ($f_{IN} \pm f_S/4$)				
f_{IN} = 450 MHz		−88		dBFS
f_{IN} = 900 MHz		−84		dBFS
f_{IN} = 1800 MHz		−78		dBFS
f_{IN} = 2700 MHz		−74	−70	dBFS
f_{IN} = 3600 MHz		−71		dBFS
f_{IN} = 4500 MHz		−70		dBFS
f_{IN} = 5400 MHz		−69		dBFS
f_{IN} = 6300 MHz		−67		dBFS
f_{IN} = 7200 MHz		−66		dBFS
TWO-TONE INTERMODULATION DISTORTION (IMD3, $2f_{IN1} - f_{IN2}$ OR $2f_{IN2} - f_{IN1}$) A_{IN1} AND A_{IN2} = −7 dBFS				
f_{IN1} = 1775 MHz, f_{IN2} = 1825 MHz		−84		dBFS
f_{IN1} = 2675 MHz, f_{IN2} = 2725 MHz		−78		dBFS
f_{IN1} = 3575 MHz, f_{IN2} = 3625 MHz		−74		dBFS
f_{IN1} = 5375 MHz, f_{IN2} = 5425 MHz		−66		dBFS
ANALOG BANDWIDTH[4]		8		GHz

1 Noise density is measured at 250 MHz input frequency at −30 dBFS, where timing jitter does not degrade noise floor.

2 Noise figure is based on a nominal full-scale input power of 4.5 dBm with an input span of 1.5 V p-p and R_{IN} = 100 Ω.

3 With background interleaving calibration converged.

4 Analog input bandwidth is the bandwidth of operation in which the full-scale input frequency response rolls off by −3 dB based on a de-embedded model of the ADC extracted from the measured frequency response on evaluation board. This bandwidth requires optimized matching network to achieve this upper bandwidth.

TIMING SPECIFICATIONS

For the minimum and maximum values, T_J = −40°C to +120°C and ±5% of nominal supply, unless otherwise noted.

Table 12.

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
SERIAL PORT INTERFACE (SPI) WRITE OPERATION						
Maximum SCLK Clock Rate	f_{SCLK}, $1/t_{SCLK}$		33			MHz
SCLK Clock High	t_{PWH}	SCLK = 33 MHz	8			ns
SCLK Clock Low	t_{PWL}	SCLK = 33 MHz	8			ns
SDIO to SCLK Setup Time	t_{DS}		4			ns
SCLK to SDIO Hold Time	t_{DH}		4			ns
CSB to SCLK Setup Time	t_S		4			ns
CLK to CSB Hold Time	t_H		4			ns
SPI READ OPERATION						
LSB First Data Format						
Maximum SCLK Clock Rate	f_{SCLK}, $1/t_{SCLK}$		33			MHz
SCLK Clock High	t_{PWH}		8			ns
SCLK Clock Low	t_{PWL}		8			ns
MSB First Data Format						
Maximum SCLK Clock Rate	f_{SCLK}, $1/t_{SCLK}$		15			MHz
SCLK Clock High	t_{PWH}		30			ns
SCLK Clock Low	t_{PWL}		30			ns
SDIO to SCLK Setup Time	t_{DS}		4			ns

SPECIFICATIONS

Table 12.

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
SCLK to SDIO Hold Time	t_{DH}		4			ns
CSB to SCLK Setup Time	t_S		4			ns
SCLK to SDIO Data Valid Time	t_{DV}		20			ns
SCLK to SDO Data Valid Time	t_{DV_SDO}		20			ns
CSB to SDIO Output Valid to High-Z	t_Z		20			ns
CSB to SDO Output Valid to High-Z	t_{Z_SDO}		20			ns
RESETB		minimum hold time to trigger a device reset	40			ns

Timing Diagrams

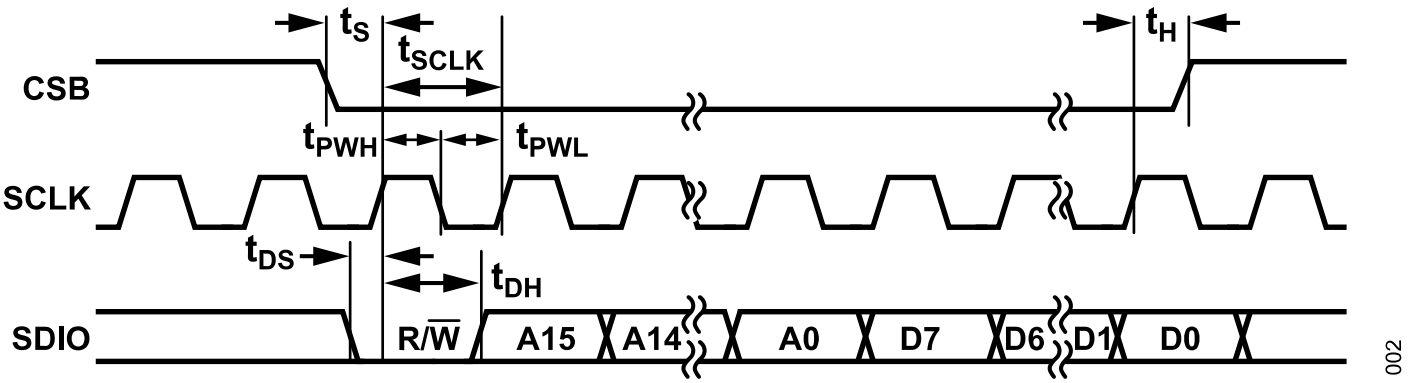

Figure 2. Timing Diagram for 3-Wire Write Operation

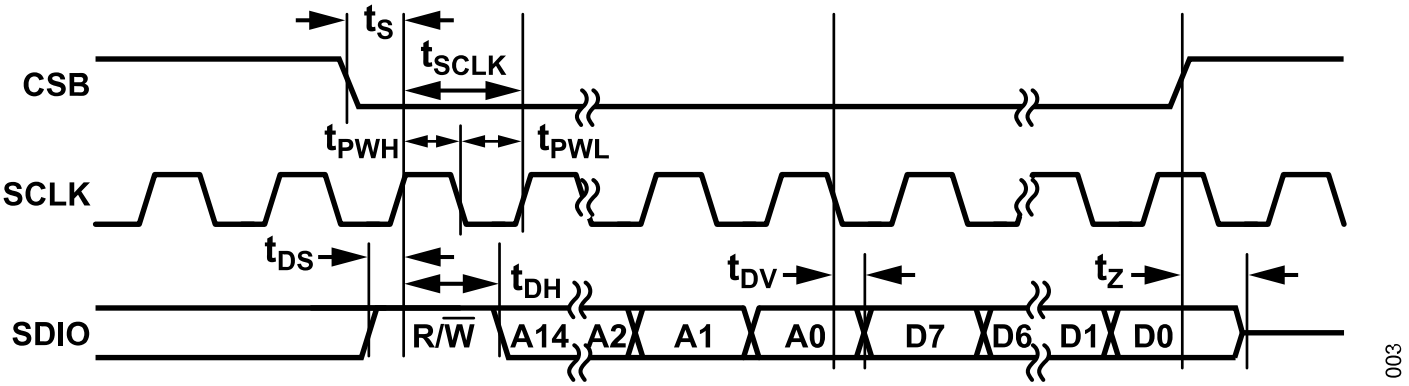

Figure 3. Timing Diagram for 3-Wire Read Operation

SPECIFICATIONS

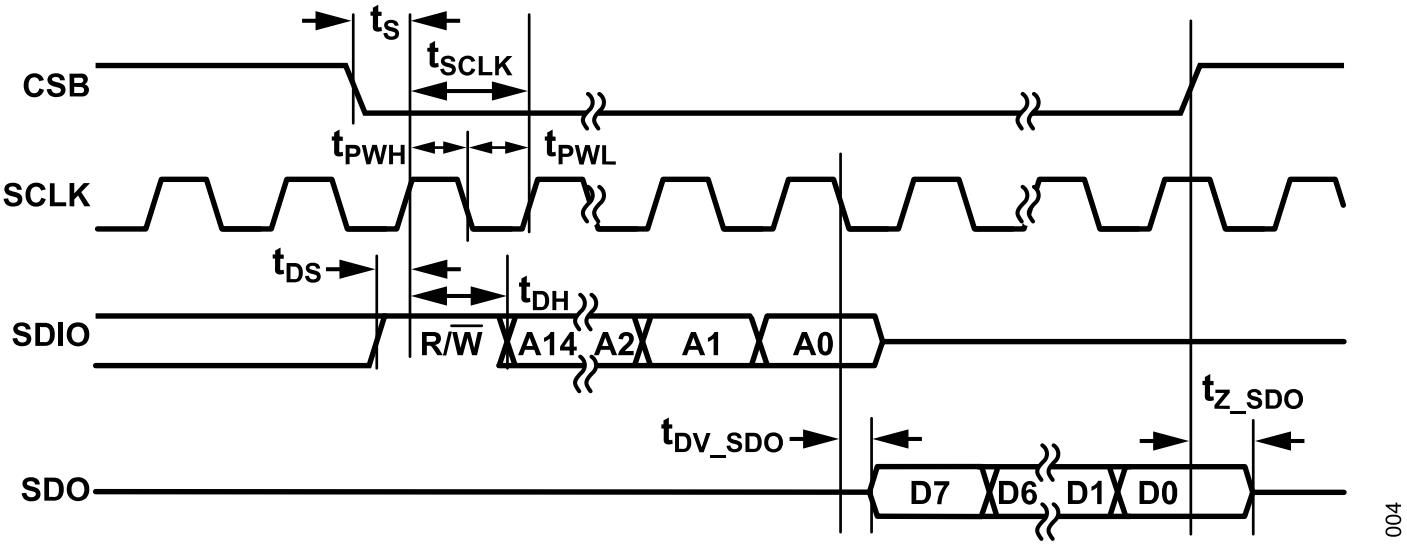

Figure 4. Timing Diagram for 4-Wire Read Operation

ABSOLUTE MAXIMUM RATINGS

Table 13.

Parameter	Rating
ISET, TDP, TDN	−0.3 V to AVDD2 + 0.3 V
VCO_COARSE, VCO_FINE, VCO_VCM, VCO_VREG	−0.3 V to AVDD2_PLL + 0.3 V
Rx Input Power (ADC0P/ADC0N, ADC1P/ADC1N, ADC2P/ADC2N, ADC3P/ADC2N)[1]	22 dBm
VCM0, VCM1, VCM2, VCM3	−0.3 V to RVDD2 + 0.3 V
CLKINP, CLKINN	−0.2 V to PLLCLKVDD1 + 0.2 V
ADCDRVN, ADCDRVP	−0.2 V to CLKVDD1 + 0.2 V
SERDOUTx±	−0.2 V to SVDD1 + 0.2 V
SYSREFP, SYSREFN, and SYNCxINB±	−0.2 V to +2.5 V
RESETB, RXENx, IRQB_x, CSB, SCLK, SDIO, SDO, TMU_REFN, TMU_REFP, ADCx_FD0, ADCx_FD1, GPIOx	−0.3 V to DVDD1P8 + 0.3 V
AVDD2, AVDD2_PLL, BVDD2, RVDD2, SVDD2_PLL, DVDD1P8	−0.3 V to +2.2 V
PLLCLKVDD1, AVDD1, AVDD1_ADC, CLKVDD1, FVDD1, DAVDD1, DVDD1_RT, DCLKVDD1, SVDD1, SVDD1_PLL	−0.2 V to +1.2 V
VNN1	−1.1 V to +0.2 V
Temperature	
Maximum Junction (T_J)[2]	120°C
Storage Range	−40°C to +150°C

[1] Tested continuously for 1000 hours with fIN = 4.7 GHz pulsed and continuous tone at maximum allowed junction temperature (TJ). Refer to UG-1578, the device user guide, for more information.

[2] Do not exceed this temperature for any duration of time when the device is powered.

Stresses at or above those listed under Absolute Maximum Ratings may cause permanent damage to the product. This is a stress rating only; functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

THERMAL RESISTANCE

Thermal performance is directly linked to PCB design and operating environment. The use of appropriate thermal management techniques is recommended to ensure that the maximum T_J does not exceed the limits shown in Table 13.

θ_{JA} is the natural convection, junction to ambient thermal resistance measured in a one cubic foot sealed enclosure.

θ_{JC_TOP} is the junction to case, thermal resistance.

θ_{JB} is the junction to board, thermal resistance.

Table 14. Simulated Thermal Resistance

PCB Type	Airflow Velocity (m/sec)	θ_{JA}[1]	θ_{JC_TOP}[1]	θ_{JB}[1]	Unit
JEDEC 2s2p Board	0.0	14.9	0.70	1.8	°C/W

[1] Thermal resistance values specified are simulated based on JEDEC specifications in compliance with JESD51-12 with the device power equal to 9 W.

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

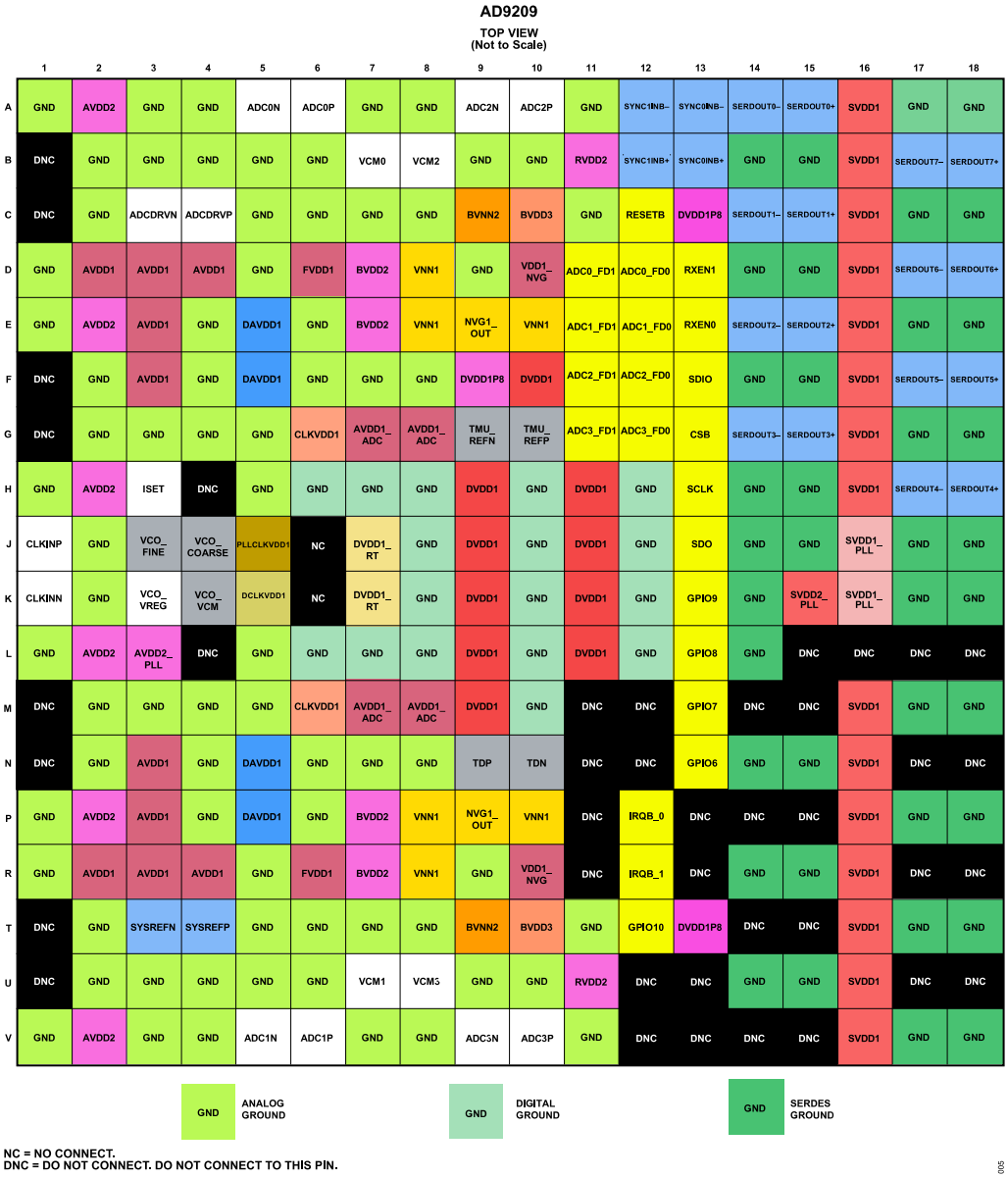

Figure 5. Pin Configuration

Table 15. Pin Function Descriptions

Pin No.	Mnemonic	Type	Description
POWER SUPPLIES			
A2, E2, H2, L2, P2, V2	AVDD2	Input	Analog 2.0 V Supply Inputs for DAC.
L3	AVDD2_PLL	Input	Analog 2.0 V Supply Input for Clock PLL Linear Dropout (LDO) Regulator.
D7, E7, P7, R7	BVDD2	Input	Analog 2.0 V Supply Inputs for ADC Buffer.
B11, U11	RVDD2	Input	Analog 2.0 V Supply Inputs for ADC Reference.
J5	PLLCLKVDD1	Input	Analog 1.0 V Supply Input for Clock PLL.
D2 to D4, E3, F3, N3, P3, R2 to R4	AVDD1	Input	Analog 1.0 V Supply Inputs for DAC Clock.
G7, G8, M7, M8	AVDD1_ADC	Input	Analog 1.0 V Supply Inputs for ADC.
G6, M6	CLKVDD1	Input	Analog 1.0 V Supply Inputs for ADC Clock.
D6, R6	FVDD1	Input	Analog 1.0 V Supply Inputs for ADC Reference.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

Table 15. Pin Function Descriptions

Pin No.	Mnemonic	Type	Description
D10, R10	VDD1_NVG	Input	Analog 1.0 V Supply Inputs for Negative Voltage Generator (NVG) Used to Generate −1 V Output.
E9, P9	NVG1_OUT	Output	Analog −1 V Supply Outputs from NVG. Decouple NVG1_OUT to GND with a 0.1 µF capacitor.
D8, E8, E10, P8, P10, R8	VNN1	Input	Analog −1 V Supply Inputs for ADC Buffer and Reference. Connect these pins to the adjacent NVG1_OUT pins.
C9, T9	BVNN2	Output	Decoupling Pin for the Internally Generated Analog −2 V ADC Buffer Supply. Decouple each BVNN2 pin to GND with a 0.1 µF capacitor.
C10, T10	BVDD3	Output	Decoupling Pin for the Internally Generated Analog 3 V ADC Buffer Supply. Decouple BVDD3 to GND with 0.1 µF capacitor.
E5, F5, N5, P5	DAVDD1	Input	Digital Analog 1.0 V Supply Inputs.
F10, H9, H11, J9, J11, K9, K11, L9, L11, M9	DVDD1	Input	Digital 1.0 V Supply Inputs.
J7, K7	DVDD1_RT	Input	Digital 1.0 V Supply Inputs for Retimer Block.
K5	DCLKVDD1	Input	Digital 1.0 V Clock Generation Supply.
A16, B16, C16, D16, E16, F16, G16, H16, M16, N16, P16, R16, T16, U16, V16	SVDD1	Input	Digital 1.0 V Supply Inputs for SERDES.
K15	SVDD2_PLL	Input	Digital 2.0 V Supply Input for SERDES LDO.
J16, K16	SVDD1_PLL	Input	Digital 1.0 V Supply Inputs for SERDES Clock Generation and PLL.
C13, F9, T13	DVDD1P8	Input	Digital Interface and Temperature Monitoring Unit (TMU) Supply Inputs (Nominal 1.8 V).
A1, A3, A4, A7, A8, A11, A17, A18, B2 to B6, B9, B10, B14, B15, C2, C5 to C8, C11, C17, C18, D1, D5, D9, D14, D15, E1, E4, E6, E17, E18, F2, F4, F6 to F8, F14, F15, G2 to G5, G17, G18, H1, H5 to H8, H10, H12, H14, H15, J2, J8, J10, J12, J14, J15, J17, J18, K2, K8, K10, K12, K14, K17, K18, L1, L5 to L8, L10, L12, L14, M2 to M5, M10, M17, M18, N2, N4, N6 to N8, N14, N15, P1, P4, P6, P17, P18, R1, R5, R9, R14, R15, T2, T5 to T8, T11, T17, T18, U2 to U6, U9, U10, U14, U15, V1, V3, V4, V7, V8, V11, V17, V18	GND	Input/output	Ground References.
ANALOG OUTPUTS			
H3	ISET	Output	DAC Bias Current Setting Pin. Connect the ISET pin with a 5 kΩ resistor to GND.
C3, C4	ADCDRVN, ADCDRVP	Output	Optional Clock Output (For Example, ADC Clock Driver for an External ADC). The ADCDRVx pins are disabled by default. Leave the ADCDRVx pins floating if unused.
B7, B8, U7, U8	VCM0, VCM2, VCM1, VCM3	Output	ADC Buffer Common-Mode Output Voltage. Decouple the VCMx pins to GND with a 0.1 µF capacitor.
K3	VCO_VREG	Output	PLL LDO Regulator Output. Decouple the VCO_VREG pin to GND with a 2.2 µF capacitor.
G9	TMU_REFN	Output	TMU ADC Negative Reference. Connect the TMU_REFN pin to GND.
G10	TMU_REFP	Output	TMU ADC Positive Reference. Connect the TMU_REFP pin to DVDD1P8.
ANALOG INPUTS			
A5, A6	ADC0N, ADC0P	Input	ADC0 Differential Inputs with Internal 100 Ω Differential Resistor. Leave the ADCxP/ADCxN pins floating if unused.
V5, V6	ADC1N, ADC1P	Input	ADC1 Differential Inputs with Internal 100 Ω Differential Resistor. Leave the ADCxP/ADCxN floating if unused.
A9, A10	ADC2N, ADC2P	Input	ADC2 Differential Inputs with Internal 100 Ω Differential Resistor. Leave the ADCxP/ADCxN floating if unused.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

Table 15. Pin Function Descriptions

Pin No.	Mnemonic	Type	Description
V9, V10	ADC3N, ADC3P	Input	ADC3 Differential Inputs with Internal 100 Ω Differential Resistor. Leave the ADCxP/ADCxN floating if unused.
J3	VCO_FINE	Input	On-Chip Device Clock Multiplier and PLL Fine Loop Filter Input. If the PLL is not in use, leave the VCO_FINE pin floating and disable the PLL via the control registers.
J4	VCO_COARSE	Input	On-Chip Device Clock Multiplier and PLL Coarse Loop Filter Input. If the PLL is not in use, leave the VCO_COARSE pin floating and disable the PLL via the control registers.
K4	VCO_VCM	Input	On-Chip Device Clock Multiplier and VCO Common-Mode Input. If the PLL is not in use, leave the VCO_VCM pin floating and disable the PLL via the control registers.
N9, N10	TDP, TDN	Input	Anode and Cathode of Temperature Diodes. This feature is not supported. Tie TDP and TDN to GND.
J1, K1	CLKINP, CLKINN	Input	Differential Clock Inputs with Nominal 100 Ω Termination. Self bias input requiring ac coupling. When the on-chip clock multiplier PLL is enabled, these inputs are the reference clock inputs. If the PLL is disabled, an RF clock equal to the DAC output sample rate is required.
CMOS INPUTS AND OUTPUTS[1]			
G13	CSB	Input	Serial Port Enable Input. Active low.
H13	SCLK	Input	Serial Port Clock Input.
F13	SDIO	Input/output	Serial Port Bidirectional Data Input and Output.
J13	SDO	Output	Serial Port Data Output.
C12	RESETB	Input	Active Low Reset Input. RESETB places digital logic and SPI registers in a known default state. RESETB must be connected to a digital IC that is capable of issuing a reset signal for the first step in the device initialization process.
D13, E13	RXEN1, RXEN0	Input	Active High ADC and Receive Datapath Enable Inputs. RXENx is also SPI configurable.
D11, D12	ADC0_FD1, ADC0_FD0	Output	ADC0 Fast Detect Outputs by Default. Do not connect if unused.
E11, E12	ADC1_FD1, ADC1_FD0	Output	ADC1 Fast Detect Outputs by Default. Do not connect if unused.
F11, F12	ADC2_FD1, ADC2_FD0	Output	ADC2 Fast Detect Outputs by Default. Do not connect if unused.
G11, G12	ADC3_FD1, ADC3_FD0	Output	ADC3 Fast Detect Outputs by Default. Do not connect if unused.
P12, R12	IRQB_0, IRQB_1	Output	Interrupt Request 0 and Interrupt Request 1 Outputs. The IRQB_x pins are an open-drain, active low output (CMOS levels with respect to DVDD1P8). Connect >5 kΩ pull-up resistor to DVDD1P8 to prevent the IRQB_x pins from floating when unused.
K13, L13, M13, N13, T12	GPIO6 to GPIO10	Input/output	General-Purpose Input or Output Pins.
JESD204B- or JESD204CCOMPATIBLE SERDES DATA LANES AND CONTROL SIGNALS[2]			
A14, A15	SERDOUT0−, SERDOUT0+	Output	JTx Lane 0 Outputs, Data True/Complement.
C14, C15	SERDOUT1−+, SERDOUT1+	Output	JTx Lane 1 Outputs, Data True/Complement.
E14, E15	SERDOUT2−, SERDOUT2+	Output	JTx Lane 2 Outputs, Data True/Complement.
G14, G15	SERDOUT3−, SERDOUT3+−	Output	JTx Lane 3 Outputs, Data True/Complement.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

Table 15. Pin Function Descriptions

Pin No.	Mnemonic	Type	Description
H17, H18	SERDOUT4−, SERDOUT4+	Output	JTx Lane 4 Outputs, Data True/Complement.
F17, F18	SERDOUT5−, SERDOUT5+	Output	JTx Lane 5 Outputs, Data True/Complement.
D17, D18	SERDOUT6−, SERDOUT6+	Output	JTx Lane 6 Outputs, Data True/Complement.
B17, B18	SERDOUT7−, SERDOUT7+	Output	JTx Lane 7 Outputs, Data True/Complement.
A13, B13	SYNC0INB−, SYNC0INB+	Input	JTx Link 0 Synchronization Inputs for JESD204B interface. The SYNCxINB± pins are LVDS or CMOS configurable and have selectable internal 100 Ω input impedance for LVDS operation
A12, B12	SYNC1INB−, SYNC1INB+	Input	JTx Link 1 Synchronization Inputs for JESD204B interface or CMOS Inputs for Receive FFH via GPIOx pins. The SYNCxINB± are LVDS or CMOS configurable and have selectable internal 100 Ω input impedance for LVDS operation.
T3, T4	SYSREFN, SYSREFP	Input	Active High JESD204 System Reference Inputs. The SYSREFx pins are configurable for differential current mode logic (CML), PECL, and LVDS with internal 100 Ω termination or single-ended CMOS.
NO CONNECTS AND DO NOT CONNECTS			
J6, K6	NC		No Connect. The NC pins can be left open or connected.
B1, C1, F1, G1, H4, L4, L15 to L18, M1, M11, M12, M14, M15, N1, N11, N12, N17, N18, P11, P13 to P15, R11, R13, R17, R18, T1, T14, T15, U1, U12, U13, U17, U18, V12 to V15	DNC	DNC	Do Not Connect. The DNC pins must be kept open.

[1] CMOS inputs do not have pull-up or pull-down resistors.

[2] SERDOUTx± include 100 Ω internal termination resistors.

TYPICAL PERFORMANCE CHARACTERISTICS

ADC

Nominal supplies, sampling rate = 4 GSPS = 12 GHz direct RF clock, full bandwidth mode operation (no decimation), T_J = 80°C (T_A = 25°C), 128k FFT sample with five averages, and A_{IN} = −1 dBFS, unless otherwise noted.

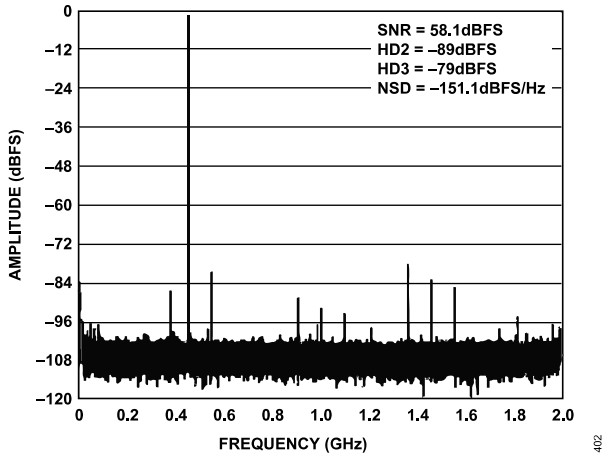

Figure 6. Single-Tone FFT at f_{IN} = 450 MHz

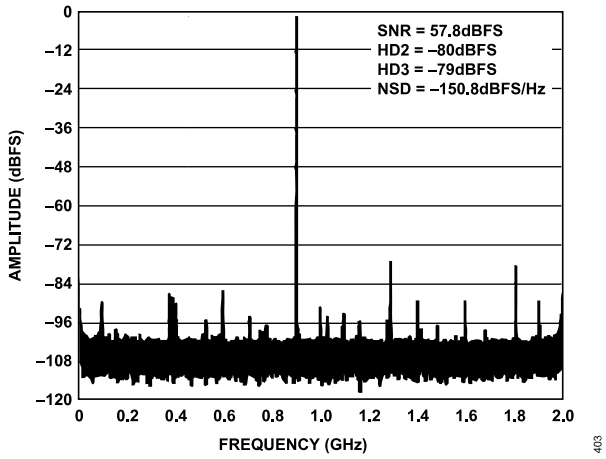

Figure 7. Single-Tone FFT at f_{IN} = 900 MHz

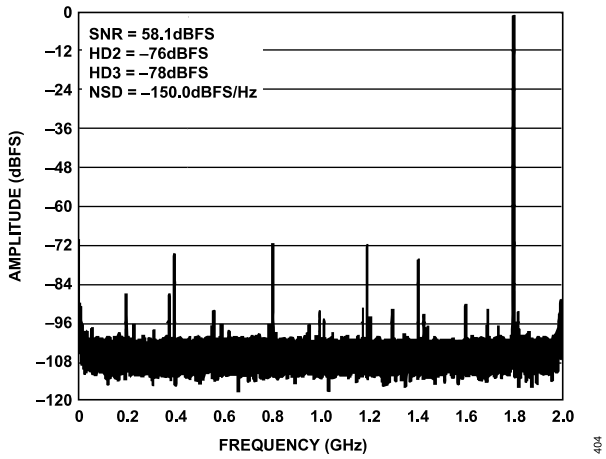

Figure 8. Single-Tone FFT at f_{IN} = 1.8 GHz

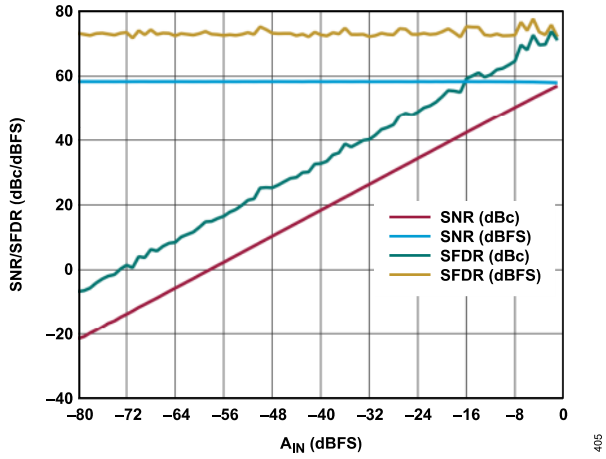

Figure 9. Single-Tone Spurious-Free Dynamic Range (SFDR) and SNR vs. A_{IN} at f_{IN} = 450 MHz

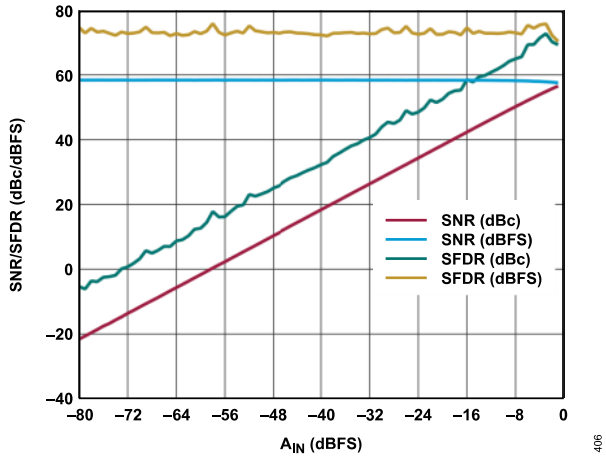

Figure 10. Single-Tone SFDR and SNR vs. Input Amplitude at f_{IN} = 900 MHz

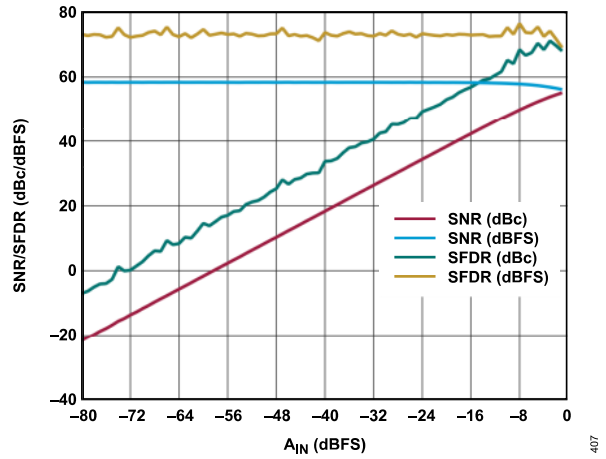

Figure 11. Single-Tone SFDR and SNR vs. A_{IN} at f_{IN} = 1.8 GHz

TYPICAL PERFORMANCE CHARACTERISTICS

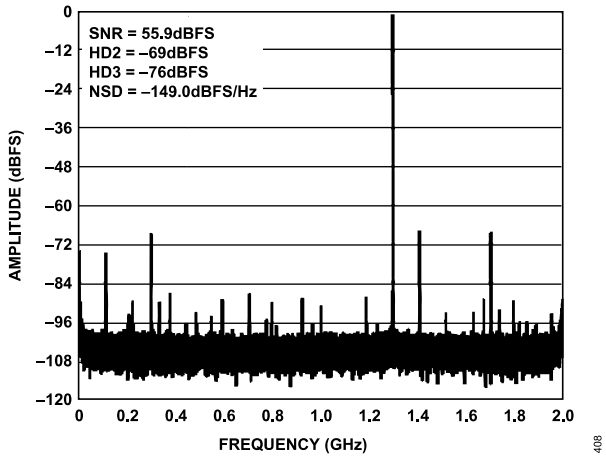

Figure 12. Single-Tone FFT at f_{IN} = 2.7 GHz

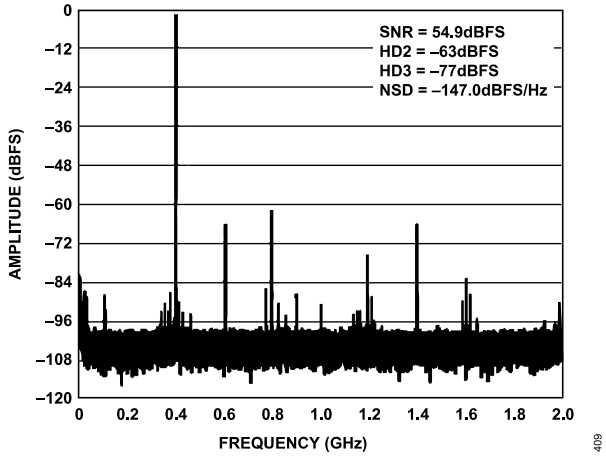

Figure 13. Single-Tone FFT at f_{IN} = 3.6 GHz

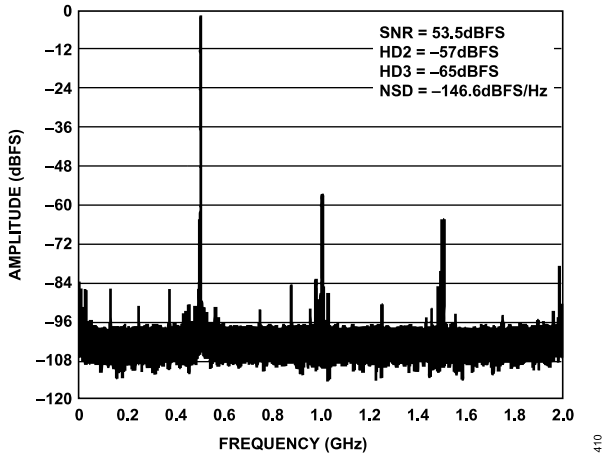

Figure 14. Single-Tone FFT at f_{IN} = 4.5 GHz

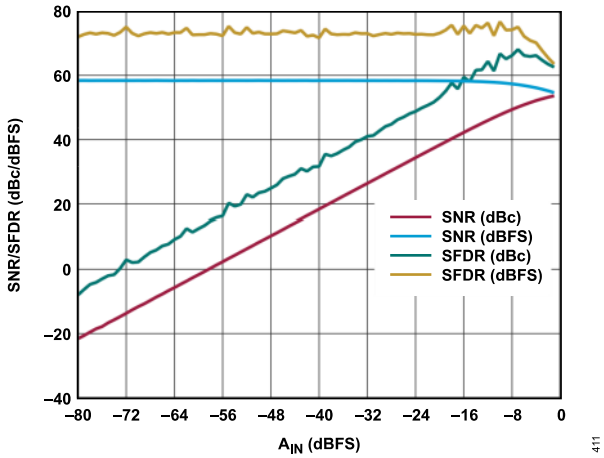

Figure 15. Single-Tone SFDR and SNR vs. A_{IN} at f_{IN} = 2.7 GHz

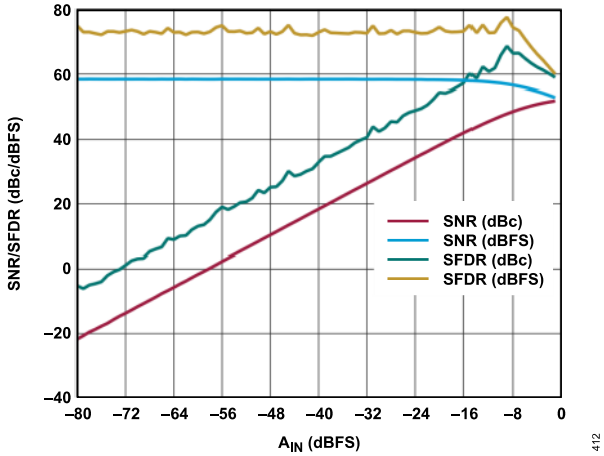

Figure 16. Single-Tone SFDR and SNR vs. A_{IN} at f_{IN} = 3.6 GHz

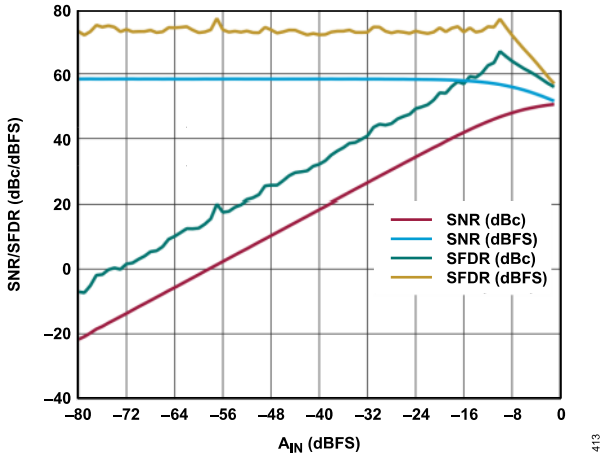

Figure 17. Single-Tone SFDR and SNR vs. A_{IN} at f_{IN} = 4.5 GHz

TYPICAL PERFORMANCE CHARACTERISTICS

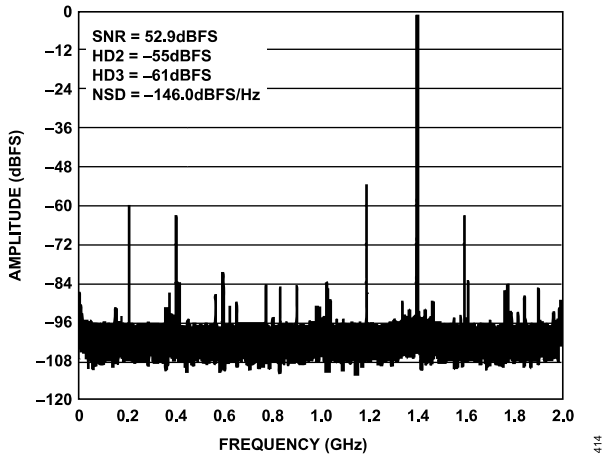

Figure 18. Single-Tone FFT at f_{IN} = 5.4 GHz

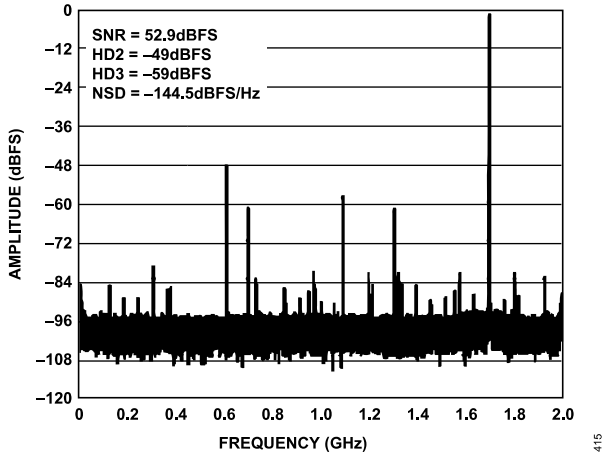

Figure 19. Single-Tone FFT at f_{IN} = 6.3 GHz

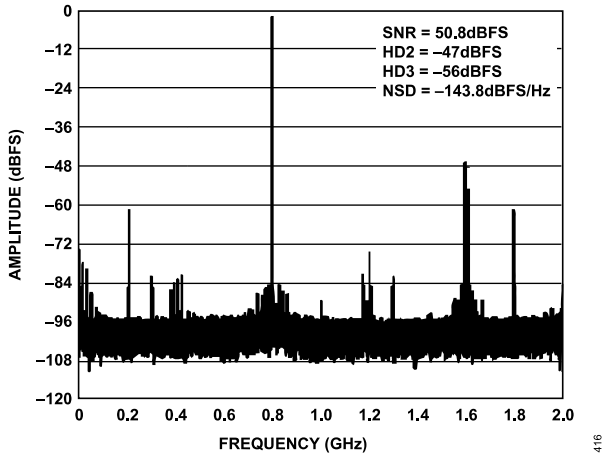

Figure 20. Single-Tone FFT at f_{IN} = 7.2 GHz

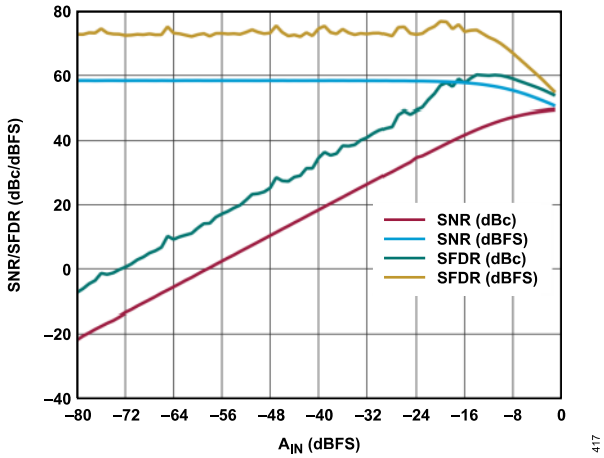

Figure 21. Single-Tone SFDR and SNR vs. A_{IN} at f_{IN} = 5.4 GHz

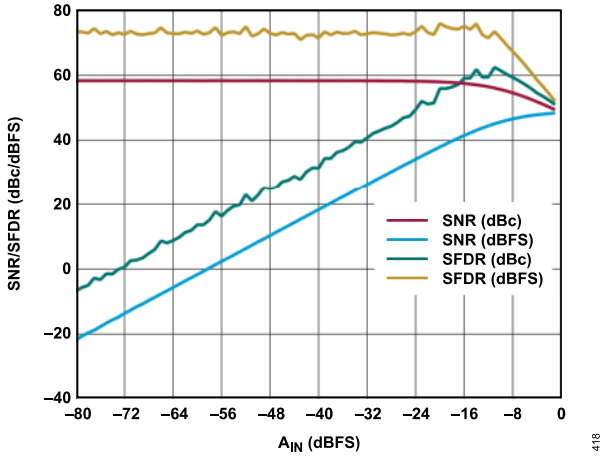

Figure 22. Single-Tone SFDR and SNR vs. A_{IN} at f_{IN} = 6.3 GHz

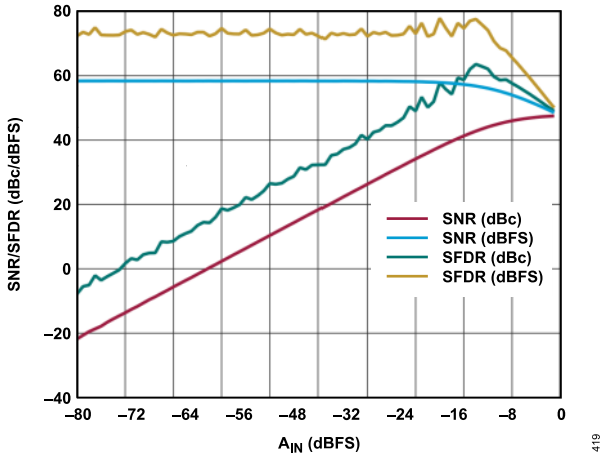

Figure 23. Single-Tone SFDR and SNR vs. A_{IN} at f_{IN} = 7.2 GHz

TYPICAL PERFORMANCE CHARACTERISTICS

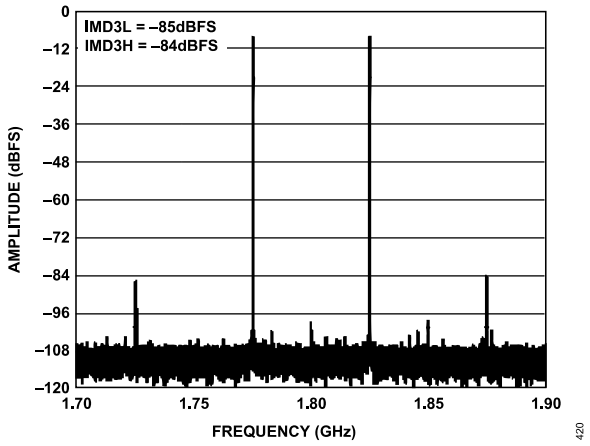

Figure 24. Two-Tone FFT, f_{IN1} = 1.775 GHz, f_{IN2} = 1.825 GHz, A_{IN1} and A_{IN2} = −7 dBFS (Note: IMD3L = $2f_{IN1} - f_{IN2}$ and IMD3H = $2f_{IN2} - f_{IN1}$, Which Are the Third-Order Intermodulation Products.)

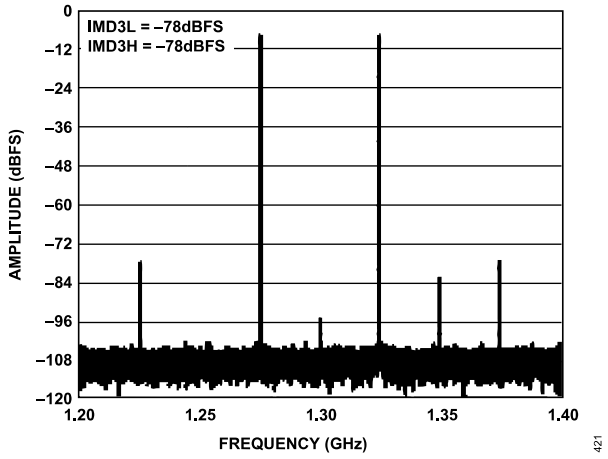

Figure 25. Two-Tone FFT, f_{IN1} = 2.675 GHz, f_{IN2} = 2.725 GHz, A_{IN1} and A_{IN2} = −7 dBFS

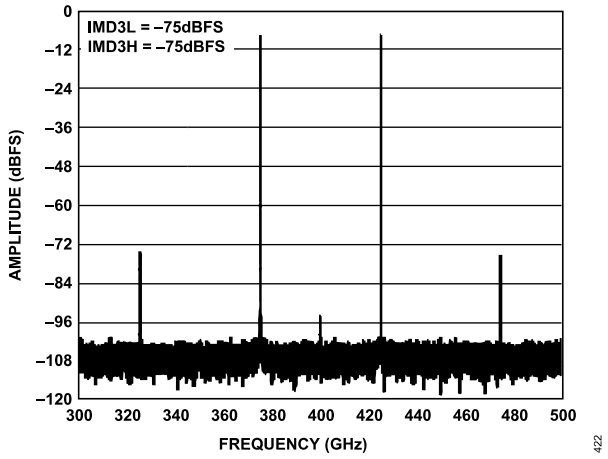

Figure 26. Two-Tone FFT, f_{IN1} = 3.575 GHz, f_{IN2} = 3.625 GHz, A_{IN1} and A_{IN2} = −7 dBFS

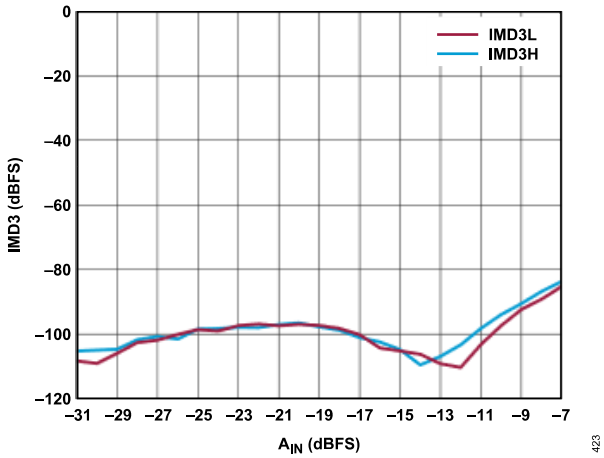

Figure 27. Two-Tone IMD3 vs. A_{IN} with f_{IN1} = 1.775 GHz, f_{IN2} = 1.825 GHz

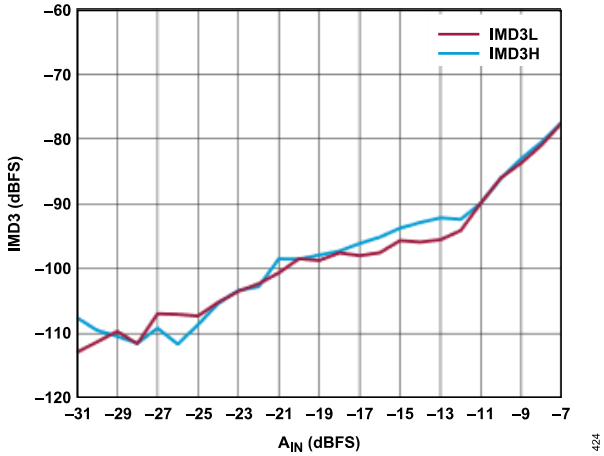

Figure 28. Two-Tone IMD3 vs. A_{IN} with f_{IN1} = 2.675 GHz, f_{IN2} = 2.725 GHz

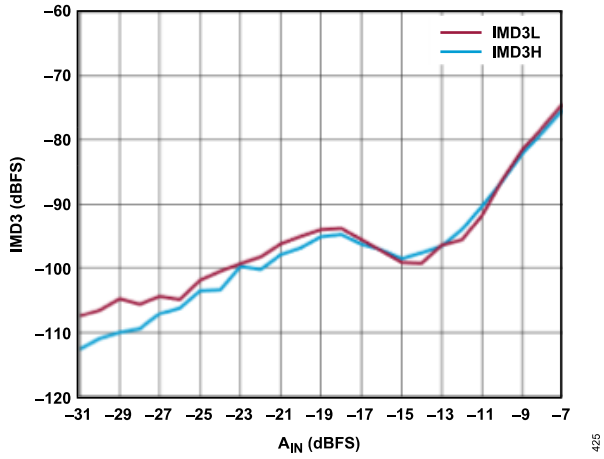

Figure 29. Two-Tone IMD3 vs. Input Amplitude with f_{IN1} = 3.575 GHz, f_{IN2} = 3.625 GHz

TYPICAL PERFORMANCE CHARACTERISTICS

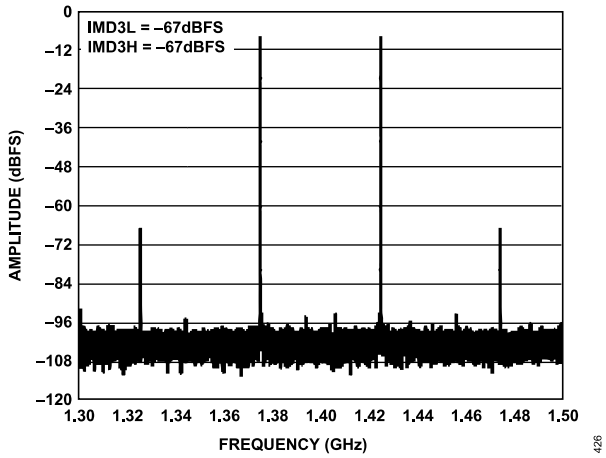

Figure 30. Two-Tone FFT, f_{IN1} = 5.375 GHz, f_{IN2} = 5.425 GHz, A_{IN1} and A_{IN2} = −7 dBFS

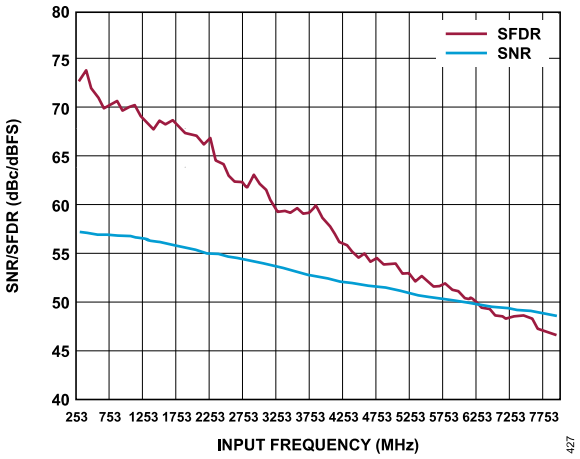

Figure 31. SNR and SFDR vs. Input Frequency with A_{IN} =−1 dBFS

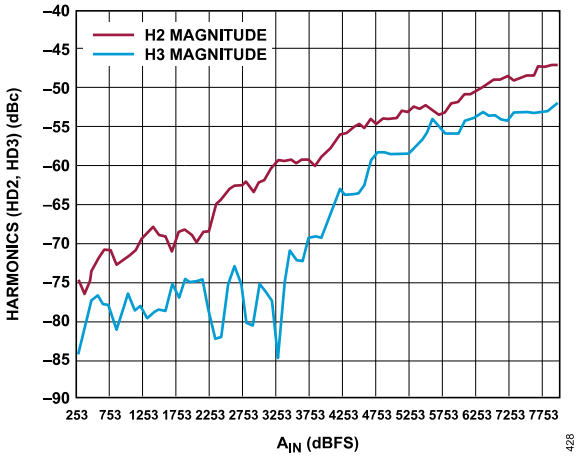

Figure 32. Harmonics (HD2, HD3) vs. Input Frequency with A_{IN} = −1 dBFS

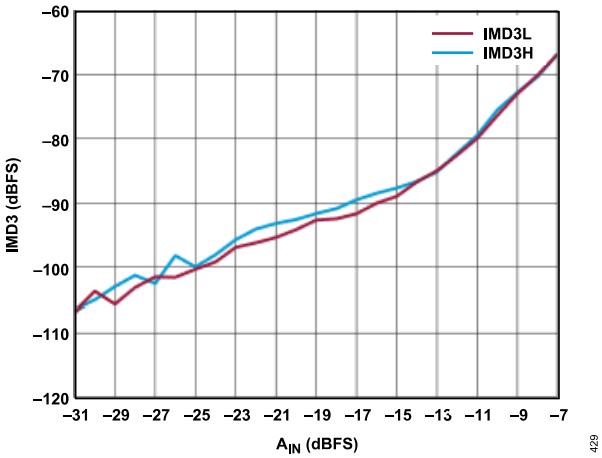

Figure 33. Two-Tone IMD3 vs. A_{IN} with f_{IN1} = 5.375 GHz, f_{IN2} = 5.425 GHz

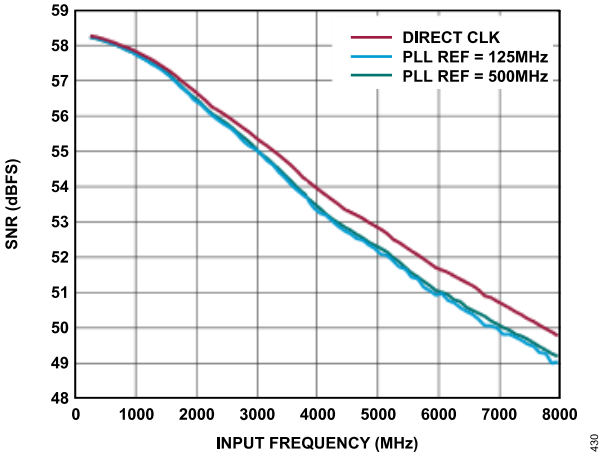

Figure 34. SNR vs. Input Frequency, Direct Clock vs. On-Chip PLL Clock, f_S = 4 GHz, A_{IN} = −1 dBFS

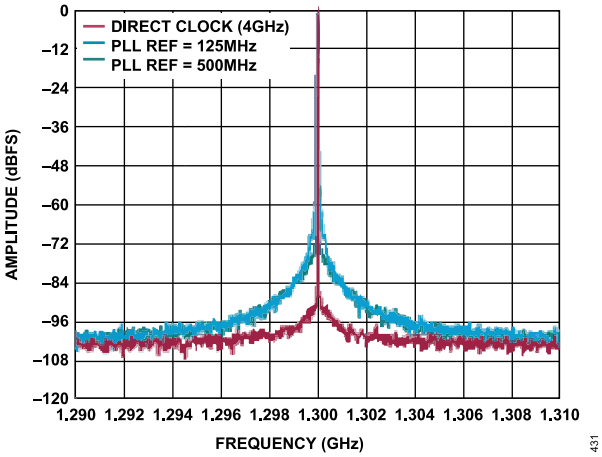

Figure 35. FFT Close-In Comparison, Direct Clock vs. On-Chip PLL Clock, f_S = 4 GHz, f_{IN} = 2.7 GHz, A_{IN} = −1 dBFS

TYPICAL PERFORMANCE CHARACTERISTICS

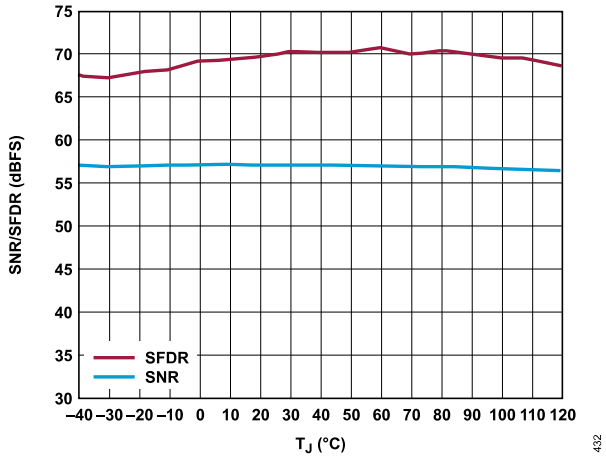

Figure 36. SNR and SFDR vs. T_J, f_{IN} = 1.85 GHz, A_{IN} = −1 dBFS

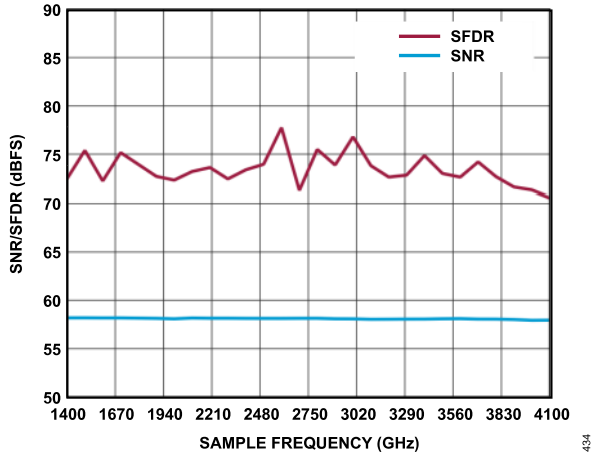

Figure 37. SNR and SFDR vs. Sample Frequency, f_{IN} = 450 MHz

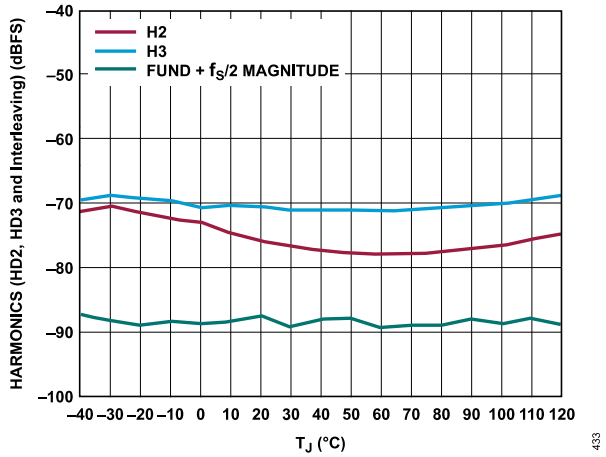

Figure 38. Harmonics (HD2, HD3, and Interleaving) vs. T_J, f_{IN} = 1.85 GHz

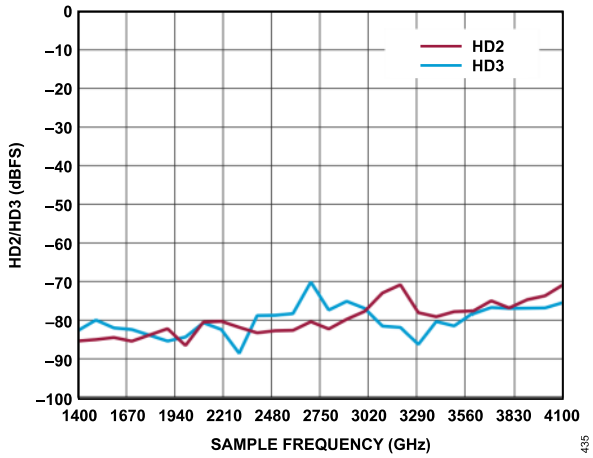

Figure 39. Harmonics (HD2 and HD3) vs. Sample Frequency, f_{IN} = 450 MHz

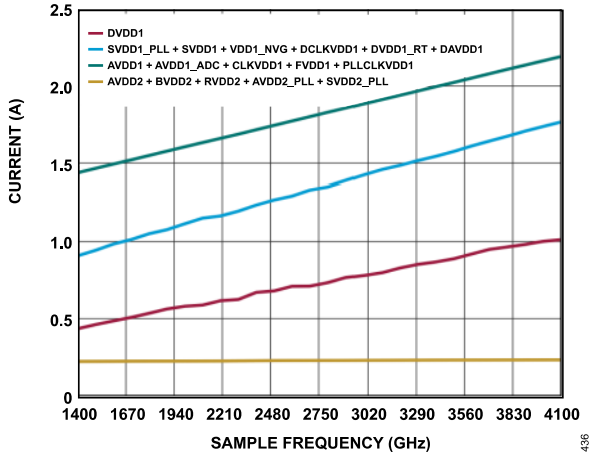

Figure 40. Current vs. Sample Frequency, f_{IN} = 3500 MHz

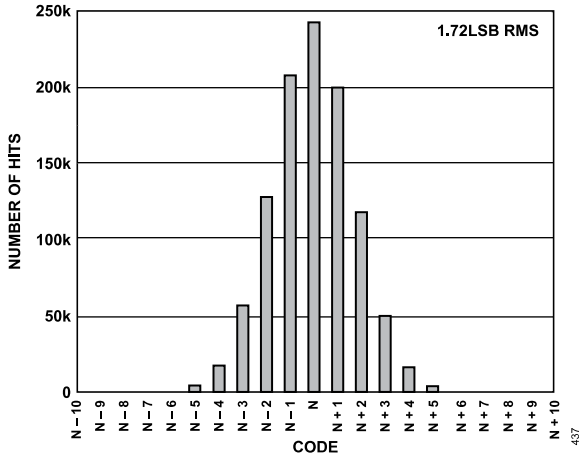

Figure 41. Input Referred Noise Histogram

TYPICAL PERFORMANCE CHARACTERISTICS

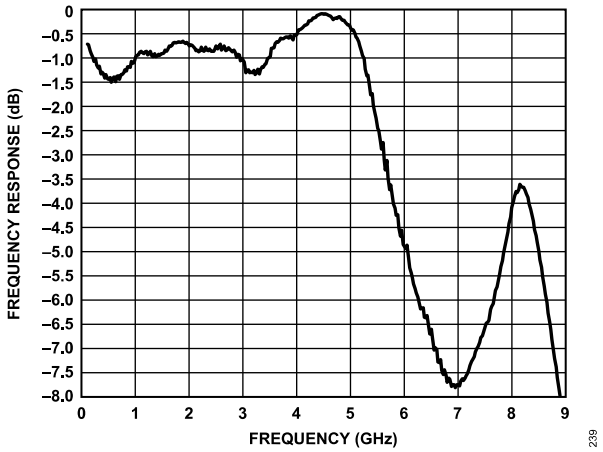

Figure 42. Measured Input Bandwidth ADC Input on AD9081-FMCA-EBZ (No Matching Network)

THEORY OF OPERATION

The AD9209 is a highly integrated, 28 nm, RF, 4-channel, 12-bit, 4 GSPS ADC (see Functional Block Diagram). To enable wide bandwidth operation, a high linearity 100 Ω differential buffer with overload protection is used to isolate the ADC core from the RF ADC driver source. An on-chip clock multiplier can be used to synthesize the RF ADC clocks or, alternatively, an external clock can be applied.

Flexible receive, DSP paths are available to downsample the desired intermediate frequency (IF) and RF signal(s) to lower the required data interface rates and efficiently align with bandwidth requirements. The channelizer datapath enables efficient data transfer to allow multiband applications where up to eight unique RF bands are supported. The receive DSP paths are symmetric and consist of four coarse DDC blocks in the main datapath along with eight fine DDC blocks in the channelizer datapath. Each DDC block includes multiple decimation stages and a 48-bit NCO configurable for integer or fractional mode of operation. The NCO in each block supports FFH, coherently, and can be controlled by using the GPIOx pins. The DDC blocks and the datapaths are fully bypassable to enable Nyquist operation.

Various auxiliary DSP features facilitate an improved system integration. The datapaths include adjustable delay lines to compensate for mismatch in channel delay paths that may occur external to the device. The receive datapath includes a flexible programmable 192-tap PFIR filter. This filter can be allocated across one or more ADCs for receive equalization with support for four different profiles. Profiles can be selected by using the GPIOx pins. The receive datapath also includes a fast and slow signal detection capability in support of the AGC. The datapaths also include features to reduce power consumption in time division duplex (TDD) applications. In addition, all the auxiliary DSP features are fully bypassable.

The data formatting of the datapaths can be real or complex (I/Q) with selectable resolutions of 8, 12, 16, and 24 bits depending on the JESD204B or the JESD204C mode.

An 8-lane JESD204 transmitter port is available to support the high data throughput rates on the receive datapaths. The transmit port supports JESD204C up to 24.75 Gbps or JESD204B up to 15.5 Gbps lane rates. The JESD204 data link layer is highly flexible, allowing to adjust the lane count (or rate) required to support a target link throughput. An external alignment signal (SYSREF) can be used to guarantee deterministic latency and phase alignment and to aid in multichip synchronization.

An on-chip TMU can be used to measure and read out the die temperature (via the SPI port), to guarantee better thermal stability during system operation.

APPLICATIONS INFORMATION

Refer to UG-1578, the device user guide, for more information on device initialization and other Applications Information.

OUTLINE DIMENSIONS

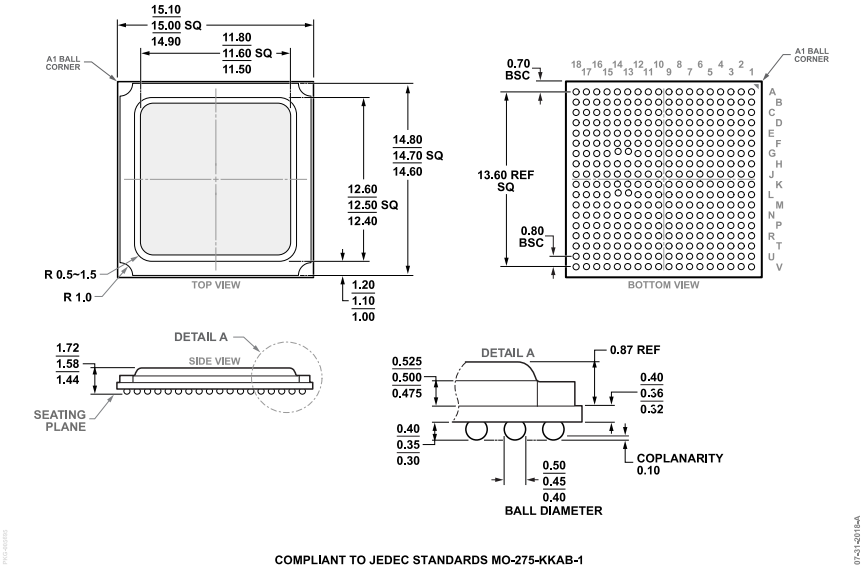

Figure 43. 324-Ball Ball Grid Array, Thermally Enhanced [BGA_ED] (BP-324-3)
Dimensions shown in millimeters

Updated: April 14, 2021

ORDERING GUIDE

Model[1]	Temperature Range	Package Description	Packing Quantity	Package Option
AD9209BBPZ-4G	−40°C to +120°C	324-Ball BGA_ED (15 mm × 15 mm × 1.58 mm)	Tray, 126	BP-324-3
AD9209BBPZRL-4G	−40°C to +120°C	324-Ball BGA_ED (15 mm × 15 mm × 1.58 mm)	Reel, 1000	BP-324-3

[1] Z = RoHS Compliant Part.

EVALUATION BOARDS

Model[1]	Description
AD9081-FMCA-EBZ	AD9081 Evaluation Board with High Performance Analog Network

[1] The AD9081-FMCA-EBZ is used to evaluate the AD9209.

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