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Dual, 14-Bit, 80 MSPS/125 MSPS, Serial LVDS 1.8 V Analog-to-Digital Converter

Data Sheet **AD9645**

FEATURES

- 1.8 V supply operation
- Low power: 122 mW per channel at 125 MSPS with scalable power options
- SNR = 74 dBFS (to Nyquist)
- SFDR = 91 dBc at 70 MHz
- DNL = ±0.65 LSB (typical); INL = ±1.5 LSB (typical)
- Serial LVDS (ANSI-644, default) and low power, reduced range option (similar to IEEE 1596.3)
- 650 MHz full power analog bandwidth
- 2 V p-p input voltage range
- Serial port control
  - Full chip and individual channel power-down modes
  - Flexible bit orientation
  - Built-in and custom digital test pattern generation
  - Clock divider
  - Programmable output clock and data alignment
  - Programmable output resolution
  - Standby mode

APPLICATIONS

- Communications
- Diversity radio systems
- Multimode digital receivers
- GSM, EDGE, W-CDMA, LTE, CDMA2000, WiMAX, TD-SCDMA
- I/Q demodulation systems
- Smart antenna systems
- Broadband data applications
- Battery-powered instruments
- Handheld scope meters
- Portable medical imaging and ultrasound
- Radar/LIDAR

GENERAL DESCRIPTION

The AD9645 is a dual, 14-bit, 80 MSPS/125 MSPS analog-to-digital converter (ADC) with an on-chip sample-and-hold circuit designed for low cost, low power, small size, and ease of use. The product operates at a conversion rate of up to 125 MSPS and is optimized for outstanding dynamic performance and low power in applications where a small package size is critical.

The ADC requires a single 1.8 V power supply and LVPECL-/CMOS-/LVDS-compatible sample rate clock for full performance operation. No external reference or driver components are required for many applications.

FUNCTIONAL BLOCK DIAGRAM

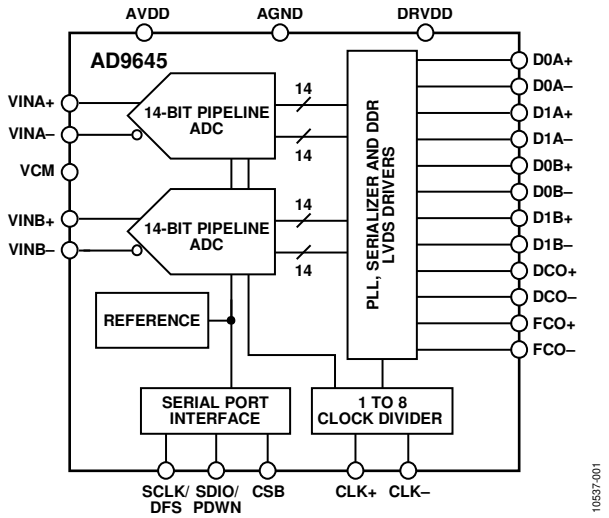

Figure 1.

The ADC automatically multiplies the sample rate clock for the appropriate LVDS serial data rate. A data clock output (DCO) for capturing data on the output and a frame clock output (FCO) for signaling a new output byte are provided. Individual channel power-down is supported; the AD9645 typically consumes less than 2 mW in the full power-down state. The ADC provides several features designed to maximize flexibility and minimize system cost, such as programmable output clock and data alignment and digital test pattern generation. The available digital test patterns include built-in deterministic and pseudorandom patterns, along with custom user-defined test patterns entered via the serial port interface (SPI).

The AD9645 is available in a RoHS-compliant, 32-lead LFCSP. It is specified over the industrial temperature range of −40°C to +85°C.

PRODUCT HIGHLIGHTS

1. Small Footprint. Two ADCs are contained in a small, space-saving package.
2. Low Power. The AD9645 uses 122 mW/channel at 125 MSPS with scalable power options.
3. Pin Compatibility with the AD9635, a 12-Bit Dual ADC.
4. Ease of Use. A data clock output (DCO) operates at frequencies of up to 500 MHz and supports double data rate (DDR) operation.
5. User Flexibility. SPI control offers a wide range of flexible features to meet specific system requirements.

Rev. B
Document Feedback

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781.329.4700
Technical Support www.analog.com

AD9645* PRODUCT PAGE QUICK LINKS

Last Content Update: 02/23/2017

COMPARABLE PARTS

View a parametric search of comparable parts.

EVALUATION KITS

- AD9645 Evaluation Board

DOCUMENTATION

Application Notes

- AN-1142: Techniques for High Speed ADC PCB Layout
- AN-501: Aperture Uncertainty and ADC System Performance
- AN-737: How ADIsimADC Models an ADC
- AN-742: Frequency Domain Response of Switched-Capacitor ADCs
- AN-756: Sampled Systems and the Effects of Clock Phase Noise and Jitter
- AN-807: Multicarrier WCDMA Feasibility
- AN-808: Multicarrier CDMA2000 Feasibility
- AN-827: A Resonant Approach to Interfacing Amplifiers to Switched-Capacitor ADCs
- AN-835: Understanding High Speed ADC Testing and Evaluation
- AN-878: High Speed ADC SPI Control Software
- AN-905: Visual Analog Converter Evaluation Tool Version 1.0 User Manual
- AN-935: Designing an ADC Transformer-Coupled Front End

Data Sheet

- AD9645: Dual, 14-Bit, 80 MSPS/125 MSPS, Serial LVDS 1.8 V Analog-to-Digital Converter

User Guides

- AD9655/AD9645/AD9635 Evaluation Documentation

TOOLS AND SIMULATIONS

- Visual Analog
- AD9645 IBIS Model
- AD9645 S-Parameter

REFERENCE MATERIALS

Press

- Analog Devices' Dual 14-bit A/D Converter Reduces Power and Size in Communications, Instrumentation, Test and Measurement Applications

Technical Articles

- MS-2210: Designing Power Supplies for High Speed ADC

DESIGN RESOURCES

- AD9645 Material Declaration
- PCN-PDN Information
- Quality And Reliability
- Symbols and Footprints

DISCUSSIONS

View all AD9645 EngineerZone Discussions.

SAMPLE AND BUY

Visit the product page to see pricing options.

TECHNICAL SUPPORT

Submit a technical question or find your regional support number.

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TABLE OF CONTENTS

REVISION HISTORY

10/15—Rev. A to Rev. B

Changed AD9516 to AD9516-0/AD9516-1/AD9516-2/AD9516-3/AD9516-4/AD9516-5, and AD9517 to AD9517-0/AD9517-1/AD9517-2/AD9517-3/AD9517-4 ... Throughout
Changes to General Description ... 1
Added Endnote 4, Table 4 ... 6
Changes to Digital Outputs and Timing Section ... 24

8/14—Rev. 0 to Rev. A

Added Propagation Delay Parameters of 1.5 ns (min) and 3.1 ns (max), Table 4 ... 6
Changes to Figure 3 ... 7
Changes to Figure 5 ... 8
Changes to Pin 21 Description ... 11
Changes to Voltage Reference Section ... 20
Changes to Table 10 and Table 11 ... 25
Changes to First Paragraph of Serial Port Interface (SPI) Section ... 27
Changes to SPI Accessible Features Section ... 28
Changes to Output Phase (Register 0x16) Bits[6:4]—Input Clock Phase Adjust Section ... 33
Changes to Resolution/Sample Rate Override (Register 0x100) Section and User I/O Control 3 (Register 0x102) Bit 3—VCM Power-Down Section ... 34
Added Clock Stability Considerations Section ... 35

6/12—Revision 0: Initial Version

SPECIFICATIONS

DC SPECIFICATIONS

AVDD = 1.8 V, DRVDD = 1.8 V, 2 V p-p differential input, 1.0 V internal reference, AIN = −1.0 dBFS, unless otherwise noted.

Table 1.

		AD9645-80			AD9645-125			
Parameter[1]	**Temp**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Unit**
RESOLUTION		14			14			Bits
ACCURACY								
No Missing Codes	Full		Guaranteed			Guaranteed		
Offset Error	Full	−0.6	−0.2	+0.1	−0.6	−0.2	+0.2	% FSR
Offset Matching	Full	−0.2	+0.1	+0.4	−0.2	+0.1	+0.4	% FSR
Gain Error	Full	−4.3	−1.0	+2.2	−5.1	−1.5	+2.3	% FSR
Gain Matching	Full		0.5	2.2		0.6	2.6	% FSR
Differential Nonlinearity (DNL)	Full	−0.6		+1.3	−0.6		+1.3	LSB
	25°C		±0.65			±0.65		LSB
Integral Nonlinearity (INL)	Full	−2.6		+2.8	−3.6		+3.4	LSB
	25°C		±1.1			±1.5		LSB
TEMPERATURE DRIFT								
Offset Error	Full		2.7			3.3		ppm/°C
INTERNAL VOLTAGE REFERENCE								
Output Voltage (1 V Mode)	Full	0.98	1.0	1.02	0.98	1.0	1.02	V
Load Regulation at 1.0 mA (V_{REF} = 1 V)	25°C		2			2		mV
Input Resistance	25°C		7.5			7.5		kΩ
INPUT-REFERRED NOISE								
V_{REF} = 1.0 V	25°C		0.95			1.0		LSB rms
ANALOG INPUTS								
Differential Input Voltage (V_{REF} = 1 V)	Full		2			2		V p-p
Common-Mode Voltage	Full		0.9			0.9		V
Common-Mode Range	25°C	0.5		1.3	0.5		1.3	V
Differential Input Resistance	25°C		5.2			5.2		kΩ
Differential Input Capacitance	25°C		3.5			3.5		pF
POWER SUPPLY								
AVDD	Full	1.7	1.8	1.9	1.7	1.8	1.9	V
DRVDD	Full	1.7	1.8	1.9	1.7	1.8	1.9	V
I_{AVDD}[2]	Full		56	61		78	83	mA
I_{DRVDD} (ANSI-644 Mode)[2]	Full		48	50		57	60	mA
I_{DRVDD} (Reduced Range Mode)[2]	25°C		39			48		mA
TOTAL POWER CONSUMPTION								
DC Input	Full		178	191		227	244	mW
Sine Wave Input (Two Channels; Includes Output Drivers in ANSI-644 Mode)	Full		187	200		243	257	mW
Sine Wave Input (Two Channels; Includes Output Drivers in Reduced Range Mode)	25°C		171			227		mW
Power-Down	25°C		2			2		mW
Standby[3]	Full		92	101		115	126	mW

[1] See the AN-835 Application Note, *Understanding High Speed ADC Testing and Evaluation*, for definitions and for details on how these tests were completed.
[2] Measured with a low input frequency, full-scale sine wave on both channels.
[3] Can be controlled via the SPI.

AC SPECIFICATIONS

AVDD = 1.8 V, DRVDD = 1.8 V, 2 V p-p differential input, 1.0 V internal reference, AIN = −1.0 dBFS, unless otherwise noted.

Table 2.

		AD9645-80			AD9645-125			
Parameter[1]	**Temp**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Unit**
SIGNAL-TO-NOISE RATIO (SNR)								
f_{IN} = 9.7 MHz	25°C		75.6			75.2		dBFS
f_{IN} = 30.5 MHz	25°C		75.4			75.0		dBFS
f_{IN} = 70 MHz	Full	73.1	74.5		72.8	74.3		dBFS
f_{IN} = 139.5 MHz	25°C		72.1			72.5		dBFS
f_{IN} = 200.5 MHz	25°C		70.0			70.3		dBFS
SIGNAL-TO-NOISE-AND-DISTORTION RATIO (SINAD)								
f_{IN} = 9.7 MHz	25°C		75.6			75.1		dBFS
f_{IN} = 30.5 MHz	25°C		75.2			75.0		dBFS
f_{IN} = 70 MHz	Full	72.7	74.4		72.4	74.2		dBFS
f_{IN} = 139.5 MHz	25°C		71.7			72.4		dBFS
f_{IN} = 200.5 MHz	25°C		69.7			70.0		dBFS
EFFECTIVE NUMBER OF BITS (ENOB)								
f_{IN} = 9.7 MHz	25°C		12.3			12.2		Bits
f_{IN} = 30.5 MHz	25°C		12.2			12.2		Bits
f_{IN} = 70 MHz	Full	11.8	12.1		11.7	12.0		Bits
f_{IN} = 139.5 MHz	25°C		11.6			11.7		Bits
f_{IN} = 200.5 MHz	25°C		11.3			11.3		Bits
SPURIOUS-FREE DYNAMIC RANGE (SFDR)								
f_{IN} = 9.7 MHz	25°C		96			93		dBc
f_{IN} = 30.5 MHz	25°C		91			97		dBc
f_{IN} = 70 MHz	Full	82	96		82	91		dBc
f_{IN} = 139.5 MHz	25°C		82			91		dBc
f_{IN} = 200.5 MHz	25°C		82			81		dBc
WORST HARMONIC (SECOND OR THIRD)								
f_{IN} = 9.7 MHz	25°C		−96			−93		dBc
f_{IN} = 30.5 MHz	25°C		−91			−97		dBc
f_{IN} = 70 MHz	Full		−96	−83		−91	−82	dBc
f_{IN} = 139.5 MHz	25°C		−82			−93		dBc
f_{IN} = 200.5 MHz	25°C		−82			−81		dBc
WORST OTHER HARMONIC OR SPUR								
f_{IN} = 9.7 MHz	25°C		−99			−96		dBc
f_{IN} = 30.5 MHz	25°C		−97			−99		dBc
f_{IN} = 70 MHz	Full		−99	−82		−96	−84	dBc
f_{IN} = 139.5 MHz	25°C		−93			−91		dBc
f_{IN} = 200.5 MHz	25°C		−91			−87		dBc
TWO-TONE INTERMODULATION DISTORTION (IMD)—AIN1 AND AIN2 = −7.0 dBFS								
f_{IN1} = 70.5 MHz, f_{IN2} = 72.5 MHz	25°C		−93			−93		dBc
CROSSTALK[2]	25°C		−97			−97		dB
CROSSTALK (OVERRANGE CONDITION)[3]	25°C		−97			−97		dB
POWER SUPPLY REJECTION RATIO (PSRR)[4]								
AVDD	25°C		42			42		dB
DRVDD	25°C		67			67		dB
ANALOG INPUT BANDWIDTH, FULL POWER	25°C		650			650		MHz

[1] See the AN-835 Application Note, *Understanding High Speed ADC Testing and Evaluation*, for definitions and for details on how these tests were completed.
[2] Crosstalk is measured at 70 MHz with −1.0 dBFS analog input on one channel and no input on the adjacent channel.
[3] Overrange condition is specified with 3 dB of the full-scale input range.
[4] PSRR is measured by injecting a sinusoidal signal at 10 MHz to the power supply pin and measuring the output spur on the FFT. PSRR is calculated as the ratio of the amplitude of the spur voltage over the amplitude of the pin voltage, expressed in decibels (dB).

DIGITAL SPECIFICATIONS

AVDD = 1.8 V, DRVDD = 1.8 V, 2 V p-p differential input, 1.0 V internal reference, AIN = −1.0 dBFS, unless otherwise noted.

Table 3.

Parameter[1]	Temp	Min	Typ	Max	Unit
CLOCK INPUTS (CLK+, CLK−)					
Logic Compliance			CMOS/LVDS/LVPECL		
Differential Input Voltage[2]	Full	0.2		3.6	V p-p
Input Voltage Range	Full	AGND − 0.2		AVDD + 0.2	V
Input Common-Mode Voltage	Full		0.9		V
Input Resistance (Differential)	25°C		15		kΩ
Input Capacitance	25°C		4		pF
LOGIC INPUT (SCLK/DFS)					
Logic 1 Voltage	Full	1.2		AVDD + 0.2	V
Logic 0 Voltage	Full	0		0.8	V
Input Resistance	25°C		30		kΩ
Input Capacitance	25°C		2		pF
LOGIC INPUT (CSB)					
Logic 1 Voltage	Full	1.2		AVDD + 0.2	V
Logic 0 Voltage	Full	0		0.8	V
Input Resistance	25°C		26		kΩ
Input Capacitance	25°C		2		pF
LOGIC INPUT (SDIO/PDWN)					
Logic 1 Voltage	Full	1.2		AVDD + 0.2	V
Logic 0 Voltage	Full	0		0.8	V
Input Resistance	25°C		26		kΩ
Input Capacitance	25°C		5		pF
LOGIC OUTPUT (SDIO/PDWN)[3]					
Logic 1 Voltage (I_{OH} = 800 µA)	Full		1.79		V
Logic 0 Voltage (I_{OL} = 50 µA)	Full			0.05	V
DIGITAL OUTPUTS (D0x±, D1x±), ANSI-644					
Logic Compliance			LVDS		
Differential Output Voltage Magnitude (V_{OD})	Full	290	345	400	mV
Output Offset Voltage (V_{OS})	Full	1.15	1.25	1.35	V
Output Coding (Default)			Twos complement		
DIGITAL OUTPUTS (D0x±, D1x±), LOW POWER, REDUCED SIGNAL OPTION					
Logic Compliance			LVDS		
Differential Output Voltage Magnitude (V_{OD})	Full	160	200	230	mV
Output Offset Voltage (V_{OS})	Full	1.15	1.25	1.35	V
Output Coding (Default)			Twos complement		

[1] See the AN-835 Application Note, *Understanding High Speed ADC Testing and Evaluation*, for definitions and for details on how these tests were completed.
[2] Specified for LVDS and LVPECL only.
[3] Specified for 13 SDIO/PDWN pins sharing the same connection.

SWITCHING SPECIFICATIONS

AVDD = 1.8 V, DRVDD = 1.8 V, 2 V p-p differential input, 1.0 V internal reference, AIN = −1.0 dBFS, unless otherwise noted.

Table 4.

Parameter[1, 2]	Temp	Min	Typ	Max	Unit
CLOCK[3]					
Input Clock Rate	Full	10		1000	MHz
Conversion Rate[4]	Full	10		80/125	MSPS
Clock Pulse Width High (t_{EH})	Full		6.25/4.00		ns
Clock Pulse Width Low (t_{EL})	Full		6.25/4.00		ns
OUTPUT PARAMETERS[3]					
Propagation Delay (t_{PD})	Full	1.5	2.3	3.1	ns
Rise Time (t_R) (20% to 80%)	Full		300		ps
Fall Time (t_F) (20% to 80%)	Full		300		ps
FCO Propagation Delay (t_{FCO})	Full	1.5	2.3	3.1	ns
DCO Propagation Delay (t_{CPD})[5]	Full		$t_{FCO} + (t_{SAMPLE}/16)$		ns
DCO to Data Delay (t_{DATA})[5]	Full	$(t_{SAMPLE}/16) - 300$	$t_{SAMPLE}/16$	$(t_{SAMPLE}/16) + 300$	ps
DCO to FCO Delay (t_{FRAME})[5]	Full	$(t_{SAMPLE}/16) - 300$	$t_{SAMPLE}/16$	$(t_{SAMPLE}/16) + 300$	ps
Lane Delay (t_{LD})			90		ps
Data-to-Data Skew ($t_{DATA-MAX} - t_{DATA-MIN}$)	Full		±50	±200	ps
Wake-Up Time (Standby)	25°C		250		ns
Wake-Up Time (Power-Down)[6]	25°C		375		µs
Pipeline Latency	Full		16		Clock cycles
APERTURE					
Aperture Delay (t_A)	25°C		1		ns
Aperture Uncertainty (Jitter, t_J)	25°C		174		fs rms
Out-of-Range Recovery Time	25°C		1		Clock cycles

[1] See the AN-835 Application Note, *Understanding High Speed ADC Testing and Evaluation*, for definitions and for details on how these tests were completed.
[2] Measured on standard FR-4 material.
[3] Can be adjusted via the SPI. The conversion rate is the clock rate after the divider.
[4] The maximum conversion rate is based on two-lane output mode. See the Digital Outputs and Timing section for the maximum conversion rate in one-lane output mode.
[5] $t_{SAMPLE}/16$ is based on the number of bits in two LVDS data lanes. $t_{SAMPLE} = 1/f_S$.
[6] Wake-up time is defined as the time required to return to normal operation from power-down mode.

TIMING SPECIFICATIONS

Table 5.

Parameter	Description	Limit	Unit
SPI TIMING REQUIREMENTS	See Figure 68		
t_{DS}	Setup time between the data and the rising edge of SCLK	2	ns min
t_{DH}	Hold time between the data and the rising edge of SCLK	2	ns min
t_{CLK}	Period of the SCLK	40	ns min
t_S	Setup time between CSB and SCLK	2	ns min
t_H	Hold time between CSB and SCLK	2	ns min
t_{HIGH}	SCLK pulse width high	10	ns min
t_{LOW}	SCLK pulse width low	10	ns min
t_{EN_SDIO}	Time required for the SDIO pin to switch from an input to an output relative to the SCLK falling edge (not shown in Figure 68)	10	ns min
t_{DIS_SDIO}	Time required for the SDIO pin to switch from an output to an input relative to the SCLK rising edge (not shown in Figure 68)	10	ns min

Timing Diagrams

Refer to the Memory Map Register Descriptions section and Table 20 for SPI register settings.

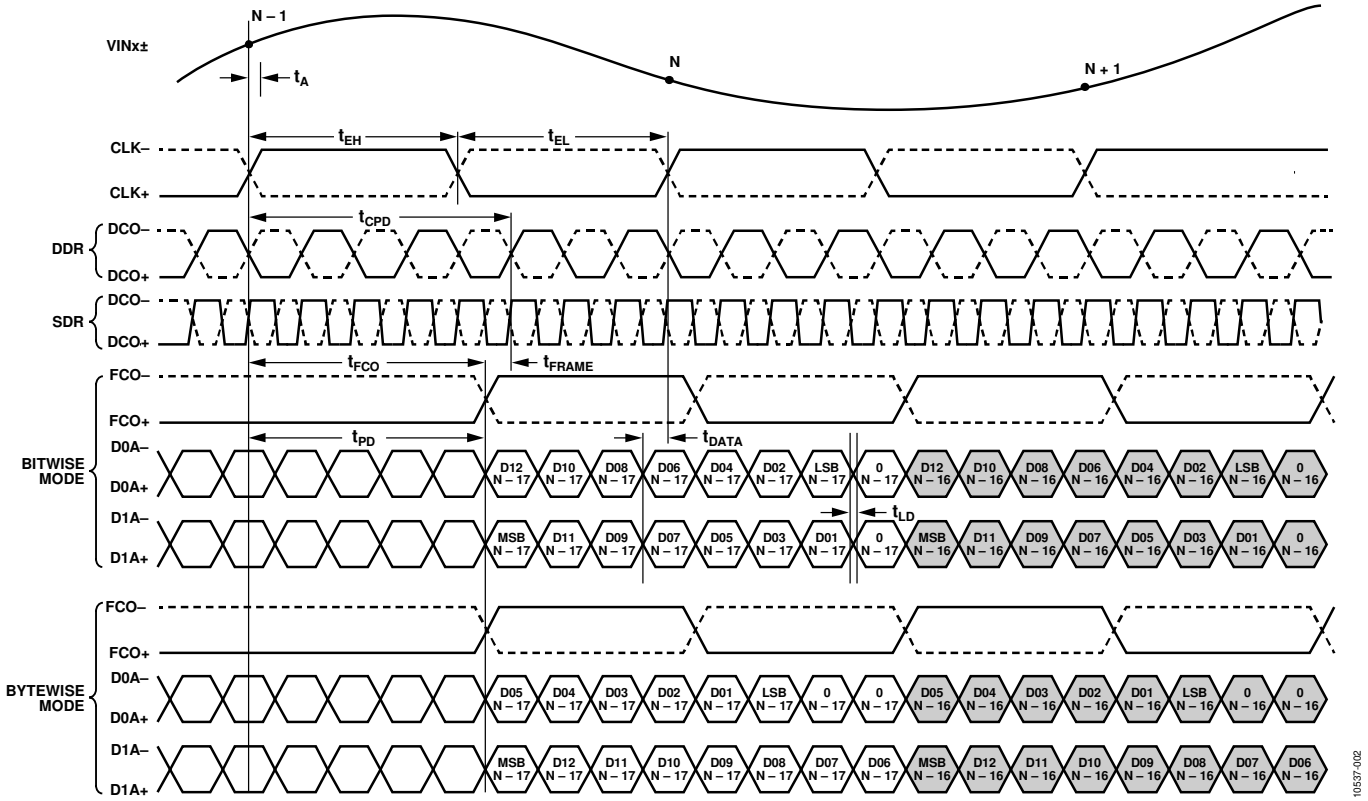

Figure 2. 16-Bit DDR/SDR, Two-Lane, 1× Frame Mode (Default)

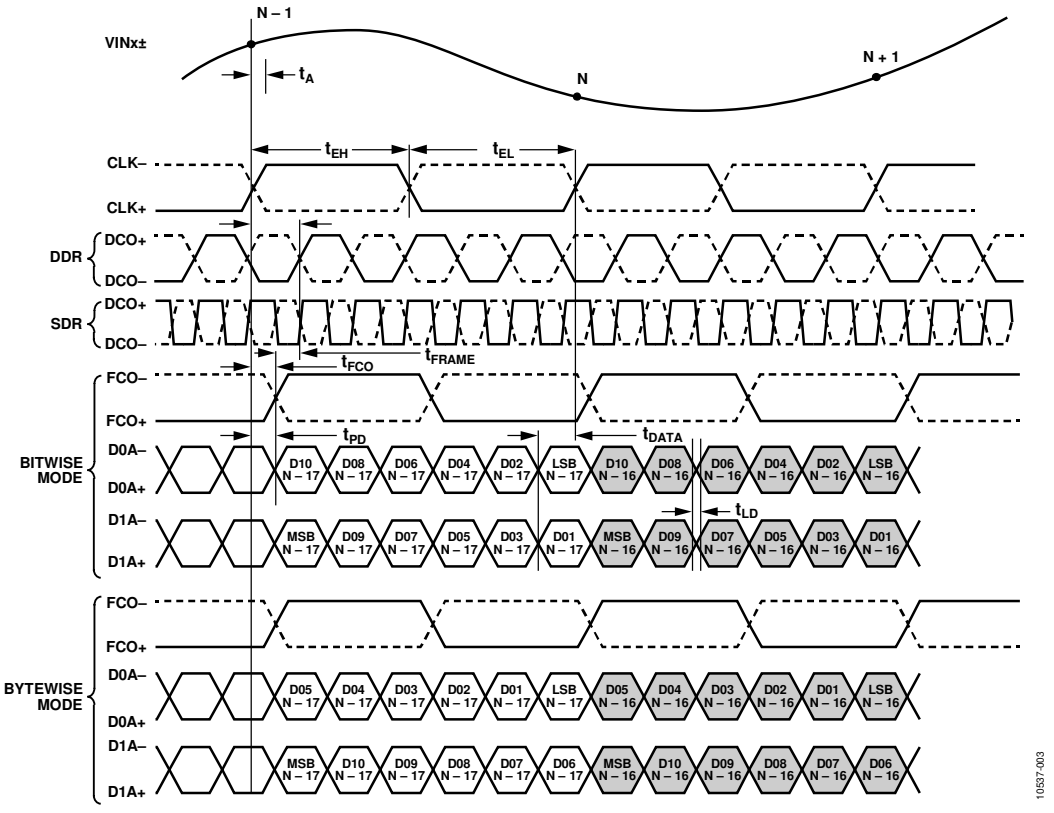

Figure 3. 12-Bit DDR/SDR, Two-Lane, 1× Frame Mode

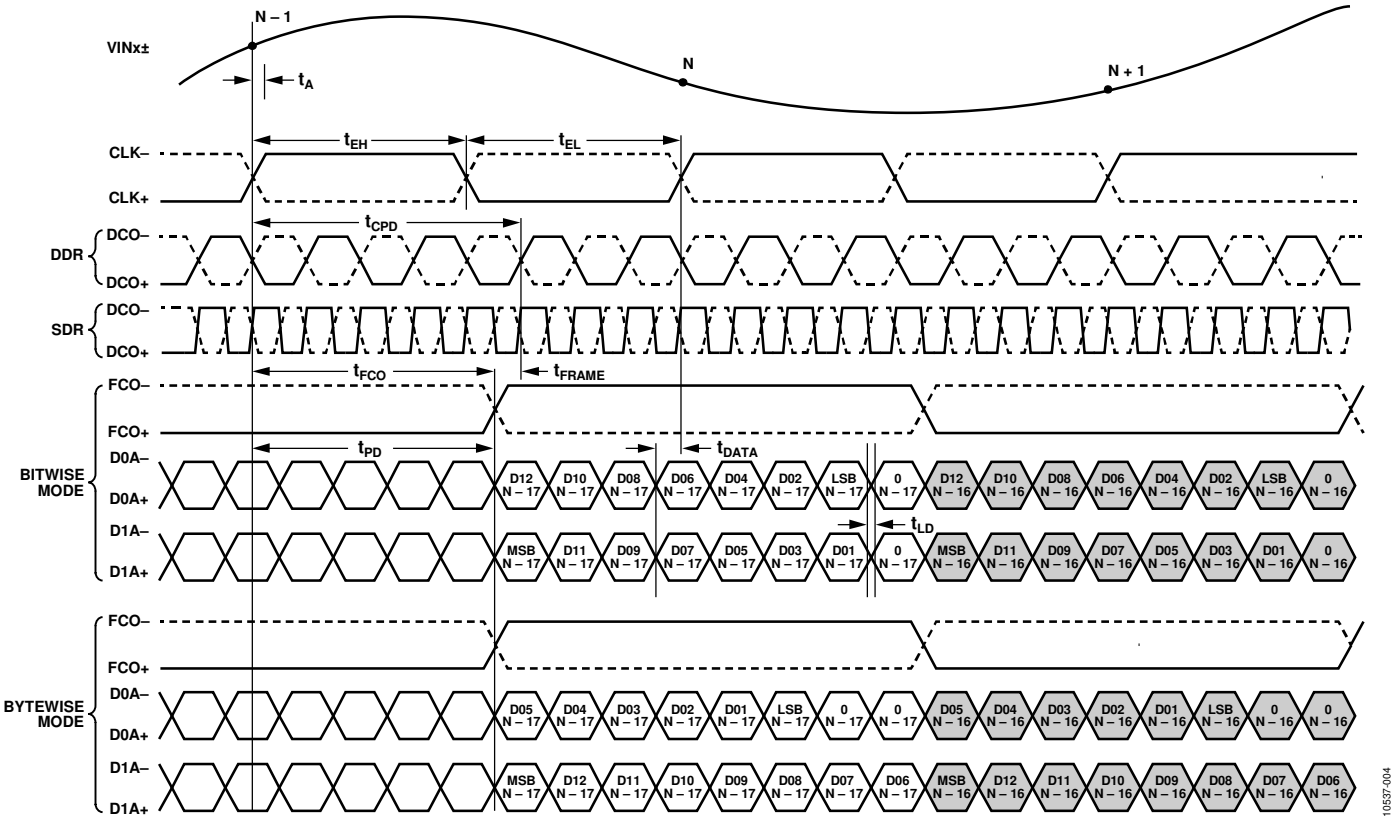

Figure 4. 16-Bit DDR/SDR, Two-Lane, 2× Frame Mode

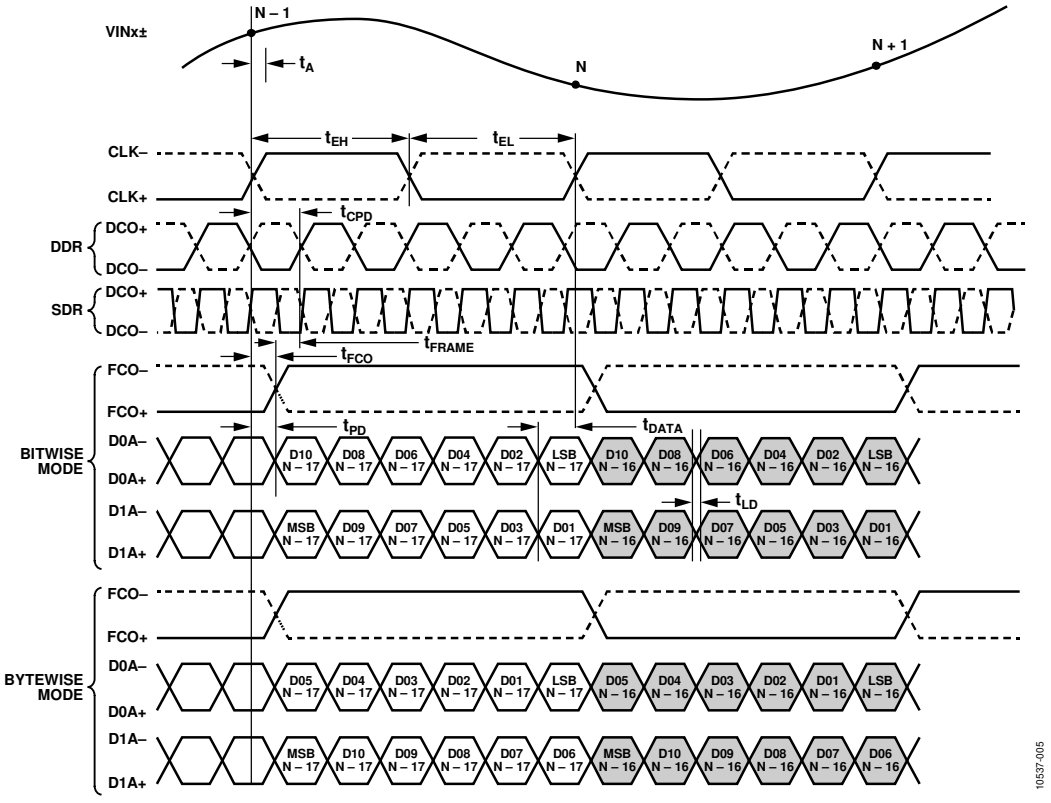

Figure 5. 12-Bit DDR/SDR, Two-Lane, 2× Frame Mode

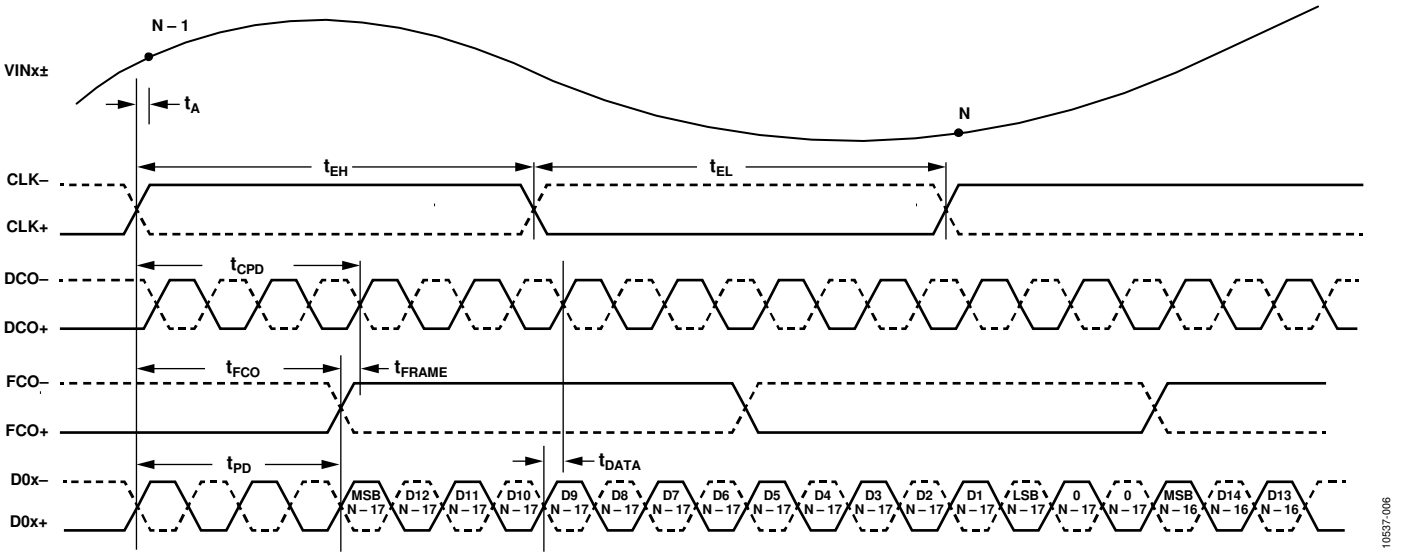

Figure 6. Wordwise DDR, One-Lane, 1× Frame, 16-Bit Output Mode

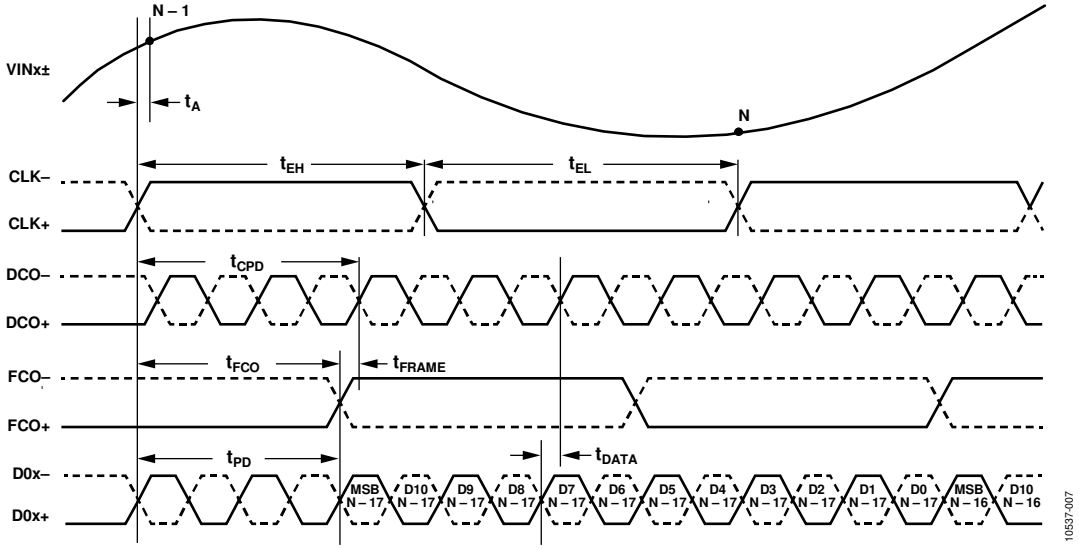

Figure 7. Wordwise DDR, One-Lane, 1× Frame, 12-Bit Output Mode

ABSOLUTE MAXIMUM RATINGS

Table 6.

Parameter	Rating
Electrical	
AVDD to AGND	−0.3 V to +2.0 V
DRVDD to AGND	−0.3 V to +2.0 V
Digital Outputs to AGND (D0x±, D1x±, DCO+, DCO−, FCO+, FCO−)	−0.3 V to +2.0 V
CLK+, CLK− to AGND	−0.3 V to +2.0 V
VINx+, VINx− to AGND	−0.3 V to +2.0 V
SCLK/DFS, SDIO/PDWN, CSB to AGND	−0.3 V to +2.0 V
RBIAS to AGND	−0.3 V to +2.0 V
VREF to AGND	−0.3 V to +2.0 V
VCM to AGND	−0.3 V to +2.0 V
Environmental	
Operating Temperature Range (Ambient)	−40°C to +85°C
Maximum Junction Temperature	150°C
Lead Temperature (Soldering, 10 sec)	300°C
Storage Temperature Range (Ambient)	−65°C to +150°C

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

The exposed paddle is the only ground connection on the chip. The exposed paddle must be soldered to the AGND plane of the user's circuit board. Soldering the exposed paddle to the user's board also increases the reliability of the solder joints and maximizes the thermal capability of the package.

Table 7. Thermal Resistance

Package Type	Airflow Velocity (m/sec)	θ_{JA} [1, 2]	θ_{JC} [1, 3]	θ_{JB} [1, 4]	Ψ_{JT} [1, 2]	Unit
32-Lead LFCSP, 5 mm × 5 mm	0	37.1	3.1	20.7	0.3	°C/W
	1.0	32.4			0.5	°C/W
	2.5	29.1			0.8	°C/W

[1] Per JEDEC JESD51-7, plus JEDEC JESD51-5 2S2P test board.
[2] Per JEDEC JESD51-2 (still air) or JEDEC JESD51-6 (moving air).
[3] Per MIL-STD 883, Method 1012.1.
[4] Per JEDEC JESD51-8 (still air).

Typical θ_{JA} is specified for a 4-layer PCB with a solid ground plane. As shown in Table 7, airflow improves heat dissipation, which reduces θ_{JA}. In addition, metal in direct contact with the package leads from metal traces, through holes, ground, and power planes reduces the θ_{JA}.

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

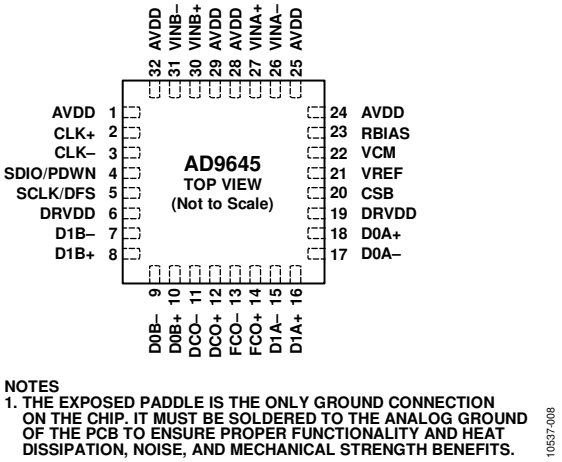

Figure 8. Pin Configuration, Top View

Table 8. Pin Function Descriptions

Pin No.	Mnemonic	Description
0	AGND, Exposed Pad	The exposed paddle is the only ground connection on the chip. It must be soldered to the analog ground of the PCB to ensure proper functionality and heat dissipation, noise, and mechanical strength benefits.
1, 24, 25, 28, 29, 32	AVDD	1.8 V Supply Pins for ADC Analog Core Domain.
2, 3	CLK+, CLK–	Differential Encode Clock for LVPECL, LVDS, or 1.8 V CMOS Inputs.
4	SDIO/PDWN	Data Input/Output in SPI Mode (SDIO). Bidirectional SPI data I/O with 30 kΩ internal pull-down. Power-Down in Non-SPI Mode (PDWN). Static control of chip power-down with 30 kΩ internal pull-down.
5	SCLK/DFS	SPI Clock Input in SPI Mode (SCLK). 30 kΩ internal pull-down. Data Format Select in Non-SPI Mode (DFS). Static control of data output format with 30 kΩ internal pull-down. DFS high = twos complement output; DFS low = offset binary output.
6, 19	DRVDD	1.8 V Supply Pins for Output Driver Domain.
7, 8	D1B–, D1B+	Channel B Digital Outputs.
9, 10	D0B–, D0B+	Channel B Digital Outputs.
11, 12	DCO–, DCO+	Data Clock Outputs.
13, 14	FCO–, FCO+	Frame Clock Outputs.
15, 16	D1A–, D1A+	Channel A Digital Outputs.
17, 18	D0A–, D0A+	Channel A Digital Outputs.
20	CSB	SPI Chip Select. Active low enable with 15 kΩ internal pull-up.
21	VREF	1.0 V Voltage Reference Output.
22	VCM	Analog Output Voltage at Mid AVDD Supply. Sets the common-mode voltage of the analog inputs.
23	RBIAS	Sets the analog current bias. Connect this pin to a 10 kΩ (1% tolerance) resistor to ground.
26, 27	VINA–, VINA+	Channel A ADC Analog Inputs.
30, 31	VINB+, VINB–	Channel B ADC Analog Inputs.

TYPICAL PERFORMANCE CHARACTERISTICS

AD9645-80

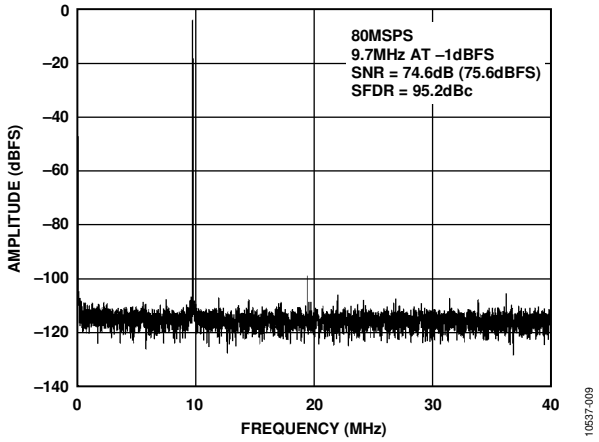

Figure 9. Single-Tone 16k FFT with f_{IN} = 9.7 MHz, f_{SAMPLE} = 80 MSPS

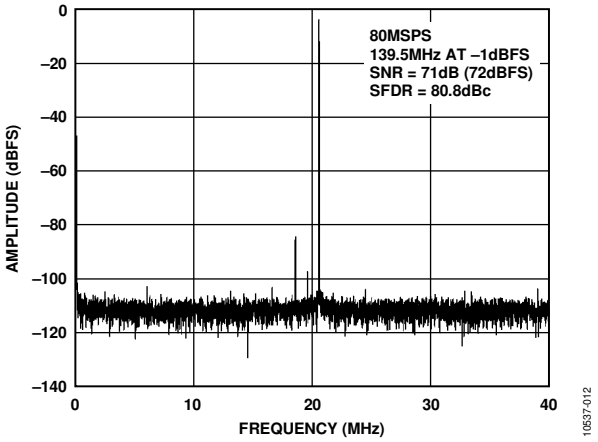

Figure 12. Single-Tone 16k FFT with f_{IN} = 139.5 MHz, f_{SAMPLE} = 80 MSPS

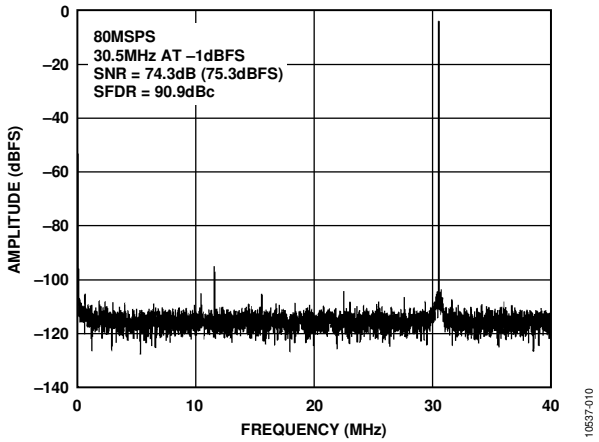

Figure 10. Single-Tone 16k FFT with f_{IN} = 30.5 MHz, f_{SAMPLE} = 80 MSPS

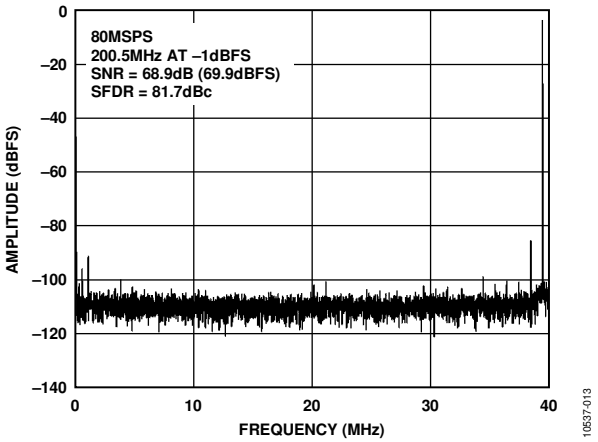

Figure 13. Single-Tone 16k FFT with f_{IN} = 200.5 MHz, f_{SAMPLE} = 80 MSPS

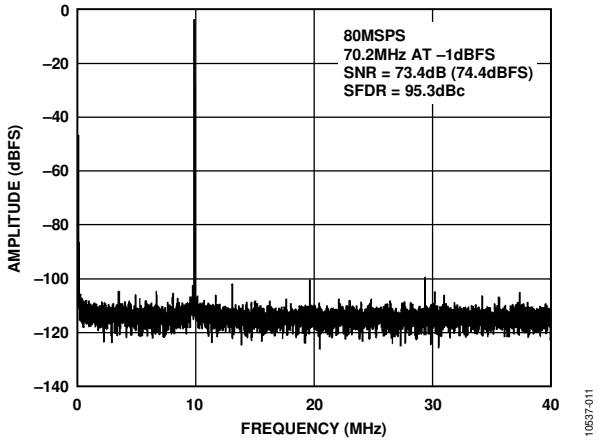

Figure 11. Single-Tone 16k FFT with f_{IN} = 70.2 MHz, f_{SAMPLE} = 80 MSPS

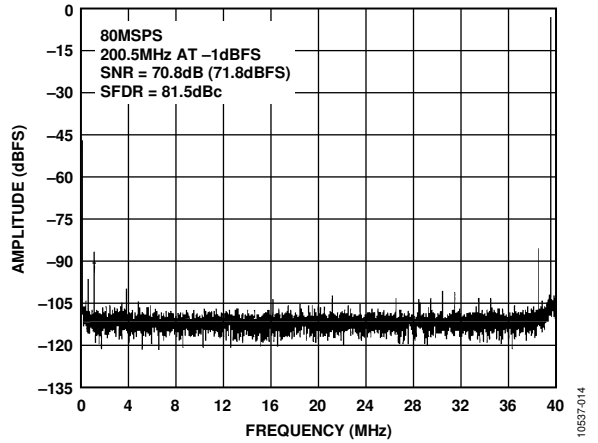

Figure 14. Single-Tone 16k FFT with f_{IN} = 200.5 MHz, f_{SAMPLE} = 80 MSPS, Clock Divide = Divide-by-8

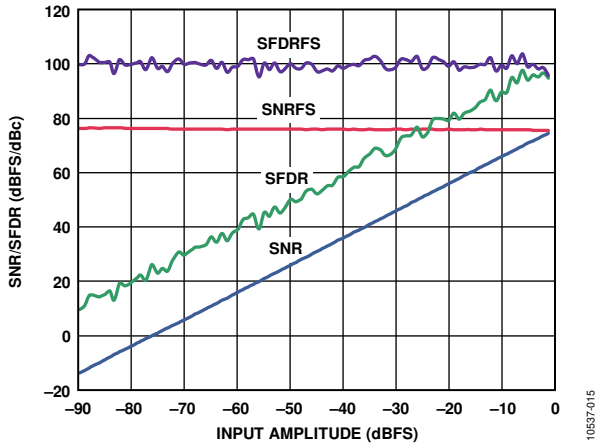

Figure 15. SNR/SFDR vs. Analog Input Level; f_{IN} = 9.7 MHz, f_{SAMPLE} = 80 MSPS

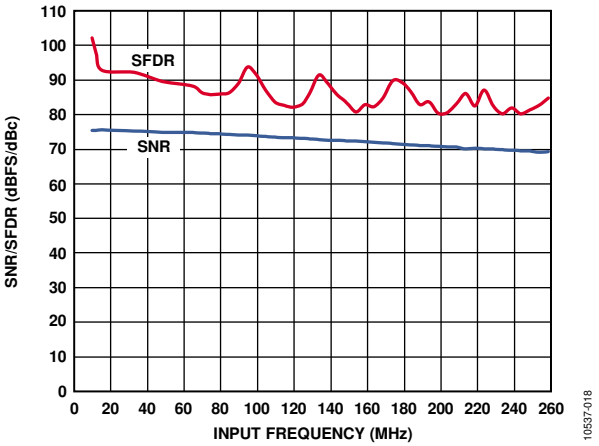

Figure 18. SNR/SFDR vs. f_{IN}; f_{SAMPLE} = 80 MSPS

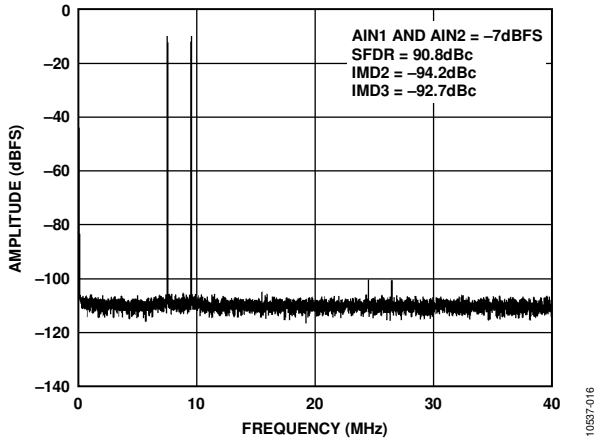

Figure 16. Two-Tone 16k FFT with f_{IN1} = 70.5 MHz and f_{IN2} = 72.5 MHz, f_{SAMPLE} = 80 MSPS

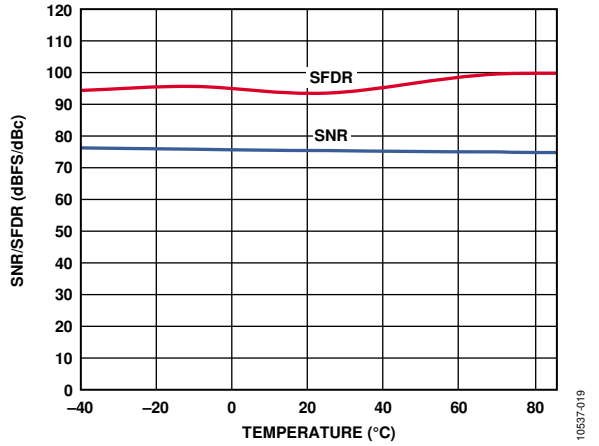

Figure 19. SNR/SFDR vs. Temperature; f_{IN} = 9.7 MHz, f_{SAMPLE} = 80 MSPS

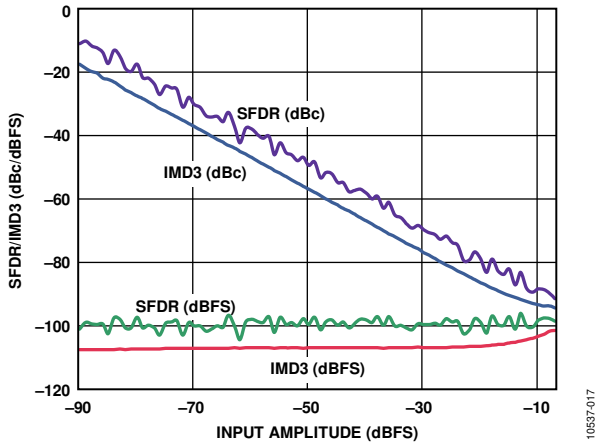

Figure 17. Two-Tone SFDR/IMD3 vs. Input Amplitude (AIN) with f_{IN1} = 70.5 MHz and f_{IN2} = 72.5 MHz, f_{SAMPLE} = 80 MSPS

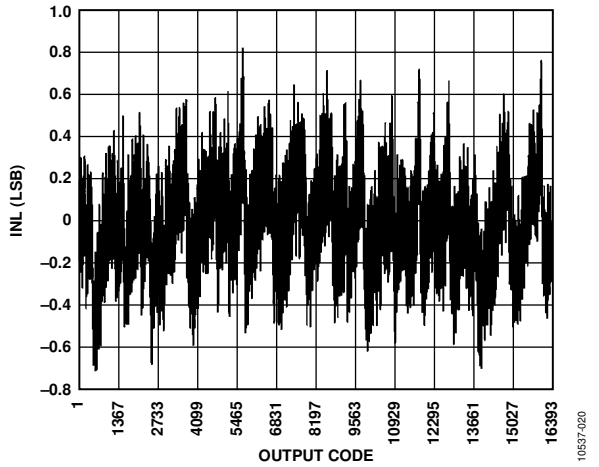

Figure 20. INL; f_{IN} = 9.7 MHz, f_{SAMPLE} = 80 MSPS

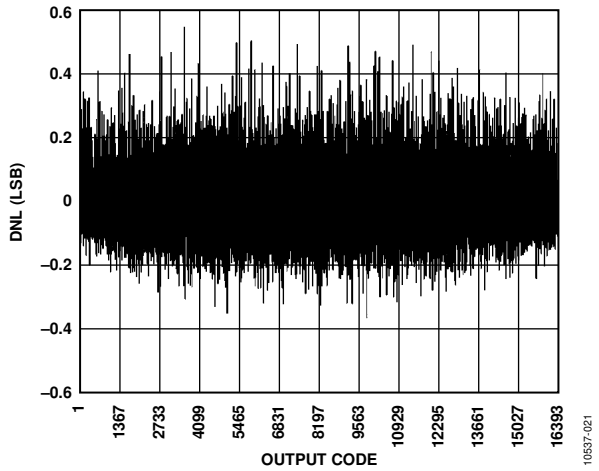

Figure 21. DNL; f_{IN} = 9.7 MHz, f_{SAMPLE} = 80 MSPS

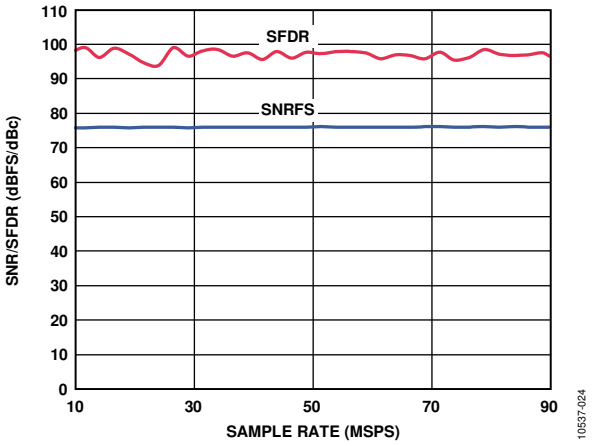

Figure 24. SNR/SFDR vs. Sample Rate; f_{IN} = 9.7 MHz, f_{SAMPLE} = 80 MSPS

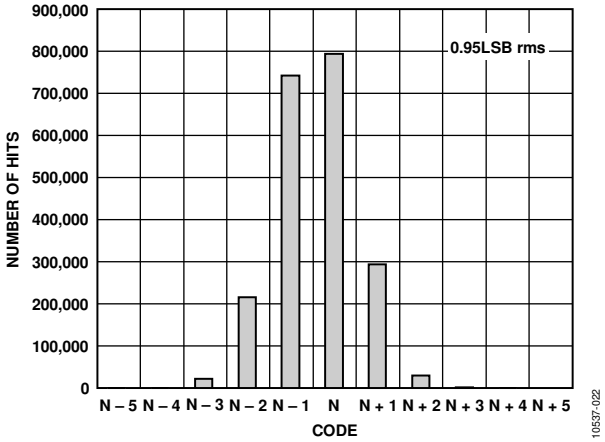

Figure 22. Input Referred Noise Histogram; f_{SAMPLE} = 80 MSPS

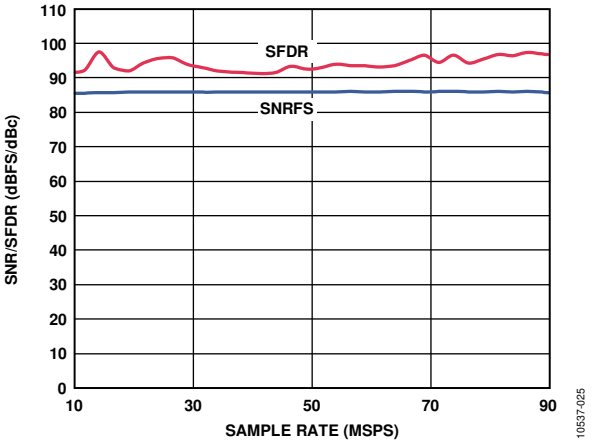

Figure 25. SNR/SFDR vs. Sample Rate; f_{IN} = 70 MHz, f_{SAMPLE} = 80 MSPS

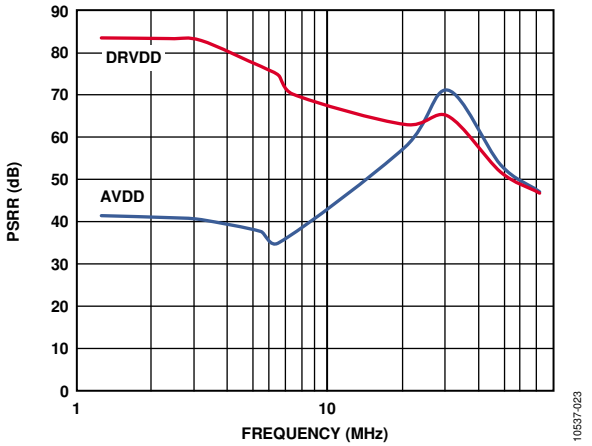

Figure 23. PSRR vs. Frequency; f_{CLK} = 125 MHz, f_{SAMPLE} = 80 MSPS

AD9645-125

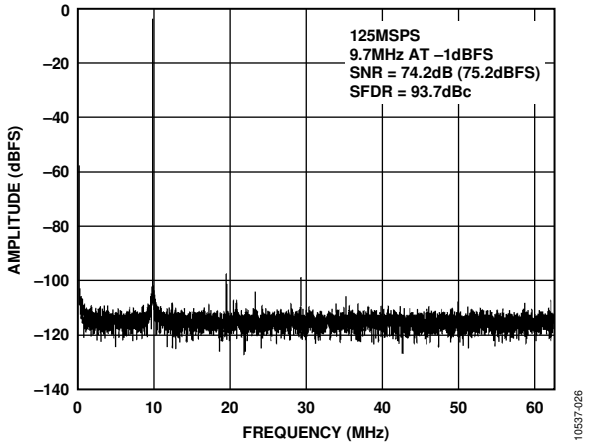

Figure 26. Single-Tone 16k FFT with f_{IN} = 9.7 MHz, f_{SAMPLE} = 125 MSPS

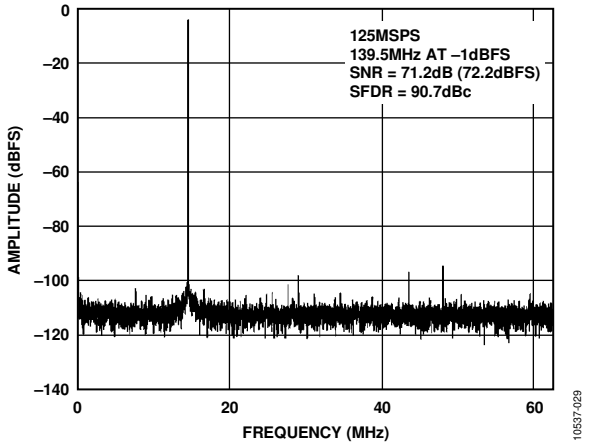

Figure 29. Single-Tone 16k FFT with f_{IN} = 139.5 MHz, f_{SAMPLE} = 125 MSPS

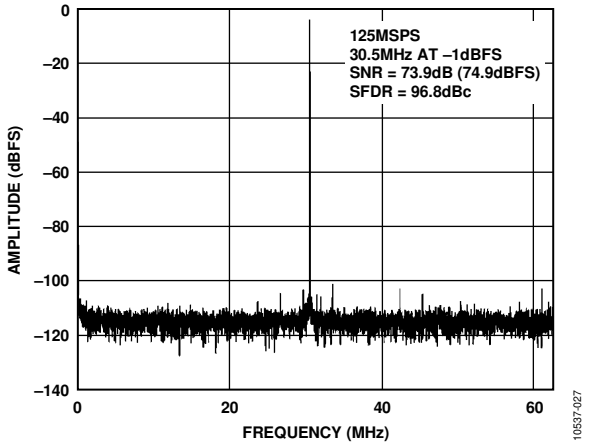

Figure 27. Single-Tone 16k FFT with f_{IN} = 30.5 MHz, f_{SAMPLE} = 125 MSPS

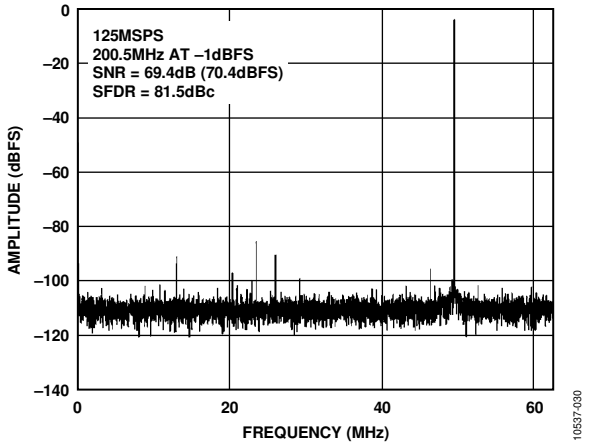

Figure 30. Single-Tone 16k FFT with f_{IN} = 200.5 MHz, f_{SAMPLE} = 125 MSPS

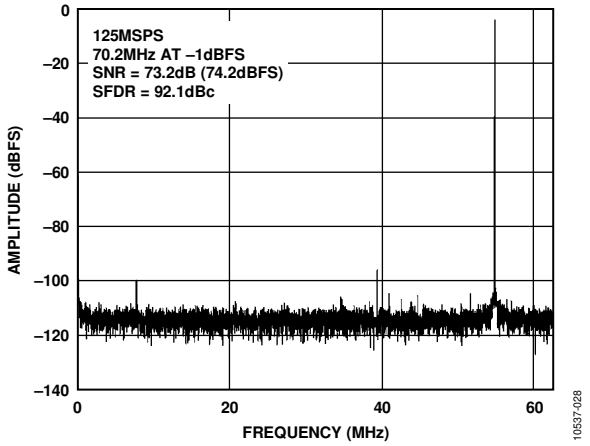

Figure 28. Single-Tone 16k FFT with f_{IN} = 70.2 MHz, f_{SAMPLE} = 125 MSPS

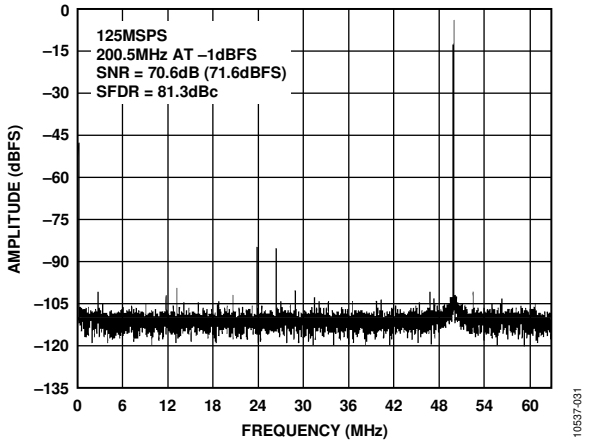

Figure 31. Single-Tone 16k FFT with f_{IN} = 200.5 MHz, f_{SAMPLE} = 125 MSPS, Clock Divide = Divide-by-8

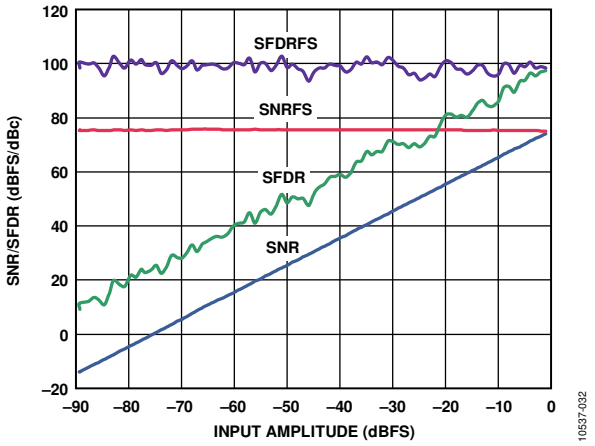

Figure 32. SNR/SFDR vs. Analog Input Level; f_{IN} = 9.7 MHz, f_{SAMPLE} = 125 MSPS

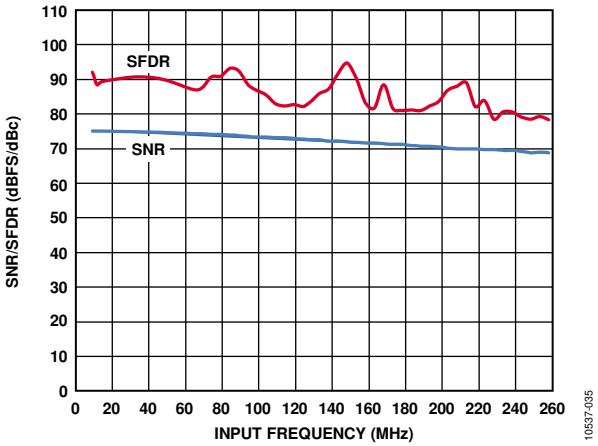

Figure 35. SNR/SFDR vs. f_{IN}; f_{SAMPLE} = 125 MSPS

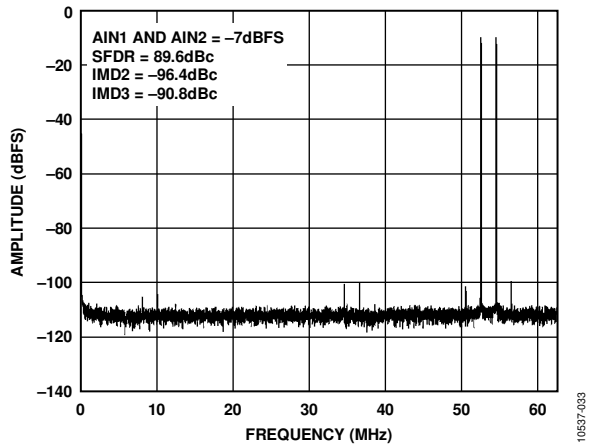

Figure 33. Two-Tone 16k FFT with f_{IN1} = 70.5 MHz and f_{IN2} = 72.5 MHz, f_{SAMPLE} = 125 MSPS

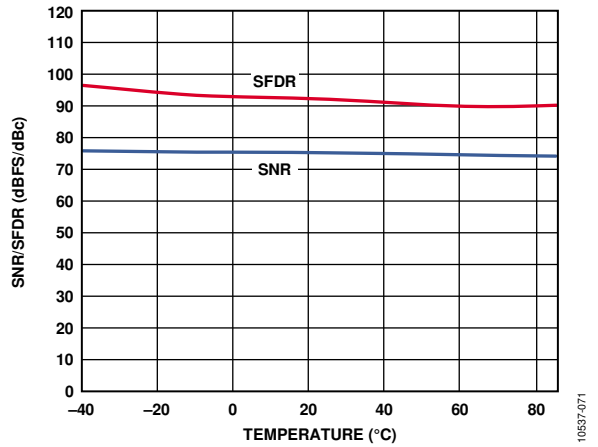

Figure 36. SNR/SFDR vs. Temperature; f_{IN} = 9.7 MHz, f_{SAMPLE} = 125 MSPS

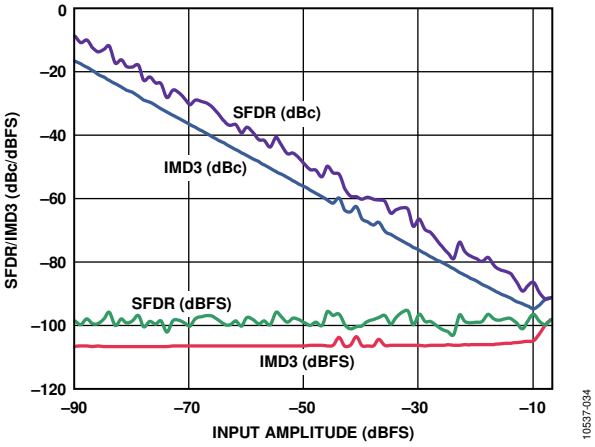

Figure 34. Two-Tone SFDR/IMD3 vs. Input Amplitude (AIN) with f_{IN1} = 70.5 MHz and f_{IN2} = 72.5 MHz, f_{SAMPLE} = 125 MSPS

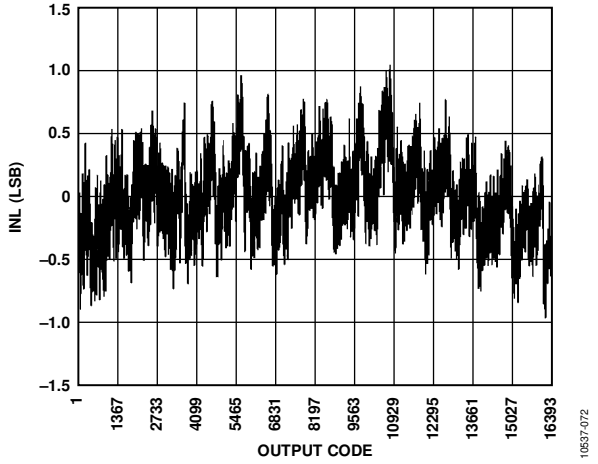

Figure 37. INL; f_{IN} = 9.7 MHz, f_{SAMPLE} = 125 MSPS

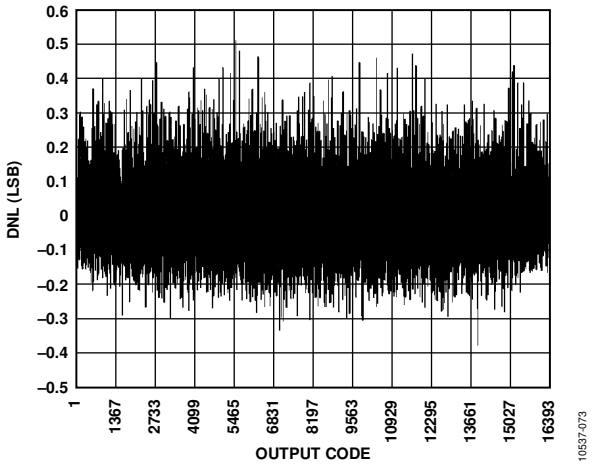

Figure 38. DNL; f_{IN} = 9.7 MHz, f_{SAMPLE} = 125 MSPS

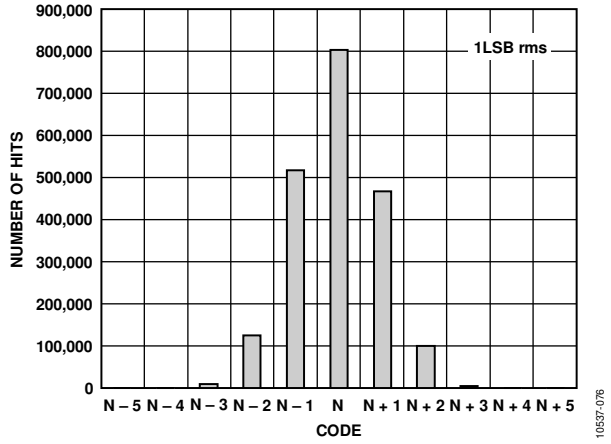

Figure 39. Input Referred Noise Histogram; f_{SAMPLE} = 125 MSPS

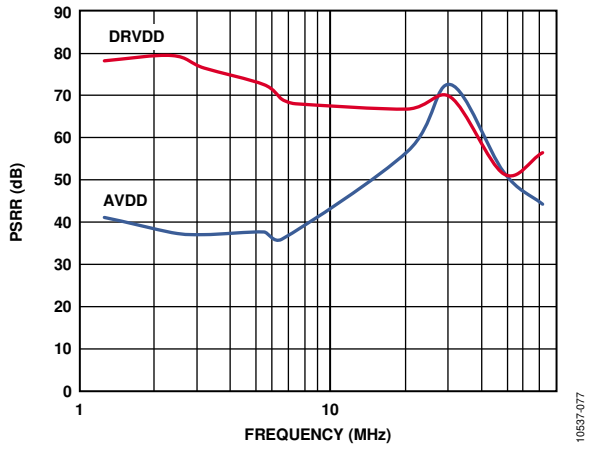

Figure 40. PSRR vs. Frequency; f_{CLK} = 125 MHz, f_{SAMPLE} = 125 MSPS

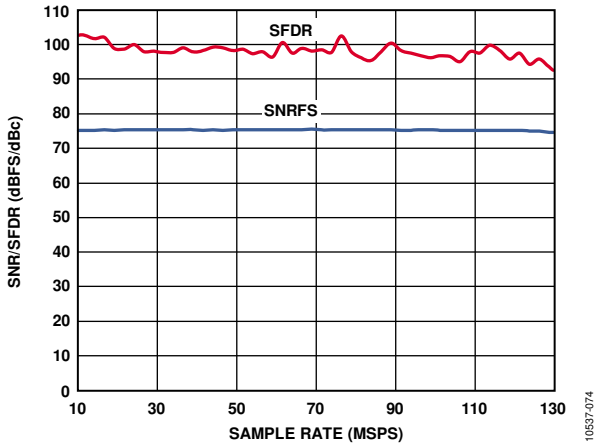

Figure 41. SNR/SFDR vs. Sample Rate; f_{IN} = 9.7 MHz, f_{SAMPLE} = 125 MSPS

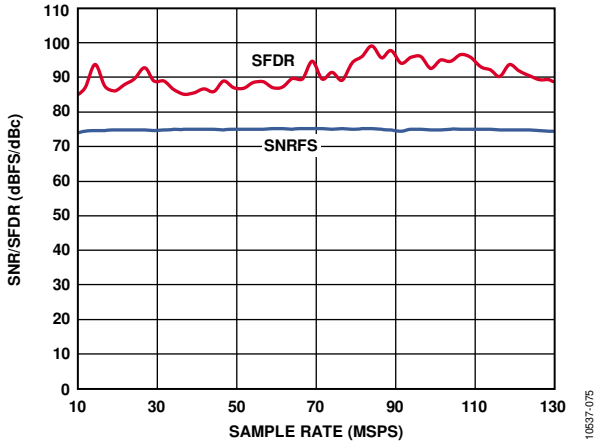

Figure 42. SNR/SFDR vs. Sample Rate; f_{IN} = 70 MHz, f_{SAMPLE} = 125 MSPS

EQUIVALENT CIRCUITS

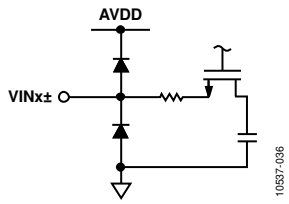

Figure 43. Equivalent Analog Input Circuit

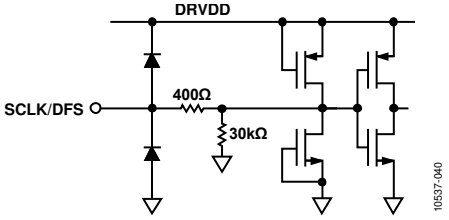

Figure 47. Equivalent SCLK/DFS Input Circuit

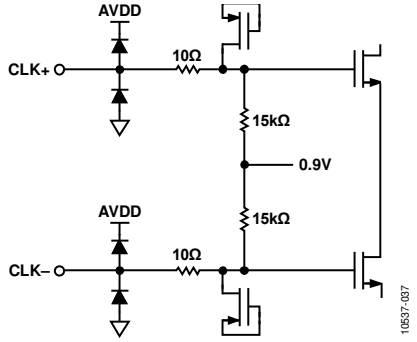

Figure 44. Equivalent Clock Input Circuit

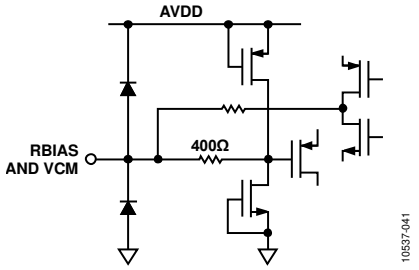

Figure 48. Equivalent RBIAS and VCM Circuit

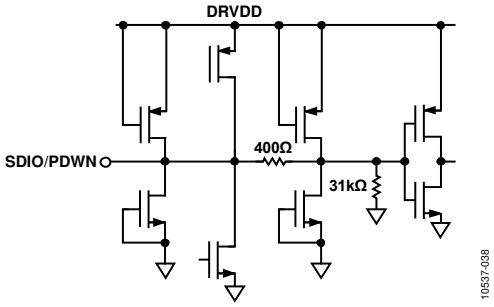

Figure 45. Equivalent SDIO/PDWN Input Circuit

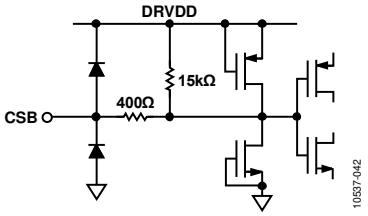

Figure 49. Equivalent CSB Input Circuit

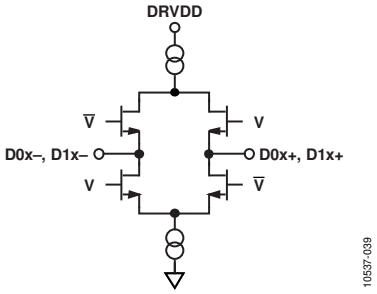

Figure 46. Equivalent Digital Output Circuit

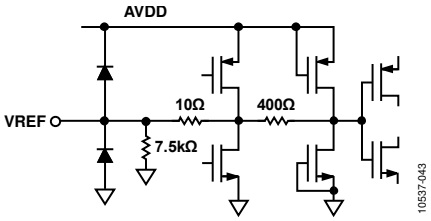

Figure 50. Equivalent VREF Circuit

THEORY OF OPERATION

The AD9645 is a multistage, pipelined ADC. Each stage provides sufficient overlap to correct for flash errors in the preceding stage. The quantized outputs from each stage are combined into a final 14-bit result in the digital correction logic. The serializer transmits this converted data in a 16-bit output. The pipelined architecture permits the first stage to operate with a new input sample while the remaining stages operate with preceding samples. Sampling occurs on the rising edge of the clock.

Each stage of the pipeline, excluding the last, consists of a low resolution flash ADC connected to a switched-capacitor DAC and an interstage residue amplifier (for example, a multiplying digital-to-analog converter (MDAC)). The residue amplifier magnifies the difference between the reconstructed DAC output and the flash input for the next stage in the pipeline. One bit of redundancy is used in each stage to facilitate digital correction of flash errors. The last stage consists of a flash ADC.

The output staging block aligns the data, corrects errors, and passes the data to the output buffers. The data is then serialized and aligned to the frame and data clocks.

ANALOG INPUT CONSIDERATIONS

The analog input to the AD9645 is a differential switched-capacitor circuit designed for processing differential input signals. This circuit can support a wide common-mode range while maintaining excellent performance. By using an input common-mode voltage of midsupply, users can minimize signal-dependent errors and achieve optimum performance.

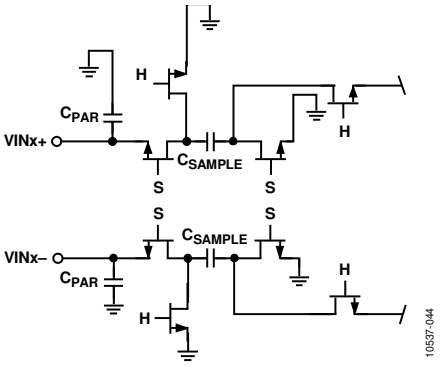

Figure 51. Switched-Capacitor Input Circuit

The clock signal alternately switches the input circuit between sample mode and hold mode (see Figure 51). When the input circuit is switched to sample mode, the signal source must be capable of charging the sample capacitors and settling within one-half of a clock cycle.

A small resistor in series with each input can help reduce the peak transient current injected from the output stage of the driving source. In addition, low Q inductors or ferrite beads can be placed on each leg of the input to reduce high differential capacitance at the analog inputs and, therefore, achieve the maximum bandwidth of the ADC. Such use of low Q inductors or ferrite beads is required when driving the converter front end at high IF frequencies. Either a differential capacitor or two single-ended capacitors can be placed on the inputs to provide a matching passive network. This ultimately creates a low-pass filter at the input to limit unwanted broadband noise. See the AN-742 Application Note, the AN-827 Application Note, and the *Analog Dialogue* article "Transformer-Coupled Front-End for Wideband A/D Converters" (Volume 39, April 2005) for more information. In general, the precise values depend on the application.

Input Common Mode

The analog inputs of the AD9645 are not internally dc biased. Therefore, in ac-coupled applications, the user must provide this bias externally. Setting the device so that V_{CM} = AVDD/2 is recommended for optimum performance, but the device can function over a wider range with reasonable performance, as shown in Figure 52.

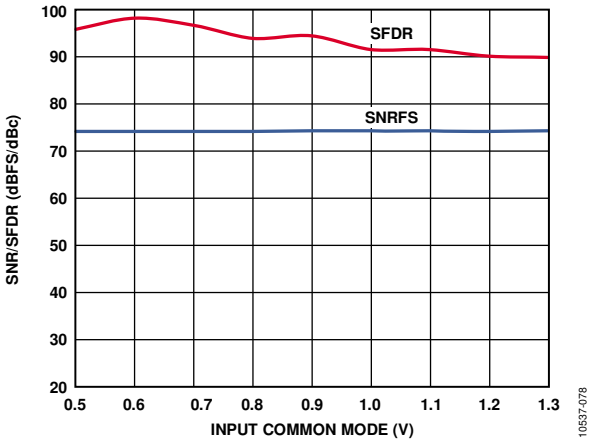

Figure 52. SNR/SFDR vs. Input Common-Mode Voltage, f_{IN} = 9.7 MHz, f_{SAMPLE} = 125 MSPS

An on-chip, common-mode voltage reference is included in the design and is available from the VCM pin. The VCM pin must be decoupled to ground by a 0.1 µF capacitor, as described in the Applications Information section.

Maximum SNR performance is achieved by setting the ADC to the largest span in a differential configuration. In the case of the AD9645, the largest input span available is 2 V p-p.

Differential Input Configurations

There are several ways to drive the AD9645 either actively or passively. However, optimum performance is achieved by driving the analog inputs differentially. Using a differential double balun configuration to drive the AD9645 provides excellent performance and a flexible interface to the ADC for baseband applications (see Figure 55).

For applications where SNR is a key parameter, differential transformer coupling is the recommended input configuration (see Figure 56) because the noise performance of most amplifiers is not adequate to achieve the true performance of the AD9645.

Regardless of the configuration, the value of the shunt capacitor, C, is dependent on the input frequency and may need to be reduced or removed.

It is not recommended to drive the AD9645 inputs single-ended.

VOLTAGE REFERENCE

A stable and accurate 1.0 V voltage reference is built into the AD9645. The VREF pin should be externally decoupled to ground with a low ESR, 1.0 µF capacitor in parallel with a low ESR, 0.1 µF ceramic capacitor.

Figure 53 shows how the internal reference voltage is affected by loading. Figure 54 shows the typical drift characteristics of the internal reference in 1.0 V mode.

The internal buffer generates the positive and negative full-scale references for the ADC core.

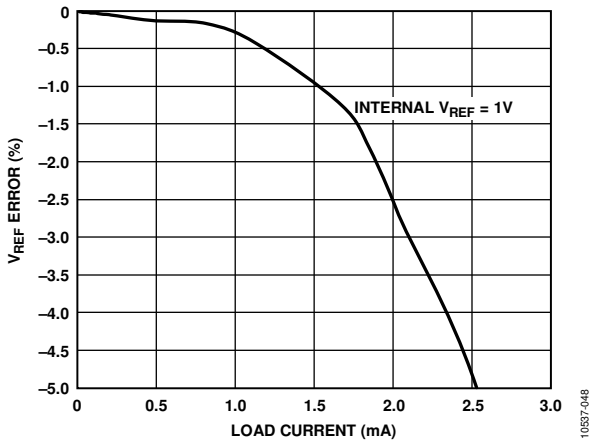

Figure 53. V_{REF} Error vs. Load Current

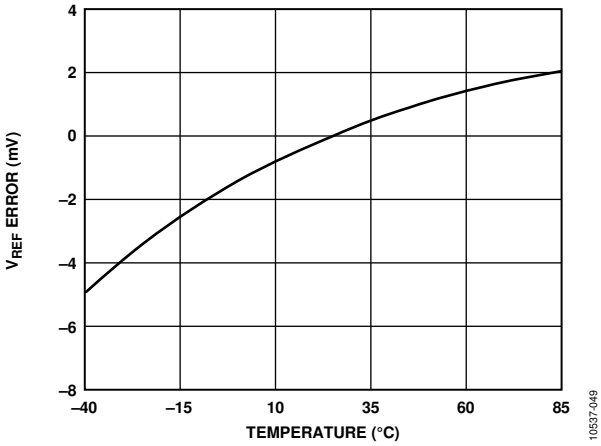

Figure 54. Typical V_{REF} Drift

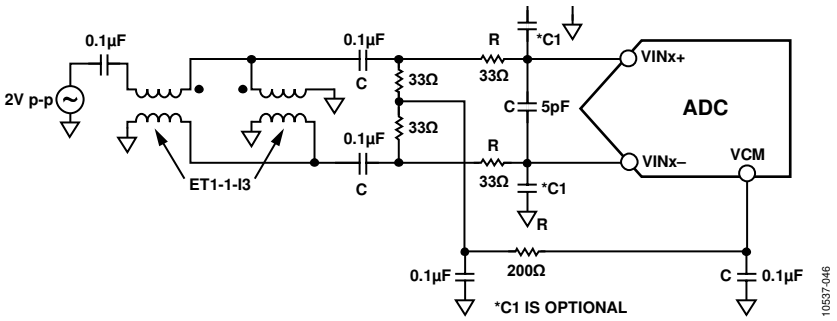

Figure 55. Differential Double Balun Input Configuration for Baseband Applications

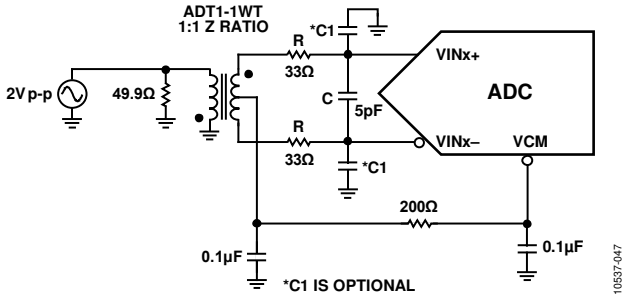

Figure 56. Differential Transformer-Coupled Configuration for Baseband Applications

CLOCK INPUT CONSIDERATIONS

For optimum performance, clock the AD9645 sample clock inputs, CLK+ and CLK–, with a differential signal. The signal is typically ac-coupled into the CLK+ and CLK– pins via a transformer or capacitors. These pins are biased internally (see Figure 44) and require no external bias.

Clock Input Options

The AD9645 has a flexible clock input structure. The clock input can be a CMOS, LVDS, LVPECL, or sine wave signal. Regardless of the type of signal being used, clock source jitter is of the most concern, as described in the Jitter Considerations section.

Figure 57 and Figure 58 show two preferred methods for clocking the AD9645 (at clock rates up to 1 GHz prior to the internal clock divider). A low jitter clock source is converted from a single-ended signal to a differential signal using either an RF transformer or an RF balun.

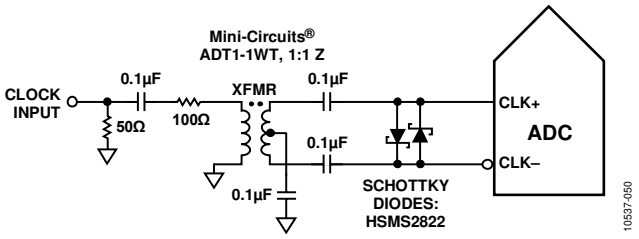

Figure 57. Transformer-Coupled Differential Clock (Up to 200 MHz)

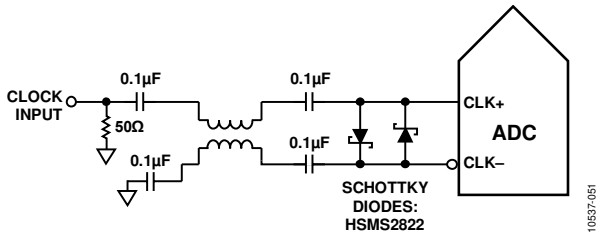

Figure 58. Balun-Coupled Differential Clock (Up to 1 GHz)

The RF balun configuration is recommended for clock frequencies between 125 MHz and 1 GHz, and the RF transformer configuration is recommended for clock frequencies from 10 MHz to 200 MHz. The back-to-back Schottky diodes across the transformer/balun secondary winding limit clock excursions into the AD9645 to approximately 0.8 V p-p differential.

This limit helps prevent the large voltage swings of the clock from feeding through to other portions of the AD9645 while preserving the fast rise and fall times of the signal that are critical to achieving low jitter performance. However, the diode capacitance comes into play at frequencies above 500 MHz. Care must be taken when choosing the appropriate signal limiting diode.

If a low jitter clock source is not available, another option is to ac couple a differential PECL signal to the sample clock input pins, as shown in Figure 59. The AD9510/AD9511/AD9512/AD9513/AD9514/AD9515/AD9516-0/AD9516-1/AD9516-2/AD9516-3/AD9516-4/AD9516-5/AD9517-0/AD9517-1/AD9517-2/AD9517-3/AD9517-4 clock drivers offer excellent jitter performance.

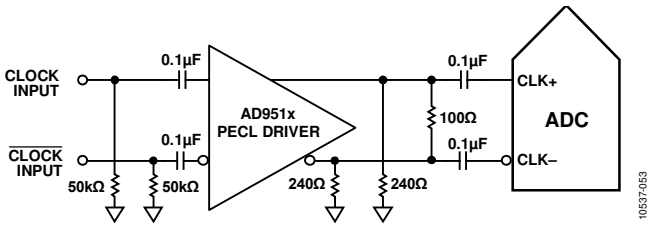

Figure 59. Differential PECL Sample Clock (Up to 1 GHz)

A third option is to ac couple a differential LVDS signal to the sample clock input pins, as shown in Figure 60. The AD9510/AD9511/AD9512/AD9513/AD9514/AD9515/AD9516-0/AD9516-1/AD9516-2/AD9516-3/AD9516-4/AD9516-5/AD9517-0/AD9517-1/AD9517-2/AD9517-3/AD9517-4 clock drivers offer excellent jitter performance.

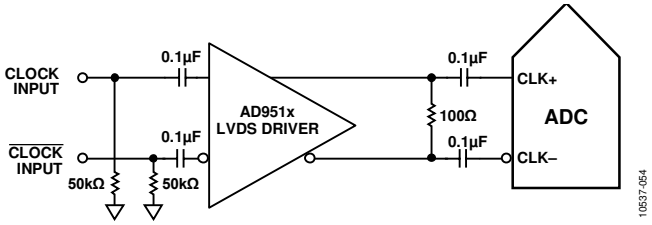

Figure 60. Differential LVDS Sample Clock (Up to 1 GHz)

In some applications, it may be acceptable to drive the sample clock inputs with a single-ended 1.8 V CMOS signal. In such applications, drive the CLK+ pin directly from a CMOS gate, and bypass the CLK– pin to ground with a 0.1 µF capacitor (see Figure 61).

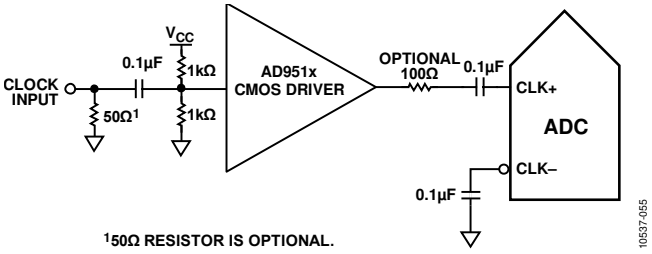

Figure 61. Single-Ended 1.8 V CMOS Input Clock (Up to 200 MHz)

Input Clock Divider

The AD9645 contains an input clock divider that can divide the input clock by integer values from 1 to 8. To achieve a given sample rate, the frequency of the externally applied clock must be multiplied by the divide value. The increased rate of the external clock normally results in lower clock jitter, which is beneficial for IF undersampling applications.

Clock Duty Cycle

Typical high speed ADCs use both clock edges to generate a variety of internal timing signals and, as a result, may be sensitive to the clock duty cycle. Commonly, a ±5% tolerance is required on the clock duty cycle to maintain dynamic performance characteristics.

The AD9645 contains a duty cycle stabilizer (DCS) that retimes the nonsampling (falling) edge, providing an internal clock signal with a nominal 50% duty cycle. This allows the user to provide a wide range of clock input duty cycles without affecting the performance of the AD9645. Noise and distortion performance are nearly flat for a wide range of duty cycles with the DCS on.

Jitter in the rising edge of the input is still of concern and is not easily reduced by the internal stabilization circuit. The duty cycle control loop does not function for clock rates of less than 20 MHz, nominally. The loop has a time constant associated with it that must be considered in applications in which the clock rate can change dynamically. A wait time of 1.5 µs to 5 µs is required after a dynamic clock frequency increase or decrease before the DCS loop is relocked to the input signal.

Jitter Considerations

High speed, high resolution ADCs are sensitive to the quality of the clock input. The degradation in SNR at a given input frequency (f_A) due only to aperture jitter (t_J) can be calculated by the following equation:

$$SNR\ Degradation = 20 \log_{10}\left(\frac{1}{2\pi \times f_A \times t_J}\right)$$

In this equation, the rms aperture jitter represents the root mean square of all jitter sources, including the clock input, analog input signal, and ADC aperture jitter specifications. IF undersampling applications are particularly sensitive to jitter (see Figure 62).

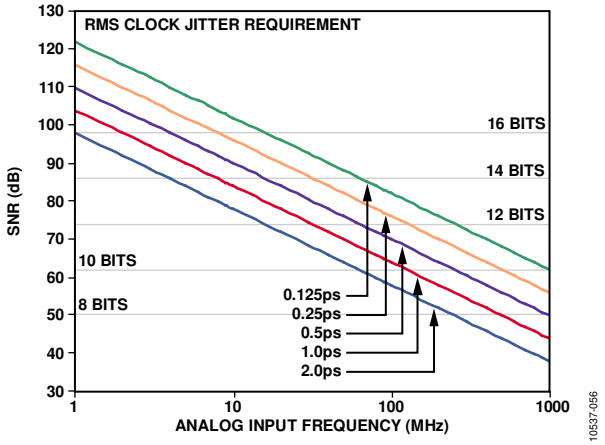

Figure 62. Ideal SNR vs. Input Frequency and Jitter

The clock input should be treated as an analog signal in cases where aperture jitter may affect the dynamic range of the AD9645. Power supplies for clock drivers should be separated from the ADC output driver supplies to avoid modulating the clock signal with digital noise. Low jitter, crystal-controlled oscillators make the best clock sources. If the clock is generated from another type of source (by gating, dividing, or other methods), it should be retimed by the original clock as the last step.

Refer to the AN-501 Application Note and the AN-756 Application Note for more in-depth information about jitter performance as it relates to ADCs.

POWER DISSIPATION AND POWER-DOWN MODE

As shown in Figure 63, the power dissipated by the AD9645 is proportional to its sample rate. The AD9645 is placed in power-down mode either by the SPI port or by asserting the PDWN pin high. In this state, the ADC typically dissipates 2 mW. During power-down, the output drivers are placed in a high impedance state. Asserting the PDWN pin low returns the AD9645 to its normal operating mode. Note that PDWN is referenced to the digital output driver supply (DRVDD) and should not exceed that supply voltage.

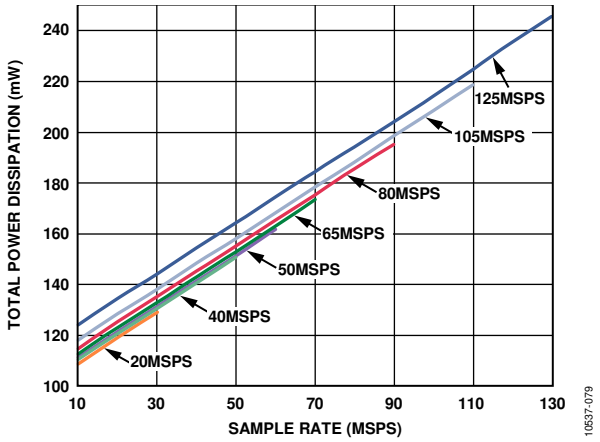

Figure 63. Total Power Dissipation vs. f_{SAMPLE} for f_{IN} = 9.7 MHz

Low power dissipation in power-down mode is achieved by shutting down the reference, reference buffer, biasing networks, and clock. Internal capacitors are discharged when the part enters power-down mode and must then be recharged when the part returns to normal operation. As a result, wake-up time is related to the time spent in power-down mode, and shorter power-down cycles result in proportionally shorter wake-up times. When using the SPI port interface, the user can place the ADC in power-down mode or standby mode. Standby mode allows the user to keep the internal reference circuitry powered when faster wake-up times are required. See the Memory Map section for more details on using these features.

DIGITAL OUTPUTS AND TIMING

The AD9645 differential outputs conform to the ANSI-644 LVDS standard on default power-up. This default setting can be changed to a low power, reduced signal option (similar to the IEEE 1596.3 standard) via the SPI. The LVDS driver current is derived on chip and sets the output current at each output equal to a nominal 3.5 mA. A 100 Ω differential termination resistor placed at the LVDS receiver inputs results in a nominal 350 mV swing (or 700 mV p-p differential) at the receiver.

When operating in reduced range mode, the output current is reduced to 2 mA. This results in a 200 mV swing (or 400 mV p-p differential) across a 100 Ω termination at the receiver.

The LVDS outputs facilitate interfacing with LVDS receivers in custom ASICs and FPGAs for superior switching performance in noisy environments. Single point-to-point net topologies are recommended with a 100 Ω termination resistor placed as close as possible to the receiver. If there is no far-end receiver termination or there is poor differential trace routing, timing errors may result. To avoid such timing errors, ensure that the trace length is less than 24 inches and that the differential output traces are close together and at equal lengths.

Figure 64 shows an example of the FCO and data stream with proper trace length and position.

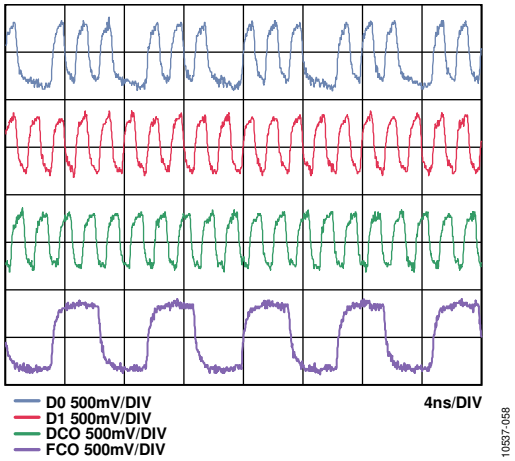

Figure 64. AD9645-125, LVDS Output Timing Example in ANSI-644 Mode (Default)

Figure 65 shows the LVDS output timing example in reduced range mode.

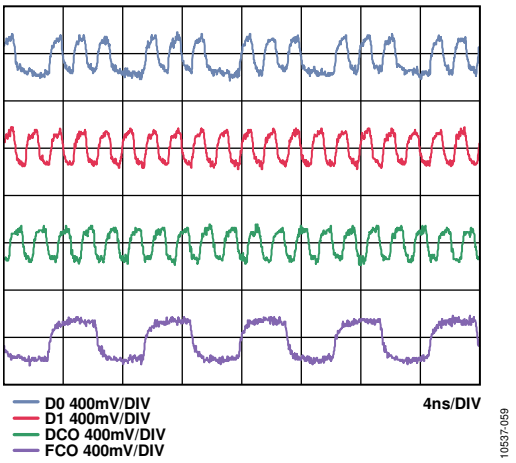

Figure 65. AD9645-125, LVDS Output Timing Example in Reduced Range Mode

Figure 66 shows an example of the LVDS output using the ANSI-644 standard (default) data eye and a time interval error (TIE) jitter histogram with trace lengths of less than 24 inches on standard FR-4 material.

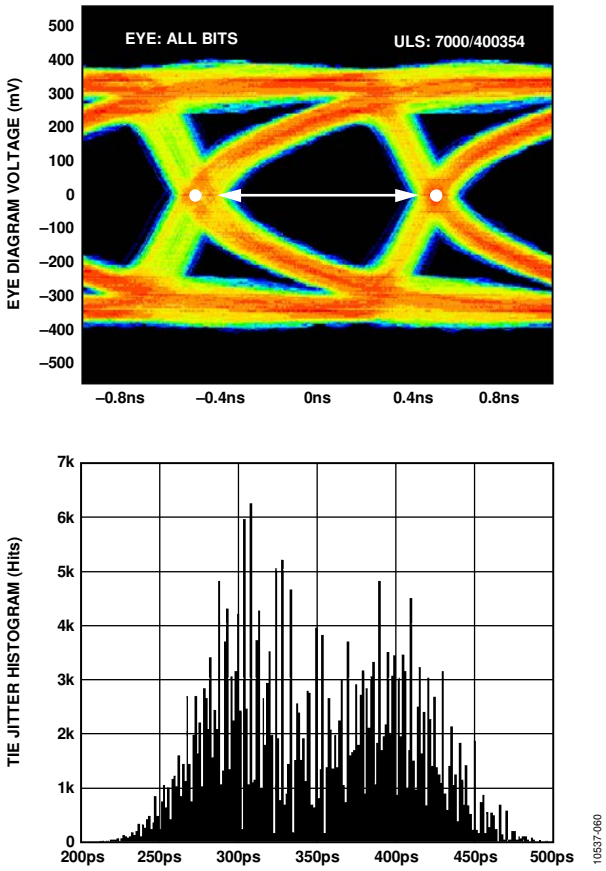

Figure 66. Data Eye for LVDS Outputs in ANSI-644 Mode with Trace Lengths of Less Than 24 Inches on Standard FR-4 Material, External 100 Ω Far-End Termination Only

Figure 67 shows an example of trace lengths exceeding 24 inches on standard FR-4 material. Note that the TIE jitter histogram reflects the decrease of the data eye opening as the edge deviates from the ideal position.

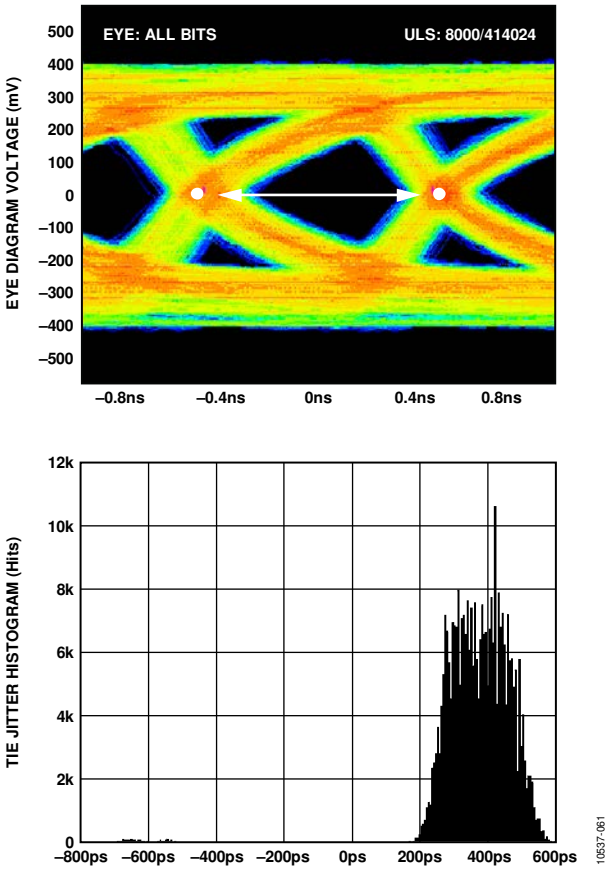

Figure 67. Data Eye for LVDS Outputs in ANSI-644 Mode with Trace Lengths Greater Than 24 Inches on Standard FR-4 Material, External 100 Ω Far-End Termination Only

It is the responsibility of the user to determine if the waveforms meet the timing budget of the design when the trace lengths exceed 24 inches. Additional SPI options allow the user to further increase the internal termination (increasing the current) of both outputs to drive longer trace lengths. This increase in current can be achieved by programming Register 0x15. Although an increase in current produces sharper rise and fall times on the data edges and is less prone to bit errors, the power dissipation of the DRVDD supply increases when this option is used.

The format of the output data is twos complement by default. An example of the output coding format can be found in Table 9. To change the output data format to offset binary, see the Memory Map section.

Data from each ADC is serialized and provided on a separate channel in two lanes in DDR mode. The data rate for each serial stream is equal to (16 bits × the sample clock rate)/2 lanes, with a maximum of 1 Gbps/lane ((16 bits × 125 MSPS)/(2 lanes) = 1 Gbps/lane)). The maximum allowable output data rate is 1 Gbps/lane. If one-lane mode is used, the data rate doubles for a given sample rate. To stay within the maximum data rate of 1 Gbps/lane, the sample rate is limited to a maximum of 62.5 MSPS in one-lane output mode.

The lowest typical conversion rate is 10 MSPS. For conversion rates of less than 20 MSPS, the SPI must be used to reconfigure the integrated PLL. See Register 0x21 in the Memory Map section for details on enabling this feature.

Two output clocks are provided to assist in capturing data from the AD9645. The DCO is used to clock the output data and is equal to 4× the sample clock (CLK) rate for the default mode of operation. Data is clocked out of the AD9645 and must be captured on the rising and falling edges of the DCO that supports double data rate (DDR) capturing. The FCO is used to signal the start of a new output byte and is equal to the sample clock rate in 1× frame mode. See the Timing Diagrams section for more information.

When the SPI is used, the DCO phase can be adjusted in 60° increments relative to the data edge. This enables the user to refine system timing margins, if required. The default DCO+ and DCO– timing, as shown in Figure 2, is 180° relative to the output data edge.

A 12-bit serial stream can also be initiated from the SPI. This allows the user to implement and test compatibility to lower resolution systems. When changing the resolution to a 12-bit serial stream, the data stream is shortened. See Figure 3 for the 12-bit example. In the default option with the serial output number of bits at 16, the data stream stuffs two 0s at the end of the 14-bit serial data.

In default mode, as shown in Figure 2, the MSB is first in the data output serial stream. This can be inverted by using the SPI so that the LSB is first in the data output serial stream.

Table 9. Digital Output Coding

Input (V)	Condition (V)	Offset Binary Output Mode	Twos Complement Mode
VIN+ – VIN–	<–VREF – 0.5 LSB	0000 0000 0000 0000	1000 0000 0000 0000
VIN+ – VIN–	–VREF	0000 0000 0000 0000	1000 0000 0000 0000
VIN+ – VIN–	0 V	1000 0000 0000 0000	0000 0000 0000 0000
VIN+ – VIN–	+VREF – 1.0 LSB	1111 1111 1111 1100	0111 1111 1111 1100
VIN+ – VIN–	>+VREF – 0.5 LSB	1111 1111 1111 1100	0111 1111 1111 1100