

# ADS92x4R Dual, Low-Latency, Simultaneous-Sampling SAR ADC

## 1 Features

- High resolution, high throughput:
  - ADS9224R: 16 bits, 3 MSPS, low latency: 333 ns
  - ADS9234R: 14 bits, 3.5 MSPS, low latency: 285 ns
- Two unipolar, fully differential simultaneously sampled channels
- Excellent DC and AC performance:
  - ADS9224R:
    - 16-bit NMC DNL,  $\pm 2$ -LSB max INL
    - 94-dB SNR,  $-109$ -dB THD
    - 88-dB SINAD at 1 MHz
  - ADS9234R:
    - 14-bit NMC DNL,  $\pm 1$ -LSB max INL
    - 85.6-dB SNR,  $-106$ -dB THD
    - 84-dB SINAD at 1 MHz
- Feature integration:
  - Internal reference and reference buffers
  - Internal REFby2 buffer for setting common-mode
  - Data averaging
- Enhanced-SPI interface for MCUs and FPGAs:
  - Wide read cycle to read data with MCUs
  - Clock re-timer for data transfers with digital isolators
  - DDR modes for FPGAs
  - Parallel byte mode for easy interface
- Extended temperature range:  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$

## 2 Applications

- Optical encoders: incremental and absolute
- SONAR receivers
- Optical networking: EDFA gain-control loop
- Power-quality measurement
- Digital power supply
- I/Q demodulators
- Medical imaging: CT scanners, MRI scanners
- Impedance analyzers

## 3 Description

The ADS92x4R is a pin-compatible, high-speed, dual, simultaneous-sampling, analog-to-digital converters (ADC) with an integrated reference and reference buffer. The device can operate on a single 5-V supply and supports unipolar, fully differential analog input signals with excellent DC and AC specifications. The device has excellent AC performance with analog input frequencies up to 1.5 MHz, which makes the device suitable for wide-bandwidth data acquisition (DAQ) systems.

The device supports SPI-compatible serial (enhanced-SPI) and byte-wide parallel interfaces, making the device easy to pair with a diversity of microcontrollers, digital signal processors (DSPs), and field-programmable gate arrays (FPGAs). This device also supports a data averaging feature that provides an AC performance boost in noisy environments.

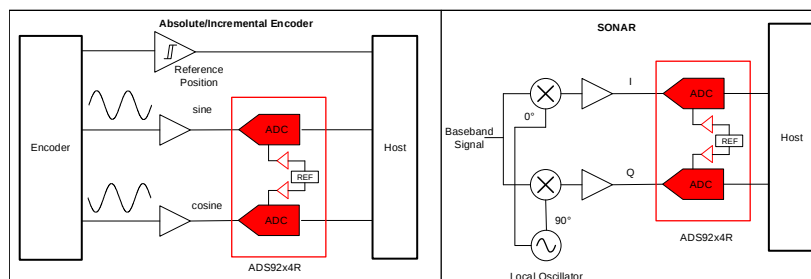
The device comes in a space-saving, 5-mm  $\times$  5-mm, VQFN package. The ADS92x4R is specified for the extended temperature range of  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

### Device Information<sup>(1)</sup>

| PART NUMBER | PACKAGE   | BODY SIZE (NOM)          |
|-------------|-----------|--------------------------|
| ADS92x4R    | VQFN (32) | 5.00 mm $\times$ 5.00 mm |

(1) For all available packages, see the orderable addendum at the end of the datasheet.

### Typical Application Diagram



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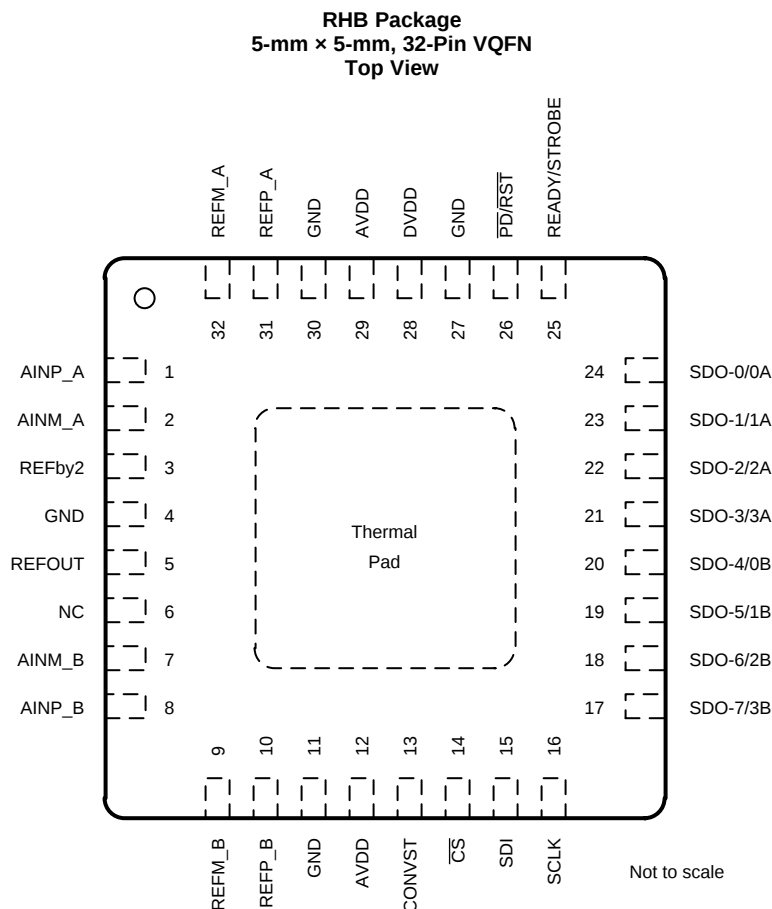
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## 4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| Changes from Revision B (May 2019) to Revision C                            | Page     |
|-----------------------------------------------------------------------------|----------|
| • Changed document status from Advance Information to Production Data ..... | <b>1</b> |

## 5 Pin Configuration and Functions



**Pin Functions**

| PIN                 |               | FUNCTION       | DESCRIPTION                                                                                                                                                       |
|---------------------|---------------|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME                | NO.           |                |                                                                                                                                                                   |
| AINM_A              | 2             | Analog input   | Negative analog input for channel A.                                                                                                                              |
| AINM_B              | 7             | Analog input   | Negative analog input for channel B.                                                                                                                              |
| AINP_A              | 1             | Analog input   | Positive analog input for channel A.                                                                                                                              |
| AINP_B              | 8             | Analog input   | Positive analog input for channel B.                                                                                                                              |
| AVDD                | 12, 29        | Power supply   | Analog power-supply pin.<br>Connect a 1-μF decoupling capacitor between pin 12 and pin 11.<br>Connect a 1-μF decoupling capacitor between pin 29 and pin 30.      |
| CONVST              | 13            | Digital input  | Conversion start input pin.<br>A CONVST rising edge starts the conversion for ADC_A and ADC_B.                                                                    |
| $\overline{CS}$     | 14            | Digital input  | Chip-select input pin; active low.<br>The host and device can communicate when $\overline{CS}$ is low.<br>The SDO-x pins go to Hi-Z when $\overline{CS}$ is high. |
| DVDD                | 28            | Power supply   | Interface power-supply pin.<br>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.<br>See the <a href="#">Reset or Power-Down</a> 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.<br>Connect a 1- $\mu$ F decoupling capacitor between pin 3 and pin 4.                                                         |
| REFOUT      | 5   | Analog output  | Internal reference output.<br>Connect a 1- $\mu$ F 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.<br>Externally connect to the device GND.                                 |
| REFM_B      | 9   | Analog output  | Negative output of reference buffer B. Negative reference input for ADC_B.<br>Externally connect to the device GND.                                 |
| REFP_A      | 31  | Analog output  | Positive output of reference buffer A. Positive reference input for ADC_A.<br>Connect a 10- $\mu$ F 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.<br>Connect a 10- $\mu$ F 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.<br>This pin is used to program the device registers.                                                                         |
| SDO-0/0A    | 24  | Digital output | SPI mode: data output 0 for channel A.<br>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.<br>Parallel byte mode: LSB+1 from the data byte.                                                             |
| SDO-2/2A    | 22  | Digital output | SPI mode: data output 2 for channel A.<br>Parallel byte mode: LSB+2 from the data byte.                                                             |
| SDO-3/3A    | 21  | Digital output | SPI mode: data output 3 for channel A.<br>Parallel byte mode: LSB+3 from the data byte.                                                             |
| SDO-4/0B    | 20  | Digital output | SPI mode: data output 0 for channel B.<br>Parallel byte mode: LSB+4 from the data byte.                                                             |
| SDO-5/1B    | 19  | Digital output | SPI mode: data output 1 for channel B.<br>Parallel byte mode: LSB+5 from the data byte.                                                             |
| SDO-6/2B    | 18  | Digital output | SPI mode: data output 2 for channel B.<br>Parallel byte mode: LSB+6 from the data byte.                                                             |
| SDO-7/3B    | 17  | Digital output | SPI mode: data output 3 for channel B.<br>Parallel byte mode: most significant bit (MSB) from the data byte.                                        |
| Thermal 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)<sup>(1)</sup>

|                                                            | MIN       | MAX        | UNIT |
|------------------------------------------------------------|-----------|------------|------|
| AVDD to GND                                                | −0.3      | 6          | V    |
| DVDD to GND                                                | −0.3      | 6          | V    |
| Digital input pins                                         | GND − 0.3 | DVDD + 0.3 | V    |
| Digital output pins                                        | GND − 0.3 | DVDD + 0.3 | V    |
| AINP_A, AINP_B to GND, AINM_A, AINM_B to GND               | −0.3      | AVDD + 0.3 | V    |
| REFM_A, REFM_B                                             | GND − 0.1 | GND + 0.1  | V    |
| REFP_A, REFP_B, REFOUT, REFby2 to GND                      | GND − 0.3 | AVDD + 0.3 | V    |
| Input or output current to any pin except power-supply pin | −10       | 10         | mA   |
| Junction temperature, T <sub>J</sub>                       |           | 150        | °C   |
| Storage temperature, T <sub>stg</sub>                      | −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 <sub>(ESD)</sub> | Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins <sup>(1)</sup>              | ±2000 |
|                    |                         | Charged device model (CDM), per JEDEC specification JESD22-C101, all pins <sup>(2)</sup> | ±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    |
| DVDD           | Digital supply voltage operating range   | 1.65 | 3.3 | 5.5 | V    |
|                | Digital supply voltage for SCLK > 20 MHz | 2.35 | 3.3 | 5.5 | V    |
| T <sub>A</sub> | Ambient temperature                      | −40  |     | 125 | °C   |

### 6.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                              | ADS92x4R   | UNIT |
|-------------------------------|----------------------------------------------|------------|------|
|                               |                                              | RHB (VQFN) |      |
|                               |                                              | 32 PINS    |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance       | 29         | °C/W |
| R <sub>θJC(top)</sub>         | Junction-to-case (top) thermal resistance    | 17.1       | °C/W |
| R <sub>θJB</sub>              | Junction-to-board thermal resistance         | 9.4        | °C/W |
| Ψ <sub>JT</sub>               | Junction-to-top characterization parameter   | 0.2        | °C/W |
| Ψ <sub>JB</sub>               | Junction-to-board characterization parameter | 9.4        | °C/W |
| R <sub>θJC(bot)</sub>         | 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

at AVDD = 4.5 V to 5.5V, DVDD = 2.35 V to 5.5 V,  $V_{CM} = V_{REFP\_X/2}$ , Internal reference and maximum throughput (unless otherwise noted); minimum and maximum values at  $T_A = -40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ; typical values at  $T_A = 25^{\circ}\text{C}$ , AVDD = 5V, DVDD = 3.3 V

| PARAMETER                                    |                                                  | TEST CONDITIONS                                                   | MIN        | TYP    | MAX        | UNIT              |
|----------------------------------------------|--------------------------------------------------|-------------------------------------------------------------------|------------|--------|------------|-------------------|
| ANALOG INPUT                                 |                                                  |                                                                   |            |        |            |                   |
| FSR <sup>(1)</sup>                           | Full-scale input voltage (AINP_x - AINM_x)       |                                                                   | -4.096     |        | 4.096      | V                 |
| V <sub>IN</sub>                              | Absolute input voltage (AINP_x or AINM_x to GND) |                                                                   | 0          |        | 4.096      | V                 |
| V <sub>CM</sub>                              | Common-mode input range                          |                                                                   | 1.848      |        | 2.248      | V                 |
| I <sub>IN</sub>                              | Analog input leakage current                     |                                                                   |            | ±1     |            | μA                |
| C <sub>i</sub>                               | Input capacitance                                | Sample mode                                                       |            | 16     |            | pF                |
|                                              |                                                  | Hold mode                                                         |            | 1      |            |                   |
| BW                                           | Analog input bandwidth                           | -3-dB input signal                                                |            | 52     |            | MHz               |
|                                              |                                                  | -0.1-dB input signal                                              |            | 4.2    |            | MHz               |
| VOLTAGE REFERENCE OUTPUT                     |                                                  |                                                                   |            |        |            |                   |
| V <sub>REFOUT</sub> <sup>(2)</sup>           | REFOUT voltage                                   |                                                                   | 2.496      | 2.5    | 2.504      | V                 |
| ΔV <sub>REF</sub> /ΔT                        | V <sub>REFOUT</sub> drift                        |                                                                   |            | 5.5    | 15         | ppm/°C            |
| ΔV <sub>REFOUT</sub> /ΔAVDD                  | V <sub>REFOUT</sub> line regulation              | AVDD variation 4.5 V to 5.5 V                                     |            | 200    |            | μV/V              |
| I <sub>REFOUT</sub>                          | REFOUT output current capability                 | ΔV <sub>REF</sub>   < 2 mV                                        |            | 1.5    |            | μA                |
| C <sub>REFOUT</sub>                          | REFOUT capacitor                                 | For specified performance                                         |            | 1      |            | μF                |
| INTERNAL REFERENCE BUFFER                    |                                                  |                                                                   |            |        |            |                   |
| G <sub>REFBUF</sub>                          | Reference buffer Gain                            |                                                                   |            | 1.6388 |            | V/V               |
| E <sub>O-REFBUF</sub>                        | Reference buffer output offset                   |                                                                   | -1         | ±0.2   | 1          | mV                |
| ΔE <sub>O-REFBUF</sub> /ΔT                   | Reference buffer output offset temperature drift |                                                                   |            | 10     |            | μV/°C             |
| (V <sub>REFP_A</sub> - V <sub>REFP_B</sub> ) | Reference buffer output mismatch                 |                                                                   | -500       | ±50    | 500        | μV                |
| C <sub>REFP_x</sub>                          | Reference buffer output capacitor                | For specified performance, between each pair of REFP_x and REFM_x | 7          | 10     | 27         | μF                |
| REFby2 OUTPUT                                |                                                  |                                                                   |            |        |            |                   |
| V <sub>REFby2</sub>                          | REFby2 output voltage                            | EN_REFBY2_OFFSET = 0                                              | 2.043      | 2.048  | 2.053      | V                 |
|                                              |                                                  | EN_REFBY2_OFFSET = 1                                              | 2.133      | 2.148  | 2.163      | V                 |
| I <sub>REFby2</sub>                          | REFby2 output current capability                 |                                                                   |            | ±3     |            | mA                |
|                                              | REFby2 output capacitor                          |                                                                   | 1          |        |            | μF                |
|                                              | REFby2 output noise                              | With specified output capacitor                                   |            | 10     |            | μV <sub>RMS</sub> |
| Digital Outputs                              |                                                  |                                                                   |            |        |            |                   |
| V <sub>OH</sub>                              | High level output voltage                        | I <sub>OH</sub> = 500-μA source                                   | 0.8 × DVDD |        | DVDD       | V                 |
| V <sub>OL</sub>                              | Low level output voltage                         | I <sub>OL</sub> = 500-μA sink                                     | 0          |        | 0.2 × DVDD | V                 |
| Digital Inputs                               |                                                  |                                                                   |            |        |            |                   |
| V <sub>IH</sub>                              | High level input voltage                         | DVDD > 2.3 V                                                      | 0.7 × DVDD |        | DVDD +0.3  | V                 |
| V <sub>IL</sub>                              | Low level input voltage                          |                                                                   | -0.3       |        | 0.3 × DVDD | V                 |
| V <sub>IH</sub>                              | High level input voltage                         | DVDD ≤ 2.3 V                                                      | 0.8 × DVDD |        | DVDD +0.3  | V                 |
| V <sub>IL</sub>                              | Low level input voltage                          |                                                                   | -0.3       |        | 0.2 × DVDD | V                 |

(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)

at AVDD = 4.5 V to 5.5V, DVDD = 2.35 V to 5.5 V,  $V_{CM} = V_{REFP\_x/2}$ , Internal reference and maximum throughput (unless otherwise noted); minimum and maximum values at  $T_A = -40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ; typical values at  $T_A = 25^{\circ}\text{C}$ , AVDD = 5V, DVDD = 3.3 V

| PARAMETER           |                              | TEST CONDITIONS                                                | MIN  | TYP  | MAX  | UNIT |
|---------------------|------------------------------|----------------------------------------------------------------|------|------|------|------|
| <b>Power Supply</b> |                              |                                                                |      |      |      |      |
| AVDD                | Analog supply voltage        |                                                                | 4.5  | 5    | 5.5  | V    |
| DVDD                | Digital supply voltage       |                                                                | 1.65 | 3.3  | 5.5  | V    |
| I <sub>AVDD</sub>   | Analog supply current        | f <sub>SAMPLE</sub> = 3 MSPS                                   |      | 24.3 | 30.4 | mA   |
|                     |                              | AVDD = 5 V, no conversion                                      |      | 7.8  |      | mA   |
|                     |                              | Power down ( $\overline{\text{PD}}/\overline{\text{RST}}$ Low) |      | 1    |      | μA   |
| I <sub>DVDD</sub>   | Digital supply current       | f <sub>SAMPLE</sub> = 3 MSPS, C <sub>SDO-x/y</sub> = 10 pF     |      | 2.8  |      | mA   |
| PSRR <sup>(3)</sup> | Power-supply rejection ratio | 100-mV <sub>PP</sub> 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

at AVDD = 4.5 V to 5.5V, DVDD = 2.35 V to 5.5 V,  $V_{CM} = V_{REFP\_x/2}$ , Internal reference and maximum throughput (unless otherwise noted); minimum and maximum values at  $T_A = -40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ; typical values at  $T_A = 25^{\circ}\text{C}$ , AVDD = 5V, DVDD = 3.3 V

| PARAMETER               |                                                                     | TEST CONDITIONS                                                        | MIN   | TYP   | MAX  | UNIT   |
|-------------------------|---------------------------------------------------------------------|------------------------------------------------------------------------|-------|-------|------|--------|
| <b>DC ACCURACY</b>      |                                                                     |                                                                        |       |       |      |        |
|                         | Resolution, no missing codes                                        |                                                                        | 16    |       |      | Bits   |
| DNL                     | Differential nonlinearity                                           |                                                                        | -0.5  | ±0.2  | 0.5  | LSB    |
| INL                     | Integral nonlinearity                                               |                                                                        | -2    | ±1    | 2    | LSB    |
| E <sub>O</sub>          | Offset error                                                        |                                                                        | -9    | ±1    | 9    | LSB    |
| G <sub>E</sub>          | Cummulative gain error for ADC <sub>x</sub> and REFBUF <sub>x</sub> |                                                                        | -0.02 | ±0.01 | 0.02 | %FSR   |
| ΔG <sub>E</sub> /ΔT     | Gain drift                                                          |                                                                        |       | 5     |      | ppm/°C |
|                         | Transition noise                                                    | Mid-code, PFS-1000, NFS+1000                                           |       | 0.4   |      | LSB    |
| <b>AC ACCURACY</b>      |                                                                     |                                                                        |       |       |      |        |
| SNR <sup>(1)</sup>      | Signal-to-noise ratio                                               | f <sub>IN</sub> = 2 kHz                                                | 91.3  | 94.5  |      | dB     |
|                         |                                                                     | f <sub>IN</sub> = 100 kHz, FSR = -3 dBFS                               |       | 93    |      |        |
|                         |                                                                     | f <sub>IN</sub> = 1 MHz, FSR = -3 dBFS, f <sub>SAMPLE</sub> = 2.9 MSPS |       | 89.5  |      |        |
| SINAD <sup>(1)(2)</sup> | Signal-to-noise plus distortion                                     | f <sub>IN</sub> = 2 kHz                                                |       | 94.3  |      | dB     |
|                         |                                                                     | f <sub>IN</sub> = 100 kHz, FSR = -3 dBFS                               |       | 92.7  |      |        |
|                         |                                                                     | f <sub>IN</sub> = 1 MHz, FSR = -3 dBFS                                 |       | 87.9  |      |        |
| THD <sup>(1)(2)</sup>   | Total harmonic distortion                                           | f <sub>IN</sub> = 2 kHz                                                |       | -109  |      | dB     |
|                         |                                                                     | f <sub>IN</sub> = 100 kHz, FSR = -3 dBFS                               |       | -106  |      |        |
|                         |                                                                     | f <sub>IN</sub> = 1 MHz, FSR = -3 dBFS                                 |       | -93   |      |        |
| SFDR <sup>(1)</sup>     | Spurious-free dynamic range                                         | f <sub>IN</sub> = 2 kHz                                                |       | 112   |      | dB     |
|                         |                                                                     | f <sub>IN</sub> = 100 kHz, FSR = -3 dBFS                               |       | 112   |      |        |
|                         |                                                                     | f <sub>IN</sub> = 1 MHz, FSR = -3 dBFS                                 |       | 100   |      |        |
| CMRR <sup>(1)</sup>     | Common-mode rejection ratio                                         | f <sub>IN</sub> = dc to 1-MHz, V <sub>IN</sub> = 100-mV <sub>PP</sub>  |       | 80    |      | 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.

## Electrical Characteristics: ADS9224R (continued)

at AVDD = 4.5 V to 5.5V, DVDD = 2.35 V to 5.5 V,  $V_{CM} = V_{REFP\_X/2}$ , Internal reference and maximum throughput (unless otherwise noted); minimum and maximum values at  $T_A = -40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ; typical values at  $T_A = 25^{\circ}\text{C}$ , AVDD = 5V, DVDD = 3.3 V

| PARAMETER            | TEST CONDITIONS              | MIN                                                                                                          | TYP  | MAX | UNIT |
|----------------------|------------------------------|--------------------------------------------------------------------------------------------------------------|------|-----|------|
| ISOXT <sup>(1)</sup> | Channel-to-channel isolation | $f_{IN\_ADCA} = 15\text{ kHz at } 10\% \text{ FSR,}$<br>$f_{IN\_ADCB} = 25\text{ kHz at } 100\% \text{ FSR}$ | -120 |     | dB   |

## 6.7 Electrical Characteristics: ADS9234R

at AVDD = 4.5 V to 5.5V, DVDD = 2.35 V to 5.5 V,  $V_{CM} = V_{REFP\_X/2}$ , Internal reference and maximum throughput (unless otherwise noted); minimum and maximum values at  $T_A = -40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ; typical values at  $T_A = 25^{\circ}\text{C}$ , AVDD = 5V, DVDD = 3.3 V

| PARAMETER               | TEST CONDITIONS                               | MIN                                                                                                          | TYP        | MAX   | UNIT                    |
|-------------------------|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------|------------|-------|-------------------------|
| <b>DC ACCURACY</b>      |                                               |                                                                                                              |            |       |                         |
|                         | Resolution, no missing codes                  | 14                                                                                                           |            |       | Bits                    |
| DNL                     | Differential nonlinearity                     | -0.5                                                                                                         | $\pm 0.15$ | 0.5   | LSB                     |
| INL                     | Integral nonlinearity                         | -1                                                                                                           | $\pm 0.3$  | 1     | LSB                     |
| E <sub>O</sub>          | Offset error                                  | -3.5                                                                                                         | $\pm 0.8$  | 3.5   | LSB                     |
| G <sub>E</sub>          | Cummulative gain error for ADC_x and REFBUF_x | -0.025                                                                                                       | $\pm 0.01$ | 0.025 | %FSR                    |
| $\Delta G_E/\Delta T$   | Gain drift                                    |                                                                                                              | 5          |       | ppm/ $^{\circ}\text{C}$ |
|                         | Transition noise                              | Mid-code, PFS-1000, NFS+1000                                                                                 | 0.3        |       | LSB                     |
| <b>AC ACCURACY</b>      |                                               |                                                                                                              |            |       |                         |
| SNR <sup>(1)</sup>      | Signal-to-noise ratio                         | $f_{IN} = 2\text{ kHz}$                                                                                      | 84.1       | 85.6  | dB                      |
|                         |                                               | $f_{IN} = 100\text{ kHz, FSR} = -3\text{ dBFS}$                                                              |            | 85.5  |                         |
|                         |                                               | $f_{IN} = 1\text{ MHz, FSR} = -3\text{ dBFS}$                                                                |            | 85    |                         |
| SINAD <sup>(1)(2)</sup> | Signal-to-noise plus distortion               | $f_{IN} = 2\text{ kHz}$                                                                                      |            | 85.5  | dB                      |
|                         |                                               | $f_{IN} = 100\text{ kHz, FSR} = -3\text{ dBFS}$                                                              |            | 85.4  |                         |
|                         |                                               | $f_{IN} = 1\text{ MHz, FSR} = -3\text{ dBFS}$                                                                |            | 84.4  |                         |
| THD <sup>(1)(2)</sup>   | Total harmonic distortion                     | $f_{IN} = 2\text{ kHz}$                                                                                      |            | -106  | dB                      |
|                         |                                               | $f_{IN} = 100\text{ kHz, FSR} = -3\text{ dBFS}$                                                              |            | -106  |                         |
|                         |                                               | $f_{IN} = 1\text{ MHz, FSR} = -3\text{ dBFS}$                                                                |            | -94   |                         |
| SFDR <sup>(1)</sup>     | Spurious-free dynamic range                   | $f_{IN} = 2\text{ kHz}$                                                                                      |            | 109   | dB                      |
|                         |                                               | $f_{IN} = 100\text{ kHz, FSR} = -3\text{ dBFS}$                                                              |            | 107   |                         |
|                         |                                               | $f_{IN} = 1\text{ MHz, FSR} = -3\text{ dBFS}$                                                                |            | 101   |                         |
| CMRR <sup>(1)</sup>     | Common-mode rejection ratio                   | $f_{IN} = \text{dc to } 1\text{-MHz, } V_{IN} = 100\text{-mV}_{PP}$                                          |            | 75    | dB                      |
| ISOXT <sup>(1)</sup>    | Channel-to-channel isolation                  | $f_{IN\_ADCA} = 15\text{ kHz at } 10\% \text{ FSR,}$<br>$f_{IN\_ADCB} = 25\text{ kHz at } 100\% \text{ FSR}$ |            | -115  | 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

at AVDD = 4.5 V to 5.5V, DVDD = 2.35 V to 5.5 V,  $V_{CM} = V_{REFP\_X/2}$ , Internal reference and maximum throughput (unless otherwise noted); minimum and maximum values at  $T_A = -40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ; typical values at  $T_A = 25^{\circ}\text{C}$ , AVDD = 5V, DVDD = 3.3 V

|                                                                                                |                                                                                             | MIN                         | NOM                   | MAX | UNIT |
|------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|-----------------------------|-----------------------|-----|------|
| <b>CONVERSION CONTROL AND DATA TRANSFER (See Figure 1 and Figure 2)</b>                        |                                                                                             |                             |                       |     |      |
| $t_{D\_CONVST\_CS}$                                                                            | Delay time: CONVST high to $\overline{CS}$ Falling for zero cycle latency (zone 1 transfer) | $t_{DRDY}^{(1)}$            |                       |     | ns   |
| $t_{CYCLE}$                                                                                    | Time between two adjacent CONVST rising edges for zero cycle latency (zone 1 transfer)      | $t_{DRDY} + t_{READ}^{(2)}$ |                       |     | ns   |
|                                                                                                | Time between two adjacent CONVST rising edges for zone 2 transfer, ADS9224R                 | 333                         |                       |     | ns   |
|                                                                                                | Time between two adjacent CONVST rising edges for zone 2 transfer, ADS9234R                 | 285                         |                       |     |      |
| $f_{SAMPLE}$                                                                                   | Sampling rate, ADS9224R                                                                     |                             |                       | 3   | MSPS |
|                                                                                                | Sampling rate, ADS9234R                                                                     |                             |                       | 3.5 |      |
| $t_{ACQ}$                                                                                      | Acquisition time                                                                            | 140                         |                       |     | ns   |
| $t_{D\_CONVST\_CS}$                                                                            | Delay time: CONVST high to $\overline{CS}$ falling for zone 2 transfer                      | 15                          |                       | 180 | ns   |
| $t_{WL\_CONVST}$                                                                               | Pulse duration : CONVST low                                                                 | 15                          |                       |     | ns   |
| $t_{WH\_CONVST}$                                                                               | Pulse duration : CONVST high                                                                | 15                          |                       |     | ns   |
| <b>SPI-COMPATIBLE AND PARALLEL BYTE PROTOCOL (See Figure 3)</b>                                |                                                                                             |                             |                       |     |      |
| $t_{CLK}$                                                                                      | Serial clock time period                                                                    | $1/f_{CLK}$                 |                       |     |      |
| $t_{PH\_CLK}$                                                                                  | SCLK high time                                                                              | $0.45 \times t_{CLK}$       | $0.55 \times t_{CLK}$ |     | ns   |
| $t_{PL\_CLK}$                                                                                  | SCLK low time                                                                               | $0.45 \times t_{CLK}$       | $0.55 \times t_{CLK}$ |     | ns   |
| $t_{SU\_CCLK}$                                                                                 | Setup time: $\overline{CS}$ falling to first SCLK capture edge                              | 12                          |                       |     | ns   |
| $t_{SU\_CKDI}$                                                                                 | Setup Time: SDI data valid to SCLK capture edge                                             | 2.5                         |                       |     | ns   |
| $t_{HT\_CKDI}$                                                                                 | Hold Time: SCLK capture edge to previous data valid on SDI                                  | 1.5                         |                       |     | ns   |
| $t_{HT\_CKCS}$                                                                                 | Delay Time: last SCLK capture edge to $\overline{CS}$ rising                                | 14                          |                       |     | ns   |
| $f_{CLK}$                                                                                      | Serial clock frequency for SPI protocols with single data rate                              |                             |                       | 60  | MHz  |
|                                                                                                | Serial clock frequency for SPI protocols with double data rate                              |                             |                       | 22  | MHz  |
|                                                                                                | Serial clock frequency for parallel byte protocol                                           |                             |                       | 45  | MHz  |
| <b>CLOCK RE-TIMER PROTOCOL WITH STROBE = SCLK (EXTERNAL CLOCK)<sup>(3)</sup>(See Figure 4)</b> |                                                                                             |                             |                       |     |      |
| $f_{CLK}$                                                                                      | Serial clock frequency with single data rate                                                |                             |                       | 60  | MHz  |
|                                                                                                | Serial clock frequency with double data rate                                                |                             |                       | 22  | MHz  |
| <b>ASYNCHRONOUS RESET AND POWER-DOWN TIMING (See Figure 6)</b>                                 |                                                                                             |                             |                       |     |      |
| $t_{WL\_RST}$                                                                                  | Pulse duration (low) for reset                                                              | 50                          |                       | 500 | ns   |
| $t_{WL\_PD\_min}$                                                                              | 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

at AVDD = 4.5 V to 5.5V, DVDD = 2.35 V to 5.5 V,  $V_{CM} = V_{REF/2}$ , Internal reference and maximum throughput (unless otherwise noted); minimum and maximum values at  $T_A = -40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ; typical values at  $T_A = 25^{\circ}\text{C}$ , AVDD = 5V, DVDD = 3.3 V

| PARAMETER                                                                                      | TEST CONDITIONS                                                              | MIN                                               | TYP  | MAX                   | UNIT |
|------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|---------------------------------------------------|------|-----------------------|------|
| <b>CONVERSION CONTROL AND DATA TRANSFER (See Figure 1 and Figure 2)</b>                        |                                                                              |                                                   |      |                       |      |
| $t_{DRDY}$                                                                                     | Data ready time for present sample: CONVST high to READY high                | Zero cycle latency (zone 1 transfer) for ADS9224R |      | 315                   | ns   |
|                                                                                                | Data ready time for present sample: CONVST high to READY high                | Zero cycle latency (zone 1 transfer) for ADS9234R |      | 280                   | ns   |
| <b>SPI-COMPATIBLE AND PARALLEL BYTE PROTOCOL (See Figure 3)</b>                                |                                                                              |                                                   |      |                       |      |
| $t_{DEN\_CSDO}$                                                                                | Delay time: $\overline{CS}$ falling to data valid on SDO-x                   |                                                   |      | 12                    | ns   |
| $t_{DZ\_CSDO}$                                                                                 | Delay time: $\overline{CS}$ rising edge to SDO-x tristate                    |                                                   |      | 12                    | ns   |
| $t_{D\_CKDO}$                                                                                  | Delay time: SCLK launch edge to next data valid on SDO-x                     | SPI-compatible protocols with single data rate    |      | 15.8                  | ns   |
| $t_{D\_CKDO}$                                                                                  | Delay time: SCLK launch edge to next data valid on SDO-x                     | SPI-compatible protocols with double data rate    |      | 21                    | ns   |
| $t_{D\_CKDO}$                                                                                  | Delay time: SCLK launch edge to next data valid on SDO-x                     | Parallel byte protocol                            |      | 21                    | ns   |
| $t_A$                                                                                          | Aperture delay                                                               |                                                   | 8    |                       | ns   |
|                                                                                                | $t_A$ mismatch                                                               |                                                   | 40   |                       | ps   |
| $t_{JITTER}$                                                                                   | Aperture jitter                                                              |                                                   | 2    |                       | ps   |
| <b>CLOCK RE-TIMER PROTOCOL WITH STROBE = SCLK (EXTERNAL CLOCK)<sup>(1)</sup>(See Figure 4)</b> |                                                                              |                                                   |      |                       |      |
| $t_{OFF\_STROBE\_DO}$                                                                          | Time offset: STROBE edge to next data valid on SDO-x                         |                                                   | -2.5 | 2.5                   | ns   |
| $t_{D\_CS\_READY}$                                                                             | Delay time: $\overline{CS}$ rising to READY displaying internal device state |                                                   |      | 13.5                  | ns   |
| $t_{D\_CKSTROBE\_r}$                                                                           | Delay time: SCLK rising edge to STROBE rising                                |                                                   |      | 21.5                  | ns   |
| $t_{D\_CKSTROBE\_f}$                                                                           | Delay time: SCLK falling edge to STROBE falling                              |                                                   |      | 21.5                  | ns   |
| $t_{PH\_STROBE}$                                                                               | Strobe output high time                                                      | $0.45 \times t_{STR}$                             |      | $0.55 \times t_{STR}$ | ns   |
| $t_{PL\_STROBE}$                                                                               | Strobe output low time                                                       | $0.45 \times t_{STR}$                             |      | $0.55 \times t_{STR}$ | ns   |
| <b>CLOCK RE-TIMER PROTOCOL WITH STROBE = INTERNAL CLOCK<sup>(1)</sup>(See Figure 5)</b>        |                                                                              |                                                   |      |                       |      |
| $t_{D\_CS\_STROBE}$                                                                            | Delay time : $\overline{CS}$ falling to 1 <sup>st</sup> STROBE rising        |                                                   | 15   | 50                    | ns   |
| $t_{OFF\_STROBE\_DO}$                                                                          | Time offset : STROBE edge to next data valid on SDO-x                        |                                                   | -2.5 | 2.5                   | ns   |
| $t_{D\_CS\_READY}$                                                                             | Delay time: $\overline{CS}$ rising to READY displaying internal device state |                                                   |      | 13.5                  | ns   |
| $t_{INTCLK}$                                                                                   | INTCLK period                                                                |                                                   | 15   |                       | ns   |
| $t_{STR}$                                                                                      | STROBE period                                                                | INTCLK                                            | 16   |                       | ns   |
|                                                                                                |                                                                              | INTCLK / 2                                        | 30   |                       | ns   |
|                                                                                                |                                                                              | INTCLK / 4                                        | 60   |                       | ns   |
| $t_{WH\_STR}$                                                                                  | STROBE high period                                                           | $0.45 \times t_{STR}$                             |      | $0.55 \times t_{STR}$ | ns   |
| $t_{WL\_STR}$                                                                                  | STROBE low period                                                            | $0.45 \times t_{STR}$                             |      | $0.55 \times t_{STR}$ | ns   |

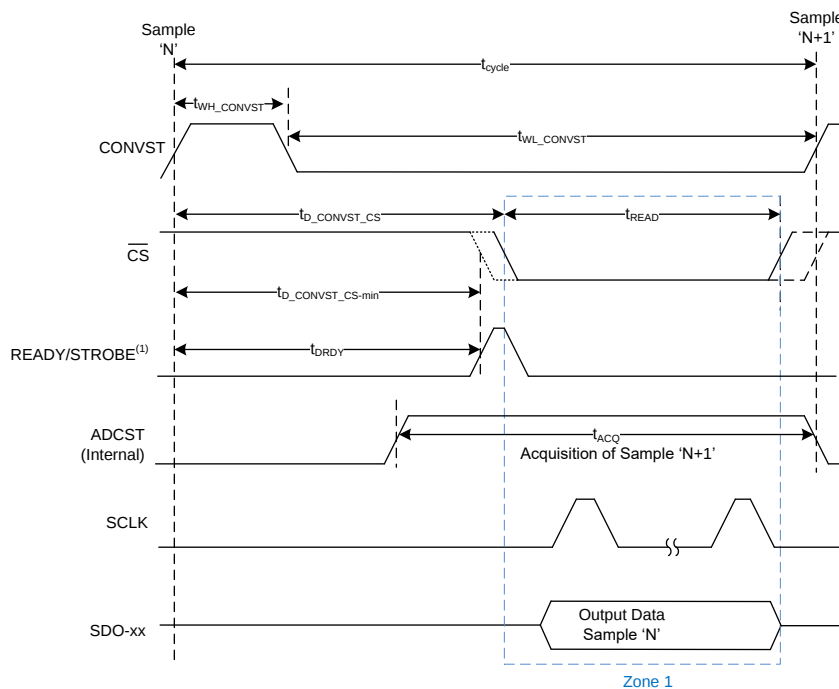
(1) Other parameters are the same as the SPI-compatible and Parallel Byte Protocols.

## Switching Characteristics (continued)

at AVDD = 4.5 V to 5.5V, DVDD = 2.35 V to 5.5 V,  $V_{CM} = V_{REF/2}$ , Internal reference and maximum throughput (unless otherwise noted); minimum and maximum values at  $T_A = -40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ; typical values at  $T_A = 25^{\circ}\text{C}$ , AVDD = 5V, DVDD = 3.3 V

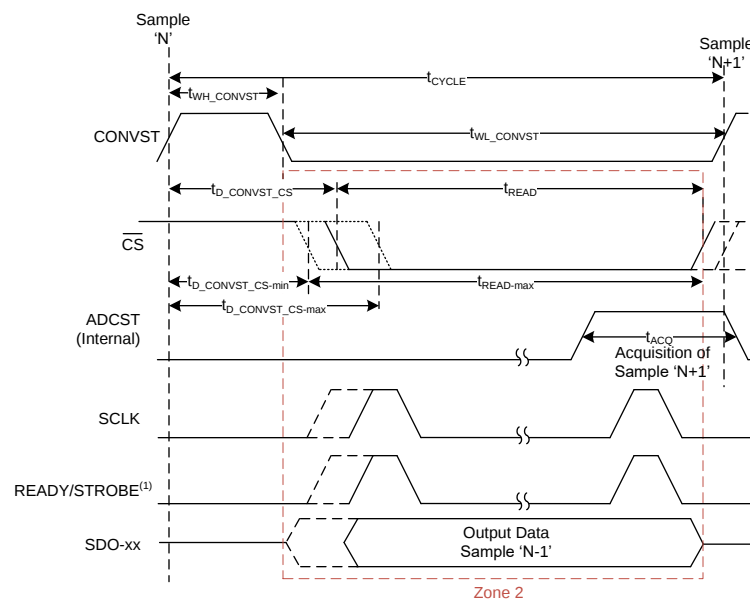
| PARAMETER                                                      | TEST CONDITIONS                       | MIN                           | TYP  | MAX | UNIT          |
|----------------------------------------------------------------|---------------------------------------|-------------------------------|------|-----|---------------|
| <b>ASYNCHRONOUS RESET AND POWER-DOWN TIMING (See Figure 6)</b> |                                       |                               |      |     |               |
| $t_{RST-WKUP}$                                                 | Wake up time from reset               |                               |      | 1   | $\mu\text{s}$ |
| $t_{PD-WKUP}^{(2)}$                                            | Wake up time from power-down          |                               | 18   | 150 | ms            |
| $t_{WKUP-REFOUT}$                                              | REFOUT wake-up time                   |                               | 15.6 | 140 | ms            |
| $t_{REFP\_X-SETTLE}$                                           | Reference buffer output settling time | $C_{REFP\_X} = 10\mu\text{F}$ | 18   | 150 | ms            |

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



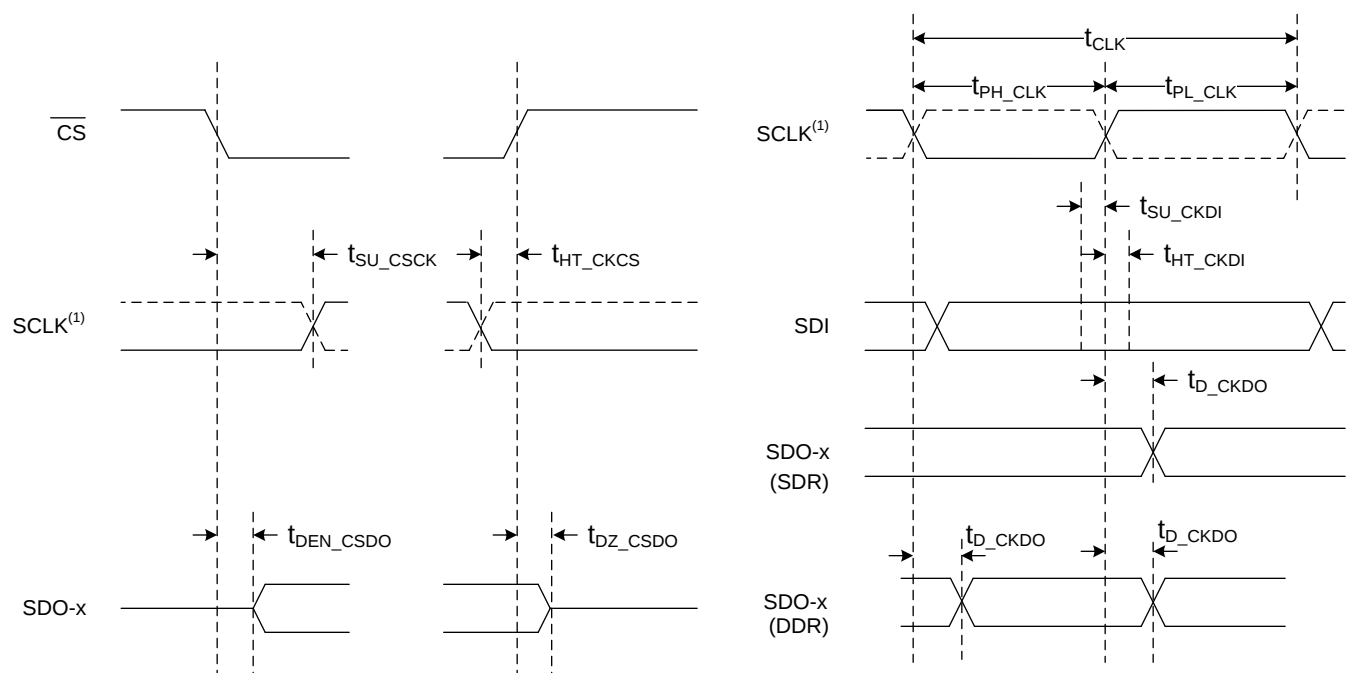
(1) The READY output is required for data transfer with zero cycle latency. The STROBE output is required only for clock re-timer (CRT) protocols.

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



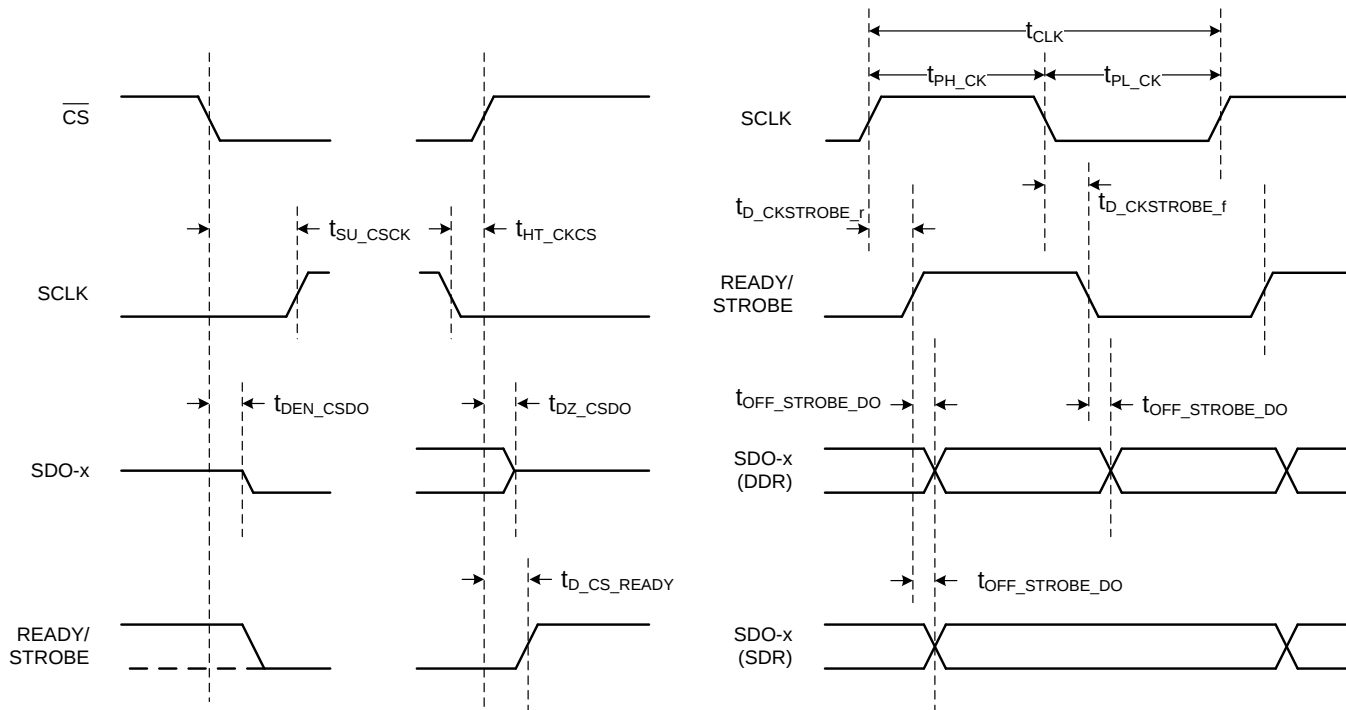
- (1) The READY output is not required for zone 2 data transfer. The STROBE output is required only for clock re-timer protocols.

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

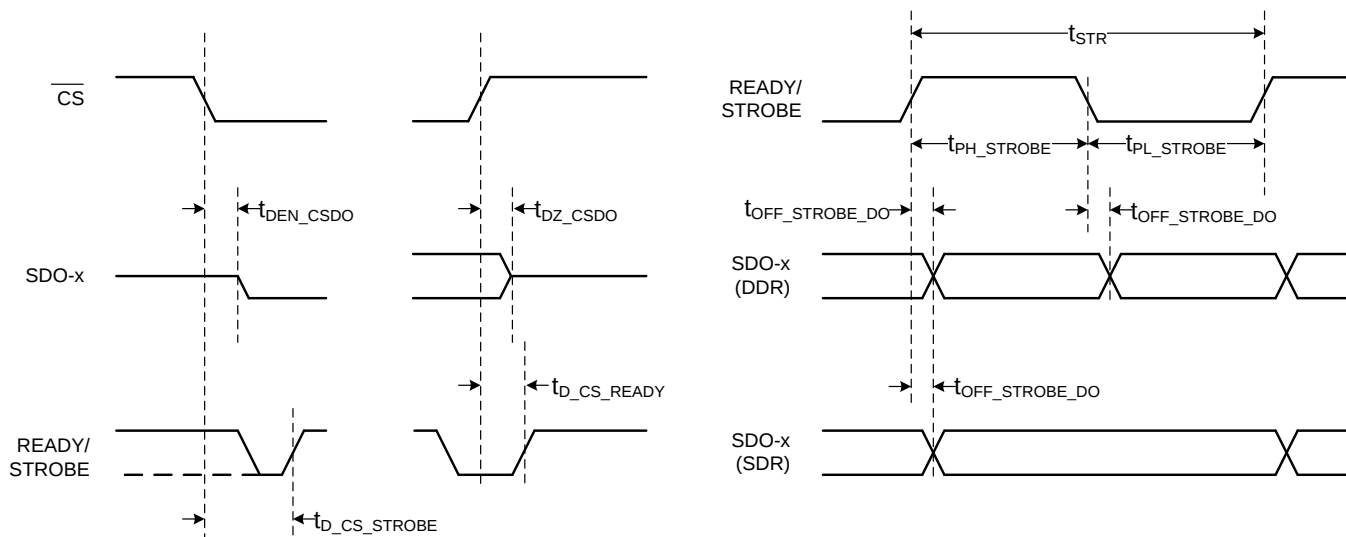


- (1) The SCLK polarity, launch edge, and capture edge depend on the SPI protocol selected. DDR is not supported with the parallel byte protocol.

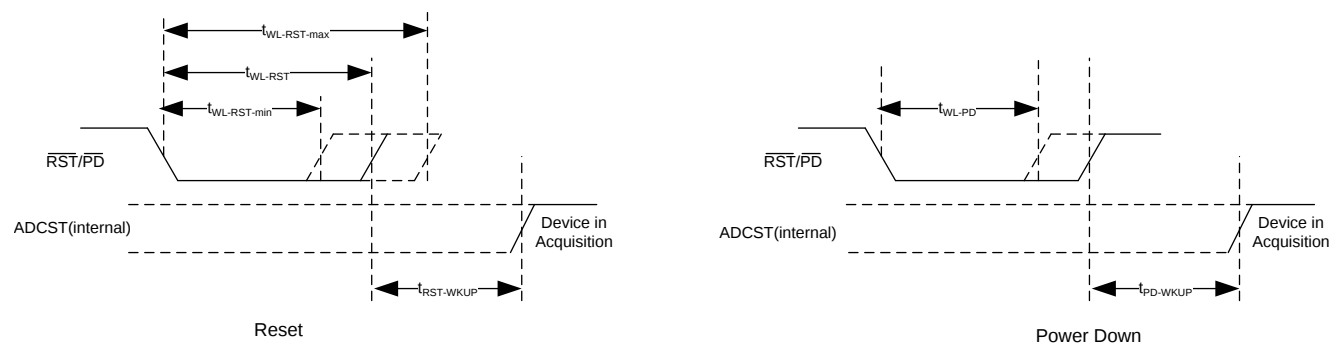
**Figure 3. SPI-Compatible and Parallel Byte Protocols Timing**



**Figure 4. Clock Re-Timer Protocol (External Clock) Timing**



**Figure 5. Clock Re-Timer Protocol (Internal Clock) Timing**



**Figure 6. Asynchronous Reset and Power-Down Timing**

## 6.10 Typical Characteristics: ADS9224R

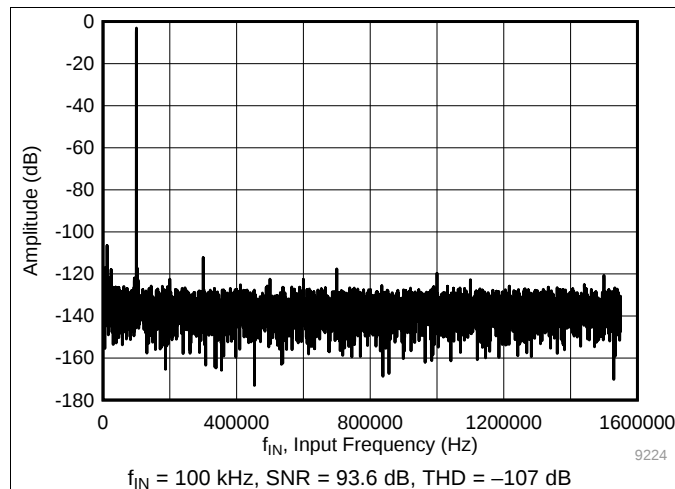


Figure 7. Typical FFT at  $f_{IN} = 100$  kHz

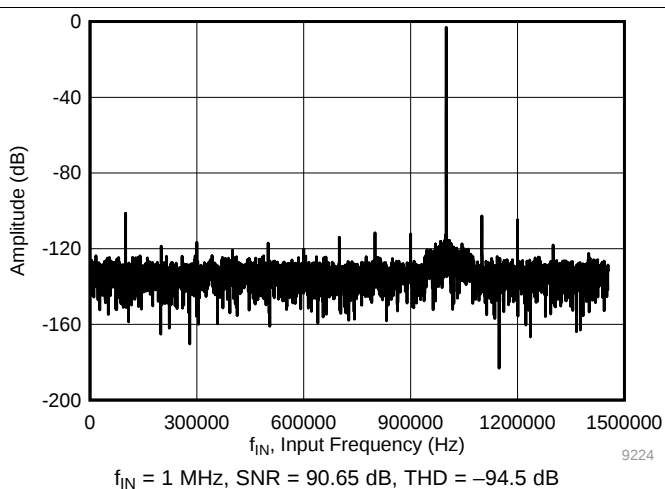


Figure 8. Typical FFT at  $f_{IN} = 1$  MHz

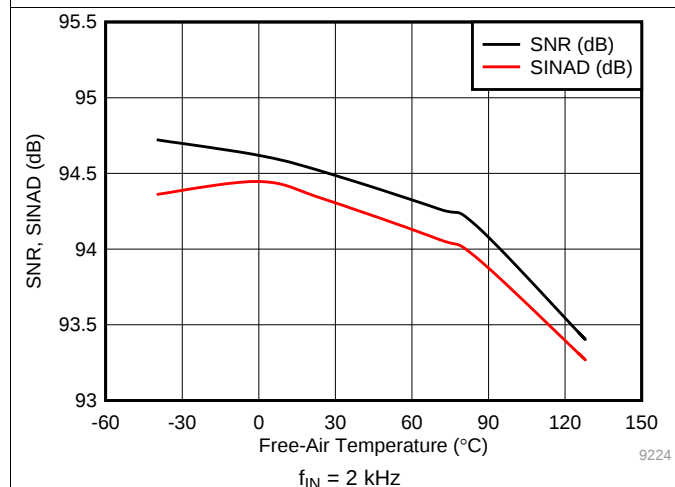


Figure 9. Noise Performance vs Temperature

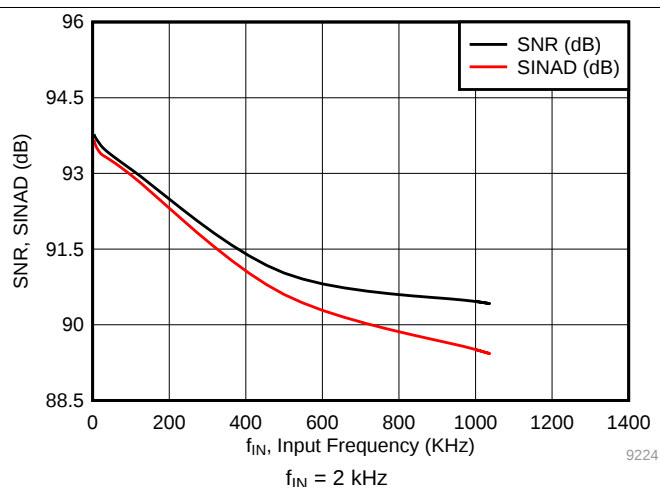


Figure 10. Noise Performance vs Frequency

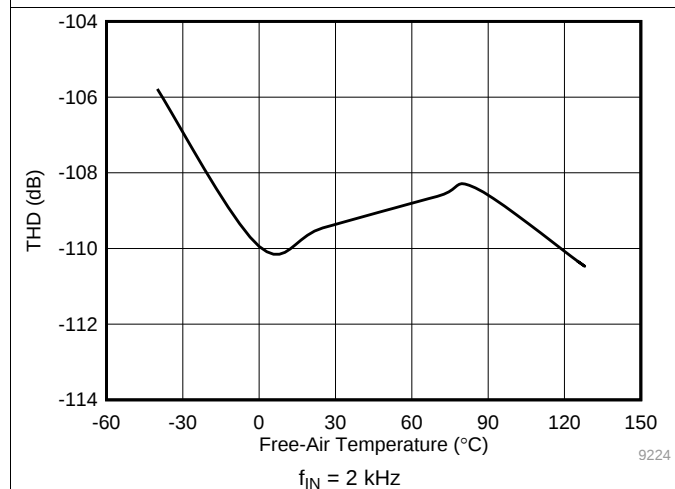


Figure 11. Distortion Performance vs Temperature

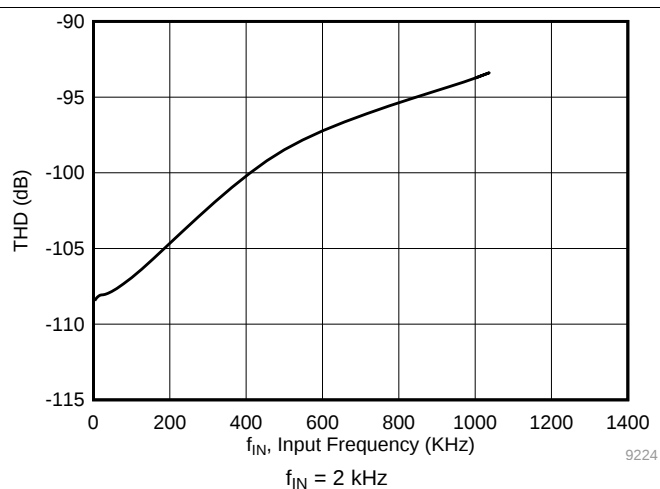


Figure 12. Distortion Performance vs Frequency

## Typical Characteristics: ADS9224R (continued)

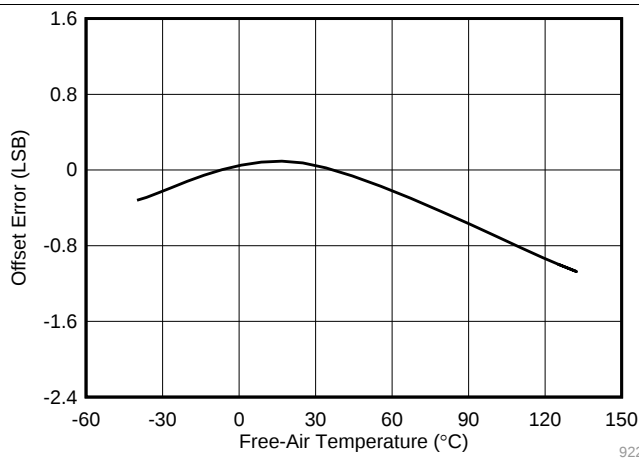


Figure 13. Offset Error vs Temperature

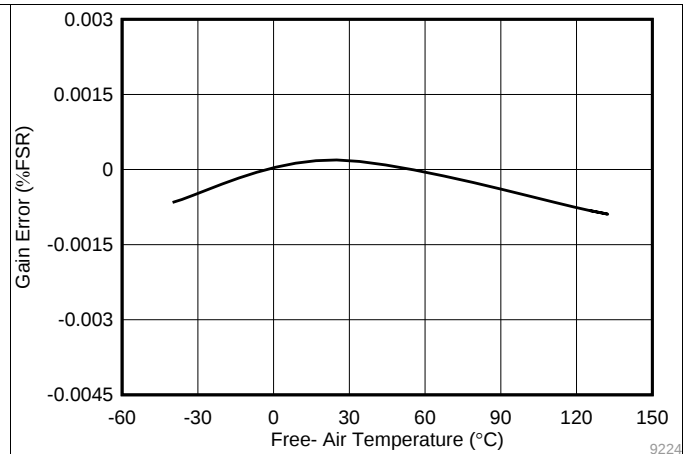


Figure 14. Gain Error vs Temperature

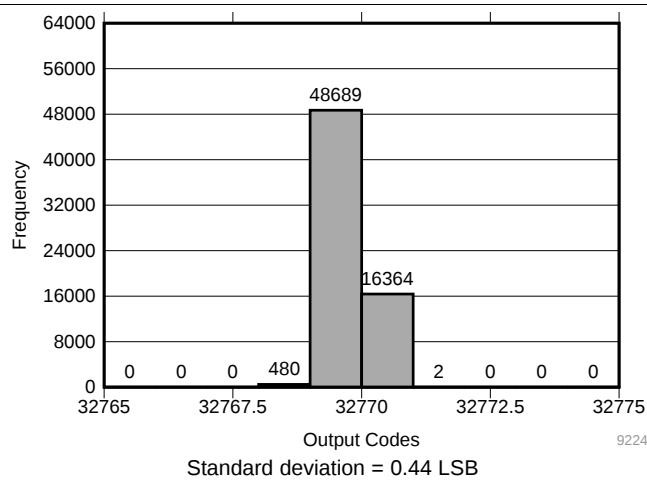


Figure 15. DC Input Histogram

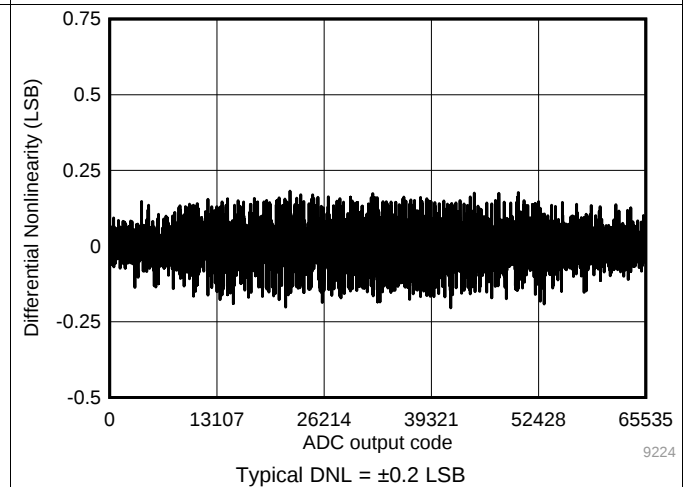


Figure 16. Typical DNL

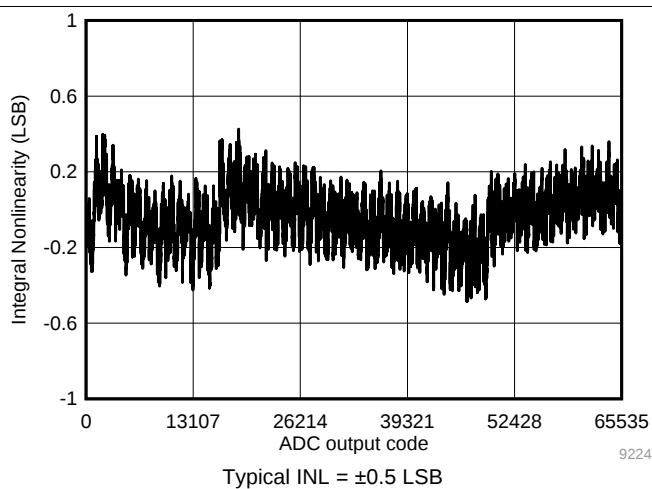


Figure 17. Typical INL

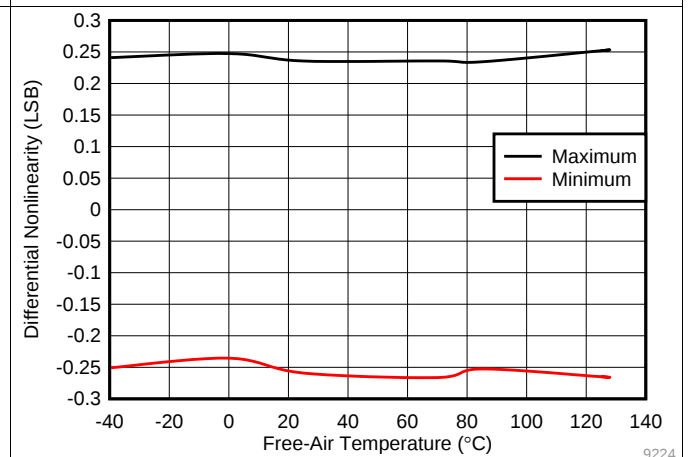
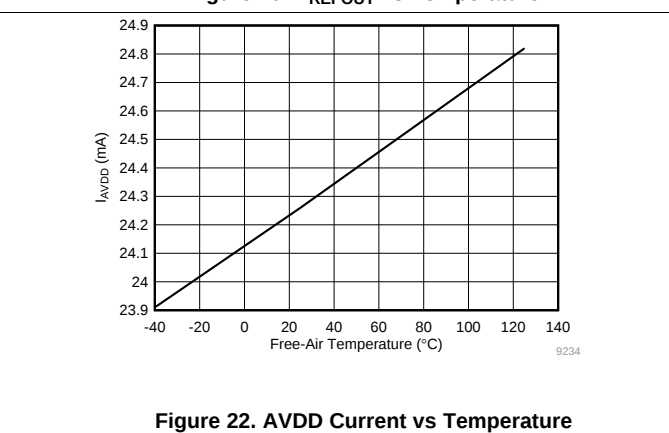
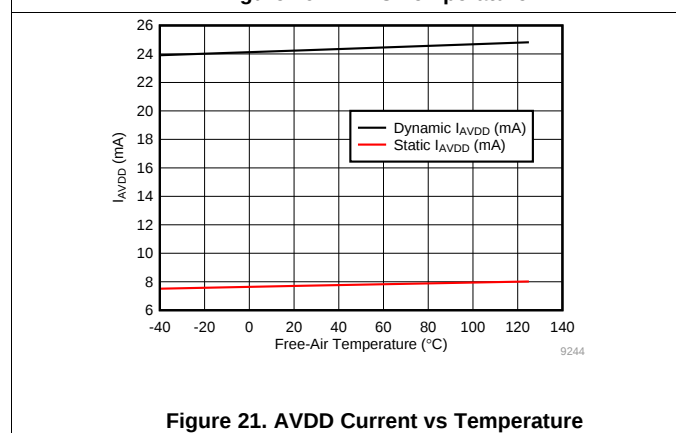
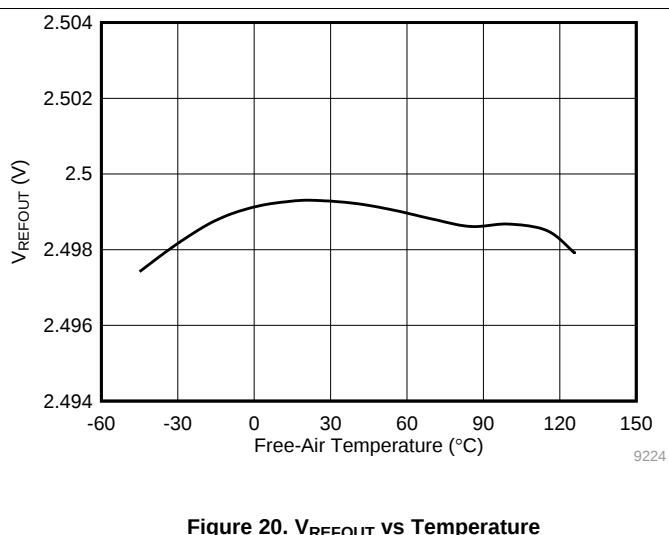
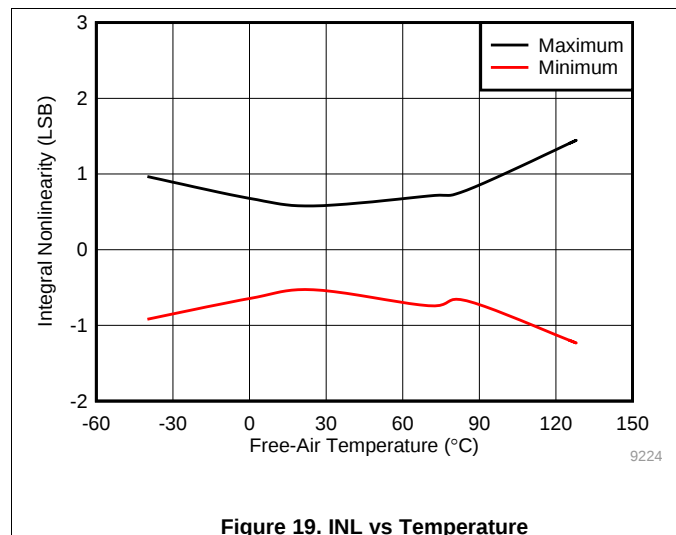


Figure 18. DNL vs Temperature

## Typical Characteristics: ADS9224R (continued)



## 6.11 Typical Characteristics: ADS9234R

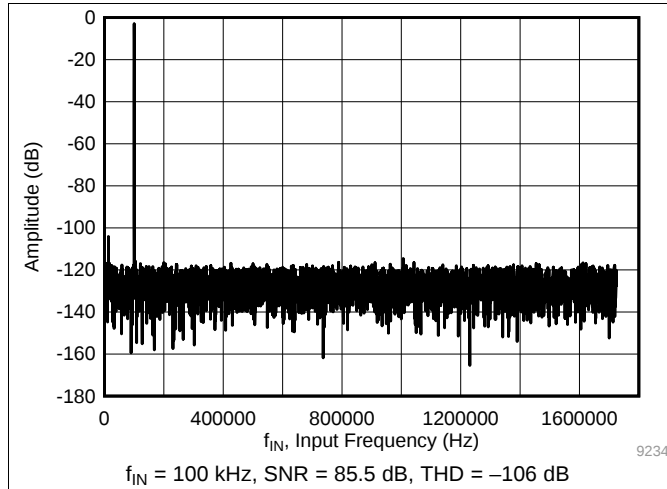


Figure 23. Typical FFT at  $f_{IN} = 100$  kHz

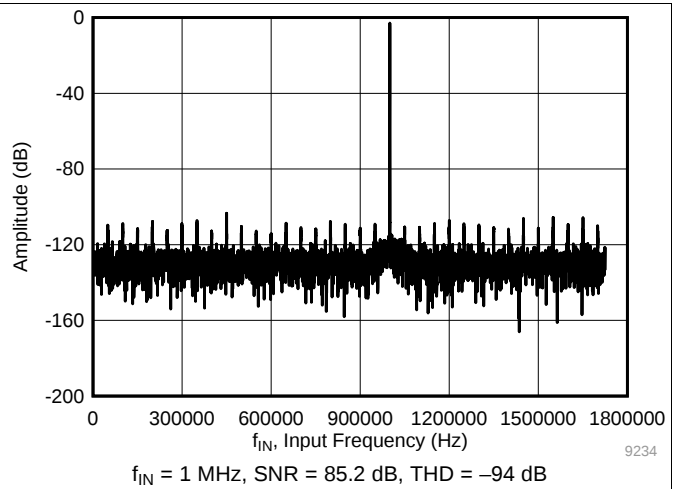


Figure 24. Typical FFT at  $f_{IN} = 1$  MHz

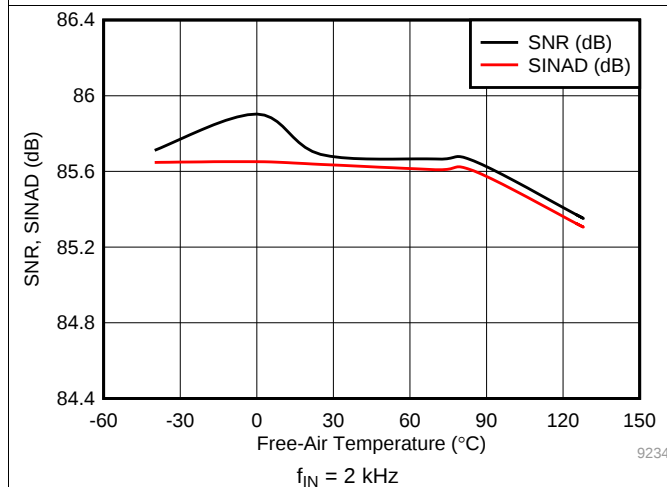


Figure 25. Noise Performance vs Temperature

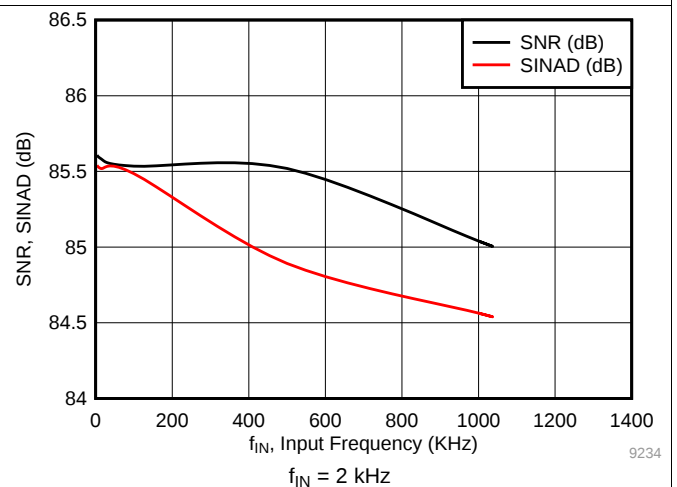


Figure 26. Noise Performance vs Frequency

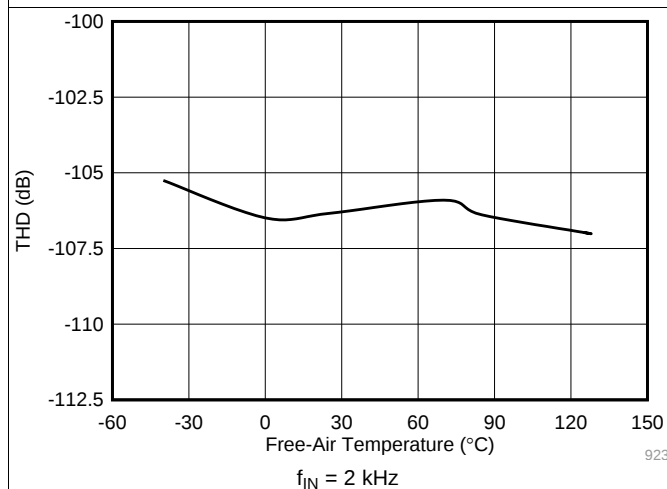


Figure 27. Distortion Performance vs Temperature

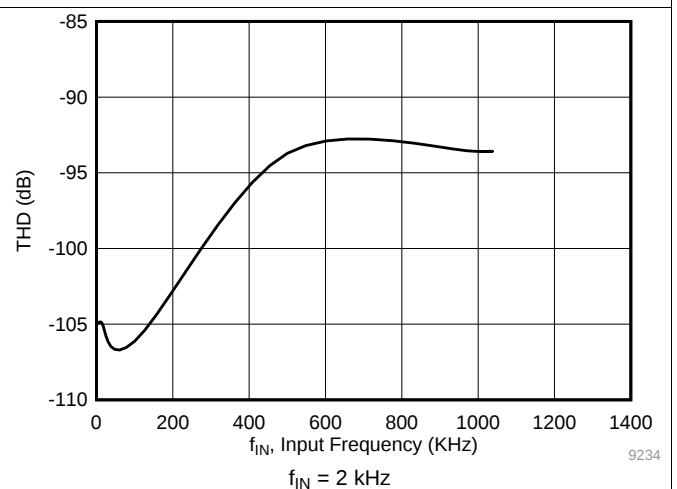
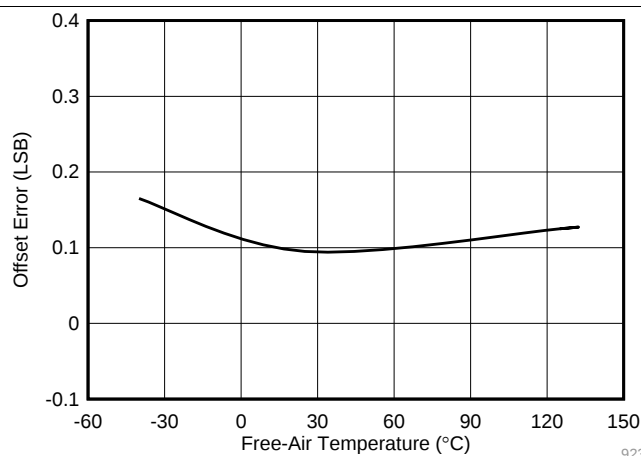
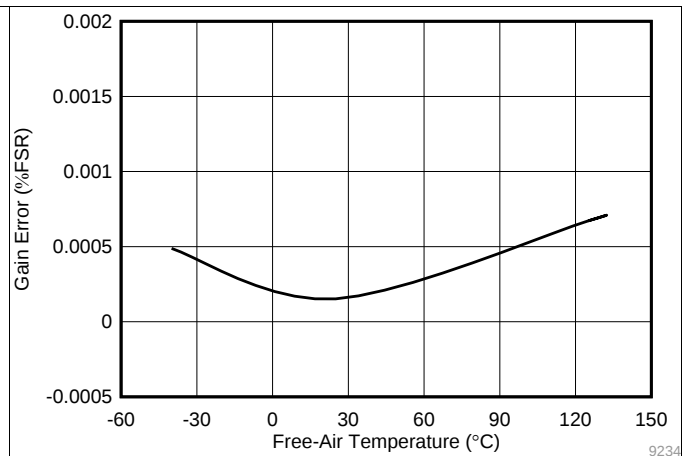


Figure 28. Distortion Performance vs Frequency

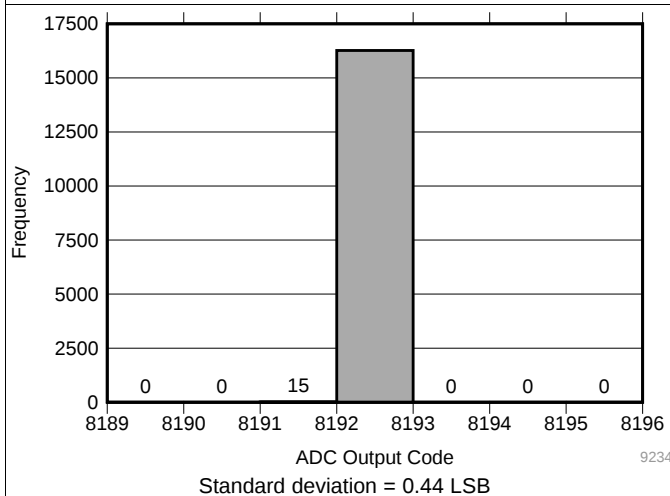
## Typical Characteristics: ADS9234R (continued)



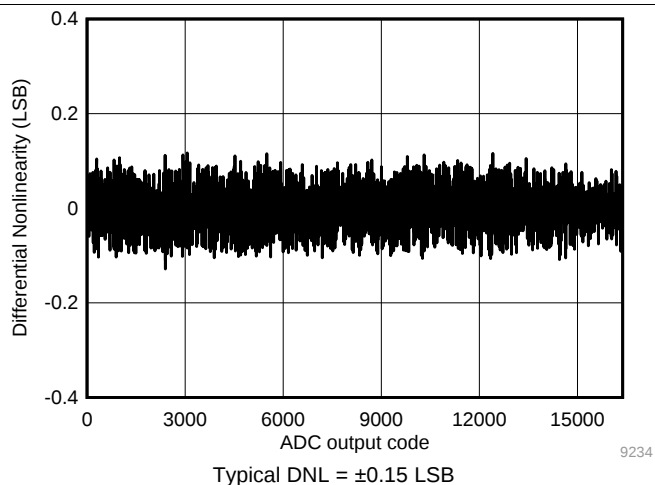
**Figure 29. Offset Error vs Temperature**



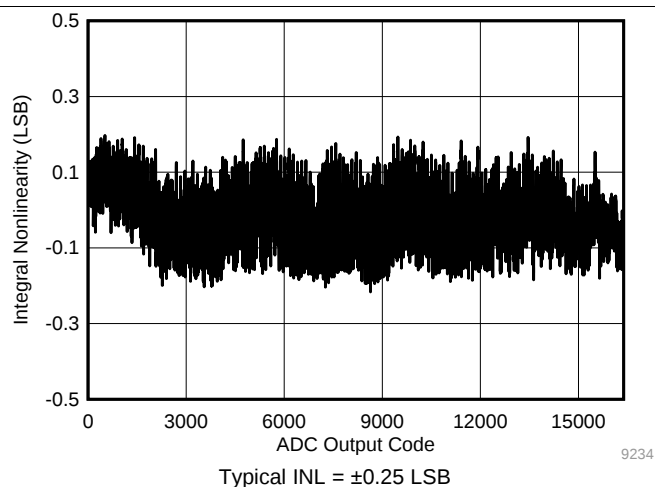
**Figure 30. Gain Error vs Temperature**



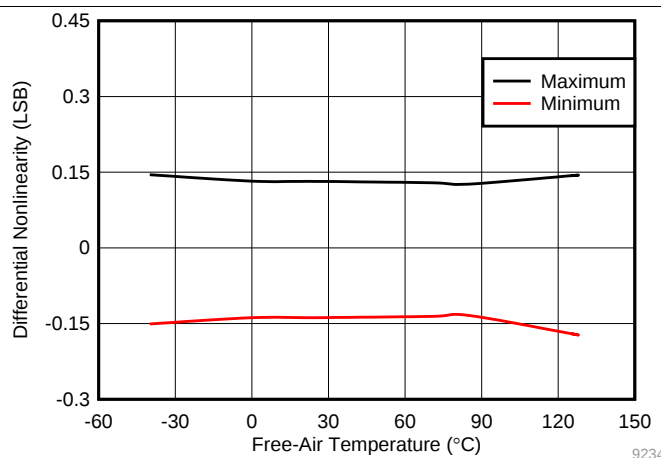
**Figure 31. DC Input Histogram**



**Figure 32. Typical DNL**



**Figure 33. Typical INL**



**Figure 34. DNL vs Temperature**

## Typical Characteristics: ADS9234R (continued)

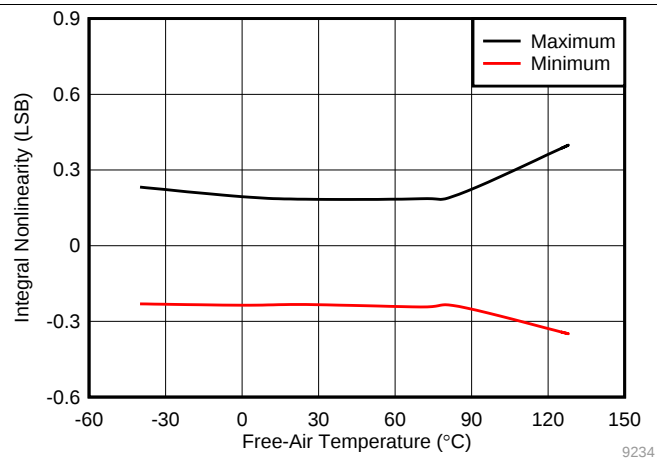


Figure 35. INL vs Temperature

## 7 Detailed Description

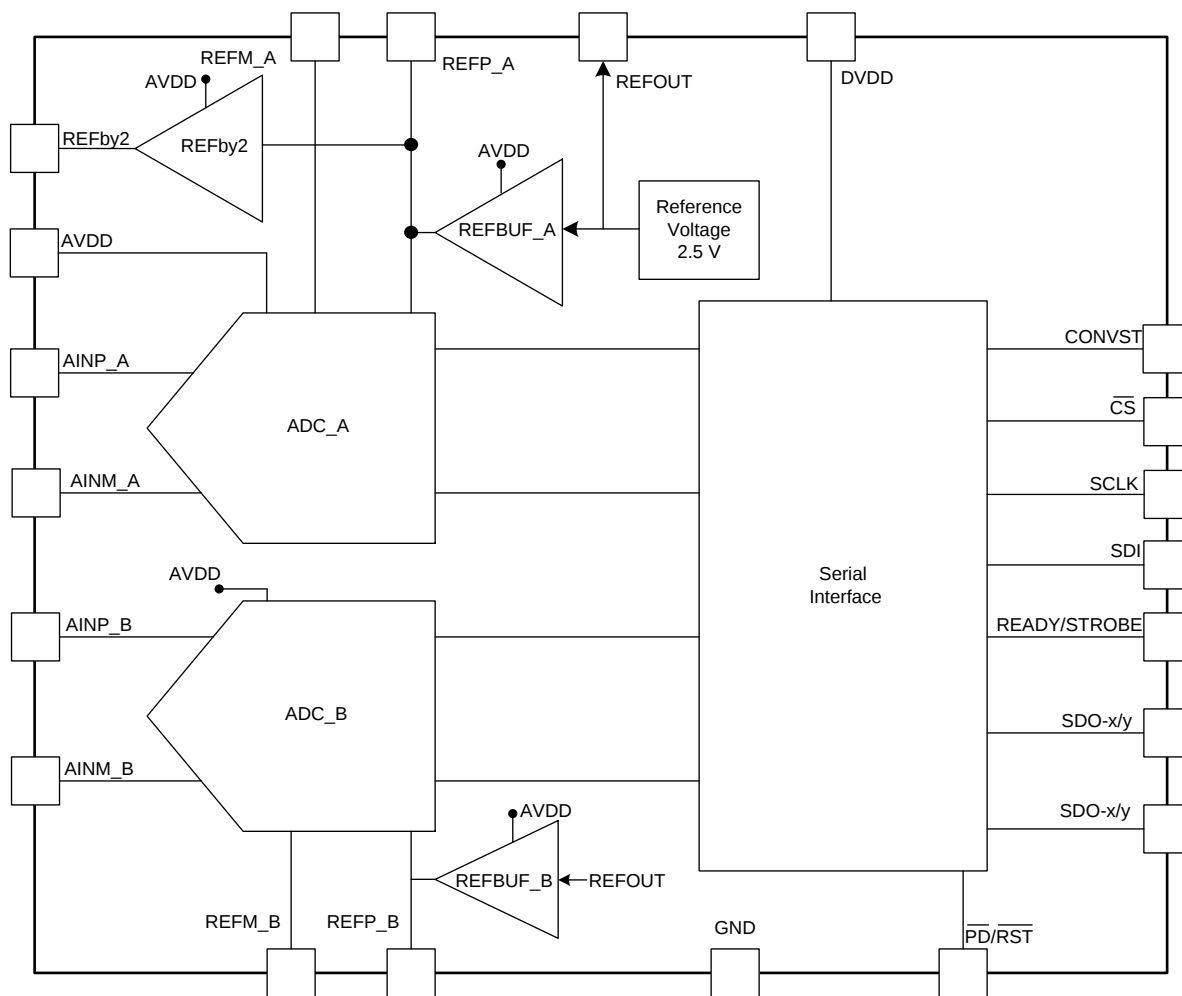
### 7.1 Overview

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  $2 \times V_{REFP\_x}$ .

When a conversion is initiated, the difference voltage 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 sampling capacitors. 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 has internal reference and 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 (eSPI) digital interface is backward-compatible with traditional SPI protocols. eSPI 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 ensure data integrity when data are transferred 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

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 [Figure 36](#), both converter modules sample the analog input signal, 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 module receives the PD/RST and CONVST inputs from the interface module, and output the ADCST signal and the conversion result back to the interface module.

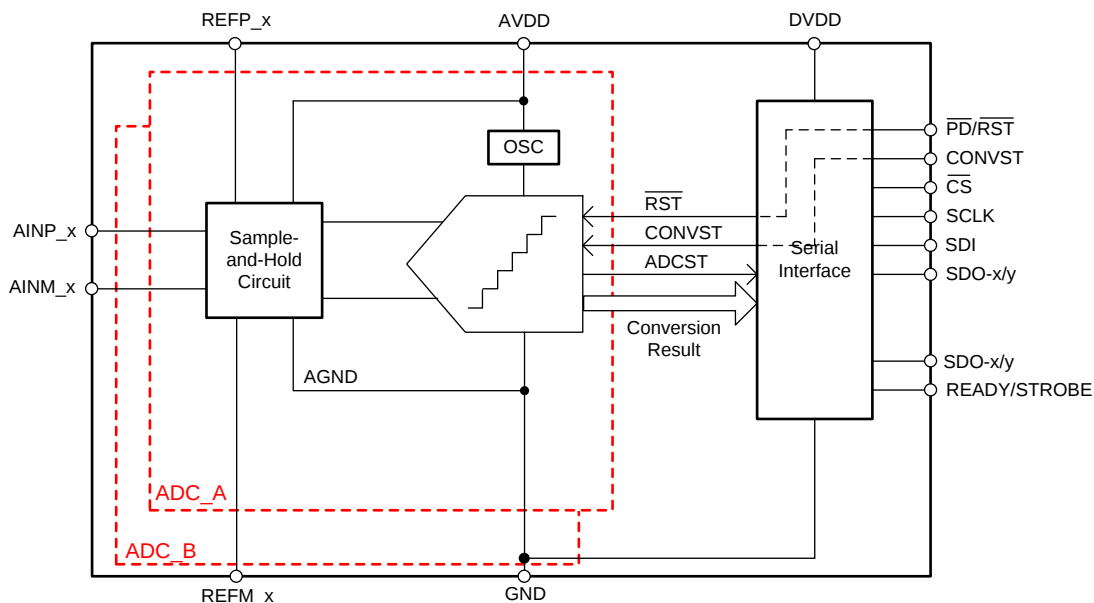


Figure 36. Converter Modules

#### 7.3.1.1 Analog Input With Sample-and-Hold

This device supports unipolar, fully differential, analog input signals. [Figure 37](#) 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  $\Omega$ ) in series with an ideal switch ( $SW_1$  and  $SW_2$ ). The sampling capacitors,  $C_{S1}$  and  $C_{S2}$ , are typically 16 pF.

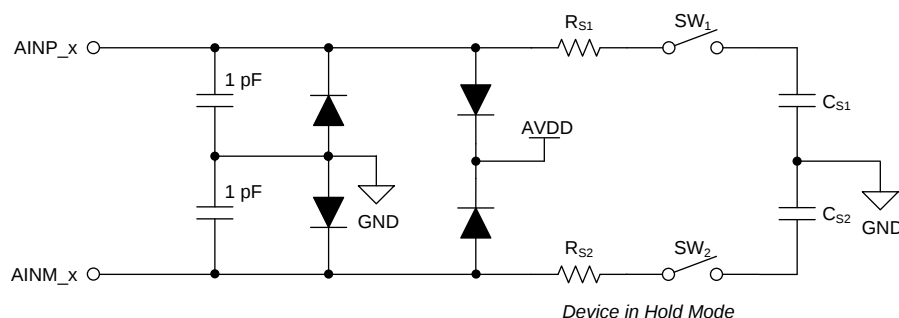


Figure 37. Analog Input Structure for Converter Module

## Feature Description (continued)

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:  $V_{AINP\_x} - V_{AINM\_x}$ .

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

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

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

### 7.3.1.2 ADC Transfer Function

The device output is in two's complement format. Table 1 and Figure 38 show the ideal transfer characteristics for the device. Equation 3 gives the least significant bit (LSB) for the ADC.

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

where

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

(3)

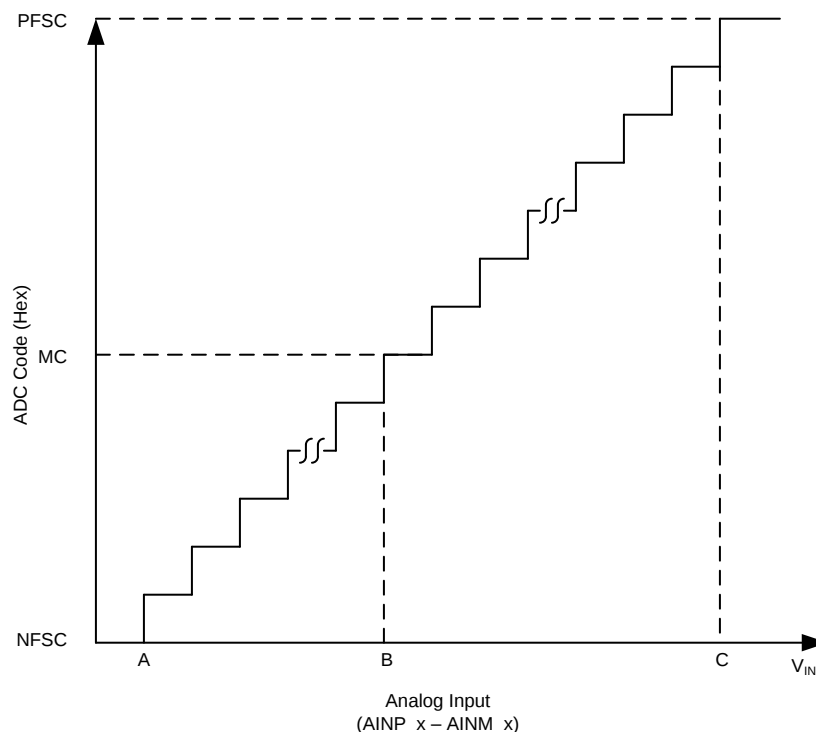


Figure 38. Ideal Transfer Characteristics

Table 1. Transfer Characteristics

| STEP | INPUT VOLTAGE<br>( $A_{INP\_x} - A_{INM\_x}$ )     | CODE | DESCRIPTION              | IDEAL OUTPUT CODE<br>(R = 16) | IDEAL OUTPUT CODE<br>(R = 14) |
|------|----------------------------------------------------|------|--------------------------|-------------------------------|-------------------------------|
| A    | $\leq -(1.6384 \times V_{REFOUT} - 1 \text{ LSB})$ | NFSC | Negative full-scale code | 8000                          | 2000                          |
| B    | 0 LSB to 1 LSB                                     | MC   | Mid code                 | 0000                          | 0000                          |
| C    | $\geq (1.6384 \times V_{REFOUT} - 1 \text{ LSB})$  | 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 ADC internal reference voltage is brought out on the REFOUT pin. A 1- $\mu$ F decoupling capacitor ( $C_{REFOUT}$ ), as shown in Figure 39, 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.

All performance characteristics of the device are specified with the internal reference buffer and a specified value of  $C_{REFP\_x}$ . As shown in Figure 39, place a decoupling capacitor  $C_{REFP\_x}$  between the REFP\_x and REFM\_x pins as close to the device as possible.

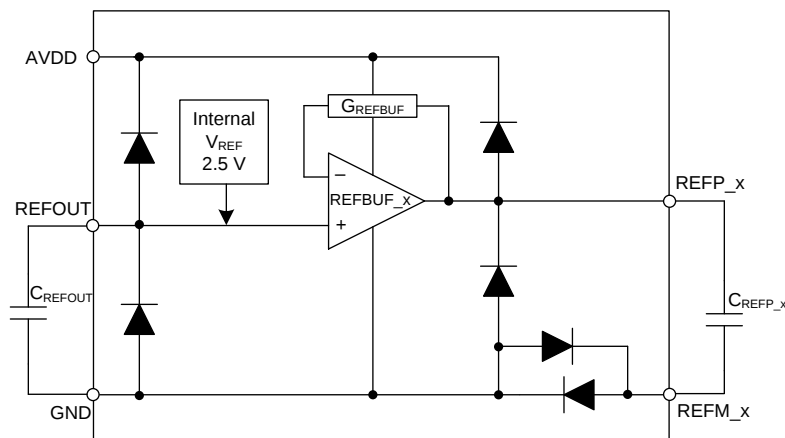


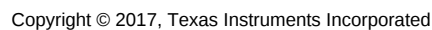
Figure 39. Connection Diagram for Reference and Reference Buffers

### 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  $V_{REFP\_x} = G_{REFBUF} \times V_{REFOUT}$ .

### 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 used to drive the  $V_{OCM}$  common-mode input 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](#). Figure 40 depicts a block diagram for the REFby2 buffer.



### 7.3.5 Data Averaging

#### 7.3.5.1 Averaging of Two Samples

The diagram illustrates the timing relationships for the AD7715 across four samples: Sample 'N', Sample 'N+1', Sample 'N+2', and Sample 'N+3'. The signals shown are:

- CONVST**: A periodic pulse train. The period between the start of one pulse and the next is  $t_{\text{cycle}}$ . The pulse width is  $t_{\text{WL\_CONVST}}$ .
- READY/STROBE**: A signal that transitions from low to high at the start of Sample 'N+1' and returns to low at the start of Sample 'N+2'. The pulse width is  $t_{\text{RDY}}$ .
- CS**: A signal that transitions from high to low at the start of Sample 'N+1' and returns to high at the start of Sample 'N+3'. The pulse width is  $t_{\text{READ}}$ .
- SCLK**: A periodic clock signal.
- SDO-xx**: The output data bus, which is shown as a single continuous pulse spanning from the start of Sample 'N' to the start of Sample 'N+1'. This indicates that the output data is valid for the duration of one sample period.

At the bottom, the output data is defined as:

$$\text{Output Data} = [\text{Sample 'N'} + \text{Sample 'N+1'}]/2$$

25

### 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  $t_{\text{CYCLE}}$  (see  $t_{\text{CYCLE}}$  for a zone 2 transfer in the [Specifications](#) section) on the CONVST pin. The device sets the READY pin high after a time of  $t_{\text{DRDY}}$  (see  $t_{\text{DRDY}}$  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  $t_{\text{READ}} < [4 \times t_{\text{CYCLE}}]$ . [Figure 42](#) provides the timing for the averaging of four samples.

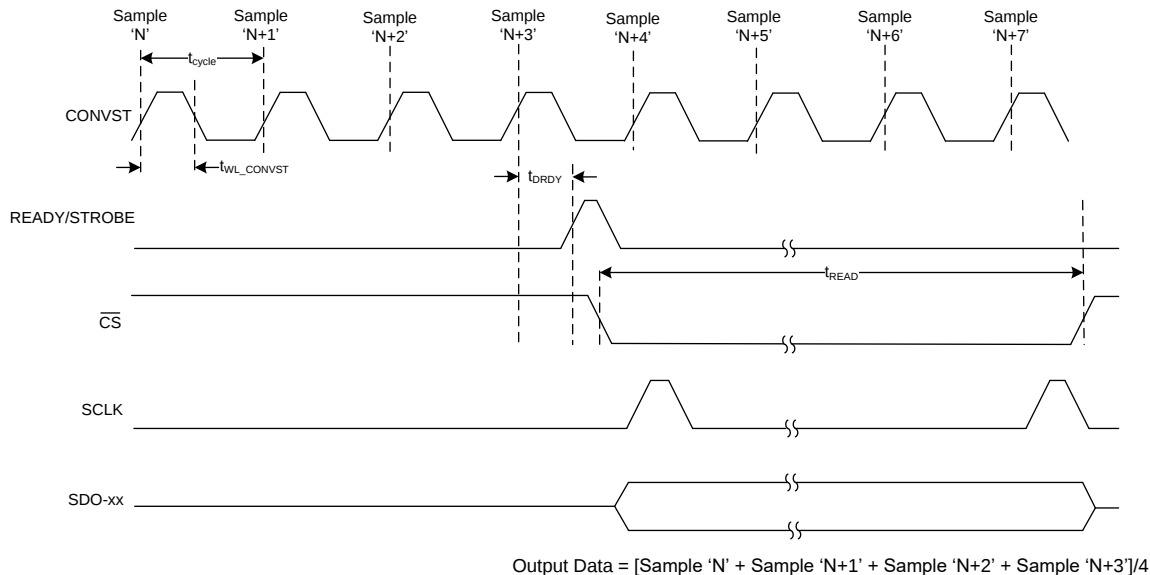


Figure 42. Timing for Averaging of Four Samples

## 7.4 Device Functional Modes

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 PD/RST control signals provided by the host controller.

### 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 PD/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.

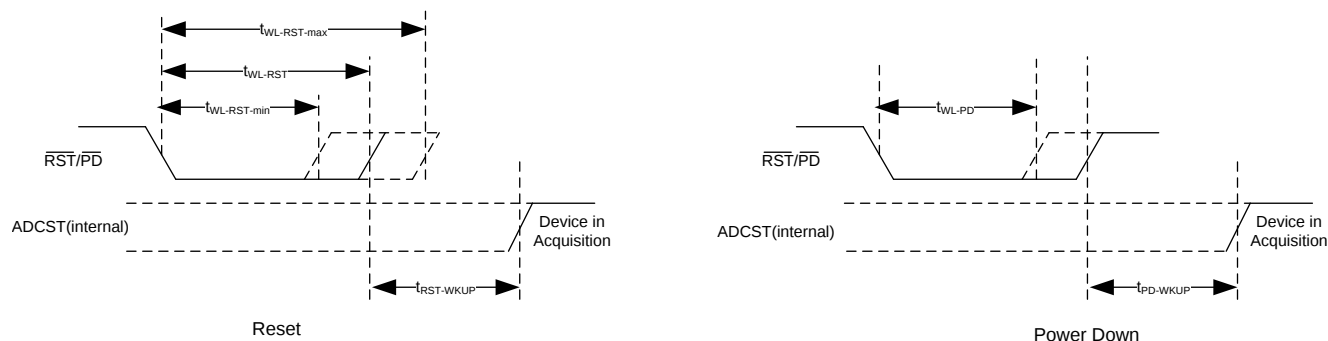
### 7.4.2 CNV State

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  $t_{\text{CYCLE}}$  between two subsequent start of conversions.

### 7.4.3 Reset or Power-Down

The PD/RST pin is an asynchronous digital input for the device. The pulse duration (low) on the PD/RST pin decides the state for the device (reset or power-down). [Figure 43](#) 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.

## Device Functional Modes (continued)



**Figure 43. Reset or Power Down**

### 7.4.3.1 Reset

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

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.

After a delay of  $t_{RST-WKUP}$ , the device enters ACQ state.

### 7.4.3.2 Power-Down

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

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  $\overline{PD}/\overline{RST}$  pin high. After a delay of  $t_{PD-WKUP}$ , the device powers up and enters ACQ state.

## Device Functional Modes (continued)

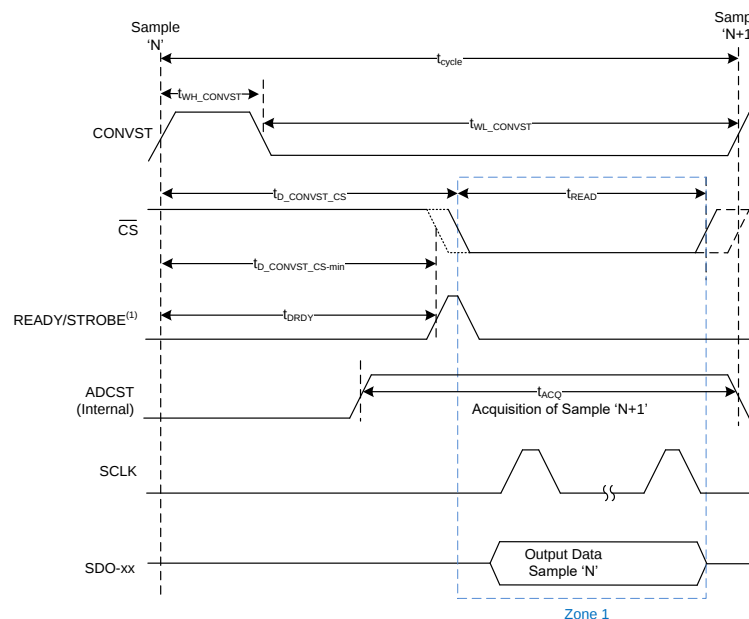
### 7.4.4 Conversion Control and Data Transfer Frame

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 Figure 44, the host must pull  $\overline{CS}$  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  $\overline{CS}$ .

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  $\overline{CS}$  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. 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  $t_{CYCLE} = t_{DRDY} + t_{READ}$ .



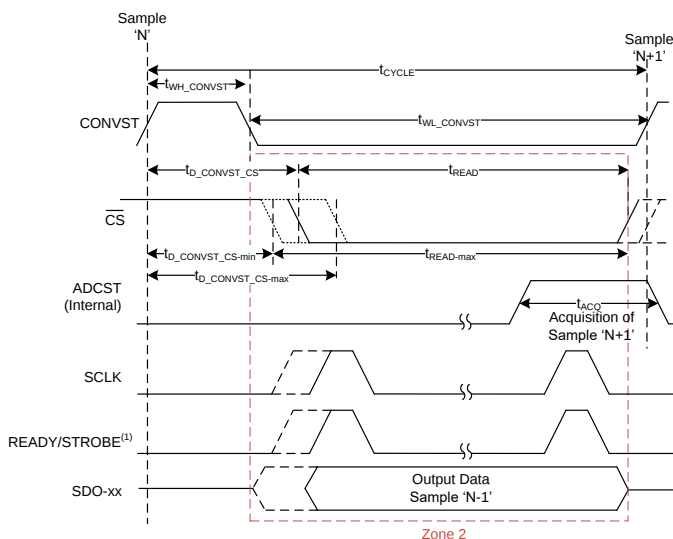
- (1) The READY output is required for data transfer with zero cycle latency. The STROBE output is required only for clock re-timer (CRT) protocols. See the [READY/STROBE Output](#) section for details.
- (2) For  $t_{READ}$  with different data transfer protocols; see the [Protocols for Reading From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

**Figure 44. Conversion Control and Data Transfer Frame With Zero Cycle Latency (Zone 1 Transfer)**

## Device Functional Modes (continued)

### 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 CS low and provide clocks on the SCLK pin to read the data in zone 2. As shown in [Figure 45](#), 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 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. 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)  $f_{Sample} = 1 / t_{cycle}$ .

**Figure 45. Conversion Control and Data Transfer Frame With Wide Read Cycle (Zone 2 Transfer)**

#### NOTE

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 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 44](#)), 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 edge 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.

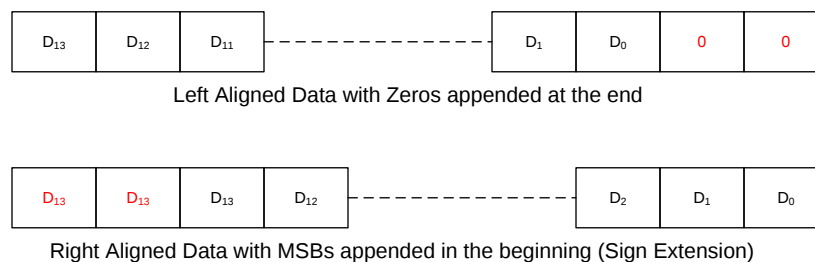
**Table 2. Output Data Word**

| DEVICE   | RESOLUTION OF DEVICE (R) | WIDTH OF OUTPUT DATA WORD (N) | CONTENT OF OUTPUT DATA WORD <sup>(1)(2)</sup> | 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    | $D_{N-1}$ (= $D_{13}$ )                      | $D_{N-3}$ (= $D_{13}$ )                       |

(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 46](#) shows the data alignment in the data output word.



**Figure 46. 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. [Table 3](#) provides the details of different legacy SPI protocols to read data from the device.

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

| PROTOCOL <sup>(1)</sup> | SCLK POLARITY (CPOL <sup>(2)</sup> ) | SCLK PHASE (CPHA <sup>(2)</sup> ) <sup>(3)(4)</sup> | MSB LAUNCH EDGE              | BUS WIDTH | t <sub>READ</sub> <sup>(5)(6)</sup> | TIMING DIAGRAM            |
|-------------------------|--------------------------------------|-----------------------------------------------------|------------------------------|-----------|-------------------------------------|---------------------------|
| SPI-00-S-SDR            | Low (CPOL = 0)                       | Rising (CPHA = 0)                                   | $\overline{CS}$ falling      | 1         | $[15.5 \times t_{CLK} + k]$         | <a href="#">Figure 47</a> |
| SPI-01-S-SDR            | Low (CPOL = 0)                       | Falling (CPHA = 1)                                  | 1 <sup>st</sup> SCLK rising  | 1         | $[15.5 \times t_{CLK} + k]$         | <a href="#">Figure 48</a> |
| SPI-10-S-SDR            | High (CPOL = 1)                      | Falling (CPHA = 0)                                  | $\overline{CS}$ falling      | 1         | $[15.5 \times t_{CLK} + k]$         | <a href="#">Figure 47</a> |
| SPI-11-S-SDR            | High (CPOL = 1)                      | Rising (CPHA = 1)                                   | 1 <sup>st</sup> SCLK falling | 1         | $[15.5 \times t_{CLK} + k]$         | <a href="#">Figure 48</a> |

(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.

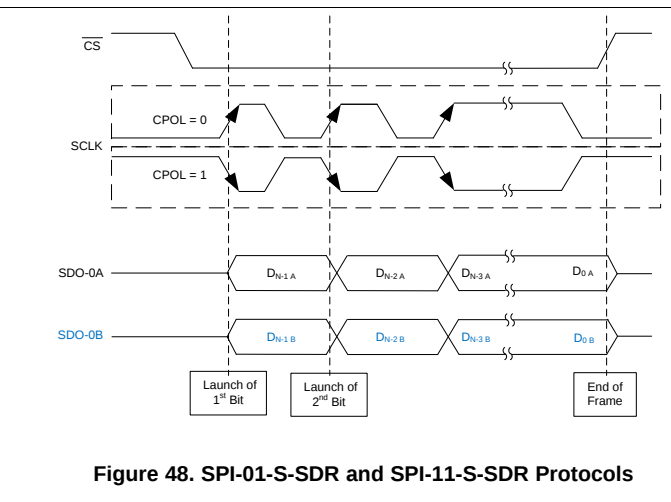
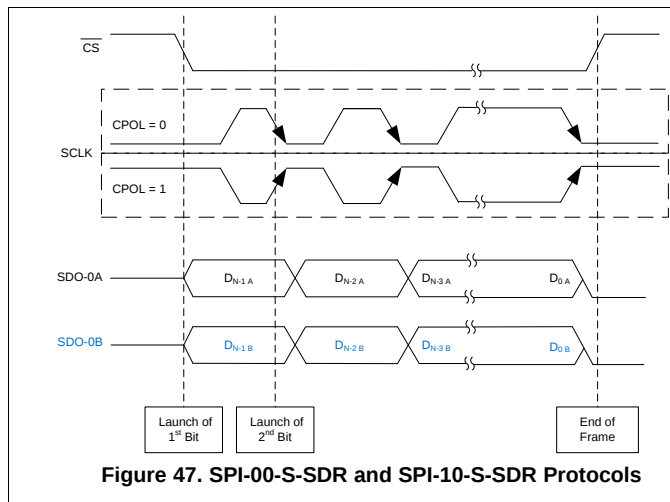
(3) With SCLK  $\geq$  30 MHz, TI recommends data capture on the launch edge for the next bit.

(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<sub>READ</sub> 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  $[13.5 \times t_{CLK} + k]$ .

Figure 47 and Figure 48 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)

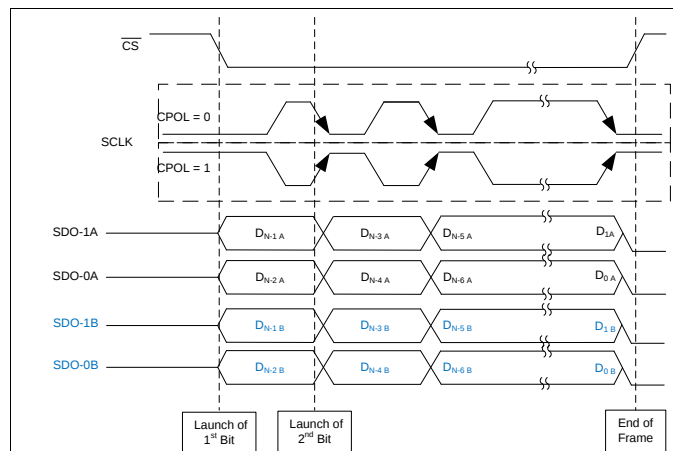
In this data transfer protocol, the bus width of reading data from each ADC can be increased to two SDOs or four SDOs. All combinations of clock phase and polarity are supported. The read time required for reading the output data word reduces with increases in bus width and, thus,  $t_{\text{CYCLE}}$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

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

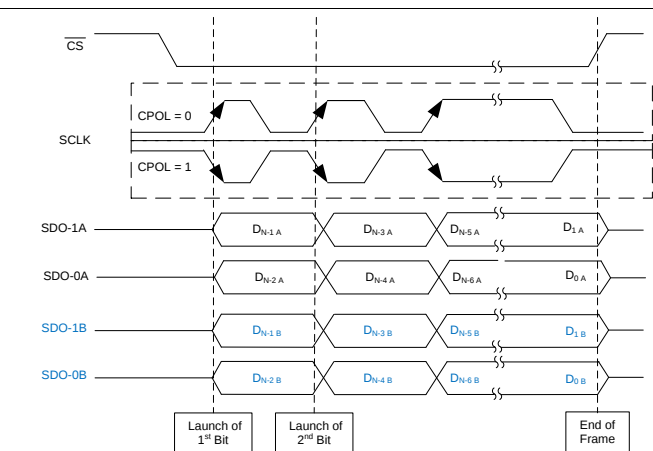
| PROTOCOL <sup>(1)</sup> | SCLK POLARITY (CPOL) <sup>(2)</sup> | SCLK PHASE (CPHA) <sup>(3)(4)</sup> | MSB LAUNCH EDGE                | BUS WIDTH <sup>(5)</sup> | $t_{\text{READ}}$ <sup>(6)(7)</sup> | TIMING DIAGRAM            |
|-------------------------|-------------------------------------|-------------------------------------|--------------------------------|--------------------------|-------------------------------------|---------------------------|
| SPI-00-D-SDR            | Low (CPOL = 0)                      | Rising (CPHA = 0)                   | $\overline{\text{CS}}$ falling | 2                        | $[7.5 \times t_{\text{CLK}} + k]$   | <a href="#">Figure 49</a> |
| SPI-01-D-SDR            | Low (CPOL = 0)                      | Falling (CPHA = 1)                  | 1 <sup>st</sup> SCLK rising    | 2                        | $[7.5 \times t_{\text{CLK}} + k]$   | <a href="#">Figure 50</a> |
| SPI-10-D-SDR            | High (CPOL = 1)                     | Falling (CPHA = 0)                  | $\overline{\text{CS}}$ falling | 2                        | $[7.5 \times t_{\text{CLK}} + k]$   | <a href="#">Figure 49</a> |
| SPI-11-D-SDR            | High (CPOL = 1)                     | Rising (CPHA = 1)                   | 1 <sup>st</sup> SCLK falling   | 2                        | $[7.5 \times t_{\text{CLK}} + k]$   | <a href="#">Figure 50</a> |
| SPI-00-Q-SDR            | Low (CPOL = 0)                      | Rising (CPHA = 0)                   | $\overline{\text{CS}}$ falling | 4                        | $[3.5 \times t_{\text{CLK}} + k]$   | <a href="#">Figure 51</a> |
| SPI-01-D-SDR            | Low (CPOL = 0)                      | Falling (CPHA = 1)                  | 1 <sup>st</sup> SCLK rising    | 4                        | $[3.5 \times t_{\text{CLK}} + k]$   | <a href="#">Figure 52</a> |
| SPI-10-D-SDR            | High (CPOL = 1)                     | Falling (CPHA = 0)                  | $\overline{\text{CS}}$ falling | 4                        | $[3.5 \times t_{\text{CLK}} + k]$   | <a href="#">Figure 51</a> |
| SPI-11-D-SDR            | High (CPOL = 1)                     | Rising (CPHA = 1)                   | 1 <sup>st</sup> SCLK falling   | 4                        | $[3.5 \times t_{\text{CLK}} + k]$   | <a href="#">Figure 52</a> |

- (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  $\geq 30$  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)  $t_{\text{READ}}$  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.

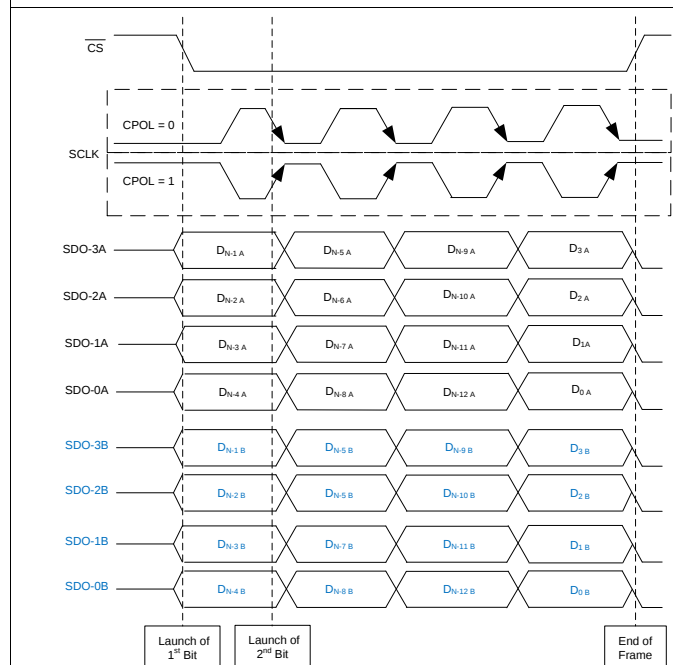
Figure 49, Figure 50, Figure 51, and Figure 52 show timing diagrams for the SPI-00-D-SDR and SPI-10-D-SDR, SPI-01-D-SDR and SPI-11-D-SDR, SPI-00-Q-SDR and SPI-10-Q-SDR, and SPI-01-Q-SDR and SPI-11-Q-SDR protocols, respectively.



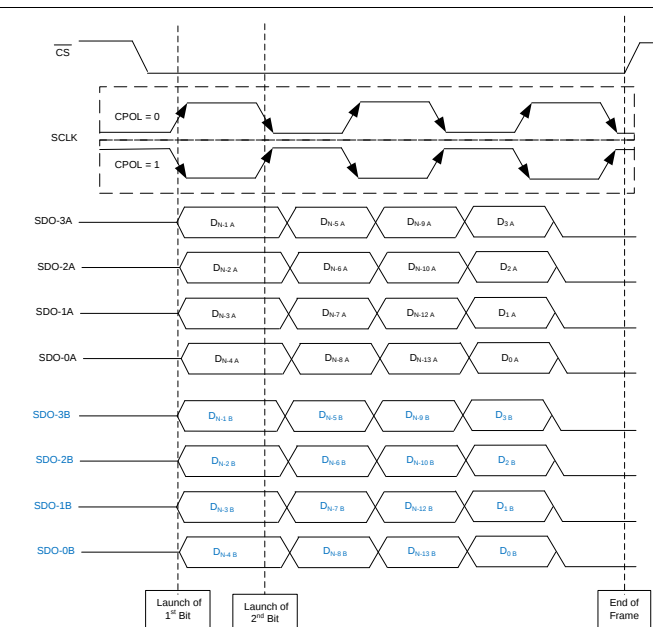
**Figure 49. SPI-00-D-SDR and SPI-10-D-SDR Protocols**



**Figure 50. SPI-01-D-SDR and SPI-11-D-SDR Protocols**



**Figure 51. SPI-00-Q-SDR and SPI-10-Q-SDR Protocols**



**Figure 52. 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)

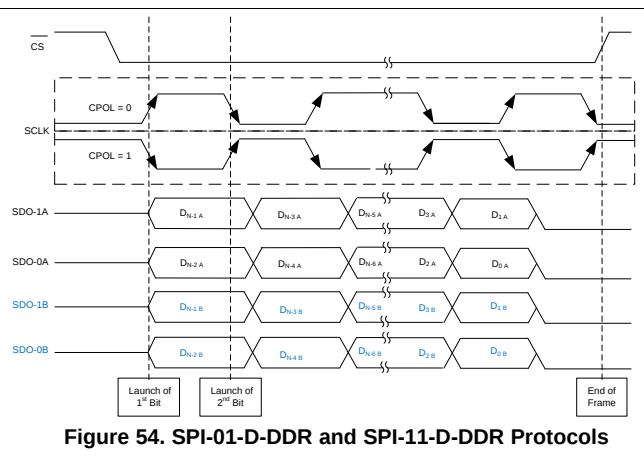
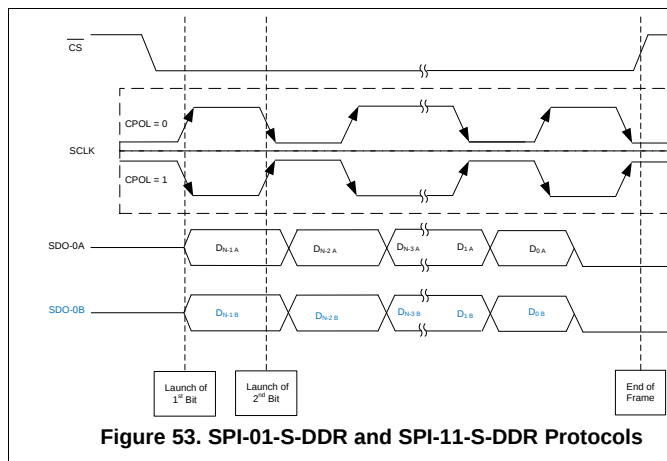
In this data transfer protocol, the data rate for data transfer can be increased to double data rate. With double data rate, the device launches data on both edges (rising and falling) of the SCLK. The device supports both polarities of the clock and only one phase of clock (CPHA = 1). The read time 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. [Table 5](#) provides the details of different SPI protocols with bus width options and double data rate to read data from the device.

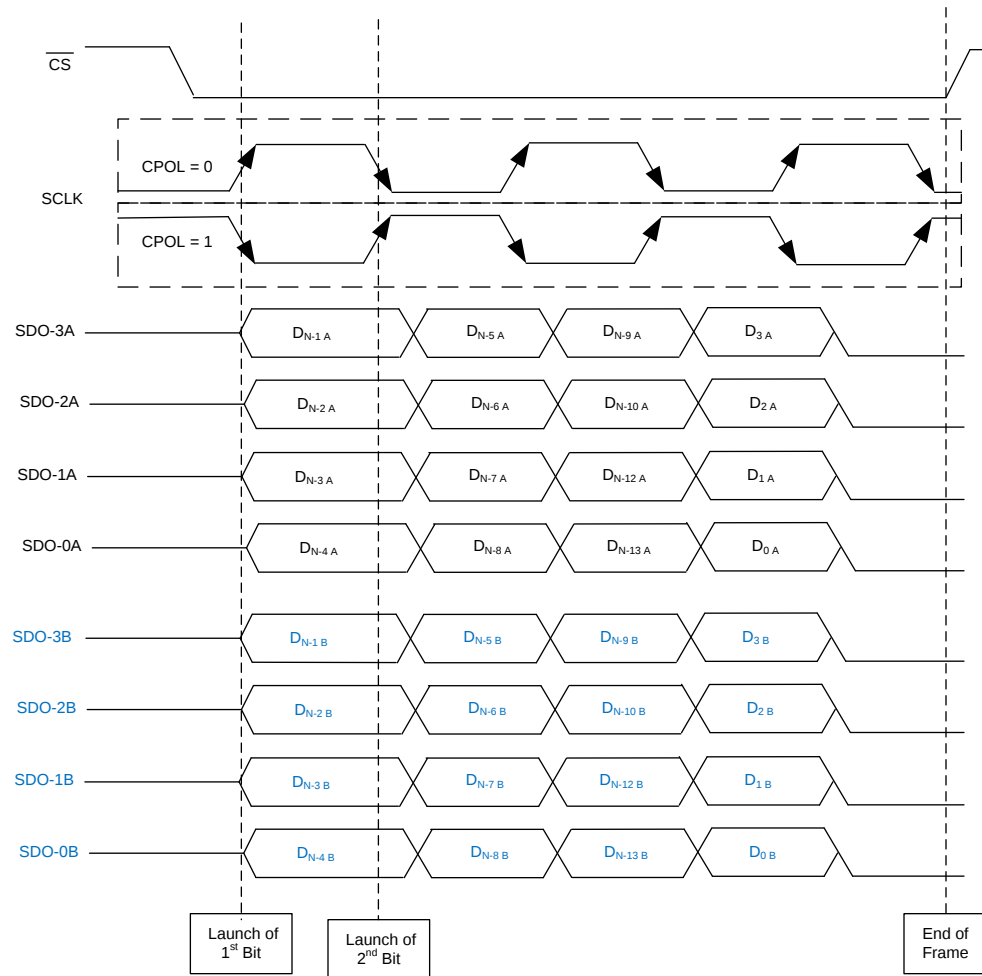
**Table 5. SPI-x1-S-DDR, SPI-x1-D-DDR, and SPI-x1-Q-DDR Protocols for Reading From Device**

| PROTOCOL <sup>(1)</sup> | SCLK POLARITY (CPOL) <sup>(2)</sup> | SCLK PHASE <sup>(2)</sup> | MSB LAUNCH EDGE              | BUS WIDTH <sup>(3)</sup> | t <sub>READ</sub> <sup>(4)(5)</sup> | TIMING DIAGRAM            |
|-------------------------|-------------------------------------|---------------------------|------------------------------|--------------------------|-------------------------------------|---------------------------|
| SPI-01-S-DDR            | Low (CPOL = 0)                      | Falling (CPHA = 1)        | 1 <sup>st</sup> SCLK rising  | 1                        | [9 × t <sub>CLK</sub> + k]          | <a href="#">Figure 53</a> |
| SPI-11-S-DDR            | High (CPOL = 1)                     | Rising (CPHA = 1)         | 1 <sup>st</sup> SCLK falling | 1                        | [9 × t <sub>CLK</sub> + k]          | <a href="#">Figure 53</a> |
| SPI-01-D-DDR            | Low (CPOL = 0)                      | Falling (CPHA = 1)        | 1 <sup>st</sup> SCLK rising  | 2                        | [5 × t <sub>CLK</sub> + k]          | <a href="#">Figure 54</a> |
| SPI-11-D-DDR            | High (CPOL = 1)                     | Rising (CPHA = 1)         | 1 <sup>st</sup> SCLK falling | 2                        | [5 × t <sub>CLK</sub> + k]          | <a href="#">Figure 54</a> |
| SPI-01-Q-DDR            | Low (CPOL = 0)                      | Falling (CPHA = 1)        | 1 <sup>st</sup> SCLK rising  | 4                        | [3 × t <sub>CLK</sub> + k]          | <a href="#">Figure 55</a> |
| SPI-11-Q-DDR            | High (CPOL = 1)                     | Rising (CPHA = 1)         | 1 <sup>st</sup> SCLK falling | 4                        | [3 × t <sub>CLK</sub> + k]          | <a href="#">Figure 55</a> |

- (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<sub>READ</sub> is the read time for reading the 16-bit output data word. k = (t<sub>SU\_CSCSK</sub> + t<sub>HT\_CKCS</sub>).
- (5) For ADS9234R devices, the read time for reading the 14-bit output data word is [7.5 × t<sub>CLK</sub> + k] for a bus width of 1, [3.5 × t<sub>CLK</sub> + k] for a bus width of 2, and [3 × t<sub>CLK</sub> + k] for a bus width of 4.

[Figure 53](#), [Figure 54](#), and [Figure 55](#) 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.





**Figure 55. 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)

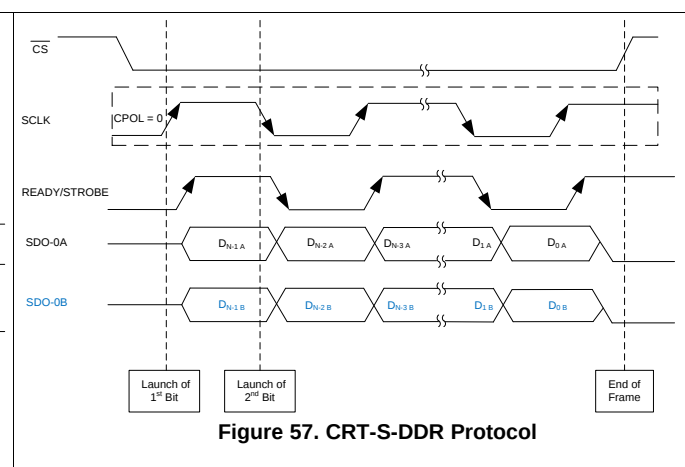
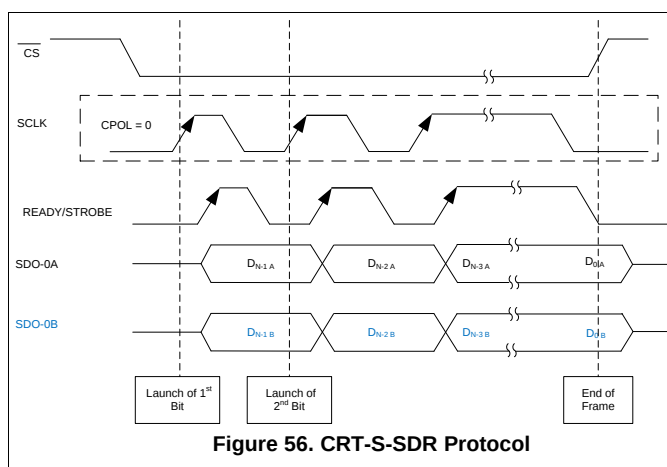
In clock re-timer (CRT) protocols, the device sends out data on the SDO lines with a synchronized clock on the STROBE line. The data are synchronized to the rising edges of the STROBE pulses. For CRT protocols with a single data rate, the host can capture data on the falling edges of the STROBE pulses. 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. [Table 6](#) provides the details of different CRT protocols to read data from the device.

**Table 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 <sup>(1)</sup> | SCLK POLARITY <sup>(2)</sup> | CAPTURE EDGE              | MSB LAUNCH EDGE               | BUS WIDTH <sup>(3)</sup> | t <sub>READ</sub> <sup>(4)</sup> | TIMING DIAGRAM            |
|-------------------------|------------------------------|---------------------------|-------------------------------|--------------------------|----------------------------------|---------------------------|
| CRT-S-SDR               | Low (CPOL = 0)               | STROBE falling            | 1 <sup>st</sup> STROBE rising | 1                        | [15.5 × t <sub>STROBE</sub> + m] | <a href="#">Figure 56</a> |
| CRT-D-SDR               | Low (CPOL = 0)               | STROBE falling            | 1 <sup>st</sup> STROBE rising | 2                        | [7.5 × t <sub>STROBE</sub> + m]  | <a href="#">Figure 58</a> |
| CRT-Q-SDR               | Low (CPOL = 0)               | STROBE falling            | 1 <sup>st</sup> STROBE rising | 4                        | [3.5 × t <sub>STROBE</sub> + m]  | <a href="#">Figure 60</a> |
| CRT-S-DDR               | Low (CPOL = 0)               | STROBE rising and falling | 1 <sup>st</sup> STROBE rising | 1                        | [7.5 × t <sub>STROBE</sub> + m]  | <a href="#">Figure 57</a> |
| CRT-D-DDR               | Low (CPOL = 0)               | STROBE rising and falling | 1 <sup>st</sup> STROBE rising | 2                        | [3.5 × t <sub>STROBE</sub> + m]  | <a href="#">Figure 59</a> |
| CRT-Q-DDR               | Low (CPOL = 0)               | STROBE rising and falling | 1 <sup>st</sup> STROBE rising | 4                        | [1.5 × t <sub>STROBE</sub> + m]  | <a href="#">Figure 61</a> |

- (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<sub>READ</sub> is the read time for reading the 16-bit output data word. For an external clock m = (t<sub>SU\_CSCK</sub> + t<sub>HT\_CKCS</sub>), and for an internal clock m = t<sub>D\_CS\_STROBE</sub>.

[Figure 56](#) through [Figure 61](#) 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.



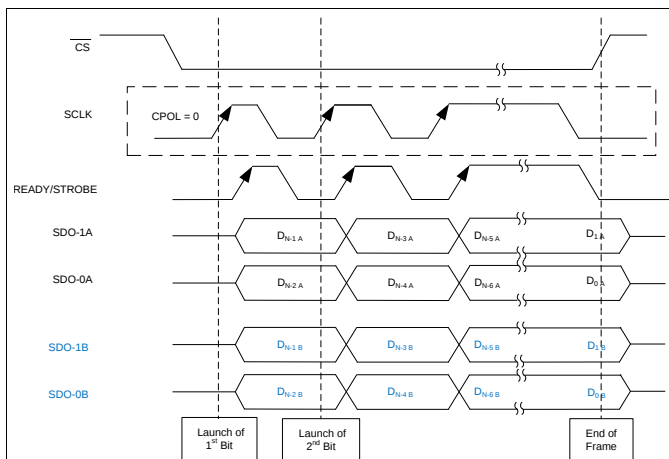


Figure 58. CRT-D-SDR Protocol

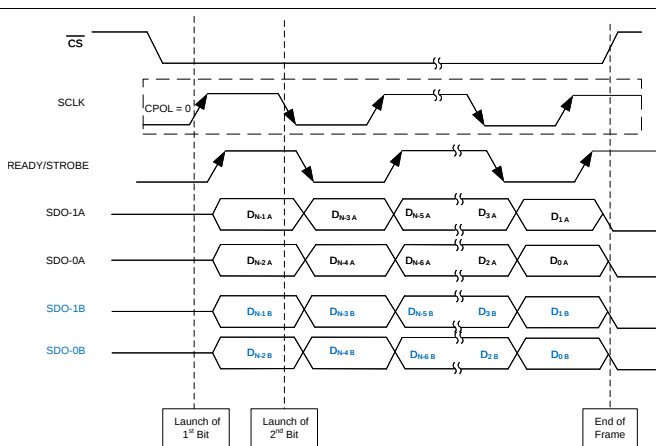


Figure 59. CRT-D-DDR Protocol

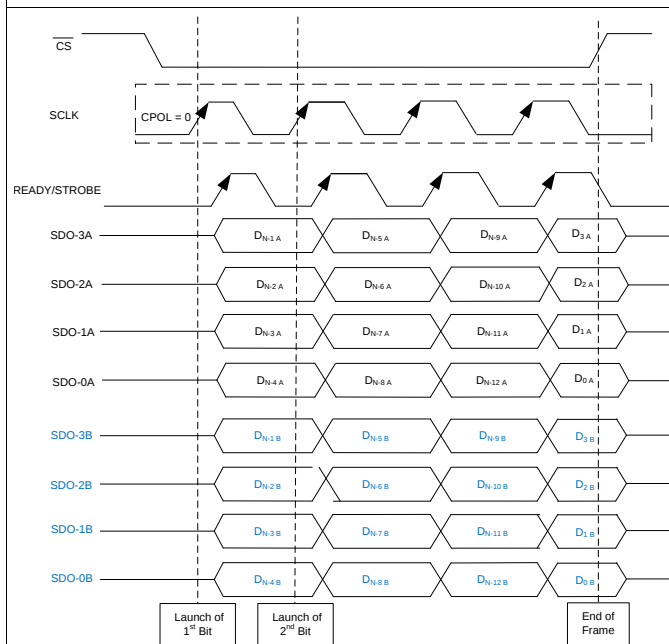


Figure 60. CRT-Q-SDR Protocol

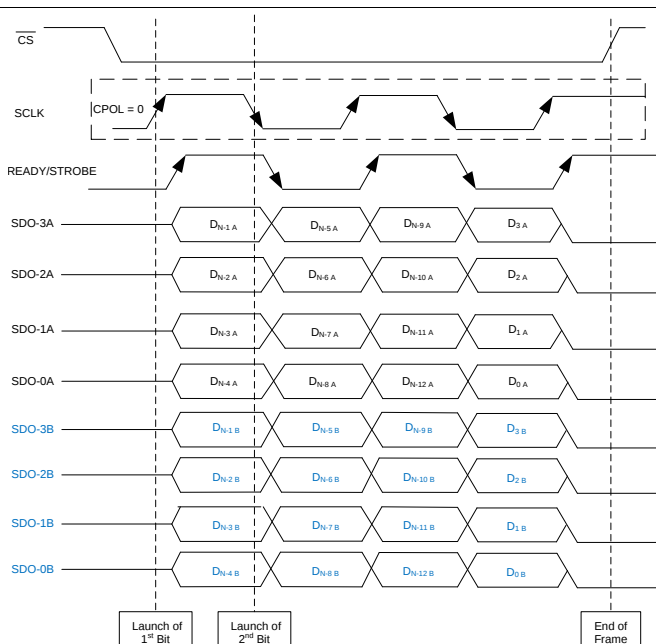


Figure 61. CRT-Q-DDR Protocol

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)

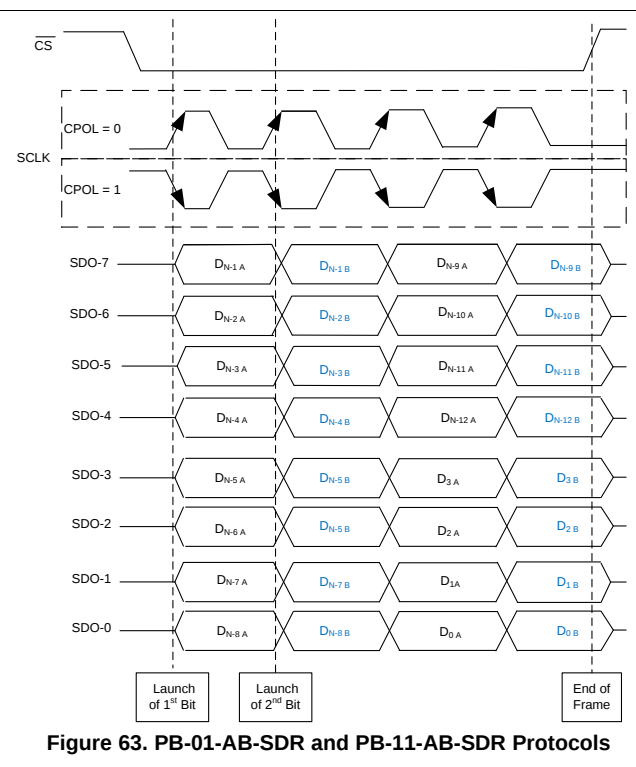
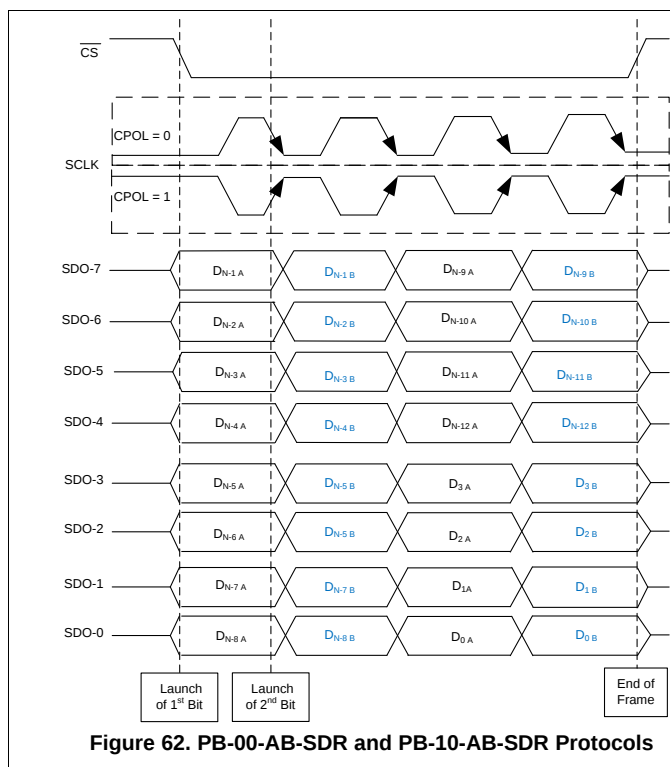
In parallel byte protocols, the device sends out data from each ADC on all SDO lines in a byte format. The device supports all combinations of CPOL and CPHA in these protocols. The format of the data byte for these protocols can be set by the `PARALLEL_MODE_DATA_FORMAT` bits in the [OUTPUT\\_DATA\\_WORD\\_CFG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

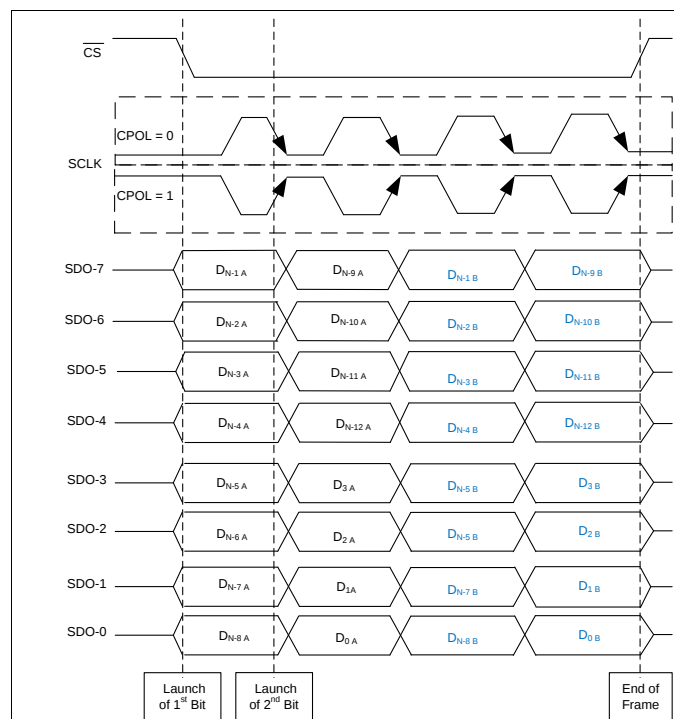
**Table 7. PB-xy-AB-SDR, PB-xy-AA-SDR Protocols for Reading Data**

| PROTOCOL <sup>(1)</sup> | SCLK POLARITY (CPOL) <sup>(2)</sup> | SCLK PHASE (CPHA)  | MSB LAUNCH EDGE              | DATA FORMAT <sup>(3)</sup> | t <sub>READ</sub> <sup>(4)</sup> | TIMING DIAGRAM            |
|-------------------------|-------------------------------------|--------------------|------------------------------|----------------------------|----------------------------------|---------------------------|
| PB-00-AB-SDR            | Low (CPOL = 0)                      | Rising (CPHA = 0)  | $\overline{CS}$ falling      | AB                         | $[3.5 \times t_{CLK} + k]$       | <a href="#">Figure 62</a> |
| PB-01-AB-SDR            | Low (CPOL = 0)                      | Falling (CPHA = 1) | 1 <sup>st</sup> SCLK rising  | AB                         | $[3.5 \times t_{CLK} + k]$       | <a href="#">Figure 63</a> |
| PB-10-AB-SDR            | High (CPOL = 1)                     | Falling (CPHA = 1) | $\overline{CS}$ falling      | AB                         | $[3.5 \times t_{CLK} + k]$       | <a href="#">Figure 62</a> |
| PB-11-AB-SDR            | High (CPOL = 1)                     | Rising (CPHA = 0)  | 1 <sup>st</sup> SCLK falling | AB                         | $[3.5 \times t_{CLK} + k]$       | <a href="#">Figure 63</a> |
| PB-00-AA-SDR            | Low (CPOL = 0)                      | Rising (CPHA = 0)  | $\overline{CS}$ falling      | AA                         | $[3.5 \times t_{CLK} + k]$       | <a href="#">Figure 64</a> |
| PB-01-AA-SDR            | Low (CPOL = 0)                      | Falling (CPHA = 1) | 1 <sup>st</sup> SCLK rising  | AA                         | $[3.5 \times t_{CLK} + k]$       | <a href="#">Figure 65</a> |
| PB-10-AA-SDR            | High (CPOL = 1)                     | Falling (CPHA = 1) | $\overline{CS}$ falling      | AA                         | $[3.5 \times t_{CLK} + k]$       | <a href="#">Figure 64</a> |
| PB-11-AA-SDR            | High (CPOL = 1)                     | Rising (CPHA = 0)  | 1 <sup>st</sup> SCLK falling | AA                         | $[3.5 \times t_{CLK} + k]$       | <a href="#">Figure 65</a> |

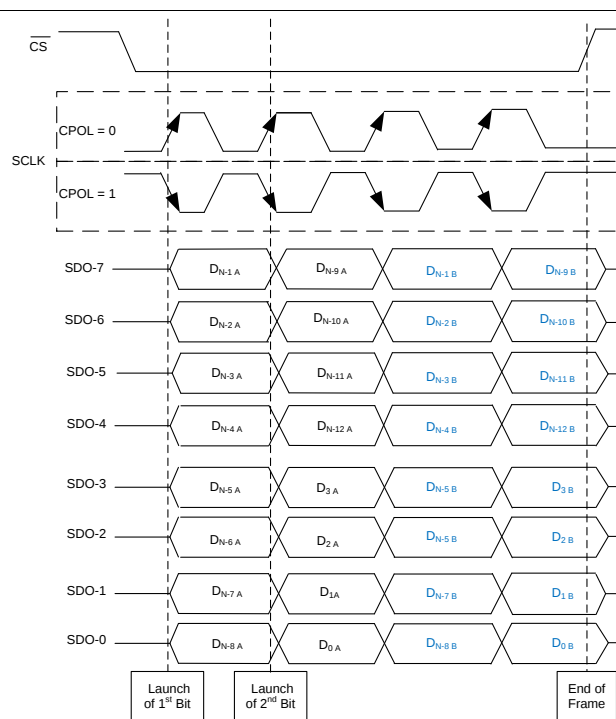
- (1) For parallel byte protocols, set the SDO\_PROTOCOL bits in the [PROTOCOL\\_CFG register](#) to 1xxb.
- (2) Configure the SPI\_CPOL and SPI\_CPHA bits in the [PROTOCOL\\_CFG register](#) for the desired CPOL and CPHA.
- (3) For selecting the data format for parallel byte protocols, configure the `PARALLEL_MODE_DATA_FORMAT` bits in the [OUTPUT\\_DATA\\_WORD\\_CFG register](#).
- (4) t<sub>READ</sub> is the read time for reading the 16-bit output data word.  $k = (t_{SU\_CSCS} + t_{HT\_CKCS})$ .

[Figure 62](#), [Figure 63](#), [Figure 64](#), and [Figure 65](#) 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.





**Figure 64. PB-00-AA-SDR and PB-10-AA-SDR Protocols**



**Figure 65. PB-01-AA-SDR and PB-11-AA-SDR Protocols**

### 7.6.2.2 Device Setup

The enhanced-SPI digital interface and the device configuration registers offer multiple operation modes. This section describes how to select the hardware connection topology to meet different system requirements.

#### 7.6.2.2.1 Single Device: All Enhanced-SPI Options

Figure 66 shows the connections between a host controller and a single device in order to exercise all options provided by the enhanced-SPI digital interface.

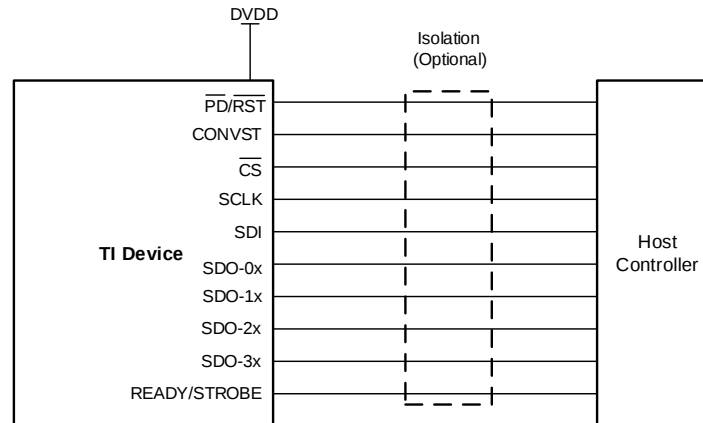


Figure 66. Enhanced-SPI Digital Interface, All Pins

#### 7.6.2.2.2 Single Device: Minimum Pins for a Standard SPI Interface

Figure 67 shows the minimum-pin interface for applications using a standard SPI protocol.

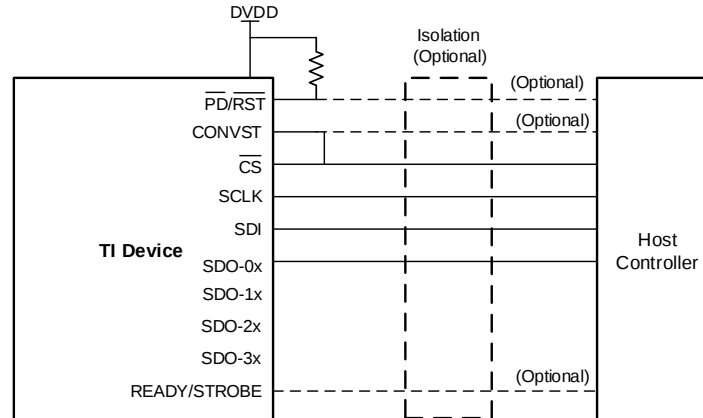


Figure 67. SPI Interface, Minimum Pins

The  $\overline{CS}$ , SCLK, SDI, and SDO-0x pins constitute a standard SPI port of the host controller. The CONVST pin is tied to  $\overline{CS}$ , and the  $\overline{PD/RST}$  pin is tied to DVDD. The SDO-1x, SDO-2x, and SDO-3x pins have no external connections. The following features are also available:

- Control the CONVST pin independently to get additional timing flexibility.
- Control  $\overline{PD/RST}$  pin independently to add asynchronous reset functionality.
- Monitor the READY/STROBE pin for additional timing benefits.

### 7.6.2.3 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 [Table 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.

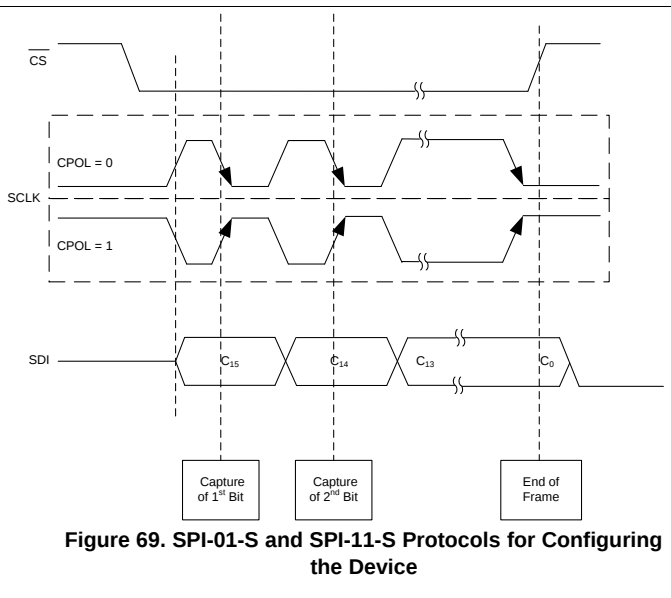
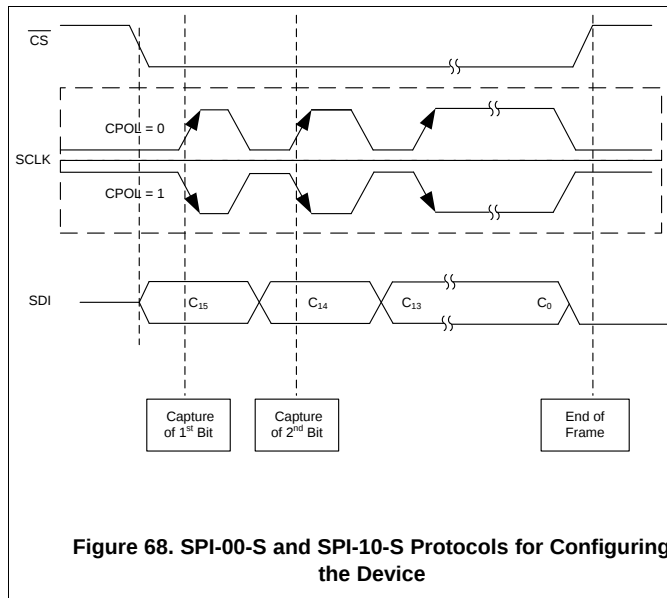
**Table 8. SPI Protocols for Configuring the Device**

| PROTOCOL | SCLK POLARITY (CPOL) <sup>(1)</sup> | SCLK PHASE (CPHA) <sup>(1)</sup> | MSB CAPTURE EDGE             | t <sub>WRITE</sub> <sup>(2)</sup> | TIMING DIAGRAM            |
|----------|-------------------------------------|----------------------------------|------------------------------|-----------------------------------|---------------------------|
| SPI-00-S | Low (CPOL= 0)                       | Rising (CPHA = 0)                | 1 <sup>st</sup> SCLK rising  | [15.5 × t <sub>CLK</sub> + k]     | <a href="#">Figure 68</a> |
| SPI-01-S | Low (CPOL= 0)                       | Falling (CPHA = 1)               | 1 <sup>st</sup> SCLK falling | [15.5 × t <sub>CLK</sub> + k]     | <a href="#">Figure 69</a> |
| SPI-10-S | High (CPOL= 1)                      | Falling (CPHA = 1)               | 1 <sup>st</sup> SCLK falling | [15.5 × t <sub>CLK</sub> + k]     | <a href="#">Figure 68</a> |
| SPI-11-S | High (CPOL= 1)                      | Rising (CPHA = 0)                | 1 <sup>st</sup> SCLK rising  | [15.5 × t <sub>CLK</sub> + k]     | <a href="#">Figure 69</a> |

(1) Configure the SPI\_CPOL and SPI\_CPHA bits in the [PROTOCOL\\_CFG register](#) for the desired CPOL and CPHA.

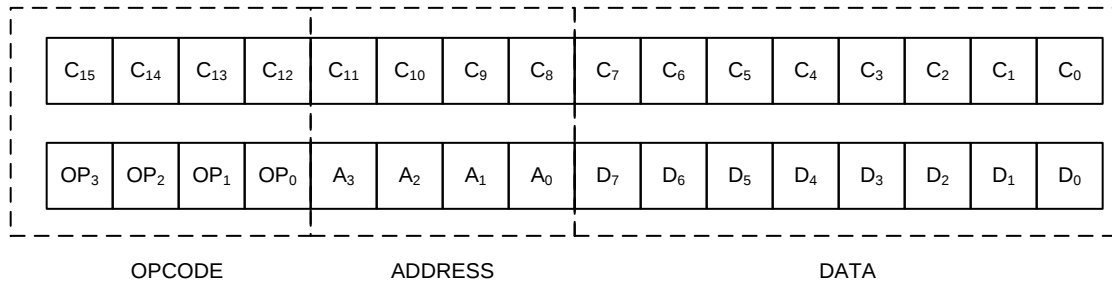
(2) t<sub>WRITE</sub> is the write time for writing the 16-bit data word. k = (t<sub>SU\_CSCS</sub> + t<sub>HT\_CKCS</sub>).

[Figure 68](#) and [Figure 69](#) 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. [Figure 70](#) shows the command frame. [Table 9](#) provides the details of commands for reading and writing registers.



**Figure 70. Command Frame C[15:0]**

**Table 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 <sup>(1)</sup> | 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                                                                                                   |
| Remain<br>ing<br>combin<br>ations | xxxxxxxx            | xxxxxxxx                                                                         | Reserved               | These commands are reserved and are treated by the device as no operation                             |

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

## 7.7 Register Maps

### 7.7.1 ADS92x4R Registers

Table 10 lists the ADS92x4R registers. All register offset addresses not listed in Table 10 should be considered as reserved locations and the register contents should not be modified.

**Table 10. ADS92X4R Registers**

| Offset | Acronym              | Register Name                           | Section                                                  |
|--------|----------------------|-----------------------------------------|----------------------------------------------------------|
| 0h     | DEVICE_STATUS        | Device status register                  | DEVICE_STATUS Register (Offset = 0h) [reset = 0h]        |
| 1h     | POWER_DOWN_CFG       | Power down configuration register       | POWER_DOWN_CFG Register (Offset = 1h) [reset = 0h]       |
| 2h     | PROTOCOL_CFG         | Protocol configuration register         | PROTOCOL_CFG Register (Offset = 2h) [reset = 0h]         |
| 3h     | BUS_WIDTH            | Bus width configuration register        | BUS_WIDTH Register (Offset = 3h) [reset = 0h]            |
| 4h     | CRT_CFG              | Clock re-timer configuration register   | CRT_CFG Register (Offset = 4h) [reset = 0h]              |
| 5h     | OUTPUT_DATA_WORD_CFG | Output data word configuration register | OUTPUT_DATA_WORD_CFG Register (Offset = 5h) [reset = 0h] |
| 6h     | DATA_AVG_CFG         | Data averaging configuration register   | DATA_AVG_CFG Register (Offset = 6h) [reset = 0h]         |
| 7h     | REFBY2_OFFSET        | REFby2 offset selection register        | REFBY2_OFFSET Register (Offset = 7h) [reset = 0h]        |

Complex bit access types are encoded to fit into small table cells. Table 11 shows the codes that are used for access types in this section.

**Table 11. ADS92x4R Access Type Codes**

| Access Type                     | Code | Description                                                                                                                                                                                                                                                                          |
|---------------------------------|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Read Type</b>                |      |                                                                                                                                                                                                                                                                                      |
| R                               | R    | Read                                                                                                                                                                                                                                                                                 |
| <b>Write Type</b>               |      |                                                                                                                                                                                                                                                                                      |
| W                               | W    | Write                                                                                                                                                                                                                                                                                |
| <b>Reset or Default Value</b>   |      |                                                                                                                                                                                                                                                                                      |
| -n                              |      | Value after reset or the default value                                                                                                                                                                                                                                               |
| <b>Register Array Variables</b> |      |                                                                                                                                                                                                                                                                                      |
| i,j,k,l,m,n                     |      | When these variables are used in a register name, an offset, or an address, they refer to the value of a register array where the register is part of a group of repeating registers. The register groups form a hierarchical structure and the array is represented with a formula. |
| y                               |      | When this variable is used in a register name, an offset, or an address it refers to the value of a register array.                                                                                                                                                                  |

**7.7.1.1 DEVICE\_STATUS Register (Offset = 0h) [reset = 0h]**

DEVICE\_STATUS is shown in [Figure 71](#) and described in [Table 12](#).

Return to the [Summary Table](#).

Device status register

**Figure 71. DEVICE\_STATUS Register**

| 7        | 6 | 5 | 4 | 3 | 2                  | 1         | 0        |
|----------|---|---|---|---|--------------------|-----------|----------|
| RESERVED |   |   |   |   | ZONE2_TRAN<br>SFER | AVG_ERROR | RESERVED |
| R-00000b |   |   |   |   | R/W-0b             | R/W-0b    | R-0b     |

**Table 12. DEVICE\_STATUS Register Field Descriptions**

| Bit | Field          | Type | Reset  | Description                                                                                                                                                               |
|-----|----------------|------|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7-3 | RESERVED       | R    | 00000b | Reserved bits. Do not write to these bits. Read returns 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 CS before the current averaging operation is complete. This bit is a sticky bit. Write 1 to this bit to clear. |
| 0   | RESERVED       | R    | 0b     | Reserved bits. Do not write to this bit. Read returns 0b.                                                                                                                 |

**7.7.1.2 POWER\_DOWN\_CFG Register (Offset = 1h) [reset = 0h]**

POWER\_DOWN\_CFG is shown in [Figure 72](#) and described in [Table 13](#).

Return to the [Summary Table](#).

Power down configuration register

**Figure 72. POWER\_DOWN\_CFG Register**

| 7        | 6 | 5         | 4        | 3       | 2        | 1       | 0      |
|----------|---|-----------|----------|---------|----------|---------|--------|
| RESERVED |   | PD_REFBY2 | RESERVED | PD_ADCB | RESERVED | PD_ADCA | PD_REF |
| R-00b    |   | R/W-0b    | R-0b     | R/W-0b  | R-0b     | R/W-0b  | R/W-0b |

**Table 13. POWER\_DOWN\_CFG Register Field Descriptions**

| Bit | Field     | Type | Reset | Description                                                                                                                                                  |
|-----|-----------|------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7-6 | RESERVED  | R    | 00b   | Reserved bits. Do not write to these bits. Read returns 00b.                                                                                                 |
| 5   | PD_REFBY2 | R/W  | 0b    | This bit powers down REFby2 output.<br>0b = _1 : REFby2 is not powered down.<br>1b = _2 : REFby2 is powered down.                                            |
| 4   | RESERVED  | R    | 0b    | Reserved bits. Do not write to this bit. Read returns 0b.                                                                                                    |
| 3   | PD_ADCB   | R/W  | 0b    | This bit powers down ADC_B and REFBUF_B.<br>0b = _1 : ADC_B and REFBUF_B are not powered down.<br>1b = _2 : ADC_B and REFBUF_B are powered down.             |
| 2   | RESERVED  | R    | 0b    |                                                                                                                                                              |
| 1   | PD_ADCA   | R/W  | 0b    | This bit powers down ADC_A and REFBUF_A.<br>0b = _1 : ADC_A and REFBUF_A are not powered down.<br>1b = _2 : ADC_A and REFBUF_A are powered down.             |
| 0   | PD_REF    | R/W  | 0b    | This bit powers down ADC's internal reference.<br>0b = _1 : ADC internal reference is not powered down.<br>1b = _2 : ADC internal reference is powered down. |

### 7.7.1.3 **PROTOCOL\_CFG Register (Offset = 2h) [reset = 0h]**

PROTOCOL\_CFG is shown in [Figure 73](#) and described in [Table 14](#).

Return to the [Summary Table](#).

Protocol configuration register

**Figure 73. PROTOCOL\_CFG Register**

| 7        | 6                 | 5 | 4 | 3        | 2 | 1        | 0        |
|----------|-------------------|---|---|----------|---|----------|----------|
| RESERVED | SDO_PROTOCOL[2:0] |   |   | RESERVED |   | SPI_CPOL | SPI_CPHA |
| R-0b     | R/W-000b          |   |   | R-00b    |   | R/W-0b   | R/W-0b   |

**Table 14. PROTOCOL\_CFG Register Field Descriptions**

| Bit | Field             | Type | Reset | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-----|-------------------|------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7   | RESERVED          | R    | 0b    | Reserved bit. Do not write to this bit. Read returns 0b.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 6-4 | SDO_PROTOCOL[2:0] | R/W  | 000b  | These bits set the protocol for reading data from the device.<br>000b = <b>_1</b> : 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.<br>001b = <b>_2</b> : SPI compatible protocols with bus width options and DDR (SPI-x1-S-DDR, SPI-x1-D-DDR, SPI-x1-Q-DDR) protocols.<br>010b = <b>_3</b> : Clock re-timer (CRT) protocols with SDR (CRT-S-SDR, CRT-D-SDR, CRT-Q-SDR).<br>011b = <b>_4</b> : CRT protocols with DDR (CRT-S-DDR, CRT-D-DDR, CRT-Q-DDR).<br>100b = <b>_5</b> : Parallel byte protocol. Writing 1xx enables parallel byte protocol.<br>101b = <b>_6</b> : Parallel byte protocol. Writing 1xx enables parallel byte protocol.<br>110b = <b>_7</b> : Parallel byte protocol. Writing 1xx enables parallel byte protocol.<br>111b = <b>_8</b> : Parallel byte protocol. Writing 1xx enables parallel byte protocol. |
| 3-2 | RESERVED          | R    | 00b   | Reserved bits. Do not write to these bits. Read returns 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.<br>0b = <b>_1</b> : CPOL = 0<br>1b = <b>_2</b> : 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.<br>0b = <b>_1</b> : CPHA = 0<br>1b = <b>_2</b> : CPHA = 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

### 7.7.1.4 **BUS\_WIDTH Register (Offset = 3h) [reset = 0h]**

BUS\_WIDTH is shown in [Figure 74](#) and described in [Table 15](#).

Return to the [Summary Table](#).

Bus width configuration register

**Figure 74. BUS\_WIDTH Register**

| 7         | 6 | 5 | 4 | 3 | 2 | 1              | 0 |
|-----------|---|---|---|---|---|----------------|---|
| RESERVED  |   |   |   |   |   | SDO_WIDTH[1:0] |   |
| R-000000b |   |   |   |   |   | R/W-00b        |   |

**Table 15. BUS\_WIDTH Register Field Descriptions**

| Bit | Field          | Type | Reset   | Description                                                                                                                                                                                                                                                                                                                                                                        |
|-----|----------------|------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7-2 | RESERVED       | R    | 000000b | Reserved bits. Do not write to these bits. Read returns 000000b.                                                                                                                                                                                                                                                                                                                   |
| 1-0 | SDO_WIDTH[1:0] | R/W  | 00b     | These bits set the number of SDO lines for reading data from the device. 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.<br><br>00b = _1 : One SDO per ADC.<br>01b = _2 : One SDO per ADC.<br>10b = _3 : Dual SDO per ADC.<br>11b = _4 : Quad SDO per ADC. |

**7.7.1.5 CRT\_CFG Register (Offset = 4h) [reset = 0h]**

CRT\_CFG is shown in [Figure 75](#) and described in [Table 16](#).

Return to the [Summary Table](#).

Clock re-timer configuration register

**Figure 75. CRT\_CFG Register**

|           |   |   |   |   |   |                     |   |
|-----------|---|---|---|---|---|---------------------|---|
| 7         | 6 | 5 | 4 | 3 | 2 | 1                   | 0 |
| RESERVED  |   |   |   |   |   | CRT_CLK_SELECT[1:0] |   |
| R-000000b |   |   |   |   |   | R/W-00b             |   |

**Table 16. CRT\_CFG Register Field Descriptions**

| Bit | Field               | Type | Reset   | Description                                                                                                                                                                                                                                                                                                  |
|-----|---------------------|------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7-2 | RESERVED            | R    | 000000b | Reserved bits. Do not write to these bits. Read returns 000000b.                                                                                                                                                                                                                                             |
| 1-0 | CRT_CLK_SELECT[1:0] | R/W  | 00b     | These bits select the clock source for the strobe output for CRT protocols.<br><br>00b = _1 : Serial clock (SCLK) is used for STROBE output.<br>01b = _2 : INTCLK is used for the STROBE output.<br>10b = _3 : INTCLK/2 is used for the STROBE output.<br>11b = _4 : INTCLK/4 is used for the STROBE output. |

**7.7.1.6 OUTPUT\_DATA\_WORD\_CFG Register (Offset = 5h) [reset = 0h]**

OUTPUT\_DATA\_WORD\_CFG is shown in [Figure 76](#) and described in [Table 17](#).

Return to the [Summary Table](#).

Output data word configuration register

**Figure 76. OUTPUT\_DATA\_WORD\_CFG Register**

|          |   |            |                           |          |   |                    |                    |
|----------|---|------------|---------------------------|----------|---|--------------------|--------------------|
| 7        | 6 | 5          | 4                         | 3        | 2 | 1                  | 0                  |
| RESERVED |   | READY_MASK | PARALLEL_MODE_DATA_FORMAT | RESERVED |   | FIXED_PATTERN_DATA | DATA_RIGHT_ALIGNED |
| R-00b    |   | R/W-0b     | R/W-0b                    | R-00b    |   | R/W-0b             | R/W-0b             |

**Table 17. OUTPUT\_DATA\_WORD\_CFG Register Field Descriptions**

| Bit | Field                     | Type | Reset | Description                                                                                                                                                                                                                                                                                                                                 |
|-----|---------------------------|------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7-6 | RESERVED                  | R    | 00b   | Reserved bits. Do not write to these bits. Read returns 00b.                                                                                                                                                                                                                                                                                |
| 5   | READY_MASK                | R/W  | 0b    | This bit masks the READY output. 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.<br>0b = _1 : Does not mask the READY output.<br>1b = _2 : Masks the READY output. |
| 4   | PARALLEL_MODE_DATA_FORMAT | R/W  | 0b    | This bit selects the format for the output data word in the parallel byte protocol.<br>0b = _1 : Data format AA: byte from ADC_A followed by byte from ADC_A (PB-xy-AA-zDR protocol).<br>1b = _2 : Data format AB: byte from ADC_A followed by byte from ADC_B (PB-xy-AB-zDR protocol).                                                     |
| 3-2 | RESERVED                  | R    | 00b   | Reserved bits. Do not write to these bits. Read returns 00b.                                                                                                                                                                                                                                                                                |
| 1   | FIXED_PATTERN_DATA        | R/W  | 0b    | This bit enables a fixed pattern in the output data word.<br>0b = _1 : Device provides the conversion results from the register data in the output word.<br>1b = _2 : 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 device.<br>0b = _1 : Data are left-aligned in the output data word.<br>1b = _2 : Data are right-aligned in the output data word.                                                                                                                                  |

#### 7.7.1.7 DATA\_AVG\_CFG Register (Offset = 6h) [reset = 0h]

DATA\_AVG\_CFG is shown in [Figure 77](#) and described in [Table 18](#).

Return to the [Summary Table](#).

Data averaging configuration register

**Figure 77. DATA\_AVG\_CFG Register**

|           |   |   |   |   |   |                  |   |
|-----------|---|---|---|---|---|------------------|---|
| 7         | 6 | 5 | 4 | 3 | 2 | 1                | 0 |
| RESERVED  |   |   |   |   |   | EN_DATA_AVG[1:0] |   |
| R-000000b |   |   |   |   |   | R/W-00b          |   |

**Table 18. DATA\_AVG\_CFG Register Field Descriptions**

| Bit | Field            | Type | Reset   | Description                                                                                                                                                                                                                       |
|-----|------------------|------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7-2 | RESERVED         | R    | 000000b | Reserved bits. Do not write to these bits. Read returns 000000b.                                                                                                                                                                  |
| 1-0 | EN_DATA_AVG[1:0] | R/W  | 00b     | These bits enable averaging of conversion results.<br>00b = _1 : No averaging.<br>01b = _2 : No averaging.<br>10b = _3 : Enables averaging of two conversion results.<br>11b = _4 : Enables averaging of four conversion results. |

#### 7.7.1.8 REFBY2\_OFFSET Register (Offset = 7h) [reset = 0h]

REFBY2\_OFFSET is shown in [Figure 78](#) and described in [Table 19](#).

Return to the [Summary Table](#).

REFby2 offset selection register

**Figure 78. REFBY2\_OFFSET Register**

| 7          | 6 | 5 | 4 | 3 | 2 | 1 | 0                |
|------------|---|---|---|---|---|---|------------------|
| RESERVED   |   |   |   |   |   |   | EN_REFBY2_OFFSET |
| R-0000000b |   |   |   |   |   |   | R/W-0b           |

**Table 19. REFBY2\_OFFSET Register Field Descriptions**

| Bit | Field            | Type | Reset    | Description                                                                                                                                                                                               |
|-----|------------------|------|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7-1 | RESERVED         | R    | 0000000b | Reserved bits. Do not write to these bits. Read returns 0000000b.                                                                                                                                         |
| 0   | EN_REFBY2_OFFSET | R/W  | 0b       | This bit enables the offset for the REFby2 output.<br>0b = _1 : Offset for the REFby2 output is disabled.<br>1b = _2 : Offset for the REFby2 output is enabled and the REFby2 output increases by 100 mV. |

## 8 Application and Implementation

### NOTE

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

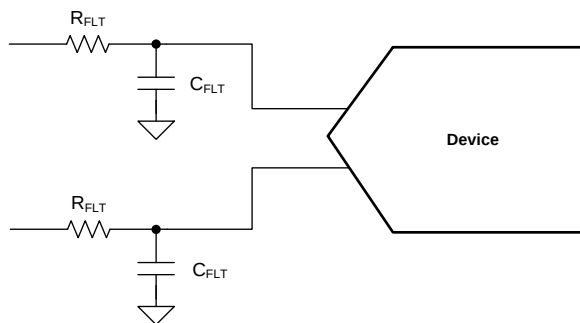
This section presents general principles for designing these circuits, followed by an application circuit designed using the ADS92x4R.

#### 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 Figure 79), 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 C0G- or NP0-type. The type of dielectric used in C0G or NP0 ceramic capacitors provides the most stable electrical properties over voltage, frequency, and temperature changes.



**Figure 79. 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 (continued)

### 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. [Equation 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. [Equation 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. [Equation 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  $\mu V$
  - $e_{n\_RMS}$  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.

For additional details on SAR ADC input architecture and SAR ADC driver amplifier design, see the [TI Precision Labs for ADCs](#).

## 8.2 Typical Application

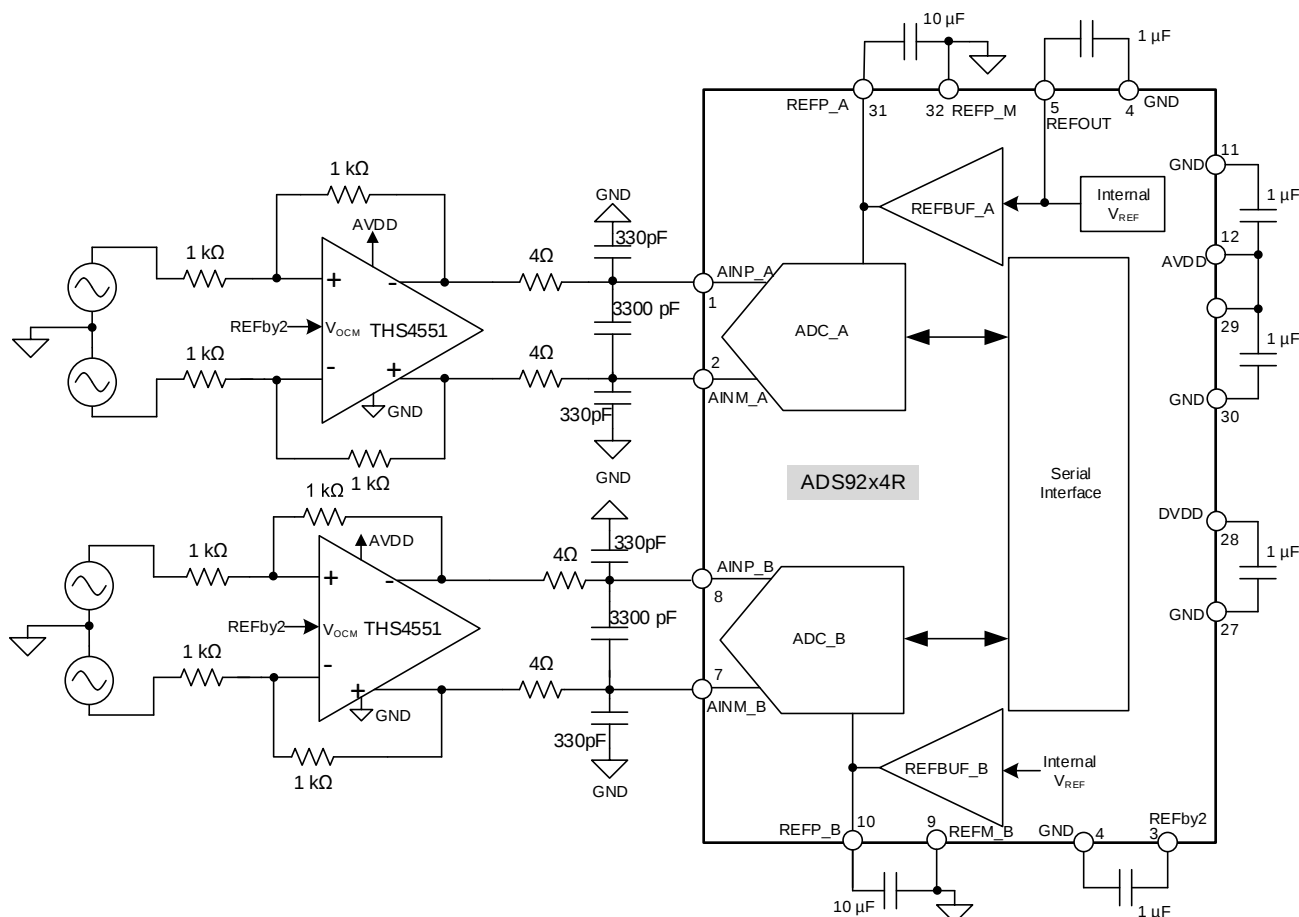


Figure 80. DAQ Circuit for Lowest Distortion and Noise With the ADS92x4R for a 100-kHz Input Signal

### 8.2.1 Design Requirements

The design parameters are listed in Table 20 for this example.

Table 20. Design Parameters

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

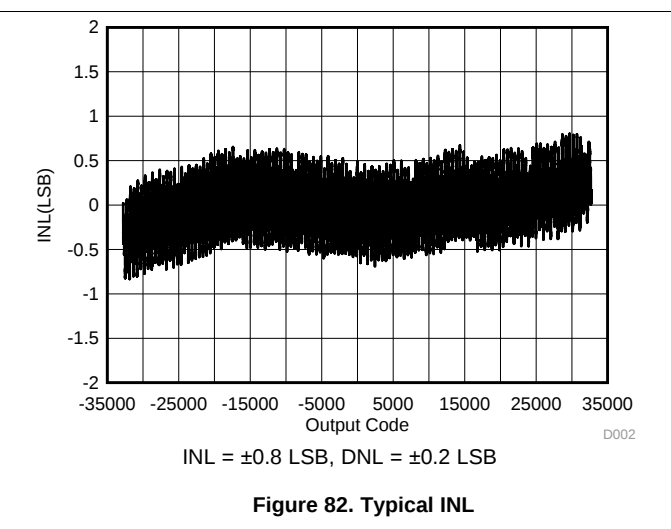
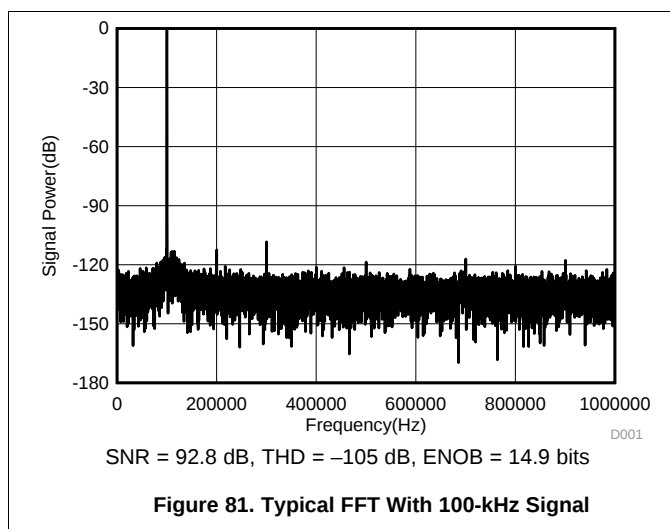
### 8.2.2 Detailed Design Procedure

Figure 80 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 Figure 80 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 VOCM input pin from the FDA. The ADS92x4R incorporates a REFby2 buffer output for setting the common-mode voltage. The ADS92x4R REFby2 output is decoupled using a 1- $\mu$ F capacitor and connected to each FDA VOCM input pin. Each VOCM pin is decoupled using a 0.1- $\mu$ F 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

Figure 81 provides the typical FFT for the circuit in Figure 80 and Figure 82 provides the typical INL for the circuit in Figure 80.

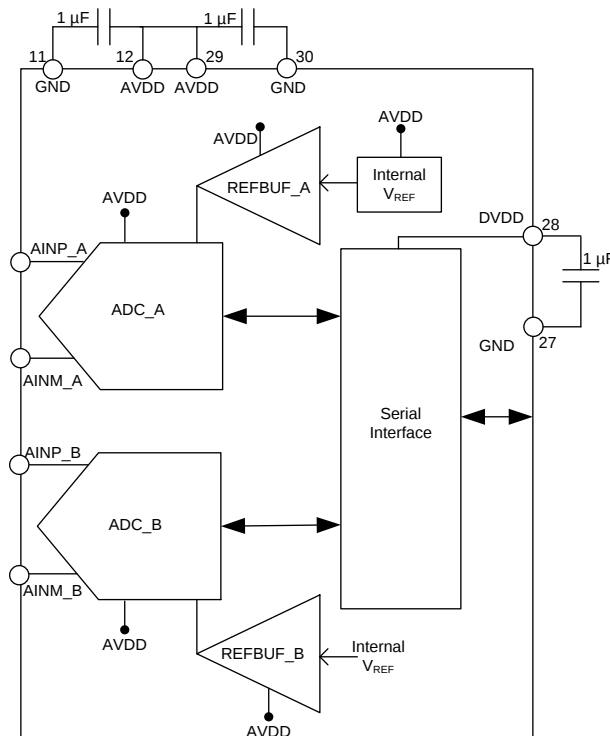


## 9 Power Supply Recommendations

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 83](#), connect pins 12 and 29 together and place 1- $\mu\text{F}$  decoupling capacitors between pin 12 (AVDD) and pin11 (GND), and between pin 29 (AVDD) and pin 30 (GND). To decouple the DVDD supply, place a 1- $\mu\text{F}$  decoupling capacitor between pin 28 (DVDD) and pin 27 (GND).



**Figure 83. 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 84](#), 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.

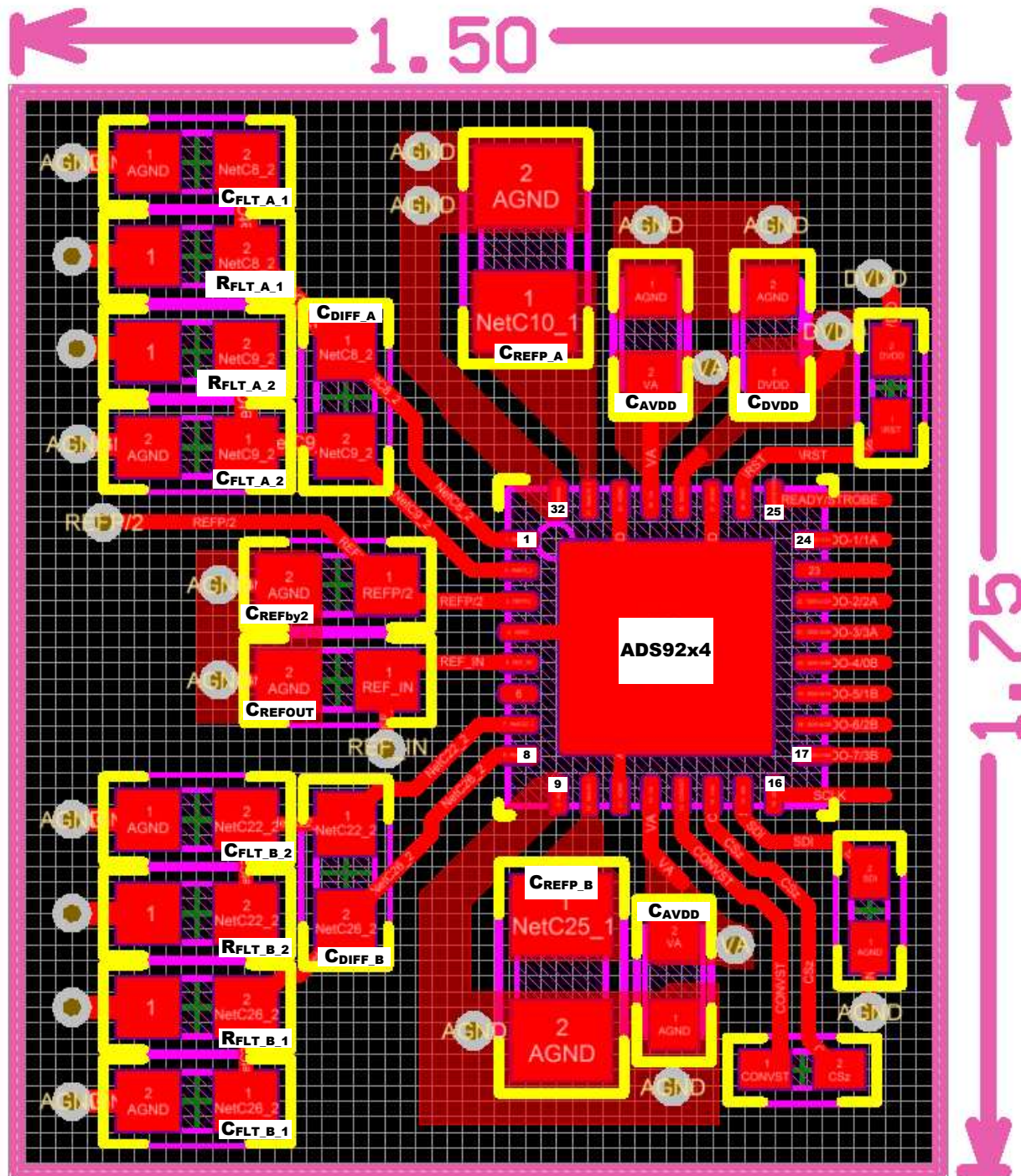
#### 10.1.4 Reference Decoupling

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 84](#). 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.

Figure 84. Example Layout for the ADS92x4R

## 11 Device and Documentation Support

### 11.1 Device Support

#### 11.1.1 Development Support

[TI Precision Labs for ADCs](#)

### 11.2 Related Documentation

For related documentation see the following:

- Texas Instruments, [THS4551 Low-Noise, Precision, 150-MHz, Fully Differential Amplifier](#) data sheet
- Texas Instruments, [12 Bit 1 MSPS Single Supply Dual Channel Data Acquisition System for Optical Encoders in Motor Control Application](#) reference guide
- Texas Instruments, [REF50xx Low-Noise, Very Low Drift, Precision Voltage Reference](#) data sheet
- Texas Instruments, [OPAx350 High-Speed, Single-Supply, Rail-to-Rail Operational Amplifiers MicroAmplifier Series](#) data sheet
- Texas Instruments, [THS452x Very Low Power, Negative Rail Input, Rail-To-Rail Output, Fully Differential Amplifier](#) data sheet
- Texas Instruments, [ADS9224REVM-PDK](#) user's guide

### 11.3 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to order now.

**Table 21. Related Links**

| PARTS    | PRODUCT FOLDER             | ORDER NOW                  | TECHNICAL DOCUMENTS        | TOOLS & SOFTWARE           | SUPPORT & COMMUNITY        |
|----------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| ADS9224R | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| ADS9234R | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |

### 11.4 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 11.5 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

**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.

### 11.6 Trademarks

TINA-TI, E2E are trademarks of Texas Instruments.  
All other trademarks are the property of their respective owners.

### 11.7 Electrostatic Discharge Caution



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

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

## 11.8 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

## 12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

## PACKAGING INFORMATION

| Orderable part number         | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|-------------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">ADS9224RIRHBR</a> | Active        | Production           | VQFN (RHB)   32 | 3000   LARGE T&R      | Yes         | NIPDAUAG                             | Level-2-260C-1 YEAR               | -40 to 125   | ADS9224             |
| ADS9224RIRHBR.B               | Active        | Production           | VQFN (RHB)   32 | 3000   LARGE T&R      | Yes         | NIPDAUAG                             | Level-2-260C-1 YEAR               | -40 to 125   | ADS9224             |
| <a href="#">ADS9224RIRHBT</a> | Active        | Production           | VQFN (RHB)   32 | 250   SMALL T&R       | Yes         | NIPDAUAG                             | Level-2-260C-1 YEAR               | -40 to 125   | ADS9224             |
| ADS9224RIRHBT.B               | Active        | Production           | VQFN (RHB)   32 | 250   SMALL T&R       | Yes         | NIPDAUAG                             | Level-2-260C-1 YEAR               | -40 to 125   | ADS9224             |
| <a href="#">ADS9234RIRHBR</a> | Active        | Production           | VQFN (RHB)   32 | 3000   LARGE T&R      | Yes         | NIPDAUAG                             | Level-2-260C-1 YEAR               | -40 to 125   | ADS9234             |
| ADS9234RIRHBR.B               | Active        | Production           | VQFN (RHB)   32 | 3000   LARGE T&R      | Yes         | NIPDAUAG                             | Level-2-260C-1 YEAR               | -40 to 125   | ADS9234             |
| <a href="#">ADS9234RIRHBT</a> | Active        | Production           | VQFN (RHB)   32 | 250   SMALL T&R       | Yes         | NIPDAUAG                             | Level-2-260C-1 YEAR               | -40 to 125   | ADS9234             |
| ADS9234RIRHBT.B               | Active        | Production           | VQFN (RHB)   32 | 250   SMALL T&R       | Yes         | NIPDAUAG                             | Level-2-260C-1 YEAR               | -40 to 125   | ADS9234             |

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "-" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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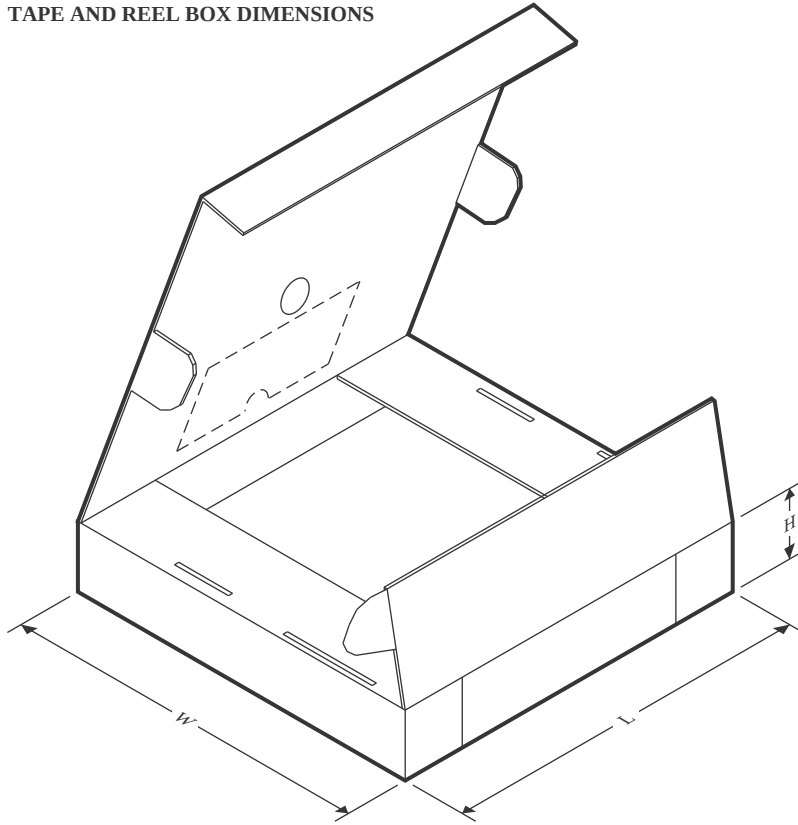
## TAPE AND REEL INFORMATION



\*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            |
| ADS9234RIRHBR | VQFN         | RHB             | 32   | 3000 | 330.0              | 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        |
| ADS9234RIRHBR | VQFN         | RHB             | 32   | 3000 | 350.0       | 350.0      | 43.0        |

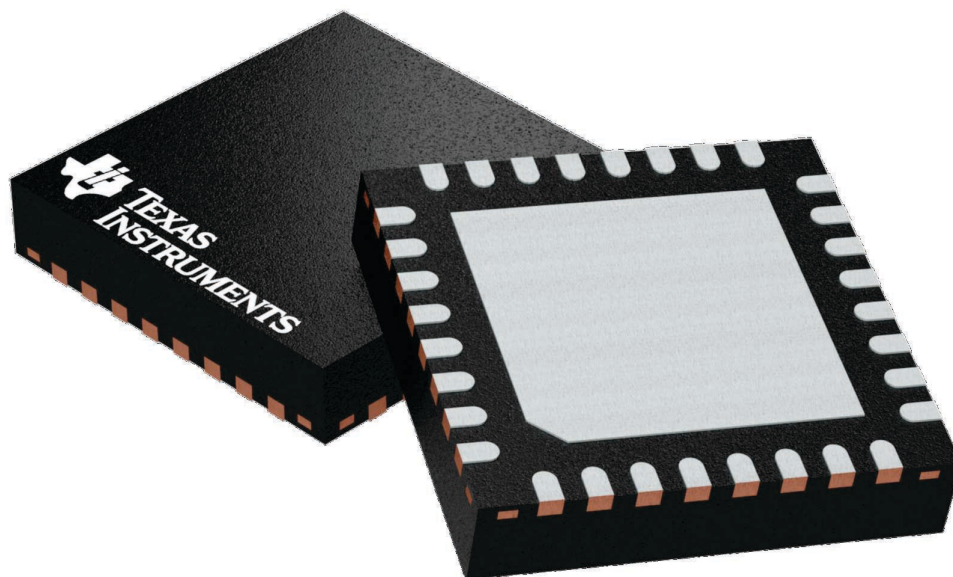
## GENERIC PACKAGE VIEW

**RHB 32**

**VQFN - 1 mm max height**

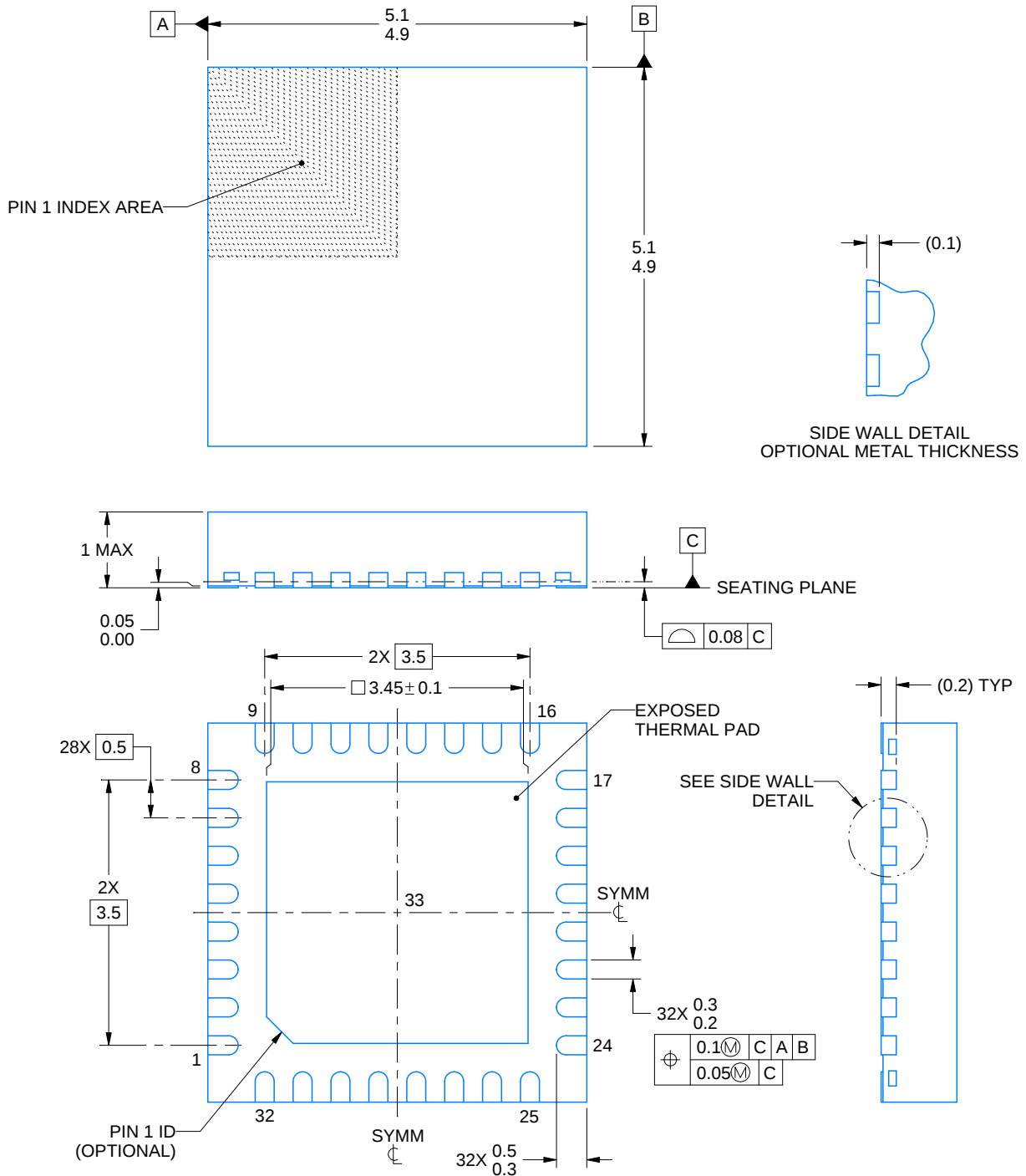
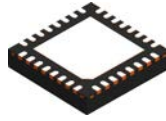
5 x 5, 0.5 mm pitch

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.

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4223442/B 08/2019

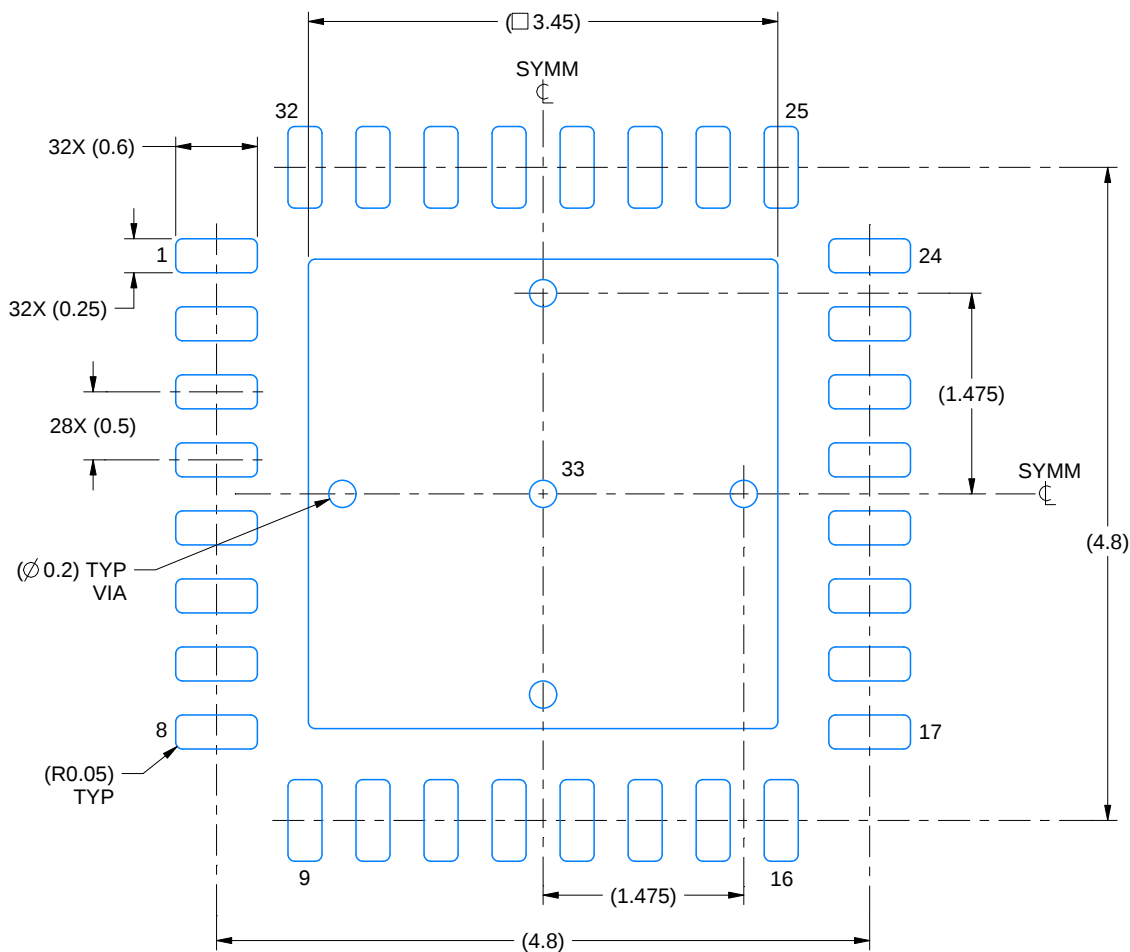
## NOTES:

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.

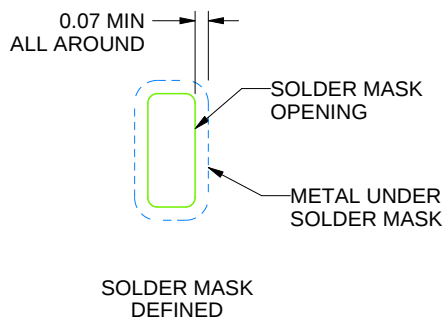
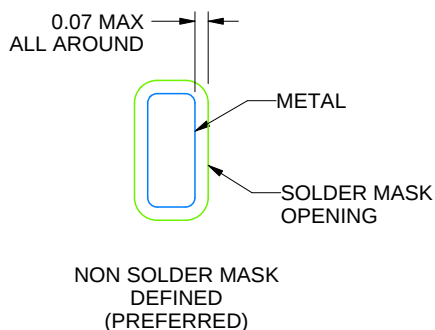
**RHB0032E**

**VQFN - 1 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE  
SCALE:18X



## SOLDER MASK DETAILS

4223442/B 08/2019

NOTES: (continued)

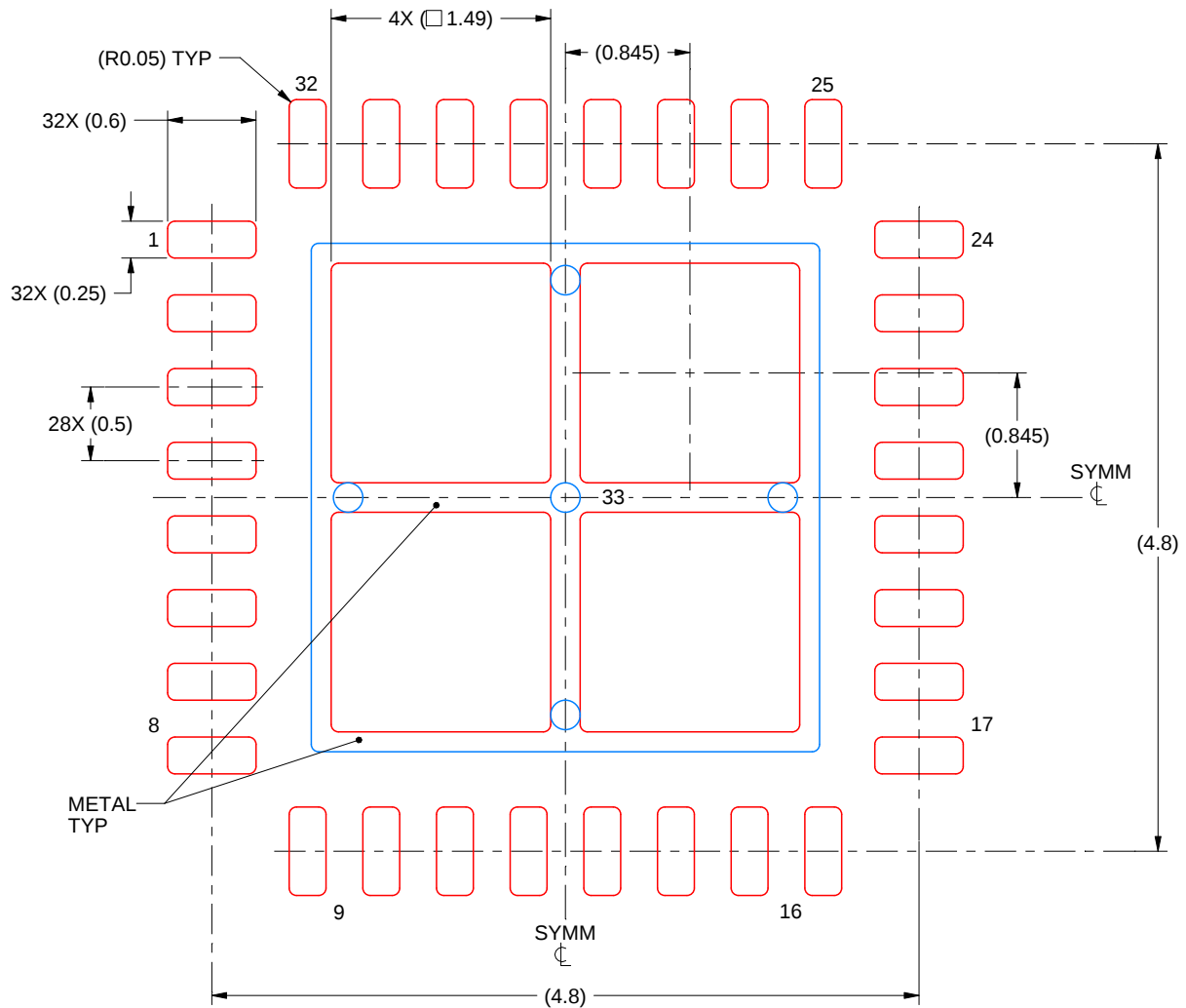
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/slua271](http://www.ti.com/lit/slua271)).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, 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

4223442/B 08/2019

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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