1 Features

- Industry's First SAR ADC with Nanowatt Power Consumption:
  - 261 µW at 1 MSPS with 1.8-V AVDD
  - 900 µW at 1 MSPS with 3-V AVDD
  - 90 µW at 100 kSPS with 3-V AVDD
  - Less than 1 µW at 1 kSPS with 3-V AVDD
- Industry's Smallest SAR ADC:
  - X2QFN-8 Package with 2.25-mm² Footprint
- 1-MSPS Throughput with Zero Data Latency
- Wide Operating Range:
  - AVDD: 1.65 V to 3.6 V
  - DVDD: 1.65 V to 3.6 V (Independent of AVDD)
  - Temperature Range: –40°C to 125°C
- Excellent Performance:
  - 12-Bit Resolution with NMC
  - ±1-LSB (Max) DNL and INL
  - 71-dB SNR with 3-V AVDD
  - –85-dB THD with 3-V AVDD
- Unipolar, Differential Input Range:
  - AVDD to AVDD
- Integrated Offset Calibration
- SPI™-Compatible Serial Interface: 16 MHz
- JESD8-7A Compliant Digital I/O

2 Applications

- Low-Power Data Acquisition
- Battery-Powered Handheld Equipment
- Level Sensors
- Ultrasonic Flow Meters
- Motor Controls
- Wearable Fitness
- Portable Medical Equipment
- Hard Drives
- Glucose Meters

3 Description

The ADS7044 is a 1-MSPS, analog-to-digital converter (ADC). The device supports a wide analog input voltage range (±1.65 V to ±3.6 V) and includes a capacitor-based, successive-approximation register (SAR) ADC with an inherent sample-and-hold circuit. The SPI-compatible serial interface is controlled by the CS and SCLK signals. The input signal is sampled with the CS falling edge and SCLK is used for conversion and serial data output. The device supports a wide digital supply range (1.65 V to 3.6 V), enabling direct interface to a variety of host controllers. The device complies with the JESD8-7A standard for normal DVDD range (1.65 V to 1.95 V).

The device is available in 8-pin, miniature, leaded, and X2QFN packages and is specified for operation from –40°C to 125°C. Miniature form-factor and extremely low-power consumption make this device suitable for space-constrained, battery-powered applications.

Device Information

<table>
<thead>
<tr>
<th>PART NAME</th>
<th>PACKAGE</th>
<th>BODY SIZE (NOM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADS7044</td>
<td>X2QFN (8)</td>
<td>1.50 mm × 1.50 mm</td>
</tr>
<tr>
<td></td>
<td>VSSOP (8)</td>
<td>2.30 mm × 2.00 mm</td>
</tr>
</tbody>
</table>

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

NOTE: The device is smaller than a 0805 (2012 metric) SMD component.
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4 Revision History

Changes from Revision C (February 2015) to Revision D

- Changed Figure 1 ............................................................................................................................ 8
- Changed Serial Interface section: changed last half of first paragraph, changed Figure 35 .......... 19
- Changed Figure 38 ....................................................................................................................... 22
- Added Community Resources section ......................................................................................... 31

Changes from Revision B (December 2014) to Revision C

- Changed Wide Operating Range Features bullet: changed the value of AVDD from 1.8 V to 1.65 V ...... 1
- Changed the wide analog input voltage range value to ±1.65 V in first paragraph of Description section .... 1
- Changed AVDD parameter minimum specification in Recommended Operating Conditions table .......... 5
- Changed $E_C$ parameter uncalibrated test conditions in Electrical Characteristics table .................. 6
- Changed Maximum throughput rate parameter test conditions in Electrical Characteristics table ........ 6
- Changed AVDD parameter minimum specification in Electrical Characteristics table .................... 7
- Changed conditions for Timing Characteristics table: changed range of AVDD and added $C_{LOAD}$ condition ... 7
- Changed $I_{O_{CLK}}$ specification in Timing Characteristics table ......................................................... 7
- Added $I_{SCLK}$ minimum specification to Timing Characteristics table ............................................. 7
- Changed titles of Figure 26 to Figure 30 ....................................................................................... 12
- Changed Reference sub-section in Feature Description section ....................................................... 16
- Changed AVDD range in description of $f_{CLK-Cal}$ parameter in Table 2 ........................................ 21
- Changed AVDD range in description of $f_{CLK-Cal}$ parameter in Table 3 ........................................ 22
- Changed Reference Circuit section in Application Information ...................................................... 25
- Added last two sentences to AVDD and DVDD Supply Recommendations section ...................... 29
Changes from Revision A (November 2014) to Revision B

- Changed ESD Ratings table to latest standards ................................................................. 5
- Added footnote 3 to Electrical Characteristics table .......................................................... 6
- Changed y-axis unit in Figure 30 ....................................................................................... 13

Changes from Original (November 2014) to Revision A

- Made changes to product preview data sheet ................................................................. 1
## 5 Pin Configuration and Functions

### RUG Package 8-Pin X2QFN

<table>
<thead>
<tr>
<th>Pin</th>
<th>RUG No.</th>
<th>DCU No.</th>
<th>I/O</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AINM</td>
<td>8</td>
<td>5</td>
<td>Analog input</td>
<td>Analog signal input, negative</td>
</tr>
<tr>
<td>AINP</td>
<td>7</td>
<td>6</td>
<td>Analog input</td>
<td>Analog signal input, positive</td>
</tr>
<tr>
<td>AVDD</td>
<td>6</td>
<td>7</td>
<td>Supply</td>
<td>Analog power-supply input, also provides the reference voltage to the ADC</td>
</tr>
<tr>
<td>CS</td>
<td>1</td>
<td>4</td>
<td>Digital input</td>
<td>Chip-select signal, active low</td>
</tr>
<tr>
<td>DVDD</td>
<td>4</td>
<td>1</td>
<td>Supply</td>
<td>Digital I/O supply voltage</td>
</tr>
<tr>
<td>GND</td>
<td>5</td>
<td>8</td>
<td>Supply</td>
<td>Ground for power supply, all analog and digital signals are referred to this pin</td>
</tr>
<tr>
<td>SCLK</td>
<td>3</td>
<td>2</td>
<td>Digital input</td>
<td>Serial clock</td>
</tr>
<tr>
<td>SDO</td>
<td>2</td>
<td>3</td>
<td>Digital output</td>
<td>Serial data out</td>
</tr>
</tbody>
</table>

### DCU Package 8-Pin Leaded VSSOP

<table>
<thead>
<tr>
<th>Pin</th>
<th>RUG No.</th>
<th>DCU No.</th>
<th>I/O</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVDD</td>
<td>1</td>
<td>8</td>
<td>GND</td>
<td></td>
</tr>
<tr>
<td>SCLK</td>
<td>2</td>
<td>7</td>
<td>AVDD</td>
<td></td>
</tr>
<tr>
<td>SDO</td>
<td>3</td>
<td>6</td>
<td>AINP</td>
<td></td>
</tr>
<tr>
<td>CS</td>
<td>4</td>
<td>5</td>
<td>AINM</td>
<td></td>
</tr>
</tbody>
</table>
6 Specifications

6.1 Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVDD to GND</td>
<td>–0.3</td>
<td>3.9</td>
</tr>
<tr>
<td>DVDD to GND</td>
<td>–0.3</td>
<td>3.9</td>
</tr>
<tr>
<td>AINP to GND</td>
<td>–0.3</td>
<td>AVDD + 0.3</td>
</tr>
<tr>
<td>AINM to GND</td>
<td>–0.3</td>
<td>AVDD + 0.3</td>
</tr>
<tr>
<td>Digital input voltage to GND</td>
<td>–0.3</td>
<td>DVDD + 0.3</td>
</tr>
<tr>
<td>Storage temperature, (T_{stg})</td>
<td>–60</td>
<td>150</td>
</tr>
</tbody>
</table>

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

6.2 ESD Ratings

<table>
<thead>
<tr>
<th>(V_{\text{ESD}}) (ESD)</th>
<th>VALUE</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human body model (HBM), per ANSI/ESDA/JEDEC JS-001</td>
<td>±2000</td>
<td>V</td>
</tr>
<tr>
<td>Charged device model (CDM), per JEDEC specification JESD22-C101</td>
<td>±1000</td>
<td>V</td>
</tr>
</tbody>
</table>

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

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

6.3 Recommended Operating Conditions

<table>
<thead>
<tr>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVDD</td>
<td>Analog supply voltage range</td>
<td>1.65</td>
</tr>
<tr>
<td>DVDD</td>
<td>Digital supply voltage range</td>
<td>1.65</td>
</tr>
<tr>
<td>(T_A)</td>
<td>Operating free-air temperature</td>
<td>–40</td>
</tr>
</tbody>
</table>

6.4 Thermal Information

<table>
<thead>
<tr>
<th>THERMAL METRIC(^{(1)})</th>
<th>ADS7044</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RUG (X2QFN)</td>
</tr>
<tr>
<td>(R_{JA})</td>
<td>Junction-to-ambient thermal resistance</td>
</tr>
<tr>
<td>(R_{J,C(\text{top})})</td>
<td>Junction-to-case (top) thermal resistance</td>
</tr>
<tr>
<td>(R_{JB})</td>
<td>Junction-to-board thermal resistance</td>
</tr>
<tr>
<td>(\psi_{JT})</td>
<td>Junction-to-top characterization parameter</td>
</tr>
<tr>
<td>(\psi_{JB})</td>
<td>Junction-to-board characterization parameter</td>
</tr>
<tr>
<td>(R_{J,C(\text{bot})})</td>
<td>Junction-to-case (bottom) thermal resistance</td>
</tr>
</tbody>
</table>

(1) For more information about traditional and new thermal metrics, see the IC Package Thermal Metrics application report, SPRA953.
6.5 Electrical Characteristics

At $T_A = -40°C$ to 125°C, AVDD = 3 V, DVDD = 1.65 V to 3.6 V, $f_{SAMPLE} = 1$ MSPS, unless otherwise noted.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANALOG INPUT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full-scale input voltage span$^{(1)}$</td>
<td>–AVDD to AVDD</td>
<td>V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute input voltage range</td>
<td>AINP to GND</td>
<td>–0.1 AVDD + 0.1 V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AINM to GND</td>
<td>–0.1 AVDD + 0.1 V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$C_{S}$</td>
<td>Sampling capacitance</td>
<td>15 pF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SYSTEM PERFORMANCE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resolution</td>
<td></td>
<td>12</td>
<td>Bits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NMC</td>
<td>No missing codes</td>
<td>12</td>
<td>Bits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INL</td>
<td>Integral nonlinearity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AVDD = 3 V</td>
<td>–1 ±0.7 1 LSB$^{(2)}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AVDD = 1.8 V</td>
<td>–2 ±1 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DNL</td>
<td>Differential nonlinearity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AVDD = 3 V</td>
<td>–0.99 ±0.5 1 LSB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AVDD = 1.8 V</td>
<td>–0.99 ±0.7 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$E_{O}$</td>
<td>Uncalibrated offset error</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AVDD = 1.65 V to 3.6 V</td>
<td>±12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$E_{O}$</td>
<td>Calibrated offset error$^{(3)}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AVDD = 3 V</td>
<td>–3 ±0.5 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AVDD = 1.8 V</td>
<td>–4 ±1 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$dV_{OS}/dT$</td>
<td>Offset error drift with temperature</td>
<td>5 ppm/°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$E_{O}$</td>
<td>Gain error</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AVDD = 3 V</td>
<td>–0.1 ±0.05 0.1 %FS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AVDD = 1.8 V</td>
<td>–0.2 ±0.1 0.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gain error drift with temperature</td>
<td>2 ppm/°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMRR</td>
<td>Common-mode rejection ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$f_{IN} = 2$ kHz, AVDD = 3 V</td>
<td>53 dB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAMPLING DYNAMICS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$t_{ACQ}$</td>
<td>Acquisition time</td>
<td>200 ns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum throughput rate</td>
<td>16-MHz SCLK, AVDD = 1.65 V to 3.6 V</td>
<td>1 MHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DYNAMIC CHARACTERISTICS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SNR</td>
<td>Signal-to-noise ratio$^{(4)}$</td>
<td>$f_{IN} = 2$ kHz, AVDD = 3 V</td>
<td>70</td>
<td>71 dB</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$f_{IN} = 2$ kHz, AVDD = 1.8 V</td>
<td>70</td>
<td>dB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>THD</td>
<td>Total harmonic distortion$^{(4,5)}$</td>
<td>$f_{IN} = 2$ kHz, AVDD = 3 V</td>
<td>–85 dB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SINAD</td>
<td>Signal-to-noise and distortion$^{(6)}$</td>
<td>$f_{IN} = 2$ kHz, AVDD = 3 V</td>
<td>69.5 dB</td>
<td>71</td>
<td>dB</td>
</tr>
<tr>
<td></td>
<td>$f_{IN} = 2$ kHz, AVDD = 1.8 V</td>
<td>70</td>
<td>dB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SFDR</td>
<td>Spurious-free dynamic range$^{(6)}$</td>
<td>$f_{IN} = 2$ kHz, AVDD = 3 V</td>
<td>85 dB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW</td>
<td>Full-power bandwidth</td>
<td>At $–3$ dB, AVDD = 3 V</td>
<td>25 MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIGITAL INPUT/OUTPUT (CMOS Logic Family)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{IH}$</td>
<td>High-level input voltage$^{(6)}$</td>
<td></td>
<td>0.65 DVDD</td>
<td>DVDD + 0.3 V</td>
<td></td>
</tr>
<tr>
<td>$V_{IL}$</td>
<td>Low-level input voltage$^{(6)}$</td>
<td></td>
<td>–0.3</td>
<td>0.35 DVDD</td>
<td>V</td>
</tr>
<tr>
<td>$V_{OH}$</td>
<td>High-level output voltage$^{(6)}$</td>
<td>At $I_{source} = 500$ µA</td>
<td>0.8 DVDD</td>
<td>DVDD</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At $I_{source} = 2$ mA</td>
<td>DVDD – 0.45</td>
<td>DVDD</td>
<td></td>
</tr>
<tr>
<td>$V_{OL}$</td>
<td>Low-level output voltage$^{(6)}$</td>
<td>At $I_{sink} = 500$ µA</td>
<td>0</td>
<td>0.2 DVDD</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At $I_{sink} = 2$ mA</td>
<td>0</td>
<td>0.45</td>
<td>V</td>
</tr>
</tbody>
</table>

$^{(1)}$ Ideal input span; does not include gain or offset error.
$^{(2)}$ LSB means least significant bit.
$^{(3)}$ Refer to the Offset Calibration section for more details.
$^{(4)}$ All specifications expressed in decibels (dB) refer to the full-scale input (FSR) and are tested with an input signal 0.5 dB below full-scale, unless otherwise specified.
$^{(5)}$ Calculated on the first nine harmonics of the input frequency.
$^{(6)}$ Digital voltage levels comply with the JESD8-7A standard for DVDD from 1.65 V to 1.95 V. See the Digital Voltage Levels section for more details.
Electrical Characteristics (continued)

At $T_A = -40^\circ C$ to 125$^\circ C$, $AVDD = 3$ V, $DVDD = 1.65$ V to 3.6 V, $f_{SAMPLE} = 1$ MSPS, unless otherwise noted.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>POWER-SUPPLY REQUIREMENTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$AVDD$ Analog supply voltage</td>
<td></td>
<td>1.65</td>
<td>3</td>
<td>3.6</td>
<td>V</td>
</tr>
<tr>
<td>$DVDD$ Digital I/O supply voltage</td>
<td></td>
<td>1.65</td>
<td>3</td>
<td>3.6</td>
<td>V</td>
</tr>
<tr>
<td>$I_{AVDD}$ Analog supply current</td>
<td>At 1 MSPS with $AVDD = 3$ V</td>
<td>300</td>
<td></td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td></td>
<td>At 100 kSPS with $AVDD = 3$ V</td>
<td>30</td>
<td></td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td></td>
<td>At 1 MSPS with $AVDD = 1.8$ V</td>
<td>145</td>
<td></td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>$P_D$ Power dissipation</td>
<td>At 1 MSPS with $AVDD = 3$ V</td>
<td>900</td>
<td></td>
<td></td>
<td>µW</td>
</tr>
<tr>
<td></td>
<td>At 100 kSPS with $AVDD = 3$ V</td>
<td>90</td>
<td></td>
<td></td>
<td>µW</td>
</tr>
<tr>
<td></td>
<td>At 1 MSPS with $AVDD = 1.8$ V</td>
<td>261</td>
<td></td>
<td></td>
<td>µW</td>
</tr>
</tbody>
</table>

6.6 Timing Characteristics

All specifications are at $T_A = -40^\circ C$ to 125$^\circ C$, $AVDD = 1.65$ V to 3.6 V, $DVDD = 1.65$ V to 3.6 V, and $C_{LOAD}$ on SDO = 20 pF, unless otherwise specified.

<table>
<thead>
<tr>
<th>TIMING SPECIFICATIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_{THROUGHPUT}$ Throughput</td>
<td>1</td>
<td></td>
<td>1</td>
<td>MSPS</td>
</tr>
<tr>
<td>$t_{CYCLE}$ Cycle time</td>
<td></td>
<td></td>
<td>1</td>
<td>µs</td>
</tr>
<tr>
<td>$t_{CONV}$ Conversion time</td>
<td>12.5</td>
<td>$t_{SCLK} + t_{SU_CSCK}$</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>$t_{DV_CSDO}$ Delay time: CS falling to data enable</td>
<td>10</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>$t_{D_CKDO}$ Delay time: SCLK falling to (next) data valid on DOUT, AVDD = 1.8 V to 3.6 V</td>
<td>30</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td>Delay time: SCLK falling to (next) data valid on DOUT, AVDD = 1.65 V to 1.8 V</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$t_{DOZ_CSDO}$ Delay time: CS rising to DOUT going to 3-state</td>
<td>5</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TIMING REQUIREMENTS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{ACQ}$ Acquisition time</td>
<td>200</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>$f_{SCLK}$ SCLK frequency</td>
<td>0.016</td>
<td>16</td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td>$t_{SCLK}$ SCLK period</td>
<td>62.5</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>$t_{PH_CK}$ SCLK high time</td>
<td>0.45</td>
<td>0.55</td>
<td>$t_{SCLK}$</td>
<td></td>
</tr>
<tr>
<td>$t_{PL_CK}$ SCLK low time</td>
<td>0.45</td>
<td>0.55</td>
<td>$t_{SCLK}$</td>
<td></td>
</tr>
<tr>
<td>$t_{PH_CS}$ CS high time</td>
<td>60</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>$t_{SU_CSCK}$ Setup time: CS falling to SCLK falling</td>
<td>15</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>$t_{DCCKC}$ Delay time: last SCLK falling to CS rising</td>
<td>10</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
</tbody>
</table>
Figure 1. Timing Diagram
6.7 Typical Characteristics
At $T_A = 25^\circ C$, AVDD = 3 V, DVDD = 1.8 V, and $f_{SAMPLE} = 1$ MSPS, unless otherwise noted.

SNR = 72.58 dB
THD = –93 dB
$f_{IN} = 2$ kHz
Number of samples = 32768

SNR = 71.95 dB
THD = –76.5 dB
$f_{IN} = 250$ kHz
Number of samples = 32768

Figure 2. Typical FFT
Figure 3. Typical FFT

SNR
SINAD

f$_{IN}$ = 2 kHz

Free-Air Temperature (°C)

75
74
73
72
71
70

40
-7
26
59
92
125

Figure 4. SNR and SINAD vs Temperature

SNR
SINAD

f$_{IN}$ = 2 kHz

Input Frequency (kHz)

76
74
72
70
68
66

0
50
100
150
200
250

Figure 5. SNR and SINAD vs Input Frequency

SNR
SINAD

f$_{IN}$ = 2 kHz

Reference Voltage (V)

75
74
73
72
71
70
69
1.8
2.1
2.4
2.7
3
3.3
3.6

Figure 6. SNR and SINAD vs Reference Voltage (AVDD)

Total Harmonic Distortion (dB)

-83
-85
-87
-89
-91
-93

-40
-7
26
59
92
125

Figure 7. THD vs Free-Air Temperature
Typical Characteristics (continued)

At $T_A = 25^\circ C$, AVDD = 3 V, DVDD = 1.8 V, and $f_{SAMPLE} = 1$ MSPS, unless otherwise noted.

![Figure 8. THD vs Input Frequency](image1)

![Figure 9. THD vs Reference Voltage (AVDD)](image2)

![Figure 10. SFDR vs Free-Air Temperature](image3)

![Figure 11. SFDR vs Input Frequency](image4)

![Figure 12. SFDR vs Reference Voltage (AVDD)](image5)

![Figure 13. DC Input Histogram](image6)

Mean code = 2046.98
Sigma = 0.14
Typical Characteristics (continued)

At $T_A = 25^\circ C$, $AVDD = 3\, V$, $DVDD = 1.8\, V$, and $f_{SAMPLE} = 1\, MSPS$, unless otherwise noted.

Figure 14. Offset vs Free-Air Temperature

Figure 15. Offset vs Reference Voltage (AVDD)

Figure 16. Gain Error vs Free-Air Temperature

Figure 17. Gain Error vs Reference Voltage (AVDD)

Figure 18. Typical DNL

Figure 19. Typical INL
Typical Characteristics (continued)

At $T_A = 25^\circ C$, $AVDD = 3\, V$, $DVDD = 1.8\, V$, and $f_{SAMPLE} = 1\, \text{MSPS}$, unless otherwise noted.

**Figure 20. Typical DNL**

**Figure 21. Typical INL**

**Figure 22. DNL vs Free-Air-Temperature**

**Figure 23. DNL vs Reference Voltage (AVDD)**

**Figure 24. INL vs Free-Air Temperature**

**Figure 25. INL vs Reference Voltage (AVDD)**
Typical Characteristics (continued)

At $T_A = 25^\circ C$, $AVDD = 3$ V, $DVDD = 1.8$ V, and $f_{\text{SAMPLE}} = 1$ MSPS, unless otherwise noted.

![Figure 26. AVDD Supply Current vs Free-Air Temperature](image1)

$AVDD = 3$ V

![Figure 27. AVDD Supply Current vs Throughput](image2)

$AVDD = 1.8$ V

![Figure 28. AVDD Supply Current vs Throughput](image3)

$AVDD$ Static Current vs Free-Air Temperature

![Figure 30. AVDD Static Current vs Free-Air Temperature](image4)
7 Parameter Measurement Information

7.1 Digital Voltage Levels

The device complies with the JESD8-7A standard for DVDD from 1.65 V to 1.95 V. Figure 31 shows voltage levels for the digital input and output pins.

Figure 31. Digital Voltage Levels as per the JESD8-7A Standard
8 Detailed Description

8.1 Overview

The ADS7044 is an ultralow-power, ultra-small analog-to-digital converter (ADC) that supports a wide analog input range. The analog input range for the device is defined by the AVDD supply voltage. The device samples the input voltage across the AINP and AINM pins on the CS falling edge and starts the conversion. The clock provided on the SCLK pin is used for conversion and data transfer. During conversions, both the AINP and AINM pins are disconnected from the sampling circuit. After the conversion completes, the sampling capacitors are reconnected across the AINP and AINM pins and the device enters acquisition phase.

The device has an internal offset calibration. The offset calibration can be initiated by the user either on power-up or during normal operation; see the Offset Calibration section for more details.

The device also provides a simple serial interface to the host controller and operates over a wide range of digital power supplies. The device requires only a 16-MHz SCLK for supporting a throughput of 1 MSPS. The digital interface also complies with the JESD8-7A (normal range) standard. The Functional Block Diagram section provides a block diagram of the device.

8.2 Functional Block Diagram
8.3 Feature Description

8.3.1 Reference

The device uses the analog supply voltage (AVDD) as a reference, as shown in Figure 32. TI recommends decoupling the AVDD pin with a 1-µF, low equivalent series resistance (ESR) ceramic capacitor. The minimum capacitor value required for AVDD is 200 nF. The AVDD pin functions as a switched capacitor load to the source powering AVDD. The decoupling capacitor provides the instantaneous charge required by the internal circuit and helps in maintaining a stable dc voltage on the AVDD pin. TI recommends powering the AVDD pin with a low output impedance and low-noise regulator (such as the TPS79101).

![Figure 32. Reference for the Device](image-url)
Feature Description (continued)

8.3.2 Analog Input

The device supports differential analog inputs. The ADC samples the difference between AINP and AINM and converts for this voltage. The device is capable of accepting a signal from 0 V to AVDD on the AINM input and a signal from 0 V to AVDD on the AINP input. Figure 33 represents the equivalent analog input circuits for the sampling stage. The device has a low-pass filter followed by the sampling switch and sampling capacitor. The sampling switch is represented by an $R_s$ (typically $50 \, \Omega$) resistor in series with an ideal switch and $C_s$ (typically $15 \, \text{pF}$) is the sampling capacitor. The ESD diodes are connected from both analog inputs to AVDD and ground.

![Equivalent Input Circuit for the Sampling Stage](image)

The analog input full-scale range (FSR) is defined by the reference voltage of the ADC. The relationship between the FSR and the reference voltage can be determined by: $\text{FSR} = 2 \times V_{\text{REF}} = 2 \times AVDD$.

8.3.3 ADC Transfer Function

The device output is in twos compliment format. The device resolution can be computed by Equation 1:

$$1 \, \text{LSB} = \frac{\text{FSR}}{2^N}$$

where:

- $\text{FSR} = 2 \times V_{\text{REF}} = 2 \times AVDD$ and
- $N = 12$  

(Eq. 1)
Feature Description (continued)

Figure 34 and Table 1 show the ideal transfer characteristics for the device.

![Ideal Transfer Characteristics Diagram](attachment:image.png)

**Figure 34. Ideal Transfer Characteristics**

<table>
<thead>
<tr>
<th>INPUT VOLTAGE (AINP-AINM)</th>
<th>CODE</th>
<th>DESCRIPTION</th>
<th>IDEAL OUTPUT CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\leq -(V_{REF} - 1 \text{ LSB}))</td>
<td>NFSC</td>
<td>Negative full-scale code</td>
<td>800</td>
</tr>
<tr>
<td>(-(V_{REF} - 1 \text{ LSB})) to (-(V_{REF} - 2 \text{ LSBs}))</td>
<td>NFSC + 1</td>
<td>—</td>
<td>801</td>
</tr>
<tr>
<td>0 to 1 (\text{ LSB})</td>
<td>MC</td>
<td>Mid code</td>
<td>000</td>
</tr>
<tr>
<td>1 (\text{ LSB}) to 2 (\text{ LSBs})</td>
<td>MC + 1</td>
<td>—</td>
<td>001</td>
</tr>
<tr>
<td>(\geq V_{REF} - 1 \text{ LSB})</td>
<td>PFSC</td>
<td>Positive full-scale code</td>
<td>7FF</td>
</tr>
</tbody>
</table>
8.3.4 Serial Interface

The device supports a simple, SPI-compatible interface to the external host. The CS signal defines one conversion and serial transfer frame. A frame starts with a CS falling edge and ends with a CS rising edge. The SDO pin outputs the ADC conversion results. Figure 35 shows a detailed timing diagram for the serial interface. A minimum delay of $t_{SU_{CSCK}}$ must elapse between the CS falling edge and the first SCLK falling edge. The device uses the clock provided on the SCLK pin for conversion and data transfer. The conversion result is available on the SDO pin with the first two bits set to 0, followed by 12 bits of the conversion result. The first zero is launched on the SDO pin on the CS falling edge. Subsequent bits (starting with another 0 followed by the conversion result) are launched on the SDO pin on subsequent SCLK falling edges. The SDO output remains low after 14 SCLKs. A CS rising edge ends the frame and brings the serial data bus to 3-state. For the acquisition of the next sample, a minimum time of $t_{ACQ}$ must be provided after the conversion of the current sample is completed. For details on timing specifications, see the Timing Characteristics table.

The device initiates offset calibration on first CS falling edge after power-up and the SDO output remains low during the first serial transfer frame after power-up. For details, refer to the Offset Calibration section.

Figure 35. Serial Interface Timing Diagram
8.4 Device Functional Modes

8.4.1 Offset Calibration

The device includes a feature to calibrate its internal offset. The device initiates offset calibration on the first CS falling edge after power up and during offset calibration, the analog input pins (AINP and AINM) are disconnected from the sampling stage. After the first serial transfer frame, the device starts operating with either uncalibrated or calibrated offset, depending on the number of SCLKs provided in the first serial transfer frame. Offset calibration can also be initiated by the user during normal operation. Figure 36 shows the offset calibration process. The SDO output remains low during the first serial transfer frame.

The device includes an internal offset calibration register (OCR) that stores the offset calibration result. The OCR is an internal register and cannot be accessed by the user through the serial interface. The OCR is reset to zero on power-up. Therefore, TI recommends calibrating the offset on power-up to bring the offset within the specified limits. If there is a significant change in operating temperature or analog supply voltage, the offset can be recalibrated during normal operation.

(1) See the Timing Characteristics section for timing specifications.
(2) See the Offset Calibration During Normal Operation section for details.
(3) See the Offset Calibration on Power-Up section for details.
(4) The power recycle on the AVDD supply is required to reset the offset calibration and to bring the device to a power-up state.

Figure 36. Offset Calibration
Device Functional Modes (continued)

8.4.1.1 Offset Calibration on Power-Up

The device starts offset calibration on the first CS falling edge after power-up and calibration completes if the CS pin remains low for at least 16 SCLKs after the first CS falling edge. The SDO output remains low during calibration. The minimum acquisition time must be provided after calibration for acquiring the first sample. If the device is not provided with at least 16 SCLKs during the first serial transfer frame after power-up, the OCR is not updated. Table 2 provides the timing parameters for offset calibration on power-up.

For subsequent samples, the device adjusts the conversion results with the value stored in the OCR. The conversion result adjusted with the value stored in OCR is provided by the device on the SDO output. Figure 37 shows the timing diagram for offset calibration on power-up.

Table 2. Offset Calibration on Power-Up

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f_{\text{CLK-CAL}} )</td>
<td>16</td>
<td></td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td>SCLK frequency for calibration at 2.25 V &lt; AVDD &lt; 3.6 V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( f_{\text{CLK-CAL}} )</td>
<td>12</td>
<td></td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td>SCLK frequency for calibration at 1.65 V &lt; AVDD &lt; 2.25 V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( t_{\text{POWERUP-CAL}} )</td>
<td>16</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>Calibration time at power-up</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( t_{\text{ACQ}} )</td>
<td>200</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>Acquisition time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( t_{\text{PH_CS}} )</td>
<td></td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>CS high time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 37. Offset Calibration on Power-Up Timing Diagram
8.4.1.2 Offset Calibration During Normal Operation

The offset can also be calibrated during normal device operation. Offset calibration can be done during normal device operation if at least 32 SCLKs are provided in one serial transfer frame. During the first 14 SCLKs, the device converts the sample acquired on the CS falling edge and provides data on the SDO output. The device initiates the offset calibration on the 17th SCLK falling edge and calibration is completed on the 32nd SCLK falling edge. The SDO output remains low after the 14th SCLK falling edge and SDO goes to 3-state after CS goes high. If the device is provided with less than 32 SCLKs during a serial transfer frame, the OCR is not updated. Table 3 provides the timing parameters for offset calibration during normal operation.

For subsequent samples, the device adjusts the conversion results with the value stored in OCR. The conversion result adjusted with the value stored in the OCR is provided by the device on the SDO output. Figure 38 shows the timing diagram for offset calibration during normal operation.

### Table 3. Offset Calibration During Normal Operation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f_{\text{CLK-CAL}} )</td>
<td>SCLK frequency for calibration for 2.25 V &lt; AVDD &lt; 3.6 V</td>
<td>16</td>
<td>MHz</td>
<td></td>
</tr>
<tr>
<td>( f_{\text{CLK-CAL}} )</td>
<td>SCLK frequency for calibration for 1.65 V &lt; AVDD &lt; 2.25 V</td>
<td>12</td>
<td>MHz</td>
<td></td>
</tr>
<tr>
<td>( t_{\text{CAL}} )</td>
<td>Calibration time during normal operation</td>
<td>16 ( t_{\text{SCLK}} )</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>( t_{\text{ACQ}} )</td>
<td>Acquisition time</td>
<td>200</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>( t_{\text{PH-CS}} )</td>
<td>CS high time</td>
<td>( t_{\text{ACQ}} )</td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 38. Offset Calibration During Normal Operation Timing Diagram**
9 Application and Implementation

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

9.1 Application Information
The two primary circuits required to maximize the performance of a high-precision, successive approximation register (SAR), analog-to-digital converter (ADC) are the input driver and the reference driver circuits. This section details some general principles for designing the input driver circuit, reference driver circuit, and provides some application circuits designed for the ADS7044.

9.2 Typical Applications

9.2.1 Single-Supply DAQ with the ADS7044

9.2.1.1 Design Requirements
The goal of this application is to design a single-supply digital acquisition (DAQ) circuit based on the ADS7044 with SNR greater than 71 dB and THD less than –85 dB for a differential input signal having an amplitude of AVDD with a common-mode voltage of AVDD / 2 and input frequencies of 5 kHz at a throughput of 1 MSPS.

9.2.1.2 Detailed Design Procedure
The input driver circuit for a high-precision ADC mainly consists of two parts: a driving amplifier and an antialiasing filter. Careful design of the front-end circuit is critical to meet the linearity and noise performance of a high-precision ADC.
Typical Applications (continued)

9.2.1.2.1 Antialiasing Filter

Converting analog-to-digital signals requires sampling an input signal at a rate greater than or equal to the Nyquist rate. Any higher frequency content in the input signal beyond half the sampling frequency is digitized and folded back into the low-frequency spectrum. This process is called **aliasing**. Therefore, an external, antialiasing filter must be used to remove the harmonic content from the input signal before being sampled by the ADC. An antialiasing filter is designed as a low-pass RC filter, for which the 3-dB bandwidth is optimized for noise, response time, and throughput. For dc signals with fast transients (including multiplexed input signals), a high-bandwidth filter is designed to allow the signal to be accurately set at the ADC inputs during the small acquisition time window. Figure 40 provides the equation for determining the bandwidth of antialiasing filter.

![Antialiasing Filter](image)

**Figure 40. Antialiasing Filter**

For ac signals, the filter bandwidth must be kept low to band limit the noise fed into the ADC input, thereby increasing the signal-to-noise ratio (SNR) of the system. Besides filtering the noise from the front-end drive circuitry, the RC filter also helps attenuate the sampling charge injection from the switched-capacitor input stage of the ADC. A filter capacitor, $C_{FLT}$, is connected across the ADC inputs. This capacitor helps reduce the sampling charge injection and provides a charge bucket to quickly charge the internal sample-and-hold capacitors during the acquisition process. As a rule of thumb, the value of this capacitor must be at least 20 times the specified value of the ADC sampling capacitance. For this device, the input sampling capacitance is equal to 15 pF. Thus, the value of $C_{FLT}$ must be greater than 300 pF. The capacitor must be a COG- or NPO-type because these capacitor types have a high-Q, low-temperature coefficient, and stable electrical characteristics under varying voltages, frequency, and time.

Note that driving capacitive loads can degrade the phase margin of the input amplifiers, thus making the amplifier marginally unstable. To avoid amplifier stability issues, series isolation resistors ($R_{FLT}$) are used at the output of the amplifiers. A higher value of $R_{FLT}$ is helpful from the amplifier stability perspective, but adds distortion as a result of interactions with the nonlinear input impedance of the ADC. Distortion increases with source impedance, input signal frequency, and input signal amplitude. Therefore, the selection of $R_{FLT}$ requires balancing the stability and distortion of the design.

The input amplifier bandwidth must be much higher than the cutoff frequency of the antialiasing filter. TI strongly recommends performing a SPICE simulation to confirm that the amplifier has more than 40° phase margin with the selected filter. Simulation is critical because even with high-bandwidth amplifiers, some amplifiers may require more bandwidth than others to drive similar filters.
Typical Applications (continued)

9.2.1.2.2 Input Amplifier Selection

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

- Small-signal bandwidth: Select the small-signal bandwidth of the input amplifiers to be high enough to settle the input signal in the acquisition time of the ADC. Higher bandwidth reduces the closed-loop output impedance of the amplifier, thus allowing the amplifier to more easily drive the low cutoff frequency RC filter at the ADC inputs. Higher bandwidth also minimizes the harmonic distortion at higher input frequencies. In order to maintain the overall stability of the input driver circuit, select the amplifier bandwidth as described in **Equation 2**:

\[
\text{GBW} \geq 4 \times \frac{1}{2\pi \times 2R_{\text{LT}} \times C_{\text{LT}}}
\]

where:

- \( \text{GBW} \) = Unity-gain bandwidth

- Noise: Noise contribution of the front-end amplifiers must be low enough to prevent any degradation in SNR performance of the system. As a rule of thumb, to ensure that the noise performance of the data acquisition system is not limited by the front-end circuit, keep the total noise contribution from the front-end circuit below 20% of the input-referred noise of the ADC. Noise from the input driver circuit is band limited by designing a low cutoff frequency RC filter, as explained in **Equation 3**.

\[
\frac{V_{\text{1/f, AMP, PP}}}{6.63 \times 2\beta} \leq \frac{2kT R_0 R_3}{(2\beta)^2} + \frac{2kT (R_0 + R_3)}{(2\beta)^2} + kT R_0 R_3 \left( \frac{1}{2\beta} \right) \leq \frac{1}{3} \times \frac{V_{\text{REF}}}{\sqrt{2}} \times 10^{-\frac{\text{SNR}_{\text{dB}}}{20}}
\]

where:

- \( V_{\text{1/f, AMP, PP}} \) is the peak-to-peak flicker noise in \( \mu \text{VRms} \),
- \( e_{\text{np, RMS}} \) is the amplifier broadband noise,
- \( f_{\text{-3dBi}} \) is the –3-dB bandwidth of the RC filter,
- \( k \) is the Boltzmann’s constant, and
- \( T \) is absolute temperature in kelvin.

- For symmetrical feedback, \( \beta = R_1 / (R_1 + R_2) = R_3 / (R_3 + R_4) \).

- For details on noise analysis, refer to the technical brief *Analysis of fully differential amplifiers (SLYT157)*

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

The **OPA316** is selected for this application for its rail-to-rail input and output swing, low-noise (11 nV/\( \sqrt{\text{Hz}} \)), and low-power (400 \( \mu \text{A} \)) performance to support a single-supply data acquisition circuit.

9.2.1.2.3 Reference Circuit

The analog supply voltage of the device is also used as a voltage reference for conversion. TI recommends decoupling the AVDD pin with a 1-\( \mu \text{F} \), low-ESR ceramic capacitor. The minimum capacitor value required for AVDD is 200 nF.
9.2.1.3 Application Curve

Figure 41 shows the FFT plot for the device with a 5-kHz input frequency for the circuit in Figure 39.

![FFT plot]

SNR = 72.2 dB     THD = –85.7 dB     SINAD = 72 dB
Number of samples = 8192

Figure 41. Test Results for the ADS7044 and OPA316 for a 5-kHz Input
9.2.2 Ultra-Low Power and Ultra-Small, High CMRR DAQ Circuit with the ADS7044

![Diagram of the DAQ Circuit]

Figure 42. ADS7044 DAQ Circuit

9.2.2.1 Design Requirements

For this design example, use the parameters listed in Table 4 as input parameters.

<table>
<thead>
<tr>
<th>DESIGN PARAMETER</th>
<th>GOAL VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SINAD</td>
<td>71 dB</td>
</tr>
<tr>
<td>Throughput</td>
<td>1 MSPS</td>
</tr>
<tr>
<td>AVDD</td>
<td>3.3 V</td>
</tr>
<tr>
<td>AVDD current consumption</td>
<td>800 µA (at a 5-kHz fIN) and 1500 µA (at a 25-kHz fIN)</td>
</tr>
<tr>
<td>VIN to the THS4531A</td>
<td>–AVDD to AVDD</td>
</tr>
<tr>
<td>Common-mode voltage for VIN to the THS4531A</td>
<td>0 V to AVDD / 2</td>
</tr>
</tbody>
</table>

9.2.2.2 Detailed Design Procedure

See the Detailed Design Procedure section in the Single-Supply DAQ with the ADS7044 application for further details.

To achieve a SINAD of 71 dB, the operational amplifier must have high bandwidth to settle the input signal within the acquisition time of the ADC. The operational amplifier must have low noise to keep the total system noise below 20% of the input-referred noise of the ADC.

For the application circuit shown in Figure 42, the THS4531A is selected for its high bandwidth (36 MHz), low noise (10 nV/√Hz), and for its capability to set the common-mode voltage for the ADC. The THS4531A rejects the variation of common-mode at its input and provides a CMRR of 90 dB (min).
9.2.2.3 Application Curves

Figure 43 shows the FFT plot for the device with a 5-kHz input frequency for the circuit in Figure 42. Figure 44 shows the FFT plot for the device with a 25-kHz input frequency for the circuit in Figure 42.

![FFT Plot for 5-kHz Input](image1)

**Figure 43.** Test Results for the ADS7044 and THS4531A for a 5-kHz Input

SNR = 72.3 dB  
THD = –87.8 dB  
SINAD = 72.2 dB  
AVDD current = 740 µA, Number of samples = 8192

![FFT Plot for 25-kHz Input](image2)

**Figure 44.** Test Results for the ADS7044 and THS4531A for a 25-kHz Input

SNR = 71.6 dB  
THD = –85 dB  
SINAD = 71.4 dB  
AVDD current = 1375 µA, Number of samples = 8192
10 Power-Supply Recommendations

10.1 AVDD and DVDD Supply Recommendations

The device has two separate power supplies: AVDD and DVDD. The device operates on AVDD; DVDD is used for the interface circuits. AVDD and DVDD can be independently set to any value within the permissible ranges. The AVDD supply also defines the full-scale input range of the device. Decouple the AVDD and DVDD pins individually with 1-µF ceramic decoupling capacitors, as shown in Figure 45. The minimum capacitor value required for AVDD and DVDD is 200 nF and 20 nF, respectively. If both supplies are powered from the same source, a minimum capacitor value of 220 nF is required for decoupling.

![Figure 45. Power-Supply Decoupling](image)

10.2 Estimating Digital Power Consumption

The current consumption from the DVDD supply depends on the DVDD voltage, load capacitance on the SDO line, and the output code. The load capacitance on the SDO line is charged by the current from the SDO pin on every rising edge of the data output and is discharged on every falling edge of the data output. The current consumed by the device from the DVDD supply can be calculated by Equation 4:

\[
I_{DVDD} = C \times V \times f
\]

where:
- \(C\) = Load capacitance on the SDO line,
- \(V\) = DVDD supply voltage, and
- \(f\) = Number of transitions on the SDO output. \(\text{(4)}\)

The number of transitions on the SDO output depends on the output code, and thus changes with the analog input. The maximum value of \(f\) occurs when data output on the SDO change on every SCLK. SDO changing on every SCLK results in an output code of AAAh or 555h. For an output code of AAAh or 555h at a 1-MSPS throughput, the frequency of transitions on the SDO output is 6 MHz.

To keep the current consumption at the lowest possible value, the DVDD supply must be kept at the lowest permissible value and the capacitance on the SDO line must be kept as low as possible.

10.3 Optimizing Power Consumed by the Device

- Keep the analog supply voltage (AVDD) as per the analog input full-scale range (FSR) requirement.
- Keep the digital supply voltage (DVDD) at the lowest permissible value.
- Reduce the load capacitance on the SDO output.
- Run the device at optimum throughput. Power consumption reduces with throughput.
11 Layout

11.1 Layout Guidelines

Figure 46 shows a board layout example for the ADS7044. Use a ground plane underneath the device and partition the PCB into analog and digital sections. Avoid crossing digital lines with the analog signal path and keep the analog input signals and the reference input signals away from noise sources. In Figure 46, the analog input and reference signals are routed on the top and left side of the device while the digital connections are routed on the bottom and right side of the device.

The power sources to the device must be clean and well-bypassed. Use 1-μF ceramic bypass capacitors in close proximity to the analog (AVDD) and digital (DVDD) power-supply pins. Avoid placing vias between the AVDD and DVDD pins and the bypass capacitors. Connect all ground pins to the ground plane using short, low-impedance paths. The AVDD supply voltage for the ADS7044 also functions as a reference for the device. Place the decoupling capacitor (C_{REF}) for AVDD close to the device AVDD and GND pins. C_{REF} must be connected to the device pins with thick copper tracks, as shown in Figure 46.

The fly-wheel RC filters are placed close to the device. Among ceramic surface-mount capacitors, COG (NPO) ceramic capacitors provide the best capacitance precision. The type of dielectric used in COG (NPO) ceramic capacitors provides the most stable electrical properties over voltage, frequency, and temperature changes.

11.2 Layout Example

![Diagram](image-url)
12 Device and Documentation Support

12.1 Documentation Support

12.1.1 Related Documentation

For related documentation see the following:

- OPA316 Data Sheet, SBOS703
- OPA835 Data Sheet, SLOS713
- THS4531A Data Sheet, SLOS823
- TPS79101 Data Sheet, SLVS325
- Analysis of fully differential amplifiers, SLYT157

12.2 Community Resources

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

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

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

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E2E is a trademark of Texas Instruments.

TINA is a trademark of Texas Instruments, Inc.

SPI is a trademark of Motorola.

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12.4 Electrostatic Discharge Caution

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

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

12.5 Glossary

**SLYZ022 — Ti Glossary.**

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

13 Mechanical, Packaging, and Orderable Information

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

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
EXAMPLE BOARD LAYOUT
RUG0008A
X2QFN - 0.4 mm max height
PLASTIC QUAD FLATPACK - NO LEAD

LAND PATTERN EXAMPLE
SCALE: 25X

SOLDER MASK DETAILS
NOT TO SCALE

NOTES: (continued)

3. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
# Packaging Information

<table>
<thead>
<tr>
<th>Orderable Device</th>
<th>Status (1)</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>Package Qty</th>
<th>Eco Plan (2)</th>
<th>Lead/Ball Finish</th>
<th>MSL Peak Temp</th>
<th>Op Temp (°C)</th>
<th>Device Marking (4/5)</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADS7044IDCUR</td>
<td>ACTIVE</td>
<td>VSSOP</td>
<td>DCU</td>
<td>8</td>
<td>3000</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 125</td>
<td>7044</td>
<td>Samples</td>
</tr>
<tr>
<td>ADS7044IDCUT</td>
<td>ACTIVE</td>
<td>VSSOP</td>
<td>DCU</td>
<td>8</td>
<td>250</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 125</td>
<td>7044</td>
<td>Samples</td>
</tr>
<tr>
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<td>RUG</td>
<td>8</td>
<td>3000</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>NIPDAUAG</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 125</td>
<td>FX</td>
<td>Samples</td>
</tr>
</tbody>
</table>

(1) The marketing status values are defined as follows:
- **ACTIVE**: Product device recommended for new designs.
- **LIFEBUY**: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
- **NRND**: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
- **PREVIEW**: Device has been announced but is not in production. Samples may or may not be available.
- **OBSOLETE**: TI has discontinued the production of the device.

(2) **RoHS**: TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
- **RoHS Exempt**: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
- **Green**: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

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

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

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

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### TAPE AND REEL INFORMATION

#### TAPE DIMENSIONS

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A0</td>
<td>Dimension designed to accommodate the component width</td>
</tr>
<tr>
<td>B0</td>
<td>Dimension designed to accommodate the component length</td>
</tr>
<tr>
<td>K0</td>
<td>Dimension designed to accommodate the component thickness</td>
</tr>
<tr>
<td>W</td>
<td>Overall width of the carrier tape</td>
</tr>
<tr>
<td>P1</td>
<td>Pitch between successive cavity centers</td>
</tr>
</tbody>
</table>

#### REEL DIMENSIONS

- Reel Diameter
- Reel Width (W1)

#### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE

- Q1, Q2, Q3, Q4
- Sprocket Holes
- User Direction of Feed
- Pocket Quadrants

*All dimensions are nominal.*

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Reel Diameter W1 (mm)</th>
<th>Reel Width W1 (mm)</th>
<th>A0 (mm)</th>
<th>B0 (mm)</th>
<th>K0 (mm)</th>
<th>P1 (mm)</th>
<th>W (mm)</th>
<th>Pin1 Quadrant</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADS7044IDCUR</td>
<td>VSSOP</td>
<td>DCU</td>
<td>8</td>
<td>3000</td>
<td>180.0</td>
<td>8.4</td>
<td>2.25</td>
<td>3.35</td>
<td>1.05</td>
<td>4.0</td>
<td>8.0</td>
<td>Q3</td>
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<td>DCU</td>
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<td>250</td>
<td>180.0</td>
<td>8.4</td>
<td>2.25</td>
<td>3.35</td>
<td>1.05</td>
<td>4.0</td>
<td>8.0</td>
<td>Q3</td>
</tr>
<tr>
<td>ADS7044IRUGR</td>
<td>X2QFN</td>
<td>RUG</td>
<td>8</td>
<td>3000</td>
<td>180.0</td>
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<td>1.6</td>
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<td>0.66</td>
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<td>8.0</td>
<td>Q2</td>
</tr>
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</table>
### TAPE AND REEL BOX DIMENSIONS

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Height (mm)</th>
</tr>
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<tbody>
<tr>
<td>ADS7044IDCUT</td>
<td>VSSOP</td>
<td>DCU</td>
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<td>250</td>
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<td>28.0</td>
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<tr>
<td>ADS7044IDCUR</td>
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<td>DCU</td>
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<td>3000</td>
<td>202.0</td>
<td>201.0</td>
<td>28.0</td>
</tr>
<tr>
<td>ADS7044IRUGR</td>
<td>X2QFN</td>
<td>RUG</td>
<td>8</td>
<td>3000</td>
<td>202.0</td>
<td>201.0</td>
<td>28.0</td>
</tr>
</tbody>
</table>

*All dimensions are nominal*
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
D. Falls within JEDEC MO-187 variation CA.

4200503/F 07/05
NOTES:  
A. All linear dimensions are in millimeters.  
B. This drawing is subject to change without notice.  
C. Publication IPC-7351 is recommended for alternate designs.  
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.  
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.
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