12-Bit, 200-MSPS, Ultralow-Power ADC

Check for Samples: ADS4128

FEATURES

- **Maximum Sample Rate: 200 MSPS**
- **Ultralow Power with 1.8-V Single Supply:**
  - **230-mW Total Power at 200 MSPS**
- **High Dynamic Performance:**
  - **SNR: 69 dBFS at 170 MHz**
  - **SFDR: 85 dBc at 170 MHz**
- **Dynamic Power Scaling with Sample Rate**
- **Output Interface:**
  - **Double Data Rate (DDR) LVDS with Programmable Swing and Strength**
    - **Standard Swing: 350 mV**
    - **Low Swing: 200 mV**
    - **Default Strength: 100-Ω Termination**
    - **2x Strength: 50-Ω Termination**
  - **1.8-V Parallel CMOS Interface Also Supported**
- **Programmable Gain up to 6 dB for SNR and SFDR Trade-Off**
- **DC Offset Correction**
- **Supports Low Input Clock Amplitude Down To 200 mV_{PP}**
- **Package: 7-mm × 7-mm QFN-48**

DESCRIPTION

The ADS4128 is a 12-bit analog-to-digital converter (ADC) with sampling rates up to 200 MSPS. This device uses innovative design techniques to achieve high dynamic performance, while consuming extremely low power at 1.8-V supply. The device is well-suited for multi-carrier, wide-bandwidth communications applications.

The ADS4128 has fine-gain options that can be used to improve SFDR performance at lower full-scale input ranges, especially at high input frequencies. It includes a dc offset correction loop that can be used to cancel the ADC offset. At lower sampling rates, the ADC automatically operates at scaled-down power with no loss in performance.

The ADS4128 is available in a compact QFN-48 package and is specified over the industrial temperature range (–40°C to +85°C)

Family Comparison

FAMILY	SAMPLING RATE					WITH ANALOG INPUT BUFFERS	
	65 MSPS	125 MSPS	160 MSPS	200 MSPS	250 MSPS	200 MSPS	250 MSPS
ADS412x 12-bit family	ADS4122	ADS4125	ADS4126	ADS4128	ADS4129	—	ADS41B29
ADS414x 14-bit family	ADS4142	ADS4145	ADS4146	—	ADS4149	—	ADS41B49
9-bit	—	—	—	—	—	—	ADS58B19
11-bit	—	—	—	—	—	ADS58B18	—

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

ORDERING INFORMATION(1)

PRODUCT	PACKAGE-LEAD	PACKAGE DESIGNATOR	SPECIFIED TEMPERATURE RANGE	ECO PLAN(2)	LEAD AND BALL FINISH	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
ADS4128	QFN-48	RGZ	–40°C to +85°C	GREEN (RoHS, no Sb/Br)	Cu and NiPdAu	AZ4128	ADS4128IRGZR	Tape and Reel, 2500
							ADS4128IRGZT	Tape and Reel, 250

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or visit the device product folder at www.ti.com.

(2) Eco Plan is the planned eco-friendly classification. Green (RoHS, no Sb/Br): TI defines *Green* to mean Pb-Free (RoHS compatible) and free of Bromine- (Br) and Antimony- (Sb) based flame retardants. Refer to the Quality and Lead-Free (Pb-Free) Data web site for more information.

The ADS4128 is pin-compatible with the previous generation ADS6149 family; this architecture enables easy migration. However, there are some important differences between the generations, as summarized in Table 1.

Table 1. MIGRATING FROM THE ADS6149 FAMILY

ADS6149 FAMILY	ADS4149 FAMILY (Includes ADS4128)
PINS	
Pin 21 is NC (not connected)	Pin 21 is NC (not connected)
Pin 23 is MODE	Pin 23 is RESERVED in the ADS4128. It is reserved as a digital control pin for an (as yet) undefined function in the next-generation ADC series.
SUPPLY	
AVDD is 3.3 V	AVDD is 1.8 V
DRVDD is 1.8 V	No change
INPUT COMMON-MODE VOLTAGE	
VCM is 1.5 V	VCM is 0.95 V
SERIAL INTERFACE	
Protocol: 8-bit register address and 8-bit register data	No change in protocol
	New serial register map
EXTERNAL REFERENCE MODE	
Supported	Not supported
ADS61B49 FAMILY	**ADS41B49 AND ADS58B18 FAMILY**
PINS	
Pin 21 is NC (not connected)	Pin 21 is 3.3-V AVDD_BUF (supply for the analog input buffers)
Pin 23 is MODE	Pin 23 is a digital control pin for the RESERVED function. Pin 23 functions as SNR Boost enable (B18 only).
SUPPLY	
AVDD is 3.3 V	AVDD is 1.8 V, AVDD_BUF is 3.3 V
DRVDD is 1.8 V	No change
INPUT COMMON-MODE VOLTAGE	
VCM is 1.5 V	VCM is 1.7 V
SERIAL INTERFACE	
Protocol: 8-bit register address and 8-bit register data	No change in protocol New serial register map
EXTERNAL REFERENCE MODE	
Supported	Not supported

ABSOLUTE MAXIMUM RATINGS(1)

Over operating free-air temperature range, unless otherwise noted.

		VALUE	UNIT
Supply voltage range	AVDD	–0.3 to 2.1	V
	DRVDD	–0.3 to 2.1	V
Voltage	Between AGND and DRGND	–0.3 to 0.3	V
	Between AVDD to DRVDD (when AVDD leads DRVDD)	0 to 2.1	V
	Between DRVDD to AVDD (when DRVDD leads AVDD)	0 to 2.1	V
Voltage applied to input pins	INP, INM	–0.3 to minimum (1.9, AVDD + 0.3)	V
	CLKP, CLKM(2), DFS, OE	–0.3 to AVDD + 0.3	V
	RESET, SCLK, SDATA, SEN	–0.3 to 3.9	V
Temperature range	Operating free-air, T_A	–40 to +85	°C
	Operating junction, T_J	+125	°C
	Storage, T_{stg}	–65 to +150	°C
Electrostatic discharge (ESD) ratings	Human body model (HBM)	2	kV

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.

(2) When AVDD is turned off, it is recommended to switch off the input clock (or ensure the voltage on CLKP and CLKM is less than |0.3 V|. This setting prevents the ESD protection diodes at the clock input pins from turning on.

THERMAL INFORMATION

THERMAL METRIC(1)		ADS4128 RGZ (QFN) 48 PINS	UNITS
θ_{JA}	Junction-to-ambient thermal resistance	27.9	°C/W
θ_{JCtop}	Junction-to-case (top) thermal resistance	15.1	
θ_{JB}	Junction-to-board thermal resistance	5.4	
ψ_{JT}	Junction-to-top characterization parameter	0.3	
ψ_{JB}	Junction-to-board characterization parameter	5.4	
θ_{JCbot}	Junction-to-case (bottom) thermal resistance	1.7	

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953.

RECOMMENDED OPERATING CONDITIONS

Over operating free-air temperature range, unless otherwise noted.

		ADS4128			UNIT
		MIN	TYP	MAX	
SUPPLIES					
AVDD	Analog supply voltage	1.7	1.8	1.9	V
DRVDD	Digital supply voltage	1.7	1.8	1.9	V
ANALOG INPUTS					
Differential input voltage range(1)			2		V_{PP}
Input common-mode voltage			V_{CM} ± 0.05		V
Maximum analog input frequency	With 2-V_{PP} input amplitude(2)		400		MHz
	With 1-V_{PP} input amplitude(2)		800		MHz
CLOCK INPUT					
Input clock sample rate					
Low-speed mode	Enabled(3)	20		80	MSPS
	Disabled(3)	> 80		200	MSPS
Input clock amplitude differential (V_{CLKP} – V_{CLKM})	Sine wave, ac-coupled	0.2	1.5		V_{PP}
	LVPECL, ac-coupled		1.6		V_{PP}
	LVDS, ac-coupled		0.7		V_{PP}
	LVCMOS, single-ended, ac-coupled		1.8		V
Input clock duty cycle	Low-speed mode enabled	40	50	60	%
	Low-speed mode disabled	35	50	65	%
DIGITAL OUTPUTS					
C_{LOAD}	Maximum external load capacitance from each output pin to DRGND		5		pF
R_{LOAD}	Differential load resistance between the LVDS output pairs (LVDS mode)		100		Ω
T_A	Operating free-air temperature	–40		+85	°C

(1) With 0-dB gain. See the *Fine Gain* section in the *Application Information* for relation between input voltage range and gain.
(2) See the *Theory of Operation* section in the *Application Information*.
(3) See the *Serial Interface* section for details on low-speed mode.

Table 2. HIGH PERFORMANCE MODES(1)(2)(3)

MODE	DESCRIPTION
Mode 1	Set the MODE 1 register bits to get best performance across sample clock and input signal frequencies. Register address = 03h, register data = 03h
Mode 2	Set the MODE 2 register bit to get best performance at high input signal frequencies. Register address = 4Ah, register data = 01h

(1) It is recommended to use these modes to get best performance. These modes can be set using the serial interface only.
(2) See the *Serial Interface* section for details on register programming.
(3) Note that these modes cannot be set when the serial interface is not used (when the RESET pin is tied high); see the *Device Configuration* section.

ELECTRICAL CHARACTERISTICS

Typical values are at +25°C, AVDD = 1.8 V, DRVDD = 1.8 V, 50% clock duty cycle, –1-dBFS differential analog input, 1-dB gain, and DDR LVDS interface, unless otherwise noted.
Minimum and maximum values are across the full temperature range: T_{MIN} = –40°C to T_{MAX} = +85°C, AVDD = 1.8 V, and DRVDD = 1.8 V. Note that after reset, the device is in 0-dB gain mode.

PARAMETER		TEST CONDITIONS	ADS4128			UNIT
			MIN	TYP	MAX	
	Resolution					Bits
SNR	Signal-to-noise ratio, LVDS	f_{IN} = 10 MHz		70		dBFS
		f_{IN} = 70 MHz		70		dBFS
		f_{IN} = 100 MHz		69.7		dBFS
		f_{IN} = 170 MHz	65.8	69		dBFS
		f_{IN} = 300 MHz		68.2		dBFS
SINAD	Signal-to-noise and distortion ratio, LVDS	f_{IN} = 10 MHz		69.8		dBFS
		f_{IN} = 70 MHz		69.2		dBFS
		f_{IN} = 100 MHz		69.1		dBFS
		f_{IN} = 170 MHz	65.5	68.8		dBFS
		f_{IN} = 300 MHz		67		dBFS
SFDR	Spurious-free dynamic range	f_{IN} = 10 MHz		87		dBc
		f_{IN} = 70 MHz		80		dBc
		f_{IN} = 100 MHz		82		dBc
		f_{IN} = 170 MHz	70	85		dBc
		f_{IN} = 300 MHz		74		dBc
THD	Total harmonic distortion	f_{IN} = 10 MHz		84		dBc
		f_{IN} = 70 MHz		78		dBc
		f_{IN} = 100 MHz		79		dBc
		f_{IN} = 170 MHz	69	83		dBc
		f_{IN} = 300 MHz		73		dBc
HD2	Second-harmonic distortion	f_{IN} = 10 MHz		90		dBc
		f_{IN} = 70 MHz		84		dBc
		f_{IN} = 100 MHz		83		dBc
		f_{IN} = 170 MHz	70	85		dBc
		f_{IN} = 300 MHz		74		dBc
HD3	Third-harmonic distortion	f_{IN} = 10 MHz		87		dBc
		f_{IN} = 70 MHz		80		dBc
		f_{IN} = 100 MHz		82		dBc
		f_{IN} = 170 MHz	70	86		dBc
		f_{IN} = 300 MHz		79		dBc
	Worst spur (other than second and third harmonics)	f_{IN} = 10 MHz		93		dBc
		f_{IN} = 70 MHz		93		dBc
		f_{IN} = 100 MHz		91		dBc
		f_{IN} = 170 MHz	75	90		dBc
		f_{IN} = 300 MHz		88		dBc
IMD	Two-tone intermodulation distortion	f_1 = 46 MHz, f_2 = 50 MHz, each tone at –7 dBFS		–85		dBFS
		f_1 = 185 MHz, f_2 = 190 MHz, each tone at –7 dBFS		–90		dBFS
	Input overload recovery	Recovery to within 1% (of final value) for 6-dB overload with sine-wave input		1		Clock cycles
PSRR	AC power-supply rejection ratio	For 50-mV_{PP} signal on AVDD supply, up to 10 MHz		> 30		dB
ENOB	Effective number of bits	f_{IN} = 170 MHz		11.2		LSBs
DNL	Differential nonlinearity	f_{IN} = 170 MHz	–0.95	±0.2	1.6	LSBs
INL	Integrated nonlinearity	f_{IN} = 170 MHz		±0.5	±5	LSBs

ELECTRICAL CHARACTERISTICS: GENERAL

Typical values are at +25°C, AVDD = 1.8 V, DRVDD = 1.8 V, 50% clock duty cycle, and 0-dB gain, unless otherwise noted. Minimum and maximum values are across the full temperature range: T_{MIN} = –40°C to T_{MAX} = +85°C, AVDD = 1.8 V, and DRVDD = 1.8 V.

PARAMETER		ADS4128 MIN	ADS4128 TYP	ADS4128 MAX	UNIT
ANALOG INPUTS					
	Differential input voltage range		2		V_{PP}
	Differential input resistance (at dc); see Figure 41		> 1		MΩ
	Differential input capacitance; see Figure 42		4		pF
	Analog input bandwidth		550		MHz
	Analog input common-mode current (per input pin)		0.6		µA/MSPS
VCM	Common-mode output voltage		0.95		V
	VCM output current capability		4		mA
DC ACCURACY					
	Offset error	–15	2.5	15	mV
	Temperature coefficient of offset error		0.003		mV/°C
E_{GREF}	Gain error as a result of internal reference inaccuracy alone	–2		2	%FS
E_{GCHAN}	Gain error of channel alone		–0.2	±1	%FS
	Temperature coefficient of E_{GCHAN}		0.001		Δ%/°C
POWER SUPPLY					
IAVDD	Analog supply current		85	113	mA
IDRVDD(1)	Output buffer supply current LVDS interface with 100-Ω external termination Low LVDS swing (200 mV)		43		mA
	Output buffer supply current LVDS interface with 100-Ω external termination Standard LVDS swing (350 mV)		55	72	mA
	Output buffer supply current(1)(2) CMOS interface(2) 8-pF external load capacitance f_{IN} = 2.5 MHz		33		mA
	Analog power		153		mW
	Digital power LVDS interface Low LVDS swing (200 mV)		77		mW
	Digital power CMOS interface(2) 8-pF external load capacitance f_{IN} = 2.5 MHz		59		mW
	Global power-down		10	25	mW
	Standby		185		mW

(1) The maximum DRVDD current with CMOS interface depends on the actual load capacitance on the digital output lines. Note that the maximum recommended load capacitance on each digital output line is 10 pF.

(2) In CMOS mode, the DRVDD current scales with the sampling frequency, the load capacitance on the output pins, input frequency, and the supply voltage (see the *CMOS Interface Power Dissipation* section in the *Application Information*).

DIGITAL CHARACTERISTICS

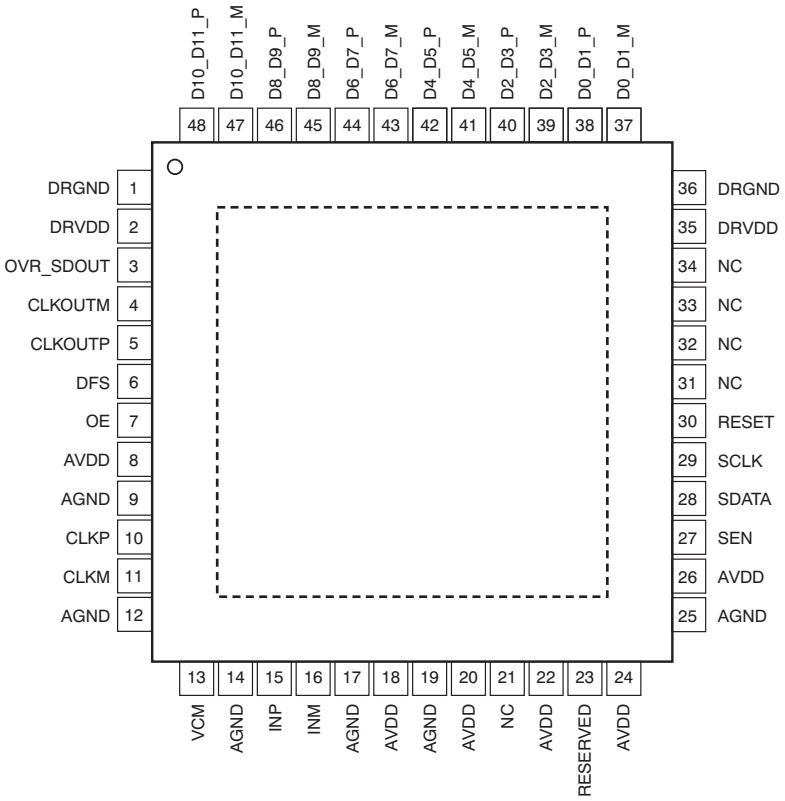
Typical values are at +25°C, AVDD = 1.8 V, DRVDD = 1.8 V, and 50% clock duty cycle, unless otherwise noted. Minimum and maximum values are across the full temperature range: T_{MIN} = –40°C to T_{MAX} = +85°C, AVDD = 1.8 V, and DRVDD = 1.8 V.

PARAMETER			TEST CONDITIONS	ADS4128			UNIT
				MIN	TYP	MAX	
DIGITAL INPUTS (RESET, SCLK, SDATA, SEN, OE)							
V_{IH}	Input voltage	High	RESET, SCLK, SDATA, and SEN support 1.8-V and 3.3-V CMOS logic levels	1.3			V
V_{IL}		Low				0.4	V
V_{IH}		High	OE only supports 1.8-V CMOS logic levels	1.3			V
V_{IL}		Low				0.4	V
I_{IH}	Input current	High, SDATA, SCLK(1)	V_{HIGH} = 1.8 V		10		µA
		High, SEN	V_{HIGH} = 1.8 V		0		µA
I_{IL}		Low, SDATA, SCLK	V_{LOW} = 0 V		0		µA
		Low, SEN	V_{LOW} = 0 V		10		µA
DIGITAL OUTPUTS (CMOS interface: D0 to D11, OVR_SDOUT)							
V_{OH}	Output voltage	High		DRVDD – 0.1	DRVDD		V
V_{OL}		Low			0	0.1	V
DIGITAL OUTPUTS (LVDS interface: DA0P and DA0M to DA11P and DA11M, DB0P and DB0M to DB11P and DB11M, CLKOUTP and CLKOUTM)							
V_{ODH}	Output voltage(2)	High	Standard-swing LVDS	270	+350	430	mV
			Low-swing LVDS		+200		mV
V_{ODL}		Low	Standard-swing LVDS	–430	–350	–270	mV
			Low-swing LVDS		–200		mV
V_{OCM}	Output common-mode voltage			0.85	1.05	1.25	V

(1) SDATA and SCLK have an internal 180-kΩ pull-down resistor.
(2) With an external 100-Ω termination.

PIN CONFIGURATION (LVDS MODE)

RGZ PACKAGE(1)
QFN-48
(TOP VIEW)



(1) The PowerPAD™ is connected to DRGND.

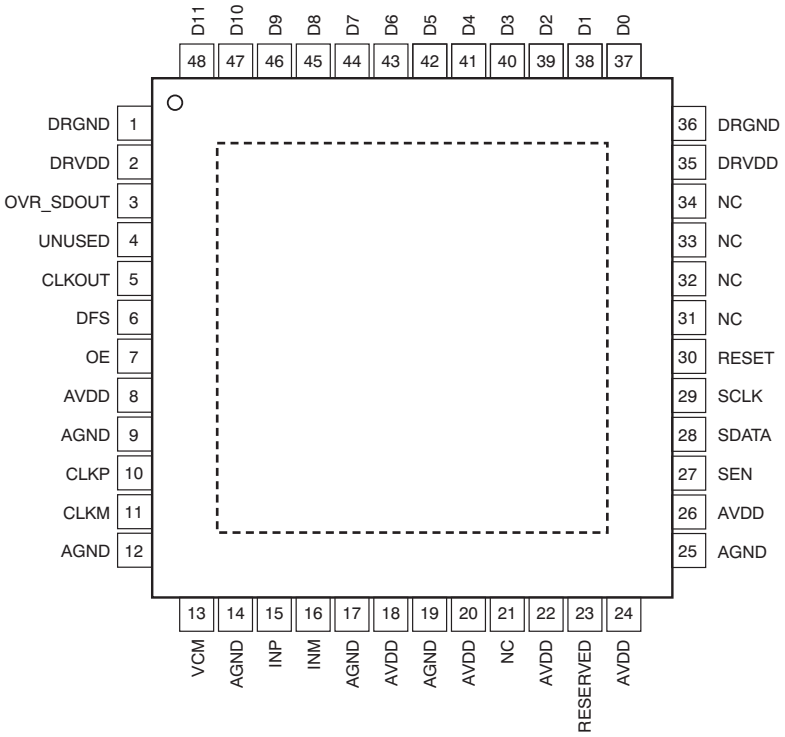
Figure 1. LVDS Pinout

Pin Assignments (LVDS Mode)

PIN NAME	PIN NUMBER	PINS	FUNCTION	DESCRIPTION
AGND	9, 12, 14, 17, 19, 25	6	I	Analog ground
AVDD	8, 18, 20, 22, 24, 26	6	I	1.8-V analog power supply
CLKM	11	1	I	Differential clock input, negative
CLKOUTM	4	1	O	Differential output clock, complement
CLKOUTP	5	1	O	Differential output clock, true
CLKP	10	1	I	Differential clock input, positive
D0_D1_P	Refer to Figure 1	1	O	Differential output data D0 and D1 multiplexed, true
D0_D1_M	Refer to Figure 1	1	O	Differential output data D0 and D1 multiplexed, complement
D2_D3_P	Refer to Figure 1	1	O	Differential output data D2 and D3 multiplexed, true
D2_D3_M	Refer to Figure 1	1	O	Differential output data D2 and D3 multiplexed, complement
D4_D5_P	Refer to Figure 1	1	O	Differential output data D4 and D5 multiplexed, true
D4_D5_M	Refer to Figure 1	1	O	Differential output data D4 and D5 multiplexed, complement
D6_D7_P	Refer to Figure 1	1	O	Differential output data D6 and D7 multiplexed, true
D6_D7_M	Refer to Figure 1	1	O	Differential output data D6 and D7 multiplexed, complement
D8_D9_P	Refer to Figure 1	1	O	Differential output data D8 and D9 multiplexed, true
D8_D9_M	Refer to Figure 1	1	O	Differential output data D8 and D9 multiplexed, complement
D10_D11_P	Refer to Figure 1	1	O	Differential output data D10 and D11 multiplexed, true
D10_D11_M	Refer to Figure 1	1	O	Differential output data D10 and D11 multiplexed, complement
DFS	6	1	I	Data format select input. This pin sets the DATA FORMAT (twos complement or offset binary) and the LVDS and CMOS output interface type. See Table 8 for detailed information.
DRGND	1, 36, PAD	2	I	Digital and output buffer ground
DRVDD	2, 35	2	I	1.8-V digital and output buffer supply
INM	16	1	I	Differential analog input, negative
INP	15	1	I	Differential analog input, positive
NC	Refer to Figure 1	5	—	Do not connect
OE	7	1	I	Output buffer enable input, active high; this pin has an internal 180-kΩ pull-up resistor to DRVDD.
OVR_SDOUT	3	1	O	This pin functions as an out-of-range indicator after reset when register bit READOUT = 0, and functions as a serial register readout pin when READOUT = 1.
RESERVED	23	1	I	Digital control pin, reserved for future use
RESET	30	1	I	Serial interface RESET input. When using the serial interface mode, the internal registers must initialize through hardware RESET by applying a high pulse on this pin or by using the software reset option; refer to the *Serial Interface* section. When RESET is tied high, the internal registers are reset to the default values. In this condition, SEN can be used as an analog control pin. RESET has an internal 180-kΩ pull-down resistor.
SCLK	29	1	I	This pin functions as a serial interface clock input when RESET is low. When RESET is high, SCLK has no function and should be tied to ground. This pin has an internal 180-kΩ pull-down resistor.
SDATA	28	1	I	This pin functions as a serial interface data input when RESET is low. When RESET is high, SDATA functions as a STANDBY control pin (see Table 10). This pin has an internal 180-kΩ pull-down resistor.
SEN	27	1	I	This pin functions as a serial interface enable input when RESET is low. When RESET is high, SEN has no function and should be tied to AVDD. This pin has an internal 180-kΩ pull-up resistor to AVDD.
VCM	13	1	O	Outputs the common-mode voltage (0.95 V) that can be used externally to bias the analog input pins.

PIN CONFIGURATION (CMOS MODE)

RGZ PACKAGE(2)
QFN-48
(TOP VIEW)



(2) The PowerPAD is connected to DRGND.

Figure 2. CMOS Pinout

Pin Assignments (CMOS Mode)

PIN NAME	PIN NUMBER	PINS	FUNCTION	DESCRIPTION
AGND	9, 12, 14, 17, 19, 25	6	I	Analog ground
AVDD	8, 18, 20, 22, 24, 26	6	I	1.8-V analog power supply
CLKM	11	1	I	Differential clock input, negative
CLKOUT	5	1	O	CMOS output clock
CLKP	10	1	I	Differential clock input, positive
D0	Refer to Figure 2	1	O	12-bit CMOS output data
D1	Refer to Figure 2	1	O	12-bit CMOS output data
D2	Refer to Figure 2	1	O	12-bit CMOS output data
D3	Refer to Figure 2	1	O	12-bit CMOS output data
D4	Refer to Figure 2	1	O	12-bit CMOS output data
D5	Refer to Figure 2	1	O	12-bit CMOS output data
D6	Refer to Figure 2	1	O	12-bit CMOS output data
D7	Refer to Figure 2	1	O	12-bit CMOS output data
D8	Refer to Figure 2	1	O	12-bit CMOS output data
D9	Refer to Figure 2	1	O	12-bit CMOS output data
D10	Refer to Figure 2	1	O	12-bit CMOS output data
D11	Refer to Figure 2	1	O	12-bit CMOS output data
DFS	6	1	I	Data format select input. This pin sets the DATA FORMAT (twos complement or offset binary) and the LVDS and CMOS output interface type. See Table 8 for detailed information.
DRGND	1, 36, PAD	2	I	Digital and output buffer ground
DRVDD	2, 35	2	I	1.8-V digital and output buffer supply
INP	15	1	I	Differential analog input, positive
INM	16	1	I	Differential analog input, negative
NC	Refer to Figure 2	5	—	Do not connect
OE	7	1	I	Output buffer enable input, active high; this pin has an internal 180-kΩ pull-up resistor to DRVDD.
OVR_SDOUT	3	1	O	This pin functions as an out-of-range indicator after reset when register bit READOUT = 0, and functions as a serial register readout pin when READOUT = 1.
RESET	30	1	I	Serial interface RESET input. When using the serial interface mode, the internal registers must initialize through hardware RESET by applying a high pulse on this pin or by using the software reset option; refer to the *Serial Interface* section. When RESET is tied high, the internal registers are reset to the default values. In this condition, SEN can be used as an analog control pin. RESET has an internal 180-kΩ pull-down resistor.
RESERVED	23	1	I	Digital control pin, reserved for future use
SCLK	29	1	I	This pin functions as a serial interface clock input when RESET is low. When RESET is high, SCLK has no function and should be tied to ground. This pin has an internal 180-kΩ pull-down resistor.
SDATA	28	1	I	This pin functions as a serial interface data input when RESET is low. When RESET is high, SDATA functions as a STANDBY control pin (see Table 10). This pin has an internal 180-kΩ pull-down resistor.
SEN	27	1	I	This pin functions as a serial interface enable input when RESET is low. When RESET is high, SEN has no function and should be tied to AVDD. This pin has an internal 180-kΩ pull-up resistor to AVDD.
UNUSED	4	1	—	Unused pin in CMOS mode
VCM	13	1	O	Outputs the common-mode voltage (0.95 V) that can be used externally to bias the analog input pins.

FUNCTIONAL BLOCK DIAGRAM

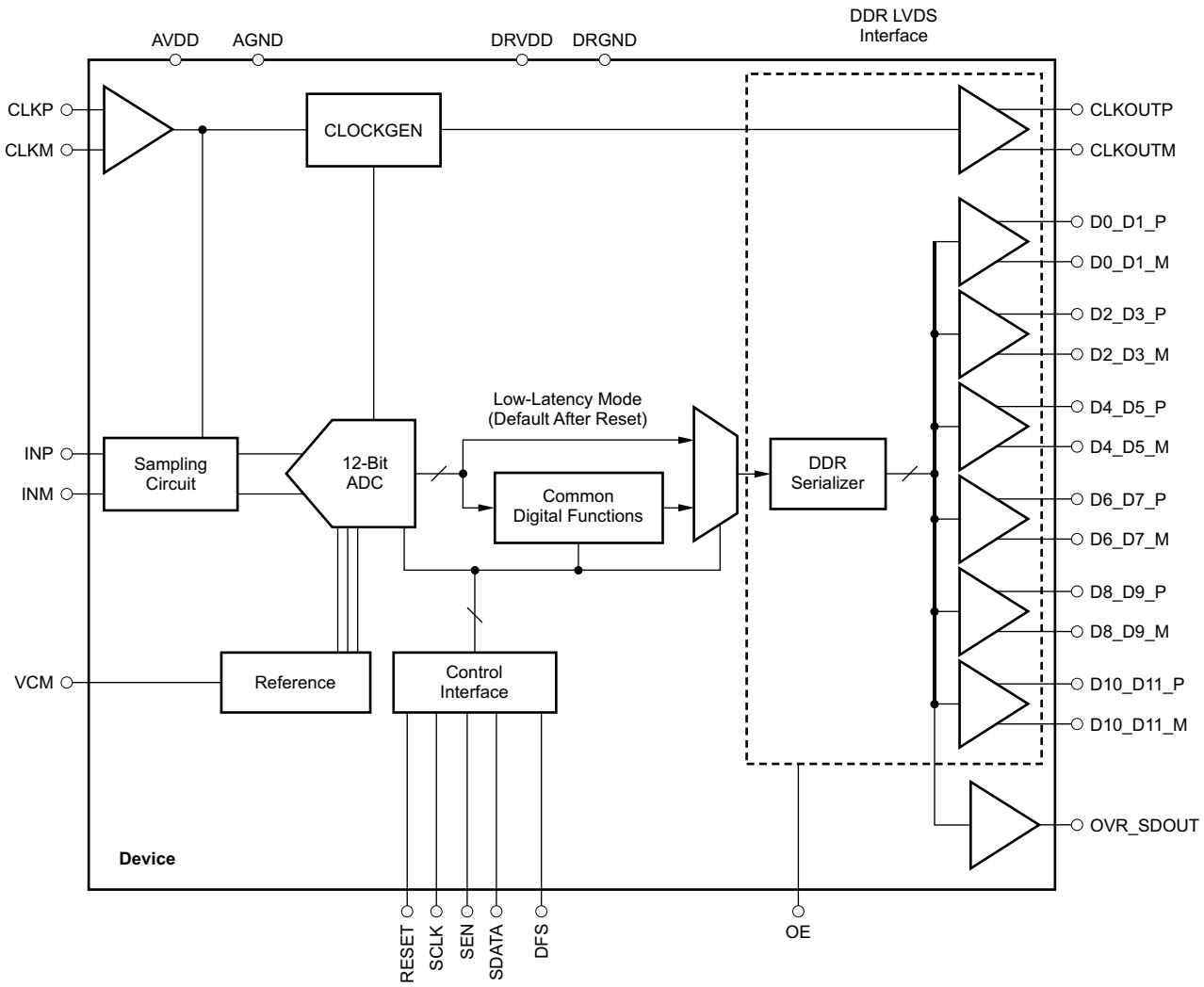
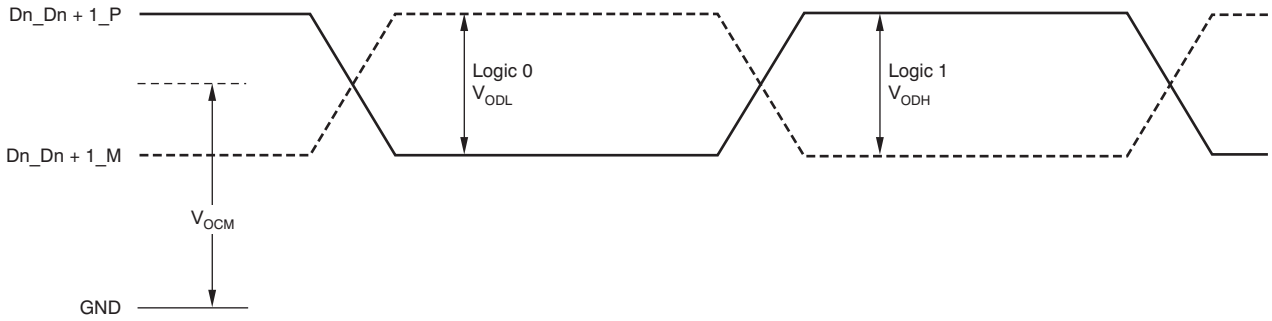


Figure 3. Block Diagram

TIMING CHARACTERISTICS



(1) With external 100-Ω termination.

Figure 4. LVDS Output Voltage Levels

TIMING REQUIREMENTS: LVDS and CMOS Modes(1)

Typical values are at +25°C, AVDD = 1.8 V, DRVDD = 1.8 V, sampling frequency = 200 MSPS, sine wave input clock, C_{LOAD} = 5 pF(2), and R_{LOAD} = 100 Ω(3), unless otherwise noted. Minimum and maximum values are across the full temperature range: T_{MIN} = –40°C to T_{MAX} = +85°C, AVDD = 1.8 V, and DRVDD = 1.7 V to 1.9 V.

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNIT
t_A	Aperture delay		0.6	0.8	1.2	ns
	Aperture delay variation	Between two devices at the same temperature and DRVDD supply		±100		ps
t_J	Aperture jitter			100		f_S rms
	Wakeup time	Time to valid data after coming out of STANDBY mode		5	25	µs
		Time to valid data after coming out of PDN GLOBAL mode		100	500	µs
	ADC latency(4)	Low-latency mode (default after reset)		10		Clock cycles
		Low-latency mode disabled (gain enabled, offset correction disabled)		16		Clock cycles
		Low-latency mode disabled (gain and offset correction enabled)		17		Clock cycles
DDR LVDS MODE(5)(6)						
t_{SU}	Data setup time(3)	Data valid(7) to zero-crossing of CLKOUTP	1.05	1.55		ns
t_H	Data hold time(3)	Zero-crossing of CLKOUTP to data becoming invalid(7)	0.35	0.6		ns
t_{PDI}	Clock propagation delay	Input clock rising edge crossover to output clock rising edge crossover *1 MSPS ≤ sampling frequency ≤ 200 MSPS*	3	4.2	5.4	ns
	Variation of t_{PDI}	Between two devices at the same temperature and DRVDD supply		±0.6		ns

(1) Timing parameters are ensured by design and characterization but are not production tested.
(2) C_{LOAD} is the effective external single-ended load capacitance between each output pin and ground.
(3) R_{LOAD} is the differential load resistance between the LVDS output pair.
(4) At higher frequencies, t_{PDI} is greater than one clock period and overall latency = ADC latency + 1.
(5) Measurements are done with a transmission line of 100-Ω characteristic impedance between the device and the load. Setup and hold time specifications take into account the effect of jitter on the output data and clock.
(6) The LVDS timings are unchanged for low latency disabled and enabled.
(7) Data valid refers to a logic high of 1.26 V and a logic low of 0.54 V.

TIMING REQUIREMENTS: LVDS and CMOS Modes[1] (continued)

Typical values are at +25°C, AVDD = 1.8 V, DRVDD = 1.8 V, sampling frequency = 200 MSPS, sine wave input clock, C_{LOAD} = 5 pF[2], and R_{LOAD} = 100 Ω[3], unless otherwise noted. Minimum and maximum values are across the full temperature range: T_{MIN} = –40°C to T_{MAX} = +85°C, AVDD = 1.8 V, and DRVDD = 1.7 V to 1.9 V.

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNIT
DDR LVDS MODE (continued)						
	LVDS bit clock duty cycle	Duty cycle of differential clock, (CLKOUTP – CLKOUTM) *1 MSPS ≤ sampling frequency ≤ 200 MSPS*	42	48	54	%
t_{RISE}, t_{FALL}	Data rising time, Data falling time	Rising time measured from –100 mV to +100 mV Falling time measured from +100 mV to –100 mV *1 MSPS ≤ sampling frequency ≤ 200 MSPS*		0.14		ns
$t_{CLKRISE}$, $t_{CLKFALL}$	Output clock rising time, Output clock falling time	Rising time measured from –100 mV to +100 mV Falling time measured from +100 mV to –100 mV *1 MSPS ≤ sampling frequency ≤ 200 MSPS*		0.14		ns
t_{OE}	Output enable (OE) to data delay	Time to valid data after OE becomes active		50	100	ns
PARALLEL CMOS MODE[8]						
t_{START}	Input clock to data delay	Input clock rising edge crossover to start of data valid[9]			–0.3	ns
t_{DV}	Data valid time	Time interval of valid data[9]	3.5	4.2		ns
t_{PDI}	Clock propagation delay	Input clock rising edge crossover to output clock rising edge crossover *1 MSPS ≤ sampling frequency ≤ 200 MSPS*	4	5.5	7	ns
	Output clock duty cycle	Duty cycle of output clock, CLKOUT *1 MSPS ≤ sampling frequency ≤ 200 MSPS*		47		%
t_{RISE}, t_{FALL}	Data rising time, Data falling time	Rising time measured from 20% to 80% of DRVDD Falling time measured from 80% to 20% of DRVDD *1 ≤ sampling frequency ≤ 200 MSPS*		0.35		ns
$t_{CLKRISE}$, $t_{CLKFALL}$	Output clock rising time, Output clock falling time	Rising time measured from 20% to 80% of DRVDD Falling time measured from 80% to 20% of DRVDD *1 ≤ sampling frequency ≤ 200 MSPS*		0.35		ns
t_{OE}	Output enable (OE) to data delay	Time to valid data after OE becomes active		20	40	ns

(8) Low-latency mode enabled.
(9) Data valid refers to a logic high of 1.26 V and a logic low of 0.54 V.

Table 3. LVDS Timing Across Sampling Frequencies

SAMPLING FREQUENCY (MSPS)	SETUP TIME (ns)			HOLD TIME (ns)		
	MIN	TYP	MAX	MIN	TYP	MAX
200	1.05	1.55	—	0.35	0.6	—
185	1.1	1.7	—	0.35	0.6	—
160	1.6	2.1	—	0.35	0.6	—
125	2.3	3	—	0.35	0.6	—
80	4.5	5.2	—	0.35	0.6	—

Table 4. CMOS Timing Across Sampling Frequencies (Low Latency Enabled)

SAMPLING FREQUENCY (MSPS)	TIMING SPECIFIED WITH RESPECT TO OUTPUT CLOCK								
	t_{SETUP} (ns)			t_{HOLD} (ns)			t_{PDI} (ns)		
	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX
200	1.6	2.2	—	1.8	2.5	—	4	5.5	7
185	1.8	2.4	—	1.9	2.7	—	4	5.5	7
160	2.3	2.9	—	2.2	3	—	4	5.5	7
125	3.1	3.7	—	3.2	4	—	4	5.5	7
80	5.4	6	—	5.4	6	—	4	5.5	7

Table 5. CMOS Timing Across Sampling Frequencies (Low Latency Disabled)

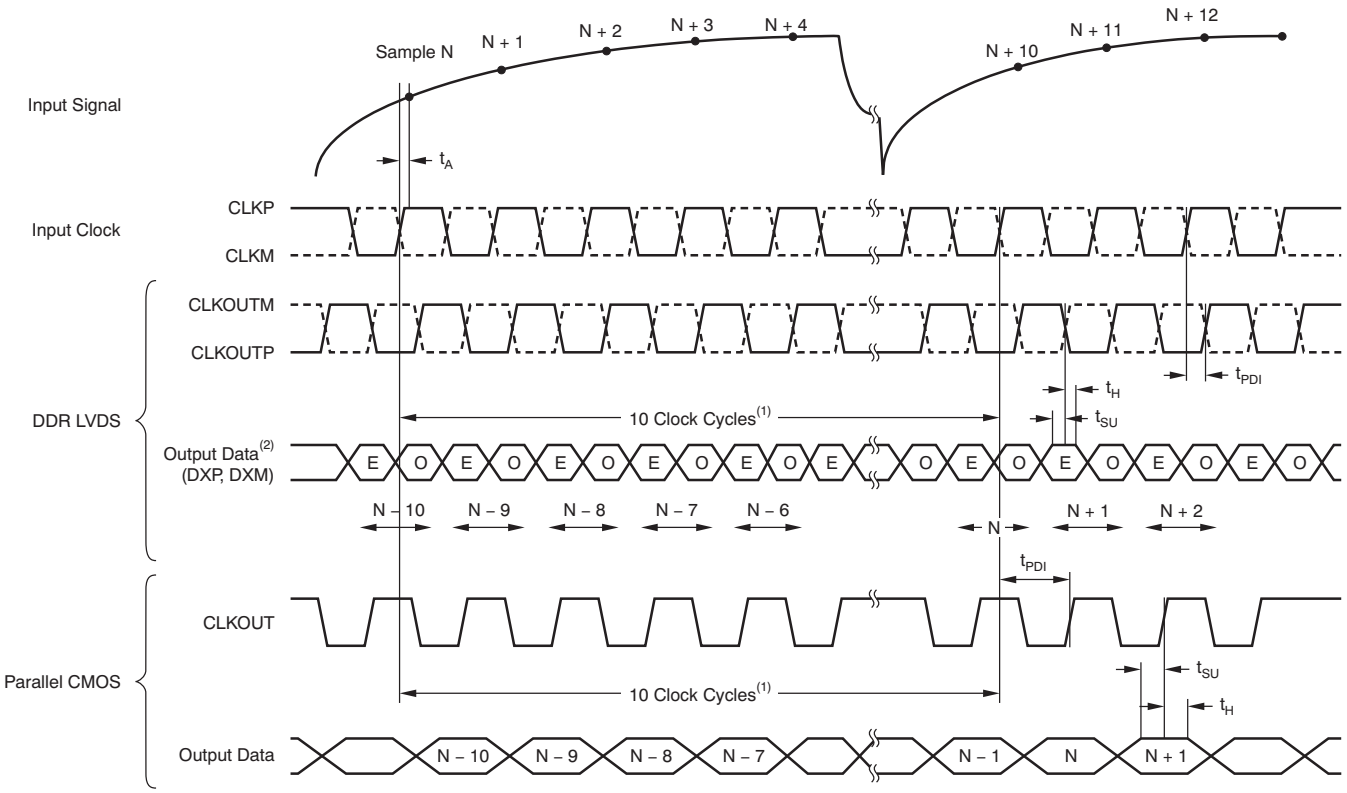
SAMPLING FREQUENCY (MSPS)	TIMING SPECIFIED WITH RESPECT TO OUTPUT CLOCK								
	t_{SETUP} (ns)			t_{HOLD} (ns)			t_{PDI} (ns)		
	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX
200	1	1.6	—	2	2.8	—	4	5.5	7
185	1.3	2	—	2.2	3	—	4	5.5	7
160	1.8	2.5	—	2.5	3.3	—	4	5.5	7
125	2.5	3.2	—	3.5	4.3	—	4	5.5	7
80	4.8	5.5	—	5.7	6.5	—	4	5.5	7

Table 6. CMOS Timing Across Sampling Frequencies (Low Latency Enabled)

SAMPLING FREQUENCY (MSPS)	TIMING SPECIFIED WITH RESPECT TO INPUT CLOCK					
	t_{START} (ns)			t_{DV} (ns)		
	MIN	TYP	MAX	MIN	TYP	MAX
200	—	—	–0.3	3.5	4.2	—
185	—	—	–1	3.9	4.5	—
170	—	—	–1.5	4.3	5	—

Table 7. CMOS Timing Across Sampling Frequencies (Low Latency Disabled)

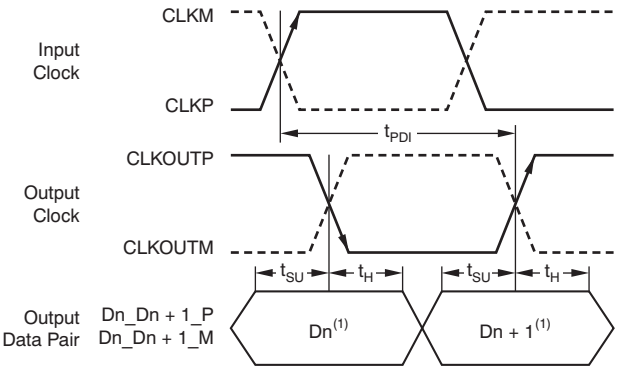
SAMPLING FREQUENCY (MSPS)	TIMING SPECIFIED WITH RESPECT TO INPUT CLOCK					
	t_{START} (ns)			t_{DV} (ns)		
	MIN	TYP	MAX	MIN	TYP	MAX
200	—	—	0.3	3.5	4.2	—
185	—	—	0	3.9	4.5	—
170	—	—	–1.3	4.3	5	—



(1) ADC latency in low-latency mode. At higher sampling frequencies, t_{DPI} is greater than one clock cycle which then makes the overall latency = ADC latency + 1.

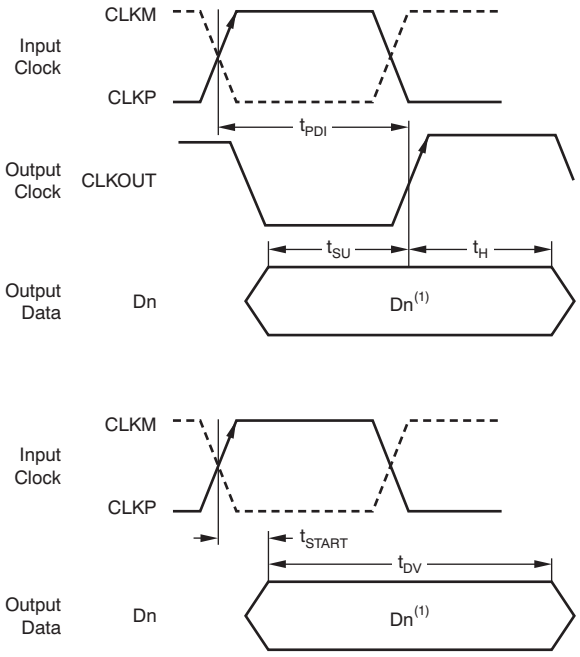
(2) E = Even bits (D0, D2, D4, and so on). O = Odd bits (D1, D3, D5, and so on).

Figure 5. Latency Diagram



(1) Dn = bits D0, D2, D4, and so on. Dn + 1 = bits D1, D3, D5, and so on.

Figure 6. LVDS Mode Timing



Dn = bits D0, D1, D2, and so on.

Figure 7. CMOS Mode Timing

DEVICE CONFIGURATION

The ADS4128 has several modes that can be configured using a serial programming interface, as described in Table 8, Table 9, and Table 10. In addition, the device has two dedicated parallel pins for quickly configuring commonly used functions. The parallel pins are DFS (analog 4-level control pin) and OE (digital control pin). The analog control pins can be easily configured using a simple resistor divider (with 10% tolerance resistors).

Table 8. DFS: Analog Control Pin

VOLTAGE APPLIED ON DFS	DESCRIPTION (Data Format and Output Interface)
0, +100 mV/–0 mV	Twos complement and DDR LVDS
(3/8) AVDD ± 100 mV	Twos complement and parallel CMOS
(5/8) AVDD ± 100 mV	Offset binary and parallel CMOS
AVDD, +0 mV/–100 mV	Offset binary and DDR LVDS

Table 9. OE: Digital Control Pin

VOLTAGE APPLIED ON OE	DESCRIPTION
0	Output data buffers disabled
AVDD	Output data buffers enabled

When the serial interface is not used, the SDATA pin can also be used as a digital control pin to place the device in standby mode. To enable this, the RESET pin must be tied high. In this mode, SEN and SCLK do not have any alternative functions. Keep SEN tied high and SCLK tied low on the board.

Table 10. SDATA: Digital Control Pin

VOLTAGE APPLIED ON SDATA	DESCRIPTION
0	Normal operation
Logic high	Device enters standby

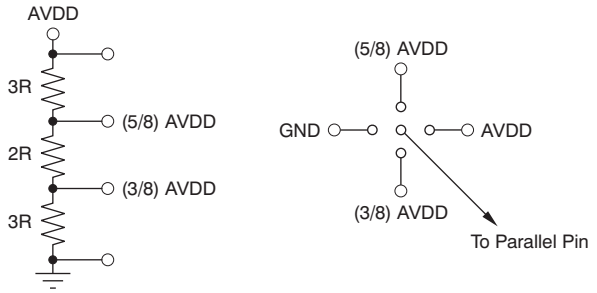


Figure 8. Simplified Diagram to Configure DFS Pin

SERIAL INTERFACE

The analog-to-digital converter (ADC) has a set of internal registers that can be accessed by the serial interface formed by the SEN (serial interface enable), SCLK (serial interface clock), and SDATA (serial interface data) pins. Serial shift of bits into the device is enabled when SEN is low. Serial data SDATA are latched at every SCLK falling edge when SEN is active (low). The serial data are loaded into the register at every 16th SCLK falling edge when SEN is low. If the word length exceeds a multiple of 16 bits, the excess bits are ignored. Data can be loaded in multiples of 16-bit words within a single active SEN pulse. The first eight bits form the register address and the remaining eight bits are the register data. The interface can function with an SCLK frequency from 20 MHz down to very low speeds (of a few Hertz) and also with a non-50% SCLK duty cycle.

Register Initialization

After power-up, the internal registers must be initialized to default values. This initialization can be accomplished in one of two ways:

1. Either through hardware reset by applying a high pulse on the RESET pin (of widths greater than 10 ns), as shown in Figure 9; or
2. By applying a software reset. When using the serial interface, set the RESET bit (D7 in register 00h) high. This setting initializes the internal registers to default values and then self-resets the RESET bit low. In this case, the RESET pin is kept low.

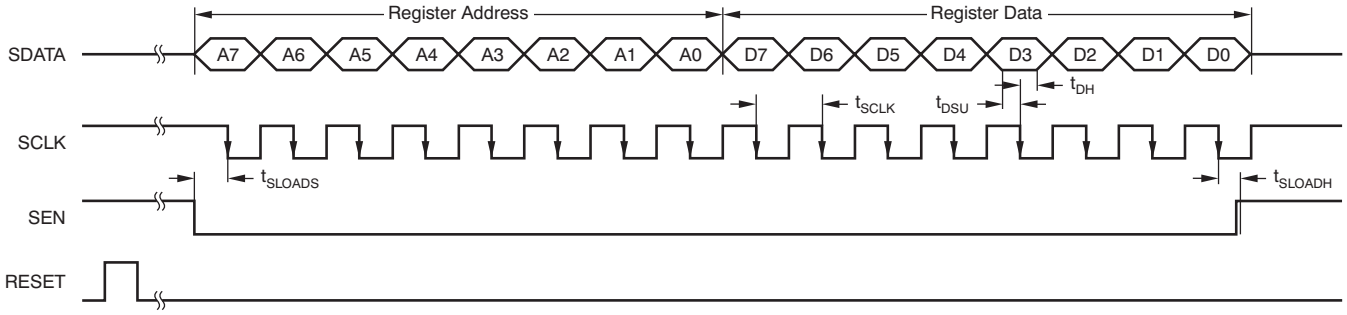


Figure 9. Serial Interface Timing

SERIAL INTERFACE TIMING CHARACTERISTICS

Typical values are at +25°C, minimum and maximum values are across the full temperature range: T_{MIN} = –40°C to T_{MAX} = +85°C, AVDD = 1.8 V, and DRVDD = 1.8 V, unless otherwise noted.

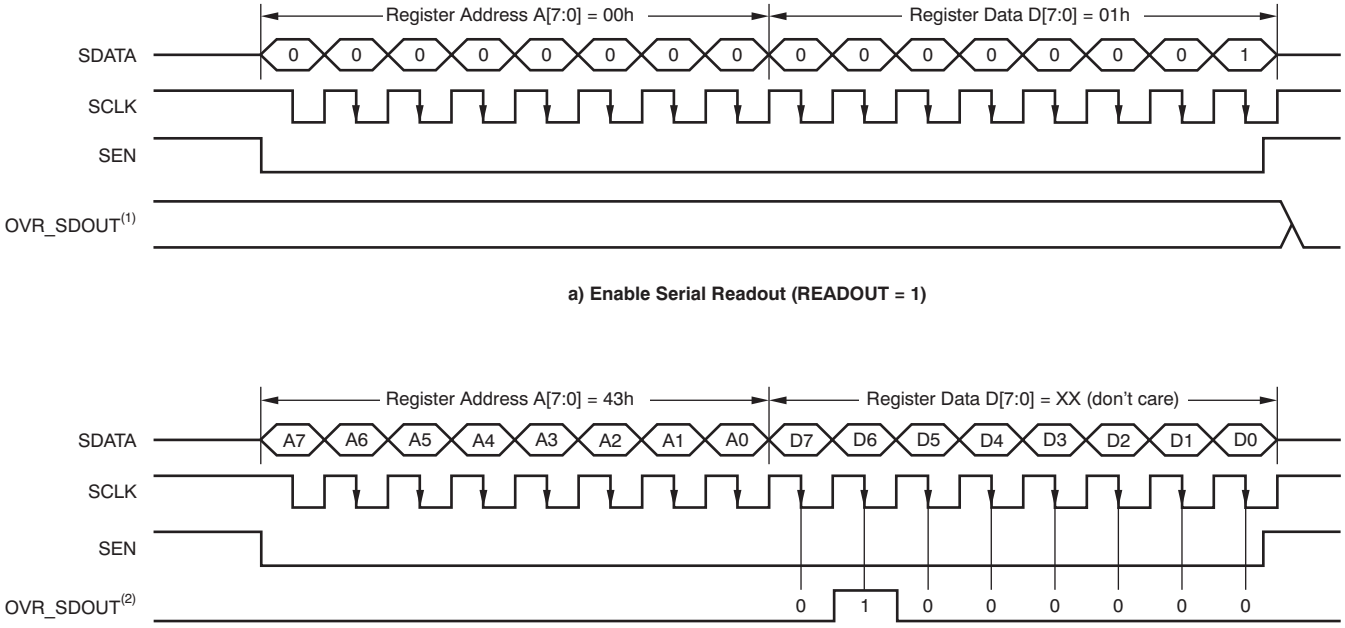
PARAMETER		MIN	TYP	MAX	UNIT
f_{SCLK}	SCLK frequency (equal to $1/t_{SCLK}$)	> dc		20	MHz
t_{SLOADS}	SEN to SCLK setup time	25			ns
t_{SLOADH}	SCLK to SEN hold time	25			ns
t_{DSU}	SDATA setup time	25			ns
t_{DH}	SDATA hold time	25			ns

Serial Register Readout

The serial register readout function allows the contents of the internal registers to be read back on the OVR_SDOUT pin. This readback may be useful as a diagnostic check to verify the serial interface communication between the external controller and the ADC.

After power-up and device reset, the OVR_SDOUT pin functions as an over-range indicator pin by default. When the readout mode is enabled, OVR_SDOUT outputs the contents of the selected register serially:

1. Set the READOUT register bit to '1'. This setting puts the device in serial readout mode and disables any further writes to the internal registers **except** the register at address 0. Note that the READOUT bit itself is also located in register 0. The device can exit readout mode by writing READOUT = 0. Only the contents of the register at address 0 cannot be read in the register readout mode.
2. Initiate a serial interface cycle specifying the address of the register (A7 to A0) whose content has to be read.
3. The device serially outputs the contents (D7 to D0) of the selected register on the OVR_SDOUT pin.
4. The external controller can latch the contents at the falling edge of SCLK.
5. To exit the serial readout mode, the reset register bit READOUT = 0 enables writes into all registers of the device. At this point, the OVR_SDOUT pin becomes an over-range indicator pin.

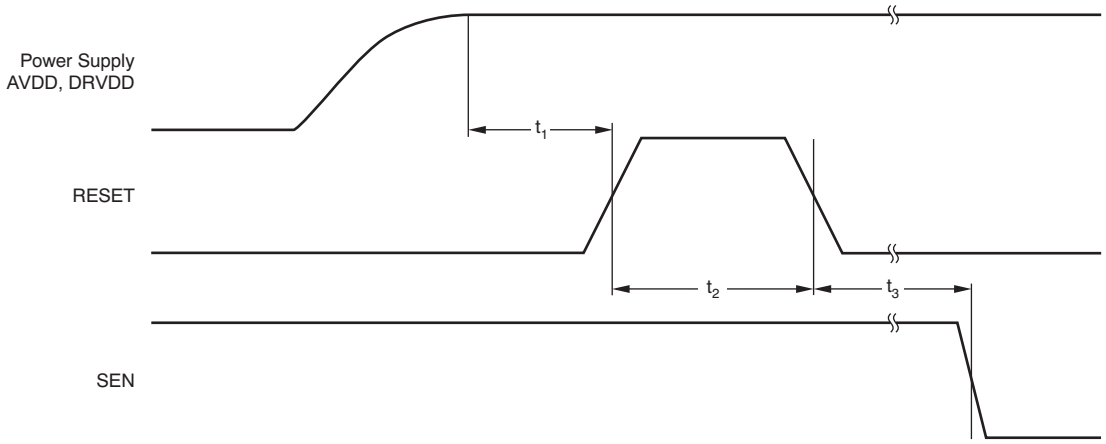


(1) The OVR_SDOUT pin functions as OVR (READOUT = 0).

(2) The OVR_SDOUT pin functions as a serial readout (READOUT = 1).

Figure 10. Serial Readout Timing Diagram

RESET TIMING CHARACTERISTICS



NOTE: A high pulse on the RESET pin is required in the serial interface mode in case of initialization through hardware reset. For parallel interface operation, RESET must be permanently tied high.

Figure 11. Reset Timing Diagram

RESET TIMING REQUIREMENTS

Typical values are at +25°C and minimum and maximum values are across the full temperature range: T_{MIN} = –40°C to T_{MAX} = +85°C, unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_1	Power-on delay	Delay from power-up of AVDD and DRVDD to RESET pulse active	1			ms
t_2	Reset pulse width	Pulse width of active RESET signal that resets the serial registers	10			ns
					1 (1)	µs
t_3		Delay from RESET disable to SEN active	100			ns

(1) The reset pulse is needed only when using the serial interface configuration. If the pulse width is greater than 1 µs, the device can enter the parallel configuration mode briefly and then return back to serial interface mode.

SERIAL REGISTER MAP

Table 11 summarizes the functions supported by the serial interface.

Table 11. Serial Interface Register Map(1)

REGISTER ADDRESS	DEFAULT VALUE AFTER RESET	REGISTER DATA							
A[7:0] (Hex)	D[7:0] (Hex)	D7	D6	D5	D4	D3	D2	D1	D0
00	00	0	0	0	0	0	0	RESET	READOUT
01	00	LVDS SWING						0	0
03	00	0	0	0	0	0	0	HIGH PERF MODE 1	
25	00	GAIN				DISABLE GAIN	TEST PATTERNS		
26	00	0	0	0	0	0	0	LVDS CLKOUT STRENGTH	LVDS DATA STRENGTH
3D	00	DATA FORMAT		EN OFFSET CORR	0	0	0	0	0
3F	00	CUSTOM PATTERN HIGH D[11:4]							
40	00	CUSTOM PATTERN D[3:0]				0	0	0	0
41	00	LVDS CMOS		CMOS CLKOUT STRENGTH		EN CLKOUT RISE	CLKOUT RISE POSN		EN CLKOUT FALL
42	00	CLKOUT FALL POSN		0	0	DIS LOW LATENCY	STBY	0	0
43	00	0	PDN GLOBAL	0	PDN OBUF	0	0	EN LVDS SWING	
4A	00	0	0	0	0	0	0	0	HIGH PERF MODE 2
BF	00	OFFSET PEDESTAL						0	0
CF	00	FREEZE OFFSET CORR	0	OFFSET CORR TIME CONSTANT				0	0
DF	00	0	0	LOW SPEED		0	0	0	0

(1) Multiple register functions can be programmed in a single write operation.

DESCRIPTION OF SERIAL REGISTERS

For best performance, two special mode register bits must be enabled:

HI PERF MODE 1 and HI PERF MODE 2.

Register Address 00h (Default = 00h)

7	6	5	4	3	2	1	0
0	0	0	0	0	0	RESET	READOUT

Bits[7:2] Always write '0'

Bit 1 RESET: Software reset applied

This bit resets all internal registers to default values and self-clears to 0 (default = 1).

Bit 0 READOUT: Serial readout

This bit sets the serial readout of the registers.
0 = Serial readout of registers disabled; the OVR_SDOUT pin functions as an over-voltage indicator.
1 = Serial readout enabled; the OVR_SDOUT pin functions as a serial data readout.

Register Address 01h (Default = 00h)

7	6	5	4	3	2	1	0
LVDS SWING						0	0

Bits[7:2] LVDS SWING: LVDS swing programmability(1)

000000 = Default LVDS swing; ±350 mV with external 100-Ω termination
011011 = LVDS swing *increases* to ±410 mV
110010 = LVDS swing *increases* to ±465 mV
010100 = LVDS swing *increases* to ±570 mV
111110 = LVDS swing *decreases* to ±200 mV
001111 = LVDS swing *decreases* to ±125 mV

Bits[1:0] Always write '0'

(1) The EN LVDS SWING register bits must be set to enable LVDS swing control.

Register Address 03h (Default = 00h)

7	6	5	4	3	2	1	0
0	0	0	0	0	0	HI PERF MODE 1	

Bits[7:2] Always write '0'

Bits[1:0] HI PERF MODE 1: High-performance mode 1

00 = Default performance after reset
01 = Do not use
10 = Do not use
11 = For best performance across sampling clock and input signal frequencies, set the HIGH PERF MODE 1 bits

Register Address 25h (Default = 00h)

7	6	5	4	3	2	1	0
GAIN				DISABLE GAIN	TEST PATTERNS		

Bits[7:4] GAIN: Gain programmability

These bits set the gain programmability in 0.5-dB steps.

0000 = 0-dB gain (default after reset)
0001 = 0.5-dB gain
0010 = 1.0-dB gain
0011 = 1.5-dB gain
0100 = 2.0-dB gain
0101 = 2.5-dB gain
0110 = 3.0-dB gain
0111 = 3.5-dB gain
1000 = 4.0-dB gain
1001 = 4.5-dB gain
1010 = 5.0-dB gain
1011 = 5.5-dB gain
1100 = 6.0-dB gain

Bit 3 DISABLE GAIN: Gain setting

This bit sets the gain.
0 = Gain enabled; gain is set by the GAIN bits only if low-latency mode is disabled
1 = Gain disabled

Bits[2:0] TEST PATTERNS: Data capture

These bits verify data capture.
000 = Normal operation
001 = Outputs all '0's
010 = Outputs all '1's
011 = Outputs toggle pattern

Output data D[11:0] is an alternating sequence of *010101010101* and *101010101010*.

100 = Outputs digital ramp

Output data increments by one LSB (12-bit) every fourth clock cycle from code 0 to code 4095

101 = Output custom pattern (use registers 3Fh and 40h for setting the custom pattern)
110 = Unused
111 = Unused

Register Address 26h (Default = 00h)

7	6	5	4	3	2	1	0
0	0	0	0	0	0	LVDS CLKOUT STRENGTH	LVDS DATA STRENGTH

Bits[7:2] Always write '0'

Bit 1 LVDS CLKOUT STRENGTH: LVDS output clock buffer strength

This bit determines the external termination to be used with the LVDS output clock buffer.
0 = 100-Ω external termination (default strength)
1 = 50-Ω external termination (2x strength)

Bit 0 LVDS DATA STRENGTH: LVDS data buffer strength

This bit determines the external termination to be used with all of the LVDS data buffers.
0 = 100-Ω external termination (default strength)
1 = 50-Ω external termination (2x strength)

Register Address 3Dh (Default = 00h)

7	6	5	4	3	2	1	0
DATA FORMAT		EN OFFSET CORR	0	0	0	0	0

Bits[7:6] DATA FORMAT: Data format selection

These bits selects the data format.
00 = The DFS pin controls data format selection
10 = Twos complement
11 = Offset binary

Bit 5 ENABLE OFFSET CORR: Offset correction setting

This bit sets the offset correction.
0 = Offset correction disabled
1 = Offset correction enabled

Bits[4:0] Always write '0'

Register Address 3Fh (Default = 00h)

7	6	5	4	3	2	1	0
CUSTOM PATTERN D11	CUSTOM PATTERN D10	CUSTOM PATTERN D9	CUSTOM PATTERN D8	CUSTOM PATTERN D7	CUSTOM PATTERN D6	CUSTOM PATTERN D5	CUSTOM PATTERN D4

Bits[7:0] CUSTOM PATTERN

These bits set the custom pattern.

Register Address 40h (Default = 00h)

7	6	5	4	3	2	1	0
CUSTOM PATTERN D3	CUSTOM PATTERN D2	CUSTOM PATTERN D1	CUSTOM PATTERN D0	0	0	0	0

Bits[7:2] CUSTOM PATTERN

These bits set the custom pattern.

Bits[3:0] Always write '0'

Register Address 41h (Default = 00h)

7	6	5	4	3	2	1	0
LVDS CMOS		CMOS CLKOUT STRENGTH		EN CLKOUT RISE	CLKOUT RISE POSN		EN CLKOUT FALL

Bits[7:6] LVDS CMOS: Interface selection

These bits select the interface.
00 = The DFS pin controls the selection of either LVDS or CMOS interface
10 = The DFS pin controls the selection of either LVDS or CMOS interface
01 = DDR LVDS interface
11 = Parallel CMOS interface

Bits[5:4] CMOS CLKOUT STRENGTH

Controls strength of CMOS output clock only.
00 = Maximum strength (recommended and used for specified timings)
01 = Medium strength
10 = Low strength
11 = Very low strength

Bit 3 ENABLE CLKOUT RISE

0 = Disables control of output clock rising edge
1 = Enables control of output clock rising edge

Bits[2:1] CLKOUT RISE POSN: CLKOUT rise control

Controls position of output clock rising edge

LVDS interface:
00 = Default position (timings are specified in this condition)
01 = Setup reduces by 500 ps, hold increases by 500 ps
10 = Data transition is aligned with rising edge
11 = Setup reduces by 200 ps, hold increases by 200 ps

CMOS interface:
00 = Default position (timings are specified in this condition)
01 = Setup reduces by 100 ps, hold increases by 100 ps
10 = Setup reduces by 200 ps, hold increases by 200 ps
11 = Setup reduces by 1.5 ns, hold increases by 1.5 ns

Bit 0 ENABLE CLKOUT FALL

0 = Disables control of output clock falling edge
1 = Enables control of output clock falling edge

Register Address 42h (Default = 00h)

7	6	5	4	3	2	1	0
CLKOUT FALL CTRL		0	0	DIS LOW LATENCY	STBY	0	0

Bits[7:6] CLKOUT FALL CTRL

Controls position of output clock falling edge

LVDS interface:
00 = Default position (timings are specified in this condition)
01 = Setup reduces by 400 ps, hold increases by 400 ps
10 = Data transition is aligned with rising edge
11 = Setup reduces by 200 ps, hold increases by 200 ps

CMOS interface:
00 = Default position (timings are specified in this condition)
01 = Falling edge is advanced by 100 ps
10 = Falling edge is advanced by 200 ps
11 = Falling edge is advanced by 1.5 ns

Bits[5:4] Always write '0'

Bit 3 DIS LOW LATENCY: Disable low latency

This bit disables low-latency mode.
0 = Low-latency mode is enabled. Digital functions such as gain, test patterns, and offset correction are disabled.
1 = Low-latency mode is disabled. This setting enables the digital functions. See the *Digital Functions and Low-Latency Mode* section.

Bit 2 STBY: Standby mode

This bit sets the standby mode.
0 = Normal operation
1 = Only the ADC and output buffers are powered down; internal reference is active; wake-up time from standby is fast

Bits[1:0] Always write '0'

Register Address 43h (Default = 00h)

7	6	5	4	3	2	1	0
0	PDN GLOBAL	0	PDN OBUF	0	0	EN LVDS SWING	

Bit 0 **Always write '0'**

Bit 6 **PDN GLOBAL: Power-down**

This bit sets the state of operation.
0 = Normal operation
1 = Total power down; the ADC, internal references, and output buffers are powered down; slow wake-up time.

Bit 5 **Always write '0'**

Bit 4 **PDN OBUF: Power-down output buffer**

This bit set the output data and clock pins.
0 = Output data and clock pins enabled
1 = Output data and clock pins powered down and put in high-impedance state

Bits[3:2] **Always write '0'**

Bits[1:0] **EN LVDS SWING: LVDS swing control**

00 = LVDS swing control using LVDS SWING register bits is disabled
01 = Do not use
10 = Do not use
11 = LVDS swing control using LVDS SWING register bits is enabled

Register Address 4Ah (Default = 00h)

7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	HI PERF MODE 2

Bits[7:1] **Always write '0'**

Bit[0] **HI PERF MODE 2: High-performance mode 2**

This bit is recommended for high input signal frequencies greater than 230 MHz.
0 = Default performance after reset
1 = For best performance with high-frequency input signals, set the HIGH PERF MODE 2 bit

Register Address BFh (Default = 00h)

7	6	5	4	3	2	1	0
OFFSET PEDESTAL				0	0	0	0

Bits[7:4] OFFSET PEDESTAL

These bits set the offset pedestal.
When the offset correction is enabled, the final converged value after the offset is corrected is the ADC mid-code value. A pedestal can be added to the final converged value by programming these bits.

OFFSET PEDESTAL VALUE	PEDESTAL
0111	7 LSB
0110	6 LSB
0101	5 LSB
—	—
000000	0 LSB
—	—
1111	–1 LSB
1110	–2 LSB
—	—
1000	–8 LSB

Bits[3:0] Always write '0'

Register Address CFh (Default = 00h)

7	6	5	4	3	2	1	0
FREEZE OFFSET CORR	BYPASS OFFSET CORR	OFFSET CORR TIME CONSTANT				0	0

Bit 7 **FREEZE OFFSET CORR**

This bit sets the freeze offset correction.
0 = Estimation of offset correction is not frozen (bit EN OFFSET CORR must be set)
1 = Estimation of offset correction is frozen (bit EN OFFSET CORR must be set). When frozen, the last estimated value is used for offset correction every clock cycle. See OFFSET CORRECTION, *Offset Correction*.

Bit 6 **Always write '0'**

Bits[5:2] **OFFSET CORR TIME CONSTANT**

These bits set the offset correction time constant for the correction loop time constant in number of clock cycles.

VALUE	TIME CONSTANT (Number of Clock Cycles)
0000	1 M
0001	2 M
0010	4 M
0011	8 M
0100	16 M
0101	32 M
0110	64 M
0111	128 M
1000	256 M
1001	512 M
1010	1 G
1011	2 G

Bits[1:0] **Always write '0'**

Register Address DFh (Default = 00h)

7	6	5	4	3	2	1	0
0	0	LOW SPEED		0	0	0	0

Bits[7:1] **Always write '0'**

Bit 0 **LOW SPEED: Low-speed mode**

00, 01, 10 = Low-speed mode disabled (default state after reset); this setting is recommended for sampling rates greater than 80 MSPS.
11 = Low-speed mode enabled; this setting is recommended for sampling rates less than or equal to 80 MSPS.

TYPICAL CHARACTERISTICS

At +25°C, AVDD = 1.8 V, DRVDD = 1.8 V, maximum rated sampling frequency, sine wave input clock, 1.5-V_{PP} differential clock amplitude, 50% clock duty cycle, –1-dBFS differential analog input, 0-dB gain, low-latency mode, DDR LVDS output interface, and 32k-point FFT, unless otherwise noted.

FFT FOR 10-MHz INPUT SIGNAL

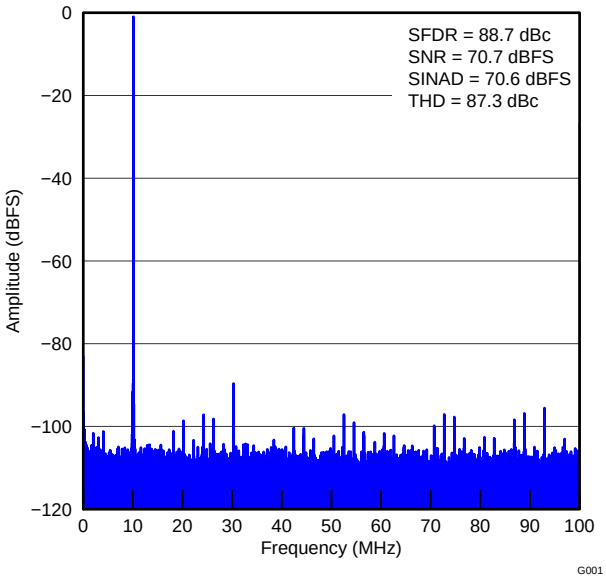


Figure 12.

FFT FOR 170-MHz INPUT SIGNAL

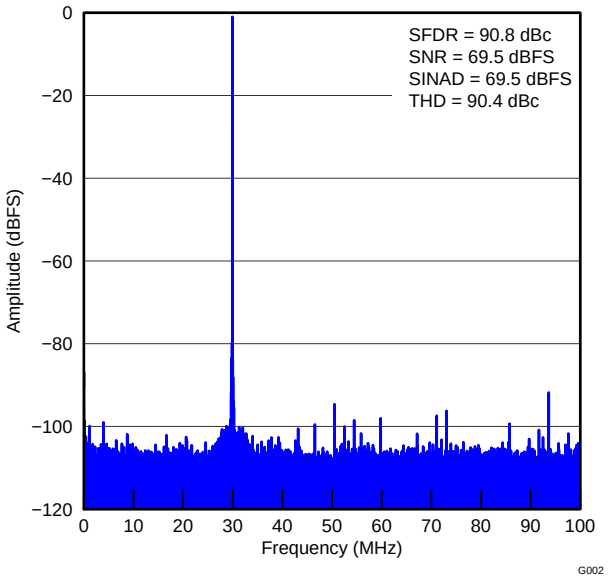


Figure 13.

FFT FOR 300-MHz INPUT SIGNAL

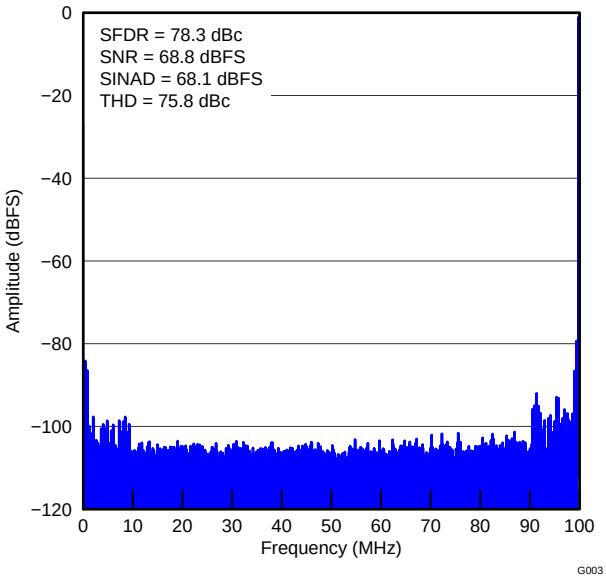


Figure 14.

FFT FOR TWO-TONE INPUT SIGNAL

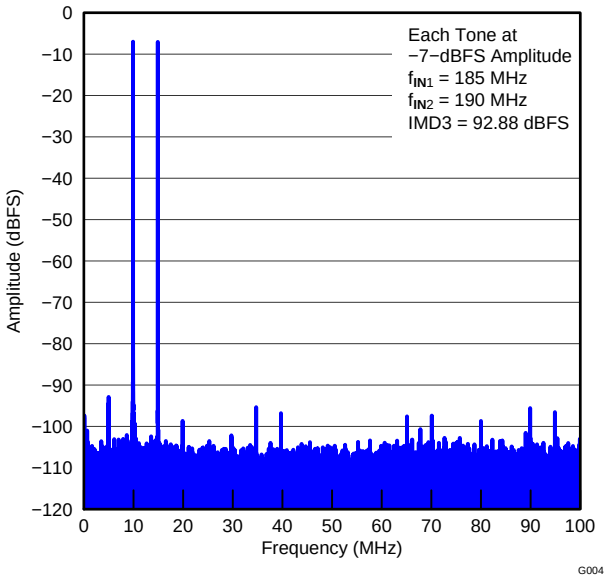


Figure 15.

TYPICAL CHARACTERISTICS (continued)

At +25°C, AVDD = 1.8 V, DRVDD = 1.8 V, maximum rated sampling frequency, sine wave input clock, 1.5-V_{PP} differential clock amplitude, 50% clock duty cycle, –1-dBFS differential analog input, 0-dB gain, low-latency mode, DDR LVDS output interface, and 32k-point FFT, unless otherwise noted.

FFT FOR TWO-TONE INPUT SIGNAL

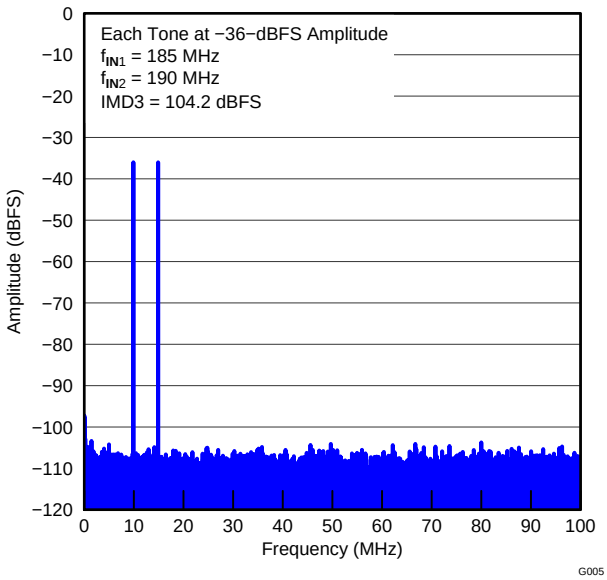


Figure 16.

SFDR vs INPUT FREQUENCY

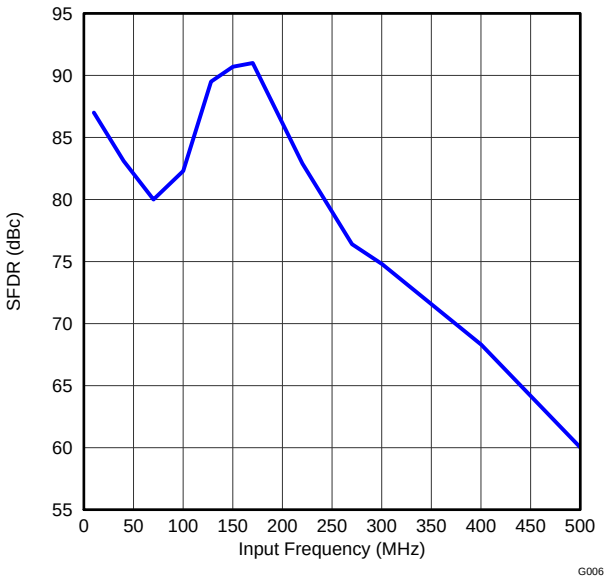


Figure 17.

SNR vs INPUT FREQUENCY

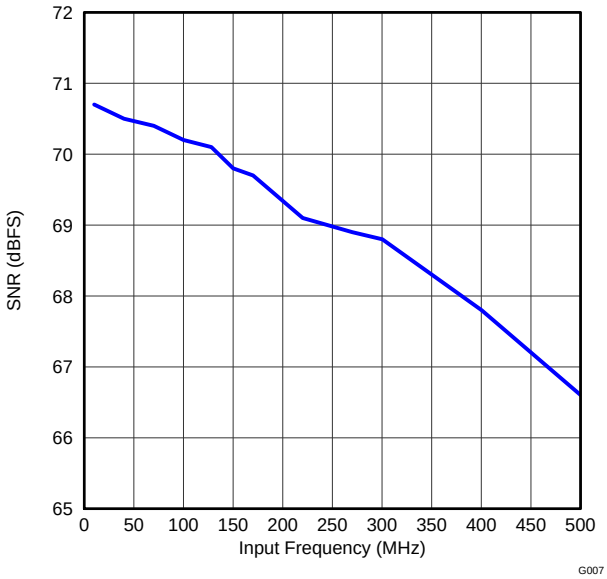


Figure 18.

SFDR vs DIGITAL GAIN

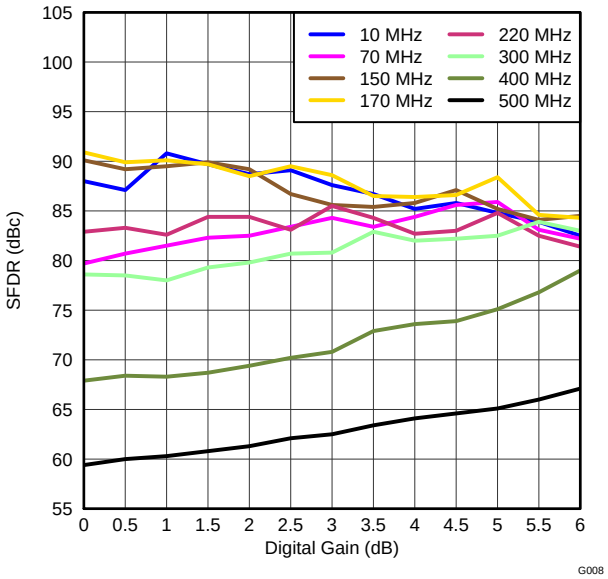


Figure 19.

TYPICAL CHARACTERISTICS (continued)

At +25°C, AVDD = 1.8 V, DRVDD = 1.8 V, maximum rated sampling frequency, sine wave input clock, 1.5-V_{PP} differential clock amplitude, 50% clock duty cycle, –1-dBFS differential analog input, 0-dB gain, low-latency mode, DDR LVDS output interface, and 32k-point FFT, unless otherwise noted.

SINAD vs DIGITAL GAIN

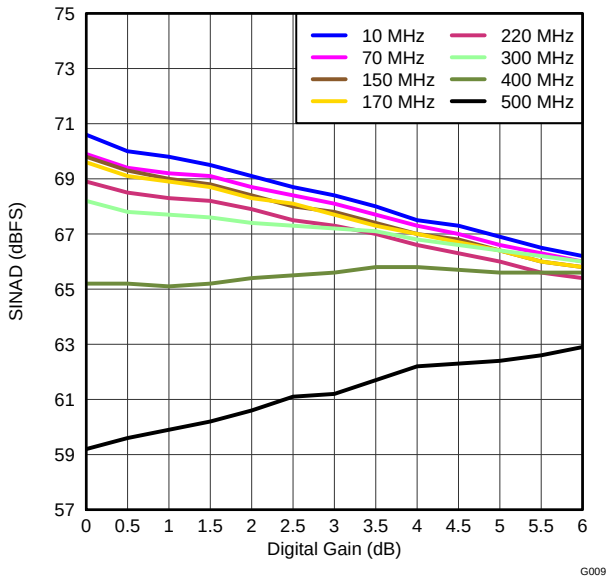


Figure 20.

PERFORMANCE ACROSS INPUT AMPLITUDE

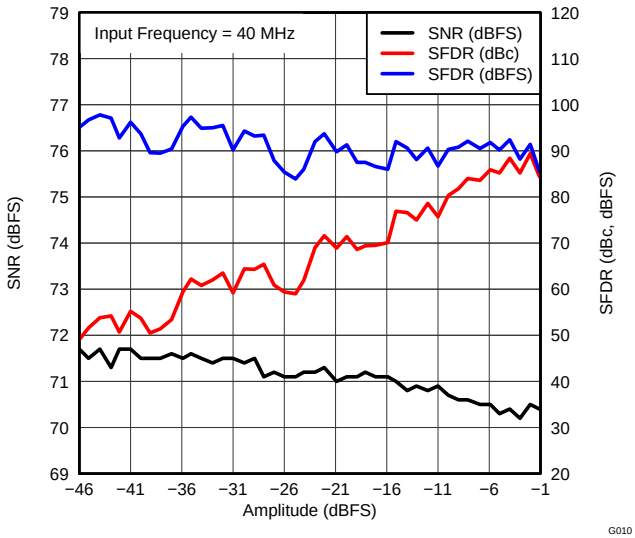


Figure 21.

PERFORMANCE ACROSS INPUT AMPLITUDE

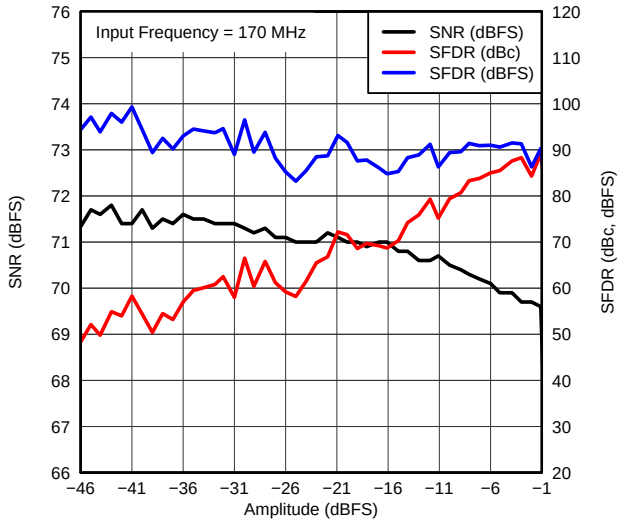


Figure 22.

PERFORMANCE vs INPUT COMMON-MODE VOLTAGE

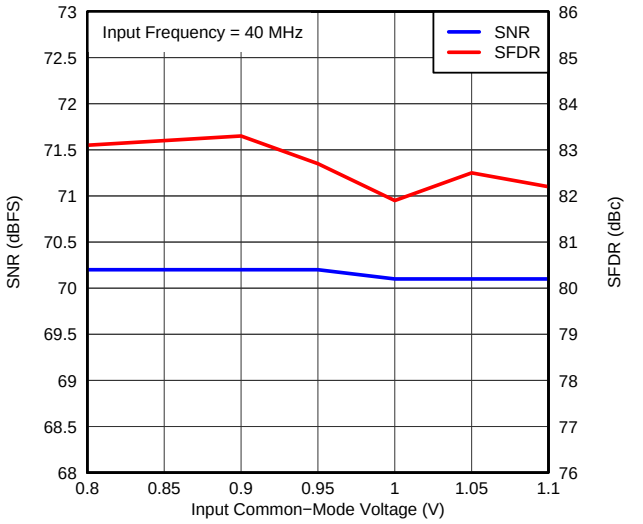


Figure 23.

TYPICAL CHARACTERISTICS (continued)

At +25°C, AVDD = 1.8 V, DRVDD = 1.8 V, maximum rated sampling frequency, sine wave input clock, 1.5-V_{PP} differential clock amplitude, 50% clock duty cycle, –1-dBFS differential analog input, 0-dB gain, low-latency mode, DDR LVDS output interface, and 32k-point FFT, unless otherwise noted.

SFDR vs AVDD SUPPLY AND TEMPERATURE

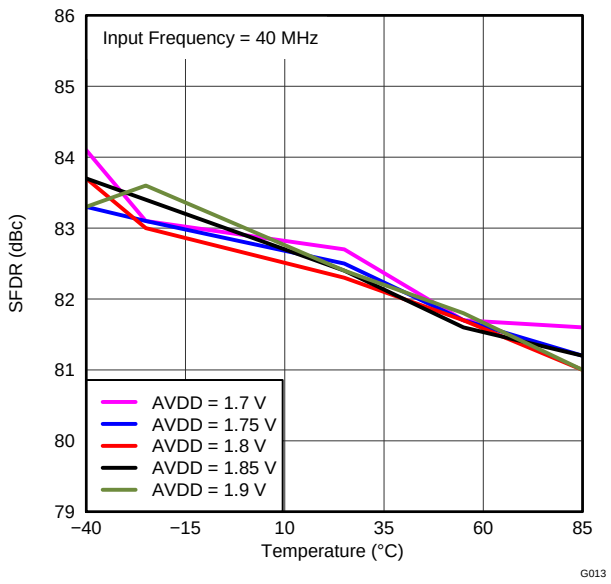


Figure 24.

SNR vs AVDD SUPPLY AND TEMPERATURE

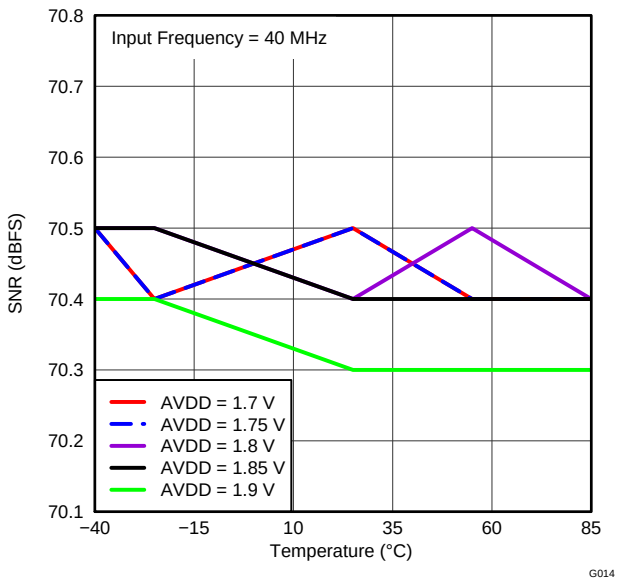


Figure 25.

PERFORMANCE vs DRVDD SUPPLY

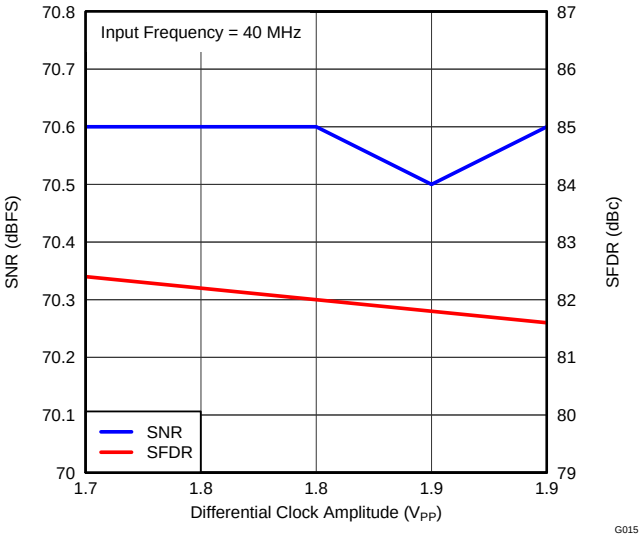


Figure 26.

PERFORMANCE vs CLOCK AMPLITUDE

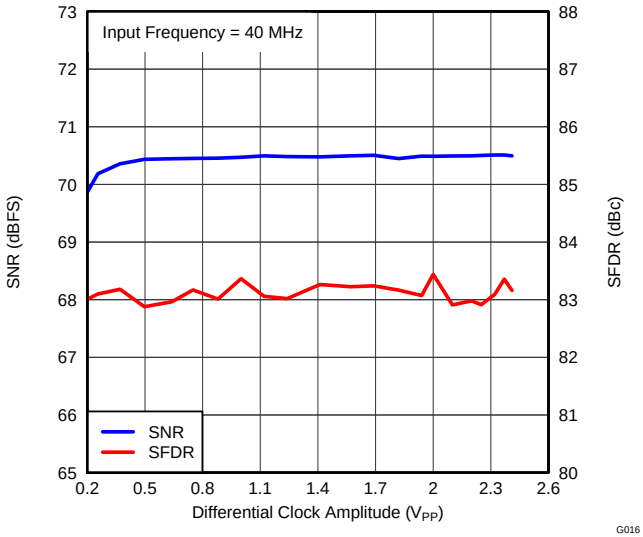


Figure 27.

TYPICAL CHARACTERISTICS (continued)

At +25°C, AVDD = 1.8 V, DRVDD = 1.8 V, maximum rated sampling frequency, sine wave input clock, 1.5-V_{PP} differential clock amplitude, 50% clock duty cycle, –1-dBFS differential analog input, 0-dB gain, low-latency mode, DDR LVDS output interface, and 32k-point FFT, unless otherwise noted.

PERFORMANCE vs CLOCK AMPLITUDE

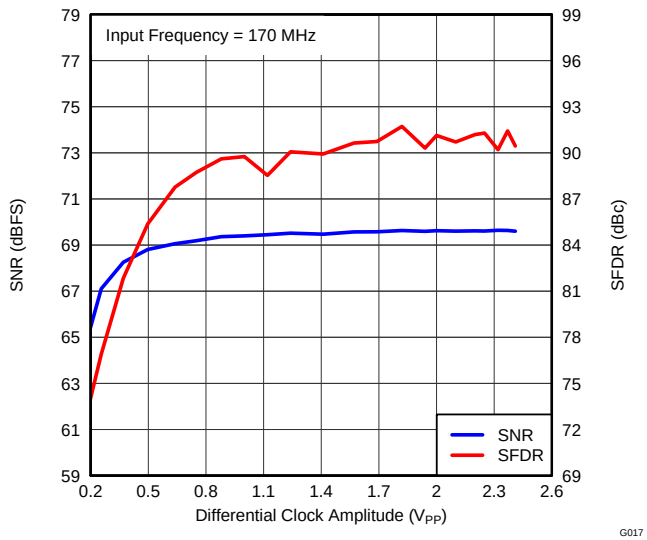


Figure 28.

PERFORMANCE vs CLOCK DUTY CYCLE

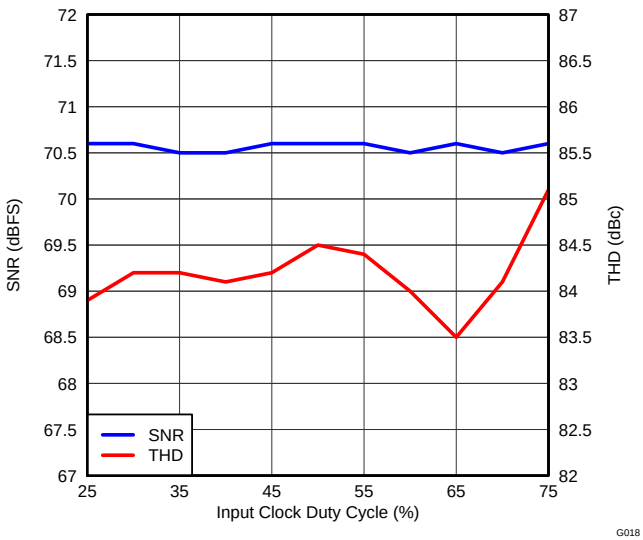


Figure 29.

CMRR vs FREQUENCY

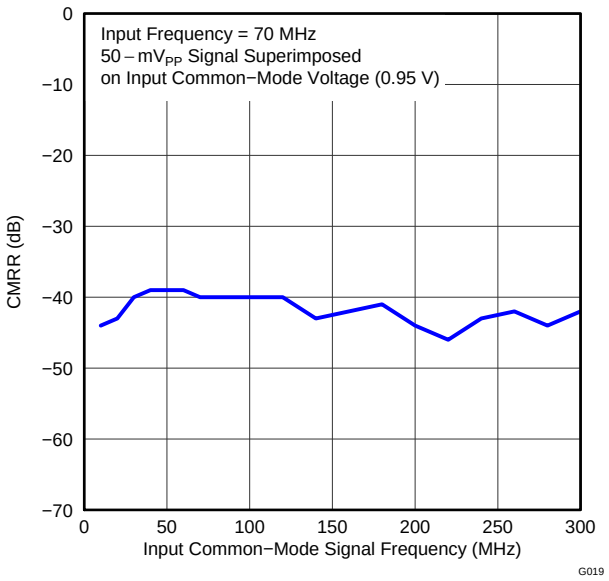


Figure 30.

CMRR SPECTRUM

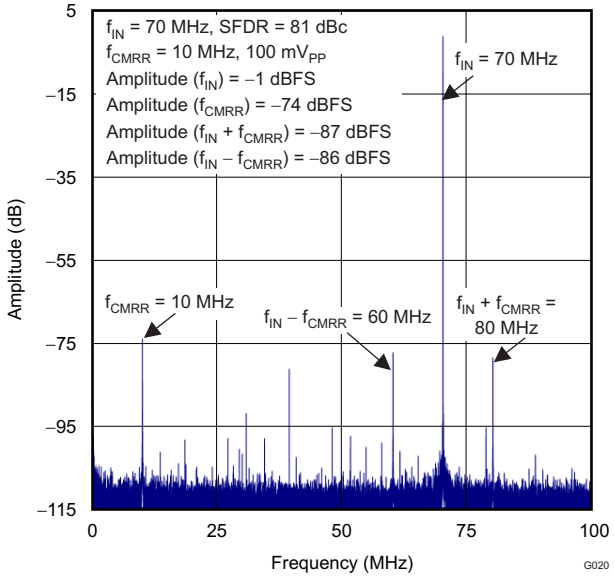


Figure 31.

TYPICAL CHARACTERISTICS (continued)

At +25°C, AVDD = 1.8 V, DRVDD = 1.8 V, maximum rated sampling frequency, sine wave input clock, 1.5-V_{PP} differential clock amplitude, 50% clock duty cycle, –1-dBFS differential analog input, 0-dB gain, low-latency mode, DDR LVDS output interface, and 32k-point FFT, unless otherwise noted.

PSRR vs FREQUENCY

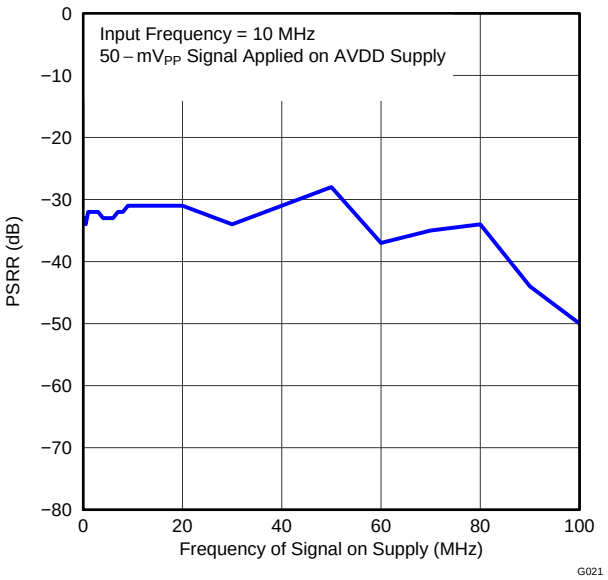


Figure 32.

ZOOMED VIEW OF SPECTRUM WITH PSRR SIGNAL

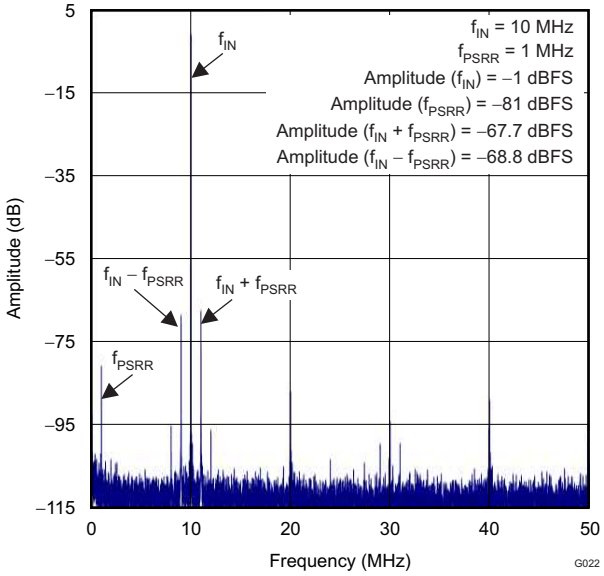


Figure 33.

POWER vs SAMPLING FREQUENCY

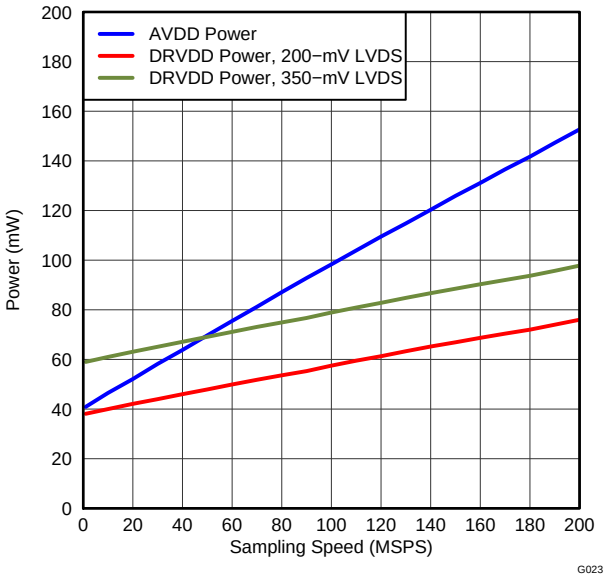


Figure 34.

DRVDD CURRENT vs SAMPLING FREQUENCY

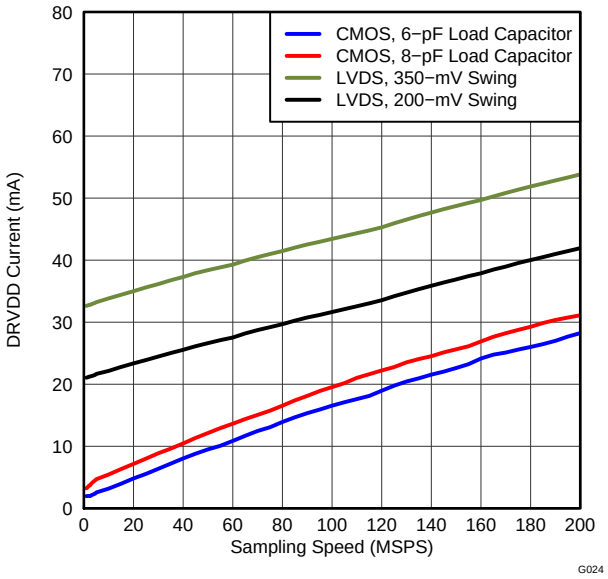


Figure 35.

TYPICAL CHARACTERISTICS: Contour

At +25°C, AVDD = 1.8 V, DRVDD = 1.8 V, maximum rated sampling frequency, sine wave input clock, 1.5-V_{PP} differential clock amplitude, 50% clock duty cycle, –1-dBFS differential analog input, 0-dB gain, low-latency mode, DDR LVDS output interface, and 32k-point FFT, unless otherwise noted.

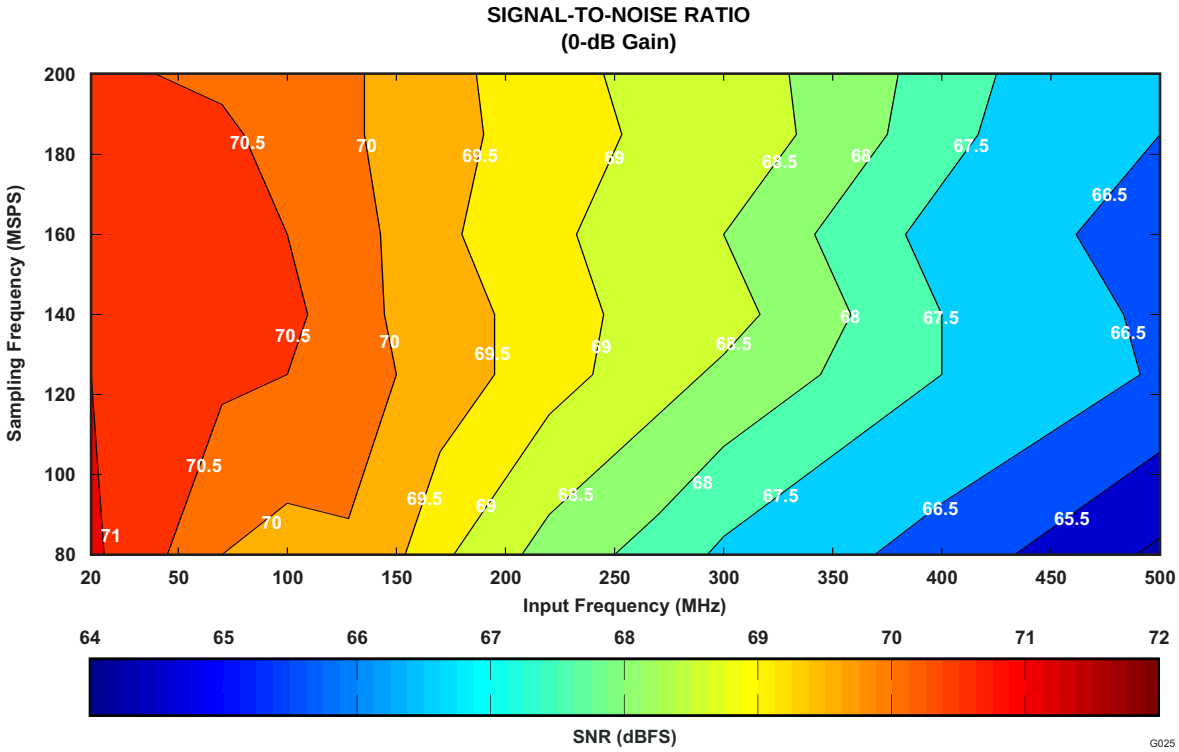


Figure 36.

TYPICAL CHARACTERISTICS: Contour (continued)

At +25°C, AVDD = 1.8 V, DRVDD = 1.8 V, maximum rated sampling frequency, sine wave input clock, 1.5-V_{PP} differential clock amplitude, 50% clock duty cycle, –1-dBFS differential analog input, 0-dB gain, low-latency mode, DDR LVDS output interface, and 32k-point FFT, unless otherwise noted.

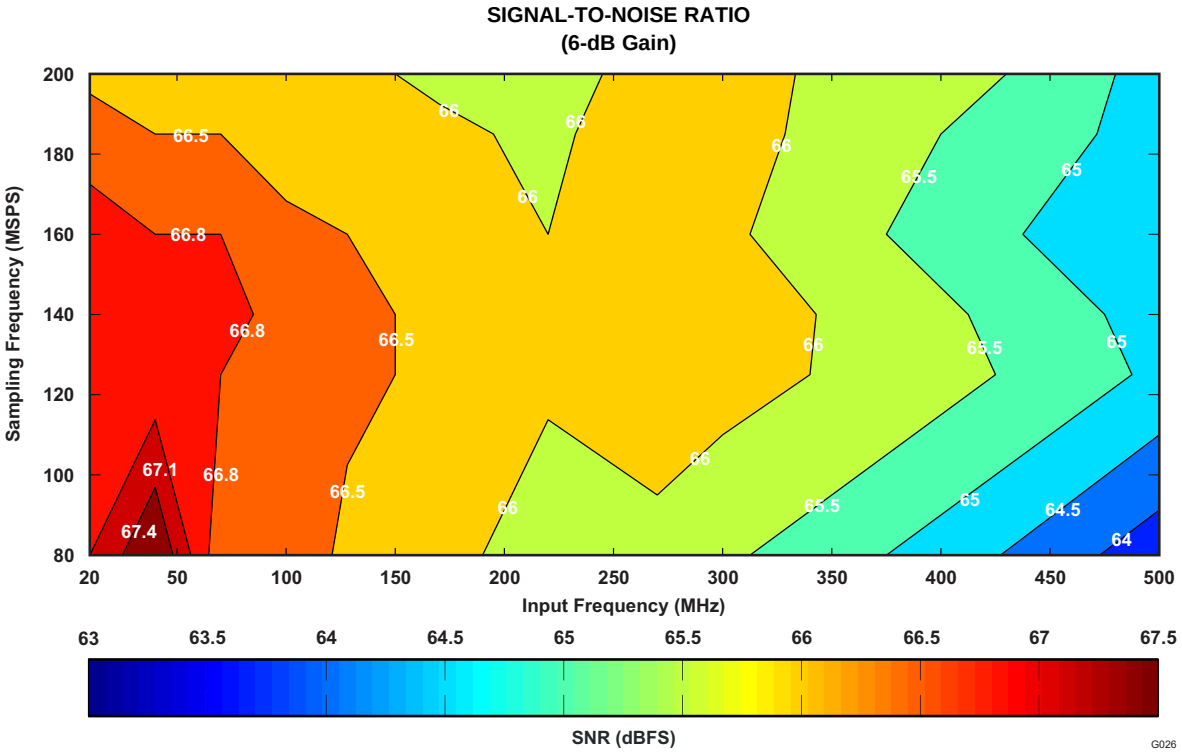


Figure 37.

TYPICAL CHARACTERISTICS: Contour (continued)

At +25°C, AVDD = 1.8 V, DRVDD = 1.8 V, maximum rated sampling frequency, sine wave input clock, 1.5-V_{PP} differential clock amplitude, 50% clock duty cycle, –1-dBFS differential analog input, 0-dB gain, low-latency mode, DDR LVDS output interface, and 32k-point FFT, unless otherwise noted.

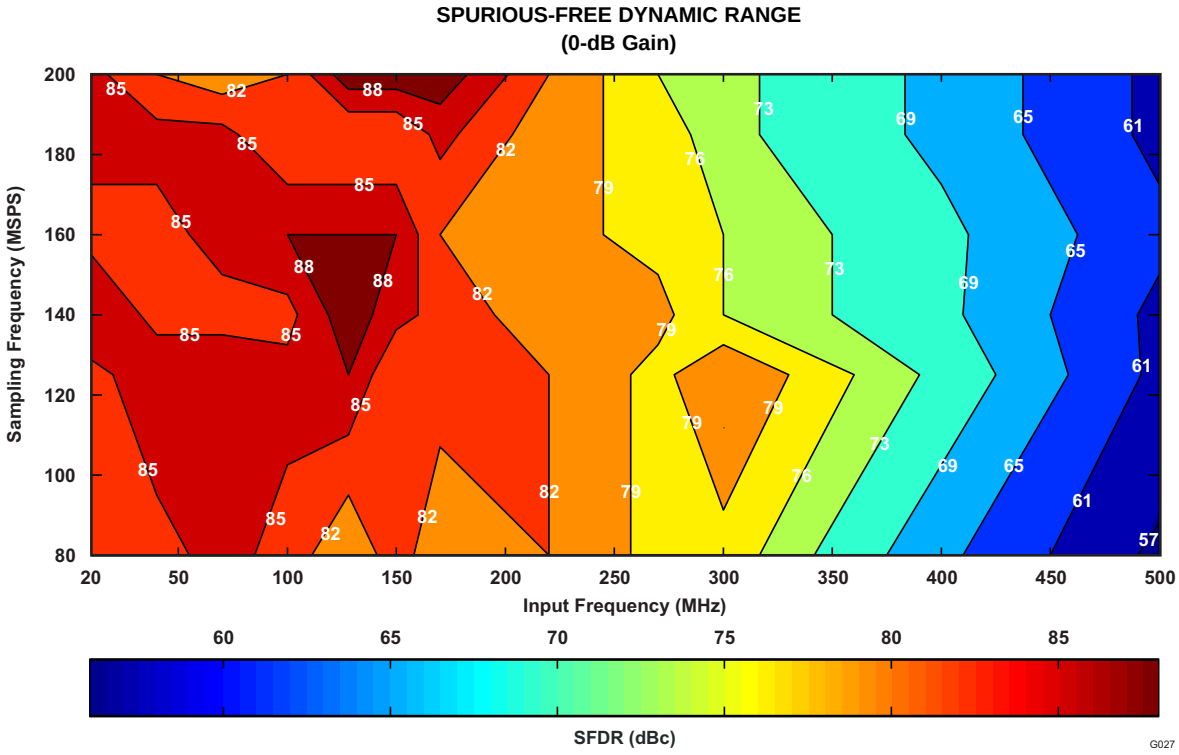


Figure 38.

TYPICAL CHARACTERISTICS: Contour (continued)

At +25°C, AVDD = 1.8 V, DRVDD = 1.8 V, maximum rated sampling frequency, sine wave input clock, 1.5-V_{PP} differential clock amplitude, 50% clock duty cycle, –1-dBFS differential analog input, 0-dB gain, low-latency mode, DDR LVDS output interface, and 32k-point FFT, unless otherwise noted.

SPURIOUS-FREE DYNAMIC RANGE
(6-dB Gain)

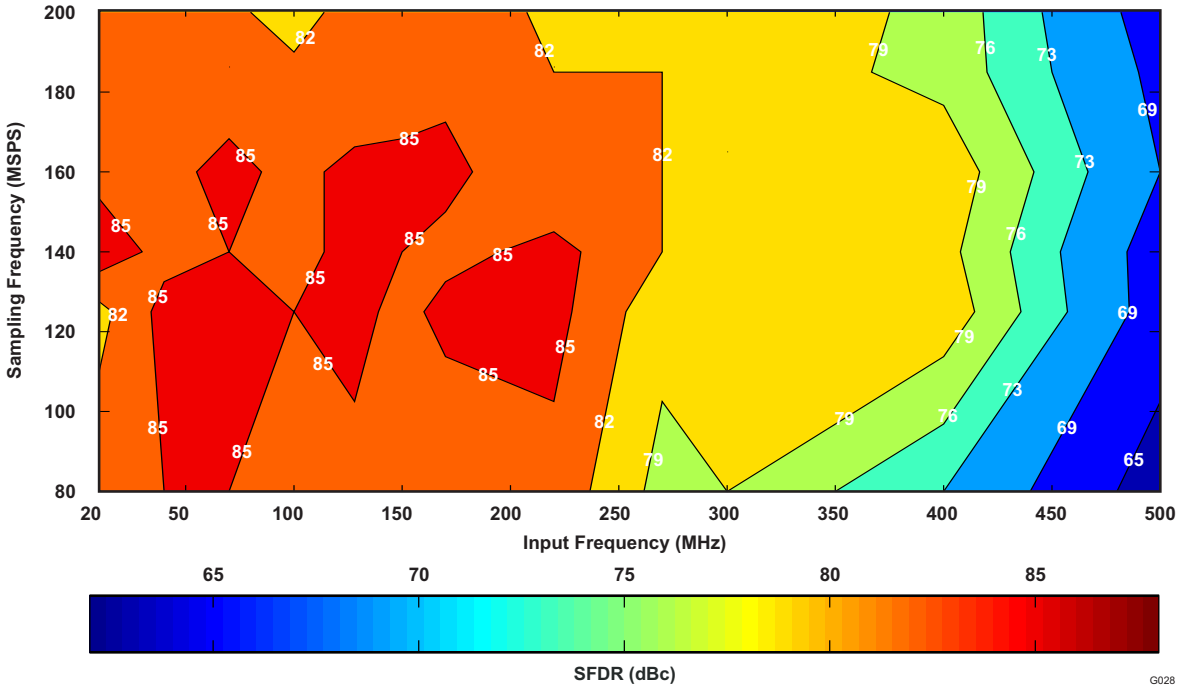


Figure 39.

APPLICATION INFORMATION

THEORY OF OPERATION

The ADS4128 is a high-performance, low-power, 12-bit analog-to-digital converter (ADC) with maximum sampling rates up to 200 MSPS. The conversion process is initiated by a rising edge of the external input clock when the analog input signal is sampled. The sampled signal is sequentially converted by a series of small resolution stages, with the outputs combined in a digital correction logic block. At every clock edge the sample propagates through the pipeline, resulting in a data latency of 10 clock cycles. The output is available as 12-bit data, in DDR LVDS mode or CMOS mode, and coded in either straight offset binary or binary twos complement format.

ANALOG INPUT

The analog input consists of a switched-capacitor-based, differential, sample-and-hold architecture. This differential topology results in very good ac performance even for high input frequencies at high sampling rates. The INP and INM pins must be externally biased around a common-mode voltage of 0.95 V, available on the VCM pin. For a full-scale differential input, each input INP and INM pin must swing symmetrically between (VCM + 0.5 V) and (VCM – 0.5 V), resulting in a 2-V_{PP} differential input swing. The input sampling circuit has a high 3-dB bandwidth that extends up to 550 MHz (measured from the input pins to the sampled voltage). Figure 40 shows an equivalent circuit for the analog input.

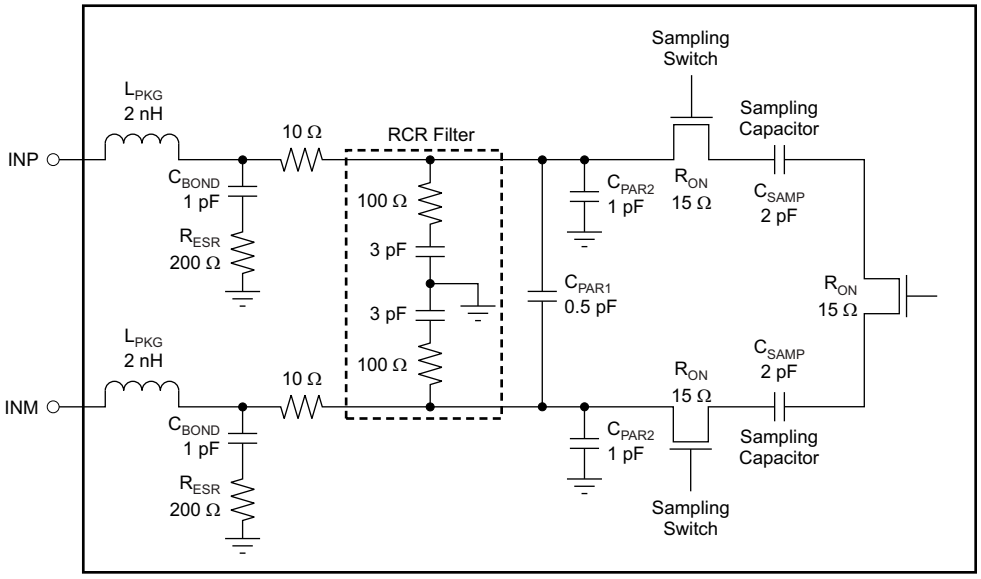


Figure 40. Analog Input Equivalent Circuit

Drive Circuit Requirements

For optimum performance, the analog inputs must be driven differentially. This technique improves the common-mode noise immunity and even-order harmonic rejection. A 5-Ω to 15-Ω resistor in series with each input pin is recommended to damp out ringing caused by package parasitics. It is also necessary to present low impedance (less than 50 Ω) for the common-mode switching currents. This impedance can be achieved by using two resistors from each input terminated to the common-mode voltage (VCM).

Note that the device includes an internal R-C filter from each input to ground. The purpose of this filter is to absorb the glitches created when the sampling capacitors open and close. The R-C filter cutoff frequency involves a trade-off. A lower cutoff frequency (larger C) absorbs glitches better, but also reduces the input bandwidth and maximum input frequency that can be supported. On the other hand, with no internal R-C filter, high input frequency can be supported but now the sampling glitches must be supplied by the external driving circuit. The inductance of the package bond wires limits the ability of the external driving circuit to support the sampling glitches.

In the ADS4128, the R-C component values have been optimized while supporting high input bandwidth (550 MHz). However, in applications where very high input frequency support is not required, glitch filtering can be further improved with an external R-C-R filter; see Figure 43 and Figure 44).

In addition, the drive circuit may have to be designed to provide a low insertion loss over the desired frequency range and matched source impedance. While designing the drive circuit, the ADC impedance must be considered. Figure 41 and Figure 42 show the impedance ($Z_{IN} = R_{IN} \parallel C_{IN}$) looking into the ADC input pins.

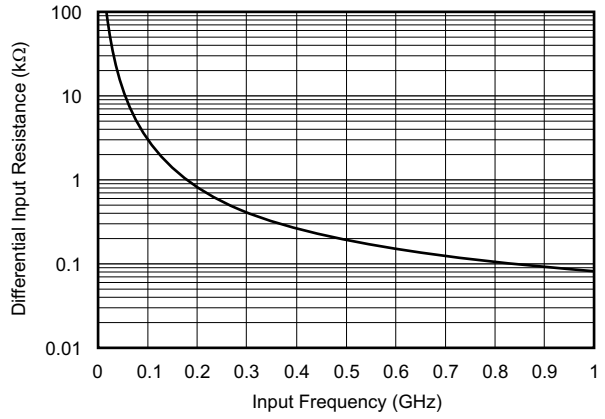


Figure 41. ADC Analog Input Resistance (R_{IN}) Across Frequency

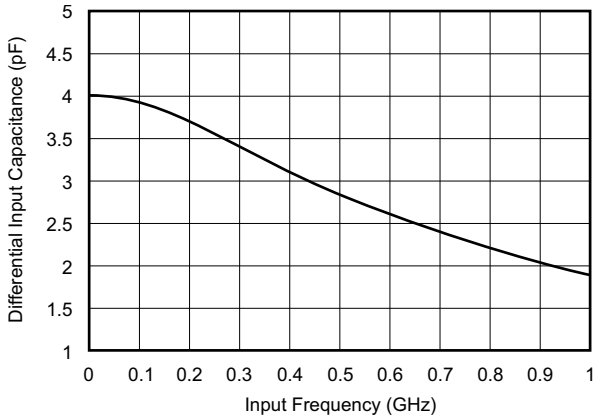


Figure 42. ADC Analog Input Capacitance (C_{IN}) Across Frequency

Driving Circuit

Two example driving circuit configurations are shown in Figure 43 and Figure 44—one is optimized for low bandwidth and the other is optimized for high bandwidth to support higher input frequencies. In Figure 43, an external R-C-R filter with 3.3 pF is used to help absorb sampling glitches. The R-C-R filter limits the drive circuit bandwidth, making it suitable for low input frequencies (up to 250 MHz). Transformers such as ADT1-1WT or WBC1-1 can be used up to 250 MHz.

For higher input frequencies, the R-C-R filter can be dropped. Together with the lower series resistors (5 Ω to 10 Ω), this drive circuit provides higher bandwidth to support frequencies up to 500 MHz (as shown in Figure 44). A transmission line transformer (such as ADTL2-18) can be used.

Note that both drive circuits are terminated by 50 Ω near the ADC side. The termination is accomplished by a 25-Ω resistor from each input to the 0.95-V common-mode (VCM) from the device. This termination allows the analog inputs to be biased around the required common-mode voltage.

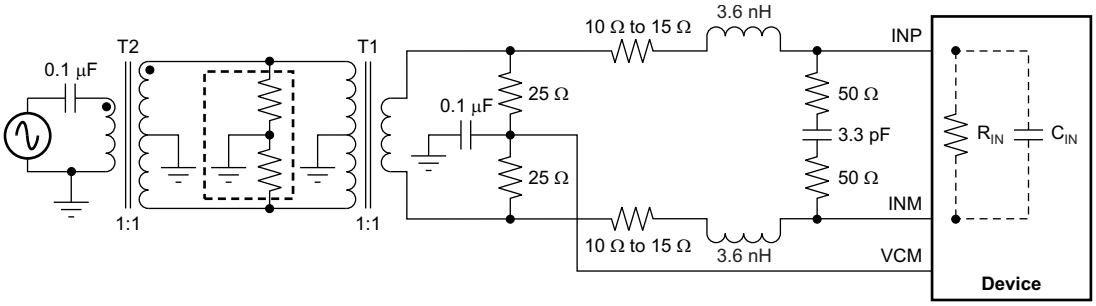


Figure 43. Drive Circuit with Low Bandwidth (for Low Input Frequencies)

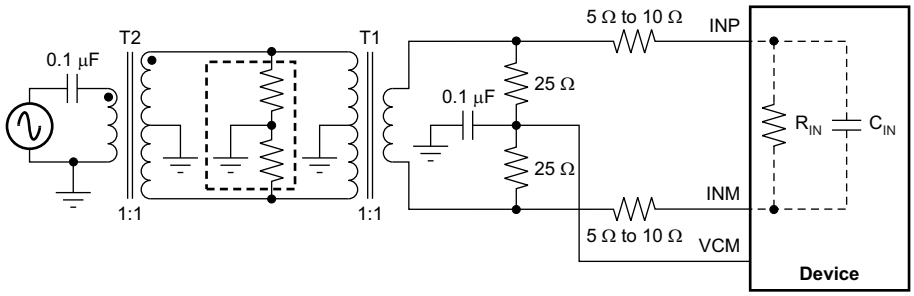


Figure 44. Drive Circuit with High Bandwidth (for High Input Frequencies)

The transformer parasitic capacitance mismatch (between the windings) results in degraded even-order harmonic performance. Connecting two identical RF transformers back-to-back helps minimize this mismatch and good performance is obtained for high-frequency input signals. An additional termination resistor pair may be required between the two transformers; refer to Figure 43 and Figure 44. The termination center point is connected to ground to improve the balance between the P (positive) and M (negative) sides. The termination values between the transformers and on the secondary side must be chosen to obtain an effective 50 Ω (for a 50-Ω source impedance).

Figure 43 and Figure 44 use 1:1 transformers with a 50-Ω source. As explained in the *Drive Circuit Requirements* section, this architecture helps to present a low source impedance to absorb sampling glitches. With a 1:4 transformer, the source impedance is 200 Ω. The higher source impedance is unable to absorb the sampling glitches effectively and can lead to degradation in performance (compared to using 1:1 transformers).

In almost all cases, either a band-pass or low-pass filter is needed to get the desired dynamic performance, as shown in Figure 45. Such a filter presents low source impedance at the high frequencies corresponding to the sampling glitch and helps avoid performance loss with the high source impedance.

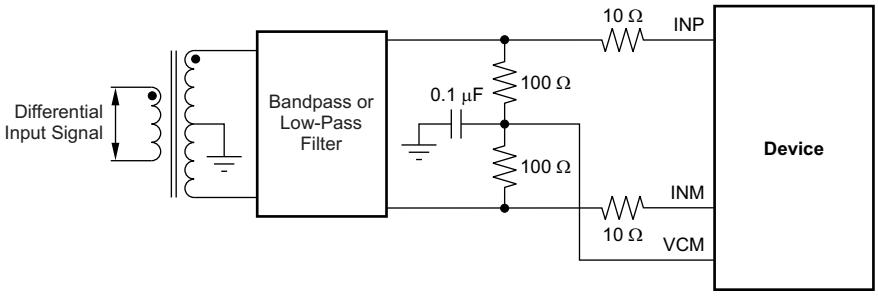


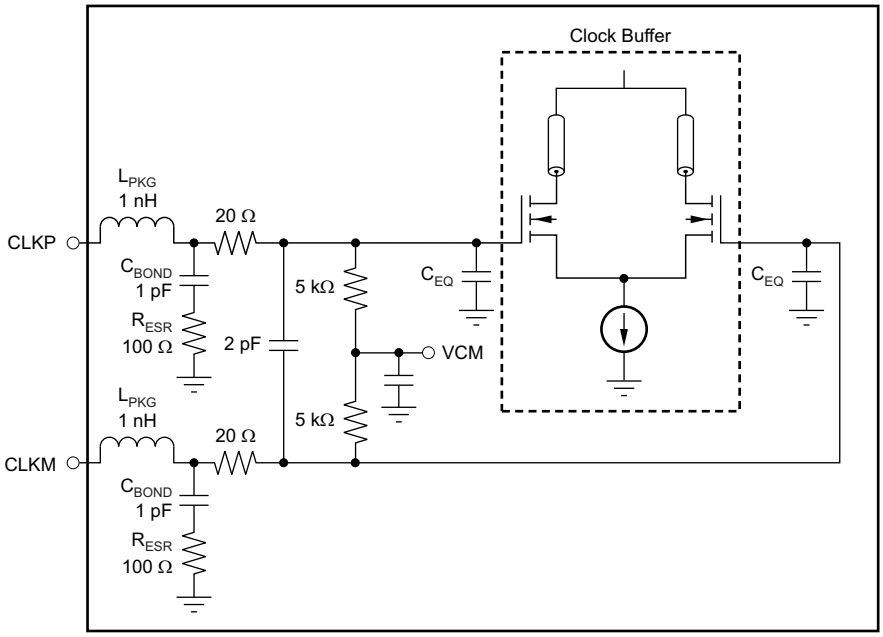
Figure 45. Drive Circuit with 1:4 Transformer

Input Common-Mode

To ensure a low-noise, common-mode reference, the VCM pin is filtered with a 0.1-µF low-inductance capacitor connected to ground. The VCM pin is designed to directly drive the ADC inputs. Each ADC input pin sinks a common-mode current of approximately 0.6 µA per MSPS of clock frequency.

CLOCK INPUT

The ADS4128 clock inputs can be driven differentially (sine, LVPECL, or LVDS) or single-ended (LVCMOS), with little or no difference in performance between them. The common-mode voltage of the clock inputs is set to VCM using internal 5-kΩ resistors. This setting allows the use of transformer-coupled drive circuits for sine-wave clock or ac-coupling for LVPECL and LVDS clock sources. Figure 46 shows an equivalent circuit for the input clock.



NOTE: C_{EQ} is 1 pF to 3 pF and is the equivalent input capacitance of the clock buffer.

Figure 46. Input Clock Equivalent Circuit

A single-ended CMOS clock can be ac-coupled to the CLKP input, with CLKM connected to ground with a 0.1-µF capacitor, as shown in Figure 47. For best performance, the clock inputs must be driven differentially, reducing susceptibility to common-mode noise. For high input frequency sampling, it is recommended to use a clock source with very low jitter. Band-pass filtering of the clock source can help reduce the effects of jitter. There is no change in performance with a non-50% duty cycle clock input. Figure 48 shows a differential circuit.

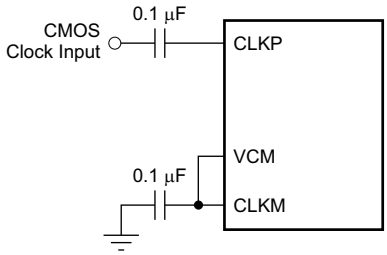


Figure 47. Single-Ended Clock Driving Circuit

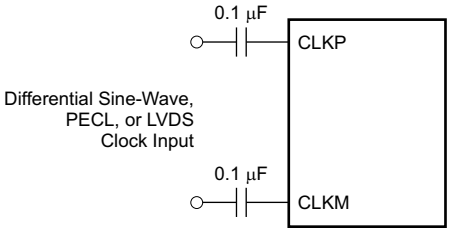


Figure 48. Differential Clock Driving Circuit

DIGITAL FUNCTIONS AND LOW-LATENCY MODE

The device has several useful digital functions such as test patterns, gain, and offset correction. All of these functions require extra clock cycles for operation and increase the overall latency and power of the device. Alternately, the device has a low-latency mode in which the raw ADC output is routed to the output data pins with a latency of 10 clock cycles. In this mode, the digital functions are bypassed. Figure 49 shows more details of the processing after the ADC.

The device is in low-latency mode after reset. In order to use any digital functions, low-latency mode must first be disabled by setting the DIS LOW LATENCY register bit to '1'. Afterwards, the respective register bits must be programmed as described in the following sections and in the *Serial Register Map* section.

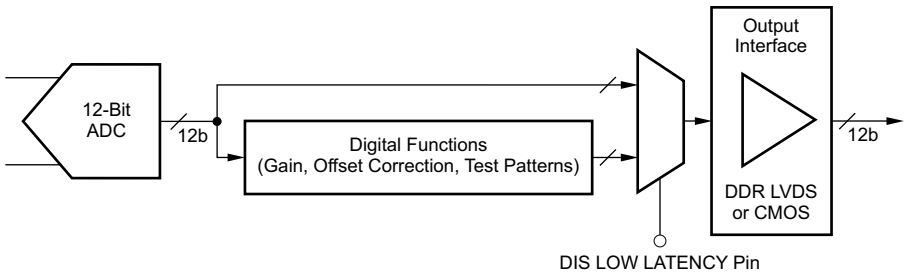


Figure 49. Digital Processing Block Diagram

GAIN FOR SFDR AND SNR TRADE-OFF

The ADS4128 includes gain settings that can be used to get improved SFDR performance. Gain is programmable from 0 dB to 6 dB (in 0.5-dB steps) using the GAIN register bits. For each gain setting, the analog input full-scale range scales proportionally, as shown in Table 12.

The SFDR improvement is achieved at the expense of SNR; for each gain setting, SNR degrades approximately between 0.5 dB and 1 dB. SNR degradation is reduced at high input frequencies. As a result, gain is very useful at high input frequencies because SFDR improvement is significant with marginal SNR degradation. Therefore, gain can be used to trade-off between SFDR and SNR.

After a reset, the device is in low-latency mode and the gain function is disabled. To use gain:

- First, disable low-latency mode (DIS LOW LATENCY = 1).
- This setting enables the gain and puts the device in a 0-dB gain mode.
- For other gain settings, program the GAIN bits.

Table 12. Full-Scale Range Across Gains

GAIN (dB)	TYPE	FULL-SCALE (V_{PP})
0	Default after reset	2
1	Programmable gain	1.78
2	Programmable gain	1.59
3	Programmable gain	1.42
4	Programmable gain	1.26
5	Programmable gain	1.12
6	Programmable gain	1.00

OFFSET CORRECTION

The ADS4128 has an internal offset correction algorithm that estimates and corrects dc offset up to ±10 mV. The correction can be enabled using the EN OFFSET CORR serial register bit. Once enabled, the algorithm estimates the channel offset and applies the correction every clock cycle. The correction loop time constant is a function of the sampling clock frequency. The time constant can be controlled using the OFFSET CORR TIME CONSTANT register bits, as described in Table 13.

Table 13. Offset Correction Loop Time Constant

OFFSET CORR TIME CONSTANT	TIME CONSTANT, TC_{CLK} (Number of Clock Cycles)	TIME CONSTANT, $TC_{CLK} \times 1/f_S$ (sec)(1)
0000	1 M	4 ms
0001	2 M	8 ms
0010	4 M	16.7 ms
0011	8 M	33.5 ms
0100	16 M	67 ms
0101	32 M	134 ms
0110	64 M	268 ms
0111	128 M	537 ms
1000	256 M	1.1 s
1001	512 M	2.15 s
1010	1 G	4.3 s
1011	2 G	8.6 s
1100	Reserved	—
1101	Reserved	—
1110	Reserved	—
1111	Reserved	—

(1) Sampling frequency, f_S = 200 MSPS.

After the offset is estimated, the correction can be frozen by setting FREEZE OFFSET CORR = 1. Once frozen, the last estimated value is used for every clock cycle offset correction. Note that offset correction is disabled by default after reset.

After a reset, the device is in low-latency mode and offset correction is disabled. To use offset correction:

- First, disable low-latency mode (DIS LOW LATENCY = 1).
- Then set EN OFFSET CORR to '1' and program the required time constant.

POWER DOWN

The ADS4128 has three power-down modes: power-down global, standby, and output buffer disable.

Power-Down Global

In this mode, the entire chip (including the ADC, internal reference, and the output buffers) are powered down, resulting in reduced total power dissipation of approximately 10 mW. The output buffers are in a high-impedance state. The wake-up time from the global power-down to data becoming valid in normal mode is typically 100 µs. To enter the global power-down mode, set the PDN GLOBAL register bit.

Standby

In this mode, only the ADC is powered down and the internal references are active, resulting in a fast wake-up time of 5 µs. The total power dissipation in standby mode is approximately 185 mW. To enter standby mode, set the STBY register bit.

Output Buffer Disable

The output buffers can be disabled and put in a high-impedance state; wakeup time from this mode is fast, approximately 100 ns. This mode can be controlled by using the PDN OBUF register bit or the OE pin.

Input Clock Stop

In addition, the converter enters low-power mode when the input clock frequency falls below 1 MSPS. Power dissipation is approximately 80 mW.

POWER-SUPPLY SEQUENCE

During power-up, the AVDD and DRVDD supplies can come up in any sequence. The two supplies are separated in the device. Externally, they can be driven from separate supplies or from a single supply.

DIGITAL OUTPUT INFORMATION

The ADS4128 provides 12-bit data and an output clock synchronized with the data.

Output Interface

Two output interface options are available: double data rate (DDR) LVDS and parallel CMOS. These modes can be selected by using the LVDS CMOS serial interface register bit or the DFS pin.

DDR LVDS Outputs

In this mode, the data bits and clock are output using low voltage differential signal (LVDS) levels. Two data bits are multiplexed and output on each LVDS differential pair, as shown in Figure 50.

Even data bits (D0, D2, D4, and so on) are output at the CLKOUTP falling edge and the odd data bits (D1, D3, D5, and so on) are output at the CLKOUTP rising edge. Both the CLKOUTP rising and falling edges must be used to capture all 12 data bits, as shown in Figure 51.

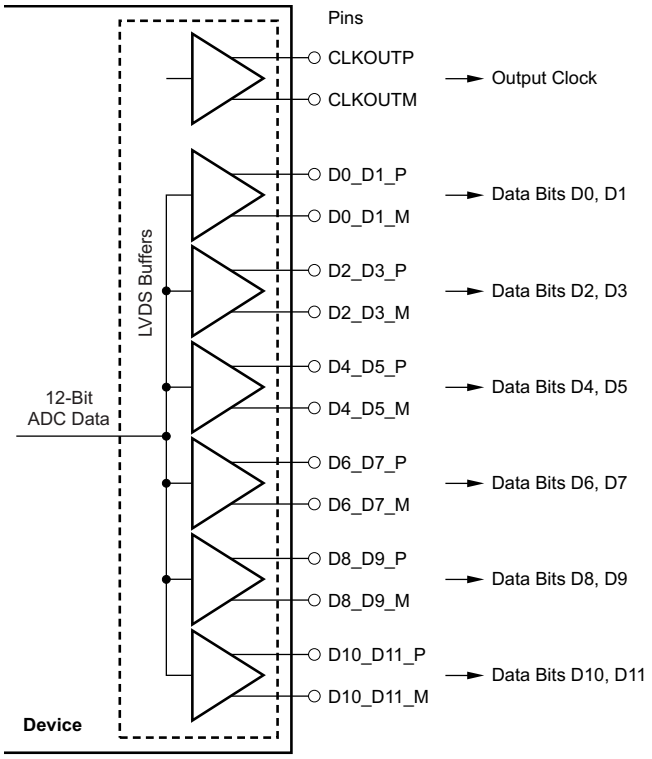


Figure 50. LVDS Data Outputs

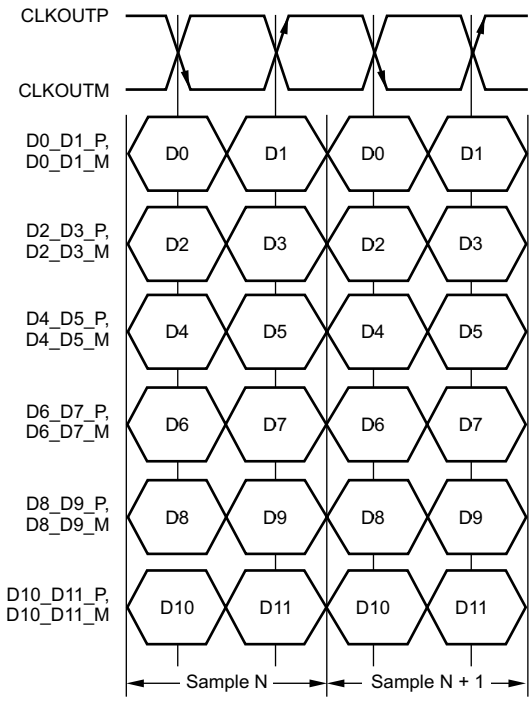


Figure 51. DDR LVDS Interface

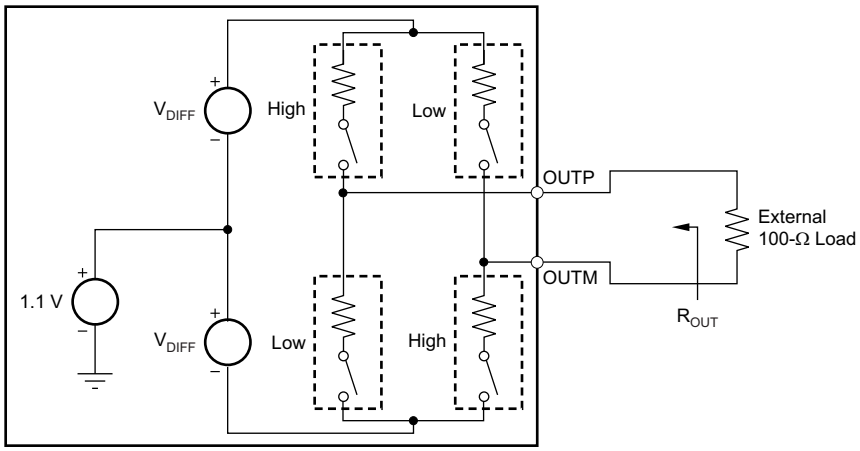
LVDS Output Data and Clock Buffers

The equivalent circuit of each LVDS output buffer is shown in Figure 52. After reset, the buffer presents a 100-Ω output impedance to match the external 100-Ω termination.

V_{DIFF} voltage is nominally 350 mV, resulting in a ±350-mV output swing with a 100-Ω external termination. V_{DIFF} voltage is programmable using the LVDS SWING register bits from ±125 mV to ±570 mV.

Additionally, a mode exists to double the LVDS buffer strength to support 50-Ω differential termination. This mode can be used when the output LVDS signal is routed to two separate receiver chips, each using a 100-Ω termination. This mode can be enabled using the LVDS DATA STRENGTH and LVDS CLKOUT STRENGTH register bits for data and output clock buffers, respectively.

The buffer output impedance behaves in the same way as a source-side series termination. By absorbing reflections from the receiver end, it helps to improve signal integrity.



NOTE: Use the default buffer strength to match the 100-Ω external termination (R_{OUT} = 100 Ω). To match with a 50-Ω external termination, set the LVDS STRENGTH bit (R_{OUT} = 50 Ω).

Figure 52. LVDS Buffer Equivalent Circuit

Parallel CMOS Interface

In CMOS mode, each data bit is output on a separate pin as the CMOS voltage level, for every clock cycle. The output clock CLKOUT rising edge can be used to latch data in the receiver. Figure 53 depicts the CMOS output interface.

Switching noise (caused by CMOS output data transitions) can couple into the analog inputs and degrade SNR. The coupling and SNR degradation increases as the output buffer drive is made stronger. To minimize this degradation, the CMOS output buffers are designed with controlled drive strength. The default drive strength ensures a wide data stable window (even at 200 MSPS) is provided so the data outputs have minimal load capacitance. It is recommended to use short traces (one to two inches or 2,54 cm to 5,08 cm) terminated with less than 5-pF load capacitance; see Figure 54.

In some high-speed applications using CMOS interface, it may be required to use an external clock to capture data. For such cases, delay from the input clock to output data and the data valid times are specified for higher sampling frequencies. These timings can be used to delay the input clock appropriately and use it to capture data.

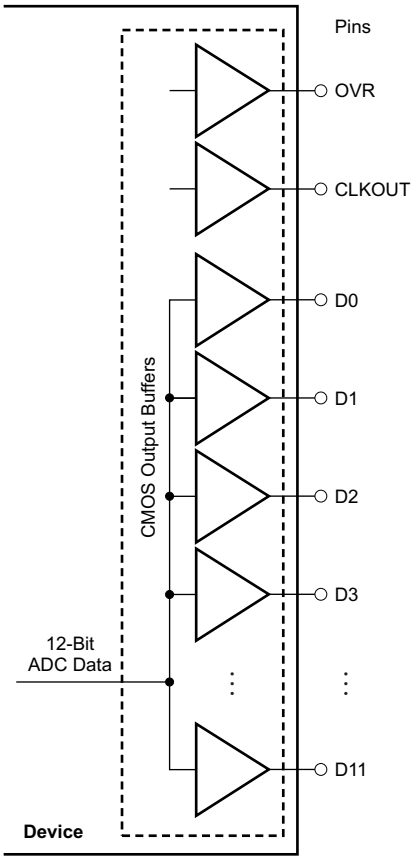


Figure 53. CMOS Output Interface

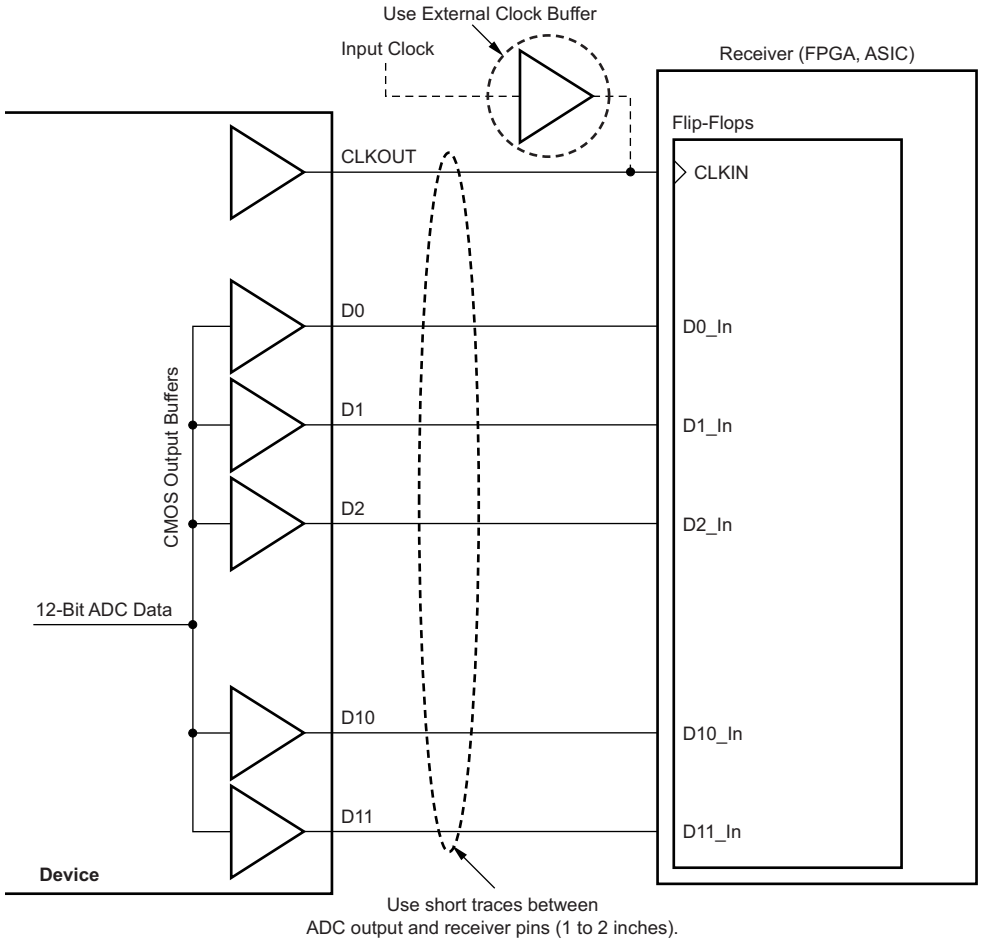


Figure 54. Using the CMOS Data Outputs

CMOS Interface Power Dissipation

With CMOS outputs, the DRVDD current scales with the sampling frequency and load capacitance on every output pin. The maximum DRVDD current occurs when each output bit toggles between '0' and '1' every clock cycle. In actual applications, this condition is unlikely to occur. The actual DRVDD current is determined by the average number of output bits switching, which is a function of the sampling frequency and the nature of the analog input signal.

Digital Current as a Result of CMOS Output Switching = $C_L \times DRVDD \times (N \times f_{AVG})$

where:

C_L = load capacitance,

$N \times F_{AVG}$ = average number of output bits switching. (1)

shows the current across sampling frequencies at a 2-MHz analog input frequency.

Input Over-Voltage Indication (OVR Pin)

The device has an OVR pin that provides information about analog input overload. At any clock cycle, if the sampled input voltage exceeds the positive or negative full-scale range, the OVR pin goes high. OVR remains high as long as the overload condition persists. The OVR pin is a CMOS output buffer (running off of a DRVDD supply), independent of the output data interface (DDR LVDS or CMOS).

For a positive overload, the D[11:0] output data bits are FFFh in offset binary output format and 7FFh in twos complement output format. For a negative input overload, the output code is 000h in offset binary output format and 800h in twos complement output format.

Output Data Format

Two output data formats are supported: binary twos complement and offset binary. These formats can be selected by using the DATA FORMAT serial interface register bit or controlling the DFS pin in parallel configuration mode. In the event of an input voltage overdrive, the digital outputs go to the appropriate full-scale level.

BOARD DESIGN CONSIDERATIONS

Grounding

A single ground plane is sufficient to give good performance, provided the analog, digital, and clock sections of the board are cleanly partitioned. See the *ADS414x, ADS412x EVM User Guide* (SLWU067) for details on layout and grounding.

Supply Decoupling

Because the ADS4128 already includes internal decoupling, minimal external decoupling can be used without loss in performance. Note that decoupling capacitors can help filter external power-supply noise, so the optimum number of capacitors depends on the actual application. The decoupling capacitors should be placed very close to the converter supply pins.

Exposed Pad

In addition to providing a path for heat dissipation, the PowerPAD is also electrically internally connected to the digital ground. Therefore, it is necessary to solder the exposed pad to the ground plane for best thermal and electrical performance. For detailed information, see application notes *QFN Layout Guidelines* (SLOA122) and *QFN/SON PCB Attachment* (SLUA271), both available for download at www.ti.com.

DEFINITION OF SPECIFICATIONS

Analog Bandwidth – The analog input frequency at which the power of the fundamental is reduced by 3 dB with respect to the low-frequency value.

Aperture Delay – The delay in time between the rising edge of the input sampling clock and the actual time at which the sampling occurs. This delay is different across channels. The maximum variation is specified as aperture delay variation (channel-to-channel).

Aperture Uncertainty (Jitter) – The sample-to-sample variation in aperture delay.

Clock Pulse Width/Duty Cycle – The duty cycle of a clock signal is the ratio of the time the clock signal remains at a logic high (clock pulse width) to the period of the clock signal. Duty cycle is typically expressed as a percentage. A perfect differential sine-wave clock results in a 50% duty cycle.

Maximum Conversion Rate – The maximum sampling rate at which specified operation is given. All parametric testing is performed at this sampling rate unless otherwise noted.

Minimum Conversion Rate – The minimum sampling rate at which the ADC functions.

Differential Nonlinearity (DNL) – An ideal ADC exhibits code transitions at analog input values spaced exactly 1 LSB apart. The DNL is the deviation of any single step from this ideal value, measured in units of LSBs.

Integral Nonlinearity (INL) – The INL is the deviation of the ADC transfer function from a best fit line determined by a least squares curve fit of that transfer function, measured in units of LSBs.

Gain Error – Gain error is the deviation of the ADC actual input full-scale range from its ideal value. The gain error is given as a percentage of the ideal input full-scale range. Gain error has two components: error as a result of reference inaccuracy and error as a result of the channel. Both errors are specified independently as E_{GREF} and E_{GCHAN}.

To a first-order approximation, the total gain error is $E_{TOTAL} \sim E_{GREF} + E_{GCHAN}$.

For example, if $E_{TOTAL} = \pm 0.5\%$, the full-scale input varies from $(1 - 0.5/100) \times FS_{ideal}$ to $(1 + 0.5/100) \times FS_{ideal}$.

Offset Error – The offset error is the difference, given in number of LSBs, between the ADC actual average idle channel output code and the ideal average idle channel output code. This quantity is often mapped into millivolts.

Temperature Drift – The temperature drift coefficient (with respect to gain error and offset error) specifies the change per degree Celsius of the parameter from T_{MIN} to T_{MAX}. It is calculated by dividing the maximum deviation of the parameter across the T_{MIN} to T_{MAX} range by the difference $T_{MAX} – T_{MIN}$.

Signal-to-Noise Ratio – SNR is the ratio of the power of the fundamental (P_S) to the noise floor power (P_N), excluding the power at dc and the first nine harmonics.

$$SNR = 10Log^{10} \frac{P_S}{P_N} \quad (2)$$

SNR is either given in units of dBc (dB to carrier) when the absolute power of the fundamental is used as the reference, or dBFS (dB to full-scale) when the power of the fundamental is extrapolated to the converter full-scale range.

Signal-to-Noise and Distortion (SINAD) – SINAD is the ratio of the power of the fundamental (P_S) to the power of all the other spectral components including noise (P_N) and distortion (P_D), but excluding dc.

$$SINAD = 10Log^{10} \frac{P_S}{P_N + P_D} \quad (3)$$

SINAD is either given in units of dBc (dB to carrier) when the absolute power of the fundamental is used as the reference, or dBFS (dB to full-scale) when the power of the fundamental is extrapolated to the converter full-scale range.

Effective Number of Bits (ENOB) – ENOB is a measure of the converter performance as compared to the theoretical limit based on quantization noise.

$$\text{ENOB} = \frac{\text{SINAD} - 1.76}{6.02} \tag{4}$$

Total Harmonic Distortion (THD) – THD is the ratio of the power of the fundamental (P_S) to the power of the first nine harmonics (P_D).

$$\text{THD} = 10\text{Log}^{10} \frac{P_S}{P_N} \tag{5}$$

THD is typically given in units of dBc (dB to carrier).

Spurious-Free Dynamic Range (SFDR) – The ratio of the power of the fundamental to the highest other spectral component (either spur or harmonic). SFDR is typically given in units of dBc (dB to carrier).

Two-Tone Intermodulation Distortion – IMD3 is the ratio of the power of the fundamental (at frequencies f_1 and f_2) to the power of the worst spectral component at either frequency $2f_1 - f_2$ or $2f_2 - f_1$. IMD3 is either given in units of dBc (dB to carrier) when the absolute power of the fundamental is used as the reference, or dBFS (dB to full-scale) when the power of the fundamental is extrapolated to the converter full-scale range.

DC Power-Supply Rejection Ratio (DC PSRR) – DC PSSR is the ratio of the change in offset error to a change in analog supply voltage. The dc PSRR is typically given in units of mV/V.

AC Power-Supply Rejection Ratio (AC PSRR) – AC PSRR is the measure of rejection of variations in the supply voltage by the ADC. If ΔV_{SUP} is the change in supply voltage and ΔV_{OUT} is the resultant change of the ADC output code (referred to the input), then:

$$\text{PSRR} = 20\text{Log}^{10} \frac{\Delta V_{OUT}}{\Delta V_{SUP}} \text{ (Expressed in dBc)} \tag{6}$$

Voltage Overload Recovery – The number of clock cycles taken to recover to less than 1% error after an overload on the analog inputs. This is tested by separately applying a sine wave signal with 6-dB positive and negative overload. The deviation of the first few samples after the overload (from the expected values) is noted.

Common-Mode Rejection Ratio (CMRR) – CMRR is the measure of rejection of variation in the analog input common-mode by the ADC. If ΔV_{CM_IN} is the change in the common-mode voltage of the input pins and ΔV_{OUT} is the resulting change of the ADC output code (referred to the input), then:

$$\text{CMRR} = 20\text{Log}^{10} \frac{\Delta V_{OUT}}{\Delta V_{CM}} \text{ (Expressed in dBc)} \tag{7}$$

Crosstalk (only for multi-channel ADCs) – This is a measure of the internal coupling of a signal from an adjacent channel into the channel of interest. It is specified separately for coupling from the immediate neighboring channel (near-channel) and for coupling from channel across the package (far-channel). It is usually measured by applying a full-scale signal in the adjacent channel. Crosstalk is the ratio of the power of the coupling signal (as measured at the output of the channel of interest) to the power of the signal applied at the adjacent channel input. It is typically expressed in dBc.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
ADS4128IRGZ25	ACTIVE	VQFN	RGZ	48	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 85	AZ4128	Samples
ADS4128IRGZR	ACTIVE	VQFN	RGZ	48	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 85	AZ4128	Samples
ADS4128IRGZT	ACTIVE	VQFN	RGZ	48	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 85	AZ4128	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

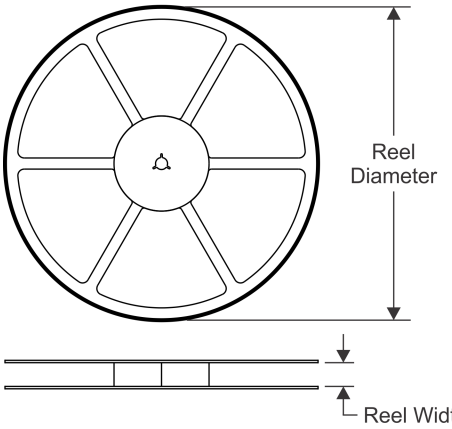
(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

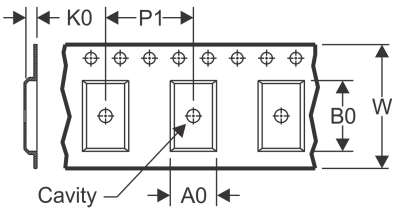
(4) Multiple Top-Side Markings will be inside parentheses. Only one Top-Side Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Top-Side Marking for that device.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

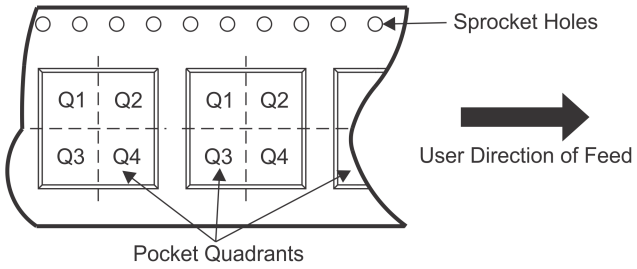


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

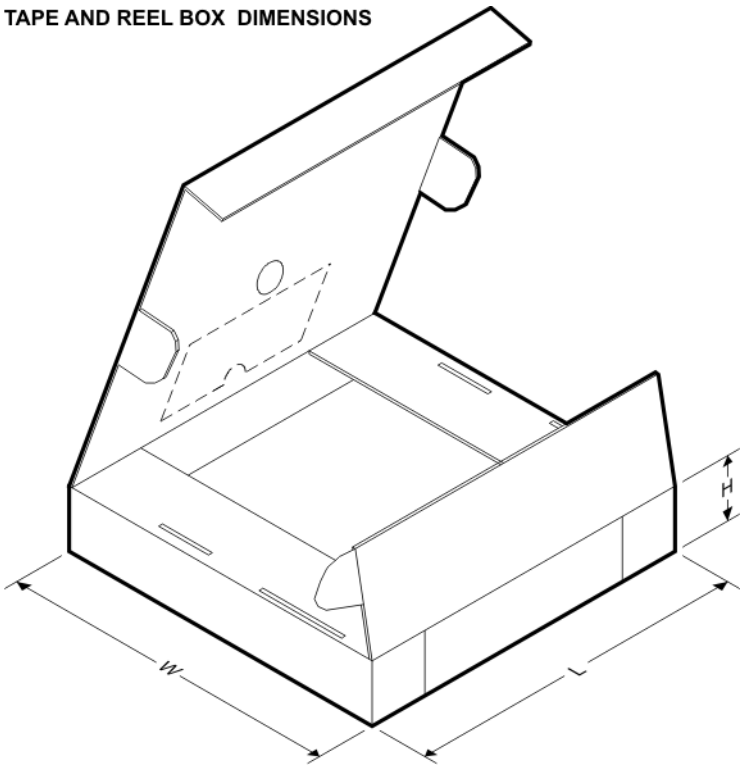
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
ADS4128IRGZR	VQFN	RGZ	48	2500	330.0	16.4	7.3	7.3	1.5	12.0	16.0	Q2
ADS4128IRGZT	VQFN	RGZ	48	250	180.0	16.4	7.3	7.3	1.5	12.0	16.0	Q2

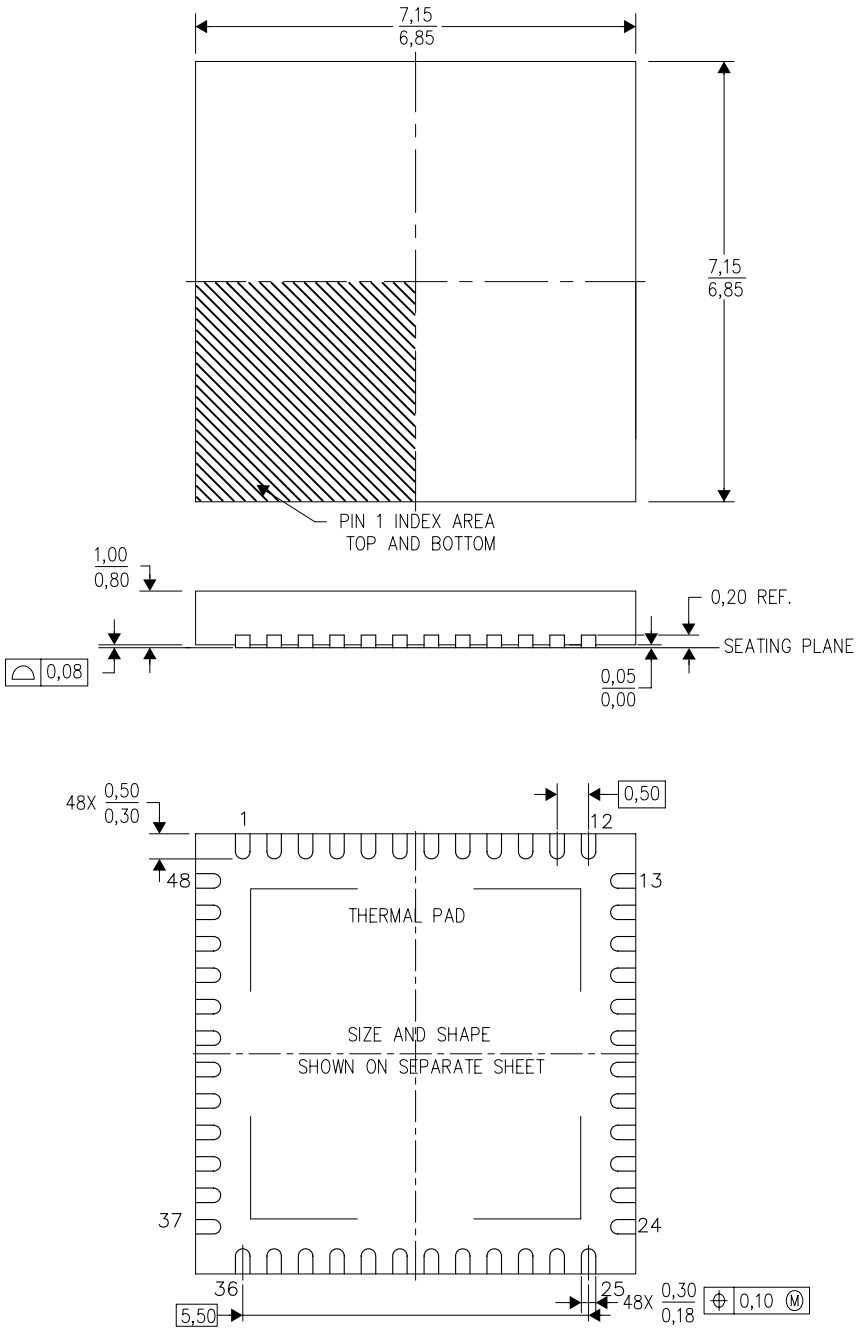
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
ADS4128IRGZR	VQFN	RGZ	48	2500	336.6	336.6	28.6
ADS4128IRGZT	VQFN	RGZ	48	250	213.0	191.0	55.0

RGZ (S–PVQFN–N48) PLASTIC QUAD FLATPACK NO–LEAD



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

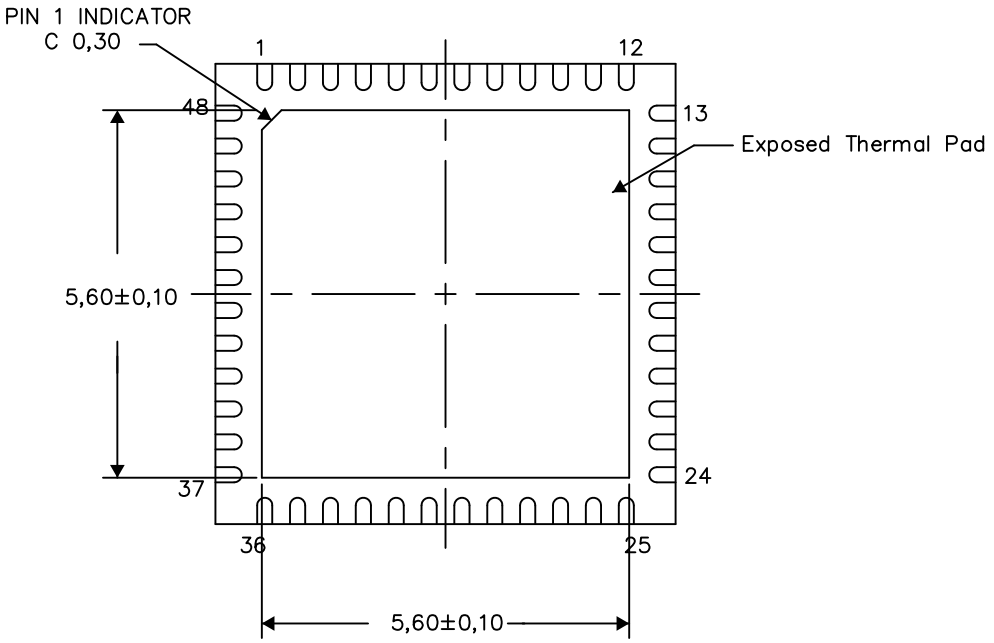
RGZ (S–PVQFN–N48) PLASTIC QUAD FLATPACK NO–LEAD

THERMAL INFORMATION

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

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

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



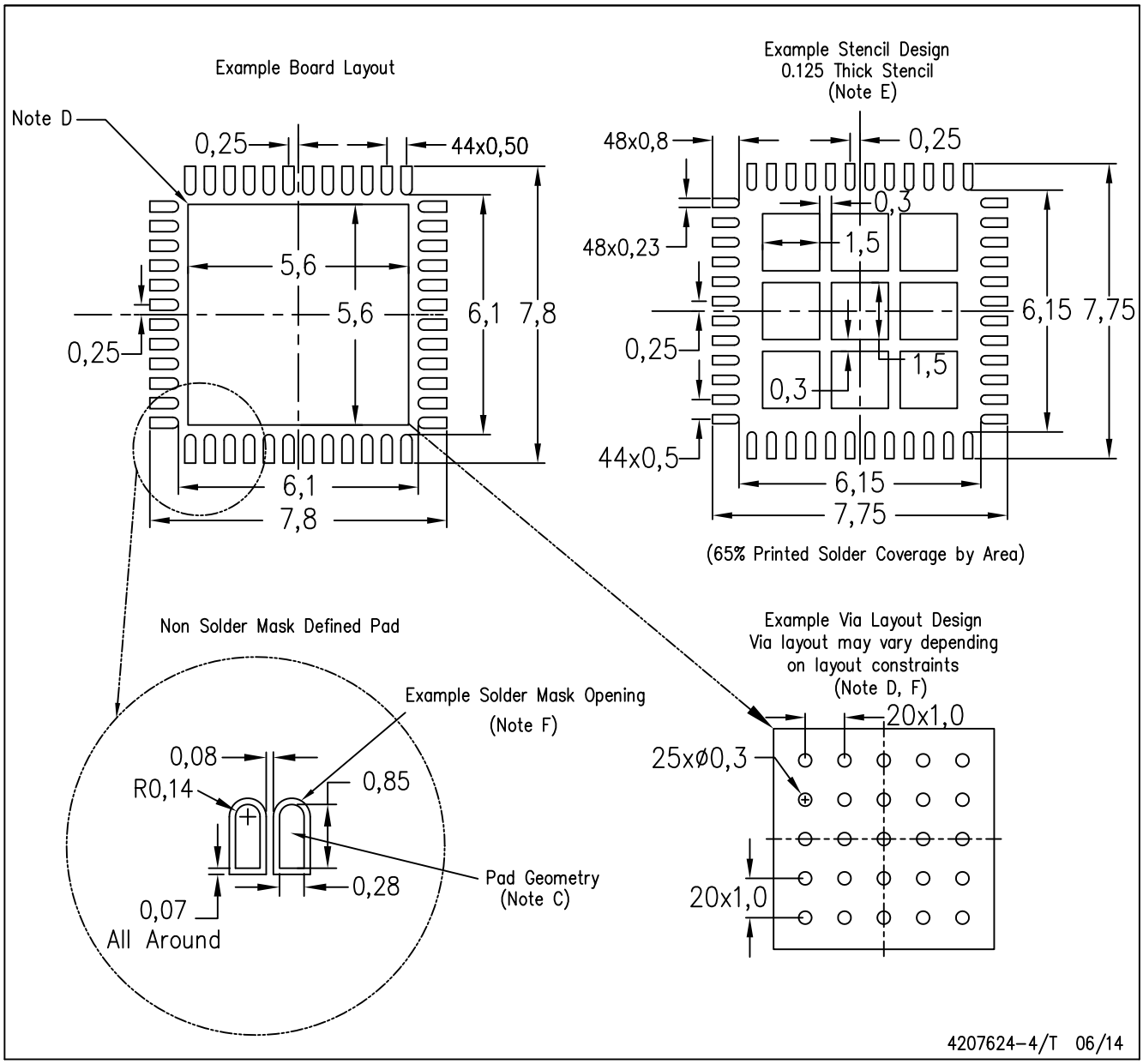
Bottom View

Exposed Thermal Pad Dimensions

4206354–5/Y 06/14

NOTE: All linear dimensions are in millimeters

RGZ (S–PVQFN–N48) PLASTIC QUAD FLATPACK NO–LEAD



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

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265