

ADS92x4R 双通道低延迟同步采样 SAR ADC

1 特性

- 高分辨率、高吞吐量：
 - ADS9224R: 16 位 3MSPS
 - ADS9234R: 14 位 3.5MSPS
- 低延迟快速响应时间: 333ns
- 在宽模拟带宽范围内具有更高性能：
 - ADS9224R: 1.4MHz 时为 83dB SINAD
 - ADS9234R: 1.4MHz 时为 80dB SINAD
- 两个同步采样通道
- 单极全差分输入
- 宽共模电压范围
- 出色的直流和交流性能：
 - ADS9224R:
 - 16 位 NMC DNL, ± 2 LSB 最大 INL
 - 93.5dB SNR, -110 dB THD
 - 80dB CMRR
 - ADS9234R:
 - 14 位 NMC DNL, ± 1 LSB 最大 INL
 - 85.6dB SNR, -106 dB THD
 - 75dB CMRR
- 集成基准和基准缓冲器
- 用于设置共模的集成式 REFby2 缓冲器
- 集成数据平均
- 适用于 MCU 和 FPGA 的增强型 SPI 接口：
 - 宽读取周期, 可借助 MCU 读取数据
 - 用于通过数字隔离器进行数据传输的 CRT
 - 适用于 FPGA 的 DDR 模式
- 并行字节模式, 方便对接
- 扩展温度范围: -40°C 至 $+125^{\circ}\text{C}$
- 小型封装: 5mm x 5mm VQFN

2 应用

- 光学编码器: 增量和绝对编码器
- 声纳接收器
- 光纤网络: EDFA 增益控制环路
- 电源质量测量
- 数字电源
- I/Q 解调器
- 医疗成像: CT 扫描仪、MRI 扫描仪

3 说明

ADS92x4R 是一款引脚兼容型高速双通道同步采样模数转换器 (ADC), 具有集成基准电压和基准电压缓冲器。该器件可由 5V 单电源供电运行, 支持单极和全差分模拟输入信号, 具有出色的直流和交流规格。

该器件支持 SPI 兼容串行 (增强型 SPI) 和字节宽并行接口, 因此该器件易于与多种微控制器、数字信号处理器 (DSP) 和现场可编程门阵列 (FPGA) 搭配使用。

该器件采用节省空间的 5mm x 5mm VQFN 封装。

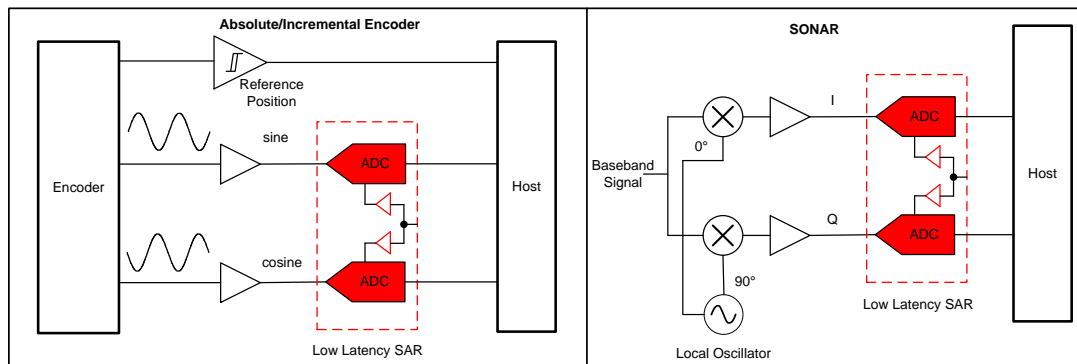
ADS92x4R 的额定扩展温度范围为 -40°C 至 $+125^{\circ}\text{C}$ 。

器件信息⁽¹⁾

器件型号	封装	封装尺寸 (标称值)
ADS92x4R	VQFN (32)	5.00mm x 5.00mm

(1) 如需了解所有可用封装, 请参阅产品说明书末尾的可订购产品附录。

典型应用图



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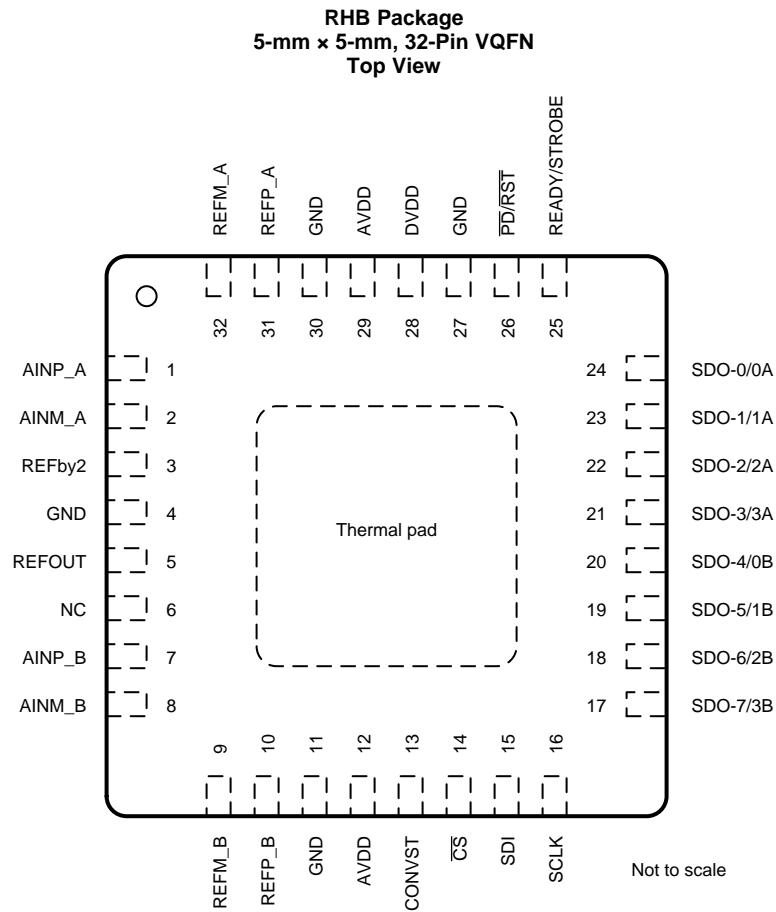
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4 修订历史记录

注：之前版本的页码可能与当前版本有所不同。

Changes from Original (August 2018) to Revision A	Page
• 已添加 向文档中添加 ADS9234R	1
• 已更改 通篇将 ADS9234R MSPS 额定值从 3MSPS 更改为 3.5MSPS	1
• Changed BW parameter typical specifications from 100 MHz to 52 MHz (-3dB Input Signal) and from 20 MHz to 4.2 MHz (-0.1 dB Input Signal) in <i>Electrical Characteristics: ADS92x4R</i> table	5
• Changed $t_{\text{wakeup-REFOUT}}$ parameter typical specification from 10 ms to 15.6 ms in <i>Electrical Characteristics: ADS92x4R</i> table	5
• Changed $t_{\text{REFBUF-SETTLE}}$ parameter typical specification from 25 ms to 18 ms in <i>Electrical Characteristics: ADS92x4R</i> table	5
• Changed $t_{\text{PD-WKUP}}$ parameter typical specification from 25 ms to 18 ms in <i>Switching Characteristics</i> table	5
• 已更改 <i>READY Output</i> section	23
• 已更改 SPI-10-SDR to SPI-10-S-SDR in title of <i>SPI-00-S-SDR and SPI-10-S-SDR Protocols</i> figure	25
• 已更改 SPI-11-SDR to SPI-11-S-SDR in title of <i>SPI-01-S-SDR and SPI-11-S-SDR Protocols</i> figure	25

5 Pin Configuration and Functions



Pin Functions

PIN		FUNCTION	DESCRIPTION
NAME	NO.		
AINM_A	2	Analog input	Negative analog input for channel A.
AINP_A	1	Analog input	Positive analog input for channel A.
AINM_B	8	Analog input	Negative analog input for channel B.
AINP_B	7	Analog input	Positive analog input for channel B.
AVDD	12, 29	Power supply	Analog power-supply pin. Connect a 1-μF decoupling capacitor between pin 12 and pin 11. Connect pins 12 and 29 together. Connect a 1-μF decoupling capacitor between pin 29 and pin 30.
CONVST	13	Digital input	Conversion start input pin. A CONVST rising edge starts the conversion for ADC_A and ADC_B.
\overline{CS}	14	Digital input	Chip-select input pin; active low. The device takes control of the data bus when \overline{CS} is low. The SDO-x pins go to Hi-Z when \overline{CS} is high.
DVDD	28	Power supply	Interface power-supply pin. Connect a 1-μF decoupling capacitor between pin 27 and pin 28.
GND	4, 11, 27, 30	Power supply	Ground
NC	6	—	No external connection
$\overline{PD/RST}$	26	Digital input	Asynchronous reset or power-down input pin. See the Reset or Power-Down section.
READY/STROBE	25	Digital output	Indicates data ready or strobe output for data capture.

Pin Functions (continued)

PIN		FUNCTION	DESCRIPTION
NAME	NO.		
REFby2	3	Analog output	REFby2 buffer output. Connect a 1-μF decoupling capacitor between pin 3 and pin 4.
REFOUT	5	Analog output	Internal reference output. Connect a 1-μF decoupling capacitor between pin 5 and pin 4.
REFM_A	32	Analog output	Negative output of reference buffer A. Negative reference input for ADC_A. Externally connect to the device GND.
REFM_B	9	Analog output	Negative output of reference buffer B. Negative reference input for ADC_B. Externally connect to the device GND.
REFP_A	31	Analog output	Positive output of reference buffer A. Positive reference input for ADC_A. Connect a 10-μF decoupling capacitor between pin 31 and pin 32.
REFP_B	10	Analog output	Positive output of reference buffer B. Positive reference input for ADC_B. Connect a 10-μF decoupling capacitor between pin 9 and pin 10.
SCLK	16	Digital input	Clock input pin for the serial interface.
SDI	15	Digital input	Serial data input pin. This pin is used to program the device registers.
SDO-0/0A	24	Digital output	SPI mode: data output 0 for channel A. Parallel byte mode: least significant bit (LSB) from the data byte.
SDO-1/1A	23	Digital output	SPI mode: data output 1 for channel A. Parallel byte mode: LSB+1 from the data byte.
SDO-2/2A	22	Digital output	SPI mode: data output 2 for channel A. Parallel byte mode: LSB+2 from the data byte.
SDO-3/3A	21	Digital output	SPI mode: data output 3 for channel A. Parallel byte mode: LSB+3 from the data byte.
SDO-4/0B	20	Digital output	SPI mode: data output 0 for channel B. Parallel byte mode: LSB+4 from the data byte.
SDO-5/1B	19	Digital output	SPI mode: data output 1 for channel B. Parallel byte mode: LSB+5 from the data byte.
SDO-6/2B	18	Digital output	SPI mode: data output 2 for channel B. Parallel byte mode: LSB+6 from the data byte.
SDO-7/3B	17	Digital output	SPI mode: data output 3 for channel B. Parallel byte mode: most significant bit (MSB) from the data byte.
Thermal pad	Pad	Power supply	Exposed thermal pad. TI recommends connecting this pin to the printed circuit board (PCB) ground.

6 Specifications

6.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
Analog supply voltage	AVDD to GND	−0.3	6	V
Digital supply voltage	DVDD to GND	−0.3	6	V
Digital input voltage	$\overline{\text{CS}}$, CONVST, SDI, SCLK, $\overline{\text{PD/RST}}$ to GND	−0.3	DVDD + 0.3	V
Analog input voltage	AINP_A, AINP_B to GND	−0.3	AVDD + 0.3	V
Analog input voltage	AINM_A, AINM_B to GND	−0.3	AVDD + 0.3	V
Input or output current to any pin except power supply pin		−10	10	mA
Maximum virtual junction temperature	T _J		150	°C
Storage temperature	T _{stg}	−65	150	°C

- (1) Stresses beyond those listed under *Absolute Maximum Rating* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Condition*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

6.2 ESD Ratings

			VALUE	UNIT
V _(ESD)	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins ⁽¹⁾	±2000	V
		Charged device model (CDM), per JEDEC specification JESD22-C101, all pins ⁽²⁾	±500	

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
AVDD	Analog supply voltage	4.5	5	5.5	V
	Digital supply voltage operating range	1.65	3.3	5.5	V
DVDD	Digital supply voltage for SCLK > 20 MHz	2.35	3.3	5.5	V
T _A	Ambient temperature	−40		125	°C

6.4 Thermal Information

THERMAL METRIC ⁽¹⁾		ADS92x4R	UNIT
		RHB (VQFN)	
		32 PINS	
R _{θJA}	Junction-to-ambient thermal resistance	29	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	17.1	°C/W
R _{θJB}	Junction-to-board thermal resistance	9.4	°C/W
Ψ _{JT}	Junction-to-top characterization parameter	0.2	°C/W
Ψ _{JB}	Junction-to-board characterization parameter	9.4	°C/W
R _{θJC(bot)}	Junction-to-case (bottom) thermal resistance	0.8	°C/W

- (1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

6.5 Electrical Characteristics: ADS92x4R

all minimum and maximum specifications are at $T_A = -40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$, $AVDD = 4.5\text{ V}$ to 5.5 V , $DVDD = 2.35$ to 5.5 V and $f_{\text{SAMPLE}} = 3\text{ MSPS}$ (unless otherwise noted); Typical values are at $T_A = 25^{\circ}\text{C}$, $AVDD = 5\text{ V}$, and $DVDD = 3.3\text{ V}$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
ANALOG INPUT						
FSR	Full-scale input voltage ⁽¹⁾	V _{REF} = 2.5 V	-4.096		4.096	V
V _{IN}	Absolute input voltage (AINP or AINM to GND)	V _{REF} = 2.5 V	0		4.096	V
V _{CM}	Common-mode input range	V _{REF} = 2.5 V	1.848		2.248	V
I _{IN}	Analog input leakage current		±1			µA
C _i	Input capacitance	Sample Mode	16			pF
		Hold Mode	1			
SAMPLING DYNAMICS						
t _{CYCLE}	Cycle time		333			ns
f _{SAMPLE}	Sampling rate	ADS9224R			3	MSPS
f _{SAMPLE}	Sampling rate	ADS9234R			3.5	MSPS
t _{ACQ}	Acquisition time		140			ns
t _A	Aperture delay		8			ns
	t _A mismatch		40			ps
t _{JITTER}	Aperture jitter		2			ps
BW	Analog input bandwidth	-3dB Input Signal	52			MHz
		-0.1 dB Input Signal	4.2			MHz
VOLTAGE REFERENCE OUTPUT						
V _{REF} ⁽²⁾	REFOUT voltage	T _A = 25°C	2.498	2.5	2.502	V
ΔV _{REF} /ΔT	V _{REF} drift		7.5		20	ppm/°C
ΔV _{REF} /ΔAVDD	V _{REF} line regulation	AVDD variation 4.5 V to 5.5 V	200			µV/V
I _{REFOUT}	REFOUT output current capability	ΔV _{REF} < 2 mV	1.5			µA
C _{REFOUT}	REFOUT capacitor	For specified performance	1			µF
t _{wkup-REFOUT}	REFOUT wake-up time	C _{REFOUT} = 1 µF	15.6			ms
INTERNAL REFERENCE BUFFER						
G _{REFBUF}	Reference buffer Gain		1.6388			V/V
E _{O-REFBUF}	Reference buffer output offset (V _{REFP_x} - V _{REF})	At T _A = 25°C	±500			µV
		T _A = -40°C to 125°C	-1	0	1	mV
ΔE _{O-REFBUF} /ΔT	Reference buffer output offset temperature drift		10			µV/°C
(V _{REFP_A} - V _{REFP_B})	Reference buffer output mismatch	T _A = -40°C to 125°C	-500	±50	500	µV
C _{REFP_x}	Reference buffer output capacitor	For specified performance, between each pair of REFP and REFM	7	10	27	µF
t _{REFBUF-SETTLE}	Reference buffer output settling time	C _{REFP_x} = 10 µF	18			ms
REFby2 OUTPUT						
V _{REFby2}	REFby2 output voltage	EN_REFBY2_OFFSET = 0, V _{REF} = 2.5 V	2.043	2.048	2.053	V
		EN_REFBY2_OFFSET = 1, V _{REF} = 2.5 V	2.133	2.148	2.163	V
I _{REFby2}	REFby2 output current capability		±3			mA

(1) Ideal input span; does not include gain or offset error.

(2) Does not include the variation in voltage resulting from solder shift effects.

Electrical Characteristics: ADS92x4R (continued)

all minimum and maximum specifications are at $T_A = -40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$, $\text{AVDD} = 4.5\text{ V}$ to 5.5 V , $\text{DVDD} = 2.35$ to 5.5 V and $f_{\text{SAMPLE}} = 3\text{ MSPS}$ (unless otherwise noted); Typical values are at $T_A = 25^{\circ}\text{C}$, $\text{AVDD} = 5\text{ V}$, and $\text{DVDD} = 3.3\text{ V}$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	REFby2 output capacitor		1			μF
	REFby2 output noise	With specified output capacitor		10		μV _{RMS}
Digital Outputs						
V _{OH}	High level output voltage	I _{OH} = 500 μA source	0.8 × DVDD		DVDD	V
V _{OL}	Low level output voltage	I _{OL} = 500 μA sink	0		0.2 × DVDD	V
Digital Inputs						
V _{IH}	High level input voltage	DVDD > 2.3 V	0.7 × DVDD		DVDD +0.3	V
V _{IL}	Low level input voltage		−0.3		0.3 × DVDD	V
V _{IH}	High level input voltage	DVDD ≤ 2.3 V	0.8 × DVDD		DVDD +0.3	V
V _{IL}	Low level input voltage		−0.3		0.2 × DVDD	V
Power Supply						
AVDD	Analog supply voltage		4.5	5	5.5	V
DVDD	Digital supply voltage		1.65	3.3	5.5	V
I _{AVDD}	Analog supply current	AVDD = 5 V, f _{SAMPLE} = 3 MSPS		24		mA
		AVDD = 5 V, No Conversion		8		mA
		AVDD = 5 V, Power down (PD/RST Low)		1		μA
I _{DVDD}	Digital supply current	DVDD = 3.3 V, C _{SDO-x/y} = 10 pF		0.75		mA
PSRR ⁽³⁾	Power supply rejection ratio	100mVp-p Ripple on AVDD of frequency < 100kHz		70		dB

(3) All specifications expressed in decibels (dB) refer to the full-scale input (FSR) and are tested with an input signal 0.5 dB below full-scale, unless otherwise specified.

6.6 Electrical Characteristics: ADS9224R

all minimum and maximum specifications are at $T_A = -40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$, $\text{AVDD} = 4.5\text{ V}$ to 5.5 V , $\text{DVDD} = 2.35$ to 5.5 V , and $f_{\text{SAMPLE}} = 3\text{ MSPS}$ (unless otherwise noted); Typical values are at $T_A = 25^{\circ}\text{C}$, $\text{AVDD} = 5\text{ V}$, and $\text{DVDD} = 3.3\text{ V}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
DC ACCURACY					
	Resolution, no missing codes	16			bit
DNL	Differential nonlinearity	-0.99	± 0.5	0.99	LSB
INL	Integral nonlinearity	-2	± 1	2	LSB
E_{O}	Offset error	-6	± 1	6	LSB
G_{E}	Cummulative gain error for ADC_x and REFBUF_x	-0.05	± 0.01	0.05	%FSR
$\Delta G_{\text{E}}/\Delta T$	Gain drift		5		ppm/ $^{\circ}\text{C}$
	Transition noise	Mid-code, PFS-1000, NFS+1000	0.4		LSB
CMRR ⁽¹⁾	Common-mode rejection ratio	$F_{\text{IN}} = \text{dc to } 1\text{-MHz}$, $V_{\text{IN}} = 100\text{ mVp-p}$	80		dB
AC ACCURACY					
SNR ⁽¹⁾	Signal-to-noise ratio	$F_{\text{IN}} = 2\text{ kHz}$	89	93.5	dB
		$F_{\text{IN}} = 100\text{ kHz}$		90.5	dB
		$F_{\text{IN}} = 1400\text{ kHz}$		88.5	dB

(1) All specifications expressed in decibels (dB) refer to the full-scale input (FSR) and are tested with an input signal 0.5 dB below full-scale, unless otherwise specified.

Electrical Characteristics: ADS9224R (continued)

all minimum and maximum specifications are at $T_A = -40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$, $AVDD = 4.5\text{ V}$ to 5.5 V , $DVDD = 2.35$ to 5.5 V , and $f_{\text{SAMPLE}} = 3\text{ MSPS}$ (unless otherwise noted); Typical values are at $T_A = 25^{\circ}\text{C}$, $AVDD = 5\text{ V}$, and $DVDD = 3.3\text{ V}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SINAD ⁽¹⁾⁽²⁾	Signal-to-noise plus distortion	$F_{\text{IN}} = 2\text{ kHz}$	90.8		dB
		$F_{\text{IN}} = 100\text{ kHz}$	90.3		dB
		$F_{\text{IN}} = 1400\text{ kHz}$	83		dB
THD ⁽¹⁾⁽²⁾	Total harmonic distortion	$F_{\text{IN}} = 2\text{ kHz}$	-110		dB
		$F_{\text{IN}} = 100\text{ kHz}$	-105		dB
		$F_{\text{IN}} = 1400\text{ kHz}$	-85		dB
SFDR ⁽¹⁾	Spurious-free dynamic range	$F_{\text{IN}} = 2\text{ kHz}$	115		dB
		$F_{\text{IN}} = 100\text{ kHz}$	110		dB
		$F_{\text{IN}} = 1400\text{ kHz}$	90		dB
ISOXT ⁽¹⁾	Channel-to-channel isolation	$F_{\text{IN_ADCA}} = 15\text{ kHz}$ at 10% FSR, $F_{\text{IN_ADCB}} = 25\text{ kHz}$ at 100% FSR	-120		dB

(2) Calculated on the first nine harmonics of the input frequency.

6.7 Electrical Characteristics: ADS9234R

all minimum and maximum specifications are at $T_A = -40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$, $AVDD = 4.5\text{ V}$ to 5.5 V , $DVDD = 2.35$ to 5.5 V , and $f_{\text{SAMPLE}} = 3.5\text{ MSPS}$ (unless otherwise noted); Typical values are at $T_A = 25^{\circ}\text{C}$, $AVDD = 5\text{ V}$, and $DVDD = 3.3\text{ V}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
DC ACCURACY					
	Resolution, no missing codes	14			bit
DNL	Differential nonlinearity	-0.99	± 0.15	0.99	LSB
INL	Integral nonlinearity	-1	± 0.3	1	LSB
E_O	Offset error	-2.5	± 0.8	2.5	LSB
G_E	Cummulative gain error for ADC_x and REFBUF_x	-0.05	± 0.01	0.05	%FSR
$\Delta G_E / \Delta T$	Gain drift		5		ppm/ $^{\circ}\text{C}$
	Transition noise	Mid-code, PFS-1000, NFS+1000	0.3		LSB
CMRR ⁽¹⁾	Common mode rejection ratio	$F_{\text{IN}} = \text{dc to } 1\text{-MHz}$, $V_{\text{IN}} = 100\text{ mVp-p}$	75		dB
AC ACCURACY					
SNR ⁽¹⁾	Signal-to-noise ratio	$F_{\text{IN}} = 2\text{ kHz}$	82	85.6	dB
		$F_{\text{IN}} = 100\text{ kHz}$		84	dB
		$F_{\text{IN}} = 1400\text{ kHz}$		82	dB
SINAD ⁽¹⁾⁽²⁾	Signal-to-noise plus distortion	$F_{\text{IN}} = 2\text{ kHz}$		85.6	dB
		$F_{\text{IN}} = 100\text{ kHz}$		84	dB
		$F_{\text{IN}} = 1400\text{ kHz}$		80	dB
THD ⁽¹⁾⁽²⁾	Total harmonic distortion	$F_{\text{IN}} = 2\text{ kHz}$		-106	dB
		$F_{\text{IN}} = 100\text{ kHz}$		-105	dB
		$F_{\text{IN}} = 1400\text{ kHz}$		-85	dB
SFDR ⁽¹⁾	Spurious-free dynamic range	$F_{\text{IN}} = 2\text{ kHz}$		108	dB
		$F_{\text{IN}} = 100\text{ kHz}$		107	dB
		$F_{\text{IN}} = 1400\text{ kHz}$		90	dB
ISOXT ⁽¹⁾	Channel-to-channel isolation	$F_{\text{IN_ADCA}} = 15\text{ kHz}$ at 10% FSR, $F_{\text{IN_ADCB}} = 25\text{ kHz}$ at 100% FSR	-110		dB

(1) All specifications expressed in decibels (dB) refer to the full-scale input (FSR) and are tested with an input signal 0.5 dB below full-scale, unless otherwise specified.

(2) Calculated on the first nine harmonics of the input frequency.

6.8 Timing Requirements

all minimum and maximum specifications are at $T_A = -40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$, $\text{AVDD} = 4.5\text{ V}$ to 5.5 V , $\text{DVDD} = 2.35\text{ V}$ to 5.5 V , and $f_{\text{SAMPLE}} = 3\text{ MSPS}$ (unless otherwise noted); typical values are at $T_A = 25^{\circ}\text{C}$, $\text{AVDD} = 5\text{ V}$, and $\text{DVDD} = 3.3\text{ V}$

		MIN	NOM	MAX	UNIT
Conversion Control and Data Transfer (See 图 1 and 图 2)					
$t_{\text{D_CONVST_CS}}$	Delay time: CONVST high to $\overline{\text{CS}}$ Falling for zero cycle latency (zone 1 transfer)	$t_{\text{DRDY}}^{(1)}$			ns
$t_{\text{D_CONVST_CS}}$	Delay time: CONVST high to $\overline{\text{CS}}$ falling for zone 2 transfer	15		180	ns
$t_{\text{WL_CONVST}}$	Pulse duration : CONVST low	15			ns
$t_{\text{WH_CONVST}}$	Pulse duration : CONVST high	15			ns
t_{CYCLE}	Time between two adjacent CONVST rising edges for zero cycle latency (zone 1 transfer)		$t_{\text{DRDY}} + t_{\text{READ}}^{(2)}$		ns
t_{CYCLE}	Time between two adjacent CONVST rising edges for zone 2 transfer	333			ns
SPI-compatible and Parallel Byte Protocols (See 图 3)					
t_{CLK}	Serial clock time period	$1/f_{\text{CLK}}$			
$t_{\text{PH_CLK}}$	SCLK high time	$0.45 \times t_{\text{CLK}}$		$0.55 \times t_{\text{CLK}}$	ns
$t_{\text{PL_CLK}}$	SCLK low time	$0.45 \times t_{\text{CLK}}$		$0.55 \times t_{\text{CLK}}$	ns
$t_{\text{SU_CSCK}}$	Setup time: $\overline{\text{CS}}$ falling to first SCLK capture edge	12			ns
$t_{\text{SU_CKDI}}$	Setup Time: SDI data valid to SCLK capture edge	1.5			ns
$t_{\text{HT_CKDI}}$	Hold Time: SCLK capture edge to previous data valid on SDI	1.5			ns
$t_{\text{HT_CKCS}}$	Delay Time: last SCLK capture edge to $\overline{\text{CS}}$ rising	7			ns
f_{CLK}	Serial clock frequency for SPI protocols with single data rate			60	MHz
f_{CLK}	Serial clock frequency for SPI protocols with double data rate			22	MHz
f_{CLK}	Serial clock frequency for parallel byte protocol			45	MHz
Clock Re-Timer protocol with STROBE = SCLK (External Clock)⁽³⁾(See 图 4)					
f_{CLK}	Serial clock frequency with single data rate			60	MHz
f_{CLK}	Serial clock frequency with double data rate			22	MHz
Asynchronous Reset and Power Down Timing (See 图 6)					
$t_{\text{WL_RST}}$	Pulse duration (Low) for reset	50		500	ns
$t_{\text{WL_PD-min}}$	Minimum pulse duration (Low) for power down	1000			ns

(1) See Switching Characteristics

(2) See [Protocols for Reading From the Device](#) for t_{READ}

(3) Other parameters are the same as the SPI-compatible and Parallel Byte Protocols.

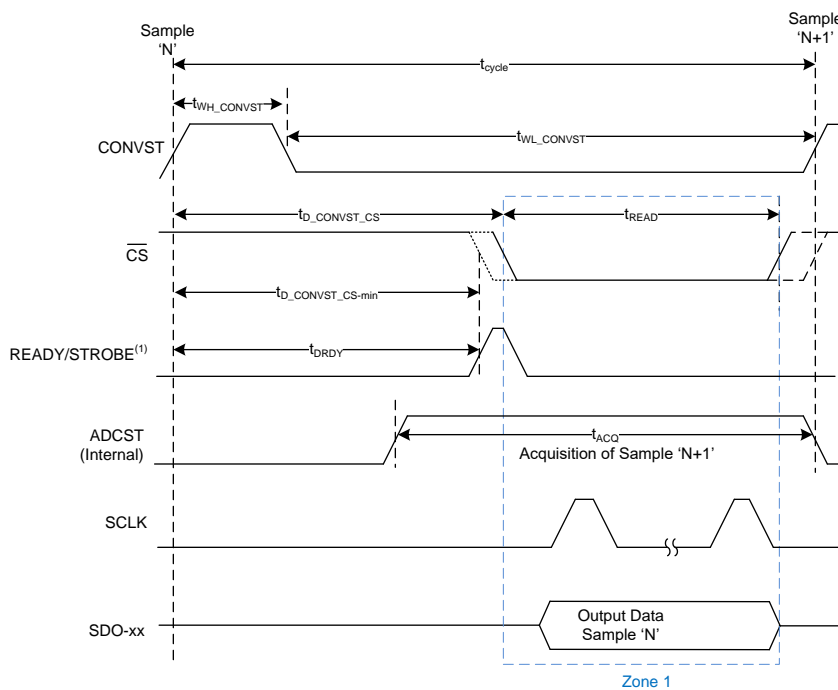
6.9 Switching Characteristics

all minimum and maximum specifications are at $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$, $AVDD = 4.5\text{ V}$ to 5.5 V , $DVDD = 2.35\text{ V}$ to 5.5 V , and $f_{\text{Sample}} = 3\text{ MSPS}$ (unless otherwise noted); typical values are at $T_A = 25^\circ\text{C}$, $AVDD = 5\text{ V}$, and $DVDD = 3.3\text{ V}$

		MIN	TYP	MAX	UNIT
Conversion Control and Data Transfer (See 图 1 and 图 2)					
t_{DRDY}	Data ready time for present sample: CONVST high to READY high with zero cycle latency (zone 1 transfer) for ADS9224x (16-bit)			300	ns
	Data ready time for present sample: CONVST high to READY high with zero cycle latency (zone 1 transfer) for ADS9234x (14-bit)			285	ns
SPI-compatible and Parallel Byte Protocols (See 图 3)					
$t_{\text{DEN_CSDO}}$	Delay time: $\overline{\text{CS}}$ falling to data valid on SDO-x			12	ns
$t_{\text{DZ_CSDO}}$	Delay time: $\overline{\text{CS}}$ rising edge to SDO-x tristate			12	ns
$t_{\text{D_CKDO}}$	Delay time: SCLK launch edge to next data valid on SDO-x for SPI-compatible protocols with single data rate	TBD		15.8	ns
$t_{\text{D_CKDO}}$	Delay time: SCLK launch edge to next data valid on SDO-x for SPI-compatible protocols with double data rate	TBD		21	ns
$t_{\text{D_CKDO}}$	Delay time: SCLK launch edge to next data valid on SDO-x for parallel byte protocol	TBD		21	ns
Clock Re-Timer protocol with STROBE = SCLK (External Clock)⁽¹⁾(See 图 4)					
$t_{\text{OFF_STROBE_DO}}$	Time offset: STROBE edge to next data valid on SDO-x	-2.5		2.5	ns
$t_{\text{D_CS_READY}}$	Delay time: $\overline{\text{CS}}$ rising to READY displaying internal device state			13.5	ns
$t_{\text{D_CKSTROBE_r}}$	Delay time: SCLK rising edge to STROBE rising			21.5	ns
$t_{\text{D_CKSTROBE_f}}$	Delay time: SCLK falling edge to STROBE falling			21.5	ns
$t_{\text{PH_STROBE}}$	Strobe output high time	$0.45 \times t_{\text{STR}}$		$0.55 \times t_{\text{STR}}$	ns
$t_{\text{PL_STROBE}}$	Strobe output low time	$0.45 \times t_{\text{STR}}$		$0.55 \times t_{\text{STR}}$	ns
Clock Re-Timer protocol with STROBE = Internal Clock.⁽¹⁾(See 图 5)					
$t_{\text{D_CS_STROBE}}$	Delay time : $\overline{\text{CS}}$ falling to 1 st STROBE rising	15		50	ns
$t_{\text{OFF_STROBE_DO}}$	Time offset : STROBE edge to next data valid on SDO-x	-2.5		2.5	ns
$t_{\text{D_CS_READY}}$	Delay time: $\overline{\text{CS}}$ rising to READY displaying internal device state			13.5	ns
t_{INTCLK}	INTCLK period		15		ns
t_{STR}	STROBE period (INTCLK)		15		ns
	INTCLK/2		30		ns
	INTCLK/4		60		ns
$t_{\text{WH_STR}}$	STROBE high period	$0.45 \times t_{\text{STR}}$		$0.55 \times t_{\text{STR}}$	ns
$t_{\text{WL_STR}}$	STROBE low period	$0.45 \times t_{\text{STR}}$		$0.55 \times t_{\text{STR}}$	ns
Asynchronous Reset and Power Down Timing (See 图 6)					
$t_{\text{RST_WKUP}}$	Wake up time from reset			1	μs
$t_{\text{PD_WKUP}}^{(2)}$	Wake up time from power down		18		ms

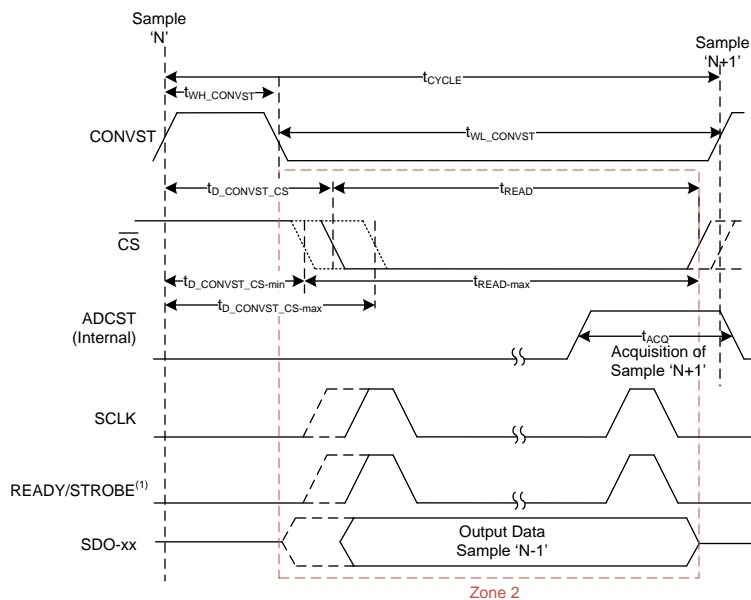
(1) Other parameters are the same as the SPI-compatible and Parallel Byte Protocols.

(2) With $C_{\text{REFP_x}} = 10\mu\text{F}$



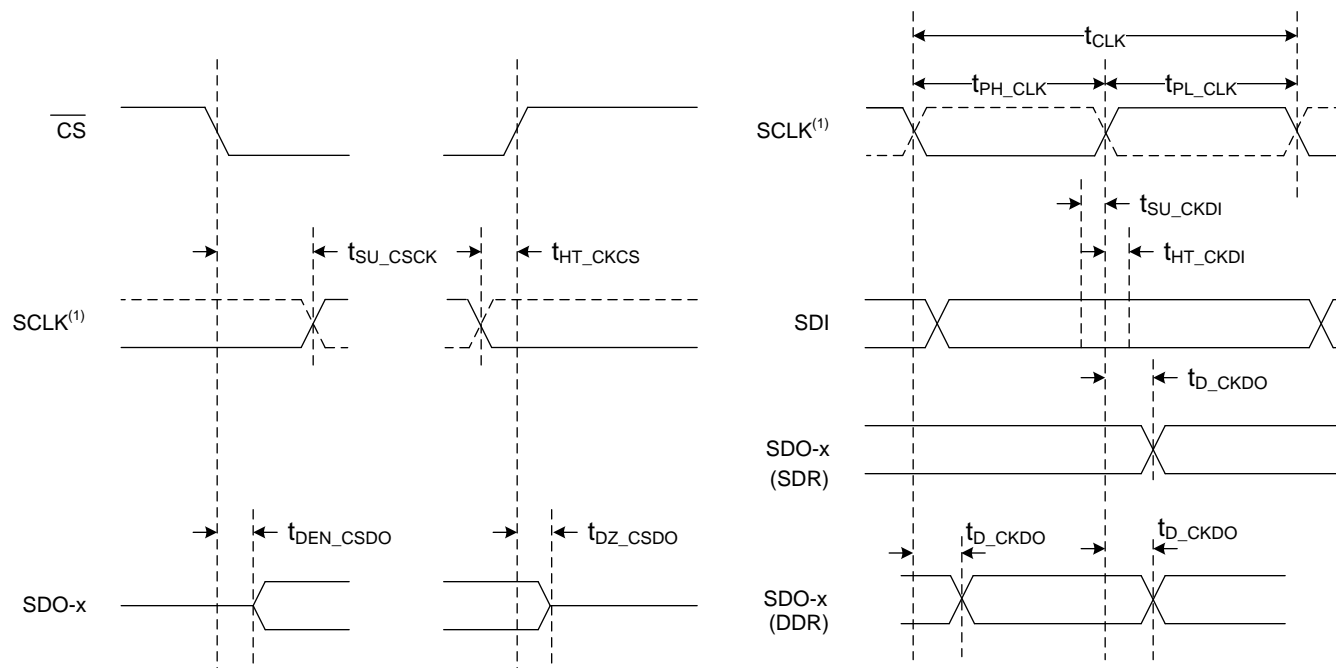
- (1) The READY output is required for data transfer with zero cycle latency. The STROBE output is required only for clock re-timer (CRT) protocols.

图 1. Conversion Control and Data Transfer With Zero Cycle Latency (Zone 1 Transfer)



- (1) The READY output is not required for zone 2 data transfer. The STROBE output is required only for clock re-timer protocols.

图 2. Conversion Control and Data Transfer With Wider Read Cycle (Zone 2 Transfer)



- (1) The SCLK polarity, launch edge, and capture edge depend on the SPI protocol selected. DDR is not supported with the parallel byte protocol.

图 3. SPI-Compatible and Parallel Byte Protocols Timing

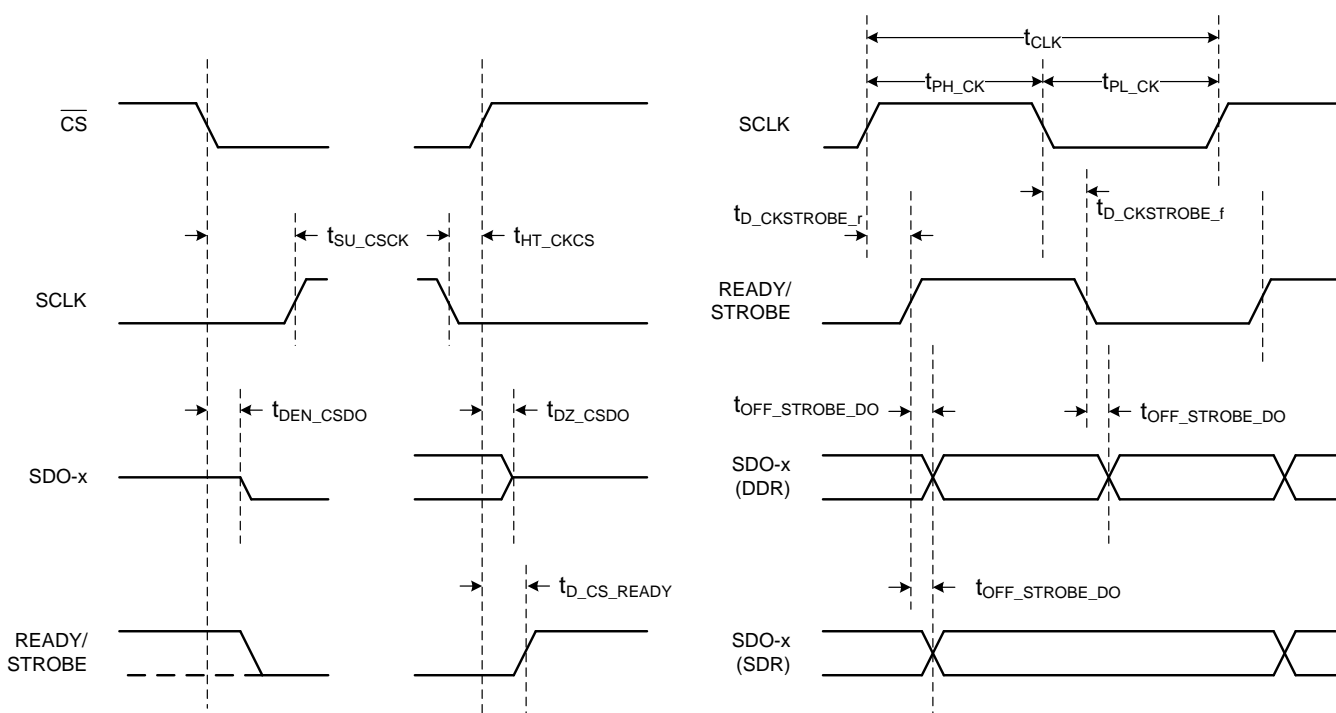


图 4. Clock Re-Timer Protocol (External Clock) Timing

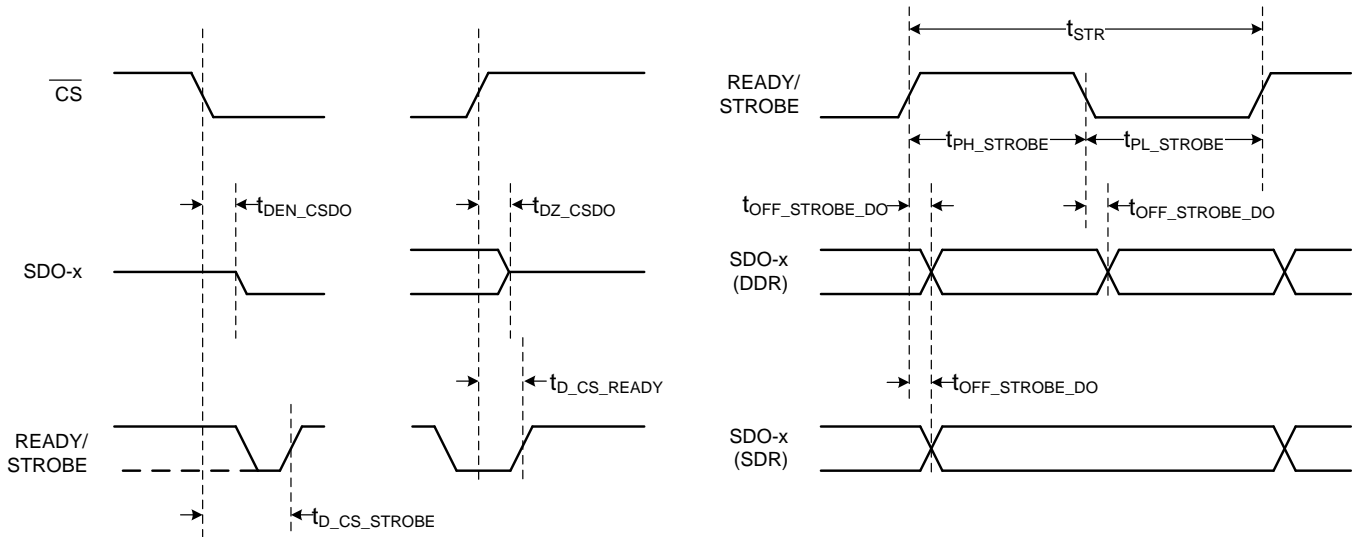


图 5. Clock Re-Timer Protocol (Internal Clock) Timing

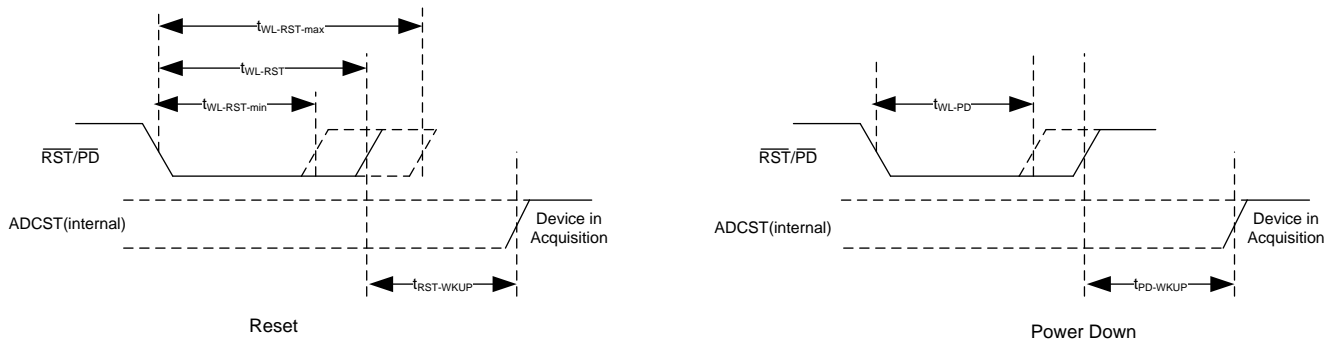


图 6. Asynchronous Reset and Power-Down Timing

7 Detailed Description

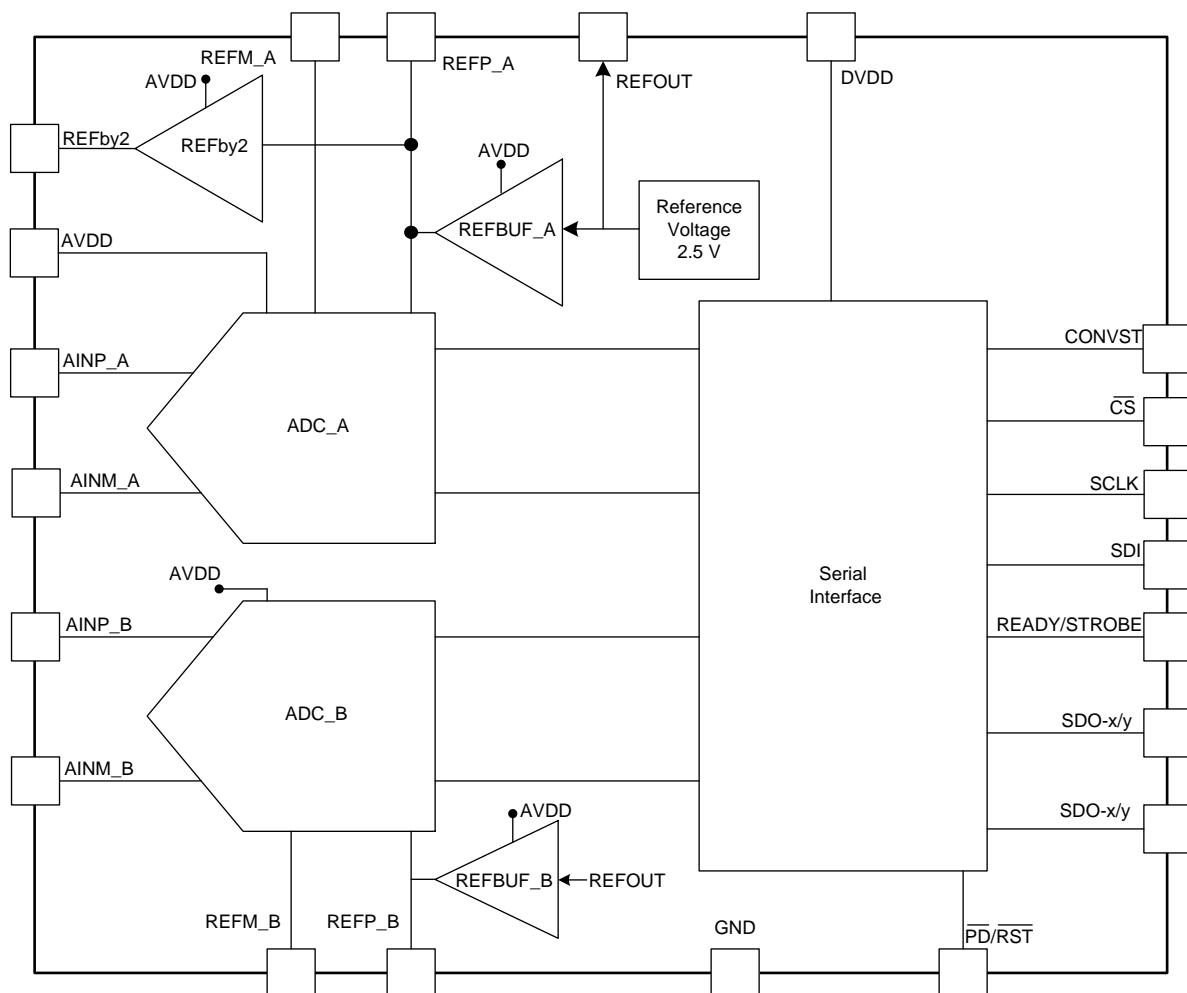
7.1 Overview

The device belongs to a family of dual, high-speed, simultaneous-sampling, analog-to-digital converters (ADCs). The device supports fully differential input signals and a full-scale input range equal to $3.2678 \times V_{REF}$.

When a conversion is initiated, the input between the AINP_x and AINM_x pins is sampled on the internal capacitor array. The device uses an internal clock to perform conversions. During the conversion process, both analog inputs are disconnected from the internal circuit. At the end of conversion process, the device reconnects the sampling capacitors to the AINP_x and AINM_x pins and enters an acquisition phase. The device includes reference buffers to provide the charge required by the ADCs during conversion. The device includes a reference voltage for the ADCs.

The enhanced serial programming interface (SPI) digital interface is backward-compatible with traditional SPI protocols. Configurable features simplify board layout, timing, and firmware and support high throughput at lower clock speeds, thus allowing an easy interface with a variety of microcontrollers, digital signal processors (DSPs), and field-programmable gate arrays (FPGAs). The device also provides a byte mode and a wide read cycle to reduce the clock frequency required for data transfer. The device includes a clock re-timer (CRT) to enable data transfer through digital isolators. The device also supports double data rate (DDR) with SPI-compatible serial interface modes and with a clock re-timer.

7.2 Functional Block Diagram



7.3 Feature Description

From a functional perspective, the device is comprised of seven modules: two converters (ADC_A, ADC_B), two reference buffers (REFBUF_A, REFBUF_B), the REFby2 buffer, the reference voltage, and the serial interface, as shown in the [Functional Block Diagram](#) section.

The converter module samples and converts the analog input into an equivalent digital output code. The reference buffers provide the charge required by the converters for the conversion process. The serial interface module facilitates communication and data transfer between the device and the host controller. The REFby2 buffer provides the common-mode voltage for the amplifiers input driving the analog of the device. The reference voltage is used by the converters for conversion process.

7.3.1 Converter Modules

As shown in [图 7](#), both converter modules sample the analog input signal (provided between the AINP_x and AINM_x pins), compare this signal with the reference voltage (between the pair of REFP_x and REFM_x pins), and generate an equivalent digital output code. The converter modules receive PD/RST and the CONVST inputs from the interface module, and output the ADCST signal and the conversion result back to the interface module.

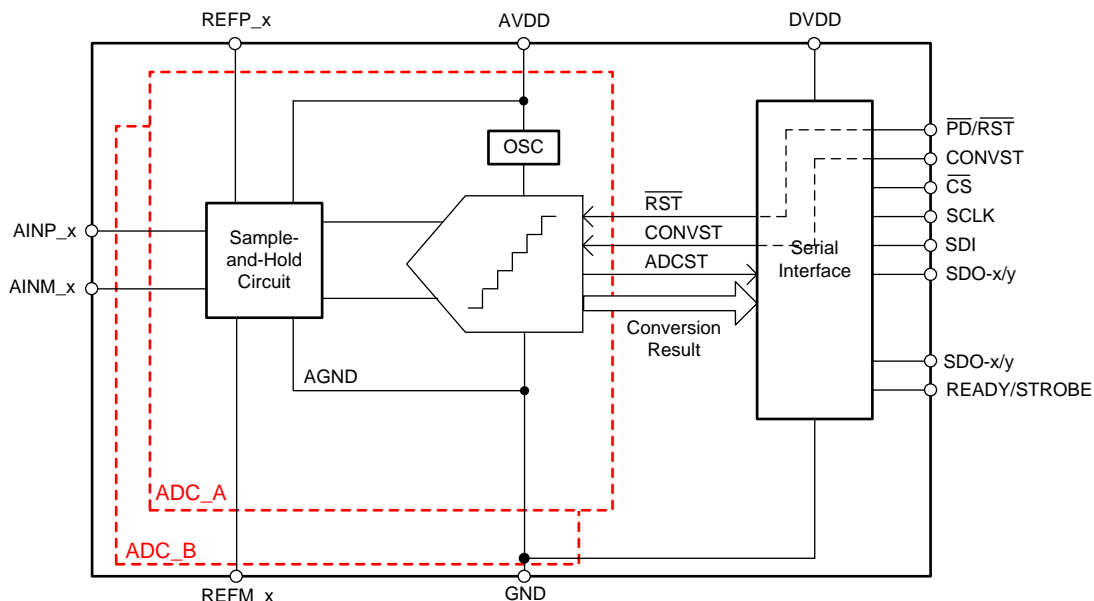


图 7. Converter Modules

7.3.1.1 Analog Input With Sample-and-Hold

This device supports unipolar, fully differential, analog input signals. [图 8](#) shows a small-signal equivalent circuit of the sample-and-hold circuit. Each sampling switch is represented by a resistance (R_{S1} and R_{S2} , typically 120 Ω) in series with an ideal switch (SW_1 and SW_2). The sampling capacitors, C_{S1} and C_{S2} , are typically 16 pF.

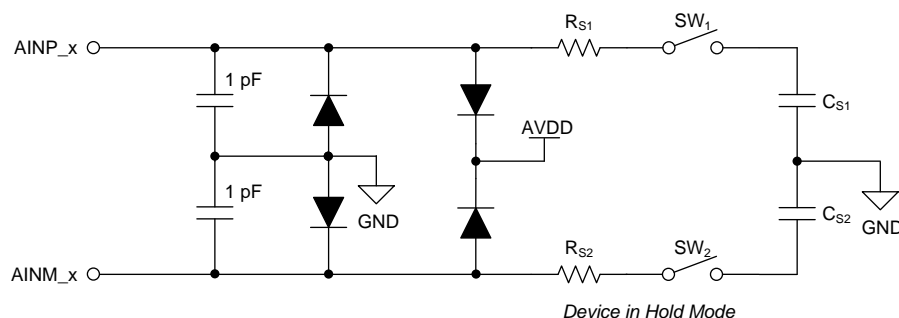


图 8. Analog Input Structure for Converter Module

Feature Description (接下页)

During the acquisition process, both inputs are individually sampled on C_{S1} and C_{S2} , respectively. During the conversion process, both converters convert for the respective voltage difference between the sampled values: $V_{AINP_x} - V_{AINM_x}$.

公式 1 和 公式 2 provide the full-scale input range (FSR) and common-mode voltage (VCM), supported at the analog inputs for reference voltage (V_{REF}) on the REFOUT pin.

$$FSR = \pm 1.6384 \times V_{REF} = 3.2768 \times V_{REF} \quad (1)$$

$$V_{CM} = 0.8192 \times V_{REF} \pm 0.2 \text{ V} \quad (2)$$

7.3.1.2 ADC Transfer Function

This device supports unipolar, fully differential input signals. The device output is in two's complement format. 表 1 和 图 9 show the ideal transfer characteristics for the device. 公式 3 gives the least significant bit (LSB) for the ADC.

$$1 \text{ LSB} = FSR / 2^R$$

where

- FSR is defined in 公式 1
- R = Resolution of the device

(3)

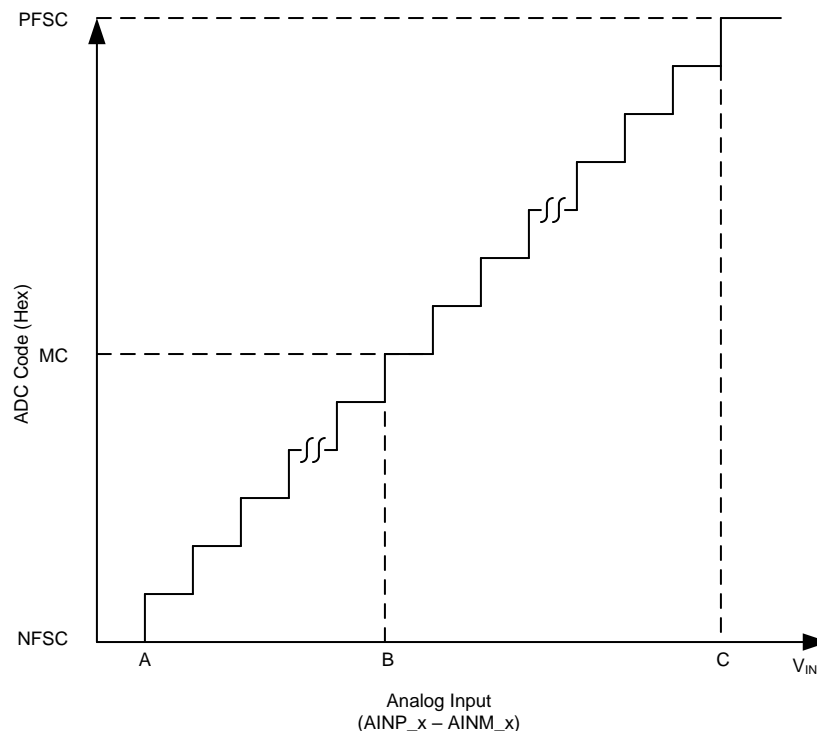


图 9. Ideal Transfer Characteristics

表 1. Transfer Characteristics

STEP	INPUT VOLTAGE ($A_{INP_x} - A_{INM_x}$)	CODE	DESCRIPTION	IDEAL OUTPUT CODE (R = 16)	IDEAL OUTPUT CODE (R = 14)
A	$\leq -(1.6384 \times V_{REF} - 1 \text{ LSB})$	NFSC	Negative full-scale code	8000	2000
B	0 LSB to 1 LSB	MC	Mid code	0000	0000
C	$\geq (1.6384 \times V_{REF} - 1 \text{ LSB})$	PFSC	Positive full-scale code	7FFF	1FFF

7.3.2 Internal Reference Voltage

The device features an internal reference source with a nominal output value of 2.5 V. The REFOUT pin is an output with the internal reference value. A 1- μ F decoupling capacitor (C_{REFOUT}), as shown in 图 10, is recommended to be placed between the REFOUT pin and GND pin. The capacitor must be placed as close to the REFOUT pin as possible. The output impedance of the internal band-gap circuit creates a low-pass filter with this capacitor to band-limit the noise of the reference. The initial accuracy specification for the internal reference can be degraded if the die is exposed to any mechanical or thermal stress. Heating the device when being soldered to a printed circuit board (PCB) and any subsequent solder reflow is a primary cause for shifts in the V_{REF} value.

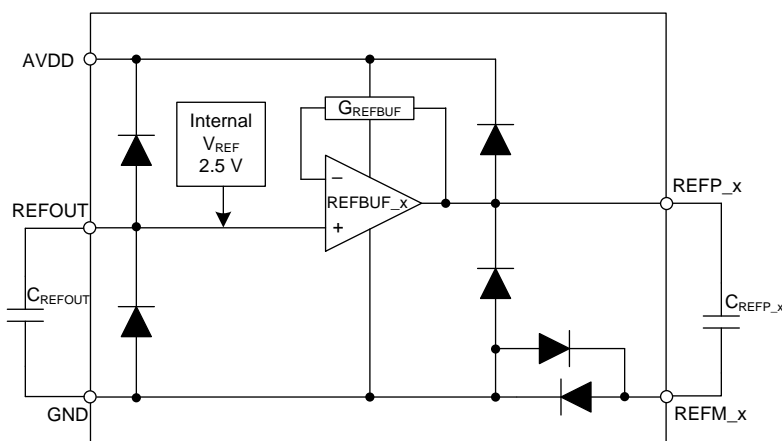


图 10. Connection Diagram for Reference and Reference Buffers

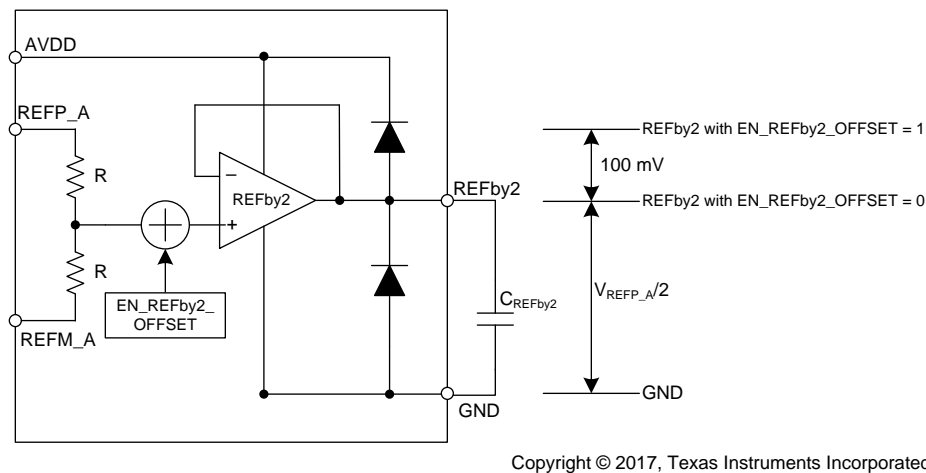
7.3.3 Reference Buffers

On the CONVST rising edge, both converters start converting the sampled value on the analog input, and the internal capacitors are switched to the REFP_x pins. Most of the switching charge required during the conversion process is provided by the external decoupling capacitor C_{REFP_x} . If the charge lost from C_{REFP_x} is not replenished before the next CONVST rising edge, the subsequent conversion occurs with this different reference voltage and causes a proportional error in the output code. To eliminate these errors, the internal reference buffers of the device maintains the voltage on the REFP_x pins. The reference buffers have a gain of G_{REFBUF} , as specified in the [Specifications](#) section. The voltage at the REFP_x pins can be calculated as $V_{REFP_x} = G_{REFBUF} \times V_{REF}$.

All performance characteristics of the device are specified with the internal reference buffer and a specified value of C_{REFP_x} . As shown in 图 10, place a decoupling capacitor C_{REFP_x} between the REFP_x pins and the REFM_x pin as close to the device as possible.

7.3.4 REFby2 Buffer

The device includes a REFby2 buffer for setting the common-mode voltage required by the converter modules. The REFby2 output can be provided to the V_{OCM} pin of the fully differential amplifiers (similar to the [THS4551](#)). The REFby2 output can be increased by 100 mV (for specifications of the REFby2 output, see the [Specifications](#) section) for providing headroom from GND for the fully differential amplifier. To increase the REFby2 output, set the EN_REFby2_OFFSET bit to 1 in the [REFby2_OFFSET](#) register. 图 11 depicts a block diagram for the REFby2 buffer.



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图 11. REFby2 Buffer

7.3.5 Data Averaging

The device can be configured to average two or four samples and provide the averaged value as output data. To configure the data averaging, configure the [DATA_AVG_CFG register](#).

7.3.5.1 Averaging of Two Samples

To enable averaging of two samples, set the EN_DATA_AVG bits in the [DATA_AVG_CFG register](#) to 10b. In this mode, the device averages two samples and provides the average of two samples as output data. The output data rate reduces by a factor of two. In this mode, the host must provide two pulses separated by a time of t_{CYCLE} (see t_{CYCLE} for a zone 2 transfer in the [Specifications](#) section) on the CONVST pin. The device sets the READY pin high after a time of t_{DRDY} (see t_{DRDY} in the [Specifications](#) section) from the second rising edge on the CONVST pin. After the READY pin is set high, the host can read the data by using one of the [protocols for reading from the device](#). The host can read the data while providing the two CONVST pulses for acquiring the next two samples. The host must keep $t_{\text{READ}} < [2 \times t_{\text{CYCLE}}]$. 图 12 provides the timing for the averaging of two samples.

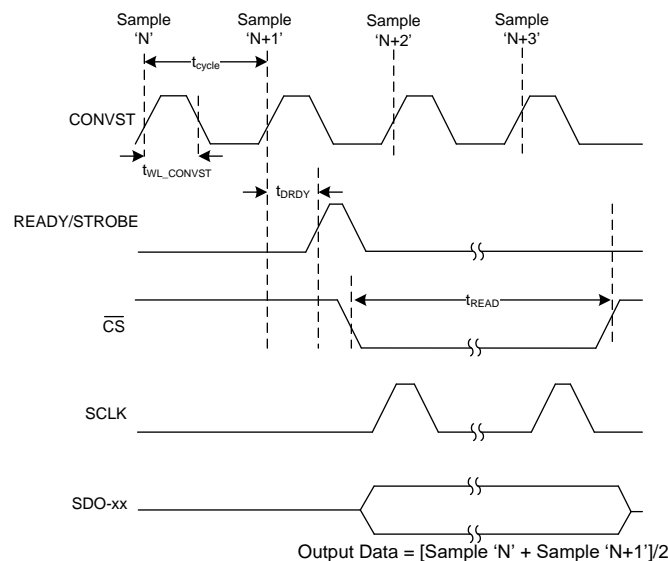


图 12. Timing for Averaging of Two Samples

7.3.5.2 Averaging of Four Samples

To enable averaging of four samples, set the EN_DATA_AVG bits in the [DATA_AVG_CFG register](#) to 11b. In this mode, the device averages four samples and provides the average of four samples as output data. The output data rate reduces by a factor of four. In this mode, the host must provide four pulses separated by a time of t_{CYCLE} (see t_{CYCLE} for a zone 2 transfer in the [Specifications](#) section) on the CONVST pin. The device sets the READY pin high after a time of t_{DRDY} (see t_{DRDY} in the [Specifications](#) section) from the fourth rising edge on the CONVST pin. After the READY pin is set high, the host can read the data by using one of the [protocols for reading from the device](#). The host can read the data while providing the four CONVST pulses for acquiring the next four samples. The host must keep $t_{\text{READ}} < [4 \times t_{\text{CYCLE}}]$. [图 13](#) provides the timing for the averaging of four samples.

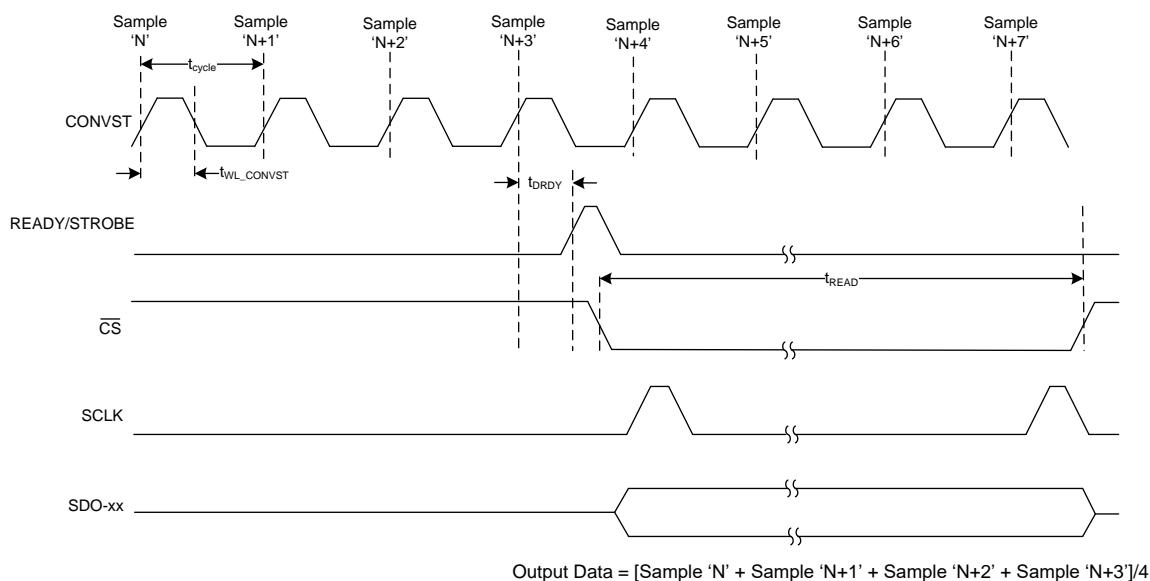


图 13. Timing for Averaging of Four Samples

7.4 Device Functional Modes

As shown in [图 14](#), this device supports three functional states: RST or power-down, ACQ, and CNV. The device state is determined by the status of the CONVST and $\overline{\text{PD/RST}}$ control signals provided by the host controller.

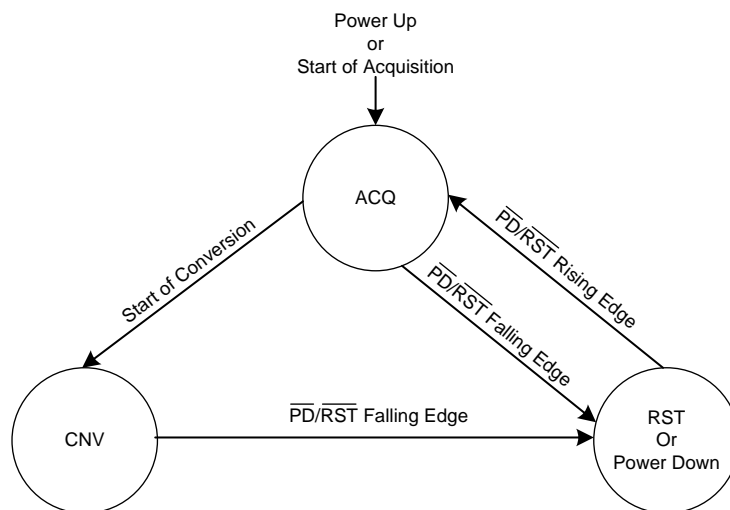


图 14. Device Functional States

Device Functional Modes (接下页)

7.4.1 ACQ State

In ACQ state, the device acquires the analog input signal. The device enters ACQ state at power-up, when coming out of power down, after any asynchronous reset, and by the ADCST signal (internal). A $\overline{\text{PD}}/\overline{\text{RST}}$ falling edge takes the device from ACQ state to RST state. A CONVST rising edge takes the device from ACQ state to CNV state.

7.4.2 CNV State

The device moves from ACQ state to CNV state and starts conversion on a rising edge of a CONVST pin. The conversion process uses an internal clock. The host must provide a minimum time of t_{CYCLE} between two subsequent start of conversions.

7.4.3 Reset or Power-Down

The $\overline{\text{PD}}/\overline{\text{RST}}$ pin is an asynchronous digital input for the device. The pulse duration (low) on the $\overline{\text{PD}}/\overline{\text{RST}}$ pin decides the state for the device (reset or power-down). 图 15 provides the timing diagram for these states. On power-up or after reset the device supports the SPI-00-S protocol for configuring the device and the SPI-00-S-SDR protocol for reading the data from the device. See the [Protocols for Reading From the Device](#) and [Protocols for Configuring the Device](#) sections for details.

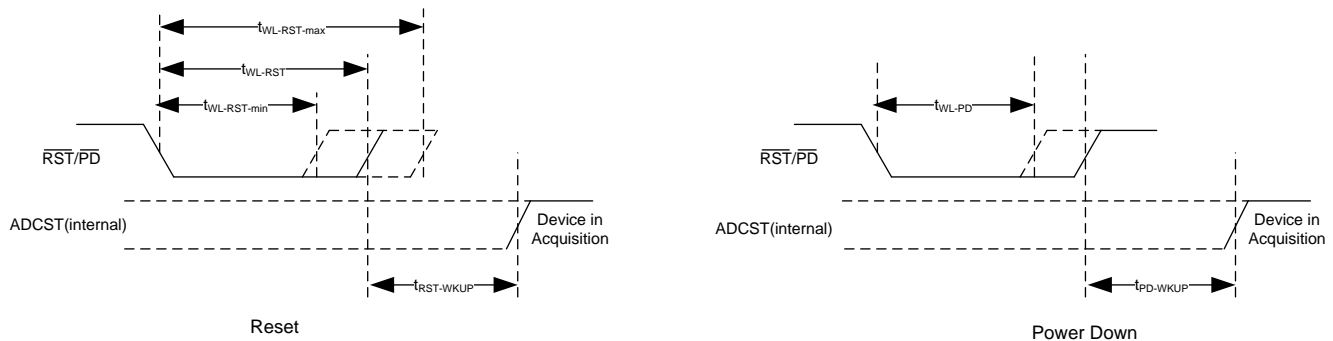


图 15. Reset or Power Down

7.4.3.1 Reset

To enter reset state, the host controller pulls and keeps the $\overline{\text{PD}}/\overline{\text{RST}}$ pin low for a duration of $t_{\text{WL_RST}}$ ($t_{\text{WL_RST-min}} \leq t_{\text{WL_RST}} \leq t_{\text{WL_RST-max}}$).

In reset state, the device terminates the ongoing conversion or acquisition process and all configuration registers (see the [Register Maps](#) section) are reset to their default values.

To exit reset state, the host controller pulls the $\overline{\text{PD}}/\overline{\text{RST}}$ pin high. After a delay of $t_{\text{RST-WKUP}}$, the device enters ACQ state.

7.4.3.2 Power-Down

To enter power-down state, the host controller pulls and keeps the $\overline{\text{PD}}/\overline{\text{RST}}$ pin low for a minimum duration of $t_{\text{WL_PD}}$.

In power-down state, all device blocks are powered down and all configuration registers (see the [Register Maps](#) section) are reset to their default values.

To exit power-down state, the host controller pulls the $\overline{\text{PD}}/\overline{\text{RST}}$ pin high. After a delay of $t_{\text{PD-WKUP}}$, the device powers up and enters ACQ state.

Device Functional Modes (接下页)

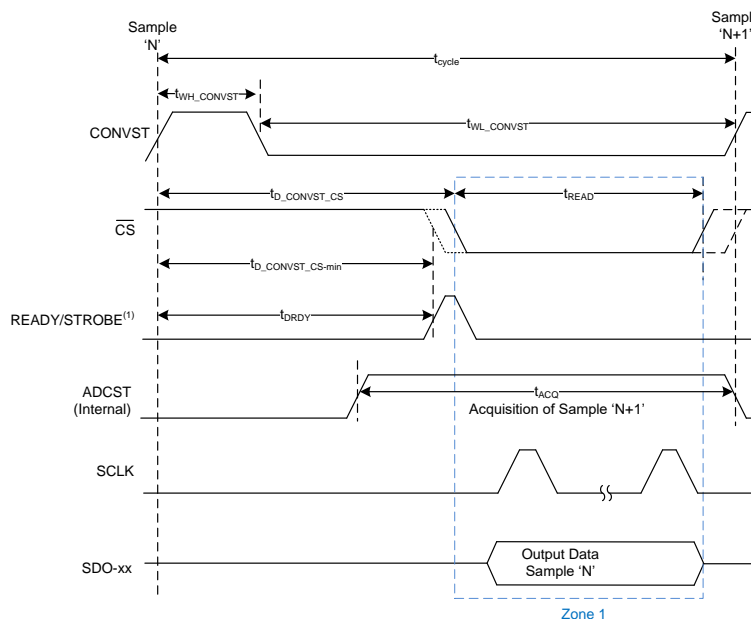
7.4.4 Conversion Control and Data Transfer Frame

The device supports two modes of conversion control and data transfer, one with zero cycle latency (zone 1 transfer) and another with a wide read cycle (zone 2 transfer).

7.4.4.1 Conversion Control and Data Transfer Frame With Zero Cycle Latency (Zone 1 Transfer)

In this mode of conversion control and data transfer, the device starts conversion on the rising edge of CONVST. The CONVST pin can be pulled low after a minimum time of t_{WH_CONVST} . After the conversion is finished, the rising edge of the READY/STROBE pin indicates that the data are ready and the data can be read by the host. After the READY pin is set high, as shown in 图 16, the host must pull CS low and provide clocks on the SCLK pin to read the data in zone 1 without cycle latency. For a zone 1 transfer, the host must provide a minimum delay time of $t_{D_CONVST_CS}$ ($= t_{DRDY}$) between the rising edge of CONVST and the falling edge of CS.

The data for the present sample (sample N) is provided by the device on the SDO pins. After all bits are read, the host can pull the CS pin high to end the data transfer frame. After pulling CS high, the host can pull the CONVST pin high to start the next conversion. The host must keep the SDI pin low (NOP0) or high (NOP1) for conversion control and for getting conversion results from the device. In this mode of conversion control, the time between two adjacent rising edges of the CONVST signal (t_{CYCLE}) is determined as $t_{CYCLE} = t_{DRDY} + t_{READ}$.



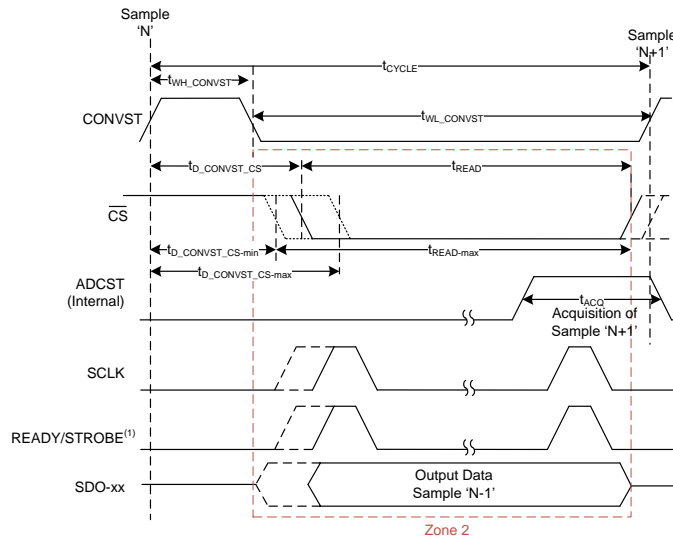
- (1) The READY output is required for data transfer with zero cycle latency. The STROBE output is required only for clock re-timer (CRT) protocols. See the [READY/STROBE Output](#) section for details.
- (2) For t_{READ} with different data transfer protocols; see the [Protocols for Reading From the Device](#) section.
- (3) $f_{Sample} = 1 / t_{cycle}$.

图 16. Conversion Control and Data Transfer Frame With Zero Cycle Latency (Zone 1 Transfer)

Device Functional Modes (接下页)

7.4.4.2 Conversion Control and Data Transfer Frame With Wide Read Cycle (Zone 2 Transfer)

In this mode of conversion control and data transfer, the device starts conversion on the rising edge of CONVST. The CONVST pin can be pulled low after a minimum time of t_{WH_CONVST} . After a time of $t_{D_CONVST_CS}$ (see $t_{D_CONVST_CS}$ for zone 2 transfer in the [Specifications](#) section), the host must pull \overline{CS} low and provide clocks on the SCLK pin to read the data in zone 2. As shown in [图 17](#), a zone 2 transfer provides more read time (t_{read}). The read time available for reading data is maximized when $t_{D_CONVST_CS}$ is set to the minimum permissible value. The data for the previous sample (sample N-1) is provided by the device on the SDO pins. After all bits are read, the host can pull the \overline{CS} pin high to end the data transfer frame. After pulling \overline{CS} high, the host can pull the CONVST pin high to start the next conversion. In this mode of conversion control, a minimum time of t_{CYCLE} (see t_{CYCLE} for zone 2 transfer in the [Specifications](#) section) is required between two adjacent rising edges of the CONVST signal. The host must keep the SDI pin low (NOP0) or high (NOP1) for conversion control and for getting conversion results from the device.



- (1) The READY output is not required for zone 2 data transfer. The STROBE output is required only for clock re-timer (CRT) protocols. See the [READY/STROBE Output](#) section for details.
- (2) For t_{READ} with different data transfer protocols; see the [Protocols for Reading From the Device](#) section.
- (3) $f_{Sample} = 1 / t_{cycle}$.

图 17. Conversion Control and Data Transfer Frame With Wide Read Cycle (Zone 2 Transfer)

注

For optimum performance with zone 2 transfer, TI recommends masking the READY output by setting the READY_MASK bit in the [OUTPUT_DATA_WORD_CFG](#) register and using a data transfer protocol with a bus width of more than 2 SDOs or the parallel byte protocol to keep $[t_{D_CONVST_CS} + t_{READ}]$ below 150 ns. See the [Protocols for Reading From the Device](#) section for details on different protocols for reading the data.

7.5 READY/STROBE Output

The READY/STROBE pin has multiple functions. The READY and STROBE signals are multiplexed to this pin. When \overline{CS} is low, STROBE is output and when \overline{CS} is high, READY is output.

7.5.1 READY Output

After power-up or after exiting power-down (a rising edge on $\overline{PD}/\overline{RST}$), the READY signal is set high. After a time of 0.9 ms, this signal goes low, indicating that the device is initialized and the registers can be configured. However, conversions can only be performed with the desired accuracy only after a time of $t_{PD-WKUP}$ (see the [Specifications](#) section). After power-up, for a zone 1 transfer (see [Figure 16](#)), the device starts conversion on the CONVST rising edge and the READY pin remains low during the conversion process. After a time of t_{DRDY} , the conversion process completes, READY is set high, and data can be read by the host. The host can read data by bringing \overline{CS} high and by providing clocks on SCLK. After \overline{CS} is brought low, READY is set low. For a zone 2 transfer, TI recommends masking the READY output by setting the READY_MASK bit in the OUTPUT_DATA_WORD_CFG register.

7.5.2 STROBE Output

In clock re-timer protocols, the device sends out data on the SDO lines with synchronized clock on the STROBE line. The data are synchronized to the rising edges of the STROBE pulses. In CRT protocols, the host can use the STROBE output for latching the data. The STROBE for the CRT protocols is either derived from the external SCLK provided by the host or from the internal oscillator. The STROBE signal is held low for protocols other than the CRT protocols.

7.6 Programming

7.6.1 Output Data Word

The output data word, as shown in [Table 2](#), consists of a conversion result of N bits, where N is the width of the output data word. The output data word is provided on data lines (SDO-xx) for each ADC.

表 2. Output Data Word

DEVICE	RESOLUTION OF DEVICE (R)	WIDTH OF OUTPUT DATA WORD (N)	CONTENT OF OUTPUT DATA WORD ⁽¹⁾⁽²⁾	MSB OF CONVERSION RESULT WITH LEFT ALIGNMENT	MSB OF CONVERSION RESULT WITH RIGHT ALIGNMENT
ADS9224R	16	16	16-bit conversion in 2's compliment format	D_{N-1} (= D_{15})	D_{N-1} (= D_{15})
ADS9234R	14	16	14-bit conversion in 2's compliment format	D_{N-1} (= D_{15})	D_{N-3} (= D_{13})

(1) The device provides register data in the output data word during register read operation.

(2) When a fixed pattern data is enabled, the device provides a fixed pattern in the output data word.

For ADS9234R devices with 14-bit resolution, the output data word can be left-aligned or right-aligned by configuring the DATA_RIGHT_ALIGNED bit. With left alignment, the device appends zeros in the end of the output data word. With right alignment, the device appends MSBs in the beginning of the output data word. [Figure 18](#) shows the data alignment in the data output word.

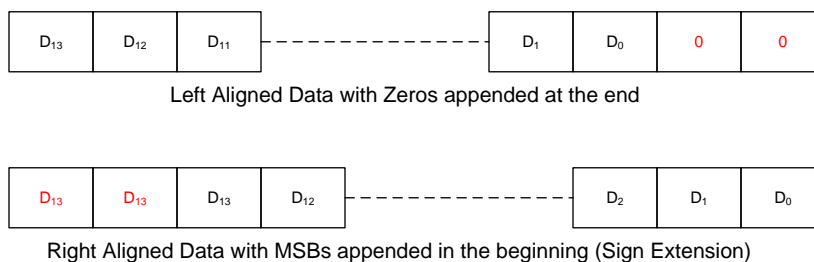


图 18. Data Alignment for ADS9234R Devices

7.6.2 Data Transfer Protocols

This device features an enhanced-SPI digital interface that allows the host controller to operate at slower SCLK speeds and still achieve the required throughput and response time. The enhanced-SPI digital interface module offers three options to reduce the SCLK speed required for data transfer:

- Increase the width of the output data bus (dual SDO, quad SDO, or parallel byte)
- Enable double data rate (DDR) transfer
- Wider read cycle by extending the data transfer window (zone 2 transfer)

These three options can be combined to achieve further reduction in SCLK speed.

7.6.2.1 Protocols for Reading From the Device

The protocols for the data-read operation can be broadly classified into five categories:

1. Legacy, SPI-compatible protocols (SPI-xy-S-SDR)
2. SPI-compatible protocols with bus width options and single data rate (SPI-xy-D-SDR and SPI-xy-Q-SDR)
3. SPI-compatible protocols with bus width options and double data rate (SPI-x1-S-DDR, SPI-x1-D-DDR, and SPI-x1-Q-DDR)
4. Clock re-timer (CRT) protocols (CRT-S-SDR, CRT-D-SDR, CRT-Q-SDR, CRT-S-DDR, CRT-D-DDR, and CRT-Q-DDR)
5. Parallel byte protocol (PB-xy-AB-SDR, PB-xy-AA-SDR)

7.6.2.1.1 Legacy, SPI-Compatible Protocols (SPI-xy-S-SDR)

The device supports legacy, SPI-compatible protocols with all combinations of clock phase and polarity. In this data transfer protocol, the device provides data from ADC_A on SDO-0A and data from ADC_B on SDO-0B. On power-up or after reset, the device supports the SPI-00-S-SDR protocol for reading data from the device. 表 3 provides the details of different legacy SPI protocols to read data from the device.

表 3. SPI-xy-S-SDR Protocols for Reading From Device

PROTOCOL ⁽¹⁾	SCLK POLARITY (CPOL ⁽²⁾)	SCLK PHASE (CPHA ⁽²⁾) ⁽³⁾⁽⁴⁾	MSB LAUNCH EDGE	BUS WIDTH	t _{READ} ⁽⁵⁾⁽⁶⁾	TIMING DIAGRAM
SPI-00-S-SDR	Low (CPOL = 0)	Rising (CPHA = 0)	\overline{CS} falling	1	[15.5 × t _{CLK} + k]	图 19
SPI-01-S-SDR	Low (CPOL = 0)	Falling (CPHA = 1)	1 st SCLK rising	1	[15.5 × t _{CLK} + k]	图 20
SPI-10-S-SDR	High (CPOL = 1)	Falling (CPHA = 0)	\overline{CS} falling	1	[15.5 × t _{CLK} + k]	图 19
SPI-11-S-SDR	High (CPOL = 1)	Rising (CPHA = 1)	1 st SCLK falling	1	[15.5 × t _{CLK} + k]	图 20

(1) For legacy SPI-compatible protocols, set the SDO_PROTOCOL bits in [PROTOCOL_CFG register](#) to 000b.

(2) Configure the SPI_CPOL and SPI_CPHA bits in the [PROTOCOL_CFG register](#) for the desired CPOL and CPHA.

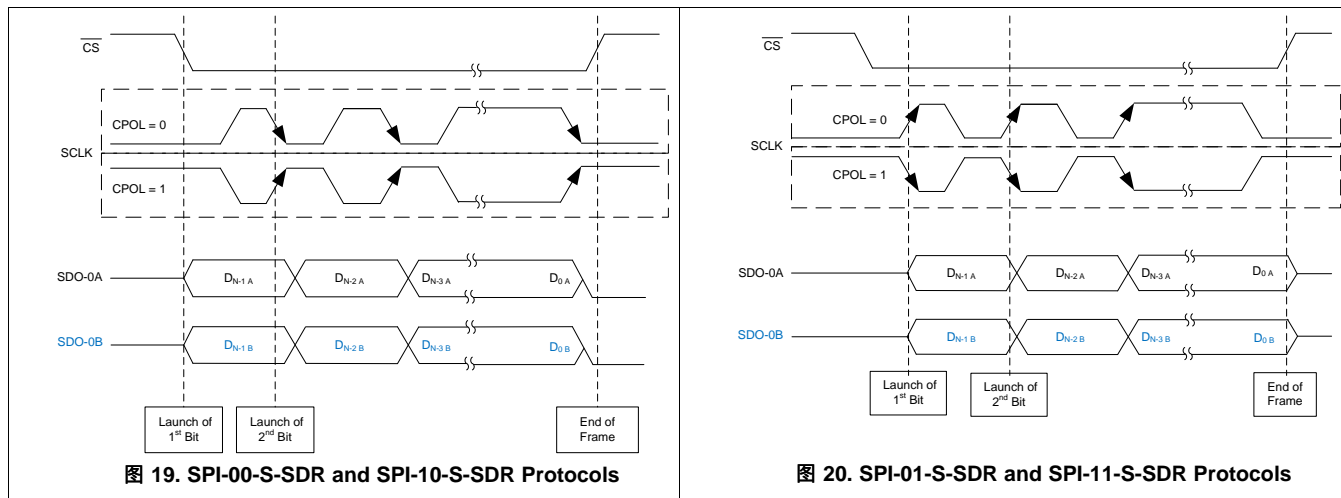
(3) With SCLK ≥ 30 MHz, TI recommends data capture on the launch edge for the next bit.

(4) With SCLK < 30 MHz, data can be captured either on the same edge as the SCLK phase or on the launch edge for the next bit.

(5) t_{READ} is the read time for reading the 16-bit output data word. k = (t_{SU_CSCK} + t_{HT_CKCS}).

(6) For ADS9234R devices, the read time for reading the 14-bit output data word is [13.5 × t_{CLK} + k].

图 19 和 图 20 show timing diagrams for the SPI-00-S-SDR, SPI-10-S-SDR and SPI-01-S-SDR, SPI-11-S-SDR protocols, respectively.



7.6.2.1.2 SPI-Compatible Protocols With Bus Width Options and Single Data Rate (SPI-xy-D-SDR and SPI-xy-Q-SDR)

In this data transfer protocol, the bus width of reading data from each ADC can be increased to two SDOs or four SDOs. All combinations of clock phase and polarity are supported. The read time required for reading the output data word reduces with increases in bus width and, thus, t_{CYCLE} for zone 1 transfer reduces. The SDOs that are not enabled by the [BUS_WIDTH](#) register are set to tri-state. 表 4 provides the details of different SPI protocols with bus width options and single data rate to read data from the device.

表 4. SPI-xy-D-SDR and SPI-xy-Q-SDR Protocols for Reading From Device

PROTOCOL ⁽¹⁾	SCLK POLARITY (CPOL) ⁽²⁾	SCLK PHASE (CPHA) ⁽³⁾⁽⁴⁾	MSB LAUNCH EDGE	BUS WIDTH ⁽⁵⁾	t_{READ} ⁽⁶⁾⁽⁷⁾	TIMING DIAGRAM
SPI-00-D-SDR	Low (CPOL = 0)	Rising (CPHA = 0)	$\overline{\text{CS}}$ falling	2	$[7.5 \times t_{\text{CLK}} + k]$	图 21
SPI-01-D-SDR	Low (CPOL = 0)	Falling (CPHA = 1)	1 st SCLK rising	2	$[7.5 \times t_{\text{CLK}} + k]$	图 22
SPI-10-D-SDR	High (CPOL = 1)	Falling (CPHA = 0)	$\overline{\text{CS}}$ falling	2	$[7.5 \times t_{\text{CLK}} + k]$	图 21
SPI-11-D-SDR	High (CPOL = 1)	Rising (CPHA = 1)	1 st SCLK falling	2	$[7.5 \times t_{\text{CLK}} + k]$	图 22
SPI-00-Q-SDR	Low (CPOL = 0)	Rising (CPHA = 0)	$\overline{\text{CS}}$ falling	4	$[3.5 \times t_{\text{CLK}} + k]$	图 23
SPI-01-D-SDR	Low (CPOL = 0)	Falling (CPHA = 1)	1 st SCLK rising	4	$[3.5 \times t_{\text{CLK}} + k]$	图 24
SPI-10-D-SDR	High (CPOL = 1)	Falling (CPHA = 0)	$\overline{\text{CS}}$ falling	4	$[3.5 \times t_{\text{CLK}} + k]$	图 23
SPI-11-D-SDR	High (CPOL = 1)	Rising (CPHA = 1)	1 st SCLK falling	4	$[3.5 \times t_{\text{CLK}} + k]$	图 24

- (1) For SPI-compatible protocols with bus width options and SDR, set the SDO_PROTOCOL bits in the [PROTOCOL_CFG](#) register to 000b.
- (2) Configure the SPI_CPOL and SPI_CPHA bits in the [PROTOCOL_CFG](#) register for the desired CPOL and CPHA.
- (3) With SCLK ≥ 30 MHz, TI recommends data capture on the launch edge for the next bit.
- (4) With SCLK < 30 MHz, data can be captured either on the same edge as the SCLK phase or on the launch edge for the next bit.
- (5) For configuring the bus width, configure the [BUS_WIDTH](#) register.
- (6) t_{READ} is the read time for reading the 16-bit output data word. $k = (t_{\text{SU_CSCK}} + t_{\text{HT_CKCS}})$.
- (7) For ADS9234R devices, the read time for reading the 14-bit output data word is $[6.5 \times t_{\text{CLK}} + k]$ for a bus width of 2 and $[3.5 \times t_{\text{CLK}} + k]$ for a bus width of 4.

图 21, 图 22, 图 23, 和 图 24 show timing diagrams for the SPI-00-D-SDR and SPI-10-D-SDR, SPI-01-D-SDR and SPI-11-D-SDR, SPI-00-Q-SDR and SPI-10-Q-SDR, and SPI-01-Q-SDR and SPI-11-Q-SDR protocols, respectively.

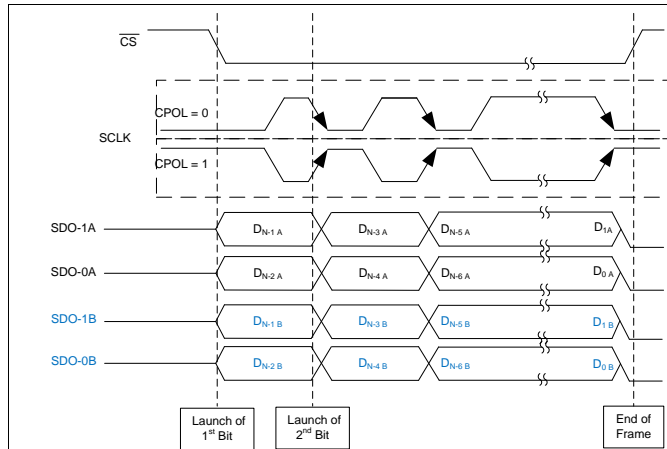


图 21. SPI-00-D-SDR and SPI-10-D-SDR Protocols

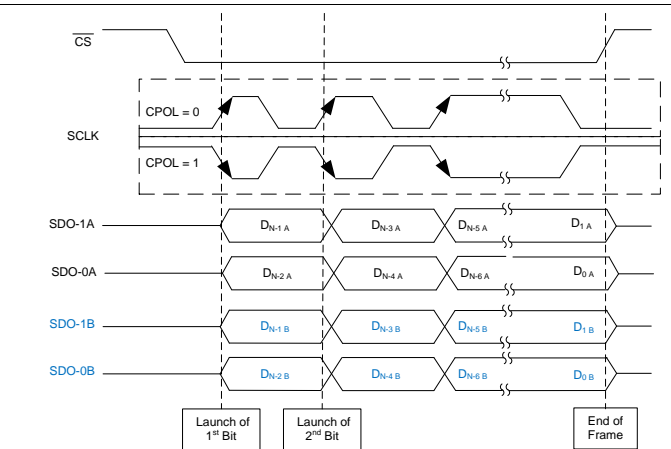


图 22. SPI-01-D-SDR and SPI-11-D-SDR Protocols

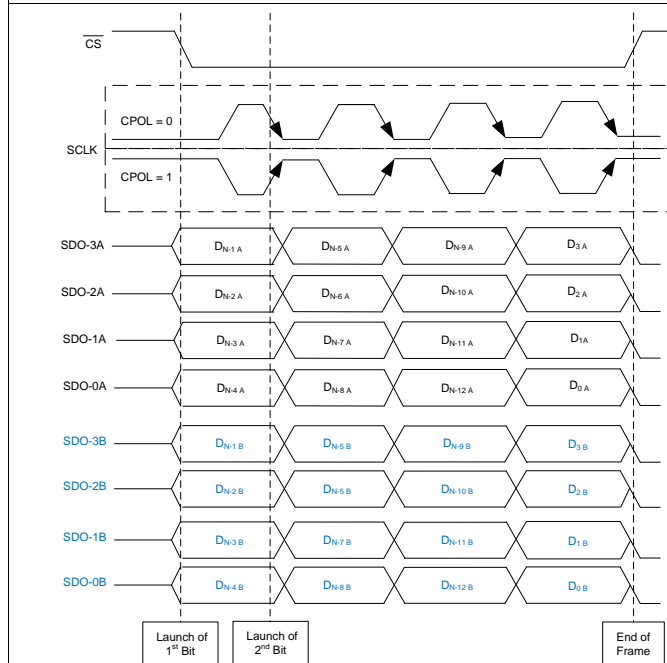


图 23. SPI-00-Q-SDR and SPI-10-Q-SDR Protocols

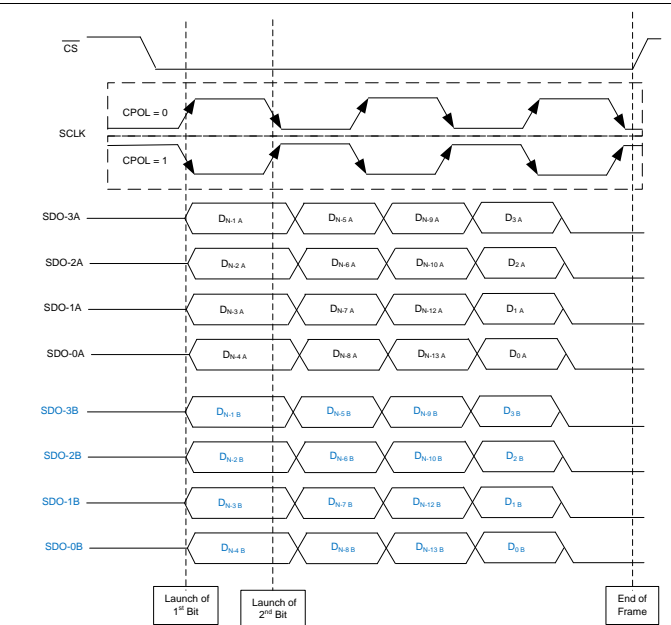


图 24. SPI-01-Q-SDR and SPI-11-Q-SDR Protocols

7.6.2.1.3 SPI-Compatible Protocols With Bus Width Options and Double Data Rate (SPI-x1-S-DDR, SPI-x1-D-DDR, SPI-x1-Q-DDR)

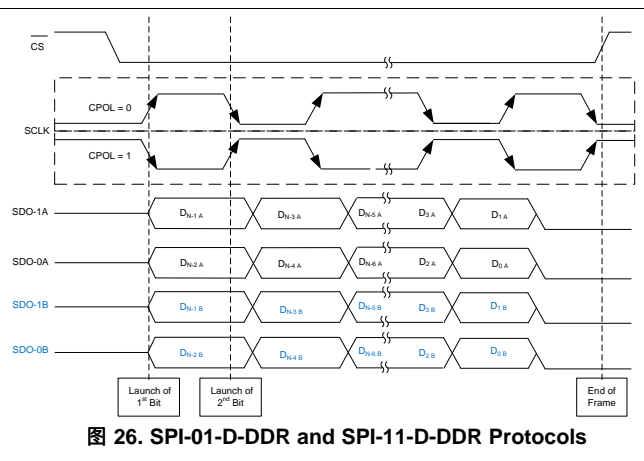
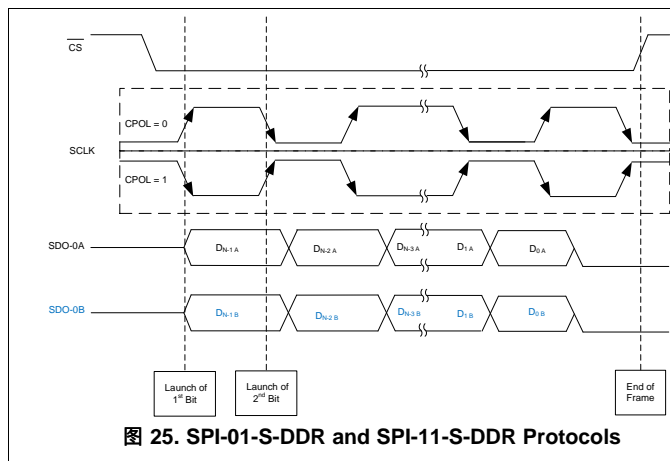
In this data transfer protocol, the data rate for data transfer can be increased to double data rate. With double data rate, the device launches data on both edges (rising and falling) of the SCLK. The device supports both polarities of the clock and only one phase of clock (CPHA = 1). The read time required for reading the output data word reduces with increases in bus width and data rate. The SDOs that are not enabled by the [BUS_WIDTH](#) register are set to tri-state. [表 5](#) provides the details of different SPI protocols with bus width options and double data rate to read data from the device.

表 5. SPI-x1-S-DDR, SPI-x1-D-DDR, and SPI-x1-Q-DDR Protocols for Reading From Device

PROTOCOL ⁽¹⁾	SCLK POLARITY (CPOL) ⁽²⁾	SCLK PHASE ⁽²⁾	MSB LAUNCH EDGE	BUS WIDTH ⁽³⁾	t _{READ} ⁽⁴⁾⁽⁵⁾	TIMING DIAGRAM
SPI-01-S-DDR	Low (CPOL = 0)	Falling (CPHA = 1)	1 st SCLK rising	1	[9 × t _{CLK} + k]	图 25
SPI-11-S-DDR	High (CPOL = 1)	Rising (CPHA = 1)	1 st SCLK falling	1	[9 × t _{CLK} + k]	图 25
SPI-01-D-DDR	Low (CPOL = 0)	Falling (CPHA = 1)	1 st SCLK rising	2	[5 × t _{CLK} + k]	图 26
SPI-11-D-DDR	High (CPOL = 1)	Rising (CPHA = 1)	1 st SCLK falling	2	[5 × t _{CLK} + k]	图 26
SPI-01-Q-DDR	Low (CPOL = 0)	Falling (CPHA = 1)	1 st SCLK rising	4	[3 × t _{CLK} + k]	图 27
SPI-11-Q-DDR	High (CPOL = 1)	Rising (CPHA = 1)	1 st SCLK falling	4	[3 × t _{CLK} + k]	图 27

- (1) For SPI-compatible protocols with bus width options and DDR, set the SDO_PROTOCOL bits in the [PROTOCOL_CFG](#) register to 001b.
- (2) Configure the SPI_CPOL bits in the [PROTOCOL_CFG](#) register for the desired CPOL. The device supports CPHA = 1 only for SPI-compatible protocols with bus width options and DDR.
- (3) For configuring the bus width, configure the [BUS_WIDTH](#) register.
- (4) t_{READ} is the read time for reading the 16-bit output data word. k = (t_{SU_CSCK} + t_{HT_CKCS}).
- (5) For ADS9234R devices, the read time for reading the 14-bit output data word is [7.5 × t_{CLK} + k] for a bus width of 1, [3.5 × t_{CLK} + k] for a bus width of 2, and [3 × t_{CLK} + k] for a bus width of 4.

[图 25](#), [图 26](#), and [图 27](#) illustrate timing diagrams for the SPI-01-S-DDR and SPI-11-S-DDR, SPI-01-D-DDR and SPI-11-D-DDR, and SPI-01-Q-DDR and SPI-11-Q-DDR protocols, respectively.



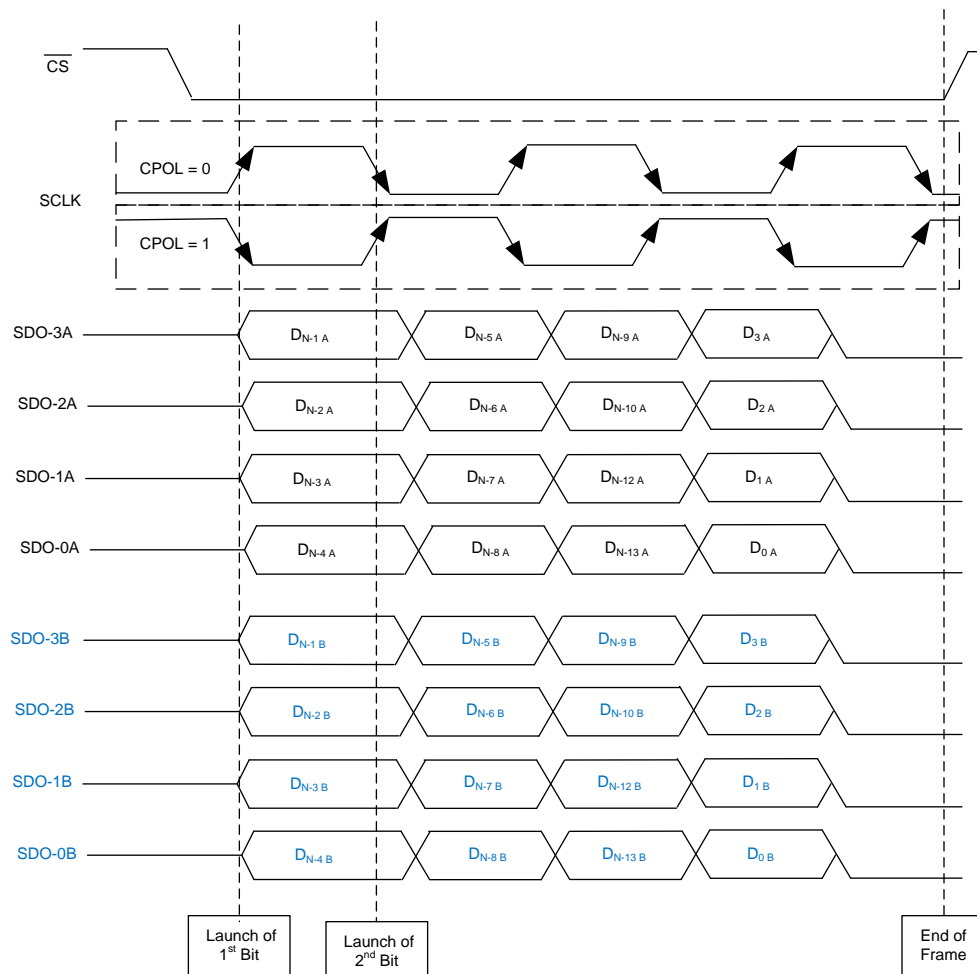


图 27. SPI-01-Q-DDR and SPI-11-Q-DDR Protocols

7.6.2.1.4 Clock Re-Timer (CRT) Protocols (CRT-S-SDR, CRT-D-SDR, CRT-Q-SDR, CRT-S-DDR, CRT-D-DDR, CRT-Q-DDR)

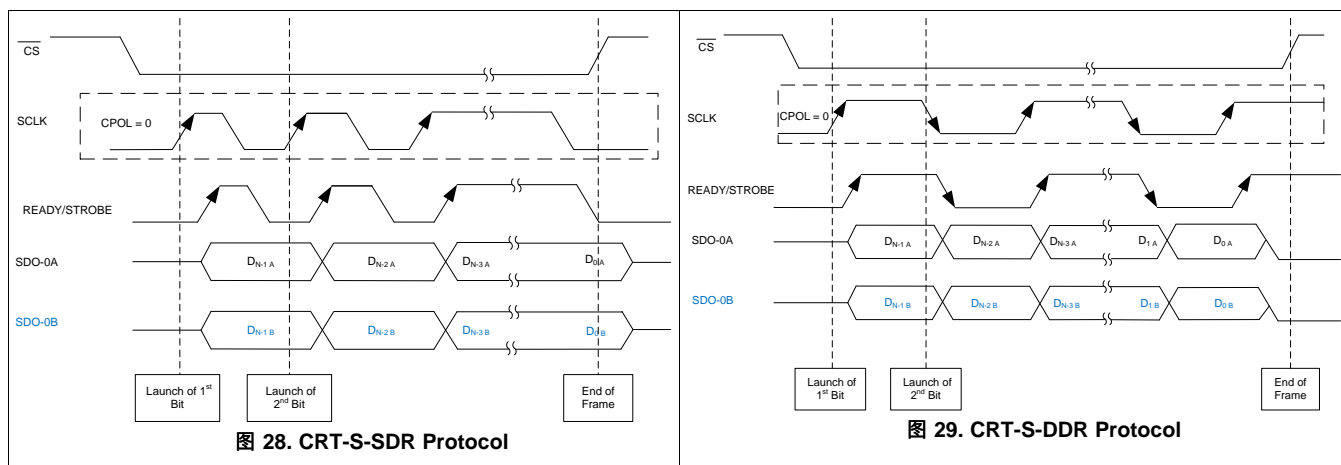
In clock re-timer (CRT) protocols, the device sends out data on the SDO lines with a synchronized clock on the STROBE line. The data are synchronized to the rising edges of the STROBE pulses. For CRT protocols with a single data rate, the host can capture data on the falling edges of the STROBE pulses. For double data rate, the host must capture data on both edges of STROBE. The clock source for the STROBE output can be selected as an external clock (SCLK) or an internal clock by configuring the CRT_CLK_SELECT bits in the [CRT_CFG register](#). For reading data from the device, SCLK is only required when the STROBE output is selected as an external clock. The SDOs that are not enabled by the [BUS_WIDTH register](#) are set to tri-state. 表 6 provides the details of different CRT protocols to read data from the device.

表 6. CRT-S-SDR, CRT-D-SDR, CRT-Q-SDR, CRT-S-DDR, CRT-D-DDR, and CRT-Q-DDR Protocols for Reading From Device

PROTOCOL ⁽¹⁾	SCLK POLARITY ⁽²⁾	CAPTURE EDGE	MSB LAUNCH EDGE	BUS WIDTH ⁽³⁾	t _{READ} ⁽⁴⁾	TIMING DIAGRAM
CRT-S-SDR	Low (CPOL = 0)	STROBE falling	1 st STROBE rising	1	[15.5 × t _{STROBE} + m]	图 28
CRT-D-SDR	Low (CPOL = 0)	STROBE falling	1 st STROBE rising	2	[7.5 × t _{STROBE} + m]	图 30
CRT-Q-SDR	Low (CPOL = 0)	STROBE falling	1 st STROBE rising	4	[3.5 × t _{STROBE} + m]	图 32
CRT-S-DDR	Low (CPOL = 0)	STROBE rising and falling	1 st STROBE rising	1	[7.5 × t _{STROBE} + m]	图 29
CRT-D-DDR	Low (CPOL = 0)	STROBE rising and falling	1 st STROBE rising	2	[3.5 × t _{STROBE} + m]	图 31
CRT-Q-DDR	Low (CPOL = 0)	STROBE rising and falling	1 st STROBE rising	4	[1.5 × t _{STROBE} + m]	图 33

- (1) For CRT protocols with SDR, set the SDO_PROTOCOL bits in the [PROTOCOL_CFG register](#) to 010b. For CRT protocols with DDR, set the SDO_PROTOCOL bits to 011b in the [PROTOCOL_CFG register](#).
- (2) The device only supports CPOL = 0 for CRT protocols with an external clock.
- (3) For configuring the bus width, configure the [BUS_WIDTH register](#).
- (4) t_{READ} is the read time for reading the 16-bit output data word. For an external clock m = (t_{SU_CSCK} + t_{HT_CKCS}), and for an internal clock m = t_{D_CS_STROBE}.

图 28 through 图 33 illustrate timing diagrams for the CRT-S-SDR, CRT-S-DDR, CRT-D-SDR, CRT-D-DDR, CRT-Q-SDR, and CRT-Q-DDR protocols, respectively.



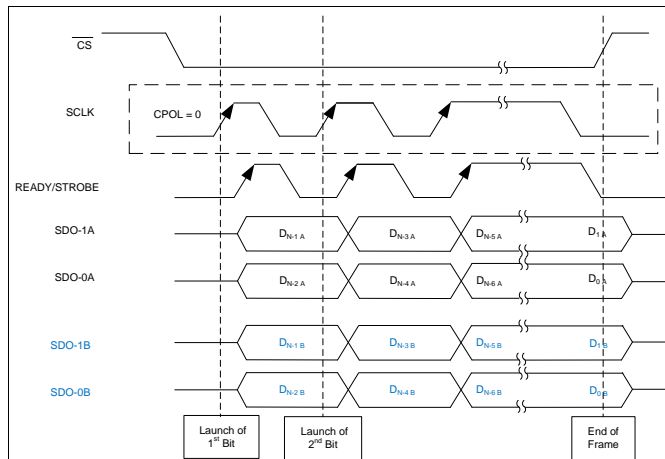


图 30. CRT-D-SDR Protocol

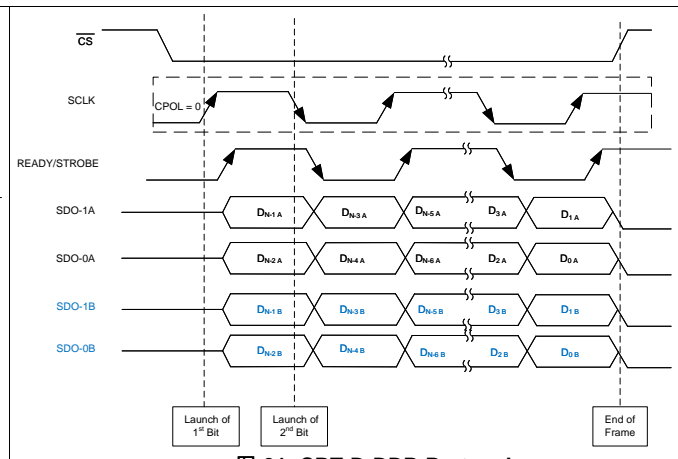


图 31. CRT-D-DDR Protocol

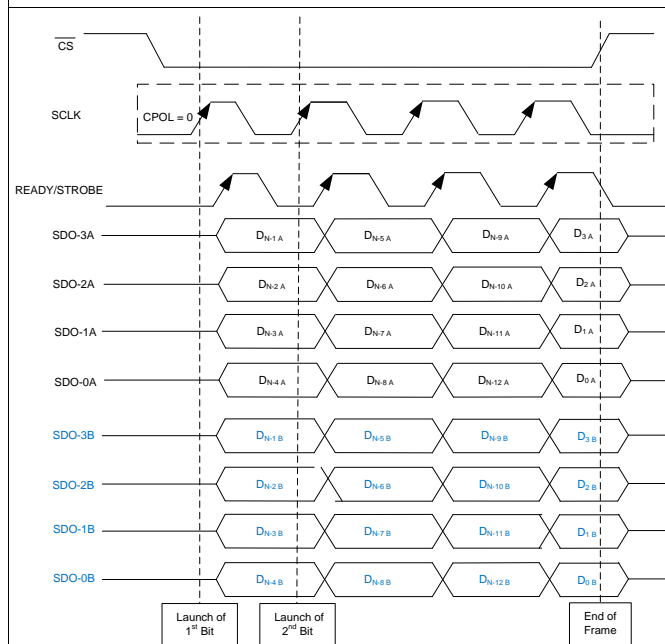


图 32. CRT-Q-SDR Protocol

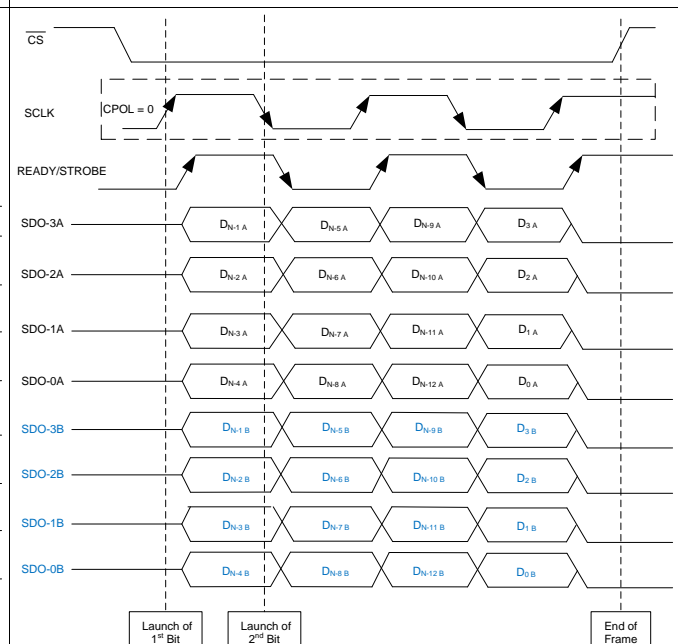


图 33. CRT-Q-DDR Protocol

For reading data, SCLK is only required when the STROBE output is selected as SCLK (external clock) in the [CRT_CFG register](#). However, for configuring registers, SCLK is always required.

7.6.2.1.5 Parallel Byte Protocols (PB-xy-AB-SDR, PB-xy-AA-SDR)

In these protocols, the device sends out data from each ADC on all SDO lines in a byte format. The device supports all combinations of CPOL and CPHA in these protocols. The format of the data byte for these protocols can be set by the PARALLEL_MODE_DATA_FORMAT bits in the [OUTPUT_DATA_WORD_CFG](#) register. The device only supports a single data rate (SDR) in parallel byte protocols. 表 7 provides the details of different parallel byte protocols to read data from the device.

表 7. PB-xy-AB-SDR, PB-xy-AA-SDR Protocols for Reading Data

PROTOCOL ⁽¹⁾	SCLK POLARITY (CPOL) ⁽²⁾	SCLK PHASE (CPHA)	MSB LAUNCH EDGE	DATA FORMAT ⁽³⁾	t _{READ} ⁽⁴⁾	TIMING DIAGRAM
PB-00-AB-SDR	Low (CPOL = 0)	Rising (CPHA = 0)	\overline{CS} falling	AB	$[3.5 \times t_{CLK} + k]$	图 34
PB-01-AB-SDR	Low (CPOL = 0)	Falling (CPHA = 1)	1 st SCLK rising	AB	$[3.5 \times t_{CLK} + k]$	图 35
PB-10-AB-SDR	High (CPOL = 1)	Falling (CPHA = 1)	\overline{CS} falling	AB	$[3.5 \times t_{CLK} + k]$	图 34
PB-11-AB-SDR	High (CPOL = 1)	Rising (CPHA = 0)	1 st SCLK falling	AB	$[3.5 \times t_{CLK} + k]$	图 35
PB-00-AA-SDR	Low (CPOL = 0)	Rising (CPHA = 0)	\overline{CS} falling	AA	$[3.5 \times t_{CLK} + k]$	图 36
PB-01-AA-SDR	Low (CPOL = 0)	Falling (CPHA = 1)	1 st SCLK rising	AA	$[3.5 \times t_{CLK} + k]$	图 37
PB-10-AA-SDR	High (CPOL = 1)	Falling (CPHA = 1)	\overline{CS} falling	AA	$[3.5 \times t_{CLK} + k]$	图 36
PB-11-AA-SDR	High (CPOL = 1)	Rising (CPHA = 0)	1 st SCLK falling	AA	$[3.5 \times t_{CLK} + k]$	图 37

- (1) For parallel byte protocols, set the SDO_PROTOCOL bits in the [PROTOCOL_CFG](#) register to 1xxb.
- (2) Configure the SPI_CPOL and SPI_CPHA bits in the [PROTOCOL_CFG](#) register for the desired CPOL and CPHA.
- (3) For selecting the data format for parallel byte protocols, configure the PARALLEL_MODE_DATA_FORMAT bits in the [OUTPUT_DATA_WORD_CFG](#) register.
- (4) t_{READ} is the read time for reading the 16-bit output data word. $k = (t_{SU_CSCS} + t_{HT_CKCS})$.

图 34, 图 35, 图 36, and 图 37 illustrate timing diagrams for the PB-00-AB-SDR and PB-10-AB-SDR, protocols, PB-01-AB-SDR and PB-11-AB-SDR, PB-00-AA-SDR and PB-10-AA-SDR, and PB-01-AA-SDR and PB-11-AA-SDR, respectively.

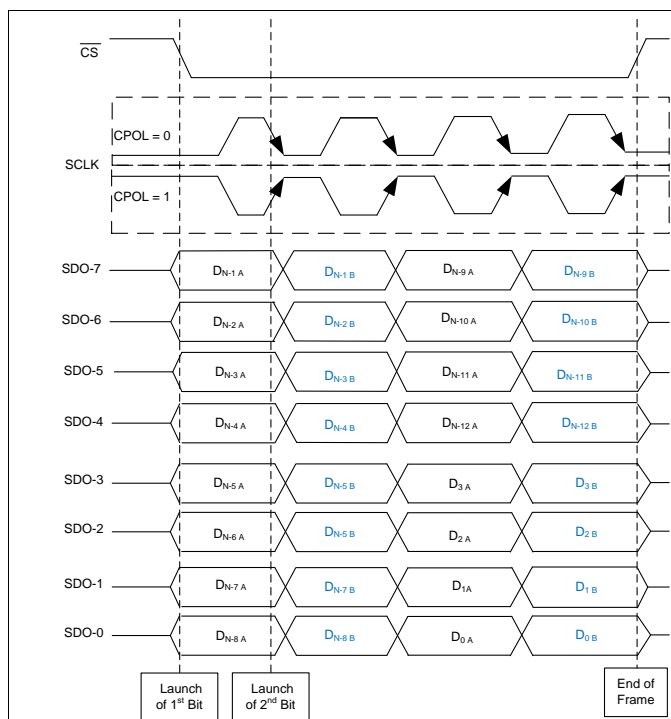


图 34. PB-00-AB-SDR and PB-10-AB-SDR Protocols

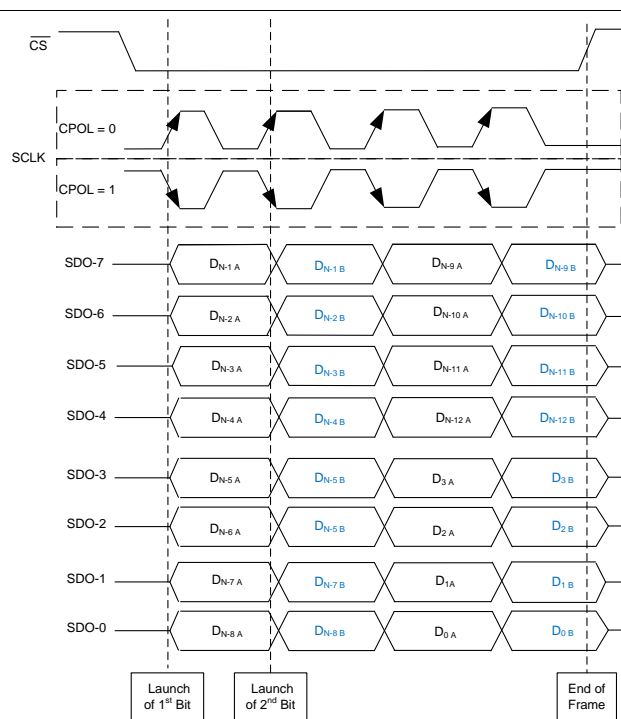


图 35. PB-01-AB-SDR and PB-11-AB-SDR Protocols

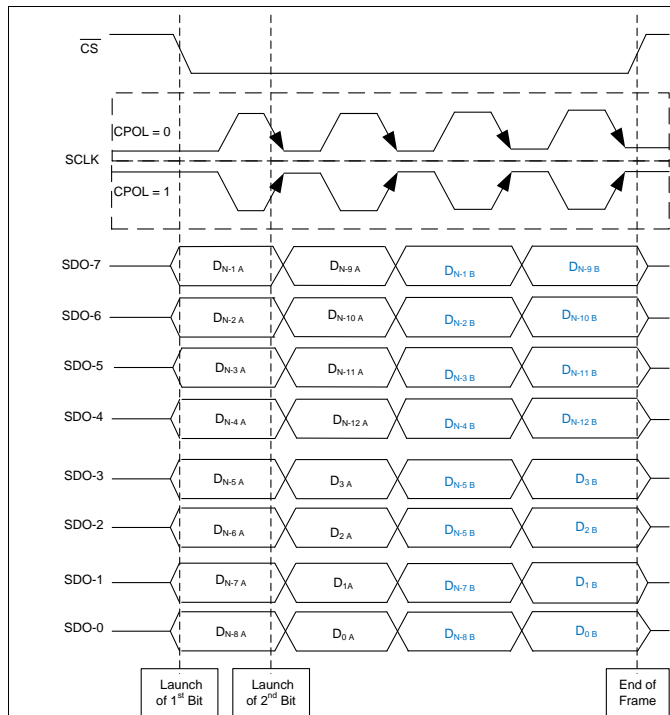


图 36. PB-00-AA-SDR and PB-10-AA-SDR Protocols

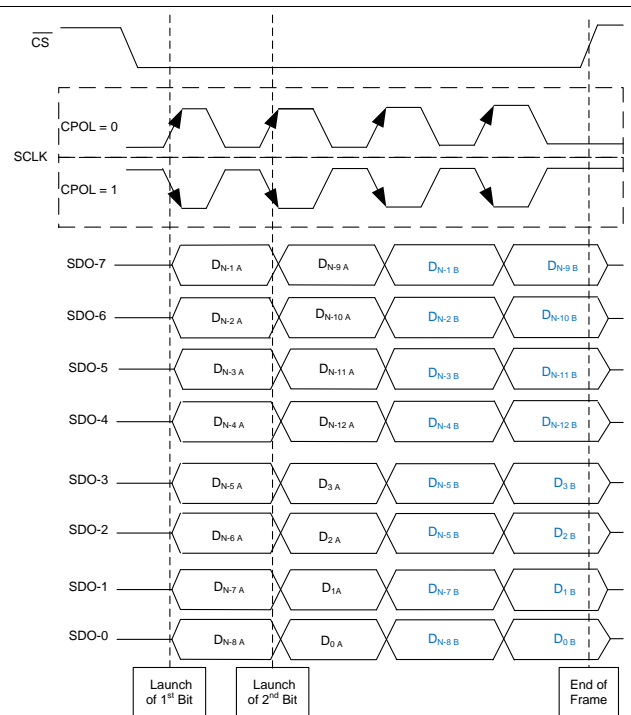


图 37. PB-01-AA-SDR and PB-11-AA-SDR Protocols

7.6.2.2 Protocols for Configuring the Device

The device supports an SPI protocol for writing into the device with all combinations of clock polarity and phase. On power-up or after reset, the device supports the SPI-00-S protocol for configuring the device. As shown in 表 8, the host controller can use any of the four legacy, SPI-compatible protocols (SPI-00-S, SPI-01-S, SPI-10-S, or SPI-11-S) to write data to the device.

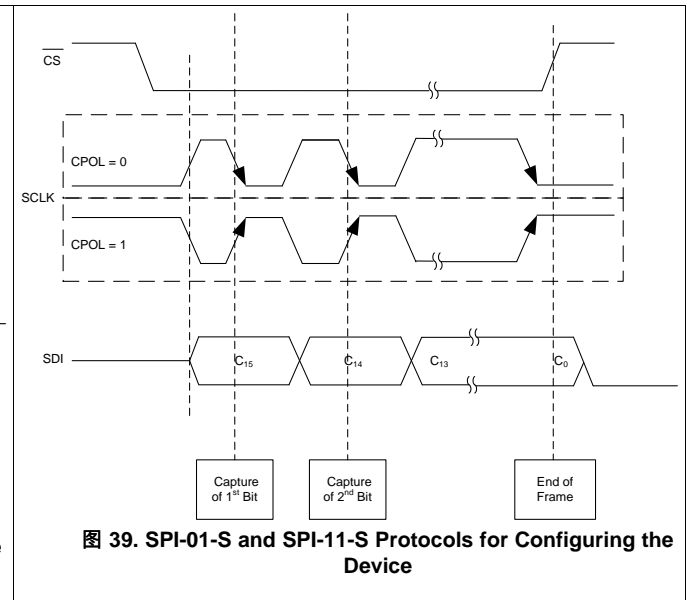
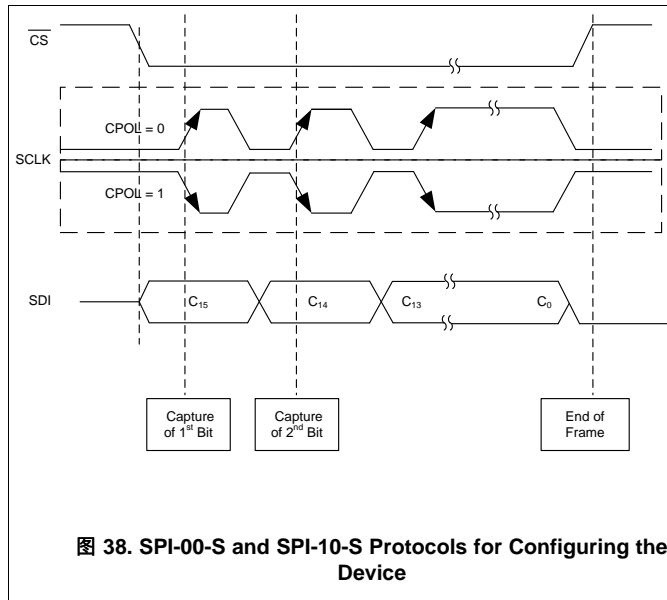
表 8. SPI Protocols for Configuring the Device

PROTOCOL	SCLK POLARITY (CPOL) ⁽¹⁾	SCLK PHASE (CPHA) ⁽¹⁾	MSB CAPTURE EDGE	t _{WRITE} ⁽²⁾	TIMING DIAGRAM
SPI-00-S	Low (CPOL= 0)	Rising (CPHA = 0)	1 st SCLK rising	[15.5 × t _{CLK} + k]	图 38
SPI-01-S	Low (CPOL= 0)	Falling (CPHA = 1)	1 st SCLK falling	[15.5 × t _{CLK} + k]	图 39
SPI-10-S	High (CPOL= 1)	Falling (CPHA = 1)	1 st SCLK falling	[15.5 × t _{CLK} + k]	图 38
SPI-11-S	High (CPOL= 1)	Rising (CPHA = 0)	1 st SCLK rising	[15.5 × t _{CLK} + k]	图 39

(1) Configure the SPI_CPOL and SPI_CPHA bits in the [PROTOCOL_CFG register](#) for the desired CPOL and CPHA.

(2) t_{WRITE} is the write time for writing the 16-bit data word. k = (t_{SU_CSCK} + t_{HT_CKCS}).

图 38 和 图 39 show timing diagrams for the SPI-00-S, SPI-10-S and SPI-01-S, SPI-11-S protocols, respectively, for configuring the device.



7.6.3 Reading and Writing Registers

To read a register or write into a register, the host must provide a 16-bit command frame C[15:0] on SDI. A command frame consists of an OPCODE[3:0], ADDRESS[3:0], and DATA[7:0]. The host must keep the CONVST signal high for reading and writing the registers. 图 40 shows the command frame. 表 9 provides the details of commands for reading and writing registers.

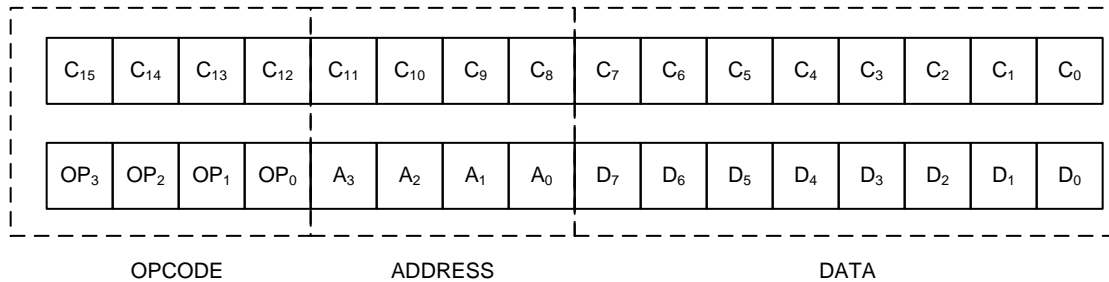


图 40. Command Frame C[15:0]

表 9. Commands for Reading and Writing Registers

OPCODE[3:0]		DESCRIPTION	ADDRESS[3:0]	DATA[7:0]
0000	NOP0	Command for conversion control and reading conversion results	N/A	N/A
0001	WRITE	Command for writing registers	4-bit register address	8-bit register data
0010	READ ⁽¹⁾	Command for reading registers	4-bit register address	00h or FFh
0101	Set bit	Command for setting specific bits in a register without changing the other bits	4-bit register address	Bits with values of 1 in DATA are set and bits with values of 0 in register data are not changed.
0110	Clear bit	Command for clearing specific bits in a register without changing the other bits	4-bit register address	Bits with values of 1 in DATA are cleared and bits with values of 0 in register data are not changed.
1111	NOP1	Command for conversion control and reading conversion results	N/A	N/A

(1) Register data for READ command is provided by device in the next frame.

7.7 Register Maps

表 10 lists the access codes for the ADS9224R, ADS9234R registers.

表 10. ADS9224R, ADS9234R Access Type Codes

Access Type	Code	Description
Read Type		
R	R	Read
R-W	R/W	Read or write
Write Type		
W	W	Write
Reset or Default Value		
-n		Value after reset or the default value

7.7.1 DEVICE_STATUS Register (address = 0h) [reset = 00h]

This register provides the error status of averaging mode and the status of zone 2 data transfer mode.

图 41. DEVICE_STATUS

7	6	5	4	3	2	1	0
0	0	0	0	0	ZONE2_TRANSFER	AVG_ERROR	0
R-0b	R-0b	R-0b	R-0b	R-0b	R/W-0b	R/W-0b	R-0b

表 11. DEVICE_STATUS Field Descriptions

Bit	Field	Type	Reset	Description
7-3	RESERVED	R	00000b	Reserved bits. Do not write. Reads return 00000b.
2	ZONE2_TRANSFER	R/W	0b	This bit is set when the device operates in zone 2 transfer mode with a wide read cycle. This bit is a sticky bit. Write 1 to this bit to clear.
1	AVG_ERROR	R/W	0b	This bit is set when the device receives a falling edge of \overline{CS} before the current averaging operation is complete. This bit is a sticky bit. Write 1 to this bit to clear.
0	RESERVED	R	00000b	Reserved bits. Do not write. Reads return 00000b.

7.7.2 POWER_DOWN_CFG Register (address = 1h) [reset = 00h]

This register powers down different blocks in the device.

图 42. POWER_DOWN_CFG

7	6	5	4	3	2	1	0
0	0	PD_REFby2	0	PD_ADCB	0	PD_ADCA	PD_REF
R-0b	R-0b	R/W-0b	R-0b	R/W-0b	R-0b	R/W-0b	R/W-0b

表 12. POWER_DOWN_CFG Field Descriptions

Bit	Field	Type	Reset	Description
7-6	RESERVED	R	00b	Reserved bits. Do not write. Reads return 00b.
5	PD_REFby2	R/W	0b	This bit powers down the REFby2 output. 0: REFby2 is not powered down 1: REFby2 is powered down
4	RESERVED	R	0b	Reserved bits. Do not write. Reads return 00b.
3	PD_ADCB	R/W	0b	This bit powers down the ADC_B and REFBUF_B. 0: ADC_B and REFBUF_B are not powered down 1: ADC_B and REFBUF_B are powered down
2	RESERVED	R	0b	Reserved bits. Do not write. Reads return 00b.
1	PD_ADCA	R/W	0b	This bit powers down the ADC_A and REFBUF_A. 0: ADC_A and REFBUF_A are not powered down 1: ADC_A and REFBUF_A are powered down
0	PD_REF	R/W	0b	This bit powers down the internal reference voltage. 0: Internal reference voltage is not powered down 1: Internal reference voltage is powered down

7.7.3 PROTOCOL_CFG Register (address = 2h) [reset = 00h]

This register configures the clock polarity (CPOL), clock phase (CPHA) for data transfer, and sets the protocol for reading data from the device.

图 43. PROTOCOL_CFG

7	6	5	4	3	2	1	0
0	SDO_PROTOCOL			0	0	SPI_CPOL	SPI_CPHA
R-0b	R/W-0b			R-0b	R-0b	R/W-0b	R/W-0b

表 13. PROTOCOL_CFG Field Descriptions

Bit	Field	Type	Reset	Description
7	RESERVED	R	0b	Reserved bits. Do not write. Reads return 0b.
6-4	SDO_PROTOCOL	R/W	000b	These bits set the protocol for reading data from the device. 000: Legacy, SPI-compatible protocols (SPI-xy-S-SDR); SPI-compatible protocols with bus width options and SDR (SPI-xy-D-SDR and SPI-xy-Q-SDR) protocols 001: SPI-compatible protocols with bus width options and DDR (SPI-x1-S-DDR, SPI-x1-D-DDR, SPI-x1-Q-DDR) protocols 010: Clock re-timer (CRT) protocols with SDR (CRT-S-SDR, CRT-D-SDR, CRT-Q-SDR) 011: CRT protocols with DDR (CRT-S-DDR, CRT-D-DDR, CRT-Q-DDR) 1xx: Parallel byte protocols.
3-2	RESERVED	R	00b	Reserved bits. Do not write. Reads return 00b.
1	SPI_CPOL	R/W	0b	This bit sets the clock polarity for reading data from the device and writing data into the device. 0: CPOL = 0 1: CPOL = 1
0	SPI_CPHA	R/W	0b	This bit sets the clock phase for reading data from the device and writing data into the device. 0: CPHA = 0 1: CPHA = 1

7.7.4 BUS_WIDTH Register (address = 3h) [reset = 00h]

This register configures the bus width (number of SDO Lines) for reading data from the device.

图 44. BUS_WIDTH

7	6	5	4	3	2	1	0
0	0	0	0	0	0	SDO_WIDTH	
R-0b	R-0b	R-0b	R-0b	R-0b	R-0b	R/W-00b	

表 14. BUS_WIDTH Field Descriptions

Bit	Field	Type	Reset	Description
7-2	RESERVED	R	000000b	Reserved bits. Do not write. Reads return 000000b.
1-0	SDO_WIDTH	R/W	00b	These bits set the number of SDO lines for reading data from the device. 0x: One SDO per ADC 10: Dual SDO per ADC 11: Quad SDO per ADC If the device is configured for parallel byte protocol, then SDO_WIDTH is ignored and the device sends data over all eight SDO lines as per the parallel byte protocol.

7.7.5 CRT_CFG Register (address = 4h) [reset = 00h]

This register selects the clock source for the strobe output for clock re-timer (CRT) protocols.

图 45. CRT_CFG

7	6	5	4	3	2	1	0
0	0	0	0	0	0	CRT_CLK_SELECT	
R-0b	R-0b	R-0b	R-0b	R-0b	R-0b	R/W-00b	

表 15. CRT_CFG Field Descriptions

Bit	Field	Type	Reset	Description
7-2	RESERVED	R	000000b	Reserved bits. Do not write. Reads return 000000b.
1-0	CRT_CLK_SELECT	R/W	00b	These bits select the clock source for the strobe output for CRT protocols. 00: SCLK is used for the STROBE output 01: INTCLK is used for the STROBE output 10: INTCLK/2 is used for the STROBE output 11: INTCLK/4 is used for the STROBE output INTCLK is generated from the internal oscillator of the device.

7.7.6 OUTPUT_DATA_WORD_CFG Register (address = 5h) [reset = 00h]

This register configures the alignment of output data word, sets the output data word to a fixed pattern, and selects the format for the output data word in the parallel byte protocol.

图 46. OUTPUT_DATA_WORD_CFG

7	6	5	4	3	2	1	0
0	0	READY_MASK	PARALLEL_MODE_DATA_FORMAT	0	0	FIXED_PATTERN_DATA	DATA_RIGHT_ALIGNED
R-0b	R-0b	R/W-0b	R-0b	R-0b	R-0b	R/W-0b	R/W-0b

表 16. OUTPUT_DATA_WORD_CFG Field Descriptions

Bit	Field	Type	Reset	Description
7-6	RESERVED	R	00b	Reserved bits. Do not write. Reads return 00b.
5	READY_MASK	R/W	0b	This bit masks the READY output. 0: Does not mask the READY output 1: Masks the READY output, READY is set to 0 The STROBE output is provided in CRT protocols even if READY_MASK is set to 1. TI recommends masking the READY output for the Conversion Control and Data Transfer Frame With Wide Read Cycle (Zone 2 Transfer) section.
4	PARALLEL_MODE_DATA_FORMAT	R/W	0b	This bit selects the format for the output data word in the parallel byte protocol. 0: Data format AA: byte from ADC_A followed by byte from ADC_A (PB-xy-AA-zDR protocols) 1: Data format AB: byte from ADC_A followed by byte from ADC_B (PB-xy-AB-zDR protocols)
3-2	RESERVED	R	00b	Reserved bits. Do not write. Reads return 00b.
1	FIXED_PATTERN_DATA	R/W	0b	This bit enables a fixed pattern in the output data word. 0: Device provides the conversion results from the register data in the output data word 1: Device provides a fixed pattern (A55AA55Ah) in the output data word
0	DATA_RIGHT_ALIGNED	R/W	0b	This bit enables the right alignment in the output data word for ADS9234R devices. 0: Data are left-aligned in the output data word 1: Data are right-aligned in the output data word

7.7.7 DATA_AVG_CFG Register (address = 6h) [reset = 00h]

This register configures the averaging of conversion results.

图 47. DATA_AVG_CFG

7	6	5	4	3	2	1	0
0	0	0	0	0	0	EN_DATA_AVG	
R-0b	R-0b	R-0b	R-0b	R-0b	R-0b	R/W-00b	

表 17. DATA_AVG_CFG Field Descriptions

Bit	Field	Type	Reset	Description
7-2	RESERVED	R	000000b	Reserved bits. Do not write. Reads return 000000b.
1-0	EN_DATA_AVG	R/W	00b	These bits enable averaging of conversion results. 0x: No averaging 10: Enables averaging of two conversion results 11: Enables averaging of four conversion results

7.7.8 REFby2_OFFSET (address = 7h) [reset = 00h]

This register enables the offset for the REFby2 output.

图 48. REFby2_OFFSET

7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	EN_REFby2_OFFSET
R-0b	R-0b	R-0b	R-0b	R-0b	R-0b	R-0b	R/W-00b

表 18. REFby2_OFFSET Field Descriptions

Bit	Field	Type	Reset	Description
7-1	RESERVED	R	0000000b	Reserved bits. Do not write. Reads return 000000b.
0	EN_REFby2_OFFSET	R/W	0b	This bit enables the offset for the REFby2 output. 0: Offset for the REFby2 output is disabled 1: Offset for the REFby2 output is enabled and the REFby2 output increases by 100 mV

8 Application and Implementation

注

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The two primary circuits required to maximize the performance of a high-precision, successive approximation register (SAR) analog-to-digital converter (ADC) are the input driver and the reference driver circuits. This section presents general principles for designing these circuits, followed by an application circuit designed using the ADS92x4R.

8.1.1 ADC Input Driver

The input driver circuit for a high-precision ADC mainly consists of two parts: a driving amplifier and a charge kickback filter. The amplifier is used for signal conditioning of the input signal and the low output impedance of the amplifier provides a buffer between the signal source and the switched capacitor inputs of the ADC. The charge kickback filter helps attenuate the sampling charge injection from the switched-capacitor input stage of the ADC, and band-limits the wideband noise contributed by the front-end circuit. Careful design of the front-end circuit is critical to meet the linearity and noise performance of the ADS92x4R.

8.1.1.1 Charge-Kickback Filter

The charge-kickback filter is an RC filter at the input pins of the ADC that filters the broadband noise from the front-end drive circuitry, and attenuates the sampling charge injection from the switched-capacitor input stage of the ADC. A filter capacitor, C_{FLT} (as shown in 图 49), is connected from each input pin of the ADC to the ground. This capacitor helps reduce the sampling charge injection and provides a charge bucket to quickly charge the internal sample-and-hold capacitors during the acquisition process. Generally, the value of this capacitor must be at least 20 times the specified value of the ADC sampling capacitance. For the ADS92x4R, the input sampling capacitance is equal to 16 pF; therefore, for optimal performance, keep C_{FLT} greater than 320 pF. This capacitor must be a COG- or NPO-type. The type of dielectric used in COG or NPO ceramic capacitors provides the most stable electrical properties over voltage, frequency, and temperature changes.

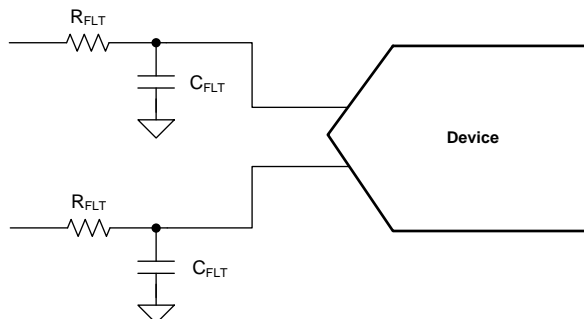


图 49. Charge Kickback Filter

Driving capacitive loads can degrade the phase margin of the input amplifier, thus making the amplifier marginally unstable. To avoid amplifier stability issues, series isolation resistors (R_{FLT}) are used at the output of the amplifiers. A higher value of R_{FLT} helps with amplifier stability, but adds distortion as a result of interactions with the nonlinear input impedance of the ADC. Distortion increases with source impedance, input signal frequency, and input signal amplitude. Therefore, the selection of R_{FLT} requires balancing the stability of the driver amplifier and distortion performance of the design. Always verify the stability and settling behavior of the driving amplifier and charge-kickback filter by TINA-TI™ SPICE simulation. Keep the tolerance of the selected resistors less than 1% to keep the inputs balanced.

Application Information (接下页)

8.1.2 Input Amplifier Selection

Selection criteria for the input amplifiers is highly dependent on the input signal type, as well as the performance goals, of the data acquisition system. Some key amplifier specifications to consider when selecting an appropriate amplifier to drive the inputs of the ADC are:

- Small-signal bandwidth. Select the small-signal bandwidth of the input amplifiers to be as high as possible after meeting the power budget of the system. Higher bandwidth reduces the closed-loop output impedance of the amplifier, thus allowing the amplifier to more easily drive the ADC sample-and-hold capacitor and the RC filter (the charge-kickback filter) at the inputs of the ADC. Higher bandwidth amplifiers offer faster settling times when driving the capacitive load of the charge-kickback filter, thus reducing harmonic distortion at higher input frequencies. 公式 4 describes the unity gain bandwidth (UGB) of the amplifier to be selected in order to maintain the overall stability of the input driver circuit:

$$UGB \geq 4 \times \left(\frac{1}{2\pi \times R_{FLT} \times C_{FLT}} \right) \quad (4)$$

- Distortion. Both the ADC and the input driver introduce distortion in a data acquisition block. 公式 5 shows that to make sure that the distortion performance of the data acquisition system is not limited by the front-end circuit, the distortion of the input driver must be at least 10 dB less than the distortion of the ADC:

$$THD_{AMP} \leq THD_{ADC} - 10 \text{ (dB)} \quad (5)$$

- Noise. Noise contribution of the front-end amplifiers must be as low as possible to prevent any degradation in SNR performance of the system. Generally, to make sure that the noise performance of the data acquisition system is not limited by the front-end circuit, the total noise contribution from the front-end circuit must be kept below 20% of the input-referred noise of the ADC. 公式 6 explains that noise from the input driver circuit is band-limited by designing a low cutoff frequency, charge-kickback filter:

$$N_G \times \sqrt{2} \times \sqrt{\left(\frac{V_{1/f_AMP_PP}}{6.6} \right)^2 + e_{n_RMS}^2 \times \frac{\pi}{2} \times f_{-3dB}} \leq \frac{1}{5} \times \frac{V_{REF}}{\sqrt{2}} \times 10^{\left(\frac{SNR(dB)}{20} \right)}$$

where

- V_{1/f_AMP_PP} is the peak-to-peak flicker noise in μV
 - e_{n_RMS} is the amplifier broadband noise density in nV/\sqrt{Hz}
 - f_{-3dB} is the 3-dB bandwidth of the charge-kickback filter
 - N_G is the noise gain of the front-end circuit that is equal to 1 in a buffer configuration
- (6)
- Settling Time. For DC signals with fast transients that are common in a multiplexed application, the input signal must settle within an 16-bit accuracy at the device inputs during the acquisition time window. This condition is critical to maintain the overall linearity performance of the ADC. Typically, amplifier data sheets specify the output settling performance only up to 0.1% to 0.001%, which may not be sufficient for the desired 16-bit accuracy. Therefore, always verify the settling behavior of the input driver by TINA-TI SPICE simulations before selecting the amplifier.

8.2 Typical Application

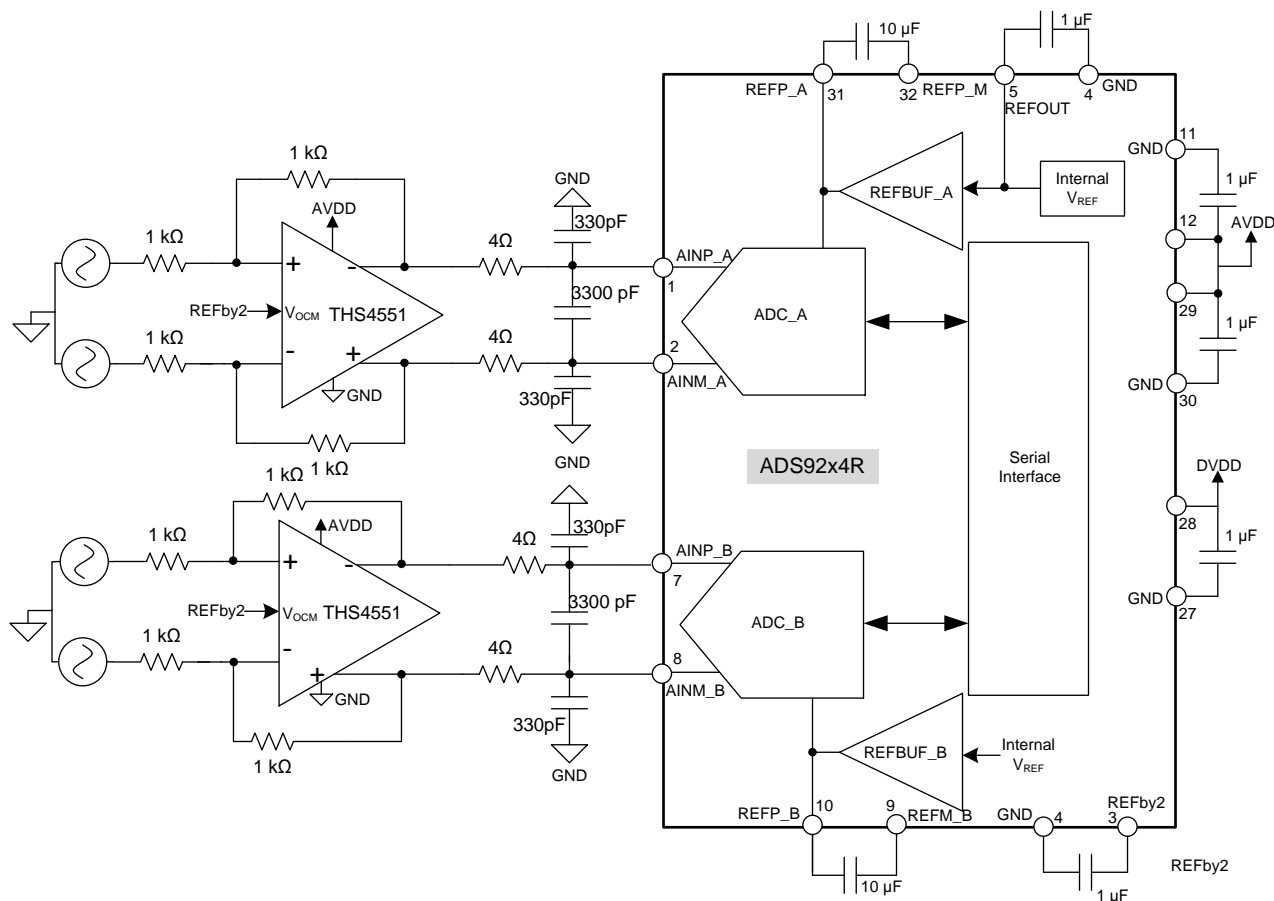


图 50. DAQ Circuit for Lowest Distortion and Noise With the ADS92x4R for a 100-kHz Input Signal

8.2.1 Design Requirements

The design parameters are listed in 表 19 for this example.

表 19. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
ADC sample rate	3 MSPS
Analog input signal	100 kHz, 8.192 V _{pp} , fully differential
SNR	> 92 dB
THD	< -105dB
INL	< ±1 LSB
Power supply	5-V analog, 3.3-V digital

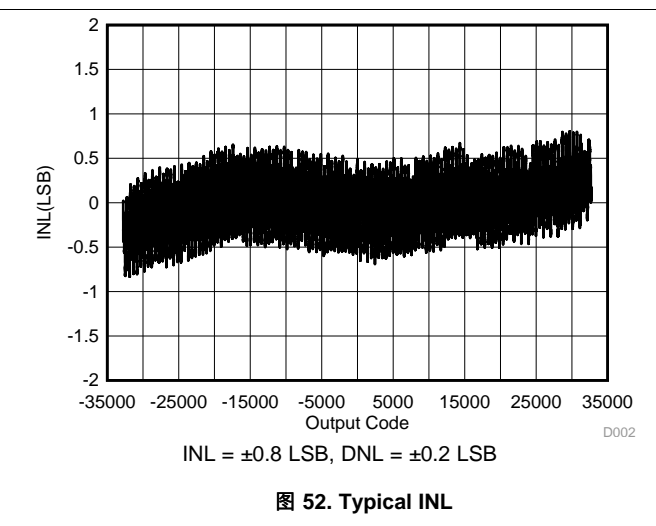
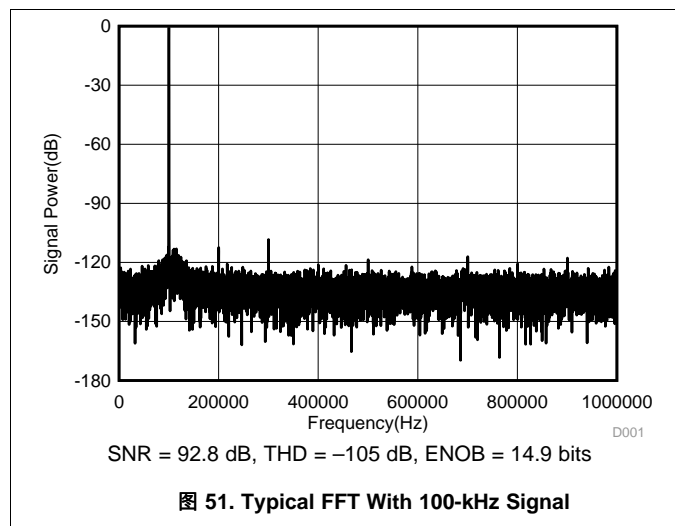
8.2.2 Detailed Design Procedure

图 50 shows an application circuit for this example. The device incorporates an internal 2.5-V reference voltage and independent matched reference buffers for each ADC. The internal reference output (REFOUT) is decoupled with a 1-μF capacitor. The matched reference buffers provide a gain of 1.6384 V/V and generate a high-precision, 4.096-V reference voltage for each ADC channel. Decouple the reference buffer outputs (the REFP_A and REFP_B pins) with the REFM_A and REFM_B pins, respectively, with 10-μF decoupling capacitors. The circuit in 图 50 shows a fully-differential data acquisition (DAQ) block optimized for low distortion and noise using the THS4551 and the ADS92x4R. Both differential ADC inputs are driven using a high-bandwidth, low-distortion, fully differential amplifier (FDA) designed in a gain of 1 V/V and an optimal RC charge-kickback filter before going

to the ADC. Generally, the distortion from the input driver must be at least 10 dB less than the ADC distortion. Therefore, these circuits use the low-power THS4551 as an input driver that provides exceptional AC performance because of its extremely low-distortion and high bandwidth specifications. In addition, the components of the charge kickback filter are selected to keep the noise from the front-end circuit low without adding distortion. This front-end circuit configuration requires a differential signal at the input of the FDA and provides a differential output to drive the ADC inputs. The FDA establishes a fixed common-mode voltage at the ADC inputs using the V_{OCM} input pin from the FDA. The ADS92x4R incorporates a REF_{by2} buffer output for setting the common-mode voltage. The ADS92x4R REF_{by2} output is decoupled using a 1-μF capacitor and connected to each FDA V_{OCM} input pin. Each V_{OCM} pin is decoupled using a 0.1-μF capacitor. For a complete schematic, see the [ADS9224REVM-PDK user's guide](#) located in the [ADS9224R SAR analog to digital converter evaluation module tool folder](#).

8.2.3 Application Curves

图 51 provides the typical FFT for the circuit in 图 50 and 图 52 provides the typical INL for the circuit in 图 50.



9 Power Supply Recommendations

The devices have two separate power supplies: AVDD and DVDD. The reference buffers, internal reference voltage, and converter modules (ADC_A and ADC_B) operate on AVDD. The serial interface operates on DVDD. AVDD and DVDD can be independently set to any value within their permissible ranges.

To operate the device with SCLK more than 20-MHz, TI recommends to set the DVDD voltage as: $2.35\text{ V} \leq \text{DVDD} \leq 5.5\text{ V}$.

As shown in [Figure 53](#), connect pins 12 and 29 together and place 1- μF decoupling capacitors between pin 12 (AVDD) and pin 11 (GND), and between pin 29 (AVDD) and pin 30 (GND). To decouple the DVDD supply, place a 1- μF decoupling capacitor between pin 28 (DVDD) and pin 27 (GND).

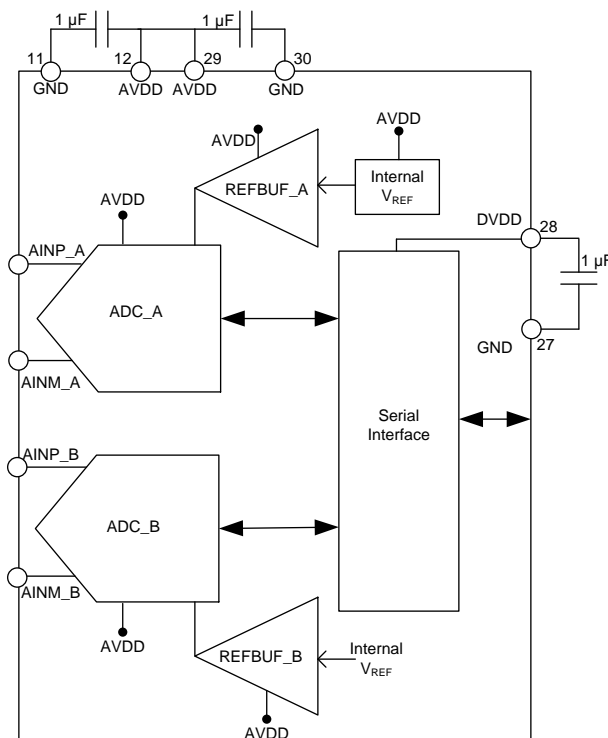


图 53. Power-Supply Decoupling

10 Layout

10.1 Layout Guidelines

This section provides some layout guidelines for achieving optimum performance with the ADS92x4R.

10.1.1 Signal Path

As illustrated in [Figure 54](#), the analog input signals are routed in opposite directions to the digital connections. The reference decoupling components are kept away from the switching digital signals. This arrangement prevents noise generated by digital switching activity from coupling to sensitive analog signals.

10.1.2 Grounding and PCB Stack-Up

Low inductance grounding is critical for achieving optimum performance. Grounding inductance is kept below 1 nH with 15-mil grounding vias and a printed circuit board (PCB) layout design that has at least four layers. Place all critical components of the signal chain on the top layer with a solid analog ground from subsequent inner layers to minimize via length to ground.

10.1.3 Decoupling of Power Supplies

Place the decoupling capacitors on AVDD and DVDD within 20 mil from the respective pins, and use a 15-mil via to ground from each capacitor. Avoid placing vias between any supply pin and the respective decoupling capacitor.

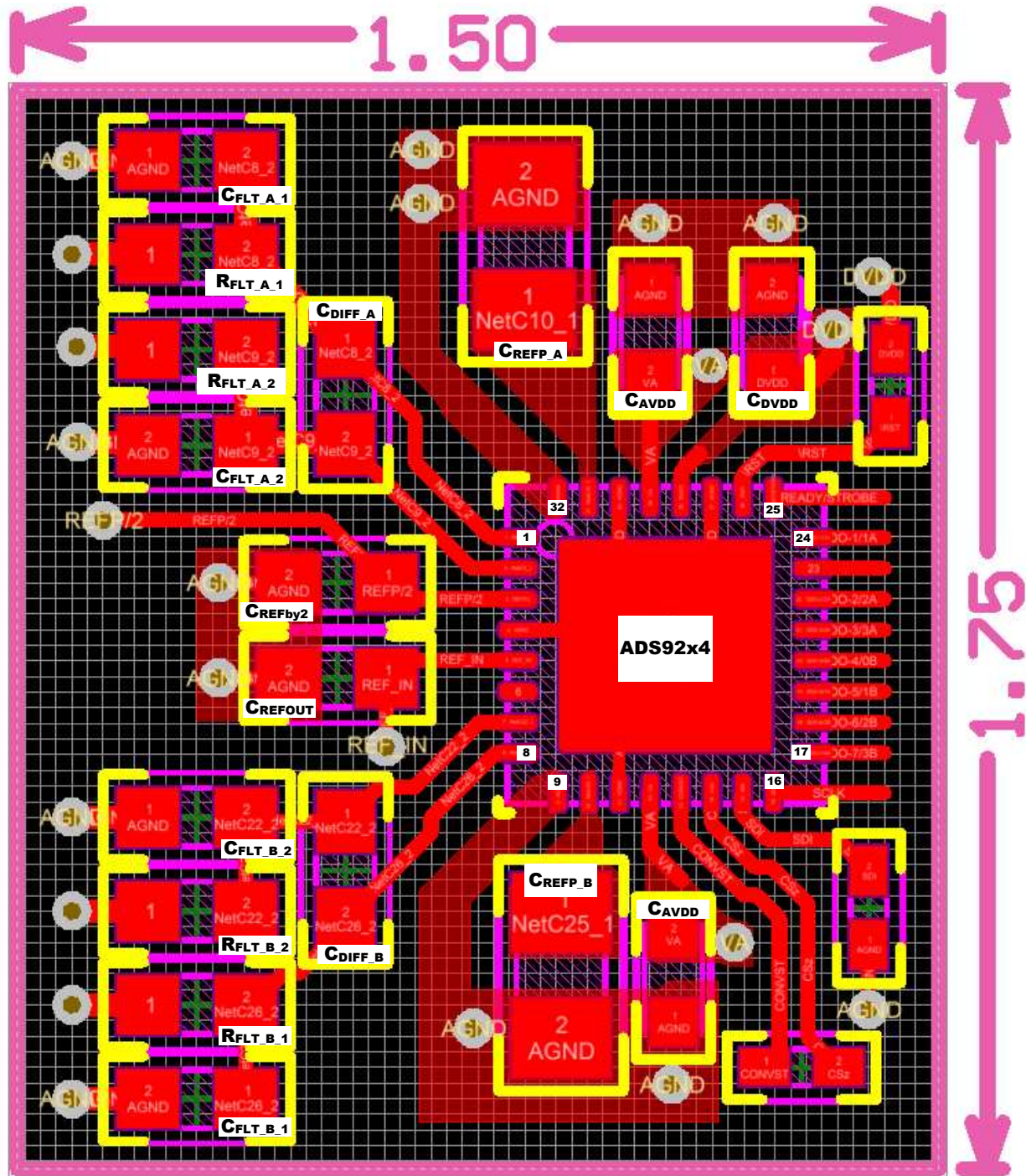
10.1.4 Reference Decoupling

Dynamic currents are present at the REFP_x and REFM_x pins during the conversion phase, and excellent decoupling is required to achieve optimum performance. Place a 10-μF, X7R-grade, ceramic capacitor with at least a 10-V rating, as illustrated in [Figure 54](#). Select 0603- or 0805-size capacitors to keep equivalent series inductance (ESL) low. Connect the REFM_x pins to the decoupling capacitor before a ground via. Also place decoupling capacitors on the REFOUT and REFby2 pins.

10.1.5 Differential Input Decoupling

Dynamic currents are also present at the differential analog inputs of the ADS92x4R. Use C0G- or NPO-type capacitors to decouple these inputs because with these type of capacitors, capacitance stays almost constant over the full input voltage range. Lower-quality capacitors (such as X5R and X7R) have large capacitance changes over the full input-voltage range that may cause degradation in the performance of the device.

10.2 Layout Example



NOTE: Dimensions are in cm.

图 54. Example Layout for the ADS92x4R

ADVANCE INFORMATION

11 器件和文档支持

11.1 相关文档

请参阅如下相关文档：

- 德州仪器 (TI), 《[THS4551 低噪声、高精度的 150MHz 全差分放大器](#)》数据表
- 德州仪器 (TI), 《[在电机控制应用中用于光学编码器的 12 位 1MSPS 单电源双通道数据采集系统](#)》参考指南
- 德州仪器 (TI), 《[REF50xx 低噪声、极低漂移、精密电压基准](#)》数据表
- 德州仪器 (TI), 《[OPAx350 高速单电源轨至轨运算放大器 MicroAmplifier 系列](#)》数据表
- 德州仪器 (TI), 《[THS452x 极低功耗、负轨输入、轨至轨输出、全差分放大器](#)》数据表
- 德州仪器 (TI), 《[ADS9224REVM-PDK 用户指南](#)》

11.2 相关链接

下表列出了快速访问链接。类别包括技术文档、支持和社区资源、工具和软件，以及立即订购快速访问。

表 20. 相关链接

器件	产品文件夹	立即订购	技术文档	工具与软件	支持和社区
ADS9224R	单击此处	单击此处	单击此处	单击此处	单击此处
ADS9234R	单击此处	单击此处	单击此处	单击此处	单击此处

11.3 接收文档更新通知

要接收文档更新通知，请导航至 [TI.com.cn](#) 上的器件产品文件夹。单击右上角的 [通知我](#) 进行注册，即可每周接收产品信息更改摘要。有关更改的详细信息，请查看任何已修订文档中包含的修订历史记录。

11.4 社区资源

下列链接提供到 TI 社区资源的连接。链接的内容由各个分销商“按照原样”提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参阅 TI 的《[使用条款](#)》。

TI E2E™ Online Community *TI's Engineer-to-Engineer (E2E) Community*. Created to foster collaboration among engineers. At [e2e.ti.com](#), you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.5 商标

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All other trademarks are the property of their respective owners.

11.6 静电放电警告



ESD 可能会损坏该集成电路。德州仪器 (TI) 建议通过适当的预防措施处理所有集成电路。如果不遵守正确的处理措施和安装程序，可能会损坏集成电路。

ESD 的损坏小至导致微小的性能降级，大至整个器件故障。精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

11.7 术语表

[SLYZ022](#) — TI 术语表。

这份术语表列出并解释术语、缩写和定义。

12 机械、封装和可订购信息

以下页面包含机械、封装和可订购信息。这些信息是指定器件的最新可用数据。数据如有变更，恕不另行通知，且不会对此文档进行修订。如需获取此数据表的浏览器版本，请查阅左侧的导航栏。

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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
ADS9224RIRHBR	ACTIVE	VQFN	RHB	32	3000	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	ADS9224	Samples
ADS9224RIRHBT	ACTIVE	VQFN	RHB	32	250	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	ADS9224	Samples
ADS9234RIRHBR	ACTIVE	VQFN	RHB	32	3000	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	ADS9234	Samples
ADS9234RIRHBT	ACTIVE	VQFN	RHB	32	250	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	ADS9234	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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device 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 Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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TAPE AND REEL INFORMATION


*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
ADS9224RIRHBR	VQFN	RHB	32	3000	330.0	12.4	5.3	5.3	1.5	8.0	12.0	Q2
ADS9224RIRHBT	VQFN	RHB	32	250	180.0	12.4	5.3	5.3	1.5	8.0	12.0	Q2
ADS9234RIRHBR	VQFN	RHB	32	3000	330.0	12.4	5.3	5.3	1.5	8.0	12.0	Q2
ADS9234RIRHBT	VQFN	RHB	32	250	180.0	12.4	5.3	5.3	1.5	8.0	12.0	Q2

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
ADS9224RIRHBR	VQFN	RHB	32	3000	350.0	350.0	43.0
ADS9224RIRHBT	VQFN	RHB	32	250	210.0	185.0	35.0
ADS9234RIRHBR	VQFN	RHB	32	3000	350.0	350.0	43.0
ADS9234RIRHBT	VQFN	RHB	32	250	210.0	185.0	35.0

GENERIC PACKAGE VIEW

RHB 32

VQFN - 1 mm max height

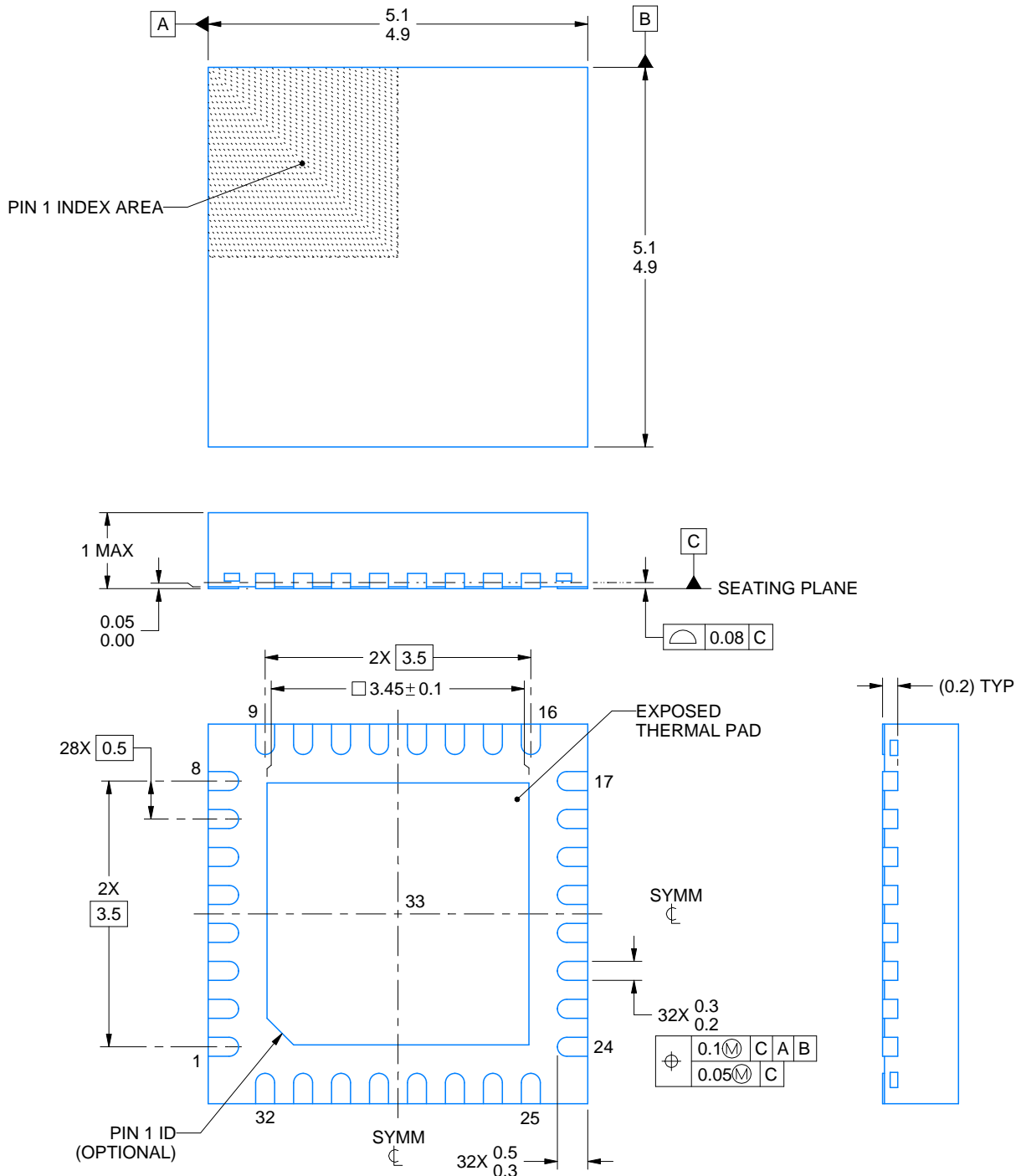
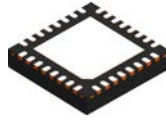
5 x 5, 0.5 mm pitch

PLASTIC QUAD FLATPACK - NO LEAD



Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

4224745/A



4223442/A 11/2016

NOTES:

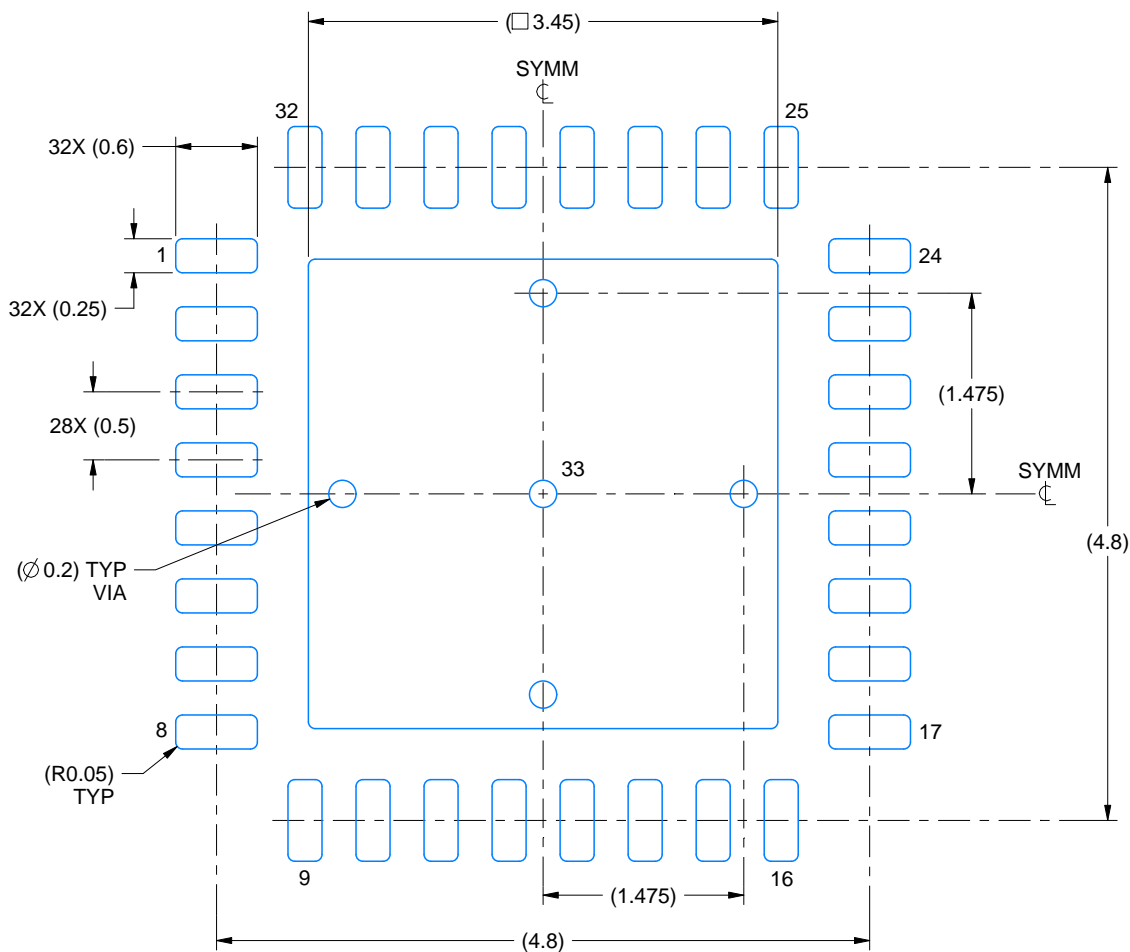
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

EXAMPLE BOARD LAYOUT

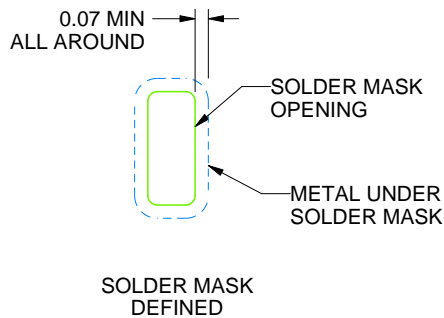
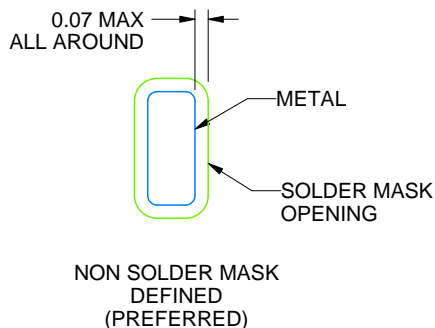
RHB0032E

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE
SCALE:18X



SOLDER MASK DETAILS

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NOTES: (continued)

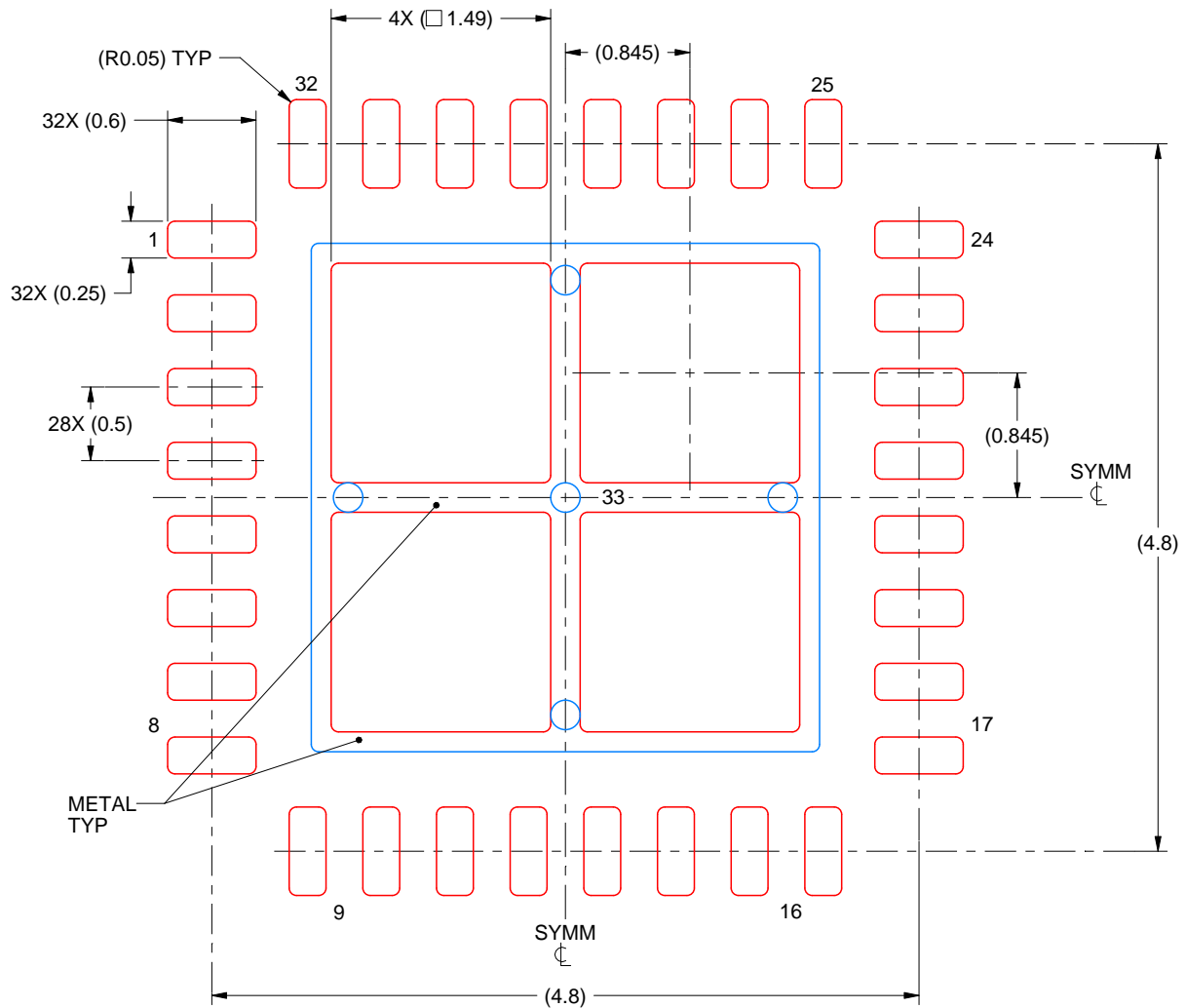
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/sluea271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

EXAMPLE STENCIL DESIGN

RHB0032E

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE
 BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 33:
 75% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
 SCALE:20X

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NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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