Next Generation SAR ADC Simplifies Precision Measurement

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Agenda

► Introduction

► AD400X Ease of Use System-Level Benefits
  - Ease of Drive
  - Internal Overvoltage Clamp
  - Span Compression
  - Efficient Digital interface

► Performance Benefits

► Key Attributes and End Applications

► Design Resources

► ADI’s First 20-bit Precision SAR ADC

► Conclusion
AD400X: Next Generation of Industry Leading 16/18/20-Bit Precision SAR ADC Family

- Enables low power precision data acquisition
- Signal conditioning can be optimized for frequency bandwidth of interest
- Easy to achieve datasheet performance
  - Reduces design time, debug, risk

**Key Benefits**

- **Ease of Drive**
  - High-Z mode plus long acquisition phase enables the use of low power precision ADC drive amplifier when the bandwidth of interest is low
  - Reduces signal chain power consumption

- **Ease-of-Digital interface**
  - Low SPI clock rate requirements reduce IO power consumption and simplifies the requirements on digital isolation

- **Reduced sensitivity to external circuitry**
  - Reduced performance sensitivity to resistor values in RC filter
AD4003: 18-Bit, 2MSPS Precision SAR ADC

Benefits and Features

► Ease of Use

► High Performance
  - Throughput: 2 MSPS
  - DNL: 18-bit No Missing Codes
  - INL: ±1.0LSB (± 3.8ppm) Max
  - SNR: 100.5dB typ @ 1Khz
  - THD: -123dB typ @ 1Khz

► True differential analog input range: ±V<sub>REF</sub>
  - 0 V to V<sub>REF</sub> with V<sub>REF</sub> between 2.4 V to 5.1 V

► Low Power: Scales linearly with throughput
  - 80 µW typ @ 10kSPS
  - 16 mW typ @ 2MSPS (Total)

► Small Form Factor

► Guaranteed Operation: - 40°C to +125°C

<table>
<thead>
<tr>
<th>Resolution</th>
<th>VREF</th>
<th>VDD</th>
<th>Interface</th>
<th>Input</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 Bits</td>
<td>2.4V to 5.1V</td>
<td>1.8V</td>
<td>SPI</td>
<td>Differential ±V&lt;sub&gt;REF&lt;/sub&gt;</td>
<td>10-ld MSOP 3x4.9mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.8V/2.5V/3V/5V</td>
<td></td>
<td>10-ld LFCSP 3x3mm</td>
</tr>
</tbody>
</table>
AD400X: Ease of Use Features

Ease of Drive

Span Compression

Internal Overvoltage Clamp

Efficient Digital Interface
Ease of Drive

Traditional SAR

<table>
<thead>
<tr>
<th>CNV</th>
<th>CONVERSION</th>
<th>ACQ/TRACK</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHASE</td>
<td>DATA</td>
<td></td>
</tr>
<tr>
<td>SCK</td>
<td>ADC INPUT</td>
<td></td>
</tr>
</tbody>
</table>

ADC INPUT HIGH-Z ENABLED

AD4003

CONV | ACQUISITION/TRACK

ADC DRIVER

DAC

R

VREF

C

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Ease of Drive: High-Z Mode

- Reducing the input current change versus input voltage change to ±1.5µA, which is 40x smaller versus previous SAR ADC products (AD7982 and AD7960 ±30µA/MSPS)
  - Reduces the nonlinearity error source from the external RC filter
  - Improves the signal chain INL and THD performance
- When high-Z mode is enabled, the ADC consumes ~2 mW/MSPS extra power
Ease of Drive: High-Z Mode Benefits

- Enables low input current and improved THD with low power/BW amplifiers.
- ADC can be driven directly with precision amplifiers or signal conditioning stage.
- Eliminates the need of using dedicated high speed ADC driver when the input frequency of interest is low (<10kHz).

![Typical Customer’s Signal Chain](image)
Ease of Drive: AD4003 vs AD7982 Driver Comparison

High-Z Mode Disabled

2.5x Lower Power

High-Z Mode Enabled

Higher performance with lower RC BW

(Fs = 1MSPS, fin = 1kHz)
Eliminates the need for external protection diodes and protects the ADC inputs against DC over voltage.

When the clamp turns on, it can sink up to 50mA of current and current will flow through clamp into ground.

NO current is pushed into the REF pin causing a disturbance on the reference. This is important if the reference is shared among multiple ADCs.
Span Compression

- Enables single positive supply rail to power the driver amplifier
  - Simplifies the power supply design. Lowers power consumption

- ADC performs a digital scaling function that maps zero-scale code from 0V to 0.1 \times V_{\text{REF}} and full-scale code from V_{\text{REF}} to 0.9 \times V_{\text{REF}}.

- SNR takes about \sim 1.9\text{dB} hit for the reduced input range \rightarrow 20\log(8/10)
## Efficient Digital Interface

<table>
<thead>
<tr>
<th>Features</th>
<th>System Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbo mode</td>
<td>Broadens selection of processors including lower end processors. Allows <strong>2.5x slower SPI clock rate</strong> than AD798x when running at <strong>1MSPS</strong>. Simplify isolation solution. Higher throughput with existing components. Error/status checking for functional safety.</td>
</tr>
<tr>
<td>Lower interface clock rates</td>
<td></td>
</tr>
<tr>
<td>Register programmability and Status bits</td>
<td></td>
</tr>
<tr>
<td>Option</td>
<td></td>
</tr>
</tbody>
</table>

**Turbo Mode**

![Turbo Mode Diagram](image-url)
Performance Benefits

**INL: ±1.0 LSB (± 3.8ppm) Max Guaranteed**

Power: 80µW @10kSPS; 8mW @ 1MSPS
Key Attributes and End Applications

AD4000/3 Key Attributes

- Easy to Use
- Reduces Design Time
- Low Power
  - 16mW @ 2MSPS
  - 80µW @ 10kSPS
- Small Footprint
  - 3mm x 3mm
- High Precision
  - 18-Bit INL ±1.52ppm
  - SNR 100.5dB
- Overvoltage Robust
- High Throughput
  - 2MSPS

High Precision Data Acquisition Applications

- Automated Test
- Electrical Test and Measurement
- Machine Automation
- Optical Communications
- Medical Imaging CT and Digital X-Ray
- Avionics Measurement and Control
- Optical Communications

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Instrumentation Applications

**Improvements Realized with the AD400x Family**

- Enables wider bandwidth high precision instrumentation equipment
- Enables higher performing battery powered instrumentation devices
  - Hi-Z mode allows for lower power conditioning circuitry
  - ADC power scales linearly with throughput
  - Simplify signal chain BOM
  - Small footprint for handheld devices

**Functional & Dynamic Performance Tests**

- Signal Condition & Buffer
- SAR ADC

**Opportunity to Improve Density & Power Efficiency of Signal Chain**

**SINAD vs Frequency for AD4003 and AD7982**

- SINAD dB vs Frequency KHz

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Go Beyond Silicon: Design Resources

- Data Sheet
- EVAL-AD400xFMCZ Boards
  - Needs EVAL-SDP-CH1Z controller board
- Companion Products
  - ADC Drivers: ADA4807-1, ADA4805-1, ADA4897-1, ADA4940-1
  - Reference Buffer: ADA4807-1
  - Instrumentation Amplifier: AD825x
  - Reference: ADR45XX, ADR43X, ADR345X
  - Multiplexer: ADG5207, ADG120x
  - Isolator: ADuM141E
  - LDO: ADP7118
- CN-0385: 18-bit, 2MPS Isolated Multiplexed Data Acquisition System
- IBIS Model
- FPGA Code
- Technical Article on Analog Dialogue (To be published in Dec 2016)
- Engineer Zone: Precision ADCs
AD4020: 20-Bit, 1MSPS Precision SAR ADC

Benefits and Features

► Ease of Use

► High Performance
  - INL: ± 3 ppm Max Guaranteed
  - DNL: 20-bit No Missing Codes
  - Throughput: 1 MSPS
  - SNR: 101dB typ @ 1Khz
  - THD: -123dB typ @ 1Khz

► True differential analog input range: ±V_{REF}
  - 0 V to V_{REF} with V_{REF} between 2.4 V to 5.1 V

► Low Power
  - 12 mW typ @ 1MSPS (Total)

► Small Form Factor

► Guaranteed Operation: -40°C to +125°C

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<td>2.4V to 5.1V</td>
<td>1.8V</td>
<td>SPI 1.8V/2.5V/3V/5V</td>
<td>Differential ±V_{REF}</td>
<td>10-ld MSOP 3x4.9mm</td>
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Preliminary Results: Typical Linearity Plot

DNL: +/- 0.66 ppm

INL: +1.62/-1.05 ppm
Structural Health Monitoring Demo

- AD4003 is used within a high precision data acquisition solution to sequentially digitise multiple sensor types that monitor vitals of railway tracks.
- Accelerometer (ADXL354), AMR Magnetic Sensor (ADA4571), Force/Pressure Sensor
- Results sent to Cloud, displayed on Dashboard
Conclusion

► The AD400x family
  ▪ 16/18/20-bits SAR ADCs
    ▪ Pin-for-pin compatible with AD798x/AD769x ADC Family
  ▪ Pseudo-differential / Differential analog inputs
    ▪ AD4000: 16-bit, 2MSPS Pseudo-Differential Precision SAR ADC (Released)
  ▪ Different sample rate grades

► Ease of Use Features
  ▪ High input impedance mode and span compression reduces the design challenge associated with the ADC driver stage and increases the flexibility in amplifier selection.
  ▪ Low SPI clock rate reduces latency requirements on digital isolators

► High Performance
  ▪ Improves measurement accuracy, sensitivity and repeatability
  ▪ High throughput improves control loop response time
QUESTIONS