



# 16-Bit, 100 kSPS PuLSAR® Unipolar CMOS ADC

## AD7660\*

### FEATURES

Throughput: 100 kSPS

INL:  $\pm 3$  LSB Max ( $\pm 0.0046\%$  of Full-Scale)

16-Bit Resolution with No Missing Codes

S/(N+D): 87 dB Min @ 10 kHz, 90 dB Typ @ 45 kHz

THD:  $-96$  dB Max @ 10 kHz

Analog Input Voltage Range: 0 V to 2.5 V

Both AC and DC Specifications

No Pipeline Delay

Parallel and Serial 5 V/3 V Interface

SPI®/QSPI™/MICROWIRE™/DSP Compatible

Single 5 V Supply Operation

21 mW Typical Power Dissipation, 21  $\mu$ W @ 100 SPS

Power-Down Mode: 7  $\mu$ W Max

Package: 48-Lead Quad Flatpack (LQFP)

48-Lead Chip Scale Package (LFCSP)

Pin-to-Pin Compatible with the AD7664

### APPLICATIONS

Data Acquisition

Battery-Powered Systems

PCMCIA

Instrumentation

Automatic Test Equipment

Scanners

Medical Instruments

Process Control

### GENERAL DESCRIPTION

The AD7660 is a 16-bit, 100 kSPS, charge redistribution SAR, analog-to-digital converter that operates from a single 5 V power supply. The part contains an internal conversion clock, error correction circuits, and both serial and parallel system interface ports.

The AD7660 is hardware factory-calibrated and is comprehensively tested to ensure ac parameters such as signal-to-noise ratio (SNR) and total harmonic distortion (THD), in addition to the more traditional dc parameters of gain, offset, and linearity.

It is fabricated using Analog Devices' high performance, 0.6 micron CMOS process with correspondingly low cost and is available in a 48-lead LQFP and a tiny 48-lead LFCSP with operation specified from  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ .

### FUNCTIONAL BLOCK DIAGRAM

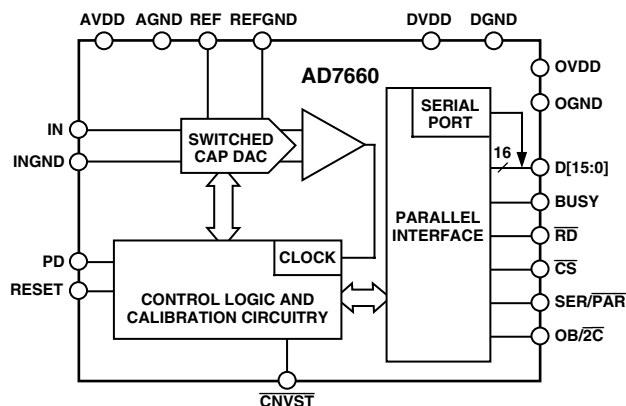


Table I. PuLSAR Selection

| Type/kSPS                     | 100–250                 | 500–570                        | 800–1000         |
|-------------------------------|-------------------------|--------------------------------|------------------|
| Pseudo Differential           | AD7651<br>AD7660/AD7661 | AD7650/AD7652<br>AD7664/AD7666 | AD7653<br>AD7667 |
| True Bipolar                  | AD7663                  | AD7665                         | AD7671           |
| True Differential             | AD7675                  | AD7676                         | AD7677           |
| 18-Bit                        | AD7678                  | AD7679                         | AD7674           |
| Simultaneous/<br>Multichannel |                         | AD7654<br>AD7655               |                  |

### PRODUCT HIGHLIGHTS

- Fast Throughput**  
The AD7660 is a 100 kSPS, charge redistribution, 16-bit SAR ADC with internal error correction circuitry.
- Superior INL**  
The AD7660 has a maximum integral nonlinearity of 3 LSBs with no missing 16-bit code.
- Single-Supply Operation**  
The AD7660 operates from a single 5 V supply and only dissipates 21 mW typical. Its power dissipation decreases with the throughput to, for instance, only 21  $\mu$ W at a 100 SPS throughput. It consumes 7  $\mu$ W maximum when in power-down.
- Serial or Parallel Interface**  
Versatile parallel or 2-wire serial interface arrangement compatible with both 3 V or 5 V logic.

\*Patent pending

REV. D

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# AD7660—SPECIFICATIONS (–40°C to +85°C, AVDD = DVDD = 5 V, OVDD = 2.7 V to 5.25 V, unless otherwise noted.)

| Parameter                        | Conditions                         | Min  | Typ                                                                 | Max         | Unit             |
|----------------------------------|------------------------------------|------|---------------------------------------------------------------------|-------------|------------------|
| RESOLUTION                       |                                    | 16   |                                                                     |             | Bits             |
| ANALOG INPUT                     |                                    |      |                                                                     |             |                  |
| Voltage Range                    | $V_{IN} - V_{INGND}$               | 0    |                                                                     | $V_{REF}$   | V                |
| Operating Input Voltage          | $V_{IN}$                           | –0.1 |                                                                     | +3          | V                |
|                                  | $V_{INGND}$                        | –0.1 |                                                                     | +0.5        | V                |
| Analog Input CMRR                | $f_{IN} = 25$ kHz                  |      | 70                                                                  |             | dB               |
| Input Current                    | 100 kSPS Throughput                |      | 325                                                                 |             | nA               |
| Input Impedance                  |                                    |      | See Analog Input Section                                            |             |                  |
| THROUGHPUT SPEED                 |                                    |      |                                                                     |             |                  |
| Complete Cycle                   |                                    |      |                                                                     | 10          | μs               |
| Throughput Rate                  |                                    | 0    |                                                                     | 100         | kSPS             |
| DC ACCURACY                      |                                    |      |                                                                     |             |                  |
| Integral Linearity Error         |                                    | –3   |                                                                     | +3          | LSB <sup>1</sup> |
| Differential Linearity Error     |                                    | –1   |                                                                     | +1.75       | LSB              |
| No Missing Codes                 |                                    | 16   |                                                                     |             | Bits             |
| Transition Noise <sup>2</sup>    |                                    |      | 0.75                                                                |             | LSB              |
| Full-Scale Error <sup>3</sup>    | REF = 2.5 V                        |      | ±0.045                                                              | ±0.08       | % of FSR         |
| Unipolar Zero Error <sup>3</sup> |                                    |      | ±1                                                                  | ±5          | LSB              |
| Power Supply Sensitivity         | AVDD = 5 V ±5%                     |      | ±3                                                                  |             | LSB              |
| AC ACCURACY                      |                                    |      |                                                                     |             |                  |
| Signal-to-Noise                  | $f_{IN} = 10$ kHz                  | 87   | 90                                                                  |             | dB <sup>4</sup>  |
|                                  | $f_{IN} = 45$ kHz                  |      | 90                                                                  |             | dB               |
| Spurious-Free Dynamic Range      | $f_{IN} = 10$ kHz                  | 96   |                                                                     |             | dB               |
|                                  | $f_{IN} = 45$ kHz                  |      | 100                                                                 |             | dB               |
| Total Harmonic Distortion        | $f_{IN} = 10$ kHz                  |      |                                                                     | –96         | dB               |
|                                  | $f_{IN} = 45$ kHz                  |      | –100                                                                |             | dB               |
| Signal-to-(Noise+Distortion)     | $f_{IN} = 10$ kHz                  | 87   |                                                                     |             | dB               |
|                                  | $f_{IN} = 45$ kHz                  |      | 90                                                                  |             | dB               |
| –3 dB Input Bandwidth            | –60 dB Input                       |      | 30                                                                  |             | dB               |
|                                  |                                    |      | 820                                                                 |             | kHz              |
| SAMPLING DYNAMICS                |                                    |      |                                                                     |             |                  |
| Aperture Delay                   |                                    |      | 2                                                                   |             | ns               |
| Aperture Jitter                  |                                    |      | 5                                                                   |             | ps rms           |
| Transient Response               | Full-Scale Step                    |      |                                                                     | 8           | μs               |
| REFERENCE                        |                                    |      |                                                                     |             |                  |
| External Reference Voltage Range |                                    | 2.3  | 2.5                                                                 | AVDD – 1.85 | V                |
| External Reference Current Drain | 100 kSPS Throughput                |      | 22                                                                  |             | μA               |
| POWER SUPPLIES                   |                                    |      |                                                                     |             |                  |
| Specified Performance            |                                    |      |                                                                     |             |                  |
| AVDD                             |                                    | 4.75 | 5                                                                   | 5.25        | V                |
| DVDD                             |                                    | 4.75 | 5                                                                   | 5.25        | V                |
| OVDD                             |                                    | 2.7  |                                                                     | 5.25        | V                |
| Operating Current                | 100 kSPS Throughput                |      |                                                                     |             |                  |
| AVDD                             |                                    |      | 3.2                                                                 |             | mA               |
| DVDD <sup>5</sup>                |                                    |      | 1                                                                   |             | mA               |
| OVDD <sup>5</sup>                |                                    |      | 10                                                                  |             | μA               |
| Power Dissipation <sup>5</sup>   | 100 kSPS Throughput                |      | 21                                                                  | 25          | mW               |
|                                  | 100 SPS Throughput                 |      | 21                                                                  |             | μW               |
|                                  | in Power-Down Mode <sup>5, 6</sup> |      |                                                                     | 7           | μW               |
| DIGITAL INPUTS                   |                                    |      |                                                                     |             |                  |
| Logic Levels                     |                                    |      |                                                                     |             |                  |
| $V_{IL}$                         |                                    | –0.3 |                                                                     | +0.8        | V                |
| $V_{IH}$                         |                                    | +2.0 |                                                                     | OVDD + 0.3  | V                |
| $I_{IL}$                         |                                    | –1   |                                                                     | +1          | μA               |
| $I_{IH}$                         |                                    | –1   |                                                                     | +1          | μA               |
| DIGITAL OUTPUTS                  |                                    |      |                                                                     |             |                  |
| Data Format                      |                                    |      | Parallel or Serial 16-Bit                                           |             |                  |
| Pipeline Delay                   |                                    |      | Conversion Results Available Immediately after Completed Conversion |             |                  |
| $V_{OL}$                         | $I_{SINK} = 1.6$ mA                |      |                                                                     | 0.4         | V                |
| $V_{OH}$                         | $I_{SOURCE} = -500$ μA             |      | OVDD – 0.6                                                          |             | V                |

| Parameter                                  | Conditions                           | Min | Typ | Max | Unit |
|--------------------------------------------|--------------------------------------|-----|-----|-----|------|
| TEMPERATURE RANGE<br>Specified Performance | T <sub>MIN</sub> to T <sub>MAX</sub> | −40 |     | +85 | °C   |

## NOTES

<sup>1</sup>LSB means least significant bit. With the 0 V to 2.5 V input range, one LSB is 38.15  $\mu$ V.

<sup>2</sup>Typical rms noise at worst-case transitions and temperatures.

<sup>3</sup>See Definition of Specifications section. These specifications do not include the error contribution from the external reference.

<sup>4</sup>All specifications in dB are referred to a full-scale input FS. Tested with an input signal at 0.5 dB below full-scale unless otherwise specified.

<sup>5</sup>Tested in Parallel Reading Mode.

<sup>6</sup>With all digital inputs forced to DVDD or DGND respectively.

Specifications subject to change without notice.

## TIMING SPECIFICATIONS (−40°C to +85°C, AVDD = DVDD = 5 V, OVDD = 2.7 V to 5.25 V, unless otherwise noted.)

| Parameter                                                              | Symbol          | Min | Typ | Max | Unit    |
|------------------------------------------------------------------------|-----------------|-----|-----|-----|---------|
| REFER TO FIGURES 11 AND 12                                             |                 |     |     |     |         |
| Convert Pulsewidth                                                     | t <sub>1</sub>  | 5   |     |     | ns      |
| Time between Conversions                                               | t <sub>2</sub>  | 10  |     |     | $\mu$ s |
| CNVST LOW to BUSY HIGH Delay                                           | t <sub>3</sub>  |     |     | 15  | ns      |
| BUSY HIGH All Modes Except in<br>Master Serial Read after Convert Mode | t <sub>4</sub>  |     |     | 2   | $\mu$ s |
| Aperture Delay                                                         | t <sub>5</sub>  |     | 2   |     | ns      |
| End of Conversion to BUSY LOW Delay                                    | t <sub>6</sub>  | 10  |     |     | ns      |
| Conversion Time                                                        | t <sub>7</sub>  |     |     | 2   | $\mu$ s |
| Acquisition Time                                                       | t <sub>8</sub>  | 8   |     |     | $\mu$ s |
| RESET Pulsewidth                                                       | t <sub>9</sub>  | 10  |     |     | ns      |
| REFER TO FIGURES 13, 14, AND 15 (Parallel Interface Modes)             |                 |     |     |     |         |
| CNVST LOW to DATA Valid Delay                                          | t <sub>10</sub> |     |     | 2   | $\mu$ s |
| DATA Valid to BUSY LOW Delay                                           | t <sub>11</sub> | 45  |     |     | ns      |
| Bus Access Request to DATA Valid                                       | t <sub>12</sub> |     |     | 40  | ns      |
| Bus Relinquish Time                                                    | t <sub>13</sub> | 5   |     | 15  | ns      |
| REFER TO FIGURE 16 AND 17 (Master Serial Interface Modes) <sup>1</sup> |                 |     |     |     |         |
| $\overline{\text{CS}}$ LOW to SYNC Valid Delay                         | t <sub>14</sub> |     |     | 10  | ns      |
| $\overline{\text{CS}}$ LOW to Internal SCLK Valid Delay                | t <sub>15</sub> |     |     | 10  | ns      |
| $\overline{\text{CS}}$ LOW to SDOUT Delay                              | t <sub>16</sub> |     |     | 10  | ns      |
| CNVST LOW to SYNC Delay                                                | t <sub>17</sub> |     | 500 |     | ns      |
| SYNC Asserted to SCLK First Edge Delay                                 | t <sub>18</sub> | 4   |     |     | ns      |
| Internal SCLK Period                                                   | t <sub>19</sub> | 40  |     | 75  | ns      |
| Internal SCLK HIGH (INVCLK Low) <sup>2</sup>                           | t <sub>20</sub> | 30  |     |     | ns      |
| Internal SCLK LOW (INVCLK Low) <sup>2</sup>                            | t <sub>21</sub> | 9.5 |     |     | ns      |
| SDOUT Valid Setup Time                                                 | t <sub>22</sub> | 4.5 |     |     | ns      |
| SDOUT Valid Hold Time                                                  | t <sub>23</sub> | 3   |     |     | ns      |
| SCLK Last Edge to SYNC Delay                                           | t <sub>24</sub> | 3   |     |     | ns      |
| $\overline{\text{CS}}$ HIGH to SYNC HI-Z                               | t <sub>25</sub> |     |     | 10  | ns      |
| $\overline{\text{CS}}$ HIGH to Internal SCLK HI-Z                      | t <sub>26</sub> |     |     | 10  | ns      |
| $\overline{\text{CS}}$ HIGH to SDOUT HI-Z                              | t <sub>27</sub> |     |     | 10  | ns      |
| BUSY HIGH in Master Serial Read after Convert                          | t <sub>28</sub> |     |     | 3.2 | $\mu$ s |
| CNVST LOW to SYNC Asserted Delay                                       | t <sub>29</sub> |     | 1.5 |     | $\mu$ s |
| SYNC Deasserted to BUSY LOW Delay                                      | t <sub>30</sub> |     | 50  |     | ns      |
| REFER TO FIGURES 18 AND 20 (Slave Serial Interface Modes) <sup>1</sup> |                 |     |     |     |         |
| External SCLK Setup Time                                               | t <sub>31</sub> | 5   |     |     | ns      |
| External SCLK Active Edge to SDOUT Delay                               | t <sub>32</sub> | 3   |     | 16  | ns      |
| SDIN Setup Time                                                        | t <sub>33</sub> | 5   |     |     | ns      |
| SDIN Hold Time                                                         | t <sub>34</sub> | 5   |     |     | ns      |
| External SCLK Period                                                   | t <sub>35</sub> | 25  |     |     | ns      |
| External SCLK HIGH                                                     | t <sub>36</sub> | 10  |     |     | ns      |
| External SCLK LOW                                                      | t <sub>37</sub> | 10  |     |     | ns      |

## NOTES

<sup>1</sup>In serial interface modes, the SYNC, SCLK, and SDOUT timings are defined with a maximum load C<sub>L</sub> of 10 pF; otherwise, the load is 60 pF maximum.

<sup>2</sup>If the polarity of SCLK is inverted, the timing references of SCLK are also inverted.

Specifications subject to change without notice.

# AD7660

## ABSOLUTE MAXIMUM RATINGS<sup>1</sup>

### Analog Inputs

IN<sup>2</sup>, REF, INGND, REFGND ..... AVDD + 0.3 V to AGND – 0.3 V

### Ground Voltage Differences

AGND, DGND, OGND ..... ±0.3 V

### Supply Voltages

AVDD, DVDD, OVDD ..... –0.3 V to +7 V

AVDD to DVDD, AVDD to OVDD ..... ±7 V

DVDD to OVDD ..... ±7 V

### Digital Inputs

Except the Databus D(7:4) ... –0.3 V to DVDD + 0.3 V

Databus Inputs D(7:4) ..... –0.3 V to OVDD + 0.3 V

Internal Power Dissipation<sup>3</sup> ..... 700 mW

Internal Power Dissipation<sup>4</sup> ..... 2.5 W

Junction Temperature ..... 150°C

Storage Temperature Range ..... –65°C to +150°C

Lead Temperature Range

(Soldering 10 sec) ..... 300°C

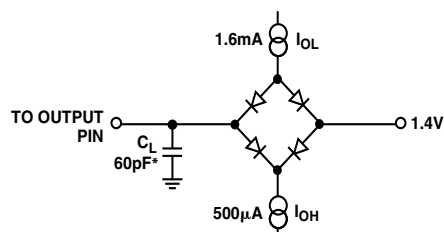
## NOTES

<sup>1</sup> Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

<sup>2</sup> See Analog Input section.

<sup>3</sup> Specification is for device in free air: 48-Lead LQFP:  $\theta_{JA} = 91^{\circ}\text{C/W}$ ,  $\theta_{JC} = 30^{\circ}\text{C/W}$ .

<sup>4</sup> Specification is for device in free air: 48-Lead LFCSP:  $\theta_{JA} = 26^{\circ}\text{C/W}$ .



\*IN SERIAL INTERFACE MODES, THE SYNC, SCLK, AND SDOUT TIMINGS ARE DEFINED WITH A MAXIMUM LOAD  $C_L$  OF 10pF; OTHERWISE, THE LOAD IS 60pF MAXIMUM.

Figure 1. Load Circuit for Digital Interface Timing

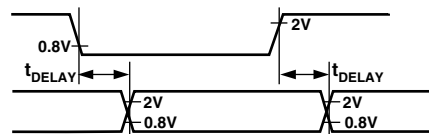
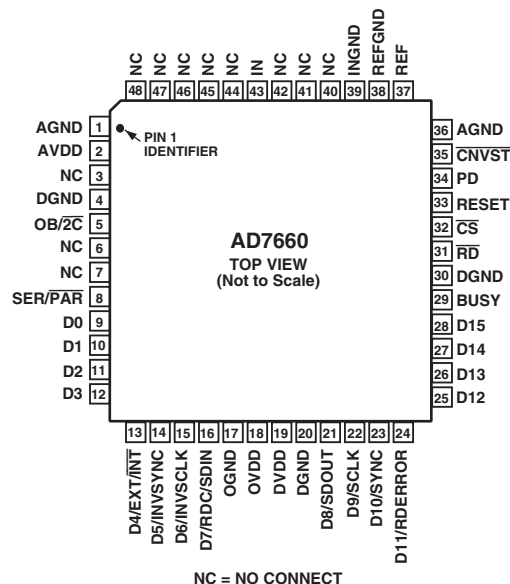


Figure 2. Voltage Reference Levels for Timings

## PIN CONFIGURATION



## ORDERING GUIDE

| Model                         | Temperature Range | Package Description  | Package Option |
|-------------------------------|-------------------|----------------------|----------------|
| AD7660AST                     | –40°C to +85°C    | Quad Flatpack (LQFP) | ST-48          |
| AD7660ASTRL                   | –40°C to +85°C    | Quad Flatpack (LQFP) | ST-48          |
| AD7660ACP                     | –40°C to +85°C    | Chip Scale (LFCSP)   | CP-48          |
| AD7660ACPRL                   | –40°C to +85°C    | Chip Scale (LFCSP)   | CP-48          |
| EVAL-AD7660CB <sup>1</sup>    |                   | Evaluation Board     |                |
| EVAL-CONTROL BRD <sup>2</sup> |                   | Controller Board     |                |

## NOTES

<sup>1</sup> This board can be used as a standalone evaluation board or in conjunction with the EVAL-CONTROL BRD2 for evaluation/demonstration purposes.

<sup>2</sup> This board allows a PC to control and communicate with all Analog Devices evaluation boards ending in the CB designators.

## CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the AD7660 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.



## PIN FUNCTION DESCRIPTIONS

| Pin No.                     | Mnemonic                       | Type | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|-----------------------------|--------------------------------|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1                           | AGND                           | P    | Analog Power Ground Pin                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 2                           | AVDD                           | P    | Input Analog Power Pins. Nominally 5 V.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 3, 6, 7,<br>40–42,<br>44–48 | NC                             |      | No Connect                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 4                           | DGND                           | DI   | Must Be Tied to Digital Ground                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 5                           | OB/ $\overline{2C}$            | DI   | Straight Binary/Binary Twos Complement. When OB/ $\overline{2C}$ is HIGH, the digital output is straight binary; when LOW, the MSB is inverted resulting in a twos complement output from its internal shift register.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 8                           | SER/ $\overline{PAR}$          | DI   | Serial/Parallel Selection Input. When LOW, the Parallel Port is selected; when HIGH, the Serial Interface Mode is selected and some bits of the DATA bus are used as a Serial Port.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 9–12                        | D[0:3]                         | DO   | Bit 0 to Bit 3 of the Parallel Port Data Output Bus. These pins are always outputs regardless of the state of SER/ $\overline{PAR}$ .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 13                          | D4<br>or EXT/ $\overline{INT}$ | DI/O | When SER/ $\overline{PAR}$ is LOW, this output is used as the Bit 4 of the Parallel Port Data Output Bus.<br>When SER/ $\overline{PAR}$ is HIGH, this input, part of the Serial Port, is used as a digital select input for choosing the internal or an external data clock. With EXT/ $\overline{INT}$ tied LOW, the internal clock is selected on the SCLK output. With EXT/ $\overline{INT}$ set to a logic HIGH, output data is synchronized to an external clock signal connected to the SCLK input.                                                                                                                                                                                                                                                                                                                                                     |
| 14                          | D5<br>or INVSCLK               | DI/O | When SER/ $\overline{PAR}$ is LOW, this output is used as the Bit 5 of the Parallel Port Data Output Bus.<br>When SER/ $\overline{PAR}$ is HIGH, this input, part of the Serial Port, is used to select the active state of the SYNC signal. When LOW, SYNC is active HIGH. When HIGH, SYNC is active LOW.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 15                          | D6<br>or INVSCCLK              | DI/O | When SER/ $\overline{PAR}$ is LOW, this output is used as the Bit 6 of the Parallel Port Data Output Bus.<br>When SER/ $\overline{PAR}$ is HIGH, this input, part of the Serial Port, is used to invert the SCLK signal. It is active in both Master and Slave Modes.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 16                          | D7<br>or RDC/SDIN              | DI/O | When SER/ $\overline{PAR}$ is LOW, this output is used as the Bit 7 of the Parallel Port Data Output Bus.<br>When SER/ $\overline{PAR}$ is HIGH, this input, part of the Serial Port, is used as either an external data input or a Read Mode selection input depending on the state of EXT/ $\overline{INT}$ .<br>When EXT/ $\overline{INT}$ is HIGH, RDC/SDIN could be used as a data input to daisy-chain the conversion results from two or more ADCs onto a single SDOUT line. The digital data level on SDIN is output on DATA with a delay of 16 SCLK periods after the initiation of the read sequence.<br>When EXT/ $\overline{INT}$ is LOW, RDC/SDIN is used to select the Read Mode. When RDC/SDIN is HIGH, the data is output on SDOUT during conversion. When RDC/SDIN is LOW, the data is output on SDOUT only when the conversion is complete. |
| 17                          | OGND                           | P    | Input/Output Interface Digital Power Ground                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 18                          | OVDD                           | P    | Input/Output Interface Digital Power. Nominally at the same supply as the supply of the host interface (5 V or 3 V).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 19                          | DVDD                           | P    | Digital Power. Nominally at 5 V.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 20                          | DGND                           | P    | Digital Power Ground                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 21                          | D8<br>or SDOUT                 | DO   | When SER/ $\overline{PAR}$ is LOW, this output is used as Bit 8 of the Parallel Port Data Output Bus.<br>When SER/ $\overline{PAR}$ is HIGH, this output, part of the Serial Port, is used as a serial data output synchronized to SCLK. Conversion results are stored in an on-chip register. The AD7660 provides the conversion result, MSB first, from its internal shift register. The DATA format is determined by the logic level of OB/ $\overline{2C}$ . In Serial Mode, when EXT/ $\overline{INT}$ is LOW, SDOUT is valid on both edges of SCLK.<br>In Serial Mode, when EXT/ $\overline{INT}$ is HIGH:<br>If INVSCLK is LOW, SDOUT is updated on the SCLK rising edge and valid on the next falling edge.<br>If INVSCLK is HIGH, SDOUT is updated on the SCLK falling edge and valid on the next rising edge.                                       |

## PIN FUNCTION DESCRIPTIONS (continued)

| Pin No. | Mnemonic                  | Type | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|---------|---------------------------|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 22      | D9<br>or SCLK             | DI/O | When $\overline{\text{SER/}\overline{\text{PAR}}}$ is LOW, this output is used as Bit 9 of the Parallel Port Data Output Bus. When $\overline{\text{SER/}\overline{\text{PAR}}}$ is HIGH, this pin, part of the Serial Port, is used as a serial data clock input or output, dependent upon the logic state of the $\overline{\text{EXT/}\overline{\text{INT}}}$ pin. The active edge where the data SDO <sub>UT</sub> is updated depends upon the logic state of the INV <sub>SCLK</sub> pin.                                                                                                                                                                                               |
| 23      | D10<br>or SYNC            | DO   | When $\overline{\text{SER/}\overline{\text{PAR}}}$ is LOW, this output is used as Bit 10 of the Parallel Port Data Output Bus. When $\overline{\text{SER/}\overline{\text{PAR}}}$ is HIGH, this output, part of the Serial Port, is used as a digital output frame synchronization for use with the internal data clock ( $\overline{\text{EXT/}\overline{\text{INT}}} = \text{Logic LOW}$ ). When a read sequence is initiated and INV <sub>SYNC</sub> is LOW, SYNC is driven HIGH and remains HIGH while SDO <sub>UT</sub> output is valid. When a read sequence is initiated and INV <sub>SYNC</sub> is HIGH, SYNC is driven LOW and remains LOW while SDO <sub>UT</sub> output is valid. |
| 24      | D11<br>or RDERROR         | DO   | When $\overline{\text{SER/}\overline{\text{PAR}}}$ is LOW, this output is used as the Bit 11 of the Parallel Port Data Output Bus. When $\overline{\text{SER/}\overline{\text{PAR}}}$ is HIGH and $\overline{\text{EXT/}\overline{\text{INT}}}$ is HIGH, this output, part of the Serial Port, is used as an incomplete read error flag. In Slave Mode, when a data read is started and not complete when the following conversion is complete, the current data is lost and RDERROR is pulsed HIGH.                                                                                                                                                                                         |
| 25–28   | D[12:15]                  | DO   | Bit 12 to Bit 15 of the Parallel Port Data Output Bus. These pins are always outputs regardless of the state of $\overline{\text{SER/}\overline{\text{PAR}}}$ .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 29      | BUSY                      | DO   | Busy Output. Transitions HIGH when a conversion is started and remains HIGH until the conversion is complete and the data is latched into the on-chip shift register. The falling edge of BUSY could be used as a data-ready clock signal.                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 30      | DGND                      | P    | Must Be Tied to Digital Ground                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 31      | $\overline{\text{RD}}$    | DI   | Read Data. When $\overline{\text{CS}}$ and $\overline{\text{RD}}$ are both LOW, the interface parallel or serial output bus is enabled.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 32      | $\overline{\text{CS}}$    | DI   | Chip Select. When $\overline{\text{CS}}$ and $\overline{\text{RD}}$ are both LOW, the interface parallel or serial output bus is enabled. $\overline{\text{CS}}$ is also used to gate the external clock.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 33      | RESET                     | DI   | Reset Input. When set to a logic HIGH, reset the AD7660. Current conversion, if any, is aborted.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 34      | PD                        | DI   | Power-Down Input. When set to a logic HIGH, power consumption is reduced and conversions are inhibited after the current one is completed.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 35      | $\overline{\text{CNVST}}$ | DI   | Start Conversion. If $\overline{\text{CNVST}}$ is HIGH when the acquisition phase ( $t_g$ ) is complete, the next falling edge on $\overline{\text{CNVST}}$ puts the internal sample-and-hold into the hold state and initiates a conversion. This mode is the most appropriate if low sampling jitter is desired. If $\overline{\text{CNVST}}$ is LOW when the acquisition phase ( $t_g$ ) is complete, the internal sample-and-hold is put into the hold state and a conversion is immediately started.                                                                                                                                                                                    |
| 36      | AGND                      | P    | Must Be Tied to Analog Ground                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 37      | REF                       | AI   | Reference Input Voltage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 38      | REFGND                    | AI   | Reference Input Analog Ground                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 39      | INGND                     | AI   | Analog Input Ground                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 43      | IN                        | AI   | Primary Analog Input with a Range of 0 V to $V_{\text{REF}}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

## NOTES

AI = Analog Input

DI = Digital Input

DI/O = Bidirectional Digital

DO = Digital Output

P = Power

**DEFINITION OF SPECIFICATIONS****Integral Nonlinearity Error (INL)**

Linearity error refers to the deviation of each individual code from a line drawn from “negative full scale” through “positive full scale.” The point used as negative full scale occurs 1/2 LSB before the first code transition. Positive full scale is defined as a level 1 1/2 LSB beyond the last code transition. The deviation is measured from the middle of each code to the true straight line.

**Differential Nonlinearity Error (DNL)**

In an ideal ADC, code transitions are 1 LSB apart. Differential nonlinearity is the maximum deviation from this ideal value. It is often specified in terms of resolution for which no missing codes are guaranteed.

**Full-Scale Error**

The last transition (from 011 . . . 10 to 011 . . . 11 in twos complement coding) should occur for an analog voltage 1 1/2 LSB below the nominal full scale (2.49994278 V for the 0 V–2.5 V range). The full-scale error is the deviation of the actual level of the last transition from the ideal level.

**Unipolar Zero Error**

The first transition should occur at a level 1/2 LSB above analog ground (19.073  $\mu$ V for the 0 V–2.5 V range). Unipolar zero error is the deviation of the actual transition from that point.

**Spurious-Free Dynamic Range (SFDR)**

The difference, in decibels (dB), between the rms amplitude of the input signal and the peak spurious signal.

**Effective Number of Bits (ENOB)**

ENOB is a measurement of the resolution with a sine wave input. It is related to  $S/[N+D]$  by the following formula:

$$ENOB = \left( S/[N+D]_{dB} - 1.76 \right) / 6.02$$

and is expressed in bits.

**Total Harmonic Distortion (THD)**

THD is the ratio of the rms sum of the first five harmonic components to the rms value of a full-scale input signal and is expressed in decibels.

**Signal-to-Noise Ratio (SNR)**

SNR is the ratio of the rms value of the actual input signal to the rms sum of all other spectral components below the Nyquist frequency, excluding harmonics and dc. The value for SNR is expressed in decibels.

**Signal-to-(Noise + Distortion) Ratio ( $S/[N+D]$ )**

$S/(N+D)$  is the ratio of the rms value of the actual input signal to the rms sum of all other spectral components below the Nyquist frequency, including harmonics but excluding dc. The value for  $S/(N+D)$  is expressed in decibels.

**Aperture Delay**

Aperture delay is a measure of the acquisition performance and is measured from the falling edge of the  $\overline{CNVST}$  input to when the input signal is held for a conversion.

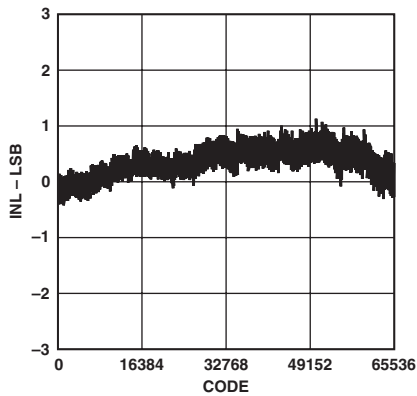
**Transient Response**

The time required for the AD7660 to achieve its rated accuracy after a full-scale step function is applied to its input.

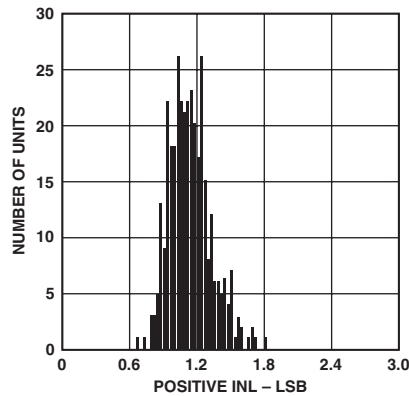
**Overvoltage Recovery**

The time required for the ADC to recover to full accuracy after an analog input signal 150% of full-scale is reduced to 50% of the full-scale value.

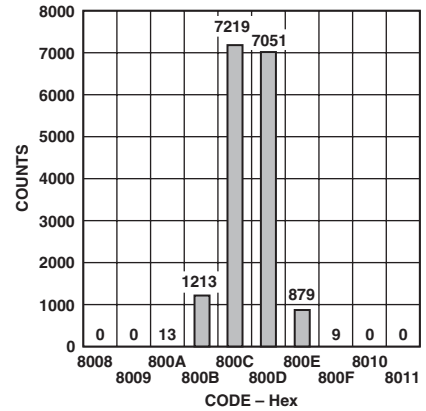
# AD7660—Typical Performance Characteristics



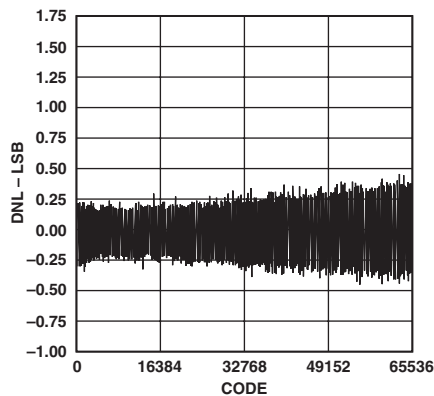
TPC 1. Integral Nonlinearity vs. Code



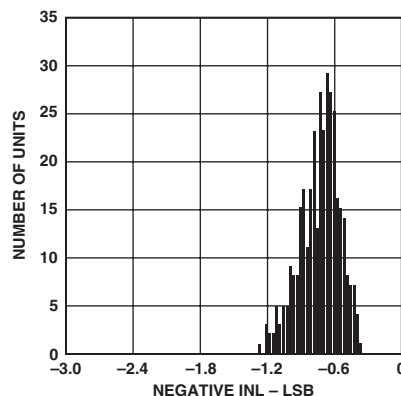
TPC 2. Typical Positive INL Distribution (350 Units)



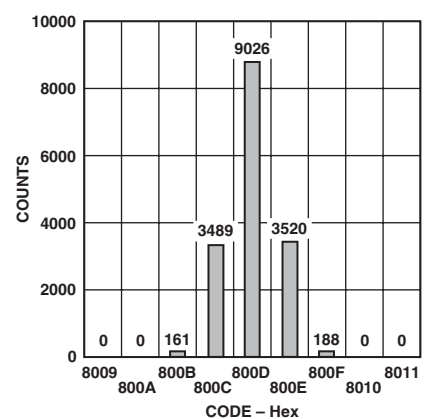
TPC 3. Histogram of 16,384 Conversions of a DC Input at the Code Transition



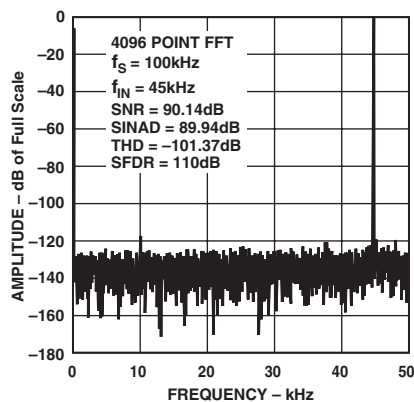
TPC 4. Differential Nonlinearity vs. Code



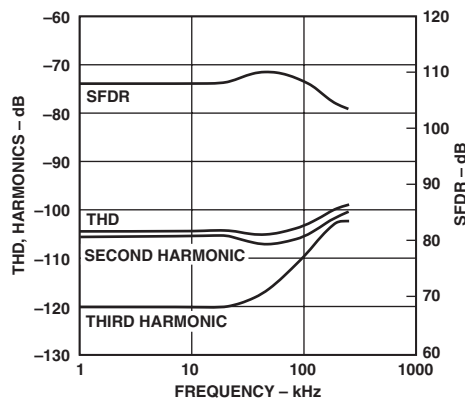
TPC 5. Typical Negative INL Distribution (350 Units)



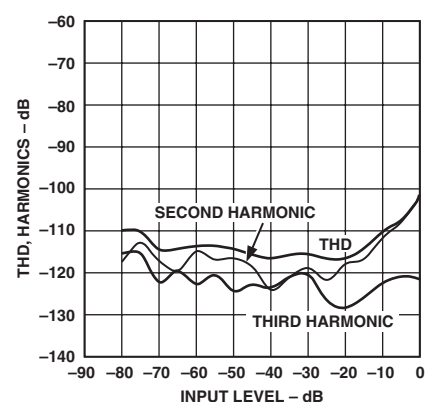
TPC 6. Histogram of 16,384 Conversions of a DC Input at the Code Center



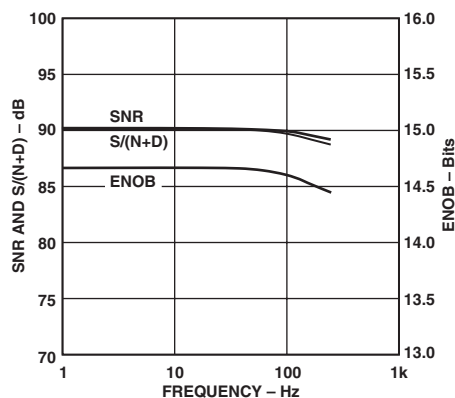
TPC 7. FFT Plot



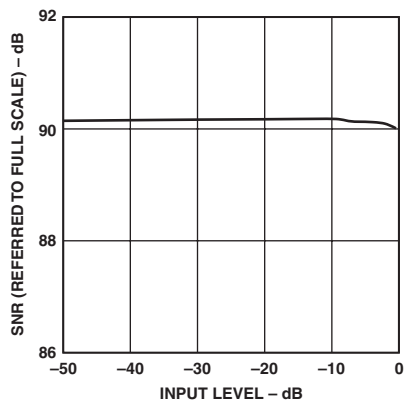
TPC 8. THD, Harmonics, and SFDR vs. Frequency



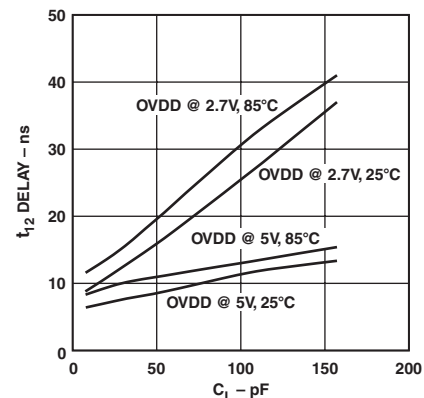
TPC 9. THD, Harmonics vs. Input Level



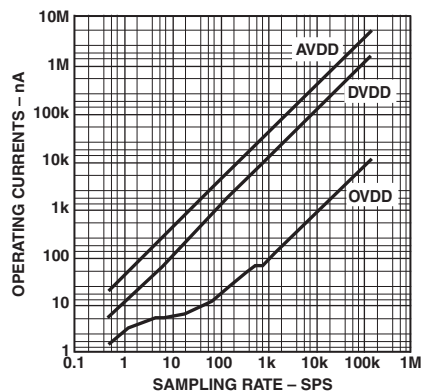
TPC 10. SNR,  $S/(N+D)$ , and ENOB vs. Frequency



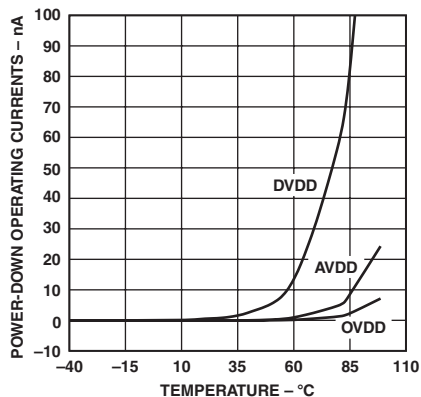
TPC 11. SNR vs. Input Level (Referred to Full Scale)



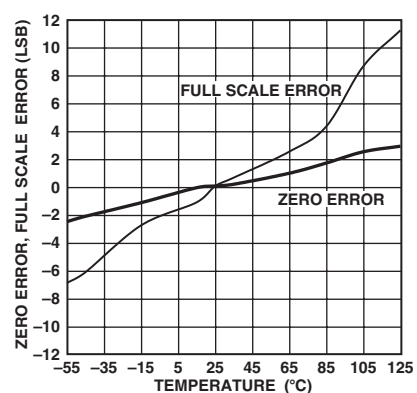
TPC 12. Typical Delay vs. Load Capacitance  $C_L$



TPC 13. Operating Currents vs. Sample Rate



TPC 14. Power-Down Operating Currents vs. Temperature



TPC 15. Zero Error, Full Scale vs. Temperature

# AD7660

## CIRCUIT INFORMATION

The AD7660 is a fast, low power, single-supply, precise 16-bit analog-to-digital converter (ADC). The AD7660 is capable of converting 100,000 samples per second (100 kSPS) and allows power saving between conversions. When operating at 100 SPS, for example, it consumes typically only 21  $\mu$ W. This feature makes the AD7660 ideal for battery-powered applications.

The AD7660 provides the user with an on-chip track-and-hold, successive-approximation ADC that does not exhibit any pipeline or latency, making it ideal for multiple multiplexed channel applications.

The AD7660 can be operated from a single 5 V supply and be interfaced to either 5 V or 3 V digital logic. It is housed in a 48-lead LQFP package or a 48-lead LFCSP package that combines space savings and allows flexible configurations as either serial or parallel interface. The AD7660 is pin-to-pin compatible with the AD7664.

## CONVERTER OPERATION

The AD7660 is a successive-approximation analog-to-digital converter based on a charge redistribution DAC. Figure 3 shows the simplified schematic of the ADC. The capacitive DAC consists of an array of 16 binary weighted capacitors and an additional LSB capacitor. The comparator's negative input is connected to a "dummy" capacitor of the same value as the capacitive DAC array.

During the acquisition phase, the common terminal of the array tied to the comparator's positive input is connected to AGND via  $SW_A$ . All independent switches are connected to the analog input IN. Thus, the capacitor array is used as a sampling capacitor and acquires the analog signal on IN input. Similarly, the dummy capacitor acquires the analog signal on the INGND input.

When the acquisition phase is complete and the  $\overline{CNVST}$  input goes or is LOW, a conversion phase is initiated. When the conversion phase begins,  $SW_A$  and  $SW_B$  are opened first. The capacitor array and the dummy capacitor are then disconnected from the inputs and connected to the REFGND input. Therefore, the differential voltage between IN and INGND captured at the end of the acquisition phase is applied to the comparator inputs, causing the comparator to become unbalanced.

By switching each element of the capacitor array between REFGND or REF, the comparator input varies by binary weighted voltage steps ( $V_{REF}/2$ ,  $V_{REF}/4$  . . .  $V_{REF}/65536$ ). The control logic toggles these switches, starting with the MSB first, in order to bring the comparator back into a balanced condition. After the completion of this process, the control logic generates the ADC output code and brings BUSY output LOW.

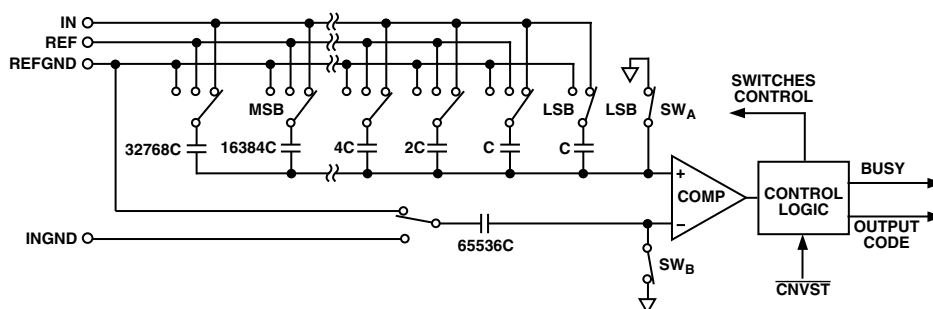


Figure 3. ADC Simplified Schematic

## Transfer Functions

Using the  $\text{OB}/\overline{\text{2C}}$  digital input, the AD7660 offers two output codings: straight binary and twos complement. The LSB size is  $V_{\text{REF}}/65536$ , which is about  $38.15 \mu\text{V}$ . The ideal transfer characteristic for the AD7660 is shown in Figure 4 and Table II.

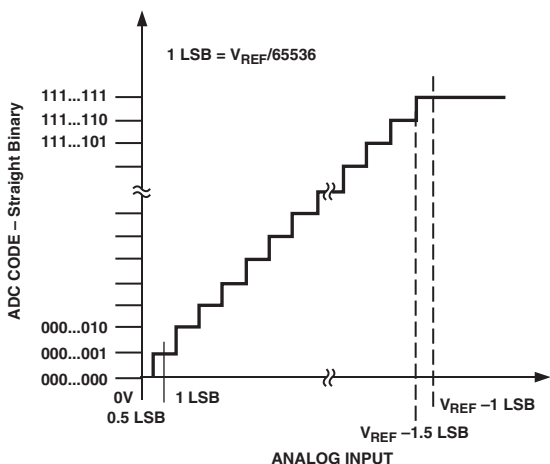


Figure 4. ADC Ideal Transfer Function

Table II. Output Codes and Ideal Input Voltages

| Description      | Analog Input     | Digital Output Code (Hex) |                   |
|------------------|------------------|---------------------------|-------------------|
|                  |                  | Straight Binary           | Twos Complement   |
| FSR - 1 LSB      | 2.499962 V       | FFFF <sup>1</sup>         | 7FFF <sup>1</sup> |
| FSR - 2 LSB      | 2.499923 V       | FFFE                      | 7FFE              |
| Midscale + 1 LSB | 1.250038 V       | 8001                      | 0001              |
| Midscale         | 1.25 V           | 8000                      | 0000              |
| Midscale - 1 LSB | 1.249962 V       | 7FFF                      | FFFF              |
| -FSR + 1 LSB     | 38 $\mu\text{V}$ | 0001                      | 8001              |
| -FSR             | 0 V              | 0000 <sup>2</sup>         | 8000 <sup>2</sup> |

### NOTES

<sup>1</sup>This is also the code for overrange analog input ( $V_{\text{IN}} - V_{\text{INGND}}$  above  $V_{\text{REF}} - V_{\text{REFGND}}$ ).

<sup>2</sup>This is also the code for underrange analog input ( $V_{\text{IN}}$  below  $V_{\text{INGND}}$ ).

## TYPICAL CONNECTION DIAGRAM

Figure 5 shows a typical connection diagram for the AD7660.

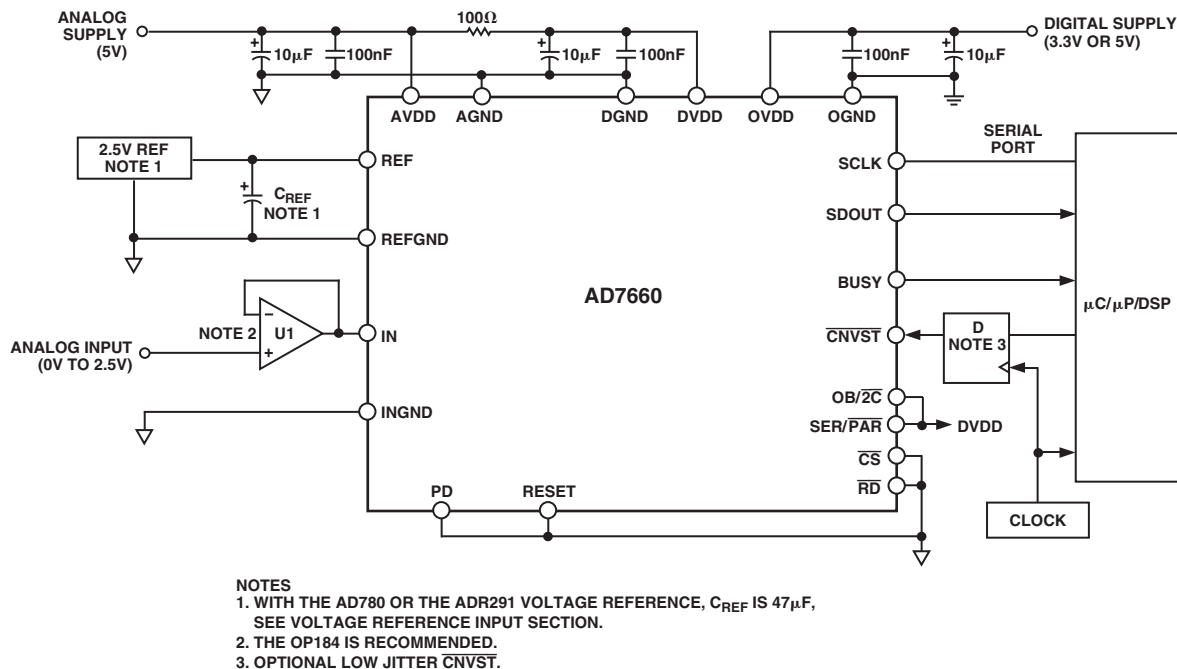


Figure 5. Typical Connection Diagram

# AD7660

## Analog Input

Figure 6 shows an equivalent circuit of the input structure of the AD7660.

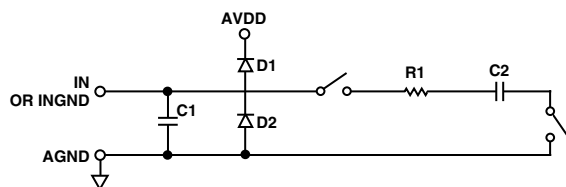


Figure 6. Equivalent Analog Input Circuit

The two diodes D1 and D2 provide ESD protection for the analog inputs IN and INGND. Care must be taken to ensure that the analog input signal never exceeds the supply rails by more than 0.3 V. This will cause these diodes to become forward-biased and start conducting current. These diodes can handle a forward-biased current of 100 mA maximum. For instance, these conditions could eventually occur when the input buffer's (U1) supplies are different from AVDD. In such cases, an input buffer with a short circuit current limitation can be used to protect the part.

This analog input structure allows the sampling of the differential signal between IN and INGND. Unlike other converters, the INGND input is sampled at the same time as the IN input. By using this differential input, small signals common to both inputs are rejected as shown in Figure 7, which represents the typical CMRR over frequency. For instance, by using INGND to sense a remote signal ground, difference of ground potentials between the sensor and the local ADC ground is eliminated.

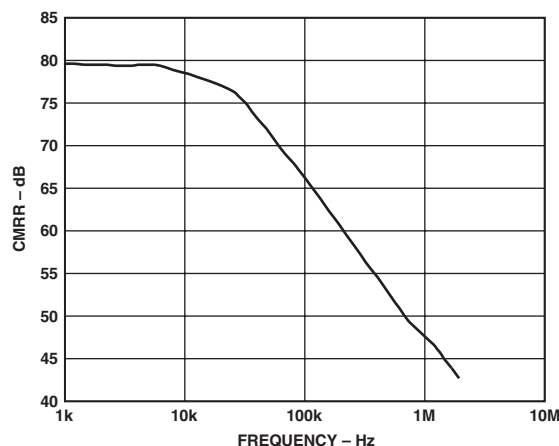


Figure 7. Analog Input CMRR vs. Frequency

During the acquisition phase, the impedance of the analog input IN can be modeled as a parallel combination of capacitor C1 and the network formed by the series connection of R1 and C2. Capacitor C1 is primarily the pin capacitance. The resistor R1 is typically 3242  $\Omega$  and is a lumped component made up of some serial resistors and the on resistance of the switches. The capacitor C2 is typically 60 pF and is mainly the ADC sampling capacitor. During the conversion phase, where the switches are opened, the input impedance is limited to C1. It has to be noted that the input impedance of the AD7660, unlike other SAR ADCs, is not a pure capacitance and thus, inherently reduces the kickback transient at the beginning of the acquisition phase. The R1, C2 makes a one-pole low-pass filter with a typical cutoff frequency of 820 kHz that reduces undesirable aliasing effect and limits the noise.

When the source impedance of the driving circuit is low, the AD7660 can be driven directly. Large source impedances will significantly affect the ac performances, especially the total harmonic distortion (THD). The maximum source impedance depends on the amount of THD that can be tolerated. The THD degrades in function of the source impedance and the maximum input frequency as shown in Figure 8.

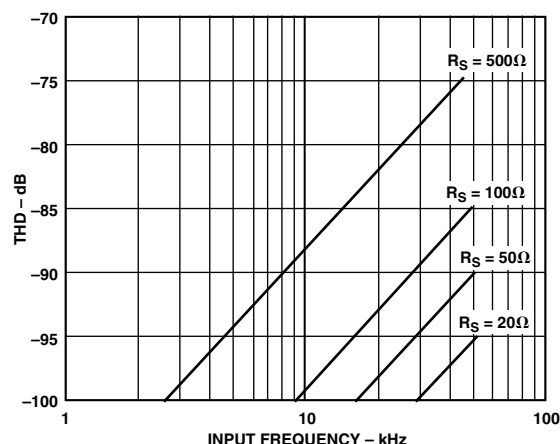


Figure 8. THD vs. Analog Input Frequency and Source Resistance

## Driver Amplifier Choice

Although the AD7660 is easy to drive, the driver amplifier needs to meet at least the following requirements:

- The driver amplifier and the AD7660 analog input circuit must be able, together, to settle for a full-scale step of the capacitor array at a 16-bit level (0.0015%). For instance, operation at the maximum throughput of 100 kSPS requires a minimum gain bandwidth product of 5 MHz.
- The noise generated by the driver amplifier needs to be kept as low as possible in order to preserve the SNR and transition noise performance of the AD7660. The noise coming from the driver is filtered by the AD7660 analog input circuit one-pole low-pass filter made by R1 and C2. For instance, a driver with an equivalent input noise of 4 nV/ $\sqrt{\text{Hz}}$  like the OP184 and configured as a buffer, thus with a noise gain of +1, degrades the SNR by only 0.1 dB.
- The driver needs to have a THD performance suitable to that of the AD7660. TPC 8 gives the THD versus frequency that the driver should preferably exceed.

The SNR degradation due to the amplifier is:

$$SNR_{LOSS} = 20 \log \left( \frac{28}{\sqrt{784 + \frac{\pi}{2} f_{-3dB} (N e_N)^2}} \right)$$

where:

$f_{-3dB}$  is the -3 dB input bandwidth in MHz of the AD7660 (0.82 MHz) or the cutoff frequency of the input filter if any are used.

$N$  is the noise factor of the amplifier (1 if in buffer configuration).

$e_N$  is the equivalent input noise voltage of the op amp in nV/ $\sqrt{\text{Hz}}$ .

The AD8519, OP162, or the OP184 meet these requirements and are usually appropriate for almost all applications. As an alternative, in very high speed and noise-sensitive applications, the AD8021 with an external compensation capacitor of 10 pF or the AD829 with an external compensation capacitor of 82 pF can be used. This capacitor should have good linearity as an NPO ceramic or mica type. Moreover, the use of a noninverting +1 gain arrangement is recommended and helps to obtain the best signal-to-noise ratio.

#### Voltage Reference Input

The AD7660 uses an external 2.5 V voltage reference.

The voltage reference input REF of the AD7660 has a dynamic input impedance; it should therefore be driven by a low impedance source with an efficient decoupling between REF and REFGND inputs. This decoupling depends on the choice of the voltage reference but usually consists of a 1  $\mu$ F ceramic capacitor and a low ESR tantalum capacitor connected to the REF and REFGND inputs with minimum parasitic inductance. 47  $\mu$ F is an appropriate value for the tantalum capacitor when used with one of the recommended reference voltages:

- The low noise, low temperature drift ADR421 and AD780 voltage references
- The low power ADR291 voltage reference
- The low cost AD1582 voltage reference

For applications using multiple AD7660s, it is more effective to buffer the reference voltage with a low noise, very stable op amp like the AD8031.

Care should also be taken with the reference temperature coefficient of the voltage reference that directly affects the full-scale accuracy if this parameter matters. For instance, a  $\pm 15$  ppm/ $^{\circ}$ C tempco of the reference changes the full scale by  $\pm 1$  LSB/ $^{\circ}$ C.

$V_{REF}$ , as mentioned in the specification table, could be increased to AVDD – 1.85 V. The benefit here is the increased SNR obtained as a result of this increase. Since the input range is defined in terms of  $V_{REF}$ , this would essentially increase the range to make it a  $\pm 3$  V input range with an AVDD above 4.85 V. The theoretical improvement as a result of this increase in reference is 1.58 dB ( $20 \log [3/2.5]$ ). Due to the theoretical quantization noise, however, the observed improvement is approximately 1 dB. The AD780 can be selected with a 3 V reference voltage.

#### Power Supply

The AD7660 uses three sets of power supply pins: an analog 5 V supply AVDD, a digital 5 V core supply DVDD, and a digital input/output interface supply OVDD. The OVDD supply allows direct interface with any logic working between 2.7 V and 5.25 V. To reduce the number of supplies needed, the digital core (DVDD) can be supplied through a simple RC filter from the analog supply, as shown in Figure 5. The AD7660 is independent

of power supply sequencing and thus free from supply voltage induced latch-up. Additionally, it is very insensitive to power supply variations over a wide frequency range, as shown in Figure 9.

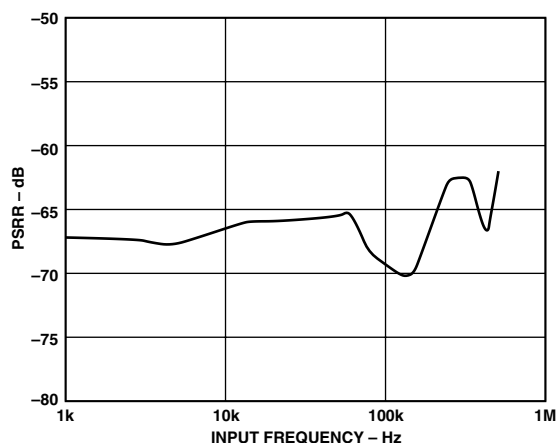


Figure 9. PSRR vs. Frequency

#### POWER DISSIPATION VS. THROUGHPUT

The AD7660 automatically reduces its power consumption at the end of each conversion phase. During the acquisition phase, the operating currents are very low, which allows a significant power saving when the conversion rate is reduced, as shown in Figure 10. This feature makes the AD7660 ideal for very low power battery applications. It should be noted that the digital interface remains active even during the acquisition phase. To reduce the operating digital supply currents even further, the digital inputs need to be driven close to the power rails (i.e., DVDD and DGND for all inputs except EXT/INT, INVSYN, INVSCLK, RDC/SDIN, and OVDD or OGND for the last four inputs).

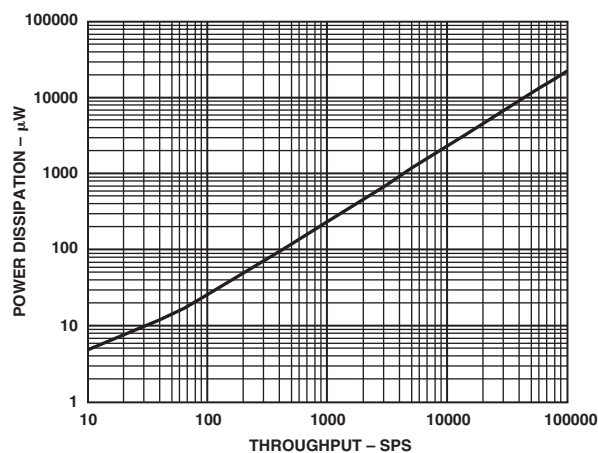


Figure 10. Power Dissipation vs. Sample Rate

# AD7660

## CONVERSION CONTROL

Figure 11 shows the detailed timing diagrams of the conversion process. The AD7660 is controlled by the signal  $\overline{\text{CNVST}}$ , which initiates conversion. Once initiated, it cannot be restarted or aborted, even by the power-down input PD, until the conversion is complete. The  $\overline{\text{CNVST}}$  signal operates independently of CS and  $\overline{\text{RD}}$  signals.

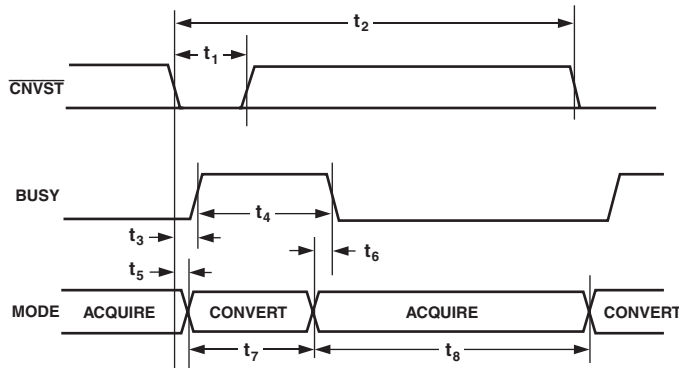


Figure 11. Basic Conversion Timing

For a true sampling application, the recommended operation of the  $\overline{\text{CNVST}}$  signal is the following:

$\overline{\text{CNVST}}$  must be held HIGH from the previous falling edge of BUSY, and during a minimum delay corresponding to the acquisition time  $t_8$ ; then, when  $\overline{\text{CNVST}}$  is brought LOW, a conversion is initiated and the BUSY signal goes HIGH until the completion of the conversion. Although  $\overline{\text{CNVST}}$  is a digital signal, it should be designed with special care with fast, clean edges and levels, with minimum overshoot and undershoot or ringing. For applications where the SNR is critical, the  $\overline{\text{CNVST}}$  signal should have a very low jitter. This may be achieved by using a dedicated oscillator for  $\overline{\text{CNVST}}$  generation or, at least, to clock it with a high frequency low jitter clock, as shown in Figure 5.

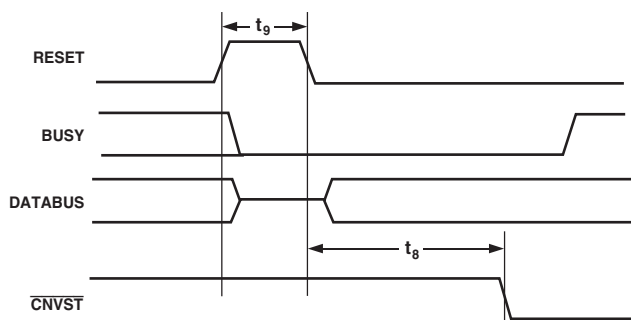


Figure 12. RESET Timing

For other applications, conversions can be automatically initiated. If  $\overline{\text{CNVST}}$  is held LOW when BUSY is LOW, the AD7660 controls the acquisition phase and then automatically initiates a new conversion. By keeping  $\overline{\text{CNVST}}$  LOW, the AD7660 keeps the conversion process running by itself. It should be noted that the analog input has to be settled when BUSY goes LOW. Also, at power-up,  $\overline{\text{CNVST}}$  should be brought LOW once to initiate the conversion process. In this mode, the AD7660 could sometimes run slightly faster than the guaranteed limit of 100 kSPS.

## DIGITAL INTERFACE

The AD7660 has a versatile digital interface; it can be interfaced with the host system by using either a serial or parallel interface. The serial interface is multiplexed on the parallel data bus. The AD7660 digital interface also accommodates both 3 V or 5 V logic by simply connecting the OVDD supply pin of the AD7660 to the host system interface digital supply. Finally, by using the  $\text{OB}/\overline{2\text{C}}$  input pin, both twos complement or straight binary coding can be used.

The two signals  $\overline{\text{CS}}$  and  $\overline{\text{RD}}$  control the interface.  $\overline{\text{CS}}$  and  $\overline{\text{RD}}$  have a similar effect because they are together internally. When at least one of these signals is HIGH, the interface outputs are in high impedance. Usually,  $\overline{\text{CS}}$  allows the selection of each AD7660 in multicircuit applications and is held LOW in a single AD7660 design.  $\overline{\text{RD}}$  is generally used to enable the conversion result on the data bus.

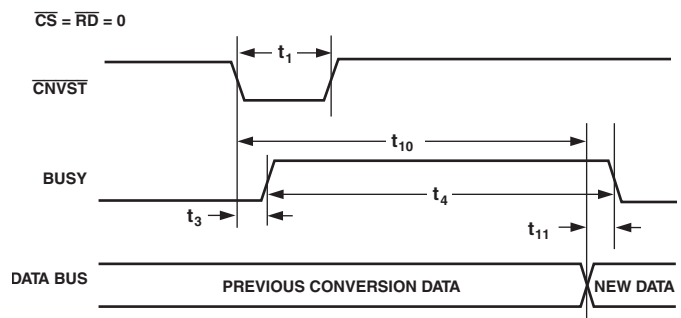


Figure 13. Master Parallel Data Timing for Reading (Continuous Read)

## PARALLEL INTERFACE

The AD7660 is configured to use the parallel interface when the  $\text{SER}/\overline{\text{PAR}}$  is held LOW. The data can be read either after each conversion, which is during the next acquisition phase, or during the following conversion as shown, respectively, in Figures 14 and 15. When the data is read during the conversion, however, it is recommended that it is read-only during the first half of the conversion phase. This avoids any potential feedthrough between voltage transients on the digital interface and the most critical analog conversion circuitry.

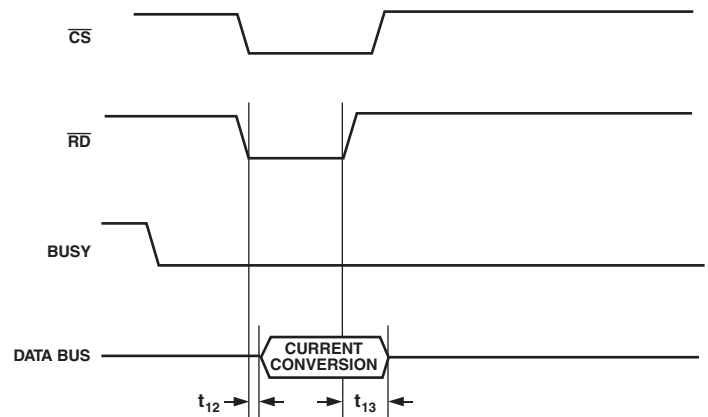


Figure 14. Slave Parallel Data Timing for Reading (Read after Convert)

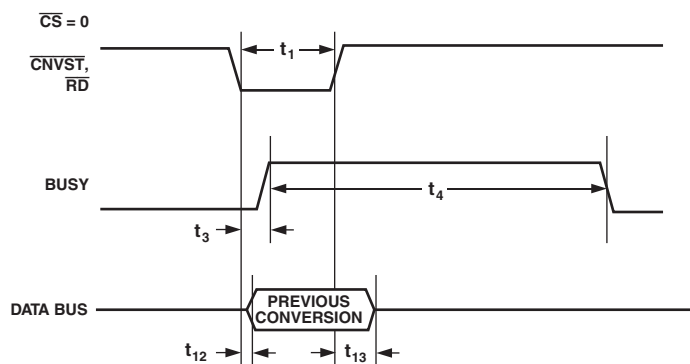


Figure 15. Slave Parallel Data Timing for Reading (Read during Convert)

## SERIAL INTERFACE

The AD7660 is configured to use the serial interface when the  $\text{SER}/\overline{\text{PAR}}$  is held HIGH. The AD7660 outputs 16 bits of data, MSB first, on the SDOUT pin. This data is synchronized with the 16 clock pulses provided on the SCLK pin.

## MASTER SERIAL INTERFACE

### Internal Clock

The AD7660 is configured to generate and provide the serial data clock SCLK when the  $\text{EXT}/\overline{\text{INT}}$  pin is held LOW. The AD7660 also generates a SYNC signal to indicate to the host when the serial data is valid. The serial clock SCLK and the SYNC signal can be inverted if desired. The output data is valid on both the rising and falling edge of the data clock. Depending on RDC/SDIN input, the data can be read after each conversion or during the following conversion. Figures 16 and 17 show the detailed timing diagrams of these two modes.

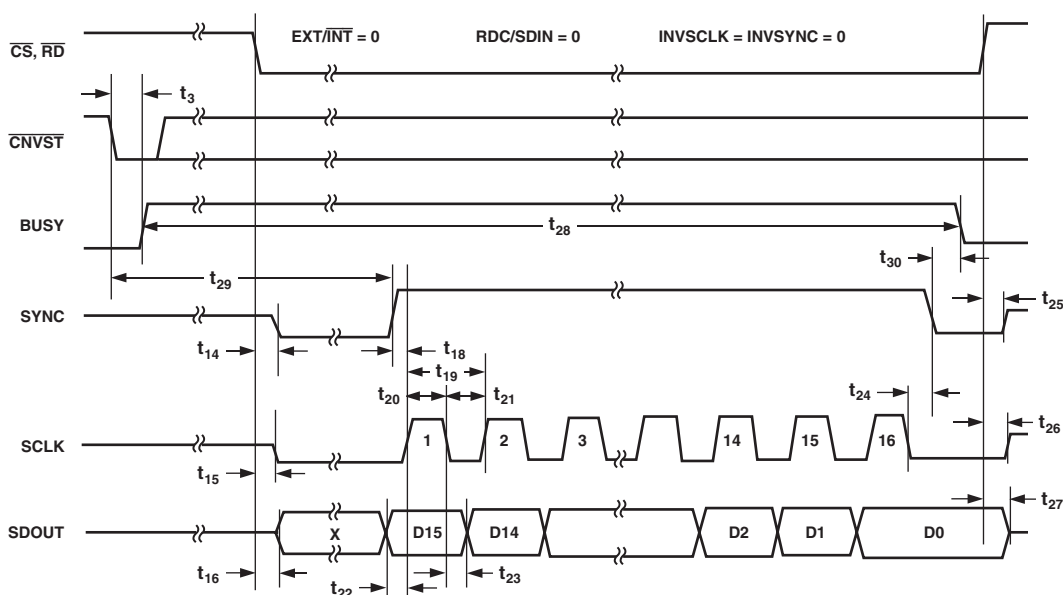


Figure 16. Master Serial Data Timing for Reading (Read after Convert)

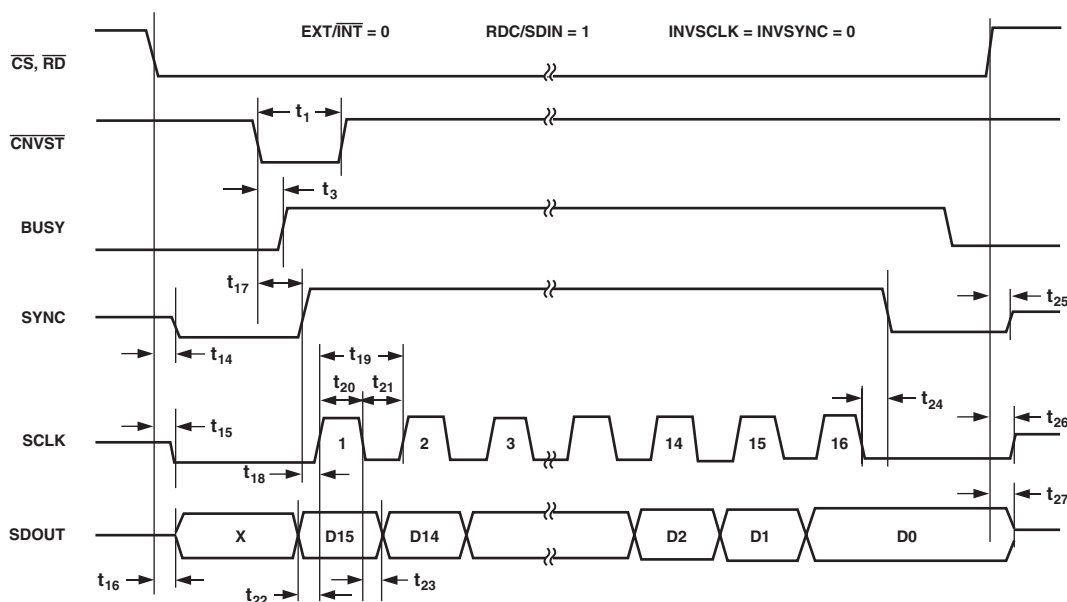


Figure 17. Master Serial Data Timing for Reading (Read Previous Conversion during Convert)

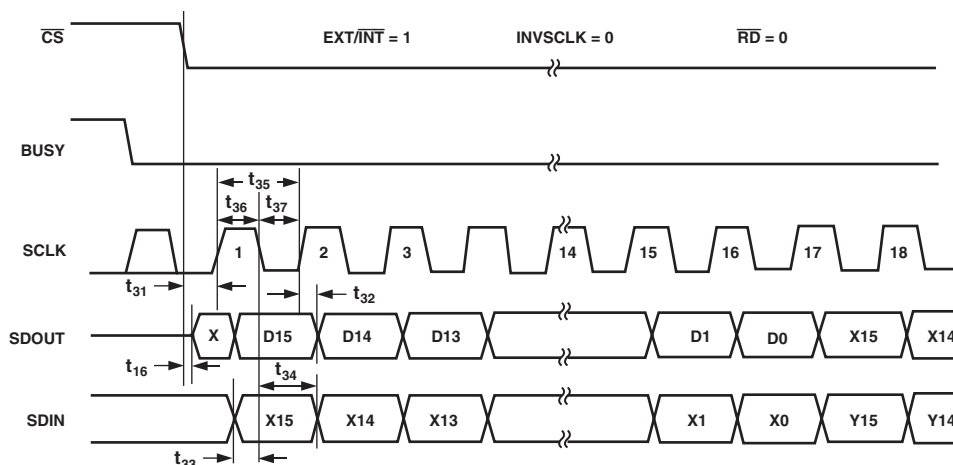


Figure 18. Slave Serial Data Timing for Reading (Read after Convert)

Usually, because the AD7660 has a longer acquisition phase than the conversion phase, the data is read immediately after conversion. This makes the Master Read after conversion the most recommended Serial Mode when it can be used. In this mode, it should be noted that, unlike in other modes, the signal BUSY returns LOW after the 16 data bits are pulsed out and not at the end of the conversion phase, which results in a longer BUSY width.

In Read-during-Conversion Mode, the serial clock and data toggle at appropriate instants, which minimizes potential feedthrough between digital activity and the critical conversion decisions.

## SLAVE SERIAL INTERFACE

### External Clock

The AD7660 is configured to accept an externally supplied serial data clock on the SCLK pin when the EXT/INT pin is held HIGH. In this mode, several methods can be used to read the data. When  $\overline{CS}$  and  $\overline{RD}$  are both LOW, the data can be read after each conversion or during the following conversion. The external clock can be either a continuous or discontinuous clock. A discontinuous clock can be either normally HIGH or normally LOW when inactive. Figures 18 and 20 show the detailed timing diagrams of these methods. Usually, because the AD7660 has a longer acquisition phase than the conversion phase, the data are read immediately after conversion.

While the AD7660 is performing a bit decision, it is important that voltage transients not occur on digital input/output pins or degradation of the conversion result could occur. This is particularly important during the second half of the conversion phase because the AD7660 provides error correction circuitry that can correct for an improper bit decision made during the first half of the conversion phase. For this reason, it is recommended that when an external clock is being provided, it is a discontinuous clock that is toggling only when BUSY is LOW or, more importantly, that it does not transition during the latter half of BUSY HIGH.

### External Discontinuous Clock Data Read after Conversion

This mode is the most recommended of the serial slave modes. Figure 18 shows the detailed timing diagrams of this method. After a conversion is complete, indicated by BUSY returning LOW,

the result of this conversion can be read while both  $\overline{CS}$  and  $\overline{RD}$  are LOW. The data is shifted out, MSB first, with 16 clock pulses and is valid on both the rising and falling edge of the clock.

Among the advantages of this method, the conversion performance is not degraded because there are no voltage transients on the digital interface during the conversion process.

Another advantage is the ability to read the data at any speed up to 40 MHz, which accommodates both slow digital host interface and the fastest serial reading.

Finally, in this mode only, the AD7660 provides a “daisy-chain” feature using the RDC/SDIN input pin for cascading multiple converters together. This feature is useful for reducing component count and wiring connections when it is desired as it is, for instance, in isolated multiconverter applications.

An example of the concatenation of two devices is shown in Figure 19. Simultaneous sampling is possible by using a common  $\overline{CNVST}$  signal. It should be noted that the RDC/SDIN input is latched on the opposite edge of SCLK of the one used to shift out the data on SDOUT. Therefore, the MSB of the “upstream” converter just follows the LSB of the “downstream” converter on the next SCLK cycle. Up to 20 AD7660s running at 100 kSPS can be daisy-chained using this method.

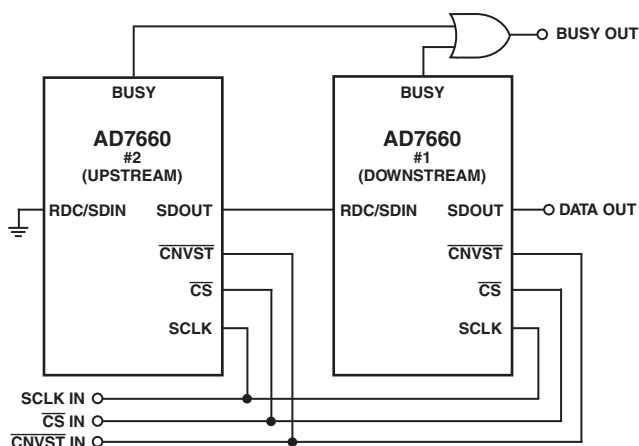


Figure 19. Two AD7660s in a Daisy-Chain Configuration

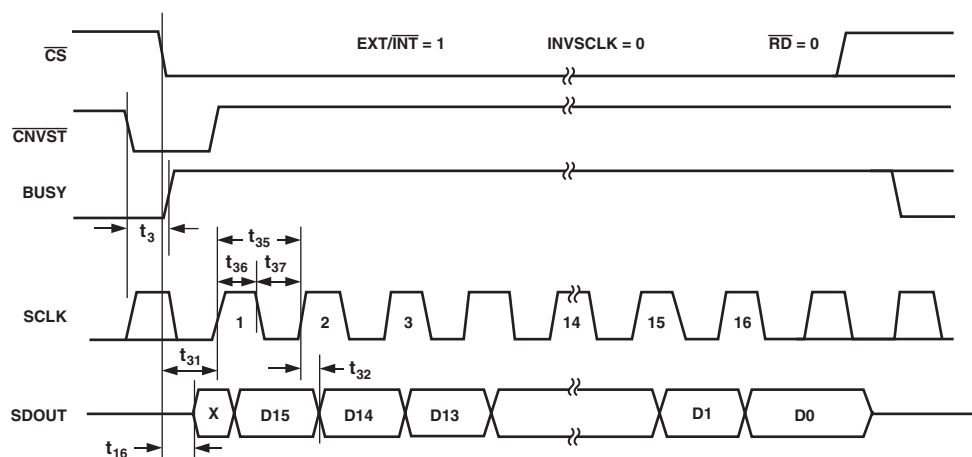


Figure 20. Slave Serial Data Timing for Reading (Read Previous Conversion during Convert)

### External Clock Data Read during Conversion

Figure 20 shows the detailed timing diagrams of this method. During a conversion, while both  $\overline{CS}$  and  $\overline{RD}$  are LOW, the result of the previous conversion can be read. The data is shifted out, MSB first, with 16 clock pulses, and is valid on both the rising and falling edges of the clock. The 16 bits have to be read before the current conversion is complete; this, otherwise,  $RDERROR$  is pulsed HIGH and can be used to interrupt the host interface to prevent incomplete data reading. There is no daisy-chain feature in this mode, and  $RDC/SDIN$  input should always be tied either HIGH or LOW.

To reduce performance degradation due to digital activity, a fast discontinuous clock of at least 18 MHz is recommended to ensure that all the bits are read during the first half of the conversion phase. For this reason, this mode is more difficult to use.

### MICROPROCESSOR INTERFACING

The AD7660 is ideally suited for traditional dc measurement applications supporting a microprocessor, and for ac signal processing applications interfacing to a digital signal processor. The AD7660 is designed to interface either with a parallel 8-bit or 16-bit wide interface, or with a general-purpose serial port or I/O ports on a microcontroller. A variety of external buffers can be used with the AD7660 to prevent digital noise from coupling into the ADC. The following section discusses the use of an AD7660 with an ADSP-219x SPI equipped DSP.

### SPI Interface (ADSP-219x)

Figure 21 shows an interface diagram between the AD7660 and an SPI-equipped ADSP-219x. To accommodate the slower speed of the DSP, the AD7660 acts as a slave device and data must be read after conversion. This mode also allows the daisy-chain feature. The convert command can be initiated in response to an internal timer interrupt. The reading process can be initiated in response to the end-of-conversion signal ( $BUSY$  going LOW) using an interrupt line of the DSP. The serial interface (SPI) on the ADSP-219x is configured for master mode—( $MSTR$ ) = 1, Clock Polarity bit ( $CPOL$ ) = 0, Clock Phase bit ( $CPHA$ ) = 1, and SPI Interrupt Enable ( $TIMOD$ ) = 00—by writing to the SPI control register ( $SPICLTx$ ). To meet all timing requirements, the SPI clock should be limited to 17 Mbps, which allows it to read an ADC result in less than 1  $\mu$ s. When a higher sampling rate is desired, use of one of the parallel interface modes is recommended.

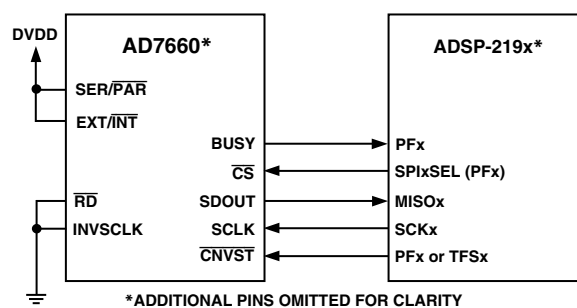


Figure 21. Interfacing the AD7660 to an SPI Interface

# AD7660

## APPLICATION HINTS

### Bipolar and Wider Input Ranges

In some applications, it is desired to use a bipolar or wider analog input range like, for instance,  $\pm 10$  V,  $\pm 5$  V, or 0 V to 5 V. Although the AD7660 has only one unipolar range, by simple modifications of the input driver circuitry, bipolar and wider input ranges can be used without any performance degradation.

Figure 22 shows a connection diagram that allows this. Component values required and resulting full-scale ranges are shown in Table III.

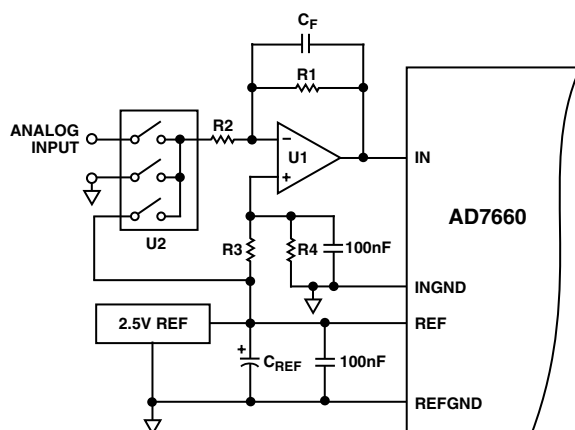


Figure 22. Using the AD7660 in 16-Bit Bipolar and/or Wider Input Ranges

Table III. Component Values and Input Ranges

| Input Range   | R1 (k $\Omega$ ) | R2 (k $\Omega$ ) | R3 (k $\Omega$ ) | R4 (k $\Omega$ ) |
|---------------|------------------|------------------|------------------|------------------|
| $\pm 10$ V    | 1                | 8                | 10               | 8                |
| $\pm 5$ V     | 1                | 4                | 10               | 6.67             |
| 0 V to $-5$ V | 1                | 2                | None             | 0                |

For bipolar range applications where accurate gain and offset are desired, they can be calibrated by acquiring a ground and a voltage reference using an analog multiplexer U2, as shown in Figure 22. Also,  $C_F$  can be used as a one-pole antialiasing filter.

### Layout

The AD7660 has very good immunity to noise on the power supplies as can be seen in Figure 9. However, care should still be taken with regard to grounding layout.

The printed circuit board that houses the AD7660 should be designed so the analog and digital sections are separated and confined to certain areas of the board. This facilitates the use of ground planes that can be easily separated. Digital and analog ground planes should be joined in only one place, preferably underneath the AD7660, or, at least, as close as possible to the AD7660. If the AD7660 is in a system where multiple devices require analog to digital ground connections, the connection should still be made at one point only, a star ground point that should be established as close as possible to the AD7660.

It is recommended to avoid running digital lines under the device as these will couple noise onto the die. The analog ground plane should be allowed to run under the AD7660 to avoid noise coupling. Fast switching signals like  $\overline{CNVST}$  or clocks should be shielded with digital ground to avoid radiating noise to other sections of the board and should never run near analog signal paths. Crossover of digital and analog signals should be avoided. Traces on different but close layers of the board should run at right angles to each other. This will reduce the effect of feedthrough through the board.

The power supply lines to the AD7660 should use as large a trace as possible to provide low impedance paths and reduce the effect of glitches on the power supply lines. Good decoupling is also important to lower the supply's impedance presented to the AD7660 and to reduce the magnitude of the supply spikes. Decoupling ceramic capacitors, typically 100 nF, should be placed on each power supply pins AVDD, DVDD, and OVDD close to, and ideally right up against, these pins and their corresponding ground pins. Additionally, low ESR 10  $\mu$ F capacitors should be located in the vicinity of the ADC to further reduce low frequency ripple.

The DVDD supply of the AD7660 can be either a separate supply or come from the analog supply, AVDD, or from the digital interface supply, OVDD. When the system digital supply is noisy, or fast switching digital signals are present, it is recommended if no separate supply is available, to connect the DVDD digital supply to the analog supply AVDD through an RC filter as shown in Figure 6 and to connect the system supply to the interface digital supply OVDD and the remaining digital circuitry. When DVDD is powered from the system supply, it is useful to insert a bead to further reduce high frequency spikes.

The AD7660 has five different ground pins: INGND, REFGND, AGND, DGND, and OGND. INGND is used to sense the analog input signal. REFGND senses the reference voltage and should be a low impedance return to the reference because it carries pulsed currents. AGND is the ground to which most internal ADC analog signals are referenced. This ground must be connected with the least resistance to the analog ground plane. DGND must be tied to the analog or digital ground plane depending on the configuration. OGND is connected to the digital system ground.

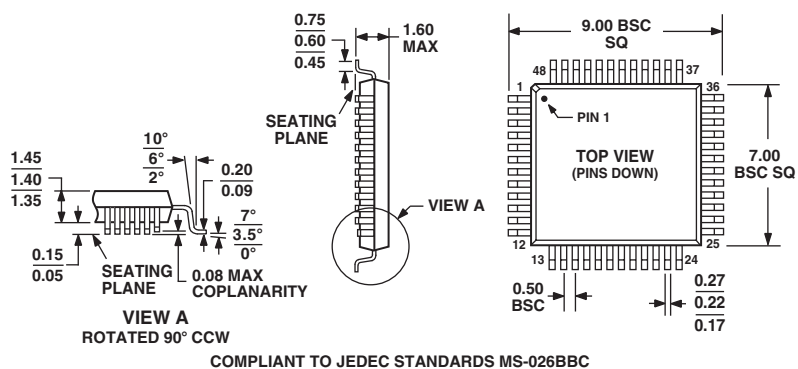
### Evaluating the AD7660 Performance

A recommended layout for the AD7660 is outlined in the EVAL-AD7660 evaluation board for the AD7660. The evaluation board package includes a fully assembled and tested evaluation board, documentation, and software for controlling the board from a PC via the EVAL-CONTROL-BRD2.

## OUTLINE DIMENSIONS

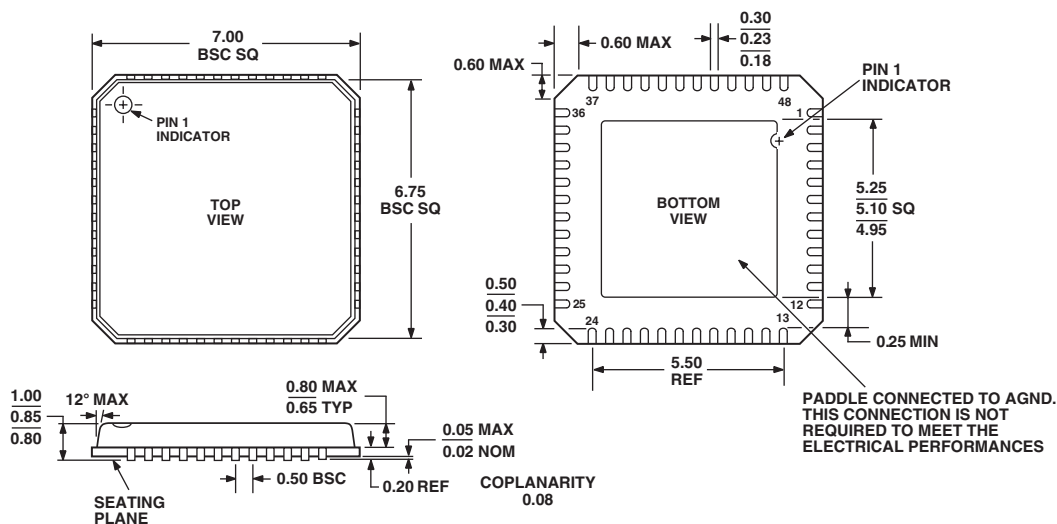
**48-Lead Plastic Quad Flatpack [LQFP]**  
**1.4 mm Thick**  
**(ST-48)**

Dimensions shown in millimeters



**48-Lead Frame Chip Scale Package [LFCSP]**  
**(CP-48)**

Dimensions shown in millimeters



## Revision History

| Location                                               | Page      |
|--------------------------------------------------------|-----------|
| <b>10/03—Data Sheet changed from REV. C to REV. D.</b> |           |
| Update format                                          | Universal |
| Changes to Table I                                     | 1         |
| Added PulSAR Selection table                           | 1         |
| Changes to FEATURES                                    | 1         |
| Changes to GENERAL DESCRIPTION                         | 1         |
| Changes to SPECIFICATIONS                              | 2         |
| Changes to ABSOLUTE MAXIMUM RATINGS                    | 4         |
| Changes to ORDERING GUIDE                              | 4         |
| Added Overvoltage Recovery section                     | 7         |
| Added TPC 15                                           | 9         |
| Changes to CIRCUIT INFORMATION section                 | 10        |
| Changes to Figure 3                                    | 10        |
| Renamed Table I to Table II                            | 11        |
| Changes to Figure 5 Notes                              | 11        |
| Changes to Figure 8 caption                            | 12        |
| Changes to Driver Amplifier Choise section             | 12        |
| Replaced Figure 10                                     | 13        |
| Changes to DIGITAL INTERFACE section                   | 14        |
| Replaced Figure 21                                     | 17        |
| Deleted Figure 22 and renumbered successive figures    | 18        |
| Replaced MICROPROCESSOR INTERFACING section            | 18        |
| Changes in Bipolar and Wider Input Ranges section      | 18        |
| Changes to Table III                                   | 18        |
| Added CP-48 package                                    | 19        |
| Update OUTLINE DIMENSIONS                              | 19        |
| <b>1/02—Data Sheet changed from REV. B to REV. C.</b>  |           |
| Edits to FEATURES                                      | 1         |
| Edits to FUNCTIONAL BLOCK DIAGRAM                      | 1         |
| Edits to SPECIFICATIONS                                | 2         |
| Edits to PIN FUNCTION DESCRIPTION                      | 6         |
| Edits to Driver Amplifier Choise section               | 12        |
| New Voltage Reference Input section                    | 13        |
| Edits to DIGITAL INTERFACE section                     | 14        |
| New ST-48 Package Outline                              | 20        |
| <b>9/01—Data Sheet changed from REV. A to REV. B.</b>  |           |
| Edit to Specifications                                 | 2         |
| Edit to Timing Specifications                          | 3         |
| Edit to ABSOLUTE MAXIMUM RATINGS                       | 4         |
| Edit to ORDERING GUIDE                                 | 4         |
| Edit to TYPICAL PERFORMANCE CHARACTERISTICS graphs     | 9, 10     |
| Edit to DRIVER AMPLIFIER CHOICE section                | 13        |
| Edit to Figure 18                                      | 17        |
| Edit to Figure 20                                      | 18        |
| Edit to Table II                                       | 19        |
| Edit to Bipolar and Wider Input Ranges section         | 19        |

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