

# ADS8353-Q1 Automotive, 16-bit, 2-channel, simultaneous-sampling, 600-kSPS, analog-to-digital converter

## 1 Features

- Qualified for automotive applications
- AEC-Q100 qualified with the following results:
  - Temperature grade 1:  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ,  $T_A$
  - Device HBM ESD classification level 2
  - Device CDM ESD classification level C4B
- 16-bit resolution
- Simultaneous sampling of two channels
- Supports single-ended and pseudo-differential inputs
- Two software-selectable, unipolar input ranges:
  - (0 V to  $V_{\text{REF}}$ ) or (0 V to  $2 \times V_{\text{REF}}$ )
- Up to 600-kSPS sampling speed
- Excellent dc performance:
  - $\pm 1$ -LSB typ DNL
  - $\pm 1$ -LSB typ INL
  - $\pm 0.05\%$  gain error
- Excellent ac performance:
  - 89-dB SNR
  - $-100$ -dB THD
- Dual, low-drift ( $10 \text{ ppm}/^{\circ}\text{C}$ ), programmable 2.5-V internal reference

## 2 Applications

- Battery management systems (BMS)
- Motor controls:
  - Resolvers for EV/HEV drive motor
- Isolation fault detection
- Engine control units (ECU)
- Automotive sensor digitization

## 3 Description

The ADS8353-Q1 is a 16-bit, dual-channel, high-speed, simultaneous-sampling, analog-to-digital converter (ADC) that supports single-ended and pseudo-differential analog inputs.

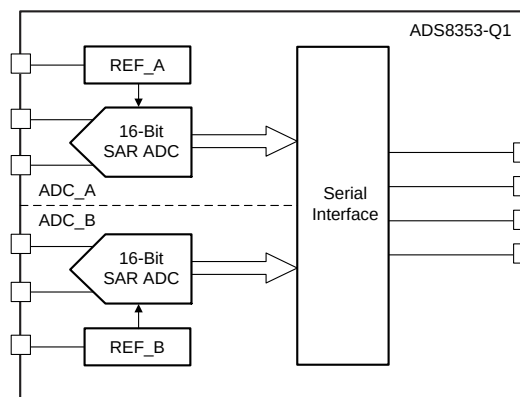
The ADS8353-Q1 includes two individually programmable reference sources that can be used for system-level gain calibration. Also, a flexible serial interface that can operate over a wide power-supply range enables easy communication with a large variety of host controllers. Power consumption for a given throughput can be optimized by using the two low-power modes supported by the device. The ADS8353-Q1 is fully specified over the temperature range ( $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ) and is available in a 16-pin TSSOP package.

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

| PART NUMBER | PACKAGE    | BODY SIZE (NOM)          |
|-------------|------------|--------------------------|
| ADS8353-Q1  | TSSOP (16) | 5.00 mm $\times$ 4.40 mm |

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

### Typical Application Diagram



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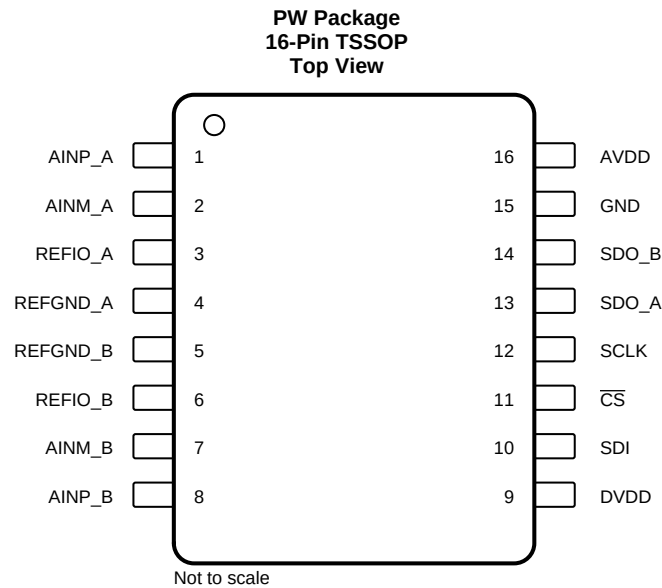
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## 4 Revision History

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

| Changes from Original (January 2019) to Revision A                        | Page     |
|---------------------------------------------------------------------------|----------|
| • Changed device status from Advance Information to Production Data ..... | <b>1</b> |

## 5 Pin Configuration and Functions



**Pin Functions**

| PIN                    |       | I/O                 | DESCRIPTION                                                   |
|------------------------|-------|---------------------|---------------------------------------------------------------|
| NAME                   | TSSOP |                     |                                                               |
| AINM_A                 | 2     | Analog input        | Negative analog input, channel A                              |
| AINM_B                 | 7     | Analog input        | Negative analog input, channel B                              |
| AINP_A                 | 1     | Analog input        | Positive analog input, channel A                              |
| AINP_B                 | 8     | Analog input        | Positive analog input, channel B                              |
| AVDD                   | 16    | Supply              | Supply voltage for ADC operation                              |
| $\overline{\text{CS}}$ | 11    | Digital input       | Chip-select signal; active low                                |
| DVDD                   | 9     | Digital I/O supply  | Digital I/O supply                                            |
| GND                    | 15    | Supply              | Digital ground                                                |
| REFGND_A               | 4     | Supply              | Reference ground potential A                                  |
| REFGND_B               | 5     | Supply              | Reference ground potential B                                  |
| REFIO_A                | 3     | Analog input/output | Reference voltage input/output, channel A                     |
| REFIO_B                | 6     | Analog input/output | Reference voltage input/output, channel B                     |
| SCLK                   | 12    | Digital input       | Clock for serial communication                                |
| SDI                    | 10    | Digital input       | Data input for serial communication                           |
| SDO_A                  | 13    | Digital output      | Data output for serial communication, channel A and channel B |
| SDO_B                  | 14    | Digital output      | Data output for serial communication, channel B               |

## 6 Specifications

### 6.1 Absolute Maximum Ratings

over operating ambient temperature range (unless otherwise noted)<sup>(1)</sup>

|                                                                                                          | MIN            | MAX        | UNIT |
|----------------------------------------------------------------------------------------------------------|----------------|------------|------|
| AVDD to REFGND_x <sup>(2)</sup> or GND                                                                   | −0.3           | 6          | V    |
| DVDD to GND                                                                                              | −0.3           | 6          | V    |
| Analog (AINP_x and AINM_x) <sup>(3)</sup> and reference input (REFIO_x) voltage with respect to REFGND_x | REFGND_x − 0.3 | AVDD + 0.3 | V    |
| Digital input voltage with respect to GND                                                                | DVDD + 0.3     | DVDD + 0.3 | V    |
| REFGND_x                                                                                                 | GND − 0.3      | GND + 0.3  | V    |
| Input current to any pin except supply pins                                                              | −10            | 10         | mA   |
| Junction temperature, T <sub>J</sub>                                                                     | −40            | 125        | °C   |
| Storage temperature, T <sub>stg</sub>                                                                    | −65            | 150        | °C   |

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

(2) REFGND\_x refers to REFGND\_A and REFGND\_B. REFIO\_x refers to REFIO\_A and REFIO\_B.

(3) AINP\_x refers AINP\_A and AINP\_B. AINM\_x refers to AINM\_A and AINM\_B.

### 6.2 ESD Ratings

|                    |                         |                                                         | VALUE | UNIT |
|--------------------|-------------------------|---------------------------------------------------------|-------|------|
| V <sub>(ESD)</sub> | Electrostatic discharge | Human-body model (HBM), per AEC Q100-002 <sup>(1)</sup> | ±2000 | V    |
|                    |                         | Charged-device model (CDM), per AEC Q100-001, level C4B | ±750  |      |
|                    |                         | Corner pins (1,8,9 and 16)                              | ±500  |      |
|                    |                         | All other pins                                          | ±500  |      |

(1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

### 6.3 Recommended Operating Conditions

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

| PARAMETER                                         |                                                                                    | TEST CONDITIONS                                                                                                          | MIN                       | TYP | MAX                       | UNIT |
|---------------------------------------------------|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|---------------------------|-----|---------------------------|------|
| POWER SUPPLY                                      |                                                                                    |                                                                                                                          |                           |     |                           |      |
| AVDD                                              | Analog supply voltage (AVDD to AGND)                                               | V <sub>REF</sub> range, internal reference                                                                               | 4.5                       | 5   | 5.5                       | V    |
|                                                   |                                                                                    | V <sub>REF</sub> range, external reference V <sub>EXT_REF</sub> < 4.5 V                                                  | 4.5                       | 5   | 5.5                       |      |
|                                                   |                                                                                    | V <sub>REF</sub> range, external reference V <sub>EXT_REF</sub> > 4.5 V                                                  | V <sub>EXT_REF</sub>      | 5   | 5.5                       |      |
|                                                   |                                                                                    | 2x V <sub>REF</sub> range, internal reference                                                                            | 5                         | 5   | 5.5                       |      |
|                                                   |                                                                                    | 2x V <sub>REF</sub> range, external reference                                                                            | 2 x V <sub>EXT_REF</sub>  | 5   | 5.5                       |      |
| DVDD                                              | Digital supply voltage                                                             |                                                                                                                          | 1.65                      | 3.3 | 5.5                       | V    |
| ANALOG INPUTS (Single-Ended Configuration)        |                                                                                    |                                                                                                                          |                           |     |                           |      |
| FSR                                               | Full-scale input range (A <sub>INP_x</sub> to A <sub>INM_x</sub> ) <sup>(1)</sup>  | V <sub>REF</sub> range, single-ended input, A <sub>INM_x</sub> = GND                                                     | 0                         |     | V <sub>REF</sub>          | V    |
|                                                   |                                                                                    | 2x V <sub>REF</sub> range, single-ended input, A <sub>INM_x</sub> = GND                                                  | 0                         |     | 2 x V <sub>REF</sub>      |      |
| V <sub>INP</sub>                                  | Absolute input voltage (A <sub>INP_x</sub> to REFGND <sub>x</sub> ) <sup>(2)</sup> | V <sub>REF</sub> range                                                                                                   | 0                         |     | V <sub>REF</sub>          | V    |
|                                                   |                                                                                    | 2x V <sub>REF</sub> range, AVDD ≥ 2x V <sub>REF</sub>                                                                    | 0                         |     | 2 x V <sub>REF</sub>      |      |
| V <sub>INM</sub>                                  | Absolute input voltage (A <sub>INM_x</sub> to REFGND <sub>x</sub> )                | V <sub>REF</sub> range, single-ended input                                                                               | −0.1                      |     | 0.1                       | V    |
|                                                   |                                                                                    | 2x V <sub>REF</sub> range, single-ended input, AVDD ≥ 2 x V <sub>REF</sub>                                               | −0.1                      |     | 0.1                       |      |
| ANALOG INPUTS (Pseudo-Differential Configuration) |                                                                                    |                                                                                                                          |                           |     |                           |      |
| FSR                                               | Full-scale input range (A <sub>INP_x</sub> -A <sub>INM_x</sub> )                   | V <sub>REF</sub> range, pseudo-differential input, A <sub>INM_x</sub> = V <sub>REF</sub> /2                              | −V <sub>REF</sub> / 2     |     | V <sub>REF</sub> / 2      | V    |
|                                                   |                                                                                    | 2x V <sub>REF</sub> range, pseudo-differential input, A <sub>INM_x</sub> = V <sub>REF</sub> , AVDD ≥ 2x V <sub>REF</sub> | −V <sub>REF</sub>         |     | V <sub>REF</sub>          |      |
| V <sub>INP</sub>                                  | Absolute input voltage (A <sub>INP_x</sub> to REFGND <sub>x</sub> )                | V <sub>REF</sub> range                                                                                                   | 0                         |     | V <sub>REF</sub>          | V    |
|                                                   | Absolute input voltage (A <sub>INP_x</sub> to REFGND <sub>x</sub> ) <sup>(2)</sup> | 2x V <sub>REF</sub> range, AVDD ≥ 2x V <sub>REF</sub>                                                                    | 0                         |     | 2 x V <sub>REF</sub>      |      |
| V <sub>INM</sub>                                  | Absolute input voltage (A <sub>INM_x</sub> -REFGND <sub>x</sub> )                  | V <sub>REF</sub> range, pseudo-differential input                                                                        | V <sub>REF</sub> / 2 −0.1 |     | V <sub>REF</sub> / 2 +0.1 | V    |
|                                                   | Absolute input voltage (A <sub>INM_x</sub> -REFGND <sub>x</sub> )                  | 2x V <sub>REF</sub> range, single-ended input, AVDD ≥ 2x V <sub>REF</sub>                                                | V <sub>REF</sub> −0.1     |     | V <sub>REF</sub> +0.1     |      |
| EXTERNAL REFERENCE INPUT                          |                                                                                    |                                                                                                                          |                           |     |                           |      |
| V <sub>REFIO</sub>                                | REFIO <sub>x</sub> <sup>(3)</sup> input voltage                                    | V <sub>REF</sub> range                                                                                                   | 2.4                       | 2.5 | AVDD                      | V    |
|                                                   |                                                                                    | 2x V <sub>REF</sub> range                                                                                                | 2.4                       | 2.5 | AVDD / 2                  |      |
| TEMPERATURE RANGE                                 |                                                                                    |                                                                                                                          |                           |     |                           |      |
| T <sub>A</sub>                                    | Ambient temperature                                                                |                                                                                                                          | −40                       | 25  | 125                       | °C   |

(1) A<sub>INP\_x</sub> refers to analog input pins A<sub>INP\_A</sub> and A<sub>INP\_B</sub>. A<sub>INM\_x</sub> refers to analog input pins A<sub>INM\_A</sub> and A<sub>INM\_B</sub>.

(2) REFGND<sub>x</sub> refers to reference ground pins REFGND<sub>A</sub> and REFGND<sub>B</sub>.

(3) REFIO<sub>x</sub> refers to voltage reference inputs REFIO<sub>A</sub> and REFIO<sub>B</sub>.

## 6.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                              | ADS8353-Q1 | UNIT |
|-------------------------------|----------------------------------------------|------------|------|
|                               |                                              | PW (TSSOP) |      |
|                               |                                              | 16 PINS    |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance       | 99         | °C/W |
| R <sub>θJC(top)</sub>         | Junction-to-case (top) thermal resistance    | 29.6       | °C/W |
| R <sub>θJB</sub>              | Junction-to-board thermal resistance         | 45         | °C/W |
| Ψ <sub>JT</sub>               | Junction-to-top characterization parameter   | 1.4        | °C/W |
| Y <sub>JB</sub>               | Junction-to-board characterization parameter | 44.5       | °C/W |
| R <sub>θJC(bot)</sub>         | Junction-to-case (bottom) thermal resistance | N/A        | °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

at AVDD = 5 V, DVDD = 3.3 V, V<sub>REF\_A</sub> = V<sub>REF\_B</sub> = V<sub>REF</sub> = 2.5 V (internal), and f<sub>DATA</sub> = 600 kSPS (unless otherwise noted); minimum and maximum values at T<sub>A</sub> = –40°C to 125°C; typical values are at T<sub>A</sub> = 25°C

| PARAMETER                  |                              | TEST CONDITIONS                                            | MIN   | TYP   | MAX   | UNIT   |
|----------------------------|------------------------------|------------------------------------------------------------|-------|-------|-------|--------|
| RESOLUTION                 |                              |                                                            |       |       |       |        |
|                            | Resolution                   |                                                            | 16    |       |       | Bits   |
| DC ACCURACY                |                              |                                                            |       |       |       |        |
| NMC                        | No missing codes             |                                                            | 16    |       |       | Bits   |
| INL                        | Integral nonlinearity        |                                                            | −4    | ±1    | 4     | LSB    |
| DNL                        | Differential nonlinearity    |                                                            | ±0.6  |       |       | LSB    |
| E <sub>IO</sub>            | Input offset error           |                                                            | −1    | ±0.5  | 1     | mV     |
|                            | E <sub>IO</sub> match        | ADC_A to ADC_B                                             | −1    | ±0.5  | 1     | mV     |
| dE <sub>IO</sub> /dT       | Input offset thermal drift   |                                                            | 1     |       |       | μV/°C  |
| E <sub>G</sub>             | Gain error                   | Referenced to the voltage at REFIO_x                       | −0.1  | ±0.05 | 0.1   | %FS    |
|                            | E <sub>G</sub> match         | ADC_A to ADC_B                                             | −0.1  | ±0.05 | 0.1   | %FS    |
| dE <sub>G</sub> /dT        | Gain error thermal drift     | Referenced to the voltage at REFIO_x                       | 1     |       |       | ppm/°C |
| AC ACCURACY                |                              |                                                            |       |       |       |        |
| SINAD                      | Signal-to-noise + distortion | V <sub>REF</sub> = 2.5 V, V <sub>REF</sub> input range     | 80.2  | 83    |       | dB     |
|                            |                              | V <sub>REF</sub> = 2.5 V, 2x V <sub>REF</sub> input range  | 83.9  |       |       |        |
|                            |                              | V <sub>REF</sub> = 5 V, V <sub>REF</sub> input range       | 88.7  |       |       |        |
| SNR                        | Signal-to-noise ratio        | V <sub>REF</sub> = 2.5 V, V <sub>REF</sub> input range     | 80.5  | 83    |       | dB     |
|                            |                              | V <sub>REF</sub> = 2.5 V, 2x V <sub>REF</sub> input range  | 84    |       |       |        |
|                            |                              | V <sub>REF</sub> = 5 V, V <sub>REF</sub> input range       | 89    |       |       |        |
| THD                        | Total harmonic distortion    | V <sub>REF</sub> = 2.5 V, V <sub>REF</sub> input range     | −100  |       | dB    |        |
|                            |                              | V <sub>REF</sub> = 2.5 V, 2x V <sub>REF</sub> input range  | −100  |       |       |        |
|                            |                              | V <sub>REF</sub> = 5 V, V <sub>REF</sub> input range       | −100  |       |       |        |
| SFDR                       | Spurious-free dynamic range  | V <sub>REF</sub> = 2.5 V, V <sub>REF</sub> input range     | 105   |       | dB    |        |
|                            |                              | V <sub>REF</sub> = 2.5 V, 2 x V <sub>REF</sub> input range | 105   |       |       |        |
|                            |                              | V <sub>REF</sub> = 5 V, V <sub>REF</sub> input range       | 105   |       |       |        |
| ANALOG INPUT               |                              |                                                            |       |       |       |        |
| C <sub>i</sub>             | Input capacitance            | In sample mode                                             | 40    |       |       | pF     |
|                            |                              | In hold mode                                               | 4     |       |       |        |
| I <sub>lkg</sub>           | Input leakage current        |                                                            | 0.1   |       |       | μA     |
| INTERNAL VOLTAGE REFERENCE |                              |                                                            |       |       |       |        |
| V <sub>REFOUT</sub>        | Reference output voltage     | REFDAC_x = 1FFh (default) at 25°C                          | 2.495 | 2.5   | 2.505 | V      |
| V <sub>REF-match</sub>     | VREF_A to VREF_B matching    | REFDAC_x = 1FFh (default) at 25°C                          | ±1    |       |       | mV     |

## Electrical Characteristics (continued)

at AVDD = 5 V, DVDD = 3.3 V, V<sub>REF\_A</sub> = V<sub>REF\_B</sub> = V<sub>REF</sub> = 2.5 V (internal), and f<sub>DATA</sub> = 600 kSPS (unless otherwise noted); minimum and maximum values at T<sub>A</sub> = –40°C to 125°C; typical values are at T<sub>A</sub> = 25°C

| PARAMETER                            |                                      | TEST CONDITIONS                                                  | MIN      | TYP        | MAX | UNIT   |
|--------------------------------------|--------------------------------------|------------------------------------------------------------------|----------|------------|-----|--------|
| REFDAC_x resolution <sup>(1)</sup>   |                                      |                                                                  |          | 1.1        |     | mV     |
| dV <sub>REFOUT</sub> /dT             | Reference voltage temperature drift  | REFDAC_x = 1FFh (default) at 25°C                                |          | ±10        |     | ppm/°C |
| dV <sub>REFOUT</sub> /dt             | Long-term stability                  | 1000 hours                                                       |          | 150        |     | ppm    |
| R <sub>O</sub>                       | Internal reference output impedance  |                                                                  |          | 1          |     | Ω      |
| I <sub>REFOUT</sub>                  | Reference output dc current          |                                                                  |          | 2          |     | mA     |
| C <sub>REFOUT</sub>                  | Reference output capacitor           |                                                                  |          | 10         |     | μF     |
| t <sub>REFON</sub>                   | Reference output settling time       |                                                                  |          | 8          |     | ms     |
| <b>VOLTAGE REFERENCE INPUT</b>       |                                      |                                                                  |          |            |     |        |
| I <sub>REF</sub>                     | Average reference input current      | Per ADC                                                          |          | 300        |     | μA     |
| C <sub>REF</sub>                     | External ceramic reference capacitor |                                                                  |          | 10         |     | μF     |
| I <sub>lkg(dc)</sub>                 | DC leakage current                   |                                                                  |          | ±0.1       |     | μA     |
| <b>SAMPLING DYNAMICS</b>             |                                      |                                                                  |          |            |     |        |
| t <sub>A</sub>                       | Aperture delay                       |                                                                  |          | 8          |     | ns     |
|                                      | t <sub>A</sub> match                 | ADC_A to ADC_B                                                   |          | 40         |     | ps     |
| t <sub>AJIT</sub>                    | Aperture jitter                      |                                                                  |          | 50         |     | ps     |
| <b>DIGITAL INPUTS<sup>(2)</sup></b>  |                                      |                                                                  |          |            |     |        |
| V <sub>IH</sub>                      | High-level input voltage             | DVDD > 2.3 V                                                     | 0.7 DVDD | DVDD + 0.3 |     | V      |
|                                      |                                      | DVDD ≤ 2.3 V                                                     | 0.8 DVDD | DVDD + 0.3 |     | V      |
| V <sub>IL</sub>                      | Low-level input voltage              | DVDD > 2.3 V                                                     | –0.3     | 0.3 DVDD   |     | V      |
|                                      |                                      | DVDD ≤ 2.3 V                                                     | –0.3     | 0.2 DVDD   |     | V      |
|                                      | Input current                        |                                                                  |          | ±10        |     | nA     |
| <b>DIGITAL OUTPUTS<sup>(2)</sup></b> |                                      |                                                                  |          |            |     |        |
| V <sub>OH</sub>                      | High-level output voltage            | I <sub>OH</sub> = 500-μA source                                  | 0.8 DVDD | DVDD       |     | V      |
| V <sub>OL</sub>                      | Low-level output voltage             | I <sub>OL</sub> = 500-μA sink                                    | 0        | 0.2 DVDD   |     | V      |
| <b>POWER SUPPLY</b>                  |                                      |                                                                  |          |            |     |        |
| AIDD                                 | Analog supply current                | AVDD = 5 V, fastest throughput internal reference                |          | 8.5        | 10  | mA     |
|                                      |                                      | AVDD = 5 V, fastest throughput external reference <sup>(3)</sup> |          | 7.5        | 3.6 |        |
|                                      |                                      | AVDD = 5V, no conversion internal reference                      |          | 5.5        | 7   |        |
|                                      |                                      | AVDD = 5 V, no conversion external reference <sup>(3)</sup>      |          | 4.5        |     |        |
|                                      |                                      | AVDD = 5 V, STANDBY mode internal reference                      |          | 2.5        |     |        |
|                                      |                                      | AVDD = 5 V, STANDBY mode external reference <sup>(3)</sup>       |          | 1          |     |        |
|                                      |                                      | Power-down mode                                                  |          | 10         | 50  | μA     |

(1) Refer to the Reference section for more details.

(2) Specified by design; not production tested.

(3) With internal reference powered down, CFR.B6 = 0.

## Electrical Characteristics (continued)

at AVDD = 5 V, DVDD = 3.3 V, V<sub>REF\_A</sub> = V<sub>REF\_B</sub> = V<sub>REF</sub> = 2.5 V (internal), and f<sub>DATA</sub> = 600 kSPS (unless otherwise noted); minimum and maximum values at T<sub>A</sub> = –40°C to 125°C; typical values are at T<sub>A</sub> = 25°C

| PARAMETER      |                                      | TEST CONDITIONS                                             | MIN | TYP  | MAX | UNIT |
|----------------|--------------------------------------|-------------------------------------------------------------|-----|------|-----|------|
| DIDD           | Digital supply current               | DVDD = 3.3 V, C <sub>load</sub> = 10 pF, fastest throughput |     | 0.5  |     | mA   |
|                |                                      | DVDD = 5 V, C <sub>load</sub> = 10 pF, fastest throughput   |     | 1    |     |      |
| P <sub>D</sub> | Power dissipation (normal operation) | AVDD = 5 V, fastest throughput, internal reference          |     | 42.5 | 50  | mW   |

## 6.6 Timing Requirements

at AVDD = 5 V, DVDD = 1.65 V to 5.5 V, and maximum throughput (unless otherwise noted); minimum and maximum values at T<sub>A</sub> = –40°C to +125°C; typical values at T<sub>A</sub> = 25°C.

|                         |                                                                          |                           | MIN | NOM | MAX                                       | UNIT             |
|-------------------------|--------------------------------------------------------------------------|---------------------------|-----|-----|-------------------------------------------|------------------|
| t <sub>PH_CK</sub>      | CLOCK high time                                                          |                           | 0.4 |     | 0.6                                       | t <sub>CLK</sub> |
| t <sub>PL_CK</sub>      | CLOCK low time                                                           |                           | 0.4 |     | 0.6                                       | t <sub>CLK</sub> |
| f <sub>CLK</sub>        | CLOCK frequency                                                          |                           |     |     | 20                                        | MHz              |
| t <sub>ACQ</sub>        | Acquisition time                                                         | 32-clock, dual SDO mode   |     |     | 33 x t <sub>CLK</sub> - t <sub>CONV</sub> | ns               |
|                         |                                                                          | 32-clock, single SDO mode |     |     | 49 x t <sub>CLK</sub> - t <sub>CONV</sub> |                  |
| t <sub>CONV</sub>       | Conversion time                                                          |                           |     |     | 730                                       | ns               |
| t <sub>PH_CS</sub>      | $\overline{\text{CS}}$ high time                                         |                           | 40  |     |                                           | ns               |
| t <sub>PH_CS_SHRT</sub> | $\overline{\text{CS}}$ high time after frame abort                       |                           | 150 |     |                                           | ns               |
| t <sub>SU_CSCK</sub>    | Setup time: $\overline{\text{CS}}$ falling edge to SCLK falling edge     |                           | 15  |     |                                           | ns               |
| t <sub>D_CKCS</sub>     | Delay time: Last SCLK falling edge to $\overline{\text{CS}}$ rising edge |                           | 15  |     |                                           | ns               |
| t <sub>SU_CKDI</sub>    | Setup time: DIN data valid to SCLK falling edge                          |                           | 5   |     |                                           | ns               |
| t <sub>HT_CKDI</sub>    | Hold time: SCLK falling edge to (previous) data valid on DIN             |                           | 5   |     |                                           | ns               |
| t <sub>PU_STDBY</sub>   | Power-up time from STANDBY mode                                          |                           | 1   |     |                                           | μs               |
| t <sub>PU_SPD</sub>     | Power-up time from SPD mode                                              | With internal reference   | 3   |     |                                           | ms               |
|                         |                                                                          | With external reference   | 1   |     |                                           |                  |

## 6.7 Switching Characteristics

at AVDD = 5 V, DVDD = 1.65 V to 5.5 V, and maximum throughput (unless otherwise noted); minimum and maximum values at T<sub>A</sub> = –40°C to +125°C; typical values at T<sub>A</sub> = 25°C.

| PARAMETER               |                                                                         | TEST CONDITIONS | MIN   | TYP | MAX | UNIT |
|-------------------------|-------------------------------------------------------------------------|-----------------|-------|-----|-----|------|
| t <sub>THROUGHPUT</sub> | Throughput time                                                         |                 | 1.666 |     |     | μs   |
| f <sub>THROUGHPUT</sub> | Throughput                                                              |                 |       |     | 600 | kSPS |
| t <sub>DV_CSDO</sub>    | Delay time: $\overline{\text{CS}}$ falling edge to data enable          |                 |       |     | 12  | ns   |
| t <sub>DZ_CSDO</sub>    | Delay time: $\overline{\text{CS}}$ rising edge to data going to 3-state |                 |       |     | 12  | ns   |
| t <sub>D_CKDO</sub>     | Delay time: SCLK falling edge to next data valid                        |                 |       |     | 20  | ns   |

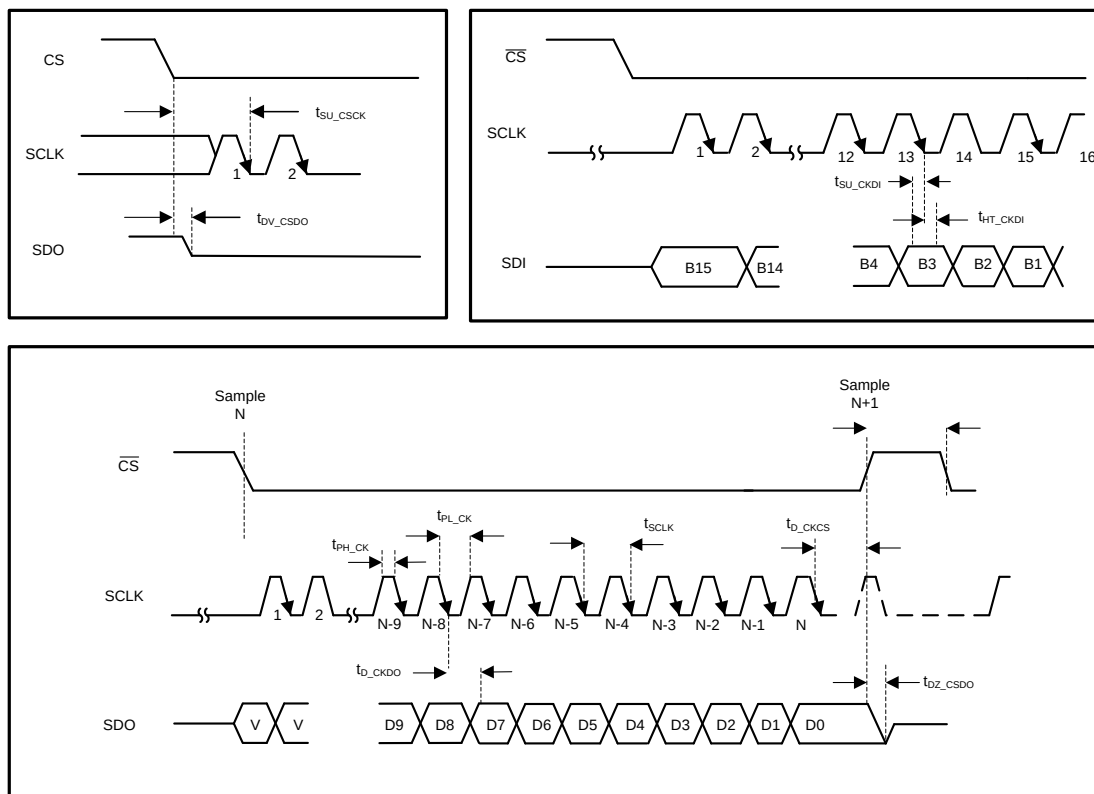
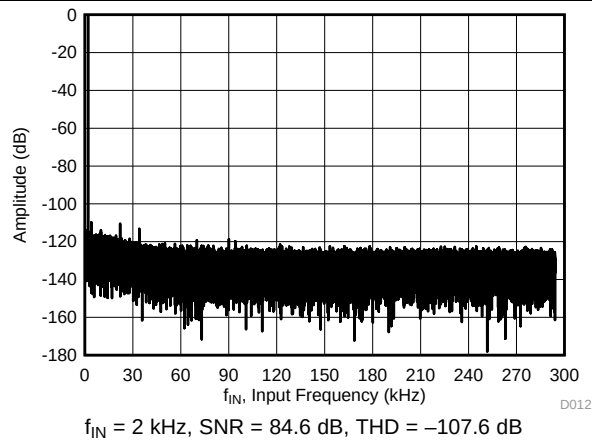
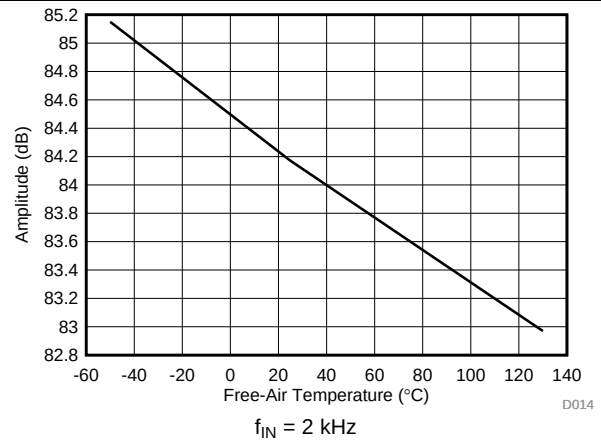
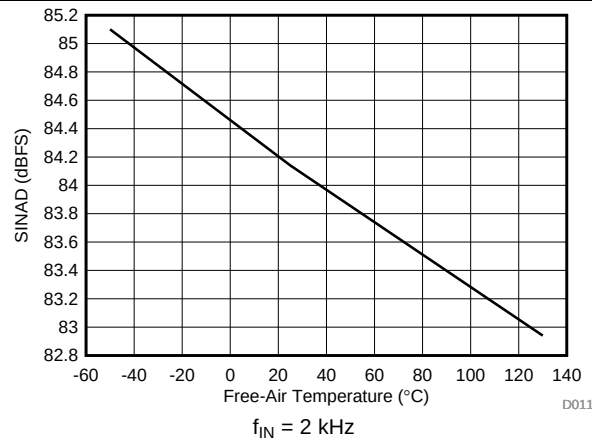
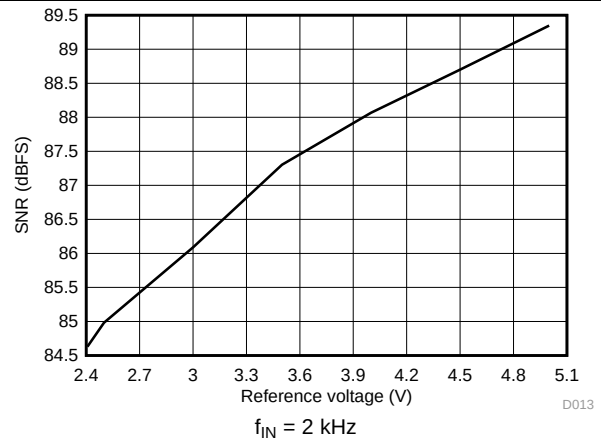
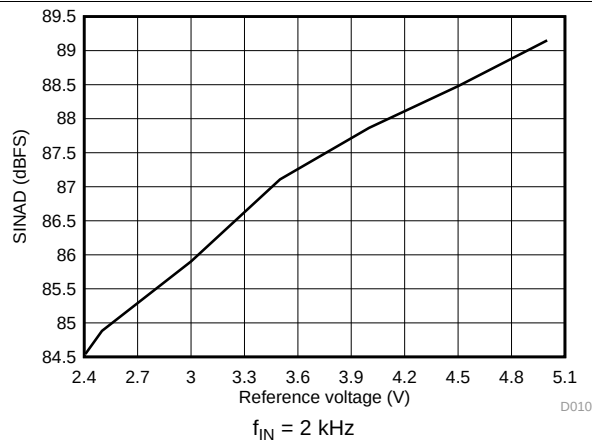
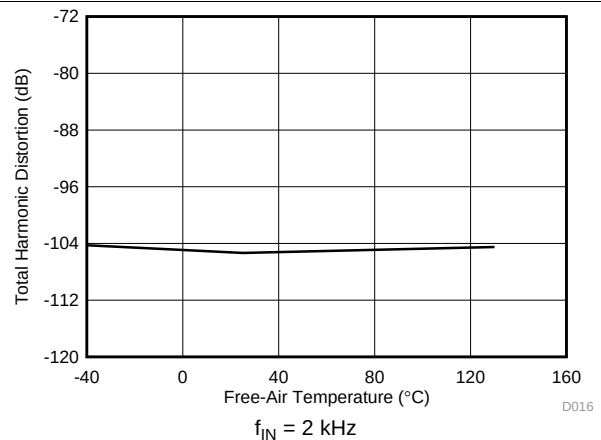


**Figure 1. Serial Interface Timing Diagram**

## 6.8 Typical Characteristics

at  $T_A = 25^\circ\text{C}$ ,  $AVDD = 5\text{ V}$ ,  $DVDD = 3.3\text{ V}$ ,  $V_{REF} = 2.5\text{ V}$  (internal), and  $f_{DATA} = 600\text{ kSPS}$  (unless otherwise noted)


**Figure 2. Typical FFT**

**Figure 3. SNR vs Temperature**

**Figure 4. SINAD vs Temperature**

**Figure 5. SNR vs Reference Voltage**

**Figure 6. SINAD vs Reference Voltage**

**Figure 7. THD vs Temperature**

## Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$ ,  $AVDD = 5\text{ V}$ ,  $DVDD = 3.3\text{ V}$ ,  $V_{REF} = 2.5\text{ V}$  (internal), and  $f_{DATA} = 600\text{ kSPS}$  (unless otherwise noted)

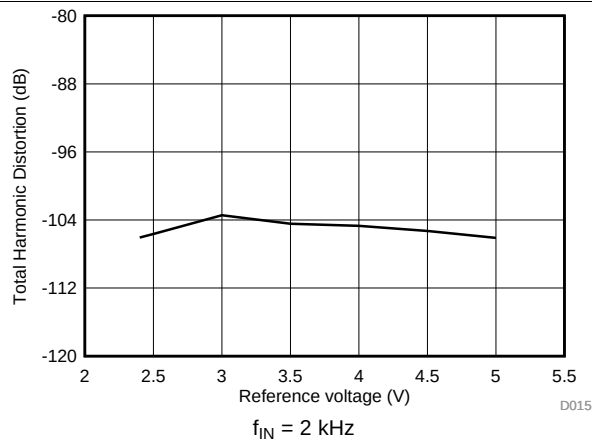


Figure 8. THD vs Reference Voltage

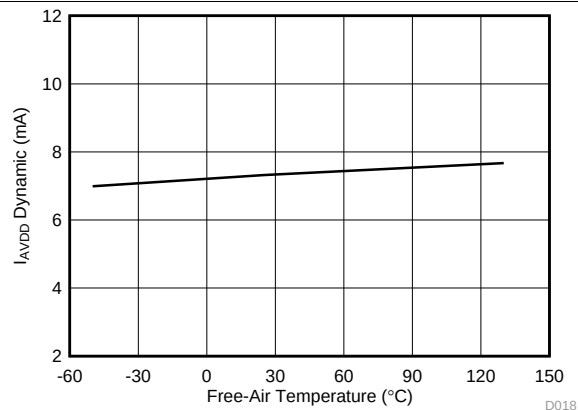


Figure 9. Analog Supply Current vs Temperature

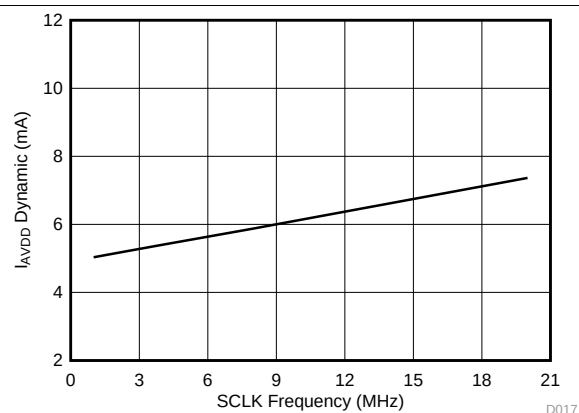


Figure 10. Analog Supply Current vs SCLK Frequency

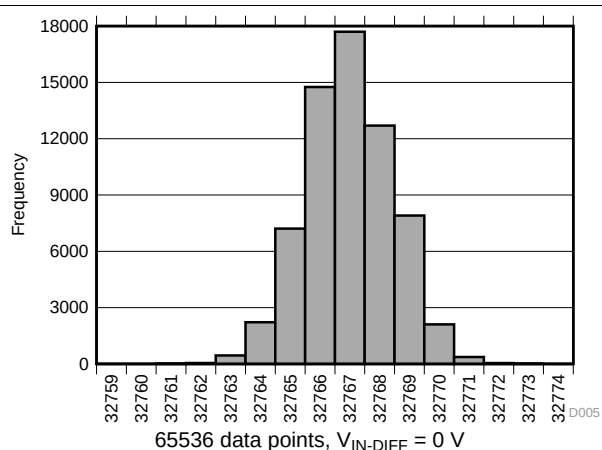


Figure 11. DC Histogram

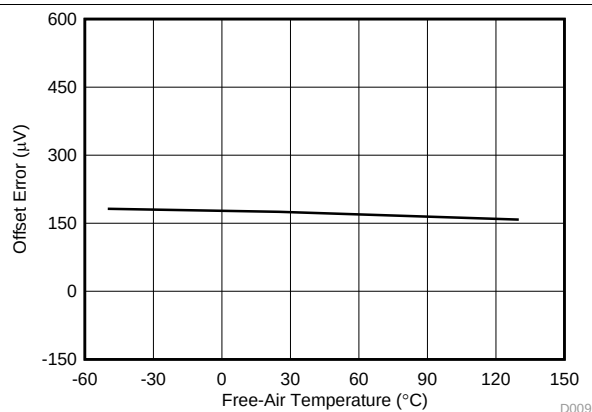


Figure 12. Offset Error vs Temperature

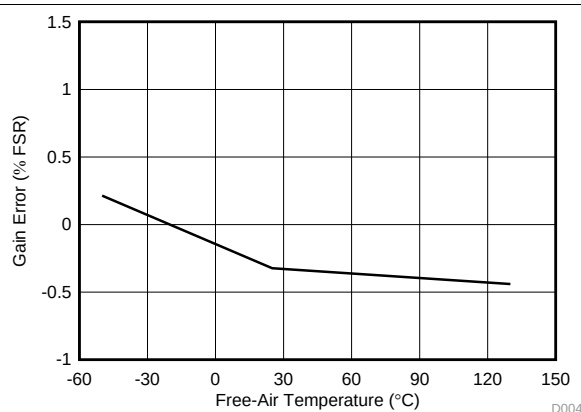


Figure 13. Gain Error vs Temperature

## Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$ ,  $AVDD = 5\text{ V}$ ,  $DVDD = 3.3\text{ V}$ ,  $V_{REF} = 2.5\text{ V}$  (internal), and  $f_{DATA} = 600\text{ kSPS}$  (unless otherwise noted)

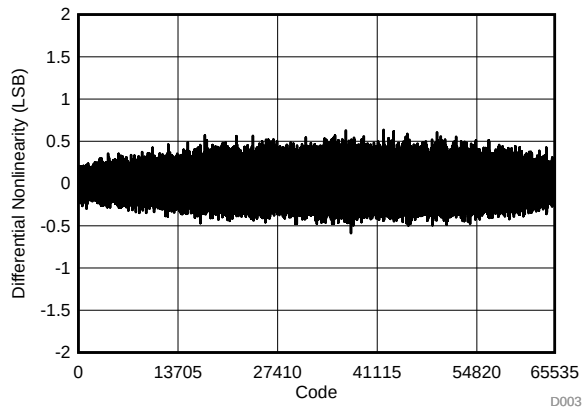


Figure 14. Typical DNL

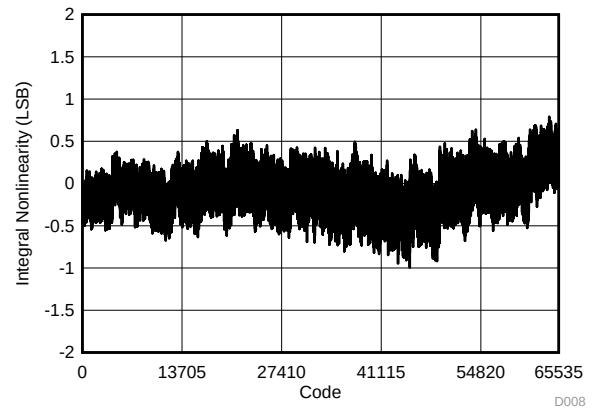


Figure 15. Typical INL

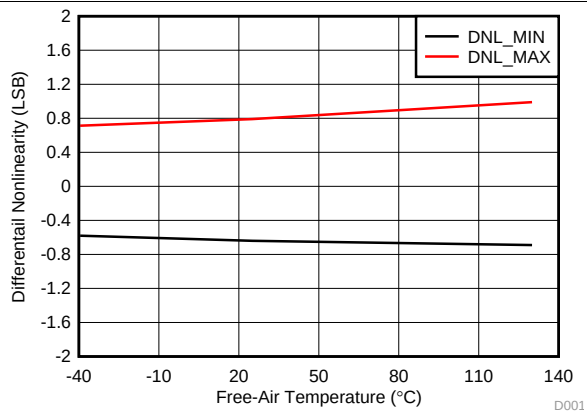


Figure 16. DNL vs Temperature

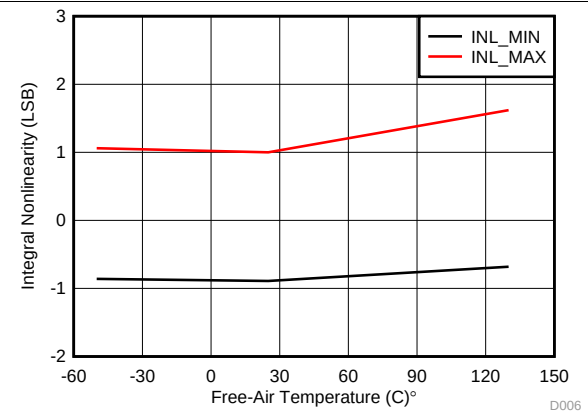


Figure 17. INL vs Temperature

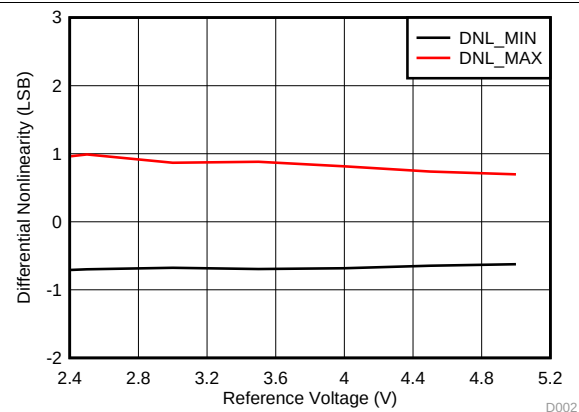


Figure 18. DNL vs Reference Voltage

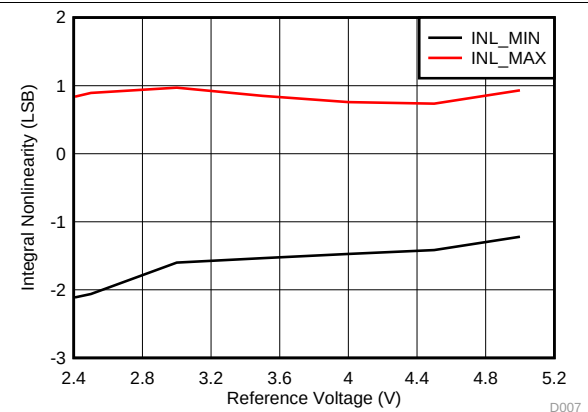


Figure 19. INL vs Reference Voltage

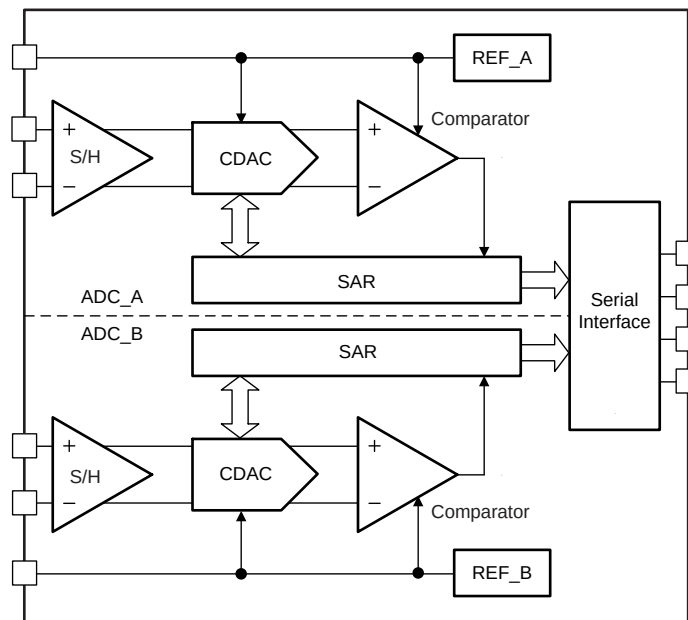
## 7 Detailed Description

### 7.1 Overview

The ADS8353-Q1 is a 16-bit, dual-channel, high-speed, simultaneous-sampling, analog-to-digital converter (ADC). The ADS8353-Q1 supports single-ended and pseudo-differential input signals. The device provides a simple, serial interface to the host controller and operates over a wide range of analog and digital power supplies.

The device has two independently programmable internal references to achieve system-level gain error correction. The [Functional Block Diagram](#) section provides a functional block diagram of the device.

### 7.2 Functional Block Diagram



## 7.3 Feature Description

### 7.3.1 Reference

The device has two simultaneous sampling ADCs (ADC\_A and ADC\_B). ADC\_A and ADC\_B operate with reference voltages present on the REFIO\_A and REFIO\_B pins, respectively. Decouple the REFIO\_A and REFIO\_B pins with the REFGND\_A and REFGND\_B pins, respectively, with 10-μF decoupling capacitors.

Figure 20 shows that the device supports operation either with an internal or external reference source. The reference voltage source is determined by setting bit 6 of the configuration register (CFR.B6). This bit is common to ADC\_A and ADC\_B.

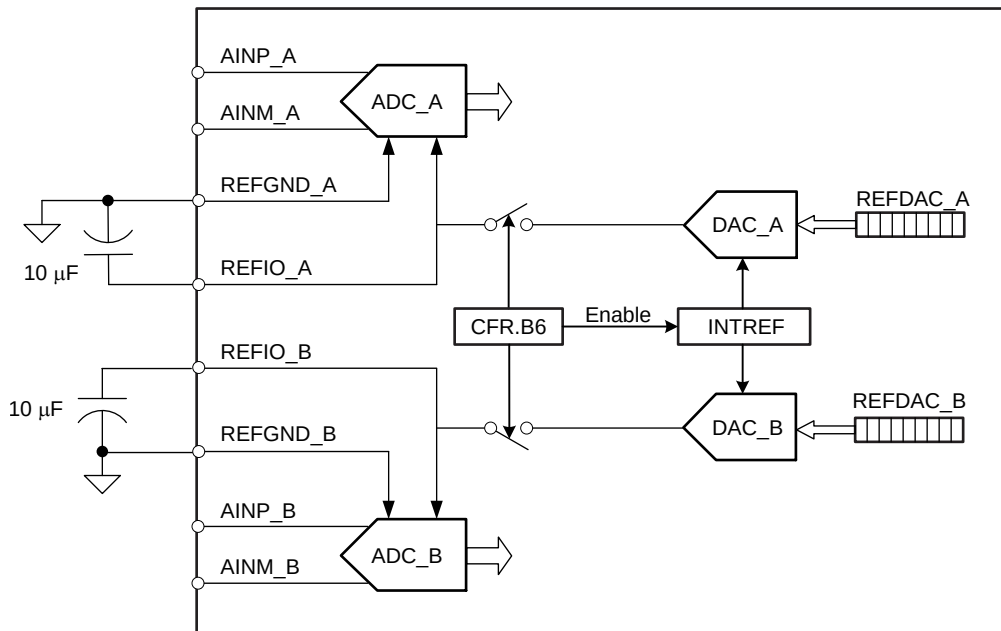


**Figure 20. Reference Configurations and Connections**

When CFR.B6 is 0, the device shuts down the internal reference source (INTREF) and ADC\_A and ADC\_B operate on external reference voltages provided by the user on the REFIO\_A and REFIO\_B pins, respectively.

When CFR.B6 is 1, the device operates with the internal reference source (INTREF) connected to REFIO\_A and REFIO\_B via DAC\_A and DAC\_B, respectively. In this configuration,  $V_{REF\_A}$  and  $V_{REF\_B}$  can be changed independently by writing to the respective user-programmable registers, REFDAC\_A and REFDAC\_B, respectively. See the [Register Maps](#) section for more details.

## Feature Description (continued)

### 7.3.2 Analog Inputs

The ADS8353-Q1 supports single-ended or pseudo-differential analog inputs on both ADC channels. These inputs are sampled and converted simultaneously by the two ADCs, ADC\_A and ADC\_B. ADC\_A samples and converts ( $V_{AINP\_A} - V_{AINM\_A}$ ), and ADC\_B samples and converts ( $V_{AINP\_B} - V_{AINM\_B}$ ).

Figure 21a and Figure 21b show equivalent circuits for the ADC\_A and ADC\_B analog input pins, respectively. Series resistance,  $R_S$ , represents the on-state sampling switch resistance (typically 50  $\Omega$ ) and  $C_{SAMPLE}$  is the device sampling capacitor (typically 40 pF).

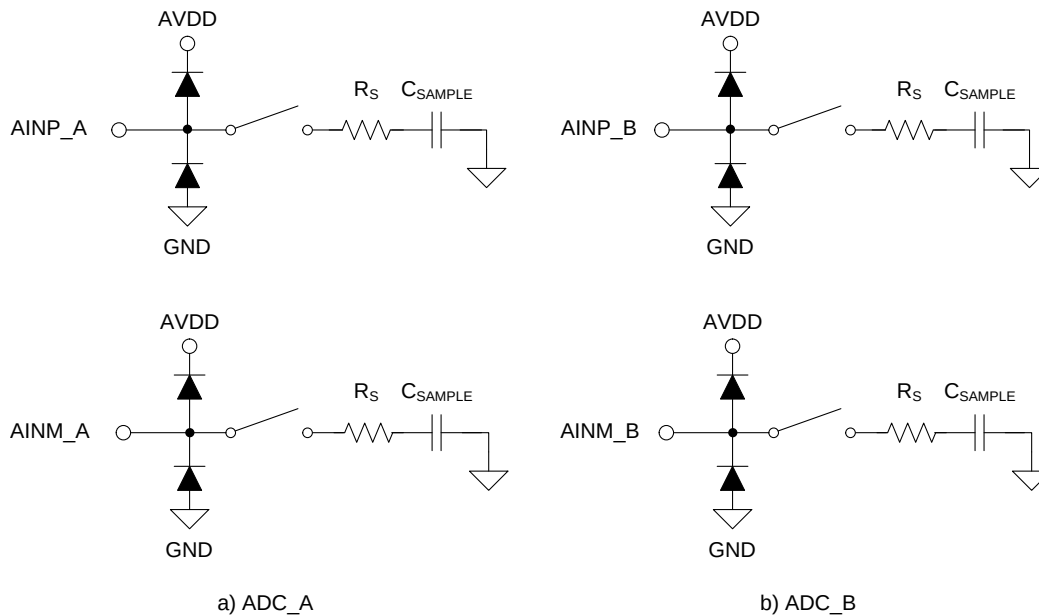


**Figure 21. Equivalent Circuit for the Analog Input Pins**

#### 7.3.2.1 Analog Input: Full-Scale Range Selection

The full-scale range (FSR) supported at the analog inputs of the device is programmable with bit B9 of the configuration register (CFR.B9). This bit is common for both ADCs (ADC\_A and ADC\_B). Equation 1 and Equation 2 give the FSR:

$$\text{For CFR.B9} = 0, \text{FSR\_ADC\_A} = 0 \text{ to } V_{REF\_A} \text{ and } \text{FSR\_ADC\_B} = 0 \text{ to } V_{REF\_B} \quad (1)$$

$$\text{For CFR.B9} = 1, \text{FSR\_ADC\_A} = 0 \text{ to } 2 \times V_{REF\_A} \text{ and } \text{FSR\_ADC\_B} = 0 \text{ to } 2 \times V_{REF\_B}$$

where:

- $V_{REF\_A}$  and  $V_{REF\_B}$  are the reference voltages going to ADC\_A and ADC\_B, respectively (as described in the [Reference](#) section). (2)

Therefore, with appropriate settings of the REFDAC\_A and REFDAC\_B registers, CFR.B7, and CFR.B9, the maximum dynamic range of the ADC can be used.

Make sure that the ADC analog supply (AVDD) is as in Equation 3 and Equation 4 when CFR.B9 is set to 1:

$$2 \times V_{REF\_A} \leq AVDD \leq AVDD(\text{max}) \quad (3)$$

$$2 \times V_{REF\_B} \leq AVDD \leq AVDD(\text{max}) \quad (4)$$

## Feature Description (continued)

### 7.3.2.2 Analog Input: Single-Ended and Pseudo-Differential Configurations

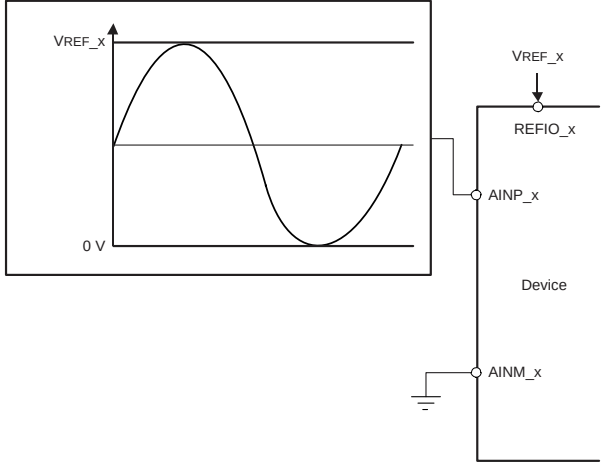
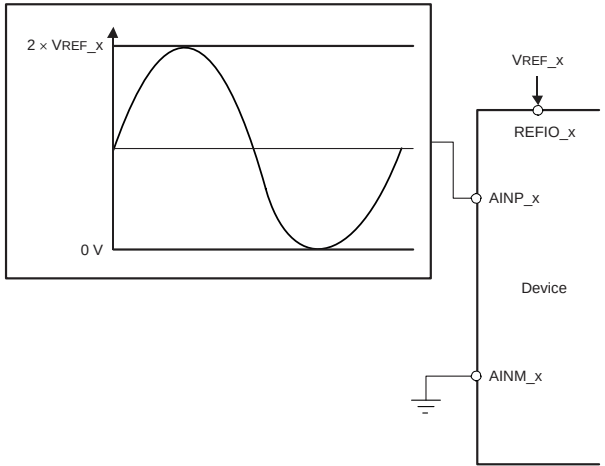
The ADS8353-Q1 can support single-ended or pseudo-differential input configurations.

For supporting single-ended inputs, B7 in the configuration register (CFR.B7) must be set to 0 (CFR.B7 = 0) and AINM\_A and AINM\_B must be externally connected to GND.

For supporting pseudo-differential inputs, CFR.B7 must be set to 1 (CFR.B7 = 1) and AINM\_A and AINM\_B must be externally connected to FSR\_ADC\_A / 2 and FSR\_ADC\_B / 2, respectively. CFR.B7 is common to both ADCs.

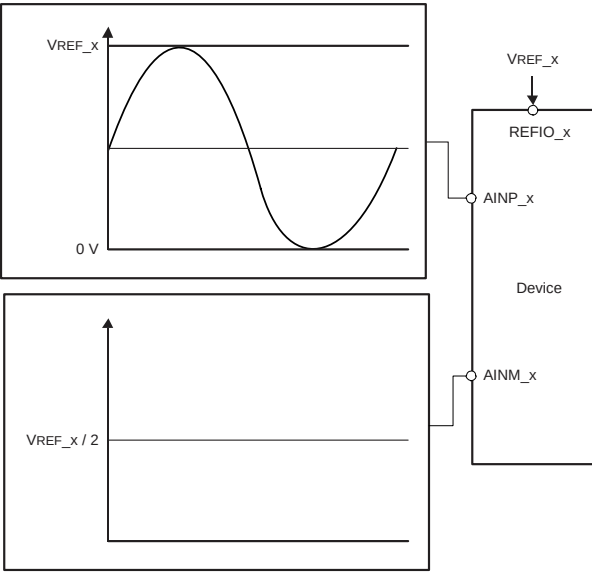
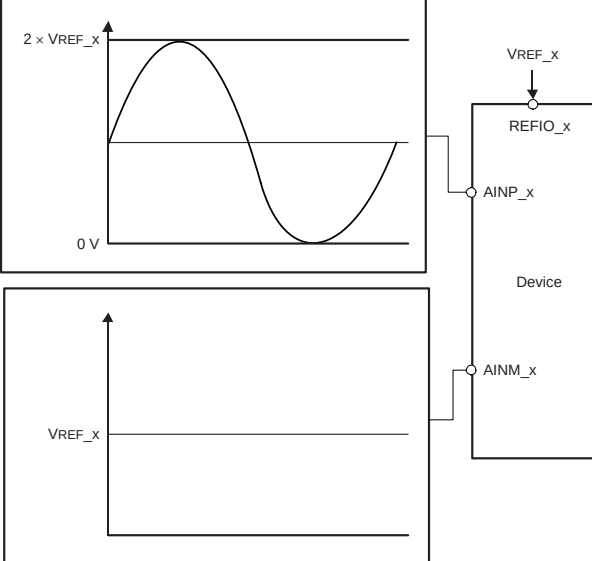
The CFR.B9 and CFR.B7 settings can be combined as shown in [Table 1](#) to select the desired input configuration.

**Table 1. Input Configurations**

| INPUT RANGE SELECTION                                                                                | AINM SELECTION                                 | CONNECTION DIAGRAM                                                                   |
|------------------------------------------------------------------------------------------------------|------------------------------------------------|--------------------------------------------------------------------------------------|
| CFR.B9 = 0<br>(FSR_ADC_A = 0 to $V_{REF\_A}$ )<br>(FSR_ADC_B = 0 to $V_{REF\_B}$ )                   | CFR.B7 = 0<br>(AINM_A = GND)<br>(AINM_B = GND) |   |
| CFR.B9 = 1<br>(FSR_ADC_A = 0 to $2 \times V_{REF\_A}$ )<br>(FSR_ADC_B = 0 to $2 \times V_{REF\_B}$ ) | CFR.B7 = 0<br>(AINM_A = GND)<br>(AINM_B = GND) |  |

## Feature Description (continued)

**Table 1. Input Configurations (continued)**

| INPUT RANGE SELECTION                                                                                                   | AINM SELECTION                                                                                      | CONNECTION DIAGRAM                                                                  |
|-------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| <p>CFR.B9 = 0<br/>(FSR_ADC_A = <math>V_{REF\_A}</math>)<br/>(FSR_ADC_B = <math>V_{REF\_B}</math>)</p>                   | <p>CFR.B7 = 1<br/>(AINM_A = <math>V_{REF\_A}/2</math>)<br/>(AINM_B = <math>V_{REF\_B}/2</math>)</p> |   |
| <p>CFR.B9 = 1<br/>(FSR_ADC_A = <math>2 \times V_{REF\_A}</math>)<br/>(FSR_ADC_B = <math>2 \times V_{REF\_B}</math>)</p> | <p>CFR.B7 = 1<br/>(AINM_A = <math>V_{REF\_A}</math>)<br/>(AINM_B = <math>V_{REF\_B}</math>)</p>     |  |

### 7.3.3 Transfer Function

The device supports two input configurations:

1. Single-ended inputs, CFR.B7 = 0 (default), or
2. Pseudo-differential inputs, CFR.B7 = 1

The device also supports two output data formats:

1. Straight binary output, CFR.B4 = 0 (default), or
2. Two's compliment output, CFR.B4 = 1

Equation 5 calculates the device resolution:

$$1 \text{ LSB} = (\text{FSR\_ADC\_x}) / (2^N)$$

where:

- N = 16
- FSR\_ADC\_x = the full-scale input range of the ADC (see the [Analog Inputs](#) section for more details) (5)

Table 2 and Table 3 show the different input voltages and the corresponding output codes from the device.

**Table 2. Transfer Characteristics for Straight Binary Output (CFR.B4 = 0, Default)**

| INPUT CONFIGURATION                   | INPUT VOLTAGE                             |                          |                                                | OUTPUT CODE (Hex)                     |            |
|---------------------------------------|-------------------------------------------|--------------------------|------------------------------------------------|---------------------------------------|------------|
|                                       |                                           |                          |                                                | STRAIGHT BINARY (CFR.B4 = 0, Default) |            |
|                                       | AINP_x                                    | AINM_x                   | AINP_x - AINM_x                                | CODE                                  | ADS8353-Q1 |
| Single-ended<br>(CFR.B7 = 0, default) | $\leq 1 \text{ LSB}$                      | 0                        | $\leq 1 \text{ LSB}$                           | ZC                                    | 0000       |
|                                       | $\text{FSR\_ADC\_x} / 2$                  |                          | $\text{FSR\_ADC\_x} / 2$                       | MC                                    | 7FFF       |
|                                       | $\geq \text{FSR\_ADC\_x} - 1 \text{ LSB}$ |                          | $\geq \text{FSR\_ADC\_x} - 1 \text{ LSB}$      | FSC                                   | FFFF       |
| Pseudo-differential<br>(CFR.B7 = 1)   | $\leq 1 \text{ LSB}$                      | $\text{FSR\_ADC\_x} / 2$ | $\leq -\text{FSR\_ADC\_x} / 2 + 1 \text{ LSB}$ | ZC                                    | 0000       |
|                                       | $\text{FSR\_ADC\_x} / 2$                  |                          | 0                                              | MC                                    | 7FFF       |
|                                       | $\geq \text{FSR\_ADC\_x} - 1 \text{ LSB}$ |                          | $\geq \text{FSR\_ADC\_x} / 2 - 1 \text{ LSB}$  | FSC                                   | FFFF       |

**Table 3. Transfer Characteristics for Two's Complement Output (CFR.B4 = 1)**

| INPUT CONFIGURATION                   | INPUT VOLTAGE                             |                          |                                                | OUTPUT CODE (Hex)                      |            |
|---------------------------------------|-------------------------------------------|--------------------------|------------------------------------------------|----------------------------------------|------------|
|                                       |                                           |                          |                                                | TWO'S COMPLIMENT (CFR.B4 = 1, Default) |            |
|                                       | AINP_x                                    | AINM_x                   | AINP_x - AINM_x                                | CODE                                   | ADS8353-Q1 |
| Single-ended<br>(CFR.B7 = 0, default) | $\leq 1 \text{ LSB}$                      | 0                        | $\leq 1 \text{ LSB}$                           | NFSC                                   | 8000       |
|                                       | $\text{FSR\_ADC\_x} / 2$                  |                          | $\text{FSR\_ADC\_x} / 2$                       | MC                                     | 0000       |
|                                       | $\geq \text{FSR\_ADC\_x} - 1 \text{ LSB}$ |                          | $\geq \text{FSR\_ADC\_x} - 1 \text{ LSB}$      | PFSC                                   | 7FFF       |
| Pseudo-differential<br>(CFR.B7 = 1)   | $\leq 1 \text{ LSB}$                      | $\text{FSR\_ADC\_x} / 2$ | $\leq -\text{FSR\_ADC\_x} / 2 + 1 \text{ LSB}$ | NFSC                                   | 8000       |
|                                       | $\text{FSR\_ADC\_x} / 2$                  |                          | 0                                              | MC                                     | 0000       |
|                                       | $\geq \text{FSR\_ADC\_x} - 1 \text{ LSB}$ |                          | $\geq \text{FSR\_ADC\_x} / 2 - 1 \text{ LSB}$  | PFSC                                   | 7FFF       |

Figure 22 shows the ideal device transfer characteristics for the single-ended analog input.

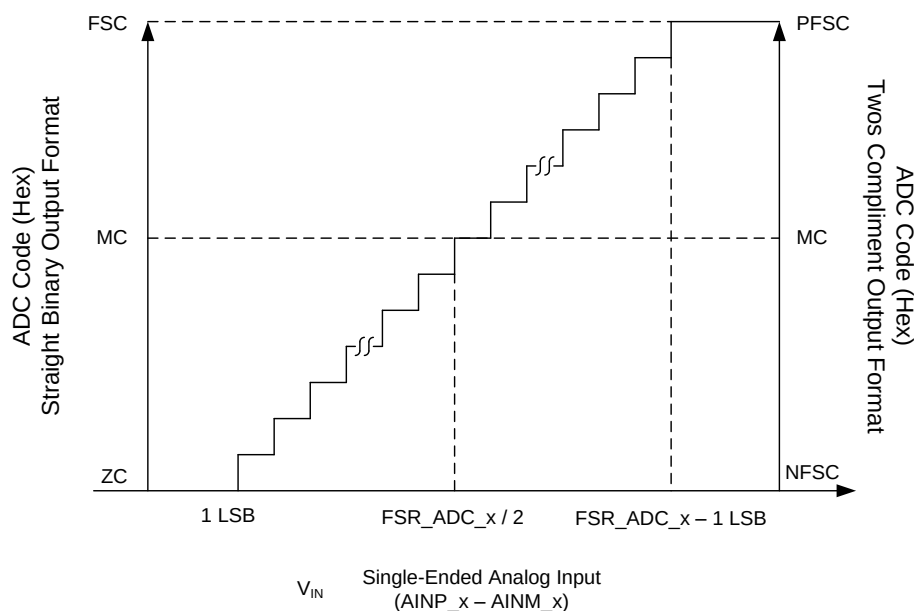


**Figure 22. Ideal Transfer Characteristics for a Single-Ended Analog Input**

Figure 23 shows the ideal device transfer characteristics for the pseudo-differential analog input.

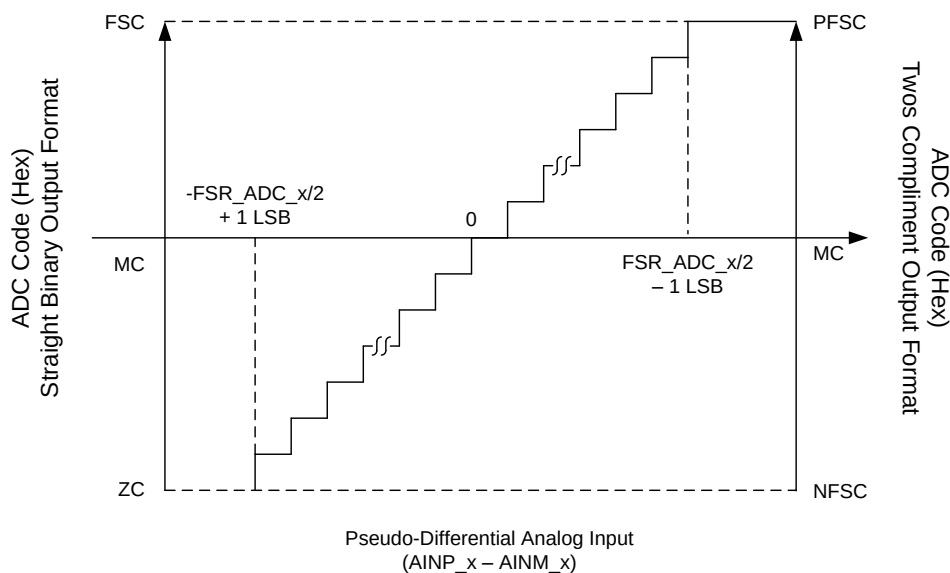


**Figure 23. Ideal Transfer Characteristics for a Pseudo-Differential Analog Input**

## 7.4 Device Functional Modes

The device provides three user-programmable registers: the configuration register (CFR), the REFDAC\_A register, and the REFDAC\_B register. These registers support write (see the [Write to User-Programmable Registers](#) section) and readback (see the [Reading User-Programmable Registers](#) section) operations and allow the ADC behavior to be customized for specific application requirements.

The device supports two interface modes (see the [Conversion Data Read](#) section), two low-power modes (see the [Low-Power Modes](#) section), and a short-cycling or reconversion feature (see the [Frame Abort, Reconversion, or Short-Cycling](#) section).

## 7.5 Programming

### 7.5.1 Serial Interface

The device uses the serial clock (SCLK) for synchronizing data transfers in and out of the device.

The  $\overline{CS}$  signal defines one conversion and serial transfer frame. A frame starts with a  $\overline{CS}$  falling edge and ends with a  $\overline{CS}$  rising edge. Between the start and end of the frame, a minimum of  $N$  SCLK falling edges must be provided to validate the read or write operation. As shown in [Table 4](#),  $N$  depends upon the interface mode used to read the conversion result. When  $N$  SCLK falling edges are provided, the write operation attempted in the frame is validated and the internal user-programmable registers are updated on the subsequent  $\overline{CS}$  rising edge. This  $\overline{CS}$  rising edge also ends the frame.

**Table 4. SCLK Falling Edges for a Valid Write Operation**

| INTERFACE MODE                                                                         | MINIMUM SCLK FALLING EDGES REQUIRED TO VALIDATE WRITE OPERATION $N$ |
|----------------------------------------------------------------------------------------|---------------------------------------------------------------------|
| 32-CLK, dual-SDO mode (default); see the <a href="#">32-CLK, Dual-SDO Mode</a> section | 32                                                                  |
| 32-CLK, single-SDO mode; see the <a href="#">32-CLK, Single-SDO Mode</a> section       | 48                                                                  |

If  $\overline{CS}$  is brought high before providing  $N$  SCLK falling edges, the write operation attempted in the frame is not valid. See the [Frame Abort, Reconversion, or Short-Cycling](#) section for more details.

### 7.5.2 Write to User-Programmable Registers

The device features three user-programmable registers: the configuration register (CFR), the REFDAC\_A register, and the REFDAC\_B register. These registers can be written with the device SDI pin. The first 16 bits of data on SDI are latched into the device on the first 16 SCLK falling edges. However, the new configuration takes effect only when the read or write operation is validated. If these registers are not required to update, SDI must remain low during the respective frames.

The first four SDI data bits (B[15:12]) determine what operation is performed (that is, either a read or write operation or no operation), which register address the operation uses, and the function of the next 12 SDI data bits (B[11:0]). [Table 5](#) lists the various combinations supported for B[15:12].

**Table 5. Data Write Operation**

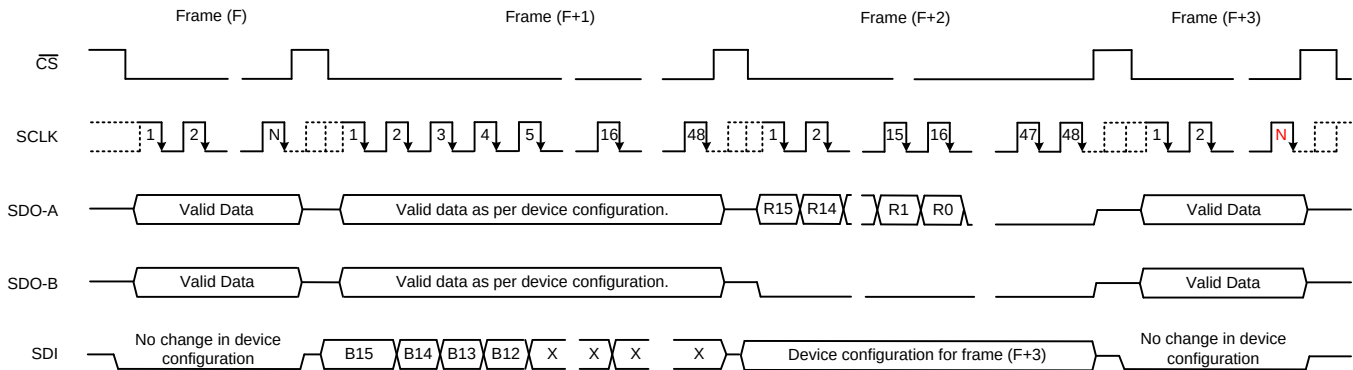
| B15 | B14 | B13 | B12 | OPERATION                 | FUNCTION OF BITS B[11:0]                                                  |
|-----|-----|-----|-----|---------------------------|---------------------------------------------------------------------------|
| 0   | 0   | 0   | 0   | No operation is performed | These bits are ignored                                                    |
| 0   | 0   | 0   | 1   | REFDAC_A read             | 000h; see the <a href="#">Reading User-Programmable Registers</a> section |
| 0   | 0   | 1   | 0   | REFDAC_B read             | 000h; see the <a href="#">Reading User-Programmable Registers</a> section |
| 0   | 0   | 1   | 1   | CFR read                  | 000h; see the <a href="#">Reading User-Programmable Registers</a> section |
| 1   | 0   | 0   | 0   | CFR write                 | See the <a href="#">CFR register</a>                                      |
| 1   | 0   | 0   | 1   | REFDAC_A write            | See the <a href="#">REFDAC register</a>                                   |
| 1   | 0   | 1   | 0   | REFDAC_B write            | See the <a href="#">REFDAC register</a>                                   |
| 1   | 0   | 1   | 1   | No operation is performed | These bits are ignored                                                    |
| X   | 1   | X   | X   | No operation is performed | These bits are ignored                                                    |

### 7.5.3 Data Read Operation

The device supports two types of read operations: reading user-programmable registers and reading conversion results.

#### 7.5.3.1 Reading User-Programmable Registers

The device supports a readback option for all user-programmable registers: CFR, REFDAC\_A, and REFDAC\_B. Figure 24 shows a detailed timing diagram for this operation.



NOTE: *N* is a function of the device configuration, as described in Table 4.

Figure 24. Register Readback Timing

To readback the user-programmable register settings, transmit the appropriate control word, as shown in Table 6, to the device during frame (F+1). Frame (F+1) must have at least 48 SCLK falling edges.

Table 6. Control Word to Readback User-Programmable Registers

| USER-PROGRAMMABLE REGISTER | CONTROL WORD TO BE PROGRAMMED IN FRAME (F+1) |               |
|----------------------------|----------------------------------------------|---------------|
|                            | B[15:12] (Binary)                            | B[11:0] (Hex) |
| CFR                        | 0011b                                        | 000h          |
| REFDAC_A                   | 0001b                                        | 000h          |
| REFDAC_B                   | 0010b                                        | 000h          |

Frame (F+2) must have at least 48 SCLK falling edges. During frame (F+2), SDO\_A outputs the contents of the selected user-programmable register on the first 16 SCLK falling edges (as shown in Table 7) and then outputs 0's for any subsequent SCLK falling edges. The SDO\_B pin outputs 0's for all SCLK falling edges.

Table 7. Register Data Read Back

| USER-PROGRAMMABLE REGISTER | DATA READ ON SDO-A IN FRAME (F+2) |     |     |     |             |   |             |        |        |        |
|----------------------------|-----------------------------------|-----|-----|-----|-------------|---|-------------|--------|--------|--------|
|                            | R15                               | R14 | R13 | R12 | R11         | — | R3          | R2     | R1     | R0     |
| CFR                        | 0                                 | 0   | 1   | 1   | CFG.B11     | — | CFG.B3      | CFG.B2 | CFG.B1 | CFG.B0 |
| REFDAC_A                   | 0                                 | 0   | 0   | 1   | REFDAC_A.D8 | — | REFDAC_A.D0 | 0      | 0      | 0      |
| REFDAC_B                   | 0                                 | 0   | 1   | 0   | REFDAC_B.D8 | — | REFDAC_B.D0 | 0      | 0      | 0      |

Register settings programmed during frame (F+2) determine the device configuration in frame (F+3).

### 7.5.3.2 Conversion Data Read

The device provides two different interface modes for reading the conversion result. These modes offer flexible hardware connections and firmware programming. [Table 8](#) shows how to select one of the two interface modes.

**Table 8. Interface Mode Selection**

| CFR.B11 | CFR.B10 | INTERFACE MODE                  | MINIMUM SCLK FALLING EDGES REQUIRED TO VALIDATE WRITE OPERATION N |
|---------|---------|---------------------------------|-------------------------------------------------------------------|
| 0       | 0       | 32-CLK, dual-SDO mode (default) | 32                                                                |
| 0       | 1       | 32-CLK, single-SDO mode         | 48                                                                |

In the 32-CLK interface modes, the device uses an internal clock to convert the sampled analog signal. The conversion is completed during the first 16 periods of SCLK and the conversion result can be read on the subsequent SCLK falling edges.

The following sections detail the various interface modes supported by the device.

#### 7.5.3.2.1 32-CLK, Dual-SDO Mode (CFR.B11 = 0, CFR.B10 = 0, Default)

The 32-CLK, dual-SDO mode is the default mode supported by the device. This mode can also be selected by writing CFR.B11 = 0 and CFR.B10 = 0.

In this mode, the SDO\_A pin outputs the ADC\_A conversion result and the SDO\_B pin outputs the ADC\_B conversion result. [Figure 25](#) shows a detailed timing diagram for this mode.

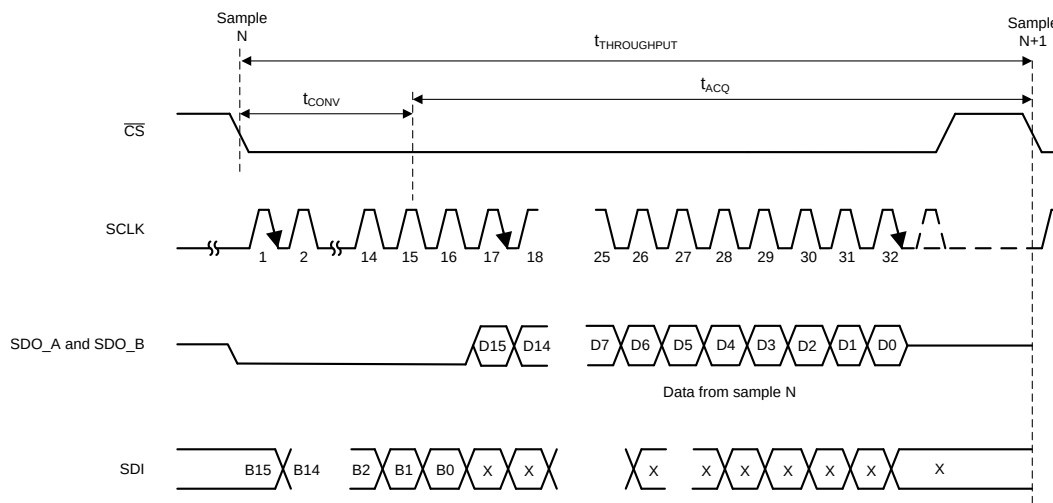


**Figure 25. 32-CLK, Dual-SDO Mode Timing Diagram**

A  $\overline{CS}$  falling edge brings the serial data bus out of 3-state and also outputs a 0 on the SDO\_A and SDO\_B pins. The device converts the sampled analog input during the conversion time ( $t_{CONV}$ ). SDO\_A and SDO\_B read 0 during this period. After completing the conversion process, the sample-and-hold circuit returns to sample mode. The device outputs the MSBs of ADC\_A and ADC\_B on the SDO\_A and SDO\_B pins, respectively, on the 16th SCLK falling edge. As shown in [Table 9](#), the subsequent SCLK falling edges are used to shift out the rest of the bits of the conversion result.

**Table 9. Data Launch Edge**

| DEVICE     | PINS  | LAUNCH EDGE            |      |   |     |       |   |      |      |      |      |      |                        |      |
|------------|-------|------------------------|------|---|-----|-------|---|------|------|------|------|------|------------------------|------|
|            |       | $\overline{\text{CS}}$ | SCLK |   |     |       |   |      |      |      |      |      | $\overline{\text{CS}}$ |      |
|            |       | ↓                      | ↓1   | — | ↓15 | ↓16   | — | ↓27  | ↓28  | ↓29  | ↓30  | ↓31  | ↓32 ...                | ↑    |
| ADS8353-Q1 | SDO-A | 0                      | 0    | — | 0   | D15_A | — | D4_A | D3_A | D2_A | D1_A | D0_A | 0 ...                  | Hi-Z |
|            | SDO-B | 0                      | 0    | — | 0   | D15_B | — | D4_B | D3_B | D2_B | D1_B | D0_B | 0 ...                  | Hi-Z |

In this mode, at least 32 SCLK falling edges must be given to validate the read or write frame. A  $\overline{\text{CS}}$  rising edge ends the frame and puts the serial bus into 3-state.

See the [Timing Requirements](#) table for timing specifications specific to this serial interface mode.

#### 7.5.3.2.2 32-CLK, Single-SDO Mode (CFR.B11 = 0, CFR.B10 = 1)

The 32-CLK, single-SDO mode provides the option of using only one SDO pin (SDO\_A) to read conversion results from both ADCs (ADC\_A and ADC\_B). SDO\_B remains in 3-state and can be treated as a no connect (NC) pin.

This mode can be selected by writing CFR.B11 = 0 and CFR.B10 = 1. [Figure 26](#) shows a detailed timing diagram for this mode.

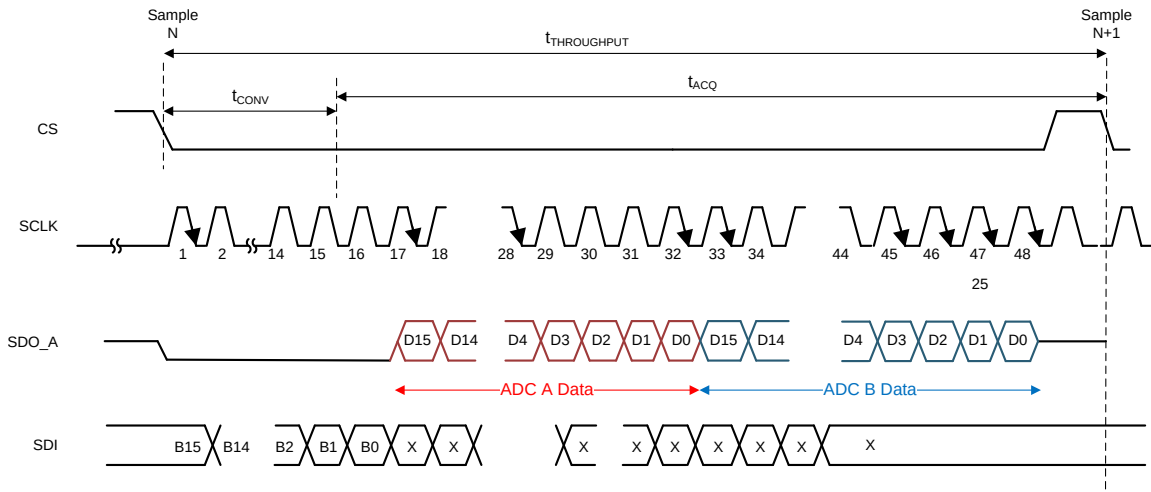


Figure 26. 32-CLK, Single-SDO Mode Timing Diagram

A  $\overline{\text{CS}}$  falling edge brings the serial data bus out of 3-state and also outputs a 0 on the SDO\_A pin. The device converts the sampled analog input during the conversion time ( $t_{\text{CONV}}$ ). SDO\_A reads 0 during this period. After completing the conversion process, the sample-and-hold circuit goes back into sample mode. The device outputs the MSB of ADC\_A on the SDO\_A pin on the 16th SCLK falling edge. As shown in [Table 10](#), the subsequent SCLK falling edges are used to shift out the conversion result of ADC\_A followed by the conversion result of ADC\_B on the SDO\_A pin.

Table 10. Data Launch Edge

| DEVICE     | PIN   | LAUNCH EDGE            |      |   |     |       |   |      |      |      |      |      |       |   |      |      |      |      |      |                        |      |
|------------|-------|------------------------|------|---|-----|-------|---|------|------|------|------|------|-------|---|------|------|------|------|------|------------------------|------|
|            |       | $\overline{\text{CS}}$ | SCLK |   |     |       |   |      |      |      |      |      |       |   |      |      |      |      |      | $\overline{\text{CS}}$ |      |
|            |       | ↓                      | ↓1   | — | ↓15 | ↓16   | — | ↓27  | ↓28  | ↓29  | ↓30  | ↓31  | ↓32   | — | ↓43  | ↓44  | ↓45  | ↓46  | ↓47  | ↓48 ...                | ↑    |
| ADS8353-Q1 | SDO-A | 0                      | 0    | — | 0   | D15_A | — | D4_A | D3_A | D2_A | D1_A | D0_A | D15_B | — | D4_B | D3_B | D2_B | D1_B | D0_B | 0 ...                  | Hi-Z |

In this mode, at least 48 SCLK falling edges must be given to validate the read or write frame. A  $\overline{\text{CS}}$  rising edge ends the frame and puts the serial bus into 3-state.

See the [Timing Requirements](#) table for timing specifications specific to this serial interface mode.

#### 7.5.4 Low-Power Modes

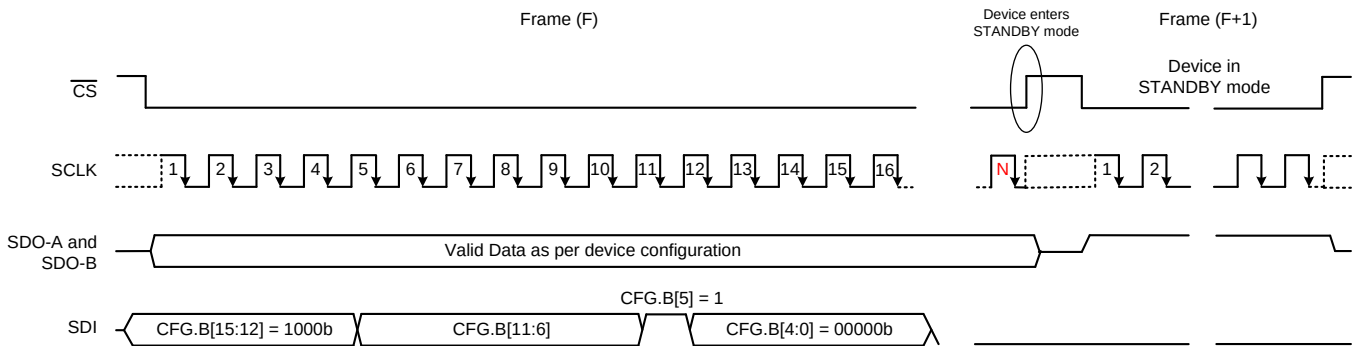
In normal mode of operation, all internal circuits of the device are always powered up and the device is always ready to commence a new conversion. This mode enables the device to support the rated throughput. The device also supports two low-power modes to optimize the power consumption at lower throughputs: STANDBY mode and software power-down (SPD) mode.

### 7.5.4.1 STANDBY Mode

The device supports a STANDBY mode of operation where some of the internal circuits of the device are powered down. However, if bit 6 in configuration register is set to 1 (CFR.B6 = 1), then the internal reference is not powered down and the contents of the REFDAC\_A and REFDAC\_B registers are retained to enable faster power-up to a normal mode of operation.

As shown in Figure 27, a valid write operation in frame (F) programs the configuration register with B5 set to 1 (CFR.B5 = 1) and places the device into a STANDBY mode of operation on the following CS rising edge. While in STANDBY mode, SDO\_A and SDO\_B output all 1s when CS is low and remain in 3-state when CS is high.

To remain in STANDBY mode, SDI must remain low in the subsequent frames.

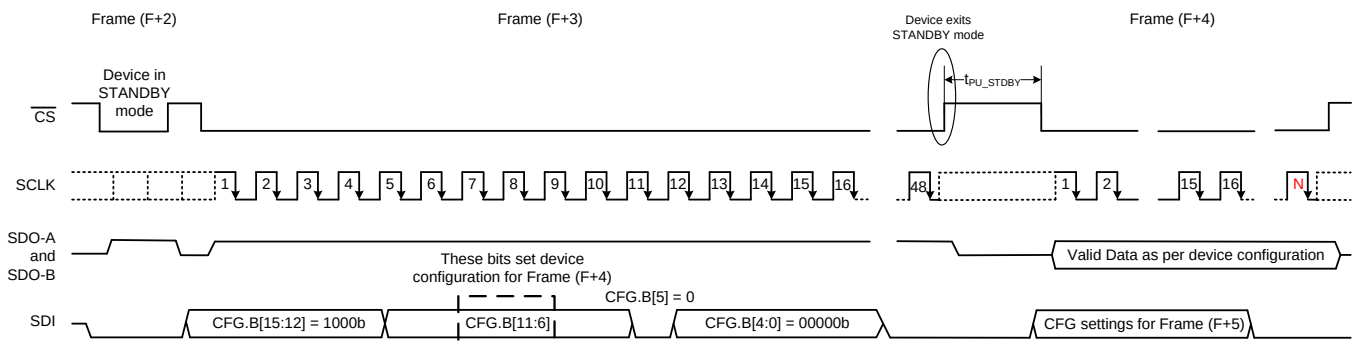


NOTE: N is a function of the device configuration, as described in Table 4.

**Figure 27. Enter STANDBY Mode**

As shown in Figure 28, a valid write operation in frame (F+3) writes the configuration register with B5 set to 0 (CFR.B5 = 0) and brings the device out of STANDBY mode on the following CS rising edge. Frame (F+3) must have at least 48 SCLK falling edges.

After exiting the STANDBY mode, a delay of  $t_{PU\_STDBY}$  must elapse for the internal circuits to fully power-up and resume normal operation in frame (F+4). Device configuration for frame (F+4) is determined by the status of the CFR.B[11:6] bits programmed during frame (F+3).



NOTE: N is a function of the device configuration, as described in Table 4.

**Figure 28. Exit STANDBY Mode**

See the [Timing Requirements](#) table for timing specifications for this operating mode.

### 7.5.4.2 Software Power-Down (SPD) Mode

In software power-down (SPD) mode, all internal circuits (including the internal references) are powered down. However, the contents of the REFDAC\_A and REFDAC\_B registers are retained.

As shown in [Figure 29](#), to enter SPD mode, the device must be selected (by bringing  $\overline{\text{CS}}$  low) and SDI must be kept high for a minimum of 48 SCLK cycles during frame (F). The device goes to SPD on the  $\overline{\text{CS}}$  rising edge following frame (F). While in SPD mode, SDO\_A and SDO\_B go to 3-state irrespective of the status of the  $\overline{\text{CS}}$  signal.

To remain in SPD mode, SDI must remain high in all subsequent frames.

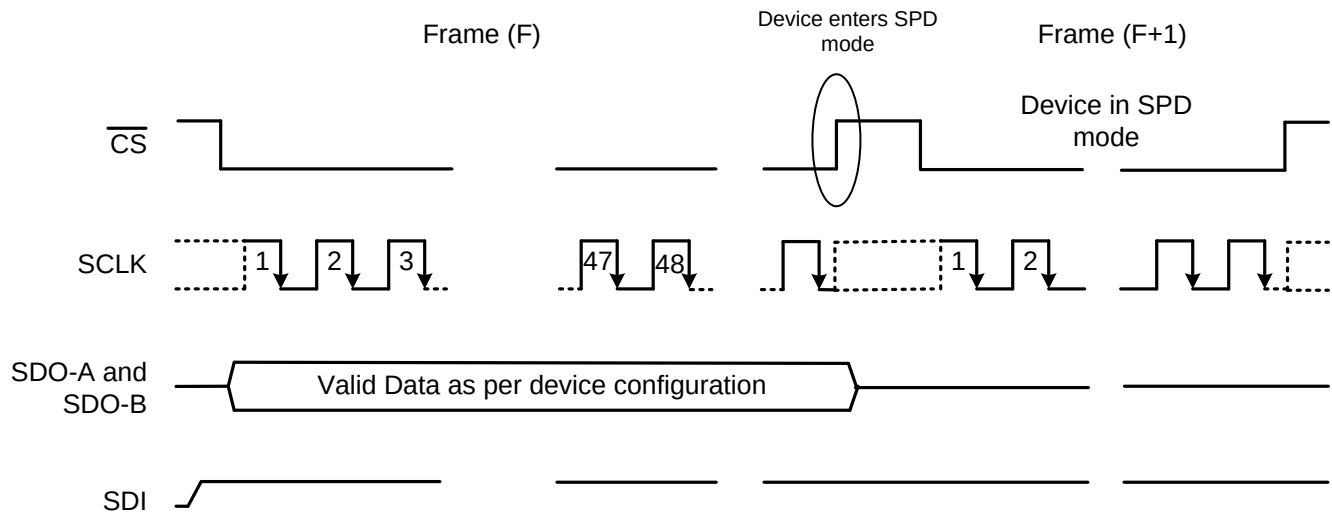
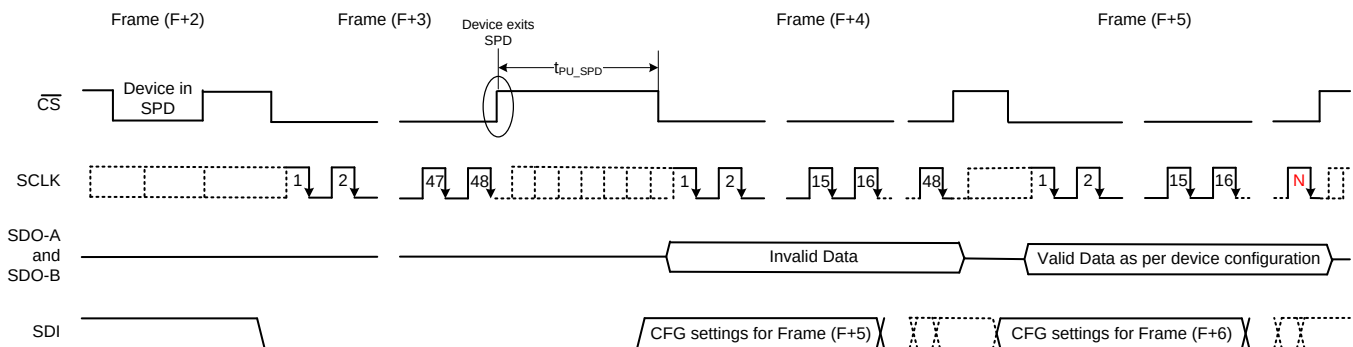


**Figure 29. Enter SPD Mode**

As shown in [Figure 30](#), to exit SPD mode, the device must be selected (by bringing  $\overline{\text{CS}}$  low) and SDI must be kept low for a minimum of 48 SCLK cycles during frame (F+3). The device starts powering-up on a  $\overline{\text{CS}}$  rising edge following frame (F+3). After frame (F+3), a delay of  $t_{\text{PU\_SPD}}$  must elapse before programming the configuration register.

A valid write operation in frame (F+4) sets the device configuration for frame (F+5). Frame (F+4) must have at least 48 SCLK falling edges. Discard the output data in frame (F+4).



NOTE:  $N$  is a function of the device configuration, as described in [Table 4](#).

**Figure 30. Exit SPD Mode**

See the [Timing Requirements](#) table for timing specifications for this operating mode.

### 7.5.5 Frame Abort, Reconversion, or Short-Cycling

As shown in [Figure 31](#), the minimum number of SCLK falling edges ( $N$ ) that must be provided between the beginning and end of the frame depends on the serial interface mode. The SCLK falling edges ( $N$ ) program the device and retrieve the conversion result. If  $\overline{\text{CS}}$  is brought high before the expected number of SCLK falling edges are provided, the current frame is aborted and the device starts sampling the new analog input signal.

If frame (F) is aborted, then the register write operation attempted in frame (F) is considered invalid and the internal registers are not updated. The device continues to have the same configuration in frame (F+1) from frame (F).

The output data bits latched before the  $\overline{\text{CS}}$  rising edge are still valid data that correspond to sample N.

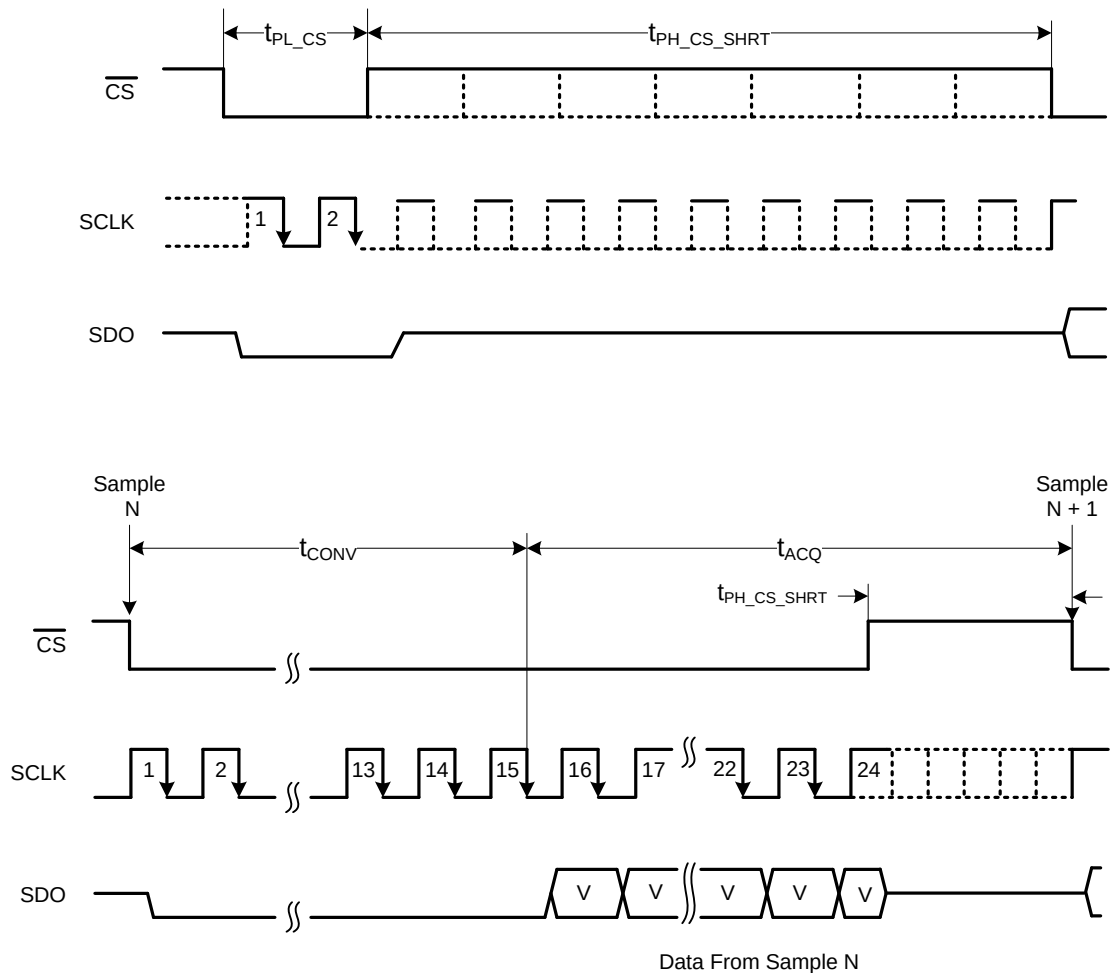


**Figure 31. Frame Abort, Reconversion, or Short-Cycling Feature**

See the [Timing Requirements](#) table for timing specifications for this operating mode.

## 7.6 Register Maps

### 7.6.1 ADS8353-Q1 Registers

[Table 11](#) lists the memory-mapped registers for the ADS8353-Q1 registers. Consider any register offset addresses not listed in [Table 11](#) as reserved locations and, therefore, do not modify the register contents.

**Table 11. ADS8353-Q1 Registers**

| Offset | Acronym | Register Name   | Section                                                    |
|--------|---------|-----------------|------------------------------------------------------------|
| 0h     | CFR     | CFR register    | <a href="#">CFR Register (Offset = 0h) [reset = 0h]</a>    |
| 2h     | REFDAC  | REFDAC register | <a href="#">REFDAC Register (Offset = 2h) [reset = 0h]</a> |

Complex bit access types are encoded to fit into small table cells. [Table 12](#) shows the codes that are used for access types in this section.

**Table 12. ADS8353-Q1 Access Type Codes**

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

### 7.6.1.1 CFR Register (Offset = 0h) [reset = 0h]

CFR is shown in [Figure 32](#) and described in [Table 13](#).

Return to [Summary Table](#).

**Figure 32. CFR Register**

| 15                  | 14      | 13      | 12             | 11          | 10            | 9           | 8        |
|---------------------|---------|---------|----------------|-------------|---------------|-------------|----------|
| WRITE_READ_CFR[3:0] |         |         |                | RD_CLK_MODE | RD_DATA_LINES | INPUT_RANGE | RESERVED |
| R/W-0000b           |         |         |                | R/W-0b      | R/W-0b        | R/W-0b      | R/W-0b   |
| 7                   | 6       | 5       | 4              | 3           | 2             | 1           | 0        |
| INM_SEL             | REF_SEL | STANDBY | RD_DATA_FORMAT | 0[3:0]      |               |             |          |
| R/W-0b              | R/W-0b  | W-0b    | R/W-0b         | R/W-0000b   |               |             |          |

**Table 13. CFR Register Field Descriptions**

| Bit   | Field               | Type | Reset | Description                                                                                                                                                                                                                                         |
|-------|---------------------|------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 15-12 | WRITE_READ_CFR[3:0] | R/W  | 0000b | These bits select the user-programmable register.<br>0011b = Select this combination to read the CFR register<br>1000b = Select this combination to write to CFR register and enable bits 11:0                                                      |
| 11    | RD_CLK_MODE         | R/W  | 0b    | This bit must be set to 0 (default).                                                                                                                                                                                                                |
| 10    | RD_DATA_LINES       | R/W  | 0b    | This bit provides data line selection for the serial interface.<br>0b = Use SDO_A to output ADC_A data and SDO_B to output of ADC_B data (default)<br>1b = Use only SDO_A to output of ADC_A data followed by ADC_B data                            |
| 9     | INPUT_RANGE         | R/W  | 0b    | This bit selects the maximum input range for the ADC as a function of the reference voltage provided to the ADC. See the <a href="#">Analog Inputs</a> section for more details.<br>0b = FSR equals $V_{REF}$<br>1b = FSR equals $2 \times V_{REF}$ |
| 8     | RESERVED            | R/W  | 0b    | This bit must be set to 0 (default).                                                                                                                                                                                                                |
| 7     | INM_SEL             | R/W  | 0b    | This bit selects the voltage to be externally connected to the INM pin.<br>0b = INM must be externally connected to the GND potential (default)<br>1b = INM must be externally connected to the FSR_ADC_x / 2                                       |
| 6     | REF_SEL             | R/W  | 0b    | This bit selects the ADC reference voltage source. See the <a href="#">Reference</a> section for more details.<br>0b = Use external reference (default)<br>1b = Use internal reference                                                              |
| 5     | STANDBY             | W    | 0b    | This bit is used by the device to enter or exit STANDBY mode. See the <a href="#">STANDBY Mode</a> section for more details.                                                                                                                        |
| 4     | RD_DATA_FORMAT      | R/W  | 0b    | This bit selects the output data format.<br>0b = Output is in straight binary format (default)<br>1b = Output is in two's complement format                                                                                                         |
| 3-0   | 0[3:0]              | R/W  | 0000b | These bits must be set to 0 (default).                                                                                                                                                                                                              |

### 7.6.1.2 REFDAC Register (Offset = 2h) [reset = 0h]

REFDAC is shown in [Figure 33](#) and described in [Table 14](#).

Return to [Summary Table](#).

**Figure 33. REFDAC Register**

|                        |    |    |    |                |    |   |   |
|------------------------|----|----|----|----------------|----|---|---|
| 15                     | 14 | 13 | 12 | 11             | 10 | 9 | 8 |
| WRITE_READ_REFDAC[3:0] |    |    |    | D[8:0]         |    |   |   |
| R/W-0000b              |    |    |    | R/W-000000000b |    |   |   |
| 7                      | 6  | 5  | 4  | 3              | 2  | 1 | 0 |
| D[8:0]                 |    |    |    | RESERVED       |    |   |   |
| R/W-000000000b         |    |    |    | R/W-000b       |    |   |   |

**Table 14. REFDAC Register Field Descriptions**

| Bit   | Field                  | Type | Reset      | Description                                                                                                                                                                                                                                  |
|-------|------------------------|------|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 15-12 | WRITE_READ_REFDAC[3:0] | R/W  | 0000b      | These bits select the configurable register address. 1001 = Select this combination to write to the REFDAC_A register. 1010 = Select this combination to write to the REFDAC_B register.                                                     |
| 11-3  | D[8:0]                 | R/W  | 000000000b | Data to program the individual DAC output voltage. These bits are valid only for bits 15:12 = 1001 or bits 15:12 = 1010. <a href="#">Table 15</a> shows the relationship between the REFDAC_x programmed value and the DAC_x output voltage. |
| 2-0   | RESERVED               | R/W  | 000b       | This bit must be set to 0 (default).                                                                                                                                                                                                         |

**Table 15. REFDAC Settings**

| REFDAC_x VALUE (Bits 11:3 in Hex) | B[2:0] | Typical DAC_x OUTPUT VOLTAGE (V) <sup>(1)</sup> |
|-----------------------------------|--------|-------------------------------------------------|
| 1FF (default)                     | 000    | 2.5000                                          |
| 1FE                               | 000    | 2.4989                                          |
| 1FD                               | 000    | 2.4978                                          |
| —                                 | —      | —                                               |
| 1D7                               | 000    | 2.45                                            |
| —                                 | —      | —                                               |
| 1AE                               | 000    | 2.40                                            |
| —                                 | —      | —                                               |
| 186                               | 000    | 2.35                                            |
| —                                 | —      | —                                               |
| 15D                               | 000    | 2.30                                            |
| —                                 | —      | —                                               |
| 134                               | 000    | 2.25                                            |
| —                                 | —      | —                                               |
| 10C                               | 000    | 2.20                                            |
| —                                 | —      | —                                               |
| 0E3                               | 000    | 2.15                                            |
| —                                 | —      | —                                               |
| 0BA                               | 000    | 2.10                                            |
| —                                 | —      | —                                               |
| 091                               | 000    | 2.05                                            |
| —                                 | —      | —                                               |
| 069                               | 000    | 2.00                                            |
| —                                 | —      | —                                               |
| 064 to 000                        | 000    | Do not use                                      |

(1) Actual output voltage may vary by a few millivolts from the specified value. To obtain the desired output voltage, TI recommends starting with the specified register setting and then experimenting with five codes on either side of the specified register setting.

## 8 Application and Implementation

### NOTE

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

### 8.1 Application Information

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

The device supports operation either with an internal or external reference source. See the [Reference](#) section for details about the decoupling requirements.

The reference source to the ADC must provide low-drift and very accurate dc voltage and support the dynamic charge requirements without affecting the noise and linearity performance of the device. The output broadband noise (typically in the order of a few 100  $\mu\text{V}_{\text{RMS}}$ ) of the reference source must be appropriately filtered by using a low-pass filter with a cutoff frequency of a few hundred hertz. After band-limiting the noise from the reference source, the next important step is to design a reference buffer that can drive the dynamic load posed by the reference input of the ADC. At the start of each conversion, the reference buffer must regulate the voltage of the reference pin within 1 LSB of the intended value. This condition necessitates the use of a large filter capacitor at the reference pin of the ADC. The amplifier selected to drive the reference input pin must be stable while driving this large capacitor and must have low output impedance, low offset, and temperature drift specifications. To reduce the dynamic current requirements and crosstalk between the channels, a separate reference buffer is recommended for driving the reference input of each ADC channel.

The input driver circuit for a high-precision ADC mainly consists of two parts: a driving amplifier and a fly-wheel RC filter. The amplifier is used for signal conditioning of the input voltage and its low output impedance provides a buffer between the signal source and the switched capacitor inputs of the ADC. The RC filter helps attenuate the sampling charge injection from the switched-capacitor input stage of the ADC and functions as a charge kickback filter to band-limit 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 a high-precision ADC.

#### 8.1.1 Input Amplifier Selection

Selection criteria for the input amplifiers is highly dependent on the input signal type and the performance goals of the data acquisition system. Some key amplifier specifications to consider while 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 low cutoff frequency RC filter at the ADC inputs. Higher bandwidth also minimizes the harmonic distortion at higher input frequencies. Select the amplifier bandwidth as described in [Equation 6](#) to maintain the overall stability of the input driver circuit:

$$\text{Unity – Gain Bandwidth} \geq 4 \times \left( \frac{1}{2\pi \times (R_{FLT} + R_{FLT}) \times C_{FLT}} \right) \quad (6)$$

## Application Information (continued)

- **Noise.** Noise contribution of the front-end amplifiers must be as low as possible to prevent any degradation in SNR performance of the system. As a rule of thumb, to ensure that the noise performance of the data acquisition system is not limited by the front-end circuit, keep the total noise contribution from the front-end circuit below 20% of the input-referred noise of the ADC. Equation 7 calculates noise from the input driver circuit. This noise is band-limited by designing a low cutoff frequency RC 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:

- $V_{1/f\_AMP\_PP}$  = the peak-to-peak flicker noise in  $\mu V$
- $e_{n\_RMS}$  = the amplifier broadband noise density in  $nV/\sqrt{Hz}$
- $f_{-3dB}$  = the 3-dB bandwidth of the RC filter
- $N_G$  = the noise gain of the front-end circuit, which is equal to 1 in a buffer configuration (7)
- **Distortion.** Both the ADC and the input driver introduce nonlinearity in a data acquisition block. As a rule of thumb, the distortion of the input driver must be at least 10 dB lower than the distortion of the ADC, as shown in Equation 8, to ensure that the distortion performance of the data acquisition system is not limited by the front-end circuit.

$$THD_{AMP} \leq THD_{ADC} - 10 \text{ (dB)} \quad (8)$$

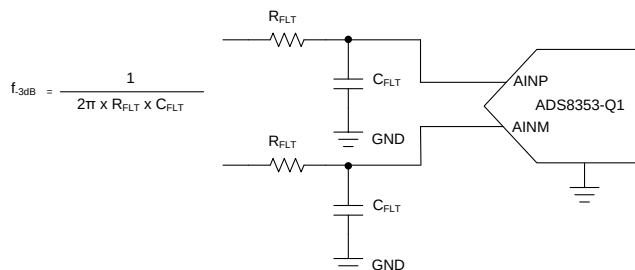
- **Settling Time.** For dc signals with fast transients that are common in a multiplexed application, the input signal must settle to the desired accuracy at the inputs of the ADC during the acquisition time window. This condition is critical to maintain the overall linearity performance of the ADC. Typically, the amplifier data sheets specify the output settling performance only up to 0.1% to 0.001%, which may not be sufficient for the desired accuracy. Therefore, always verify the settling behavior of the input driver with TINA™-SPICE simulations before selecting the amplifier.

### 8.1.2 Charge Kickback Filter

Converting analog-to-digital signals requires sampling an input signal at a constant rate. Any higher frequency content in the input signal beyond half the sampling frequency is digitized and folded back into the low-frequency spectrum. This process is called *aliasing*. Therefore, an analog, charge kickback filter must be used to remove the harmonic content from the input signal before being sampled by the ADC. A charge kickback filter is designed as a low-pass, RC filter, for which the 3-dB bandwidth is optimized based on specific application requirements. For dc signals with fast transients (including multiplexed input signals), a high-bandwidth filter is designed to allow accurately settling the signal at the ADC inputs during the small acquisition time window. For ac signals, keep the filter bandwidth low to band-limit the noise fed into the ADC input, thereby increasing the signal-to-noise ratio (SNR) of the system.

A filter capacitor,  $C_{FLT}$ , connected across the ADC inputs (see Figure 34), filters the noise from the front-end drive circuitry, reduces the sampling charge injection, and provides a charge bucket to quickly charge the internal sample-and-hold capacitors during the acquisition process. As a rule of thumb, the value of this capacitor must be at least 10 times the specified value of the ADC sampling capacitance. For these devices, the input sampling capacitance is equal to 40 pF. Thus, the value of  $C_{FLT}$  must be greater than 400 pF. The capacitor must be a COG- or NPO-type because these capacitor types have a high-Q, low-temperature coefficient, and stable electrical characteristics under varying voltages, frequency, and time.

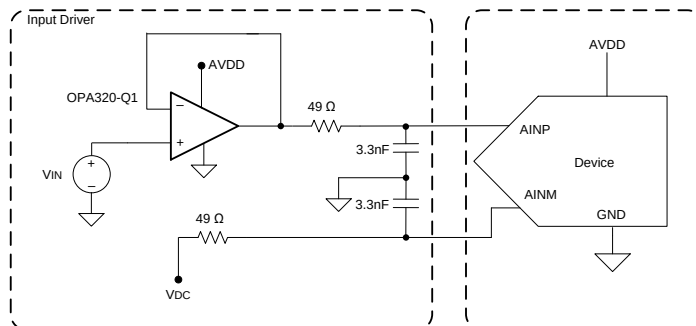
### Application Information (continued)



### Figure 34. Charge Kickback Filter

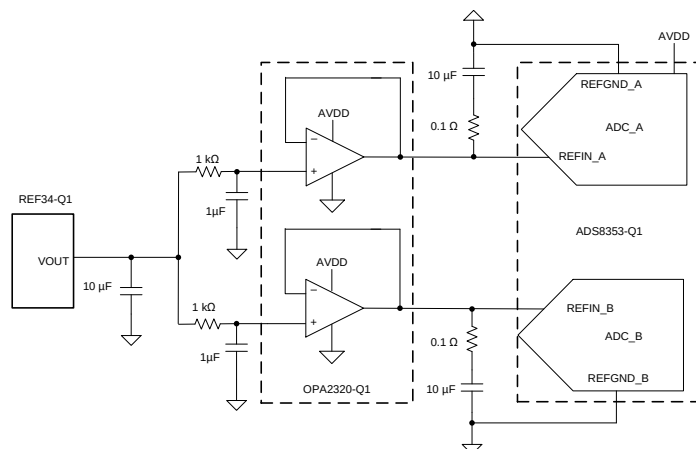
Driving capacitive loads can degrade the phase margin of the input amplifiers, thus making the amplifier marginally unstable. To avoid amplifier stability issues, series isolation resistors ( $R_{FLT}$ ) are used at the output of the amplifiers. A higher value of  $R_{FLT}$  is helpful from the amplifier stability perspective, 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 and distortion of the design. For more information on ADC input R-C filter component selection, see the [TI Precision Labs](#) on ti.com.

## 8.2 Typical Application



NOTE: Only one ADC channel is shown in this diagram. Replicate the same circuit for other ADC channels.

**Figure 35. DAQ Circuit: Maximum SINAD for a 10-kHz Input Signal at Full Throughput, 32-CLK Interface**



### Figure 36. Reference Drive Circuit

## Typical Application (continued)

### 8.2.1 Design Requirements

Table 16 lists the target specifications for this application.

**Table 16. Target Specifications**

| TARGET SPECIFICATIONS |           | TEST CONDITIONS |                        |                   |                  |
|-----------------------|-----------|-----------------|------------------------|-------------------|------------------|
| SNR                   | THD       | DEVICE          | INPUT SIGNAL FREQUENCY | THROUGHPUT        | INTERFACE MODE   |
| > 83 dB               | < –100 dB | ADS8353-Q1      | 10 kHz                 | Maximum supported | 32-CLK, dual-SDO |

### 8.2.2 Detailed Design Procedure

Best practice is for the distortion from the input driver to be at least 10 dB less than the ADC distortion. The distortion resulting from variation in the common-mode signal is eliminated by using the amplifier in an inverting gain configuration that establishes a fixed common-mode level for the circuit. This configuration also eliminates the requirement of rail-to-rail swing at the amplifier input. The low-power [OPA320-Q1](#), used as an input driver, provides exceptional ac performance because of its extremely low-distortion and high-bandwidth specifications. In addition, the components of the antialiasing filter are such that the noise from the front-end circuit is kept low without adding distortion to the input signal.

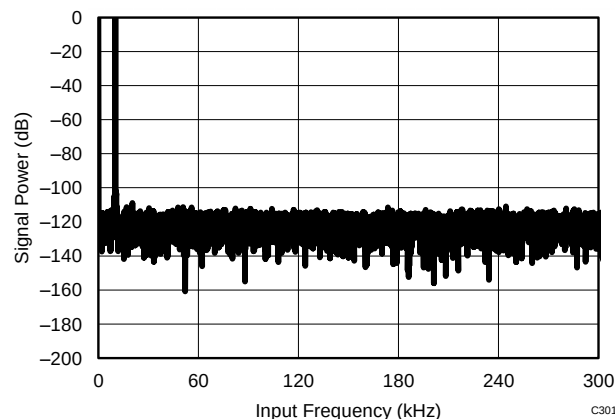
The application circuit illustrated in [Figure 35](#) is optimized to achieve the lowest distortion and lowest noise for a 10-kHz input signal fed to the ADS8353-Q1 operating at full throughput with the default 32-CLK, dual-SDO interface mode. The input signal is processed through a high-bandwidth, low-distortion amplifier in an inverting gain configuration and a low-pass RC filter before being fed into the device.

[Figure 36](#) illustrates the reference driver circuit when operation with an external reference is desired. The reference voltage is generated by the high-precision, low-noise [REF34-Q1](#) circuit. The output broadband noise of the reference is heavily filtered by a low-pass filter with a 3-dB cutoff frequency of 160 Hz. The decoupling capacitor on each reference pin is selected to be 10 µF. The low output impedance, low noise, and fast settling time make the [OPA2320-Q1](#) a good choice for driving this high capacitive load.

### 8.2.3 Application Curve

To minimize external components and to maximize the dynamic range of the ADC, the device is configured to operate with internal reference (CFR.B6 = 1) and 2x  $V_{REF\_X}$  input full-scale range (CFR.B9 = 1).

[Figure 37](#) shows the FFT plot and test result obtained with the ADS8353-Q1 operating at full throughput with a 32-CLK interface and the circuit configuration of [Figure 35](#).



SNR = 83.5 dB, THD = –101.2 dB,  $f_{IN}$  = 10.1 kHz

**Figure 37. ADS8353-Q1 in 32-CLK Interface Mode**

## 9 Power Supply Recommendations

The device has two separate power supplies: AVDD and DVDD. The device operates on AVDD; DVDD is used for the interface circuits. AVDD and DVDD can be independently set to any value within the permissible ranges.

When using the device with the  $2 \times V_{REF}$  input range ( $CFR.B9 = 1$ ), the AVDD supply voltage value defines the permissible voltage swing on the analog input pins. AVDD must be set as shown in [Equation 9](#), [Equation 10](#), and [Equation 11](#) to avoid saturation of output codes and to use the full dynamic range on the analog input pins:

$$AVDD \geq 2 \times V_{REF\_A} \quad (9)$$

$$AVDD \geq 2 \times V_{REF\_B} \quad (10)$$

$$4.75 \text{ V} \leq AVDD \leq 5.25 \text{ V} \quad (11)$$

Decouple the AVDD and DVDD pins, as shown in [Figure 38](#), with the GND pin using individual 10-μF decoupling capacitors.

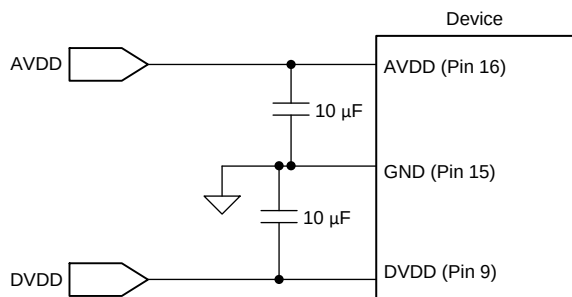


**Figure 38. Power-Supply Decoupling**

## 10 Layout

### 10.1 Layout Guidelines

Figure 39 shows a board layout example for the ADS8353-Q1 TSSOP package. Partition the printed circuit board (PCB) into analog and digital sections. Avoid crossing digital lines with the analog signal path and keep the analog input signals and the reference input signals away from noise sources. As shown in Figure 39, the analog input and reference signals are routed on the left side of the board and the digital connections are routed on the right side of the device.

The power sources to the device must be clean and well-bypassed. Use 10- $\mu$ F, ceramic bypass capacitors in close proximity to the analog (AVDD) and digital (DVDD) power-supply pins. Avoid placing vias between the AVDD and DVDD pins and the bypass capacitors. Connect all ground pins to the ground plane using short, low impedance paths.

The REFIO-A and REFIO-B reference inputs and outputs are bypassed with 10- $\mu$ F, X7R-grade, 0805-size, 16-V rated ceramic capacitors ( $C_{REF-x}$ ). Place the reference bypass capacitors as close as possible to the reference REFIO-x pins and connect the bypass capacitors using short, low-inductance connections. Avoid placing vias between the REFIO-x pins and the bypass capacitors. Small 0.1- $\Omega$  to 0.2- $\Omega$  resistors ( $R_{REF-x}$ ) are used in series with the reference bypass capacitors to improve stability.

The fly-wheel RC filters are placed immediately next to the input pins. Among ceramic surface-mount capacitors, COG (NPO) ceramic capacitors provide the best capacitance precision. The type of dielectric used in COG (NPO) ceramic capacitors provides the most stable electrical properties over voltage, frequency, and temperature changes. Figure 39 shows  $C_{IN-A}$  and  $C_{IN-B}$  filter capacitors placed across the analog input pins of the device.

### 10.2 Layout Example

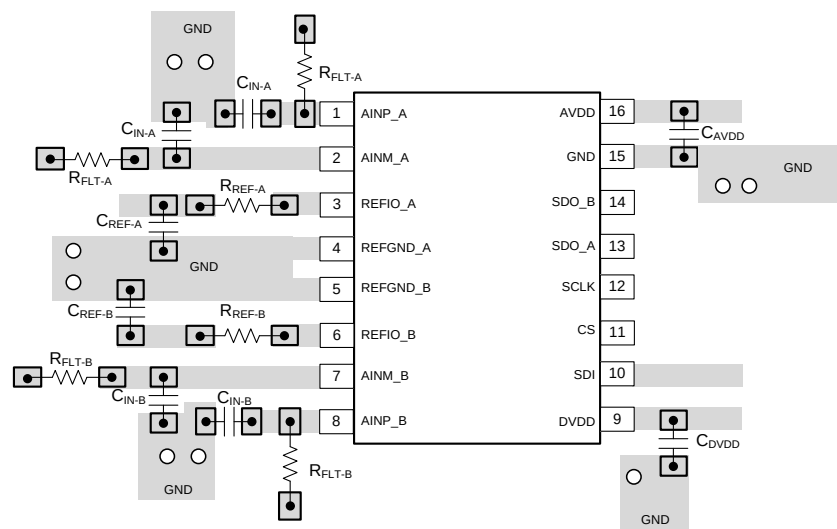


Figure 39. Recommended Layout

## 11 Device and Documentation Support

### 11.1 Device Support

#### 11.1.1 Development Support

Texas Instruments, [TI Precision Labs TI training and videos site](#)

### 11.2 Documentation Support

#### 11.2.1 Related Documentation

For related documentation see the following:

- Texas Instruments, [OPAx320-Q1 Precision, 20-MHz, 0.9-pA, low-noise, RRIO, CMOS operational amplifier data sheet](#)
- Texas Instruments, [REF34-Q1 Low-drift, low-power, small-footprint series voltage references data sheet](#)

### 11.3 Receiving Notification of Documentation Updates

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

### 11.4 Community Resources

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

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

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

### 11.5 Trademarks

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### 11.6 Electrostatic Discharge Caution



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

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

### 11.7 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 12 Mechanical, Packaging, and Orderable Information

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

## PACKAGING INFORMATION

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| ADS8353QPWQ1     | ACTIVE        | TSSOP        | PW                 | 16   | 90             | Green (RoHS<br>& no Sb/Br) | NIPDAU                  | Level-2-260C-1 YEAR  | -40 to 125   | A8353Q                  | <a href="#">Samples</a> |
| ADS8353QPWRQ1    | ACTIVE        | TSSOP        | PW                 | 16   | 2000           | Green (RoHS<br>& no Sb/Br) | NIPDAU                  | Level-2-260C-1 YEAR  | -40 to 125   | A8353Q                  | <a href="#">Samples</a> |

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

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

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

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

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

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

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

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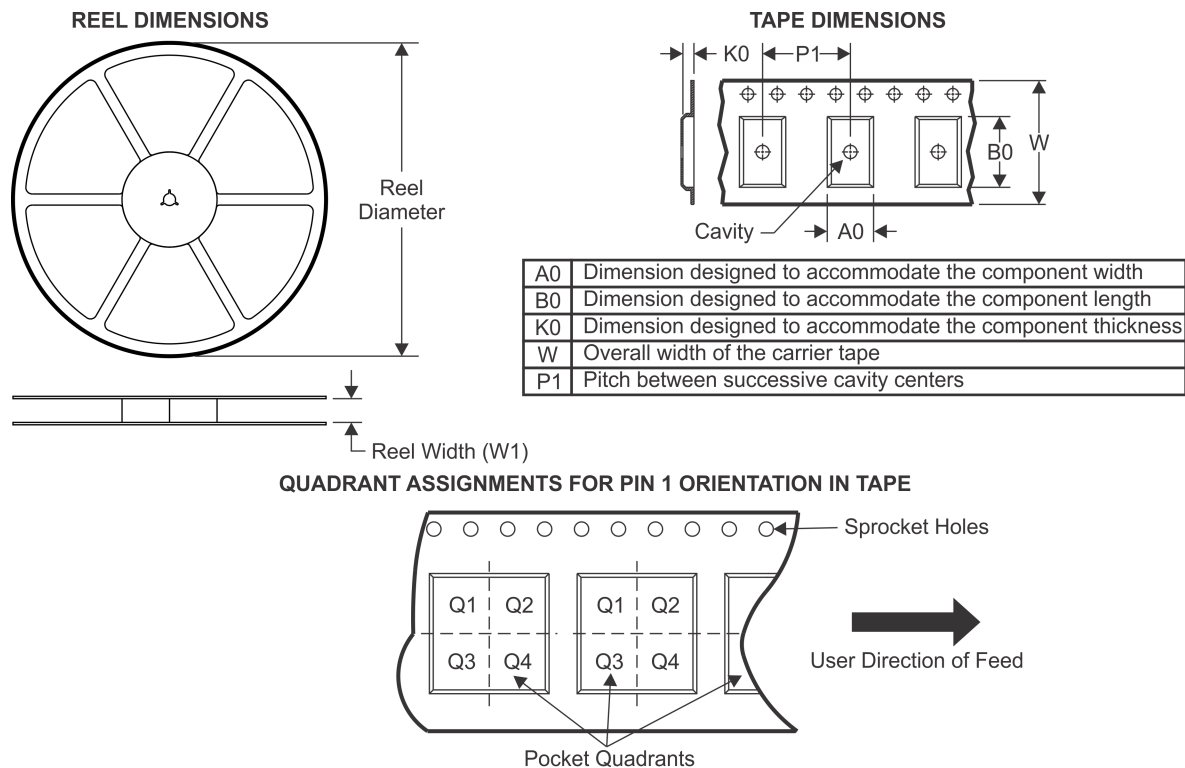
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**OTHER QUALIFIED VERSIONS OF ADS8353-Q1 :**

- Catalog: [ADS8353](#)

**NOTE:** Qualified Version Definitions:

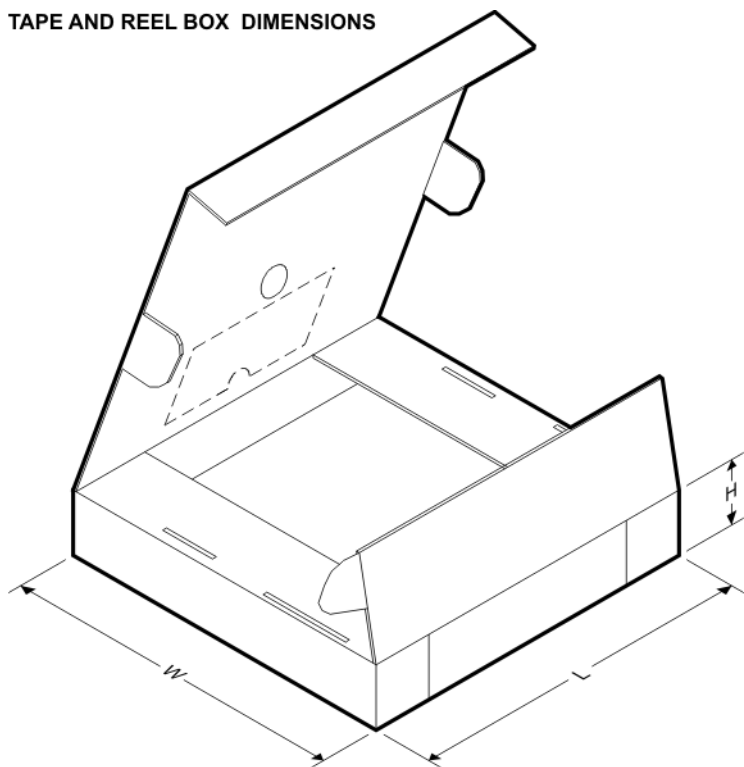
- Catalog - TI's standard catalog product

**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 |
|---------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| ADS8353QPWRQ1 | TSSOP        | PW              | 16   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device        | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|---------------|--------------|-----------------|------|------|-------------|------------|-------------|
| ADS8353QPWRQ1 | TSSOP        | PW              | 16   | 2000 | 350.0       | 350.0      | 43.0        |

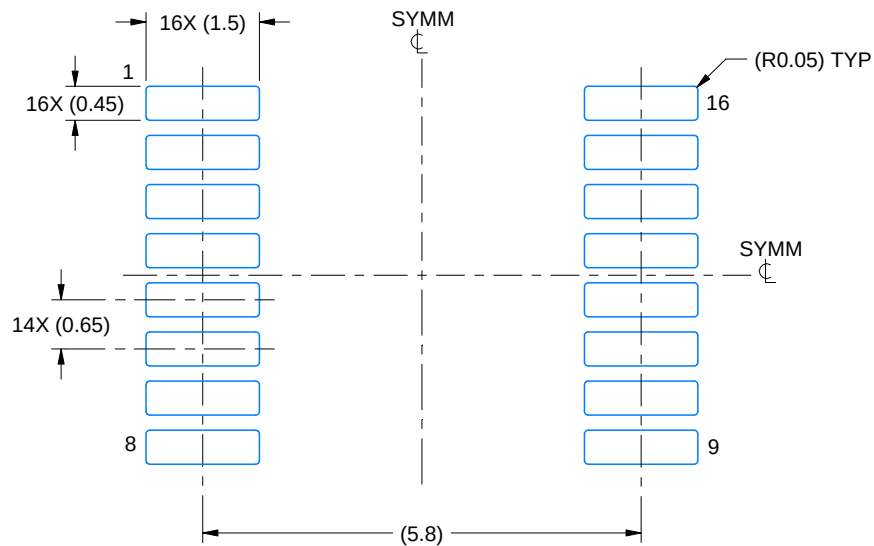


# EXAMPLE BOARD LAYOUT

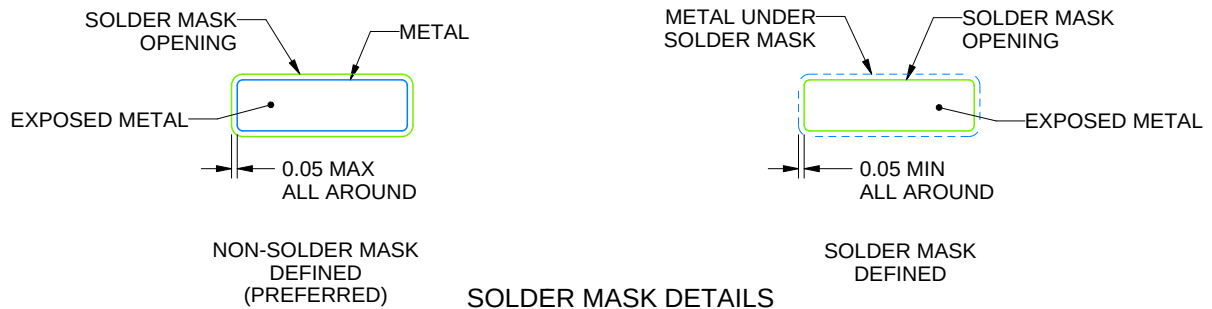
PW0016A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 10X



4220204/A 02/2017

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

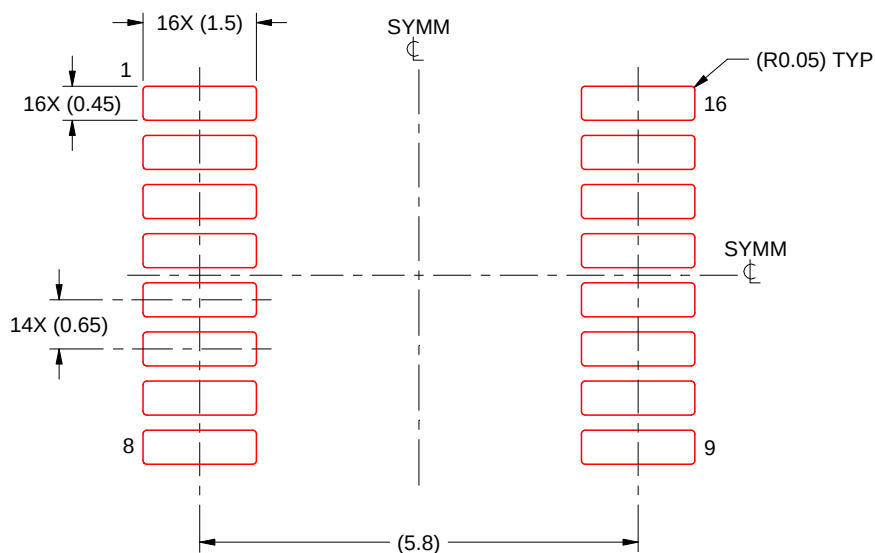
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

PW0016A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE: 10X

4220204/A 02/2017

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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