

ADS92x4R 双通道低延迟同步采样 SAR ADC

1 特性

- 高分辨率、高吞吐量：
 - ADS9224R: 16 位、3MSPS、低延迟: 333ns
 - ADS9234R: 14 位、3.5MSPS、低延迟: 285ns
- 两个单极、完全差分同步采样通道
- 出色的直流和交流性能：
 - ADS9224R:
 - 16 位 NMC DNL, ± 2 LSB 最大 INL
 - 94dB SNR、-109dB THD
 - 1MHz 时为 88dB SINAD
 - ADS9234R:
 - 14 位 NMC DNL, ± 1 LSB 最大 INL
 - 85.6dB SNR、-106dB THD
 - 1MHz 时为 84dB SINAD
- 特性集成：
 - 内部基准和基准缓冲器
 - 用于设置共模的内部 REFby2 缓冲器
 - 数据平均
- 适用于 MCU 和 FPGA 的增强型 SPI 接口：
 - 宽读取周期, 可借助 MCU 读取数据
 - 用于通过数字隔离器进行数据传输的时钟重计时器
 - 适用于 FPGA 的 DDR 模式
 - 并行字节模式, 方便对接
- 扩展温度范围: -40°C 至 +125°C

2 应用

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

3 说明

ADS92x4R 是一款引脚兼容型高速双通道同步采样模数转换器 (ADC), 具有集成基准电压和基准电压缓冲器。该器件可由 5V 单电源供电运行, 支持单极和全差分模拟输入信号, 具有出色的直流和交流规格。该器件具有高达 1.5MHz 的模拟输入频率, 交流性能出色, 因此适合高带宽数据采集 (DAQ) 系统。

该器件支持 SPI 兼容串行 (增强型 SPI) 和字节宽并行接口, 因此易于与多种微控制器、数字信号处理器 (DSP) 和现场可编程门阵列 (FPGA) 搭配使用。此器件还支持数据平均功能, 该功能可提升高噪声环境中的交流性能。

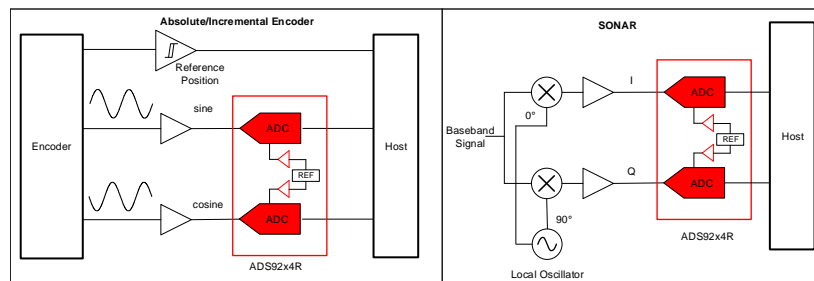
该器件采用节省空间的 5mm x 5mm VQFN 封装。ADS92x4R 的额定扩展温度范围为 -40°C 至 +125°C。

器件信息⁽¹⁾

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

(1) 如需了解所有可用封装, 请参阅产品说明书末尾的可订购产品附录。

典型应用图



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4 修订历史记录

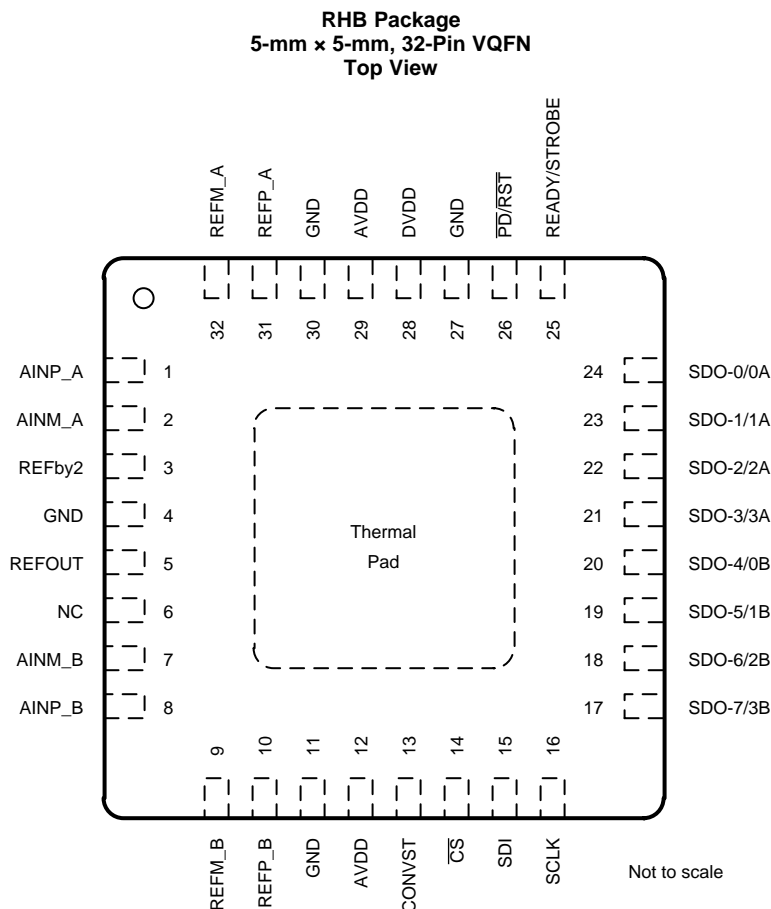
注：之前版本的页码可能与当前版本有所不同。

Changes from Revision B (May 2019) to Revision C

Page

| | |
|-----------------------------|---|
| • 已更改 将文档状态从“预告信息”更改为“生产数据” | 1 |
|-----------------------------|---|

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. Connect a 1-μF decoupling capacitor between pin 12 and pin 11. Connect a 1-μF decoupling capacitor between pin 29 and pin 30. |
| CONVST | 13 | Digital input | Conversion start input pin. A CONVST rising edge starts the conversion for ADC_A and ADC_B. |
| \overline{CS} | 14 | Digital input | Chip-select input pin; active low. The host and device can communicate when \overline{CS} is low. The SDO-x pins go to Hi-Z when \overline{CS} is high. |
| DVDD | 28 | Power supply | Interface power-supply pin. Connect a 1-μF decoupling capacitor between pin 27 and pin 28. |
| GND | 4, 11, 27, 30 | Power supply | Ground |
| NC | 6 | — | No external connection |
| $\overline{PD/RST}$ | 26 | Digital input | Asynchronous reset or power-down input pin. See the Reset or Power-Down section. |
| READY/STROBE | 25 | Digital output | Indicates data ready or strobe output for data capture. |

Pin Functions (continued)

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

6 Specifications

6.1 Absolute Maximum Ratings

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

| | MIN | MAX | UNIT |
|--|-----------|------------|------|
| 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 _J | | 150 | °C |
| Storage temperature, T _{stg} | −65 | 150 | °C |

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

6.2 ESD Ratings

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

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

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

6.3 Recommended Operating Conditions

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

| | | MIN | NOM | MAX | UNIT |
|----------------|--|------|-----|-----|------|
| AVDD | Analog supply voltage | 4.5 | 5 | 5.5 | V |
| 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 _A | Ambient temperature | −40 | | 125 | °C |

6.4 Thermal Information

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

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

6.5 Electrical Characteristics: ADS92x4R

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 ⁽¹⁾ | Full-scale input voltage (AINP_x - AINM_x) | | -4.096 | | 4.096 | V |
| V _{IN} | Absolute input voltage (AINP_x or AINM_x to GND) | | 0 | | 4.096 | V |
| V _{CM} | Common-mode input range | | 1.848 | | 2.248 | V |
| I _{IN} | Analog input leakage current | | | ±1 | | μA |
| C _i | 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 _{REFOUT} ⁽²⁾ | REFOUT voltage | | 2.496 | 2.5 | 2.504 | V |
| ΔV _{REF} /ΔT | V _{REFOUT} drift | | | 5.5 | 15 | ppm/°C |
| ΔV _{REFOUT} /ΔAVDD | V _{REFOUT} line regulation | AVDD variation 4.5 V to 5.5 V | | 200 | | μV/V |
| I _{REFOUT} | REFOUT output current capability | ΔV _{REF} < 2 mV | | 1.5 | | μA |
| C _{REFOUT} | REFOUT capacitor | For specified performance | | 1 | | μF |
| INTERNAL REFERENCE BUFFER | | | | | | |
| G _{REFBUF} | Reference buffer Gain | | | 1.6388 | | V/V |
| E _{O-REFBUF} | Reference buffer output offset | | -1 | ±0.2 | 1 | mV |
| ΔE _{O-REFBUF} /ΔT | Reference buffer output offset temperature drift | | | 10 | | μV/°C |
| (V _{REFP_A} - V _{REFP_B}) | Reference buffer output mismatch | | -500 | ±50 | 500 | μV |
| C _{REFP_x} | Reference buffer output capacitor | For specified performance, between each pair of REFP_x and REFM_x | 7 | 10 | 27 | μF |
| REFby2 OUTPUT | | | | | | |
| V _{REFby2} | 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 _{REFby2} | REFby2 output current capability | | | ±3 | | mA |
| | REFby2 output capacitor | | 1 | | | μF |
| | REFby2 output noise | With specified output capacitor | | 10 | | μV _{RMS} |
| Digital Outputs | | | | | | |
| V _{OH} | High level output voltage | I _{OH} = 500-μA source | 0.8 × DVDD | | DVDD | V |
| V _{OL} | Low level output voltage | I _{OL} = 500-μA sink | 0 | | 0.2 × DVDD | V |
| Digital Inputs | | | | | | |
| V _{IH} | High level input voltage | DVDD > 2.3 V | 0.7 × DVDD | | DVDD +0.3 | V |
| V _{IL} | Low level input voltage | | -0.3 | | 0.3 × DVDD | V |
| V _{IH} | High level input voltage | DVDD ≤ 2.3 V | 0.8 × DVDD | | DVDD +0.3 | V |
| V _{IL} | Low level input voltage | | -0.3 | | 0.2 × DVDD | V |

(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 |
|---------------------|------------------------------|--|------|------|------|------|
| Power Supply | | | | | | |
| AVDD | Analog supply voltage | | 4.5 | 5 | 5.5 | V |
| DVDD | Digital supply voltage | | 1.65 | 3.3 | 5.5 | V |
| I _{AVDD} | Analog supply current | f _{SAMPLE} = 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 _{DVDD} | Digital supply current | f _{SAMPLE} = 3 MSPS, C _{SDO-x/y} = 10 pF | | 2.8 | | mA |
| PSRR ⁽³⁾ | Power-supply rejection ratio | 100-mV _{PP} 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 |
|-------------------------|---|--|-------|-------|------|--------|
| DC ACCURACY | | | | | | |
| | Resolution, no missing codes | | 16 | | | Bits |
| DNL | Differential nonlinearity | | -0.5 | ±0.2 | 0.5 | LSB |
| INL | Integral nonlinearity | | -2 | ±1 | 2 | LSB |
| E _O | Offset error | | -9 | ±1 | 9 | LSB |
| G _E | Cummulative gain error for ADC _x and REFBUF _x | | -0.02 | ±0.01 | 0.02 | %FSR |
| ΔG _E /ΔT | Gain drift | | | 5 | | ppm/°C |
| | Transition noise | Mid-code, PFS-1000, NFS+1000 | | 0.4 | | LSB |
| AC ACCURACY | | | | | | |
| SNR ⁽¹⁾ | Signal-to-noise ratio | f _{IN} = 2 kHz | 91.3 | 94.5 | | dB |
| | | f _{IN} = 100 kHz, FSR = -3 dBFS | | 93 | | |
| | | f _{IN} = 1 MHz, FSR = -3 dBFS, f _{SAMPLE} = 2.9 MSPS | | 89.5 | | |
| SINAD ⁽¹⁾⁽²⁾ | Signal-to-noise plus distortion | f _{IN} = 2 kHz | | 94.3 | | dB |
| | | f _{IN} = 100 kHz, FSR = -3 dBFS | | 92.7 | | |
| | | f _{IN} = 1 MHz, FSR = -3 dBFS | | 87.9 | | |
| THD ⁽¹⁾⁽²⁾ | Total harmonic distortion | f _{IN} = 2 kHz | | -109 | | dB |
| | | f _{IN} = 100 kHz, FSR = -3 dBFS | | -106 | | |
| | | f _{IN} = 1 MHz, FSR = -3 dBFS | | -93 | | |
| SFDR ⁽¹⁾ | Spurious-free dynamic range | f _{IN} = 2 kHz | | 112 | | dB |
| | | f _{IN} = 100 kHz, FSR = -3 dBFS | | 112 | | |
| | | f _{IN} = 1 MHz, FSR = -3 dBFS | | 100 | | |
| CMRR ⁽¹⁾ | Common-mode rejection ratio | f _{IN} = dc to 1-MHz, V _{IN} = 100-mV _{PP} | | 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 ⁽¹⁾ | Channel-to-channel isolation | $f_{IN_ADCA} = 15\text{ kHz at } 10\% \text{ FSR,}$ $f_{IN_ADCB} = 25\text{ kHz at } 100\% \text{ FSR}$ | -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 |
|-------------------------|---|--|------------|-------|-------------------------|
| DC ACCURACY | | | | | |
| | Resolution, no missing codes | 14 | | | Bits |
| DNL | Differential nonlinearity | -0.5 | ± 0.15 | 0.5 | LSB |
| INL | Integral nonlinearity | -1 | ± 0.3 | 1 | LSB |
| E _O | Offset error | -3.5 | ± 0.8 | 3.5 | LSB |
| G _E | Cummulative gain error for ADC _x and REFBUF _x | -0.025 | ± 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 |
| AC ACCURACY | | | | | |
| SNR ⁽¹⁾ | 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 ⁽¹⁾⁽²⁾ | 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 ⁽¹⁾⁽²⁾ | 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 ⁽¹⁾ | 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 ⁽¹⁾ | Common-mode rejection ratio | $f_{IN} = \text{dc to } 1\text{-MHz, } V_{IN} = 100\text{-mV}_{PP}$ | | 75 | dB |
| ISOXT ⁽¹⁾ | Channel-to-channel isolation | $f_{IN_ADCA} = 15\text{ kHz at } 10\% \text{ FSR,}$ $f_{IN_ADCB} = 25\text{ kHz at } 100\% \text{ FSR}$ | -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 |
|---|---|-----------------------------|-----------------------|-----|------|
| CONVERSION CONTROL AND DATA TRANSFER (See 图 1 and 图 2) | | | | | |
| $t_{D_CONVST_CS}$ | 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 |
| SPI-COMPATIBLE AND PARALLEL BYTE PROTOCOL (See 图 3) | | | | | |
| 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_CSCK} | 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 |
| CLOCK RE-TIMER PROTOCOL WITH STROBE = SCLK (EXTERNAL CLOCK)⁽³⁾(See 图 4) | | | | | |
| f_{CLK} | Serial clock frequency with single data rate | | | 60 | MHz |
| | Serial clock frequency with double data rate | | | 22 | MHz |
| ASYNCHRONOUS RESET AND POWER-DOWN TIMING (See 图 6) | | | | | |
| 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 |
|---|--|---|------|-----------------------|------|
| CONVERSION CONTROL AND DATA TRANSFER (See 图 1 and 图 2) | | | | | |
| 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 |
| SPI-COMPATIBLE AND PARALLEL BYTE PROTOCOL (See 图 3) | | | | | |
| 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 |
| CLOCK RE-TIMER PROTOCOL WITH STROBE = SCLK (EXTERNAL CLOCK)⁽¹⁾(See 图 4) | | | | | |
| $t_{OFF_STROBE_DO}$ | 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 |
| CLOCK RE-TIMER PROTOCOL WITH STROBE = INTERNAL CLOCK ⁽¹⁾(See 图 5) | | | | | |
| $t_{D_CS_STROBE}$ | Delay time : \overline{CS} falling to 1 st 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 |

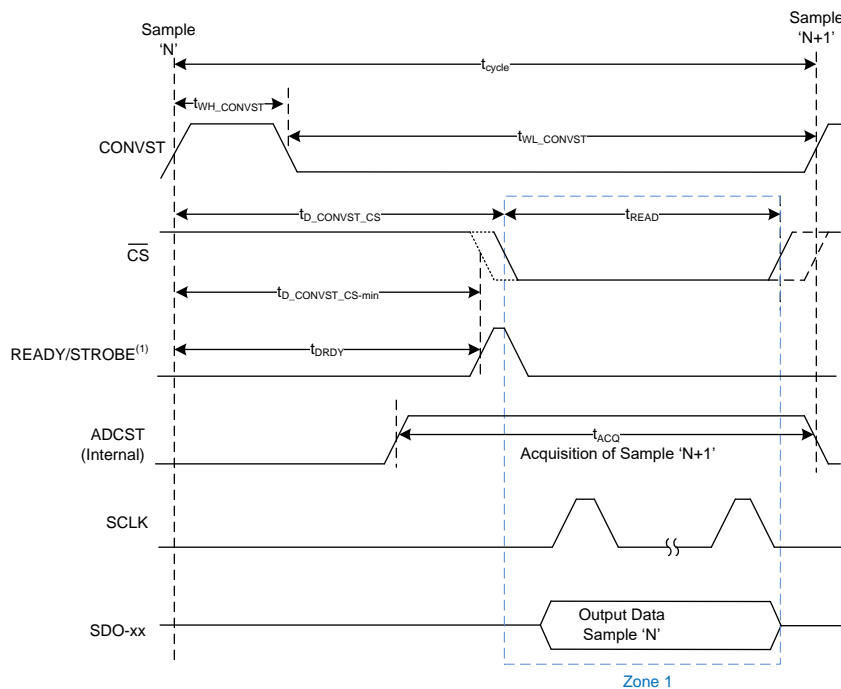
(1) Other parameters are the same as the SPI-compatible and Parallel Byte Protocols.

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

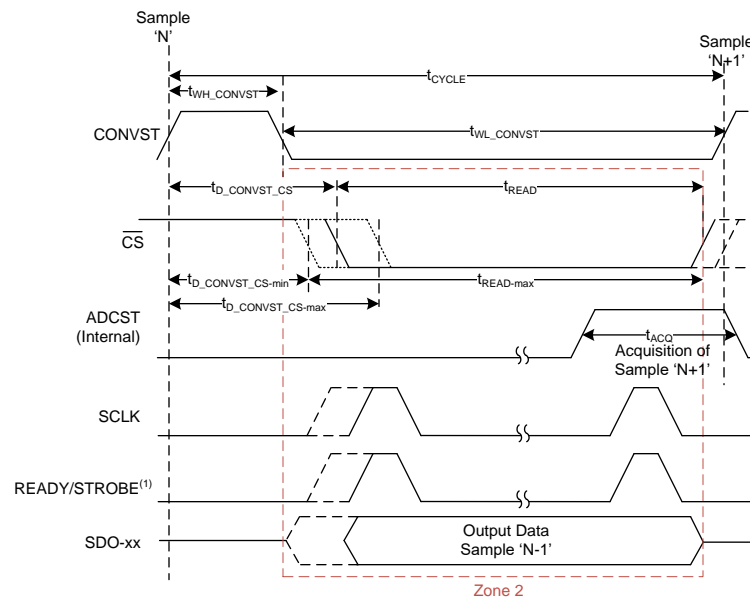
| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---------------------------------------|-------------------------------|------|-----|---------------|
| ASYNCHRONOUS RESET AND POWER-DOWN TIMING (See 图 6) | | | | | |
| $t_{RST-WKUP}$ | Wake up time from reset | | | 1 | μs |
| $t_{PD-WKUP}^{(2)}$ | 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 $C_{REFP_X} = 10\mu\text{F}$



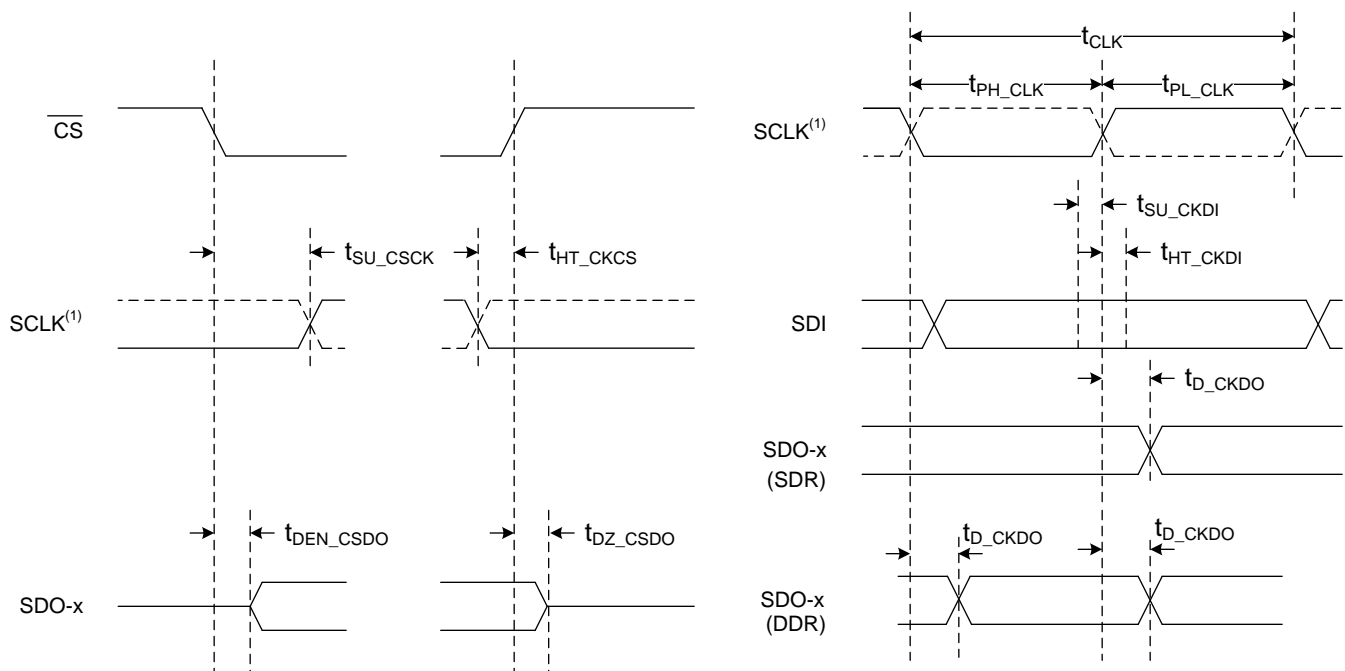
- (1) The READY output is required for data transfer with zero cycle latency. The STROBE output is required only for clock re-timer (CRT) protocols.

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



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

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



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

图 3. SPI-Compatible and Parallel Byte Protocols Timing

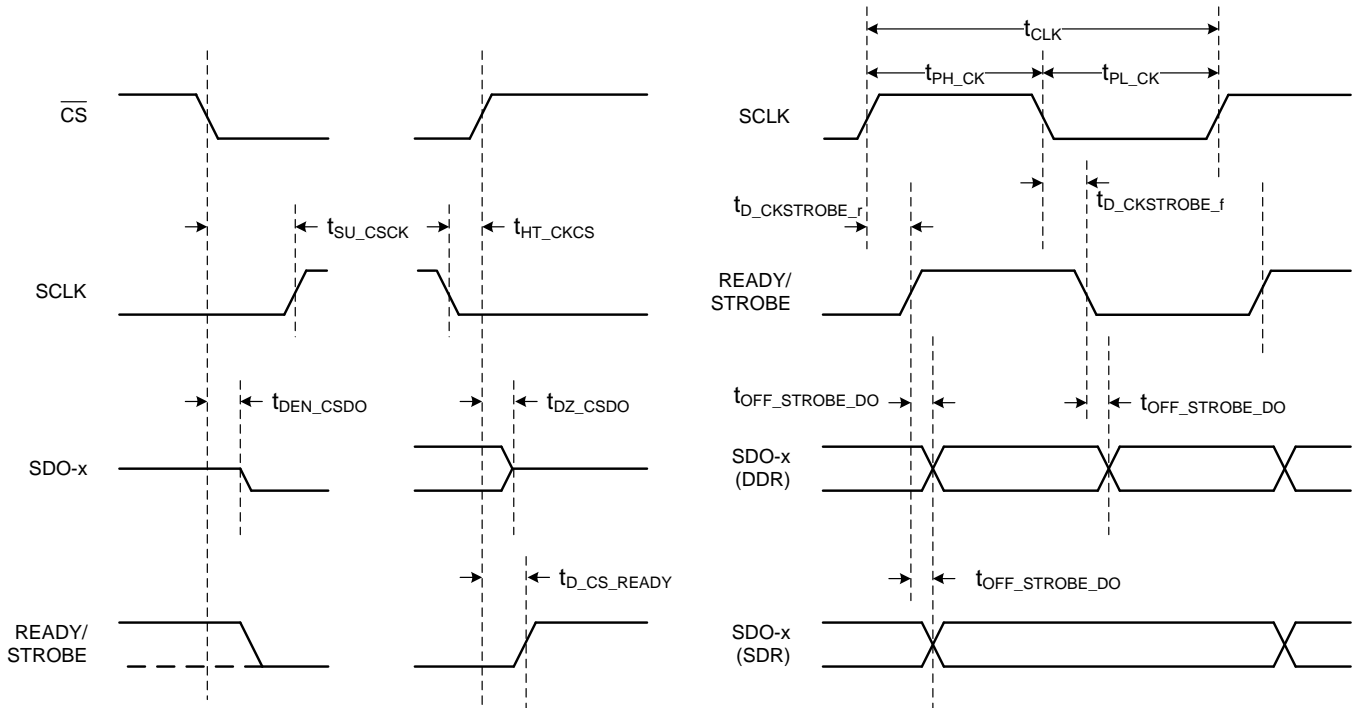


图 4. Clock Re-Timer Protocol (External Clock) Timing

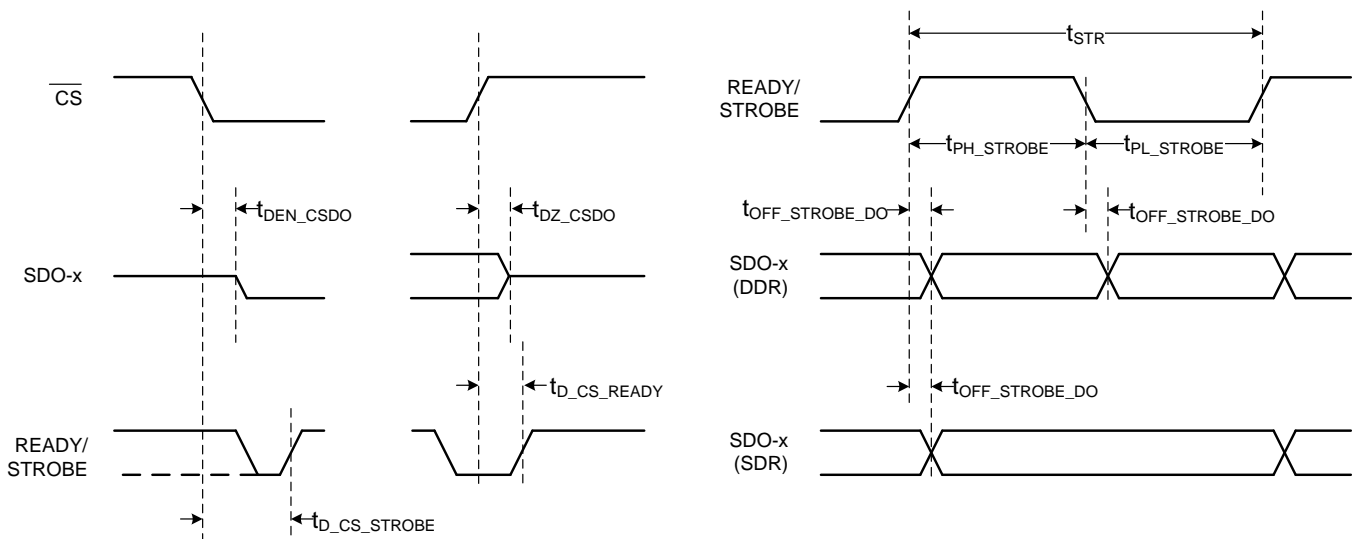


图 5. Clock Re-Timer Protocol (Internal Clock) Timing

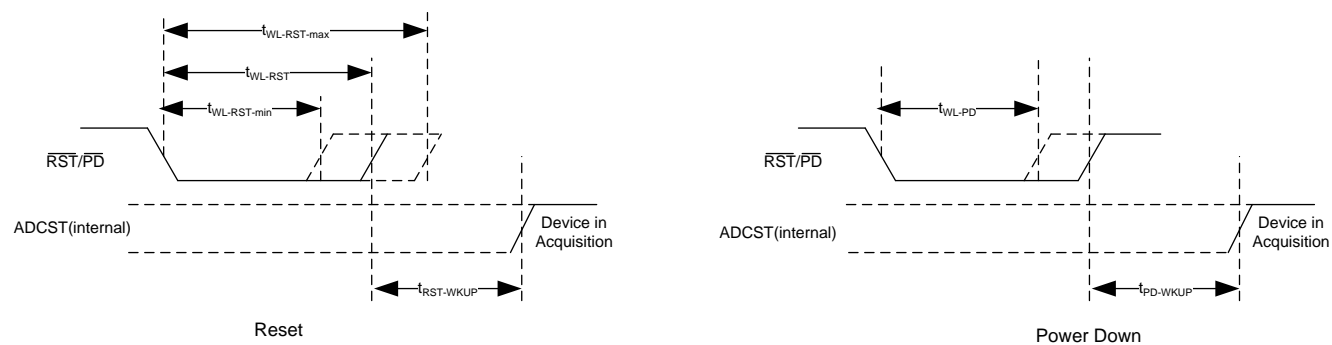


图 6. Asynchronous Reset and Power-Down Timing

6.10 Typical Characteristics: ADS9224R

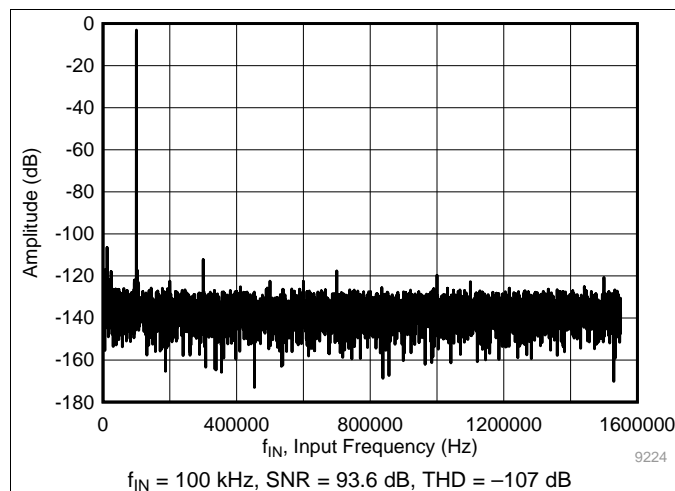


图 7. Typical FFT at $f_{IN} = 100 \text{ kHz}$

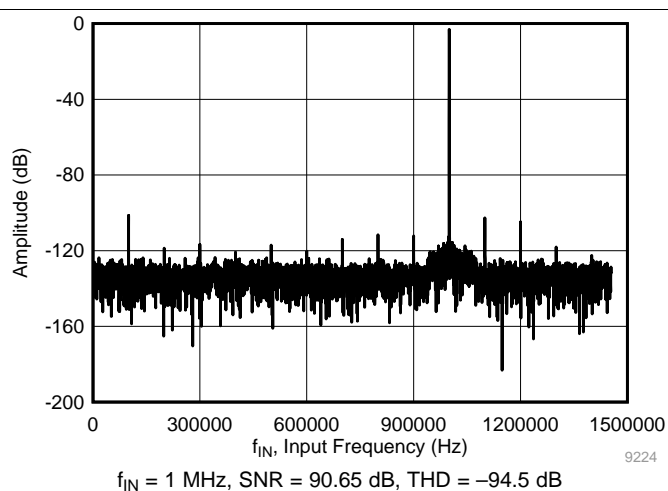


图 8. Typical FFT at $f_{IN} = 1 \text{ MHz}$

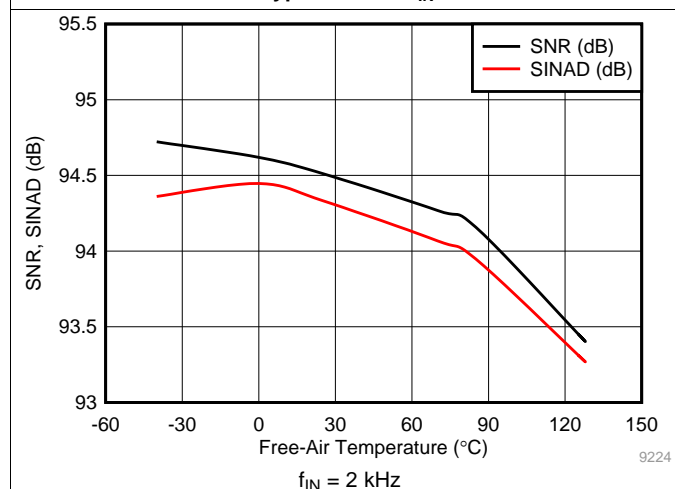


图 9. Noise Performance vs Temperature

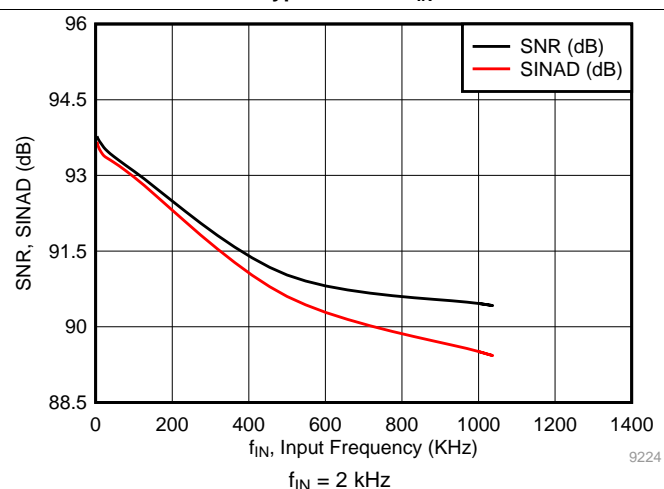


图 10. Noise Performance vs Frequency

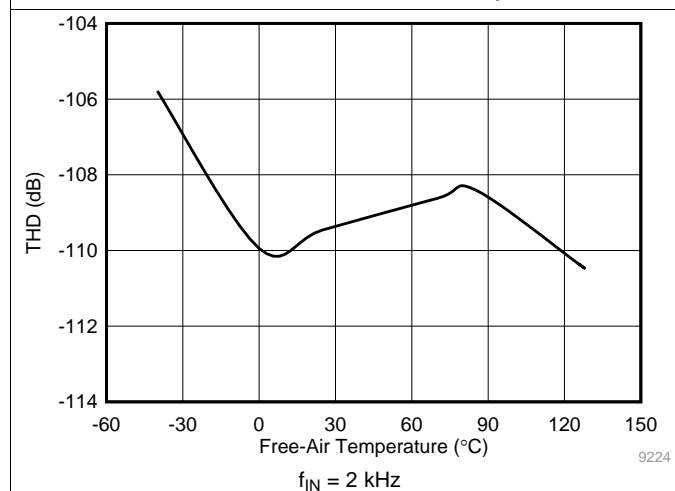


图 11. Distortion Performance vs Temperature

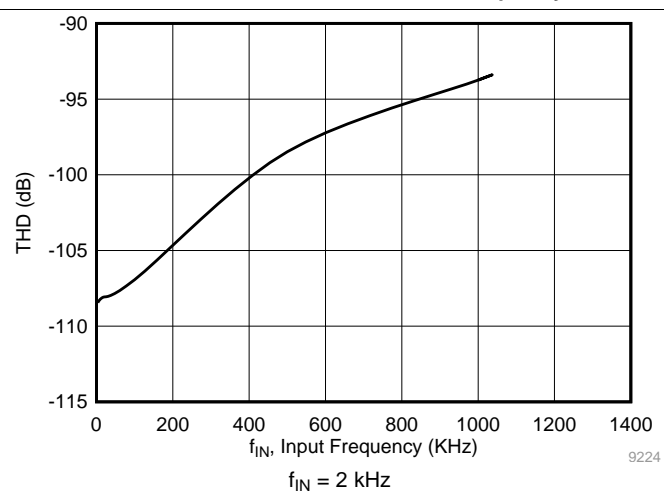


图 12. Distortion Performance vs Frequency

Typical Characteristics: ADS9224R (接下页)

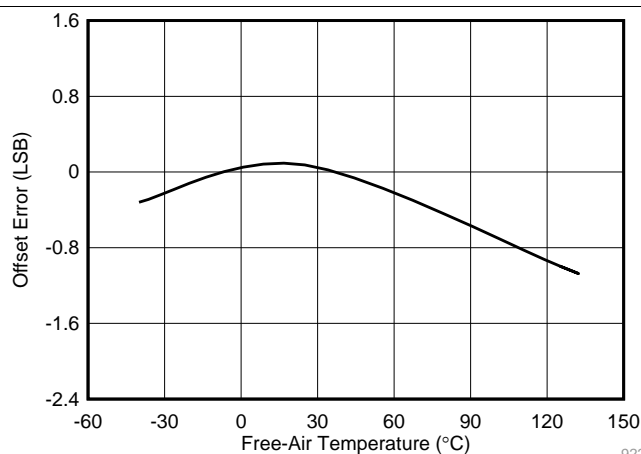


图 13. Offset Error vs Temperature

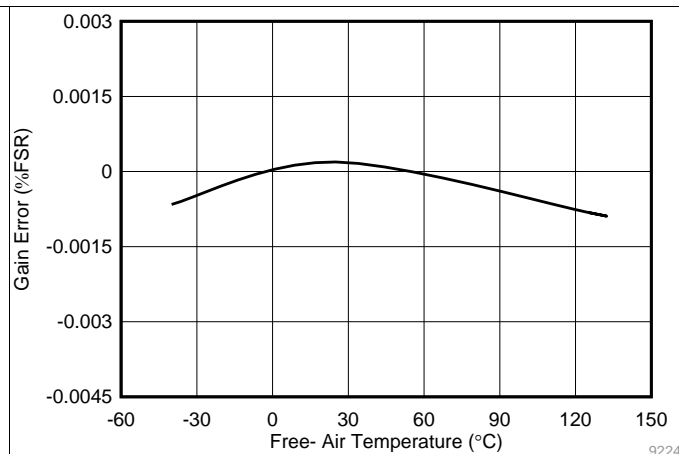


图 14. Gain Error vs Temperature

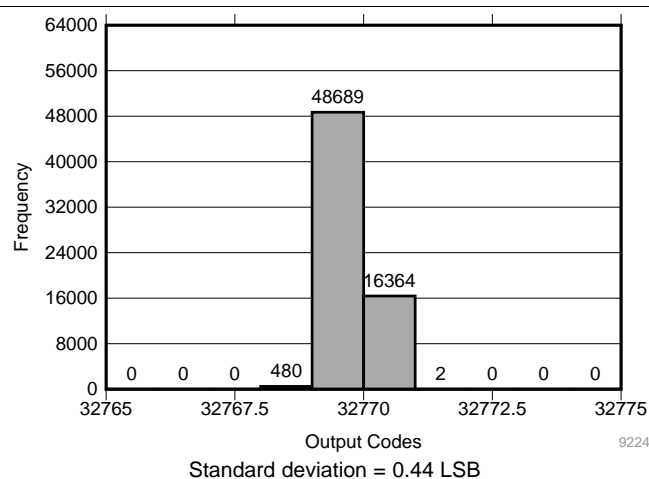


图 15. DC Input Histogram

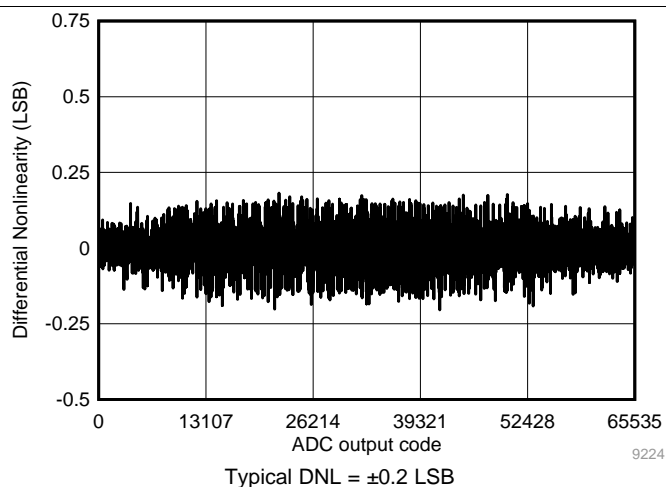


图 16. Typical DNL

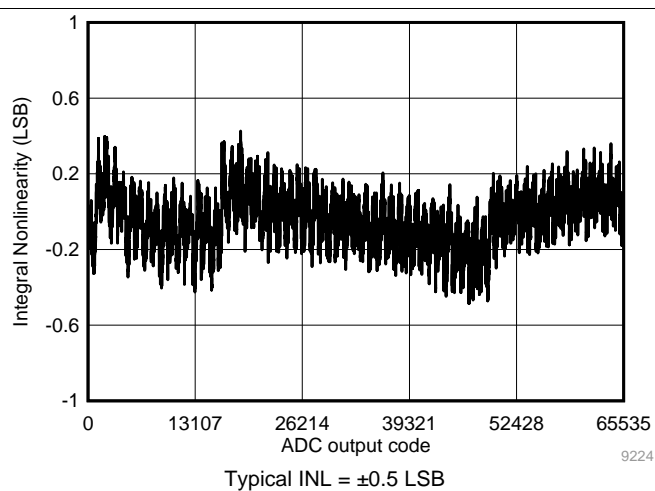


图 17. Typical INL

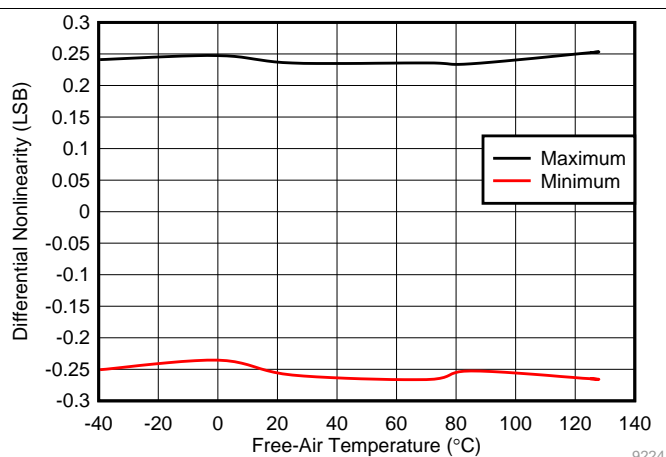
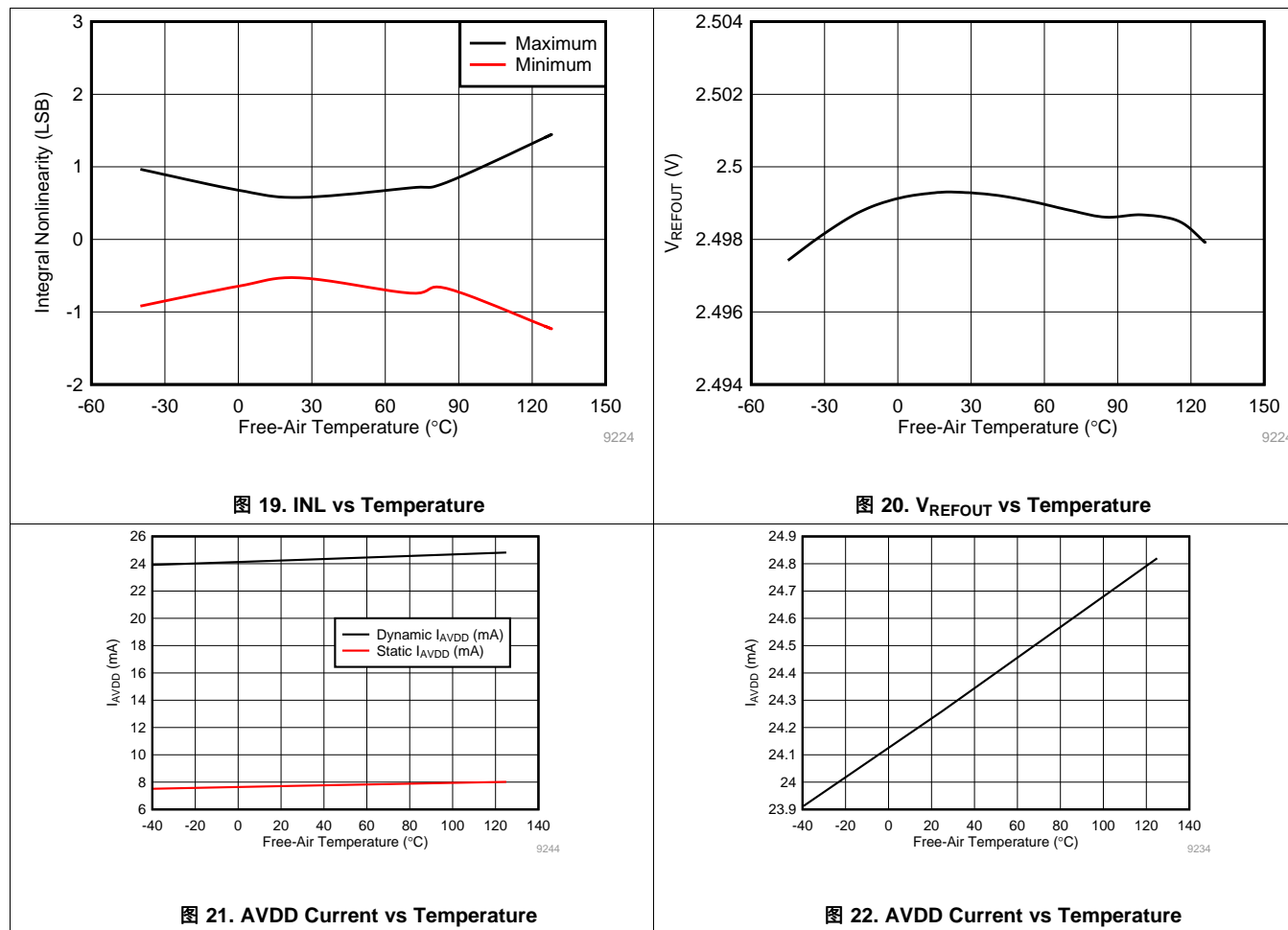


图 18. DNL vs Temperature

Typical Characteristics: ADS9224R (接下页)



6.11 Typical Characteristics: ADS9234R

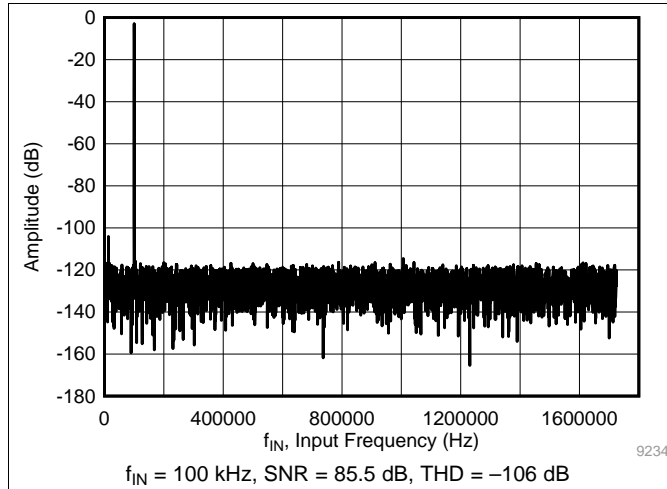


图 23. Typical FFT at $f_{IN} = 100 \text{ kHz}$

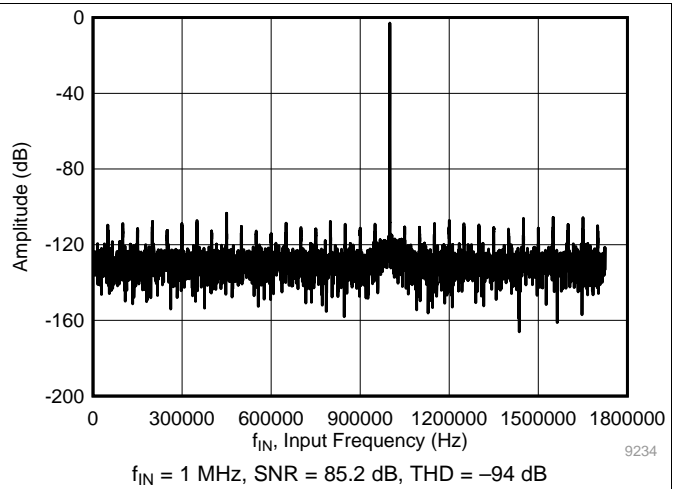


图 24. Typical FFT at $f_{IN} = 1 \text{ MHz}$

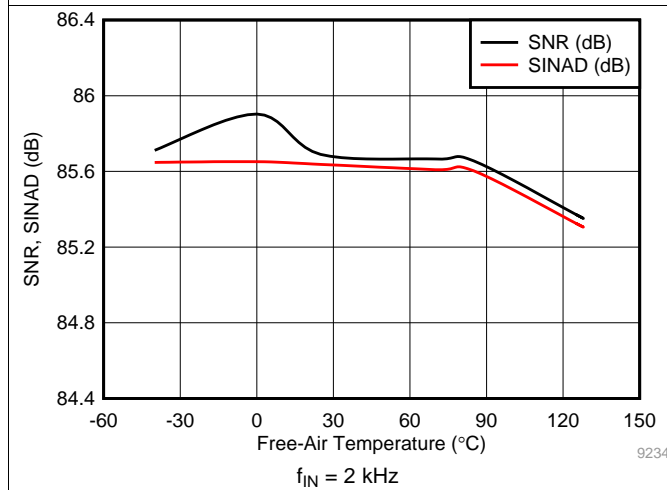


图 25. Noise Performance vs Temperature

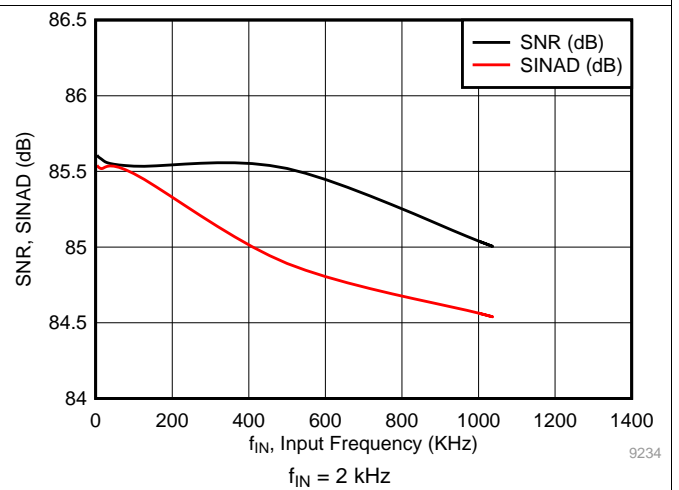


图 26. Noise Performance vs Frequency

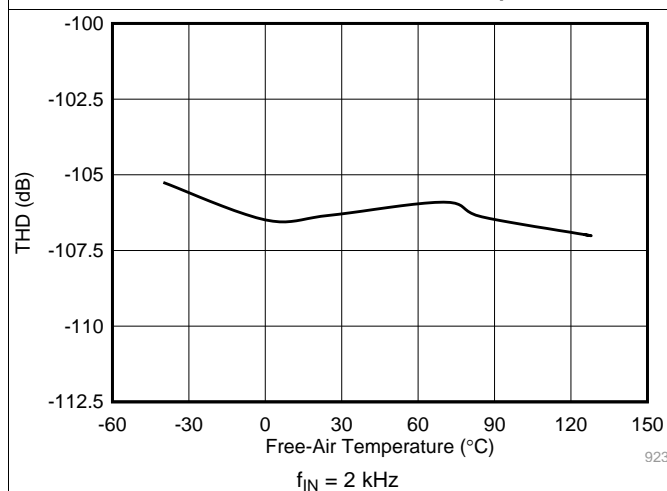


图 27. Distortion Performance vs Temperature

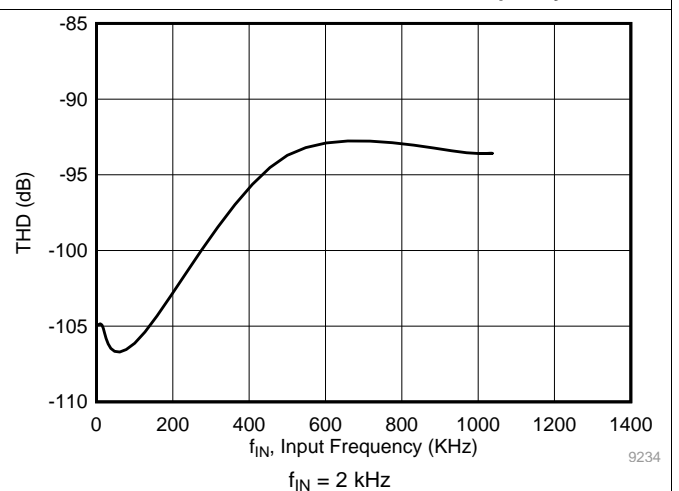


图 28. Distortion Performance vs Frequency

Typical Characteristics: ADS9234R (接下页)

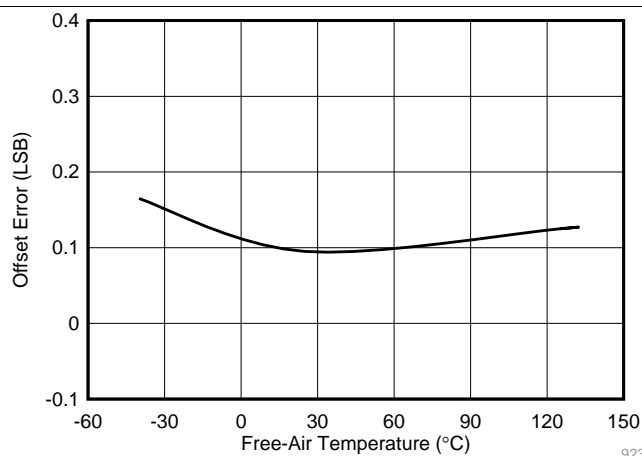


图 29. Offset Error vs Temperature

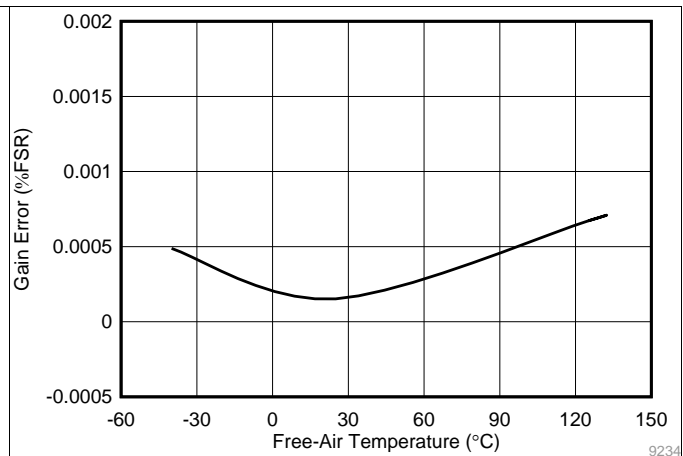


图 30. Gain Error vs Temperature

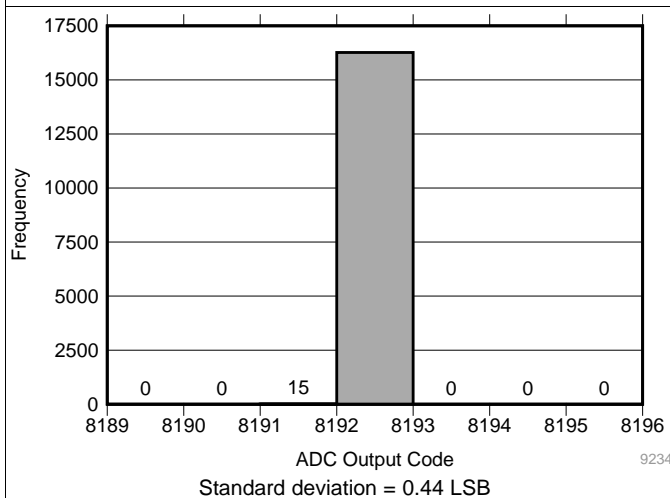


图 31. DC Input Histogram

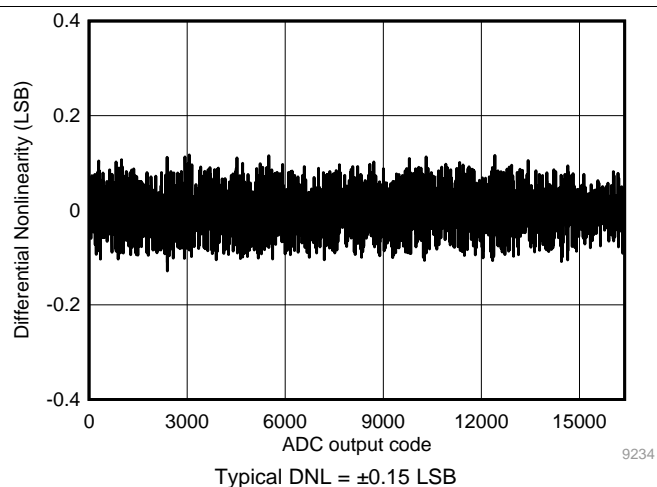


图 32. Typical DNL

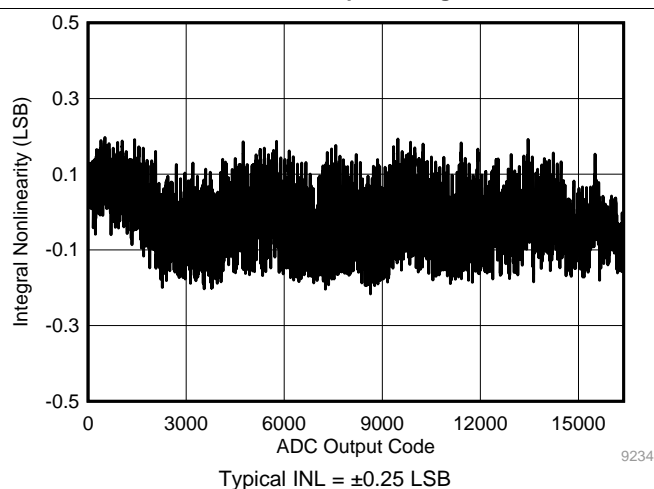


图 33. Typical INL

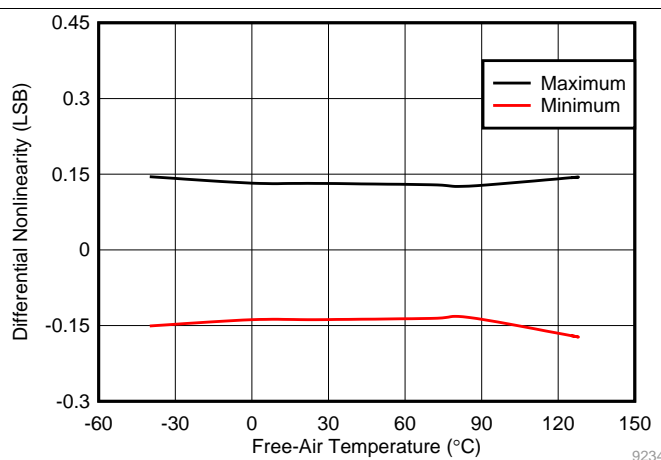


图 34. DNL vs Temperature

Typical Characteristics: ADS9234R (接下页)

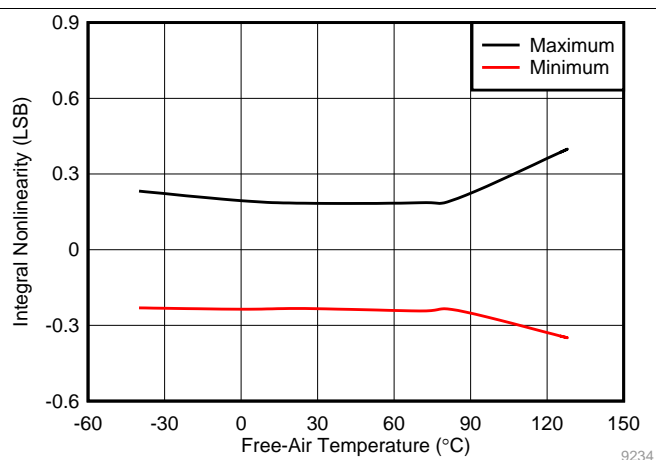


图 35. INL vs Temperature

7 Detailed Description

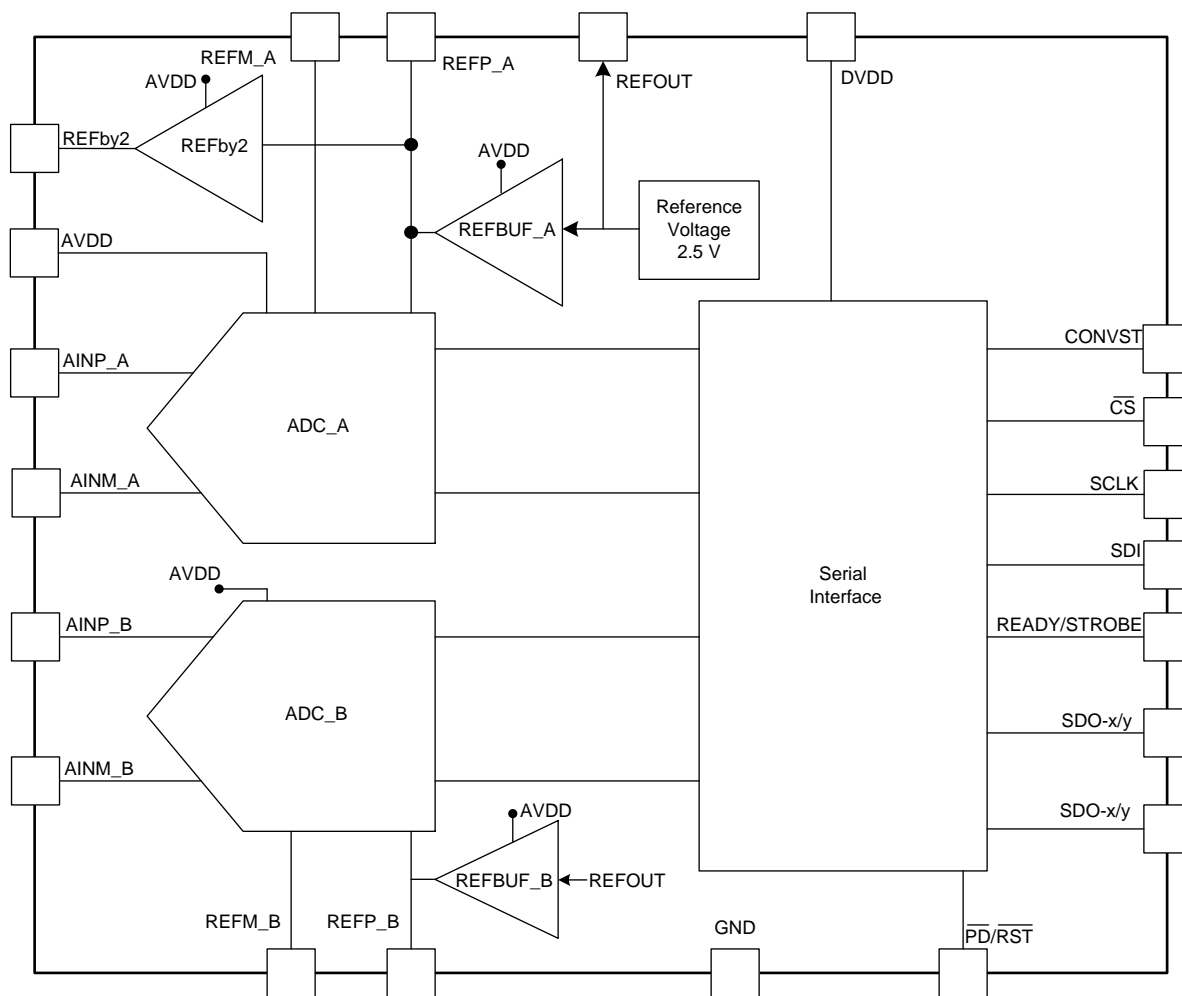
7.1 Overview

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 图 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.

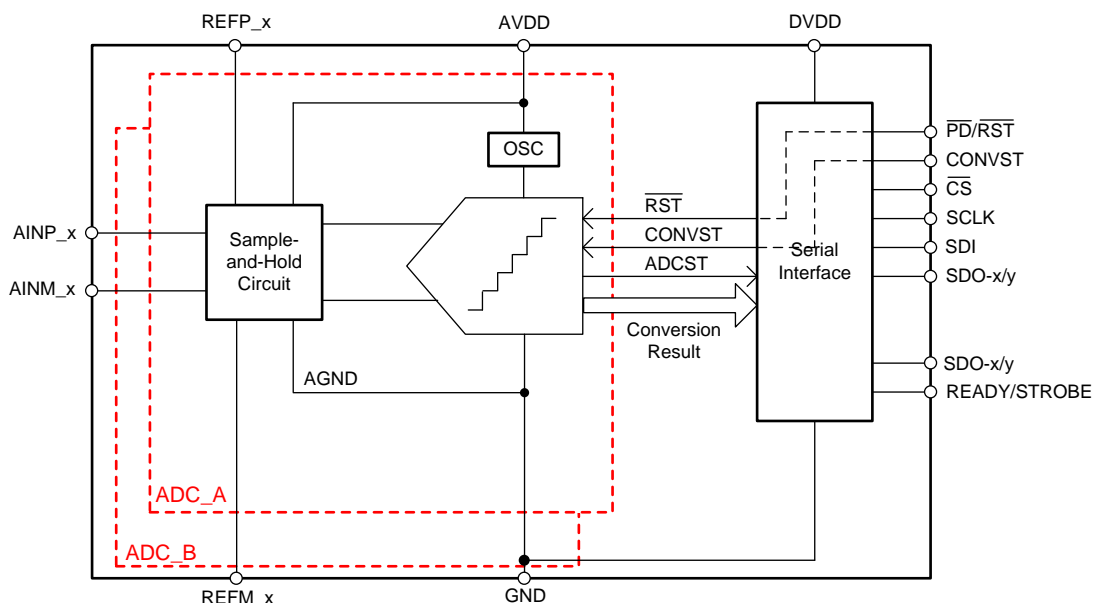


图 36. Converter Modules

7.3.1.1 Analog Input With Sample-and-Hold

This device supports unipolar, fully differential, analog input signals. 图 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 Ω) in series with an ideal switch (SW_1 and SW_2). The sampling capacitors, C_{S1} and C_{S2} , are typically 16 pF.

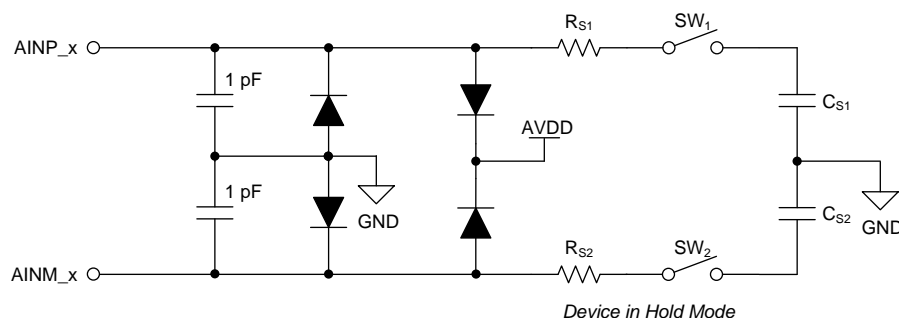


图 37. Analog Input Structure for Converter Module

Feature Description (接下页)

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

公式 1 和 公式 2 provide the full-scale input range (FSR) and common-mode voltage (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. 表 1 和 图 38 show the ideal transfer characteristics for the device. 公式 3 gives the least significant bit (LSB) for the ADC.

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

where

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

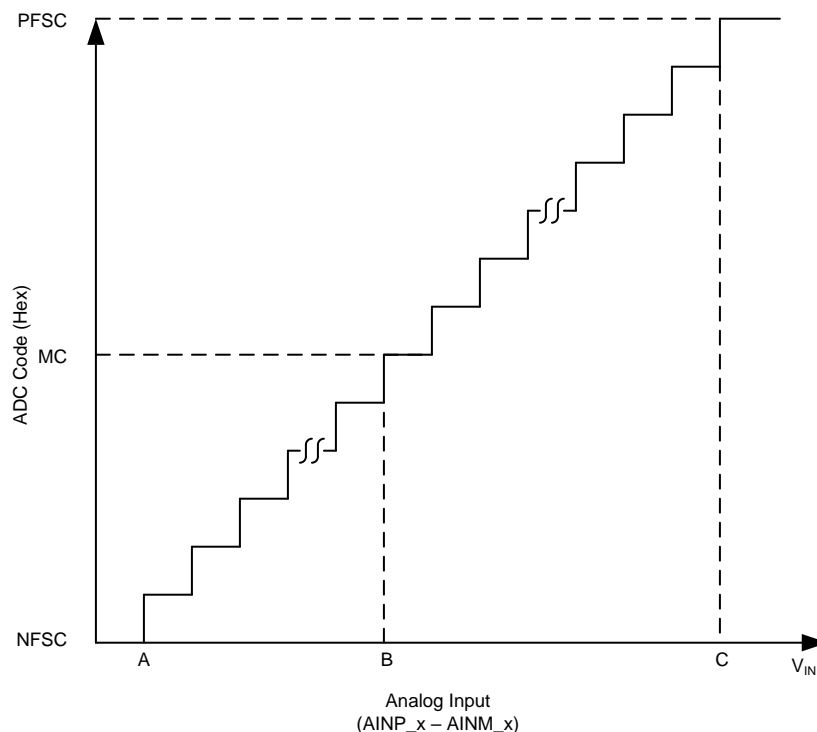


图 38. Ideal Transfer Characteristics

表 1. Transfer Characteristics

| STEP | INPUT VOLTAGE (AINP_x-AINM_x) | CODE | DESCRIPTION | IDEAL OUTPUT CODE (R = 16) | IDEAL OUTPUT CODE (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- μ F decoupling capacitor (C_{REFOUT}), as shown in 图 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 图 39, place a decoupling capacitor C_{REFP_X} between the REFP_x and REFM_x pins as close to the device as possible.

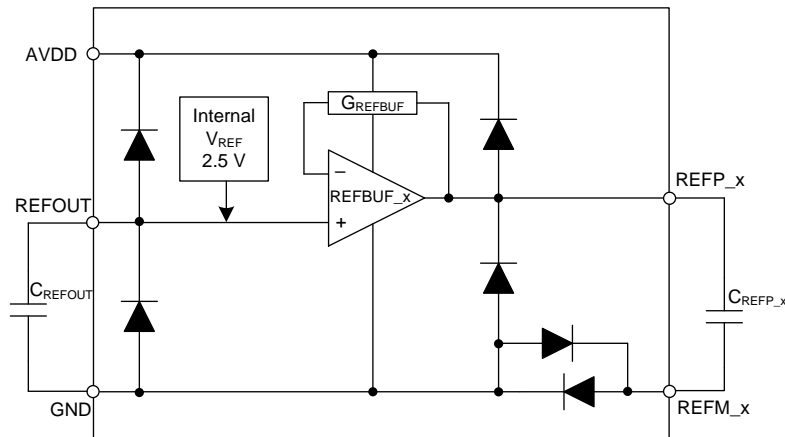


图 39. Connection Diagram for Reference and Reference Buffers

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. 图 40 depicts a block diagram for the REFby2 buffer.

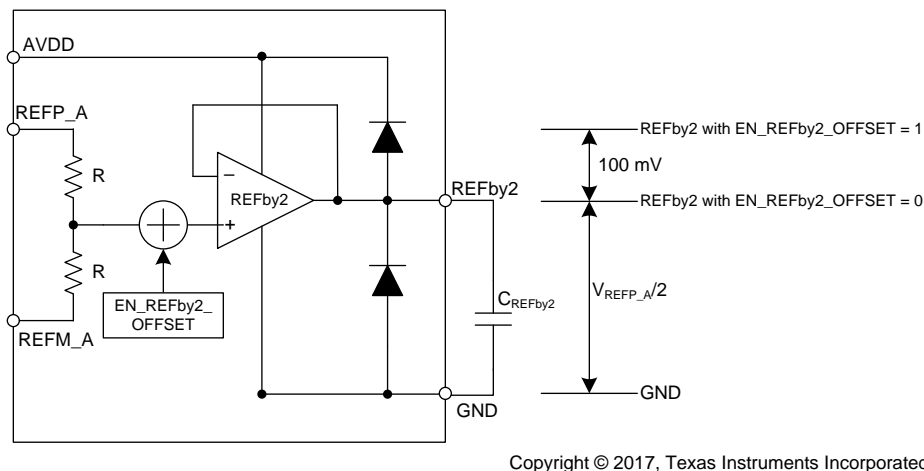


图 40. REFby2 Buffer

7.3.5 Data Averaging

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

7.3.5.1 Averaging of Two Samples

To enable averaging of two samples, set the EN_DATA_AVG bits in the [DATA_AVG_CFG register](#) to 10b. In this mode, the device averages two samples and provides the average of two samples as output data. The output data rate reduces by a factor of two. In this mode, the host must provide two pulses separated by a time of t_{CYCLE} (see t_{CYCLE} for a zone 2 transfer in the [Specifications](#) section) on the CONVST pin. The device sets the READY pin high after a time of t_{DRDY} (see t_{DRDY} in the [Specifications](#) section) from the second rising edge on the CONVST pin. After the READY pin is set high, the host can read the data by using one of the [protocols for reading from the device](#). The host can read the data while providing the two CONVST pulses for acquiring the next two samples. The host must keep $t_{\text{READ}} < [2 \times t_{\text{CYCLE}}]$. 图 41 provides the timing for the averaging of two samples.

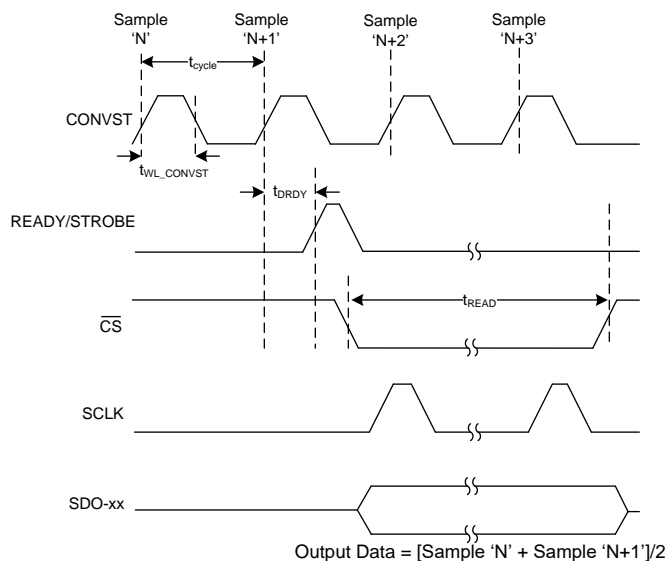


图 41. Timing for Averaging of Two Samples

7.3.5.2 Averaging of Four Samples

To enable averaging of four samples, set the EN_DATA_AVG bits in the [DATA_AVG_CFG register](#) to 11b. In this mode, the device averages four samples and provides the average of four samples as output data. The output data rate reduces by a factor of four. In this mode, the host must provide four pulses separated by a time of t_{CYCLE} (see t_{CYCLE} for a zone 2 transfer in the [Specifications](#) section) on the CONVST pin. The device sets the READY pin high after a time of t_{DRDY} (see t_{DRDY} in the [Specifications](#) section) from the fourth rising edge on the CONVST pin. After the READY pin is set high, the host can read the data by using one of the [protocols for reading from the device](#). The host can read the data while providing the four CONVST pulses for acquiring the next four samples. The host must keep $t_{\text{READ}} < [4 \times t_{\text{CYCLE}}]$. [图 42](#) provides the timing for the averaging of four samples.

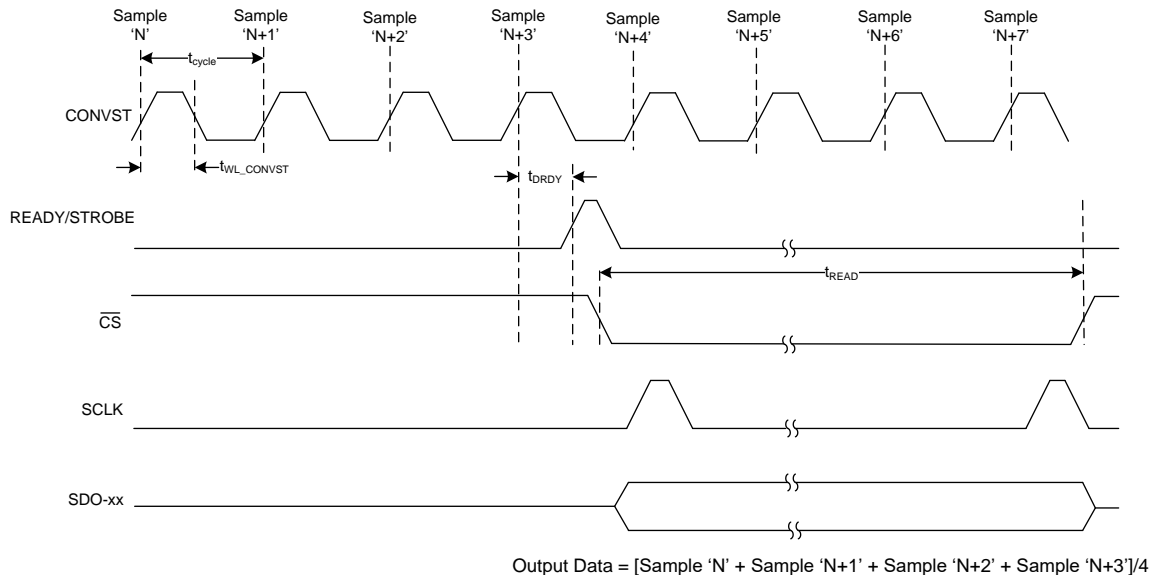


图 42. Timing for Averaging of Four Samples

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 $\overline{\text{PD/RST}}$ 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 $\overline{\text{PD/RST}}$ 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_{CYCLE} between two subsequent start of conversions.

7.4.3 Reset or Power-Down

The $\overline{\text{PD/RST}}$ pin is an asynchronous digital input for the device. The pulse duration (low) on the $\overline{\text{PD/RST}}$ pin decides the state for the device (reset or power-down). [图 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 (接下页)

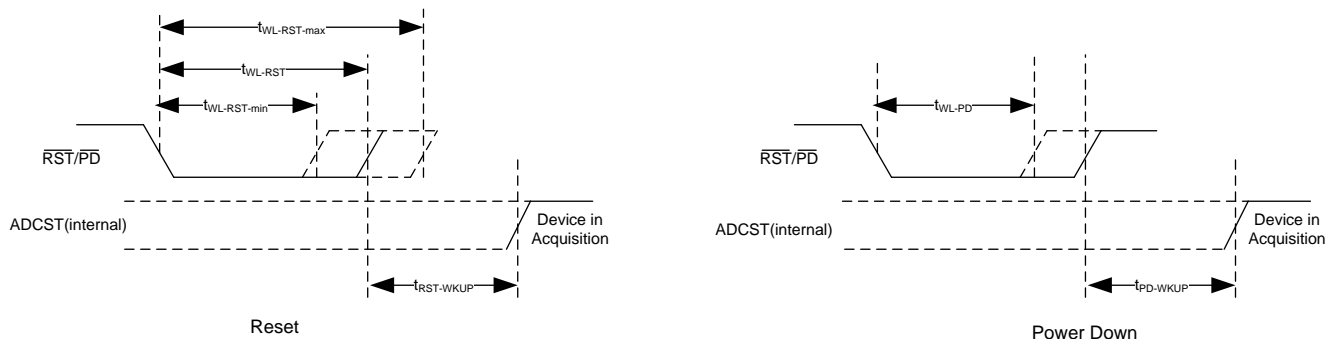


图 43. Reset or Power Down

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 (接下页)

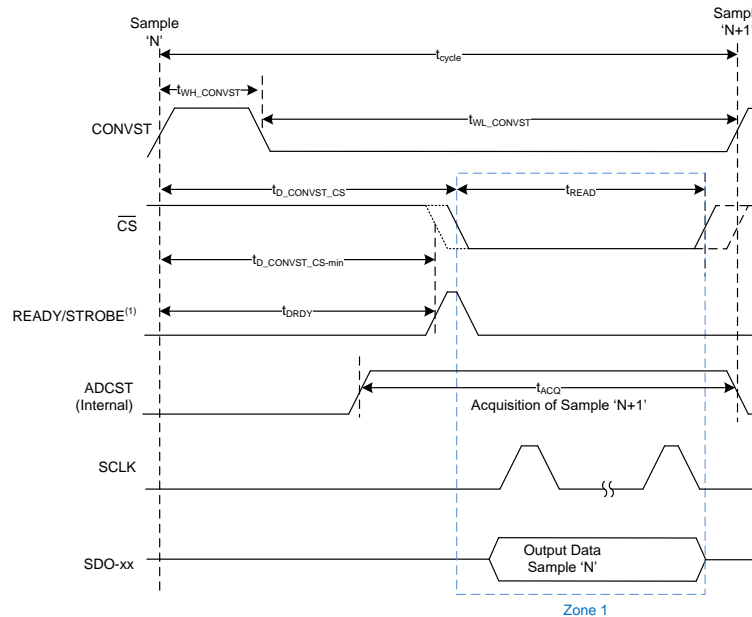
7.4.4 Conversion Control and Data Transfer Frame

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

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

In this mode of conversion control and data transfer, the device starts conversion on the rising edge of CONVST. The CONVST pin can be pulled low after a minimum time of t_{WH_CONVST} . After the conversion is finished, the rising edge of the READY/STROBE pin indicates that the data are ready and the data can be read by the host. After the READY pin is set high, as shown in 图 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 $t_{CYCLE} = t_{DRDY} + t_{READ}$.



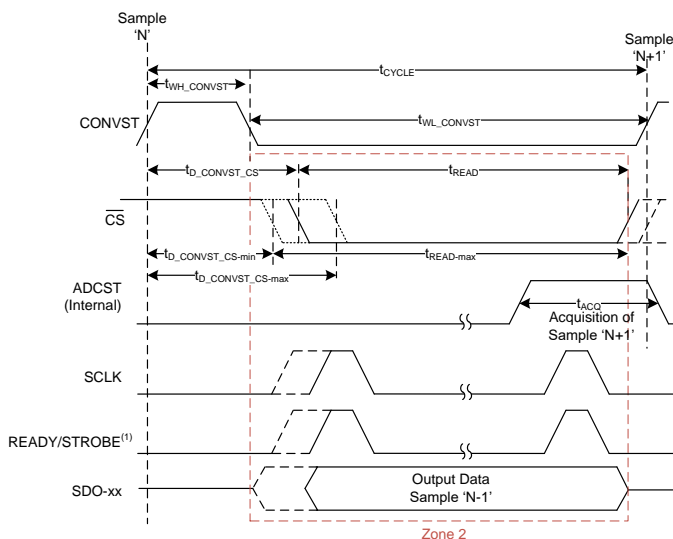
- (1) The READY output is required for data transfer with zero cycle latency. The STROBE output is required only for clock re-timer (CRT) protocols. See the [READY/STROBE Output](#) section for details.
- (2) For t_{READ} with different data transfer protocols; see the [Protocols for Reading From the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

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

Device Functional Modes (接下页)

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

In this mode of conversion control and data transfer, the device starts conversion on the rising edge of CONVST. The CONVST pin can be pulled low after a minimum time of t_{WH_CONVST} . After a time of $t_{D_CONVST_CS}$ (see $t_{D_CONVST_CS}$ for zone 2 transfer in the [Specifications](#) section), the host must pull \overline{CS} low and provide clocks on the SCLK pin to read the data in zone 2. As shown in [图 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 \overline{CS} pin high to end the data transfer frame. After pulling \overline{CS} high, the host can pull the CONVST pin high to start the next conversion. In this mode of conversion control, a minimum time of t_{CYCLE} (see t_{CYCLE} for zone 2 transfer in the [Specifications](#) section) is required between two adjacent rising edges of the CONVST signal. The host must keep the SDI pin low (NOP0) or high (NOP1) for conversion control and for getting conversion results from the device.



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

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

注

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

7.5 READY/STROBE Output

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

7.5.1 READY Output

After power-up or after exiting power-down (a rising edge on $\overline{PD}/\overline{RST}$), the READY signal is set high. After a time of 0.9 ms, this signal goes low, indicating that the device is initialized and the registers can be configured. However, conversions can 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.

表 2. Output Data Word

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

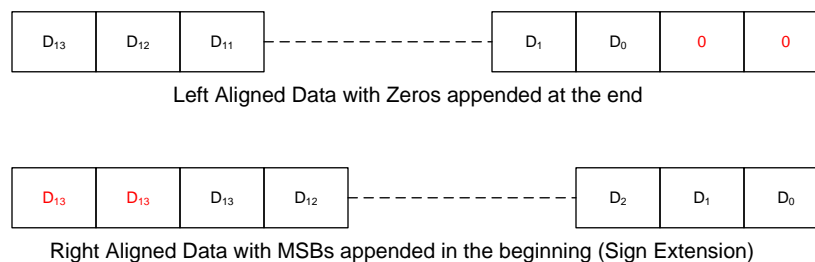


图 46. Data Alignment for ADS9234R Devices

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. 表 3 provides the details of different legacy SPI protocols to read data from the device.

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

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

(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.

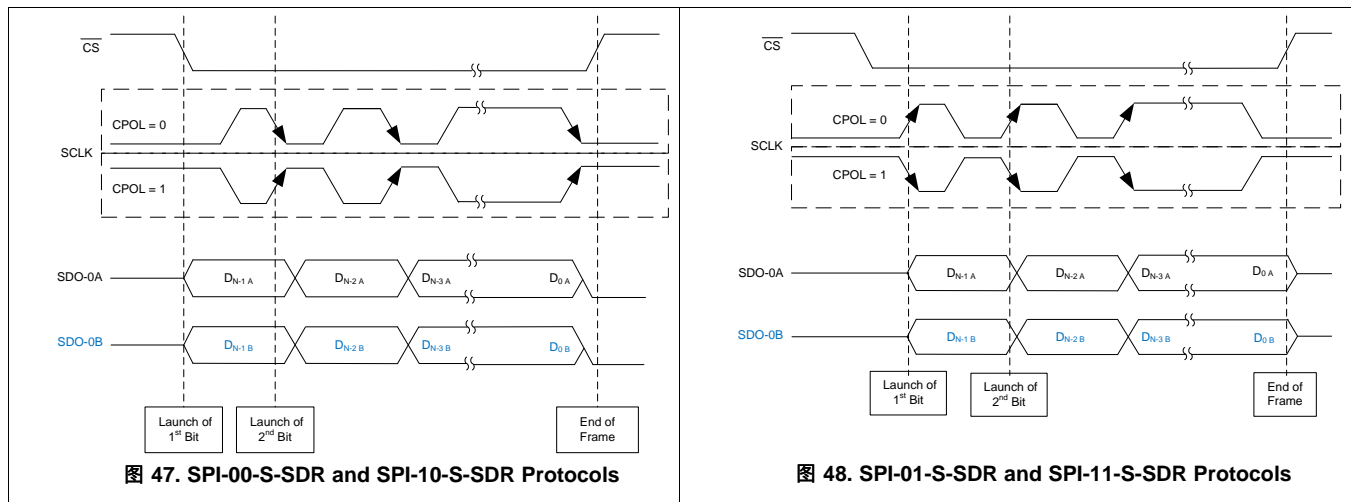
(3) With SCLK \geq 30 MHz, TI recommends data capture on the launch edge for the next bit.

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

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

图 47 和 图 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_{CYCLE} for zone 1 transfer reduces. The SDOs that are not enabled by the [BUS_WIDTH](#) register are set to tri-state. 表 4 provides the details of different SPI protocols with bus width options and single data rate to read data from the device.

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

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

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

图 49, 图 50, 图 51, 和 图 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.

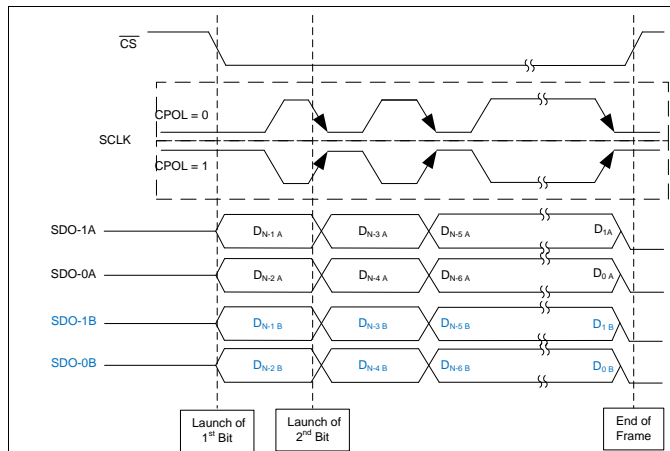


图 49. SPI-00-D-SDR and SPI-10-D-SDR Protocols

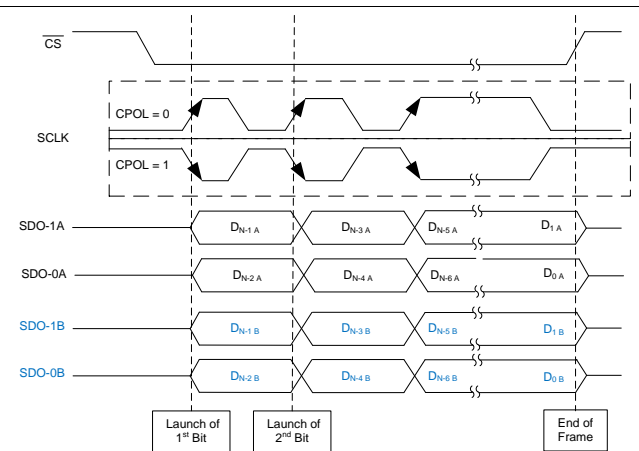


图 50. SPI-01-D-SDR and SPI-11-D-SDR Protocols

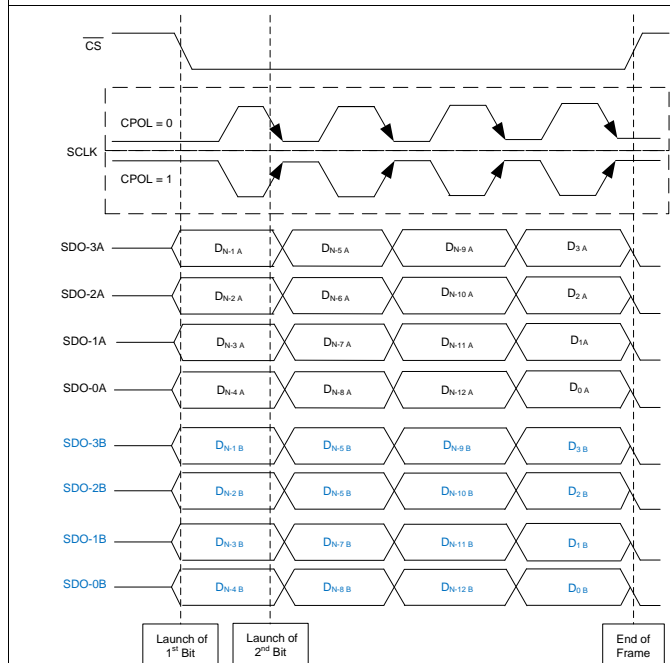


图 51. SPI-00-Q-SDR and SPI-10-Q-SDR Protocols

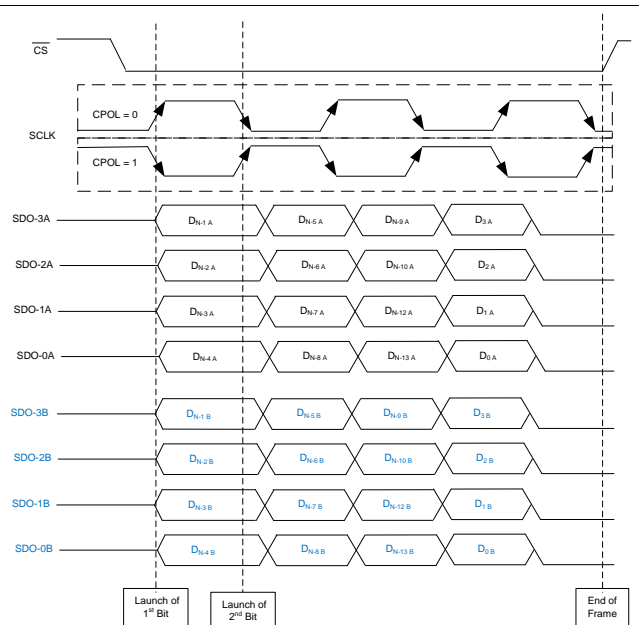


图 52. SPI-01-Q-SDR and SPI-11-Q-SDR Protocols

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)

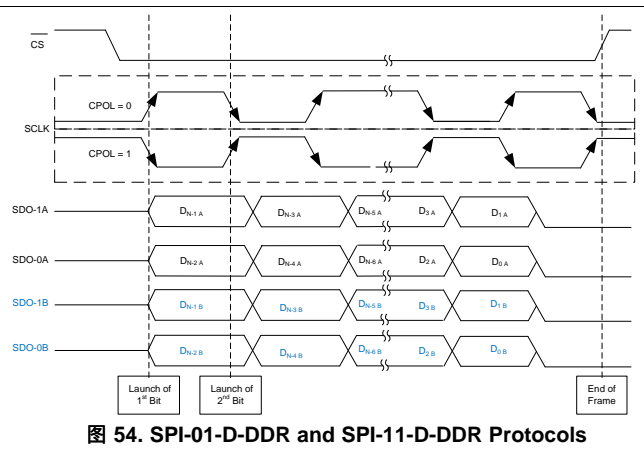
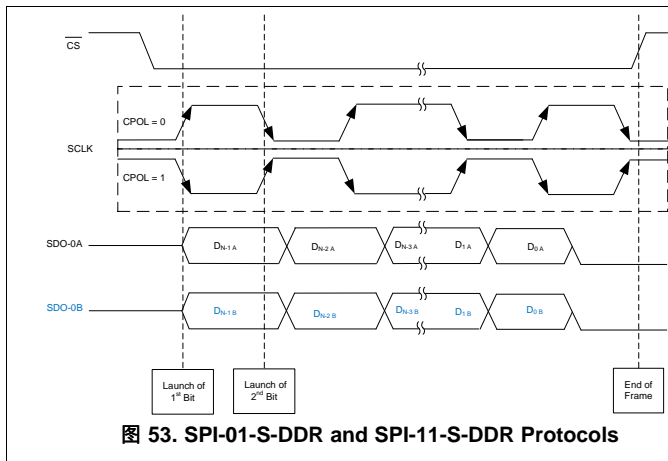
In this data transfer protocol, the data rate for data transfer can be increased to double data rate. With double data rate, the device launches data on both edges (rising and falling) of the SCLK. The device supports both polarities of the clock and only one phase of clock (CPHA = 1). The read time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

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

| PROTOCOL ⁽¹⁾ | SCLK POLARITY (CPOL) ⁽²⁾ | SCLK PHASE ⁽²⁾ | MSB LAUNCH EDGE | BUS WIDTH ⁽³⁾ | t _{READ} ⁽⁴⁾⁽⁵⁾ | TIMING DIAGRAM |
|-------------------------|-------------------------------------|---------------------------|------------------------------|--------------------------|-------------------------------------|----------------------|
| SPI-01-S-DDR | Low (CPOL = 0) | Falling (CPHA = 1) | 1 st SCLK rising | 1 | [9 × t _{CLK} + k] | 图 53 |
| SPI-11-S-DDR | High (CPOL = 1) | Rising (CPHA = 1) | 1 st SCLK falling | 1 | [9 × t _{CLK} + k] | 图 53 |
| SPI-01-D-DDR | Low (CPOL = 0) | Falling (CPHA = 1) | 1 st SCLK rising | 2 | [5 × t _{CLK} + k] | 图 54 |
| SPI-11-D-DDR | High (CPOL = 1) | Rising (CPHA = 1) | 1 st SCLK falling | 2 | [5 × t _{CLK} + k] | 图 54 |
| SPI-01-Q-DDR | Low (CPOL = 0) | Falling (CPHA = 1) | 1 st SCLK rising | 4 | [3 × t _{CLK} + k] | 图 55 |
| SPI-11-Q-DDR | High (CPOL = 1) | Rising (CPHA = 1) | 1 st SCLK falling | 4 | [3 × t _{CLK} + k] | 图 55 |

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

[图 53](#), [图 54](#), and [图 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.



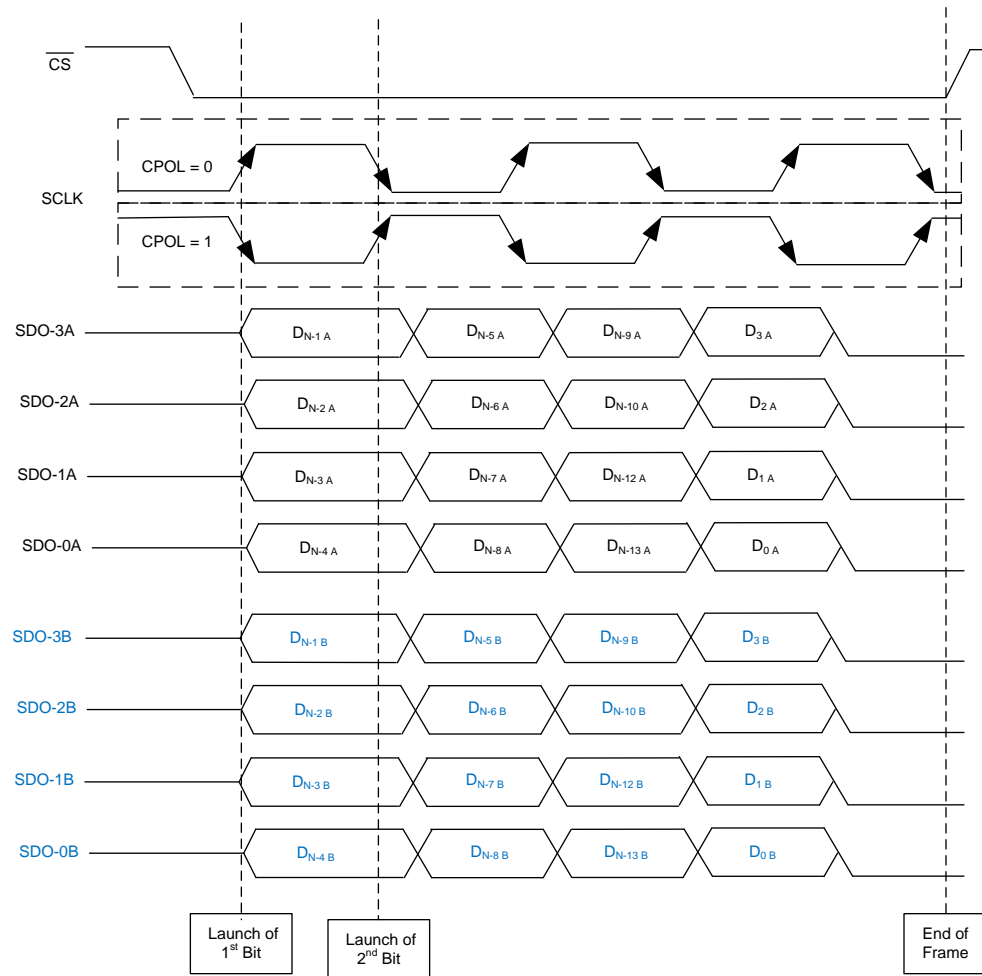


图 55. SPI-01-Q-DDR and SPI-11-Q-DDR Protocols

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)

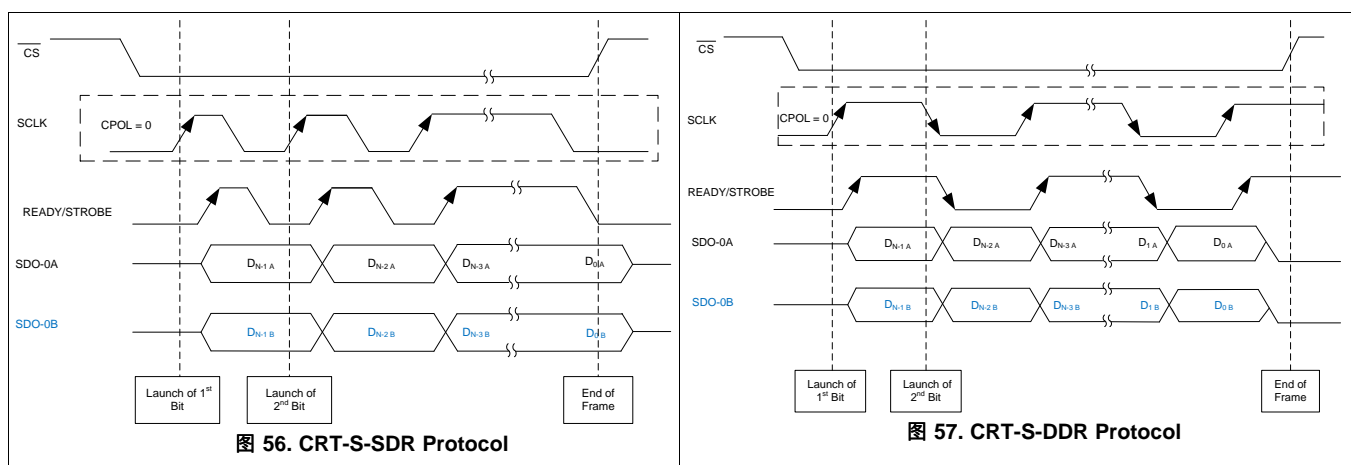
In clock re-timer (CRT) protocols, the device sends out data on the SDO lines with a synchronized clock on the STROBE line. The data are synchronized to the rising edges of the STROBE pulses. For CRT protocols with a single data rate, the host can capture data on the falling edges of the STROBE pulses.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

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

| PROTOCOL ⁽¹⁾ | SCLK POLARITY ⁽²⁾ | CAPTURE EDGE | MSB LAUNCH EDGE | BUS WIDTH ⁽³⁾ | t _{READ} ⁽⁴⁾ | TIMING DIAGRAM |
|-------------------------|------------------------------|---------------------------|-------------------------------|--------------------------|----------------------------------|----------------|
| CRT-S-SDR | Low (CPOL = 0) | STROBE falling | 1 st STROBE rising | 1 | [15.5 × t _{STROBE} + m] | 图 56 |
| CRT-D-SDR | Low (CPOL = 0) | STROBE falling | 1 st STROBE rising | 2 | [7.5 × t _{STROBE} + m] | 图 58 |
| CRT-Q-SDR | Low (CPOL = 0) | STROBE falling | 1 st STROBE rising | 4 | [3.5 × t _{STROBE} + m] | 图 60 |
| CRT-S-DDR | Low (CPOL = 0) | STROBE rising and falling | 1 st STROBE rising | 1 | [7.5 × t _{STROBE} + m] | 图 57 |
| CRT-D-DDR | Low (CPOL = 0) | STROBE rising and falling | 1 st STROBE rising | 2 | [3.5 × t _{STROBE} + m] | 图 59 |
| CRT-Q-DDR | Low (CPOL = 0) | STROBE rising and falling | 1 st STROBE rising | 4 | [1.5 × t _{STROBE} + m] | 图 61 |

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

图 56 through 图 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.



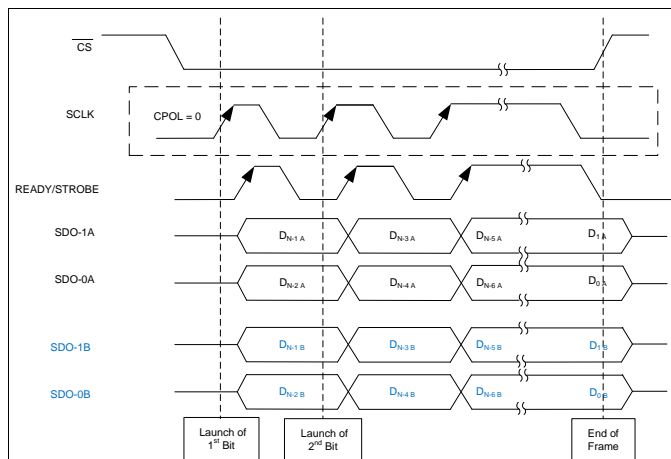


图 58. CRT-D-SDR Protocol

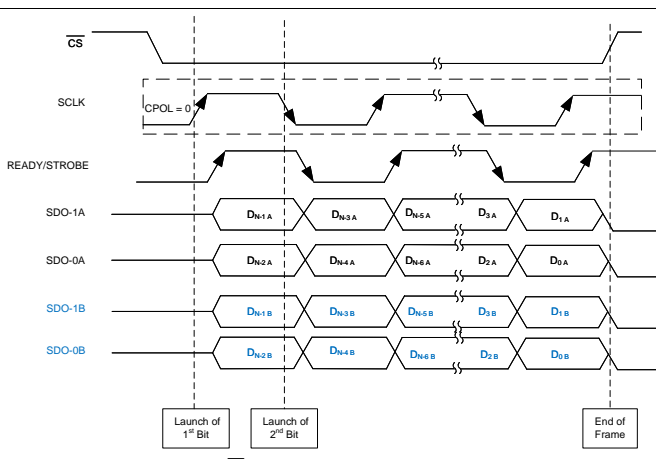


图 59. CRT-D-DDR Protocol

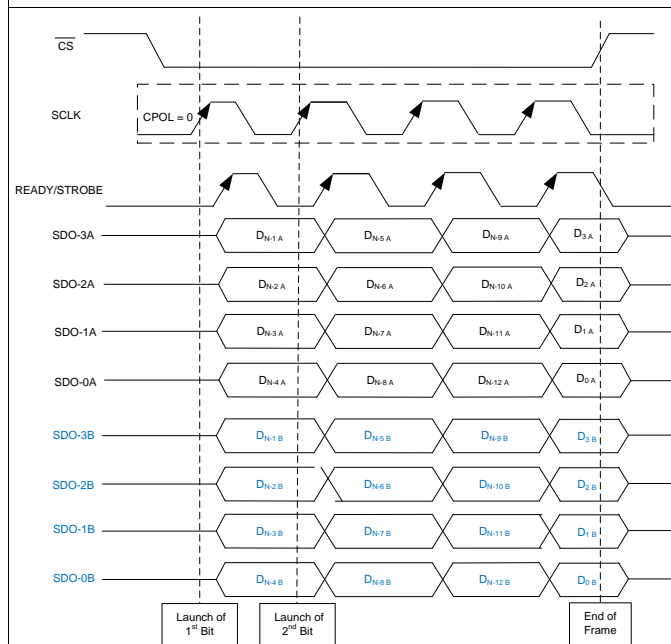


图 60. CRT-Q-SDR Protocol

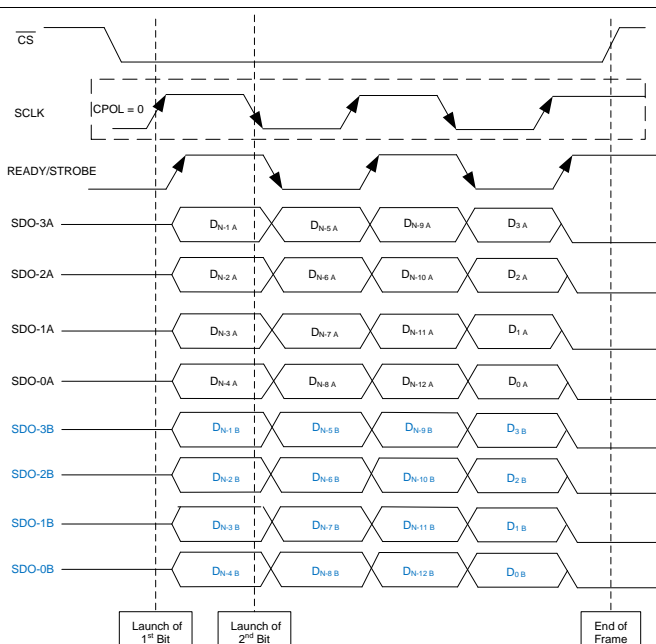


图 61. CRT-Q-DDR Protocol

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. 表 7 provides the details of different parallel byte protocols to read data from the device.

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

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

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

图 62, 图 63, 图 64, and 图 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.

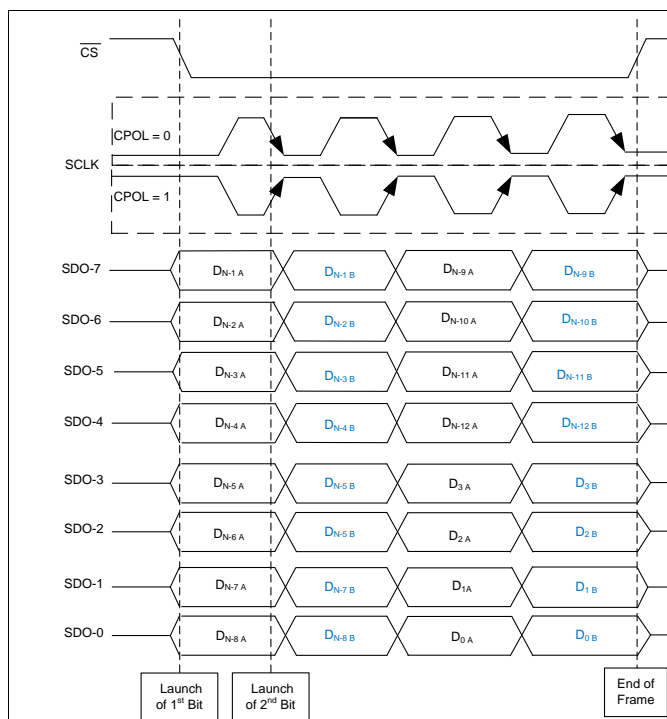


图 62. PB-00-AB-SDR and PB-10-AB-SDR Protocols

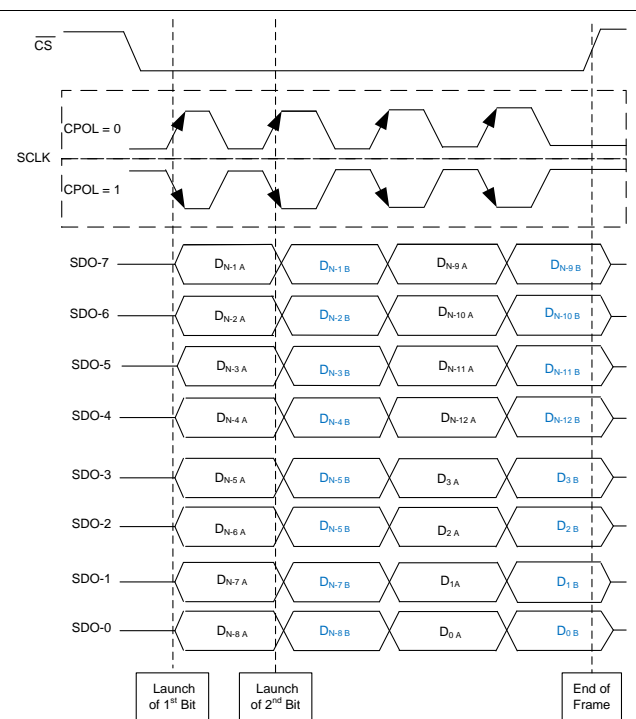


图 63. PB-01-AB-SDR and PB-11-AB-SDR Protocols

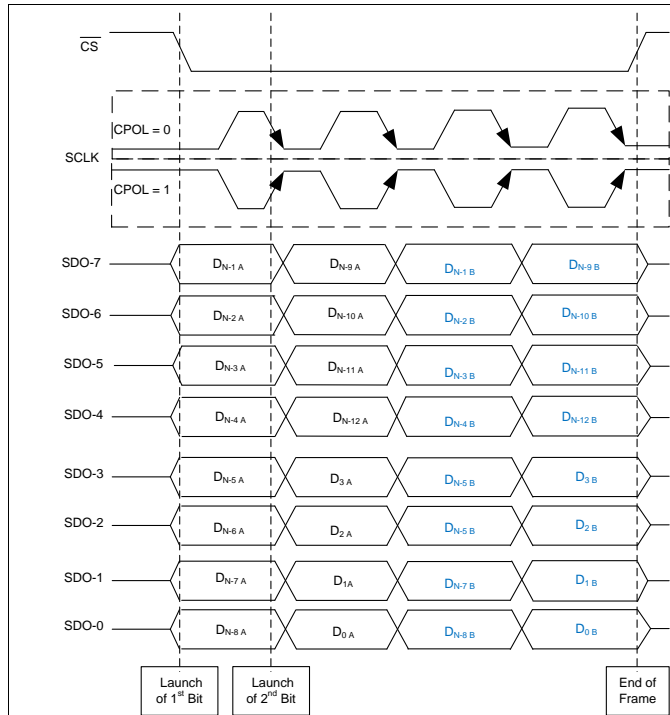


图 64. PB-00-AA-SDR and PB-10-AA-SDR Protocols

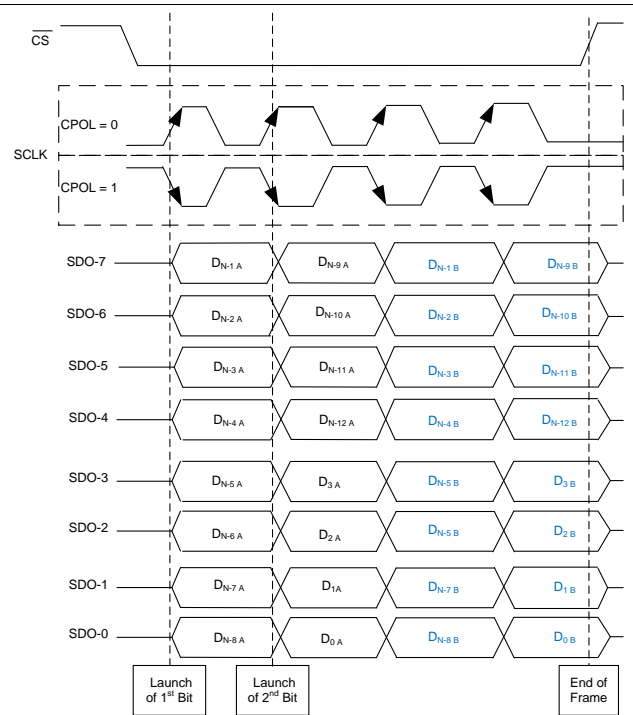


图 65. PB-01-AA-SDR and PB-11-AA-SDR Protocols

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

图 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.

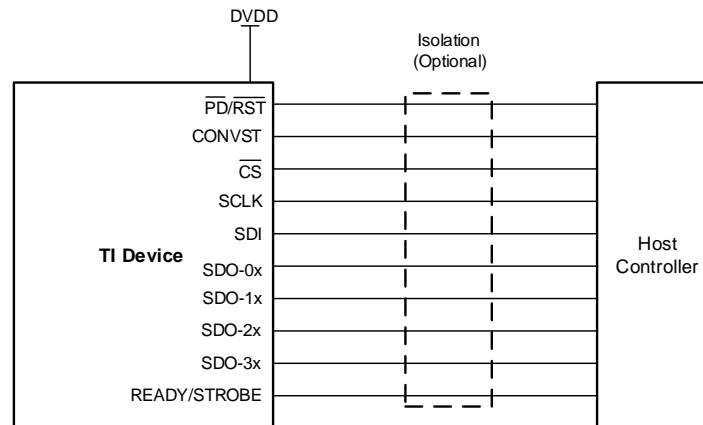


图 66. Enhanced-SPI Digital Interface, All Pins

7.6.2.2.2 Single Device: Minimum Pins for a Standard SPI Interface

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

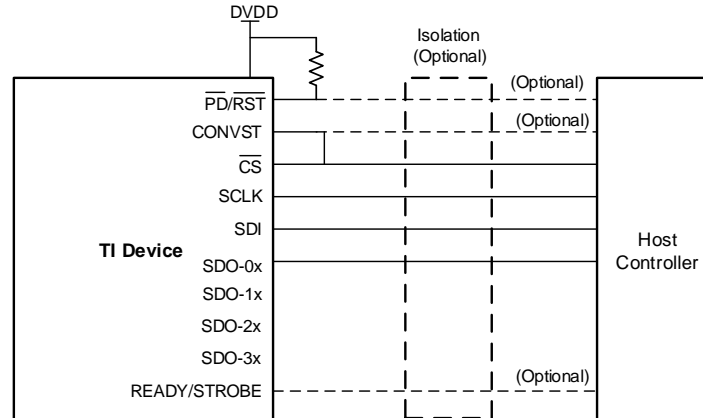


图 67. SPI Interface, Minimum Pins

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 [表 8](#), the host controller can use any of the four legacy, SPI-compatible protocols (SPI-00-S, SPI-01-S, SPI-10-S, or SPI-11-S) to write data to the device.

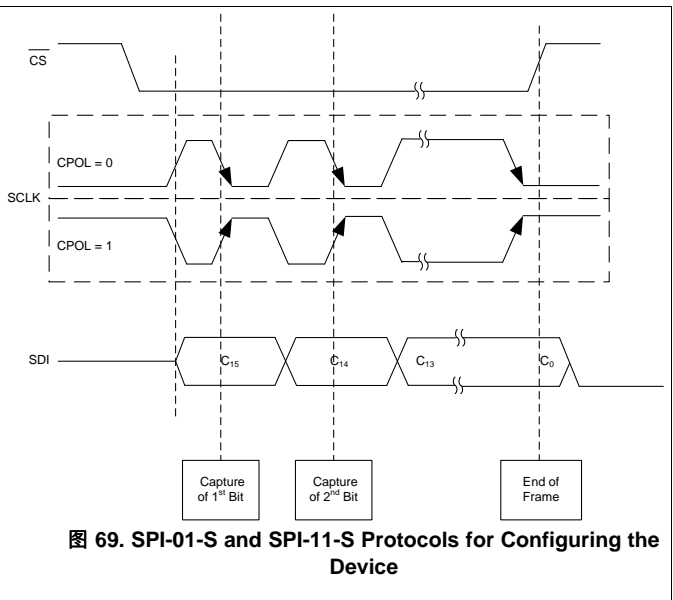
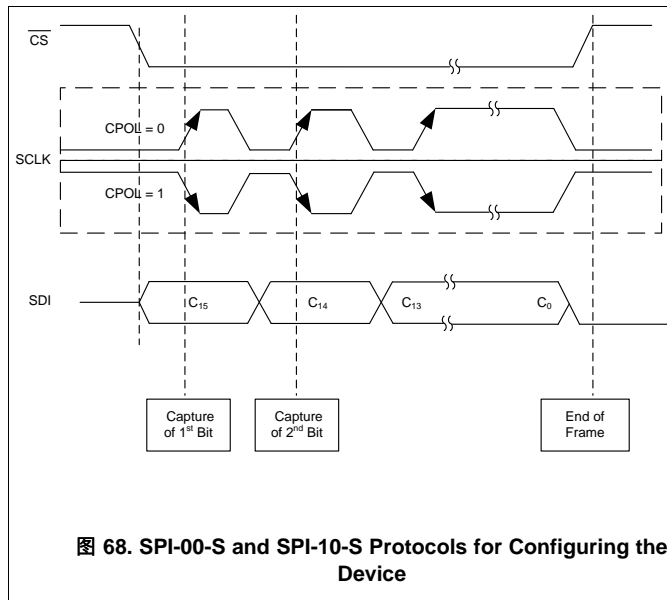
表 8. SPI Protocols for Configuring the Device

| PROTOCOL | SCLK POLARITY (CPOL) ⁽¹⁾ | SCLK PHASE (CPHA) ⁽¹⁾ | MSB CAPTURE EDGE | t _{WRITE} ⁽²⁾ | TIMING DIAGRAM |
|----------|-------------------------------------|----------------------------------|------------------------------|-----------------------------------|----------------------|
| SPI-00-S | Low (CPOL= 0) | Rising (CPHA = 0) | 1 st SCLK rising | [15.5 × t _{CLK} + k] | 图 68 |
| SPI-01-S | Low (CPOL= 0) | Falling (CPHA = 1) | 1 st SCLK falling | [15.5 × t _{CLK} + k] | 图 69 |
| SPI-10-S | High (CPOL= 1) | Falling (CPHA = 1) | 1 st SCLK falling | [15.5 × t _{CLK} + k] | 图 68 |
| SPI-11-S | High (CPOL= 1) | Rising (CPHA = 0) | 1 st SCLK rising | [15.5 × t _{CLK} + k] | 图 69 |

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

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

[图 68](#) 和 [图 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. 图 70 shows the command frame. 表 9 provides the details of commands for reading and writing registers.

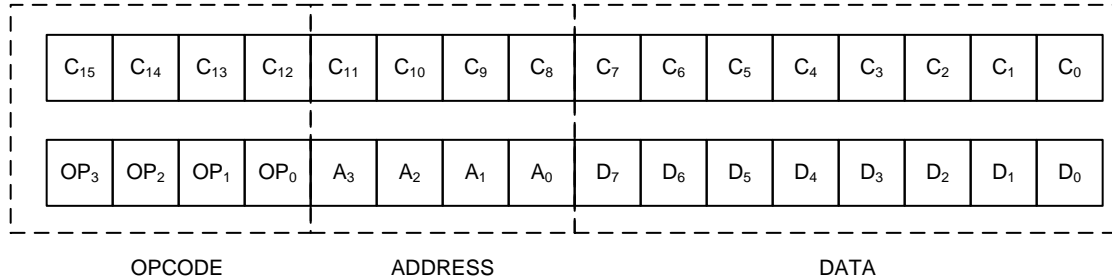


图 70. Command Frame C[15:0]

表 9. Commands for Reading and Writing Registers

| OPCODE[3:0] | | DESCRIPTION | ADDRESS[3:0] | DATA[7:0] |
|-----------------------------------|---------------------|--|------------------------|---|
| 0000 | NOP0 | Command for conversion control and reading conversion results | N/A | N/A |
| 0001 | WRITE | Command for writing registers | 4-bit register address | 8-bit register data |
| 0010 | READ ⁽¹⁾ | Command for reading registers | 4-bit register address | 00h or FFh |
| 0101 | Set bit | Command for setting specific bits in a register without changing the other bits | 4-bit register address | Bits with values of 1 in DATA are set and bits with values of 0 in register data are not changed. |
| 0110 | Clear bit | Command for clearing specific bits in a register without changing the other bits | 4-bit register address | Bits with values of 1 in DATA are cleared and bits with values of 0 in register data are not changed. |
| 1111 | NOP1 | Command for conversion control and reading conversion results | N/A | N/A |
| Remain ing combin ations | xxxxxxx | xxxxxxx | 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 |
|---------------------------------|------|--|
| Read Type | | |
| R | R | Read |
| Write Type | | |
| W | W | Write |
| Reset or Default Value | | |
| -n | | Value after reset or the default value |
| Register Array Variables | | |
| 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 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. 0b = _1 : REFby2 is not powered down. 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. 0b = _1 : ADC_B and REFBUF_B are not powered down. 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. 0b = _1 : ADC_A and REFBUF_A are not powered down. 1b = _2 : ADC_A and REFBUF_A are powered down. |
| 0 | PD_REF | R/W | 0b | This bit powers down ADC's internal reference. 0b = _1 : ADC internal reference is not powered down. 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. 000b = _1 : 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. 001b = _2 : SPI compatible protocols with bus width options and DDR (SPI-x1-S-DDR, SPI-x1-D-DDR, SPI-x1-Q-DDR) protocols. 010b = _3 : Clock re-timer (CRT) protocols with SDR (CRT-S-SDR, CRT-D-SDR, CRT-Q-SDR). 011b = _4 : CRT protocols with DDR (CRT-S-DDR, CRT-D-DDR, CRT-Q-DDR). 100b = _5 : Parallel byte protocol. Writing 1xx enables parallel byte protocol. 101b = _6 : Parallel byte protocol. Writing 1xx enables parallel byte protocol. 110b = _7 : Parallel byte protocol. Writing 1xx enables parallel byte protocol. 111b = _8 : 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. 0b = _1 : CPOL = 0 1b = _2 : 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. 0b = _1 : CPHA = 0 1b = _2 : 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. 00b = _1 : One SDO per ADC. 01b = _2 : One SDO per ADC. 10b = _3 : Dual SDO per ADC. 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. 00b = _1 : Serial clock (SCLK) is used for STROBE output. 01b = _2 : INTCLK is used for the STROBE output. 10b = _3 : INTCLK/2 is used for the STROBE output. 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_M ODE_DATA_F ORMAT | RESERVED | | FIXED_PATTE RN_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. 0b = _1 : Does not mask the READY output. 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. 0b = _1 : Data format AA: byte from ADC_A followed by byte from ADC_A (PB-xy-AA-zDR protocol). 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. 0b = _1 : Device provides the conversion results from the register data in the output word. 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. 0b = _1 : Data are left-aligned in the output data word. 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. 00b = _1 : No averaging. 01b = _2 : No averaging. 10b = _3 : Enables averaging of two conversion results. 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. 0b = _1 : Offset for the REFby2 output is disabled. 1b = _2 : Offset for the REFby2 output is enabled and the REFby2 output increases by 100 mV. |

8 Application and Implementation

注

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

8.1 Application Information

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

8.1.1 ADC Input Driver

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

8.1.1.1 Charge-Kickback Filter

The charge-kickback filter is an RC filter at the input pins of the ADC that filters the broadband noise from the front-end drive circuitry, and attenuates the sampling charge injection from the switched-capacitor input stage of the ADC. A filter capacitor, C_{FLT} (as shown in 图 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.

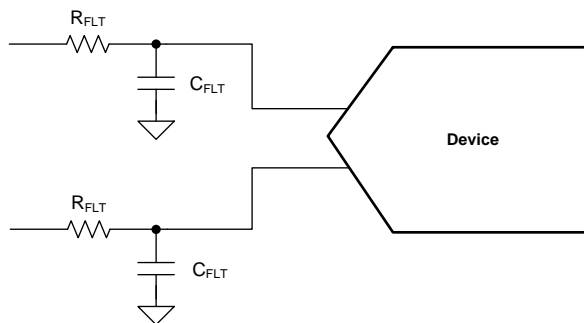


图 79. Charge Kickback Filter

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 (接下页)

8.1.2 Input Amplifier Selection

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

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

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

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

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

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

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

where

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

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

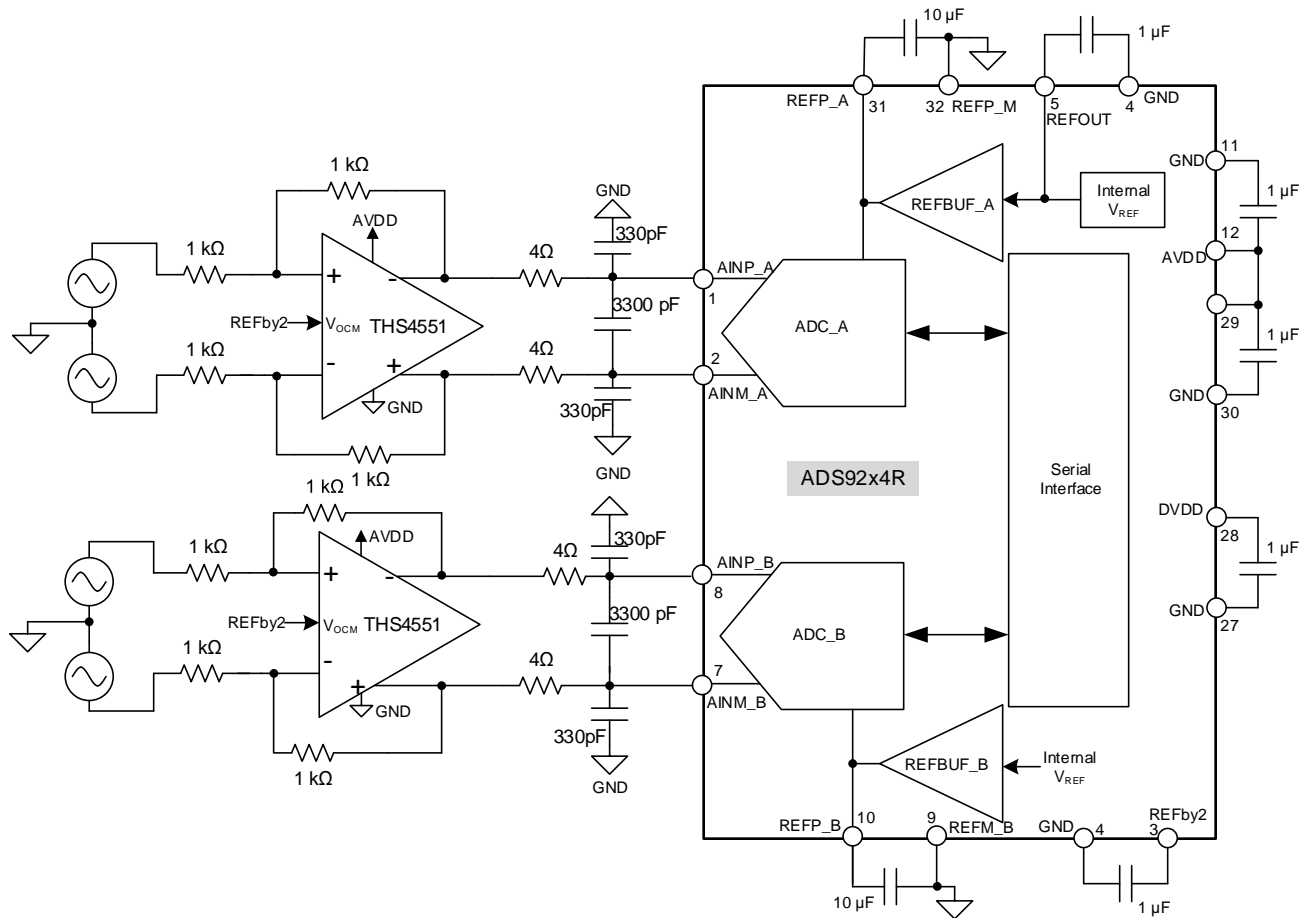


图 80. DAQ Circuit for Lowest Distortion and Noise With the ADS92x4R for a 100-kHz Input Signal

8.2.1 Design Requirements

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

表 20. Design Parameters

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

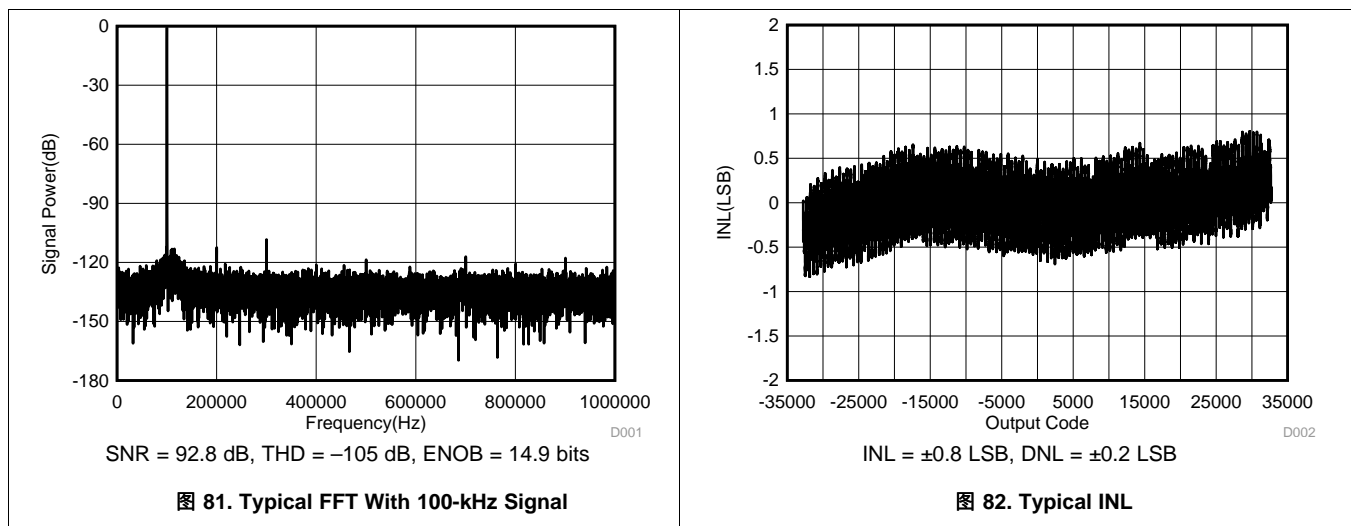
8.2.2 Detailed Design Procedure

图 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 图 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 V_{OCM} input pin from the FDA. The ADS92x4R incorporates a REF_by2 buffer output for setting the common-mode voltage. The ADS92x4R REF_by2 output is decoupled using a 1-μF capacitor and connected to each FDA V_{OCM} input pin. Each V_{OCM} pin is decoupled using a 0.1-μF capacitor. For a complete schematic, see the [ADS9224REVM-PDK user's guide](#) located in the [ADS9224R SAR analog to digital converter evaluation module tool folder](#).

8.2.3 Application Curves

图 81 provides the typical FFT for the circuit in 图 80 and 图 82 provides the typical INL for the circuit in 图 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-μF decoupling capacitors between pin 12 (AVDD) and pin 11 (GND), and between pin 29 (AVDD) and pin 30 (GND). To decouple the DVDD supply, place a 1-μF decoupling capacitor between pin 28 (DVDD) and pin 27 (GND).

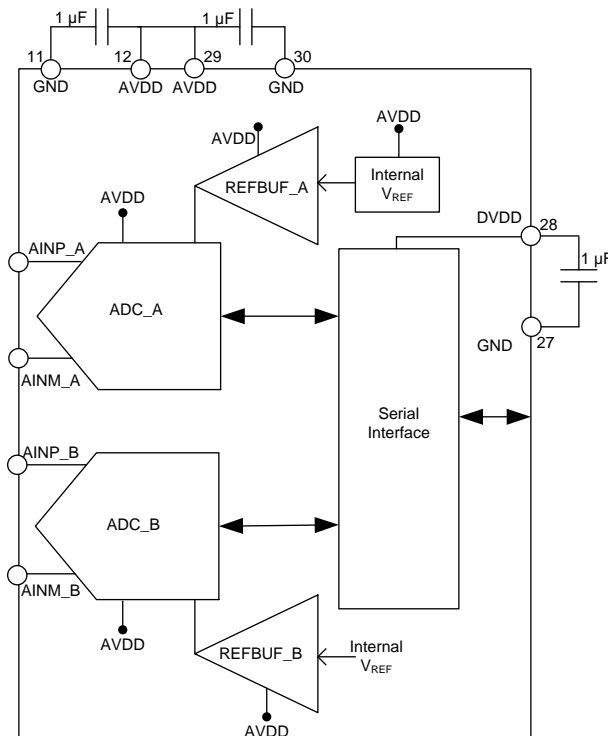


图 83. Power-Supply Decoupling

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.

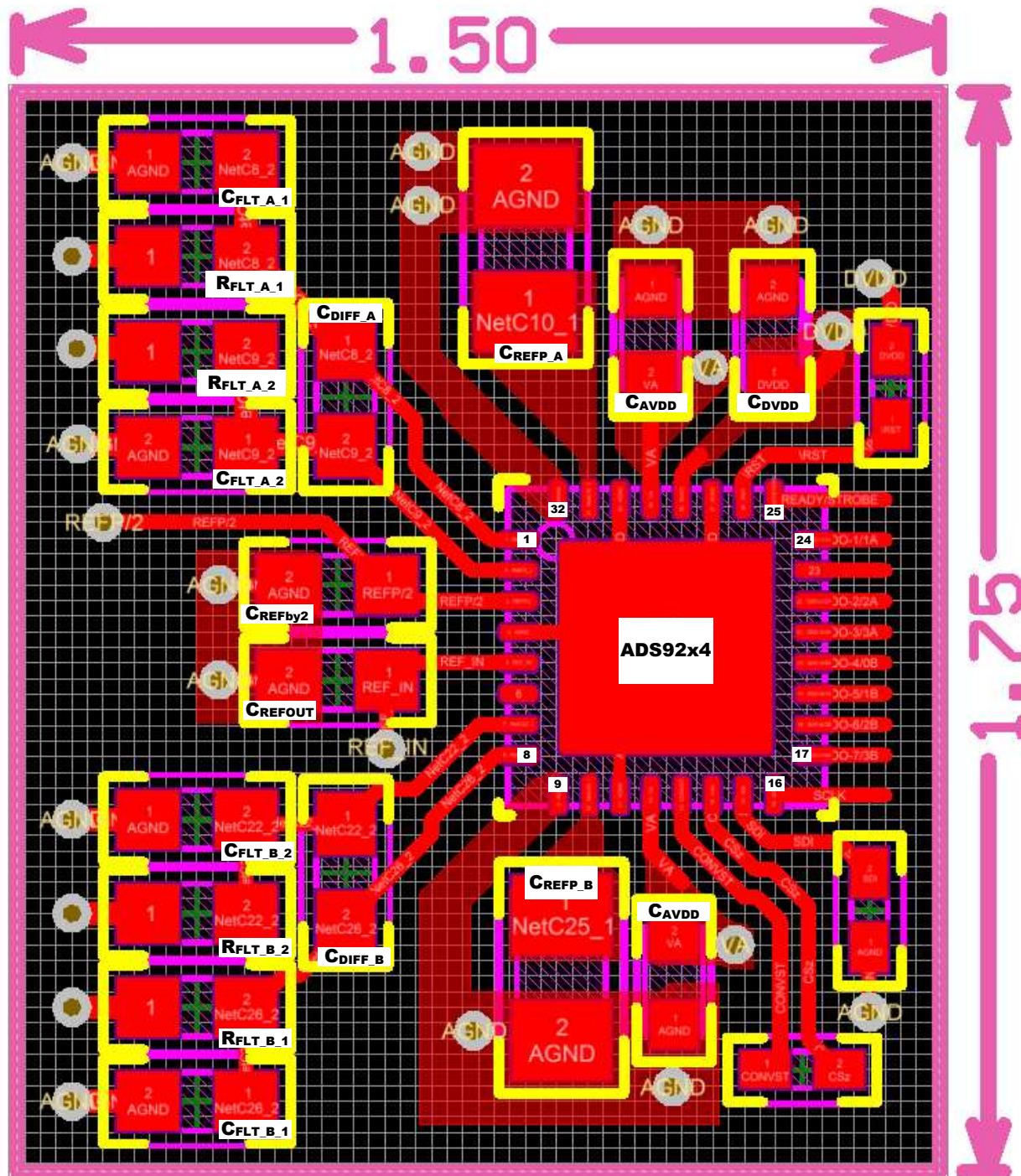
10.1.4 Reference Decoupling

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- μ F, 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.

图 84. Example Layout for the ADS92x4R

11 器件和文档支持

11.1 器件支持

11.1.1 开发支持

[TI 高精度 ADC 实验室](#)

11.2 相关文档

请参阅如下相关文档：

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

11.3 相关链接

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

表 21. 相关链接

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

11.4 接收文档更新通知

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

11.5 社区资源

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 商标

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11.7 静电放电警告



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

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

11.8 Glossary

[SLYZ022](#) — *TI Glossary*.

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

12 机械、封装和可订购信息

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

PACKAGING INFORMATION

| Orderable part number | Status (1) | Material type (2) | Package Pins | Package qty Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|-------------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| ADS9224RIRHBR | 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 |
| ADS9224RIRHBT | 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 |
| ADS9234RIRHBR | 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 |
| ADS9234RIRHBT | 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 |

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

(2) **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.

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

(4) **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.

(5) **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.

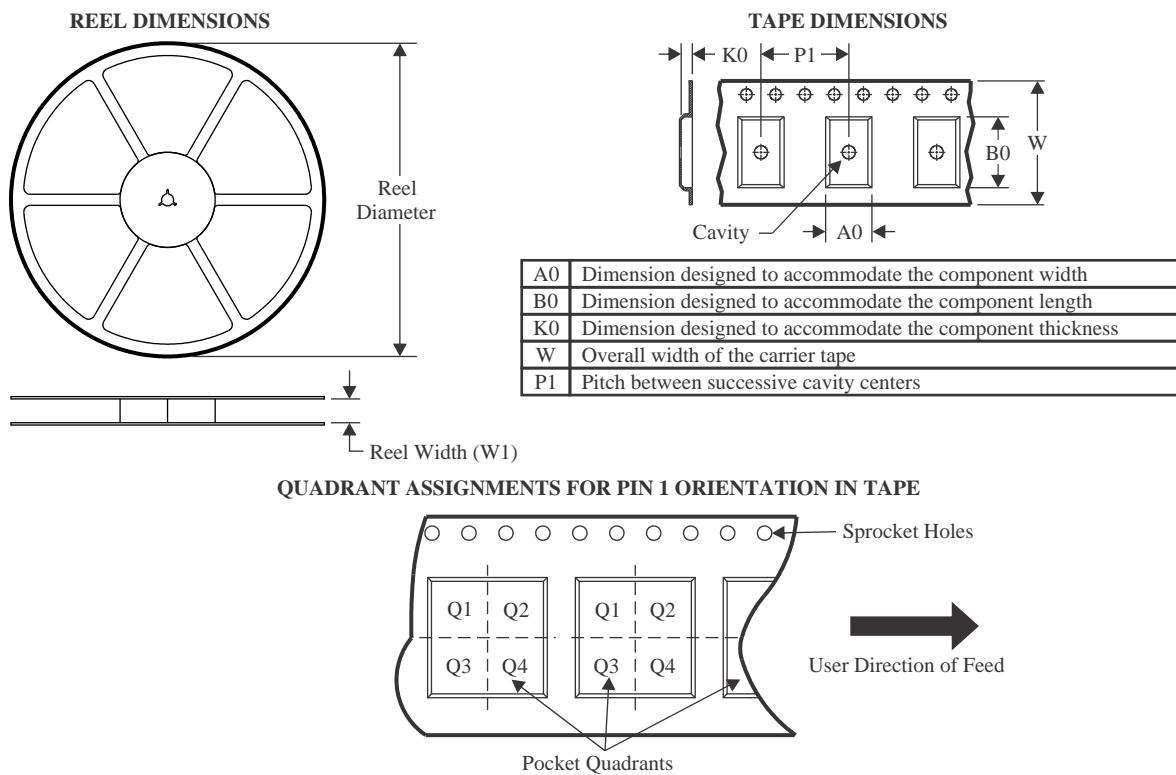
(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

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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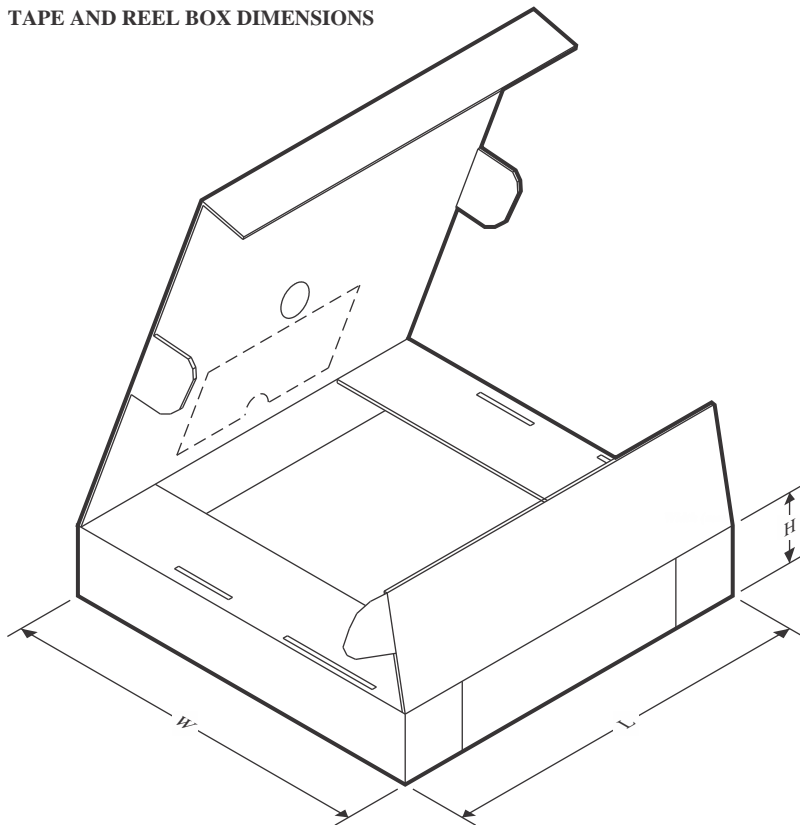
TAPE AND REEL INFORMATION



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

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

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

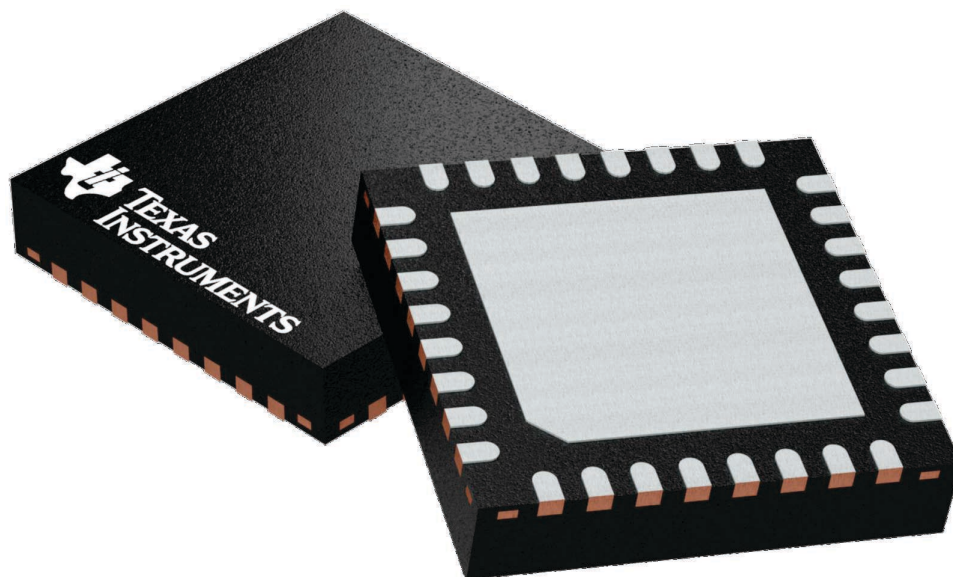
GENERIC PACKAGE VIEW

RHB 32

VQFN - 1 mm max height

5 x 5, 0.5 mm pitch

PLASTIC QUAD FLATPACK - NO LEAD



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

4224745/A

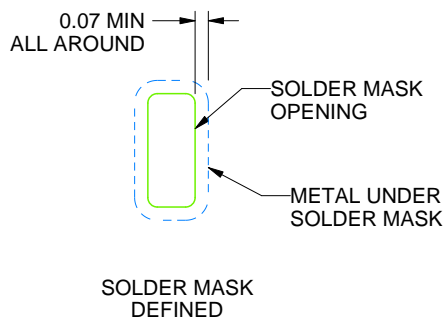
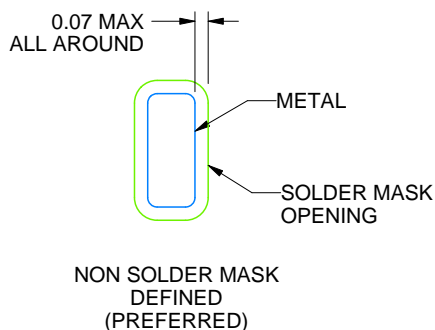
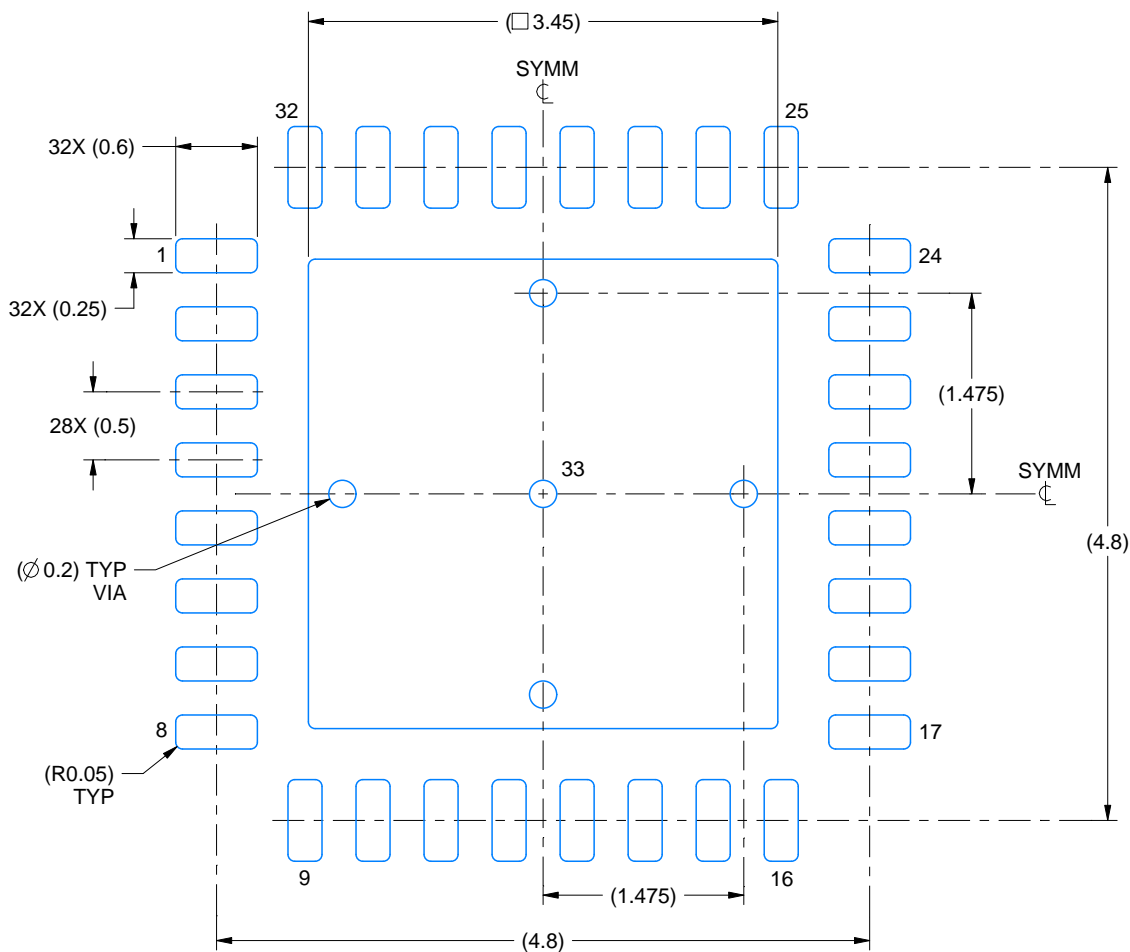
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

EXAMPLE BOARD LAYOUT

RHB0032E

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER MASK DETAILS

4223442/B 08/2019

NOTES: (continued)

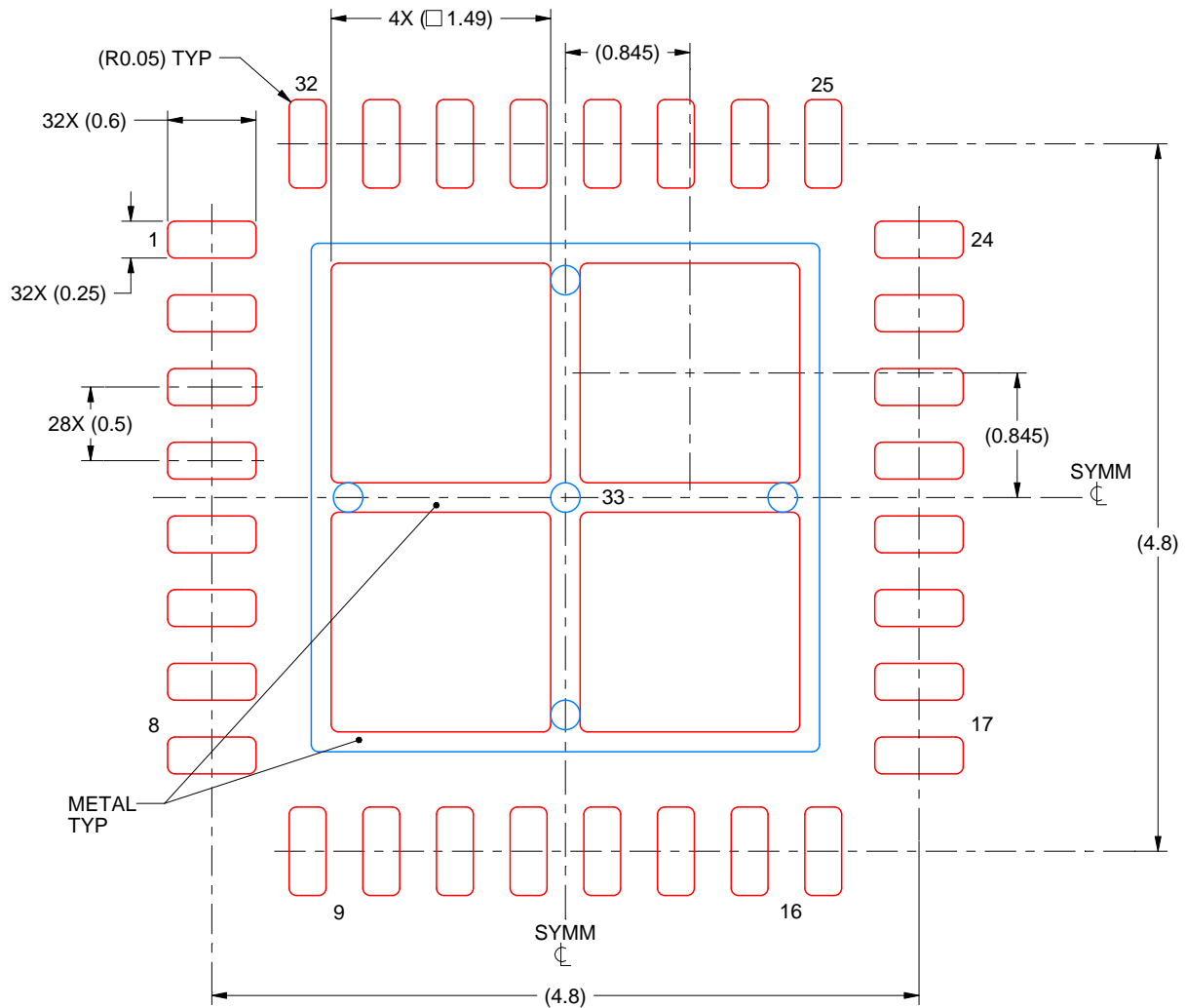
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/sluea271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown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

EXAMPLE STENCIL DESIGN

RHB0032E

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE
 BASED ON 0.125 mm THICK STENCIL

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

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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